TECHNICAL REVIEW

OF THE

SIGNIFICANCE DETERMINATION PROCESS APPENDIX F

Determining Potential Risk Significance Of Fire Protection And Post-Fire Safe Shutdown Inspection Findings

A Letter Report to the USNRC

Revision 2
March 12, 2002

Prepared by

F. J. Wyant, S. P. Nowlen, and J. L. LaChance

Sandia National Laboratories
Albuquerque, New Mexico 87185-0744

Prepared for

Probabilistic Risk Assessment Branch
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington DC 20555
USNRC JCN Y6037

INTRODUCTION

This report summarizes the results of Sandia National Laboratories' technical review of Appendix F to the Significance Determination Process (SDP), Manual Chapter 0609 of the NRC Inspection Manual, including the two attachments to the appendix. The version reviewed was that made available through the U.S. Nuclear Regulatory Commission internet web site; issue date 02/27/01.

Comments, questions, and findings of interest from the Sandia review are grouped into one of two areas: technical comments and editorial comments. The principal focus of this review was the technical aspects of the fire SDP. In particular, the review focuses on the overall SDP analysis process, its completeness, and its description. Editorial comments were generated solely as a by-product of the technical review process. Responses to questions posed by NRC staff have also been included.

A. TECHNICAL COMMENTS

Most of the technical comments are organized by section following the current structure of Appendix F of the SDP procedures guide. The first section below is an exception and covers more general comments that apply to more than one section of the document.

GENERAL COMMENTS

Comment G-1: SNL has reviewed the overall fire SDP process. We find that the process represents a reasonable approach to the assessment of inspection findings within its stated limitations. The SDP guidance derives from commonly applied fire PRA analysis methods and assumptions. While SNL did not explicitly review the individual probability numbers, those that we did review correspond well to accepted fire PRA practice. The process appears to retain a modest level of conservatism as appropriate to a screening tool. The fire SDP appears to have reasonably achieved the stated intent; namely, provide a screening tool for use by persons who may not be expert in PRA analysis that yields an initial assessment of the risk significance of inspection findings.

Recommendation G-1: As currently structured, the process appears to view the Phase 2 SDP analysis results in their appropriate context; that is, Phase 2 yields screening results. We find the allowance for a more detailed (Phase 3) analysis as a follow-up to a Phase 2 screening analysis to be a critical aspect of the process.

Comment G-2: We find the approach to be suitable for application by the target audience - e.g., regional inspectors. We recognize that the target audience may not be experts in fire science, fire protection, or fire risk analysis. Hence, the simplification of the analysis process as implemented in the fire SDP is recognized as a necessary element of the process. It is our judgement that the simplifications employed have not seriously compromised the process to the point that one would anticipate many false results, in particular, in the false screening of potentially significant findings.

Recommendation G-2: The current guidance provides inspectors with substantial direction in many of the key areas (e.g., qualitative degradation rankings). However, we caution that the analysis of fire growth and damage behavior can be quite complex. The documents that we reviewed did not contain very much information on this topic. We recommend that in training inspectors, particularly those with little background in fire science or fire protection, considerable time be devoted to fire growth and damage analysis. (Note that SNL was not privy to all of the training provided to inspectors and is not attempting to judge the quality of the training already provided. Rather, we are citing this as a precautionary note for future planning.)

Comment G-3: The type of inspection findings that trigger an SDP analysis are not described consistently in Appendix F. The descriptive text states that the FPRSSM "was developed to evaluate the potential fire risk significance of *any* fire protection DID weaknesses that are important to post-fire safe shutdown" (Section F.1, 2nd paragraph, emphasis added). However, the next sentence narrows the focus to "fire protection features and systems"[1] and per Figure 4-1, the first screening step screens findings 'in' only if they impact detection, manual suppression, fixed suppression, or fire barriers. Hence, the screening process appears to screen 'out' any finding related to the safe shutdown (SSD) provisions - a large class of potential findings that are elements of DID. Given the screening criteria, it appears that only findings related to fire protection systems and features will trigger the SDP process.

We note that the third element of fire protection DID (as listed in F.1 Introduction) includes post-fire SSD provisions (e.g., the SSD equipment list, SSD analysis, SSD procedures, planned operator actions, adequacy of alternate or remote shutdown, etc.). Again, while the initial text states that any DID element is fair game, the scope is quickly narrowed to eliminate the SSD elements. (We do note that Phase 2 focuses considerable attention to crediting/analyzing the safe shutdown capability (e.g., see end of F.3). However, the question here is would an SSD finding trigger a SDP analysis in and of itself.) Findings relating to the approach to safe shutdown have come up recently so this topic is timely. EXAMPLE:

> An inspector finds that potential failures involving a particular component or system were not included in the safe shutdown analysis. Failure of the component or system could lead to failure of the designated SSD path (e.g., open a diversion path or cause a loss of power to the SSD equipment). SDP phase 1 - step 1 would screen this finding 'out' because it does not impact any of the DID elements called out in the Figure 4-1 (flow chart, right-most box). Hence, a SDP analysis would not be pursued under any such circumstances. Is this the intent?

Recommendation G-3: It appears appropriate to either explicitly include or exclude the analysis of findings impacting the DID elements related to the selection and analysis of the

[1]Per NFPA 805: "Features" covers administrative controls, barriers, fire brigade, and other similar provisions of the fire protection program; "Systems" covers detection, alarm, and suppression systems installed and maintained according to standards. Hence, fire protection "systems and features" does not cover the safe shutdown path/approach itself.

SSD path/method/process. Per the NFPA definitions, these elements of DID are not considered fire protection features or systems.

In general, we recommend that SSD-related findings be included in the SDP scope. If included, then the criteria for screening a finding 'in' as shown in Figure 4-1 should include a fourth check-list element - safe shutdown capability. Note that a SDP screening analysis could be performed to assess the risk implication of the example situation without any fundamental changes to the method.

Comment G-4: A list of definitions would help. Several terms are used that could be interpreted ambiguously by different readers.

Recommendation G-4: Recommendations for specific term definition are scattered through the remaining technical comments. A specific list of recommended definitions is provided in Attachment 1 to this review. We have recommended NFPA 805 definitions when possible.

