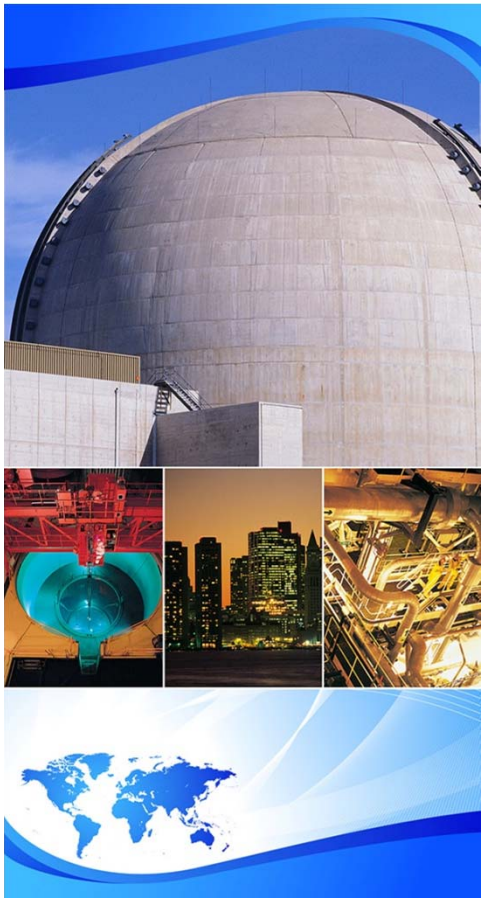

EPRI/NRC-RES FIRE PRA METHODOLOGY

Task 14 – Fire Risk Quantification

Fire PRA Workshop 2012
Bethesda, MD

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

Fire Risk Quantification
Purpose (per 6850/1011989)

- Purpose: describe the procedure for performing fire risk quantification.
- Provides a general method for quantifying the final Fire PRA Model to generate the final fire risk results

Fire Risk Quantification
Corresponding PRA Standard Element

- Primary match is to element FQ – Fire Risk Quantification
  - FQ Objectives (as stated in the PRA standard):

    (a) quantify the fire-induced CDF and LERF contributions to plant risk.(b) understand what are the significant contributors to the fire-induced CDF and LERF."

Fire Risk Quantification
HLRs (per the PRA Standard)

- HLR-FQ-A: Quantification of the Fire PRA shall quantify the fire-induced CDF
- HLR-FQ-B: The fire-induced CDF quantification shall use appropriate models and codes and shall account for method-specific limitations and features.
- HLR-FQ-C: Model quantification shall determine that all identified dependencies are addressed appropriately.
- HLR-FQ-D: The frequency of different containment failure modes leading to a fire-induced large early release shall be quantified and aggregated, thus determining the fire-induced LERF.

Fire Risk Quantification HLRs (per the PRA Standard)

- HLR-FQ-E: The fire-induced CDF and LERF quantification results shall be reviewed, and significant contributors to CDF and LERF, such as fires and their corresponding plant initiating events, fire locations, accident sequences, basic events (equipment unavailabilities and human failure events), plant damage states, containment challenges, and failure modes, shall be identified. The results shall be traceable to the inputs and assumptions made in the Fire PRA.
- HLR-FQ-F: The documentation of CDF and LERF analyses shall be consistent with the applicable SRs.

Fire Risk Quantification
Scope (per 6850/1011989)

- Task 14: Fire Risk Quantification
  - Obtaining best-estimate quantification of fire risk
  - Step 1–Quantify Final Fire CDF Model
  - Step 2–Quantify Final Fire LERF Model
  - Step 3–Conduct Uncertainty Analysis

Task 14: Fire Risk Quantification
General Objectives

Purpose: perform final (best-estimate) quantification of fire risk

- Calculate CDF/LERF as the primary risk metrics
- Include uncertainty analysis / sensitivity results (see Task 15)
- Identify significant contributors to fire risk
- Carry along insights from Task 13 to documentation but this is not an explicit part of “quantifying” the Fire PRA model
- Carry along residual risk from screened compartments and scenarios (Task 7); both (final fire risk and residual risk) are documented in Task 16 to provide total risk perspective

Task 14: Fire Risk Quantification
Inputs/Outputs

Task inputs:

- Inputs from other tasks:
  - Task 5 (Fire-Induced Risk Model) as modified/run thru Task 7 (Quantitative Screening),
  - Task 10 (Circuit Failure Mode Likelihood Analysis),
  - Task 11 (Detailed Fire Modeling), and
  - Task 12 (Post-Fire HRA Detailed Analysis)

Task 14: Fire Risk Quantification
Inputs/Outputs

- Output is the quantified fire risk results including the uncertainty and sensitivity analyses directed by Task 15 (Uncertainty and Sensitivity Analysis), all of which is documented per Task 16 (Fire PRA Documentation)

