Pacific Gas and Electric Company

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PG&E Letter DCL-14-110

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Diablo Canyon Units 1 and 2
Docket No. 50-275, OL-DPR-80
Docket No. 50-323, OL-DPR-82

<u>One-Hundred-Twenty-Day Response to NRC Request for Additional Information – National Fire Protection Association Standard 805</u>

References:

(1) PG&E Letter DCL-13-065, "License Amendment Request 13-03, License Amendment Request to Adopt NFPA 805 Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants (2001 Edition)," dated June 26, 2013
(2) NRC Letter, "Diablo Canyon Power Plant, Units 1 and 2 – Request for Additional Information Re: License Amendment Request to Adopt National Fire Protection Association Standard 805 (TAC Nos. MF2333 and MF2334)," dated July 31, 2014
(3) PG&E Letter DCL-14-093, "Revision to Response Date for NRC Request for Additional Information – Fire Modeling 3 – National Fire Protection Association Standard 805," dated October 27, 2014

Dear Commissioners and Staff:

In Reference 1, Pacific Gas and Electric Company (PG&E) submitted a license amendment request to adopt National Fire Protection Association Standard 805.

In Reference 2, the NRC provided a request for additional information (RAI) regarding Reference 1. The RAI questions were discussed in draft form in a teleconference on July 8, 2014, and during an audit performed at Diablo Canyon Power Plant during the week of July 14, 2014. Enclosed are PG&E's 120-day responses to the RAI questions.

The Fire Modeling RAI 3 is being submitted with the 120-day RAI response, as stated in Reference 3.

PG&E makes no regulatory commitments (as defined by NEI 99-04) in this letter. This letter includes no revisions to existing regulatory commitments.

If you have any questions or require additional information, please contact Mr. Tom Baldwin at 805-545-4720.

I have been delegated the authority of Barry S. Allen, Site Vice President, during his absence. I state under penalty of perjury that the foregoing is true and correct.

Executed on November 26, 2014.

Sincerely,

Jeffrey S. Summy

Jeffrey S. Summy
Senior Director Engineering and Technical Services

mjrm/4557/50037411-12
Enclosure

cc:	Diablo Distribution
cc/enc:	Marc L. Dapas, NRC Region IV Administrator
	Thomas R. Hipschman, NRC Senior Resident Inspector
	Eric R. Oesterle, NRC Senior Project Manager
	Gonzalo L. Perez, California Department of Public Health

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1. PG&E Letter DCL-13-065, "License Amendment Request 13-03, License Amendment Request to Adopt NFPA 805 Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants (2001 Edition)," dated June 26, 2013

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Attachment 1 of this enclosure includes a list of acronyms used in this response for convenience.

On July 31, 2014, the NRC provided a RAI (Reference 2) regarding LAR 13-03 (Reference 1), herein referred to as "LAR" or "the LAR." PG&E's 120-day responses to the NRC questions are provided below.

NRC FM RAI 1:

NFPA 805, Section 2.4.3.3, states that the PRA approach, methods, and data shall be acceptable to the NRC. The NRC staff noted that fire modeling comprised the following:

- The algebraic equations implemented in FDTs (Fire Dynamics Tools) and Fire Induced Vulnerability Evaluation, Revision 1 (FIVE) were used to characterize flame radiation (heat flux), flame height, plume temperature, ceiling jet temperature, hot gas layer (HGL) temperature, sprinkler activation, and smoke detector actuation.

- The FLASH-CAT model was used to calculate the fire propagation in a vertical stack of horizontal cable trays.

- The Consolidated Model of Fire and Smoke Transport (CFAST) was used in the temperature sensitive equipment HGL study, in HGL calculations for various compartments and the control room abandonment calculation.

- Fire Dynamics Simulator (FDS) was used in the plume/HGL interaction and temperature sensitive equipment zone of influence (ZOI) studies, as well as an additional study as part of the MCR abandonment calculation and analysis in Fire Zone 8-G.

LAR Section 4.5.1.2, "Fire PRA" states that fire modeling was performed as part of the Fire PRA (FPRA) development (NFPA 805 Section 4.2.4.2). Reference is made to LAR Attachment J, "Fire Modeling V&V," for a discussion of the acceptability of the fire models that were used.

Regarding the acceptability of the FPRA approach, methods, and data:

a) Please identify whether any fire modeling tools and methods have been used in the development of the LAR that are not discussed in LAR Attachment J *(e.g.,* using FDS in the MCR abandonment calculation, Fire Zone 8-G, or using CFAST in a specific analysis for Fire Zone 14-D).

b) Please describe how non-cable intervening combustibles were identified and accounted for in the fire modeling analyses.

c) It appears that, for fire areas that have mixed amounts of thermoplastic and thermoset cables, a sliding scale was used to determine the assumed heat release rate (HRR) and flame spread rate of the cable tray in a fire propagation analysis. Please provide the technical justification for this methodology.

d) The HRR of electrical cabinets throughout the plant appears to be based on the assumption that they are either Case 3 (fire limited to a single bundle of unqualified cable) or Case 4 (closed doors and fire involving multiple bundles of unqualified cable) as described in Table E-1 of NUREG/CR-6850, "EPRI (Electric Power Research Institute)/NRC-RES Fire PRA Methodology for Nuclear Power Facilities, Volume 2: Detailed Methodology," September 2005 (ADAMS Accession No. ML052580118). The NRC staff notes that typically, during maintenance or measurement activities in the plant, electrical cabinet doors remain open for a certain period of time. Please describe whether there are any administrative controls in place to minimize the likelihood of fires involving such a cabinet, and describe how cabinets with temporarily open doors were treated in the fire modeling analysis.

e) Please explain how the model assumptions in terms of location and HRR of transient combustibles in a fire area or zone will not be violated during and post-transition. Provide the technical justification for the assumption that in specific scenarios, the HRR of transient fires is 69 kilowatts (kW) (e.g., fire zone 8-G).

f) Specifically regarding the use of the algebraic models:

    i. Please describe how horizontal vents and vents at or near the ceiling of the compartment were treated in the Method of McCaffrey, Quintiere, and Harkleroad (MQH) calculations; and

    ii. Please describe how the time to sprinkler activation and the time to heat and smoke detector actuation was calculated.

g) Please describe how high energy arcing fault (HEAF) initiated fires were addressed, including in the HGL calculation, and provide the technical justification for the approach that was used to calculate HGL development timing.

h) Specifically regarding the CFAST analysis in Fire Zone 14-D, please describe the input parameters for the fire modeling and detailed results of this assessment.

i) Specifically regarding the use of CFAST and FDS in the MCR abandonment calculations:

   i. It appears that only one set of MCR calculations were performed and the results were applied to both units. Please provide the technical justification for applying results from one unit to the other unit. In addition, describe the MCR configurations for both units and compare the similarities and differences.

   ii. Please clarify whether the volumes of the main control boards (MCBs), electrical panels, raised platforms or other obstructions were excluded from the effective volume used for calculating the MCR abandonment time. If these volumes were not included, provide a technical justification for this assumption.

   iii. It appears that the growth time for transient fires was assumed to be 10 minutes. Please provide the technical justification for the use of this 10-minute growth time based on the transient combustibles expected to be present in the MCR or provide a sensitivity study to evaluate how growth times would affect the MCR abandonment time.

   iv. The analysis does not appear to consider fire spread to adjacent cabinets. NUREG/CR-6850 Appendix S indicates that fires may spread to the adjacent cabinet in 10 minutes if the cabinets are separated by a single wall and will not spread if the cabinets are separated by a double wall with an air gap. Please provide a technical justification for not considering propagating panel fires to adjacent cabinets, or perform a sensitivity study to evaluate how propagating panel fires would affect the abandonment time.

   v. In the analysis, it is assumed that the external doors to the MCR open at 10 minutes is based on an estimated fire brigade arrival time. Please provide a technical justification for the assumption that the fire brigade will arrive 10 minutes after the start of a fire event based on historic drill records or demonstrate that this assumption is conservative.

j) Specifically regarding the multi-compartment analysis (MCA):

   i. Please describe the criteria that were used to screen multi-compartment scenarios based on the size of the exposing and exposed compartments.

   ii. Please explain how the size of the vents in the exposing compartments used in the MQH HGL calculations was determined, and to what extent these vent sizes are representative of conditions in the plant.

<u>PG&E Response</u>:

a) The V&V basis for the fire modeling tools and methods used in the development of the LAR are either included in LAR Attachment J or are discussed in the response to FM RAI-03.b.

Regarding the examples cited in this RAI:

- FDS was only used in the MCR fire modeling analysis as a sensitivity study to benchmark and confirm that CFAST results were conservative. The FDS analysis was not used for the base case PRA. The FDS MCR sensitivity study will be removed from DCPP MCR fire modeling analysis.

- PAU 8-G did not use specific CFAST or FDS analyses. Generic studies (i.e., plume/HGL interaction study, temperature sensitive equipment ZOI & HGL study) using FDS and CFAST were applied to PAU 8-G and these are already listed in LAR Attachment J.

- CFAST was used to analyze the HGL for a catastrophic turbine generator fire within Fire Zones 14-D and 19-D. This analysis also placed targets at selected locations to analyze the temperature where structural steel is exposed. Subsequent to the LAR, this CFAST analysis is no longer being used in the Fire PRA, and instead, an FDS analysis is being used to analyze the catastrophic TG fire scenario. The V&V basis for the FDS analysis will be reflected in the response to FM RAI-03.b, including any updates to Attachment J of the LAR.

  There are no other cases outside the examples listed by the RAI.

b) As part of the Detailed Fire Modeling procedure utilized by DCPP, the fire modeling analyst is required to quantify the fire ignition, propagation, and spread associated with secondary combustibles. This step mainly focuses on cable trays as these are the most abundant secondary combustible in the plant. Small combustible items, such as small plastic signs, fiberglass ladders, plastic telephones, etc., are screened as negligible, as the small amount of combustible loading would be bound by the conservative HRR of the fire scenarios.

As part of the non-cable secondary combustibles review, walkdown notes, photographs, and videos collected during the initial fire modeling effort were reviewed in conjunction with the Diablo Canyon combustible loading calculation for all fire compartments where detailed fire modeling was performed. This review identified fire compartments containing non-cable secondary combustibles (e.g., clothing/rags, miscellaneous plastic, large rubber hoses, etc.).

Additional plant walkdowns of the identified fire compartments were performed to confirm the previous fire modeling approaches and assumptions regarding the presence, quantity, and location of non-cable combustible materials. These secondary combustibles were then analyzed to determine if they were bounded by existing transient or fixed ignition source scenarios as applicable. The non-cable secondary combustibles were determined to be bounded by an existing scenario if there were no nearby PRA targets, conservative secondary combustible growth (i.e., using cable trays, etc.) was already modeled, or whole room HGL damage was already postulated. If any non-cable secondary combustibles could not be bounded as previously described, the fire scenarios (i.e., transient floor area, scenario description, and damage states, etc.) were modified to account for the non-cable secondary combustibles. The updates required were minor and had limited impact on fire modeling results with no impact to the postulated target sets.

c) A review of cable insulation and jacket material was performed at DCPP to determine the type (i.e., thermoset or thermoplastic) of cables installed at DCPP in order to estimate the appropriate cable tray HRRs for fire modeling purposes.

NUREG/CR-6850, Appendix R provides cable tray properties and guidance on calculating flame spread rates in cable trays. This was validated by the results of NUREG/CR-7010, "Cable Heat Release, Ignition, and Spread in Tray Installations During Fire (CHRISTIFIRE) - Phase 1: Horizontal Trays." Using the NUREG/CR-7010 recommended HRRs per unit of tray area and spread rates, a mass-weighted average was developed between the thermoplastic and thermoset properties based on the percentage of thermoplastic cables in a given tray. The mass-weighted average method is recommended by NUREG/CR-7010. Seven categories were developed representing 0, 5, 10, 25, 50, 75, and 100 percent thermoplastic cable respectively. Cable trays were then assigned to a group that bounded the percentage of thermoplastic cables in the tray. These thermoplastic cable tray groups and their respective values are represented as follows:

Thermoplastic Cable Tray Grouping			
%Thermoplastic Group	**Thermoplastic %**	**HRR per Unit [kW/ft²]**	**Fire Spread Rate [in/min]**
0	TP=0%	14	0.71
1	TP<5%	15	0.78
2	5%≤TP≤10%	15	0.85
3	10%≤TP<25%	17	1.06
4	25%≤TP<50%	19	1.42
5	50%≤TP<75%	21	1.77
6	75%≤TP≤100%	24	2.13

d) The assumption in the fire modeling analysis of no open cabinets was based on plant procedures and personnel practices. Plant procedures require that proper housekeeping be maintained related to fire prevention and protection of equipment. However, a plant procedure has been revised allowing certain cabinets and panels to remain open and unattended during maintenance activities, based on being evaluated for seismic impact. If this procedure is not revised back to a state that supports the original assumption of no open unattended cabinets, then this will be tracked by the NFPA 805 monitoring program.

