Exercise #1a:

Background:

The licensee's fire protection program included a commitment to install a Halon fire extinguishing system in the cable spreading room. Per the original design specifications (accepted by the NRC), the system was to achieve a suppressant concentration from 5-7% with a minimum hold time of 15 minutes to ensure the extinguishment of a deep-seated cable fire. Licensee testing documents show the system could achieve a delivered Halon concentration of 6% and hold that concentration for 4 minutes. Based on this result, the licensee showed by calculation that at about 10 minutes, the concentration would drop to below the 5% design goal.

Finding:

The Halon system, as installed, fails to meet the design as committed to in the licensee's fire protection program.

Other relevant facts:

The system design configuration has not changed since originally installed in 1981. Halon actuation is controlled by a cross-zone smoke detection system. The two zones are configured with alternating detectors spaced in a 10-foot grid.

The cable spreading room contains cables for all trains of the safe shutdown systems. All cables are thermoplastic, but have been qualified as low flame spread. The trays are relatively full and measure 18" wide.

The safe shutdown path for this fire area involves use of critical functions from one equipment train (Train B). The SSD path is designated as the post safe shutdown path in the fire protection program and is supported by a documented post-fire SSD analysis. Use of the SSD path is documented in operating procedures. Assume that the safe shutdown path has a nominal unavailability estimated at 0.1.

Cables associated with the designated safe shutdown path that are within the fire area are routed in conduits protected by a 1-hour fire wrap. The wrapped conduits are located near the ceiling of the room in an area remote from the fixed fire ignition sources. The fire wrap is not degraded.

Train A control and indication cables are known to be present in exposed trays (no fire barrier protection provided). The exact location of cables associated with the exposed train (Train A) are not known.

The fire area is provided with automatic fire detection (cross-zone smoke detectors). The Halon system is the only installed fixed fire suppression system. Fire extinguishers and manual hose stations are available to support manual fire fighting.

The fire area is a limited access / access controlled space. Hot work is disallowed during at power operations and transient combustibles are strictly controlled. No violations of these measures are evident.

In addition to the cables, the following electrical components are also identified in the fire area:

1 bank of vented, electrical termination cabinets containing 4 individual panels
2 dry transformers

A stack of 6 cable trays is routed above and parallel to the termination panels. The lowest tray is approximately 18 inches above the tops of the panels. The height of the trays above the panels is consistent for all panels. The electrical termination cabinets are in an open area away from walls and corners.

Similarly, a stack of 5 cable trays is routed above each of the two transformers. The lowest tray is approximately 60 inches above the top of each transformer. The transformers are in an open area away from walls and corners.

In other portions of the fire area, the lowest cable trays are all located approximately 8 feet above floor level. Such trays exist in several locations. The specific locations for Train A cables of interest has not been identified.

The boundaries of the fire area are all rated at a minimum of two hours fire endurance. No deficiencies are noted.

Room dimensions are 50' x 35' x 20'(H).

Attachment 1

Part 1: Fire Protection SDP Phase 1 Worksheet

Facility: Exercise #1a

Performance Issue: The Halon system, as installed, is unable to maintain adequate suppressant concentration for required design time - can achieve concentration, but hold time is inadequate.

Step 1.1

Assign a finding category:

- O Cold Shutdown
- O Fire Prevention and Administrative Controls
- ● Fixed Fire Protection Systems
- O Fire Confinement
- O Localized Cable or Component Protection
- O Post-fire SSD

Basis for selection/comments:

Fixed fire suppression system (automatic or manual) (p. F-5)

Step 1.2

Assign a degradation rating:

- O Low
- ● Moderate
- O Moderate A (applies only to Fire Confinement and Localized Cable or Component Protection Issues)
- O Moderate B (applies only to Fire Confinement and Localized Cable or Component Protection Issues)
- O High

Basis for selection/comments:

Design concentration achieved but cannot be maintained for sufficient time to ensure fire extinguishment (Attachment 2, p. F2-4)

Step 1.3
Task 1.3.1: Qualitative Screening for All Finding Categories

Question 1: Was the finding assigned a Low degradation rating?
- O Yes – Screens to Green, no further analysis required
- ● No – Continue to next question

Question 2: Does the finding only affect ability to reach and maintain cold shutdown conditions?
- O Yes - Screen to Green, no further analysis required
- ● No – Continue to Step 1.4, unless the finding category was "Fire Confinement," in which case, proceed to Task 1.3.2

Task 1.3.2: Supplemental Screening for Fire Confinement Findings
If the finding category assigned in Step 1.1 is "Fire Confinement" and the degradation rating assigned in Step 1.2 is "Moderate," perform a supplemental qualitative screening check based on the following questions. Otherwise, proceed to Step 1.4.

Question 1: Will the barrier in its degraded condition provide a 2-hour or greater fire endurance rating?
- O Yes – Screens to Green, no further analysis required
- O No – Continue to next question

Question 2: Is there a non-degraded automatic gaseous room-flooding fire suppression system in the exposing fire area?
- O Yes – Screen to Green, no further analysis required
- O No – Continue to next question

Question 3: Is there a non-degraded or no more than moderately degraded automatic full area water-based fire suppression system in the exposing fire area?
- O Yes – Screen to Green, no further analysis required
- O No – Continue to next question

Question 4: Can it be determined that the exposed fire area contain no potential damage targets that are unique from those in the exposing fire area (damage targets may include post-fire safe shutdown components or other plant components whose loss might lead to a demand for safe shutdown (e.g., a plant trip))?
- O Yes – Screen to Green, no further analysis required
- O No – Continue to next question

Question 5: Are all potential damage targets in the exposed fire area (as described in question 4) provided with passive fire barrier protection with no more than a moderate degradation that will provide a minimum of 20 minutes fire endurance?

- O Yes – Screen to Green, no further analysis required
- O No – Continue to next question

Question 6: Is a non-degraded or no more than moderately degraded partial-coverage automatic water based fire suppression system installed in the exposing fire area and are all the fixed or *in-situ* fire ignition sources included within the zone of coverage for this system?

- O Yes – Screen to Green, no further analysis required
- O No – Continue to next question

Question 7: Does the degraded barrier provide a minimum of 20 minutes fire endurance protection and are the fixed or *in situ* fire ignition sources and combustible or flammable materials positioned such that, even considering fire spread to secondary combustibles, the degraded barrier or barrier element will not be subject to direct flame impingement?

- O Yes – Screen to Green, no further analysis required
- O No – Continue to Step 1.4

Step 1.4 - Initial Quantitative Screening

Task 1.4.1: Assign a duration factor (DF)	O	< 3 Days	(0.01)
	O	3 – 30 Days	(0.10)
(given - existed since 1981)	●	> 30 Days	(1.00)

Task 1.4.2: Estimate the fire frequency for the fire area (from Generic Fire Area Fire Frequency Table)

AREA	F_{AREA}
Cable Spreading Room - Cables plus other electrical equipment (p. F-9, Table 1.4.2)	6E-3
$(\sum F_{AREA}) =$	6E-3

Task 1.4.3: Screening Check

$$\Delta CDF_{1.4} \approx (\sum F_{AREA}) \times DF = \underline{\ 6E\text{-}3 \times 1.0 = 6E\text{-}3\ }$$

Table A1.1 - Phase 1 Quantitative Screening Criteria

Assigned Finding Category (from Step 1.1):	$\Delta CDF_{1.4}$ Screening Criteria	
	Moderate Degradation	High Degradation
Fire Prevention and Administrative Controls	N/A	1E-6
Fixed Fire Protection Systems	1E-5	
Fire Confinement	1E-5	
Localized Cable or Component Protection	1E-5	
Post-fire SSD	1E-6	

- O $\Delta CDF_{1.4}$ is lower than the corresponding value in Table A1.1 - the finding screens to Green and the analysis is complete (no Phase 2 analysis is required)

- ● $\Delta CDF_{1.4}$ is greater than or equal to the corresponding value in Table A1.1 - the finding does not screen to Green, and the analysis continues to Phase 2

Part 2: Fire Protection SDP Phase 2 Worksheet

Facility: Exercise #1a

Results from FP SDP Phase 1 Review: $\Delta CDF_{1.4} \approx (SF_{AREA}) \times DF =$ 6E-3

Request and review the following licensee documents:

- The fire hazards analysis for the fire areas to be evaluated
- The post-fire safe shutdown analysis for the fire areas to be evaluated
- The licensee's lists of required and associated circuits
- Post-fire operating procedures applicable to the fire areas to be assessed
- Documentation for any USNRC approved deviations or exemptions relevant to the fire areas to be assessed.

Step 2.1 - Independent SSD Path First Screening Assessment

Task 2.1.1: Identify the Designated Post-fire SSD Path

The identified SSD path must meet the following criteria in order to be considered at this stage of the Phase 2 analysis:

- The SSD path must be identified as the designated post-fire SSD path in the plant's fire protection program.
- The SSD path must be supported by a documented post-fire SSD analysis consistent with regulatory requirements.
- Use of the SSD path must be documented and included in the plant operating procedures.

SSD Path: Redundant train (Train B) as specified in problem statement

Task 2.1.2: Assess the Unavailability Factor for the Identified SSD Path

$CCDP_{2.1.2}$ = (SSD Unavailability Factor) = 0.1 (Credited as either 1.0, 0.1, or 0.01)

Basis for selection/comments:

Given information in problem statement

If $CCDP_{2.1.2}$ = 1.0, proceed to Step 2.2.

Task 2.1.3: Assess Independence of the Identified SSD Path

Criteria satisfied: $CCDP_{2.1.3}$ = $CCDP_{2.1.2}$ = (SSD Unavailability Factor)

● Criteria not satisfied: $CCDP_{2.1.3}$ = 1.0. Proceed to Step 2.2

Basis for criteria not met/comments:

For III.G.2 separation based on one-hour wrap plus auto detection/suppression, all features must be non-degraded to meet independence criteria. Auto suppression is degraded - not independent. (p. F-13, Table 2.1.2)

Task 2.1.4: Screening Check

$$\Delta CDF_{2.1} \approx DF \times (SF_{Area}) \times CCDP_{2.1.2} = \_\_\_\_\_\_\_\_$$

Table A1.2 Phase 2 Screening Step 1 Quantitative Screening Criteria		
Assigned Finding Category (from Step 1.1):	Δ $CDF_{2.1}$ Screening Value	
	Moderate Degradation	High Degradation
Fire Prevention and Administrative Controls	N/A	1E-6
Fixed Fire Protection Systems	1E-5	
Fire Confinement	1E-5	
Localized Cable or Component Protection	1E-5	
Post-fire SSD	1E-6	

O Δ $CDF_{2.1}$ is lower than the corresponding value in Table A1.2 - the finding screens to Green and the analysis is complete.

O Δ $CDF_{2.1}$ is greater than or equal to the corresponding value in Table A1.2. The analysis continues to Step 2.2

Step 2.2 - Fire Damage State Determination

Task 2.2.1: Initial FDS Assignment

(Check all that apply from Appendix F, Table 2.2.1)

● FDS1
● FDS2
● FDS3

Basis for selection(s)/FDS3 assessment/comments: (p. F-15, Table 2.2.1) Finding on fixed fire protection system. FDS3 scenarios screen out given the 2-hour fire endurance rating and the non-degraded fire area boundaries (First question in Task 2.2.2)

Task 2.2.2: Screening Assessment for FDS3 Scenarios

If the finding category assigned in Step 1.1 is "Fire Confinement," retain the FDS3 scenarios and continue the analysis with Step 2.3. For all other finding categories, conduct a screening check for the FDS3 scenarios based on the following questions:

Question 1: Does the fire barrier separating the exposed and the exposing fire areas have a non-degraded 2-hour or greater fire endurance rating?
- ● Yes – FDS3 scenarios screen out, continue to Step 2.3.
- O No – Continue to next question

Question 2: Is there a non-degraded automatic gaseous room-flooding fire suppression system either in the exposed or in the exposing fire area?
- O Yes – FDS3 scenarios screen out, continue to Step 2.3.
- O No – Continue to next question

Question 3: Is there a non-degraded or no more than moderately degraded automatic full area water-based fire suppression system either in the exposed or in the exposing fire area?
- O Yes – FDS3 scenarios screen out, continue to Step 2.3.
- O No – Continue to next question

Question 4: Can it be determined that the exposed fire area contain no potential damage targets that are unique from those in the exposing fire area (damage targets may include post-fire safe shutdown components or other plant components whose loss might lead to a demand for safe shutdown (e.g., a plant trip))?
- O Yes – FDS3 scenarios screen out, continue to Step 2.3.
- O No – Continue to next question

Question 5: If the exposed fire area does contain post-fire safe shutdown components or components whose fire-induced failure might lead to a demand for safe shutdown, are all such components located at least 20 feet from the intervening fire barrier, and/or provided with passive fire protection with a minimum one-hour fire endurance rating?
- O Yes – FDS3 scenarios screen out, continue to Step 2.3.
- O No – Continue to next question

Question 6: Is a partial-coverage automatic water based fire suppression system installed in the exposing fire area and are all the fixed or *in-situ* fire ignition sources included within the zone of coverage for this system?
- O Yes – FDS3 scenarios screen out, continue to Step 2.3.
- O No – Continue to next question

Question 7: Does the fire barrier provide a minimum of 20 minutes fire endurance protection and are the fixed or *in situ* fire ignition sources and combustible or flammable materials in the exposing fire area positioned such that, even considering fire spread to secondary combustibles, the barrier will not be subject to direct flame impingement?