Task 14: Fire Risk Quantification
Steps in Procedure

Four major steps in the procedure*:

- Step 1: Quantify CDF
- Step 2: Quantify LERF
- Step 3: Perform uncertainty analyses including propagation of uncertainty bounds as directed under step 4 of Task 15
- Step 4: Perform sensitivity analyses as directed under step 4 of Task 15

* In each case, significant contributors are also identified

Task 14: Fire Risk Quantification
Quantification Process

Characteristics of the quantification process:

- Procedure is “general”; i.e., not tied to a specific method (event tree with boundary conditions, fault tree linking…)
- Can calculate CDF/LERF directly by explicitly including fire scenario frequencies or first calculate CCDP/CLERP and then combine with fire scenario frequencies
- Quantify consistent with relevant ASME-ANS PRA Standard (RA-Sa-2009) supporting requirements
  - Many cross-references from FQ to internal events section (Part 2) for most aspects of risk quantification

Task 14: Fire Risk Quantification
Steps in Procedure/Details

Step 1 (2): Quantify Final Fire CDF/LERF Model

Step 1.1 (2.1): Quantify Final Fire CCDP/CLERP Model

– Corresponding SRs: FQ-A1, A2, A3, A4, B1, C1, D1, E1

- Final HRA probabilities including dependencies
- Final cable failure probabilities
- Final cable impacts

Task 14: Fire Risk Quantification
Steps in Procedure/Details

Step 1.2 (2.2): Quantify Final Fire CDF/LERF Frequencies

– Corresponding SRs: FQ-A1-A4, B1, C1, D1, E1

- Final compartment frequencies
- Final scenario frequencies
- Final fire modeling parameters (i.e., severity factors, non-suppression probabilities, etc)

Task 14: Fire Risk Quantification
Steps in Procedure/Details

Step 1.3 (2.3): Identify Main Contributors to Fire CDF/LERF

- Corresponding SRs: FQ-A1-A3, E1

- Contributions by fire scenarios, compartments where fire ignition occurs, plant damage states, post-fire operator actions, etc.

Task 14: Fire Risk Quantification
Steps in Procedure/Details

Step 3: Propagate Uncertainty Distributions

- Probability distributions of epistemic uncertainties propagated through the CDF and LERF calculations
- Monte Carlo or Latin hypercube protocols

Task 14: Fire Risk Quantification
Steps in Procedure/Details

Step 4.1: Identification of Final Set of Sensitivity Analysis Cases

- Review sensitivity cases identified in Task 15
- Finalize sensitivity cases for Step 4.2

Task 14: Fire Risk Quantification
Steps in Procedure/Details

Step 4.2: CDF and/or LERF Computations and Comparison

- Mean CDF/LERF values computed for each sensitivity analysis case considered in Step 4.1
- The results should be compared with the base-case considered in Steps1 and 2

Mapping HLRs & SRs for the FQ technical element to NUREG/CR-6850, EPRI TR 1011989

Technical element	HLR	SR	6850/1011989 sections that cover SR	Comments
FQ	A	Quantification of the Fire PRA shall quantify the fire-induced CDF.		
		1	14.5.1.1, 14.5.1.2, 14.5.2.1, 14.5.2.2, 14.5.2.3	
		2	14.5.1.1, 14.5.1.2, 14.5.2.1, 14.5.2.2, 14.5.2.3	
		3	14.5.1.1, 14.5.1.2, 14.5.2.1, 14.5.2.2, 14.5.2.3	
		4	14.5.1.1, 14.5.1.2, 14.5.2.1, 14.5.2.2	
	B	The fire-induced CDF quantification shall use appropriate models and codes and shall account for method-specific limitations and features.		
		1	14.5.1.1, 14.5.1.2, 14.5.2.1, 14.5.2.2	
	C	Model quantification shall determine that all identified dependencies are addressed appropriately.		
		1	14.5.1.1, 14.5.1.2, 14.5.2.1, 14.5.2.2	
	D	The frequency of different containment failure modes leading to a fire-induced large early release shall be quantified and aggregated, thus determining the fire-induced LERF		
		1	14.5.1.1, 14.5.1.2, 14.5.2.1, 14.5.2.2	
	E	The fire-induced CDF and LERF quantification results shall be reviewed, and significant contributors to CDF and LERF, such as fires and their corresponding plant initiating events, fire locations, accident sequences, basic events (equipment unavailabilities and human failure events), plant damage states, containment challenges, and failure modes, shall be identified. The results shall be traceable to the inputs and assumptions made in the Fire PRA		
		1	14.5.1.1, 14.5.1.2, 14.5.2.1, 14.5.2.2, 14.5.2.3	
	F	The documentation of CDF and LERF analyses shall be consistent with the applicable SRs.		
		1	n/a	Documentation not covered in 6850/1011989
		2	n/a	Documentation not covered in 6850/1011989