The fire modeling assumptions regarding the condition of cabinet doors will be included in the monitoring program. LAR Attachment S, Table S-3, describes the Implementation Items that will be completed prior to the implementation of the new NFPA 805 Fire Protection Program. A new Implementation Item will be added to Table S-3. The new Implementation Item will read: "Verification of the condition of electrical cabinet doors to meet fire modeling assumptions will be included in the monitoring program."

e) Transient fires were evaluated based on the 98th percentile HRR (i.e., 317 kW) specified in NUREG/CR-6850, "EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities," Table G-1, except in Fire Zones 4-A, 6-A-3, 8-G, and 8-H.

The 98th percentile HRR for transient fires listed in NUREG/CR-6850, Table G-1 are based on tested fuel package configurations identified in NUREG/CR-6850, Table G-7. The configurations tested are various solid fuel packages such as cardboard, paper, plastics, cotton rags, and acetone. The model assumptions regarding location and HRR of transient combustibles in a fire area or zone will not be violated because Diablo Canyon plant procedures require that paper, cardboard, scrap wood, rags, and other trash combustibles shall not be allowed to accumulate in any critical building/location except in metal containers with metal covers. Walkdowns were performed and the room usage was also considered when prescribing the transient HRR. This provided assurance that the HRRs used for the transient scenarios, modeled in the Fire PRA, would be appropriate representation of any potential transient fire in the area.

Since transient combustibles are strictly controlled, any temporary storage of transient materials for maintenance in excess of 15 pounds will require special permitting from the job supervisor. Permitting requires controls on proper use and removal of transient materials as well as any compensatory measures that need to be enacted while the maintenance occurs. This enables proper notification and alert to the job supervisor of additional hazards and the duration for which this hazard exists to enable a prompt response in the event of an incident during maintenance.

The guidance provided in the June 21, 2012, memo from Joseph Giitter to Biff Bradley ("Recent Fire PRA Methods review Panel Decisions and EPRI 1022993, 'Evaluation of Peak Heat Release Rates in Electrical Cabinets Fires'," ADAMS Accession No. ML12171A583) allows the user to choose a lower screening HRR for transient fires in a fire compartment based on "the specific attributes and considerations applicable to that location." The guidance indicates that "plant administrative controls should be considered in the appropriate HRR for a postulated transient fire" and that "a lower screening HRR can be used for individual plant specific locations if the 317kW value is judged to be unrealistic given the specific attributes and considerations applicable to that location."

Fire Zone 6-A-3 does not contain pumps, motors, or potential oil fires. For this fire compartment, the 75th percentile transient HRR of 142 kW was applied to transient fires in the Battery Charger Room. The 75th percentile HRR bounds the likely transient ignition sources which were fire tested and identified in NUREG/CR-6850, Appendix G, Table G-7, with the exception of tests involving untreated wood (untreated wood is prohibited at DCPP in areas with safety-related equipment), airline trash bags with over 2 kg of paper products (such large quantity of paper products will not be present in Fire Zone 6-A-3) or over 4 kg of straw/grass/eucalyptus duff (this type and quantity of plant matter will not be present in Fire Zone 6-A-3).

A 69 kW transient HRR was justified for Fire Zones 8-G, 8-H, and the cable chase areas of Fire Zone 4-A based on several factors:

- All areas which were credited for a reduced HRR are subject to strict combustible controls (areas designated as "No Combustible Storage"); therefore, paper, cardboard, scrap wood, rags and other trash shall not be allowed to accumulate in the area.

- Large combustible liquid fires are will not occur in these areas since activities in the areas do not include maintenance of oil containing equipment.

- Records dated between January 2009 and October 2014 identifying violations of hot work and transient combustible controls were reviewed. During this period, there were no notifications written for hot work control issues or transient combustible control issues in Fire Compartments 8-G, 8-H, 6-A-3, or 4-A.

- A transient fire in an area of strict combustible controls, where only small amounts of contained trash are considered possible due to DCPP plant procedure requirements, is judged to be no larger than the 75th percentile fire in an electrical cabinet with one bundle of qualified cable.

- The materials composing the fuel packages included in Table G-7 of NUREG/CR-6850 (e.g., eucalyptus duff, one quart of acetone, 5.9 kg of methyl alcohol, etc.) are not representative of the typical materials expected to be located in these areas due to DCPP plant procedure reqirements.

- A review of the transient ignition source tests in Table G-7 of NUREG/CR-6850 indicates that of the type of transient fires that can be expected in these rooms (i.e., polyethylene trash can or bucket containing rags and paper) were measured at peak HRRs of 50 kW or below.

Therefore, based on the above discussion, the use of a reduced transient HRR bounds the expected transient fire size in Fire Zones 8-G, 8-H, 6-A-3, and 4-A.

f) (i) When the algebraic models were implemented for HGL calculations using the method of MQH, horizontal vents and vents at or near the ceiling were evaluated and modeled as a single, vertical, square or rectangular wall opening (as required by FDT 02.1_Temperature_NV.xls). This is a conservative method since the vent soffit was considered to be at the ceiling elevation which is where the horizontal vent is located and the same vent opening area was used. Horizontal vents and vents at or near the ceiling were evaluated on a fire compartment by fire compartment basis and were not always included in the detailed fire modeling. Fire compartments that modeled horizontal ventilation openings and/or vents located at the ceiling of the compartment are shown in the table below with a description of how the ventilation opening was modeled. Horizontal vents not listed in the table below were omitted from the HGL calculation. This is considered conservative because the inclusion of the vent would result in additional room cooling and therefore lower predicted HGL temperatures.

<table>
<tr><th>Fire Compartment</th><th>Opening Area (ft^2)</th><th>Opening Soffit Elevation (ft)</th><th>Ceiling Height (ft)</th><th>Opening Description</th></tr>
<tr><td>3-BB-85</td><td>133.0</td><td>13.1</td><td>13.1</td><td rowspan="16">Each of the openings is a single horizontal opening in the ceiling to the elevation above.

These were modeled as a vertical vent using the area of the opening, with the top (i.e., soffit) of the vent located at the ceiling height of the fire compartment.</td></tr>
<tr><td>3-BB-100</td><td>160.5</td><td>13.0</td><td>13.0</td></tr>
<tr><td>3-BB-115</td><td>160.5</td><td>22.3</td><td>22.3</td></tr>
<tr><td>3Q2</td><td>39.0</td><td>13.0</td><td>13.0</td></tr>
<tr><td>12-A</td><td>9.0</td><td>11.0</td><td>11.0</td></tr>
<tr><td>12-B</td><td>9.0</td><td>11.0</td><td>11.0</td></tr>
<tr><td>12-C</td><td>9.0</td><td>11.0</td><td>11.0</td></tr>
<tr><td>14-D</td><td>1510.0</td><td>78.0</td><td>78.0</td></tr>
<tr><td>3-CC-85</td><td>133.0</td><td>13.1</td><td>13.1</td></tr>
<tr><td>3-CC-100</td><td>160.5</td><td>13.0</td><td>13.0</td></tr>
<tr><td>3-CC-115</td><td>160.5</td><td>22.3</td><td>22.3</td></tr>
<tr><td>3T2</td><td>39.0</td><td>13.0</td><td>13.0</td></tr>
<tr><td>19-D</td><td>1510.0</td><td>78.0</td><td>78.0</td></tr>
<tr><td>23-A</td><td>9.0</td><td>11.0</td><td>11.0</td></tr>
<tr><td>23-B</td><td>9.0</td><td>11.0</td><td>11.0</td></tr>
<tr><td>23-C</td><td>9.0</td><td>11.0</td><td>11.0</td></tr>
<tr><td>10-76</td><td>66.0</td><td>8.5</td><td>8.5</td><td rowspan="2">These openings are stairwells open to the above elevation.

These were modeled as a vertical vent using the combined stairwell opening area, with the top (i.e., soffit) of the vent located at the ceiling height.</td></tr>
<tr><td>20-76</td><td>66.0</td><td>8.5</td><td>8.5</td></tr>
<tr><td>13-A</td><td>30.0</td><td>11.0</td><td>20.2</td><td rowspan="6">There is one 3 ft x 7 ft ’ doorway and one 3 ft x 3 ft opening in ceiling.

These were modeled as a single vertical vent using the combined area of the doorway and ceiling opening, with the top (i.e., soffit) of the vent located at the effective height of both openings.</td></tr>
<tr><td>13-B</td><td>30.0</td><td>11.0</td><td>20.2</td></tr>
<tr><td>13-C</td><td>30.0</td><td>11.0</td><td>20.2</td></tr>
<tr><td>24-A</td><td>30.0</td><td>11.0</td><td>20.2</td></tr>
<tr><td>24-B</td><td>30.0</td><td>11.0</td><td>20.2</td></tr>
<tr><td>24-C</td><td>30.0</td><td>11.0</td><td>20.2</td></tr>
</table>

(ii) Detection timing was determined using NUREG-1805 FDT, Chapter 11, “Estimating Smoke Detector Response Time,” and FDT, Chapter 12, “Estimating Heat Detector Response Time.” Using the physical parameters (radial distance from fire source to detector, height of ceiling above the fire source, and ambient temperature) determined for the specific fire scenario, and the minimum fire size required to activate the detector, the corresponding time required for activation was calculated. If the devices were located outside of the validated range of the NUREG-1824 parameter for 'ceiling jet radial distance' the use of the correlation outside of the validated range has been justified in Attachment J of the LAR.

If the minimum HRR required to activate the detector was less than the critical HRR being evaluated for target damage, then detection was considered possible and the time was evaluated further using the detailed fire modeling workbooks, which have a standard t^2 fire growth profile programmed for each detailed fire scenario. The t^2 fire growth profile was used to determine and compare the time to reach the HRRs for detector activation and target damage. For electrical fires, the t^2 fire growth profile was used with the peak HRR being reached at 12 minutes (NUREG/CR-6850, Appendix G, Section G.3.1). For transient fires, the t^2 fire growth profile was used with the peak HRR in accordance with Supplement 1 to NUREG/CR-6850.

Note that the delay to detector activation, as calculated by FDT, Chapter 10 (FDT 10), "Estimating Sprinkler Response Time," was omitted for t^2 fire growth profiles. The FDT 10 activation time is calculated based on exposure to the selected HRR from time zero. In using a t^2 fire growth profile, the detector is subject to smoke/heat exposure prior to the activation HRR. In other words, the calculated thermal response delay to detector activation is accounted for during the t^2 time to reach the necessary HRR.

For scenarios requiring the activation of two cross-zoned smoke detectors to initiate an automatic suppression system (e.g., CO_2), the second detector farthest from the fire was considered when calculating time to detection. It was assumed that the detector closest to the fire will activate prior to the analyzed detector.

The time to suppression activation is dependent on the type of system under evaluation. For those systems activated by an automatic detection system, rather than directly by a sprinkler bulb or link, the time to suppression was dependent upon the time to detector activation and any delay in the delivery of the suppression (e.g., a delay for CO_2 delivery). For those detection dependent systems, see the detection analysis above. For those systems requiring activation of a bulb or link (i.e., wet-pipe or preaction systems), the sprinkler response time was determined using NUREG-1805 FDT 10. The process of comparing critical HRRs of sprinkler activation versus target damage is similar to determining detector response times.

With the physical parameters (height of ceiling above the fuel source, radial distance to the sprinkler head, ambient temperature, sprinkler Response Time Index (RTI), and activation temperature of the sprinkler) entered into FDT 10, a fire size was determined that activates the sprinkler. If the device was outside of the validated range of the NUREG-1824 parameter for 'ceiling jet radial distance,' the use of the correlation outside of the validated range has been justified in Attachment J of the LAR.

