Appendix F

DETERMINING POTENTIAL RISK SIGNIFICANCE OF FIRE PROTECTION AND POST-FIRE SAFE SHUTDOWN INSPECTION FINDINGS

F.1 Introduction

The fire protection defense-in-depth (DID) elements are

1. Prevent fires from starting.

2. Rapidly detect and suppress those fires that do occur.

3. Protect structures, systems, and components important to safety so that a fire that is not promptly extinguished by fire suppression activities will not prevent the safe shutdown of the plant[1].

A fire protection program finding can generally be classified as a weakness associated with meeting the objectives of one of the preceding DID elements. As a result, the Fire Protection Risk Significance Screening Methodology (FPRSSM), a two-phase screening methodology, was developed to evaluate the potential fire risk significance of any fire protection DID weaknesses that are important to post-fire safe shutdown. If no DID related findings against a fire protection feature or system are observed, the fire protection feature and system is considered to be capable of performing its intended function and in its normal (standby) operating state.

Phase 1 of the FPRSSM is a screening method that is used by the resident or regional inspector to screen out fire protection findings (e.g., impairments to any fire protection feature) that are primarily unrelated to fire protection systems and features used to protect safe shutdown (SSD) capability. Phase 1 is used as an oversight process to monitor operational conditions affecting fire protection systems and features. This monitoring process identifies conditions that could have a potential impact on the capability to maintain one SSD success path[2] free of fire damage.

Findings that do not screen out as result of the Phase 1 screening should be subjected to the more detailed Phase 2 analysis. The Phase 2 analysis evaluates the synergistic impact that these findings may have on risk by treating them collectively for a fire area. The phase 2 analysis allows for equipment beyond Appendix R to mitigate core damage. Because of the integrated approach taken by the Phase 2 analysis, this analysis is generally performed, with technical support from NRC fire protection engineers and risk analysts, to better understand the potential fire risk significance posed by the identified DID Phase 1 findings. For those cases where Phase 2 method

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[1] Fire protection features sufficient to protect against the fire hazards in the area, zone, or room under consideration must be capable of assuring that necessary structures, systems, and components needed for achieving and maintaining safe shutdown are free of fire damage (see Section III.G.2a, b, and c of Appendix R to 10 CFR Part 50); that is, the structure, system, or component under consideration is capable of performing its intended function during and after the postulated fire, as needed.

[2] An SSD success path must be capable of maintaining the reactor coolant process variables within those predicted for a loss of AC power , and the fission product boundary integrity must not be affected (i.e., there must be no fuel cladding damage, rupture of any primary coolant boundary, or rupture of the containment boundary).

determines that the inspection findings have potential risk significance, Phase 3, which is a more refined analysis, can be performed.

F.2 Purpose

The purpose of this two-phase screening methodology is to (1) focus resources on monitoring the performance and effectiveness of those fire protection mitigation features that are important to protecting post-fire safe shutdown capability; (2) establish a threshold method (Phase 1 method is described in Section 4.0) that will assist in recognizing which fire protection mitigation findings may have the potential to affect post-fire safe shutdown capability; and (3) determine the potential fire risk significance of observed findings associated with fire protection mitigation features and systems used to protect SSD capability by performing screening assessment (Phase 2 method is described in Section 5.0) of the as-found condition(s). The Phase 2 screening analysis portion evaluates the “as-found” conditions associated with each fire protection mitigating element of the fire protection DID philosophy (e.g., detection, suppression, and passive protection separating post-fire SSD functions) within each of the DID elements. The potential fire risk significance of the as-found condition(s) is determined by performing an integrated assessment of the fire protection mitigation findings and the potential impact they may have on SSD capability.

The Phase 2 methodology can also be used by an NRR fire protection reviewer or a regional inspector as an aid for determining the potential risk/safety significance of: (1) a fire protection design condition that deviates from the intent of the facilities licensing/design basis; or (2) a Generic Letter 86-10 or 10 CFR 50.59 engineering evaluation documenting a change in a licensee’s fire protection program.

For the purpose of this guidance, weaknesses or findings will be defined as conclusions or factual observations of those “in-plant” conditions that do not meet regulatory requirements, do not conform to the facilities operating license fire protection condition, or are considered to have risk implications due to an inherent fire protection/post-fire safe shutdown system design weakness (degradations) of critical elements associated with a fire protection feature or system ability to promptly react to, passively resist, control, or suppress a fire. The fire protection industry has developed design and installation codes and standards that govern the design and installation of fire protection features and systems. The fire protection standard or codes-of-record establishes the minimum design, performance, and acceptance criteria a given fire protection system or feature must meet. This minimum design, installation, and acceptance criteria establish the assurance that the feature or system, when called upon, will perform its intended fire detection, control, suppression, and extinguishment function.

F.3 Scope

The scope of Phase 1 is to present a process that can help inspectors determine whether a particular fire protection finding is important to the protection of the safe shutdown capability and has the potential of being risk significant.

Fire protection DID findings that have been determined to imply potential risk by the Phase 1 screening method are subjected to a Phase 2 review. The scope of Phase 2 is to present a process for regional and headquarters fire protection engineers and risk analysts to further evaluate how a particular fire protection DID finding or set of findings affects SSD capability. In order to evaluate the potential risk significance, Phase 2 integrates the “as-found” degradations or findings and evaluates their potential affects on fire mitigation effectiveness and SSD capability. Phase 2 is focused on the following specific areas of fire mitigation:

- fire barrier effectiveness
- twenty-foot separation

- fire detection/automatic suppression system effectiveness
- manual suppression effectiveness
- safe shutdown capability

F.4 Fire Protection Risk Significance Screening Methodology—Phase 1

Not all plant fire protection systems and features are considered to be important to the protection of post-fire SSD capability. The results of the fire IPEEE (individual plant evaluation of external events) can provide a relative ranking of the plant areas that are the major contributors to fire risk. The top ten areas identified by this IPEEE/PRA (probabilistic risk assessment) ranking are generally important to post-fire SSD. (If the control room, cable spreading room, and switchgear room are not included in the top ten, theses rooms should be considered potentially important since they generally are risk significant[3].) These plant areas also present the greatest challenges with respect to separation of redundant trains of post-fire SSD capability, protection of this capability, and the ability to perform the operator actions necessary to achieve and maintain post-fire SSD conditions.

Phase 1 method consists of two steps. Step 1 is a screening evaluation of a fire protection finding or a set of findings and is intended to screen out findings that do not impact the effectiveness of a fire protection DID element. For those findings that impact the effectiveness of one or more of the DID elements, Step 2 is performed. Step 2 integrates the findings with the SSD capability provided for the fire area, zone, or room of concern and then presents insights with respect to the potential importance that these fire protection findings have on maintaining one success path of SSD capability free from fire damage.

The steps that follow describe the general process for implementing Phase 1.

Step 1: Screening of Fire Protection Findings

The Step 1 screening process is described by Figure 4-1. This process identifies those fire protection findings that impact the mitigation effectiveness of one fire protection DID element. Findings that impact the effectiveness of one or more of the fire protection DID elements potentially have risk implications[4]. Once identified, findings affecting one or more of the DID elements require further screening in order to determine if they are potentially important to maintaining one success path of SSD capability free of fire damage. This screening is performed by Step 2 below.

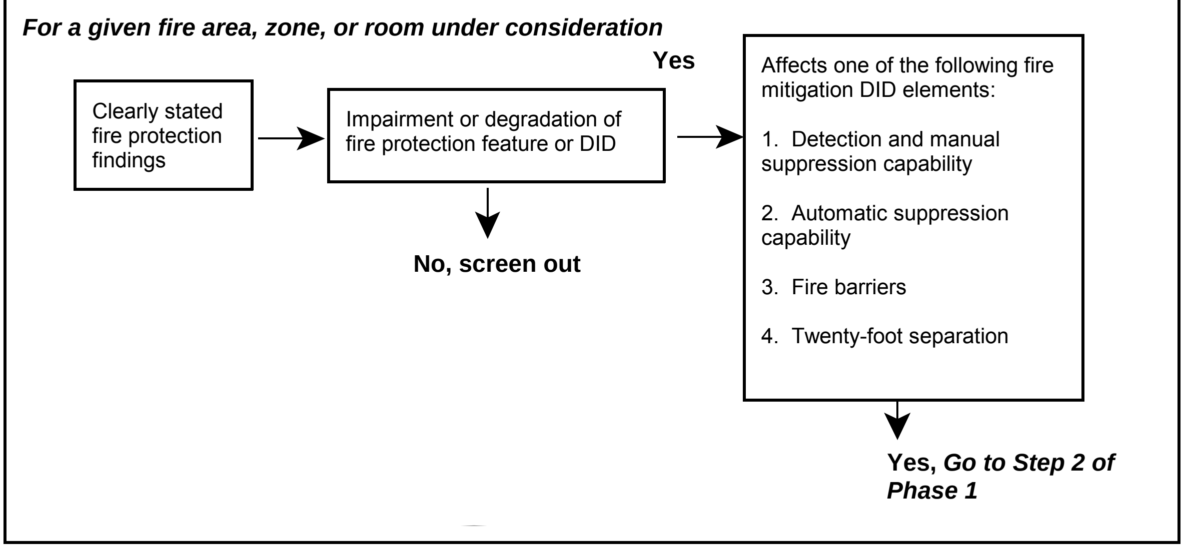
Making judgments regarding how effective a fire brigade can be in extinguishing a challenging plant fire requires an evaluator to have a comprehensive understanding of manual fire fighting techniques and operations. It is not the intent of Step 1 to expect resident inspectors to have the expertise to evaluate fire brigade effectiveness and performance. In most cases, fire brigade performance can be important to mitigating a fire and reducing its potential risk and should be

[3] Contained in NRC memorandum to the Commission from L. Joseph Callan, EDO, entitled "Preliminary IPEEE Insights Report," dated January 20, 1998.

