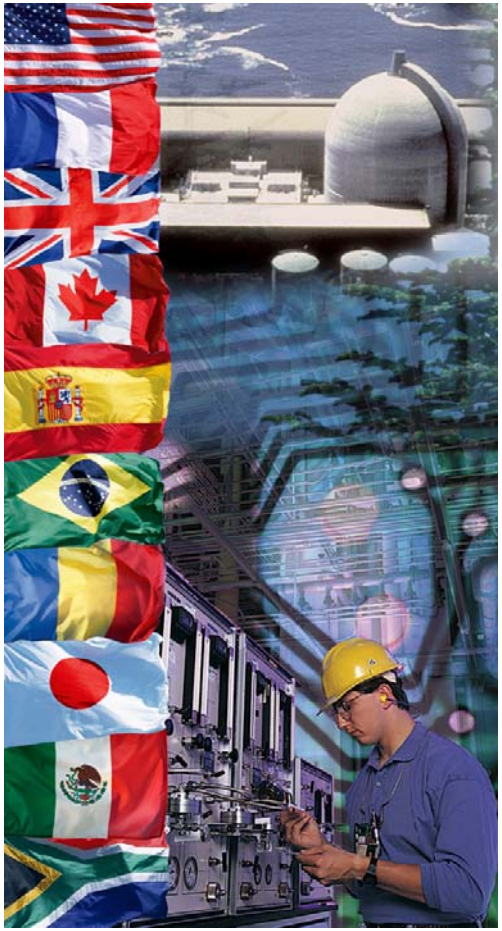


EPRI/NRC-RES FIRE PRA METHODOLOGY

Task 1: Plant Partitioning

Joint RES/EPRI Fire PRA Workshop
August, 2007
Palo Alto, CA

A Collaboration of U.S. NRC Office of Nuclear Regulatory Research (RES) & Electric Power Research Institute (EPRI)

Plant Partitioning
Scope

The following topics are covered:

- Task 1: Plant Partitioning Analysis
  - Define Global Analysis Boundary
  - Partition into physical analysis units or Compartments
  - Problem sets from the Sample Problem

Support Task A: Plant Walkdowns
Just a Quick Note….

- You *cannot* complete a Fire PRA without walkdowns
- Expect to conduct a number of walkdowns, especially for key areas (e.g., those analyzed in detail)
- Walkdowns can have many objectives and support many tasks:
  - Partitioning features, equipment/cable mapping, fire ignition source counting, fire scenario definitions, fire modeling, detection and suppression features, recovery actions HRA
- Walkdowns are generally a team activity so coordinate them to optimize personnel time and resources

Plant Partitioning
General Comment/Observation

- The recommended practice for Task 1 has changed little from prior methods.
  - That means you can likely benefit from a previous analysis
    - e.g., your IPEEE fire analysis
    - However: watch out for new equipment/cables, new initiators when screening

Task 1: Plant Partitioning
Key Definitions: Compartment vs. Fire Area/Zone

- We talk mainly about Fire Compartments which are defined in the context of the Fire PRA only
  - Defining Fire Compartments is necessary for analysis management
  - Also known as Physical Analysis Units
- Fire Areas are defined in the context of your regulatory compliance fire protection program
- Fire Zones are generally defined in the context of fire protection features (e.g., detection, suppression, hazards)
  - Fire zones have no direct meaning to the Fire PRA context and we avoid using this term
- Physical Analysis Unit is another term coined lately

Task 1: Plant Partitioning
Task Objectives and Output

- There are two main objectives to Task 1:
  1. Define the Global Analysis Boundary
     - The maximum physical extent of the plant that will be considered in the Fire PRA
  2. Divide the areas within the Global Analysis Boundary into analysis Compartments (Physical Analysis Units)
     - The basic physical units that will be analyzed and for which risk results will be reported

- Task output is the definition of these two aspects of the analysis

Task 1: Plant Partitioning
Task Input

- No real input from any other task is required (it is, after all, Task 1)
  - There *is* a link to the equipment and cable selection Tasks 2 and 3
  - You may also find yourself iterating back to this task later in the analysis – that is fine, just be careful to track any changes

- What do you need to support this Task?
  - Layout drawings that identify major structures, walls, openings
    - Drawings that identify Fire Areas are especially helpful
  - Plan <u>and</u> elevation drawings are helpful
  - You *will* need to do a walkdown to support/verify decisions

Task 1: Plant Partitioning
Task Breakdown in Steps

- Task 1 is defined in terms of the following steps:

Step 1: Selection of Global Plant Analysis Boundary

Step 2: Plant Partitioning

Step 3: Compartment Information Gathering and Characterization

Step 4: Documentation

Task 1: Plant Partitioning
Selection of Global Plant Analysis Boundary

- We want a *Liberal* definition of the global analysis boundary
  - It's OK to include obviously unimportant areas, we'll drop them quickly, but better to do this formally
- Encompass all areas of the plant associated with both normal and emergency reactor operating and support systems, as well as power production
- Sister Units should be included unless they are physically and functionally separated
  - No shared areas, no shared systems, no shared components and associated cables, no conjoined areas (e.g., shared walls)

Task 1: Plant Partitioning
Selection of Global Plant Analysis Boundary (2)

- Begin with your protected area: everything within the protected area should be included in the Global Analysis Boundary
  - In most cases that will capture all risk-important locations

- If necessary, expand the boundary to include any other locations that house equipment or cables identified in Tasks 2 or 3
  - This is the Task 2/3 link mentioned before!
  - Example: If your offsite power related equipment is outside the protected area, you need to expand Global Analysis Boundary to capture it

Task 1: Plant Partitioning
Selection of Global Plant Analysis Boundary (3)

- *Problem Set 01-01*

- By the end of the analysis, you need to provide a fire risk disposition for all locations within the global analysis boundary
  - That may be anything from screened out qualitatively to a detailed risk quantification result

Task 1: Plant Partitioning
Plant Partitioning into Fire Compartments (1)

- We divide the Global Analysis Boundary into smaller pieces (compartments) for the purpose of tracking and reporting risk results

- A compartment can be many things, but when it comes down to it, a compartment is:

A well-defined volume within the plant … that is expected to substantially contain the adverse effects of fires within the compartment.

Task 1: Plant Partitioning
Plant Partitioning into Fire Compartments (2)

- This task is often subjective – judgment *is* required

- Ideally: Compartments = Rooms
  - Locations that are fully defined by physical partitioning features such as walls, floors, and ceilings

- But the ideal is not the only solution - other features and elements may be credited in partitioning
  - That's where judgment comes into play!
  - What will you credit as a Partitioning Feature?

Task 1: Plant Partitioning
Plant Partitioning into Fire Compartments (3)

- A good starting point is your Fire Areas, but you are *by no means limited* to equating Fire Compartments to Fire Areas
  - A Fire Area may be partitioned to two or more Compartments
  - You may combine two or more Fire Areas into a single Compartment

- In the end: { ∑ Compartments } = { Global Analysis Bnd. }
  - No omissions
  - No overlap!

Task 1: Plant Partitioning
Plant Partitioning into Fire Compartments (4)

- So what can you credit as a partitioning feature:
  - Bottom line: anything you can justify – see text for examples
    - You do need to justify your decisions with the exception of structural elements maintained as rated fire barriers
  - In the end, your partitioning decisions should not affect the risk results, but . .
  - Don't go crazy – there are disadvantages to over-partitioning
  - General guideline: try to minimize the need to develop and analyze multi-compartment scenarios

Task 1: Plant Partitioning
Plant Partitioning into Fire Compartments (6)

- There are some things that you should not credit in partitioning:
  - Partial height walls
  - Radiant energy shields
  - Beam pockets
  - Equipment obstructions (e.g., pipes)
  - (ANS Draft Standard says: Raceway or other localized fire barriers *may not be credited* in partitioning)

- *Problem Set 01-02*

Task 1: Plant Partitioning
Plant Partitioning into Fire Compartments (7)

- Final Point: You need a system to identify/name your Fire Compartments
  - Something both consistent and logical – but whatever works for your application and plant
  - Often makes sense to use Fire Area designations in naming schemes
    - Example: Fire Area 42 might become Fire Compartments 42A, 42B…
  - Use your naming scheme consistently throughout the Fire PRA
    - Documentation, equipment/cable tracing, database, etc.

Task 1: Plant Partitioning
Compartment Information Gathering and . . . (1)

- Later tasks need certain information about each compartment. They include, but are not limited to the following:
  - Compartment boundary characteristics
  - Ventilation features, and connections
  - Fire protection features
  - Fire source hazards
  - Identification of all adjacent compartments
  - Identification of components/systems/cables
  - Access routes to the fire compartment
  - SSD human actions credited in each compartment

Task 1: Plant Partitioning
Compartment Information Gathering and . . . (1)

- A thorough plant walkdown is needed to confirm and gather information about each fire compartment.
- Initially it is not expected that all information pieces to be collected and documented.
- As work on fire PRA progresses, additional information, as needed, is collected and documented
- This task, similar to other later tasks, is expected to be revisited and compartment definitions modified as additional information is obtained.

Task 1: Plant Partitioning
Compartment Information Gathering and . . . (2)

Fire Compartment ID #	1
Fire Compartment	Switchgear Access Room
Building	Auxiliary Building
Boundary Characteristics	The compartment is bounded by 3-hr rated fire walls, ceiling and floor.
Ventilation Features	The ventilation is provided by the Auxiliary Building HVAC system(1). The equipment housed in this compartment can function properly and perform their safe shutdown duties in case of total loss of the HVAC system.
Fire Protection Features	The fire protection features of this compartment includes: 1. Handheld extinguishers inside the compartment (2 units) (1) 2. Wet hose reel outside the door inside the stairwell(1) 3. Smoke detectors attached to the ceiling (6 units) (1)
Fire Sources	The following ignition sources were identified in this compartment. 1. MCC-A 2. MCC-B 3. 125VAC-A 4. 125VAC-B 5. ATS 6. Lighting Fixtures (10 units)(1) Additionally the following combustibles are present: 1. Cable trays containing thermoset control cables 2. Wooden desk used by the electrical department(1)
Adjacent Compartments	The following compartments share a wall, ceiling or floor with this compartment: 1. Switchgear Room A 2. Switchgear Room B 3. Stairwell 4. Charging pump room 5. Cable spreading room
Access Routes	1. This room can be accessed from outside through the stairwell 2. Switchgear Rooms A and B are accessed through this room
Components/Systems/Cables Present	See the component and cable lists provided in Tasks 2 and 3.
SSD Human Actions Credited in this Compartment	To be completed after Task 12 is completed.

(1) Provided here to demonstrate how this part of the step may be addressed. These features are not intended to be included in the fire PRA of this example plant.

Task 1: Plant Partitioning
Summary

- Plant Partitioning is the first step of fire PRA.

- Done in three steps
  1. Define global plant analysis boundaries to include all those area that will be addressed by the fire PRA
  2. Define fire compartments in such a way that all the areas identified in the preceding step are covered, there are no overlaps and there is a balance between size and number of compartments selected
  3. Confirm the selected compartments through a walkdown and record important information that will be used later.

Workshop Problems for Task 1: Plant Boundary Definition and Partitioning

Workshop Problem Set 01-01

Step 1 - Selection of Global Plant Analysis Boundary: Using Drawing # 01 in the Sample Package and the information provided in other drawings, identify the Global Plant Analysis Boundaries in terms of plant areas. Make a complete list of plant areas shown on Drawing #01 in the matrix provided below. Specify whether or not the area shall be included within the Global Plant Analysis Boundaries and then provide the basis of your decision.

Plant Area	Included?	Basis

Plant Area	Included?	Basis

Workshop Problem Set 01-02

Step 2: Plant Partitioning: Using the drawings provided in the Sample Package, identify the set of fire compartments that you will consider for the fire PRA. In the following matrix (1) list selected compartments, (2) give each an identification number, (3) identify the associated plant area for each compartment from the Solution Statement for Problem Set 01-01. Provide comments where warranted.

Fire Comp. ID #	Fire Compartment Descriptor	Plant Area	Comments

Fire Comp. ID #	Fire Compartment Descriptor	Plant Area	Comments

Workshop Problems for Task 1: Plant Boundary Definition and Partitioning

Workshop Problem Set 01-01

Step 1 - Selection of Global Plant Analysis Boundary: Using Drawing # 01 in the Sample Package and the information provided in other drawings, identify the Global Plant Analysis Boundaries in terms of plant areas. Make a complete list of plant areas shown on Drawing #01 in the matrix provided below. Specify whether or not the area shall be included within the Global Plant Analysis Boundaries and then provide the basis of your decision.

Plant Area	Included?	Basis
Auxiliary Building	Yes	Contains equipment and cables that may be included in the fire PRA analysis
Containment	Yes	Contains equipment and cables that may be included in the fire PRA analysis
Diesel Generator Building	Yes	Contains equipment and cables that may be included in the fire PRA analysis
Turbine Building	Yes	Contains equipment and cables that may be included in the fire PRA analysis
Yard	Yes	Contains equipment and cables that may be included in the fire PRA analysis
Security Building	No	There are no equipment or cables in this building needed for safe shutdown
Switchyard	No	Offsite power is impacted from equipment or cable failure in the Switchyard. However, the impact of a fire event in the switchyard would be limited to loss of offsite power and no other safe shutdown related functions. Therefore, switchyard fires are considered a part of loss of offsite
Intake Structure	Yes	Contains equipment and cables that may be included in the fire PRA analysis

Intentionally Left Blank

Workshop Problem Set 01-02

Step 2: Plant Partitioning: Using the drawings provided in the Sample Package, identify the set of fire compartments that you will consider for the fire PRA. In the following matrix (1) list selected compartments, (2) give each an identification number, (3) identify the associated plant area for each compartment from the Solution Statement for Problem Set 01-01. Provide comments where warranted.

Fire Comp. ID #	Fire Compartment Descriptor	Plant Area	Comments
1	Main Control Room	Auxiliary Building	Includes the kitchen and Shift Supervisor's Office
2	Aux Bldg El. 0 Ft	Auxiliary Building	
3	Cable Spreading Room	Auxiliary Building	
4A	Aux Bldg. El. -20 Ft, RHR Room	Auxiliary Building	
4B	Aux Bldg. El. -20 Ft, AFW Room	Auxiliary Building	
5	Battery Room A	Auxiliary Building	1 hour rated walls and 2 hour rated ceiling within the Switchgear rooms
6	Battery Room B	Auxiliary Building	1 hour rated walls and 2 hour rated ceiling within the Switchgear rooms
7	Containment	Containment	
8A	DG-A Room	Diesel Generator Building	

Fire Comp. ID #	Fire Compartment Descriptor	Plant Area	Comments
8B	DG-B Room	Diesel Generator Building	
9	SWG Access Room	Auxiliary Building	
10	Switchgear Room A	Auxiliary Building	
11	Switchgear Room B	Auxiliary Building	
12	Turbine Bldg El. 0 Ft	Turbine Building	
13	Yard	Yard	Includes the Transformers next to the Diesel Generator Building and the two safety related tanks.
14	Intake Structure	Intake Structure	A long building with some divisions with large openings among them with no doors isolating each compartment from other compartments.
15	Battery Room 1	Turbine Building	1 hour rated walls and 2 hour rated ceiling within the Switchgear rooms
16	Stairway	Auxiliary Building	All doors are 1 hour rated
17	Control Room Access	Auxiliary Building	

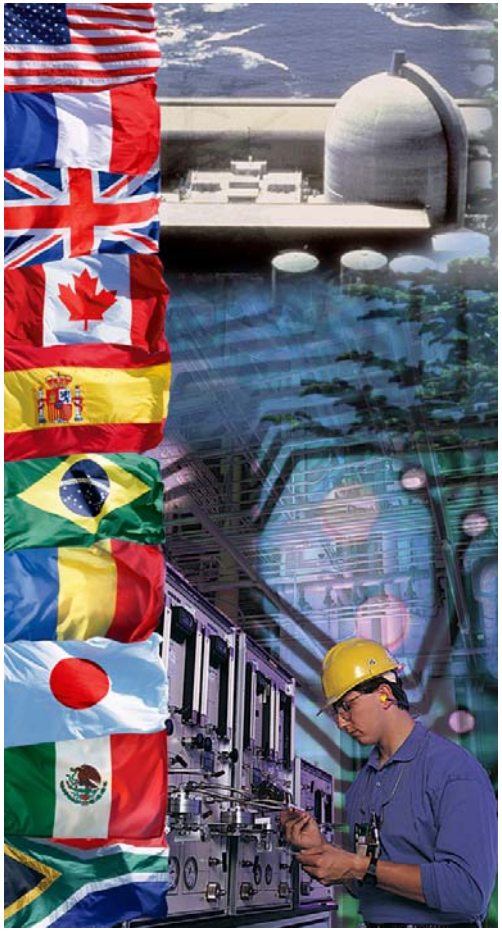
Workshop Example

Step 3: Compartment Information Gathering and Characterization: The following tabulation provides an example of the information about fire compartments that may be used in a fire PRA project.

Item	**Resolution**
Fire Compartment ID #	9
Fire Compartment	Switchgear Access Room
Building	Auxiliary Building
Boundary Characteristics	The compartment is bounded by 3-hr rated fire walls, ceiling and floor.
Ventilation Features	The ventilation is provided by the Auxiliary Building HVAC system [(1)]. The equipment housed in this compartment can function properly and perform their safe shutdown duties in case of total loss of the HVAC system.
Fire Protection Features	The fire protection features of this compartment includes: 1. Handheld extinguishers inside the compartment (2 units) [(1)] 2. Wet hose reel outside the door inside the stairwell[(1)] 3. Smoke detectors attached to the ceiling (6 units) [(1)] 4. Automatic CO_2 system
Fire Sources	The following ignition sources were identified in this compartment. 1. MCC-A 2. MCC-B 3. 125VAC-A 4. 125VAC-B 5. ATS 6. Lighting Fixtures (10 units)[(1)] Additionally the following combustibles are present: 1. Cable trays containing thermoset control cables 2. Wooden desk used by the electrical department[(1)]
Adjacent Compartments	The following compartments share a wall, ceiling or floor with this compartment: 1. Switchgear Room A 2. Switchgear Room B 3. Stairwell 4. Charging pump room 5. Cable spreading room
Access Routes	1. This room can be accessed from outside through the stairwell

Item	Resolution
	2. Switchgear Rooms A and B are accessed through this room
Components /Systems / Cables Present	See the component and cable lists provided in Tasks 2 and 3.
SSD Human Actions Credited in this Compartment	To be completed after Task 12 is completed.

(1) Provided here to demonstrate how this part of the step may be addressed. These features are not intended to be included in the Fire PRA of this Sample Package.



EPRI/NRC-RES FIRE PRA METHODOLOGY

Task 6: Fire Ignition Frequency

Joint RES/EPRI Fire PRA Workshop
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FIRE IGNITION FREQUENCIES
Purpose of Task 6

In Task 6, the ignition frequencies associated with fire ignition sources are established.

- Generic frequencies
- Plant specific experience
- Uncertainties

To be presented in two parts:

- 1. How to estimate location specific frequencies
- 2. How generic frequencies were put together

FIRE IGNITION FREQUENCIES
Assumptions

The model developed for estimating fire ignition frequencies is based on the following assumptions:

- Frequencies remain constant over time
- Total ignition frequency for an equipment type is the same for all plants
- Within each plant, ignition frequency is the same for all equipment of the same type.

FIRE IGNITION FREQUENCIES
General Approach

To establish the fire frequency of a fire compartment, the ignition frequencies associated with each ignition source of the compartment are added together.