Once the HRR that activates suppression was established, all values were entered and the activation time calculated by FDT 10 was recorded. Using a standard t^2 fire growth profile, the time to reach the activation HRR was calculated. The total time to suppression is the sprinkler activation time added to the detection activation time (if applicable) and any delay to suppression delivery. If this activation time is less than the time to reach the critical HRR under evaluation (e.g., time to critical target damage), suppression is credited at this activation time.

The delay to sprinkler activation, as calculated by FDT 10, was omitted from the total time for sprinkler activation if a t^2 fire growth profile is employed. The FDT 10 activation time is calculated based on exposure to the selected HRR from time zero. In using a t^2 fire growth profile, the scenario provides a slow heating of the bulb or link until the critical HRR is achieved. Discounting the activation delay is justified based on this fire growth profile and the conservatisms applied to target damage (i.e., target damage is assumed once the fire reaches the critical HRR on the t^2 curve, without additional delay or use of the NUREG-CR/6850).

g) The guidance in Appendix M of NUREG/CR-6850, Volume 2 was used to determine fire damage due to HEAFs. Fire PRA targets within the initial blast ZOI (i.e., 3 feet horizontally and 5 feet vertically), as defined in Section M.4.2 of NUREG/CR-6850, were considered damaged and/or ignited in HEAF scenarios at time zero. Cable tray enclosures and fire wrap, if determined to be located within the HEAF ZOI, were assumed to be physically damaged by the initial explosion and were not credited in the analysis.

   For purposes of fire modeling, including calculating HGL timing, the ensuing cabinet fire occurring after the HEAF event has been modeled as a 1002 kW fire, with a peak HRR occurring at time 0 and lasting for a duration of 40 minutes. This HRR is based on the recommended HRR value in NUREG/CR-6850, Table G-1, for a 98th percentile electrical fire in a cabinet with unqualified cables, with more than one cable bundle, and open doors. The 40 minute duration of the fire scenarios bounds the total recommended timing for electrical cabinet fires in Table G-2 of NUREG/CR-6850.

   HEAF fires associated with bus ducts were modeled following the guidance in Section 7 of Supplement 1 to NUREG/CR-6850. There are limited combustibles within the bus duct that will ignite after the energetic phase; therefore, a HRR of 0 kW was applied to the bus duct itself. Ignition of secondary combustibles within the initial ZOI of the bus duct HEAF was analyzed following the guidance in Section 7 of Supplement 1 to NUREG/CR-6850.

h) The CFAST analysis performed for compartment 14-D is no longer used in the DCPP FPRA. An FDS analysis was conducted to reassess the catastrophic

TG fire within Fire Compartments 14-D and 19-D. The input parameters of the FDS analysis are as follows:

Compartment configuration and construction:

The length and width of the Unit 1 turbine deck (Fire Compartment 14-D) was measured using drawings and validated during walkdowns to be 112 meters by 43.8 meters. This was conservatively modeled in FDS as an area of 100 meters by 45 meters. The Unit 1 and Unit 2 turbine decks are open to each other. The Unit 1 and Unit 2 below turbine deck elevations have ventilation to the outside of the building along with large openings to each other. The condenser pit is located below the 85 foot elevation of the sub-turbine deck elevation and is open to the sub-turbine deck.

Based on the plant configuration, the most likely scenario would be the collecting of TG oil in the condenser pit due to the open grating in the floors above and since the main lube oil pipe that could be impacted by a catastrophic fire is directly above the condenser pit. The condenser pit is located below the 85 foot elevation at the approximate center of the unit. The condenser pit is approximately 7200 square feet (669 square meters). Obstructions are present within the pit to limit the area in which oil can collect. Walkdowns and field measurements determined that approximately 418 square meters of the condenser pit is available for oil to collect.

The material for all modeled walls and the roof above the turbine deck were modeled as 3/8 inch steel. This is a conservative thickness which will restrict heat loss from the structure. The floor of the turbine deck and the ceiling for the sub-turbine deck areas were modeled as concrete. The material properties for concrete and 3/8 inch steel were selected from the "SFPE Handbook of Fire Protection Engineering" and determined to be appropriate for use in the fire modeling analysis. The values are presented below in Table-1:

Table-1: Thermo-Physical Properties

Material	Thermal Conductivity (W•m-1•K-1)	Specific Heat (J•kg-1•K-1)	Density (kg/m³)
Concrete	1.75	1000	2200
Steel	48	559	7854

Simulation Environment:

The ambient temperature was modeled as 85°F (29.4°C) for this analysis. This temperature was estimated based on the room use (i.e., operation of motors, pumps, etc.) and was further verified via a walkdown of the area. Normal atmospheric pressure, 101 kPa, was applied to each compartment. A lower oxygen limit of 0 percent was utilized to ensure the fire would not be limited by lack of oxygen.

Ventilation openings:

For this analysis, natural ventilation was analyzed based on actual vents between compartments and to the atmosphere.

Horizontal and vertical openings (i.e. grated floors, open stairwells, etc.) from the compartments of this analysis have been measured during walkdowns. The FDS simulation considered vertical openings in both units from the sub-turbine deck to the turbine deck and from the turbine deck to the atmosphere. Horizontal openings were considered between units and to the atmosphere.

Vertical openings between the sub-turbine deck and the turbine deck provide a total area of 220 square meters. The turbine deck has an opening in the center of the roof that runs most of the length of the area. This opening provides 70 square meters of ventilation to the atmosphere per Unit. The area of the condenser pit that can collect oil is completely open to the sub-turbine deck. Therefore, the connection between the condenser pit and the sub-turbine deck is modeled as an open hole.

Horizontal openings are provided between the Unit 1 sub-turbine deck and Unit 2 sub-turbine deck as well as both of the sub-turbine deck areas to the atmosphere. There are 5 horizontal openings between each sub-turbine deck and the atmosphere that total 79 square meters. The horizontal opening between the units of the sub-turbine deck totals 41.8 square meters.

Criteria for Structural Steel Damage:

The structural framework of the turbine building consists mainly of unprotected structural steel. The critical temperature of steel is often used to define failure for a steel structural member. The critical temperature is the temperature at which steel begins to lose its structural integrity. For structural steel columns the critical temperature is 538 degrees C, and 593 degrees C for steel beams per SFPE Handbook of Fire Protection Engineering, Section 4, Chapter 11. This FDS analysis determines if and when damaging conditions formed by a catastrophic fire could occur by analyzing the gas temperature at critical locations, such as the ceilings and walls. Results were considered acceptable if the hot gases at these locations were less than the critical temperature of the structural members near that location.

Critical Target Locations:

Strings of temperature devices are strategically placed from floor to ceiling around the perimeter of the model to analyze the temperature at representative column and beam locations where structural steel is exposed. These devices, along with an FDS Z-plane slice file, measuring temperature near the ceiling, allow for a temperature profile of the walls and ceiling to be analyzed for potential structural steel damage. If any temperature device in a floor to ceiling string for a given location reached the critical temperature of steel, it was assumed structural damage was possible for any members at that location. No devices were placed directly above the fire as localized damage (i.e., within the flame/plume) is assumed above the pit. If timing for purposes of calculating nonsuppression probabilities is performed, the structural steel beams and columns within the flame/plume region would need to be assumed failed in the early stages of the fire scenario. The temperature gauge layout is shown in the Figure 1 below.

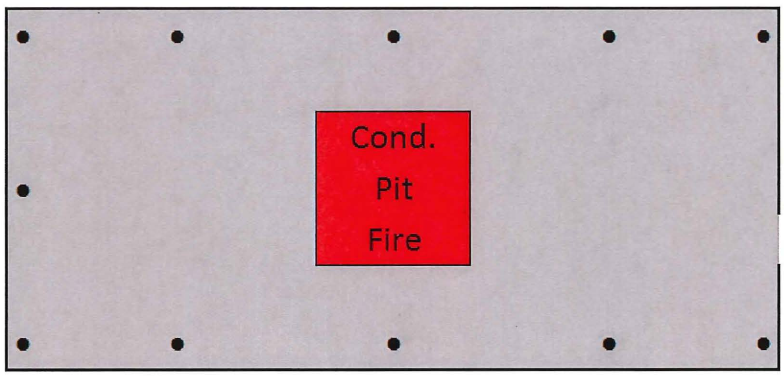

Figure 1: Turbine building temperature gauge layout

<u>HRR profiles and fire locations</u>:

The analyzed fire for this scenario is a catastrophic oil fire, which includes both lube oil and hydrogen. The most likely location that the oil will collect is in the condenser pit in the center of the unit. The available spill area of the condenser pit was determined to be approximately 418 square meters (as described previously), which correlates to a 754 MW fire.

The flame height for the hydrogen fire was based on the catastrophic event at Chernobyl in 1991, which had a reported 8m high hydrogen flame. The diameter of the leak was applied as 4 inches (0.1016 meters). This information was then used to interpolate the HRR of the hydrogen fire using the buoyant diffusion equation (Equation 4.40) as discussed in the "An Introduction to Fire Dynamics." This experimentally derived equation uses the leak diameter and the flame height to calculate the HRR. This results in a 7.4 MW hydrogen contribution to the overall scenario HRR.

The total fire size including both the oil and hydrogen fires was calculated to be 761.4 MW. The fire burns at peak from 0 seconds until 1800 seconds. This duration was selected to allow sufficient time for the room to reach steady state conditions and observe the time to critical temperature throughout the model.

Soot Yield:

The soot yield varies based on the type of material burning. Since the majority of the fuel load comes from lube oil, the most appropriate soot yield available is that of hydrocarbon. The soot yield for hydrocarbons is 0.059 grams per gram, per the SFPE Handbook, Table 3-4.16.

Summary of Results:

The FDS output files were evaluated to determine if temperatures greater than the critical member temperatures could potentially be formed in any area. The temperature at the ceiling of each compartment was analyzed using the slice files as well as the temperature gauge results. Figure 2 displays the maximum temperatures reached at each location in the compartment.

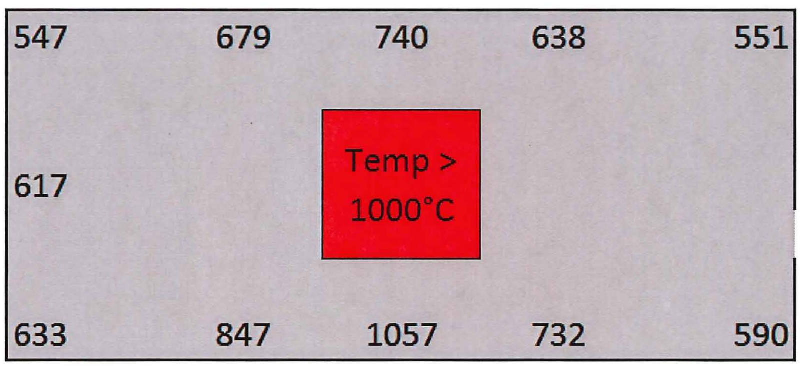

Figure 2: Maximum turbine building temperatures (°C) by location

The results revealed that a catastrophic TG fire can potentially generate temperatures in excess of the critical failure temperature of exposed structural steel members at several locations throughout the building. These temperatures can be used to assess the potential and timing for structural damage in the Turbine Building for determining manual suppression probability.

The updated catastrophic TG fire scenario will be reflected in the updated fire risk results that will be provided to the NRC after the Fire PRA is updated and additional quantification is performed in the response to PRA RAI-03.

i) (i) As discussed in the response to FM RAI-01.a, the FDS MCR sensitivity study will be removed from the MCR fire modeling analysis. The following, and all subsequent FM RAI-01.i responses, pertain only to the CFAST abandonment models and the associated PRA calculations.

With respect to the fire modeling for the MCR abandonment calculations, only one set of abandonment calculations was conducted because the MCR at DCPP is a shared space between both units and was modeled as a single space, reflecting the as-built plant. The overall results (i.e., fire scenarios, their frequencies and impacts) of the MCR analysis apply to both units as the layout, type and numbers of the control boards/consoles and other electrical cabinets are similar between units.

The MCR for DCPP Units 1 and 2 is located at elevation 140 foot of the Auxiliary Building with room dimensions approximately 91 feet by 47 feet by 13 feet. The MCR contains the MCB, Control Console and other electrical cabinets for both Unit 1 and Unit 2. The Unit 1 and Unit 2 Computer Rooms are adjacent to the MCR at either end (designated North and South respectively). There are also two offices along the West side of the MCR, one adjacent to the Unit 1 Control Room which is used as the Shift Manager's office and the other adjacent to the Unit 2 Control Room, which includes a crew briefing room and general office storage.

