UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

July 19, 2012

Mr. R. W. Borchardt
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: DRAFT FINAL NUREG-1934 (EPRI 1023259), "NUCLEAR POWER PLANT FIRE MODELING ANALYSIS GUIDELINES (NPP FIRE MAG)"

Dear Mr. Borchardt:

During the 596th meeting of the Advisory Committee on Reactor Safeguards, July 11-13, 2012, we completed our review of the draft report NUREG-1934 (EPRI 1023259)[1], "Nuclear Power Plant Fire Modeling Analysis Guidelines (NPP FIRE MAG)." Our Subcommittee on Reliability and Probabilistic Risk Assessment (PRA) also reviewed this matter during its meeting on March 21, 2012. During these meetings, we had the benefit of discussions with representatives of the NRC staff, the Electric Power Research Institute (EPRI), and the National Institute of Standards and Technology (NIST). We also had the benefit of the documents referenced.

CONCLUSION AND RECOMMENDATIONS

1. NUREG-1934 provides valuable guidance on the use of fire modeling techniques to support nuclear power plant fire analysis applications. It should be issued after Recommendations 1.a and 1.b are addressed.

   1.a. Section 1.6.2 should be revised to clarify the guidance and objectives for modeling fire-induced circuit failures for deterministic licensing applications and for risk-informed, performance-based applications.

   1.b. The uncertainty analysis examples in Section 4.4.1, Appendix B, and Appendix E should be expanded to better describe how the uncertainty results could affect the fire modeling conclusions and applications.

2. After NUREG-1934 is issued, the staff should develop a separate case study to demonstrate how uncertainties are assessed and quantified in an integrated analysis of a typical nuclear power plant fire hazard and its consequential fire damage scenarios.

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[1] Hereinafter referred to as NUREG-1934 for brevity

BACKGROUND

Our letter report of October 25, 2006, summarized our review of NUREG-1824 (EPRI 1011999), "Verification and Validation of Selected Fire Models for Nuclear Power Plant Applications." In that report, we recommended that a "user's guide" for the five selected fire models should include:

a. Estimates of the ranges of normalized parameters to be expected in nuclear plant applications

b. Quantitative estimates of the uncertainties associated with each model's predictions, preferably in the form of probability distributions

NUREG-1934 was developed under research sponsored jointly by the NRC Office of Nuclear Regulatory Research (RES) and EPRI. The primary objectives of the report are to provide guidance on the application of fire models to nuclear power plant (NPP) fire scenarios and to serve as a teaching tool for the Advanced Fire Modeling module in the Fire PRA Course that is conducted jointly by RES and EPRI. NUREG-1934 also addresses our recommendation that guidance for the use of fire models should address methods to identify and quantify uncertainties in the model predictions.

DISCUSSION

NUREG-1824 (EPRI 1011999) presents the results of verification and validation studies on five modeling tools that are used commonly in NPP fire analyses. Those tools are:

- Fire Dynamics Tools (FDTs), developed by the NRC
- Fire-Induced Vulnerability Evaluation, Revision 1 (FIVE-Rev1), developed by EPRI
- Consolidated Model of Fire Growth and Smoke Transport (CFAST), developed by NIST
- MAGIC, developed by Electricité de France (EdF)
- Fire Dynamics Simulator (FDS), developed by NIST

NUREG-1934 is not intended to be a detailed "user's guide" for any of these specific tools. Users' guides for these computational tools are available. NUREG-1934 provides practical guidance for a fire analyst who must select tools to solve the technical problems that are presented by a particular fire scenario, within constraints imposed by the available information and resources.

In the context of NUREG-1934, FDTs and FIVE-Rev1 are classified as algebraic models, CFAST and MAGIC are classified as zone models, and FDS is classified as a computational fluid dynamics (CFD) model. The guidance addresses the benefits and limitations of each general class of the fire models for particular applications, rather than critiquing details of each tool. This focus and level of detail are appropriate for the objectives of the report.

NUREG-1934 provides guidance for the identification and evaluation of uncertainties that are associated with completeness of the fire models, fidelity of the models and their algorithms, and sources of aleatory variability and epistemic knowledge about the input parameters. Uncertainties that are related to model completeness and fidelity are characterized by a bias factor and a distribution for the variability in the predicted model results. Those assessments are performed for each of the five modeling tools and are based on comparisons of the model predictions with experimental data, as documented in NUREG-1824.

The effects from uncertainties in the model input parameters are quantified using Monte Carlo methods or other sampling techniques to propagate those uncertainties through the relevant model algorithms. The required time and computational resources for explicit propagation of parameter uncertainties increase for the zone models and substantially for CFD models, because their algorithms are not currently configured for sampling of variable parameter values. The applied techniques and examples describe how uncertainties may be quantified using each of the tools, and they provide useful state-of-the-practice guidance for fire analysts.

NUREG-1934 contains valuable engineering insights from practical fire modeling experience that is useful for practicing fire analysts and reviewers of fire modeling applications. The examples in the appendices demonstrate benefits and limitations in the use of each class of model for problems that are encountered in typical NPP applications.

NUREG-1934 should be issued after the following two items are addressed.