[4] Rigorous compensatory measures that are functionally equivalent (e.g., temporary fire barrier penetration seal, extension of fire hose from an operable hose station to provide fire fighting capability for those areas affected by an inoperable hose station) may offset the loss of the DID related fire protection feature or system. The technical merits of these compensatory measures to perform in a equivalent manner to the inoperable or degraded functions should be evaluated on a case-by-case basis.

considered when performing a Phase 2 evaluation. 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. In those cases in which manual fire fighting (i.e., fire brigade) is used as the sole means to control and extinguish a fire, one success path of SSD capability is generally maintained free of fire damage by a passive fire barrier having a fire resistive rating of 3-hours. In Step 2, where fire barriers or fire barriers in combination with an automatic fire suppression system are used as the primary protection scheme for maintaining an SSD success path free of fire damage, manual fire fighting performance or effectiveness is not considered the dominant protective element of the primary protection scheme. For those protection schemes that use passive fire barriers as primary protection, findings related to only manual firefighting or fire brigade effectiveness typically do not warrant the performance of a Phase 2 evaluation.

Figure 4-1: Screening Process Phase 1 (Step 1)



Step 2: Safety Importance Determination

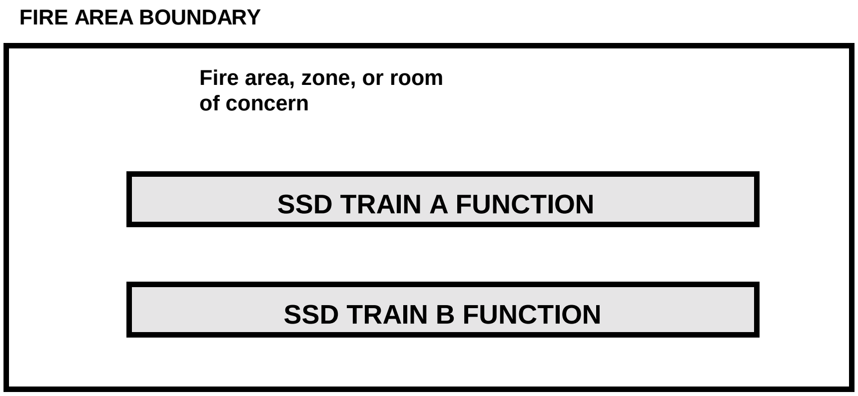
When findings affect one or more of the fire protection DID elements in a given fire area, zone, or room of concern, it is necessary to perform an additional screening. In order to implement this screening step and determine if the findings are potentially risk significant, the post-fire SSD capability for the fire area, zone, or room of concern and the fire protection schemes used to maintain one SSD success path free of fire damage will have to be determined. For those findings that do not screen out[5], a Phase 2 evaluation will be performed.

The SSD determination can be made by reviewing the plant's Fire Safe Shutdown Analysis (FSSA). Using the FSSA information, the method and equipment being used to achieve and maintain post-fire SSD for each fire area, zone, or room of concern can be determined. In addition, the FSSA will identify fire protection schemes used to protect the analyzed SSD success path. Depending on the degree of physical and electrical separation provided for the various SSD success paths, different fire protection schemes are used to ensure that one SSD success path is free of fire

[5]Findings that do screen out should not be disregarded, they should be referred to the licensee and placed in the licensee corrective action program.

damage. Figures 4-2 through 4-5 below, presents additional screening guidance for determining if the fire protection DID findings are potentially significant.

SSD system with redundancy is located in the area, zone, or room of concern. The remaining recovery capability is none. No additional recovery capability exists for performing the essential SSD functions external to the area, zone, or room of concern.



No remaining capability exists for performing essential SSD functions external to the area, zone, or room of concern.

Figure 4-2

For the SSD interaction as noted in Figure 4-2 above (which corresponds to 0 column in table 5.6), the following three basic fire protection schemes are used outside of primary containment to protect and maintain one train of SSD capability free from fire damage:

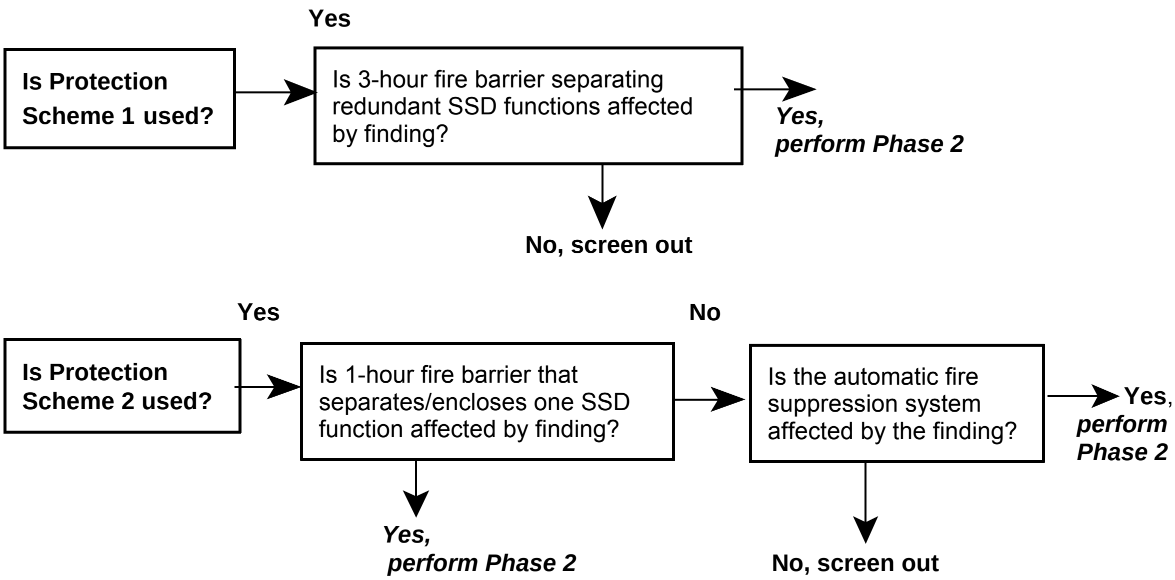
Scheme 1 Provide a 3-hour fire barrier separation that either encloses one SSD train or provides wall-to-wall and floor-to-floor separation between the redundant trains; or

Scheme 2 Provide a 1-hour fire barrier enclosing one of the SSD trains. The area must be protected by automatic fire detection and suppression systems; or

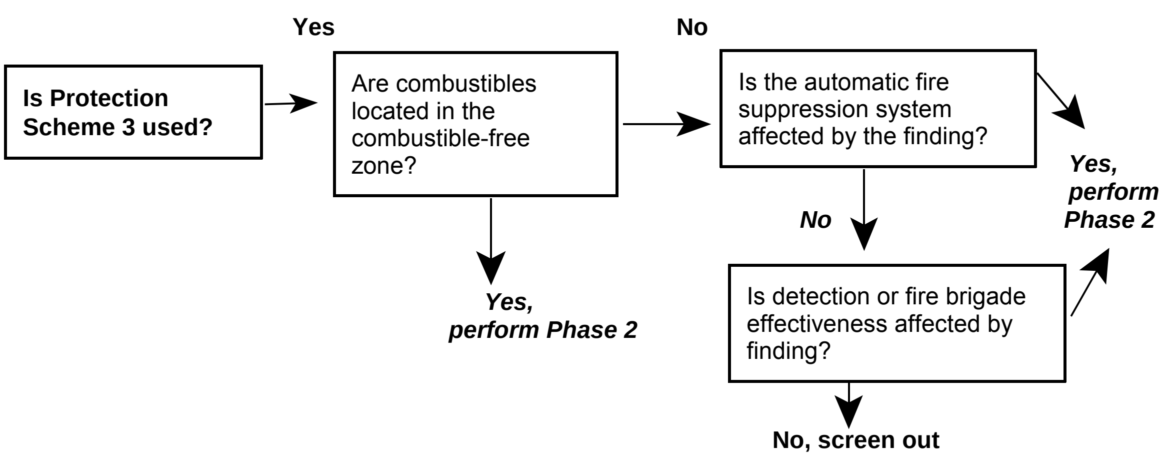
Scheme 3 Provide more than 20 feet of horizontal separation between the redundant SSD trains. The spatial separation between the redundant SSD trains must be free of intervening combustibles. The area must be protected by automatic fire detection and suppression systems.

Determine which protection scheme is used.

Screening Criteria for Figure 4-2



Screening Criteria for Figure 4-2



SSD system with redundancy is located in the area, zone, or room of concern. Remaining mitigation capability is recovery of one fire-affected SSD train (e.g., alternative shutdown method for the control room) .

