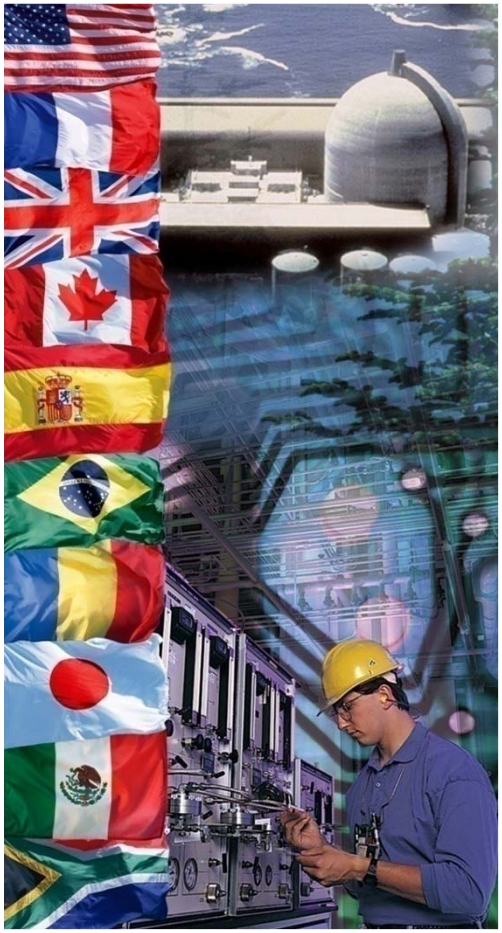

EPRI/NRC-RES FIRE PRA METHODOLOGY

Task 2 - Fire PRA Component Selection

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Joint RES/EPRI Fire PRA Training Workshop 2012
Bethesda, MD

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

Component Selection
Purpose (per 6850/1011989)

- Purpose: describe the procedure for selecting plant components to be modeled in a Fire PRA
- Fire PRA Component List
  - Key source of information for developing Fire PRA Model (Task 5)
    - Used to identify cables that must be located (Task 3)
- Process is iterative to ensure appropriate agreement among fire PRA Component List, Fire PRA Model, and cable identification

Corresponding PRA Standard Element

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

    "Select plant equipment that will be included/credited in the fire PRA plant response model."

HLRs (per the PRA Standard)

- HLR-ES-A: The Fire PRA shall identify equipment whose failure caused by an initiating fire including spurious operation will contribute to or otherwise cause an initiating event (6 SRs)
- HLR-ES-B: The Fire PRA shall identify equipment whose failure including spurious operation would adversely affect the operability/functionality of that portion of the plant design to be credited in the Fire PRA (5 SRs)
- HLR-ES-C: The Fire PRA shall identify instrumentation whose failure including spurious operation would impact the reliability of operator actions associated with that portion of the plant design to be credited in the Fire PRA (2 SRs)
- HLR-ES-D: The Fire PRA shall document the fire PRA equipment selection, including that information about the equipment necessary to support the other fire PRA tasks (e.g. equipment identification, equipment type, normal, desired, failed states of equipment) in a manner that facilitates fire PRA applications, upgrades, and peer review (1 SR)

Task 2: Fire PRA Component Selection
Scope (per 6850/1011989)

Fire PRA Component List should include the following major categories of equipment:

- Equipment whose fire-induced failure (including spurious actuation) causes an initiating event
- Equipment needed to perform mitigating safety functions and to support operator actions
- Equipment whose fire-induced failure or spurious actuation may adversely impact credited mitigating safety functions
- Equipment whose fire-induced failure or spurious actuation may cause inappropriate or unsafe operator actions