Modeling Objectives for Fire-Induced Circuit Failures

Section 1.6.2 of the report contains a summary of guidance and objectives for the use of fire models to evaluate fire-induced damage to electrical cables, which may result in open circuits or spurious actuations of one or more components. The fire modeling objectives refer to analyses that are typically performed to demonstrate lack of fire damage to a safe shutdown success path. The cited guidance and objectives apply primarily to fire modeling applications that support deterministic licensing decisions. The report refers only to Regulatory Guide 1.189.

Regulatory Guide 1.205 contains guidance for the evaluation of fire-induced circuit failures in applications that support risk-informed, performance-based decisions. The fire modeling objectives for those applications are generally different from a deterministic demonstration of circuit protection. For example, risk-informed applications typically require evaluations of a range of fire sizes that may damage cables at varying distances from an ignition source, with the corresponding times for fire growth to those damaging sizes.

Section 1.6.2 should be expanded to also summarize the guidance and fire modeling objectives for risk-informed, performance-based applications.

Characterization and Use of Uncertainty Analysis Results

Section 4.4.1 in the main report, Section B.5.3 in Appendix B, and Section E.5.4 in Appendix E contain examples that show how uncertainty in the heat release rate (HRR) can affect the overall model results and conclusions about the potential fire damage. The discussions of these examples should be expanded to better describe how the uncertainty analysis results affect the fire modeling conclusions and how those uncertainties would be used in an integrated fire analysis application.

In one of the examples, it is shown that uncertainty in the HRR from an electrical cabinet fire affects the modeled flame height and the potential for damage to cables that are located above the top of the cabinet. The results from a screening analysis that uses the 98^{th} percentile HRR from the underlying uncertainty distribution conclude that cable damage will occur. The results from a "best estimate" analysis that uses only the mean HRR would conclude that the flame does not hit the cables. The results from the full uncertainty analysis indicate that there is approximately a 31% probability that the flame will impinge on the cables. As intended, the screening analysis provides a conservative assessment of the potential consequences from this fire scenario. However, the "best estimate" analysis that uses only the mean HRR without explicit quantification of the uncertainties could result in an optimistic modeling conclusion and an inappropriate evaluation of this scenario in the integrated fire analysis. The discussion of this example should be expanded to provide fire analysts better guidance about how to use the full uncertainty distribution.

Case Study of Integrated Fire Analysis Uncertainties

Regulatory Guide 1.200, NUREG/CR-6850, and the ASME/ANS Standard for performing fire PRA contain high-level guidance regarding the need to address uncertainties. Fire analyses that are performed to support risk-informed, performance-based decisions contain numerous sources of uncertainty that must be characterized and quantified consistently through the integrated analysis process. Examples of these uncertainties include the fire ignition frequencies; fire source and target locations within a compartment; fire growth and consequential damage; conditional probabilities of fire-induced equipment failure modes (e.g., cable open circuits, single or multiple spurious actuations); unavailability of equipment that is not damaged by the fire; and personnel responses to prevent or mitigate the effects from fire damage. The guidance and examples in NUREG-1934 are limited to the specific context of the fire models and their results, and they do not address the integrated treatment of those modeling uncertainties in the analyzed fire scenarios.

Fire analysts and reviewers of risk-informed applications would benefit substantially from an example case study that demonstrates how major sources of uncertainty are assessed and quantified in an integrated analysis of a typical NPP fire hazard and its consequential damage scenarios. For example, a case study of an electrical cabinet fire in a location that contains multiple overhead cable trays with three or more different consequential equipment damage scenarios could show how the integrated analysis process combines the fire model uncertainties from NUREG-1934 with uncertainties from the other analysis elements to quantify the composite uncertainty for the frequency of each scenario end state.

Sincerely,

/RA/

J. Sam Armijo
Chairman

REFERENCES

1. U.S. Nuclear Regulatory Commission and Electric Power Research Institute, "Nuclear Power Plant Fire Modeling Analysis Guidelines (NPP FIRE MAG)," NUREG-1934 (EPRI 1023259), to be published in September 2012. (ML120470149)

2. Letter to L. Reyes, "Draft Final NUREG-1824,'Verification and Validation of Selected Fire Models for Nuclear Power Plant Applications' ", ACRS Letter, October 25, 2006. (ML062980154)

3. Regulatory Guide 1.200, "An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities," Revision 2, March 2009. (ML090410014)

4. U.S. Nuclear Regulatory Commission and Electric Power Research Institute, "EPRI / NRC-RES Fire PRA Methodology for Nuclear Power Facilities," NUREG/CR-6850, EPRI 1011989, September 2005. (ML052580075 and ML052580118)

5. ASME/ANS RA-Sa-2009, Addenda to ASME/ANS RA-S–2008, "Standard for Level 1 / Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications," American Society of Mechanical Engineers, New York, NY, February 2009

6. Regulatory Guide 1.189, "Fire Protection for Nuclear Power Plants," Revision 2, U.S. Nuclear Regulatory Commission, Washington, DC, October 2009. (ML092580550)

7. Regulatory Guide 1.205, "Risk-Informed, Performance-Based Fire Protection for Existing Light-Water Nuclear Power Plants," Revision 1, U.S. Nuclear Regulatory Commission, Washington, DC, December 2009. (ML092730314)

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Letter to R. W. Borchardt, EDO, from J. Sam Armijo, ACRS Chairman, dated July 18, 2012

SUBJECT: DRAFT FINAL NUREG-1934 (EPRI 1023259), "NUCLEAR POWER PLANT FIRE MODELING ANALYSIS GUIDELINES (NPP FIRE MAG)"

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