F.1 INTRODUCTION

Comment F.1-1: The text refers to a "Phase 3" analysis. (There is also a passing mention of a Phase 3 analysis in Section F.5.) No further discussion of Phase 3 is given in the rest of the document. In fact, other sections refer to the process as a two-phase screening methodology.

Recommendation F.1-1: If the 3-phase structure is retained, the reader should be provided with a more complete description of the three analysis phases including the purpose and objectives of each. It should also be made clear that the Phase 3 analysis is not covered in this particular document. The references to a two-phase screening should be revised to reflect this structure.

As an alternative, you could remove the two cited references to "Phase 3" and rewrite the final sentence in Section F.1 as follows:

> "If the Phase 2 analysis determines that the inspection findings have potential risk significance, a more detailed and refined analysis can be performed. Such analyses are not explicitly covered by this document but would generally involve the application of a more detailed probabilistic risk analysis. The USNRC fire protection staff can be consulted for additional guidance and support."

This allows for a follow-on analysis that lies outside the scope of the guidance document.

Comment F.1-2: In the second paragraph, the requirement for maintaining "one SSD success path free of fire damage" applies to hot shutdown (Appendix R, Section G.1.a). Repairs are acceptable for cold shutdown systems if they can be made within 72 hours (Appendix R, G.1.b). It appears that the SDP is intentionally focused on systems needed to achieve hot shutdown. That is, achieving hot shutdown is considered success.

Recommendation F.1-2: We recommend explaining the difference in requirements for hot shutdown and cold shutdown in a footnote. Also explain that the SDP focuses on hot shutdown as the end state for the analysis and does not explicitly consider cold shutdown.

This recommendation clearly relegates the issue of cold shutdown and compliance with the associated regulatory requirements to a secondary status. This is consistent with

current risk analysis insights - i.e., hot shutdown is a reasonable end state for an SDP type analysis. However, the staff may also want to ensure that cold shutdown requirements are not entirely dropped from the inspection process. You might, for example, state the following:

> "Findings related to the regulatory requirements for cold shutdown are uniformly expected to yield a "green" SDP result. Hence, while these provisions are open to inspection, an SDP analysis would not be required for such findings."

Comment F.1-3: The third sentence in the third paragraph states, "The Phase 2 analysis allows for equipment beyond Appendix R to mitigate core damage." The guidance provided in Appendix F provides little additional guidance in this regard, and does not describe the role of manual actions in this process. It appears that the example worksheets provided to inspectors are relied upon to provide guidance in this regard.

Recommendation F.1-3: It would be helpful to provide some additional discussion in Appendix F as to the intent and objectives in crediting non-Appendix R systems and equipment. Some additional explicit guidance (i.e., beyond the existing examples) on crediting manual actions would also be helpful.

Comment F.1-4: The terms "fire protection features and systems" are used widely in the document. The use of these terms was a point of some discussion in the NFPA 805 process because they are not inherently clear.

Recommendation F.1-4: We recommend defining the terms "fire protection feature" and "fire protection system". NFPA 805 definitions would apply here. We also recommend a review of the text to ensure that the intent implied in their use is consistent with their definitions. (Our review took this as a given because we cannot know whether or not a different meaning was intended.)

F.2 PURPOSE

Comment F.2-1: The first paragraph introduces the concept of evaluating the "as-found" conditions of the fire protection mitigation features and systems.

Recommendation F.2-1: We recommend including a discussion of the meaning and intent of the term "as-found condition." In particular, 'as found' implies a contrast to the some baseline or expected condition. We would nominally assume that inspectors weigh the "as-found condition" against the licensing basis. However, what role do exemptions/deviations play in defining the baseline or expected condition? Are conditions per the exemption the baseline or are conditions at they would be with full Appendix R compliance and no exemption the baseline condition? These points could be clarified.

F.4 FIRE PROTECTION RISK SIGNIFICANCE SCREENING METHODOLOGY - PHASE 1

Comment F.4-1: Under the discussion of Step 2 screening, there are various fire protection schemes identified for typical safe shutdown train configurations, but the discussion does not

cover exemptions (or deviations). The current guidance does not call out an exemption as a potential compliance scheme, and provides no guidance on how to handle an exemption if encountered. However, Appendix R allows for implementation of any alternate measure that is determined by the staff to provide an adequate level of protection. The fire protection schemes discussed cover the three basic options from Appendix R, but fail to allow for exemptions or deviations. Exemptions and deviations may make the analysis problem more complex.

Recommendation F.4-1: We recommend that the user be alerted to specifically look for exemptions or deviations for the area(s) being examined. If an exemption exists, then some complication of the analysis process should be expected. It would be helpful to develop some standard process for examining cases involving exemptions and deviations. Example:

> An exemption to the 20 foot separation rule was granted for a case where less than 20 feet was available. The exemption was granted based on a very low combustible fuel loading, a lack of ignition sources, and existence of automatic detection and suppression systems. In this case, the inspector would want to look for such things as changes in the fuel loading, introduction of new ignition sources, and operability of the detection and suppression systems.

Writing such guidance would be a challenge. A review of the existing exemptions might reveal patterns that could be used to develop guidance (e.g., a common set of exemptions that might be encountered). However, this could also be very important because some plant features not normally listed among the standard DID set do appear as important factors in an exemption request (e.g., lack of ignition source, low fuel loading). By tagging the exemptions explicitly, inspectors may find plant changes that compromised the original exemption basis that would not otherwise be found.

It might also be appropriate to relegate some of the details of this discussion to the attachments. However, we recommend some discussion of the issue in the body of Appendix F.

Comment F.4-2: The first paragraph does not appear to belong in this document. It is more of an explanation of how to pick plant areas for inspection of fire protection features rather than how the SDP screening methodology is applied in those fire areas. It also does not discuss the concept of the CCDP and using that as an additional measure of zone importance.

Recommendation F.4-2 It would seem that this paragraph may be included in the Inspection Procedures Manual (IP 71111.05) rather than here. Whether the text is retained in this document, or moved to the Inspection Procedures Manual, we recommend addition of the following discussion:

> "Other areas of potential interest include those found by the IPEEE/PRA to have a high a screening conditional core damage probability (CCDP) regardless of the final estimated risk contribution (CDF). The screening CCDP generally reflects the probability of core damage given the loss of all the equipment located in a fire area or fire zone. A high CCDP (e.g., greater than or equal to about 0.1) generally indicates the presence of redundant safe shutdown systems or components. The final fire risk (CDF) estimates for such areas may be sharply reduced based on credit taken for one or more fire protection features and systems. Hence, findings related to the impairment or degradation of those same fire protection features and systems may

warrant particular attention. (Note that the IPEEE submittal may or may not provide CCDP values.)"