- O Yes – FDS3 scenarios screen out, continue to Step 2.3.
- O No – Retain the FDS3 scenarios and continue the analysis with Step 2.3.

Step 2.3 - Fire Scenario Identification and Ignition Source Screening

Task 2.3.1: Identify and Count Fire Ignition Sources

(Use the worksheet on the following pages)

Table A1.3 - Fire Frequency Evaluation Worksheet						
Nuclear Power Plant:		Exercise #1a				
Description of the Plant Area of Interest:			Cable Spreading Room			
Identifier/Designator of the Plant Area:			CSR			
Ignition Source Bin		# of Items or	Individual Base Fire	Associated Frequency	Comments	Associated HHRs
Cables - Non-Qualified (Low/Medium/High) (See Attachment 4)		N/A	1.6E-05/4.8E-05/ 1.4E-03		Cables are given as qualified so no self-ignited cable fires	Initial 70kW See Attachments 3 and 5
Electrical Cabinets:						
Switchgear Cabinets	Thermal		5.5E-05			70kW, 200kW
	High Energy		4.7E-06			See Attachment 5
General Electrical Cabinets		4	6.0E-05	2.4E-04	Treat termination panels as general electrical cabinets	70kW, 200kW
General Control Cabinets			6.0E-05			200kW, 650kW
MCR and MCR Service Cabinets			4.8E-03			200kW, 650kW
Electric Motors:						
Electric Motors (<100HP)			6.5E-04			70kW, 200kW
Electric Motors (≥100HP)			6.5E-04			200kW, 650kW
Generators - General:						
Diesel Generators			5.6E-03			70kW, 200kW
Gas Turbine Generators			3.2E-04			70kW, 200kW
Reactor Protection System MG Sets			6.7E-04			70kW, 200kW

Ignition Source Bin		# of Items or	Individual Base Fire	Associated Frequency	Comments	Associated HHRs
Hydrogen Sources:						
Hydrogen Recombiner (BWR)			5.5E-03			See Attachment 5
Hydrogen Storage Tanks (Yes / No)			6.5E-04			See Attachment 5
Hydrogen Piping - Charged (Yes / No)			9.7E-04			See Attachment 5
Hot Work (Low/Medium/High) (See Attachment 4)		N/A	2.3E-05/6.9E-05/ 6.9E-04		Hotwork is disallowed and no violations noted so we will not include in room fire frequency	See Attachment 5
Main Turbine- Generator Set:						
T/G Exciter Fire (Yes / No)			1.4E-03			70kW, 200kW
T/G Oil Fires (Yes / No)			1.7E-03			See Attachment 5
T/G Hygrogen Fire (Yes / No)			1.4E-03			See Attachment 5
Miscellaneous Components:						
Air Compressors (<100HP)	Motor Fire		1.5E-04			70kW, 200kW
	Oil Fire		1.0E-04			See Attachment 5
Air Compressors (≥100HP)	Motor Fire		1.5E-04			200kW, 650kW
	Oil Fire		1.0E-04			See Attachment 5
Battery Banks			1.9E-04			70kW, 200kW
Boiler Heating Units			9.7E-04			See Attachment 5
Electric Dryers			5.4E-04			70kW, 200kW
Ventilation Subsystems			6.0E-05			70kW, 200kW

Ignition Source Bin		# of Items or	Individual Base Fire	Associated Frequency	Comments	Associated HHRs
Pumps:						
Reactor Coolant Pump (PWR)	Motor Fire		6.2E-04			200kW, 600kW
	Oil Fire		3.1E-04			See Attachment 5
Reactor Feed Pump (BWR)	Motor Fire		8.4E-05			200kW, 650kW
	Oil Fire		8.4E-04			See Attachment 5
Main Feedwater Pumps	Motor Fire		2.7E-04			200kW, 650kW
	Oil Fire		2.7E-03			See Attachment 5
Other Pumps (<100HP)	Motor Fire		5.0E-05			70kW, 200kW
	Oil Fire		5.0E-05			See Attachment 5
Other Pumps (≥100HP)	Motor Fire		5.0E-05			200kW, 650kW
	Oil Fire		5.0E-05			See Attachment 5
Transformers:						
Transformers - Outdoor/Yard			4.2E-03			650kW, 10MW
Transformers - Indoor Dry		2	1.1E-04	2.2E-04	Two dry transformers are given in problem statement	70kW, 200kW
Transformers - Indoor Oil-Filled			1.1E-04			650kW, 2MW
Transients (Low/Medium/High) (See Attachment 4)		Low	5.5E-05/1.7E-04/ 1.7E-03	5.5E-05	Combustibles are strictly controlled and no violations noted. CSR is typical of Low fire area on transients.	70kW, 200kW or See Attachment 5

Task 2.3.2: Characterize Fire Ignition Sources and
Task 2.3.3: Identify Nearest and Most Vulnerable Ignition or Damage Targets
Task 2.3.4: Fire Ignition Source Screening (Using NUREG-1805 or Zone of Influence Chart)

Table A1.4

Source #	Source - Description/Location	Number of Sources	From Table A1.3 Expected HRR / High Confidence HRR	Severity Factor (SF)	Identify Nearest Target	Target Distance (ft) H	Target Distance (ft) R	Critical Distance (ft) (from Tables 2.3.2 thru 2.3.4) H	Critical Distance (ft) R	Number of Sources Retained (i.e. Did not screen out)
1	Dry Transformers	2	70kW	0.9	Cable trays above	5.0	n/a	4.8	1.8	0
			200kW	0.1	Cable trays above	5.0	n/a	7.3	3.0	2
2	Termination Panels	4	70kW	0.9	Cable trays above	2.5	n/a	4.8	1.8	4
			200kW	0.1	Cable trays above	2.5	n/a	7.3	3.0	4
3	Transients	1	70kW	0.9	Cable trays above	6.0	n/a	4.8	1.8	0
			200kW	0.1	Cable trays above	6.0	n/a	7.3	3.0	1

Fire Area Dimensions: (given)
Width(ft) 50
Depth (ft) 35
Height (ft) 20

Highest HRR for sources not retained: 70 kW
Does this HRR result in damaging hot gas layer?
○ Yes ● No If yes, retain scenario.

(Attach printouts of any spreadsheet calculations utilized from NUREG-1805.)

Some notes for the tabletop exercise and the above table:

It is worth developing a consistent notation for fire scenarios. One approach is to assign a single number to each of the grouped ignition sources, and use a secondary indicator (small letters) for the expected and high confidence values of HRR (e.g., source 1 is the two transformers; 1a is the expected 70 kW; 1b is the high confidence 200kW). This will allow you to follow scenarios through subsequent steps.

Target distance is from fire origin to target:

- For a panel, remember that origin is 1' below top of panel so separation for tray 18" above panel top is 30" or 2.5' (not the simple 18" given).
- For transformer, 5' is specified as distance from top of source to trays, so that works directly - place origin on top of the source.
- For transients, distance is 8' tray height minus 2' nominal height of origin above floor per generic guidance.

For this example, the radial distances R for the Ball and Column zone of influence are basically irrelevant. All targets are specified as directly above a fire ignition source so plume behavior dominates. Plume value H is always greater than radiant heating value R for the same fire.

- If a R value is desired, the correct radial distance IS NOT ZERO! Line of site applies for radial distance (R). In this case, the radial distance from the origin straight up to the targets is the same as the H value already set! One could say that for the transformers, both H and R are 5' and this would be technically correct.

If you run the hot gas layer spreadsheet for a 70 kW fire, you should find a minimal rise in room temperature - no where near enough to reach damaging levels. Using the FDT tool with a 3' open doorway, calculated HGL temperature at 30 minutes was about 128°F.

Task 2.3.5: Finding Screening Check

- O All identified fire ignition sources screened out in Task 2.3.4. The Phase 2 analysis is complete and the finding should be assigned a Green significance determination rating. Subsequent analysis tasks and steps need not be completed.

- ● One or more of the fire ignition sources is retained, even if only at the higher severity value. The analysis continues to Step 2.4.

Step 2.4 - Fire Frequency for Unscreened Fire Sources

Task 2.4.1: Nominal Fire Frequency Estimation
Task 2.4.2: Findings Quantified Based on Increase in Fire Frequency and
Task 2.4.3: Credit for Compensatory Measures that Reduce Fire Frequency

(Use the worksheet on the following page)

Table A1.5 – Step 2.4: Fire Frequency for Unscreened Fire Sources							
Source #	Unscreened Fire Source at Specified HRR Value	Number of Sources Retained (Table A1.4)	Individual Base Fire Frequency (Table A1.3)	Severity Factor (SF_i) (Table A1.4)	Adjustment Factor for Fire Frequency Increase or Compensatory Measures* ($AF_{i,x}$)	Base Frequency Increase**	Revised Fire Frequency for Unscreened Source
1b	Transformer - 200kW	2	1.1E-4	0.1	n/a	n/a	2.2E-5
2a	Termination panel - 70kW	4	6.0E-5	0.9	n/a	n/a	2.2E-4
2b	Termination panel - 200kW	4	6.0E-5	0.1	n/a	n/a	2.4E-5
3b	Transients (Low) - 200kW	1	1.6E-5	0.1	n/a	n/a	1.6E-6
Total ($\sum F_{Source\,i}$ X SF_i X $\prod AF_{i\,2.4}$):							2.7E-4

* Adjustment Factor for Fire Frequency Increase applies only to "Fire Prevention and Administrative Controls" findings (see discussion under Task 2.4.2). Credit for Compensatory Measures applies only to transient or hot work sources (see discussion under Task 2.4.3).

** Base frequency increases apply only to "Fire Prevention and Administrative Controls" findings within the combustible controls programs (see discussion under Task 2.4.2).

Assumptions/Comments/Remarks: At this point, given that the transient frequency value is near 1E-6, it seems appropriate to drop further consideration of the transient fire sources, even at the high confidence HRR value. The frequency contribution is two orders of magnitude below other fixed sources and no consideration has yet been given to suppression or weighting factors.

$$\Delta CDF_{2.4} \approx (\sum F_{Source\,i} \text{ X } SF_i \text{ X } \prod AF_{i\,2.4}) \text{ X } DF \text{ X } CCDP_{2.1.2} \text{ or } CCDP_{2.1.3}$$

$$\approx 2.7E\text{-}4 \text{ x } 1.0 \text{ x } 1.0 = 2.7E\text{-}4$$

Task 2.4.4: Finding Screening Check

Compare the updated change in CDF value, given the newly calculated fire frequency reflecting only the unscreened fire sources, with the values in the table below.

Table A1.6 - Phase 2, Screening Step 4 Quantitative Screening Criteria		
Assigned Finding Category (from Step 1.1):	**$\Delta CDF_{2.4}$ screening value**	
	Moderate Degradation	**High Degradation**
Fire Prevention and Administrative Controls	N/A	1E-6
Fixed Fire Protection Systems	1E-5	
Fire Confinement	1E-5[1]	
Localized Cable or Component Protection	1E-5[1]	
Post-fire SSD	1E-6	

[1] This entry applies to both 'Moderate A' and 'Moderate B' findings against a fire barrier.