Each side of the MCR has its own HVAC system, one for Unit 1 and one for Unit 2, both with 4 operating modes including normal operation, smoke purge, recirculation, and airborne radioactivity mode. Each system delivers a flow rate of 7,800 cfm, for a combined total of 15,600 cfm for the common MCR and adjacent rooms/offices.

The Main Control Board for each unit comprises 5 adjoining vertical sections (VB1 to VB5), which are arranged in an L-shape, with a smaller Control Console comprising adjoining 3 sections (CC1 to CC3), also L-shaped, located in front of the vertical sections.

Apart from the Main Control Board, there are a total of 72 other electrical cabinets behind the shared main control area. The type and configuration of these cabinets is nearly identical for both units.

In the MCR scenario impacts, Unit 2 PRA components impacted by a fire in the Unit 2 MCB are the same as their Unit 1 counterparts, with the Unit number "-1-" replaced by "-2-" in the component ID. Any exceptions such as Unit 1 components that have no counterpart in Unit 2, or for which the corresponding Unit 2 component has a different ID are noted in the MCR calculation.

Therefore, while only one set of calculations was conducted, the room is shared between the units, and from an abandonment perspective, the differences between the Unit 1 and Unit 2 layout, type and numbers of the control boards/consoles, other electrical cabinets, and raceways/conduit were reflected in detail in the MCR analysis. The results from the single analysis are applicable to both units without the need for additional in-depth analysis.

(ii) The volumes of the MCBs, electrical panels, raised platforms and other obstructions were excluded from the effective volume used for calculating the MCR abandonment time. The MCR dimensions were taken from plant drawings and other DCPP documentation. Using the plant drawings and walkdown information, the volume of the MCR equipment and obstructions was conservatively estimated to be 15 percent of the total room volume. The modeled volume of the room was then reduced by 15 percent by decreasing the overall room dimensions in an update to the MCR abandonment model in CFAST.

The updated MCR volume used in the MCR abandonment fire model analysis will be reflected in the updated fire risk results that will be provided to the NRC after the Fire PRA is updated and additional quantification is performed in the response to PRA RAI-03.

(iii) Supplement 1 to NUREG/CR-6850, Chapter 17, provides guidance on the growth profiles for transient fires. It states that a time dependent fire growth model is appropriate for any situation where the basis of its use can be established. Three categories of transient growth profiles are provided with their respective times to peak HRR:

- Common trash can fire (8 minutes).
- Common trash bag fire (2 minutes).
- Spilled solvents/combustible liquids (0 minutes).

Normal housekeeping practices do not permit storage or accumulation of trash bags in the MCR. As such, a trash bag left within the control room is considered unlikely. Spilled solvents and combustible liquids of a quantity large enough to be of concern are considered highly unlikely in the control room since there are no in-situ combustible liquids and only limited amounts can be introduced for maintenance.

Based on the discussion above, the HRR growth rate for transients was determined to be that of the common trash can fire scenario, or 8 minutes. Scenarios involving fires outside a trash can or involving solvents are considered to be of sufficiently low probability that they can be ruled out of the transient fire growth time determination. The MCR abandonment fire model analysis has been updated to use an 8-minute growth rate, and the existing 10-minute growth rate is no longer used.

The updated transient fire growth profile used in the MCR abandonment fire model analysis will be reflected in the updated fire risk results that will be provided to the NRC after the Fire PRA is updated and additional quantification is performed in the response to PRA RAI-03.

(iv) The MCR fire modeling analysis has been updated to include spread to adjacent cabinets.

NUREG/CR-6850, Appendix S suggests that a 10 minute delay in fire propagation can be assumed for cabinets with cables in direct contact with the wall and a 15 minute delay for cabinets without cables contacting the wall.

Based on this guidance, a delay of 10 minutes for fire propagation to adjacent cabinets was conservatively assumed.

Following the methodology in NUREG/CR-6850, Appendix S, fire propagation is limited to the adjacent cabinet (i.e., directly next to the initiating section) only. Therefore, the maximum number of cabinets to be affected is three (i.e., source plus one cabinet on either side). Walkdowns of the MCR were conducted to determine those cabinets that would be limited to a single cabinet fire and those that could propagate to an adjacent cabinet or cabinets. DCPP followed NUREG/CR-6850, Appendix S, which recommends no fire spread to adjacent cabinets when:

1. Cabinets are separated by a double wall with an air gap, or

2. Either the exposed or exposing cabinet has an open top, and there is an internal wall, possibly with some openings, and there is no diagonal cable run between the exposing and exposed cabinet.

MCR CFAST fire models using one, two, or three cabinets were developed using the 10-minute delay to adjacent vertical section spread. The CFAST results were then applied to the frequency of cabinets assigned to each group (i.e., one, two, or three cabinet spread). For the purposes of calculating the abandonment probability, the MCB was modeled as a three cabinet fire.

The updated abandonment times for propagating panel fires in the MCR abandonment fire model analysis will be reflected in the updated fire risk results that will be provided to the NRC after the Fire PRA is updated and additional quantification is performed in the DCPP response to PRA RAI-03.

v) DCPP fire drill records were examined for the previous 2 years, from March 2012 through June 2014. In this period, 55 fire drills occurred for various plant locations with an average response time of 6 minutes. Although none of these records indicate drills specifically for the MCR, they do indicate that times are consistent throughout the plant in all areas drilled. It can therefore be reasonably assumed that these times will apply to the MCR as well. Thus the assumption that the external doors to the MCR open at 10 minutes during a fire event is conservative and is consistent with historic drill records.

j) (i) The MCA only screens scenarios based on compartment size using the size of the exposing compartment.

The HRR necessary for a damaging HGL is determined for each exposing compartment and compared with the maximum HRR attainable. Those compartments whose maximum HRR is below the level required to create a damaging HGL are eliminated from further consideration providing no permanent opening is identified. For those cases where a permanent opening exists, a further check was made to determine if direct inter-compartment plume or radiant damage may occur.

For the fire compartments which have undergone detailed fire modeling, the potential of forming a damaging HGL was determined from the relevant calculations. For the remainder of the compartments, a separate walkdown and analysis was performed to determine the minimum HRR required to generate a HGL, using the McCaffrey, Quintiere, and Harkleroad (MQH) method, and the maximum possible HRR from a fire in the compartment. In some cases, compartments were screened qualitatively in this step.

For the exposed fire compartment screening step in the multi-compartment analysis, no exposed fire compartments were screened out of the analysis based on their size. If the exposing fire compartment was capable of creating a damaging HGL, the probability of HGL propagation was calculated for each exposed fire compartment where propagation was possible.

(ii) The MQH HGL calculations for determining the maximum HRR for the screening step based on low HRR utilized a 3 feet by 7 feet standard door opening. Once the fire is detected, fire brigade personnel will be dispatched to the room and are expected to open a door and perform suppression activities, which would provide the 3 feet by 7 feet opening assumed in the fire modeling analysis. Prior to this action, the single door is a representation of the various natural ventilation openings within the room (e.g., door gaps, vents, openings, etc.) because the fire compartments are connected to other areas of the plant to facilitate ventilation. This door opening is representative of the plant conditions and is conservative since some compartments have more than one door opening.

The ventilation parameters for detailed fire modeling scenarios credited in the MCA are documented in the Diablo Canyon detailed fire modeling analyses.

<u>NRC FM RAI 3</u>:

NFPA 805, Section 2.7.3.2, states that each calculational model or numerical method used shall be verified and validated through comparison to test results or comparison to other acceptable models.

LAR Section 4.5.1.2 states that fire modeling was performed as part of the FPRA development (NFPA 805, Section 4.2.4.2). Reference is made to LAR Attachment J, for a discussion of the verification and validation (V&V) of the fire models that were used. Furthermore, LAR Section 4.7.3 states that "calculational models and numerical methods used in support of compliance with 10 CFR 50.48(c) were verified and validated as required by Section 2.7.3.2 of NFPA 805."

Regarding the V&V of fire models:

a) LAR Attachment J states that the smoke detection actuation correlation (Method of Heskestad and Delichatsios) has been applied within the validated range reported in NUREG-1824, "Verification and Validation of Selected Fire Models for Nuclear Power Plant Applications." However, the latter reports a validation range only for Alpert's ceiling jet temperatures correlation. Please provide technical details to demonstrate that the temperature to smoke density correlation has been applied within the validated range, or to justify the application of the correlation outside the validated range reported in the V&V basis documents.

b) For any tool or method identified in the response to FM RAI 01(a) above, please provide the V&V basis if not already explicitly provided in the LAR (for example in LAR Attachment J).

PG&E Response:

a) The Heskestad and Delichatsios Smoke Detection Actuation Correlation is based upon the ceiling jet temperature predicted by Alpert's Ceiling Jet Correlation; therefore, the normalized parameters for the ceiling jet correlation are applicable. The normalized parameter that applies to the Alpert's ceiling jet correlation is the ceiling jet radial distance relative to the ceiling height, and the validation range is a ratio of 1.2-1.7. The Heskestad and Delichatsios Smoke Detection Actuation Correlation using Alpert's Ceiling Jet Correlation was performed within the validated range reported in NUREG-1824; therefore, the correlation was appropriately applied.

   In addition to being applied within the validation range for Alpert's ceiling jet, the smoke detection correlation was applied to fuels, configurations, and environmental conditions consistent with those described in Chapter 4-1 of the SFPE Handbook and NUREG-1805, "Fire Dynamics Tools (FDTs): Quantitative Fire Hazard Analysis Methods for the U.S. Nuclear Regulatory Commission Fire Protection Program." The correlation was also applied within the limitations described in these publications.

   Heskestad and Delichatsios correlated a smoke temperature change of 10°C (18°F) based upon typical fire fuels. The materials tested to develop the Heskestad and Delichatsios smoke detector correlation are representative of the fuels modeled for smoke detector activation. The tested materials include various plastics, foams, and paper, possessing smoke properties similar to the fires modeled at DCPP. Additionally, when implementing the Heskestad and Delichatsios Smoke Detection Actuation Correlation (i.e., FDT 10), the 10°C (18°F) ceiling jet temperature rise from ambient temperature is preserved by adjusting the activation temperature of the smoke detector accordingly.

b) The only tool used that is not explicitly listed in LAR Attachment J is a FDS analysis that analyzed the HGL temperature for structural steel failure from a catastrophic TG fire within Fire Zones 14-D and 19-D. The analysis also modeled temperature targets at critical locations to analyze the temperature where structural steel is exposed. The following is the V&V basis for HGL calculations and the use of temperature targets in FDS.

   The predictive capability of HGL temperature and height in FDS are characterized as GREEN according to Table 3-1 of NUREG-1824, Volume 1.

A GREEN characterization is given,

> "If both criteria are satisfied (i.e., the model physics are appropriate for the calculation being made and the calculated relative differences are within or very near experimental uncertainty), then the V&V team concluded that the fire model prediction is accurate for the ranges of experiments in this study, and as described in Tables 2-4 and 2-5. A grade of GREEN indicates the model can be used with confidence to calculate the specific attribute. The user should recognize, however, that the accuracy of the model prediction is still somewhat uncertain and for some attributes, such as smoke concentration and room pressure, these uncertainties may be rather large. It is important to note that a grade of GREEN indicates validation only in the parameter space defined by the test series used in this study; that is, when the model is used within the ranges of the parameters defined by the experiments, it is validated."

NUREG-1824, Volume 7, Section 6.1 summary states:

> "The FDS low Mach number hydrodynamic model is appropriate for predicting compartment temperatures and smoke filling. Note that FDS does not require the ceiling to be flat, and it can directly incorporate ceiling obstructions like ducts, beam pockets, and cable trays so long as they can be approximated as rectangular objects that conform to the overall numerical grid.
>
> The FDS predictions of the HGL temperature and height are, with a few exceptions, within experimental uncertainty."

The predictive capability of target temperature in FDS is characterized as YELLOW according to Table 3-1 of NUREG-1824, Volume 1.

A YELLOW characterization is given,

> "If the first criterion is satisfied and the calculated relative differences are outside experimental uncertainty with no consistent pattern of over- or under-prediction, then the model predictive capability is characterized as YELLOW. A YELLOW classification is also used despite a consistent pattern of under- or over-prediction if the experimental data set is limited. Caution should be exercised when using a fire model for prediction these attributes. In this case, the user is referred to the details related to the experimental conditions and validation results documented in Volumes 2 through 6. The user is advised to review and understand the model assumptions and inputs, as well as the conditions and results to determine and justify the appropriateness of the model prediction to the fire scenario for which it is being used."

