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General Comment

Entergy is submitting this letter in response to the Nuclear Regulatory Commission's (NRC's) request for comments concerning Draft "NUREG-1934 (EPRI 1019195), Nuclear Power Plant Fire Modeling Application Guide (NPP FIRE MAG), Draft Report for Comment." These comments have been developed and assembled by the Electric Power Research Institute (EPRI) in collaboration with utility engineers and other industry experts. Please consider them as an addition to our previous submittal.

Attachments

NRC-2009-0568-DRAFT-0009.1: Comment on FR Doc # 2010-02168

SUNSI Review Complete
Template = ADM-013

E-RIDS = ADM-03
Add = D. Stroop (dsw4)

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---- April 30, 2010 ----

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Rulemaking and Directives Branch
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Subject: Docket ID NRC-2009-0568 - Response to Request for Comments Concerning Draft NUREG-1934 (EPRI 1019195), "Nuclear Power Plant Fire Modeling Application Guide (NPP FIRE MAG), Draft Report for Comment." (Federal Register Notice 74 FR 68873, dated January 26, 2010)

Entergy is submitting this letter in response to the Nuclear Regulatory Commission's (NRC's) request for comments concerning Draft "NUREG-1934 (EPRI 1019195), Nuclear Power Plant Fire Modeling Application Guide (NPP FIRE MAG), Draft Report for Comment." These comments have been developed and assembled by the Electric Power Research Institute (EPRI) in collaboration with utility engineers and other industry experts. Please consider them as an addition to our previous submittal.

The U.S. NRC Office or Regulatory Research (RES) and EPRI have been working on a collaborative effort to develop guidance for use of fire modeling in nuclear power plant applications. We understand that these and other submitted public comments will be considered in finalizing the subject draft document.

Entergy appreciates the opportunity to provide these comments on draft NUREG-1934. While there is already a great deal of useful information in the draft NUREG document, Entergy believes that the document can benefit significantly through consideration of the attached comments prior to its publication as an aid to the nuclear power industry.

If you have any questions or require additional information, please do not hesitate to contact Mr. Pablo Guardado via telephone at (601) 368-5713 or via email at pguarda@entergy.com.

Pablo Guardado

General Comments

1. Overall the Fire Modeling Applications Guide does not contain sufficient guidance for a non-expert to perform fire modeling. It is suggested that the guidance be improved to include steps including typical tools, considerations in fire modeling, cautions and limitations as well as typical input and outputs. If the use of non-expert is not the intent of the NUREG than that should be made clear as well as the types of potential users the document was developed for.

2. In overview, the guide is a collection of relatively good, but simple, examples. These are useful but could be improved by the addition of more complex examples that maybe experienced in the development of a PRA.

3. Typically the goal of fire modeling in support of the fire PRA is the determination of damage and the timing of that damage. Some characterization of the sensitivity of these models and their usefulness in this mission should be provided. (It is recognized that some of this information is available in detail in others sources but summary information would be useful if repeated here).

4. Section 6 is devoted to PRA. This section is quite dated and should, at a minimum, be updated to include the current state of practice in risk informed regulation and the current utility PRAs. It should also be considered whether this section is necessary or could be replaced with a good introductory section.

5. A good introductory section would be a significant improvement to this document. The introductory section could include the goals and objectives of this report, the connection of this body of work to other work such as the Fire V&V report, NUREG/CR-6850, NUREG-1921 and others, and a summary of the uses or conclusions of this report.

6. The report does not provide a significant explanation of the basis and methods used to address the uncertainty which is depicted in Figure 6-2. Given the lack of discussion in the report it is not clear that current proposed method is an acceptable approach. More basis and documentation is required to substantiate the method and illustrate its use the treatment of fire modeling uncertainties in a typical fire PRA.

7. The purpose of the document should be clarified and expanded upon in the first or second chapter. On the one hand it attempts to be a general fire modeling process-technique guide and on the other hand it is attempting to provide specific guidance to address detailed fire modeling tasks in support of a fire PRA developed in accordance with NUREG 6850. Suggest limiting the scope to fire modeling in support of Fire PRAs developed in accordance with NUREG 6850.

8. The development of the heat release rate is not described in great detail, even though this is probably the most influential input parameter for a given geometry for a fire modeling analysis. If the focus on this document is on the construction of a fire effects model, given a heat release rate, it should be clearly stated and some detailed references provided for assigning the correct heat release rate should be provided (this includes methods and data beyond the NUREG 6850 frequency bins). If it considered in the document scope to provide this type of guidance (which would increase the usefulness of the guidance), it would warrant a full subsection. Within this section, common fuel packages should be discussed and the techniques for assigning a heat release rate should be provided. These techniques should address factors such as the applicability limits of the NUREG 6850 frequency bins, the difference between free burn and enclosure burn test data, the estimation of cable tray heat release rates when the mass per unit area is known, the difference in confined and unconfined burning for hydrocarbons, the applicability of the cable

tray stack spread model in NUREG 66850, etc. A table linking the NUREG 6850 Appendix E scenarios to specific common nuclear fuel packages with specific limits would be most beneficial. Complicating factors such as fire elevation, panel burning, vent plumes, proximity to entrainment limiting boundaries (walls and corners) would also be suggested for inclusion. Appendix D of NEI 04-02 provides some discussion on the development of the heat release rate input parameter and it could be used as a starting point for this type of discussion.

9. The fire modeling process should include a step dealing with interpretation of the model results both in terms of verifying that the results are technically accurate and applying them to resolve an issue. Some elements of this step should include verifying that the heat release rate output matches that input; verifying that the mesh resolution in FDS is reasonable; verifying that devices and targets are located where intended; and verifying that the model is not predicting conditions that lie outside its basis. For FDS, it should be verified that the heat of combustion computed by FDS (if not entered by the user) is reasonable or that the heat of combustion per unit mass of air consumed is about 13.1 MJ/kg.

10. Section 2.3, general. Suggest providing a concise tabular summary of the fire models. Included in this summary would be the level of input and output detail, the recommended applications, the strengths, and weaknesses.