- O $\Delta CDF_{2.4}$ is lower than the corresponding value in Table A1.6 - the findingscreens to Green and the analysis is complete.
- ● $\Delta CDF_{2.4}$ is greater than or equal to the corresponding value in Table A1.6. The analysis continues to Step 2.5

Step 2.5 - Definition of Specific Fire Scenarios and Independent SSD Path Second Screening Assessment:

Task 2.5.1: Identify Specific Fire Growth and Damage Scenarios (Fixed Ignition Sources)
Task 2.5.2: Identify Specific Fire Growth and Damage Scenarios (Self-ignited Cable Fire, Transients, Hot Work)
Task 2.5.3: Identify Specific Plant Damage State Scenarios and
Task 2.5.4: Assess Fire Scenario-Specific SSD Path Independence

(Use the worksheet on the following page)

Table A1.7

Source #	Unscreened Fire Source at Specified HRR Value	FDS State (carried forward unscreened from Table 2.2.1)	Plant Damage State Scenarios	Scenario-Specific SSD Path Independence (Yes / No)	Worst Case FDS (✓)	Revised Fire Frequency for Unscreened Fire Sources (from Table A1.5)	Weighting Factor* (Attachment 5)	CCDPi (from task 2.1.2 or 2.1.3)	Revised Fire Frequency X CCDP,
1b1	Dry Transformer - high confidence (200kW)	FDS1	Loss of Train A	Yes		2.2E-5	n/a	0.1	2.2E-6
1b2	Dry Transformer - high confidence (200kW)	FDS2	Loss of Trains A&B	No	✓	2.2E-5	n/a	1.0	2.2E-5
2a1	Termination panel - expected value (70kW)	FDS1	Loss of Train A	Yes		2.2E-4	n/a	0.1	2.2E-5
2a2	Termination panel - expected value (70kW)	FDS2	Loss of Trains A&B	No	✓	2.2E-4	n/a	1.0	2.2E-4
2b1	Termination panel - high confidence (200kW)	FDS1	Loss of Train A	Yes		2.4E-5	n/a	0.1	2.4E-6
2b2	Termination panel - high confidence (200kW)	FDS2	Loss of Trains A&B	No	✓	2.4E-5	n/a	1.0	2.4E-5
Total ($\sum F_{Source\,i}$ X SF_i X $\Pi AF_{i\,2.4}$ X $CCDP_{i\,2.1.2\text{ or }2.1.3}$):									

* Weighting factors apply only to transient and hot work sources (see Attachment 5).

Attach printouts of any spreadsheet calculations utilized from NUREG-1805.

Assumptions/Comments/Remarks: For each fire ignition source, the worst case scenario involves loss of the redundant SSD train (i.e., not independent). No additional credit can be taken, so screening check is not necessary. Go to Step 2.6 (p. F-31)

$$\Delta CDF_{2.5} \approx (\sum F_{Source\,i} \times SF_i \times \Pi AF_{i\,2.4} \times CCDP_{i\,2.1.2\text{ or }2.1.3}) \times DF$$

$\approx$ ____________________

Task 2.5.5: Screening Check

If the SSD path cannot be credited for any of the identified fire ignition sources given its worst-case damage state, then Step 2.5.5 is complete, and the analysis continues with Step 2.6.

If the SSD path can be credited for at least one fire ignition source, then the screening check is performed based on the values and criteria provided in the table below:

Table A1.8 Phase 2, Screening Step 5 Quantitative Screening Criteria

Assigned Finding Category (from Step 1.1):	$\Delta CDF_{2.5}$ screening value	
	Moderate Degradation	**High Degradation**
Fire Prevention and Administrative Controls	N/A	1E-6
Fixed Fire Protection Systems	1E-5	
Fire Confinement	1E-5[1]	
Localized Cable or Component Protection	1E-5[1]	
Post-fire SSD	1E-6	

[1] This entry applies to both 'Moderate A' and 'Moderate B' findings against a fire barrier.

- O The value of $\Delta CDF_{2.5}$ is lower than the corresponding value in Table A1.8. The finding Screens to Green, and the analysis is complete.
- O The value of $\Delta CDF_{2.5}$ exceeds the corresponding value in Table A1.8. The analysis continues to Step 2.6.

Step 2.6 - and **Step 2.7 -**

Fire Growth and Damage Time Analysis / **Non-Suppression Probability Analysis**

Attach printouts of any spreadsheet calculations utilized from NUREG-1805.

Table A1.9

(All times in nearest whole minute - damage times rounded down, detection/suppression and manual response times up)

Source #	Unscreened Fire Damage State Scenarios	Time to Damage (Attachment 7)	Detection Time (Attachment 8)	(T_{Damage} - $T_{Detection}$)	Fixed Suppression Actuation Time (Attachment 8 and NUREG-1805)	(T_{Damage} - $T_{Suppression}$)
1b1	Dry Transformer - high confidence (200kW) - FDS1	6 min	<<1 min	5 min	1 min	5 min
2a1	Termination panel - expected value (70kW) - FDS1	8 min	<<1min	7 min	1 min	7 min
2b1	Termination panel - high confidence (200kW) - FDS1	1 min	<<1min	0	1 min	0
1b2	Dry Transformer - high confidence (200kW) - FDS2	83 min	<<1min	> 60 min	1 min	> 60 min
2a2	Termination panel - expected value (70kW) - FDS2	> 60 min	<<1min	> 60 min	1 min	> 60 min
2b2	Termination panel - high confidence (200kW) - FDS2	> 60 min	<<1min	> 60 min	1 min	> 60 min

Assumptions/Comments/Remarks: Detection time: Assumed 1st detector directly above plume; 2nd detector 10 feet away. Assumed a 30 second delay for Halon actuation after detection.

FDS1 scenarios: Calculation details - Time to Damage; PNS, time to detection.

- All plume calculations use 6 ft^2 fire area, and 77°F ambient temperature

- 1b1: Transformer - High Confidence

HRR:	200kW
Target Distance (Plume):	5'
Temperature at target (worksheet):	589°F
Time to Damage:	6 min
Time to Detection	1 min
Time available for fire fighting:	5 min
PNS_{manual}	0.56
Time to Suppression Actuation:	1 min
Time margin (damage-suppression)	5 min
PNS_{fixed}	0.5

- 2a1: Panel - Expected

HRR:	70kW
Target Distance (Plume):	2.5'
Temperature at target (worksheet):	549°F
Time to Damage:	8 min
Time to Detection	1 min
Time available for fire fighting:	7 min
PNS_{manual}	0.44
Time to Suppression Actuation:	1 min
Time margin (damage-suppression)	7 min
PNS_{fixed}	0.25

- 2b1: Panel - High Confidence

HRR:	200kW
Target Distance (Plume):	2.5'
Temperature at target (worksheet):	1465°F
Time to Damage:	1 min
Time to Detection	1 min
Time available for fire fighting:	0 min
PNS_{manual}	1.0
Time to Suppression Actuation:	1 min
Time margin (damage-suppression)	0 min
PNS_{fixed}	1.0

FDS2 Calculations:

- From HGL worksheet: Requires 1450kW to create HGL at 400°F in this room (one open door, room dimensions as specified, HGL temperature at 10 minutes used for this calculation).

- 1b2:

- Time to ignition of first tray:	6 min
- Number of Trays in Stack above:	5
- Tray width	1.5'
- Calculated time to reach damaging HGL:	23 minutes
- Fire wrap endurance rating:	60 min
- Total fire damage time without suppression:	83 min
- PNS_{manual} at this time:	0.001 (at lower limit value already)

- 2a2 and 2b2:
  - By inspection: PNS_{manual} for these scenarios will also be 0.001 since PNS bottoms out at 0.001 at less than 60 minutes.

Task 2.7.4: Probability of Non-Suppression

Table A1.10

Source #	Unscreened Fire Damage State Scenarios	PNS_{fixed} (Table A8.2)	PNS_{manual} (Table 2.7.1)	$PNS_{scenario}$ / (Attachment 8)
1b1	Dry Transformer - high confidence (200kW) - FDS1	0.5	0.56 / 0.17	0.37
2a1	Termination panel - expected value (70kW) - FDS1	0.25	0.44 / 0.14	0.23
2b1	Termination panel - high confidence (200kW) - FDS1	1.0	1.0 / 1.0	1.0
1b2	Dry Transformer - high confidence (200kW) - FDS2	0.0	0.001	0.001
2a2	Termination panel - expected value (70kW) - FDS2	0.0	0.001	0.001
2b2	Termination panel - high confidence (200kW) - FDS2	0.0	0.001	0.001

Assumptions/Comments/Remarks: PNS is driven by manual value for all scenarios (mop-up required even if Halon discharges). FDS2 scenarios use limiting PNS value for manual suppression at 60 min as scenario value. Listing of PNS_{manual} values includes $PNS_{gas-manual}$ as second entry.

Task 2.7.5: Screening Check

The estimated risk contribution or screening CDF, for each fire scenario is based on the product of the following factors:

Table A1.11

Source #	Unscreened Fire Damage State Scenarios	Revised Fire Frequency X CCDP ($F_{Source\,i}$ X SF_i X $\Pi AF_{i\,2.4}$ X $CCDP_{i\,2.1.2\,or\,2.1.3}$) (from Table A1.7)	PNS (from Table A1.10)	Revised Fire Frequency
1b1	Dry Transformer - high confidence (200kW) - FDS1	2.2E-6	0.37	8.1E-7
2a1	Termination panel - expected value (70kW) - FDS1	2.2E-5	0.23	5.1E-6
2b1	Termination panel - high confidence (200kW) - FDS1	2.4E-6	1.0	2.4E-6
1b2	Dry Transformer - high confidence (200kW) - FDS2	2.2E-5	0.001	2.2E-8
2a2	Termination panel - expected value (70kW) - FDS2	2.2E-4	0.001	2.2E-7
2b2	Termination panel - high confidence (200kW) - FDS2	2.4E-5	0.001	2.4E-8
Total ($\sum F_{Source\,i}$ x SF_i x $\Pi AF_{i\,2.4}$ x $CCDP_{i\,2.1.2\,or\,2.1.3}$ x $PNS_{scenario\,i}$):				8.6E-6

$$\Delta CDF_{2.7} \approx DF \times (\sum F_{Source\,i} \times SF_i \times \Pi AF_{i\,2.4} \times CCDP_{i\,2.1.2\,or\,2.1.3} \times PNS_{scenario\,i})$$

$\Delta CDF_{2.7} \approx$ 1.0 x 8.6E-6 = 8.6E-6

If $\Delta CDF_{2.7}$ is less than or equal to 1E-6, then the finding screens to Green, and the analysis is complete. If $\Delta CDF_{2.7}$ is greater than 1E-6, then the analysis continues to Step 2.8.

Step 2.8 - Plant Safe Shutdown Response Analysis

Using the appropriate plant initiating event worksheet(s) from the plant risk-informed inspection notebook, carry out the guidance provided under Step 2.8 of Appendix F, to account for the plant SSD response and required human recovery actions in order to quantify the factor "$CCDP_i$" for each fire growth and damage scenario of interest.

Attach any internal event worksheets and manual action evaluation table determinations used to quantify each $CCDP_i$.

(Use the worksheet on the following page)

Table A1.12 - Step 2.8: Plant Safe Shutdown Response Analysis							
Source #	Unscreened Fire Damage State Scenarios	HEP_i (from Table 2.8.1 or 2.8.2)	P_{SPi} (from Table 2.8.3)	CCDP (given successful manual action)	CCDP (given manual action fails and spurious actuation)	CCDP (given manual action fails and no spurious actuation)	$CCDP_i$

$CCDP_i$ = [(1-HEP_i) x CCDP(given successful manual action)] +
[HEP_i x P_{SPi} x CCDP(given manual action fails and spurious actuation)] +
[HEP_i x (1 - P_{SPi}) x CCDP(given manual action fails and no spurious actuation)]

where: HEP_i is the true value of the human error probability for scenario i (not the exponent value derived from the HEP tables), and
P_{SPi} is the probability of a spurious actuation for scenario I.