Comment F.4-3: The discussion specifically notes the MCR and CSR as potentially important fire areas. In the inspections that SNL has supported to date, these areas were typically walked down, but were not chosen as areas of focus for the inspection. The teams always held out the possibility that should any unusual conditions relevant to the fire protection DID elements be noted, then these areas might become the focus during the inspection. However, none of the inspections SNL has participated in to date has picked either the MCR or CSR as an area for detailed inspection.

Recommendation F.4-3: The basis for our experience in this regard is not clear. However, our experience may indicate a need for additional guidance regarding inspections in especially challenging areas such as the MCR and CSR.

Comment F.4-4: This comment relates to the second paragraph under "Step 1: Screening of Fire Protection Findings" beginning with "Making judgments regarding ..." This paragraph describes an exception to the screening process. The closing sentence states that "findings related to only manual firefighting or fire brigade effectiveness typically do not warrant the performance of a Phase 2 evaluation."

Recommendation F.4-4: It appears inappropriate to spell out exceptions to the process in the text that explains how the process works. The discussion distracts from the flow of the document. It would seem better to simply spell out the process in Appendix F and let such observations as this paragraph fall to the application guidance (i.e., Attachment 1). After all, this is certainly not the only exception one might come up with based on experience. It is not even stated as a global exception, only as "typically do not warrant." Hence, an inspector must presumably still verify whether or not a Phase 2 analysis is needed.

Comment F.4-5: Given Figure 4-2, the screening criteria logic diagram for Protection Scheme 2 (one hour barrier), findings against detection or manual suppression do not trigger an SDP analysis. However, findings against detection or manual suppression do trigger an analysis if Protection Scheme 3 (spatial separation) is used. This implies a much greater degree of reliance on detection and manual intervention is assumed given spatial separation than given a one hour fire barrier.

Recommendation F.4-5: We recommend a review to ensure that this reflects the intent of the authors for these cases. The apparent unstated assumption is that an intact 1-hour fire barrier gives enough time for detection and manual suppression even given some finding against those features whereas 20-feet of spatial separation does not. Certainly fire barriers provide some substantial delay that spatial separation may not assure. Hence, the intent may be exactly as stated. We simply recommend a review to ensure that is, indeed, the case.

Comment/Recommendation F.4-6: With regard to the fire protection redundancy configuration illustrated in Figure 4-3, recovery of one SSD train, an example that illustrates the configuration would be very useful. For example, are cold shutdown repair actions

intended to be covered by the post-fire SSD interaction shown in Figure 4-3? Is the manual (via hand-wheel) opening of an MOV to be considered as an example of this case?

Comment F.4-7: The description of the fire protection scheme generally applied for the SSD configuration shown in Figure 4-3 (last sentence) states that "this scheme provides an alternative shutdown system that is electrically and physically independent of the fire area…" However, an important element of the scheme is reliance on alternative shutdown and manual actions to operate and control SSD equipment in areas that are physically separate and electrically independent (or can be isolated from) the fire-affected area, zone or room.

Recommendation F.4-7: We recommend that the text be revised as follows:

> "…this scheme provides an alternative shutdown <u>method that depends on manual actions to operate and control SSD equipment in areas that are physically separated and electrically independent (or can be isolated from) the fire-affected</u> area, zone or room of concern." (Underlining indicates added or revised text.)

Comment/Recommendation F.4-8: Based on the above comments and the description of the SSD interaction provided in Figure 4-3, we recommend an alternate/expanded screening process and criteria as follows:

- Does the fire area boundary interface with any recovery area, including acess routes? (No - screen out; Yes - continue)
- Are any of these interfacing fire area boundaries affected by the finding? (No - continue; Yes - go to Phase 2 analysis)
- Are any of these fire area boundary barriers rated for less than 3-hours? (No - screen out; Yes - continue).
- Is the fixed fire suppression system affected by the finding? (No - continue; Yes - go to Phase 2 analysis)
- Is the detection system or the brigade effectiveness affected by the finding? (No - screen out; Yes - go to Phase 2 analysis)

The rationale for this recommendation is two-fold: (1) it explicitly requires consideration of access routes required for SSD train recovery actions with respect to the fire-affected area boundaries, and (2) the implied assumption in the current screening criteria figure is that the fire area boundary is rated for 1-hour of protection, which would require the presence of automatic detection and suppression systems in the scenario. However, if the fire area boundary is not affected by the finding <u>and</u> if it is rated at 3-hours of protection or better, then consideration of automatic detection and suppression system operability is not warranted.

However, even this recommended change in screening criteria for Figure 4-3 does not cover everything. The important items that are required for performing recovery actions are time, location and procedures. The process described above only addresses the location issue. How are time and procedures to be evaluated and assessed in the Phase 1 screening process? Furthermore, the issue of spurious actuation, possibly leading to equipment damage (e.g., the IN 92-18 concern), and the resulting impact on SSD train recovery is also

not explicitly discussed in this process description. Some additional discussion of these issues may be warranted.

Comment/Recommendation F.4-9: With regard to Figure 4-4, we recommend that a statement be included to clarify that the physically independent train depicted in the figure is not a designated SSD system, but rather, is an alternate system that can perform the same function as either of the two designated SSD trains located within the fire area.

Comment/Recommendation F.4-10: With regard to the Screening Criteria for Figure 4-4, in the bottom boxes of the logic trains shown, we recommend identifying that the train of safe shutdown capability is a non-SSD system.

Comment/Recommendation F.4-11: With regard to Figure 4-5, it would be useful to provide examples of the types of redundant systems that are intended to be represented in this figure.

F.5 FIRE PROTECTION RISK SIGNIFICANCE SCREENING METHODOLOGY - PHASE 2

Comment/Recommendation F.5-1: It would help clarify the nine-step integrated risk assessment process if figure 5.1 were moved from the end of Appendix F to just below the introductory paragraph in this section.