11. The examples provide a significant amount of redundant information, both in Section 3 and in the appendices. If some of the comments regarding streamlining the process and technique discussions are incorporated, this could free up space and effort to focus on the key aspects of the scenarios that should be illustrated. In addition, a greater number of examples could be provided. One possibility would be to develop a fire modeling cross-index table, which would contain among other things a problem class and a recommended solution strategy (see related comment on fire model applicability table). The examples in the appendix could focus on a single problem class – solution strategy (i.e., model approach). The appendix could highlight the specific nuances of modeling the class of problem with the particular tool, emphasize where the tool becomes invalid, and provide guidance on the types of output generate, how to use it, and any sensitivity that would need to be conducted for the given input set. Scenario complexities could be provided as variants to the problem class (i.e., fire burning in a corner configuration; secondary ignition treatment; detection/suppression). As Chapter 3 and the appendices are presently structured, much of this gets lost in the attempt to keep track of the three different model class input and provides information that is too broad. It would seem that the essence of a fire modeling guide would be to show the user how to take some configuration, apply certain assumptions, run the model, interpret the results, be assured they are operating within acceptable model bounds, and provide options or a path forward if the results are too conservative or they are not within bounds.

12. There are no examples provided of a multiple fire object scenario, though several scenarios involve a cable tray. These scenarios introduce complications such as the ignition time of the secondary object and the correct the fire elevation to assume (if combined into a single fire source: transient that ignites a cable tray).

13. Suggest providing the input files for the zone model and CFD models.

14. Appendices. The document frequently states when developing the model that "it is assumed that ..." For example, it is assumed that "none of the panels open during the fire," or "it is assumed that the properties are X," or "it is assumed to be X m thick", or "cable fire spread is assumed to

be X mm/s". The assumptions are a mix of true assumptions given an input and assumed input for convenience of illustrating a point. Suggest presenting the examples clearer to indicate what is truly an assumption, what the basis is for the assumption, and the potential implications. These assumptions provide key insight into knowledge limits and recommended strategies for the given fire modeling tools. Suggest making all assumptions that are just for convenience "given input" so as to allow the user to focus on the real issues.

15. The examples should provide a step where the results are checked to verify they are correct and within bounds of the model basis. For example, it should be verified in Appendix C, E, and F that the hot gas layer temperature would not invalidate the localized temperature (flux and plume) predictions of FDTS. At least one of the FDS simulations should provide a grid sensitivity study example. The volumetric flow rates in the MCR abandonment example predicted by the zone models should be compared against the input values.

16. Section 2.6. The documentation should include an approach and model justification, the model and model revision being used, and input and output files or data should be provided in the attachments.

17. Appendix B, Section B.6.2 (and other examples with plume/flux development and a hot gas layer formation). The interaction of a hot gas layer and a thermal plume model is not described for the spreadsheet type models (FDTS in particular). As a minimum, a step should be included to verify that the hot gas layer temperature would not substantially affect the target temperature, target heat flux, or detection time.

18. Section 3, Table 3-1, Scenario 5 (and elsewhere). The control room abandonment calculations are not standard tenability computations (life safety implication). Rather, they are habitability calculations. The abandonment models assumed operators remain at their stations for conditions that are far worse than is typically assumed for egress and life safety. They are also assumed to don protective gear such that toxic products are not an issue.

19. Section 3.2.2, page 3-12, "Mechanical Ventilation." All sections relating to mechanical ventilation should address the effect of the mechanical ventilation system being unavailable due to random failure or consequential failure as a result of fire damage.

20. Fire PRA Application: The primary applications of fire modeling in Fire PRA are 1) using FDTs to predict zone-of-influence, 2) determining time to target damage / HGL for non-suppression probability calculation, and 3) determining MCR abandonment times. Consider adding some discussion and guidance on each of these elements (i.e., what tools to use, how to do it, what are the limitations, etc.).

21. Chapter 2: A standard checklist or template might help in the step by step application to prompt the user to the next step in the method. User could always refer back to the text for further explanation. Would be nice to make it easier for the user to implement and may help to standardize the documentation package.

22. Chapter 3, Input Values: Where do we find the input values for typical NPP targets, boundary materials, intervening combustibles, smoke obscuration factors, ignition thresholds, etc.? Are they generic or model specific?

General Comments

23. Chapter 4: When we did the FIVE method way back the idea was not to get caught up in calculating an exact number or time to damage. Calculations and models were used in a deterministic assessment of conditions that could lead to damage and possibly expose overriding or driving conditions that if changed or altered would reduce the exposure and risk. The models were intended as a risk informed tool to evaluate and consider the factors contributing to risk. An uncertainty or sensitivity analysis was intended to check the sensitivity of assumptions and inputs that drive the result. This would also require knowledge of the limitations of the models parameters and through the V&V how close the model represents reality. Iterations of the calculations changing key parameters or assumptions would provide a range of results and thereby test the sensitivity of application. The sensitivity of some of the parameters is highlighted in Table 4-1, 4-2 and 4-3 which is helpful insight when using the parameters and models and points out which parameters to focus on.

24. Chapter 4: Chapter 4 again seems to be a derivation of the procedure or methodology, but not a step by step guide for application. Although there are some good insights of the models and input parameters the derivation of the procedure doesn't lend itself to a clear step by step application.

25. Uncertainty in PRA is considered when best estimate calculations are performed. The use of calculations demonstrated to be conservative that still produce an acceptable conclusion do not require uncertainty evaluations. This type of approach is used in the internal event modeling of T/H codes. If the use of a conservative calculation does not affect the conclusions significantly, then the conservative calculations are used without uncertainty evaluations. As the provided approach seems quite complicated to implement (Sections 4 to 6), I would recommend at least as alternative approach identification what parameter/modeling adjustments are required to be made to ensure that the calculation bias identified in Table 4-1 is conservative. The uncertainty for each input parameter could then be characterized as to the degree of conservatism. A detailed uncertainty evaluation would only be required for Capability Category II (CCII) on only those risk significant threshold scenarios. If the CDF/LERF deltas and absolute numbers are acceptable using a conservative, then CCI would be acceptable for NFPA805 applications.

