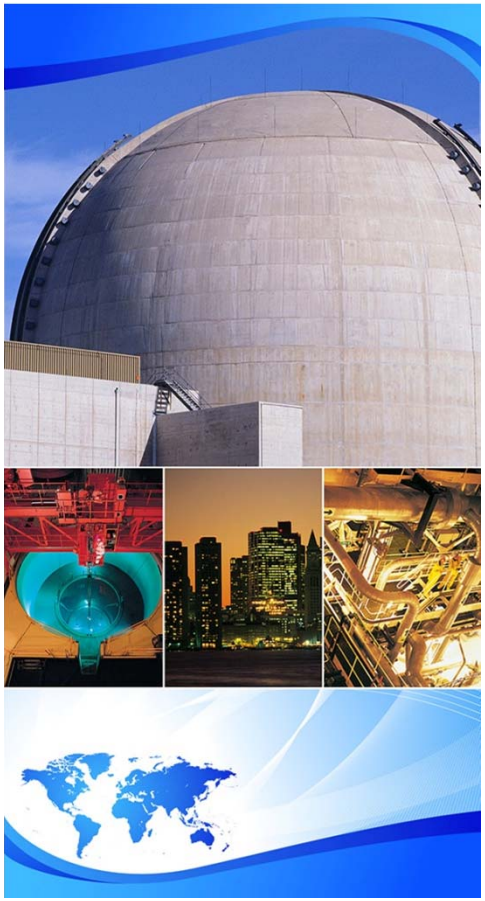


EPRI/NRC-RES FIRE PRA METHODOLOGY

Task 5 - Fire-Induced Risk Model Development

Joint RES/EPRI Fire PRA Workshop 2012
Bethesda MD

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

Fire PRA Risk Model
Purpose (per 6850/1011989)

- Purpose: describe the procedure for developing the Fire PRA model to calculate CDF, CCDP, LERF, and CLERP for fire ignition events.
- Fire Risk Model
  - Key input for Quantitative Screening (Task 7)
    - Used to quantify CDF/CCDP and LERF/CLERP
- Process is iterative to ensure appropriate agreement among fire PRA Component List, Fire PRA Model, cable identification, and quantitative screening

Fire PRA Risk Model
Corresponding PRA Standard Element

- Primary match is to element PRM - Equipment Selection
  - PRM Objectives (as stated in the PRA standard):

    "(a) to identify the initiating events that can be caused by a fire event and develop a related accident sequence model. (b) to depict the logical relationships among equipment failures (both random and fire induced) and human failure events (HFEs) for CDF and LERF assessment when combined with the initiating event frequencies."

Fire PRA Risk Model
HLRs (per the PRA Standard)

- HLR-PRM-A: The Fire PRA shall include the Fire PRA plant response model capable of supporting the HLR requirements of FQ.
- HLR-PRM-B: The Fire PRA plant response model shall include fire-induced initiating events, both fire induced and random failures of equipment, fire-specific as well as non–fire-related human failures associated with safe shutdown, accident progression events (e.g., containment failure modes), and the supporting probability data (including uncertainty) based on the SRs provided under this HLR that parallel, as appropriate, Part 2 of this Standard, for Internal Events PRA.
- HLR-PRM-C: The Fire PRA shall document the Fire PRA plant response model in a manner that facilitates Fire PRA applications, upgrades, and peer review.

Fire PRA Risk Model
Scope (per 6850/1011989)

- Task 5: Fire-Induced Risk Model Development
  - Constructing the PRA model
  - Step 1–Develop the Fire PRA CDF/CCDP Model.
  - Step 2–Develop the Fire PRA LERF/CLERP Model

Fire PRA Risk Model
General Comment/Observation

- Task 5 does not represent any changes from past practice, but what is modeled is largely based on Task 2 with HRA input from Task 12

- Bottom line – just “tweaking” your Internal Events PRA is probably NOT sufficient

Task 5: Fire Risk Model Development
General Objectives

Purpose: Configure the Internal Events PRA to provide fire risk metrics of interest (primarily CDF and LERF).

