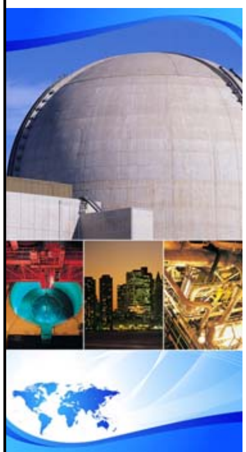
Presentation Schedule for Tuesday AM introductory session:

Time	**Topic**	**Presenter**
8:00-8:15 am	High level overview of course	Hyslop
8:15-9:15 am	Detailed course overview	Nowlen/Najafi
9:15-10:15 am	Relationship of regulations, standard, and the fire PRA methods	Drouin
10:15-10:30 am	Break	
10:30-10:45 am	Fire Model Applications Guide	Joglar
10:45-11:00 am	Christi-fire	Stroup
11:00-11:15 am	HRR analytical method	Najafi
11:15-11:30 am	DESIREE	Nowlen
11:30-11:45 am	Improved FEDB	Hyslop
11:45 am	Adjourn for lunch Return at 1:00 pm Go directly to your training module	

EPRI/NRC-RES FIRE PRA METHODOLOGY

Module I-1: Fire Risk Requantification Project



J.S. Hyslop – NRC/RES
R.P. Kassawara – EPRI

Joint RES/EPRI Fire PRA Workshop
September and October 2010

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

General

- Based on MOU between NRC-RES and EPRI on fire risk
- Needed to provide more realistic methods for risk-informed, performance-based fire protection activities
- Scope is full power, CDF and LERF
- Course does not provide official NRC positions, but does represent the expertise of authors of NUREG/CR-6850 (EPRI 1011989)

Quality Product

- Participation by industry and the public
- Formal process to resolve technical disputes within NUREG/CR-6850 (EPRI 1011989) team
- Improvements made in areas important to fire risk
- Fire PRA methodology still evolving
  - Solutions provided to fifteen fire PRA questions in NFPA 805 frequently asked questions (FAQ) process

Uses Of Methodology

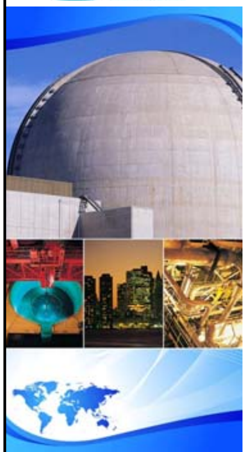
- Support for 10CFR50.48(c) implementation
  - Plants using technology for fire PRA development/upgrade
- ANS fire risk standard development
  - Typically defines state-of-art, although supports lesser capability categories as well
- Reactor Oversight Process analyses
  - Refined phase 3 analyses
  - Development of phase 2 Fire Protection SDP (IMC 0609, Appendix F)
- Other expected uses
  - Analyses under the current fire protection regulations (i.e. exemptions/deviations or plant changes due to risk-informed technical specifications)

Fire Model Validation and Verification (V&V)

- Fire modeling is an integral part of fire PRA
- Fire model verification and validation (V&V) is required for NFPA 805 applications
- Most fire models are computational
- Some are based only on empirical correlations
  - Address cases where computational fire models inadequate
  - Fill important gaps in fire PRA
- PRA Methodology document not a reference for fire models
- EPRI/RES V&V of fire models EPRI 101999/NUREG-1824

Related Activities

• EPRI 1011989/NUREG/CR-6850	
– Publication	2005
– General Workshops	2005, 2006
– Detailed courses	2007-2009
• EPRI 1011999/NUREG-1824	2007
• Fire HRA Methodology Development	Dec 2010
• Fire Modeling Application Guide	Mar 2011
• Fire Events Database	Late 2011
• FAQ Support	Ongoing
• Fire Modeling Training	Ongoing
• Low Power/Shutdown Fire PRA Methods	NRC



EPRI/NRC-RES FIRE PRA METHODOLOGY

Introduction and Overview: the Fire PRA Methodology and Course Structure

Steve Nowlen - Sandia National Laboratories
Bijan Najafi - Science Applications International Corp.
Joint RES/EPRI Fire PRA Training Workshop
Washington, DC
September and October 2010

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

Overview of this morning's presentations

I. An Overview of the EPRI/NRC-RES Fire PRA Methodology
   – Fire PRA Course

II. An overview of the ASME/ANS PRA Standard

III. EPRI and NRC-RES Fire Research Activities Related to Fire PRA
   – DESIREE-Fire, RES project
   – CHRISTIFIRE, RES project
   – Fire Event Database Update, joint EPRI & RES project
   – Fire Model Users' Guide, joint EPRI & RES project
   – Heat Release Rates, EPRI project

PART I

An Overview of the EPRI/NRC-RES Fire PRA Methodology

&

The Fire PRA Course

BACKGROUND
Fire PRA has a long history…

- Prior to IPEEE (1979-1990) early development and application of methods, tools and data
  - Relatively simple by comparison to today
  - Basic framework developed at UCLA (e.g., NUREG/CR-2258) remains largely unchanged. Applied in many early fire PRAs.
- EPRI FIVE (1992)
  - A "vulnerability evaluation" methodology developed in response to IPEEE program
- EPRI Fire PRA Implementation Guide (1995)
  - Developed as a complement to FIVE for detailed evaluation of unscreened fire areas/compartments
  - More robust methods (compared to FIVE) for:
    - Development and evaluation of fire risk model, including human actions
    - Assessment of fire growth and damage, detection and suppression
    - Control room and multi-compartment fire risk

EPRI/NRC-RES FIRE PRA METHODOLOGY
NUREG/CR-6850, EPRI TR 1011989

- The methodology is presented in the form technical task procedures within an overall process
- The process is intended as a guide and should fit most cases
- User may adjust process based on plant-specific information, efficiency, economy and desired applications

EPRI/NRC-RES FIRE PRA METHODOLOGY
NUREG/CR-6850, EPRI TR 1011989

- Procedures cover the following technical areas
  - Plant analysis boundary and partitioning
  - Fire PRA component selection and risk model
  - Circuit/cable selection, routing and failure modes analysis
  - Screening, qualitative and quantitative
  - Fire ignition frequency
  - Fire modeling; fire growth, damage and detection/suppression
  - Post-fire human reliability analysis (HRA)
  - Seismic-fire interactions, and
  - Fire risk quantification, including uncertainties, and documentation

PROCEDURE CONTENT
NUREG/CR-6850, EPRI TR 1011989

1. Purpose
2. Scope
3. Background information: General approach and assumptions
4. Interfaces: Input/output to other tasks, plant and other information needed, walk-downs
5. Procedure: Step-by-step instructions for conduct of the technical task
6. References

Appendices: Technical bases, data, examples, special models or instructions, tools or databases

New to this year's training

- Addition of a fire human reliability analysis (HRA) module
- Making the link between methods and the PRA standard

Fire HRA module is a new element to training for this year

- 6850/1011989 did not address detailed HRA quantification methods
- A Joint EPRI/NRC-RES development project has been underway to fill this gap
- Draft guidance published November 2009:
  - *EPRI/NRC-RES Fire Human Reliability Analysis Guidelines – Draft Report for Comment*, EPRI 1019196, NUREG-1921
- Final publication pending
- Now integrated into this fire PRA training program
  - Full training module
  - Based on draft report plus public comment resolution

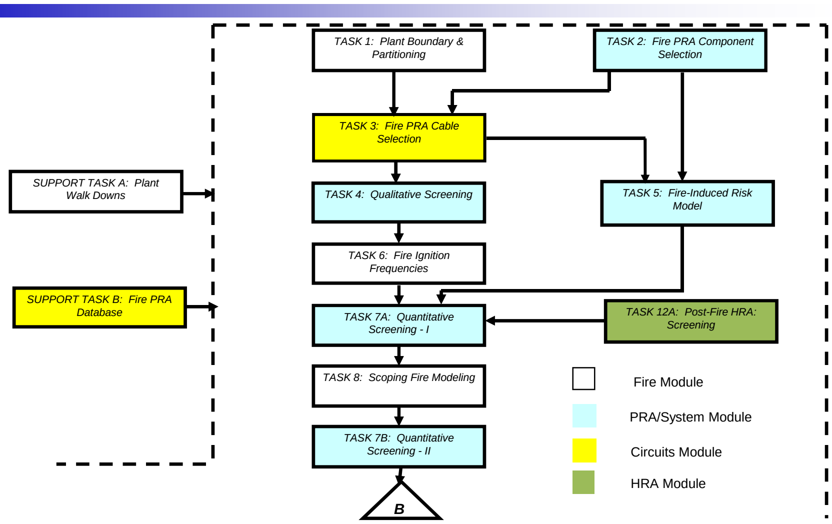
The PRA Quality Standard

- ASME/ANS RA-Sa–2009:
  - Addenda to ASME/ANS RA-S-2008: *Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications*
- The training slides updated to provide links from elements of the methodology to requirements of the standard
  - Not intended to “teach” the standard
  - Intended to provide a road map between the methods and the standard’s Supporting Requirements
- A separate presentation this morning will provide a high-level introduction to the standard