Specific Comments

1. Section 3.1.2, Page 3-5, Top of page (and elsewhere). The fire footprint information should include whether the fires are confined, unconfined (hydrocarbon fuels), the aspect ratio (rectangular), the burning orientation (horizontal or vertical).

2. Section 3.1.2, Page 3-5, top of page (and elsewhere). The heat release rate characteristics (actually the fuel and burning characteristics) should include whether the fire is ventilation limited (burning within a sub-enclosure), the type of fuel (wood based, polymer, melting, charring), and whether room effects could affect the burning rate. This information would be needed to determine whether a free burn, axisymmetric plume model is appropriate, for example, or if a burning vertical lining or a line type fire would be more appropriate.

3. Section A.4; page A-6, "Fire." Here and throughout electrical cabinet fires are assumed to decay in 12 mins. Whereas NUREG/CR-6850, Table G-2 derives a value of 19 mins.

4. Figure 2-1. The process diagram does not completely reflect the fire modeling process described. There is no iteration about the model selection. If the model is not suitable, a different model could be selected. Also, suitable results is ambiguous – desired answer or technically defensible or both?

5. Section 3-1. The information for each scenario is excessively redundant. Suggest providing a section of generic information and for each scenario describe which of the generic elements apply, what is unique about the scenario, and which models apply and over what range. The SFPE Engineering Guide to Predicting Room of Origin Fire Hazards (2007) provides a good fire modeling process overview and lists the various types of inputs necessary for different fire model classes. Suggest reviewing this document and making use of this type of presentation.

6. Section 2.4, Page 2-17, last paragraph. Suggest noting other post-processing software such as Techplot. Also should mention the availability of pre-processing software for FDS and the implications of using such software.

7. Section 3.1.2, page 3-4, 1st bullet. Reference is made to the peak heat release rates given in NUREG/CR-6850. These are generally given as probability distributions, so the guidance should explain which HRR value(s) should be used in the fire modeling. It only becomes apparent in the examples given in the Appendices that 98th percentile values are used.

8. Section 3.4.2, page 3-21, "Compartments with Complex Geometries." It should be noted here that CFAST does allow for changes in compartment cross-section.
9. Section A.4; page A-7, "Habitability." The heat flux and optical density criteria in NUREG/CR-6850 are both based on the values at 6 ft. above the floor. This should be checked throughout the Appendices.

10. Section A.5.1; page A-8, "General." It should be stated at what height relative to the flames the point source should be assumed to be (e.g. mid-height?).

11. Table 3-1: Scenario 1. Consider adding evaluation of target damage due to radiant heating. Although often the weakest damage mode, the calculated radioactive ZOI can be significant, especially for larger heat release rates. There are also some subtle issues with the applicability of the point-source model, which many/most plants are using for radioactive ZOI determination.

Specific Comments

12. Sections 2.3.3 and 2.3.4 describe the zone models CFAST and MAGIC, which are fairly similar models. Yet, the emphasis and content of each section are entirely different. Suggest aligning the two sections or describe zone models in general and then what is unique to CFAST and MAGIC in sub-sections.

13. All of the "yellows" in Table 2-3 should be explained in detail how to deal with the issues associated with the yellow finding. For example, if the FDT plume temperature under prediction can just be solved by using the HGL temperature as ambient, then that should be stated.

14. Section 2.2 and 2.3. These sections describe a process for identifying a fire scenario and selecting the proper tool for evaluation. The sections as written contain a number of useful insights but the reader may benefit by presenting the information in a different manner. The information is presented in an almost haphazard manner. Suggest reviewing the SFPE Engineering Guide to Predicting Room of Origin Fire Hazards (2007) and develop a presentation and level of detail that is similar, but adapted as necessary for nuclear power plant/NUREG 6850 based Fire PRA applications.

15. There are a number of sub-models used in the supporting examples that have not been through the NUREG 1824 V&V process, viz. those dealing with sprinkler actuation, smoke detection, and THIEF. Suggest including a section or expanding Section 2.3.6 to cover what is expected from the user when one of these sub-models are employed and provide a template process for this (ASTM E1355 via NUREG 1824).

16. Table 2-3. Some guidance should be provided on the use of parameters that are flagged as YELLOW and the expectation of the user when such a parameter is the desired output. Incorporation of this into one of the examples would also be helpful for illustrating the significance of a YELLOW vs. GREEN V&V result when used in an actual application.

17. Section 2.5 provides a high level discussion on sensitivity and uncertainty, but does not follow through with how it is used. In addition, if fire modeling is used deterministically, some discussion on an acceptable safety margin should be provided. In this regard, some discussion should be provided on how to use the V&V model uncertainty in a deterministic sense: should one assume the most appropriate input parameters and then conservatively reduce the threshold value based on some percentile of the results uncertainty or should one conservatively skew the input parameters and demonstrate that this exceeds the results uncertainty?

18. Appendix G, multi-compartment corridor. The zone model treatment subdivides the corridor into 8 spaces. However, subdividing volumes that do not have an actual flow resistance is not consistent with the zone modeling premise. The zone models will treat the flow connections as openings and introduce upper layer-lower layer mixing and will apply a flow coefficient. Three spaces should be used in this case: 1&2; 6; and 3-4-5-7-8. The effective dimensions of each enclosure should be determined using an effective length, width, and height.

19. Appendix D.5.2. The subdivision of the irregularly shaped compartment is not consistent with the zone modeling premise. A horizontal flow path that has an area on the order of the enclosure floor area is not representative of the smoke filling that would occur. Suggest either using the variable cross-sectional feature (in CFAST) or treating the high portion (from floor to ceiling) of the space as one enclosure and the low portion of the space as a second enclosure.

Specific Comments

20. Section 2.3.6, Page 2-14, fourth paragraph, last sentence. This does not logically flow. FDS can predict localized effects (fluxes distributions on surfaces, exposure temperatures, flow fields) but the resolution required for such a calculation may be considerably greater than if one were interested in the bulk smoke flow and layer formation in a large space. FDS is also limited to one-dimensional heat transfer, so localized effects that have significant lateral heat dissipation would not necessarily be treated more accurately. The emphasis of the fourth paragraph appears to be on the general fire environment in the enclosure and not on localized fire effects.