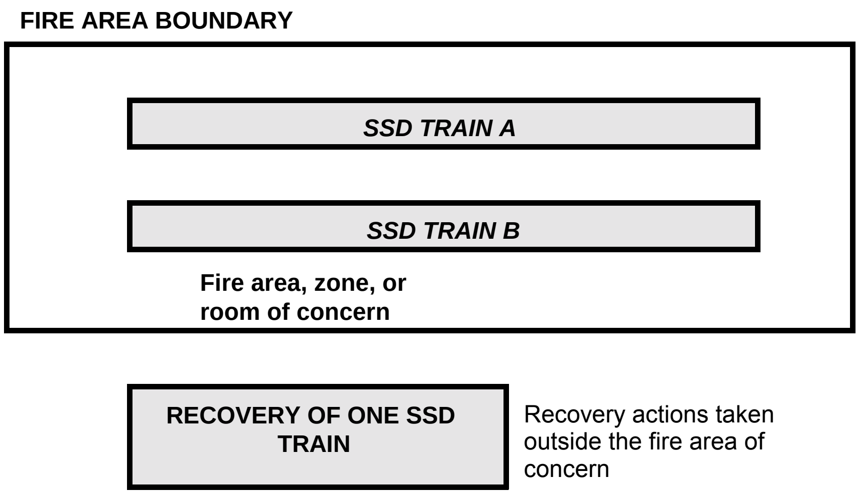
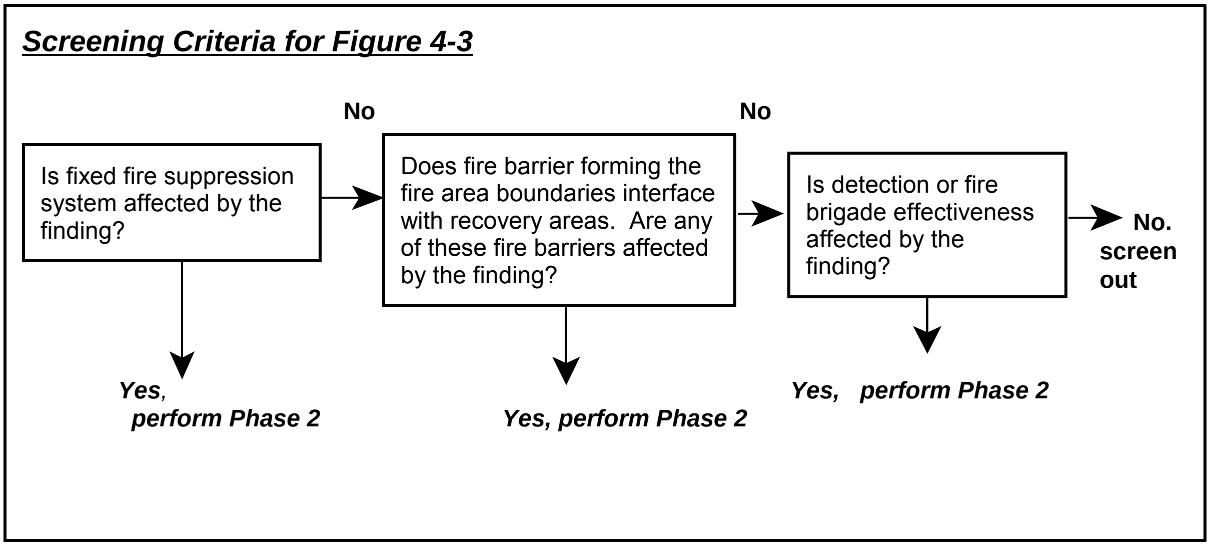


Figure 4-3

For the post-fire SSD interaction noted in Figure 4-3 above (which corresponds to the -1 column in table 5.6), one basic type of fire protection scheme is generally used.

Scheme This scheme minimizes fire damage to the preferred SSD trains by providing automatic detection and fixed suppression in the fire area, zone, or room of concern (the control room is an exception, no fixed fire suppression is provided). In addition, this scheme provides an alternative shutdown system that is electrically and physically independent of the fire area, zone, or room of concern.



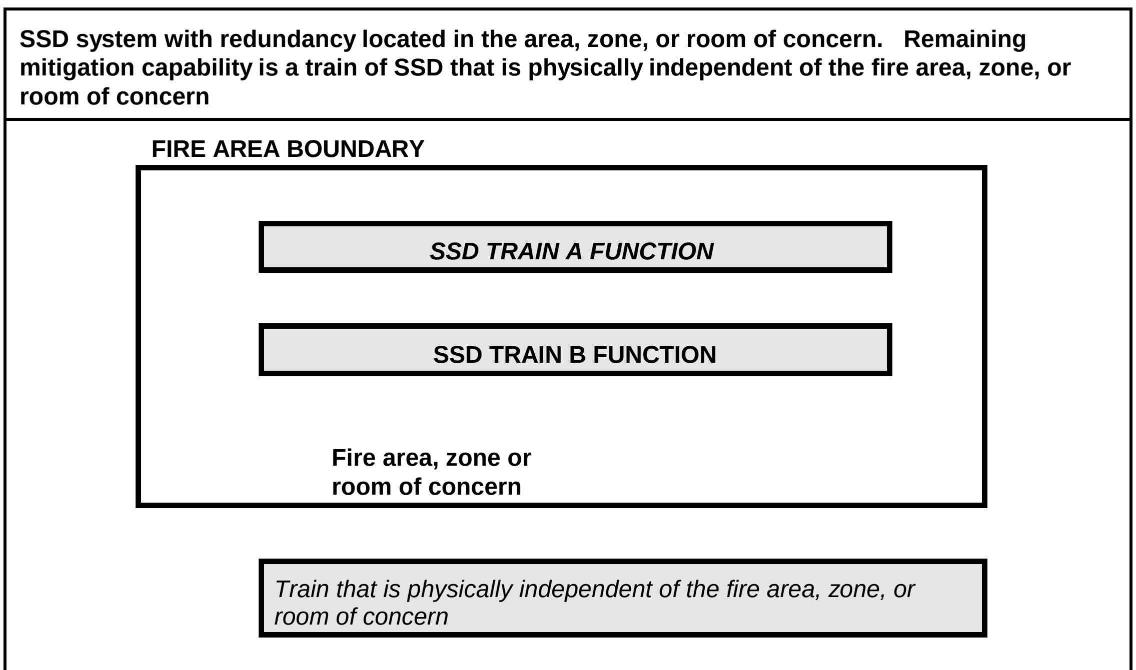
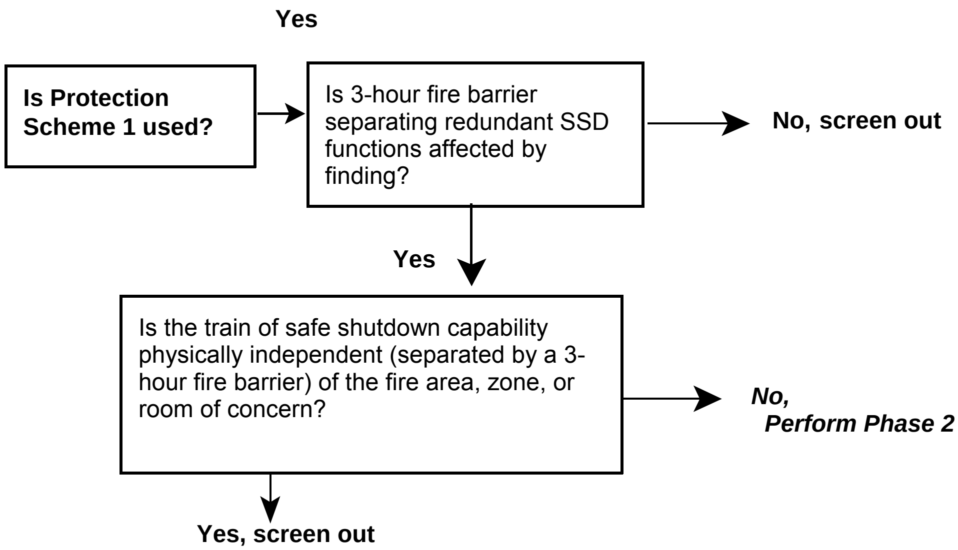