NUREG-1824, Volume 7, Section 6.8 summary states:

> "FDS has the appropriate radiation and solid phase models for predicting the radiative and convective heat flux to targets, assuming the targets are relatively simple in shape. FDS is capable of predicting the surface temperature of a target, assuming that its shape is relatively simple and its composition fairly uniform.
>
> FDS predictions of heat flux and surface temperature are generally within experimental uncertainty, but there are numerous exceptions attributable to a variety of reasons. The accuracy of the predictions generally decreases as the targets move closer to, or go inside of, the fire. There is not enough near-field data to challenge the model in this regard."

All of the analyzed targets are relatively simple in shape and composition (i.e., steel beams and columns). None of the analyzed column targets are located in the flame or plume of the fire. Therefore, column target temperatures will generally fall within experimental uncertainty. Beam targets traversing the condenser pit may be directly impinged by the flames. Although the accuracy of the predictions generally decreases as the targets move closer to, or go inside of, the fire, the model results show these beams reach the failure criteria. Therefore the beam targets are conservatively assumed to be damaged immediately, which bounds any potential accuracy uncertainty.

Attachment J of the LAR will be revised to add the following:

Calculation	**Application**	**V&V Basis**	**Discussion**
Structural Steel Temperature Calculations for a Catastrophic T/G fire using FDS	Calculate HGL and target temperatures at critical locations, such as ceilings and walls	• NIST Special Publication 1018, 2010 • FDS Version 5 • NUREG-1824, Volume 7, 2007 • NUREG-1934, Chapter 2, 2012 • R2044-311-001, "Verification and Validation of Fire Modeling Tools and Approaches for Use in NFPA 805 and Fire PRA".	• V&V of the FDS code is documented in the NIST Special Publication 1018. • The V&V of FDS specifically for Nuclear Power Plant applications is documented in NUREG-1824. • It is concluded in NUREG-1824, Volume 7, Chapter 6, "Model Validation," that FDS is suitable for predicting HGL height and temperature, with no specific caveats.

Calculation	Application	V&V Basis	Discussion
		• SFPE Handbook of Fire Protection Engineering, 4th Edition, Chapter 1-10, Kodur V.K.R. and Harmathy T.Z., 2008	• The model has been applied within its limits of applicability and within the validated range reported in NUREG-1824 or, if applied outside the validated range, the model has been justified as acceptable, either by qualitative analysis, or by quantitative sensitivity analysis. The methodology for justifying application of the fire model outside the range is in accordance with methods documented in NUREG-1934. • Structural Steel damage criteria is documented in an authoritative publication of the "SFPE Handbook of Fire Protection Engineering."

NRC FM RAI 4:

NFPA 805, Section 2.7.3.3, states that acceptable engineering methods and numerical models shall only be used for applications to the extent these methods have been subject to V&V. These engineering methods shall only be applied within the scope, limitations, and assumptions prescribed for that method.

LAR Section 4.7.3 states that engineering methods and numerical models used in support of compliance with 10 CFR 50.48(c) are used and were applied appropriately as required by Section 2.7.3.3 of NFPA 805.

Regarding the limitations of use:

a) The NRC staff notes that algebraic models cannot be used outside the range of conditions covered by the experiments on which the model is based. NUREG-1805, "Fire Dynamics Tools (FDTs): Quantitative Fire Hazard

Analysis Methods for the U.S. Nuclear Regulatory Commission Fire Protection Inspection Program," dated December 2004 (ADAMS Accession No. ML043290075), includes a section on assumptions and limitations that provides guidance to the user in terms of proper and improper use for each FDT. It appears that the licensee has provided a general discussion of the limitations of use for the algebraic equations that were utilized for hand calculations. It is not clear, however, how these limitations were applied for the individual fire areas or for the MCA. Please provide a description of how the limit of applicability was determined for each fire area.

b) Please identify uses, if any, of CFAST outside the limits of applicability of the model and explain how the use of CFAST was justified.

c) Please identify uses, if any, of FDS outside the limits of applicability of the model and explain how the use of FDS was justified.

PG&E Response:

a) The limitations and assumptions associated with the FDT fire modeling tools are documented in NUREG-1805, NUREG-1824, and the DCPP fire modeling verification and validation documentation. Using this guidance, the fire modeling analyst manually calculates and verifies that the fire modeling tools are used within the limits and ranges of applicability.

   To demonstrate that the FDTs were used within the applicable guidelines for nuclear power plants, the FDT input parameters were analyzed within the normalized parameter ranges summarized in NUREG-1934. In most cases, the subject correlations have been applied within the validated range reported in NUREG-1824. In cases where the models have been applied outside the validated range reported in NUREG-1824, these have been justified as acceptable, either by qualitative analysis, or by quantitative sensitivity analysis. Technical details demonstrating the models are within range, as well as any justification of models outside the range, are outlined in Attachment J of the LAR, and documented in the DCPP FM V&V documentation.

b) CFAST was verified and validated by NUREG-1824, "Verification and Validation of Selected Fire Models for Nuclear Power Plant Applications," which provides the limitations of model applicability. This analysis utilized CFAST within the limitations discussed in NUREG-1824 by conservatively following the guidance provided in model preparation.

   To demonstrate that the CFAST analyses were performed within the applicable guidelines for nuclear power plants, the model input parameters were analyzed within the normalized parameters ranges summarized in NUREG-1934. In most cases, the subject correlations have been applied within the normalized parameter range reported in NUREG-1934. In cases where the models have been applied outside the validated range, their use has been justified as acceptable, either by qualitative analysis, or by quantitative sensitivity analysis. Technical details demonstrating the models are within range, as well as any justification of models outside the range or nonapplicable parameters, have been outlined in Attachment J of the LAR, and documented in the DCPP FM V&V documentation.

c) FDS was verified and validated by NUREG-1824, "Verification and Validation of Selected Fire Models for Nuclear Power Plant Applications," which provides the limitations of model applicability. These analyses utilized FDS within the limitations discussed in NUREG-1824 by conservatively following the guidance provided in model preparation.

   To demonstrate that the FDS analyses were performed within the applicable guidelines for nuclear power plants, the model input parameters were analyzed within the normalized parameter ranges summarized in NUREG-1934. In most cases, the subject correlations have been applied within the normalized parameter range reported in NUREG-1934. In cases where the models have been applied outside the validated range, their use has been justified as acceptable, either by qualitative analysis, or by quantitative sensitivity analysis. Technical details demonstrating the models are within range, as well as any justification of models outside the range or nonapplicable parameters, have been outlined in Attachment J of the LAR, and documented in the DCPP FM V&V documentation.

<u>NRC FM RAI 6</u>:

LAR Section 4.7.3, states that uncertainty analyses were performed as required by Section 2.7.3.5 of NFPA 805 and the results were considered in the context of the application. This is of particular interest in fire modeling and FPRA development.

Regarding the uncertainty analysis for fire modeling:

a) Please describe how the uncertainty associated with the fire model input parameters (compartment geometry, radiative fraction, thermophysical properties, etc.) was addressed and accounted for in the analyses.

b) Please describe how the "model" and "completeness" uncertainties were accounted for in the fire modeling analyses.

<u>PG&E Response</u>:

As stated in LAR Section 4.7.3, PG&E performed uncertainty analyses as required by Section 2.7.3.5 of NFPA 805. The uncertainty analyses in the area of fire modeling include both the uncertainties associated with the fire model input parameters, the modeling and completeness uncertainties. The fire model input uncertainty is addressed by the response to FM RAI-06.a. The response to FM

RAI-06.b addresses the model and completeness uncertainties in the fire modeling analyses.

a) Fire modeling was performed within the Fire PRA, utilizing codes and standards developed by industry and NRC and that were verified and validated in authoritative publications such as NUREG-1824, "Verification and Validation of Selected Fire Models for Nuclear Power Plant Applications." In general, the fire modeling was performed using conservative methods and input parameters that were based upon NUREG/CR-6850, "Fire PRA Methodology for Nuclear Power Facilities." This approach was used based upon the current state of knowledge regarding the uncertainties related to the application of the fire modeling tools and associated input parameters for specific plant configurations.

Appendix V of NUREG/CR-6850 recommends that to the extent possible, modeling parameters should be expressed as probability distributions and propagated through the analysis to arrive at target failure probability distributions. These distributions should be based on the variation of experimental results as well as the analyst's judgment. To the extent possible, more than one fire model can be applied and probabilities assigned to the outcome which describe the degree of belief that each model is the correct one. The list of the fire model input parameters used in the development of the Fire PRA is provided in of the DCPP PRA Calculation along with types of distribution (e.g., lognormal, exponential) and distribution parameters (e.g., mean, median, percentile values).

Due to the uncertainty with each of these parameters, the fire modeling task has selected conservative values for some of key input parameters while utilizing the mean values for the rest to provide safety margin as described below. Per NEI 04-02, there is no clear definition of an adequate safety margin. However, the safety margin should be sufficient to bound the uncertainty within a particular calculation or application. The Detailed Fire Modeling Report for each compartment provides a list of items that were modeled conservatively and that provide safety margin. Some examples include the following items:

- Fire scenarios involving electrical equipment (including the electrical split fraction of pump fires) utilize the 98th percentile HRR for the severity factor calculated out to the nearest FPRA target. This is considered conservative.
- The fire elevation of electrical fires was modeled at the top of the cabinet or pump body. This is considered conservative, because the combustion process will occur where the fuel mixes with oxygen, which is not always at the top of the ignition source.
- The HRR value for some cabinets was based upon nonqualified internal cable. This results in a conservative HRR as these cabinets could contain some amounts qualified cable.

- The radiative fraction utilized was 0.4 and the convective HRR fraction utilized was 0.7. These figures conservatively amount to 110 percent of the modeled HRR.

- For transient fire impacts, a large bounding transient zone assumes all targets within its ZOI were affected by a fire. Time to damage is calculated based on the most severe (closest) target. This is considered conservative, because a transient fire would actually have a much smaller zone of influence and varying damage times. This approach was implemented to minimize the multitude of transient scenarios to be analyzed.

- The fire elevation for transient fires was assumed to be 2 feet to account for any transient fires not occurring at floor level.

- Not every cable tray is filled to capacity. The fire modeling assumed all cable trays were filled to capacity, which provided a conservative estimate of the contribution of cable insulation to the fire and the corresponding time to damage.

- Many cable trays have metal bottom covers which are mostly solid with the exception of infrequent small gaps (i.e., less than 1-inch). A solid metal bottom cover would normally delay ignition and damage by twenty (20) minutes. The metal bottom covers with gaps are not credited to delay damage of target cables, which is conservative.

- As the fire propagated to secondary combustibles, the fire was conservatively modeled as one single fire using the fire modeling closed-form correlations. The resulting plume temperature estimates used in this analysis were therefore also conservative, because in actuality, the fire would be distributed over a large surface area, and would be less severe at the target location.

- Target damage was assumed to occur when the exposure environment met or exceeded the damage threshold. No additional time delay due to thermal response was modeled, which is conservative.

- Oil fires were analyzed as both unconfined and confined spills with 20-minute durations. While unconfined spills resulted in large HRRs, they usually have shorter fire durations. However, all the oil fires have been conservatively analyzed for a 20-minute burn time to account for the uncertainty in the oil spill size.

- High energy arcing fault scenarios were conservatively assumed to be at peak fire intensity for 40 minutes from time zero (ignition), even though the initial arcing fault is expected to consume the contents of the cabinet and burn for only a few minutes.

- For fire spread to adjacent cabinets, this analysis assumes the worst case cable configuration (i.e., cables are in contact with the panel sides) and uses a 10 minute spread time vs. 15 minutes, in accordance with NUREG/CR-6850, Appendix S.

- For all nonrisk significant scenarios, conduit elevations were assumed to be within the flame height such that they were subjected to damaging plume temperatures and a potential damaging radiant heat flux.

- For many fire scenarios, fire brigade intervention was not credited prior to 85 minutes. A review of the fire brigade drills indicated that typical manual suppression times can be expected to be much less than 85 minutes (i.e., 15 minutes).

The propagation of fire for each nonscreened fire source has been described by a fire model (represented by a fire growth event tree) which addresses the specific characteristics of the source and the configuration of secondary combustibles.