- Based on standard state-of-the-art PRA practices
- Intended to be applicable for any PRA methodology or software
- Allows user to quantify CDF and LERF, or conditional metrics CCDP and CLERP
- *Conceptually, nothing "new" here – need to "build the PRA model" reflecting fire induced initiators, equipment and failure modes, and human actions of interest*

Task 5: Fire Risk Model Development
Inputs/Outputs

Task inputs and outputs:

- Inputs from other tasks: [Note: inclusion of spatial information requires cable locations from Task 3]
  - Sequence considerations, initiating event considerations, and components from Task 2 (Fire PRA Component Selection),
  - Unscreened fire compartments from Task 4 (Qualitative Screening),
  - HRA events from Task 12 (Post-Fire HRA)
- Output to Task 7 (Quantitative Screening) which will further modify the model development
- Can always iterate back to refine aspects of the model

Task 5: Fire Risk Model Development
Steps in Procedure

Two major steps:

- Step 1: Develop CDF/CCDP model
- Step 2: Develop LERF/CLERP model

Task 5: Fire Risk Model Development
Steps in Procedure/Details

Step 1 (2): Develop CDF/CCDP (LERF/CLERP) models

Step 1.1 (2.1): Select fire-induced initiators and sequences and incorporate into the model.

– Corresponding SRs: PRM-A1, A2, A3, B1-B15

- Fire initiators are generally defined in terms of compartment fires or fire scenarios
- Each fire initiator is mapped to one or more internal event initiators to mimic the fire-induced impact to the plant.

Task 5: Fire Risk Model Development
Steps in Procedure/Details

Step 1.1 (2.1) – continued

- Initiating events previously screened in the internal events analysis may have to be reconsidered for the Fire PRA
- Final mapping of fire initiator to internal events initiators is based on cable routing information (task 3)
- The structure of Internal Events PRA should be reviewed to determine proper mapping of fire initiators

Task 5: Fire Risk Model Development
Steps in Procedure/Details

Step 1.1 (2.1) – continued

- The Internal Events PRA should have the capability to quantify CDF and LERF sequences

- Internal events sequences form bulk of sequences for Fire PRA, but a search for new sequences should be made (see Task 2). Some new sequences may require new logic to be added to the PRA model

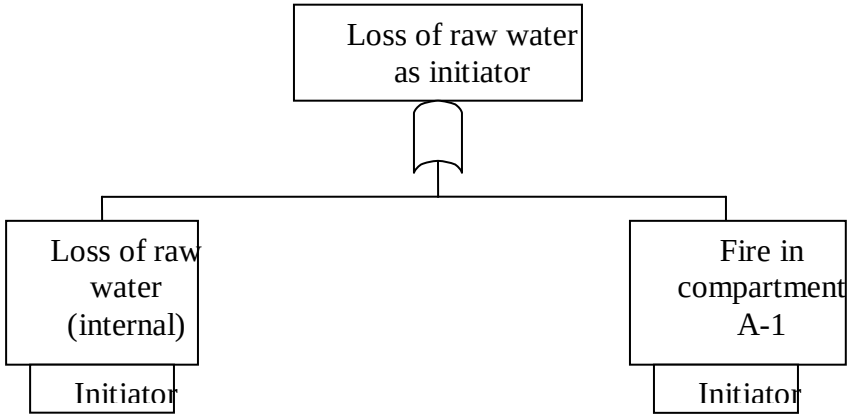
Task 5: Fire Risk Model Development
Steps in Procedure/Details

Step 1.1 (2.1) - continued

- Plants that use fire emergency procedures (FEPs) may need special models to address unique fire-related actions (e.g., pre-defined fire response actions and MCR abandonment).

- Some human actions may induce new sequences not covered in Internal Events PRA and can “fail” components
  - Example: SISBO, or partial SISBO

Task 5: Fire Risk Model Development
Steps in Procedure/Details



Example of new logic with a fire-induced loss of raw water initiating event

Task 5: Fire Risk Model Development
Steps in Procedure/Details

Step 1.2 (2.2): Incorporate fire-induced equipment failures

- Corresponding SRs: PRM-A4, B3, B6, B9

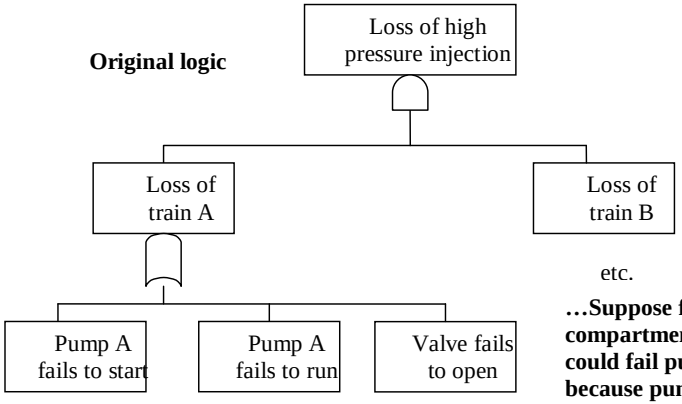
- Fire PRA database documents list of potentially failed equipment for each fire compartment