– $\lambda_{J,L} = \Sigma\, \lambda_{IS}\, W_L\, W_{IS,J,L}$
  summed over all ignition sources

Where:

$\lambda_{J,L}$: Fire frequency associated with compartment J at location L

λ_{IS}: Plant level fire ignition frequency associated with ignition source IS

W_L: Location weighting factor

$W_{IS,J,L}$: Ignition source weighting factor

FIRE IGNITION FREQUENCIES
Plant Level Frequency (λ_{IS})

Plant level fire ignition frequency covers all the equipment of the same type in the entire unit.

Examples:

- 2.1E-02 is the frequency per year of fires within a unit that involve pumps.
- 7.4E-03 is the frequency per year of transient fires within the turbine building of a unit.

FIRE IGNITION FREQUENCIES
Plant Level Frequencies (λ_{IS})

Table 6 -1
Fire Frequency Bins and Generic Frequencies

ID	Location	Ignition Source (Equipment Type)	Mode	Generic Freq (per rx yr)	Split Fractions for Fire Type					
					Electrical	Oil	Transient	Hotwork	Hydrogen	HEAF[1]
1	Battery Room	Batteries	All	7.5E-04	1.0	0	0	0	0	0
2	Containment (PWR)	Reactor Coolant Pump	Power	6.1E-03	0.14	0.86	0	0	0	0
4	Control Room	Main Control Board	All	2.5E-03	1.0	0	0	0	0	0
8	Diesel Generator Room	Diesel Generators	All	2.1E-02	0.16	0.84	0	0	0	0
11	Plant-Wide	Cable fires caused by [illegible]tting	Power	2.0E-03	0	0	0	1.0	0	0
[illegible]	Plant-Wide Components	Electric Motors	All	4.6E-03	1.0	0	0	0	0	0
15	Plant-Wide Components	Electrical Cabinets	All	4.5E-02	1.0	0	0	0	0	0
20	Plant-Wide Components	Off-gas/H2 Recombiner (BWR)	Power	4.4E-02	0	0	0	0	1.0	0
27	Transformer Yard	Transformer – Catastrophic[2]	Power	6.0E-03	1.0	0	0	0	0	
32	Turbine Building	Main Feedwater Pumps	Power	1.3E-02	0.11	0.89	0	0	0	0

1. See Appendix M for a description of high-energy arcing fault (HEAF) fires.
2. See Section 6.5.6 below for a definition.

Ignition Frequency Bin

FIRE IGNITION FREQUENCIES
Plant Level Frequencies (λ_{IS})

Table 6 -1
Fire Frequency Bins and Generic Frequencies

ID	Location	Ignition Source (Equipment Type)	Mode	Generic Freq (per rx yr)	Split Fractions for Fire Type					
					Electrical	Oil	Transient	Hotwork	Hydrogen	HEAF[1]
1	Battery Room	Batteries	All	7.5E-04	1.0	0	0	0	0	0
2	Containment (PWR)	Reactor Coolant Pump	Power	6.1E-03	0.14	0.86	0	0	0	0
4	Control Room	Main Control Board	All	2.5E-03	1.0	0	0	0	0	0
8	Di Ro				.16	0.84	0	0	0	0
11	Pl Co				0	0	0	1.0	0	0
14	Pl Co				1.0	0	0	0	0	0
15	Pl Co				1.0	0	0	0	0	0
20	Pl Co				0	0	0	0	1.0	0
27	Tr				1.0	0	0	0	0	
32	Tu				.11	0.89	0	0	0	0

1. See App
2. See Sec

ID	Location
1	Battery Room
2	Containment (PWR)
4	Control Room
8	Diesel Generator Room

FIRE IGNITION FREQUENCIES
Plant Level Frequencies (λ_{IS})

Table 6 -1
Fire Frequency Bins and Generic Frequencies

ID	Location	Ignition Source (Equipment Type)	Mode	Generic Freq (per rx yr)	Split Fractions for Fire Type					
					Electrical	Oil	Transient	Hotwork	Hydrogen	HEAF[1]
1	Battery Room	Batteries	All	7.5E-04	1.0	0	0	0	0	0
2	Containment (PWR)	Reactor Coolant Pump	Power	6.1E-03	0.14	0.86	0	0	0	0
4	Control Room	Main Control Board	All	2.5E-03	1.0	0	0	0	0	0
8	Diesel Ge Room									
11	Plant-Wid Compone									
14	Plant-Wid Compone									
15	Plant-Wid Compone									
20	Plant-Wid Compone									
27	Transform									
32	Turbine B									

1. See Appendix M
2. See Section 6.5.6 below for a definition.

ID	Location	Ignition Source (Equipment Type)
1	Battery Room	Batteries
2	Containment (PWR)	Reactor Coolant Pumps
4	Control Room	Main Control Boards
8	Diesel Generator Room	Diesel Generators

FIRE IGNITION FREQUENCIES
Plant Level Frequencies (λ_{IS})

Table 6 -1
Fire Frequency Bins and Generic Frequencies

ID	Location	Ignition Source (Equipment Type)	Mode	Generic Freq (per rx yr)	Split Fractions for Fire Type					
					Electrical	Oil	Transient	Hotwork	Hydrogen	HEAF[1]
1	Battery Room	Batteries	All	7.5E-04	1.0	0	0	0	0	0
2	Containment (PWR)	Reactor Coolant Pump	Power	6.1E-03	0.14	0.86	0	0	0	0
4	Control Room	Main Control Board	All	2.5E-03	1.0	0	0	0	0	0
32	Turbine Building	Main Feedwater Pumps	Power	1.3E-02	0.11	0.89	0	0	0	0

1. See Appendix M for a description of high-energy arcing fault (HEAF) fires.
2. See Section 6.5.6 below for a definition.

Ignition Source (Equipment Type)	Mode	Generic Freq (per rx yr)	Split Fractions for Fire Type					
			Electrical	Oil	Transient	Hotwork	Hydrogen	HEAF[1]
Batteries	All	7.5E-04	1.0	0	0	0	0	0
Reactor Coolant Pump	Power	6.1E-03	0.14	0.86	0	0	0	0
Transients and Hotwork	Power	2.0E-03	0	0	0.44	0.56	0	0
Main Control Board	All	2.5E-03	1.0	0	0	0	0	0

FIRE IGNITION FREQUENCIES
Location Weighting Factor (W_L)

Location weighting factor adjusts the plant level frequencies for those cases where a common location is shared among units of the same plant.

- All frequencies were developed per unit basis
- Examples: Turbine Building, Auxiliary Building, Control Room
- Example: W_L = 2.0 if the Turbine Building is shared between two units

FIRE IGNITION FREQUENCIES
Ignition Source Weighting Factor ($W_{IS,J,L}$)

Ignition source weighting factor is the fraction of an ignition source type found in a specific compartment.

- Need to count all the items belonging to one ignition source type in one unit
  - Necessitates a thorough plant walk-down and review of engineering documents
- Example: if there are two battery rooms in one unit, each housing one battery set, $W_{IS,J,L} = 0.5$
- Transients and cables are based on specific models

FIRE IGNITION FREQUENCIES
Procedure

The following procedure can be used to estimate location Specific fire ignition frequencies:

- Step 1. Mapping plant ignition sources to generic sources,
- Step 2. Plant fire event data collection and review,
- Step 3. Plant specific updates of generic ignition frequencies,
- Step 4. Mapping plant-specific locations to generic locations,
- Step 5. Location weighting factors,
- Step 6. Fixed fire ignition source counts,
- Step 7. Ignition source weighting factors, and
- Step 8. Ignition source and compartment fire frequency evaluation.

FIRE IGNITION FREQUENCIES
Step 1. Mapping Plant Ignition Sources

Every plant equipment item should be mapped to one of the ignition frequency bins.

- Must be capable of initiating a fire
- Must be located in the buildings, compartments and plant areas considered for fire risk analysis
- If no matching bin, then the following approach may be used:
  - Characteristics of the source
  - Percentage of the time in operation
  - Past fire histories within the plant
  - Relevant past fire histories or frequency estimates not associated with the plant

• *Problem Set 06-01*

FIRE IGNITION FREQUENCIES
Step 2. Plant Fire Event Data Collection

Plant specific fire event data is needed to establish plant specific fire ignition frequencies.

- Are plant specific fire ignition frequencies warranted?
  - Repeated set of events
  - Events that cannot be mapped to a bin
- Unusual fire occurrence patterns
- May be selective in plant specific frequencies

FIRE IGNITION FREQUENCIES
Step 2. Plant Fire Event . . . (2)

Example:

- The following events have taken place:
  - Event 1: Fire in MCC-A because of breakers not properly engaging the bus bars.
  - Event 2: Fire in 125VAC-A panel. The fire was extinguished when 4kV bus-A was de-energized from the control room. Fire resulted from arcing of supply lead to one of the fittings connecting to a controller to the bus.
- Both fires can be included in the frequency analysis.
- Plant has been in commercial operation for 10 years.
- Both events should be mapped to Bin # 15 “Electrical Cabinets”
- 2/10 = 0.2, is 4 time greater than 0.045, Bin #15 frequency

• *Problem Sets 06-02 and 06-03 (Examples)*

FIRE IGNITION FREQUENCIES
Step 3. Plant Specific Frequencies (λ_{IS})

Bayesian approach can be used to estimate plant specific fire ignition frequencies.

- Uncertainty distributions of generic frequencies as the prior
- Possible double accounting of FEDB events

FIRE IGNITION FREQUENCIES
Steps 4/5. Plant-Specific Locations and W_L

Plant specific locations should be mapped to the bin definition locations.

Example:

Plant Specific Location	Bin Location	W_L
Emergency Battery Enclosure	Battery Room	Number of site units that share common set of batteries.
Main Control Room	Control Room	Number of site units that share the same control room.
Control Building	Control / Auxiliary / Reactor Building	Number of site units that share the same building type.
Primary Auxiliary Building		

- *Problem Sets 06-04 and 06-05*

FIRE IGNITION FREQUENCIES
Step 6. Fixed Fire Ignition Source Counts

To establish ignition source weighting factor, $W_{IS,J}$, for each compartment, it is necessary to obtain the total number of relevant items per bin.

- For shared locations, entire site should be considered
- Visual examination (recommended approach)
- Document review or computerized database
- Counting method for each bin

FIRE IGNITION FREQUENCIES
Step 6. (cont'd)

Examples:

- *Bin 1– Batteries:* Each bank of interconnected sets of batteries located in one place should be counted as one battery set. Cells may not be counted individually.
- *Bin 5– Cable Fires Caused by Welding and Cutting: . . .* Assume that all exposed cables (i.e., cables that are not in conduits or wrapped by noncombustible materials) have an equal likelihood of experiencing a fire caused by welding and cutting across the entire location. . . .
- *Bin 14– Electric Cabinets:* Electrical cabinets represent . . switchgears, motor control centers, DC distribution panels, relay cabinets. . . . Free standing electrical cabinets should be counted by their vertical segments, . . .
- *Problem Sets 06-06 and 06-07*

FIRE IGNITION FREQUENCIES
Step 7. Ignition Source Weighting Factor ($W_{IS,J,L}$)

Ignition source weighting factors are evaluated for all the compartments identified in Task 1 and for all ignition sources identified in Step 1 of this Task.

- Countable items
  - Example: 2 pumps in compartment J of 50 pumps in the unit
    $W_{IS,J,L} = 2/50 = 0.04$
- Transients – apportioned based on maintenance, occupancy and storage
- Large systems – ad-hoc method based on specific characteristics of the system
  - Examples: hydrogen gas distribution system, turbine/generator oil system

• *Problem Sets 06-08, 06-09 and 06-10*

FIRE IGNITION FREQUENCIES
Step 7. $W_{IS,J,L}$ – Transients

Transient fire frequencies are apportioned based on qualitatively estimated rating levels for (1) maintenance activities, (2) occupancy level and traffic density and (3) storage (temporary and permanent) of combustible and flammable materials.

- Five rating levels are used:
  - No (0) - Can be used only for those compartments where transients are precluded by design (administrative restrictions do not apply).
  - Low (1)–Reflects minimal level of the factor.
  - Medium (3)–Reflects average level of the factor.
  - High (10)–Reflects the higher-than-average level of the factor.
  - Very high (50)–Reflects the significantly higher-than-average level of the factor
    (only for “maintenance” influencing factor).

FIRE IGNITION FREQUENCIES
Step 7. $W_{IS,J,L}$ – Transients (2)

Table 6-3
Description of Transient Fire Influencing Factors

Influencing Factor	No (0)	Low (1)	Medium (3)
Maintenance	Maintenance activities during power operation are precluded by design.	Small number of PM/CM work orders compared to the average number of work orders for a typical compartment.	Average number of PM/CM work orders.
Occupancy	Entrance to the compartment is not possible during plant operation.	Compartment with low foot traffic or out of general traffic path.	Compartment not continuously occupied, but with regular foot traffic.

FIRE IGNITION FREQUENCIES
Step 7. $W_{IS,J,L}$ – Transients (3)

The following normalization equations are used:

- For *General Transients:*

  $W_{GT,J,L} = (n_{m,J,L} + n_{o,J,L} + n_{s,J,L})/N_{GT,L}$

  $N_{GT,L} = \Sigma (n_{m,i,L} + n_{o,\,i,L} + n_{s,\,i,L})$

  (summed over i, all compartments of location L)

- For *Transient Fires Caused by Welding and Cutting:*

  $W_{WC,J,L} = n_{m,J}/N_{WC}$

  $N_{WC} = \Sigma\, n_{m,i,L}$

  (summed over i, all the compartments of location L)

- For *Cable Fires Caused by Welding and Cutting:*

  $W_{CF,J} = n_{m,J}\, W_{Cable,J}\, /N_{CF}$

  $N_{CF} = \Sigma\, n_{m,i,L}\, W_{Cable,I}$

  (summed over i, all compartments of location L)

- *<u>Problem Sets 06-11</u>*

FIRE IGNITION FREQUENCIES
Step 8. Fire Frequency Evaluation

The fire frequency (generic or plant-specific) for each ignition source, $\lambda_{IS,J}$, can now be calculated using the data quantified in the preceding steps.

– $\lambda_{J,L} = \Sigma \lambda_{IS} W_L W_{IS,J,L}$
  summed over all ignition sources

FIRE IGNITION FREQUENCIES
Determination of Generic Fire Frequencies

The generic fire frequencies are based on the collective experience of U.S. nuclear power industry.

- Large uncertainties
- Two stage Bayesian approach
- EPRI Fire Event Database (FEDB)
- Analysis of each event

FIRE IGNITION FREQUENCIES
Fire Event Data

EPRI's Fire Event Data Base (FEDB) was used to establish the historical fire events for generic fire frequency estimation.

- Licensee event reports
- Industry sources (e.g., NEIL and ANI)
- Various studies
- Specific plant data
- Individual event follow-up

FIRE IGNITION FREQUENCIES
Event Data Analysis

For each event, information was reviewed and the following were established:

Event Report Contents

- Occurrence date
- Plant type (i.e., PWR vs. BWR)
- Plant status (operating mode)
- Fire Location
- Fire Cause
- Initiating equipment and combustibles
- Detection and suppression information
- Severity related information
- Event description (narrative)

Event Analysis and Assignments

- Challenging?
- Location
- Ignition source
- Operating mode
- High energy arcing (electrical cab.)
- Suppression data
  - Prompt?
  - Supp. Curve Category (e.g. electrical)
  - Duration

FIRE IGNITION FREQUENCIES
Number of Events

For each plant and bin combination, the number of events were estimated using the following eight possible event classifications:

Table C-1
Fire Event Classifications and Frequency Estimation Action

Class. #	Information Deficiencies			Frequency Estimation Action	
	Known Plant	Known Op. Mode	Challenging Fire	Multiplier	Method of inclusion
1	Yes	Yes	Yes	1	As is
2	Yes	Yes	Undetermined	q	As is
3	Yes	No	Yes	p	As is
4	Yes	No	Undetermined	qp	As is
5	No	Yes	Yes	1	Distribute among units
6	No	Yes	Undetermined	q	Distribute among units
7	No	No	Yes	p	Distribute among units
8	No	No	Undetermined	qp	Distribute among units

FIRE IGNITION FREQUENCIES
Reactor Years

For each plant, two time periods were established – (1) power production mode and (2) low power or shutdown mode

- Assumed 62% capacity factor prior to 1994
- NUREG-1350 data for post 1994 capacity factors
- Total reactor years since initial commercial operation
- Added the reactor years of the units for multi-unit sites

FIRE IGNITION FREQUENCIES
Generic Fire Ignition Frequencies

#	Location	Ignition Source	# of Events	Total Reactor Years	RDAT Output			
					Mean	5%	50%	95%
1	Battery Room	Batteries	1.0	2486	7.5E-04	2.0E-05	3.2E-04	2.4E-03
2	Containment (PWR)	Reactor Coolant Pump	6.5	1089	6.1E-03	3.1E-04	3.6E-03	1.7E-02
3	Containment (PWR)	Transients and hotwork	2.4	1089	2.0E-03	1.3E-04	1.1E-03	5.9E-03
4	Control Room	Main control board	5.5	2486	2.5E-03	8.4E-05	1.2E-03	7.3E-03
5	Control/Auxiliary/Reactor Building	Cable fires caused by welding and cutting	2.0	1674	1.6E-03	3.1E-05	6.4E-04	5.0E-03
6	Control/Auxiliary/Reactor Building	Transient fires caused by welding and cutting	12.6	1674	9.7E-03	8.9E-05	2.4E-03	3.3E-02
7	Control/Auxiliary/Reactor Building	Transients	6.0	1674	3.9E-03	1.6E-04	2.2E-03	1.1E-02
8	Diesel Generator Room	Diesel generators	49.5	2486	2.1E-02	1.9E-03	1.2E-02	6.6E-02
9	Plant-Wide Components	Air compressors	5.0	2486	2.4E-03	3.8E-05	9.0E-04	7.9E-03

FIRE IGNITION FREQUENCIES
Concluding Remarks

Fire ignition frequency evaluation (Task 6) uses a mix of plant specific and generic information to establish the ignition frequencies for specific compartments and from that for specific fire scenarios.

- Generic fire ignition frequencies based on industry experience
- Elaborate data analysis method
- Frequencies binned by equipment type
- Methodology to apportion frequencies according to relative characteristics of each compartment

Workshop Problems for Task 6: Fire Ignition Frequency

Workshop Problem Set 06-01

Step 1: Mapping plant ignition sources to generic sources: Using the information provided in this Sample Package, map the items listed in the following table to generic sources.

Equipment ID	Equipment Description	Equipment Type	Bin #	Bin Description / Comment\
HPI-B	High pressure safety injection pump B			
MOV-1	HPI valve			
MOV-5	RWST isolation valve			
BAT-B	Train B Battery			
RCP-1	Reactor coolant pump 1			
AOV-1 / (SOV-1)	Pilot operated relief valve			
PT-1	RCS pressure transmitter			
EDG-A	Train A Emergency Diesel Generator			
MCC-B1	Train B 480 V Motor Control Center			
ATS-1	Automatic Transfer Switch Panel			
VITAL-A	Train A 120 VAC Vital Bus			
SWGR-A	Train A 4160 V Bus			
LC-A	Train A 480 V Load Center			
SST-A	Train A Station Service Transformer			
BC-A	Train A Battery Charger			
DC BUS-A	Train A 125 VDC Bus			
PNL-A	Train A 125 VDC Panel			
INV-A	Train A Inverter			
AFW-A	Motor driven AFW pump A			
AFW-B	Steam driven AFW Pump B			
SUT-1	Startup Transformer			

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Workshop Problem Set 06-02 (Example)

Step 2: Plant Fire Event Data Collection and Review: The following tables provide examples of fire events data collected for the sample nuclear power plant.