Step 1: Grouping of Fire Protection and Post-Fire Safe Shutdown Findings

Comment F.5-2: Step 1 states that "fire protection mitigation DID features are grouped according to each specific fire area, zone, or room which they impact." This is the first place where the guidance introduces the concept of fire areas versus fire zones versus a room. No explicit guidance (beyond the examples) is provided to help inspectors determine how large a chunk of the plant should be grouped together in this analysis. The selection of fire analysis zones is a critical step, and inconsistent treatment in this regard could easily lead to inconsistency in results from inspector to inspector.

Recommendation F.5-2: It is recommended that explicit guidance be provided on choosing the fire analysis zones appropriately. One can begin with the fire areas as defined in Appendix R. However, a fire area may encompass a number of rooms that might be treated as fire zones. Guidance could, for example, next partition Appendix R areas based on the existence of a fire barrier wall with at least a 2-hour fire endurance rating. Once one gets into a specific analysis, the fire's zone of influence becomes the key question, and this may be much smaller than the fire area or even fire zone.

We also recommend deleting references to 'rooms' as an analysis region. The combination of fire areas and fire zones is sufficient to cover all potential divisions of the plant. The guidance could still, for example, state that a room that does not meet the criteria of a fire area may be treated as a fire analysis zone. However, identifying a new type of analysis region, a room, is unnecessary.

Step 2: Define the Fire Scenario

Comment F.5-3: The second paragraph under Step 2 states that "The inspector should try to identify the dominant scenario(s) to limit the number of scenarios which need to be analyzed." Without further explanation this could lead inspectors to focus to early on a fire scenario that may later prove to be less significant from a risk standpoint.

Recommendation F.5-3: Some additional discussion of scenario selection would be helpful. In particular some additional cautionary guidance appears appropriate. The inspector should be cautioned not to focus too early on a single fire scenario, but rather, to include consideration of a range of scenarios with the objective of narrowing that focus as quickly as practical. It would be helpful to caution the inspector even more explicitly that risk significance is comprised of two elements - likelihood and consequences. The last sentence in this paragraph does state that "The dominant scenario(s) will be based on the frequency of the ignition source(s) which starts the fire, and the damage done by the fire." A narrow-focused reader might take this to mean that these are the factors that characterize, rather than determine, which scenarios are dominant. We suggest strengthening this point by stating "The *selection* of the dominant scenarios will be based on ..." both factors.

Comment F.5-4: The current text says "the inspector ... should postulate a large fire providing the component and configuration of the fire area, room, or zone supports such a fire. ... Since scenarios with large fires are normally expected to dominate the risk significance of an inspection finding, scenarios with small fires generally need not to be (sic) included if scenarios with large fires can be postulated." In effect, the words imply that if you find a source of big fires, don't worry about little fires. This guidance as written could lead to some misleading results, in particular, given the reliance on fire severity factors. If a severity factor is applied to reflect the likelihood of a large fire, when in fact, a small fire might still cause critical damage, then the risk impact may be under-estimated.

Recommendation F.5-4: We suggest revision of the text to acknowledge that the most severe fire in a classical sense is not necessarily the worst fire from a risk standpoint. A relatively small fire that happens in just the wrong spot may actually prove to be more challenging from a risk perspective. Rather than basing the analysis on the biggest possible fire, we recommend that inspectors be directed to postulate fires *up to an including the largest possible fire (based on the fire zone configuration, combustibles, ignition sources, etc.) but to apply severity factors that reflect the smallest fire that might lead to critical damage*. That is, if critical damage can occur given a small fire, then using a severity factor that reflects only large fires may not be the right answer.

In practice, one should see the large fires dominating the analysis as is stated in the guidance (it often takes a big fire to cause damage). However, the current discussion states this as a for-gone conclusion and could distract inspectors from consideration of fires other than the most severe possible. Our recommendation is intended to soften the discussion somewhat.

Comment/Recommendation F.5-5: We recommend adding a notice at the end of this step that reminds the inspector that:

"If no credible fire scenario can be developed, then notify the licensee of the finding (i.e., degraded fire protection feature) for inclusion in their corrective action program."

Step 3: Qualitative Evaluation of Findings

Comment/Recommendation F.5-6: The final sentence/paragraph in this section states that a qualitative degradation rating (DR) is assigned, but does not elaborate.

Recommendation F.5-6: We note that guidance on assigning DR values is provide in Attachment 2. However, it would be helpful if Appendix F went ahead and defined the qualitative DR values and spelled out what each degradation ranking generally implies, e.g.:

"High degradation implies that a fire protection system or feature is nonfunctional or is degraded such that reliability or effectiveness will be substantially reduced. Systems and features with high degradation are not credited."

"Medium degradation implies that a fire protection system or feature suffers some deficiency that may impact its reliability or effectiveness. Such degradation may, for example, involve significant deviations from the code of record in an otherwise functional system. The system is ultimately expected to be capable of performing its intended function despite the deficiency. Some credit for such systems is given in the SDP quantification process."

"The DR ranking 'normal operating state' implies that the system or feature is fully functional and in compliance with the code of record. The DR ranking of 'normal operating state' explicitly includes minor discrepancies that would have no substantive impact on the expected performance of the fire protection feature or system. (For example, if the inspector finds that a sprinkler head has not been located in full compliance with the code of record, but conclude that this mis-placement will have no substantive impact on performance of the system, the system can be assigned a DR of 'normal operating state' despite the discrepancy.) These systems are given full credit in the risk quantification process."

Step 4: Integrated Assessment of DID Findings (Excluding SSD) and Fire Ignition Frequency

Comment F.5-7: This step provides the formula for calculating the Fire Mitigation Frequency based on the quantitative values determined for each of the DID findings and the fire ignition frequency (IF) but is introduced before conversion of the qualitative degradation rankings to a quantitative value. As such it appears to be out of place at this point in the process.

