61-147, 1320

13p

POLICY ISSUE
(Information)

June 7, 1989

SECY-89-170

For: The Commissioners

From: Victor Stello, Jr., Executive Director for Operations

Subject: FIRE RISK SCOPING STUDY: SUMMARY OF RESULTS AND PROPOSED STAFF ACTIONS

Purpose: To present an overview of the results of Sandia's "Fire Risk Scoping Study" and the staff's plans for activities to be undertaken as a result of the study. This paper is for information only.

Background: Beginning in 1975, the Office of Nuclear Regulatory Research (RES) initiated research directed toward identifying, analyzing, and providing a basis for correcting potential fire vulnerabilities in nuclear power plants. The research sponsored by RES included both the development of analytical tools, the conduct of experiments which provided data on equipment survivability, and research tests on the requirements in Appendix R. As a result of this research, many experiments involving fire propagation and equipment survivability were conducted with significant steps being made towards analytical tool development. However, in 1986, after discussions with the Office of Nuclear Reactor Regulation, RES terminated all fire protection research as a result of Office budget restrictions. In reaching this decision, it was agreed that RES would initiate a Fire Risk Scoping Study to systematically assess the current status of fire risk concerns utilizing the results of the fire protection research program completed to date. It was felt that the results of such a study would provide a firm basis for recommending whether or not additional fire protection research should be performed and what research would be appropriate. Accordingly, in FY1987 the staff initiated a fire risk scoping study at Sandia National Laboratory which, utilizing the results stemming from the fire protection research performed to date, evaluated fire risk issues and the need for additional fire protection research.

CONTACT:
J. Flack, RES 49-23979

DFX 2
4/1

A17

8906260024 890607
CF SECY
89-170

Specifically, the purpose of the study was to:

1) Assess the risk significance and dominant sources of uncertainty associated with fire at nuclear power plants.

2) Assess the risk of potential fire related issues raised by the ACRS and fire protection experts.

3) Assess the need for fire protection research and appropriate areas of research (if any).

The scoping study incorporated current state-of-the-art methodology and the most up-to-date data available. Fire protection improvements, including Appendix R modifications, were integrated into the study in order to provide a current estimate of fire risk. In addition, potential fire risk issues not normally addressed in Probabilistic Risk Assessments (PRAs) were assessed which provided reasonable completeness to the study.

The study consisted of five major tasks:

Task 1 - Assess Uncertainties in Four Previous Fire PRAs.
Task 2 - Requantify Fire Scenarios from Past Fire PRAs (using up-to-date methodology and information).
Task 3 - Identify Potential Fire Risk Issues.
Task 4 - Assess the Risk Significance of Potential Issues
Task 5 - Evaluate the Completeness of Appendix R Rules in Light of the Identified Unaddressed Fire Risk Issues.

In addition to completing the above tasks, Sandia also provided recommendations for follow-on research efforts. These recommendations were taken into consideration during the staff's evaluation of the study.

Discussion: The Fire Risk Scoping Study executive summary (Enclosure 1) provides a brief overview of the study's observations and recommendations. In general, the most significant findings resulting from the Sandia Study can be summarized as follows:

1) The study determined that fire can be an important contributor to core melt frequency at some nuclear power plants, even after NRC fire regulatory criteria have been met.

2) State-of-the-art methodology for assessing fire risk and fire related effects have modeling shortcomings. These shortcomings, if not treated properly, can

result in large uncertainties in the fire risk estimates.

3) Fire PRAs do not normally address fire vulnerabilities in several important areas. These areas include:

   a. Fire induced alternate shutdown-control room panel interactions.
   b. Smoke control and manual fire fighting effectiveness.
   c. Adequacy of fire barriers.
   d. Equipment survival in fire-induced environment.
   e. Seismic/fire interactions.

The Fire Risk Scoping Study is a probabilistic study which demonstrated the potential impact of important areas to core damage. In many cases, bounding calculations were used to demonstrate core damage sensitivity rather than to identify specific risk contributors. The study noted that fire protection regulations are quite stringent in a deterministic sense. No new regulations or modifications to current regulations were recommended.