Step 2.9 - Quantification and Preliminary Significance Determination

Calculate a final quantification of the FDS scenarios of interest and assign a preliminary determination of a findings significance.

Table A1.13 - Step 2.9: Quantification of the FDS Scenarios

Source #	Unscreened Fire Damage State Scenarios	Revised Fire Frequency for Unscreened Source (from Step 2.4) ($F_{Source,i}$ x SF_i x $\Pi AF_{i2.4}$) (from Table A1.5)	Probability of Non-Suppression (PNS_i) (Table A1.10)	$CCDP_i$ (Table A1.12)	Revised Fire Frequency for Unscreened Source
Total ($\sum F_{Source\,i}$ X SF_i X $\Pi AF_{i2.4}$ X PNS_i X $CCDP_i$):					

Assumptions/Comments/Remarks:____

The estimated risk contribution or screening CDF, for each fire scenario is based on the product of the following factors:

$$\Delta CDF_{2.8} \approx DF \times \sum_{i=1}^{n} [F_i \times SF_i \times \prod AF_{i2.4} \times PNS_i \times CCDP_i]_{\text{All Scenarios}}$$

$\Delta CDF_{2.8} \approx$ ____

Where:

n	=	number of fire scenarios evaluated for a given finding (covering all relevant FDSs)
DF	=	Duration factor from Step 1.4
F_i	=	Fire frequency for the fire ignition source i from Task 2.4.1
SF_i	=	Severity factor for scenario i from Task 2.4.1
$AF_{i2.4}$	=	Ignition source specific frequency adjustment factors from Step 2.4
PNS_i	=	Probability of non-suppression for scenario i from Step 2.7
$CCDP_i$	=	Conditional core damage probability for scenario i from Step 2.8

If $\Delta CDF_{2.8}$ is less than or equal to 1E-6, then the finding screens to Green, and the analysis is complete. If $\Delta CDF_{2.8}$ is greater than 1E-6, then the finding is potential safety significant.

Intentionally Blank

Closing Notes:

Working through step 2.7 indicates a potential white preliminary color assignment for Phase 2. Possible outcomes include:

- Obtain better information regarding the actual location of the target cables of concern. Absent this information, the process will make conservative assumptions on cable locations.

- Execution of Step 2.8 (SSD analysis and refined CCDP) could be enough to find this case as green. This would be worthwhile effort if knowledge is available to refine the CCDP (e.g., a diverse path beyond appendix R might yield an additional order of magnitude risk reduction).

- If a Phase III analysis is called for, two areas would deserve additional consideration and would likely prove most fruitful:

    - A refined SSD analysis is always a possibility especially if the SSD path is a manual actions driven path. In this case, the example did not provide any information upon which to base the SSD analysis beyond nominal availability of the Appendix R SSD path.

    - The conservative Phase 2 fire characterization assumptions appear to be driving final quantification. The risk estimates are dominated by scenarios with short damage times. The damage times are, in turn, driven largely by the assumption that the fire starts at full intensity at time zero.
        - Relaxing the conservative fire modeling assumptions by allowing a fire growth profile (say an increase in fire intensity over the first ten minutes) would yield a more representative answer, and would more accurately reflect risk benefit of the fire suppression system even in it's degraded state. The short damage times meant little or no credit is given to the fixed suppression system.
        - Relaxing the conservative fire modeling assumptions is considered a Phase 3 exercise because all aspects of the fire scenario analysis must be re-considered in a self-consistent manner (detection time, growth rates, plume behavior, HGL, etc.). The Phase 2 approach simplified the fire modeling, but one artifact of the simplifications is an over-emphasis of short damage time scenarios.

Appendix F

Fire Protection Significance Determination Process

RAY'S "CHEAT SHEETS"

- **Violations of the combustible controls program**
  If the finding is against the administrative controls program and is associated with the combustible material control elements of that program, then only fires initiated in or by transient combustible materials need to be considered. Once again, no consideration of fires initiated by the fixed or *in situ* fire ignition sources is necessary, because the risk contribution arising from such fires does not change given a finding against the combustible material control programs. Note that fires initiated in a transient material may well spread to *in situ* combustible materials (e.g., cables or an adjacent electrical panel) but the fire ignition source is the transient combustible material.

Table 1.4.2 - Generic Fire Area Fire Frequencies

Room Identifier/Limited Specific Findings	Generic Fire Frequency
Auxiliary Building (PWR)	4E-2
Battery Room	4E-3
Cable Spreading Room - Cables Only	2E-3
Cable Spreading Room - Cables Plus Other Electrical Equipment	6E-3
Cable Vault or Tunnel Area - Cables Only	2E-3
Cable Vault or Tunnel Area - Cables Plus Other Electrical Equipment	6E-3
Containment - PWR or non-inerted BWR	1E-2
EDG Building	3E-2
Intake Structure	2E-2
Main Control Room	8E-3
Radwaste Area	1E-2
Reactor Building (BWR)	9E-2
Switchgear Room	2E-2
Transformer Yard	2E-2
Turbine Building - Main Deck (per unit)	8E-2
Hot Work Issues Only	2E-3
Combustible Controls Program Issues Only	5E-3

Task 1.4.3: Screening Check
Multiply the fire area fire frequency from Task 1.4.2 by the duration factor from Task 1.4.1 to generate an initial Phase 1 screening change in CDF value ($\Delta CDF_{1.4}$). *Since the probability of non-suppression and CCDP have not been considered yet, they are unwritten, but with an assumed value of 1.0.*

$$\Delta CDF_{1.4} \approx F_{Area} \times DF$$

If the finding impacts multiple fire areas, then the initial Phase 1 screening CDF value is based on the sum of the fire frequency for all impacted fire areas as follows:

$$\Delta CDF_{1.4} \approx (\Sigma F_{Area}) \times DF$$

- Cables within the fire area under analysis <u>are not</u> considered exposed <u>if</u> they are protected by a raceway fire barrier with a minimum one-hour fire endurance rating, the area is provided with automatic detection and suppression capability, and none of these elements is found to be degraded.
- Cables in an adjoining fire area <u>are not</u> considered exposed <u>if</u> the fire barrier separating adjoining fire area from the fire area under analysis is not degraded.
- If the finding category assigned in Step 1.1 was "Fire Confinement," cables located in the adjacent fire area are considered exposed <u>unless</u> they are protected by a non-degraded localized fire barrier with a minimum 1-hour fire endurance rating.

- The licensee's compliance strategy for the separation of redundant safe shutdown circuits (i.e., in the context of Appendix R Section III.G.2) are identified. If the finding category assigned in Step 1.1 is "Fire Confinement," any required or associated circuit components or cables that are located in the adjacent fire area(s) separated by the degraded fire barrier element are identified. Also, any supplemental fire protection (i.e., beyond separation by the degraded barrier element) provided for any such cable or components are identified.
- A second aspect of the independence check depends on the nature of the fire protection that has been provided for the designated SSD path (i.e., in the context of 10CFR50 Appendix R Section III.G.2). Table 2.1.2 provides a matrix of independence criteria for the major options under III.G.2.

Table 2.1.2 - SSD Path Independence Check Criteria

Section III.G.2 compliance strategy for SSD path	**Step 2.1 SSD path independence criteria (all criteria for a given strategy must be met)**
Physical separation into a separate fire area	• The fire area boundary separating the SSD path is not impacted by the finding under analysis.
Separation by a 3-hour rated localized fire barrier (e.g., a raceway barrier)	• The fire barrier qualification rating is not in question, and • The fire barrier protecting the redundant train is not impacted by the finding.
Separation by a 1-hour rated localized fire barrier (e.g., a raceway barrier) plus automatic fire detection and suppression coverage for the fire area	• The fire barrier qualification rating is not in question, • The fire barrier protecting the redundant train is not impacted by the finding, • The fire detection system is not impacted by the finding, and • The fire suppression system is not impacted by the finding.
Spatial separation or other means of protection (e.g., exemptions, deviations, reliance on remote shutdown)	• SSD Path will <u>not be credited</u> pending further refinement of the SDP fire scenarios

Step 2.2 - Fire Damage State Determination

Based on the finding category assigned in Step 1.1, analyze to determination which Fire Damage State (FDS) scenarios apply.

The FDS is a discrete stage of fire growth and damage postulated in the development of Fire Protection SDP fire scenarios. Four fire damage states are defined as follows:

> *FDS0:* Only the fire ignition source and initiating fuels are damaged by the fire. FDS0 is not analyzed in the FP SDP as a risk contributor.
> *FDS1*: Fire damage occurs to unprotected components or cables located near the fire ignition source.
> *FDS2*: Widespread fire damage occurs to unprotected components or cables within the fire area of fire origin, to components or cables protected by a degraded local fire barrier system (e.g., a degraded cable tray fire barrier wrap), or to components or cables protected by a non-degraded one-hour fire barrier.
> *FDS3*: Fire damage extends to a fire area adjacent to the fire area of fire origin, in general, due to postulated fire spread through a degraded inter-area fire barrier element (e.g., wall, ceiling, floor, damper, door, penetration seal, etc.).

<u>Task 2.2.1 - Initial FDS Assignment</u>
Using the FDS/Finding Category Matrix in Table 2.2.1 below, identify the FDSs that need to be retained given the finding category assigned in Step 1.1.

Table 2.2.1 - FDS/Finding Category Matrix

Finding Type or Category:	FDS1	FDS2	FDS3
Fire Prevention and Administrative Controls	Retain	Retain	Retain
→ Fixed Fire Protection Systems	Retain	Retain	Retain
Fire Confinement	N/A	N/A	Retain
Localized Cable or Component Protection Given a High degradation Given a Moderate degradation	 Retain(1) N/A	 Retain Retain	 Retain Retain
Post-fire SSD	Retain	Retain	Retain

Note 1: For a highly degraded local barrier, the protected components/cables are treated as fully exposed and may be assumed damaged in FDS1 scenarios, depending on their proximity to the fire ignition source.

<u>Task 2.2.2: Screening Assessment for FDS3 Scenarios</u>
If the finding category assigned Step 1.1 is "Fire Confinement," retain the FDS3 scenarios and continue the analysis with Step 2.3. For all other finding categories, conduct a screening check for the FDS3 scenarios based on the following questions. If the FDS3 scenarios "screen out," the subsequent analysis task for that finding need not consider any FDS3 fire scenarios.

The screening criteria are expressed in terms of the fire protection features for the "exposing" and "exposed" fire areas. The "exposing" fire area is the area in which the fire is assumed to

- Hot Work
  The same likelihood rating assigned to the fire area for transient fires is also used as the initial hot work fire likelihood rating. However, plant specific conditions may be considered if such information is readily available, and an alternate hot work likelihood rating may assigned as appropriate.

No other specific cases of a similar nature have been identified. However, should a fire protection program degradation finding be encounter that is very specific to fires involving one or more specific fire ignition sources, then the SDP Phase 2 analysis should be focused on only those specific sources. It is recommended that additional guidance and support in making such a decision should be sought in such cases. Careful and complete documentation of the decision will also be required.

Counting notes and guidelines are provided for each fire ignition source bin. (See Attachment 4 for counting guidance and for information on other aspects of fire ignition source treatment.)

<u>Task 2.3.2: Characterize Fire Ignition Sources</u>
For each unique fire ignition source identified in Task 2.3.1, fire intensity levels, fire severity characteristics and a nominal location are assigned. Fire ignition sources are classified into general types - 'simple' and 'non-simple.'

- Simple fire ignition sources are assigned fire intensity characteristics on a generic basis using predefined guidance (see Table 2.3.1). Most fixed fire ignition sources are of the simple type. To address the uncertainty in fire source severity, each fire ignition source is associated with two heat release rate (HRR) values:

  FIRE SEVERITY
  - The lower HRR value reflects the anticipated or expected fire severity (50th percentile fire), and will be associated with 90% of fires (a fire severity factor of 0.9).
  - The higher HRR value reflects a high confidence limit fire severity (95^{th} percentile fire) and will be associated with 10% of fires (a fire severity factor of 0.1).