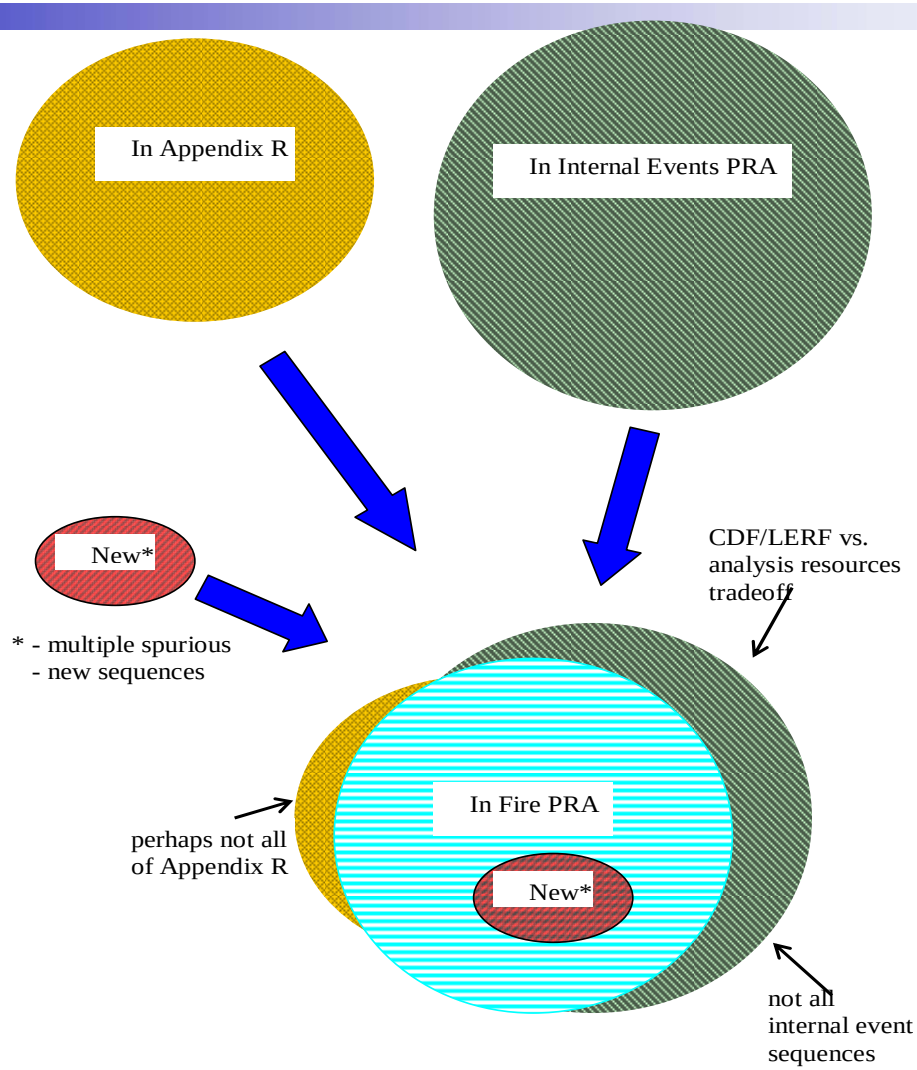
Component Selection
Approach (per 6850/1011989)

- Step 1: Identify Internal Events PRA sequences to include in fire PRA Model (necessary for identifying important equipment)
- Step 2: Review Internal Events PRA model against the Fire Safe Shutdown (SSD) Analysis and reconcile differences in the two analyses (including circuit analysis approaches)
- Step 3: Identify fire-induced initiating events based on equipment affected
- Step 4: Identify equipment subject to fire-induced spurious operation that may challenge the safe shutdown capability
- Step 5: Identify additional mitigating, instrumentation, and diagnostic equipment important to human response
- Step 6: Include “potentially high consequence” related equipment
- Step 7: Assemble the Fire PRA Component List