Because of the core damage sensitivity of some of the issues raised by the scoping study, the staff plans to take additional actions in the fire protection area. In addition to informing licensees of the study's findings via an information notice, four of the issues are under consideration for inclusion in the Individual Plant Examination for External Events (IPEEE). A brief summary of these and other issues raised by the study, and associated staff actions are provided below.

1. Fire Induced Alternate Shutdown-Control Room Panel Interactions: Control system interactions involving a combination of fire induced failures and high probability random equipment failures were identified as potentially high risk. Sensitivity studies were performed which indicated that these interactions could have a significant impact on the fire induced core damage frequency. Based on these sensitivity studies, the Fire Risk Scoping Study recommends that future investigations be undertaken to review current remote shutdown implementation practices in an attempt to assess the adequacy of those practices.

   Although protection of vulnerable safe shutdown systems from fire damage has already been addressed in the regulations, a search for remote shutdown vulnerabilities as part of the Individual Plant Examination for External Events (IPEEE) program is currently being considered. Towards that end, the External Events Fire Subcommittee has been developing submittal guidance for the industry

to ensure that important fire related issues like fire induced alternate shutdown-control room panel interactions, are considered in the context of a plant-wide fire safety review.

2. Smoke Control and Manual Fire Fighting Effectiveness: Sensitivity studies have shown that prolonged fire fighting response times can lead to noticeable increase in fire risk. Smoke, identified as one of the major contributors to prolonged response times, can also cause misdirected suppression efforts, hamper operator's ability to safely shut down the plant, initiate automatic suppression systems in areas away from the fire, and fail electrical equipment. The study recommends that efforts be undertaken to assess the responsiveness of fire brigades to real fire situations.

   An expeditious and effective course of action for determining vulnerabilities that stem from smoke control and manual fire fighting effectiveness is to have all utilities address them as part of the plant examination to be conducted in conjunction with the IPEEE program. This action in the form of guidance is currently under consideration.

3. Adequacy of Fire Barriers: The common reliance on fire barriers to prevent the spread of fire and combustion products from area to area has elevated the risk sensitivity of fire barrier performance. Degraded or unsealed fire barrier penetration seals can contribute to this source of fire risk. Very high barrier reliability is required to prevent the spread of fire to redundant trains of equipment. Based on the examination of the effects of barrier failure on fire induced core damage frequency estimates, the study recommends that an effort be undertaken to assess the reliability of barrier elements.

   The adequacy of fire barrier penetration seals is presently the focus of regional inspections. A search for fire barrier vulnerabilities as part of the IPEEE is also being considered.

4. Equipment Survival in Fire Induced Environments: The scoping study investigated the potential susceptibility of equipment to indirect, or secondary fire involvement through of the environment created by fires, fire suppression, and the spurious operation of fire suppression systems. Because of limited quantitative data and the plant-specific nature of past spurious suppression incidents, the scoping study did not draw any generic conclusions.

The study did however examine the consequences of past spurious suppression system actuation and found that a range of effects including induced plant scrams, stemmed from such occurences. Several events were identified in which significant degradation of plant operability resulted. Had these events occurred during an actual fire or other common cause initiating event, the combined negative effect on plant safety could have been substantial.

The significance of these events and the outgrowth of addional research needs are presently being assessed as part of an ongoing effort to resolve Generic Issue 57 (Effects of Fire Protection System Actuation on Safety-Related Equipment). Information from the Fire Risk Scoping Study has been factored into this program which is currently seeking resolution to this important issue.

5. Seismic/Fire Interactions: The study concluded that most of the risk associated with seismic/fire interactions could be eliminated by performing plant specific evaluations and taking necessary corrective action. A list of potential seismic/fire interactions was reported in the study which will prove useful in future plant walkdowns. This information is being utilized in developing guidelines for treating external events within the framework of the IPEEE program.

6. State-of-the-Art Methodology: Most fire PRAs to date were developed using a deterministic computer code called COMPBRN to model fire propagation. No other codes available provide both the simplicity of operation and applicability to the unique circumstances of nuclear power plant fires.