Recommendation F.5-7: The Phase 2 process logic would be enhanced by placing step 4 after step 5 and after the first part (the first two paragraphs) of step 6. The balance of step 6 (conversion of the FMF to frequency) would then become a separate step in the process. Consequently the recommended structure of the SDP Phase 2 would be as follows:

Step 1: Grouping of Fire Protection and Post-fire Safe Shutdown Findings
Step 2: Define the Fire Scenario

Step 3: Qualitative Evaluation of Findings
Step 4: Assignment of Quantitative Values (old Step 5)
Step 5: Determination of Fire Ignition Frequency (first part of current step 6)
Step 6: Integrated Assessment of DID Findings (current step 4)
Step 7: Conversion of FMF to Frequency (second part of current step 6)
Step 8: Integration of Adjusted FMF with SSD (current step 7)
Step 9: Modifications Necessary to Add Impact of Spurious Actuations (current step 8)

This change would also require modification of Fig. 5.1. (Note that current step 9 has been removed from this list for the reasons provided later in this document.)

Step 5: Assignment of Quantitative Values

Comment F.5-8: There appears to be a mixed use of terminology in this step regarding 'normal operating state' versus 'low degradation.' Table 5.1 defines three qualitative DR rankings - 'high', 'moderate', and 'normal operating state.' However, tables 5.2 and 5.3 refer to a 'low' DR ranking. We generally assume that Table 5.1 reflects the intended set of DR rankings.

Recommendation F.5-8: We recommend using the term "normal operating state" exclusively since it describes the apparent compliance with all requirements. Otherwise, another qualitative degradation level of "low degradation" should be defined in Step 3 and included in Table 5.1.

Table 5.1 Quantification of Degradation Ratings (DR) of the Individual DID Elements

Comment F.5-9: Some aspects of Table 5.1 could be enhanced and clarified.

Recommendation F.5-9: We recommend modifying the table as shown below. The changes (1) explicitly group the passive fire protection schemes under a common heading, (2) identify the first column explicitly as the qualitative DR ranking, and (3) identify the two letter acronyms corresponding to the roll-up equation discussed under Step 4. This will aid users in clearly connecting the various steps and tables.

Table 5.1 Quantification of Degradation Ratings (DR) of the Individual DID Elements

Qualitative Level of Degradation (DR)	Passive SSD Train Separation Scheme (FB)			Automatic Fire Suppression Effectiveness (AS)	Manual Fire Fighting Effectiveness (MS)	
	3-Hour Fire Barrier	1-Hour Fire Barrier	20-Feet Separation		Outside Control Room	Inside Control Room
...	...	...	...	...	...	...

Comment F.5-10: Given Comment F.5-8, some review of tables 5.2 and 5.3 may be needed. Also, the logic of the dependency factors may not be consistent.

Consider two cases. In case 1 I have moderate degradation of the automatic suppression and high degradation of the fire brigade. In case 2 I have high degradation of the automatic suppression and high degradation of the fire brigade. It appears that the final

answer for these two cases is identical since there is no dependency factor for the high-high combination. Now consider a third case where there is no automatic suppression system at all and high degradation of the fire brigade. Again we appear to get the same answer. Even a moderately degraded suppression system should provide some benefit over a highly degraded system or the lack of any system at all. Simply changing 'medium' to 'high' and 'low' to 'moderate' in the first column does not correct the apparent discrepancy because then not having a system at all would be judged better than having a highly degraded system. This does not appear warranted.

Recommendation F.5-10: We recommend reviewing the logic behind Table 5.2 and 5.3. The common cause adjustment factors appear too severe and we recommend further review of these values as well.

Step 6: Determination of Fire Ignition Frequency

Comment/Recommendation F.5-11: As indicated above, we recommend splitting step 6 into two parts and moving Step 4 to fall between these two new steps. Step 4 would fit in directly above the paragraph beginning "The next step is to convert the FMF…"

Comment F.5-12: In the first paragraph of this step, the guidance says that the fire ignition frequency for the appropriate component(s) contained in the plant-specific IPEEE should be used. Sandia's experience with the information contained in most first-tier level IPEEE documents is that the fire ignition frequencies provided are usually referenced to a particular fire area, room or zone, and not to specific components or component types. Details about component fire ignition frequencies, if provided at all, are contained in the second-tier documentation for the IPEEE. Also, when participating in fire protection inspections with Regional inspection teams, it has been our experience that the fire ignition frequency for the fire area, room or zone under consideration is used for calculating the fire mitigation frequency (FMF) when performing a Phase-2 risk determination. The use of the fire area, room or zone fire ignition frequency is a more conservative estimate of the risk associated with a degraded fire protection feature than using the IF for a particular component.

Recommendation F.5-12: Some clarification of this step may be warranted. Note, for example, that inspectors could also refer to either FIVE or the Fire PRA Implementation Guide for methods to calculate component specific fire frequencies.

Comment F.5-13: The second paragraph under Step 6 is somewhat in conflict with previous guidance. In Step 2 the inspectors were instructed to seek a minimal set of scenarios for analysis involving large fires when such were possible. Now in Step 6 the inspectors are told that many scenarios may need to be added to get the final answer. This could introduce confusion.

Recommendation F.5-13: It would be prudent to soften the tone of this paragraph and to tie it back to the scenarios identified in Step 2 explicitly. Presumably, the inspector already has the scenarios identified, and merely needs to calculate the fire frequency for those scenarios. As a part of the scenario identification in Step 2 the initiating components that can cause damage should have been identified. Hence, in Step 6 the guidance can be simplified by

stating that the objective is to estimate the fire frequency for the same set of initiating components as were identified in Step 2.

Step 7: Integration of Adjusted FMF with SSD

Comment/Recommendation F.5-14: We recommend adding a cautionary note to the end of Step 7 as follows:

"If a non-green finding is obtained, an overall review of the finding evaluation process should be performed. Include in the review the following points:

- Review and re-assess qualitative degradation ranking (DR) values assigned to the relevant DID element(s) to ensure consistency.
- Review the assigned fire ignition frequency (IF) to ensure that it reflects the conditions of the scenarios developed in the SDP. Note, for example, that some IPEEEs analyze fire scenarios using the fire frequency for the entire fire zone under analysis rather than for specific initiating components. Hence, some adjustment of the fire frequency might be appropriate to suit the fire scenario(s) developed in Step 2."