- Non-simple fire ignition sources are either unique or require the application of case-specific information. These 'Non-Simple' Fire Ignition Sources include the following:
  - Self-ignited cable fires,
  - Energetic arcing electrical faults leading to fire,
  - Transient fuel fires when the nominal as-found conditions exceed the nominal fire intensity values,
  - Hot work fires,
  - Liquid fuel spill fires including fires in the main turbine generator set, and
  - Hydrogen fires.

  Guidance for treating non-simple fire ignition sources is provided in Attachment 5.

Attachment 4

Fire Ignition Source Mapping Information:
Fire Frequency, Counting Instructions, Applicable Fire Severity Characteristics, and Applicable Manual Fire Suppression Curves

Fire Ignition Source Mapping Table:
See additional counting instructions at end of table.

A4.1 - Mapping Fire Ignition Source Scenarios to Fire Frequency, the Fire Severity Characteristics, and the Applicable Manual Fire Suppression Curve

Ignition Source Bin	Counting Unit	Fire Frequency per Counting Unit (/ry)	Use These Fire Severity Characteristics	Use This Manual Fire Suppression Curve
Cables – Thermoplastic or Non-Qualified:				
Low Loading	per fire area	1.6E-05	Self-Ignited Cable Fire	Cable Fires
Medium Loading		4.8E-04		
High Loading		1.4E-03		
Electrical Cabinets:				
Switchgear Cabinets	per distinct vertical section	5.5E-05	Small Electrical Fire	Electrical Fires
		4.7E-06	Energetic Faults	Energetic Faults
General Electrical Cabinets		6.0E-05	Small Electrical Fire	Electrical Fires
General Control Cabinets		6.0E-05	Large Electrical Fire	Electrical Fires
MCR and MCR Service Cabinets	per unit control room	4.8E-03	Large Electrical Fire	Main Control Room
Electric Motors:				
Electric Motors – (< 100HP)	per motor	6.5E-04	Small Electrical Fire	Electrical Fires
Electric Motors – (≥ 100HP)		6.5E-04	Large Electrical Fire	Electrical Fires
Generators – General:				
Diesel Generators	per generator	5.6E-03	Engines and Heaters	All Events
Gas Turbine Generators		3.2E-04		
Reactor Protection System MG Sets		6.7E-04		
Hydrogen Sources:				
H2 Recombiner (BWR)	per recombiner	5.5E-03	Gas Fire	All Events
H2 Storage Tanks	per H2 tanks	6.5E-04	Gas Fire	All Events
H2 - Normally Charged Piping	per fire area with charged piping	9.7E-04	Gas Fire	All Events
Hot Work:				
Hot Work – Low	per fire area	2.3E-05	Self-ignited cable, transient, or other (see text)	Hot Work / Welding
Hot Work – Medium		6.9E-05		
Hot Work – High		6.9E-04		
Main Turbine-Generator Set:				
TG Exciter Fire	per exciter	1.4E-03	Small Electrical Fire	Turbine Generator
TG Oil Fires	per lube oil system	1.7E-03	Oil Fire	
TG Hydrogen Fires	per H2 system	1.4E-03	Gas Fire	

A4.1 - Mapping Fire Ignition Source Scenarios to Fire Frequency, the Fire Severity Characteristics, and the Applicable Manual Fire Suppression Curve

Ignition Source Bin	Counting Unit	Fire Frequency per Counting Unit (/ry)	Use These Fire Severity Characteristics	Use This Manual Fire Suppression Curve
Miscellaneous Components:				
Air Compressors (< 100HP)	per compressor	1.6E-04	Small Electrical Fire	Electrical Fires
		1.0E-04	Oil Fire	All Events
Air Compressors (≥ 100HP)		1.6E-04	Large Electrical Fire	Electrical Fires
		1.0E-04	Oil Fire	All Events
Battery Banks	per interconnected battery set	1.9E-04	Small Electrical Fire	Electrical Fires
Boiler Heating Units	per boiler	9.7E-04	Engines and Heaters	All Events
Electric Dryers	per dryer	5.4E-04	Small Electrical Fire	Electrical Fires
Ventilation Subsystems	per major ventilation system	6.0E-05	Small Electrical Fire	Electrical Fires
Pumps:				
Reactor Coolant Pump (PWR)	per reactor coolant pump	6.2E-04	Large Electrical Fire	Electrical Fires
		3.1E-04	Oil Fire	All Events
Reactor Feed Pump (BWR)	per reactor feed pump	8.4E-05	Large Electrical Fire	Electrical Fires
		8.4E-04	Oil Fire	All Events
Main Feedwater Pumps	per main feedwater pump	2.7E-04	Large Electrical Fire	Electrical Fires
		2.7E-03	Oil Fire	All Events
Other Pumps (< 100HP)	per pump	5.0E-05	Small Electrical Fire	Electrical Fires
		5.0E-05	Oil Fire	All Events
Other Pumps (≥ 100HP)		5.0E-05	Large Electrical Fire	Electrical Fires
		5.0E-05	Oil Fire	All Events
Transformers:				
Outdoor/Yard	per transformer	4.2E-03	Very Large Fire Source	Switchyard
Indoor Dry		1.1E-04	Small Electrical Fire	Electrical Fires
Indoor Oil-Filled		1.1E-04	Indoor Oil-Filled Transformers	All Events
Transient Fuels:				
Transients – Low	per fire area	5.5E-05	Solids and Transient Combustibles	Transients
Transients – Medium		1.7E-04		
Transients – High		1.7E-03		

Additional Counting Instructions:

Electrical Cabinets - All types:

- Count distinct vertical sections
- Do not individual cubicles for devices such as breakers and MCCs - count vertical sections.
- Do not count fully enclosed wall-mounted electrical panels and junction boxes.

TERMINATION PANELS
DRY TRANSFORMERS

TRANSIENTS

Table 2.3.1 - Mapping of General Fire Scenario Characterization Type Bins to Fire Intensity Characteristics						
Fire Size Bins	Generic Fire Type Bins with Simple Predefined Fire Characteristics					
	Small Electrical Fire	Large Electrical Fire	Indoor Oil-Filled Transformers	Very Large Fire Sources	Engines and Heaters	Solid and Transient Combustibles
70 kW	50th Percentile Fire				50th Percentile Fire	50th Percentile Fire
200 kW	95th Percentile Fire	50th Percentile Fire			95th Percentile Fire	95th Percentile Fire
650 kW		95th Percentile Fire	50th Percentile Fire	50th Percentile Fire		
2 MW			95th Percentile Fire			
10 MW				95th Percentile Fire		

A nominal location, or locations, is also assigned to each unique fire ignition source:

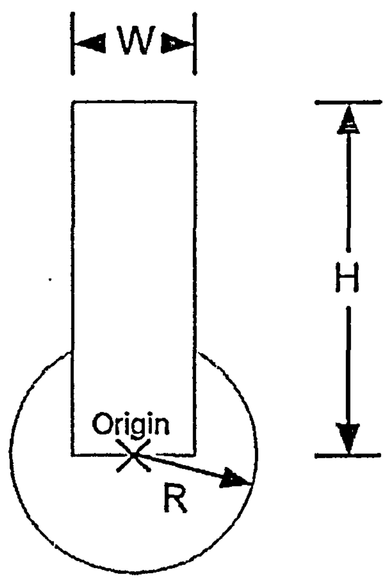
- For most stand-alone fire ignition sources, the location assigned is obvious and corresponds to the location of the individual ignition source.
- For certain types of fire ignition sources, individual fire ignition sources of the same type may be grouped for the purposes of analysis. One location is assigned to represent the group. Grouping of fire ignition sources is most commonly applied in the analysis of electrical panel fires. (See Section 5.2.3.2 of the IMC 0308, Att3, App F for further details.)
- For certain fire ignition sources, multiple locations may apply. This applies to non-fixed sources such as transient fuel fires, hot work fires, oil spill fires, and self-ignited cable fires.

Task 2.3.3: Identify Nearest and Most Vulnerable Ignition or Damage Targets
For each unique fire ignition source scenario, identify the ignition and/or damage targets that will be:

- Secondary combustible materials directly above the fire ignition source that might be ignited by the flame zone and/or plume,
- Secondary combustible materials within a direct line of sight of the fire ignition source that might be ignited by direct radiant heating,
- Thermal damage targets (components or cables) directly above the fire ignition source that might be damaged by the flame zone or plume effects,

height of the cylinder is calculated based on the ignition temperature threshold for targets located above the fire source.

The tables that follow (Tables 2.3.2 thru 2.3.4) provide pre-solved thermoplastic cable and thermoset cable critical distances for plume heights (H) and radial distances (R) for each of five discrete fire intensity levels that correspond to the simple fire ignition source types. If the distance from the fire source to the cables is greater than the distance value in the table, the cables are outside the zone of influence for that fire source. The pre-solved values are based on a point source, but the critical distance for plume height (H) should be applied at the diameter boundary (W) of the fire ignition source itself.



The origin is placed at the assigned fire location. Generally this is the top of the fire ignition source itself (i.e., top of the fuel package). Exceptions are as follows:

- For electrical cabinets, the origin is 1 foot below the top of the cabinet.
- For oil or liquid fuel spill fires, the origin is on the floor at the center of the spill.
- For transient fires, the origin is placed 2 feet above the floor at the center of the postulated location.
- For a hydrogen or other gas fire, the origin is at the point of release.

For fires in an open area away from walls or corners:

Table 2.3.2 - Calculated Values (in feet) for Use in the Ball and Column Zone of Influence Chart for Fires in an Open Location Away from Walls				
Fire HRR	Thermoplastic Cables		Thermoset Cables	
	H	R	H	R
70 kW	4.8	1.8	3.5	1.3
200 kW	7.3	3.0	5.3	2.1
650 kW	11.6	5.4	8.5	3.8
2 MW	18.2	9.5	13.3	6.7
10 MW	34.7	21.3	25.3	15.0

Calculations are based on the following damage criteria:
Thermoplastic Cables: 400°F (325°F rise above ambient) and 0.5 BTU/ft^{2}sec
Thermoset Cables: 625°F (550°F rise above ambient) and 1 BTU/ft^{2}sec

The parameters of the zone of influence chart are also dependent on the fire location, and in particular, must be adjusted for fires located near a wall or corner. For the purposes of the phase 2 analysis, a fire is considered to be "near" a wall if its outer edge is within two feet of a wall, or is "near" a corner if within two feet of each of the two walls making up the corner.

For a fire located near a wall:

Table 2.3.3 - Calculated Values (in feet) for Use in the Ball and Column Zone of Influence Chart for Fires Adjacent to a Wall				
Fire HRR	Thermoplastic Cables		Thermoset Cables	
	H	R	H	R
70 kW	6.3	2.5	4.6	1.8
200 kW	9.6	4.3	7.0	3.0
650 kW	15.3	7.7	11.2	5.4
2 MW	24.1	13.5	17.5	9.5
10 MW	45.8	30.1	33.4	21.3

Table A7.1 - Failure Time-Temperature Relationship for Thermoset Cables		
Exposure Temperature		Time to Failure (minutes)
°C	°F	
330	625	28
350	660	13
370	700	9
390	735	7
410	770	5
430	805	4
450	840	3
470	880	2
490 (or greater)	915 (or greater)	1

Table A7.2 - Failure Time-Temperature Relationship for Thermoplastic Cables		
Exposure Temperature		Time to Failure (minutes)
°C	°F	
205	400	30
220	425	25
230	450	20
245	475	15
260	500	10
275	525	8
290	550	7
300	575	6
315	600	5
330	625	4
345	650	3
355	675	2
370 (or greater)	700 (or greater)	1

← 2a1 (549°F)
← 1b1 (589°F)
← 2b1 (1465°F)

Radiant heating

The approach for radiant heating is similar to that for plume heating. An exposure heat flux is calculated using the appropriate fire modeling correlation from NUREG-1805 fire modeling tool set, and the damage time is assessed base on the intensity of the exposure. The inspector must establish the line of sight distance from the fire to the target. A second factor required is the fraction of the total fire heat output that is released as thermal radiation.

- For evaluating damage due to radiant heat, assume 30% of heat released by fire is radiant energy (radiant fraction = 0.3).