COMPBRN has undergone three revisions, none of which has been adequately validated. Although improvements have have been made to COMPBRN, the scoping study found internal inconsistencies and non-physical behavior in COMPBRN III. These deficiencies required substantial modifications by Sandia prior to use. All the modifications made to COMPBRN III by Sandia are described in the Fire Risk Scoping Study and will be useful for future fire propagation studies. They have been recently utilized, for example, in the NUREG-1150 fire risk analyses and LaSalle PRA.

COMPBRN is a "zone model" code and is therefore not well suited for treating smoke propagation, or for treating complex situations such as control room fires. For proper treatment of these situations, a more sophisticated three-dimensional "field

model" code is required. Three-dimensional codes however, are more difficult to setup, are more expensive to operate and like COMPBRN, have not been adequately validated for nuclear power plant fires.

The Fire Risk Scoping Study recommends that "...an effort be initiated to assemble, based on current state of the art, and to validate a physically consistent fire simulation model for use in nuclear power plant risk analyses." The RES Staff agrees that code validation and improvements would enhance our understanding and ability to model fire propagation more accurately. However, user requests for such a refined analytic tool have not evolved over the years. The RES Staff believes however, that the analytic tools (including component fragilities) used in the treatment of fire are sufficiently important that they plan to reconsider the need for research in this area following the peer review of the NUREG-1150 fire risk analyses and future discussions with the ACRS.

Conclusions: Resolution of four issues raised by the Fire Risk Scoping Study are being considered within the framework of the IPEEE plant examination. Although no new fire protection research is planned at this time, the need for additional research will be reconsidered following the definition of the fire related part of the IPEEE later in 1989, and also the peer review of NUREG-1150 fire analyses and discussions with the ACRS.

Victor Stello, Jr.
Executive Director
for Operations

Enclosure:
1. Fire Risk Scoping Study
Executive Summary

DISTRIBUTION:
Commissioners
OGC
OIG
GPA
REGIONAL OFFICES
EDO
ACRS
ACNW
ASLBP
ASLAP
SECY

Enclosure

1. Fire Risk Scoping Study Executive Summary

EXECUTIVE SUMMARY

Nuclear power plant fire protection research was initiated at Sandia National Laboratories in February of 1975. The program which is the primary subject of this report, known as the Fire Risk Scoping Study, was a direct outgrowth of this earlier USNRC sponsored Fire Protection Research Program. Based on the findings and insights of various individual fire research activities certain fire risk issues not previously addressed in the fire probabilistic risk assessment (PRA) context were identified. These issues represented aspects of the fire hazard which were perceived to be potentially significant contributors to fire-induced core damage frequency estimates, and had been identified subsequent to the performance of existing plant fire risk assessments. The Fire Risk Scoping Study was established in order to provide an initial assessment of the potential impact of these identified unaddressed issues and to identify areas in need of further investigation.

Execution of this effort was accomplished through five tasks as described below:

Task 1 - Assess Uncertainties in Four Previous Fire PRAs
Task 2 - Requantify Fire Scenarios from Past PRAs
Task 3 - Identify Potential Fire Risk Issues
Task 4 - Assess the Risk Significance of Potential Issues
Task 5 - Evaluate the Completeness of Appendix R Rules in Light of the Identified Unaddressed Fire Risk Issues

Under Tasks 1 and 2 a reevaluation of specific scenarios from the Oconee, Seabrook, Limerick, and Indian Point Unit #2 fire PRAs was performed. The intended objectives of this review were to (1) incorporate information made available as a result of the USNRC sponsored Fire Protection Research Program into past fire risk scenarios, (2) identify the sources of uncertainty in the analyses, (3) determine whether or not the overall perspective of fire risk had been significantly altered as a result of a greater understanding of the fire problem, and (4) determine the effects of the implementation of Appendix R to 10CFR50 fire regulations on these fire core damage frequency estimates. In the requantification process, fire areas were reevaluated based on the scope of issues, considered in the original analyses. Therefore, these tasks were constrained to the PRA methodology of the original analyses.

In general the following observations resulted from the PRA reevaluations:

1. Fire-induced core damage frequency for all four plants increased even though for certain fire scenarios there was a net decrease. For all four plants reviewed fire continues to represent a dominant risk contributor.