Fire Event # 1

Event date: January 1, 2007

Event Description: At approximately 16:49, a fire resulted from a short caused by the slabs on the MCC-A breakers not properly engaging the bus bars. As a result of a short, insulation on some wires ignited, resulting in a fire. The fire was discovered immediately by employees who extinguished the blaze with portable fire extinguishers. Damage was confined to the cabinet where the fire occurred, located inside the motor control center.

Should this event be considered in fire frequency calculation? Yes

Basis: The event occurred during power operation. Extent of damage was sufficient to render the ignition source inoperable and the flames and hot gases threatened the integrity of other items nearby.

Associated Bin ID # per Table 6-1 of Ref.1: 15

Bin Location: Plant-wide components

Bin Description: Electrical Cabinets

Basis: The fire was initiated in an MCC. An MCC is considered an electrical cabinet.

Fire Event # 2

Event date: February 1, 2007

Event Description: A fire occurred in the 120VAC-A panel. The fire was extinguished when 4kV bus-A was de- energized from the control room. Fire resulted from arcing of supply lead to one of the fittings connecting to a controller to the bus. Problems have been previously experienced with this type of devices in other plants.

Should this event be considered in fire frequency calculation? Yes

Basis: The event occurred during power operation. Extent of damage was sufficient to render the ignition source (i.e., 120VAC bus) inoperable and threaten the integrity of other items nearby.

Associated Bin ID # per Table 6-1 of Ref.1: 15

Bin Location: Plant-wide components

Bin Description: Electrical Cabinets

Basis: The fire was initiated in a 120VAC panel, which is considered as an electrical cabinet.

Workshop Problem Set 06-03 (Example)

Step 3: Plant Specific Updates of Generic Ignition Frequencies: The following bullets provide a sample discussion of how the fire events presented in the previous sections were treated in the Fire PRA.

- The two events identified in the preceding step are certainly significant and should be included in a statistical analysis of fire frequency (e.g., Bayesian update of generic frequencies.)
- Plant has been in commercial operation for 10 years.
- Both events should be mapped to Bin # 15 "Electrical Cabinets"
- The resulting frequency can be approximated by 2/10 = 0.2 per electrical cabinet year
- The estimated frequency is 4 times greater than 0.045, Bin #15 generic frequency
- Fire PRA analysts decided not to include this plant specific experience in the fire frequency analysis. The decision is based on the following: "The two events do not point out an unusual trend in electrical cabinet fires. The two panels where the fires had occurred were dissimilar items. Therefore, the plant experience is not deemed to be indicative of unusually high electrical cabinet fire tendency at this plant."
- For all other bins, the experience is no events in 10 years (both power and shutdown) or 8 years (assuming 20% outages). If subjected to Bayesian update, the impact of this experience on bin frequencies is minimal.

Workshop Problem Set 06-04

Step 4: Mapping Plant-Specific Locations to Generic Locations: Using the information provided in this Sample Package, map the items listed in the following table to the applicable generic locations provided in NUREG/CR 6850. Note that some of the compartments may map to more than one Generic Location.

Step 5: Location Weighting Factors: Assign the location weighting factors of the Fire Compartments in the following table.

Fire Comp. #	Plant Fire Compartment	Plant Area	Generic Location	W_L
1	Main Control Room	Auxiliary Building		
2	Aux Bldg El. 0 Ft	Auxiliary Building		
3	Cable Spreading Room	Auxiliary Building		
4A	RHR Pump Room	Auxiliary Building		
4B	AFW Pump Room	Auxiliary Building		
5	Battery Room A	Auxiliary Building		
6	Battery Room B	Auxiliary Building		
9	SWG Access Room	Auxiliary Building		
10	Switchgear Room A	Auxiliary Building		
11	Switchgear Room B	Auxiliary Building		
14	Stairway	Auxiliary Building		
7	Containment	Containment		
8A	DG-A Room	DG Bldg.		
8B	DG-B Room	DG Bldg.		
12	Turbine Bldg El. 0 Ft	Turbine Building		
15	Battery Room 1	Turbine Building		
13	Yard	Yard		
14	Intake Structure	Intake Structure		

Workshop Problem Set 06-05

Step 5: Location Weighting Factors: At a two-unit nuclear power plant, the Main Control Room is shared between the two units. The control room consists of two separate Main Control Boards that do not share any controls and are dedicated to one unit each. There are 5 electrical cabinets in the control room in addition to the Main Control Boards that are shared between the two units.

a. For Unit 1, establish the Location Weighting Factor of the Main Control Board

b. For Unit 1, establish the Location Weighting Factor of the electrical cabinets.

c. For Unit 1, establish the Location Weighting Factor of transient fires in the Main Control Room

Workshop Problem Set 06-06

Step 6: Fixed Fire Ignition Source Counts: Estimate the ignition source counts for only those items that are noted under each picture and are visible in the foreground of the picture:

Electrical Panels: _____

Electrical Panels: _____

Transformers: _____

Transformers: _____

Electrical Panels: _____

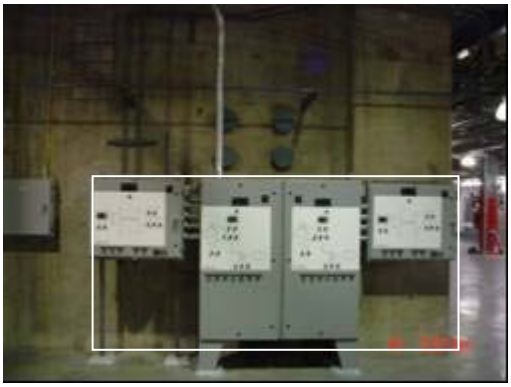
Transformers: _____

Electrical Panels: _____

Electrical Panels: _____

Electrical Panels: _____

Electrical Panels: _____



Electrical Panels: _____

<u>(These are sealed panels with low voltage circuits)</u>

Workshop Problem Set 06-07

Step 6: Fixed Fire Ignition Source Counts: Estimate the ignition source counts for the components identified in Step 1 above.

			Bin # and Description (per Table 6-1)												
			1	2	8	4	9	10	14	15	16	21	23a	23b	29
			Batteries	Reactor Coolant Pump	Diesel Generators	Main Control Board	Air Compressors	Battery Chargers	Electric Motors	Electrical Cabinets	High Energy Arcing Faults	Pumps	Transformers (Dry)	Transformers (Oil filled)	Yard transformers (Others)
#	Compartment	Plant Area	BAT	RCP	DG	MCB	AC	BC	EM	EC	HEAF	PMP	XFMR-Dry	XFMR-Oil	XFMR-Yard
1	Main Control Room	Control/Aux/Reactor Building													
2	Aux Bldg El. 0 Ft	Control/Aux/Reactor Building													
3	Cable Spreading Room	Control/Aux/Reactor Building													
4A	RHR Pump Room	Control/Aux/Reactor Building													
4B	AFW Pump Room	Control/Aux/Reactor Building													
5	Battery Room A	Plant Wide Components													
6	Battery Room B	Plant Wide Components													
9	SWG Access Room	Plant Wide Components													
10	Switchgear Room A	Plant Wide Components													
11	Switchgear Room B	Plant Wide Components													
14	Stairway	Plant Wide Components													
7	Containment	Containment													
8A	DG-A Room	Plant Wide Components													
8B	DG-B Room	Plant Wide Components													
12	Turbine Bldg El. 0 Ft	Plant Wide Components													
15	Battery Room 1	Plant Wide Components													
13	Yard	Plant Wide Components													
14	Intake Structure	Plant Wide Components													
		Total													

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Workshop Problem Set 06-08

Step 7: Ignition Source Weighting Factors: For an NPP, the fire PRA analysts have counted 23 pumps within the Plant Analysis Boundary.

- For RHR Pump RHRP-C located in RHR Pump room (FZ-03A), which in turn is located in the Auxiliary Building, establish the IS, J and L subscripts of:

  $W_{IS,J,L}$ =

- For the same RHR Pump, RHRP-C, calculate the Ignition Source Weighting Factor

  W =

- RHR Pump room FZ-03A contains three pumps. Calculate the ignition source weighting factor for the pumps in this compartment.

  W =

Workshop Problem Set 06-09

Step 7: Ignition Source Weighting Factors: For an NPP, the fire PRA analysts have counted 351 electrical cabinet vertical sections within the Plant Analysis Boundary.

- 480VAC MCC-A is composed of 32 breakers arranged in 8 vertical segments. Calculate the ignition source weighting factor for this MCC.

  $W_{MCC\text{-}B}$ =

- 4kV non-1E Switchgear 1 is composed of 8 breakers. Each breaker takes up one vertical segment of the switchgear. Calculate the ignition source weighting factor for this electrical panel.

  $W_{SWG\text{-}1}$ =

- The local control panel, CP-1, for the chemicals addition system located in the Reactor Building has the following dimensions: 2’ Deep, 12’Long, 8’High. There are no partitions within the panel. Calculate the ignition source weighting factor for this electrical panel.

  $W_{CP\text{-}1}$ =

Workshop Problem Set 06-10

Step 7: Ignition Source Weighting Factors: Using the information provided in the solution for Problem Set 06-07, calculate the component weighting factors for the components listed below.

			Bin # and Description (per Table 6-1)												
			1	2	8	4	9	10	14	15	16	21	23a	23b	29
			Batteries	Reactor Coolant Pump	Diesel Generators	Main Control Board	Air Compressors	Battery Chargers	Electric Motors	Electrical Cabinets	High Energy Arcing Faults	Pumps	Transformers (Dry)	Transformers (Oil filled)	Yard transformers (Others)
#	Compartment	Plant Area	BAT	RCP	DG	MCB	AC	BC	EM	EC	HEAF	PMP	XFMR-Dry	XFMR-Oil	XFMR-Yard
1	Main Control Room	Control/Aux/Reactor Building													
2	Aux Bldg El. 0 Ft	Control/Aux/Reactor Building													
3	Cable Spreading Room	Control/Aux/Reactor Building													
4A	RHR Pump Room	Control/Aux/Reactor Building													
4B	AFW Pump Room	Control/Aux/Reactor Building													
5	Battery Room A	Plant Wide Components													
6	Battery Room B	Plant Wide Components													
9	SWG Access Room	Plant Wide Components													
10	Switchgear Room A	Plant Wide Components													
11	Switchgear Room B	Plant Wide Components													
14	Stairway	Plant Wide Components													
7	Containment	Containment													
8A	DG-A Room	Plant Wide Components													
8B	DG-B Room	Plant Wide Components													
12	Turbine Bldg El. 0 Ft	Plant Wide Components													
15	Battery Room 1	Plant Wide Components													
13	Yard	Plant Wide Components													
14	Intake Structure	Plant Wide Components													

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Workshop Problem Set 06-11

Transient Ignition Source Weighting Factors: An NPP is composed of three compartments with the following characteristics:

Compartment 1:

- Houses the Steam Driven Auxiliary Feedwater Pump
- The pump has required major maintenance once per year
- The room is at a corner of the Auxiliary Building separated from other parts of the building with 3-hour rated walls and one access door
- The lubricating oils of this and other large safety related pumps are stored in this room.
- All cables are in open bottom and open top cable trays
- The total amount of cables in the room is 1,000 lbs.

Compartment 2:

- Houses the one of three High Pressure Injection Pumps
- The pump has required major maintenance once per three years
- The room is at a corner of the Auxiliary Building separated from other parts of the building with 3-hour rated walls and one access door
- There are no other items in this room except for the pump.
- All cables are inside conduits
- The total amount of cables in the room is 1,000 lbs.

Compartment 3:

- Houses 480VAC MCC
- The MCC has never required any major maintenance since installation 15 years ago
- The room is the passageway between the radiation control and other parts of the Auxiliary Building
- The room contains coveralls and other radiation protection related clothing items
- All cables are in open bottom and open top cable trays
- The total amount of cables in the room is 10,000 lbs.

A. Enter the influencing factors for each compartment and category:

	Influencing Factor			Cable Run (self-ignited cable fires)
Compartment	Maintenance	Occupancy	Storage	
Compartment 1				
Compartment 2				
Compartment 3				
Total				

B. Calculate the ignition source weighting factors for each compartment

Compartment	General Transients	Transients fires caused by welding and cutting	Cable fires caused by welding and cutting	Cable Run (self-ignited cable fires)
Compartment 1				
Compartment 2				
Compartment 3				
Total				

C. Calculate the ignition frequencies for each compartment

	General Transients	Transients fires caused by welding and cutting	Cable fires caused by welding and cutting	Cable Run (self-ignited cable fires)
Total Location Frequency (/ry)	*3.90E-03*	*9.70E-03*	*1.60E-03*	*4.40E-03*
Compartment 1				
Compartment 2				
Compartment 3				

Transients and Cable Fire (Count, Ignition Source Weighting Factor and Frequency)

	Count						Weighting Factors				Frequency		
	Cable Run (10^6 BTU)	Maintenance	Storage	Occupancy	Cable Quantity x Maintenance		General Transients	Cable Fires Due to Hotwork	Transients due to Hotwork		General Transients	Cable Fires Due to Hotwork	Transients due to Hotwork
	Control / Aux. / Reactor Building												
1 Main Control Room	300	1	10	10	300		0.64	3.5E-01	0.2		2.5E-03	5.6E-04	1.9E-03
2 Aux Bldg El. 0 Ft	6	1	1	1	6		0.09	7.0E-03	0.2		3.5E-04	1.1E-05	1.9E-03
3 Cable Spreading Room	549	1	1	1	549		0.09	6.4E-01	0.2		3.5E-04	1.0E-03	1.9E-03
4A RHR Pump Room	1	1	1	1	1		0.09	1.2E-03	0.2		3.5E-04	1.9E-06	1.9E-03
4B AFW Pump Room	1	1	1	1	1		0.09	1.2E-03	0.2		3.5E-04	1.9E-06	1.9E-03
Total		*5*	*14*	*14*	*857*						*3.90E-03*	*1.60E-03*	*9.70E-03*
	Plant Wide Components												
5 Battery Room A	1	1	1	1	1		0.05	4.2E-04	0.03		4.5E-04	8.3E-07	1.5E-04
6 Battery Room B	0	1	1	1	0		0.05	--	0.03		4.5E-04	--	1.5E-04
9 SWG Access Room	1.6	1	1	1	1.6		0.05	6.7E-04	0.03		4.5E-04	1.3E-06	1.5E-04
10 Switchgear Room A	10	3	1	3	30		0.11	1.3E-02	0.09		1.1E-03	2.5E-05	4.6E-04
11 Switchgear Room B	80	3	1	3	240		0.11	1.0E-01	0.09		1.1E-03	2.0E-04	4.6E-04
14 Stairway	0	1	1	3	0		0.08	--	0.03		7.5E-04	--	1.5E-04
7 Containment	0	1	1	1	0		0.05	--	0.03		4.5E-04	--	1.5E-04
8A DG-A Room	218	3	1	1	654		0.08	2.7E-01	0.09		7.5E-04	5.5E-04	4.6E-04
8B DG-B Room	218	3	1	1	654		0.08	2.7E-01	0.09		7.5E-04	5.5E-04	4.6E-04
12 Turbine Bldg El. 0 Ft	80	10	1	3	800		0.21	3.3E-01	0.31		2.1E-03	6.7E-04	1.5E-03
15 Battery Room 1	0	1	1	1	0		0.05	--	0.03		4.5E-04	--	1.5E-04
13 Yard	0	1	1	1	0		0.05	--	0.03		4.5E-04	--	1.5E-04
14 Intake Structure	6	3	1	1	18		0.08	7.5E-03	0.09		7.5E-04	1.5E-05	4.6E-04
Total		*32*	*13*	*21*	*2398.6*						*9.90E-03*	*2.00E-03*	*4.90E-03*

Ignition Frequencies by Bin and Compartment (part 1 of 2)

			Batteries	Reactor Coolant Pump	Diesel Generators	Air Compressors	Battery Chargers	Electric Motors	Electrical Cabinets	High Energy Arcing Faults	Pumps	Transformers (Dry)	Transformers (Oil filled)
Generic Frequency			7.5E-04	6.1E-03	2.1E-02	2.4E-03	1.8E-03	4.6E-03	4.5E-02	1.5E-03	2.1E-02	9.9E-03	9.9E-03
Compartment and Associated Freq.													
1	Main Control Room	1.1E-02							3.3E-04				
2	Aux Bldg El. 0 Ft	7.2E-03						2.0E-03			6.0E-03		
3	Cable Spreading Room	6.2E-03											
4A	RHR Pump Room	7.2E-03						2.0E-03			3.0E-03		
4B	AFW Pump Room	6.4E-03									6.0E-03		
5	Battery Room A	4.7E-04	2.5E-04										
6	Battery Room B	9.1E-04	2.5E-04										
9	SWG Access Room	1.1E-02							9.9E-03				
10	Switchgear Room A	1.5E-02					6.0E-04		7.9E-03	3.8E-04		5.0E-03	
11	Switchgear Room B	1.7E-02					6.0E-04		7.9E-03	3.8E-04		5.0E-03	
14	Stairway	6.6E-04											
7	Containment	3.2E-03						6.6E-04			3.0E-03		
8A	DG-A Room	1.8E-02			1.1E-02								
8B	DG-B Room	1.8E-02			1.1E-02								
12	Turbine Bldg El. 0 Ft	6.5E-02	2.5E-04			2.4E-03	6.0E-04		1.9E-02	7.5E-04	3.0E-03		9.9E-03
15	Battery Room 1	4.5E-04											
13	Yard	2.6E-03											
14	Intake Structure	1.1E-03											

Ignition Frequencies by Bin and Compartment (part 2 of 2)

		Yard transformers (Others)	Main Control Board	Cable Run (106 BTU)	Junction Box	MG Sets	MFW Pumps	TG Oil	TG Exciter	TG Hydrogen
	Generic Frequency	2.2E-03	2.5E-03	4.4E-03	1.9E-03	1.6E-03	1.3E-02	9.5E-03	3.9E-03	6.5E-03
	Compartment									
1	Main Control Room		2.5E-03	9.0E-04	3.9E-04					
2	Aux Bldg El. 0 Ft			1.8E-05	7.7E-06					
3	Cable Spreading Room			1.6E-03	7.1E-04					
4A	RHR Pump Room			3.0E-06	1.3E-06					
4B	AFW Pump Room			3.0E-06	1.3E-06					
5	Battery Room A			3.0E-06	1.3E-06					
6	Battery Room B									
9	SWG Access Room			4.8E-06	2.1E-06					
10	Switchgear Room A			3.0E-05	1.3E-05					
11	Switchgear Room B			2.4E-04	1.0E-04					
14	Stairway									
7	Containment									
8A	DG-A Room			6.5E-04	2.8E-04					
8B	DG-B Room			6.5E-04	2.8E-04					
12	Turbine Bldg El. 0 Ft			2.4E-04	1.0E-04			9.5E-03	3.9E-03	6.5E-03
15	Battery Room 1									
13	Yard	2.2E-03								
14	Intake Structure			1.8E-05	7.7E-06					

Workshop Problems for Task 6: Fire Ignition Frequency

Workshop Problem Set 06-01

Step 1: Mapping plant ignition sources to generic sources: Using the information provided in this Sample Package, map the items listed in the following table to generic sources.