Task 2.7.4 - Probability of Non-Suppression

The purpose of Task 2.7.4 is to estimate the overall probability of fire suppression failure. Failure in this context means that suppression was not achieved before the FDS of interest is reached. Fire suppression will eventually be achieved for all fires, but if the FDS is reached before suppression, then in the SDP context, fire suppression has failed to prevent fire-induced damage consistent with the postulated FDS scenario.

Fixed fire suppression systems

Both the estimates of fire damage time and the time to fixed suppression system suppressant discharge contain considerable uncertainty. Hence, the probability that the fire suppression system suppresses the fire prior to critical damage is not based on a simple comparison of the time to damage versus time to suppressant discharge. Rather, a probability of non-suppression is assigned based on the "margin" between time to damage and time to suppressant discharge.

The time margin/likelihood relationship is described in the table below. The first column presents the difference in minutes between the time to damage and the time to suppressant discharge. If the two times are close, or damage occurs before suppressant discharge, a high likelihood of damage will be assumed (PNS approaches 1.0). If the time to suppression is shorter than the time to damage, the PNS value decreases reflecting a higher likelihood of suppression success. As the time difference reaches 10 minutes, PNS approaches zero. Note that in quantification, the likelihood that the fire suppression system fails on demand is explicitly treated.

Table A8.2 - Probability of Non-suppression for Fixed Fire Suppression Systems Based on the Absolute Difference Between Damage Time and Suppression Time

Time Delta: (t_{Damage} - $t_{Suppress}$)	PNS_{Fixed}	
Negative Time up to 1 Minute	1.0	← 2b1
> 1 Minute to 2 Minutes	.95	
> 2 Minutes to 4 Minutes	.80	
> 4 Minutes to 6 Minutes	.5	← 1b1
> 6 Minutes to 8 Minutes	.25	← 2a1
> 8 Minutes to 10 Minutes	.1	
> 10 Minutes	0.0	← 1b2, 2a2, 2b2

PNS treatment for degraded gaseous fire extinguishment systems - inadequate soak time

One specific type of degradation that may be identified for a gaseous fire extinguishment systems involves the inability of the system to maintain the design concentration of fire suppressant for a sufficient time to assure the complete extinguishment of a deep-seated fire. The required suppressant concentration and maintenance time are established by the system design criteria. This degradation is commonly referred to as an "inadequate soak time." This can be an issue for Halon and Carbon Dioxide fire extinguishment systems, as well as for other gaseous suppression systems (e.g., Halon replacements).

Table 2.7.1 – Non-suppression Probability Values for Manual Fire Fighting Based on Fire Duration (Time to Damage after Detection) and Fire Type Category

	$T_{Damage} - T_{Detection}$ (min)	Mean manual non-suppression probability curve values - PNS_{manual}									
		All Events	Hot Work - Welding	Transients	Electrical Fires	Cable Fires	Switchyard	Main Control Room	Turbine Generator	Energetic Arcing Faults	Containment
	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	1	0.93	0.93	0.87	0.89	0.84	0.97	0.78	0.98	0.95	0.94
	2	0.87	0.86	0.76	0.79	0.70	0.95	0.62	0.96	0.90	0.89
	3	0.81	0.80	0.66	0.70	0.59	0.92	0.48	0.94	0.86	0.84
	4	0.76	0.74	0.58	0.63	0.49	0.90	0.38	0.92	0.81	0.80
1b1 →	5	0.71	0.69	0.51	0.56	0.41	0.88	0.30	0.90	0.77	0.75
	6	0.66	0.64	0.44	0.50	0.35	0.85	0.23	0.88	0.74	0.71
2a1 →	7	0.62	0.59	0.38	0.44	0.29	0.83	0.18	0.86	0.70	0.67
	8	0.58	0.55	0.34	0.39	0.24	0.81	0.14	0.84	0.66	0.63
	9	0.54	0.51	0.29	0.35	0.20	0.79	0.11	0.83	0.63	0.60
	10	0.50	0.47	0.26	0.31	0.17	0.77	0.09	0.81	0.60	0.57
	12	0.44	0.41	0.19	0.25	0.12	0.73	0.05	0.78	0.54	0.51
1b1(+10) →	14	0.38	0.35	0.15	0.20	0.08	0.69	0.03	0.74	0.49	0.45
2a1(+10) →	16	0.33	0.30	0.11	0.15	0.06	0.66	0.02	0.71	0.44	0.40
	18	0.29	0.26	0.09	0.12	0.042	0.62	0.013	0.68	0.40	0.36
	20	0.25	0.22	0.07	0.10	0.029	0.59	0.008	0.65	0.36	0.32
	25	0.18	0.15	0.03	0.05	0.012	0.52	0.002	0.59	0.28	0.24
	30	0.13	0.11	0.017	0.03	0.005	0.46	0.001	0.53	0.21	0.18
	35	0.09	0.07	0.008	0.017	0.002	0.40	*	0.48	0.17	0.14
	40	0.06	0.05	0.004	0.009	0.001	0.35	*	0.43	0.13	0.10
	45	0.05	0.03	0.002	0.005	*	0.31	*	0.39	0.10	0.08
	50	0.03	0.02	0.001	0.003	*	0.27	*	0.35	0.08	0.06
1b2 2a2 2b2 →	55	0.02	0.02	*	0.002	*	0.24	*	0.31	0.06	0.04
	60	0.02	0.01	*	0.001	*	0.21	*	0.28	0.05	0.03
	Mean Rate Constant (1/min)	0.069	0.075	0.137	0.117	0.177	0.026	0.242	0.021	0.051	0.057

* Value is less than 0.001. Screen using PNS_{manual}=0.001 or use formula to calculate actual value.

Manual fire fighting non-suppression curves are also provided in Attachment 8. These curves provide the same results as the PNS_{manual} table, but can be used as follows:

- If the fire detection time subtracted from the fire damage time is zero or negative, then PNS_{manual} = 1.0.

For the inadequate soak time degradation case, special consideration is required to estimate the probability on non-suppression (PNS). So long as the system can deliver an initial concentration that meets the design criteria, then some credit is given to the system for disrupting the fire growth and spread process. For this case, the following assumptions are made:

- Fires involving cables or other electrical and electronic components will be deep-seated.
- If a gaseous suppression system cannot maintain adequate concentration for a sufficient time to assure fire extinguishment (per design specifications), manual fire fighting must respond and must achieve final fire suppression.
- The fire will be held in check during the time that the fire suppressant concentration is maintained at design level.
- Assuming that the system actuation is timely (i.e., adequate margin between discharge time and the estimated fire damage time) the systems effectiveness will be reflected as a corresponding delay in the estimated fire damage time. As a result, the manual fire brigade is given an additional time to effectively respond to the fire.
- Upon dissipation of suppressant, the fire will re-flash and the fire growth and damage process will pick up where it left off.

The quantification process for this case is as follows:

- Select the appropriate manual suppression fire duration curve corresponding to the fire ignition source.

- Estimate the time to fire detection in the usual manner. In addition to any other fire detection capability, assume that a valid actuation signal for the gaseous suppression system will trigger a fire alarm.

- Using the fire damage time calculated in Step 2.6 (t_{damage}), and the estimated time to fire detection ($t_{detection}$), calculate the value of PNS_{manual} from the selected fire duration curve in the usual manner (i.e., using t_{damage}-$t_{detection}$ as the time available for manual suppression).

- Estimate discharge/actuation time ($t_{suppress}$) for the gaseous fire extinguishment system in usual manner. Recall that actuation will either be automatic or manual, and that the pre-discharge alarm/warning time must be included.

- Calculate the time margin ("time delta") between the actuation time and fire damage time in the normal manner:
  Time Delta = (t_{damage} - $t_{suppress}$)

- Use the general PNS_{fixed} probability table based on "Time Delta" to assess the likelihood that the suppression system actuation is timely in comparison to the estimated fire damage time.

- If the PNS_{fixed} value assigned is 1.0, then the gaseous system will not be credited. In this case use the value of PNS_{manual} as calculated previously as $PNS_{scenario}$ and the analysis is complete.

- If the PNS_{fixed} value is less than 1.0, then the gaseous system will be credited. Continue this analysis to estimate $PNS_{scenario}$.

- Calculate a modified fire damage time as follows:

  $t_{damage\_new} = t_{damage} + t_{maintain\_gas}$

  where $t_{maintain\_gas}$ is the length of time that the desired gaseous suppressant design concentration <u>can</u> be maintained.

- Using t_{damage_new} (i.e., in place of t_{damage}) and $t_{detection}$, estimate PNS_{gas_manual} based on the selected manual fire suppression fire duration curve. That is, calculate $[t_{damage\_new} - t_{detection}]$ as the modified time available for manual suppression, and estimate PNS_{gas_manual} in the manner normally applied to PNS_{manual}.

- Estimate $PNS_{scenario}$ by combining PNS_{fixed} , PNS_{manual} , and PNS_{gas_manual} using the following equation:

$$PNS_{scenario} = [0.95 \times (1 - PNS_{fixed}) \times PNS_{gas\_manual}] + [(0.95 \times PNS_{fixed}) \times PNS_{manual}] + [0.05 \times PNS_{manual}]$$

The calculation of $PNS_{scenario}$ combines three cases. The first case is that the suppression system works (no random failure - 95% general reliability/availability factor), the actuation is timely (1- PNS_{fixed}) and the fire brigade responds following dissipation of the fire suppressant concentration (PNS_{gas_manual}). This is reflected in the first term on the right hand side of the equation. In the second case, the fire suppression system does <u>not</u> fail randomly (the 95% reliability/availability factor), but discharge of the fire suppression system is not timely (PNS_{fixed}). In the third case, the gaseous suppression system suffers a random failure on demand (the 5% unreliability/unavailability factor). For the last two cases, the fire brigade must successfully suppress the fire within the originally estimated fire suppression time (PNS_{manual}). 161

This equation reduces to: 0.5 0.17 0.5 0.56

$$PNS_{scenario} = [0.95 \times (1 - PNS_{fixed}) \times PNS_{gas\_manual}] + [(0.95 \times PNS_{fixed}) + 0.05] \times PNS_{manual} = 0.37$$

0.37 ≤ 0.56

- Verify that ($PNS_{scenario} \not> PNS_{manual}$). As in other cases, the manual brigade response given the original fire damage time the minimum credit given to fire suppression for any scenario. If ($PNS_{scenario} \not< PNS_{manual}$), then reset ($PNS_{scenario} = PNS_{manual}$).

<u>Manual fire suppression:</u>
The following process is repeated for each fire scenario:

- Subtract the fire detection time from the fire damage time.
- Using the appropriate fire duration curve, read across the x-axis to the time difference from the above step.
- Transfer up to the corresponding point of the fire duration curve, and read across to the left to estimate the PNS_{Manual}.

- If the PNS_{fixed} value is less than 1.0, then the gaseous system will be credited. Continue this analysis to estimate $PNS_{scenario}$.

- Calculate a modified fire damage time as follows:

  $t_{damage\_new} = t_{damage} + t_{maintain\_gas}$

  where $t_{maintain\_gas}$ is the length of time that the desired gaseous suppressant design concentration <u>can</u> be maintained.

- Using t_{damage_new} (i.e., in place of t_{damage}) and $t_{detection}$, estimate PNS_{gas_manual} based on the selected manual fire suppression fire duration curve. That is, calculate $[t_{damage\_new} - t_{detection}]$ as the modified time available for manual suppression, and estimate PNS_{gas_manual} in the manner normally applied to PNS_{manual}.

- Estimate $PNS_{scenario}$ by combining PNS_{fixed}, PNS_{manual}, and PNS_{gas_manual} using the following equation:

$$PNS_{scenario} = [0.95 \times (1 - PNS_{fixed}) \times PNS_{gas\_manual}] + [(0.95 \times PNS_{fixed}) \times PNS_{manual}] + [0.05 \times PNS_{manual}]$$

The calculation of $PNS_{scenario}$ combines three cases. The first case is that the suppression system works (no random failure - 95% general reliability/availability factor), the actuation is timely ($1 - PNS_{fixed}$) and the fire brigade responds following dissipation of the fire suppressant concentration (PNS_{gas_manual}). This is reflected in the first term on the right hand side of the equation. In the second case, the fire suppression system does <u>not</u> fail randomly (the 95% reliability/availability factor), but discharge of the fire suppression system is not timely (PNS_{fixed}). In the third case, the gaseous suppression system suffers a random failure on demand (the 5% unreliability/unavailability factor). For the last two cases, the fire brigade must successfully suppress the fire within the originally estimated fire suppression time (PNS_{manual}). 2a1

This equation reduces to: 0.25 0.14 0.25 0.44

$$PNS_{scenario} = [0.95 \times (1 - PNS_{fixed}) \times PNS_{gas\_manual}] + [(0.95 \times PNS_{fixed}) + 0.05] \times PNS_{manual} = 0.23$$

0.23 ≤ 0.44

- Verify that ($PNS_{scenario} \not> PNS_{manual}$). As in other cases, the manual brigade response given the original fire damage time the minimum credit given to fire suppression for any scenario. If ($PNS_{scenario} \not> PNS_{manual}$), then reset ($PNS_{scenario} = PNS_{manual}$).