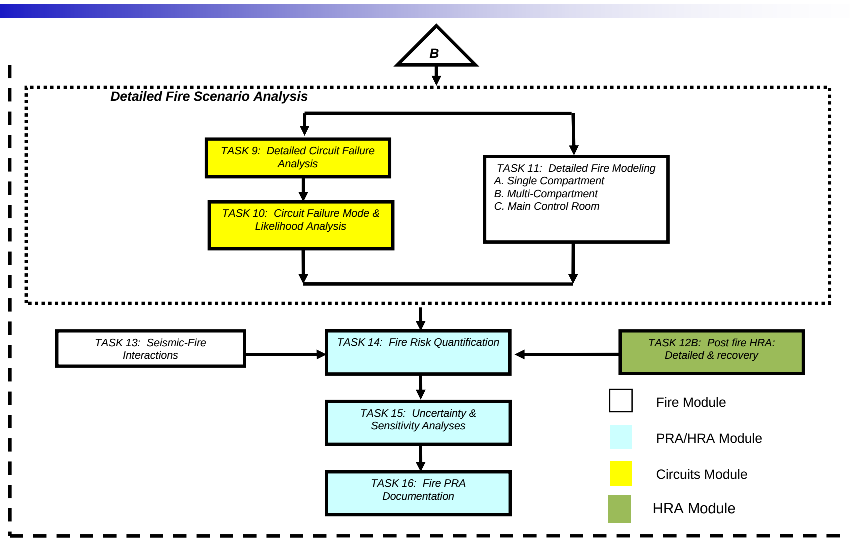
Course Structure

- Four parallel modules:
  - PRA/Systems Analysis
  - Fire Analysis
  - Electrical Analysis
  - Human Reliability Analysis (HRA)
- General structure for each module:
  - PowerPoint presentations designed to convey key concepts and the general "how to" of each task
  - Example problems designed to illustrate key elements of the procedures (more on this shortly)

OVERVIEW OF FIRE PRA PROCESS AND MODULE STRUCTURE



OVERVIEW OF FIRE PRA PROCESS AND MODULE STRUCTURE (2)



Training Objectives (1 of 3)

- Target audience:
  - FPRA practitioners
  - FPRA reviewers
- The “doer” versus the “reviewer”
  - We are targeting both types of users, but the needs are really quite similar
  - The key elements for implementation are the same as the key elements for review
  - Understanding how and why the “doer” does what they do is one key to understanding the analysis itself

Training Objectives (2 of 3)

- Our intent:
  - To deliver practical implementation training
  - To illustrate and demonstrate key aspects of the procedures
- We expect and want significant participant interaction
  - Class size should allow for *questions and discussion*
  - We will take questions about the *methodology*
  - We *cannot* answer questions about a *specific application*
  - *We* will moderate discussions, and *we* will judge when the course must move on

Module 1: PRA/Systems Analysis

- This module will cover all aspects of the plant systems accident response modeling, integration of human actions into the plant model, and quantification tasks
- Specific tasks covered are:
  - Task 2: Equipment Selection
  - Task 4: Qualitative Screening
  - Task 5: Fire-Induced Risk Model
  - Task 7: Quantitative Screening
  - Task 15: Risk Quantification
  - Task 16: Uncertainty Analysis

Module 2: Electrical Analysis

- This module covers those parts of the method specifically related to the identification and tracing of cables, and the analysis of electrical circuit failure modes and likelihood

- Tasks covered are:
  - Task 3: Cable Selection (and Routing)
  - Task 9: Detailed Circuit Analysis
  - Task 10: Failure Mode Likelihood Analysis
  - Support Task B: FPRA Database

Module 3: Fire Analysis

- This module covers those parts of the method specifically related to the identification and analysis of fires, fire damage, and fire protection systems and features

- Tasks covered are:
  - Task 1: Plant Partitioning
  - Task 6: Fire Ignition Frequency
  - Task 8: Scoping Fire Modeling
  - Task 11: Detailed Fire Scenario Analysis
  - Task 13: Seismic/Fire Interactions (briefly)
  - Support Task A: Plant Walkdowns

Module 4: Human Reliability Analysis

- This module covers the those aspects of the analysis related to the identification of human failure events (HFEs) and quantification of human error probabilities (HEPs)
- Tasks covered:
  - Task 12a: screening level HRA
  - Task 12b: detailed HRA quantification
- Note: EPRI/RES guidance includes an intermediate "scoping" approach
  - Approach more realistic than screening, yet lacks detail and realism of detailed HRA quantification

Task 1: Plant Partitioning (1 of 3)

Module 3

- Objectives:
  - Define the global analysis boundary of the FPRA
  - Divide the areas within the global analysis boundary into fire compartments
- The fire compartments become the "basic units" of analysis
  - Generally we screen based on fire compartments
  - Risk results are often rolled up to a fire compartment level
- A note on terminology:
  - The PRA standard uses "physical analysis units" rather than "fire compartments"
  - Definitions are quite similar, overall role in analysis is identical
    - Don't let the terminology difference trip you up – intent is the same

Task 1: Plant Partitioning (2 of 3)

Module 3

- The global analysis boundary is intended to be a liberal definition of the region potential interest
  - It will likely encompass areas of essentially no risk, but that is OK, screening steps will identify these
- The fire compartments are a matter of analysis convenience
  - Fire compartments may equal fire areas if you so choose
  - You can also subdivide fire areas into multiple compartments
  - The sum of the fire compartments must equal the global analysis boundary
    - No omissions, no overlap between compartments

Task 1: Plant Partitioning (3 of 3)

Module 3

- Ultimately, the FPRA is expected to provide some resolution to each defined fire compartment and to all locations within the global analysis boundary
- Module will cover:
  - Guidance and criteria for defining the global analysis boundary
  - Guidance and criteria for defining fire compartments
- Ultimately, there is not a lot of new guidance in this task
  - A lot like what was done in the IPEEE days

Task 2: Equipment Selection (1 of 2)

Module 1

- Objective: To decide what subset of the plant equipment will be modeled in the FPRA
- FPRA equipment will be drawn from:
  - Equipment from the internal events PRA
    - We do assume that an internal events PRA is available!
  - Equipment from the Post-Fire Safe Shutdown analysis
    - e.g., the Appendix R analysis or the Nuclear Safety Analysis under NFPA-805
  - Other “new” equipment not in either of these analyses

Task 2: Equipment Selection (2 of 2)

Module 1

- Many choices to be made in this task, many factors will influence these decisions
  - Fire-induced failures that might cause an initiating event
  - Mitigating equipment and operator actions
  - Fire-induced failures that adversely impact credited equipment
  - Fire-induced failures that could lead to inappropriate or unsafe operator actions
- Choices are important in part because “selecting” equipment implies a burden to *Identify and Trace* cables
  - Cable selection is Task 3 (Module 2)…

Task 3: Cable Selection (1 of 2)

Module 2

- Objectives:
  - *Identify/select* cables whose fire-induced failure could adversely affect the operation of selected equipment (from Task 2)
  - *Locate* selected cables
- Cables may include Power, Control/Indication, and Instrumentation

Task 3: Cable Selection (2 of 2)

Module 2

- Cable routing can be a major commitment of FPRA resources
  - Depends a *lot* on status of existing plant cable information
    - Scope, quality, vintage, method of documentation
  - Tracing cables is a time consuming activity
  - Intent is to allow for "work smart" approaches
    - Iteration to identify and route more cables as needed to support FPRA
- Allowances are made for making "conservative" assumptions about a cable's routing if unknown
  - e.g., exclusionary approach

Task 4: Qualitative Screening (1 of 2)

Module 1

- Objective: To identify fire compartments that can be screened out as insignificant risk contributors without quantitative analysis
- This is an *Optional* task
  - You may choose to bypass this task which means that all fire compartments will be treated quantitatively to some level of analysis (level may vary)

Task 4: Qualitative Screening (2 of 2)

Module 1

- Qualitative screening criteria consider:
  - Trip initiators
  - Presence of selected equipment
  - Presence of selected cables
- Note that any compartment that is "screened out" in this step is reconsidered in the multi-compartment fire analysis as a potential source of multi-compartment fires
  - See Module 3, Task 11c

Task 5: Fire-Induced Risk Model

Module 1

- Objective: Construct the FPRA plant response model reflecting:
  - Functional relationships among selected equipment and operator actions
- Covers both CDF and LERF
- Begins with internal events model but more than just a "tweak"
  - Adds fire unique equipment – various reasons/sources
  - May delete equipment not to be credited for fire
  - Adds fire-specific equipment failure modes
    - e.g., spurious actuations (Task 9)
  - Adds fire-specific human failure events (Task 12)

Task 6: Fire Ignition Frequency (1 of 3)

Module 3

- Objective: To define fire frequencies suitable to the analysis of fire scenarios at various stages of the FPRA
- Fire frequencies will be needed at various resolutions:
  - An entire fire area
  - A fire compartment (or physical analysis unit)
  - A group of fire ignition sources (e.g., a bank of electrical cabinets)
  - A single ignition source (e.g., one electrical panel)

Task 6: Fire Ignition Frequency (2 of 3)

Module 3

- Task begins with generic industry-average statistics on fire
  - EPRI fire event database
  - Events filtered for applicability and sorted into ignition source bins
  - Plant-wide fire frequency is provided for each bin
- The real "trick" is to convert the generic values into values specific to your plant and to a given fire scenario
  - Approach is based on ignition source counting and apportionment of the plant-wide frequency based on local population

Task 6: Fire Ignition Frequency (3 of 3)

Module 3

- Quite a bit is new relative to fire frequency:
  - The fire event data have been re-analyzed entirely to suit the new method
    - That means older IPEEE-vintage frequencies are obsolete
  - There has been a switch towards component-based fire frequencies and away from generic room-based fire frequencies
  - Some areas have received special treatment
    - e.g., main control room

Task 7: Quantitative Screening (1 of 2)

Module 1

- Objective: To identify compartments that can be shown to be insignificant contributors to fire risk based on limited quantitative considerations
- This task is *Optional*
  - Analyst may choose to retain all compartments for more detailed analysis

Task 7: Quantitative Screening (2 of 2)

Module 1

- Screening may be performed in stages of increasing complexity
- Consideration is given to:
  - Fire ignition frequency
  - Screening of specific fire sources as non-threatening (no spread, no damage)
  - Impact of fire-induced equipment and cable failures
    - conditional core damage probability (CCDP)
- A word of caution: quantitative screening criteria should consider the PRA standard and Reg. Guide 1.200
  - 6850/1011989 criteria are obsolete, but approach is unchanged

Task 8: Scoping Fire Modeling (1 of 2)

Module 3

- Objective: To identify (and screen out) fire ignition sources that are non-threatening and need not be considered in detailed fire modeling
- Non-threatening means they cannot:
  - Spread fire to other combustibles, or
  - Damage any FPRA equipment item or cable

Task 8: Scoping Fire Modeling (2 of 2)

Module 3

- Scoping fire modeling introduces a number of key concepts associated with the treatment of fire sources and damage targets
  - The Fire Severity Profile approach
  - Damage criteria for cables and equipment
  - Assumptions associated with specific fire sources

Task 9: Detailed Circuit Failure Analysis (1 of 2)

Module 2

- Objectives:
  - To identify circuit responses (failure modes) to fire-induced cable failures
  - To screen out cables that do not impact the ability of a component to complete its credited function
- This is not about failure mode *likelihoods* (that is task 10)
- This is about defining the effects that cable failure can (or cannot have) on selected equipment
  - e.g., what cables can, or cannot, cause spurious actuations?