Equipment ID	Equipment Description	Equipment Type	Bin #	Bin Description / Comment\
HPI-B	High pressure safety injection pump B	Pump	21	Pumps
MOV-1	HPI valve	MOV	14	Electric Motors
MOV-5	RWST isolation valve	MOV	--	Less than 5hp motor
BAT-B	Train B Battery	Battery	1	Batteries
RCP-1	Reactor coolant pump 1	Pump	2	Reactor Coolant Pump
AOV-1 / (SOV-1)	Pressure operated relief valve	AOV	--	Assumed as insignificant ignition source.
PT-1	RCS pressure	Instrument	--	Assumed as insignificant ignition source.
EDG-A	Train A Emergency Diesel Generator	Diesel Generator	8	Diesel Generators
MCC-B1	Train B 480 V Motor Control Center	Motor Control Center	15	Electrical Cabinets
ATS-1	Automatic Transfer Switch	ATS	15	Electrical Cabinets
VITAL-A	Train A 120 VAC Vital Bus	120VAC Bus	15	Electrical Cabinets
SWGR-A	Train A 4160 V Bus	Switchgear	15/16	Electrical Cabinets/HEAF
LC-A	Train A 480 V Load Center	Load Center	15/16	Electrical Cabinets/HEAF
SST-A	Train A Station Service Transformer	Transformer	23a	Transformers (Dry)
BC-A	Train A Battery Charger	Battery Charger	10	Battery Chargers
DC BUS-A	Train A 125 VDC Bus	DC Bus	15	Electrical Cabinets
PNL-A	Train A 125 VDC Panel	Panelboard	15	Electrical Cabinets
INV-A	Train A Inverter	Inverter	15	Electrical Cabinets
AFW-A	Motor driven AFW pump A	Pump	21	Pumps
AFW-B	Steam driven AFW Pump B	Pump	21	Pumps
SUT-1	Startup Transformer	Transformer	29	Yard transformers (Others)

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The following table provides the components specifically addressed in the Fire PRA of this Sample Package.

Equipment ID	Equipment Description	Equipment Type	Bin #	Bin Description / Comment\
TI-1	Letdown heat exchanger outlet temp	Instrument	--	Comment 1 (below)
HPI-A	High pressure safety injection pump A	Pump	21	Pumps
HPI-B	High pressure safety injection pump B	Pump	21	Pumps
AOV-2 / (SOV-2)	Letdown isolation valve	AOV	--	Comment 1
AOV-3 / (SOV-3)	Charging pump injection valve	AOV	--	Comment 1
MOV-1	HPI valve	MOV	14	Electric Motors
MOV-2	VCT isolation valve	MOV	14	Electric Motors
MOV-5	RWST isolation valve	MOV	--	Less than 5hp motor
MOV-6	RWST isolation valve	MOV	--	Less than 5hp motor
MOV-9	HPI valve	MOV	14	Electric Motors
RHR-B	RHR pump B	Pump	21	Pumps
MOV-3	Cont. sump recirc valve	MOV	14	Electric Motors
MOV-4	Cont. sump recirc valve	MOV	14	Electric Motors
MOV-8	RHR outboard suction valve	MOV	14	Electric Motors
BAT-A	Train A Battery	Battery	1	Batteries
BAT-B	Train B Battery	Battery	1	Batteries
RCP-1	Reactor coolant pump 1	Pump	2	Reactor Coolant Pump
AOV-1 / (SOV-1)	Pressure operated relief valve	AOV	--	Comment 1
MOV-7	RHR inboard suction valve	MOV	14	Electric Motors
MOV-13	PORV block valve	MOV	--	Comment 2
LI-3	Containment sump level	Instrument	--	Comment 1
LI-4	Containment sump level	Instrument	--	Comment 1
PT-1	RCS pressure	Instrument	--	Comment 1
EDG-A	Train A Emergency Diesel Generator	Diesel Generator	8	Diesel Generators
EDG-B	Train B Emergency Diesel Generator	Diesel Generator	8	Diesel Generators
ANN-1	AFW motor high temp	Annunciator	--	Comment 1
MCC-A1	Train A 480 V Motor Control Center	Motor Control Center	15	Electrical Cabinets
MCC-B1	Train B 480 V Motor Control Center	Motor Control Center	15	Electrical Cabinets
ATS-1	Automatic Transfer Switch	ATS	15	Electrical Cabinets
VITAL-A	Train A 120 VAC Vital Bus	120VAC Bus	15	Electrical Cabinets
VITAL-B	Train B 120 VAC Vital Bus	120VAC Bus	15	Electrical Cabinets
SWGR-A	Train A 4160 V Bus	Switchgear	15/16	Electrical Cabinets/HEAF
LC-A	Train A 480 V Load Center	Load Center	15/16	Electrical Cabinets/HEAF
SST-A	Train A Station Service Transformer	Transformer	23a	Transformers (Dry)
BC-A	Train A Battery Charger	Battery Charger	10	Battery Chargers
DC BUS-A	Train A 125 VDC Bus	DC Bus	15	Electrical Cabinets
PNL-A	Train A 125 VDC Panel	Panelboard	15	Electrical Cabinets
INV-A	Train A Inverter	Inverter	15	Electrical Cabinets
SWGR-B	Train B 4160 V Bus	Switchgear	15/16	Electrical Cabinets/HEAF
LC-B	Train B 480 V Load Center	Load Center	15/16	Electrical Cabinets/HEAF

The following table provides the components specifically addressed in the Fire PRA of this Sample Package.

Equipment ID	Equipment Description	Equipment Type	Bin #	Bin Description / Comment\
SST-B	Train B Station Service Transformer	Transformer	23a	Transformers (Dry)
BC-B	Train B Battery Charger	Battery Charger	10	Battery Chargers
DC BUS-B	Train B 125 VDC Bus	DC Bus	15	Electrical Cabinets
PNL-B	Train B 125 VDC Panel	Panelboard	15	Electrical Cabinets
INV-B	Train B Inverter	Inverter	15	Electrical Cabinets
LC-1	Non-Safety 480 V Load Center	Load Center	15/16	Electrical Cabinets/HEAF
LC-2	Non-Safety 480 V Load Center	Load Center	15/16	Electrical Cabinets/HEAF
SWGR-1	Non-Safety 4160 V Bus	Switchgear	15/16	Electrical Cabinets/HEAF
SWGR-2	Non-Safety 4160 V Bus	Switchgear	15/16	Electrical Cabinets/HEAF
COMP-1	Instrument air compressor	Compressor	9	Air Compressors
MOV-10	AFW discharge valve	MOV	--	Comment 2
MOV-11	AFW discharge valve	MOV	--	Comment 2
MOV-18	AFW C Pump Discharge	MOV	--	Comment 2
SST-1	Non-Safety Station Service Transformer	Transformer	23b	Transformers (Oil filled)
SST-2	Non-Safety Station Service Transformer	Transformer	23b	Transformers (Oil filled)
MCC-1	Non-Safety 480 V Motor Control Center	Motor Control Center	15	Electrical Cabinets
MCC-2	Non-Safety 480 V Motor Control Center	Motor Control Center	15	Electrical Cabinets
BC-1	Non-Safety Swing Battery Charger	Battery Charger	10	Battery Chargers
BAT-1	Non-Safety Battery	Battery	1	Batteries
DC BUS-1	Non-Safety 250 VDC Bus	DC Bus	15	Electrical Cabinets
AFW-A	Motor driven AFW pump A	Pump	21	Pumps
AFW-B	Steam driven AFW Pump B	Pump	21	Pumps
AFW-C	AFW pump C	Pump	21	Pumps
MOV-14	AFW turbine steam line isolation valve	MOV	--	Comment 2
MOV-15	AFW steam inlet throttle valve	MOV	--	Comment 2
MOV-16	AFW test line isolation valve	MOV	--	Comment 2
MOV-17	AFW test line isolation valve	MOV	--	Comment 2
MOV-19	AFW test line isolation valve	MOV	--	Comment 2
V-12	CST isolation valve	MOV	--	Comment 2
LI-1	RWST level	Instrument	--	Comment 1
LI-2	RWST level	Instrument	--	Comment 1
SUT-1	Startup Transformer	Transformer	29	Yard transformers (Others)

Comment 1: Assumed as insignificant ignition source.
Comment 2: Less than 5hp motor

Workshop Problem Set 06-04

Step 4: Mapping Plant-Specific Locations to Generic Locations: Using the information provided in this Sample Package, map the items listed in the following table to the applicable generic locations provided in NUREG/CR 6850. Note that some of the compartments may map to more than one Generic Location.

Step 5: Location Weighting Factors: Assign the location weighting factors of the Fire Compartments in the following table.

Fire Comp. #	Plant Fire Compartment	Plant Area	Generic Location	W_L
1	Main Control Room	Auxiliary Building	See Note 1	1.0
2	Aux Bldg El. 0 Ft	Auxiliary Building	See Note 2	1.0
3	Cable Spreading Room	Auxiliary Building	See Note 2	1.0
4A	RHR Pump Room	Auxiliary Building	See Note 2	1.0
4B	AFW Pump Room	Auxiliary Building	See Note 2	1.0
5	Battery Room A	Auxiliary Building	See Note 3	1.0
6	Battery Room B	Auxiliary Building	See Note 3	1.0
9	SWG Access Room	Auxiliary Building	See Note 2	1.0
10	Switchgear Room A	Auxiliary Building	See Note 2	1.0
11	Switchgear Room B	Auxiliary Building	See Note 2	1.0
14	Stairway	Auxiliary Building	See Note 2	1.0
7	Containment	Containment	Containment	1.0
8A	DG-A Room	DG Bldg.	See Note 4	1.0
8B	DG-B Room	DG Bldg.	See Note 4	1.0
12	Turbine Bldg El. 0 Ft	Turbine Building	See Note 5	1.0
15	Battery Room 1	Turbine Building	See Note 6	1.0
13	Yard	Yard	See Note 7	1.0
14	Intake Structure	Intake Structure	Plant-Wide Components	1.0

Note 1: Control Room (for the Main Control Board) and Control/Aux/Reactor Building (for cable and transient fires)

Note 2: Control/Aux/Reactor Building (for cable and transient fires) and Plant-Wide Components for all other items

Note 3: Battery Room (for the batteries) and Control/Aux/Reactor Building (for cable and transient fires)

Note 4: Diesel Generator Room (for the Diesel Generators), Control/Aux/Reactor Building (for cable and transient fires), and Plant-Wide Components for all other items

Note 5: Turbine and Plant-Wide Components (for all items not specifically assigned to the Turbine Building)

Note 6: Battery Room (for the batteries) and Turbine Building (for cable and transient fires)

Note 7: Transformer Yard and Plant-Wide Components for all other items

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Workshop Problem Set 06-05

Step 5: Location Weighting Factors: At a two-unit nuclear power plant, the Main Control Room is shared between the two units. The control room consists of two separate Main Control Boards that do not share any controls and are dedicated to one unit each. There are 5 electrical cabinets in the control room in addition to the Main Control Boards that are shared between the two units.

a. For Unit 1, establish the Location Weighting Factor of the Main Control Board

$W_{L,\ MCR,\ Main\ Control\ Board} = 1.0$

b. For Unit 1, establish the Location Weighting Factor of the electrical cabinets.

$W_{L,\ MCR,\ Electrical\ Cabinets} = 2.0$

c. For Unit 1, establish the Location Weighting Factor of transient fires in the Main Control Room

$W_{L,\ MCR,\ Transients} = 2.0$

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Workshop Problem Set 06-06

Step 6: Fixed Fire Ignition Source Counts: Estimate the ignition source counts for only those items that are noted under each picture and are visible in the foreground of the picture:

Electrical Panels: _8 vertical sections

Electrical Panels: _7 vertical sections

Transformers: __1_

Transformers: _1_

Electrical Panels: _5 vertical sections

Transformers: __2_

Electrical Panels: _2 vertical sections

Electrical Panels: _3 vertical sections

Electrical Panels: _2 vertical sections

Electrical Panels: _1vertical sections

Electrical Panels: _No count –Sealed with low voltage circuits

Workshop Problem Set 06-07

Step 6: Fixed Fire Ignition Source Counts: Estimate the ignition source counts for the components identified in Step 1 above.

			Bin # and Description (per Table 6-1)												
			1	2	8	4	9	10	14	15	16	21	23a	23b	29
			Batteries	Reactor Coolant Pump	Diesel Generators	Main Control Board	Air Compressors	Battery Chargers	Electric Motors	Electrical Cabinets	High Energy Arcing Faults	Pumps	Transformers (Dry)	Transformers (Oil filled)	Yard transformers (Others)
#	Compartment	Plant Area	BAT	RCP	DG	MCB	AC	BC	EM	EC	HEAF	PMP	XFMR-Dry	XFMR-Oil	XFMR-Yard
1	Main Control Room	Control/Aux/Reactor Building	0	0	0	1	0	0	0	1	0	0	0	0	0
2	Aux Bldg El. 0 Ft	Control/Aux/Reactor Building	0	0	0	0	0	0	3	0	0	2	0	0	0
3	Cable Spreading Room	Control/Aux/Reactor Building	0	0	0	0	0	0	0	0	0	0	0	0	0
4A	RHR Pump Room	Control/Aux/Reactor Building	0	0	0	0	0	0	3	0	0	1	0	0	0
4B	AFW Pump Room	Control/Aux/Reactor Building	0	0	0	0	0	0	0	0	0	2	0	0	0
5	Battery Room A	Plant Wide Components	1	0	0	0	0	0	0	0	0	0	0	0	0
6	Battery Room B	Plant Wide Components	1	0	0	0	0	0	0	0	0	0	0	0	0
9	SWG Access Room	Plant Wide Components	0	0	0	0	0	0	0	30	0	0	0	0	0
10	Switchgear Room A	Plant Wide Components	0	0	0	0	0	1	0	24	14	0	1	0	0
11	Switchgear Room B	Plant Wide Components	0	0	0	0	0	1	0	24	14	0	1	0	0
14	Stairway	Plant Wide Components	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Containment	Containment	0	1	0	0	0	0	1	0	0	0	0	0	0
8A	DG-A Room	Plant Wide Components	0	0	1	0	0	0	0	0	0	0	0	0	0
8B	DG-B Room	Plant Wide Components	0	0	1	0	0	0	0	0	0	0	0	0	0
12	Turbine Bldg El. 0 Ft	Plant Wide Components	1	0	0	0	2	1	0	57	28	1	0	2	0
15	Battery Room 1	Plant Wide Components	0	0	0	0	0	0	0	0	0	0	0	0	0
13	Yard	Plant Wide Components	0	0	0	0	0	0	0	0	0	0	0	0	3
14	Intake Structure	Plant Wide Components	0	0	0	0	0	0	0	0	0	0	0	0	0
		Total	**3**	**0**	**2**	**1**	**2**	**3**	**7**	**136**	**56**	**6**	**2**	**2**	**3**

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Workshop Problem Set 06-08

Step 7: Ignition Source Weighting Factors: For an NPP, the fire PRA analysts have counted 23 pumps within the Plant Analysis Boundary.

- For RHR Pump RHRP-C located in RHR Pump room (FZ-03A), which in turn is located in the Reactor Building, establish the IS, J and L subscripts of:

  $W_{IS,J,L} = W_{RHRP\text{-}C,FZ\text{-}03A,AUX\ BLDG}$

- For the same RHR Pump, RHRP-C, calculate the Ignition Source Weighting Factor

  W = 1/23 = 0.043

- RHR Pump room FZ-03A contains three pumps. Calculate the ignition source weighting factor for the pumps in this compartment.

  W = 3/23 = 0.13

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Workshop Problem Set 06-09

Step 7: Ignition Source Weighting Factors: For an NPP, the fire PRA analysts have counted 351 electrical cabinet vertical sections within the Plant Analysis Boundary.

- 480VAC MCC-A is composed of 32 breakers arranged in 8 vertical segments. Calculate the ignition source weighting factor for this MCC.

  $W_{MCC\text{-}B} = 8/351 = 0.023$

- 4kV non-1E Switchgear 1 is composed of 8 breakers. Each breaker takes up one vertical segment of the switchgear. Calculate the ignition source weighting factor for this electrical panel.

  $W_{SWG\text{-}1} = 8/351 = 0.023$

- The local control panel, CP-1, for the chemicals addition system located in the Reactor Building has the following dimensions: 2' Deep, 12'Long, 8'High. There are no partitions within the panel. Calculate the ignition source weighting factor for this electrical panel.

  $W_{CP\text{-}1} = 1/351 = 0.0028$

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Workshop Problem Set 06-10

Step 7: Ignition Source Weighting Factors: Using the information provided in the solution for Problem Set 06-07, calculate the component weighting factors for the components listed below.

			Bin # and Description (per Table 6-1)												
			1	2	8	4	9	10	14	15	16	21	23a	23b	29
			Batteries	Reactor Coolant Pump	Diesel Generators	Main Control Board	Air Compressors	Battery Chargers	Electric Motors	Electrical Cabinets	High Energy Arcing Faults	Pumps	Transformers (Dry)	Transformers (Oil filled)	Yard transformers (Others)
#	Compartment	Plant Area	BAT	RCP	DG	MCB	AC	BC	EM	EC	HEAF	PMP	XFMR-Dry	XFMR-Oil	XFMR-Yard
1	Main Control Room	Control/Aux/Reactor Building				1.0E+00				7.4E-03					
2	Aux Bldg El. 0 Ft	Control/Aux/Reactor Building							4.3E-01			3.3E-01			
3	Cable Spreading Room	Control/Aux/Reactor Building													
4A	RHR Pump Room	Control/Aux/Reactor Building							4.3E-01			1.7E-01			
4B	AFW Pump Room	Control/Aux/Reactor Building										3.3E-01			
5	Battery Room A	Plant Wide Components	3.3E-01												
6	Battery Room B	Plant Wide Components	3.3E-01												
9	SWG Access Room	Plant Wide Components								2.2E-01					
10	Switchgear Room A	Plant Wide Components						3.3E-01		1.8E-01	2.5E-01		5.0E-01		
11	Switchgear Room B	Plant Wide Components						3.3E-01		1.8E-01	2.5E-01		5.0E-01		
14	Stairway	Plant Wide Components													
7	Containment	Containment		1.0E+00					1.4E-01						
8A	DG-A Room	Plant Wide Components			5.0E-01										
8B	DG-B Room	Plant Wide Components			5.0E-01										
12	Turbine Bldg El. 0 Ft	Plant Wide Components	3.3E-01				1.0E+00	3.3E-01		4.2E-01	5.0E-01	1.7E-01		1.0E+00	
15	Battery Room 1	Plant Wide Components													
13	Yard	Plant Wide Components													1.0E+00
14	Intake Structure	Plant Wide Components													

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Workshop Problem Set 06-11

Transient Ignition Source Weighting Factors: An NPP is composed of three compartments with the following characteristics:

A. Enter the influencing factors for each compartment and category:

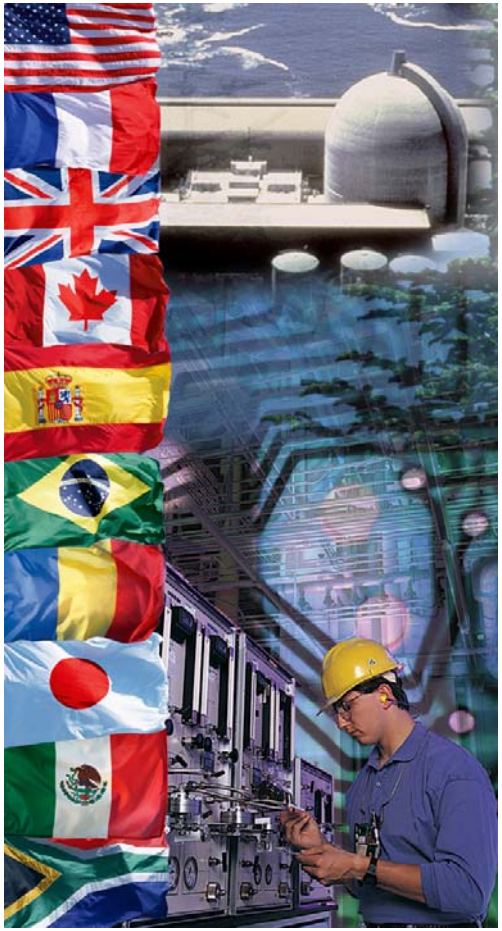
	Influencing Factor			Cable Run (self-ignited cable fires)
Compartment	Maintenance	Occupancy	Storage	
Compartment 1	10	1	10	1,000
Compartment 2	3	1	3	--
Compartment 3	1	10	10	10,000
Total	14	12	23	11,000