Component Selection
General Observations

- Two major sources of existing information are used to generate the Fire PRA Component List:
    - Internal Events PRA model
    - Fire Safe Shutdown Analysis (Appendix R assessment)
- Just "tweaking" your Internal Events PRA is probably NOT sufficient – requires additional effort
  - Consideration of fire-induced spurious operation of equipment
  - Potential for undesirable operator actions due to spurious alarms/indications
  - Additional operator actions for responding to fire (e.g., opening breakers to prevent spurious operation)
- Just crediting Appendix R components may NOT be conservative
  - True that all other components in Internal Events PRA will be assumed to fail, but:
    - May be missing components with adverse risk implications (e.g., event initiators or complicatd SSD response)
    - May miss effects of non-modeled components on credited (modeled) systems/components and on operator performance
    - Still need to consider non-credited components as sources of fires

Task 2: Fire PRA Component Selection
Overview of Scope



Task 2: Fire PRA Component Selection
Assumptions

The following assumptions underlie this procedure:

- A good quality Internal Events PRA and Appendix R Safe Shutdown (SSD) analysis are available
- Analysts have considerable collective knowledge and understanding of plant systems, operator performance, the Internal Events PRA, and Appendix R SSD analysis
- Steps 4 thru 6 are applied to determine an appropriate number of spurious actuations to consider
  - Configurations, timing, length of sustained spurious actuation, cable material, etc., among reasons to limit what will be modeled
  - Note that HS duration is a current FAQ topic…

From: Lessons Learned and Insights *In-process FAQs …*

- FAQ 08-0051
  - Issue:
    - The guidance does not provide a method for estimating the duration of a hot short once formed
    - This could be a significant factor for certain types of plant equipment that will return to a “fail safe” position if the hot short is removed or if MSO concurrence could trigger adverse impacts
  - General approach to resolution:
    - Analyze the cable fire test data to determine if an adequate basis exists to establish hot short duration distributions
  - Status:
    - Approved, but limited to AC hot shorts only
    - Will be revisited with lessons learned from DESIREE-FIRE test results for DC hot shorts (NUREG/CR-7100)

Task 2: Fire PRA Component Selection
Inputs/Outputs

Task inputs and outputs:

- Inputs from other tasks: equipment considerations for operator actions from Task 12 (Post-Fire HRA)
- Inputs from the MSO Expert Panel Reviews
- Could use inputs from other tasks to show equipment does not have to be modeled (e.g., Task 9 – Detailed Circuit Analysis or Task 11 - Fire Modeling to show an equipment item cannot spuriously fail or be affected by possible fires)
- Outputs to Task 3 (Cable Selection) and Task 5 (Risk Model)
- Choices made in this task set the overall analysis scope

Task 2: Fire PRA Component Selection
Steps In Procedure/Details

Step 1: Identify sequences to include and exclude from Fire PRA

- Some sequences can generally be excluded
  - Sequences requiring passive/mechanical failures that can not be initiated by fires (e.g., pipe-break LOCAs, SGTR, vessel rupture)
  - Sequences that can be caused by a fire but are low frequency (e.g., ATWS in a PWR)
  - It may be decided to not model certain systems (i.e., assume failed for Fire PRA) thereby excluding some sequences (e.g., main feedwater as a mitigating system not important)
- Possible additional sequences (recommend use of expert panel to address plant specific considerations)
  - Sequences associated with spurious operation (e.g., vessel/SG overfills, PORV opening, letdown or other pressure/level control anomalies)
  - MCR abandonment scenarios and other sequences arising from Fire Emergency Procedures (FEPs) and/or use of local manual actions

- Corresponding PRA Standard SRs: PRM-B5,B6

Task 2: Fire PRA Component Selection
Steps In Procedure/Details

Step 2: Review the internal events PRA model against the fire safe shutdown analysis