- Basic events for fire-induced spurious operations are defined and added to the PRA model (FAQ 08-0047)

- Inclusion of spatial information requires equipment and cable locations
  - May be an integral part of model logic, or handled with manipulation of a cable location database, etc.

Task 5: Fire Risk Model Development
Steps in Procedure/Details

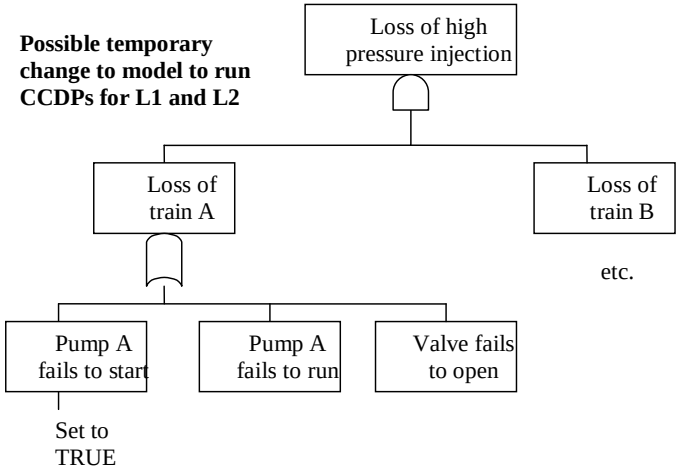
Original logic



etc.

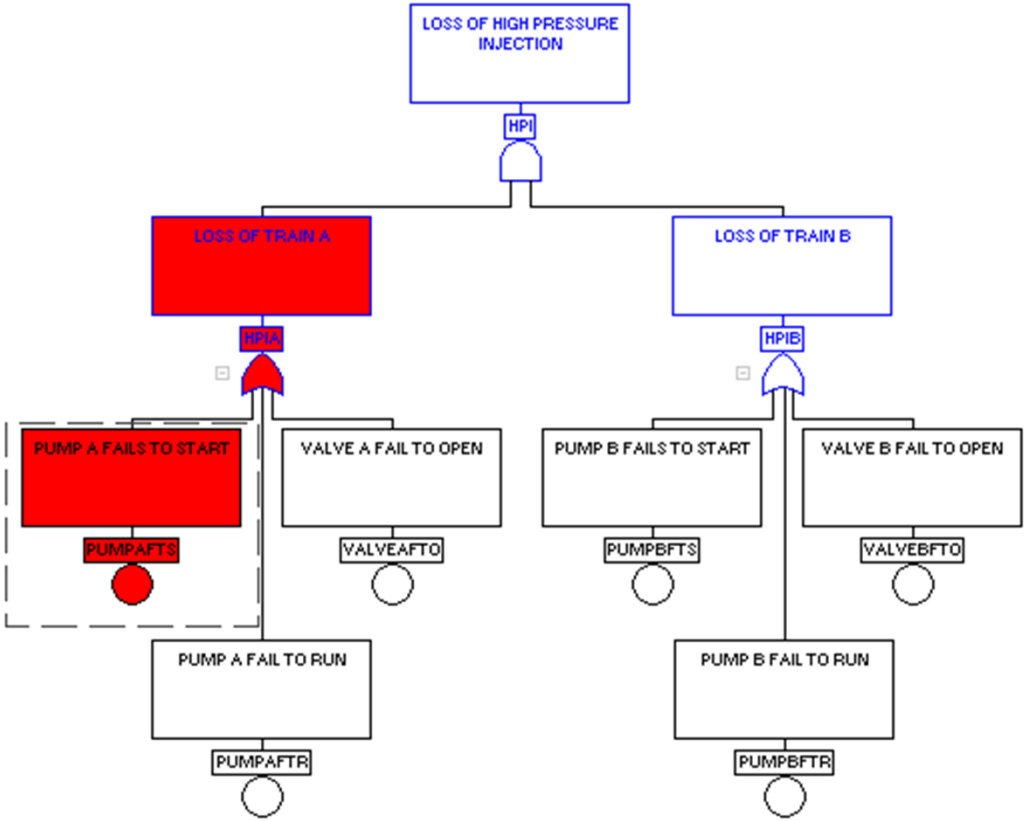
…Suppose fire in compartment L1 or L2 could fail pump A because pump A is in L1 and cable for pump A is in L2 …