B. Calculate the ignition source weighting factors for each compartment

Compartment	General Transients	Transients fires caused by welding and cutting	Cable fires caused by welding and cutting	Cable Run (self-ignited cable fires)
Compartment 1	43%	8.33%	50%	9.1%
Compartment 2	14%	8.33%	--	--
Compartment 3	43%	83.33%	50%	90.9%
Total	100.0%	100.0%	100.0%	100.0%

C. Calculate the ignition frequencies for each compartment

	General Transients	Transients fires caused by welding and cutting	Cable fires caused by welding and cutting	Cable Run (self-ignited cable fires)
Total Location Frequency (/ry)	*3.90E-03*	*9.70E-03*	*1.60E-03*	*4.40E-03*
Compartment 1	1.67E-03	6.93E-03	8.0E-04	4.00E-04
Compartment 2	5.57E-04	2.08E-03	--	--
Compartment 3	1.67E-03	6.93E-04	8.0E-04	4.00E-03



EPRI/NRC-RES FIRE PRA METHODOLOGY

Module III: Heat Release Rates Appendix G

Joint RES/EPRI Public Workshop
2007
Palo Alto, CA

A Collaboration of U.S. NRC Office of Nuclear Regulatory Research (RES) & Electric Power Research Institute (EPRI)

HEAT RELEASE RATES
Objectives

The objectives of this module are:

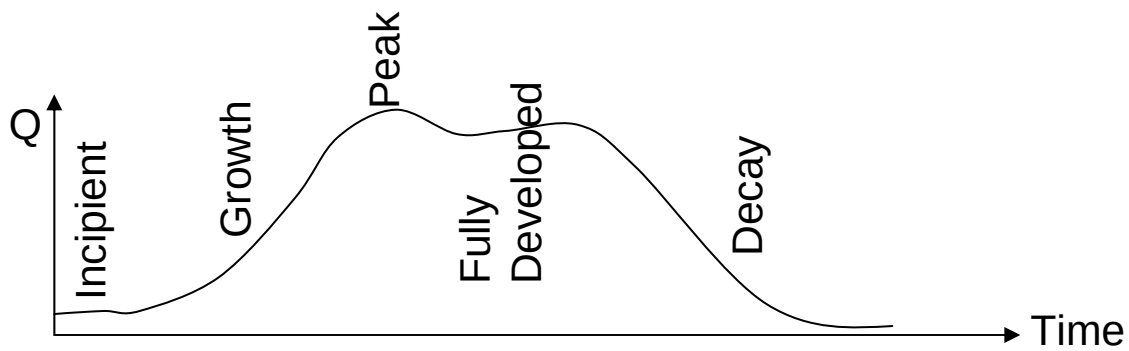
1. Define heat release rate and heat release rate profile
2. Review the recommended peak heat release rate values for typical ignition sources in NPP
3. Describe the method provided for developing heat release rate profiles for fixed and transient ignition sources in NPP

NOTE: Appendix G recommends values for ignition sources only. Heat release rates associated with fires propagating outside of the ignition source have to be evaluated accordingly.

HEAT RELEASE RATES
Definition

Definition: Heat generated by a burning object per unit time.

- $\dot{Q} = \dot{m}'' \cdot \Delta H_c \cdot A$ BTU/sec or KW
- m" is burning rate [kg/s-m^2], ΔH_c is heat of comb [kJ/kg], A is area [m^2]
- Equivalent terms: energy release rate, fire intensity, fire power
- HRR profile describes fire intensity (Q) as a function of time



HEAT RELEASE RATES
HRR Profile

The HRR profile can be expressed as a constant or as a function of time

- Incipient stage: Not recommended to be modeled
  - Duration and intensity are uncertain
- Growth: Depends on the fuel and geometry of the scenario
  - Based on engineering judgment and/or experimental observations
- Fully developed: Usually after the fire reaches its peak intensity
  - Also known as steady burning
  - Starts at ignition if the growth period is not considered
  - A constant fire intensity should the the peak heat release rate of the profile
- Decay: In general, less hazardous conditions than the growth and fully developed stage

HEAT RELEASE RATES
Fixed Ignition Sources

The methodology recommends heat release rate values for various fixed ignition sources

- Vertical cabinets
  - Open/closed
  - Qualified/Unqualified cables
- Pumps (electrical fires)
- Electric motors
- HRR for flammable liquid fires should be calculated as $\dot{Q} = \dot{m}'' \cdot \Delta H_c \cdot A$
- Separate guidance for cables, pressurized oil and hydrogen fires

HEAT RELEASE RATES
Recommended Peak HRR Values

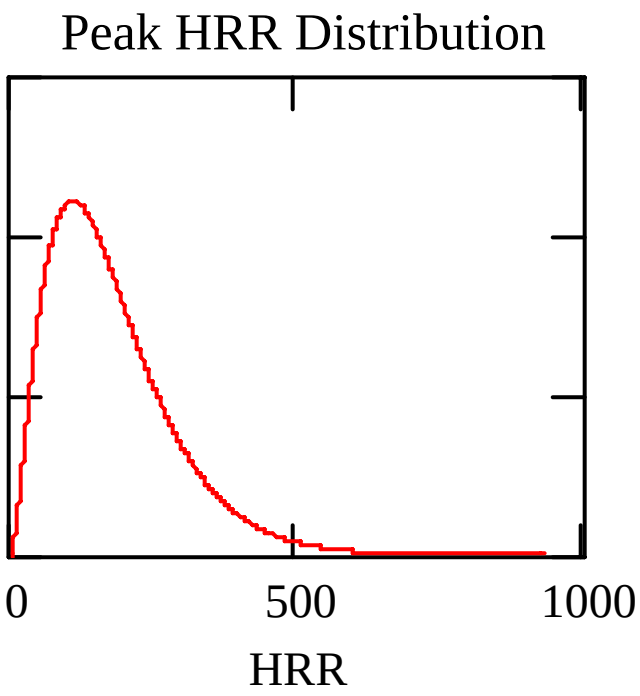
Recommended peak HRR values were developed based on expert judgment

- Expert panel included the EPRI/NRC-RES Fire Risk Re-quantification Study research team with expertise in fire behavior/phenomena.
- Values are expressed as probability distributions. The panel identified the 75th and 98th percentiles of the distribution for peak HRR.
- Primary sources of information included NUREG/CR 4527 and VTT publications
- Gamma distribution selected:
  - Only positive values starting at 0 kW
  - Values in the same order of magnitude

HEAT RELEASE RATES
Recommended Peak HRR Values

Example distribution developed by the expert panel

- 75th = 232 kW
- 98th = 464 kW
- α = 2.6
- β = 67.8



HEAT RELEASE RATES
Recommended Peak HRR Values

Ignition Source	HRR kW (Btu/s)		Gamma Distribution	
	75th	98th	α	β
Vertical cabinets with qualified cable, fire limited to one cable bundle	69 [1] (65)	211 [2] (200)	0.84 (0.83)	59.3 (56.6)
Vertical cabinets with qualified cable, fire in more than one cable bundle	211 [2] (200)	702 [3] (665)	0.7 (0.7)	216 (204)
Vertical cabinets with unqualified cable, fire limited to one cable bundle	90 [4] (85)	211 [2] (200)	1.6 (1.6)	41.5 (39.5)
Vertical cabinets with unqualified cable, fire in more than one cable bundle closed doors	232 [5] (220)	464 [6] (440)	2.6 (2.6)	67.8 (64.3)
Vertical cabinets with unqualified cable, fire in more than one cable bundle open doors	232 [5] (220)	1002 [7] (950)	0.46 (0.45)	386 (366)
Pumps (electrical fires)	69 (65)	211 [2] (200)	0.84 (0.83)	59.3 (56.6)
Motors [8]	32 (30)	69 (65)	2.0 (2.0)	11.7 (11.1)

*See report for footnotes

HEAT RELEASE RATES
Fire Growth in Electrical Cabinets

The methodology suggests a fire growth rate for electrical cabinet fires

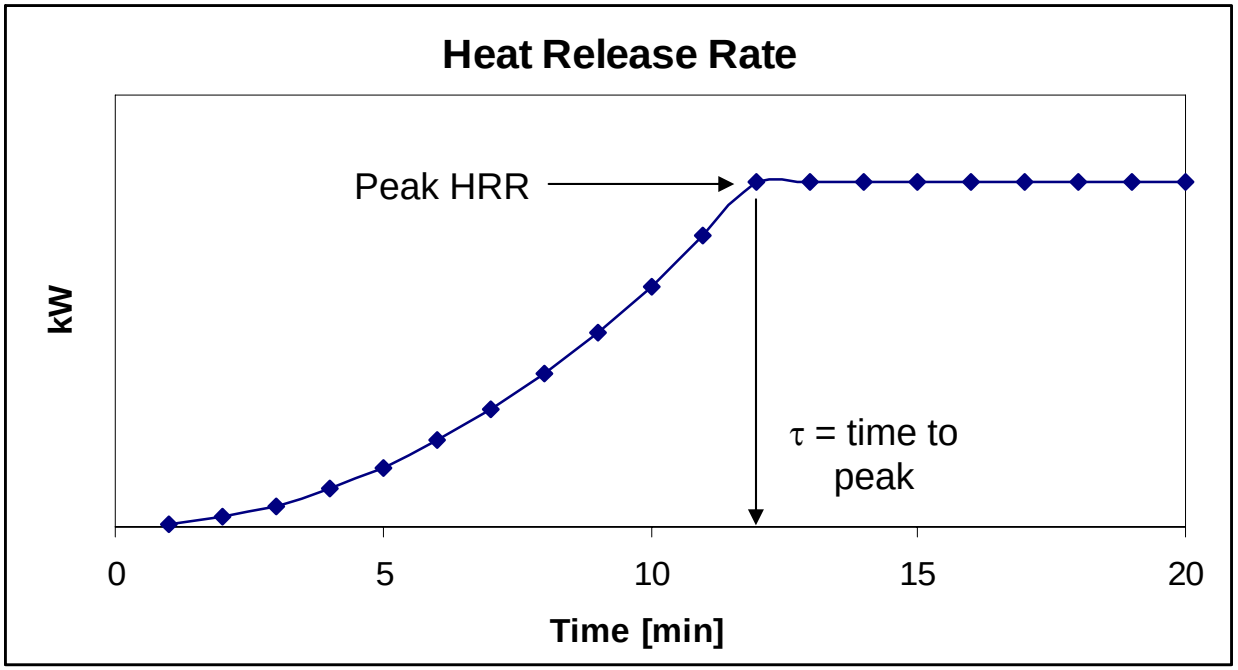
- The fire grows to its peak HRR in approximately 12 min
- The fire burns at its peak HRR for approximately 8 min
- Based on experiments reported in NUREG/CR4527

Test	Units in Minutes		
	Time to Peak	Steady Burning	Time to Decay
ST1	7	8	15
ST2	6	11	17
ST3	10	8	18
ST4	14	3	17
ST5	8	9	17
ST6	8	17	25
ST7	18	7	25
ST8	10	20	30
ST9	10	10	20
ST10	10	20	30
ST11	18	2	20
PCT1	11	10	21
PCT2	12	2	14
PCT3	13	14	27
PCT4a	16	0	16
PCT4c	16	0	16
PCT5	17	0	17
PCT6	11	0	11
Test 21	4	14	18
Test 22	9	2	11
Test 23	10	0	10
Test 24	12	0	12
Average	**11.4**	**7.1**	**19**

HEAT RELEASE RATES
Fire Growth in Electrical Cabinets

The t^2 function is recommended for modeling the growth phase of the fire

$$\dot{Q}(t) = Min\left(\dot{Q}_{peak}, \dot{Q}_{peak} \cdot \left(\frac{t}{\tau}\right)^2\right)$$



HEAT RELEASE RATES
Assigning HRR Values to Electrical Cabinets

A visual examination of the interior of the cabinet is recommended

- Identify openings in the cabinet walls
- Identify type of cable: qualified/unqualified
- Identify cable bundles
- Qualitatively determine if a fire can propagate from one bundle to another
- Select the appropriate peak HRR probability distribution

HEAT RELEASE RATES
Examples

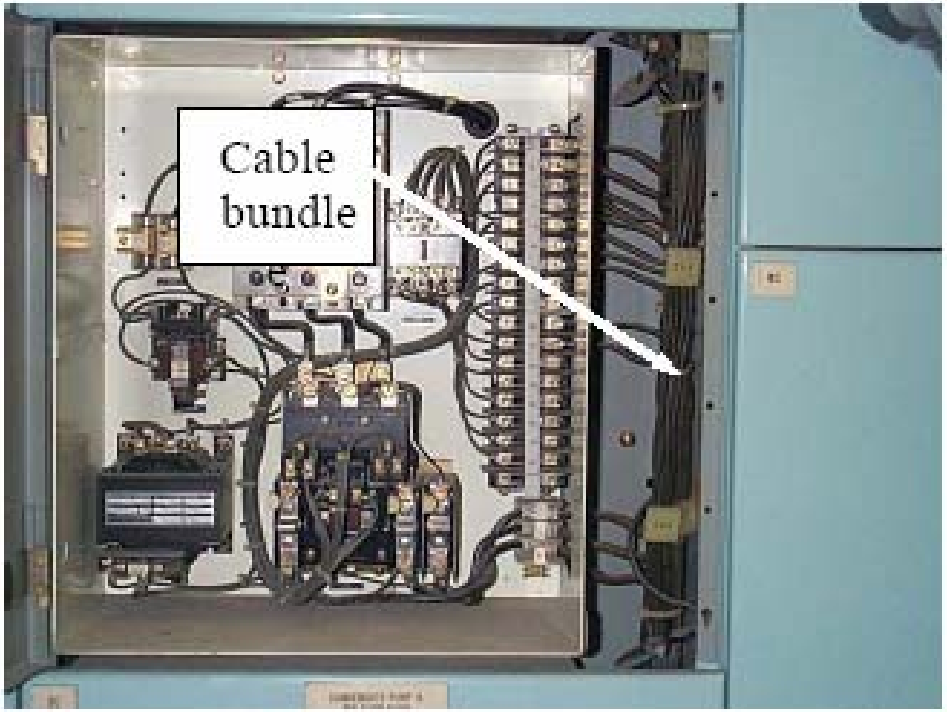
By visual examination:

- More than one cable bundle
- Assuming qualified cable, select distribution with 75th = 211 kW, 98th =702 kW

HEAT RELEASE RATES
Examples

By visual examination:

- Only one cable bundle
- Assuming qualified cable, select distribution with 75th = 69 kW, 98th = 211 kW



HEAT RELEASE RATES
Transient Ignition Sources

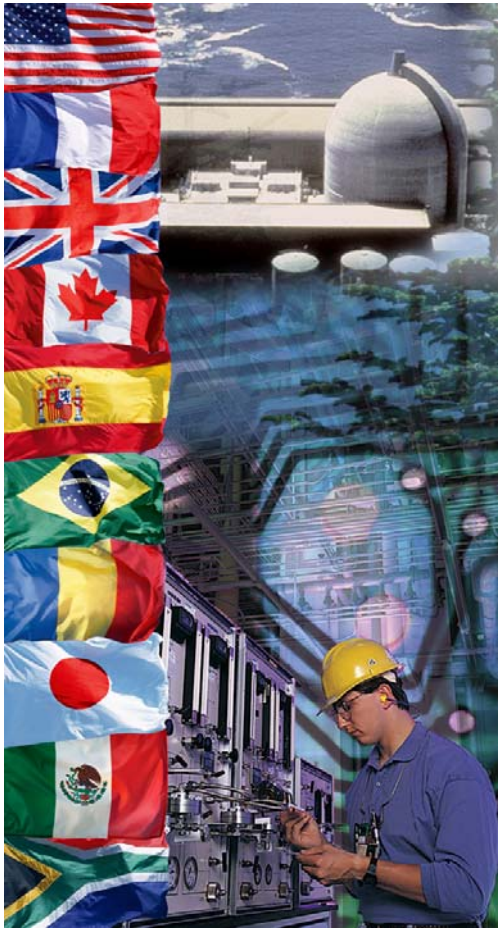
The peak HRR for transient fires is also characterized with a gamma probability distribution

- Gamma distribution:
  - 75th = 135 BTU/s, 98th = 300 BTU/s
  - $\alpha = 1.9$, $\beta = 53.7$
- Applicable only to localized transient combustibles (trash cans etc)
- Not applicable to flammable liquid transient fires

HEAT RELEASE RATES
Concluding Remarks

Peak HRR values are recommended for some typical fixed and transient ignition sources in NPP fire scenarios

- Values are for localized ignition source (not for fires propagating outside the ignition source)
- HRR for flammable liquid fires can be calculated from fundamental equations
- HRR for “solid” ignition sources are generally expressed as probability distributions based on experimental data and expert judgment



EPRI/NRC-RES FIRE PRA METHODOLOGY

Module III: Fire Severity

Joint RES/EPRI Public Workshop
July 23-27, 2007
Palo Alto, CA

A Collaboration of U.S. NRC Office of Nuclear Regulatory Research (RES) & Electric Power Research Institute (EPRI)

FIRE SEVERITY
Purpose

- A uniform methodology has been developed to define the severity of a fire.
  - Severity factor concept
  - Based on heat release rate
  - Standardized cases

FIRE SEVERITY
Severity Factor Concept

- Severity Factor is . .
  - A simplified, one parameter representation of a very complex phenomenon (i.e., fire) influenced by a large number of factors.
  - Defined as the conditional probability that given a fire has occurred, it is of certain severity (it is defined here through heat release rate).
  - Quantified in combination with *Non-Suppression Probability*.

FIRE SEVERITY
Severity Factor Concept (cont'd)

The combination of *Severity and Non-Suppression Factors* are calculated from the following equation:

$$SF_k \cdot P_{NS,k} = \int_{All\, t_{damage}} \frac{dP_{dam}(t)}{dt} P_{supp}(T_{supp} \geq t)dt$$

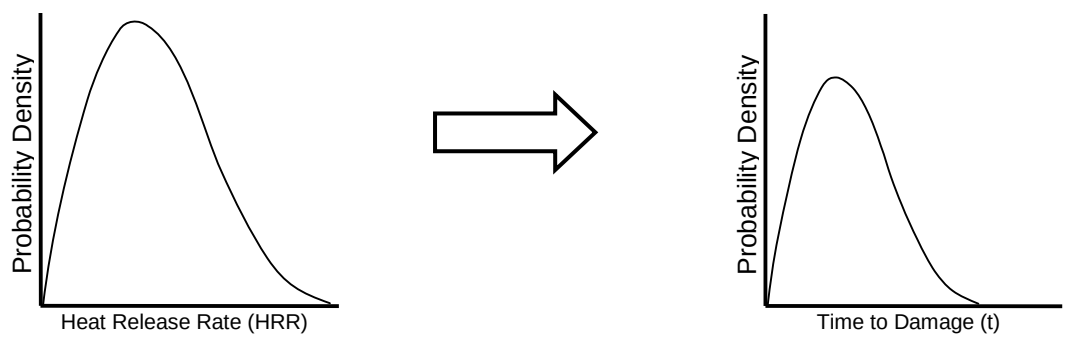
Where:

$P_{dam}(t)$: The probability of target set damage before time t.