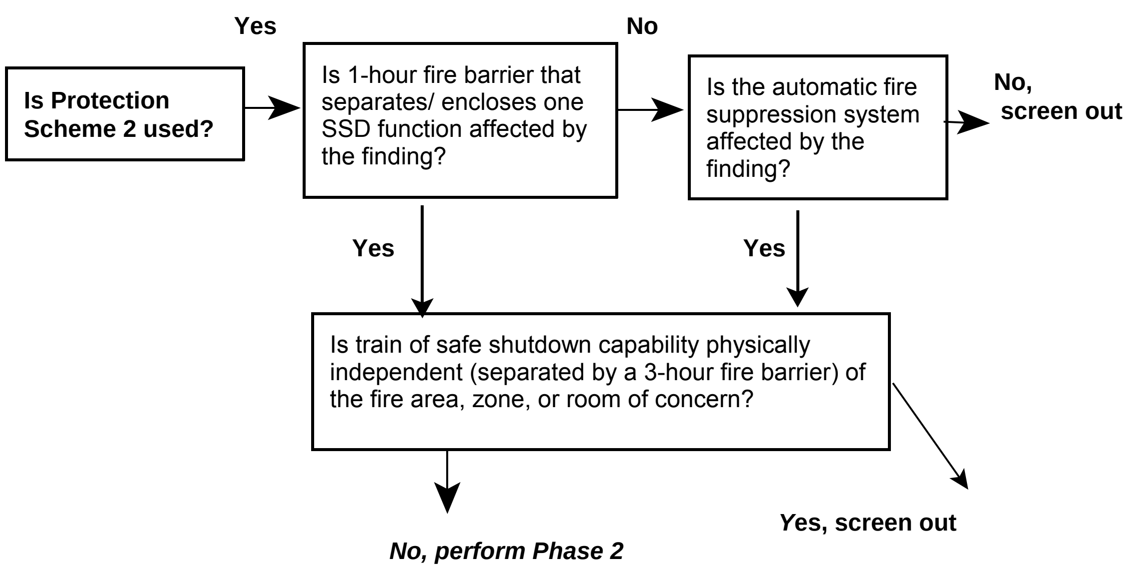
Figure 4-4

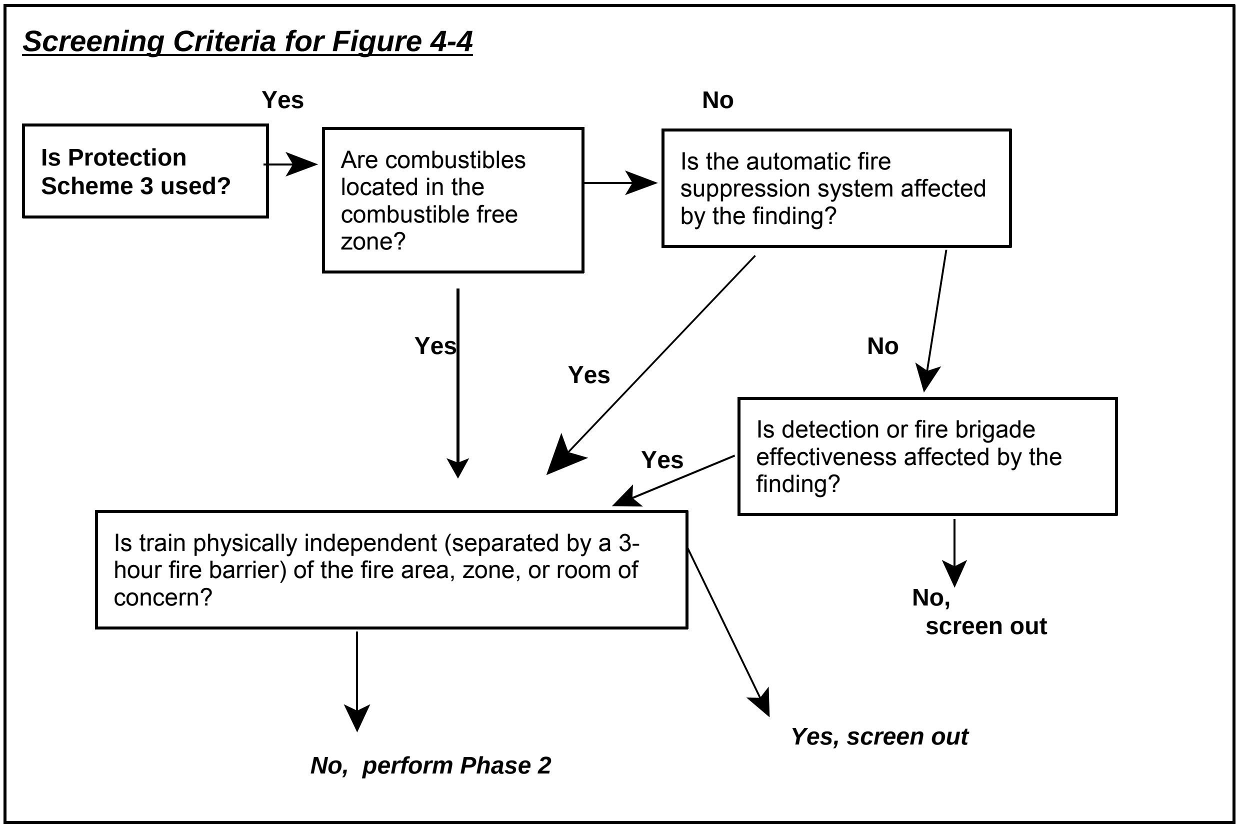
For the post-fire SSD interaction noted in Figure 4-4 above (which corresponds to the -2 column in table 5.6), three basic types of fire protection schemes are used to protect one train of SSD from fire damage within the area of concern. These fire protection schemes are the same as those described for Figure 4-2. Determine which protection scheme is used.

Screening Criteria for Figure 4-4



Screening Criteria for Figure 4-4





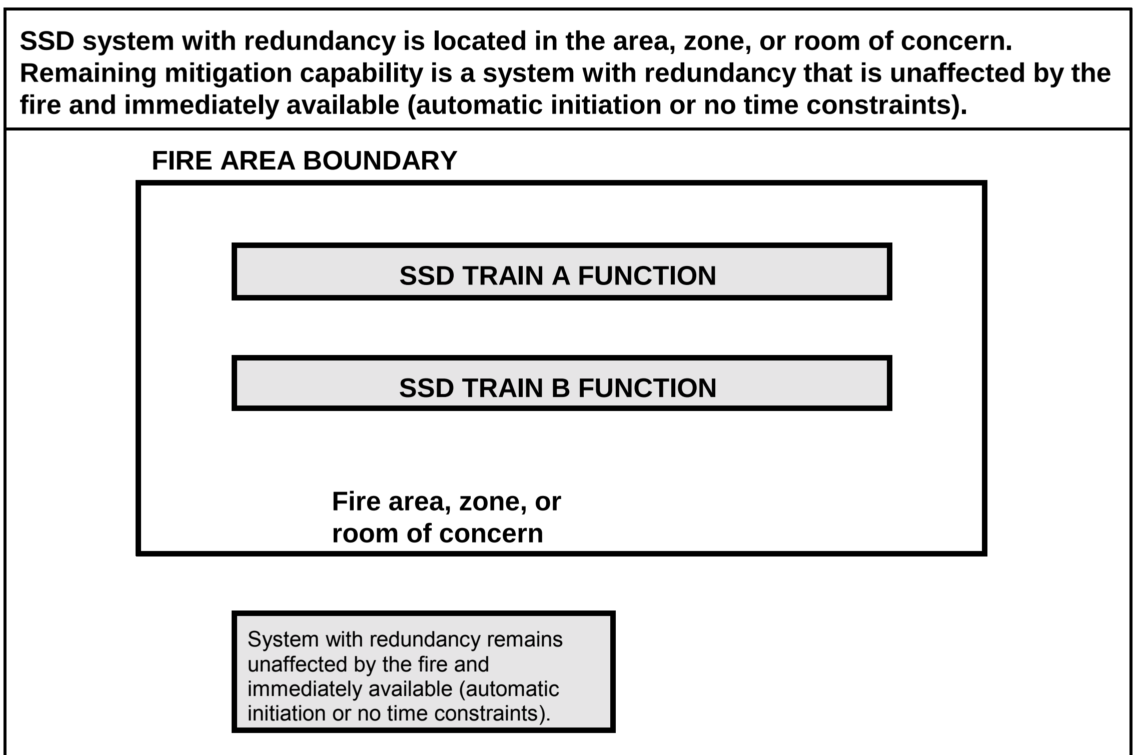
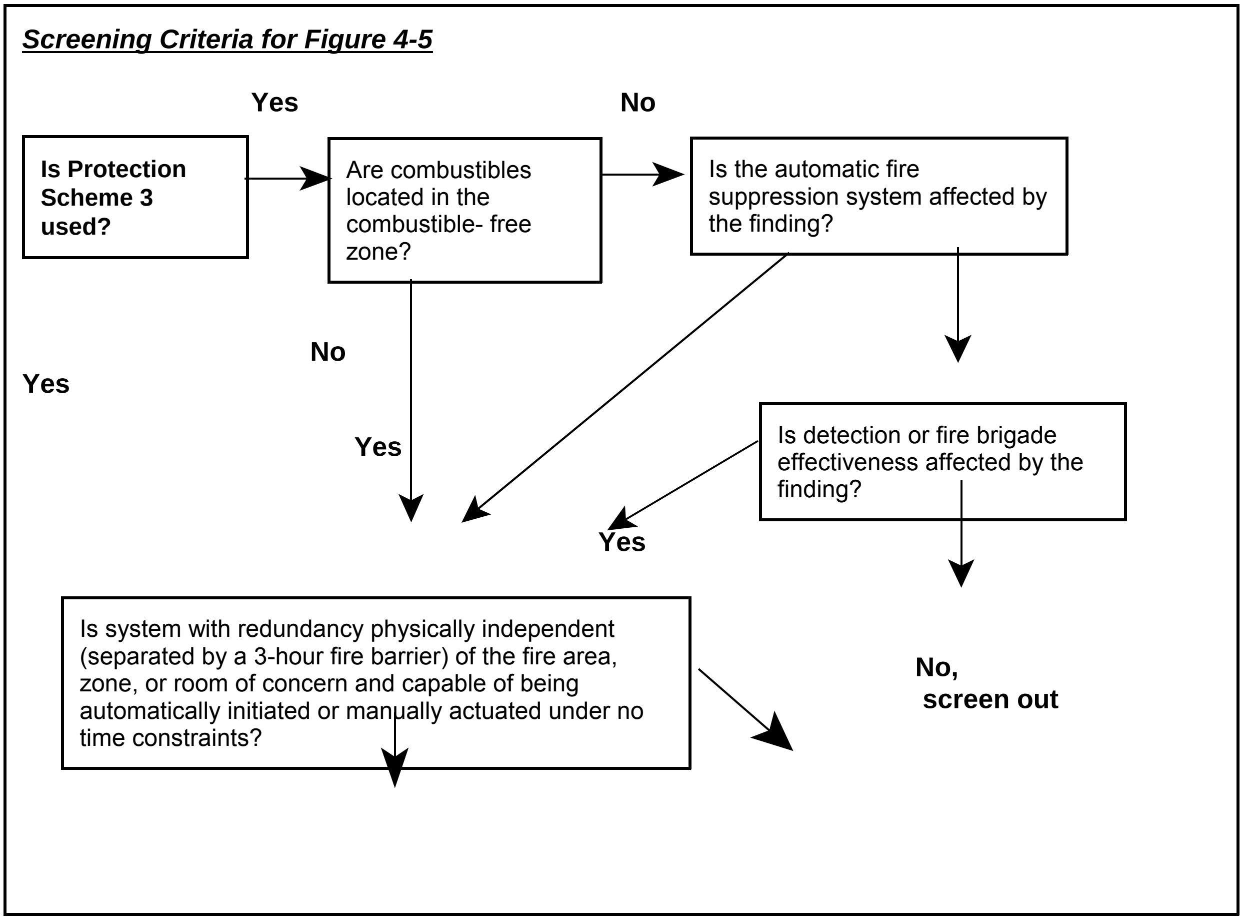