<u>Manual fire suppression:</u>
The following process is repeated for each fire scenario:

- Subtract the fire detection time from the fire damage time.
- Using the appropriate fire duration curve, read across the x-axis to the time difference from the above step.
- Transfer up to the corresponding point of the fire duration curve, and read across to the left to estimate the PNS_{Manual}.

- If the PNS_{fixed} value is less than 1.0, then the gaseous system will be credited. Continue this analysis to estimate $PNS_{scenario}$.

- Calculate a modified fire damage time as follows:

  $t_{damage\_new} = t_{damage} + t_{maintain\_gas}$

  where $t_{maintain\_gas}$ is the length of time that the desired gaseous suppressant design concentration <u>can</u> be maintained.

- Using t_{damage_new} (i.e., in place of t_{damage}) and $t_{detection}$, estimate PNS_{gas_manual} based on the selected manual fire suppression fire duration curve. That is, calculate $[t_{damage\_new} - t_{detection}]$ as the modified time available for manual suppression, and estimate PNS_{gas_manual} in the manner normally applied to PNS_{manual}.

- Estimate $PNS_{scenario}$ by combining PNS_{fixed}, PNS_{manual}, and PNS_{gas_manual} using the following equation:

$$PNS_{scenario} = [0.95 \times (1 - PNS_{fixed}) \times PNS_{gas\_manual}] + [(0.95 \times PNS_{fixed}) \times PNS_{manual}] + [0.05 \times PNS_{manual}]$$

The calculation of $PNS_{scenario}$ combines three cases. The first case is that the suppression system works (no random failure - 95% general reliability/availability factor), the actuation is timely (1- PNS_{fixed}) and the fire brigade responds following dissipation of the fire suppressant concentration (PNS_{gas_manual}). This is reflected in the first term on the right hand side of the equation. In the second case, the fire suppression system does <u>not</u> fail randomly (the 95% reliability/availability factor), but discharge of the fire suppression system is not timely (PNS_{fixed}). In the third case, the gaseous suppression system suffers a random failure on demand (the 5% unreliability/unavailability factor). For the last two cases, the fire brigade must successfully suppress the fire within the originally estimated fire suppression time (PNS_{manual}).

This equation reduces to:

$$PNS_{scenario} = [0.95 \times (1 - PNS_{fixed}) \times PNS_{gas\_manual}] + [(0.95 \times PNS_{fixed}) + 0.05] \times PNS_{manual}$$

- Verify that ($PNS_{scenario} \geq PNS_{manual}$). As in other cases, the manual brigade response given the original fire damage time the minimum credit given to fire suppression for any scenario. If ($PNS_{scenario} \geq PNS_{manual}$), then reset ($PNS_{scenario} = PNS_{manual}$).

<u>Manual fire suppression:</u>
The following process is repeated for each fire scenario:

- Subtract the fire detection time from the fire damage time.
- Using the appropriate fire duration curve, read across the x-axis to the time difference from the above step.
- Transfer up to the corresponding point of the fire duration curve, and read across to the left to estimate the PNS_{Manual}.

- If the PNS_{fixed} value is less than 1.0, then the gaseous system will be credited. Continue this analysis to estimate $PNS_{scenario}$.

- Calculate a modified fire damage time as follows:

  $t_{damage\_new} = t_{damage} + t_{maintain\_gas}$

  where $t_{maintain\_gas}$ is the length of time that the desired gaseous suppressant design concentration <u>can</u> be maintained.

- Using t_{damage_new} (i.e., in place of t_{damage}) and $t_{detection}$, estimate PNS_{gas_manual} based on the selected manual fire suppression fire duration curve. That is, calculate $[t_{damage\_new} - t_{detection}]$ as the modified time available for manual suppression, and estimate PNS_{gas_manual} in the manner normally applied to PNS_{manual}.

- Estimate $PNS_{scenario}$ by combining PNS_{fixed}, PNS_{manual}, and PNS_{gas_manual} using the following equation:

$$PNS_{scenario} = [0.95 \times (1 - PNS_{fixed}) \times PNS_{gas\_manual}] + [(0.95 \times PNS_{fixed}) \times PNS_{manual}] + [0.05 \times PNS_{manual}]$$

The calculation of $PNS_{scenario}$ combines three cases. The first case is that the suppression system works (no random failure - 95% general reliability/availability factor), the actuation is timely (1- PNS_{fixed}) and the fire brigade responds following dissipation of the fire suppressant concentration (PNS_{gas_manual}). This is reflected in the first term on the right hand side of the equation. In the second case, the fire suppression system does <u>not</u> fail randomly (the 95% reliability/availability factor), but discharge of the fire suppression system is not timely (PNS_{fixed}). In the third case, the gaseous suppression system suffers a random failure on demand (the 5% unreliability/unavailability factor). For the last two cases, the fire brigade must successfully suppress the fire within the originally estimated fire suppression time (PNS_{manual}). 1b2 2a2 2b2

This equation reduces to: 0 0.001 0 0.001

$$PNS_{scenario} = [0.95 \times (1 - PNS_{fixed}) \times PNS_{gas\_manual}] + [(0.95 \times PNS_{fixed}) + 0.05] \times PNS_{manual} = 0.001$$

0.001 ≤ 0.001

- Verify that ($PNS_{scenario} \ngtr PNS_{manual}$). As in other cases, the manual brigade response given the original fire damage time the minimum credit given to fire suppression for any scenario. If ($PNS_{scenario} \nless PNS_{manual}$), then reset ($PNS_{scenario} = PNS_{manual}$). >

<u>Manual fire suppression:</u>
The following process is repeated for each fire scenario:

- Subtract the fire detection time from the fire damage time.
- Using the appropriate fire duration curve, read across the x-axis to the time difference from the above step.
- Transfer up to the corresponding point of the fire duration curve, and read across to the left to estimate the PNS_{Manual}.

$$PNS_{scenario} = (0.98 \times PNS_{fixed\text{-}scenario}) + (0.02 \times PNS_{manual\text{-}scenario})$$

If the fire area is covered by a non-degraded dry-pipe sprinklers or deluge system, or by a non-degraded gaseous suppression system, a general reliability of 0.95 is assumed for the fixed suppression system. In this case, the PNS is quantified as follows:

$$PNS_{scenario} = (0.95 \times PNS_{fixed\text{-}scenario}) + (0.05 \times PNS_{manual\text{-}scenario})$$

One specific type of degradation that may be identified for a gaseous fire extinguishment systems involves the inability of the system to maintain the design concentration of fire suppressant for a sufficient time to assure the complete extinguishment of a deep-seated fire. The required suppressant concentration and maintenance time are established by the system design criteria. This degradation is commonly referred to as an "inadequate soak time." This can be an issue for Halon and Carbon Dioxide fire extinguishment systems, as well as for other gaseous suppression systems (e.g., Halon replacements).

For the inadequate soak time degradation case, special consideration is required to estimate $PNS_{scenario}$. See Attachment 8 for guidance on calculating $PNS_{scenario}$ involving gaseous fire extinguishment systems that are unable to maintain the design concentration of fire suppressant for a sufficient time to assure the complete extinguishment of a deep-seated fire.

Task 2.7.5: Screening Check

In Task 2.7.5, a screening check is made that considers the non-suppression probability for each fire scenario with the factors considered in previous screening checks.

The estimated risk contribution or screening CDF, for each fire scenario is based on the product of the following factors:

$$\Delta CDF_{2.7} \approx DF \times \Sigma\left[F_{Source} \times SF_{Source} \times \Pi AF_{Source\,2.4} \times PNS_{Scenario} \times CCDP_{Scenario}\right]_{All\ Scenarios}$$

If $\Delta CDF_{2.7}$ is less than or equal to 1E-6, then the finding screens to Green, and the analysis is complete. If $\Delta CDF_{2.7}$ is greater than 1E-6, then the analysis continues to Step 2.8.

Step 2.8 - Plant Safe Shutdown Response Analysis

In Step 2.8, the plant SSD response, including required human recovery actions, is analyzed and the factor "$CCDP_i$" for each fire growth and damage scenario of interest is quantified.

Task 2.8.1: Select Plant Initiating Event Worksheets

Identify which plant initiating event worksheet(s) in the plant risk-informed inspection notebook will be used to assess the fire scenario CCDP. One or more of these worksheets may be selected to represent the fire-induced SSD challenge. Typically, only one worksheet will be used, corresponding to the initiating event whose characteristics most closely resemble the impact of the fire on the plant. However, if there is a possibility of a spurious actuation that would change the nature of the event, e.g., changing a transient into a LOCA, more than one worksheet may be need to be used. The following general rules apply to the selection of the appropriate initiating event worksheets:

FYI - Not part of example

- If it cannot be assured that cables associated with offsite power distribution will not be affected by the fire, the assumption is that offsite power is lost. Use the loss of offsite power (LOOP) initiating event worksheet. If the fire response procedures are such that the plant is effectively put into a station blackout (i.e., a self-induced station blackout), use the LOOP worksheet.
- If offsite power is known not to be lost, and it cannot be assured that the power conversion system is available, use the transient without power conversion system (TPCS) initiating event worksheet.
- If neither offsite power nor the power conversion system is lost, use the general transient (TRANS) initiating event worksheet.
- If a small LOCA is possible(e.g., RCP seal failure), use the small LOCA (SLOCA) initiating event worksheet.
- If a stuck open safety/relief valve is possible, use the stuck open relief valve (SORV) initiating event worksheet.

Task 2.8.2: Identify Credited Systems and Functions
Identify those systems and functions that can be credited as available to support plant SSD response for each fire damage state scenario and initiating event of interest.

The following considerations are important to determining whether or not systems and functions should be credited in a fire scenario analysis:

- Ensure that the credited systems and functions actually be available given the postulated fire scenario. The event sequence models in the plant risk-informed inspection notebooks typically credit systems and functions not credited in the licensee's post-fire SSD analysis. In the fire protection SDP context, it is appropriate to credit all available systems and functions whether or not they are credited in the post-fire SSD analysis. However, it is not appropriate to credit the full complement of equipment associated with the plant systems and functions included in the internal event models unless it can be determined, with reasonable confidence, that they will in fact survive the fire scenario.
- System/functional loss or survival depends on the actual location of components and cables related to that system or function. The ability to credit systems and functions is largely dependent on the licensee's state of knowledge regarding cable and component routing within the plant. A significant amount of time is not expected to be spent verifying equipment or cable routing within any fire area. Use the routing information provided by the licensee. In the absence of such routing information within a fire area, unverified systems and functions are assumed to fail.
- Circuit problems may result in spurious actuation of SSCs, leading to failure of required functions.

Task 2.8.3: Identify Ex-Control Room Manual Actions
Identify manual actions included in the SSD procedures in response to a given fire scenario. The ex-control room manual actions of interest include manual actions introduced to prevent spurious actuations and manual actions required for manual control of systems. The SSD procedures may also include procedural directions to abandon the control room in favor of using the remote shutdown panel.