2. Most initiating event frequencies were increased based on a much more complete data base available on fire occurrences in nuclear

power plants. Under currently applied risk assessment methodologies this increase in initiating event frequency alone results in a direct increase in overall fire-induced core damage frequency given that all other factors remain constant.

3. Use of the latest version of the COMPBRN fire model, COMPBRN III, for the prediction of fire growth and fire damage resulted in mixed effects. Several instances of nonphysical, nonconservative code predictions were noted in the application of COMPBRN III. Some of these inconsistencies appear to be common to all versions of the code. Based on these observations the adequacy of analytical tools for fire was identified as an issue to be considered under Task 4 of the study.

4. Use of an expanded data base on historical fire suppression times for nuclear power plants resulted in a suppression probability distribution with lower probabilities of suppression within a given time than that assumed in the original risk assessments. Under current methodologies this, again, results in an increase in fire-initiated core damage frequency given that all other factors remain constant.

5. Updated information on the ignition and damage thresholds of cable insulations in some cases resulted in lower thermal damage limits. In some cases no change in damage limits was required. A decrease in the assumed thermal damage limits would, in general, be expected to lead to increased fire core damage frequency estimates.

6. Plant modifications made as a result of Appendix R requirements reduced core damage frequency at Indian Point and Limerick for the requantified fire areas by factors of ten and three, respectively. For Seabrook the identified Appendix R plant modifications did not affect the requantified fire core damage scenarios. The Oconee PRA had already incorporated Appendix R modifications and no modifications subsequent to its performance were identified. Hence, no Appendix R impact could be identified for either Seabrook or Oconee.

In the evaluation of analysis uncertainty five principal sources of uncertainty were identified:

1. Estimation of Location Specific Fire Frequencies and Sizes
2. Estimation of Detection and Suppression Times
3. Estimation of Component Damage Thresholds
4. Modeling of Fire Growth and Equipment Damage Behavior
5. Screening of Induced Off-Normal Plant States (i.e., LOCAs versus Transients)

The variations in judgemental methodologies used to establish such factors prevented consistent comparison of core damage frequency estimates between analyses. Standardized methodologies for the evaluation of these factors

would allow for a consistent basis for comparison of core damage frequency of various plant designs as well as Appendix R implementation practices.

The bulk of efforts conducted under this study involved an initial investigation of certain fire risk issues not previously addressed in a PRA context. At the outset of the program six unaddressed issues had been identified as a result of the USNRC sponsored Fire Protection Research Program (FIN A-1010). This listing of issues was utilized as a departure point for issue identification. The opinions on these identified issues, or any other such issues, of a variety of experts in the fields of fire safety, nuclear power plant design, and nuclear regulation were solicited. A limited review of the nuclear power plant operating experience base was also performed in an effort to identify any other outstanding unaddressed fire risk issues. As a result of this issue identification task the list of unaddressed issues was modified somewhat. The final list of unaddressed fire risk issues as they were analyzed for this study was comprised of the following six issues:

1. Control Systems Interactions
2. Seismic/Fire Interactions
3. Manual Fire Fighting Effectiveness (including Smoke Control)
4. Total Environment Equipment Survival (including Spurious Operation of Suppression Systems)
5. Adequacy of Fire Barriers
6. Adequacy of Analytical Tools for Fire

Each of these six issues was investigated within a limited scope. As a result of these investigations the identified issues were ranked as to their potential significance. In considering the potential significance of each of the issues two aspects were considered. The first consideration was the potential impact of a given issue on plant fire induced core damage frequency if vulnerabilities can be identified. The second consideration was the likelihood that any given plant might, in fact, display the type of vulnerabilities identified. In using these criteria the issues of control systems interactions and manual fire fighting effectiveness were identified as potentially the most significant of the unaddressed issues. The issue of the adequacy of fire analysis tools is also judged to be an issue with a very significant potential impact on the current perception of fire risk. Summarized below are the principal results and conclusions, as well as recommended follow-on efforts for each area of investigation undertaken.