Task 9: Detailed Circuit Failure Analysis (2 of 2)

Module 2

- Fundamentally a deterministic analysis of cable failure modes and effects
- Module will cover:
  - Those failure modes that are, and are not, considered plausible for various cable/circuit configurations and applications
  - Underlying assumptions of the analysis
  - Role of existing analyses (e.g., Appendix R SSD analysis)
  - Steps of the analysis

Task 10: Circuit Failure Modes Likelihood (1 of 2)

Module 2

- Objective: To establish first order estimates of the conditional probability, given failure of a specific cable, that the circuit will respond in a specific way

- This one is about the likelihood that certain equipment failure modes will be observed given fire-induced cable failure
  - Will the equipment spuriously actuate, or
  - Will it be a loss of function failure?
  - What is the relative likelihood of each failure mode of interest?

Task 10: Circuit Failure Mode Likelihood (2 of 2)

Module 2

- This is a probabilistic analysis

- Based largely on existing data including
  - The EPRI/NEI cable tests including the NRC/RES collaboration
  - The EPRI expert panel

- Module will include
  - Existing knowledge base
  - Underlying assumptions
  - Key factors in the analysis
  - Analysis approach and methods

Task 11: Detailed Fire Modeling (1 of 3)

Module 3

- Objective: To identify and analyze specific fire scenarios
- Divided into three sub-tasks:
  - 11a: General fire compartments (as individual risk contributors)
  - 11b: Main Control Room analysis
  - 11c: Multi-Compartment fire scenarios

Task 11: Detailed Fire Modeling (2 of 3)

Module 3

- Task 11 involves many key elements
  - Selection of specific fire scenarios
    - Combinations of fire sources and damage targets
  - Analysis of fire growth/spread
    - Application of fire models
  - Analysis of fire damage
    - Time to failure
  - Analysis of fire detection and suppression

Task 11: Detailed Fire Modeling (3 of 3)

Module 3

- Task 11 comes with a wide range of supporting appendices including:
  - Specific fire sources such as high energy arc faults, turbine generator fires, and hydrogen fires
  - Treatment of fire severity and severity factors
  - Treatment of manual fire suppression
  - Treatment for main control board fires
- Module will cover key appendices

Task 12: Post-fire Human Reliability Analysis

Module 4

- Objective: Identify human failure events (HFEs) to be included in the FPRA plant response model and assess corresponding human error probabilities (HEPs)
  - Some HFEs derive from internal events PRA
  - Some are unique to fire
- HRA module based on the ongoing RES/EPRI collaboration
- Substantial expansion compared to 6850/1011989:
  - Updated rules-based screening approach
  - New intermediate “scoping” approach
  - Detailed quantification guidance for fire HEPs

Task 13: Seismic/Fire Interactions

Module 3

- Objective: A *qualitative* assessment of potential fire/seismic interactions
- Module will cover this task *briefly*
  - No significant changes from IPEEE guidance (e.g., the Fire PRA Implementation Guide)

Task 14: Fire Risk Quantification

Module 1

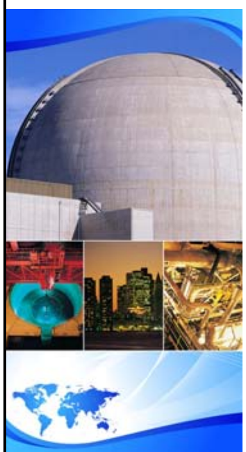
- Objective: To quantify fire-induced CDF and LERF
- Covered in limited detail
- Relatively straight-forward roll-up for fire scenarios considering
  - Ignition frequency
  - Scenario-specific equipment and cable damage
  - Equipment failure modes and likelihoods
  - Credit for fire mitigation (detection and suppression)
  - Fire-specific HEPs
  - Quantification of the FPRA plant response model

Task 15: Uncertainty and Sensitivity

Module 1

- Objective: Provide a process for identifying and quantifying uncertainties in the FPRA and for identifying sensitivity analysis cases
- Covered in limited detail
- Guidance is based on potential strategies that might be taken, but choices are largely left to the analyst
  - e.g., what uncertainties will be characterized as distributions and propagated through the model?

Any questions before we move on?



EPRI/NRC-RES FIRE PRA METHODOLOGY AND ITS RELATIONSHIP TO NRC's REGULATORY STRUCTURE

Mary Drouin
U.S. Nuclear Regulatory Commission

Joint RES/EPRI Fire PRA Workshop
September and October 2010
Washington DC

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

How Does NUREG/CR-6850 Fit into the NRC Regulatory Structure?

- The objective here is to provide an understanding, from a regulatory perspective, the need for a fire probabilistic risk assessment (PRA) methodology document, and therefore, its role in the regulatory structure.
- A major aspect of this objective is understanding what is meant by regulatory structure.

NRC Regulatory Structure

- Congressional Mandate
  - Atomic Energy Act indicates that the mission of the NRC is to ensure that commercial nuclear power plants are operated in a manner that provides adequate protection of public health and safety and is consistent with the common defense and security.
- NRC provides for public health and safety via a licensing, oversight and enforcement process.
- Licensing, oversight and enforcement all involve establishing regulations and developing the necessary supporting structure (e.g., regulatory guides).

Fire PRA Workshop, 2010, Washington DC
Insert presentation topic title here

Slide 3

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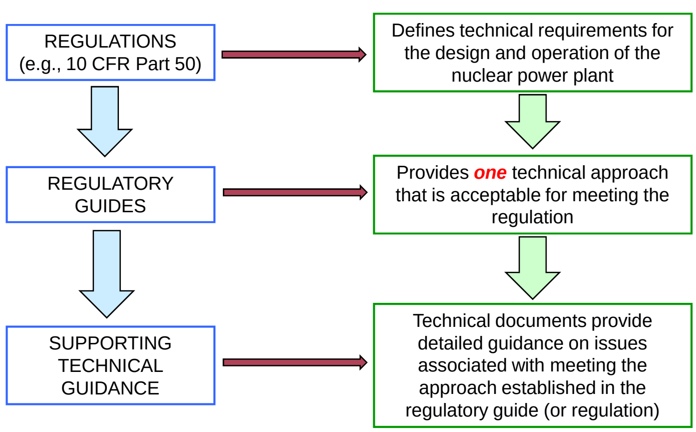
What is the Relationship Between a Regulation and a Methodology Document?



Fire PRA Workshop, 2010, Washington DC
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Slide 4

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

What is the Relationship in the Context of a Fire PRA?

- Example relevant regulations:
  - 10 CFR §50.48(c), Fire Protection, National Fire Protection Association Standard NFPA 805
  - 10 CFR §50.69, Risk-informed categorization and treatment of structures, systems and components for nuclear power reactors
  - 10 CFR §50.90, Application for amendment of license, construction permit, or early site permit
  - 10 CFR §50.36, Technical Specifications
- What is the common element among these regulations?
  - The use of risk information, and therefore, ***the need to have confidence in the risk analyses (or PRAs)*** being used to generate the information
  - ***Risk contributors to be addressed include internal fires.***

How is This Confidence Achieved?

REGULATIONS
10 CFR §50.48(c) 10 CFR §50.69 10 CFR §50.90 10 CFR §50.36 etc.

RG 1.205 RG 1.201 RG 1.174 RG 1.177

- Guidance/staff position includes use of risk/PRA information
- Reference to RG 1.200 for guidance on determining PRA technical acceptability for both internal and external hazards (e.g., internal fire)

RG 1.200

"Describes one acceptable approach for determining whether the technical adequacy of the PRA, in total or the parts that are used to support an application, is sufficient to provide confidence in the results, such that the PRA can be used in regulatory decision-making for light-water reactors."

How is This Confidence Achieved (cont'd)?

- The approach provided in RG 1.200 defines the attributes and characteristics of a technically acceptable PRA.
  - The defined attributes and characteristics are very high level.
- For example, characteristics and attributes provided in RG 1.200 for Fire Ignition Frequencies:
  - Frequencies are established for ignition sources and consequently for physical analysis units.
  - Transient fires should be postulated for all physical analysis units regardless of administrative controls.
  - Appropriate justification must be provided to use nonnuclear experience to determine fire ignition frequency.

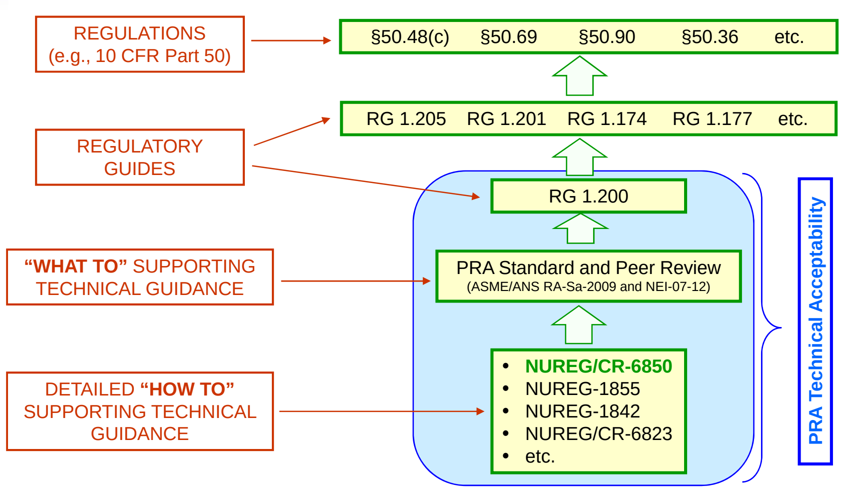
How is This Confidence Achieved (cont'd)?