Task 2.8.4: Assess the Failure Probability of Manual Actions

Assess the failure probability of manual action identified above by using the following guidance:

- For operator actions already incorporated in the internal event worksheets that are performed in the control room or are performed outside the control room but are unaffected by the fire by either spacial or temporal considerations, use the human error probabilities (HEPs) documented in the notebooks, even though it is recognized that there may be additional negative performance shaping factors on human performance given a fire.
- For ex-control room manual actions not contained in the internal event worksheets, use the tables on the following pages. Table 2.8.1 is for manual actions in a remote location; Table 2.8.2 is for manual actions at the remote shutdown panel. The general process for reviewing manual actions will be :
  - Review each Category, and its Task and Scenario Characteristics with any additional Performance Shaping Factors to determine if it is applicable to the manual action being evaluated.
  - For each that applies, record the evaluation value (i.e., α, β, 2β, or γ)
  - Sum the evaluation factors and apply the following rules sequentially in order to determine the value assigned to the HEP for that manual action, with one exception - if time is expansive, go to next bullet (○).
    - If any row is α, then use a credit of 0.
    - If the sum of rows evaluated as β or 2β is $\geq 3\beta$, then assume it is equivalent to α and use a credit of 0.
    - If all categories are γ, the use a credit of 2.
    - Otherwise, use a credit of 1.
  - If the time available is evaluated to be expansive, sum the remaining evaluation factors (other than time) and apply the following rules sequentially in order to determine the value assigned to the HEP for that manual action:
    - If any row is α, or the sum of the βs $>3\beta$, use a credit of 0.
    - If the sum of the βs $= 3\beta$, use a credit of 1.
    - If the sum of the βs $\leq 2\beta$, use a credit of 2.
  - Repeat the review for each defined manual action within the scenario.

Table 2.8.1 - Manual Actions Evaluation Table for Actions at a Remote Location				
Category	**Task and Scenario Characteristics**	**Performance Shaping Factors**	**Comments**	**Evaluation**
Direct Physical Effect of Fire (Ergonomics)	Location and fire area well separated			γ
		Operator must pass through areas affected by fire environment to reach location		2β
	No barrier or potentially significant leakage between location and fire area	Dense smoke, high temperature, and/or CO_2 impact in location	No credit for SCBAs	α
Functional Considerations (Ergonomics)	Accessibility restricted, e.g., a ladder, or special tool required	Tools properly staged		γ
		Tools must be brought in		β
	Lighting failed	Emergency lighting available		γ
		Only flashlights available		β
		Neither emergency lighting nor flashlights available		α
Procedures	Procedures specific to this activity	Procedures posted at the location, and all required actions addressed and achievable at location		γ
		Must be obtained from control room	Adjust to β if time is limited	γ/β
	No specific procedure OR procedure unclear			2β
Training/Experience	Realistic training on scenario			γ
	Little or no hands-on (vice desktop) training			β
Communications (Ergonomics)	Performance of task requires communication between operator and control room (or an operator at another location)	Communication unhindered by noise, interference		γ
		Communication difficult because of fire or location (noise, lighting, etc.)		β

Table 2.8.1 - Manual Actions Evaluation Table for Actions at a Remote Location

Category	Task and Scenario Characteristics	Performance Shaping Factors	Comments	Evaluation
Nature of Task (Complexity)	Simple task involving a change of state of an SSC			γ
	task requiring several subtasks, but all in the same general location	Procedures available and clear		γ
	Multiple tasks at different locations		In the absence of an RSP for example, it is assumed that several tasks are performed at diverse locations, requiring a significant degree of coordination.	2β
	Control task (e.g., maintaining AFW)	Indications available locally		β
		Indications not available locally		2β
Time available	Time Adequate to reach location and perform activity		Include time needed to obtain procedure if applicable	γ
	Time limited			β
	Time inadequate or barely adequate			α
	Time expansive			Note 1

Select HEP credit based on the following rules:

- If any row is α, then use 0
- If the sum of rows evaluated as β or 2 β is ≥ 3 β, then assume equivalent to α and use 0
- If all categories are γ, then use a credit of 2
- Otherwise (i.e., if the sum of rows evaluated as β or 2 β is β or 2 β), then use a credit of 1

Note 1: If sum of the other ratings is ≥α or >3β, use 0; if the sum is 3β, use a credit of 1; if the sum is ≤ 2β, use a credit of 2

Table 2.8.2 - Manual Actions Evaluation Table for Actions at Remote Shutdown Panel				
Category	**Task and Scenario Characteristics**	**Performance Shaping Factors**	**Comments**	**Evaluation**
Direct Physical Effect of Fire (Ergonomics)	RSO and all areas where local actions take place are well separated from the fire location			γ
		Operator must pass through areas affected by fire environment to reach RSO or other areas where local actions are taken		2β
	No barrier or potentially significant leakage between RSO or other required locations and fire area	Dense smoke, high temperature, and/or CO_2 impact in location	No credit for SCBAs	α
Functional Considerations (Ergonomics)	Lighting failed at any required location	Emergency lighting available		γ
		Only flashlights available		β
		Neither emergency lighting nor flashlights available		α
	Local actions required for essential functions	All equipment accessible		γ
		Accessibility limited		β
		Not accessible		α
Procedures	RSO procedure	Procedures available at RSO panel and all necessary location, and all required actions addressed		γ
		Must be obtained from control room or RSO location	Adjust to β if time is limited	γ/β
Training/Experience	Realistic training on scenario			γ
	Little or no hands-on (vice desktop) training			β

Table 2.8.2 - Manual Actions Evaluation Table for Actions at Remote Shutdown Panel				
Category	**Task and Scenario Characteristics**	**Performance Shaping Factors**	**Comments**	**Evaluation**
Nature of Task (Complexity)	Control task (e.g., maintaining AFW)	Indications available locally		β
		Indications not available locally	Requires gaining information from operators stationed throughout the plant.. Communications good.	β
			Requires gaining information from operators stationed throughout the plant. Communications problematic.	2β
Time available	Time Adequate to reach location and perform activity		Include time needed to obtain procedure if applicable	γ
	Time limited			β
	Time inadequate or barely adequate			α
	Time expansive			Note 1

Select HEP credit based on the following rules:

- If any row is α, then use 0
- If the sum of rows evaluated as β or 2 β is ≥ 3 β, then assume equivalent to α and use 0
- If all categories are γ, then use 2
- Otherwise (i.e., if the sum of rows evaluated as β or 2 β is β or 2 β), then use 1

Note 1: If sum of the other ratings is ≥α or >3β, use 0; if the sum is 3β, use a credit of 1; if the sum is ≤ 2β, use a credit of 2

Use the most limiting of the factors (e.g., if the local actions that are essential to success are in inaccessible places, use α).

Task 2.8.5: Assess the CCDP

Assess the $CCDP_I$ for each fire scenario by using the plant risk-informed inspection notebook to: (1) incorporate failure of those systems and functions that will not be credited for the initiating event identified, and (2) incorporate human error probabilities for manual actions.

For each fire damage state scenario, calculate $CCDP_I$, using the applicable initiating event worksheet as follows:

- Set the initiating event frequency to 0.
- Reduce the credit for each mitigating system function commensurate with the systems and functions available to support the plant SSD.

  Example: The internal initiating event worksheet indicates that one of two trains for a given safety function is needed to provide full creditable mitigation capability. With both trains available, a multi-train system credit of 3 is assigned. If in the fire damage state scenario only one of the two trains for that safety function is protected, the credit is reduced from a multi-train credit of 3 to a single train credit of 2 because the unprotected train is assumed to fail in the fire scenario.

- Incorporate the impact of the human error contribution.
  - When a normally automatic function is required to be performed manually, compare the credit for the manual action as determined in Task 2.8.4 with the mitigation system credit provided for that safety function in the internal worksheet, and apply the more conservative of the two credits.
  - For actions performed in accordance with fire response procedures, identify the function(s) with which they are associated, and compare the manual credit with the hardware credit, and use the more conservative.
  - For compensatory manual actions in procedures that are included specifically to prevent a spurious actuation of equipment, a different initiating event worksheet may be required, or different assessments on the same worksheet may be required depending on the consequences of the preventive action and the spurious actuation:
    - When the preventive action is successful, additional equipment over and above that made unavailable by the fire may have been disabled and this should be taken into account when quantifying the worksheet.
    - Failure to perform that action (using Task 2.8.4), may make additional equipment available because it was not disabled by procedure, but it will also result in spurious actuations with a specified probability. The $CCDP_I$ needs to be evaluated for both cases: spurious actuations occur, and spurious actuations do not occur. The consequence of the spurious actuation may result in a need to use an additional worksheet, or may result in the failure of one of the functions on the original worksheet. For the case where the spurious actuation does not occur, the original worksheet will be used taking into account only the failures caused by the fire scenario.

- The total $CCDP_i$ is a weighted sum of the three CCDPs corresponding to the following:

$CCDP_i$ = [(1-HEP_i) x CCDP(given successful manual action)] +
[HEP_i x P_{SPi} x CCDP(given manual action fails and spurious actuation)] +
[HEP_i x (1 - P_{SPi}) x CCDP(given manual action fails and no spurious actuation)]

where: HEP_i is the true value of the human error probability for scenario i (not the exponent value derived from the HEP tables), and
P_{SPi} is the probability of a spurious actuation for scenario i.

Table 2.8.3 - P_{SP} Factors Dependent on Cable Type and Failure Mode			
State of Cable Knowledge	**Thermoset**	**Thermoplastic**	**Armored**
No available information about cable type or current limiting devices (worst-case value from NEI 00-01 Table 4-4)		.6	
Cable type known, no other information known (NOI)	.6	.6	.15
Inter-cable interactions only	.02	.20	
In conduit, cable type known, NOI	.30	.6	
In conduit, inter-cable only	.01	.20	
In conduit, intra-cable	.075	.3	

- In evaluating ex-control room actions in response to plant conditions, use the same logic, as contained in the first two bullets (o) under "Incorporate the impact of the human error contribution" from the previous page, to generate CCDP values.
- For remote shutdown operations, the human error probability obtained from the appropriate table is compared to the result of evaluating the appropriate initiating event worksheet with credit only for those SSCs called for in the procedure. The more conservative value is used. A detailed analysis of individual human actions should not be attempted in the Phase 2 SDP.

Special Cases:

- Findings Against the Post-Fire SSD Program
Findings against a licensee's post-fire SSD program would be manifested by an increase in the likelihood that operators fail to achieve SSD given a fire. Such findings may have implications for fires in several locations. The Phase 2 SDP should only be applied when the finding can be identified with a specific fire area. For findings with plant-wide consequences, a Phase 3 SDP assessment should be performed.

- Findings Related to Circuit Issues
  In a similar manner to the SSD findings discussed above, circuit issues may have implications for several fire areas, since the cable associated with the circuit may run through several locations. For anything other than the case where the effect is localized, a Phase 3 SDP analysis should be performed. When there is a known issue associated with an area in which an unrelated finding is being assessed, the CCDP evaluation should account for the impact, which could be either the creation of an initiating event, or the failure of a system to perform its function.

Step 2.9 - Quantification and Preliminary Significance Determination

In Step 2.9, a final quantification of the FDS scenarios of interest is calculated, and a preliminary determination of a findings significance is assigned.

The estimated risk contribution or screening CDF, for each fire scenario is based on the product of the following factors:

$$\Delta CDF_{2.8} \approx DF \times \sum_{i=1}^{n}[F_i \times SF_i \times \Pi AF_{i2.4} \times PNS_i \times CCDP_i]_{\text{All Scenarios}}$$

Where:

n	=	number of fire scenarios evaluated for a given finding (covering all relevant FDSs)
DF	=	Duration factor from Step 1.4
F_i	=	Fire frequency for the fire ignition source i from Task 2.4.1
SF_i	=	Severity factor for scenario i from Task 2.4.1
$AF_{i2.4}$	=	Ignition source specific frequency adjustment factors from Step 2.4
PNS_i	=	Probability of non-suppression for scenario i from Step 2.7
$CCDP_i$	=	Conditional core damage probability for scenario i from Step 2.8

- If the value of $\Delta CDF_{2.8}$ is lower than or equal to 1E-6, then the finding screens to Green, and the analysis is complete.
- If the value of $\Delta CDF_{2.8}$ is greater than 1E-6, then the finding is potential risk significant.

Table 2.9.1 - Risk Significance Based on ΔCDF

Frequency Range/ry	SDP Based on ΔCDF
$\geq 10^{-4}$	Red
$< 10^{-4} - 10^{-5}$	Yellow
$< 10^{-5} - 10^{-6}$	White
$< 10^{-6}$	Green