Figure 4-5

For the post-fire SSD interaction noted in Figure 4-5 (which corresponds to column -3 in table 5.6) above, three basic types of fire protection schemes are used to protect one train of SSD from fire damage within the area of concern. These fire protection schemes are the same as those described for Figure 4-2. Determine which protection scheme is used.



F.5 Fire Protection Risk Significance Screening Methodology—Phase 2

The FPRSSM is an integrated process that can be used to assess the relative risk significance of identified weaknesses in the fire protection DID elements in a given fire area, zone, or room under consideration. The following steps describe the general process that should be followed when implementing this methodology (see Figure 5-1, "Fire Protection Risk Significance Screening Methodology—Process Diagram"). In the case that the Phase 2 method determines that the assessed findings have potential risk significance, Phase 3, which is a more refined analysis, can be performed.

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

The specific fire protection inspection findings affecting the fire protection mitigation DID features are grouped according to each specific fire area, zone, or room which they impact. Then an area-specific fire damage scenario is defined and its effects are postulated. Step 2 provides guidance for defining fire scenarios. Step 1 and Step 2 should be performed during an inspection in an integrated manner (i.e., observations of a fire protection degradation and the related fire hazards in the area of concern).

Step 2; Define the Fire Scenario

In order to properly support the FPRSSM risk estimates, the inspector or the reviewer will need to develop a postulated fire damage scenario that realistically describes the fire and its potential for propagation (see Attachment 2 of Inspection Manual Chapter 0609, Appendix F, for further guidance) within the fire area, zone, or room under consideration. Under this postulated scenario, the inspector or reviewer must make deterministic/qualitative judgments regarding the effectiveness of various degraded fire protection mitigation features or systems and their ability to protect a post-fire safe shutdown path and maintain it free from fire damage. Postulated fires involving fuel sources in an area under consideration are deemed important if they are capable of developing a plume and/or a hot gas layer that has the potential to directly affect components of equipment that are important to safety. The inspector should develop a realistic fire scenario where equipment assumed failed is supported by the scenario. The equipment assumed to fail may be a subset of the equipment in the fire area, room, or zone, or may be all the equipment in the fire area, room, or zone (or potentially covering multiple areas, rooms, or zones), as long as the damage is justified by the scenario. The inspector should try to identify the dominant scenario(s) to limit the number of scenarios which need to be analyzed. The ignition sources which can initiate the scenario form the fire ignition frequency for the scenario. The dominant fire scenario(s) will be based upon the frequency of the ignition source(s) which starts the fire, and the damage done by the fire.

Only fire scenarios which impact the fire protection DID finding need to be developed. For example, if the fire protection DID finding is against a one-hour fire barrier, only fire scenarios which impact that barrier need to be developed. If the fire protection DID finding is against a room-wide automatic suppression system, then all dominant fire scenarios for that room should be developed.

The inspector when developing the scenario, should postulate a large fire providing the component and configuration of the fire area, room, or zone supports such a fire. A large cabinet fire is one where fire damage extends initially beyond the cabinet of fire origin. For example, fire damage due to a large cabinet fire in its initial stages may extend to overhead cabling, to an adjacent cabinet, or to both. A large fire for a pump or motor can be based initially upon the size of oil spill from an individual cavity. If the configuration of the room, combustibles, etc. supports further growth of the large fire, then that growth should be postulated. Since scenarios describing large fires are normally expected to dominate the risk significance of an inspection finding, scenarios with small fires generally need not to be included if scenarios with large fires can be postulated. A small fire for an electrical cabinet is one where fire damage is confined to the cabinet. The inspector should be aware that for small fires where damage is limited to the component which initiates the fire, suppression should not be credited unless it is possible that suppression could prevent damage from occurring to the component.

Step 3: Qualitative Evaluation of Findings

Once the various inspection DID findings and a meaningful fire scenario have been established for the fire area, zone or room of concern, the individual findings must be evaluated with respect to their ability to satisfy the performance objective established by the applicable DID element. Upon determining which DID elements have been affected by the specific fire protection finding, a qualitative evaluation of each finding and its effects on accomplishing the DID objective is performed. It should be noted that many inspection findings can contribute to a degradation in a DID element. For example, poor training, poor fire brigade/operational drill performance, improperly installed detection, and inadequate hose coverage of a fire area can all contribute to the degradation rating assigned to manual suppression. Therefore, in order to perform this step, the existing plant conditions as noted by the inspection finding are evaluated against the deterministic/qualitative evaluation guidance and degradations categorization criteria established in Attachment 2 of Inspection Manual Chapter 0609, Appendix F.

The output from this deterministic/qualitative evaluation, results in a degradation rating (DR) being assigned to each DID element.

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

Once Step 3 has been completed, the respective DID findings for a given fire area, zone, or room of concern are assessed collectively by summing, using the following formula, the fire Ignition Frequency (IF) and the DR for each of the fire protection DID elements. This value is called the Fire Mitigation Frequency (FMF) and inputs into the Significance Determination Process (SDP) to determine the change in risk. (Therefore, this formula should be used to evaluate the FMF for each scenario. As a result, the steps in this methodology describe how to calculate the risk for a single scenario. For multiple scenarios, the steps must be applied multiple times, even though many values of the FMF will remain unchanged since those scenarios will occur in the same zone, room, or fire area where the same degradations of automatic and manual suppression will exist.)

$$FMF = \log_{10}(IF) + FB + MS + AS + CC \text{ (when appropriate)}$$

where IF = Fire Ignition Frequency
FB = Fire Barrier (used for DRT only; see Step 9)
MS = Manual Suppression/Detection
AS = Automatic Suppression/Detection
CC = Dependencies/Common Cause Contribution

Table 5.4 below shows the association between the FMF and the approximate frequency in Table 5.5 (same as SDP Table 1,"Estimated Likelihood Rating for Initiating Event Occurrence During Degraded Period").

Step 5: Assignment of Quantitative Values

From Step 3, "Qualitative Evaluation of the Findings," a DR is assigned to each DID element. Once the DRs for a DID element have been determined, they are quantified by assigning a value from **Table 5.1.**

Table 5.1 Quantification of Degradation Ratings (DR) of the Individual DID Elements[6]

Level of Degradation	*3-Hour Fire Barrier*	*1- Hour Fire Barrier*	*20-feet Separation*	*Automatic Fire Suppression Effectiveness*	*Manual Fire Fighting Effectiveness (Fire Brigade)*	
					Outside Control Room	Inside Control Room
High	0	0	0	0	-0.25	-0.75
Moderate	-1.25	-0.5	N/A	-0.75	-0.5	-1

[6] Each of these values in Tables 5.1, 5.2, and 5.3 is approximately an exponent of 10.

Normal Operating State	-2 (door(s), or multiple dampers, or damper & door)) -2.5 (damper or multiple penseals or both) -3	-1	-2	-1.25	-1	-1.5

The normal operating state category reflects full compliance with existing regulations and regulatory guidance. Specified by the existing regulations and regulatory guidance is the need for fire protection systems and features to meet fire protection industry codes and standards. A fire protection system or feature is considered to be in a normal operating state when its design conform with the minimum design, installation, and performance criteria specified by the code-of-record.

Rigorous[4] compensatory measures for the DID elements are credited. The credit given for an rigorous compensatory measure to a DID element is the credit provided for a moderate degradation of the DID element.