- Identify and reconcile:
  - differences in functions, success criteria, and sequences (e.g., Appendix R - no feed/bleed; PRA - feed/bleed)
  - front-line and support system differences (e.g., App. R - need HVAC; PRA - do not need HVAC)
  - system and equipment differences due to end state and mission considerations (e.g., App. R - cold shutdown; PRA - hot shutdown)
  - other miscellaneous equipment differences.
- Include review of manual actions (e.g., actions needed for safe shutdown) in conjunction with Task 12 (HRA)
- Corresponding PRA Standard SRs: ES-A3(a), ES-B1,B3

Task 2: Fire PRA Component Selection
Steps In Procedure/Details

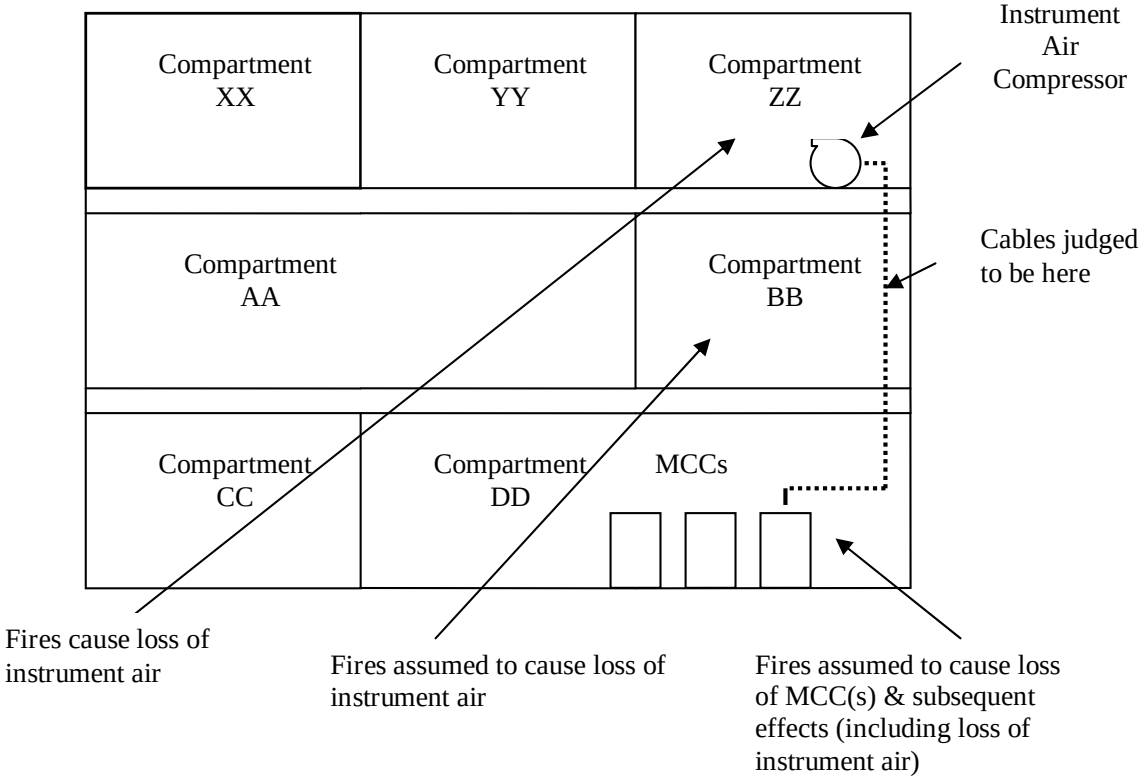
Step 3: Identify fire-induced initiating events based on equipment affected

- Consider equipment whose failure (including spurious actuation) will cause automatic plant trip
- Consider equipment whose failure (including spurious actuation) will likely result in manual plant trip, per procedures
- Consider equipment whose failure (including spurious actuation) will invoke Technical Specification Limiting Condition of Operation (LCO) necessitating a forced shutdown while fire may still be present (prior EPRI guidance recommended consideration of <8 hr LCO)
- Compartments with none of the above need not have initiator though can conservatively assume simple plant trip
- Corresponding PRA Standard SRs: ES-A1,A3 & PRM-B3,B4,B5,B6