Step 8: Modifications Necessary to Add Impact of Spurious Actuations

Comment/Recommendation F.5-15: The discussion of spurious actuations could be clarified. Points on which we were uncertain are the following:

- The first paragraph, second sentence states "For each train which experiences fire damage only in the form of spurious actuations, ..." Is this meant to mean "For each train where the only mode of failure that causes system failure in the event sequence is spurious actuation, ..." We interpreted this as applying to systems where failure to operate (e.g., loss of power) does not complicate the scenario whereas spurious actuation does complicate the scenario. In such cases, one adds in the spurious actuation likelihood as the only failure mode of interest.
- The second paragraph first sentence discusses split scenarios where one answer is obtained for the case without spurious actuation and one for the case with spurious actuation. However, the split fraction is not specified. Do we assume the same 90/10 split as for the previous case? Also it would be helpful to specify at what stage in the analysis the scenarios are to be summed. That is, once we have a color finding, we are no longer adding up scenarios, or are we? That is, if we end up with two greens from these two cases, do we add them up, or do we add them up at an earlier stage?

Step 9: General Rules for Applying FPRSSM

Comment F.5-16: This step covers the treatment of double-room scenarios which come into play when a fire barrier degradation is noted. This particular section was quite difficult to follow. Fundamentally, the analysis of multi-room scenarios remains a significant area of challenge for fire PRA in general. Hence, to expect that a simplified screening method such as SDP will provide a realistic analysis of multi-room scenarios may not be reasonable. It is clear that much work went into this section, but the result appears impractical in application. Two specific areas of concern are the following:

- The second paragraph states that for the DRT components "are assumed to fail to the extent supported by the fire scenario." Guidance on how this is to be done is not given. (Note that we also considered the supplemental guidance in Attachment 2 and found no guidance there either.) It seems unreasonable to expect an inspector to realistically assess the damage potential given fire spread through a degraded barrier. Fire spread behavior depends on many factors that the inspectors are likely not qualified to assess. Even in a full-scope fire PRA this remains a challenge.
- The rules for determining when the DRT or SRT should be applied are expressed in a rather convoluted manner. They are quite difficult to follow, and it is not clear that they truly reflect the proper correspondence between SSD credit and DR penalty factors.

Overall, this section presents the inspector with unique challenges that they are likely not adequately prepared to handle.

Recommendation F.5-16: It may be more appropriate to back off on this aspect of the method and to develop a far more simplified version. While simplification may lead to more 'non-green' findings when primary fire barriers come into question, this may be an appropriate result. The primary fire barriers represent our first and best line of defense for ensuring SSD. If fire barriers are seriously degraded, i.e. to the point we rank them as moderate or high degradation, then this becomes a very serious deficiency if that barrier is protecting our safe shutdown redundancy. The fact is that simplified screening tools that provide the level sophistication and detail implied by the current approach simply do not exist. It would be better to fall back on common PRA multi-room screening approaches that assume the loss of all equipment in both areas with some frequency and screen accordingly. Your flexibility comes in assigning the frequency of a sufficiently challenging fire, and in assigning the likelihood of barrier failure. For example, one must be able to develop a sufficiently severe fire scenario so as to challenge the fire barrier in the first place. Overall, we recommend a complete reconsideration of this particular portion of the SDP analysis process.

ENDNOTES

With regard to Endnote 2: The requirement for maintaining reactor coolant process variables within the limits predicted for a loss of AC power only applies to SSD systems designated as part of the alternative or dedicated safe shutdown systems (i.e., those governed by Section III.L of Appendix R).

With Regard to Endnote 6: We recommend changing and expanding upon this note as follows, "Each of the values in Tables 5.1, 5.2, and 5.3 approximately represent an exponent of 10 for estimating the change in risk due to the assumed failure probabilities for DID elements in the "as found" conditions existing in the fire area, room or zone of concern." (Underlining indicates new or revised text.)

ATTACHMENT 2

In item e, under Fire Scenario Considerations, it would be helpful to define the voltage ranges to be identified by "high" and "medium" voltage. The concern is that there are a

number of ways to classify voltages as low, medium, or high. For example, the National Electric Code (NFPA 70) identifies high voltage as greater than 600 volts (rms) whereas IEEE Std 141-1976 classifies medium voltages as being in the range of 1000 to 72,500 volts and high voltages are in the range of 72,500 to 242,000 volts. Our available evidence suggests (EPRI sponsored review performed as a part of the IPEEE process) explosive faults may be a problem for panels of 480V or higher. Perhaps this can be used as an alternative to"high and medium."

Some additional guidance on fire growth for cable trays would be useful. The current guidance discusses mechanisms of heat transfer and fire spread, but does not go so far as to put this into concrete terms. There are simple rules of thumb regarding fire spread rates that might be cited for general reference. One might also point out that the most significant fire spread mechanism is direct flame impingement. This is especially important for cables.

Some guidance on thermal damage limits would be helpful. In particular, thermal damage limits for cables could be described. This would help the inspector gain a general understanding of what it takes to cause thermal damage. This, coupled with the simplified fire analysis spreadsheets being developed within NRR, would make a powerful tool for inspectors.

We recommend changing the table at the end of this attachment to something like the following:

Guidance for Determining Fire Barrier Penetration Seal Thickness Degradation Categories		
High Degradation	**Moderate Degradation**	**Normal Operating State**
0 to 30 percent	**30 to 80 percent**	**80 to 100 percent**
Percentage of Required Seal Material Thickness Remaining in Penetration		

B. EDITORIAL COMMENTS

MAIN BODY OF APPENDIX F

General: In the web accessible version of Appendix F that was the subject of this Sandia review, several instances of missing special characters occur. For example, it appears that the "delta" in ? CDF is missing in several locations. Similarly, there are several instances of missing relational operators ("?" and "?") especially in Step 9. There were also many spurious characters present, and font size and type changed several times through the document. We recommend that the web version be gone over by a technical editor to ensure such problems are resolved. Publication as a PDF document would likely help in this regard.

Screening Criteria figures All of these figures, in the version we accessed from the NRC web site, printed with distortions of the arrow positions and answer/action responses to the questions posed in the boxes. This problem can easily lead to confusion and misapplication of the screening process that these figures are supposed to demonstrate. There are a total of eight figures that need to be fixed. Again, publication as a PDF document would likely help resolve such issues.

Step 1: The statement in the second paragraph, "Reliance on fire brigade performance and its effectiveness as a sole means of maintaining one success path of SSD capability free of fire damage is not viewed as an acceptable practice" is an extremely important point and we recommend that it be highlighted in some way.