P_{supp} (t_{supp} > t): Probability of suppression taking place after time t

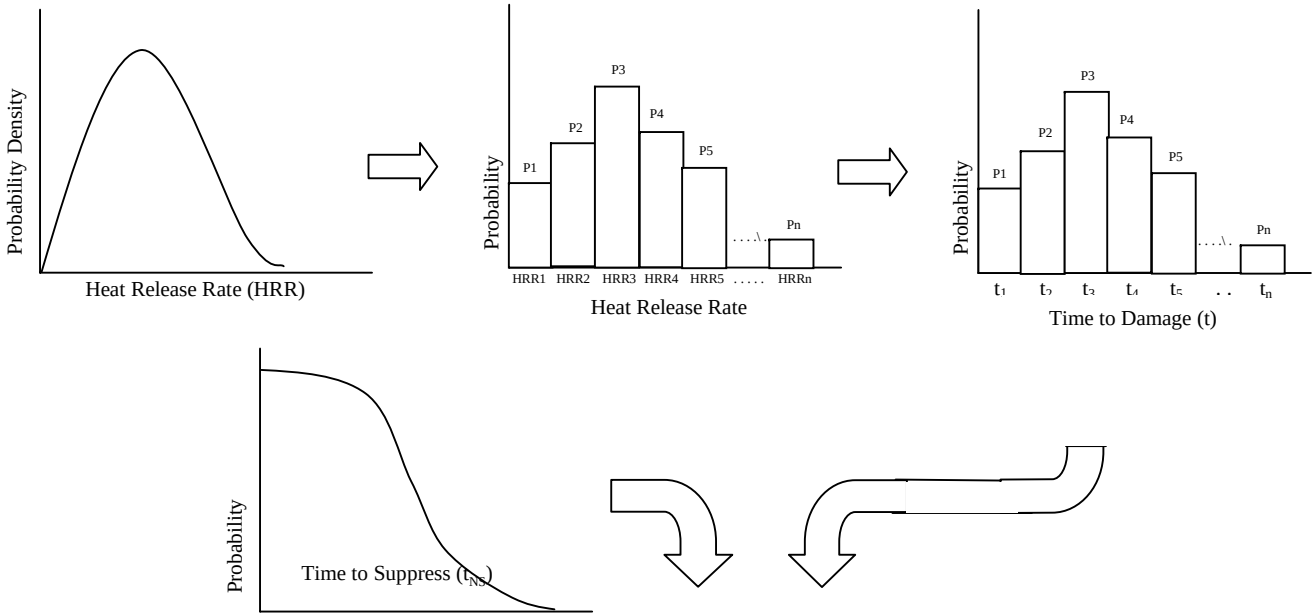
FIRE SEVERITY
Probability of Damage Estimation

- Probability of damage before time t is estimated using complex fire spread and propagation models.
  - Heat release rate is a key parameter of the analysis
  - Assuming a known heat release rate, specific features of the compartment, ignition source, and target set configuration, time to damage can be calculated.
  - Since heat release rate is expressed with a probability distribution, the time to damage can be expressed with a probability distribution



FIRE SEVERITY
Severity Factor Estimation Process

Severity factor is estimated using discretized probability distributions for heat release rate and non-suppression.



HRR Values	HRR1	HRR2	HRR3	HRR4	. . . .	HRRn
Individual Severity Factor	P_1	P_2	P_3	P_4	. . . .	P_n
Time to damage	t_1	t_2	t_3	t_4	. . . .	t_n
Prob. of supp. after damage	P_{NS1}	P_{NS2}	P_{NS3}	P_{NS4}	. . . .	P_{NSn}

FIRE SEVERITY
Heat Release Rate Distributions

The heat release rate of the following equipment classes have been defined:

Case	Ignition Source	HRR (Btu/s)	
		75th	98th
1	Vertical cabinets with qualified cable, fire limited to one cable bundle	65	200
2	Vertical cabinets with qualified cable, fire in more than one cable bundle	200	665
3	Vertical cabinets with unqualified cable, fire limited to one cable bundle	85	200
4	Vertical cabinets with unqualified cable, fire in more than one cable bundle closed doors	220	440
5	Vertical cabinets with unqualified cable, fire in more than one cable bundle open doors	220	950
6	Pumps (electrical fires)	65	200
7	Motors	30	65
8	Transient Combustibles	135	300

FIRE SEVERITY
Heat Release Rate Distribution - Example

Table E-1
HRR Distribution for Vertical Cabinets with Qualified Cables, Fire Limited to One Cable Bundle

Bin	Heat Release Rate (Btu/s)			Severity Factor (P_i)
	Lower	Upper	Point Value	
1	0	25	10.5	0.446
2	25	50	36	0.219
3	50	75	61	0.129
4	75	100	87	0.078
5	100	125	112	0.048
6	125	150	137	0.030
7	150	175	162	0.019
8	175	200	187	0.012
9	200	225	212	0.007
10	225	250	237	0.005
11	250	275	262	0.003
12	275	300	287	0.002
13	300	325	312	0.001
14	325	350	337	0.001
15	350	Infinity	405	0.001

FIRE SEVERITY
Severity Factor for Oil Spill Fires

- The severity factor for oil spills are recommended to be established from the following steps:

  1. Determine the amount of oil that can be spilled in the room.

  2. Assign a severity factor of 0.02 to a scenario consisting of 98% or more of the amount of oil spilled and ignited.

  3. Assign a severity factor of 0.98 to a scenario consisting of 10% of the amount of oil spilled and ignited.

FIRE SEVERITY
Severity Factor for Other Ignition Sources

- The following notes address ignition sources not covered in the preceding discussions:
  - Cable fires:
    - Heat release rate is established using fire propagation modeling
    - Severity factor = 1.0 may be used where target damage can be ascertained
  - High-energy arcing faults:
    - Severity factor = 1.0 within zone of influence
  - Catastrophic transformer fires in the transformer yard :
    - Severity factor = 1.0 within zone of influence
  - Non-catastrophic transformer fires in the transformer yard :
    - Generally not modeled, otherwise use severity factor = 1.0 within zone of influence
  - Other fires in the transformer yard:
    - Depending on the item burning, the heat release rate of similar devices may be used.

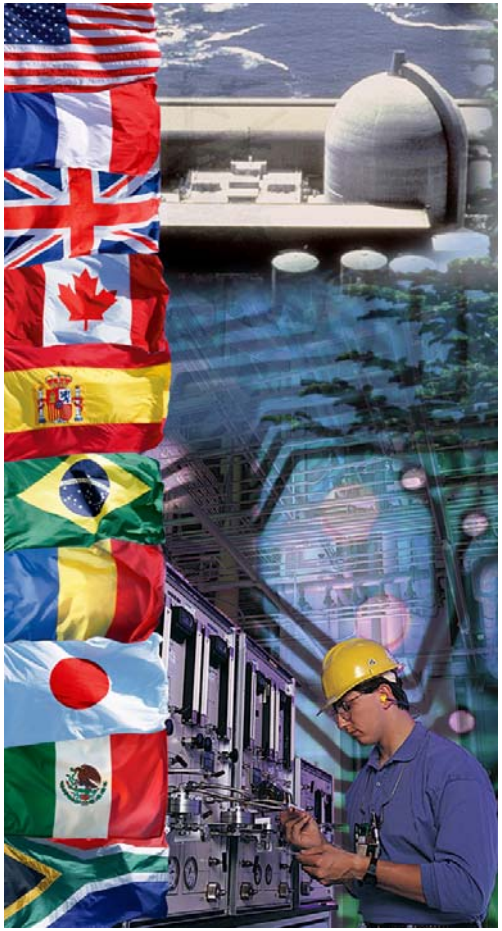
FIRE SEVERITY
Frequency Bins and HRR Distributions

Table 11-1
Recommended Severity Factors . . . for Ignition Sources in the Frequency Model

ID	Location	Ignition Source	HRR Distribution Category
1	Battery Room	Batteries	Electric motors
2	Containment (PWR)	Reactor coolant Pump	Pumps (Electrical)/Oil spills
4a	Control Room	Electrical cabinets	Applicable electrical cabinet
4b	Control Room	Main control board	See Appendix L
5	Control/Auxiliary/ Reactor Building	Cable fires caused by welding and cutting	Assume 1.0
6	Control/Auxiliary/ Reactor Building	Transient fires caused by welding and cutting	Transients
21	Plant-Wide Components	Pumps	Pump (Electrical)/Oil spills

FIRE SEVERITY
Concluding Remarks

- Severity Factor provides an adjustment to ignition frequency to account for the severity of the fire.
  - It is tied to the heat release rate
  - It is estimated in concert with probability of non-suppression
  - Specific cases have been developed
  - Guidance is provided for other cases



EPRI/NRC-RES FIRE PRA METHODOLOGY

Module III: Damage Criteria

Joint RES/EPRI Public Workshop
2007
Palo Alto, CA

A Collaboration of U.S. NRC Office of Nuclear Regulatory Research (RES) & Electric Power Research Institute (EPRI)

Damage Criteria
Damage Thresholds

- Damage (or Failure) Threshold: the minimum value of an exposure environment parameter that *can* lead to the failure of the damage target of interest within the timescale of the fire
  - Can be a temperature – exposure to high temperatures such as in a hot gas layer or fire plume
  - Can be a radiant heat flux – generally due to direct radiant heating from the luminous flame zone of a fire
  - In theory, it could be a minimum smoke density, but we aren't that smart (more on smoke shortly)

Damage Criteria
Damage Thresholds

- Damage thresholds are of primary interest to Task 8 – Scoping Fire Modeling
  - We use damage thresholds mainly when screening out specific fire ignition sources
    - If a fire source cannot damage any target, or ignite any secondary combustible, then we screen that source out of the analysis as non-threatening (more on Task 8 later)
  - *Also Note:* If an electrical cable is damaged, we assume that it will also be ignited
    - Arcing when a cable short circuits will ignite the cable based on testing experience

Damage Criteria
Damage Thresholds

- Damage Threshold is specific to the damage target and procedure deals mainly with the following:
  - Electrical Cables
    - Thermoset
    - Thermoplastic
  - Electronics and integrated circuit devices

- For other devices (e.g., motors, switchgear, etc.) look at the cables and supporting controls or electronics
  - Example: A pump is fed by power cables, and those cables are generally more vulnerable to fire damage than the pump itself

Damage Criteria
Damage Thresholds

- Some items are considered invulnerable to fire-induced damage:
  - Ferrous metal pipes and tanks
  - Passive components such as flow check valves
  - Concrete structural or partitioning elements except when considering random failure likelihood in multi-compartment scenarios
    - i.e., we *do not* consider fire-induced structural failure of concrete
- Things you still need to watch for:
  - Soldered piping (e.g., air/gas lines that are soldered copper)
  - Flexible boots/joints/sleeves on piping (e.g., the Vandellos scenario)
  - Exposed structural steel given a very large fire source (e.g., catastrophic loss of the main TG set – more later)

Damage Criteria
Damage Thresholds

- The following are defined as generic damage thresholds for the most common damage targets – cables:

Table H-1 Damage Criteria for Electrical Cables – Generic Screening Criteria for the Assessment of the Ignition and Damage Potential of Electrical Cables [See Ref 8-1]

Cable Type	Radiant Heating Criteria	Temperature Criteria
Thermoplastic	6 kW/m^2 (0.5 BTU/ft2s)	205°C (400°F)
Thermoset	11 kW/m^2 (1.0 BTU/ft2s)	330°C (625°F)

- And electronics:
  - 3 kW/m^2 (0.25 BTU/ft^2) and 65°C (150°F)
  - If needed, assume ignition properties same as thermoplastic cables: 6 kW/m^2 (0.5 BTU/ft^2) and 205°C (400°F).

Damage Criteria
Damage Thresholds

- For additional rules related to damage criteria, see H.1.1; e.g.:
  - Cables in conduit: potential damage targets, but will not contribute to fire growth and spread – no credit to conduit for delaying the onset of thermal damage.
  - Cables coated by a fire-retardant coating: treat as exposed cables for damage purposes – coating may slow the subsequent spread of fire, but we are NOT specific here.

Damage Criteria
Damage Thresholds

- Plant-specific or product-specific damage thresholds *may be used* if appropriate basis is established
  - Report provides some references for information specific to many popular types and brands of cables
  - Example:

Table H-4
Failure Temperatures for Specific Cable Products as Reported in Table 5 of Reference H.2

Cable Manufacturer	Description of Cable Tested	Failure Threshold (°C)
Brand Rex	Cross-linked polyethylene (XLPE) Insulation, Chlorosulfonated Polyethylene (CSPE) Jacket, 12 AWG, 3-Conductor (3/C), 600 Volt (V)	385
Rockbestos	Firewall III, Irradiation XLPE Insulation, Neoprene Jacket, 12 AWG, 3/C, 600 V	320-322
Raychem	Flamtrol, XLPE Insulation, 12 AWG, I/C, 600 V	385-388
Samuel Moore	Dekoron Polyset , Cross-Linked Polyolefin (XLPO) Insulation, CSPE Jacket, 12 AWG, 3/C and Drain	299-307
Anaconda	Single Conductors Removed From: Anaconda Y Flame- Guard Flame Retardant (FR) Ethylene Propylene (EP), Ethylene Propylene Rubber (EPR) Insulation, Chlorinated Polyethylene (CPE) Jacket, 12 AWG, 3/C, 600 V	381
Anaconda	Anaconda Flame-Guard EP, EPR Insulation, Individual CSPE Jacket, Overall CSPE Jacket, 12 AWG, 3/C, l000 V	394
Okonite	Okonite Okolon, EPR Insulation, CSPE Jacket, 12 AWG, I/C, 600 V	387

Damage Criteria
Damage Time

- It is both appropriate and desirable to consider damage time during Task 11 – Detailed Fire Modeling
  - At the threshold exposure condition, damage times may be prolonged (e.g., 30 minutes or more)
  - As exposure conditions increase in severity, time to damage decreases (e.g., to as little as a few seconds)
  - Consideration of time to damage allows for a more realistic assessment of the non-suppression probability
    - How long do you have to put the fire out before damage occurs?

Damage Criteria
Damage Time

- Two general approaches to damage time analysis:
  - Direct modeling of target thermal response
    - Use a fire model to predict the temperature response of the target
    - When the predicted temperature of the target reaches the damage threshold, assume target failure
    - Catch: need fire model that does target response calculation
  - Empirical approach (e.g. SDP)
    - Predict the peak exposure condition (temperature or heat flux)
    - Use a look-up table to estimate time to damage
    - Catch: look-up tables currently only available for generic thermoset and thermoplastic cables

Damage Criteria
Damage Time

- Example of the Time to Damage look-up tables:

Table H-5: Failure Time-Temperature Relationship for Thermoset cables (Table A.7.1 from reference H.6).

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

Damage Criteria
Smoke Damage

- Appendix T provides an extended discussion of current knowledge regarding smoke damage
  - This is about smoke and the failure of equipment
  - It is not about the impact of smoke on people

- We are interested in short-term damage
  - Within the time scale of the fire scenario including plant shutdown
  - We do not consider longer term issues such as corrosion leading to failure some days or weeks after a fire

Damage Criteria
Smoke Damage

- Bottom Line: Some components are known to be vulnerable to smoke damage, but it takes a dense exposure to cause short term damage

- So what are the vulnerable components?
  - High voltage switching equipment (arcing)
  - High voltage transmission lines (arcing)
  - Devices such as strip chart recorders that are dependent on fine mechanical motion (binding)
  - Un-protected printed circuit cards (deposition and shorting)
    - e.g., exposed within a panel and not provided with a protective coating

Damage Criteria
Smoke Damage

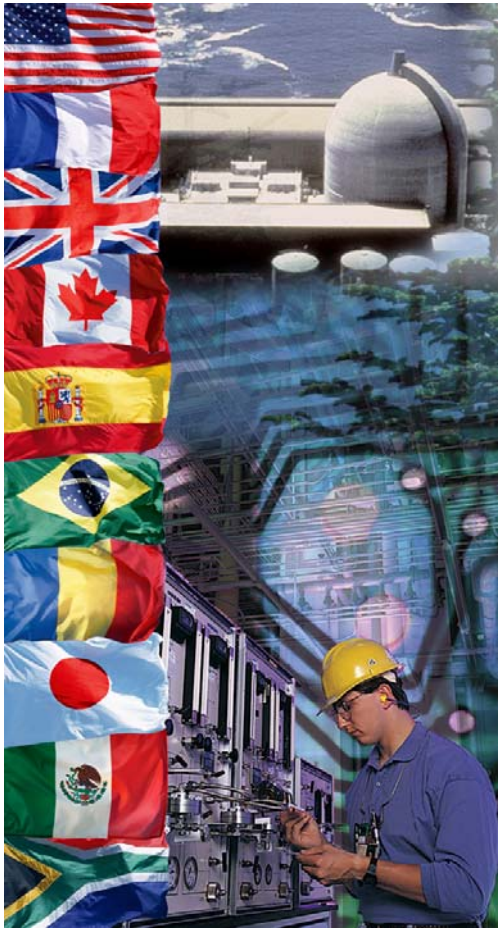
- Smoke damage is assessed on an empirical basis:
  - We don't set quantitative thresholds
  - We don't try to use fire models
  - You should consider the potential failure of vulnerable components due to smoke as a part of your damage target set

Damage Criteria
Smoke Damage

- Assume that vulnerable components adjacent to or connected to the fire source will be damaged by smoke:
  - Within the same electrical cabinet or housing as a fire source
    - e.g. given a panel fire, the whole panel is lost due to smoke and/or heat
  - In an adjacent cabinet if the cabinet-to-cabinet partitions is not well-sealed
  - In a common *stack* of electrical cubicles
  - In a nearby cabinet with a direct connection to the fire source
    - e.g., a shared or common bus-duct

Damage Criteria
End of Module

- Questions?
- Comments?
- Discussion?



EPRI/NRC-RES FIRE PRA METHODOLOGY

Module #: Scoping Fire Modeling Task 8 and Appendix F

Francisco Joglar
SAIC
Joint RES/EPRI Public Workshop
2007
Palo Alto, CA

A Collaboration of U.S. NRC Office of Nuclear Regulatory Research (RES) & Electric Power Research Institute (EPRI)

SCOPING FIRE MODELING
Objectives

The objectives of this module are:

- Describe the process of screening ignition sources
- Describe the concept of zone of influence (ZOI)
- Describe the recommended walk down
- Review the walk down forms
- Describe how to update the fire ignition frequencies calculated in Task 6 with the screening results

SCOPING FIRE MODELING
Interfaces

- Inputs for this task
  - PRA equipment list, Task 2
  - List of ignition sources in each compartment, Task 6
  - Room geometry
  - Types of ignition sources and targets

- Output from this task
  - Revised compartment fire ignition frequencies
  - List of potential fire scenarios to be analyzed in Task 11

SCOPING FIRE MODELING
Screening Ignition Sources

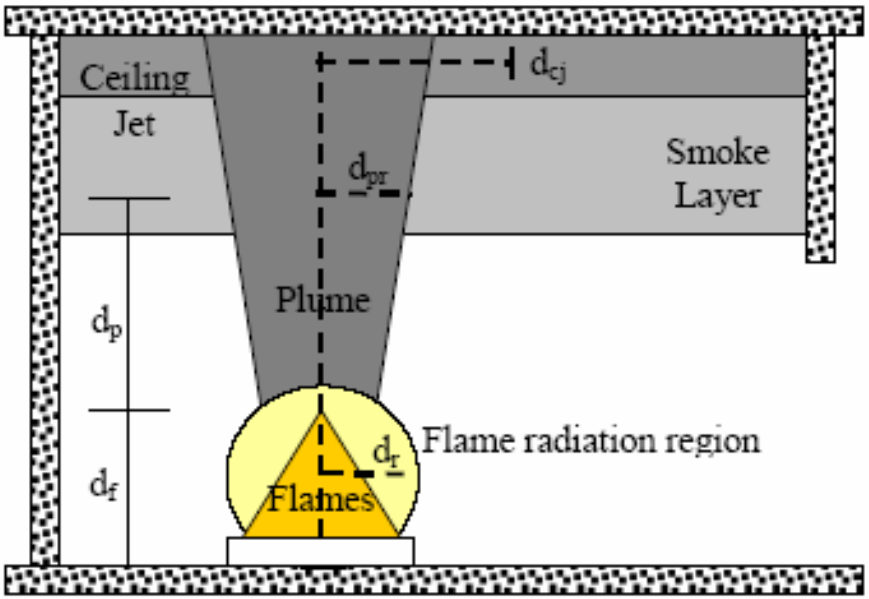
Any ignition source can be screened if a postulated fire will not damage or ignited equipment in the compartment.