The bases for the failure probabilities in Table 5.1 follow. The normal operating state probability for the 3 hour barrier is found in several NRC and industry documents (e.g. EPRI Fire PRA Implementation Guide p.4-43, NUREG/CR-4832 p.3-84, and other documents e.g. NUREG/CR-4550). The normal operating state probability for automatic suppression is found in EPRI FIVE methodology p.10.3-7 and in EPRI Fire PRA Implantation Guide p.4-38 and is used in many IPEEEs. The 1 hour barrier provides less protection than the 3 hour barrier, and the credit is assigned appropriately. Credit given for the normal operating state 20-foot separation relies on NUREG/CR-3192, and is substantial. The normal operating state probability for non-control room manual suppression is from FIVE p.6-30, and is used approximately in IPEEEs to characterize manual suppression reliability for fire areas. One basis for control room manual suppression unreliability is the estimate of suppression failure prior to forced evacuation due to smoke impaired visibility.[7] Also credit for manual suppression, in general, is limited since it is not viewed as reliable as an uncomplicated operator action.

Manual suppression capability is credited even when it is highly degraded, unlike other DID elements. This credit is based upon the potential for early detection and suppression of fires by personnel using hand-held fire extinguishers. Quantitatively, the credit provided for the control room comes from the control room severity factor (found in EPRI Fire PRA Implementation Guide p.D-14 and IPEEEs) which is partially based on detection and suppression by personnel inhabiting the control room. Less credit is given for a high degradation of non-control room areas since those are not normally manned continuously.

[7] J.C. Chavez and S.P. Nowlen, “An Experimental Investigation of Internally Ignited Fires in Nuclear Power Plant Cabinets, Part II - Room Effects Tests,” NUREG/CR-4527 Vol. 2, Sandia National Laboratories, Albuquerque, NM, October 1988. J.C. Chavez, “An Experimental Investigation of Internally Ignited Fires in Nuclear Power Plant Cabinets, Part I - Cabinet Effects Tests,” NUREG/CR-4527 Vol. 1, Sandia National Laboratories, Albuquerque, NM, April 1987. These references indicate that approximately 10 minutes are available before control room evacuation is necessary due to smoke obscuration. J. Lambright et al., “Analysis of the LaSalle Unit 2 Nuclear Power Plant: Risk Methods Integration and Evaluation Program,” NUREG/CR-4832, Vol. 9, Sandia National Laboratories, Albuquerque, NM, March 1993. J. Lambright et al., “A Review of Fire PRA Requantification Studies Reported in NSAC/181,” Sandia National Laboratories, April 1994, NUDOCS accession number 9409220104. This reference produces a probability of failure to suppress a control room fire prior to a given time.

Dependencies exist between certain DID elements. Those dependencies and their values are expressed in Table 5.2 below.

Table 5.2 Quantification of Dependencies Between DID Elements		
Automatic Fire Suppression Effectiveness Degradation	***Manual Fire Fighting Effectiveness Degradation***	***Adjustment Due to Dependency***
Medium	High	+0.75
Low	High	+0.5

These dependencies are based on the fact that automatic suppression merely controls the fire, and the fire brigade is needed to completely extinguish the fire. The resulting adjustment has the effect of providing partial credit for automatic suppression when it has a low degradation and is paired with a high degradation of manual fire fighting capability. No credit is provided for automatic suppression when it has a medium degradation and is paired with a high degradation of manual fire fighting capability.

Table 5.3 Quantification of Common Cause Contribution Between Sprinkler Systems and Manual Fire Fighting Hose Stations		
Automatic Fire Suppression Effectiveness Degradation	***Manual Fire Fighting Effectiveness Degradation***	***Adjustment Due to Common Cause***
Low	Low	+0.25

The **Table 5.3** adjustment is made since a common water delivery and supply system exists for both automatic and manual water-based systems.

<u>Step 6: Determination of Fire Ignition frequency</u>

The next step is to determine the fire ignition frequency for the scenario. This fire ignition frequency for the scenario will be the ignition frequency of the component(s) which ignite the fire and damage a set of equipment. If the fire ignition frequency for the appropriate component(s) is contained in the plant-specific IPEEE, it should be used. However, if the IPEEE does not provide the ignition frequency of the appropriate component(s), then the analyst may contact NRR/SPSB to confirm a licensee-supplied frequency, or to provide a frequency.

To develop the ignition frequency for a scenario, the ignition frequency of all components initiating the scenario are added. For example, suppose two electrical cabinets are adjacent, and each can propagate the fire to each other. Suppose a target of interest is only susceptible to damage from one electrical cabinet. Then the frequencies from both cabinets would be added to determine the scenario frequency since a fire in either cabinet would damage the other cabinet, and as a result cause damage to the target. If the electrical cabinets would not damage each other, then distinct scenarios would be developed for each cabinet, and the frequency of the appropriate cabinet used for each distinct scenario. A new scenario must be developed each time different damage is postulated by the fire.

The next step is to convert the FMF which has been developed to an approximate frequency. Table 5.4 performs this conversion.

Table 5.4 Association of FMF to Table 5.5 (SDP Table 1) Approximate Frequencies for Calculation of Delta CDF	
Fire Mitigation Frequency (FMF)	**Table 5.5 Approximate Frequencies** (per year)
FMF > -2	**1 per 10 to 10^2**
-2 $\geq$ FMF >-3	**1 per 10^2 to 10^3**
-3 $\geq$ FMF >-4	**1 per 10^3 to 10^4**
-4 $\geq$ FMF >-5	**1 per 10^4 to 10^5**
-5 $\geq$ FMF >-6	**1 per 10^5 to 10^6**
FMF $\leq$ -6	**Less than 10^6**

The approximate frequency is adjusted in Table 5.5 by the length of time that the degradation existed. In practice, as part of the initial assessment, the inspector should assume that the degradations are simultaneous, and that all occur for the length of time associated with the longest degradation. This is a conservative approach, and if desired, can be refined. (The refinement of this approach is to consider whether the DID degradations overlap in time, and perform the analysis accordingly.) To adjust the time of the degradation, a letter is selected on the basis of the degradation time from **Table 5.5**. The degradation of 3–30 days decreases the frequency by 10, and the degradation of less than 3 days decreases the frequency by 100.

Table 5.5 Estimated Likelihood Rating for Initiating Event Occurrence During Degraded Period

Approx. Freq.	Estimated Likelihood Rating		
>1 per 1 - 10 yr	A	B	C
1 per 10 - 10^2 yr	B	C	D
1 per 10^2 - 10^3 yr	C	D	E
1 per 10^3 - 10^4 yr	D	E	F
1 per 10^4 - 10^5 yr	E	F	G
1 per 10^5 -10^6 yr	F	G	H
<1 per 10^6yr	G	H	H
	> 30 days	30-3days	<3 days
	Exposure Time for Degraded Condition		

Step 7: Integration of Adjusted FMF with SSD

The FMF, which has been adjusted by the length of degradation, represents the integration of IF with the DR associated with each of the fire protection DID elements. In this step, the FMF is integrated with the SSD capability that is free from fire damage.

The SSD capability is developed by using the Reactor Safety Full Power Level 1 plant-specific event trees (worksheets) which identify the internal event initiating events and the respective sequences which lead to core damage. By understanding the systems that could be potentially affected by a fire (according to the fire scenario) in the area, room, or zone of concern, the analyst can select the appropriate initiators induced by the fire (e.g. reactor trip, LOOP, small break LOCA, or support system failure), and the appropriate internal events event tree worksheet(s). After this determination, the number of plant systems or recovery actions available to prevent core damage are credited for the sequences for the appropriate event trees. Only those fire scenarios which challenge the finding(s) should be evaluated, as indicated in Step 2. Also, only those sequences which contain components failed in the fire scenarios need to be evaluated.

The SSD capability per sequence is combined with the FMF to determine the proper color of the sequence according to Table 5.6 (same as SDP Table 2), "Risk Significance Estimation Matrix. As is directed by the internal events SDP, three green sequences represented by greens immediately to the left of a white in Table 5.6 may be added to produce a white. The basis for this addition is that multiple sequences in a PRA are added to produce the overall CDF. Generally, it is expected that addition of greens will be limited to a single fire area, but hardware degradations in fire protection systems, equipment, or components which affect DID in multiple fire areas may require addition of greens for those multiple fire areas to calculate the change in CDF.

In selecting the proper worksheet, the analyst must realize that the SORV (stuck open PORV) worksheet must be used with either the reactor trip, or LOOP, event tree worksheet. The reason is that either a reactor trip or a LOOP may cause a PORV to be challenged, which may in turn stick open. The probability associated with the PORV being challenged and stuck open is -2 (log space) or 0.01. The SORV is not generally expected to be dominant unless a spurious actuation occurs since a spurious actuation has a failure probability larger than the random failure probability. However, the importance of the stuck open PORV must be evaluated for each reactor trip or LOOP fire-induced initiating event to verify it is not important. An example of considering the SORV tree simultaneously with the Reactor Trip tree is included in the example 2.

In the FPRSSM, the ΔCDF associated with the impact of the DID findings is partially calculated since (1) only those relevant fire scenarios which impact the inspection finding(s), and (2) only those sequences which contain a component or human action failed due to the fire scenario are evaluated. Note that in the columns of SSD as the mitigating equipment increases in **Table 5.6**, failure probabilities decrease by a factor of 10.