21. Appendix B-7 Fire/Smoke Detection. The smoke detector model of Alpert is correlates smoke detector actuation to a 10°C temperature increase in the plume/ceiling jet as noted on Page B-6. This model is crude and would be affected by obstructions and the assumed fire location (top of panel, at vent, at floor). Suggest using the appropriate temperature differential and noting the intricacies of using this type model. It has also not been through the V&V process. Suggest using the obscuration density for the zone models since it is a known input.

22. Section 3.1.2, Mechanical ventilation. Suggest describing soot loading on filters, especially HEPA filters, fan performance, maintained pressure differentials, and recirculation type systems.

23. Section 3.1.3, modeling strategy. Suggest including a step to determine if the fire in the cable tray should be treated as a second separate burning object or the heat release rates can be consolidated.

24. All sections "Natural Ventilation: Horizontal Openings". More detailed consideration and guidance is required for modeling horizontal openings. The MQH correlation for calculating room temperature is strictly only applicable to natural ventilation through vertical openings and it is not clear whether two-zone methods always model these correctly either, depending on whether or not in-leakage paths exist.

25. Section 3.2.2, page 3-10, "Intervening Combustibles." What is the basis for the statement "In most cases, commercial nuclear plant fire scenarios do not require modeling of burning targets..."? Burning targets would increase the total HRR and could therefore cause damage to other targets further away. The guidance should address fire propagation to all combustibles, potentially within an expanding zone of influence.

26. Section 3.3.3, page 3-18. This section should include a strategy for screening compartments that cannot cause damage to targets in adjacent compartments.

27. Section 4.1, page 4-2. The guidance doesn't consider the overall effects of model uncertainty on the probability of target damage as it presumes that only one of the quantities in Table 4-1 need be considered in any given situation. It could happen that different quantities could affect the probability of damage to a particular target, depending on a combination of factors.

28. Section 4.3, page 4-5. The guidance doesn't explain how uncertainties in more than one input are combined.

29. Section 4.3, page 4-6. It is considered that the treatment in Section 4 generally is too simplistic to reliably predict the uncertainty in target damage probability, given the complexity of a fire model and the interaction of all the modeling and input uncertainties. Indeed, it is conceded at the end of this section that it should be used with caution for the reasons stated, but what is the alternative if caution dictates that the method is not applicable to a given situation? It is

suggested that Monte Carlo simulation is the only practicable and reliable means of treating fire modeling uncertainty and this should be advocated in the guidance.

30. Section 6.5.2, page 6-10. The guidance doesn't explain how the uncertainty bounds shown in Figure 6-2 would be determined. It is suggested that, realistically, these could only be derived using Monte Carlo simulation.

31. Section E.4; page E-5, "Fire," 2nd paragraph. The guidance should include the modeling of cable tray ignition as it would be in a real application.

32. Section H.5.2; page H-6, "General." When the curvature is small, could the annulus not be considered in a two-zone model as a rectangular volume with length equal to the circumference? This would ensure that, for large fires, HGL formation is properly accounted for.

33. Section H.5.2; page H-6, "Cables." It is considered unrealistic not to consider propagation and spread of fire in the adjacent cable tray.

34. Section 1.2, page 1-2, end of first full paragraph. The discussion talks about an approach for incorporating fire modeling results probabilistically, and uses probability of sprinkler activation before target damage as an example. Given the other issues noted in this set of comments, it is not clear that this document adequately develops an approach to achieve this objective.

35. Section 2.2, page 2-2, second paragraph. The discussion for LFS states that it "... should remain with the range of probability ...," but later also states that it can "exceed values expected to be likely or even probable." This inconsistency results in a set of guidance for LFS that is not consistent with the requirement of 10 CFR 50.48(c).

36. Section 2.2.1, page 2-3, second bullet. The discussion that is provided seems to suggest that realistic treatments should be altered if no adverse impact result by creating a more conservative or bounding treatment. This could be incorrectly interpreted to mean that the risk assessment should be based on bounding and/or conservative with an ultimate goal of generating an adverse consequence.

37. Section 2.3.1, page 2-6, last paragraph. Since the purpose of this document is to provide practical guidance using tools acceptable to the AHJ, is the use and discussion of THIEF in this document to be taken that it is approved by the AHJ to the same degree that other tools have been approved via NUREG-1824?

38. Section 4.3, page 4-5. Is the discussion and example presented intended to be applied as described? It's presence in this document would practically mean that the concept of using mean values and the associated distribution function for HRR in lieu of the values and guidance in NUREG-6850 has been approved by the AHJ.

39. Section 5.4, page 5-5, last sentence. The discussion and presentation makes an overt suggestion that quantitative uncertainty analysis is required. This is beyond the requirements of NFPA 805. The discussion in NFPA 805 indicates that qualitative treatments are appropriate and sufficient. In addition, the treatment and discussion of uncertainty seems to be limited to only the treatment of MEFS and LFS. It is unclear how fire modeling uncertainty would be treated in an integration fashion as part of a comprehensive Fire PRA such that which is required for NFPA 805.

Specific Comments

40. Section 6.2 – the discussion of PRA starts correctly, but rapidly diverges from basic concepts and incorrectly relates CDF/LERF and Level 3 PRA results to the answers to the three basic PRA questions. From an overall perspective, it would seem that this section should be providing the fire modeling analyst a context of the meaning of the HRR values being input from NUREG-6850 in a framework that relates it to the predicted fire initiating event frequencies. In that context, it would seem the more focused answers to the three questions are: What can go wrong – a fire that has some damaging potential occurs, How likely is it – since the fire modeling work as developed seems to invoke discrete values, then it would seem that the concept that not all fires generate the same HRR needs to be discussed, and , What are the consequences if it occurs – again, in the context of fire modeling, the discussion should be addressing the concern associated with fire damage to 'targets'.