- RG 1.200 allows the use of a consensus standard (as endorsed by the NRC) with a peer review to demonstrate conformance with the defined attributes and characteristics.
  - RG 1.200 endorses and provides a position on the ASME/ANS PRA Standard (ASME/ANS RA-Sa-2009).
  - ***Part 4 of this standard provides the requirements for fires at-power PRA.***
- The PRA Standard, however, only defines ***what*** is required for a technically acceptable PRA and an acceptable peer review.

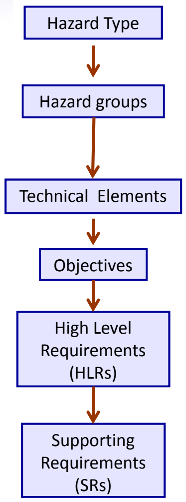
How is This Confidence Achieved (cont'd)?

- Guidance is needed for ***how*** to accomplish the requirements in the standard and guidance for the peer review in determining whether the intent of requirement is met.
- This guidance is particularly needed for those aspects in the PRA where the model is not well known.
- One major objective of NUREG/CR-6850 is to provide the detailed guidance for how to accomplish meeting the requirements for Fire PRA.

Overall Relationship



Structure of PRA Standard

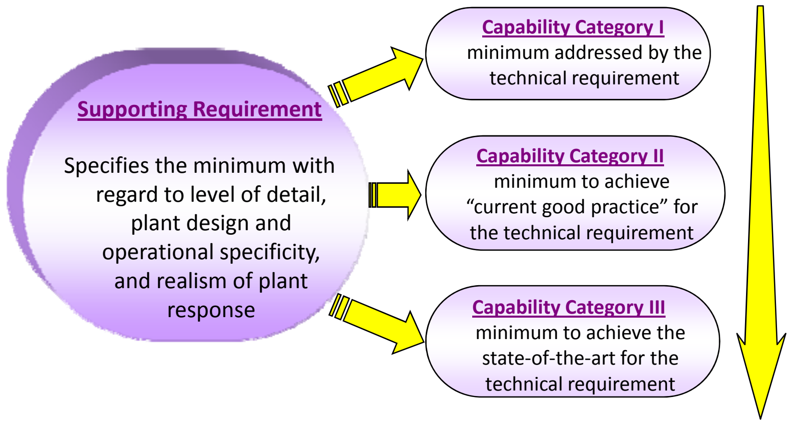


- Two different hazard types are defined in the Standard which include both internal and external hazards.
- For each hazard type, the various groups of hazards are defined, for example for internal hazards, internal events, internal flood and internal fires.
- For each hazard group, the technical elements are defined for developing the hazard-specific PRA model.
- The objective of each technical element is defined.
- High level requirements are defined which specify what is needed to accomplish the defined objective of the technical element.
- Supporting requirements are defined which, in turn, specify what is needed to accomplish the defined high level requirement.

Structure of PRA Standard (cont'd)

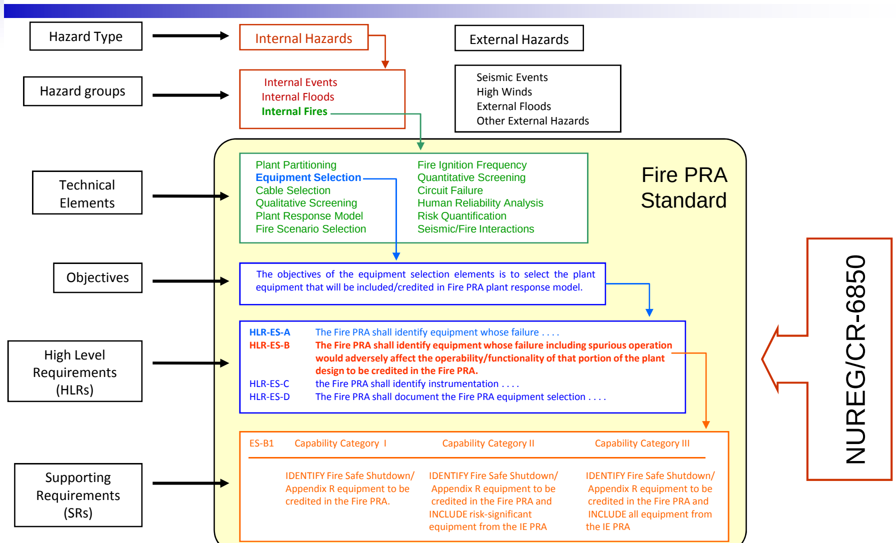
- At the supporting requirement level, it was recognized that the level of detail, the level of plant specificity, and the level of realism can vary.
- Consequently, three "categories of capability" were defined for the supporting requirements.
  - ***Capability Category I:*** Degree to which scope & level of detail of plant design, operation, and maintenance are modeled.
  - ***Capability Category II***: Degree to which plant-specific information is incorporated such that the as-built and as-operated plant is addressed.
  - ***Capability Category III***: Degree to which realism is incorporated such that the expected response of the plant is addressed.
- Only supporting requirements can be differentiated by Capability Categories.

Standard Capability Categories



- Level of detail of plant model
- Plant design and operational specificity
- Realism of plant response

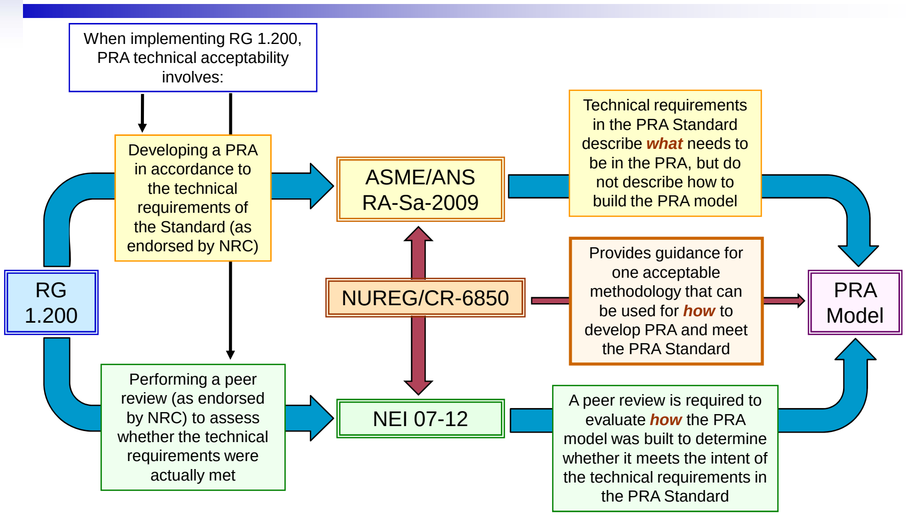
Illustration of Fire PRA Standard Structure and NUREG/CR-6850



Fire PRA Standard and NUREG/CR-6850:
Illustration of the Mapping of HLRs & SRs to 6850

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

Overall Process



Summary/Conclusion

- NUREG/CR-6850 is a methodology document and, while not required to be met, plays a major role in defining a technically acceptable Fire PRA to support NRC activities where a Fire PRA model is needed and the results of the Fire PRA model are used to meet a regulation.

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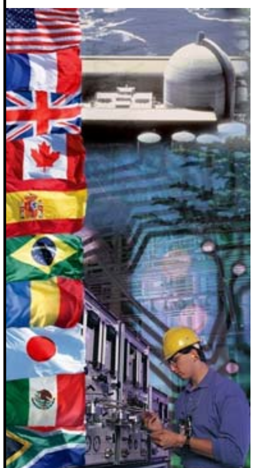
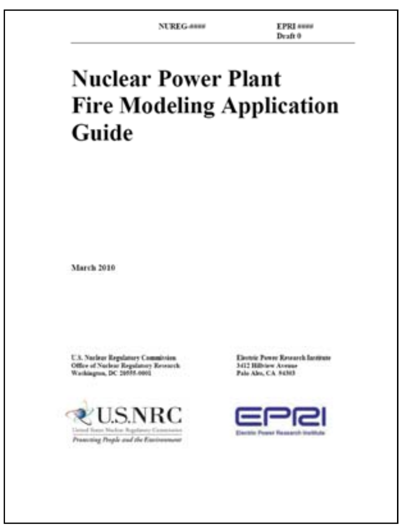
NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

SAIC Science Applications International Corporation
From Science to Solutions



Fire Modeling User's Guide

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



NUREG-#### EPRI ####
Draft 0

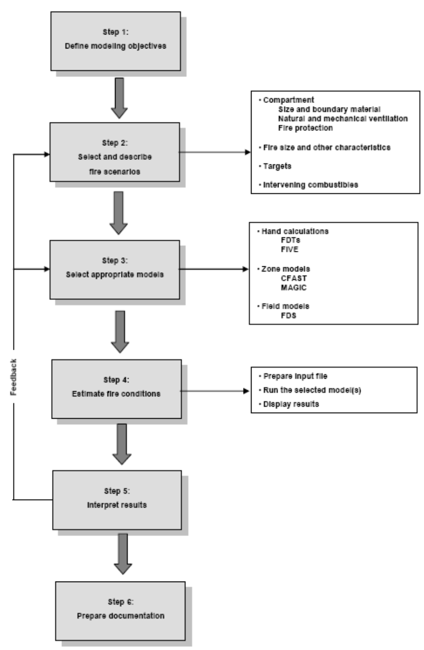
Nuclear Power Plant Fire Modeling Application Guide

March 2010

U.S. Nuclear Regulatory Commission
Office of Nuclear Regulatory Research
Washington, DC 20555-0001

Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, CA 94303

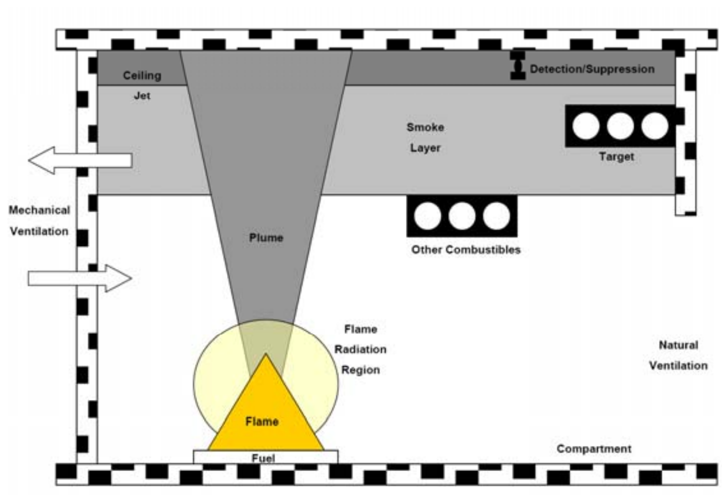
U.S.NRC
EPRI



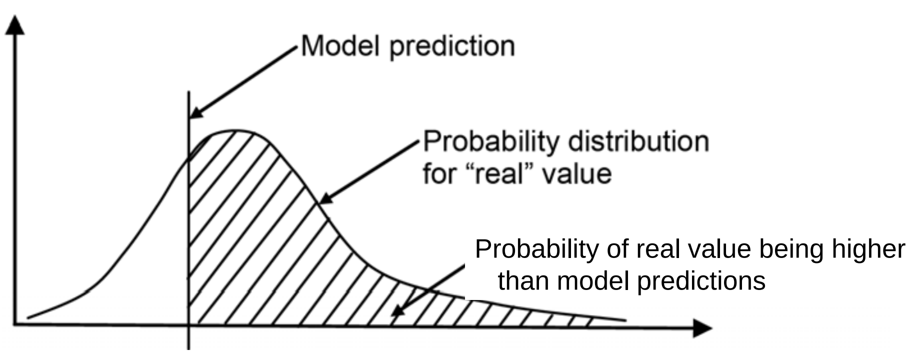
Purpose of the Guide is to help Model Users

V&V helps the model developers, but not necessarily the users

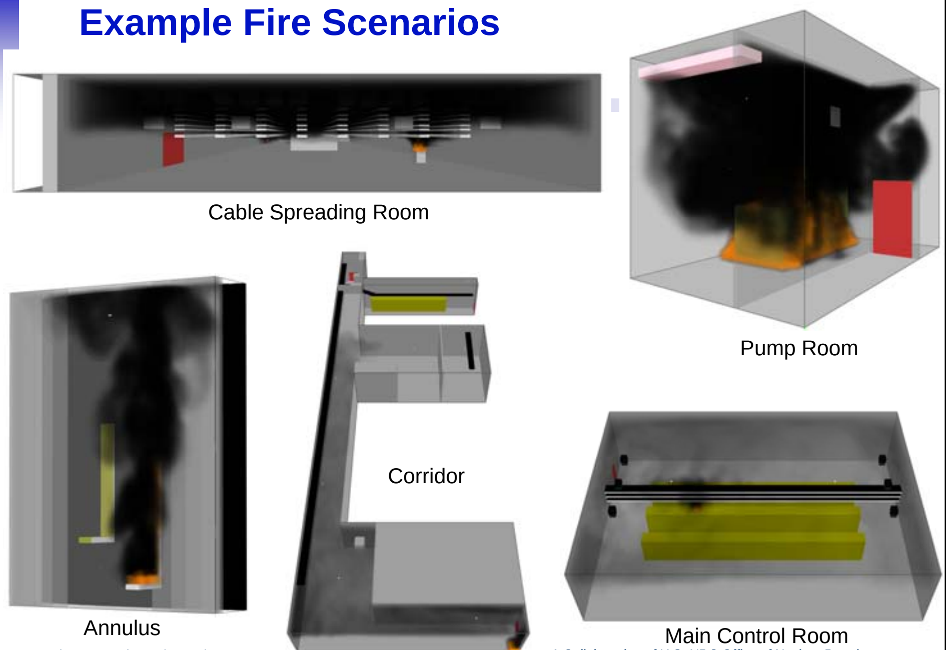
Basic Elements of a Fire Modeling Analysis



Greater Emphasis on Uncertainty



Example Fire Scenarios



Project Status

- Draft complete, Winter 2009
- Peer Review complete, Winter 2009
- 60 day Public comment ended, April 2010
- Currently addressing public comments
- Issue Winter 2010

Cable Heat Release, Ignition, and Spread in Tray Installations during Fire (CHRISTIFIRE) Phase I

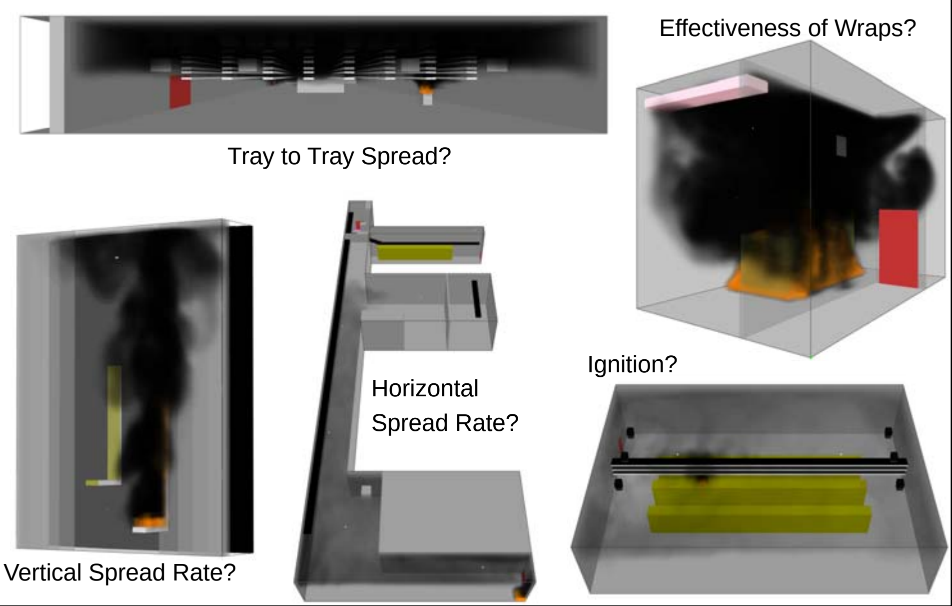
David W. Stroup
U.S. Nuclear Regulatory Commission
Washington, D.C., USA

U.S.NRC Protecting People and the Environment

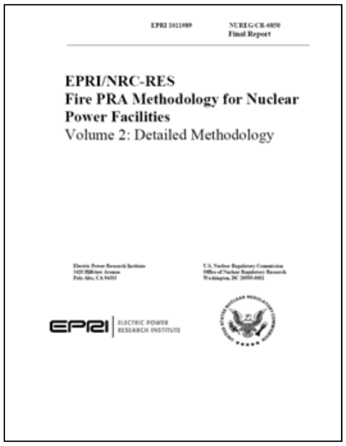
NIST National Institute of Standards and Technology U.S. Department of Commerce

What's the Problem?

Answer: Very little useful information on cables for fire modeling



Current Guidance for Modeling Cables



Problems going from "bench" to full-scale

Table R-1
Bench Scale HRR Values Under a Heat Flux of 60 kW/m², q_{bs} [R-4]

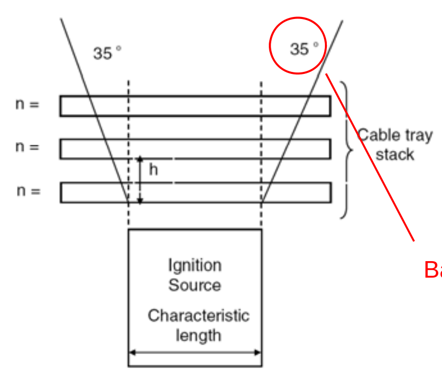
Material	Bench Scale HRR [kW/m²]
XPE/FRXPE	475
XPE/Neoprene	354
XPE/Neoprene	302
XPE/XPE	178
PE/PVC	395
PE/PVC	359
PE/PVC	312
PE/PVC	589
PE, Nylon/PVC, Nylon	231
PE, Nylon/PVC, Nylon	218

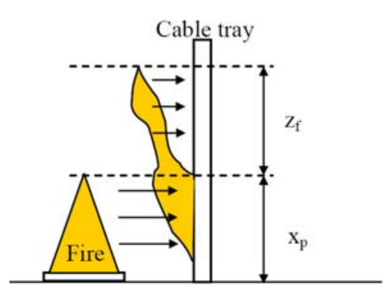
Which HRR to Use?