With respect to control systems interactions:

1. Risk significant control systems interactions scenarios involving a combination of fire induced failures and high probability random equipment failures have been identified. PRA methodologies should be expanded in scope to include identification of such scenarios.

2. The independence of remote shutdown control systems is quite difficult to prove. Standardized method and guidelines for the evaluation of electrical independence should be established.

3. The level of indication and control provided on a remote panel can significantly effect scenario quantification. A review of current practices in this regard is recommended.

With respect to manual fire fighting effectiveness:

1. Variations in the assumed responsiveness of fire fighting teams of as little as 20 minutes were observed to result in order of magnitude changes in the perceived level of risk associated with specific scenarios.

2. Practices with respect to the staffing, equipping, and training of fire brigades varies significantly from plant to plant. Current regulations require only minimal training for fire brigade members. A further review of plant practices, and the investigation of the probable linkage between plant practices and brigade effectiveness should be undertaken.

3. Certain fire scenarios have been identified in which critical damage times are so short that even a well prepared fire response team will be unable to prevent damage. Scenario assessment tools and methodologies should be refined and adapted for use in the evaluation of fire detection and suppression system adequacy for specific plant scenarios.

With respect to the adequacy of fire analytical tools:

1. Uncertainties in the analytical tools for fire modeling were found to contribute significantly to the overall assessment uncertainty. Currently available fire models applicable to nuclear power plant risk analyses were found to be inadequate, and were found to not reflect the general state of the art in fire modeling. Further, variations in modeling methodologies were demonstrated to greatly impact final core damage frequency estimates.

2. This issue is quite generic to fire risk assessment methodologies, and hence, can potentially impact the overall perception of fire risk on an industry wide basis.

3. It is recommended that an effort be initiated to assemble, based primarily on the current state of the art, and to validate a physically consistent fire simulation model for use in nuclear power plant risk analyses.

4. The validation of any fire model to be used in the analysis of nuclear power plant risk scenarios will be dependant on the availability of enclosure fire test data. Therefor, it is recommended that the processing of room fire test data already available as a result of the USNRC Fire Protection Research Program be undertaken.

5. Certain of the correlations utilized in the development of fire simulation models have not been adequately validated. It is recommended that limited scope, intermediate scale testing be undertaken to provide validation data for such critical correlations as cable fire growth phenomena and fire induced cable damage.

With respect to the issue of fire barrier adequacy:

1. No generic vulnerability of qualified fire barrier elements has been demonstrated.

2. Should barrier reliability be on the order of 99% or higher then no significant impact on core damage estimates is anticipated. However, should barrier reliability be on the order of 90% then an order of magnitude increase in perceived core damage frequency can be anticipated.

3. It is recommended that an effort be undertaken to assess the actual performance reliability of U.S. fire barrier elements. If, and only if, such a review demonstrates a reliability of less than on the order of 99%, then further testing of barrier elements under realistic fire exposure conditions may be warranted.

With respect to the issue of seismic/fire interactions:

1. Several potential plant vulnerabilities were identified. However, it was also concluded that these vulnerabilities could be easily corrected on a plant specific basis. It is recommended that an effort be undertaken to define and document the potential vulnerabilities of concern to nuclear power plants. This information could then be utilized on a plant specific basis to identify and resolve such vulnerabilities through a well focused walkdown.

With respect to the issue of total environment equipment survival:

1. As a result of a limited experience-based review of spurious fire suppression system actuation events it was concluded that while such incidents could represent significant core damage frequency contributors on a plant specific basis, the adverse impact of such events could be largely eliminated through plant specific reviews of fire protection system design and implementation practices. It is recommended that a more extensive review of the experience base in this regards be undertaken in order that potential vulnerabilities are identified, and that plants may be provided with specific guidance on plant review objectives.

2. Consideration of the damaging effects of such factors as smoke, low level heat, and water sprays was limited in that virtually no data on equipment vulnerability to such environmental effects is

available. Some evidence of equipment vulnerabilities was identified, though no specific quantification was possible. It is recommended that studies be undertaken to assess the damaging effects of smoke on high voltage equipment, and of gaseous suppression systems on control circuitry. (This recommendation is based on limited experience available from non-nuclear fire losses.)