U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Module III – Fire Analysis

Task 11c – Multi-Compartment Fire Analysis

Joint EPRI/NRC-RES Fire PRA Workshop

August 21-25, 2017

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

Multi-Compartment Fires
Objective

Fire scenarios involving multiple, interconnected or adjacent fire compartments are analyzed in this part of Task 11.

- Fire propagation
- Smoke propagation
- A rare event in U.S. NPP fire experience
- Screening process

Multi-Compartment Fires
Overall Approach

Multi-compartment analysis is focused on screening of potential scenarios before any detailed analysis is attempted.

- Single compartment analysis to be conducted before this step
- Reduce number of multi-compartment combinations
- Same analytical approach as in Detailed Fire Modeling

- Corresponding PRA Standard SRs: FSS-G1 through FSS-G6

Multi-Compartment Fires
Definitions

The following two terms are specifically defined for this part of the analysis:

- *Exposing Compartment*: The compartment where fire ignition occurs
- *Exposed Compartments*: The compartments to which fire from the exposing compartment propagates

Multi-Compartment Fires
Analysis Steps

The following steps define one possible approach for multi-compartment fire risk analysis:

- Step 1.c: Exposing and Exposed Compartments Matrix
- Step 2.c: First Screening–Qualitative
- Step 3.c: Second Screening–Low Fire Load Exposing Compartments
- Step 4.c: Third Screening–Frequency of Occurrence
- Step 5.c: Fourth Screening–CDF Based
- Step 6.c: Detailed Analysis
- Step 7.c: Document the Analysis

Multi-Compartment Fires
Step 1.c: Exposing and Exposed Compartments Matrix

Develop a matrix to identify all potential multi-compartment fire scenarios that start with an *exposing* compartment and propagate into a set of *exposed* compartments.

- Well defined pathways
- Means of propagation (i.e., hot gas, smoke, etc.)
- Special characteristics to be noted (e.g., self closing doors, fire dampers and vents near the ceiling)
- More than one exposed compartment
- Supported by a walk-down

Multi-Compartment Fires
Step 1.c: Exposing and Exposed Matrix (cont'd)

The following rules are suggested to identify multi-compartment scenarios:

- Postulate only one barrier failure (e.g., door left open)
  - Unless there is a clear reason to assume common cause failure of multiple barriers
- Assume minimal smoke damage
- Hot gas can travel to all physically possible exposed compartments
  - For a large number of compartments open into each other, detailed analysis may be warranted

Multi-Compartment Fires
Step 1.c: Exposing and Exposed Matrix (cont'd)

Example:

#	Exposing Compartment		#	Exposed Compartment		#	Path	Comments
	ID	Name		ID	Name			
1	9	SWG Access Room	1.1	10	Swtich Gear Room A	1.1.1	Door	The door is 3-hr rated and normally closed
						1.1.2	Opening	Ventilation opening between rooms with fusible link activated fire dampers.
			1.2	11	Swtich Gear Room B	1.2.1	Door	The door is 3-hr rated and normally closed
						1.2.2	Opening	Ventilation opening between rooms with fusible link activated fire dampers.
			1.3	--	Stairway	1.3.1	Door	The door is 3-hr rated and normally closed
2	4A	RHR Room	2.1	4B	AFW Pump Room	2.1.1	Door	The door is 3-hr rated and normally closed
						2.1.2	HVAC Duct	There are two HVAC ducts with opening in both compartments providing intake and discharge
			2.2	--	Stairway	2.2.1	Door	The door is 3-hr rated and normally closed
3	4B	AFW Pump Room	3.1	4A	RHR Room	3.1.1	Door	The door is 3-hr rated and normally closed
						3.1.2	HVAC Duct	There are two HVAC ducts with opening in both compartments providing intake and discharge

Multi-Compartment Fires
Step 2.c: First Screening – Qualitative

The first screening of the scenarios can be based on the contents of the exposed compartments.

The following criteria may be used:

- The exposed compartment(s) do not contain any Fire PRA components or cables, or
- The fire PRA components and cables of the exposed compartment(s) are identical to or less than those in the exposing compartment.

- Corresponding PRA Standard SRs: FSS-G2 and FSS-G3

Multi-Compartment Fires
Step 3.c: Second Screening–Low Fire Load

Exposing compartments that do not include combustible loading sufficient for generating a hot gas layer in any of the exposed compartments can be screened out.

- Conservative HRR values
  - Ignition sources with highest 98% HRR
  - Add HRR of intervening combustibles
- Determine damaging HRR values
  - Hand calculations
  - Hot gas layer damage in exposed compartment
- Compare HRRs
- Corresponding PRA Standard SRs: FSS-G2 and FSS-G3

Multi-Compartment Fires
Step 4.c: Third Screening–Occurrence Frequency

Scenario likelihood is established from the following three parameters:

- Ignition frequency
- Combined severity factor and non-suppression probability
  - HRR comparison (preceding step) can give the severity factor
  - May assume $P_{NS} = 1.0$
- Barrier failure probability
- Corresponding PRA Standard SRs: FSS-G2 through FSS-G5

Multi-Compartment Fires
Step 4.c: Third Screening / *Barrier Failure*

Generally, data on barrier failure probability is sparse, and what is available is subject to many limitations.

- Initial attempt may be based on a screening value
  - May use Pr(barrier failure) = 0.1 for screening

- For scenarios that do not screen out, may use the following:
  - For water curtain, use detection and suppression approach
  - Verify that there are no plant-specific barrier failure problems
  - Use the following *generic* barrier failure probabilities
    - Type 1 – fire, security, and water tight doors – 7.4E-03
    - Type 2 - fire and ventilation dampers – 2.7E-03
    - Type 3 - penetration seals, fire walls – 1.2E-03

Multi-Compartment Fires
Step 5.c: Fourth Screening–CDF Based

Those scenarios that survive the preceding screening steps may be screened based on their CDF.

- Assume all PRA components and cables of exposing and exposed compartments are failed
- Estimate CCDP
- Use scenario frequency of preceding step

- Corresponding PRA Standard SR: FSS-G6

Multi-Compartment Fires
Step 6.c: Detailed Analysis

Those scenarios that do not screen out in the preceding steps may be analyzed using the same methods as for single compartments.

- Same set of steps as in single compartment analysis
- Include target sets from exposed compartment(s)
- Corresponding PRA Standard SR: FSS-G1

Multi-Compartment Fires
Concluding Remarks

Multi-compartment fire analysis should be performed to ensure completeness of the Fire PRA.

- Compartment partitioning process (Task 1) has a direct impact on this task
- Develop a matrix of exposing and exposed compartments to ensure completeness
- Screening analysis is necessary to limit the level of effort
- Barrier failure probabilities should be treated conservatively
- May have to revisit some of the partitioning definitions