Figure 4-1: Screening Process Phase 1 (Step 1): The far right-hand box in this figure could be modified in the following ways:

- Change the top question line to read as follows, "Affects one or more of the following fire mitigation DID elements?"
- Add item "4. Twenty-foot separation" or change item three to read "3. Fire Barriers or spatial separation"
- Add an arrow from the box indicating the appropriate action if the response to the boxed question is negative (e.g., "No, screen out").

In addition, it would be helpful to provide an example to cover spatial separation violations (e.g., transient combustibles inadvertently placed in the in the 20-foot no-combustible zone or a plant change introduced new combustibles).

Step 2: In the first sentence of the first paragraph, we recommend replacing the word "affect" with "involve the apparent impairment or degradation of". We believe this change more accurately reflects the intent of this guidance.

Scheme 3: The last two sentences in this definition could be combined as follows, "The spatial separation between the redundant SSD trains must be free of intervening combustibles, and the area must be protected by automatic fire detection and suppression systems." This recommended change would better reflect the requirements of Section III.G.2.b of Appendix R.

Step 5: We recommend rewording the third paragraph as follows: "Rigorous compensatory measures for the DID elements are credited (refer to footnote 4, cited under Phase-1, Step 1). The credit given for a rigorous compensatory measure to a DID element is the credit that would be provided for a moderate degradation of the DID element." The version of Appendix F reviewed during this effort included reference to a non-existent footnote.

Step 5: We recommend moving the third sentence in the fourth paragraph, beginning "The normal operating state probability for automatic suppression…" so that it follows the fifth sentence in that paragraph (i.e., after "…and is substantial."). The reason is that the third sentence refers to automatic suppression while the second, fourth and fifth sentences all refer to the passive fire barrier schemes.

Step 5: The second sentence in the paragraph between Table 5.2 and Table 5.3 could be modified by replacing "…has a low degradation…" with "…is qualitatively rated as normal operating state (NOS)…" Also, the next sentence in that paragraph may be changed to begin "No net credit is provided…" and "medium" changed to "moderate."

Step 5: The last paragraph under step 5 may be changed to read as "The Table 5.3 adjustment is made since a common water delivery and supply system exists for both automatic and manual water-based systems in their normal operating state."

Table 5.2: In order to provide consistent use of terminology, "Medium" should be changed to "Moderate" and "Low" changed to "NOS" or "Normal Operating State" (per comment F.5-8).

Table 5.3: Each "Low" in this table could be changed to "NOS" or "Normal Operating State." per comment F.5-8.

Step 6: In the paragraph below Table 5.4, the word "degradation" in the first sentence could be changed to "degraded condition has".

Table 5.4: The first entry in the right-hand column, under Approximate Frequencies (per year), could be changed to read "1 per 1 to 10^2". This change will bring Table 5.4 into agreement with the Approximate Frequency categories of Table 5.5.

Step 7: We recommend adding a closing quote to "Risk Significance Estimation Matrix" in the first sentence of the third paragraph.

Step 7: The last sentence in the fourth paragraph could be rewritten to end, "…is included in Case 2 of Attachment 1."

Step 9: In order to avoid confusion, the two figures, 9.1 and 9.2, referenced in this discussion might be renumbered as figures 5.2 and 5.3, respectively. (The references themselves will also need to be corrected.)

Step 9: The word "medium" used in rules 2 and 3 should be changed to "moderate" to reflect the degradation ratings defined in Table 5.1.

ENDNOTES

With regard to Endnote 7: We recommend deleting this endnote reference in Appendix F under Phase 2 Step 5.

ATTACHMENT 1

We would remove the word "also" from the first sentence in the first paragraph under Example 1A.

We recommend changing "the rules" in the second paragraph under Example 1A to "Rule 1".

Table references throughout this attachment are incorrect. References made to "Table 5.6" could be globally changed to "Table 5.4", references to "Table 5.7" changed to "Table 5.5", and "Table 5.8" references changed to "Table 5.6."

Under Example 1B, the DRT/SRT relational check sentence may be changed to read "Since SSD(DRT) = 10 * SSD(SRT), only the SRT is necessary (Rule 3)."

In the second sentence of the first paragraph under Notes for Examples 1A and 1B, we recommend changing the second "CDF" to "? CDF".

We believe that "medium" could be changed to "moderate" in the first paragraph under Example 1C.

We recommend adding "(Rule 4)" to the end of the second paragraph under Example 1C.

We recommend changing "CDF" to "? CDF" in the first and third sentences in the paragraph under Note for Comparing Examples 1B and 1C.

We would also recommend changing "CDF" to "? CDF" in the second, third (only the first use) and fifth sentences in the last paragraph under Summary of Case 1: Cable Spreading Room.

In the Phase 2 Risk Estimation worksheet for PWR Stuck Open PORV (SORV) - SRT for AFW Room (Ex. 2A, 2C), "AFE" could be changed to "AFW" in the first and third sequences under Remaining Mitigation Capability.

In the Phase 2 Risk Estimation worksheet for PWR Stuck Open PORV (SORV) - DRT for AFW Room (Ex. 2A, 2B), "SORV (-2) BLK(-2) FB (-2) = -6" could be added to the second sequence under Remaining Mitigation Capability.

In the Phase 2 Risk Estimation worksheet for PWR Stuck Open PORV (SORV) - DRT with Spurious Actuation (Ex. 2C), we recommend removing "AFW (-2)" from the second sequence under Remaining Mitigation Capability.

In the Phase 2 Risk Estimation worksheet for PWR LOOP - SRT with Spurious Actuation (Ex. 2C), "AFW (-2)" could be added to the second sequence under Remaining Mitigation Capability.

ATTACHMENT 2

In item h, we recommend modifying the end of the sentence to read, "…in the ceiling region are assumed to be damaged."

In the first sentence in the last paragraph under Automatic Fire Detection Effectiveness, we recommend inserting a colon (:) after the word "types".

In the eighth paragraph under Spot Type Thermal Detector Placement – Minimum Design Inspection Factors, we would change "ration" to "ratio".

There are several times that the reader is told to "see Section 3.01" in the guidance provided for Fixed/Automatic Fire Suppression Systems. Some indication might be provided as to where (procedure, report, standard, etc.) the applicable section is to be found.