- By screening the ignition source, its frequency contribution is eliminated, reducing the compartment frequency.
- It is recommended to use the 98th percentile of the probability distributions for peak HRR.
- A walk down is strongly recommended.

SCOPING FIRE MODELING
The Zone of Influence (ZOI)

The zone of influence is the region in the compartment where a target will be damaged if exposed to fire conditions generated by a specific ignition source.

- The ZOI has 5 distinct regions:
  - Flames
  - The fire plume
  - The ceiling jet
  - The hot gas layer
  - Flame radiation region



SCOPING FIRE MODELING
Task 8: Recommended Steps

5 steps for conducting Task 8

1. Preparation for walk down
2. Plant walk down and screen ignition sources
3. Verification of screened ignition sources
4. Calculation of severity factors
5. Calculation of revised fire frequency

SCOPING FIRE MODELING
Step 1: Preparation for Walk down

It is recommended that walk down forms are prepared for each compartment to be visited

- Create a list of ignition sources in each compartment.
  - Equipment counted in Task 6
  - Flag equipment in the PRA equipment list created in Task 2
  - Assigned a HRR to each ignition source (98th percentile of the pdf)
- Workshop Problem 08-01

- Collect damage criteria information for the equipment in the room
  - Qualified/Unqualified cables, solid state equipment etc.
- Workshop Problem 08-02

- Develop and document zone of influences in each compartment

SCOPING FIRE MODELING
Step 1: Example of ZOI Form

Plant _____
Fire Area _____
Compartment _____

Room Geometry

Opening area [m2]	2.0
Height of opening [m]	2.0
Room length [m]	32.0
Room width [m]	32.0
Room height [m]	6.4
Ambient temperature [C]	20

Material	Concrete
Thermal conductivity [kW/mK]	0.001
Density [kg/m3]	2000
Specific heat [kJ/kg]	0.88
Wall thickness [m]	0.30

Damage Criteria	UQ	Q
Temperature [C]	205	330
Heat flux [kW/m2]	6	11

Ignition Source

Fire duration [sec]	600
Fire diameter [m]	0.60
Fire location factor	1.00
Fire elevation [m]	0.00
Radiated fraction	0.40

ZONE OF INFLUENCE

PE/PVC Cable	Vertical cabinets with qualified cable, fire limited to one cable bundle	Vertical cabinets with qualified cable, fire in more than one cable bundle	Vertical cabinets with unqualified cable, fire limited to one cable bundle	Vertical cabinets with unqualified cable, fire in more than one cable bundle closed doors	Vertical cabinets with unqualified cable, fire in more than one cable bundle open doors	Pumps	Motors	Transient combustibles
98th Per HRR (kW)	211	702	211	464	1002	211	69	317
Flames (m)	1.4	2.6	1.4	2.1	3.1	1.4	0.7	1.7
Plume (m)	2.2	3.9	2.2	3.2	4.6	2.2	1.2	2.7
Ceiling Jet (m)	0.1	0.2	0.1	0.1	0.3	0.1	0.02	0.1
Flame Radiation (m)	1.1	1.9	1.1	1.6	2.3	1.1	0.6	1.3
Smoke Layer (kW)	3198	3198	3198	3198	3198	3198	3198	3198

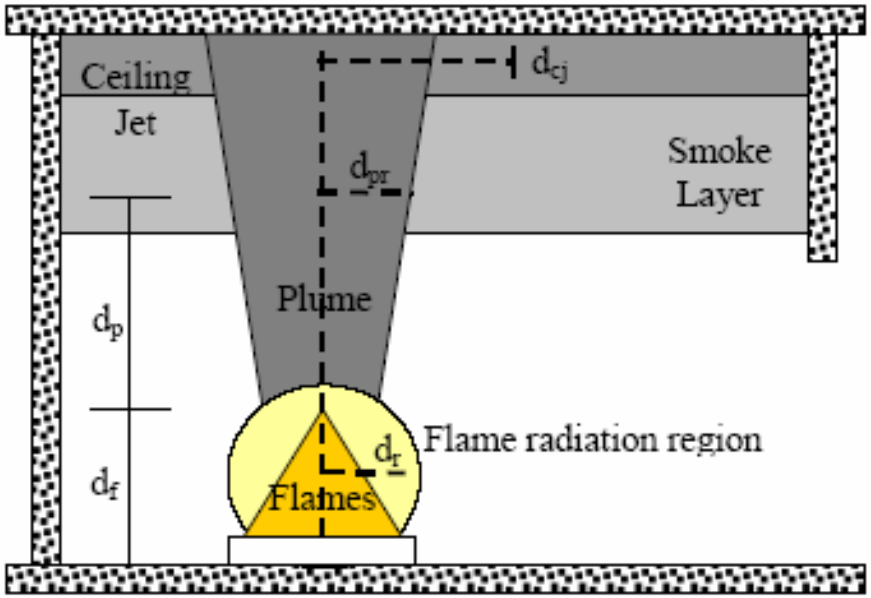
Qualified Cable								
98th Per HRR (kW)	211	702	211	464	1002	211	69	317
Flames (m)	1.4	2.6	1.4	2.1	3.1	1.4	0.7	1.7
Plume (m)	1.6	3.0	1.6	2.5	3.6	1.6	0.8	2.0
Ceiling Jet (m)	0.03	0.10	0.03	0.07	0.14	0.03	0.01	0.04
Flame Radiation (m)	0.8	1.4	0.8	1.2	1.7	0.8	0.4	1.0
Smoke Layer (kW)	6938	6938	6938	6938	6938	6938	6938	6938

SCOPING FIRE MODELING
Step 1: Alternative Models for Zone of Influence

- Smoke or hot gas layer: MQH model

$$T = T_{amb} + 6.85 \cdot \left(\frac{\dot{Q}_f^2}{A_o \sqrt{H_o} h_k A_T} \right)^{1/3}$$

$$h_k = \begin{cases} \sqrt{\dfrac{k \cdot d_m \cdot c_p}{t}} & t < t_p \\ \dfrac{k}{th} & t \geq t_p \end{cases} \qquad t_p = \frac{th^2}{4 \cdot \left(k / (d_m \cdot c_p) \right)}$$



Input Parameters:
- T_{amb}: Ambient temperature (°C)
- Q_f: Fire heat release rate (kW)
- A_o: Opening area (or sum of opening areas) (m^2)
- H_o: Height of opening [m]
- A_T: Internal surface area of the room (not including opening area) (m^2)
- k: Thermal conductivity of wall material (kW/m-°C)
- d_m: Density of wall material (kg/m^3)
- c_p: Specific heat of wall material (kJ/kg-°C)
- th: Wall thickness (m)
- t: Time value (sec)

SCOPING FIRE MODELING
Step 1: Example Calculation for Room Temperature

$$T = T_{amb} + 6.85 \cdot \left(\frac{\dot{Q}_f^2}{A_o \sqrt{H_o} h_k A_T} \right)^{1/3}$$

$$h_k = \begin{cases} \sqrt{\dfrac{k \cdot d_m \cdot c_p}{t}} & t < t_p \\ \dfrac{k}{th} & t \geq t_p \end{cases} \qquad t_p = \frac{th^2}{4 \cdot \left(k / (d_m \cdot c_p) \right)}$$

MQH Temperature Correlation	
Inputs	
Ambient temperature [C]	20
Duration [sec]	1200
Opening area [m2]	3
Height of opening [m]	3
Room length [m]	37
Room width [m]	37
Room height [m]	8
Thermal conductivity [kW/mK]	0.0014
Density [kg/m3]	2000
Specific heat [kJ/kg]	0.88
Wall thickness [m]	0.6
HRR [kW]	9500
Results	
Room Temp [C]	**327**

SCOPING FIRE MODELING
Step 1: Alternative Models for Zone of Influence

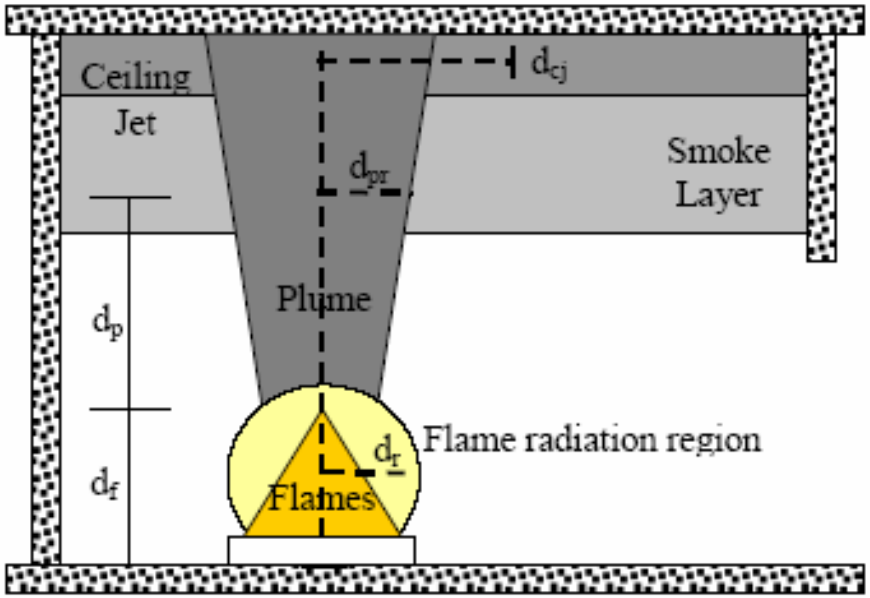
- Flame height and fire plume: Heskestad's models

$$L = 0.235\dot{Q}_f^{2/5} - 1.02D$$

Input Parameters:
- Q_f: Fire heat release rate (kW)
- D: Fire diameter (m)

$$T_{pl} = T_{amb} + 25\left(\frac{\left(k_f \dot{Q}_f (1-\chi_r)\right)^{2/5}}{\left((H_p - F_e) - z_o\right)}\right)^{5/3}$$

$$z_o = 0.083\dot{Q}_f^{2/5} - 1.02D$$



Input Parameters:
- T_{amb}: Ambient temperature (°C)
- k_f: Fire location factor
- Q_f: Fire heat release rate (kW)
- F_e: Fire elevation (m)
- H_p: Target height measured from the floor (m)
- X_r: Irradiated fraction of the heat release rate (FIVE recommends 0.4)
- D: Plume diameter (m)

SCOPING FIRE MODELING
Step 1: Example Calcs for Flame Height and Plume Temp

$$L = 0.235\dot{Q}_f^{2/5} - 1.02D$$

$$T_{pl} = T_{amb} + 25\left(\frac{\left(k_f \dot{Q}_f (1-\chi_r)\right)^{2/5}}{\left((H_p - F_e) - z_o\right)}\right)^{5/3}$$

$$z_o = 0.083\dot{Q}_f^{2/5} - 1.02D$$

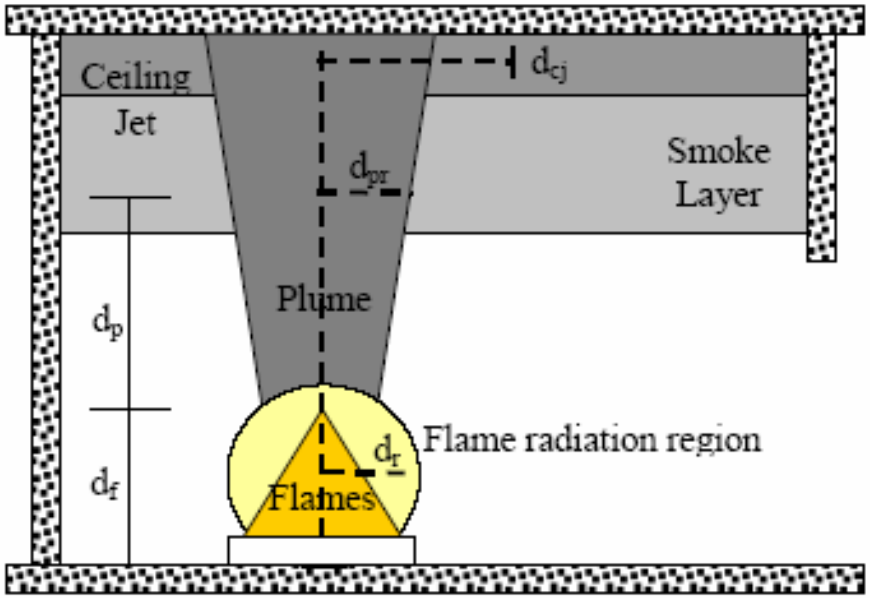
Heskdestad's Flame Height Correlation	
Inputs	
Fire diameter [m]	0.6
HRR [kW]	250
Results	[m]
Flame height [m]	**1.5**

Heskestad's Plume Temperature Correlati	
Inputs	
Ambient temperature [C]	20
Fire location factor	1
HRR [kW]	1375
Fire elevation [m]	0
Target Elevation [m]	3.7
Radiation Fraction	0.40
Fire Diameter [m]	1
Results	
Plume Temp [C]	**328**

SCOPING FIRE MODELING
Step 1: Alternative Models for Zone of Influence

- Flame Radiation: Point Source Model

$$\dot{q}''_{irr} = \frac{\dot{Q}_f \chi_r}{4\pi R^2}$$



Input Parameters:
- Q_f: Fire heat release rate (kW)
- R: Distance from flames (m)
- X_r: Irradiated fraction of the heat release rate (FIVE recommends 0.4)
- D: Fire diameter (m)

SCOPING FIRE MODELING
Step 1: Example calculation for flame radiation

$$\dot{q}''_{irr} = \frac{\dot{Q}_f \chi_r}{4\pi R^2}$$

Point Source Flame Radiation Model	
Inputs	
Fire heat release rate [kW]	317
Radiation fraction	0.40
Distance from flames [m]	1.5
Results	
Heat flux [kW/m2]	**4.5**

- Workshop problem 08-03

SCOPING FIRE MODELING
Step 2: Plant Walk down and Screening IS

During the walk down, equipment in the room is subjected to fire conditions from each ignition source using the ZOI.

- Take the opportunity to verify & improve task 6 counting
- Document location of ignition sources and reasons for screen/no-screen decisions
- If ignition sources are not screened, document location of affected equipment and which fire generated condition affected it.
- Do not screen:
  - Oil fires
  - Cables
  - Interconnected cabinets
- Workshop problem 08-04

SCOPING FIRE MODELING
Step 3: Verification of Screened IS

It is important to verify that fire damage to the ignition source itself is not risk significant

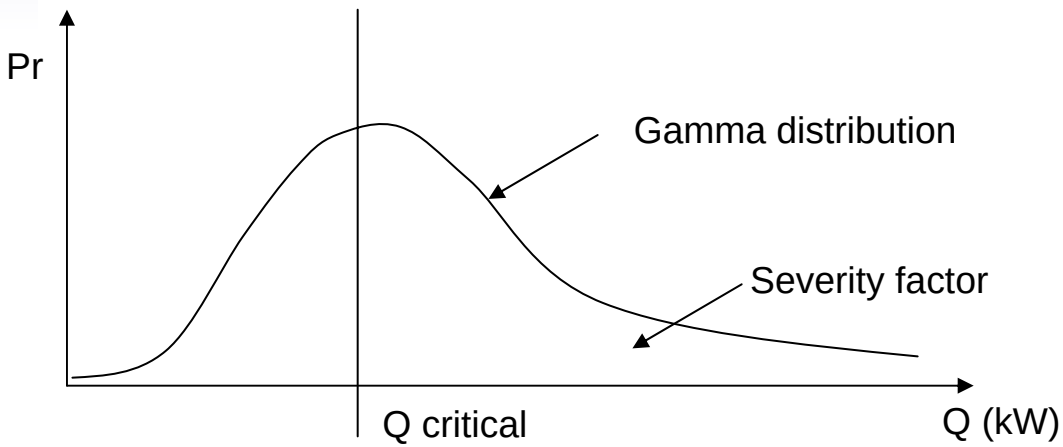
1. Do not screen equipment in the PRA equipment list
2. If loss of the ignition source results in a trip (automatic or manual) but no equipment contributing to the CCDP are lost, compare the ignition source fire frequency with the random frequency of the trip it causes.
3. If loss of the ignition source results in both a trip (automatic or manual) and loss of one or more components contributing to the CCDP, add a fire-induced sequence using the ignition source fire frequency and the corresponding CCDP model with the damaged components set to fail.

SCOPING FIRE MODELING
Task 8: Calculation of Severity Factors

For each unscreened ignition source, calculate the severity factor using the appropriate probability distribution for peak HRR.

- Determine the heat release rate required for damaging equipment
- This require information gathered during the walk downs!

SCOPING FIRE MODELING
Task 8: Calculation of Severity Factors



Case	Ignition Source	HRR kW (Btu/s)		Gamma Distribution	
		HRR	98th	α	β
1	Vertical cabinets with qualified cable, fire limited to one cable bundle	69	211	0.84	59.3
2	Vertical cabinets with qualified cable, fire in more than one cable bundle	211	702	0.7	216
3	Vertical cabinets with unqualified cable, fire limited to one cable bundle	90	211	1.6	41.5
4	Vertical cabinets with unqualified cable, fire in more than one cable bundle closed doors	232	464	2.6	67.8
5	Vertical cabinets with unqualified cable, fire in more than one cable bundle open doors	232	1002	0.46	386
6	Pumps (electrical fires)	69	211	0.84	59.3
7	Motors	32	69	2	11.7
8	Transient Combustibles	142	317	1.8	57.4

Table E-5
Discretized Distribution for Case 4 Heat Release Rate (Vertical Cabinets with Unqualified Cable, Fire in more than One Cable Bundle Closed Doors)

Bin	Heat Release Rate - kW (Btu/s)			Severity Factor (P_i)
	Lower	Upper	Point Value	
1	0 (0)	53 (50)	36 (34)	0.082
2	53 (50)	106 (100)	80 (76)	0.213
3	106 (100)	158 (150)	131 (124)	0.224
4	158 (150)	211 (200)	184 (174)	0.177
5	211 (200)	264 (250)	235 (223)	0.122
6	264 (250)	317 (300)	288 (273)	0.077
7	317 (300)	369 (350)	341 (323)	0.046
8	369 (350)	422 (400)	394 (373)	0.027
9	422 (400)	475 (450)	446 (423)	0.015
10	475 (450)	528 (500)	499 (473)	0.008
11	528 (500)	580 (550)	552 (523)	0.004
12	580 (550)	633 (600)	603 (572)	0.002
13	633 (600)	686 (650)	656 (622)	0.001
14	686 (650)	739 (700)	709 (672)	0.001
15	739 (700)	Infinity	816 (773)	0.001

- Workshop problem 08-05

SCOPING FIRE MODELING
Task 8: Calculation of Revised Fire Frequency

Plant _____
Fire Area _____
Compartment _____

Dmage Criteria	
Temperature [C]	205
Heat flux [kW/m2]	6

Pre-Walkdown Inputs		WALKDOWN INPUTS						Input	
Equip ID	HRR PDF	Fire Condition	Dist to Target (m)	Calculated HRR [kW]	Critical 98th HRR [kW]	Screen ?	SF	(Task 6) λ	Adjusted λ
Cabinet A	1	Flames	0.5	49	211	No	3.4E-01	1.0E-04	3.44E-05
Cabinet B	1	Plume	3	401	211	Yes	0.0E+00	1.0E-04	0
Cabinet C	3	Ceiling jet	1.5	4870	211	Yes	0.0E+00	1.0E-04	0
Pump	6	Plume	2	179	211	No	3.0E-02	1.0E-04	2.97E-06
Motor	7	Flame radiation	2.5	1178	69	Yes	0.0E+00	1.0E-04	0
					Adusted compartment frequency, λ_C =				3.7E-05

SCOPING FIRE MODELING
Concluding Remarks

Task 8 is intended for screening fixed ignition sources. As a result of the screening, the compartment frequencies may be reduced, and a preliminary list of potential fire scenarios for detailed evaluation in Task 11 is developed.