41. Section 6.5.1, page 6-8. There have been numerous presentations and discussions regarding the weaknesses of Task 8 and the need for a practical implementation of NUREG-6850 to alter the scope and purpose of this Task. It would seem to be a significant oversight for this document to continue to portray the implementation of this task exactly was written in NUREG-6850.

42. Section 6.5.2 – this section presents a new concept related to a probability distribution for fire damage. While the concept is fundamentally sound, its application in the context of current practices and information is unclear. It is also noted that none of the examples in the Attachments implement this treatment. It is believed that this approach could be refined and further developed but without a better basis for the mean HRR and distribution characterization for all of the related factors, it seems premature to suggest the concept in this document.

43. Attachment A – this treatment of the MCR is generally good. However, it was expected that these practical example would have fully implemented all of the concepts presented in the main body of the report. As an example, the solution for this case clearly shows that Optical Density is the controlling variable for abandonment timing. Table 4-1 (page 4-2) indicates that CFAST over-predicts smoke concentration by a factor 2.65. Since Optical Density is the controlling parameter and there is significant uncertainty in the calculated results, it was expected that the solution would have addressed this and provided the described probabilistic treatment of the need for abandonment as a function of time. Further, it would have been expected that the treatment would have address that fact that over 97% of the fires from the HRR data input source are smaller fires and consequently would have longer analyzed abandonment times. As the guidance is intended to provide practical solutions for NFPA 805, it would be appropriate for the treatment to strive for realistic results for integration into a Fire PRA.

44. Attachment B, Section B.4, page B-4. The example is unclear as to the actual fire ignition source. Based on the description and discussion, it is assumed that the fire involves a medium voltage switchgear. As such, the use of 464 kW (also note the typographical error where /m2 has been incorrectly added in the text) is inconsistent with the guidance in NUREG-6850, Appendix G, page G-25. Further, the example is based on a 98th percentile HRR for a closed cabinet. However, as described the cabinet is not closed but is ventilated with an air vent. As a consequence, the example is not internally consistent in that an HRR for a closed cabinet was selected and applied for a case involving an open cabinet. This is inconsistent with at least two NRC approved NFPA 805 FAQs. Further, on page B-5, the damage threshold is stated as 200 °C which is incorrect. It appears that the correct value is 205 °C. It is noted that elsewhere in the set of Attachments, another example occurs involving the same type of cable and a value of 205 °C is used.

Specific Comments

45. Attachment C – the discussion of oil fire and the Kaowool insulation is generally good. However, it is unclear why flame impingement is ignored. Given the size and nature of the fire it would seem that treatment of this interaction would be required. Failure to include this treatment may incorrectly lead a user to ignore this factor.

46. Attachment E – the picture provided in Figure E-2 is NOT a typical cable spreading room. The example uses a fire with a HRR of 130 kW. This is inconsistent with all prior examples where the 98th percentile HRR from NUREG-6850 is used. Referring to NUREG-6850, Appendix E, table E-1, the 75th and 98th percentile values are 142 kW and 317 kW, respectively. The example fails to provide a basis for the altered value. Again, since this document is intended to provide practical guidance, the basis and justification of this value needs to be presented. Further, the crafting of the application presented in this Attachment places the target cables in the 3rd and 6th tray in the stack above the floor. As a practical case, the primary concern would be the interaction of the trash can fire causing ignition of the lowest tray and the resultant vertical propagation of the fire to the target cables. Unfortunately, the example becomes overly simplified with the assumption provided on page E-5 where states that none of the cable trays ignite. Without any secondary ignition, the example degrades to a trivial hot gas layer calculation involving a relatively small fire in a relatively large room. The example should be expanded to solve the realistic problem and provide a practical solution.

47. Heat Release Rate (HRR) Uncertainty: Consider adding a discussion about uncertainty associated with HRR. The assumed HRR is the primary input affecting the extent of target damage. If the HRR is wrong, the results will be wrong, no matter which model is chosen or how well it's implemented. This is also a key factor driving high Fire CDFs from NUREG/CR-6850 Fire PRAs.

48. Lube Oil Fire Example: The lube oil fire example in Appendix C does not provide much value. It is an unrealistically large oil quantity (50 gallons) in a small compartment, which most Fire PRAs would generally assume damages all targets in the compartment without performing fire modeling. Consider revising the scenario to be an unconfined spill involving a modest amount of oil (e.g., 2 gallons). Current fire modeling guidance would suggest assuming the oil spreads instantly to a thickness of 0.7 mm, which causes a very high heat release rate. The industry could use some guidance here.

49. FDT Uncertainty: Table 4-1 suggests that the FDTs under-predict plume temperature rise. This could have significant implications, since many plants define their ZOIs based on the FDT plume equation. If the under-prediction is true, it could potentially result in having to re-collect a large amount of source-target mapping data. Recommend the writing team ensure they have high confidence in this aspect prior to final publication.

50. Fire PRA Chapter 6: Generally recommend expanding this chapter to more comprehensively address how fire modeling is used in Fire PRA. Some elements can simply reference other sections of the report (e.g., MCR analysis). However, several aspects of fire modeling applied to Fire PRA aren't addressed by this guidance document (e.g., application of generic models to huge number of scenarios, use of generic inputs, conservatism vs. realism, etc.).

51. Page 6-6: The last sentence in the third column for Task 8 states that "The analyst estimates severity factors for ignition sources that are not screened out." Recommend revising to describe use of FDTs and gamma distribution to calculate (not estimate) the fraction of fires not capable of damaging the nearest target.

Specific Comments

52. Page xvii: The objectives of the guide state: To provide guidance on the application of specific fire models to NPP fire protection issues To provide guidance on estimating the quantitative confidence in the predictive capability of these fire models when they are used for NPP fire modeling applications The results of this effort are presented in a step-by-step guide for using fire models. Although the outline of the document describes a step by step approach the document content provides a lot of background, historical basis for each step which is good information but complicates the use and implementation of the method. In many areas the text is repetitive for the same background input information (see Chapter 3 for various fire scenarios). This just complicates the use of the guide and step by step approach. There should be simpler guides and resources for the step by step approach, e.g., Table 2-3 is a good tool to help select an appropriate fire model. More tools should be developed like this. Possibly a flow chart method that identifies the various input variables for each model with possible data inputs that can be used. The limitations of the variables or models should also be highlighted where the model is not applicable, e.g., model may not be appropriate for ceiling heights above 40 ft. etc.