In the web accessed version of this attachment to Appendix F that is the subject of this review, a number of sub-headings were treated as bulleted items in the previous list rather than letter-indexed as a sub-head. These include

b. Automatic Sprinkler System
c. Automatic Spray Systems
e. Automatic Carbon Dioxide (CO_2) Systems

under Fixed/Automatic Fire Suppression Systems.

We would insert the word "than" between "less" and "6" in the seventh bullet under Automatic Sprinkler System.

We recommend changing the wording in the fourth bullet under high impact (degradation) on the ability of the sprinkler system, to "Two or more adjacent sprinkler heads in a combustible-free zone are affected by obstructions (horizontal, vertical, or obstructions located below) and are without adjacent obstruction heads below the obstruction."

To improve clarity, we recommend changing the wording in the first bullet under moderate impact (degradation) on the ability of the automatic water spray system, to "Spray nozzle is out of position or there is a slight obstruction."

The wording in the sixth bullet under high impact (degradation) on the ability of the CO_2 system, could be changed to read as "Discharge nozzles missing, wrong type or are damaged."

We recommend deleting the words "of area" after 130-feet in the initial paragraph under Evaluation Guidance for Manual fire suppression equipment and systems, hose station and standpipes.

We would remove the extra colon at the end of the introductory paragraphs for moderate impact (degradation) on the ability of the standpipe and hose system.

We recommend changing "stagging" to "staging" in the second bullet under effective fire brigade performance (normal operating state).

We would change "Un-analyze" to "Unanalyzed" in the fifth bullet under high impact (degradation) on the ability of the fire barrier or passive device.

We would also recommend changing "In operable" to "Inoperable" in the sixth bullet under high impact (degradation) on the ability of the fire barrier or passive device.

C. RESPONSE TO STAFF QUESTIONS

NRR staff provided a memorandum[1] identifying certain review areas for the SDP. In part, that document presented six questions that we attempt to address here.

Q.1 How important is not capturing the risk impact of problems with the screened out functional areas in the Phase 1 process?

This SDP is primarily a simple tool for use by the fire protection inspectors on site that helps them determine, quickly, how significant a particular finding is and whether or not it truly is a finding. We have cited comments specifically related to the apparent screening of potential findings related to safe shutdown adequacy. This is our most significant area of concern in this regard. It would appear appropriate to explicitly include or exclude such findings from the process. Now they are implicitly excluded in the first screening step. If such findings are not a part of the SDP then some alternate means of assessment may be needed.

Q.2 Is the equation in Phase 2 Step 4 correct? How is it to be interpreted in a PRA context?

In a literal sense, the equation in Step 4 is probably as correct as it needs to be to be used as a general quantitative tool by the on site inspector(s). That is, the process is adding up exponents of 10 which is equivalent to multiplying factors of 10. As such it offers a standard metric for assessing the potential risk associated with a particular finding that impacts one of the fire protection defense in depth elements.

In a broader context one can ask whether or not the factors are all really independent. The equation clearly implies independence of each factor. We would suggest that particular care be exercised in developing factors for this equation to ensure that independence is maintained. SNL spent only a very limited time on the individual values focusing instead on the overall process. Based on our limited review of the 'numbers' it would appear that the application of severity factors is the most significant potential pitfall in this regard. That is, severity factors are shortcuts, and if not handled with great care can introduce unintended dependencies. We understand that this is a screening tool, and that means look-up tables. In a more general context (e.g., a phase 3 analysis) reducing the reliance on severity factors would be a desirable goal.

Q.3 Assess the appropriateness of the rules for determining whether the barrier failure or barrier success term dominates.

We found this particular section of the document (i.e., Phase 2 Step 9) to be difficult to follow. It was our assessment that the implied level of analysis cannot currently be supported in practice through the use of simplified screening tools. In particular, the expectation that inspectors will assess damage commensurate with the postulated fire scenarios including spread of fire to an adjacent area appears to be difficult to achieve at best. We have recommended a complete re-examination of this particular aspect of the analysis (see comment F.5-16 above).

[1] Memorandum, Gareth Parry to Nathan Siu, "Review areas for fire SDP," dated October 4, 2001.

Q.4 Is it possible to give guidance on what types of fire sources are capable of becoming large fires?

This could be quite challenging. In theory, every fire has the potential to become severe. It all depends on the initial fire intensity, proximity to nearby combustibles, and time to intervention. The guidance directs inspectors to look for anything that might indicate the potential for a severe fire to develop. The guidance specifically calls for looking at potential fire spread, and covers some of the most significant fire sources (cabinets and pumps). One might provide a list of additional fire sources to ensure that none are overlooked. This would include all electrical equipment, flammable gas lines, fuel/oil storage tanks and lines, cables, and transient combustibles. In some sense this is covered in the Attachments.

Q.5 Is the treatment of barriers in terms of probabilities appropriate, given that the main function of barriers is to buy time?

There is always a trade-off between time and probability of failure - the longer a fire lasts, the greater the likelihood of failure. However, the treatment of failure as a probability appears appropriate for the limited purposed of the SDP Phase 1&2 analysis. The normal operating state values (Table 5.1) correspond to barrier reliability values typically applied in a fire PRA. The values with degradation then say how much more likely failure is given moderate or high degradation than given the normal operating state. The approach appears reasonable for screening purposes. If a time-dependent analysis is really needed, this would clearly fall into the scope of a Phase 3 analysis, not to the SDP Phase 1&2 screening.

Q.6 Review Attachment 2 and identify those areas where the guidance given is more compliance/standard driven than functional.

Much of the guidance in Attachment 2 does relate to compliance rather than function. However, we do not see this as cause for concern. The SDP clearly states that compliance with the code of record is considered to be the normal operating state (no degradation). Furthermore, in the fire protection community compliance with the code of record is the benchmark against which systems are measured. Nuclear plants are required to maintain their systems to these codes and standards. Hence, to rank degradations against failures in compliance appears both appropriate and practical. Any alternative approach that would be based on functional requirements would likely exceed the expertise of the intended audience. Assessment of fire protection system performance is not a simplistic exercise. We see the compliance-based guidance to be useful in establishing the criteria for determining non-compliance and, by implication, degradation. We concur with this approach as appropriate to the scope and intent of the fire SDP.