Possible temporary change to model to run CCDPs for L1 and L2

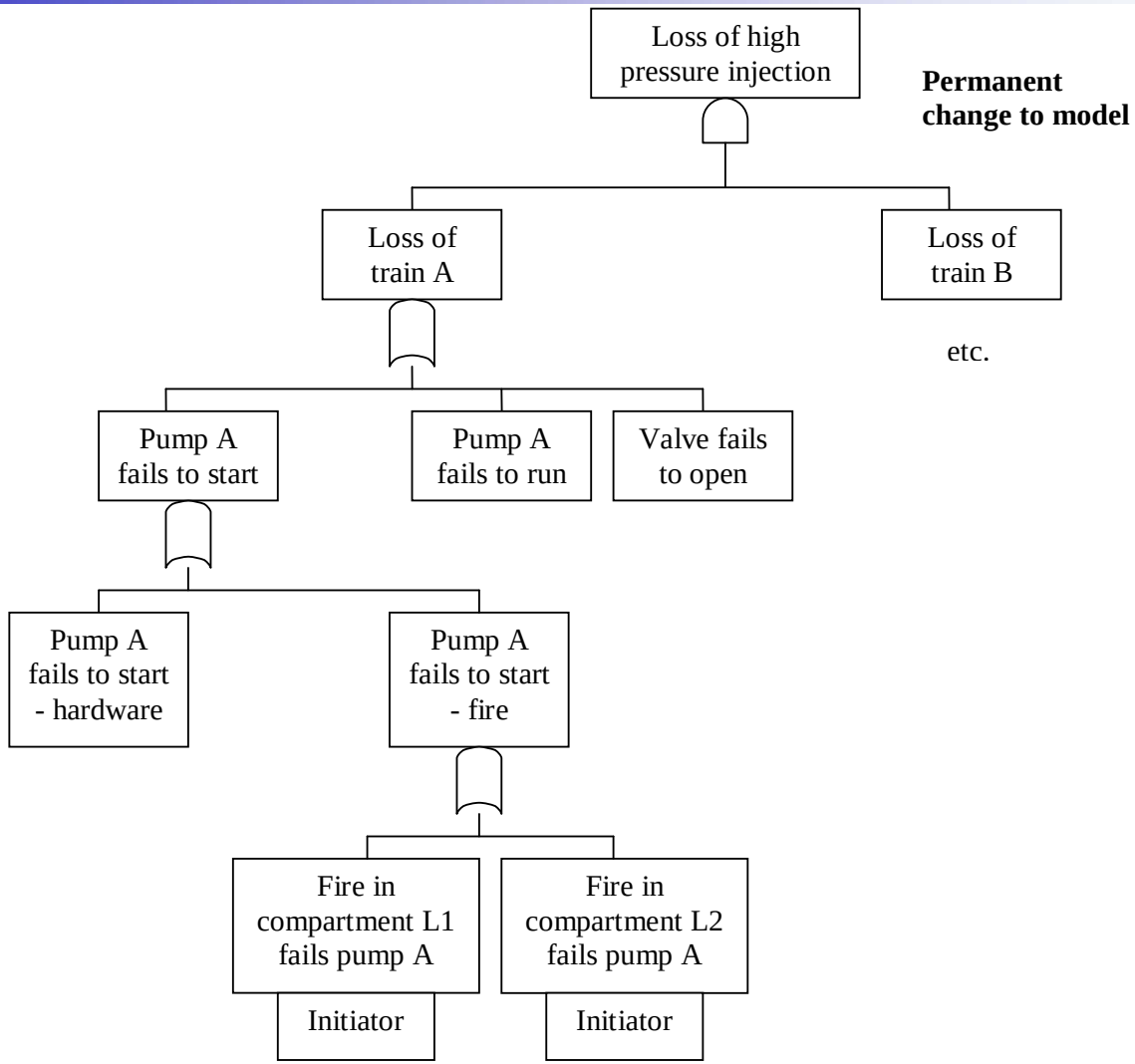


etc.