Task 2: Fire PRA Component Selection
Steps In Procedure/Details

- Since not all equipment/cable locations in the plant (e.g., all Balance of Plant systems) may be identified, judgment involved in identifying 'likely' cable paths
  - Need a basis for any case where routing is not verified
  - Routing by exclusion (e.g., from a fire area, compartment, raceway…) is a common and acceptable approach
- Should consider spurious event(s) contributing to initiators
- Related PRA standard SR: CS-A11

Task 2: Fire PRA Component Selection
Steps In Procedure/Details



Task 2: Fire PRA Component Selection
Steps In Procedure/Details

Step 4: Identify equipment whose spurious actuation may challenge the safe shutdown capability

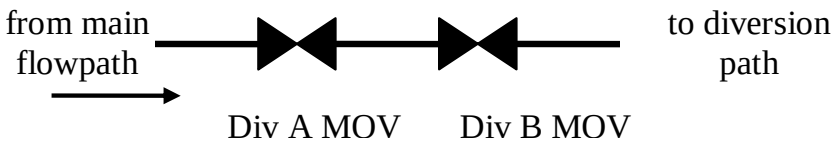
- Examine multiple spurious events within each system considering success criteria
  - PRA standard has specific requirements for multiple spurious events
- Review system P&IDs, electrical single lines, and other drawings
- Focus on equipment or failure modes not already on the component list (e.g., flow diversion paths)
- Review/Incorporate PRA related scenarios identified by the MSO Expert Panel to identify new components/failure modes
- Review Internal Events System Notebooks to identify components/failure modes screened based on low probability combinations

Task 2: Fire PRA Component Selection
Steps In Procedure/Details

Step 4: Identify equipment whose spurious actuation may challenge the safe shutdown capability (Continued)

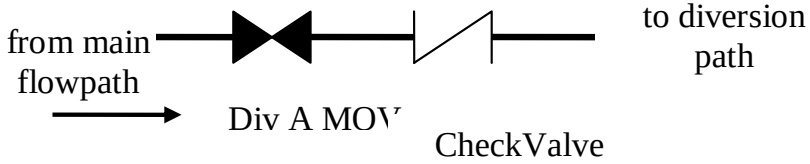
- Be aware of any failure combinations that could cause or contribute to an initiating event.
- Any new failure combinations that could cause or contribute to an initiating event should be addressed in Step 3.
- Any new equipment/failure modes should be added to component list for subsequent cable-tracing and circuit analysis
- Corresponding PRA Standard SRs: ES-B2,B3