Aleatory uncertainties identified within the fire propagation analyses (i.e., estimation of a fire scenario frequency) include:

- Detector response reliability and availability

- Automatic suppression system reliability and availability

- Manual suppression reliability with respect to time available

The DCPP PRA Calculation describes the process of deriving uncertainty distributions for the fire scenario frequencies and the results for the most risk significant fire scenarios. These fire frequency uncertainty distributions are then combined with other internal quantifications and fire modeling parameters such as SSC reliability, spurious actuation probability and human error probability to estimate uncertainty distribution of a risk matrix such as CDF.

b) In the area of the fire modeling, "model" uncertainties and associated assumptions can be introduced through two separate phases of the fire modeling; first from selection of fire modeling tools such as FDTs and CFAST, and secondly through their applications to the development of fire scenarios.

NUREG-1934 states that "model" uncertainties can be estimated using the processes of verification and validation. Model uncertainty is based primarily on comparisons of model predictions with experimental measurements as documented in NUREG-1824 and other model validation studies.

All of the fire models used and listed in Attachment J of the DCPP NFPA 805 Transition Report were within or very near the experimental uncertainty, as determined by NUREG-1824, "Verification and Validation of Selected Fire

Models for Nuclear Power Plant Applications," Final Report, dated May 2007. Where applicable, all fire models listed below were applied within the validation ranges or the use was justified as acceptable with a subsequent analysis. Each model is discussed below.

<u>HGL Temperature using FDTs</u>

The predictive capability of this parameter using FDTs is characterized as YELLOW+ according to NUREG-1824, Volume 1, Table 3-1.

As stated in NUREG-1824, Volume 1, Section 2.6.2, a YELLOW± characterization is assigned, "If the first criterion is satisfied and the calculated relative differences are outside the experimental uncertainty but indicate a consistent pattern of model over-prediction or under-prediction, then the model predictive capability is characterized as YELLOW+ for over-prediction, and YELLOW- for under-prediction. The model prediction for the specific attribute may be useful within the ranges of experiments in this study, and as described in Tables 2-4 and 2-5, but the users should use caution when interpreting the results of the model. A complete understanding of model assumptions and scenario applicability to these V&V results is necessary. The model may be used if the grade is YELLOW+ when the user ensures that model over-prediction reflects conservatism. The user must exercise caution when using models with capabilities described as YELLOW±."

NUREG 1824, Volume 3, Section 6.1 states that: "The FDTs models for HGL temperature capture the appropriate physics and are based on appropriate empirical data. FDTs generally over-predict HGL temperature, outside of uncertainty." The over prediction is expected to lead to conservative results and increased safety margin.

<u>HGL Temperature and Height using CFAST</u>

The predictive capability of these parameters in CFAST was characterized as GREEN according to NUREG-1824, Volume 1, Table 3-1. The GREEN designation is discussed above under the response to FM RAI 3.b. Specifically, the GREEN designation was assigned to the CFAST HGL temperature parameter calculated in the fire compartment of origin. Compartments remote from the fire were assigned a YELLOW designation which "suggests that one exercise caution when using the model to evaluate this quantity – consider carefully the assumptions made by the model, how the model has been applied, and the accuracy of the results."

As stated in NUREG-1824, Volume 1, Section 2.6.2, a YELLOW characterization is assigned "If the first criterion is satisfied and the calculated relative differences are outside experimental uncertainty with no consistent pattern of over- or under-prediction, then the model predictive capability is characterized as YELLOW. A YELLOW classification is also used despite a consistent pattern of under or over-prediction if the experimental data set is limited. Caution should be exercised when using a fire model for predicting these attributes. In this case, the user is referred to the details related to the experimental conditions and validation results documented in Volumes 2 through 6. The user is advised to review and understand the model assumptions and inputs, as well as the conditions and results to determine and justify the appropriateness of the model prediction to the fire scenario for which it is being used."

NUREG-1824, Volume 5, Section 6.1 summary states: "The CFAST predictions of the HGL temperature and height are, with a few exceptions, within or close to experimental uncertainty. The CFAST predictions are typical of those found in other studies where the HGL temperature is typically somewhat over-predicted and HGL height somewhat lower than experimental measurements. These differences are likely attributable to simplifications in the model dealing with mixing between the layers, entrainment in the fire plume, and flow through vents. Still, predictions are mostly within 10% to 20% of experimental measurements."

<u>Ceiling Jet Temperature using the Alpert Correlation</u>

The predictive capability of this parameter using the Alpert correlation in the FIVE fire model is characterized as YELLOW+ according to NUREG-1824, Volume 1, Table 3-1. The YELLOW+ designation is discussed above under the "HGL Temperature using FDTs" heading. Specifically, NUREG-1824, Volume 4, Section 6.2 summary states:

> "The Alpert correlation under-predicts ceiling jet temperatures in compartment fires with an established hot gas layer. This result is expected because the correlation was developed without considering HGL effects. The original version of FIVE accounted for HGL effects by adding the ceiling jet and HGL temperature. This practice results in consistent over-predictions of the ceiling jet temperature. The approach of adding ceiling jet temperatures to the calculated hot gas layer continues to be the recommended method for FIVE-Rev 1 users. Based on the above discussion, a classification of Yellow+ is recommended if HGL effects on the ceiling jet temperature are considered using the approach described in the above bullet. The Alpert correlation by itself is not intended to be used in rooms with an established hot gas layer."

The approach of adding the HGL temperature to the ceiling jet temperature was not used in the DCPP fire modeling analysis. The primary application of the ceiling jet correlation at DCPP was the determination of detection and suppression timing, in which the ceiling jet velocity is a sub-model in the analysis. Including the effects of a HGL would have resulted in shorter detection and suppression times, and therefore the DCPP approach is conservative. The use of the ceiling jet correlation for target damage was bounded by the use of the point source radiation model and is justified and discussed in the DCPP fire modeling V&V documentation.

Plume Temperature using FDTs

The predictive capability of this parameter using FDTs is characterized as YELLOW- according to NUREG-1824, Volume 1, Table 3-1. The YELLOW- designation is discussed above under the response to FM RAI 3.b.

NUREG-1824, Volume 3, Section 6.2 summary states:

> "The FDTs model for plume temperature is based on appropriate empirical data and is physically appropriate. FDTs generally under-predicts plume temperature, outside of uncertainty, because of the effects of the hot gas layer on test measurements of plume temperature. The FDTs model is not appropriate for predicting the plume temperatures at elevations within a hot gas layer."

The FDTs plume correlation for fire modeling applications was used within the limitations provided in NUREG-1824. The effects of the plume and HGL interaction were analyzed and documented in the DCPP fire modeling Verification and Validation documentation. The use of the FDTs plume correlation was used in accordance with the results of this analysis.

Flame Height using FDTs

The predictive capability of this parameter using FDTs is characterized as GREEN according to NUREG-1824, Table 3-1. The GREEN designation is discussed above under the response to FM RAI 3.b.

NUREG-1824, Volume 3, Section 6.3 summary states "The FDTs model predicted flame heights consistent with visual test observations."

Smoke Concentration using CFAST

The predictive capability of this parameter in CFAST is characterized as YELLOW according to NUREG-1824, Volume 1, Table 3-1. The YELLOW designation is discussed above under the "HGL Temperature and Height using CFAST" heading.

NUREG-1824, Volume 5, Section 6.6 summary states: "CFAST is capable of transporting smoke throughout a compartment, assuming that the production rate is known and that its transport properties are comparable to gaseous exhaust products. CFAST typically over-predicts the smoke concentration in all of the BE #3 tests, with the exception of Test 17. Predicted concentrations for open-door tests are within experimental uncertainties, but those for closed-door tests are far higher. No firm conclusions can be drawn from this single data set. The measurements in the closed-door experiments are inconsistent with basic conservation of mass arguments, or there is a fundamental change in the combustion process as the fire becomes oxygen-starved."

The smoke concentration was analyzed and was used as one criterion to determine the probability of MCR abandonment at DCPP following a fire scenario in the MCR. Because the smoke concentration was over-predicted for both the open-door and closed-door test configurations as indicated in NUREG-1824, the DCPP CFAST results were considered conservative.

The smoke production rates used in the model were conservatively selected from Table 3-4.16 of the SFPE Handbook of Fire Protection Engineering, 4th Edition. Because transport properties of the smoke are expected to be comparable to gaseous exhaust products, the use of the model is within the limitations and the experimental uncertainty.

Radiant Heat using FDTs

The predictive capability of this parameter of the FDTs is characterized as YELLOW according to NUREG-1824, Volume 1, Table 3-1. The YELLOW designation is discussed above under the "HGL Temperature and Height using CFAST" heading.

NUREG-1824, Volume 3, Section 6.4 summary states: "The FDTs point source radiation and solid flame radiation model in general are based on appropriate empirical data and is physically appropriate with consideration of the simplifying assumptions. The FDTs point source radiation and solid flame radiation model are not valid for elevations within a hot gas layer. FDTs predictions had no clear trend. The model under- and over-predicted, outside uncertainty. The point source radiation model is intended for predicting radiation from flames in an unobstructed and smoke-clear path between flames and targets."

Only the FDTs point source radiation model was used in the DCPP fire modeling. NUREG-1824 states that there is no clear trend in under- or over-prediction for the point source model. The model over-predicted heat flux for locations immersed in a HGL, which is likely due to smoke and the HGL preventing radiation from reaching the gauges. This over-prediction is expected to lead to conservative results and increased safety margin. In a smaller number of cases, the model under-predicted heat flux due to contribution of radiation from the HGL. In order to account for this potential under prediction, conservatism was built into the use of the radiation model at DCPP, including the use of a radiant HRR fraction of 0.4, as opposed to the normally recommended value of 0.3.

In addition, NUREG-1824 states that the point source model is not intended to be used for locations relatively close to the fire. In the DCPP fire modeling analysis, targets located close to the fire were conservatively failed within the early stages of fire growth.

DCPP performed the characterization of fire modeling model uncertainties and evaluated their impacts on the fire PRA model. The fire modeling at DCPP follows the guidance and requirements provided in NUREG/CR-6850 and other NRC accepted guidance documents and positions, which are generally prescriptive and conservative in nature. Since some of these uncertainties were characterized as conservatively biased or insignificant impacts on the fire PRA model, or the approaches used by DCPP were the sole acceptable analysis method available to evaluate impacts in the fire modeling analyses, no further consideration was given to this type of model uncertainties.

Model Completeness

Regarding "completeness" uncertainties, these refer to the fact that a model may not be a complete description of the phenomena it is designed to predict. Completeness associated with fire models is addressed in the DCPP Fire PRA within the overall quantification process, since the PRA is an integrated analysis. Fire Modeling provides inputs to a broad comprehensive Fire PRA which includes modeling of electrical systems, operator actions, and the plant systems and components needed to shut down the plant. One of the first steps in the fire modeling process is to identify the fire scenarios that will be analyzed. In some situations, these scenarios would require fire modeling capabilities that are not currently available, creating completeness uncertainty in the analysis. The Fire PRA resolves this uncertainty using the scenario definition and target mapping within the Fire PRA to conservatively compensate for the lack of information. In all cases conservative ZOIs are used to address radiation and plume fire damage ensuring that a conservative target impact set is generated for each scenario regardless of the scenario type or fire initiator.

For uncertainties specifically involved with ignoring the contents of a compartment, there were several areas of conservatism that mitigate the reduction in volume in HGL calculations. The following assumptions were utilized within the fire modeling which lead to conservatism or reduced the impact of ignoring the contents of a compartment in the fire modeling analysis:

- If equipment was included in HGL calculations, a large heat sink was provided in the fire compartment, which would have generated lower HGL temperatures.

- No heat passage through fire doors or dampers was considered in the HGL temperature calculations. The material properties of concrete were applied to all exterior boundaries of the fire compartment. Realistically, the heat from the HGL would be transferred to adjacent spaces more easily by a door or fire damper, which have a higher thermal conductivity than concrete. Including these passages to adjacent compartments would have generated lower HGL temperatures.

- Although obstructions within the room could reduce the effective volume when analyzing HGL temperatures, many of these obstructions (e.g., electrical cabinets, transformers) are not totally solid obstructions. Electrical cabinets are generally not full of electrical components on the inside (i.e., they have large empty spaces within the cabinets). These empty spaces within the electrical cabinets reduce the impact of including obstructions for HGL temperature calculations.