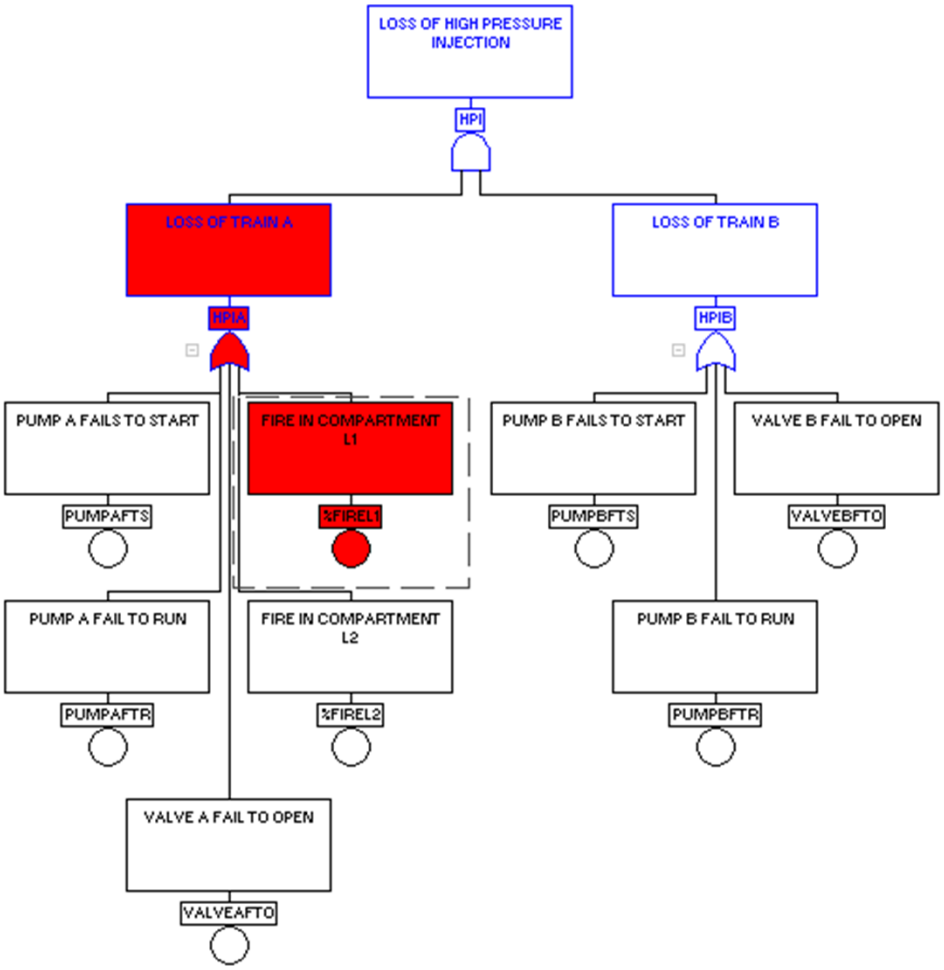
Task 5: Fire Risk Model Development
Steps in Procedure/Details