Task 2: Fire PRA Component Selection
Flow Diversion Path Examples



takes 2 spurious hot shorts to open diversion path

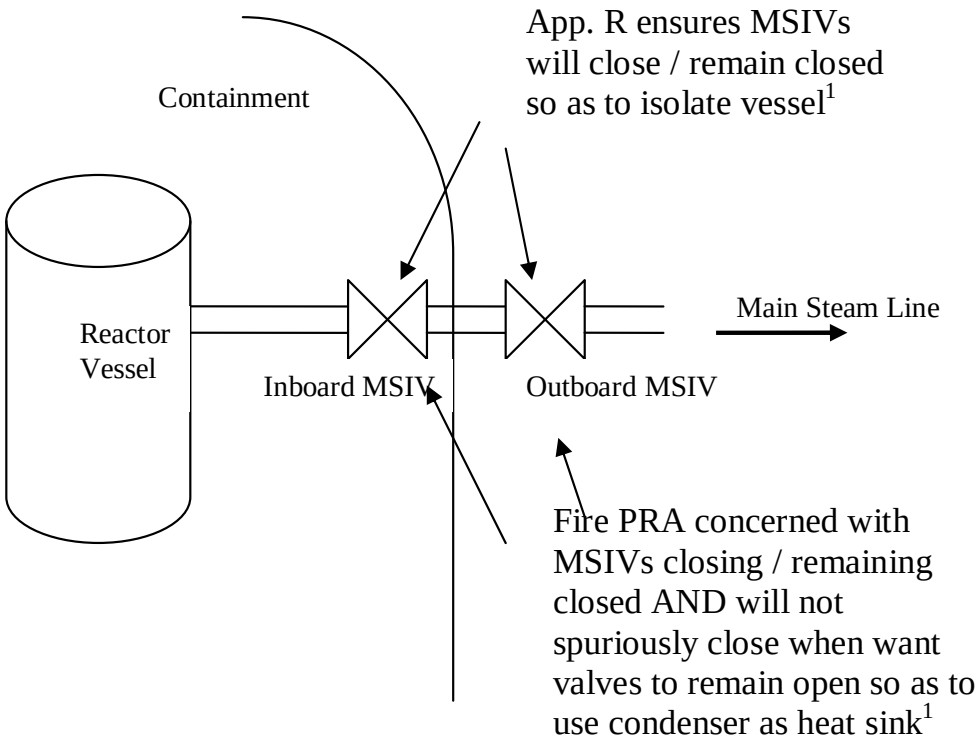
Included in model



takes 1 spurious hot short & failure of check valve to open diversion path

Screened from model if not potential high consequence event

Task 2: Fire PRA Component Selection
Example of a *New Failure Mode of a Component*



[1] different cables and corresponding circuits and analyses may need to be accounted for

Task 2: Fire PRA Component Selection MSO Expert Panel

- This approach *complements* but is *not* part of the published consensus methodology (6850/1011989)

Reference Documents

- NEI 00-01, Revision 2, "Guidance for Post-Fire Safe Shutdown Circuit Analysis", May 2009
  - ❑ Focused on use of the generic list of MSOs provided in Appendix G, and the guidance provided in Section 4.4, "Expert Panel Review of MSOs"
- NEI 04-02 Frequently Asked Question (FAQ) 07-0038, Lessons Learned on Multiple Spurious Operations
- WCAP-16933-NP, Revision 0, "PWR Generic List of Fire-Induced Multiple Spurious Operation Scenarios"**,** April 2009
- NRC Regulatory Guide 1.205, Risk-Informed, Performance-Based Fire Protection for Existing Light-Water Nuclear Power Plants, Revision 1, December 2009

Task 2: Fire PRA Component Selection
MSO Expert Panel

Purpose

- Perform a systematic and complete review of credible spurious and MSO scenarios, and determine whether or not each individual scenario is to be included or excluded from the plant specific list of MSOs to be considered in the plant specific post-fire Fire PRA and Safe Shutdown Analysis (SSA).
- Involves group “what-if” discussions of both general and specific scenarios that may occur.

Task 2: Fire PRA Component Selection
MSO Expert Panel

Expert Panel Membership:

- Fire Protection
- Fire Safe Shutdown Analysis: This expert should be familiar with the SSA input to the expert panel and with the SSA documentation for existing spurious operations.
- PRA: This expert should be familiar with the PRA input to the expert panel.
- Operations
- System Engineering
- Electrical Circuits

Task 2: Fire PRA Component Selection MSO Expert Panel

Process Overview

- Process is based on a diverse review of the Safe Shutdown Functions. Panel focuses on system and component interactions that could impact nuclear safety
- Review and discuss the potential failure modes for each safe shutdown function
- Identify MSO combinations that could defeat safe shutdown through those failure mechanisms
- Outputs are used in later tasks to identify cables and potential locations where vulnerabilities could exist
- MSOs determined to be potentially significant may be added to the PRA model and SSA