Current Guidance on Flame Spread

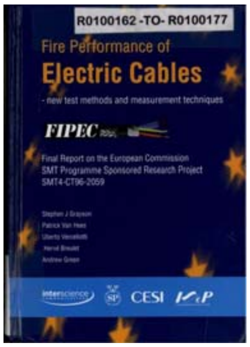
$$v = \frac{4\left(\dot{q}''_f\right)^2 \delta_f}{\pi (k\rho c)\left(T_{ig} - T_{amb}\right)^2}$$

Vague or ill-defined parameters





Based on only one experiment



Basic Outline of Experimental Program

Chemistry/Materials

- Tube Furnace testing for gaseous yields
- Microcalorimetry for thermal properties

Heat Release and Spread Rates

- Cone Calorimetry (Bench-Scale)
- Radiant Panel Tests (Intermediate-Scale)
- Multiple Tray Tests (Large-Scale)

Micro-Calorimeter

5 mg sample

Standard Test Method for Measuring Flammability Properties of Plastics and Other Solid Materials Using Microscale Combustion Calorimetry
ASTM D 7309

Cone Calorimeter

10 cm x 10 cm sample

Standard Test Method for Using a Cone Calorimeter to Determine Fire-Test-Response Characteristics of Insulating Materials Contained in Electrical or Optical Fiber Cables
ASTM D 7309

Panel Calorimeter

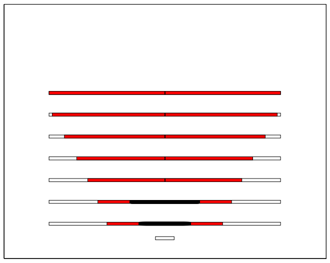
120 cm x 45 cm sample

No Applicable Standard

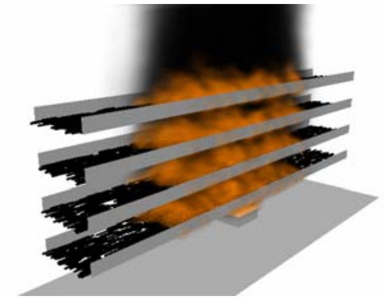
Multiple Tray Tests

Modeling

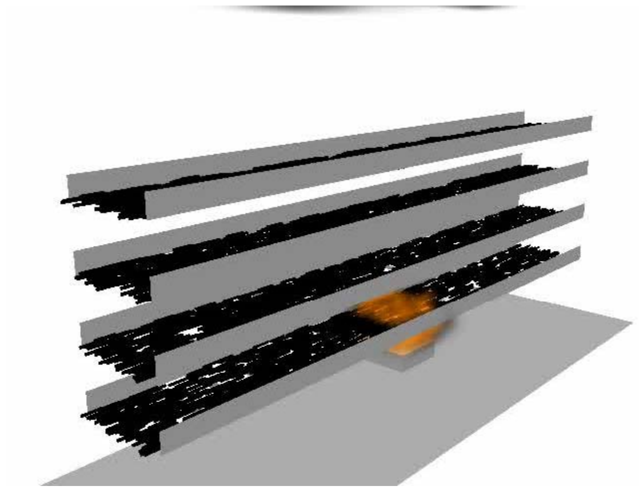
The Easy Way



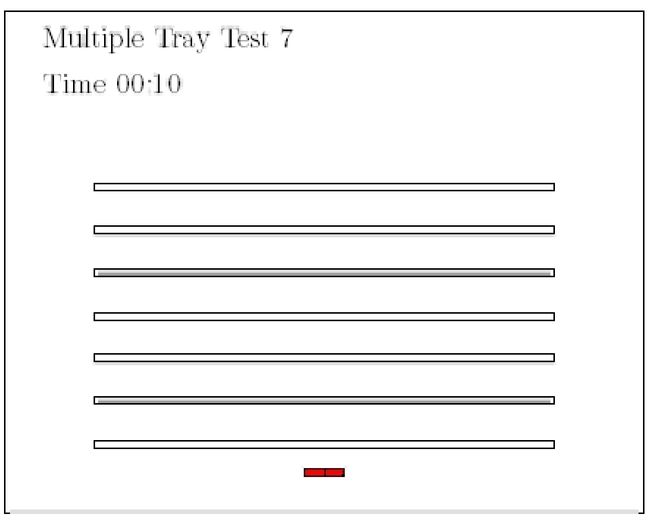
The Hard Way



Fire Dynamics Simulator

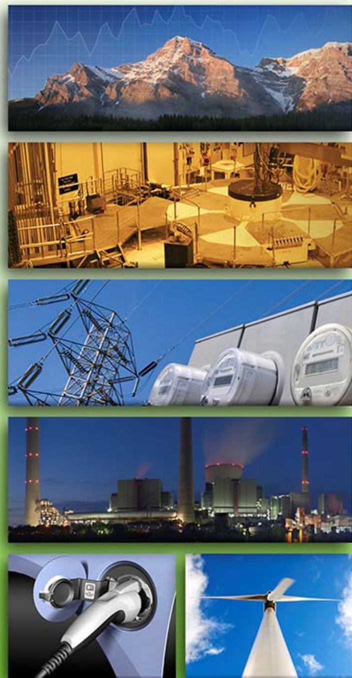


FLASH-CAT



Summary

- Measured Cable Burning Behavior
  - Micro-Scale to Full-Scale
  - HRRPUA Consistent with NUREG/CR-6850
- Developed Mathematical Model
- Future Work
  - Vertical Trays
  - Other Configurations



ELECTRIC POWER RESEARCH INSTITUTE

Electrical Cabinet Heat Release Rate – Project Update

Pierre Macheret, SAIC

Paul Amico, SAIC

Ken Canavan, EPRI

EPRI/NRC Fire PRA Course

September/October 2010

Introduction

- Purpose of study: Re-evaluate the heat release rates (HRRs) of cabinet fires recommended for use in NUREG/CR-6850 (Table G-1)

Ignition Source	HRR kW (Btu/s)		Gamma Distribution	
	75th	98th	α	β
Vertical cabinets with qualified cable, fire limited to one cable bundle	69 (65)	211 (200)	0.84 (0.83)	59.3 (56.6)
Vertical cabinets with qualified cable, fire in more than one cable bundle	211 (200)	702 (665)	0.7 (0.7)	216 (204)
Vertical cabinets with unqualified cable, fire limited to one cable bundle	90 (85)	211 (200)	1.6 (1.6)	41.5 (39.5)
Vertical cabinets with unqualified cable, fire in more than one cable bundle closed doors	232 (220)	464 (440)	2.6 (2.6)	67.8 (64.3)
Vertical cabinets with unqualified cable, fire in more than one cable bundle open doors	232 (220)	1002 (950)	0.46 (0.45)	386 (366)

- Scope limited to:
  - Vertical cabinets
  - No consideration of external influences, or of fire propagation to other cabinets
  - No consideration of fire duration

Re-Evaluation of Heat Release Rates in Vertical Cabinet Fires; *Basis*

- Re-evaluation based on fire test data from:
  - NUREG/CR-4527: Tests performed on nuclear power plant cabinets filled with cables
    - Tests in open-door cabinets
    - Tests in closed-door cabinets
    - Two types of cables considered: qualified and unqualified
  - VTT experiments: 3 series of tests, all under ventilation-limited conditions
    - Two series with vertical, closed-door relay and electronic cabinets. Observation of gaps formed by thermal stress, enhancing the fire
    - Third series involved mock-up chimney-like cabinets
  - IRSN experiments (CARMELA), under ventilation-limited conditions
    - A series of tests on real cabinets, but simulated combustible (PMMA, PE, PVC)
    - Two tests with identical, real relay cabinets (vertical, closed-door)
- Use of a probabilistic HRR model from VTT to benchmark EPRI model results

Re-Evaluation of Heat Release Rates in Vertical Cabinet Fires; *Approach*

- 3 models created to capture different fire characteristics:
  - Fires initiated in qualified cable: based on NUREG/CR-4527 fire tests, these fires:
    - tend to stay localized: fire propagation prob. is 0.0833; standard deviation: 0.1
    - have low HRR: 80 kW, standard deviation: 13 kW
  - Fires in open-door cabinets under 'flashover conditions' (i.e., fire propagates throughout vertical cabinet). Based on NUREG/CR-4527 fire tests, it was found that:
    - The HRR is in linear relationship with the energy released through combustion
    - The energy released through combustion is probabilistically linked to the initial fuel loading (combustion efficiency factor is 0.66, standard deviation: 0.13)
    - The initial fuel loading is proportional to the cabinet volume. Proportionality factors depend on 'how full' the cabinet is.

Re-Evaluation of Heat Release Rates in Vertical Cabinet Fires; *Model*

- 3 separate models created to capture various fire characteristics (continued):
  - Fires with flashover, but under ventilation-limited conditions. Based on VTT and IRSN experiments:
    - These fires have an HRR proportional to amount of air flowing through cabinet
    - Under natural ventilation conditions, flow of air can be calculated analytically based on cabinet height, total vent area, ratio of inlet over total vent area
    - Consideration taken for potential gap formation in cabinets that are not robustly secured (modeled with exponential distribution)
    - Potential external combustion due to unburned pyrolysates (products of pyrolysis) igniting at cabinet outlet is found to not significantly increase HRR
  - HRRs predicted using Bayesian approach with Markov Chain Monte Carlo (MCMC) simulations
  - Comparison of model predictions with VTT probabilistic model shows good overall agreement, with EPRI model yielding generally more conservative results.

Re-Evaluation of Heat Release Rates in Vertical Cabinet Fires; *Comparison with NUREG/CR-6850*

- Further classification of the electrical cabinet types
  - Distinction between qualified-cable initiated fires and other fires
  - Ventilation; distinction between closed-door and open-door cabinet fires
- Abandoned criterion about number of bundles in the electrical cabinet as a measure of combustible load and configuration
  - Instead cabinet size and type (two classifications reflecting fuel loading, MJ/ft^3) is used
  - Benchmarked against the VTT model (2003)
    - For open (fuel-limited) cabinet, prediction of the EPRI model for the same initial fuel loading is more conservative than the prediction of the VTT model in vast majority of cases
    - For closed (ventilation-limited) cabinet, the VTT model uses a combustion efficiency factor that decreases the HRR. This factor is not used in the EPRI model.

Re-Evaluation of Heat Release Rates in Vertical Cabinet Fires; *Comparison with NUREG/CR-6850*

- Scoping value is not 98th percentile. Instead, it can be 90th, 95th, 97.5th or bounding value depending on model and its prediction vs. observed HRR data from fire tests.
  - The scoping value is chosen such that it bounds
    - *All* fire test data in the same electrical cabinet classification, and
    - *Vast majority* of expected fire events in the same electrical cabinet classification
    - Selection of scoping value similar to 6850 which picks the scoping 98% to "*establish an anticipated "high-confidence" fire intensity value expected to bound the vast majority of fires involving a given fire source*."
- EPRI model adds refinements and thus needs more inputs:
  - Type of vertical cabinet: relay or other, generic cabinet
  - Cabinet overall dimensions (length, width, height)
  - If closed-door:
    - Determination on whether cabinet is cooled by forced or natural ventilation
    - Assessment of robustness regarding gap potential
    - Need to know vent area and position of vents (top, bottom, or vents at intermediate level)
    - If vent dimensions are unknown, open-door cabinet HRR predictions offer a conservative alternative estimate

Re-Evaluation of Heat Release Rates in Vertical Cabinet Fires; *Results*

- HRR results provided as tables of key statistical values (mean, standard deviation, 5th, 50th, and 90th, 95th, 97.5th, or bounding value).