Task 5: Fire Risk Model Development
Steps in Procedure/Details



Task 5: Fire Risk Model Development
Steps in Procedure/Details



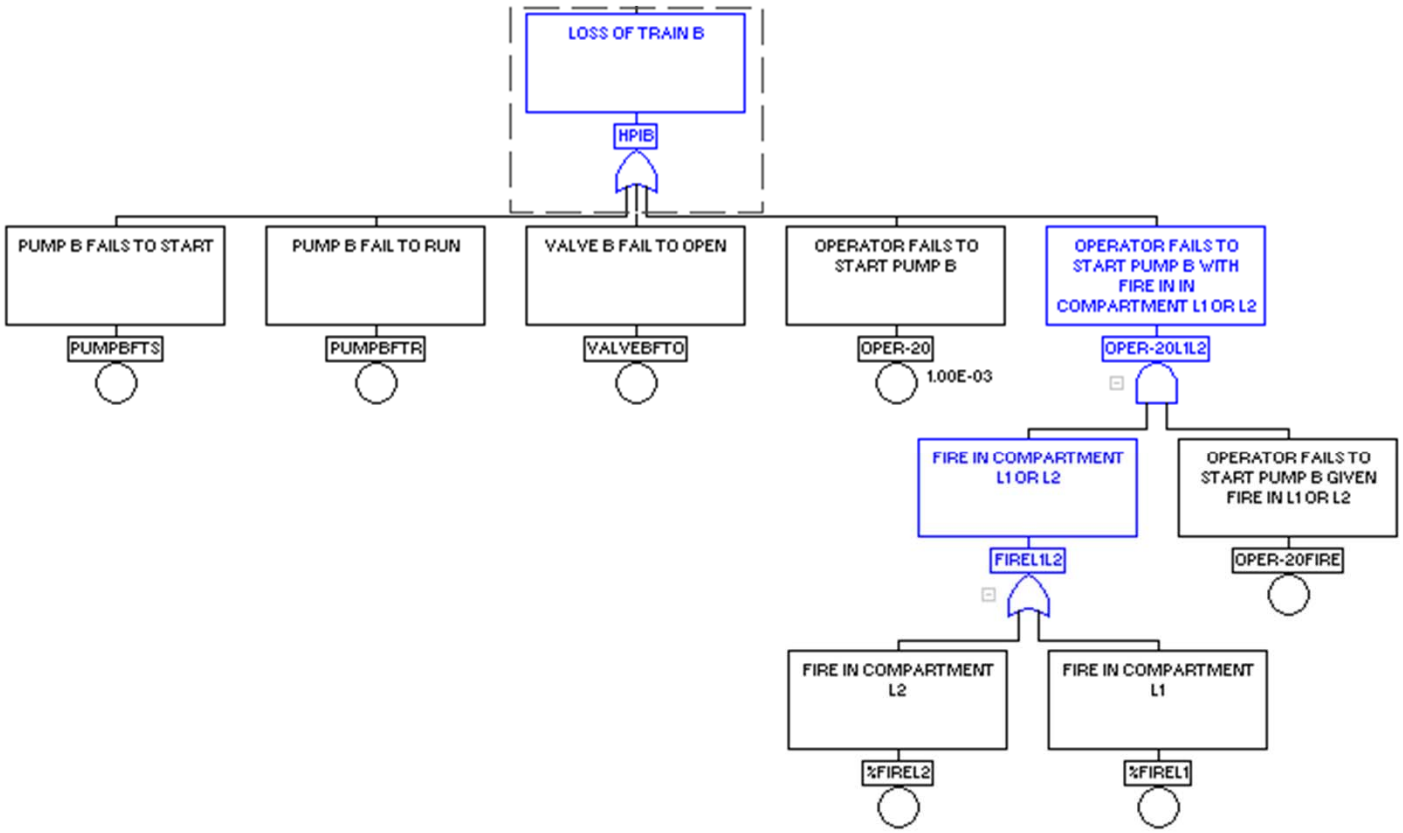
Task 5: Fire Risk Model Development
Steps in Procedure/Details