Step 8: Modifications Necessary To Add Impact of Spurious Actuations

Spurious actuations are accounted for by impacting the relevant sequences identified on the Reactor Safety Full Power internal events worksheets. For each train which experiences fire damage only in the form of spurious actuations, the train is considered failed in the sequence. A factor of -1 is then added to the cutset that is impacted by spurious actuations. (This is equivalent to saying that multiple spurious actuations occur with a probability of 0.1)

A more complicated solution exists for addressing the more difficult case where a train fails due to direct fire damage, and consequently has its recovery complicated by spurious actuations. In this case, the different sequences associated with the non-recovery without spurious actuations, and nonrecovery with spurious actuations must be calculated. For example, assume that a sequence consists of failure of two trains A and B. Assume each of those trains is damaged by fire. Also assume train B is subject to failure due to spurious actuations also. The first sequence associated with this example is failure of A and B with failure to recover each train, excluding the impact of spurious actuations. This sequence is the normal sequence which one would get without spurious actuations. The second sequence involves the impact of spurious actuations. The logic that follows in the development of this sequence is that recovery of train B occurs; however, immediately afterwards, train B experiences a spurious actuation which fails the train. Then the operators attempt to recover train B from the spurious actuation. As a result, the sequence is failure to recover train A without spurious actuations, success in recovering train B without spurious actuations, failure of train B due to spurious actuations, failure to recover train B from spurious actuations.

Step 9: General Rules for Applying FPRSSM

Since a fire barrier failure is represented by a probability, the ΔCDF for a fire area is a combination of two contributions: a contribution from barrier failure, and one from the barrier success. Table 5.1 can be used to calculate both of these terms. For purposes of discussion, the term referring to the case in which the barrier between the two fire areas fails will be called the double room term (DRT) and the case in which the barrier between the two fire areas succeeds in preventing fire damage beyond the area of fire origin will be called the single room term (SRT). The SRT is defined as the combination of the FMF and safe shutdown (SSD) capability free of fire damage due to success of the barrier, and the DRT is the FMF and SSD capability free of fire damage due to failure of the barrier. The SRT and DRT are shown by the figures 9.1 and 9.2 below. (Note that although the SRT and DRT concept is demonstrated in Figures 9.1 and 9.2 for a 3 hour barrier, it also applies to 1 hour barriers.)

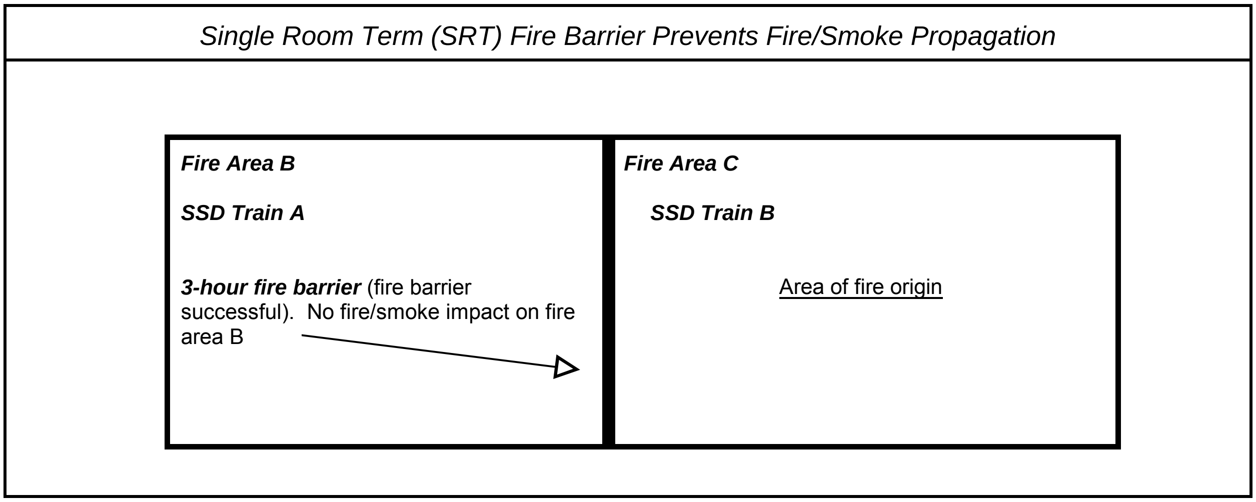


Figure 9.1

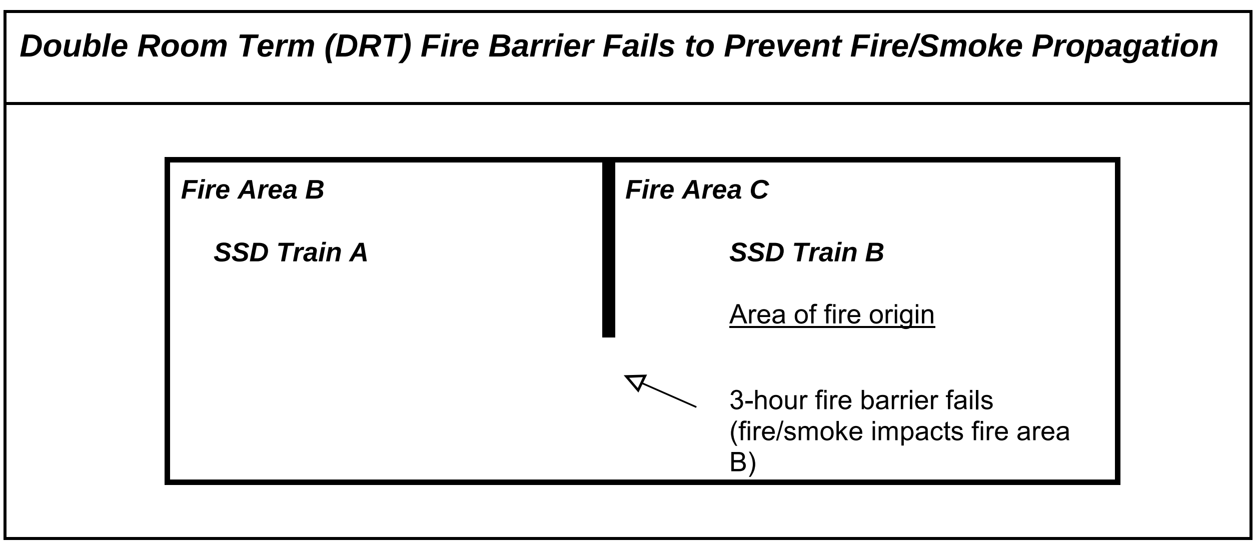


Figure 9.2

For the SRT, all equipment, cables, and actions in the area of fire origin (fire area C) and supported by the fire scenario are assumed to fail. (Note that the failure of equipment in fire area C may be a subset of the equipment in fire area C.) As a result, safe shutdown for the SRT (i.e. SSD(SRT)) is the combination of mitigating equipment, associated cables, and actions which remain free of fire damage given that fire damage is limited to fire area C. For the DRT, equipment, cables, and actions in the area of fire origin, and in the area protected by the barrier, i.e. (Fire areas B and C), are assumed to fail to the extent supported by the fire scenario. As a result, safe shutdown for the

DRT (i.e. SSD(DRT)) is due to the combination of mitigating equipment, cables, and actions free of fire damage after equipment, cables, and actions supported by the fire scenario in both fire areas B and C are lost.

The SSD impact can be different depending on whether the SRT or DRT is calculated. The equipment which mitigates core damage for the DRT is a subset of (or can be equal to) the mitigation equipment for the SRT. The logic is a follows: The appropriate (i.e. supported by the fire scenario) equipment in B and C fail for the DRT, and only that appropriate equipment in C fails for the SRT. Thus, more equipment is available to mitigate core damage for a fire which is confined to the area of fire origin (SRT) than one that fails the barrier and damages equipment on the other side of the barrier (DRT).

Other than SSD, the only other part of the CDF determination which will have different values between the SRT and DRT is the credit for the fire barrier. In the DRT, the fire barrier credit comes from Table 5.1. For instance, a medium degradation of a 3 hour barrier utilizes -1.25 as the probability of the barrier in failing to prevent fire propagation into the neighboring fire area (DRT). Yet, for the SRT no credit is given for a barrier since no barrier protects safe shutdown equipment in the room of fire origin. Therefore, for the SRT , the FB is eliminated from the FMF equation.

Both the SRT and DRT are not needed in all cases. The following rules provide guidance on when to use these terms in calculating the ΔCDF for a fire area, and are primarily for the analyst's convenience (since the SRT and DRT may be calculated and summed to get the change in CDF for a scenario whenever a barrier has a medium degradation or is in the normal operating state).

(Rule 1) If the fire barrier has a high degradation, just use the DRT to calculate ΔCDF.

(Rule 2) For a 1 hour barrier in either a medium degradation or in its normal operating state, use DRT only as long as SSD(DRT) $\geq$ 10 times SSD(SRT). Otherwise use SRT + DRT.

(Rule 3) If the 3 hour fire barrier has a medium degradation, use the SRT only if SSD(DRT) $\leq$ 10 times SSD(SRT). Otherwise, use DRT only.

(Rule 4) If the 3 hour fire barrier is in its normal operating state and has no door, no damper, and does not have multiple penseals, use only the SRT as long as SSD(DRT) $\leq$ 1000 times SSD(SRT). Otherwise use DRT only.