53. Chapter 2: Need more discussion on how fire models might be used in an analysis - for screening purposes, for risk informed decision making. This discussion should be in Chapter 2. I believe we are still using these models for risk informed decision making not an exact quantitative conclusion. My understanding was the models using quantitative techniques are only an input to a risk informed qualitative assessment. How does this all tie together overall?

54. Chapter 2, page 2-14: Paragraph 1 and 2 rightfully points out that the fire scenarios are subject to many limiting assumptions and user must be cautious applying models especially to complex scenarios. I don't recall anywhere in the text where it points out how to address this. Usually it has to do with the limitations of the model and parameters and the V&V for each model. It seems more guidance in this area is needed to help the user evaluate how to cautiously apply these calculations to the scenarios and models. This is also well stated in paragraph 5 and reference in Table 2-3. If important or critical references from NUREG 1824 provide these limitations perhaps they should be brought directly into this document rather than send the user to numerous other references. Even if the information tables are included in an attachment this would be better.

55. Chapter 2, pages 2-14 and 2-16: Table 2-3 suggests which models are best for which scenarios and which models are not acceptable for certain parameters. However, there should be more discussion on which attributes require caution and what the limits are on those attributes that imply caution. Similarly, the Green models states accurate within the experimental uncertainty associated with each particular attribute for the range of conditions from the V&V tests. Without having to dig through those past V&V tests what are the limits of the attributes (variables) from those previous tests. E.g., this model is Green for this parameter within what limits?

56. Chapter 2, page 2-18: Is 2.6 the standard AHJ approved template of information required to be documented or format for presenting the analysis. Should there be specific discussion of the important targets in the area and damage threshold? Is this the outline for the entire documentation package? What about the uncertainty analysis? If assumptions are made, what analysis or basis is there to support those assumptions from the model or data inputs? Are multiple scenarios needed to establish bounding conditions?

57. Chapter 2, page 2-18: In any application of a fire model there will be data gathered to input and certain assumptions made in application of the models. These assumptions need to be documented and justified within the limits and application of the model. Assumptions should be

substantiated with references and basis. I didn't see any discussion on this. These assumptions could be critical to the overall end result and sensitivity of the analysis.

58. Chapter 2, page 2-19: In the documentation section should there be a subsection on sensitivity analysis possibly even as it applies to each scenario and calculation bounding the conclusion and result? This is included as Step 5 in the process but not addressed in the documentation.

59. Chapter 3, 3-3 Targets: What is an acceptable damage threshold approved by the AHJ (NRC)? Page 3-5, paragraph 4; will the AHJ consider heat conduction analysis?

60. Figure 2-1 should be adjusted such that "Are the results suitable?" refers back to describe fire scenario.

61. On page 2-4 the first sub-bullet under where is the fire located should roll-in the information from the 1' below the top of the panel FAQ

62. On page 3-7 Natural Ventilation: Leakage Paths, it states that for compartments with "closed doors" leakage paths must be examined. It would be desirable to provide more detail on how to deal with a compartment with a closed door and no forced ventilation. For example, during a recent fire modeling training for 6850 well attended by the NRC and utilities, all parties agrees that it was reasonable to assume that the door was open given if the door is close the fire is starved and the fire brigade is likely to open the door to fight the fire anyway.

63. Please define what is meant by long a wall or corner (e.g. last bullet pg 3-15).

64. For scenario 3 (Figure 3-5), hand calculations are not recommended. It seems that it would be conservative to consider the room a single large volume for HGL calculation. If this is conservative and still shows no damage, then this is an acceptable approach. Can you please mention this option if viable.

65. Section 2.3.5, page 2-13, recommended mesh size. The equation for estimating the grid spacing provides a method for assessing the grid size for relatively simple fires (horizontal, approximately square). Additional guidance should be provided for other limiting features: minimum number of cells across a flow path; minimum number of cells used to represent a fuel package; estimation of cell requirements for line type fires (cable trays) and vertical burning surfaces.

66. Section 2.3.5. Suggest providing some expanded discussion on CFD modeling in spaces and the implications of including/excluding features such as ductwork, cable trays, and other obstructions. Although these will often play a minor role and may even be placed in for spatial orientation or aesthetics, they may affect the flow conditions and will provide heat loss surfaces. If a space is modeled with certain contents, and these contents change, does this invalidate the model? For example, if a short duct segment is included near the ceiling away from the area of interest, and the duct is later removed, the CFD model would no longer represent what the space. Some method or consideration is thus needed when using CFD model results to ensure that when there is a change, some determination of the impact on the model results (i.e., trivial change or model requires a rerun) is made.

67. If a panel is evaluated using FDS (or even a zone-type model) as a sub-enclosure, the vent entrainment results would improve. For large panels with vents or enclosed MCBs, this strategy

provides a sound alternative to assuming a free burn fire 1 ft below the panel top. An illustration of this technique is suggested. Not that in such case, the correct fire location is at the base.

68. Appendix F-4. The use of the ASTM E119 peak temperature criterion is not appropriate when the steel is treated as a lumped mass system or a series of 1-D computation cells. The maximum average of 1000°F should be used as the basis.

69. Appendix F. It is not clear how the column target is treated in FDS. It appears in Figure F-4 to be a hollow box; in this case, it should be emphasized that the internal boundary condition should be adiabatic. The sensitivity of the results to the resolution should also be explored, since the radiant heat flux depends on the number of rays selected and there could be grid sensitivities or location sensitivities due to the radiant beam angular distributions.

70. Appendix F. An alternate method for assessing the column response should be noted. FDS provides an adiabatic surface temperature output parameter for use in heat transfer models. Such models could provide a two or three dimensional steel response and could take advantage of the lateral heat flows in the steel.