Step 1.3 (2.3): Incorporate fire-induced human failures

– Corresponding SRs: PRM-B9, B11

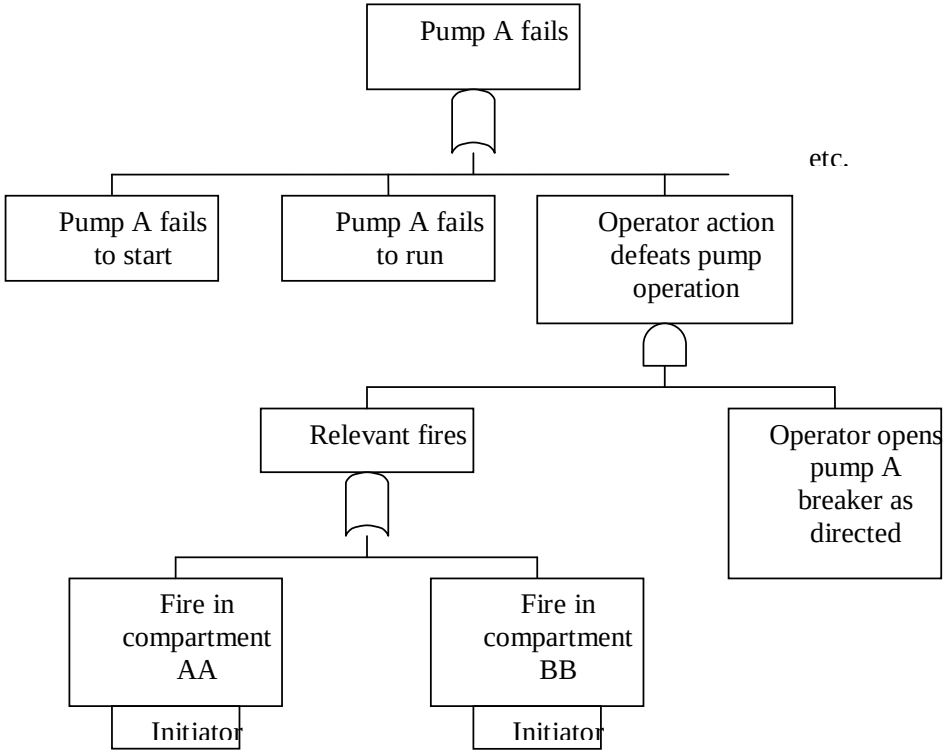
- New fire-specific HFEs may have to be added to the model to address actions specified in FEPs [Note: all HFEs will be set at screening values at first, using Task 12 guidance]
- Successful operator actions may temporarily disable ("fail") components

Task 5: Fire Risk Model Development
Steps in Procedure/Details



Task 5: Fire Risk Model Development
Steps in Procedure/Details

Suppose a proceduralized manual action carried out for fires in compartments AA & BB defeats Pump A operation by de-energizing the pump (opening its breaker drawer)…



Sample Problem Exercise for Task 5

- Distribute blank handout for Task 5, Steps 1 and 2
- Distribute completed handout for Task 5, Steps 1 and 2
- Question and Answer Session

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

Technical element	HLR	SR	6850/1011989 sections that cover SR	Comments
PRM	A	The Fire PRA shall include the Fire PRA plant response model capable of supporting the HLR requirements of FQ.		
		1	5.5.1.1, 5.5.2.1	
		2	5.5.1.1, 5.5.2.1	
		3	5.5.1.1, 5.5.2.1	
		4	5.5.1.1, 5.5.1.2, 5.5.2.1, 5.5.2.2	

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

Technical element	HLR	SR	6850/1011989 sections that cover SR	Comments
PRM	B	The Fire PRA plant response model shall include fire-induced initiating events, both fire induced and random failures of equipment, fire-specific as well as non–fire-related human failures associated with safe shutdown, accident progression events (e.g., containment failure modes), and the supporting probability data (including uncertainty) based on the SRs provided under this HLR that parallel, as appropriate, Part 2 of this Standard, for Internal Events PRA.		
		1	5.5.1.1, 5.5.2.1	
		2	5.5.1.1, 5.5.2.1	
		3	5.5.1.1, 5.5.1.2, 5.5.2.1, 5.5.2.2	
		4	5.5.1.1, 5.5.2.1	
		5	5.5.1.1, 5.5.2.1	
		6	5.5.1.1, 5.5.1.2, 5.5.2.1, 5.5.2.2	
		7	5.5.1.1, 5.5.2.1	
		8	5.5.1.1, 5.5.2.1	
		9	5.5.1.1, 5.5.1.2, 5.5.1.3, 5.5.2.1, 5.5.2.2, 5.5.2.3	
		10	5.5.1.1, 5.5.2.1	
		11	5.5.1.1, 5.5.1.3, 5.5.2.1, 5.5.2.3	
		12	5.5.1.1, 5.5.2.1	
		13	5.5.1.1, 5.5.2.1	
		14	5.5.1.1, 5.5.2.1	
		15	5.5.1.1, 5.5.2.1	
		12	5.5.1.1, 5.5.2.1	
		13	5.5.1.1, 5.5.2.1	
		14	5.5.1.1, 5.5.2.1	
		15	5.5.1.1, 5.5.2.1	

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

Technical element	HLR	SR	6850/1011989 sections that cover SR	Comments
	C	The Fire PRA shall document the Fire PRA plant response model in a manner that facilitates Fire PRA applications, upgrades, and peer review.		
		1	n/a	Documentation not covered in 6850/1011989