Task 2: Fire PRA Component Selection MSO Expert Panel

Supporting Plant Information for Reviews

- Flow Diagrams
- Control Wiring Diagrams
- Single and/or Three Line Diagrams
- Safe Shutdown Logic Diagrams
- PRA Event Sequence Diagrams
- Post-Fire Safe Shutdown Analysis
- Fire PRA models, analyses and cut-sets
- Plant operating experience

Task 2: Fire PRA Component Selection
MSO Expert Panel

MSO Selection

- Review existing Safe Shutdown Analysis (SSA) list
- Expand existing MSO's to include all possible component failures
- Verify SSA assumptions are maintained
- Review generic list of MSO's (NEI 00-01 Revision 2, Appendix G)
- Screen MSO's that do not apply to your plant (i.e., components or system do not exist)

Task 2: Fire PRA Component Selection
MSO Expert Panel

MSO Selection (Continued)

- Place all non-screened MSO's on plant specific list of MSO's
- Evaluate each MSO to determine if it can be screened due to design or operational features that would prevent it from occurring (i.e., breaker racked out during normal operation)
- Review the generic MSO list for similar or additional MSO's
- Develop and evaluate list of new MSO's

Task 2: Fire PRA Component Selection MSO Expert Panel

MSO Development

- Identify MSO combinations that could defeat safe shutdown through the previously identified failure mechanisms
  - ❑The panel will build these MSO combinations into fire scenarios to be investigated
  - ❑The scenario descriptions that result should include the identification of specific components whose failure or spurious operation would result in a loss of a safe shutdown function or lead to core damage

Task 2: Fire PRA Component Selection
MSO Expert Panel

MSO Development (Continued)

- The expert panel systematically reviews each system (P&IDs, etc) affecting safe shutdown and the core, for the following Safe Shutdown Functions:
  - ❑Reactivity Control
  - ❑Decay Heat Removal
  - ❑Reactor Coolant
  - ❑Inventory Control
  - ❑Pressure Control
  - ❑Process Monitoring
  - ❑Support Functions

Task 2: Fire PRA Component Selection
MSO Expert Panel

Typical Generic PWR MSOs

Scenario	Description
Loss of all RCP Seal Cooling	Spurious isolation of seal injection header flow, ***AND*** *Spurious isolation of CCW flow to Thermal Barrier Heat Exchanger (TBHX)*
RWST Drain Down via Containment Sump	Spurious opening of multiple series containment sump valves

Task 2: Fire PRA Component Selection
MSO Expert Panel

Typical Generic BWR MSOs

RPV coolant drain through the Scram Discharge Volume (SDV) vent and drain	MSO opening of the solenoid valves which supply control air to the air operated isolation valves
Spurious Operations that creates RHR Pump Flow Diversion from RHR/LPCI, including diversion to the Torus or Suppression Pool.	RHR flow can be diverted to the containment through the RHR Torus or Suppression Pool return line isolation valves (E11-F024A, B and E11-F028A, B).

Task 2: Fire PRA Component Selection MSO Expert Panel

Outputs and Documentation

- Plant specific list of MSO's
- MSO Expert Panel Review Report
- The MSO Expert Panel is a living entity and the Plant Specific list of MSO's is a living document
- MSO components that could have PRA impact are addressed in Task 2
- MSO scenarios that have PRA impact are addressed in Task 5.

Task 2: Fire PRA Component Selection
Steps In Procedure/Details (per 6850/1011989)

Step 5: Identify additional instrumentation/diagnostic equipment important to operator response (level of redundancy matters!)

- Identify human actions of interest in conjunction with Task 12 (HRA)
- Identify instrumentation and diagnostic equipment associated with credited and potentially harmful human actions considering spurious indications related to each action
  - Is there insufficient redundancy to credit desired actions in EOPs/FEPs/ARPs in spite of failed/spurious indications?
  - Can a spurious indication(s) cause an undesired action because action is dependent on an indication that could be 'false'?
  - If yes – put indication on component list for cable/circuit review
- See new/expanded guidance developed by the RES/EPRI fire HRA collaboration.