71. Appendix A.5.2, Fire. The recommendation to place the fire 1 ft below the top of the panel warrants additional discussion. In many control rooms, the Main Control Board has an open back. If the cables are thermoplastic, the fire base clearly would be at the floor. If the cables are thermoset, it is less clear but the floor would probably still be more representative than 1 ft below the top. Regardless, in a calculation that is driven by visibility constraints, locating the fire at the floor elevation would provide the most conservative result since a) in a zone model there is no mechanism for the layer to descend below the base of the fire and b) the layer volume increase most rapidly with a longer entrainment distance c) it is generally assumed that the doors could open since most panels could not support the fire sizes imposed with the existing vents; and d) the actual effective burning location if the panel structure remained constant would likely be below the top vent some distance approximated by an effective virtual origin.

72. Appendix A.6. The heat flux constraint as listed in Section 11 of NUREG 6850 is at 6 ft, not the floor. Additionally, when using FDS it is not clear why the temperature constraint would be applicable since it is a surrogate for a flux condition. Finally, some guidance on the correct heat flux parameter should be provided (gage heat flux, at 25°C?).

73. Table 2-1. The spreadsheet model THIEF is not shown.

74. Appendix F-6. Unclear what heat flux parameter is output (incident, gauge [reference temperature?], net)?

75. Section 2.3.5, top of Page 2-13. Numerical error increases with increasing refinement as well.

76. Section 3-7, Natural ventilation: Horizontal openings. The consolidation of horizontal flow paths is a necessary step in CFAST since it will only model one such opening per pair of connected spaces. The discussion is not applicable to a CFD analysis – suggest noting this.

77. Section 2.3.3, first paragraph, third sentence. Vent mixing provides another means by which the upper and lower layers in a zone model exchange mass.

Specific Comments

78. Appendix A.6. 1, second sentence. The smoke layer also does not descend below 1.5 m because of the assumed fire elevation.

79. Section 3.1.3, page 3-7. In Step 1, is the plume considered to have the same cross-section as the base of the fire, as for the flames? Is there no consideration of the plume temperature gradient in the radial direction?

80. Section 3.1.3, page 3-7. In Step 2 there is no reference to allowance for the times to failure as given in NUREG/CR-6850 Tables H-5, H-6, H-7 or H-8.

81. Section H.5.2; page H-6, "Fire." The derivation of the growth profile and peak HRR value of 1000kW should be shown.

82. The example is based on an HRR of 702 kW which is inconsistent with the guidance provided in NUREG-6850, Appendix G, page G-25.

83. Attachment G – the selected fuel package seems unrealistic. In addition, it is unclear how the fire is able to grow so quickly without any identifiable ignition source. From a practical perspective, it would seem that smoldering would have generated smoke and potentially provided an opportunity for smoke detection prior to the rapid growth phase considered in the treatment.

84. Attachment H, Section H.4 – the vertical spread rate that is used in the example is 25 mm/s. This value is an order of magnitude lower than provided in NUREG-6850, Appendix R, Table R-4. If this substantially lower value is correct, then the example should provide all of the necessary parameters to calculate that rate using the methodology provided in NUREG-6850. Alternatively, if the values in NUREG-6850, Appendix R, Table R-4 are in error, then a separate errata should be generated to correct it.

85. Generic Zones of Influence (ZOI): Fire PRAs often calculate a "generic" ZOI for each ignition source type, and then apply it to hundreds of scenarios. Plants are each developing their own generic ZOI calculations. Consider adding an attachment with generic ZOIs that the industry can reference, instead of each plant developing their own.

86. Location Factor: Consider including guidance on use of the "Location Factor," which is a multiplier to the heat release rate to account to wall/corner affects. There's a lot of debate and confusion about when to use this multiplier, and it can significantly affect the number of targets mapped to an ignition source. The key questions are: Should the location factor be applied in the context of Fire PRA, and if so, what criteria (e.g., distance to wall, etc.) determine when it should be applied? I've attached a draft write-up to this comment sheet as a starting point.

This location factor accounts for the entrainment restricting effects of a fire being located near a wall or corner. For example, fresh air is entrained into the hot plume as it rises above the fire source. In design applications, it is often assumed that if a fire is located in a corner, the air entrainment into the plume is reduced by a factor of four as compared to fire located in the open. This causes the plume to cool down at a slower rate as compared to a fire located in the open. As a result, it is often assumed that the vertical ZOIs of ignition sources located near a wall or corner are greater than for ignition sources located in the open.

There is evidence that wall and corner effects are relatively small. For example, page 2-80 of Reference 3 cites scientific literature demonstrating that "...if a circular burner is placed so that only one point is in contact with the wall, the fire behaves almost identically to a fire away from the wall". This is depicted in Figure 4-3 below, taken from Zukoski *et al* (Reference 10):

In configuration 'B' of Figure 4-3, the plume entrainment mass flow decreased only by 3%, which is well within the experimental scatter of the cited fire tests. This configuration therefore has a negligible effect on plume thermal characteristics as compared to fires located away from walls. This also suggests that a space on the order of a few inches between the wall and fire provides sufficient entrainment such that the plume will behave similar to a fire located away from the wall.

In typical ignition source configurations at nuclear power plants, the burning region is generally not located directly against a wall or corner. For example, if a wall-mounted electrical cabinet ignites, the majority of the fire will burn out of or near the door, which is generally on the side of the cabinet away from the wall. Sufficient space for entrainment can even be expected for transient packages located adjacent to walls.

For the purposes of this analysis, which is to provide a realistic assessment of fire risk, the location factor will be applied when the flaming region is within six inches of the wall or corner. The location factor is expected to be applicable to relatively few fire scenarios at XYZ. One example of a scenario where the location factor may be applicable is a large electrical cabinet fires where the vent is located on the bottom half of the cabinet.