- The volume of some fire compartments was reduced in the DCPP fire modeling analysis to meet the validation range for compartment aspect ratio. For fire compartments having an aspect ratio outside the validated range where detailed fire modeling was performed and whole room damage was not postulated, the height, length, or width of the fire compartment was "shortened" to values that fall within the validation range. Shortening the dimensions of the fire compartment decreases the overall volume of the compartment and creates a more severe condition. The reduction in volume in these compartments bounds the obstructions that were not considered.

Completeness associated with fire models is addressed in the Fire PRA within the overall quantification process, as the PRA is an integrated analysis. Fire Modeling provides inputs to a broad comprehensive Fire PRA which includes modeling of electrical systems, operator actions, and the plant systems and components needed to shutdown the plan. One of the first steps in the fire modeling process is to identify the fire scenarios that will be analyzed. In some situations, the scenario analysis invokes fire modeling capabilities that are not currently available, generating the completeness uncertainty situation described in the question. When the fire modeling does not provide a full answer or an answer with sufficient resolution, the scenario definition and target mapping within the Fire PRA conservatively compensates for the lack of information. The Fire PRA allows the analyst to conservatively compensate for the lack of fire modeling capabilities outside the fire modeling analysis so that the scenario is properly modeled in the Fire PRA. Some examples are listed below:

- The determination of time to automatic suppression. The DETACT model is not fully applicable to many of the postulated scenarios; therefore, as part of the scenario definition, targets are failed intentionally before the automatic suppression is credited.

- Oil spill fires are difficult to analyze; therefore, full fire zones or transient zones have been assumed failed due to oil fires (e.g., Fire Zone T-3-A).

- Both zones of multi-compartment combinations are failed conservatively when fire modeling propagation calculations from one compartment to another are not conducted.

- Full main control board panels are failed due to the lack of analytical fire modeling methods, with appropriate verification and validation studies, to predict flame propagation within a panel.

The four examples above illustrate how the completeness uncertainty associated with fire modeling calculations is addressed "outside of the fire modeling" by conservatively failing targets in the fire scenarios so that the risk contribution is bounding.

NRC PRA RAI 1:

Section 2.4.3.3 of NFPA 805 states that the probabilistic safety assessment (PSA) (PSA is also referred to as PRA) approach, methods, and data shall be acceptable to the AHJ, which is the NRC. Regulatory Guide (RG) 1.205, "Risk-Informed, Performance-Based Fire Protection for Existing Light-Water Nuclear Power Plants," Revision 1 (ADAMS Accession No. ML092730314), identifies NUREG/CR-6850 as documenting a methodology for conducting an FPRA and endorses, with exceptions and clarifications, NEI 04-02, "Guidance for Implementing a Risk- Informed, Performance-Based Fire Protection Program Under 10 CFR 50.48(c)," Revision 2 (ADAMS Accession No. ML081130188), as providing methods acceptable to the staff for adopting a fire protection program consistent with NFPA-805. RG 1.200, "An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities," Revision 2 (ADAMS Accession No. ML090410014), describes a peer review process utilizing an associated ASME/ANS standard (currently ASME/ANS-RA-Sa-2009) as one acceptable approach for determining the technical adequacy of the PRA once acceptable consensus approaches or models have been established for evaluations that could influence the regulatory decision. The primary result of a peer review are the F&Os recorded by the peer review and the subsequent resolution of these F&Os.

Please clarify the following dispositions to fire F&Os and Supporting Requirement (SR) assessment identified in LAR Attachment V that have the potential to impact the FPRA results and do not appear to be fully resolved:

a) ES-81-01-2008, ES-81-02-2008, and CS-A11-01-2008 (Lack of cable routing) These F&Os observe that a number of plant systems were not modeled (i.e., were assumed failed) due to lack of cable routing information. The analysis identifies eight systems not credited (i.e., 500kV back-feed, 12kV non-essential power, Anticipated Transient Without Scram Mitigating System Actuation Circuitry (AMSAC), Instrument Air, Feedwater and condensate systems, containment fan coolers, containment spray, and make up to refueling water storage tank from the fuel pool). The disposition to this F&O explains that exclusion of these systems is justified because of their low significance to the Internal Events PRA (IEPRA), and due to the results of a sensitivity analysis. The results of the sensitivity analysis shows that the impact of modeling these excluded systems is an increase of 6 percent (%) in core damage frequency (CDF). The sensitivity study does not present the impact on the delta (Δ) CDF and ΔLERF of modeling these systems. Explain whether conservative modeling of the compliant plant underestimates the risk contribution to ΔCDF or ΔLERF. If so, remove this conservatism as part of the integrated analysis performed in response to PRA RAI 3.

b) CS-A6-01-2008 (Inadequate circuit protection on non-safety buses D and E) The disposition to this F&O states that cable protection was found to be inadequate for non-safety related buses D and E (in both Units), and so modeling impacts of those circuits was reviewed. The analysis presents the results of a sensitivity study demonstrating that the risk associated with these circuits is small (i.e., the increase in CDF was shown to be 1.8E-7/year for Unit 1 and 1.3E-7/year for Unit 2), and as a result, these scenarios were excluded from the FPRA. Describe the method that will be put in place to ensure that the failures associated with these common enclosure related circuits will be modeled in the FPRA before using the FPRA for self-approval as requested in PRA RAI 3.b.

c) CS-A7-01-2008 and CF-A1-03-2008 (3-phase hot short)
The disposition to F&O CS-A7-01 (2008) states that valves 8701 and 8702 are considered "High Consequence" components and so hot short analysis was performed. The response to F&O CF-A 1-03 (2008) clarifies that modeling failures induced from 3-phase hot shorts for valves 8701 and 8702 are excluded from the FPRA based on low frequency of occurrence. Section 9.5.2.2 of NUREG/CR-6850 explains that the likelihood of a grounded 3-phase proper polarity hot short is low and can be screened from the FPRA as less than 1E-7/year, per Section 2.5.6 of NUREG/CR-6850. However, this same guidance also states this failure mode on an ungrounded system cannot be screened as being less than 1 E-7/year. Explain whether the electrical circuits for valves 8701 and 8702 are part of a grounded or ungrounded system. If they are part of an ungrounded system, provide justification for screening these failures and explain whether other such fire-induced failures on ungrounded systems were excluded from the FPRA.

d) CS-A8-01-2008 (Thermoset versus thermoplastic cable)
The disposition to F&O CS-A8-01 states that fire modeling of all fire areas containing thermoplastic cables was updated since the peer review to incorporate guidance from NUREG/CR-6850 related to material properties for thermoset and thermoplastic cables. The extent of thermoplastic cables was estimated in the analysis and used to update treatment of cables as FPRA targets, secondary combustibles, and ignition sources. It is not clear from the disposition to this F&O whether a distinction was made in the circuit failure analysis between thermoset and thermoplastic cables. Describe what update was made to the FPRA related to cable type since the peer review and whether it is consistent with guidance in NUREG/CR-6850 or other NRC guidance. Include in the description any changes made to the way circuit failures probabilities were determined.

e) PRM-C1-01-2010 (Modification credit)
This F&O observes that at the time of the 2010 peer review there was no description of modifications credited in the FPRA. LAR Attachment S, Table S-2, lists five modifications and indicates that all five are credited in the FPRA for "medium" or "high" contribution to risk reduction. Confirm what modifications are credited in the FPRA, and indicate which are associated with resolving a VFDR and which are non-VFDR modifications that reduce risk.

f) PRM-C1-02-2010 (RCP seal modification)

This F&O observes that installation of high temperature reactor coolant pump (RCP) seals does not exclude the possibility that RCP seals will fail, and that modeling of RCP seal failure and operator actions to trip the RCPs should be added to the FPRA model. LAR Attachment S, Table S-2 indicates that risk reduction credit is taken in the FPRA for "RCP seal cooling modification," but does not indicate what type of seal will be installed. The disposition to this F&O explains that the seal modeling was modified based on guidance in WCAP-17100-P, Supplement 1 (PRA Model for the Westinghouse Shut Down Seal (SDS)), and WCAP-17541-P (Implementation Guide for the Westinghouse Reactor Coolant Pump SHIELD Passive Thermal SDS). This implies that the new seals will be the Westinghouse RCP SHIELD Passive Thermal Shutdown Seals (SDSs). Given recent concerns about the operation of new Westinghouse RCP shutdown seals during post-service testing (see Westinghouse letter, L TR-NRC-13-52, from James Gresham to NRC dated July 26, 2013, "Notification of Potential Existence of Defects Pursuant to 10 CFR Part 21"; ADAMS Accession No. ML 13211A168), the risk reduction credit shown in LAR Attachment W, Tables W-4 and W-5 for upgraded RCP seals may be optimistic. Describe the RCP seal modification that will be performed, discuss the credit taken in the FPRA for the modification, and the technical basis for that credit (e.g., technical report submitted to or approved by the NRC) in the response to PRA RAI 3. If a technical report is the basis, compare the seal modification and credit taken with the seal addressed in the report and the associated modeling guidance.

g) FSS-A1-01-2010 (Electric distribution panels)
This F&O observes that the electrical distribution panels were "typically" excluded from fire modeling because fires in these panels are not expected to propagate beyond the ignition source. Guidance in Section 6.5.6 of NUREG/CR-6850 indicates that electrical cabinets with circuits less than 440 volts meeting the definition of a "well-sealed' cabinet, or simple wall-mounted panels housing less than four switches can be excluded from the counting process. Explain whether the electrical distribution panels that were excluded meet one of the above criteria. If electrical distribution panels were excluded that do not meet these criteria, explain whether fire propagation could lead to further target damage than is currently addressed by the FPRA. If further target damage is possible, estimate the impact of this damage on CDF, LERF, ΔCDF, and ΔLERF and include this impact in the integrated analysis performed in response to PRA RAI3.

h) FSS-B1-01-2008 (MCR abandonment scenario)
The disposition to this F&O explains that based on their significance to the overall fire risk, the MCR abandonment scenarios were screened. The analysis indicates, though it does not seem to be directly stated, that credit for MCR abandonment is considered only for loss of habitability (i.e., is not credited in non-habitability scenarios in which fire-induced failures lead to loss of control from the MCR). The analysis also present the basis for screening the abandonment scenario on low frequency and shows that even if the conditional core damage probability (CCDP) associated with failure to successfully perform shutdown from the Hot Shutdown Panel (HSDP) is

conservatively set to "1.0" that the CDF associated with MCR abandonment is only 5.98E-8/year. The staff noted that a factor in this determination is the assumption that the unavailability of the smoke purge system is "approximately 1 E-3" for scenarios outside the MCB, which seems low. The staff also noted that the basis for this assumption is not provided, and it is not clear whether this assumption considers out-of-service time for test, maintenance, or repair. Another factor presented in the analysis is that probability of abandonment for transient fires is zero. Though the basis may be explained elsewhere, the reason that transient fires do not contribute to MCR abandonment does not seem to be explained in this report. Provide the basis for the assumptions made about the smoke purge system, and explain whether transient fires were modelled in the MCR and whether they lead to MCR abandonment. If abandonment due to loss of habitability is credited, describe and justify the approach.

i) FSS-C8-01-2008 (Credit for fire wrap)
The disposition to this F&O states that fire wrap is credited in the FPRA which is consistent with LAR Table 4-3 that indicates ERFBS are credited in a number of fire areas for risk reduction. The disposition to this F&O does not provide technical justification for the fire wrap qualification as requested by the F&O.