- Corresponding PRA Standard SRs: ES-C1,C2

Task 2: Fire PRA Component Selection
Steps In Procedure/Details

Guidance on identification of harmful spurious operating instrumentation and diagnostic equipment:

- Assume instrumentation is in its normal configuration
- Focus on instrumentation with little redundancy
  - Note that fire PRA standard has language on this subject (i.e., verification of instrument redundancy in fire context)
- When verification of a spurious indication is required (and reliably performed), it may be eliminated from consideration
- When multiple and diverse indications must spuriously occur, those failures can be eliminated if the HRA shows that such failures would not likely cause a harmful operator action
- Include spurious operation of electrical equipment that would cause a faulty indication and harmful action
- Include inter-system effects

Task 2: Fire PRA Component Selection
Steps In Procedure/Details

Step 6: Include "potentially high consequence" related equipment

- High consequence events are one or more related failures at least partially caused by fire that:
  - by themselves cause core damage and large early release, or
  - single component failures that cause loss of entire safety function and lead directly to core damage
- Example of first case: spurious opening of two valves in high-pressure/low pressure RCS interface, leading to ISLOCA
- Example of second case: spurious opening of single valve that drains safety injection water source

- Corresponding PRA Standard SR: ES-A6

Task 2: Fire PRA Component Selection
Steps In Procedure/Details

Step 7: Assemble Fire PRA component list. Should include following information:

- Equipment ID and description (may be indicator or alarm)
- System designation
- Equipment type and location (at least compartment ID)
- PRA event ID and description
- Normal and desired position/status
- Failed electrical/air position
- References, comments, and notes

- Note: development of an actual/physical fire PRA component list is not a requirement of the PRA Standard

Sample Problem Exercise for Task 2, Step 1

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

Sample Problem Exercise for Task 2, Steps 2 and 3

- Distribute blank handout for Task 2, Step 2
- Distribute completed handout for Task 2, Step 2 Question and Answer Session
- Discuss Step 3
- Question and Answer Session

Sample Problem Exercise for Task 2, Steps 4 through 6

- Distribute blank handout for Task 2, Steps 4 through 6
- Distribute completed handout for Task 2, Steps 4 through 6
- Question and Answer Session

Sample Problem Exercise for Task 2, Step 7

- Distribute blank handout for Task 2, Step 7
- Distribute completed handout for Task 2, Step 7
- Question and Answer Session

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

Technical element	HLR	SR	6850/1011989 sections that cover SR	Comments
ES	A	The Fire PRA shall identify equipment whose failure caused by an initiating fire including spurious operation will contribute to or otherwise cause an initiating event.		
		1	2.5.3	
		2	3.5.3	Covered in “Cable Selection” chapter
		3	2.5.3	
		4	2.5.1, 2.5.4	
		5	2.5.4	
		6	2.5.6	
	B	The Fire PRA shall identify equipment whose failure including spurious operation would adversely affect the operability/functionality of that portion of the plant design to be credited in the Fire PRA.		
		1	2.5.2	
		2	2.5.4	
		3	5.5.1	Covered in “Fire-Induced Risk Model” chapter
		4	3.5.3	Covered in “Cable Selection” chapter
		5	n/a	Exclusion based on probability is not covered in 6850/1011989
	C	The Fire PRA shall identify instrumentation whose failure including spurious operation would impact the reliability of operator actions associated with that portion of the plant design to be credited in the Fire PRA.		
		1	2.5.5	
		2	2.5.5	
	D	The Fire PRA shall document the Fire PRA equipment selection, including that information about the equipment necessary to support the other Fire PRA tasks (e.g., equipment identification; equipment type; normal, desired, failed states of equipment; etc.) in a manner that facilitates Fire PRA applications, upgrades, and peer review.		
		1	n/a	Documentation not covered in 6850/1011989