- A detailed walk down is recommended
- Analysts should take the opportunity to review the equipment count made for task 6 and/or improve it.

Workshop Problems on Task 8: Scoping Fire Modeling

This handout includes workshop problems on the different steps of Task 8: Scoping Fire Modeling. Problems are grouped by steps.

Step 1: Preparation for Walkdown

Step 1 has three sub-steps: 1) Estimate heat release rate for fixed ignition source screening, 2) Target and intervening combustibles damage or ignition criteria, and 3) Develop a zone of influence.

Workshop problem 08-01:

Step 1.1: Estimate heat release rate for fixed ignition source screening: Assign a heat release rate to the ignition sources depicted in the pictures of the following Table 08-01. For this exercise, assume that the plant has a mix of qualified and unqualified cables. The heat release rates are listed in Table E-1 of NUREG/CR-6850.

Table 08-01: Inputs for Workshop problems 1

Ignition Source	Table E-1 Case	98th Percentile HRR	Justification
Dry transformer			
Fire protection panel			
Ventilation sub-system			

Ignition Source	Table E-1 Case	98th Percentile HRR	Justification
Pumps			

Workshop Problem Set 08-02:

Step 1.2: Target and intervening combustible damage and ignition criteria: Assign damage criteria to the ignition sources depicted in Table 08-01. For this exercise, assume that the plant has a mix of thermoset and thermoplastic cable. Generic damage criteria are listed in Table H-1 of NUREG/CR-6850.

Table 08-02: Inputs for workshop problem 2

Target/Intervening Combustible	Damage Criteria	Justification
Cables in a ladder back tray		
Cables in a solid tray		
Theromset cable in a conduit		
Motor operated valve (MOV).		
Cabinet with a solid state device		

Workshop Problem Set 08-03

Step 1.3: Develop zone of influence: Calculate the heat release rate required for generating target damage for the following ignition source/target combination and determine if the ignition source can be screened. Use the engineering calculations described in NUREG-1805 for determining the heat release rate value.

- Target in the hot gas layer:
  - A cable tray target is located near the ceiling in a room approximately 21’ by 7’ and has a normally closed door on each end. The room is approximately 20’ high. The inside walls of the MCC room are reinforced concrete. There is one MCC cabinet in the room. The MCC cabinet has unqualified cable.

- Target subjected to flame impingement or fire plume temperatures:
  - A vertical cable tray is located 5’ ft from a floor based ventilation subsystem.

- Target subjected to flame radiation:
  - A conduit is located 3 ft from a battery charger with qualified cable.

Workshop Problem Set 08-04

***Step 2: Plant Walkdown*:** Inspect the ignition source and target combination in the pictures included in Table 08-03 and determine the appropriate zone of influence calculation necessary.

Table 08-03: Inputs for Workshop problems 1

Ignition Source	Ignition Source/Target	Zone of Influence	Distance

Ignition Source	Ignition Source/Target	Zone of Influence	Distance

Step 3: Verification of Screened Ignition Sources

No workshop problem for Step 3.

Workshop Problem Set 08-05

Step 4: Calculation of Severity Factors: Calculate the severity factors for the ignition source and target combinations listed in Workshop Problem 08-03. Use the results of Workshop Problem Set 08-03 as inputs to this exercise.

- Target in the hot gas layer

- Target subjected to flame impingement or plume temperatures

- Target subjected to flame radiation

Workshop Problem Set 08-06

Step 5: Calculation of Revised Compartment Fire Frequency: Determine a revised compartment ignition frequency for switchgear room A assuming the walkdown results listed in Table 08-04.

Table 08-04: Summary of Task 8 calculations

Equipment Description	Count	Fire Condition	Measured Distance (ft)	Table E-1 Case	Critical HRR (Table E-1)	Room Area (ft2)	Room Height (ft)	Calculated HRR (kW)	Room Temp (F)	Screened	Severity Factor	Count Task 8
Train A 4160 V Bus	8	flame or plume	1.7	9	Do Not Screen	1350	20	7	N/A	No	**1.00**	**8.00**
Train A 480 V Load Center	6	flame radiation	4.9	9	Do Not Screen	1350	20	401	N/A	No	**1.00**	**6.00**
Train A Station Service Transformer	1	flame radiation	4.5	9	Do Not Screen	1350	20	336	N/A	No	**1.00**	**1.00**
Train A Battery Charger	1	flame or plume	2.9	4	464	1350	20	25	264	No	**0.98**	**0.98**
Train A 125 VDC Bus	8	flame or plume	0.7	4	464	1350	20	1	264	No	**1.00**	**8.00**
Train A 125 VDC Panel	1	flame radiation	2.8	4	464	1350	20	129	264	No	**0.60**	**0.60**
Train A Inverter	1	flame radiation	2.0	4	464	1350	20	64	264	No	**0.88**	**0.88**

Table 08-05: Comparison of switchgear room A ignition frequency

Task 6	Switchgear Room A	**≈ 1.5E-02**
Task 8	Switchgear Room A	**≈ 1.5E-02**

Workshop Problems on Task 8: Scoping Fire Modeling

This handout includes workshop problems on the different steps of Task 8: Scoping Fire Modeling. Problems are grouped by steps.

Step 1: Preparation for Walkdown

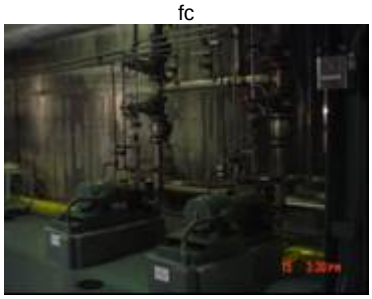
Step 1 has three sub-steps: 1) Estimate heat release rate for fixed ignition source screening, 2) Target and intervening combustibles damage or ignition criteria, and 3) Develop a zone of influence.

Workshop problem 08-01:

Step 1.1: Estimate heat release rate for fixed ignition source screening: Assign a heat release rate to the ignition sources depicted in the pictures of the following Table 08-01. For this exercise, assume that the plant has a mix of qualified and unqualified cables. The heat release rates are listed in Table E-1 of NUREG/CR-6850.

Table 08-01: Inputs for Workshop problems 1

Ignition Source	Table E-1 Case	98th Percentile HRR	Justification
Dry transformer	*7*	*69 kW*	*Table 8-1 in NUREG/CR-6850 suggests the use of the "Electric Motors" heat release rate probability distribution for dry transformers*
Fire protection panel	*4*	*464 kW*	*Fire protection panels have usually moderate to high combustible loading (including relays circuit cards etc.). It is therefore assumed that the fire may be able to propagate to more than one cable bundle.*
Ventilation sub-system	*7*	*69 kW*	*Table 8-1 in NUREG/CR-6850 suggests the use of the "Electric Motors" heat release rate probability distribution for ventilation sub-systems*

Ignition Source	Table E-1 Case	98th Percentile HRR	Justification
fc  Pumps	*6*	*211 kW*	*Table 8-1 in NUREG/CR-6850 suggests not to screen pumps due to the need of evaluating oil fires. Table E-1 suggests a heat release rate of 211 kW for electrical fires only.*

Workshop Problem Set 08-02:

Step 1.2: Target and intervening combustible damage and ignition criteria: Assign damage criteria to the ignition sources depicted in Table 08-01. For this exercise, assume that the plant has a mix of thermoset and thermoplastic cable. Generic damage criteria are listed in Table H-1 of NUREG/CR-6850.

Table 08-02: Inputs for workshop problem 2

Target/Intervening Combustible	Damage Criteria	Justification
Cables in a ladder back tray	*6 kW/m^2 (0.5 BTU/ft2s) or 205°C (400°F)*	*From Table H-1 in NUREG/CR-6850. Page H-2 of NUREG/CR-6850 suggests using the "weakest link" for determining damage criteria. Therefore the damage criteria for thermoplastic cable were selected.*
Cables in a solid tray	*6 kW/m^2 (0.5 BTU/ft2s) or 205°C (400°F)*	*Page H-2 of NUREG/CR-6850 suggests using the "weakest link" for determining damage criteria. Therefore the damage criteria for thermoplastic cable were selected. Solid trays are treated as conduits in this task. See second bullet in page H-1 of NUREG/CR-6850.*
Theromset cable in a conduit	*11 kW/m2 (1.0 BTU/ft2s) or 330°C (625°F)*	*From Table H-1 in NUREG/CR-6850. See second bullet in page H-1 of NUREG/CR-6850.*
Motor operated valve (MOV).	*6 kW/m^2 (0.5 BTU/ft2s) or 205°C (400°F)*	*See section H.2 in NUREG/CR-6850. Cables connecting the MOV are assumed thermoplastic in this example.*
Cabinet with a solid state device	*3 kW/m^2 (0.25 BTU/ft2s) or 65°C (150°F)*	*See section H.2 in NUREG/CR-6850.*

Workshop Problem Set 08-03

Step 1.3: Develop zone of influence: Calculate the heat release rate required for generating target damage for the following ignition source/target combination and determine if the ignition source can be screened. Use the engineering calculations described in NUREG-1805 for determining the heat release rate value.

- Target in the hot gas layer:
  - A cable tray target is located near the ceiling in a room approximately 21' by 7' and has a normally closed door on each end. The room is approximately 20' high. The inside walls of the MCC room are reinforced concrete. There is one MCC cabinet in the room. The MCC cabinet has unqualified cable.

The MQH room temperature correlation described in Section 2.6 of NUREG-1805 was selected for calculating the hot gas layer temperature in the room. Input values for the MQH model are listed in Table 08-03. Notice that a heat release rate of 600 kW generates room temperatures of approximately 205 ^{o}C. This calculation assumes a 20-min fire duration and one open door in the room.

Table 08-03: MQH room temperature correlation analysis

MCC Room	
Length [ft]:	*21*
Width [ft]:	*7*
Height [ft]:	*20*
MQH Temperature Correlation	
Inputs	
Ambient temperature [C]	*20*
Duration [sec]	*1200*
Opening area [m2]	*2*
Height of opening [m]	*2*
Room length [m]	*6*
Room width [m]	*2*
Room height [m]	*6*
Thermal conductivity [kW/mK]	*0.0014*
Density [kg/m3]	*2000*
Specific heat [kJ/kg]	*0.88*
Wall thickness [m]	*0.6*
HRR [kW]	*600*
Results	
Room Temp [C]	***205***

- Target subjected to flame impingement or fire plume temperatures:
  - A vertical cable tray is located 5’ ft from a floor based ventilation subsystem.

The Heskestad’ flame height and plume temperature correlations described in Chapter 3 and 9 of NUREG-1805 respectively were selected for calculating flame height and room temperature. Input values for the models are listed in Table 08-04 and Table 08-05. Notice that a heat release rate of 250 kW generates a flame height of 5’. In the case of the plume temperature correlation, a heat release rate of 165 kW generates damage temperatures of approximately 205 ^{o}C at the location of the target.

Table 08-04: Heskestad flame height correlation

Heskdestad's Flame Height Correlation		
Inputs		
Fire diameter [m]	*0.6*	
HRR [kW]	*250*	
Results	*[m]*	*[ft]*
Flame height [m]	***1.5***	***5.0***

Table 08-05: Heskestad plume temperature correlation

Heskestad Plume Temperature Correlation	
Inputs	
Ambient temperature [C]	*20*
Fire location factor	*1*
HRR [kW]	*165*
Fire elevation [m]	*0*
Target Elevation [m]	*1.5*
Radiation Fraction	*0.40*
Fire Diameter [m]	*1*
Results	
Plume Temp [C]	***202***

- Target subjected to flame radiation:
  - A conduit is located 3 ft from a battery charger with qualified cable.

The point source flame radiation model described in section 5.3 of NUREG-1805 was selected for calculating the incident heat flux at the location of the target. Input values for the point source model are listed in
Table 08-06. Notice that a heat release rate of 160 kW generates incident heat fluxes of 5 kW/m^2.

Table 08-06: Point source flame radiation model

Point Source Flame Radiation Model	
Inputs	
Fire heat release rate [kW]	*160*
Radiation fraction	*0.40*
Distance from flames [m]	*1*
Results	
Heat flux [kW/m2]	***5.1***

Workshop Problem Set 08-04

***Step 2: Plant Walkdown*:** Inspect the ignition source and target combination in the pictures included in Table 08-07 and determine the appropriate zone of influence calculation necessary.

Table 08-07: Inputs for Workshop problems 1

Ignition Source	Ignition Source/Target	Zone of Influence	Distance
	Fire protection panel/Conduits above	*Targets in the conduits will be affected by flame or plume conditions. Depending on the fire size and the characteristics of the room, the target may also be affected by hot gas layer temperatures.*	*~4'*
	Electrical cabinets/Conduit	*Targets in the conduits will be affected by flame or plume conditions. Depending on the fire size and the characteristics of the room, the target may also be affected by hot gas layer temperatures.*	*~3'*
	Ventilation Subsystem/Ventilation Subsystem	*Adjacent ventilation subsystem will be affected by flame radiation. Depending on the fire size and the characteristics of the room, the target may also be affected by hot gas layer temperatures.*	*~2'*

Ignition Source	Ignition Source/Target	Zone of Influence	Distance
	Ventilation Subsystem/MOV's	*MOV's and associated cables will be affected by flame radiation from a fire in the ventilation subsystem. Depending on the fire size and the characteristics of the room, the target may also be affected by hot gas layer temperatures.*	*~3'*
	Electrical cabinet/Cable tray	*Targets in the cable tray will be affected by flame or plume conditions. Depending on the fire size and the characteristics of the room, the target may also be affected by hot gas layer temperatures.*	*~4'*
	Transformer/Cable tray	*Targets in the cable tray will be affected by flame or plume conditions. Depending on the fire size and the characteristics of the room, the target may also be affected by hot gas layer temperatures.*	*~5'*
	Pump/Pump	*Adjacent pump will be affected by flame radiation. Depending on the fire size and the characteristics of the room, the target may also be affected by hot gas layer temperatures.*	*~4'*

Step 3: Verification of Screened Ignition Sources

No workshop problem for Step 3.

Workshop Problem Set 08-05

Step 4: Calculation of Severity Factors: Calculate the severity factors for the ignition source and target combinations listed in Workshop Problem 08-03. Use the results of Workshop Problem Set 08-03 as inputs to this exercise.

- Target in the hot gas layer
  - *Ignition source: MCC cabinet with unqualified cable*
  - *Heat release rate probability distribution: Case 4, Gamma distribution with* $\alpha = 2.6$ & $\beta = 67.8$.
  - *Critical heat release rate: 600 kW*
  - *Severity factor: Using a Microsoft Excel function,*
    SF = 1-GAMMADIST(600,2.6,67.8,TRUE) ≈ 0.004

- Target subjected to flame impingement or plume temperatures
  - *Ignition source: Ventilation subsystem*
  - *Heat release rate probability distribution: Case 7, Gamma distribution with* $\alpha = 2.0$ & $\beta = 11.7$.
  - *Critical heat release rate: 250 kW or 165 kW*
  - *Severity factor: Using a Microsoft Excel function,*
    SF = 1-GAMMADIST(250,2,11.7,TRUE) ≈ 1.2E-8 or
    SF =1-GAMMADIST(165,2,11.7,TRUE) ≈ 1.1E-5

- Target subjected to flame radiation
  - *Ignition source: Battery charger with qualified cable*
  - *Heat release rate probability distribution: Case 2, Gamma distribution with* $\alpha = 0.7$ & $\beta = 216$.
  - *Critical heat release rate: 160 kW*
  - *Severity factor: Using a Microsoft Excel function,*
    SF =1-GAMMADIST(160,0.7,216,TRUE) ≈ 0.83

It should be noted that this problem can also be solved using the discretized Gamma distribution tables in Appendix E of NUREG/CR-6850. Consider the target subjected to flame radiation, which was assigned the following Case 2 gamma distribution for heat release rate:

Bin	Heat Release Rate – kW (Btu/s)			Severity Factor (P_i)
	Lower	Upper	Point Value	
1	0 (0)	90 (85)	34 (32.7)	0.506
2	90 (85)	179 (170)	130 (123)	0.202
3	179 (170)	269 (255)	221 (209)	0.113
4	269 (255)	359 (340)	310 (294)	0.067
5	359 (340)	448 (425)	400 (379)	0.041
6	448 (425)	538 (510)	490 (464)	0.026
7	538 (510)	628 (595)	579 (549)	0.016
8	628 (595)	717 (680)	669 (634)	0.010
9	717 (680)	807 (765)	759 (719)	0.006
10	807 (765)	897 (850)	848 (804)	0.004
11	897 (850)	986 (935)	938 (889)	0.003
12	986 (935)	1076 (1020)	1028 (974)	0.002
13	1076 (1020)	1166 (1105)	1118 (1060)	0.001
14	1166 (1105)	1255 (1190)	1208 (1145)	0.001
15	1255 (1190)	Infinity	1462 (1386)	0.001

Figure 1: Table E-3 from NUREG/CR-6850

The severity factor is the sum of the severity factor column after the "Point Value" 160 kW (highlighted values in Figure 1).

Workshop Problem Set 08-06

Step 5: Calculation of Revised Compartment Fire Frequency: Determine a revised compartment ignition frequency for switchgear room A assuming the walkdown results listed in Table 08-08.

Table 08-08: Summary of Task 8 calculations

Equipment Description	Count	Fire Condition	Measured Distance (ft)	Table E-1 Case	Critical HRR (Table E-1)	Room Area (ft2)	Room Height (ft)	Calculated HRR (kW)	Room Temp (F)	Screened	Severity Factor	Count Task 8
Train A 4160 V Bus	8	flame or plume	1.7	9	Do Not Screen	1350	20	7	N/A	No	**1.00**	**8.00**
Train A 480 V Load Center	6	flame radiation	4.9	9	Do Not Screen	1350	20	401	N/A	No	**1.00**	**6.00**
Train A Station Service Transformer	1	flame radiation	4.5	9	Do Not Screen	1350	20	336	N/A	No	**1.00**	**1.00**
Train A Battery Charger	1	flame or plume	2.9	4	464	1350	20	25	264	No	**0.98**	**0.98**
Train A 125 VDC Bus	8	flame or plume	0.7	4	464	1350	20	1	264	No	**1.00**	**8.00**
Train A 125 VDC Panel	1	flame radiation	2.8	4	464	1350	20	129	264	No	**0.60**	**0.60**
Train A Inverter	1	flame radiation	2.0	4	464	1350	20	64	264	No	**0.88**	**0.88**

Table 08-09: Comparison of switchgear room A ignition frequency

Task 6	Switchgear Room A	**≈ 1.5E-02**
Task 8	Switchgear Room A	**≈ 1.5E-02**