Provide technical justification of the qualification for fire wrap credited in the FPRA for risk reduction.

j) FSS-D7-01-2010 and FSS-E2-01-2010 (Detection and suppression system availability)
F&Os FSS-D7-01 and FSS-E2-01 ask about the basis for the unavailability assumed for fire detection and suppression systems. The dispositions to these F&Os explain that review of plant-specific test and maintenance data did not reveal outlier behavior for the Cable Spreading Room (CSR) fire detection or fire suppression system. It is not clear that data limited to the CSR can be generalized to the balance of the plant. As requested by F&O FSS-D7-01, provide the results of review of plant-specific maintenance and testing data for fire suppression and detection systems credited in the FPRA that characterize the unavailability's of these systems and confirm there are no outliers.

k) FSS-E3-01-2008 (State of Knowledge Correlation)
This F&O cites the lack of qualitative or quantitative uncertainty analysis associated with fire modeling and accident sequence analysis. The F&O disposition explains that since the 2008 peer review, the analysis has been completed that provides qualitative and quantitative characterization of uncertainty and that the analysis discusses the state of knowledge correlation (SOKC) and indicates that SOKC needs to be considered for fire ignition frequencies. The analysis also states that the SOKC was taken into account for fire ignition frequencies and also indicates that the uncertainty of internal events component failure probabilities, circuit failure likelihood, and non-suppression probabilities were treated quantitatively, but does not indicate that

SOKC was taken into consideration. If SOKC for these parameters was not accounted for in the FPRA quantification, then address SOKC for these parameters in the integrated analysis performed in response to PRA RAI 3.

l) HRA-C1-01-2010 (Minimum joint Human Error Probability)
The disposition to this F&O explains that since the 2010 peer review, an updated human reliability analysis (HRA) dependency analysis was completed. The NRC staff noted that the analysis does not indicate that a minimum joint Human Error Probability (HEP) was applied to the dependency analysis. Per guidance in NUREG -1921, "EPRI/NRC-RES Fire Human Reliability Analysis Guidelines Final Report," the Human Failure Event (HFE) dependency analysis should consider the minimum joint value (i.e., floor) for multiple HFEs occurring in the same cutset. Explain whether a "floor" was applied in the HFE dependency analysis, and if so, identify the floor used and justify any value used less than 1 E-5. If a "floor" was not used, apply a floor to the HFE dependency analysis as part of the integrated analysis performed in response to PRA RAI 3, and justify the value used.

m) MU-A1-01-2008 and MU-A2-01-2008 (Procedure improvement completion)
F&O MU-A1-01 (2008) observes that the PRA administrative procedure focuses on internal events, and therefore needs to be updated to address the FPRA per the guidance in the PRA Standard. F&O MU-A2-01 (2008) observes that the licensee's procedure does not require monitoring changes in PRA technology and industry experience. The disposition to these F&Os explains that "DCPP Procedures AWP E-028 and TS3.NR1 will provide the overall program of the PRA model maintenance and upgrade." Though implementation Item S-3.26 of the LAR commits to new plant administrative procedure AWP E-028 for scheduling updates and controlling associated models and files, there does not appear to be a process for updating the applicable administrative procedures. It is not clear whether improvements to the applicable administrative procedures have been performed yet. Explain whether the cited improvements to the administrative procedures have already been performed or are included in an existing implementation item listed in LAR Attachment S, Table S-3. If the cited improvements have not yet been made and are not described in an existing implementation item, then discuss the method to ensure that the cited improvements in FPRA procedure TS3.NR1 will be made before it is used as a basis in self-approval of post-transition changes.

PG&E Response:

a) Eight (8) systems or functions were not credited in the Fire PRA because of low fire risk importance or based on a low-frequency argument as illustrated in Section 2.5.1 of NUREG/CR-6850.

Each system or function has been evaluated to determine whether conservative modeling (i.e., guaranteed failure) in the compliant plant model underestimates the fire risk contribution to ΔCDF or ΔLERF by reviewing its relationship to the SSD logics and associated VFDRs under different failure modes (i.e., demand failure or spurious actuation). The evaluations are provided below.

Makeup to the Refueling Water Storage Tank from Spent Fuel Pool, 500 kV Back-feed, 12 kV nonessential power,

These systems or functions were screened from the Fire PRA because of their low fire risk importance as verified by the sensitivity analysis. They are not credited in the NSCA and there are no associated VFDRs. They provide no support function or reasonable alternate shutdown path to the credited SSD paths because of lengthy multi-step operator recovery actions outside of the MCR. Therefore, not crediting (i.e., assumed failure) of these systems or functions in both the compliant plant and VFDR models does not underestimate the fire risk contribution to ΔCDF or ΔLERF. The current modeling of these systems or functions by setting them to fail will not be changed as part of the integrated analysis being performed in response to PRA RAI-03.

Anticipated Transient Without Scram Mitigating System Actuation Circuitry (AMSAC)

Section 2.5.1 of NUREG/CR-6850 identifies anticipated transient without scram (ATWS) sequences as a candidate for exclusion from the Fire PRA considering its low frequency event and small contribution to fire risk. The AMSAC, which is a mitigating system for ATWS sequences, is also excluded from the Fire PRA. The AMSAC generates a start signal of all three AFW pumps (2 motor driven and 1 turbine driven) redundant to other multiple diverse auto-start signals such as low SG levels, transfer to emergency diesels, trip of Main Feedwater Pumps, Safety Injection signals, and 12 kV bus undervoltage. With such redundancy and diversity in auto-starting signals of the AFW pumps, the AMSAC regardless of its availability has minimal contribution to fire risk of either the compliant plant or VFDR models. Therefore the difference in ΔCDF and ΔLERF, whether they were estimated with the AMSAC being available or unavailable in the compliant plant model, would be insignificant. Therefore the current modeling of not crediting the AMSAC in the Fire PRA will not be changed as part of the integrated analysis being performed in response to PRA RAI-03.

Instrument Air

The key support functions of the IAS are the RCS overpressure protection and F&B via the RCS PORVs. Two out of three RCS PORVs (i.e., RCS-PCV-455C and RCS-PCV-456) are equipped with high pressure backup nitrogen bottles to allow continued function without the IAS. RCS-PCV-474 has no high pressure backup bottle and fails closed on loss of the IAS to Containment. The dependency of RCS-PCV-474 on the IAS significantly impacts the reliability of the F&B function, especially in fire events. Given that the success criteria for the F&B requires at least two RCS PORVs and the unavailability of RCS-PCV-474 due to assumed guaranteed failure of the IAS, fire-damage to one of the remaining PORVs would disable the F&B function. This dependency has less impact on the RCS overpressure protection functions since the loss of this function requires failure of both remaining RCS PORVs.

For those fire scenarios impacting either RCS-PCV-455C or RCS-PCV-456, the conservative modeling of the IAS by assuming a guaranteed failure of the system in the Fire PRA could underestimate the risk importance of the F&B function. This results in a higher fire risk (CDF and LERF) estimate as compared to that of the compliant plant model without the conservative modeling. Therefore, the current modeling of the IAS has the potential to underestimate the fire risk contribution to ΔCDF and ΔLERF and will not be set to always fail in the compliant plant model as part of the integrated analysis being performed in response to PRA RAI-03.

Main Feedwater and Condensate

The primary function of the Condensate and Main Feedwater system is to provide feedwater flow to the SGs in the event that the AFW system is unavailable after a plant trip. This function is not credited in the NSCA and there are no associated VFDRs.

The secondary cooling function provided by the AFW system is a risk important function. For fire areas such as the motor driven or turbine driven AFW pump rooms, a fire could disable the AFW function, elevating the risk importance of the alternate secondary cooling function provided by the Condensate and Main Feedwater systems. Therefore, the current modeling of always failing the Condensate and Main Feedwater system could underestimate the fire risk contribution to ΔCDF and ΔLERF. As such, they will not be set to always fail in the compliant model as part of the integrated analysis being performed in response to PRA RAI-03.

In addition, the Fire PRA modeled the overfill of the SGs and subsequent loss of the turbine driven AFW pump due to fire-induced spurious actuation of the MFW regulating and bypass valves. Because this failure mode could lead to a VFDR, it was already included in both the compliant plant and variant models.

Containment Fan Cooler Units (CFCUs), Containment Spray (CS)

The primary function of the CFCUs and CS is to control the Containment environment (i.e., temperature and pressure) following a LOCA or steam line break within the design limit of the Containment structure.

The CFCUs and CS do not provide a direct core damage mitigating function but do have an impact on LERF. Not crediting (i.e., assuming failure of) the CFCUs and CS in the Fire PRA model could underestimate the fire risk contribution to ΔLERF and will not be set to always fail in the compliant plant as part of the integrated analysis being performed in response to PRA RAI-03.

A spurious actuation of the CS pump(s) concurrent with its respective discharge valve(s) could lead to an inadvertent drain down of the RWST, which affects either the availability of the RWST or the time available for manual switching over to the containment recirculation function. Because this failure mode could lead to a VFDR, it was already included in both the compliant plant and VFDR models.

Summary

In summary, the current modeling (i.e., guaranteed failure in fire events) of the following systems or functions will be removed from the compliant plant model as part of the integrated analysis being performed in response to PRA RAI-03.

- Instrument Air system
- Main Feedwater and Condensate system
- Containment Fan Cooler Units
- Containment Spray system

The current modeling of the remaining systems or functions will not be modified in the compliant model.

b) Subsequent to identification of Peer Review Finding CS-A6-01-2008 a detailed assessment of electrical protection and coordination was performed and documented in Design Calculation 90000041048, Revision 1 (Legacy No. 134A-DC-T). This assessment was performed in 2012 and includes 4.16 kV nonsafety Buses D and E for both units. The 2012 calculation includes a more comprehensive treatment of electrical protection for nonsafety Buses D and E than existed at the time of the peer review finding in 2008. The calculation considers both primary and backup overcurrent protection for the buses, unlike the original analysis which only considered primary load protection.

The calculation determines that electrical protection device settings for Units 1 and 2 4.16 kV nonsafety Buses D and E provide adequate protection against common enclosure associated circuits. The calculation also investigates the fire-induced loss of control power for circuit breakers associated with 4.16 kV nonsafety Buses D and E, which is the cause for potential inadequate cable protection as identified in the F&O disposition. This aspect of the associated circuits analysis confirms that primary and/or backup overcurrent protection will remain available for credited power lineups to provide adequate overcurrent protection for 4.16 kV nonsafety Buses D and E load cables such that fire-induced short circuits do not pose a secondary fire concern, with the exception of two locations for Unit 1. The analysis shows that two (2) Unit 1 load cables for Bus D and two (2) Unit 1 load cables for Bus E could pose common enclosure concerns in Fire Areas 4-A and 5-A-4. No exceptions were identified for Unit 2; primary and/or backup protection for credited power system lineups remain available for all cases.

Further scenario development for the four potential common enclosure cables in Unit 1 Fire Areas 4-A and 5-A-4 indicates that no credible fire in these locations will cause a secondary fire with the potential to damage fire PRA cables or equipment beyond that included in the existing Fire PRA circuit analysis and Fire PRA model.

Results of the detailed scenario assessment for the four potential common enclosure cables in Unit 1 will be documented in PRA Calculation File F.3.5, "Development of Fire-Induced Risk Model." This assessment will supersede the sensitivity study referred to in LAR Attachment V, and represents the method by which these results are formally controlled as input to the model. The disposition of LAR Table V-2, SR CS-A6, page V-15, is revised as follows:

> Section 7.4.2 of Design Calculation 90000041048 Revision 1 (Legacy No. 134ADC-T), summarizes the common enclosure analysis documented in Appendix I. The summary of results found adequate cable protection for the credited electrical power system lineups with the exception of two locations for Unit 1. The analysis shows that two (2) Unit 1 load cables for nonsafety 4.16 kV Bus D and two (2) Unit 1 load cables for nonsafety 4.16 kV Bus E could pose common enclosure concerns in Fire Areas 4-A and 5-A-4. Further scenario development for the four (4) potential common enclosure cables in unit 1 Fire Areas 4-A and 5-A-4 indicates that no credible fire in these locations will cause a secondary fire with the potential to damage Fire PRA cables or equipment beyond that included in the Fire PRA circuit analysis and Fire PRA model.
>
> The current analysis of associated circuits conforms to the approved methods of NUREG/CR-6850 and Fire PRA FAQ 13-005. The impacts of these failures are captured in the current Fire PRA circuit analysis and Fire PRA model, and will thus be included in the integrated requantification to be conducted in support of PRA RAI-03. Since all impacts associated with the common enclosure concern for the 4.16 kV nonsafety Buses D and E (Units 1 and 2) are already accounted for in the current Fire PRA model, no further model updates are necessary before using the Fire PRA for self-approval, as requested in PRA RAI-03.b.

c) RHR Valves 8701 and 8702 are powered from a 480 V ungrounded three-phase system. In accordance with the criteria in Section 9.5.2.2 of NUREG/CR-6850, these valves cannot be immediately screened because they are: (1) classified as "High Consequence" components, and (2) they are powered from an ungrounded power system. In considering further the failure of these valves due to three-phase proper polarity hot shorts, DCPP performed a plant-specific assessment of the fire-induced failure probability and concluded that the probability was below the screening criteria established by NUREG/CR-6850. On this basis RHR Valves 8701 and 8702 were screened.