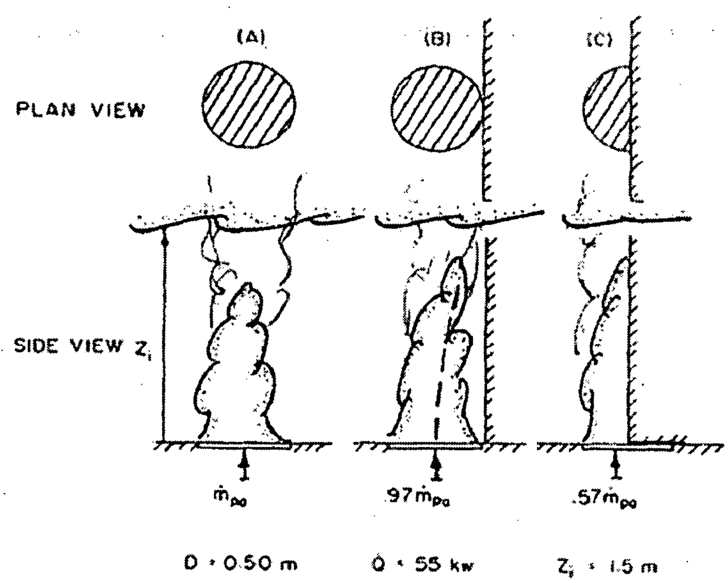

Figure 4 3: Effect of Vertical Wall on Plume Mass Flux
(Taken from Reference 10)

87. Page 3-20: Consider adding brief discussion of ZOI determination for "complex" ignition source shapes (i.e., not circular or rectangular).

88. Page A-2: Construction: One wall of the compartment is made of concrete with no additional lining material. The other exterior walls are constructed of 5/8 in (1.6 cm) gypsum board supported by steel studs. The floor is a slab of concrete covered with low-pile carpet. The ceiling is a slab of concrete with the same thickness as the floor, but with no lining material. The most realistic construction would be all walls are concrete or concrete unit masonry (CUM) since they

are required to be 3 – hour rated.

89. Page A-8: Materials: The walls, ceiling and floor were all assumed to be 5/8 inch (1.6 cm) gypsum board. Typically, the FDTs and FIVE equations can only account for one type of material at a time. The gypsum board was chosen because it is a better insulator and would lead to a higher HGL temperature, which for this scenario would be more likely to compromise human tenability. A more realistic material would be all concrete.

90. Chapter 2, page 2-3: Damage Threshold information for targets - at what point does a target fail - what is a generally and AHJ approved damage threshold.

91. Chapter 2, page 2-19: 5.0 Model Assumptions, How was a circular geometry represented in a rectangular coordinate system? How would any one address this? Is it important? Is it a qualitative discussion or something that must be quantified?

92. Chapter 3, 3-7 "find the time to damage inside the cable as a function of time." Is this an acceptable damage threshold? Can the models and quantitative analysis be that exact?

93. Section 2.3.1, second paragraph. References for FDTS methodology postdate the model. Suggest rewording or providing the actual base references.

94. Section 2.4, Page 2-17, Item 3. FDS simulations take days or weeks.

95. Figure 3-4. Where is the cable tray that ignites?

96. Section 3.1, page 3-3. Scenario 1 is defined as" Targets in the flames or plume" so an explanation is required for why Section 3.1.2 includes the fire scenario elements relating to HGL formation as well.

97. Appendix B. Reference should be made to the criterion given in NUREG/CR-6850 Appendix S, which states that damage to an adjacent cabinet can be discounted if there are two walls and an air gap between the cabinets. What is the position taken in the guidance document on this assumption?

98. The 3rd paragraph of the Abstract and the 2nd paragraph of the Foreword both talk about how fire models 'predict the consequences' of fires. I would argue that they don't predict the consequences of fires but instead provide the means to 'conservatively examine the behavior and attributes' of fires.

99. Attachment F – the damage threshold of 650 °C is used and appears to be based on ASTM E-119. It would seem appropriate to provide a better reference and to note that the selected threshold corresponds to the generally accepted value where structural steel strength decreases by 50%.

100. Page 2-17: Consider changing current Step 2 (Determine output parameters of interest) to Step 1. The desired output should be considered prior to preparing the input file.

101. Chapter 3 is intended to provide detailed guidance on model selection for different types of scenarios. The text seems to be very repetitive in each of the sections. It does suggest which types of models are best for the different scenarios, but it would be helpful if there were more discussion regarding the limitations of the models for certain parameters. Perhaps the text could

be condensed and just the recommending modeling tools addressed for each case. Only point out any specific parameter limitations for a specific model and scenario

Editorial Comments

1. Figure 3-2. No symbol for the target.

2. Section 3.1.2, Page 3-5 (and elsewhere). Irradiated is not a commonly used in the fire protection community to describe the fraction of energy released as thermal radiation. Radiant fraction would suffice.

3. Appendix G.4. Heat of combustion on Page G-5 and G-7 do not match.

4. Appendix A.5.2. The effective chemical formula for the cables is not correct. Should be C2C4.5Cl05.

5. 2.3, Page 2-6, top of page. The lower layer of a zone model is not necessarily "fresh" air.

6. Appendix A.3, Input. The detector was not used in this example.

7. Section 2.2, page 2-2, 2nd paragraph. The sentence beginning "The input values necessary to determine LFSs..." is too vague to be useful as guidance.

8. Section 3.1.4, page 3-8, 2nd paragraph. Typo "relatively closed."

9. Section 3.2.2, page 3-11, "Room Geometry..." 4th line. Typo "similar input requirements..."

10. Section 3.5.2, page 3-24, 2nd bullet. Typo ""Decide with..."

11. Section 6.5, page 6-8. 4th line. Typo "considered damaged..."

12. Section D.6, page D-9, penultimate line. Typo "...since the cables..."

13. Section F.5.2, page F-6. Note spurious change in font.

14. Section H.3; page H-2, "Cables," 3rd line. Typo "...0.6in..."

15. Note also typo "...flow out into the rest..."

16. Attachment D – the discussion refers to a motor control center yet the picture and actual installation involves a load center.

17. Page 2-19: Consider removing the Calculation File outline. Each plant has their own Calculation File format.

18. Page 2-16: Note 5 of Table 2-3 references Table 2-3 (circular). Also, the experiments referenced in Note 5 don't appear to be in Table 2-3.