- **Example**: Relay cabinet, 7-ft high x 3-ft wide x 2.5-ft deep (estimated fuel loading of 488 MJ). For closed-door configuration, additional inputs are: robustly-secured cabinet, 150 in^2 total vent area, 2 vents of equal size, one at top, one at bottom, natural ventilation

Cabinet Configuration	Mean HRR (kW)	Scoping HRR (kW) (prctl)
Open-door, fire *not* initiated in qualified cable	**355**	**555 (97.5th)**
Open-door, fire initiated in qualified cable	**103**	**171 (95th)**
Closed-door, fire *not* initiated in qualified cable	**281**	**292 (max)**
Closed-door, fire initiated in qualified cable	**97**	**144 (95th)**

Path Forward

- Peer Review — Sept 2010
  - A panel has been designated
- Publication of Rev 0 — Oct/Nov 2010
- Pilot Application
- Future enhancements being evaluated
  - In part based on the peer review and pilot applications

DESIREE-FIRE

Direct Current Electrical Shorting In Response to Exposure-FIRE

Semi-Annual Fire Protection Workshop

Office of Nuclear Regulatory Research

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DESIREE-FIRE

- Experimental testing program to evaluate direct current (dc) circuit response to fire exposure.
- Cooperative research project with EPRI
- Sandia National Laboratories conducted the testing

Need for Testing

- Lack of data and uncertainties extrapolating alternating current (ac) results to dc circuits
- Numerous safety related systems commonly powered with dc
- Duke testing in 2006 indicated that dc circuits may react differently than ac circuits to fire-induced failures

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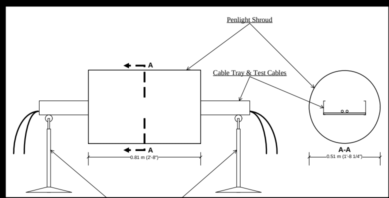
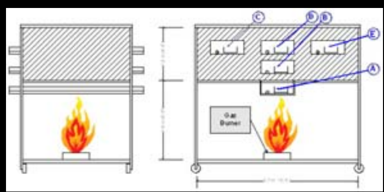
Testing Schedule

- Small-Scale
  - July to October 2009
- Intermediate-Scale
  - September 2009 to March 2010
- Draft Report
  - Summer 2010





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- **Similar to CAROLFIRE**
  - Small-scale radiant exposure
  - Intermediate-scale live fire tests
- **Numerous dc circuit types evaluated**
  - DC motor starter (MOV)
  - Small pilot DC SOV (ASCO red-hat)
  - 15 kV circuit breaker (complete breaker assembly)
  - 1” SOV
  - Large coil (similar to PORV)
  - Instrumentation loop

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Battery Bank

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Penlight

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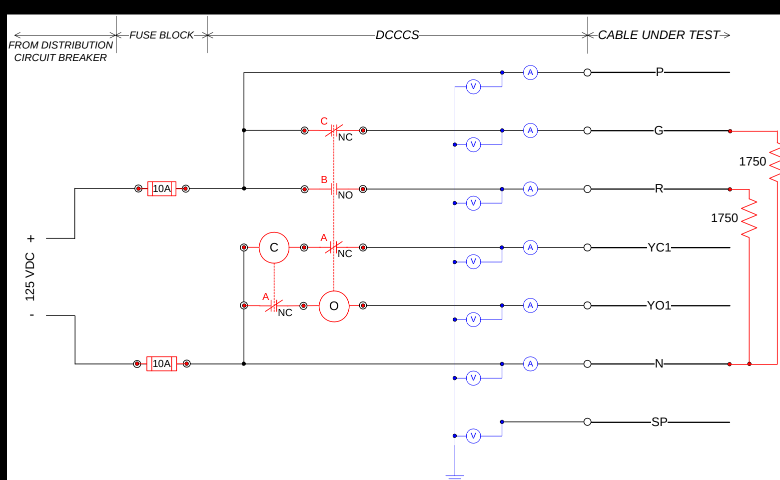

DCCCS Layout for DC MOV Control Circuit

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1” &
Large
Coil

Voltage &
Current
Transducers

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Preliminary Results

- Open Circuits

Open Circuit

Copper Slag

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Sandia National Laboratories

Preliminary Results (2)

- Arcing & Cable Ignition
  - dc electrical failures are typically more energetic than ac failures
  - In most cases arcing appears to act as the pilot for cable ignition
  - Arcing and hot short durations are linked to fuse sizing

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Preliminary Results (3)

- Fuse sizing
  - Initial observations indicate that larger fuses (15-35A) take significantly longer to clear than small 5-10A fuses
  - In some tests the 35A fuses did not clear, instead electrical arcing caused the cable conductors to open circuit

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Preliminary Results (4)

- Grounding
  - DC battery bank was intentionally left ungrounded, however a high-resistance ground connection was implemented for instrumentation purposes
  - A single short to ground (e.g., to cable raceway) won't clear a fuse
  - Presents an opportunity for inter-cable interactions
    - shorts occurred through cable raceway

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Follow-on Work

- Expert Elicitation and Phenomena Identification and Ranking Table (PIRT)
  - Expert Elicitation will provide best estimate probabilities for use in Fire PRA
  - PIRT will rank the importance of various aspects related to fire-induced cable damage

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Objectives – Analysis of Data

- Expert Elicitation will re-evaluate original spurious operation probabilities (EPRI 1006961)
- Incorporate dc results
  - Spend time to Re-evaluate dc motor starter (MOV)
  - Small pilot dc SOV (ASCO red-hat)
  - 15 kV circuit breaker (complete breaker assembly)
  - 1” SOV
  - Large coil (similar to PORV)
  - Instrumentation loop

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Questions

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EPRI ELECTRIC POWER RESEARCH INSTITUTE

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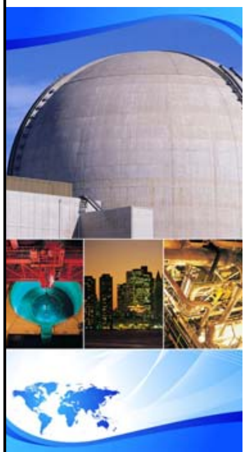
SAIC Science Applications International Corporation



Enhanced Fire Events Database to Support Fire PRA

(A joint NRC-RES/EPRI project)

By J.S. Hyslop, NRC/RES
(Acknowledgement of PSAM10 Presentation by P. Baranowsky of ERIN, et. al.)

Joint RES/EPRI Fire PRA Workshop
September and October 2010
Washington DC

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

Introduction

The Electric Power Research Institute's (EPRI) Fire Events Data Base (FEDB) is the principal source of fire incident operational data for use in fire PRAs.

This project will improve the FEDB by:

- Giving expanded and improved data fields
- Adding credibility by reducing "undetermined" data
- Improving Consistency and Quality Assurance
- Allowing for Reference Data Source Traceability

Introduction

These improvements will provide more current and useable data for Fire PRA applications to support:

- updated, improved fire frequencies
- treatment of detection & suppression
- improved fire event severity characterization and classification for reduced uncertainty in estimates of damaging fire frequencies

Improvements to the FEDB

- Improved Database Structure
- Improved Quality of Data
- Improved Fire Ignition Source Details
- Improved Fire Detection and Suppression Response Details
- Improved Fire Event Severity Classification

Data Field Content

- Plant descriptive
- Event descriptive
- Event derived/inferred
- QA/traceability

Event Descriptive

- Event Summary Description
- Location and Source Characteristics
- Fire Duration, Growth, and Damage Descriptive Details
- Detection: Time(s), Systems & Equipment, Fire Brigade and Other Personnel Role
- Suppression: Time(s), Systems and Equipment, Fire Brigade and Other Personnel Role

Event Derived/Inferred : Fire Severity

- Four severity classifications
  - Challenging
  - Potentially Challenging
  - Not Challenging
  - Undetermined
- For challenging, the fire is further developed than for potentially challenging
  - Potentially challenging fires can evolve into challenging fires in fire PRA model
- As indicated earlier, major thrust of project is to minimize undetermined fires

QA/Traceability

- Source document identifiers
- Electronic copy of cited source documents
- Plant point of contact
- Data coder and data coding reviewer
- Software built in consistency checking

EPRI/NRC-RES Fire PRA Course

September and October 2010

(Revised October 2010)

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CONTENTS

LIST OF ACRONYMS

AFW	Auxiliary Feedwater
ATWS	Anticipated Transient Without Scram
BWR	Boiling Water Reactor
CCDP	Conditional Core Damage Probability
CF	Cable (Configuration) Factors
CCW	Component Cooling Water
CDF	Core Damage Frequency
CFD	Computational Fluid Dynamics
CFR	Code of Federal Regulations
CLERP	Conditional Large Early Release Probability
CM	Corrective Maintenance
CRS	Cable and Raceway (Database) System
CVCS	Chemical and Volume Control System
EDG	Emergency Diesel Generator
EF	Error Factor
EOP	Emergency Operating Procedure
EPR	Ethylene-Propylene Rubber
EPRI	Electric Power Research Institute
FEDB	Fire Events Database
FEP	Fire Emergency Procedure
FHA	Fire Hazards Analysis
FIVE	Fire-Induced Vulnerability Evaluation (EPRI TR 100370)
FMRC	Factory Mutual Research Corporation
FPRAIG	Fire PRA Implementation Guide (EPRI TR 105928)
FRSS	Fire Risk Scoping Study (NUREG/CR-5088)
FSAR	Final Safety Analysis Report
HEAF	High Energy Arcing Fault
HEP	Human Error Probability
HFE	Human Failure Event
HPI	High Pressure Injection
HPCI	High Pressure Coolant Injection
HRA	Human Reliability Analysis
HRR	Heat Release Rate
HVAC	Heating, Ventilation, and Air Conditioning
ICDP	Incremental Core Damage Probability
ILERP	Incremental Large Early Release Probability