If the 3 hour fire barrier is in its normal operating state and has at least a door, or a damper, or multiple penseals, use only SRT if SSD(DRT) $\leq$ 100 times SSD(SRT). Otherwise, use DRT only.

(Therefore, it is expected that a 3 hour fire barrier in its normal operating state will often only require evaluation of the SRT. However, as more safe shutdown related equipment is protected by the 3 hour fire barrier, the fire barrier (and therefore the DRT) will become more important.)

As a result, it is recognized that the DRT is solely needed for a high degradation of a fire barrier. Also, the DRT is likely to dominate in most cases where any degradation exists in a 1 hour fire barrier. However, the SRT is likely to dominate whenever a 3 hour barrier exists in its normal operating state. In other words, as the barrier effectiveness decreases (e.g. from the normal operating state for a 3 hour barrier to either the moderate barrier degradation or normal operating state of 1 hour barrier), the DRT takes on more and more significance until it exclusively represents the high degradation of either barrier.

The other component of the above rules is the safe shutdown related equipment protected by the barrier. Equipment with higher reliability are more important to mitigating core damage than equipment with low reliability. Therefore, a barrier is more important if it is protecting a set of equipment with high reliability. As a result, a combination of the barrier failure probability and the failure probability of the set of equipment protected by the barrier are factored into the rules, via the comparison of SSD(SRT) and SSD(DRT) for a given barrier having a particular failure probability.

For example, since the ratio of SSD(DRT) and SSD(SRT) depicts the reliability of that equipment protected by the fire barrier, the relationship SSD(DRT) $\geq$ 100 times SSD(SRT) requires a set of higher reliability equipment be protected by the fire barrier than SSD(DRT) $\geq$ 10 times SSD(SRT). In other words, the larger SSD(DRT) is relative to SSD(SRT), then the higher the reliability of the equipment protected by the barrier. The importance of this equipment for a given barrier with its failure probability determines whether the SRT, DRT, or both are needed to calculate ΔCDF.

The SSD(SRT) and SSD(DRT) should be calculated for all sequences corresponding to the appropriate initiator(s) from the internal events SDP worksheet for the fire area to perform the above comparison which determines if both SRT and DRT are needed. Once it is established which terms (either DRT, or SRT, or both) are needed to calculate ΔCDF (by the SSD comparison) for the fire area, those terms (i.e. DRT, or SRT, or both) which consist of both the FMF and SSD (for all sequences in the event tree) are calculated to represent the change in CDF for the fire area.

Note that if the finding in the fire area is solely against the fire barrier, the inspector will need to validate that the equipment protected by that degraded barrier is an important contributor to core damage. A criteria which may be used to determine the importance of a degraded fire barrier is SSD(DRT) $\geq$ 10 times SSD(SRT). As indicated earlier, the importance of the barrier is dependent on the reliability of the set of equipment it protects, i.e. the higher the reliability of the equipment being protected by the barrier, the more important the barrier. For example, this criteria (SSD(DRT) $\geq$ 10 times SSD (SRT)) means that either the redundant train, diverse train, or recovery action in the dominant sequence is protected by the fire barrier. If this criteria is met, the degraded barrier is important. If this criteria is not met, a more refined analysis must be done to validate the importance of the degraded barrier.

Example 1 in the attachment demonstrates the difference between the SRT and DRT for the case where the cable spreading room (non- divisionalized) is adjacent to the fire area with the Remote (alternative) Shutdown Panel. Various cases of different levels of degradation exist for DID in example 1. Once the rules in example 1 are understood, the analyst should be capable of exercising the model to determine whether the SRT or DRT or both are needed. However, the analyst should realize that in order to make the determination whether the SRT or DRT or both are needed, most of the work to calculate both terms must be done to make the SSD comparisons in the rules. As a result, the real role the rules play is to identify under which circumstances only the DRT is absolutely necessary (i.e. DRT only for high degradation of barrier); and to counter arguments that only the DRT is necessary to utilize the model under all cases (since the SRT may dominate when the barrier considered is a 3 hour barrier in its normal operating state). The analyst should remember that the SRT + DRT may be used in place of the rules whenever a moderate barrier degradation or normal operating state barrier condition exists.

Table 5.6 - Risk Significance Estimation Matrix

Initiating Event Likelihood	Remaining Mitigation Capability Rating (with Examples)						
	-6	-5	-4	-3	-2	-1	0
	3 diverse trains OR 2 multi-train systems OR 1 train + 1 multi-train system + recovery of failed train	1 train + 1 multi-train system OR 2 diverse trains + recovery of failed train	2 diverse trains OR 1 multi-train system + recovery of failed train	1 train + recovery of failed train OR 1 multi-train system OR Operator action + recovery of failed train	1 train OR Operator action OR Operator action under high stress + recovery of failed train	Recovery of failed train OR Operator action under high stress	none
A	Green	White	Yellow	Red	Red	Red	Red
B	Green	Green	White	Yellow	Red	Red	Red
C	Green	Green	Green	White	Yellow	Red	Red
D	Green	Green	Green	Green	White	Yellow	Red
E	Green	Green	Green	Green	Green	White	Yellow
F	Green	Green	Green	Green	Green	Green	White
G	Green	Green	Green	Green	Green	Green	Green
H	Green	Green	Green	Green	Green	Green	Green

Figure 5.1 Fire Protection Risk Significance Screening Methodology (FPRSSM)
Determination Process of Potential Risk Significance of Fire Protection Inspection Findings

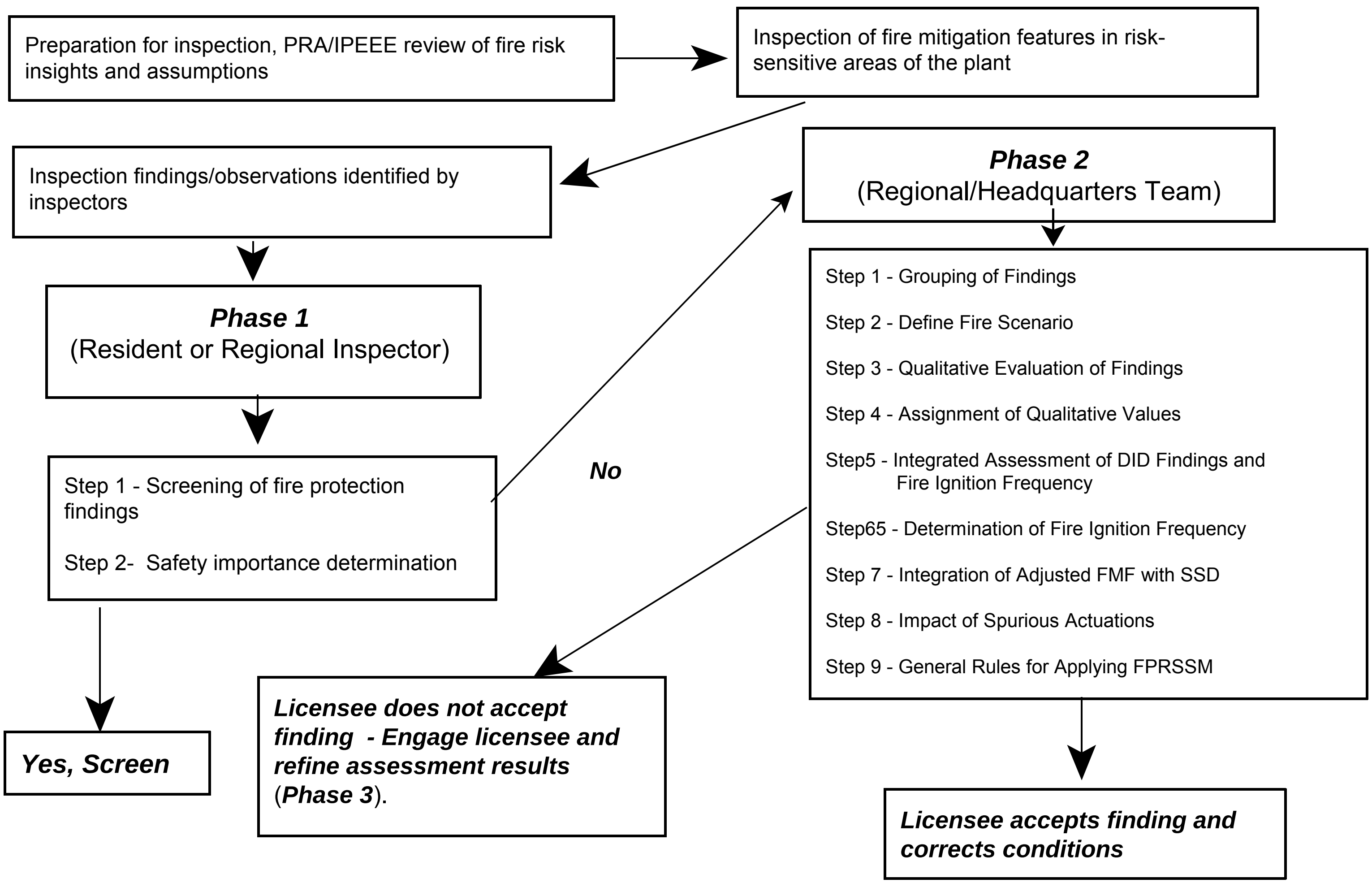


Table 3 - Remaining Capability Rating Values