IPE	Individual Plant Examination
IPEEE	Individual Plant Examination of External Events
IS	Ignition Source
ISLOCA	Interfacing Systems Loss of Coolant Accident
KS	Key Switch
LERF	Large Early Release Frequency
LFL	Lower Flammability Limit
LOC	Loss of Control
LOCA	Loss of Coolant Accident
MCC	Motor Control Center
MCR	Main Control Room
MG	Motor-Generator
MOV	Motor Operated Valve
MQH	McCaffrey, Quintiere and Harkleroad’s Method
MS	Main Steam
NC	No Consequence
NEI	Nuclear Energy Institute
NEIL	Nuclear Electric Insurance Limited
NFPA	National Fire Protection Association
NPP	Nuclear Power Plant
NPSH	Net Positive Suction Head
NQ cable	Non-Qualified (IEEE-383) cable
NRC	Nuclear Regulatory Commission
P&ID	Piping and Instrumentation Diagram
PE	Polyethylene
PM	Preventive Maintenance
PMMA	Polymethyl Methacrylate
PORV	Power Operated Relief Valve
PRA	Probabilistic Risk Assessment
PSF	Performance Shaping Factor
PVC	Polyvinyl Chloride
PWR	Pressurized Water Reactor
Q cable	Qualified (IEEE-383) cable
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
RDAT	Computer program for Bayesian analysis
RES	The Office of Nuclear Regulatory Research (at NRC)
RHR	Residual Heat Removal
RPS	Reactor Protection System
RWST	Refueling Water Storage Tank
SDP	Significance Determination Process
SGTR	Steam Generator Tube Rupture
SI	Safety Injection
SO	Spurious Operation
SOV	Solenoid Operated Valve
SRV	Safety Relief Valve

SSD	Safe Shutdown
SSEL	Safe Shutdown Equipment List
SUT	Start-up Transformer
T/G	Turbine/Generator
TGB	Turbine-Generator Building
TSP	Transfer Switch Panel
UAT	Unit Auxiliary Transformer
VCT	Volume Control Tank
VTT	Valtion Teknillinen Tutkimuskeskus (Technical Research Centre of Finland)
XLPE	Cross-Linked Polyethylene
ZOI	Zone of Influence

1 INTRODUCTION

1.1 Background

The U.S. Nuclear Regulatory Commission and Electric Power Research Institute under a Memorandum of Understanding (MOU) on Cooperative Nuclear Safety Research have been developing state of the art methods for conduct of fire PRA. In September 2005, this work produced the "EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities," EPRI 1011989, and NUREG/CR-6850 [1].

A Fire PRA Course has been put together to train interested parties in the application of this methodology. The Course/Seminar is provided in four parallel modules. The first three modules are based directly on Reference [1]. However, that document did not cover fire human reliability analysis (HRA) methods in detail. For 2010, the training materials have been enhanced to include a fourth module based on a more recent EPRI/RES collaboration and a draft guidance document, EPRI 1019196, NUREG-1921 [2] published in late 2009 based on those efforts. The training materials are based on this draft document including the consideration of public comments received on the draft report and the team's responses to those comments.

The four training modules are:

- Module 1: PRA/Systems Analysis - This module covers the technical tasks for development of the system response to a fire including human failure events. Specifically, this module covers Tasks/Sections 2, 4, 5, 7, 14, and 15 of Reference [1].
- Module 2: Electrical Analysis – This module covers the technical tasks for analysis of electrical failures as the result of a fire. Specifically, this module covers Tasks/Sections 3, 9, and 10 of Reference [1].
- Module 3: Fire Analysis – This module covers technical tasks involved in development of fire scenarios from initiation to target (e.g., cable) impact. Specifically, this module covers Tasks/Sections 1, 6, 8, 11, and 13 of Reference [1].
- Module 4: Fire Human Reliability Analysis: This module covers the technical tasks associated with identifying and analyzing operator actions and performance during a postulated fire scenario. Specifically, this module covers Task 12 as outlined in Reference [1] based on the application of the approaches documented in Reference [2].

Integral to Modules 1, 2 and 3 is a set of hands-on problems based on a fictitious, simplified nuclear power plant. The same power plant is used in all three modules. This document provides the background information for the problem sets of each module. Clearly, the power plant defined in this package is an extremely simplified one that in many cases does not meet any regulatory requirements or good engineering practices. Design features presented are focused on bringing forward the various aspects of the Fire PRA methodology. This package includes a general description of the power plant and the internal events PRA needed as input to the Fire PRA.

For Module 4, an independent set of examples are used to illustrate key points of the analysis procedures. The examples for Module 4 are not tied to the simplified plant, but rather, were derived based largely on pilot applications and on independent work of the EPRI and RES HRA teams.

The instruction package for specific technical tasks is provided in Sections 3, 4, 5 and 6 which are organized by Modules (see above). A short description of the Fire PRA technical tasks is provided below. For further details, refer to the individual task descriptions in EPRI 1011989, NUREG/CR-6850, Volume 2. The figure presented at the end of this chapter provides a simplified flow chart for the analysis process and indicates which training module covers each of the analysis tasks.

- ***Plant Boundary Definition and Partitioning (Task 1).*** The first step in a Fire PRA is to define the physical boundary of the analysis, and to divide the area within that boundary into analysis compartments.
- ***Fire PRA Component Selection (Task 2).*** The selection of components that are to be credited for plant shutdown following a fire is a critical step in any Fire PRA. Components selected would generally include many, but not necessarily all components credited in the 10 CFR 50 Appendix R post-fire SSD analysis. Additional components will likely be selected, potentially including most but not all components credited in the plant's internal events PRA. Also, the proposed methodology would likely introduce components beyond either the 10 CFR 50 Appendix R list or the internal events PRA model. Such components are often of interest due to considerations of multiple spurious actuations that may threaten the credited functions and components; as well as due to concerns about fire effects on instrumentation used by the plant crew to respond to the event.
- ***Fire PRA Cable Selection (Task 3).*** This task provides instructions and technical considerations associated with identifying cables supporting those components selected in Task 2. In previous Fire PRA methods (such as EPRI FIVE and Fire PRA Implementation Guide) this task was relegated to the SSD analysis and its associated databases. This document offers a more structured set of rules for selection of cables.
- ***Qualitative Screening (Task 4).*** This task identifies fire analysis compartments that can be shown to have little or no risk significance without quantitative analysis. Fire compartments may be screened out if they contain no components or cables identified in Tasks 2 and 3, and if they cannot lead to a plant trip due to either plant procedures, an automatic trip signal, or technical specification requirements.
- ***Plant Fire-Induced Risk Model (Task 5).*** This task discusses steps for the development of a logic model that reflects plant response following a fire. Specific instructions have been provided for treatment of fire-specific procedures or preplans. These procedures may impact

availability of functions and components, or include fire-specific operator actions (e.g., self-induced-station-blackout).

- ***Fire Ignition Frequency (Task 6).*** This task describes the approach to develop frequency estimates for fire compartments and scenarios. Significant changes from the EPRI FIVE method have been made in this task. The changes generally relate to use of challenging events, considerations associated with data quality, and increased use of a fully component-based ignition frequency model (as opposed to the location/component-based model used, for example, in FIVE).
- ***Quantitative Screening (Task 7).*** A Fire PRA allows the screening of fire compartments and scenarios based on their contribution to fire risk. This approach considers the cumulative risk associated with the screened compartments (i.e., the ones not retained for detailed analysis) to ensure that a true estimate of fire risk profile (as opposed to vulnerability) is obtained.
- ***Scoping Fire Modeling (Task 8).*** This step provides simple rules to define and screen fire ignition sources (and therefore fire scenarios) in an unscreened fire compartment.
- ***Detailed Circuit Failure Analysis (Task 9).*** This task provides an approach and technical considerations for identifying how the failure of specific cables will impact the components included in the Fire PRA SSD plant response model.
- ***Circuit Failure Mode Likelihood Analysis (Task 10).*** This task considers the relative likelihood of various circuit failure modes. This added level of resolution may be a desired option for those fire scenarios that are significant contributors to the risk. The methodology provided in this document benefits from the knowledge gained from the tests performed in response to the circuit failure issue.
- ***Detailed Fire Modeling (Task 11).*** This task describes the method to examine the consequences of a fire. This includes consideration of scenarios involving single compartments, multiple fire compartments, and the main control room. Factors considered include initial fire characteristics, fire growth in a fire compartment or across fire compartments, detection and suppression, electrical raceway fire barrier systems, and damage from heat and smoke. Special consideration is given to turbine generator (T/G) fires, hydrogen fires, high-energy arcing faults, cable fires, and main control board (MCB) fires. There are considerable improvements in the method for this task over the EPRI FIVE and Fire PRA Implementation Guide in nearly all technical areas.
- ***Post-Fire Human Reliability Analysis (Task 12).*** This task considers operator actions for manipulation of plant components. The analysis task procedure provides structured instructions for identification and inclusion of these actions in the Fire PRA. The procedure also provides instructions for incorporating human error probabilities (HEPs) into the fire PRA analysis. (Note that NUREG/CR-6850, EPRI 1011989 did not develop a detailed fire HRA methodology. Fire-specific HRA guidance can be found in NUREG-1921, EPRI 1019196, *EPRI/NRC-RES Fire Human Reliability Analysis Guidelines – Draft Report for Comment*, November 2009. Publication of the final Fire HRA report remains pending.)
- ***Seismic Fire Interactions (Task 13).*** This task is a qualitative approach to help identify the risk from any potential interactions between an earthquake and fire.

- ***Fire Risk Quantification (Task 14).*** The task summarizes what is to be done for quantification of the fire risk results.
- ***Uncertainty and Sensitivity Analyses (Task 15).*** This task describes the approach to follow for identifying and treating uncertainties throughout the Fire PRA process. The treatment may vary from quantitative estimation and propagation of uncertainties where possible (e.g., in fire frequency and non-suppression probability) to identification of sources without quantitative estimation. The treatment may also include one-at-a-time variation of individual parameter values or modeling approaches to determine the effect on the overall fire risk (sensitivity analysis).

1.2 How to Use this Package

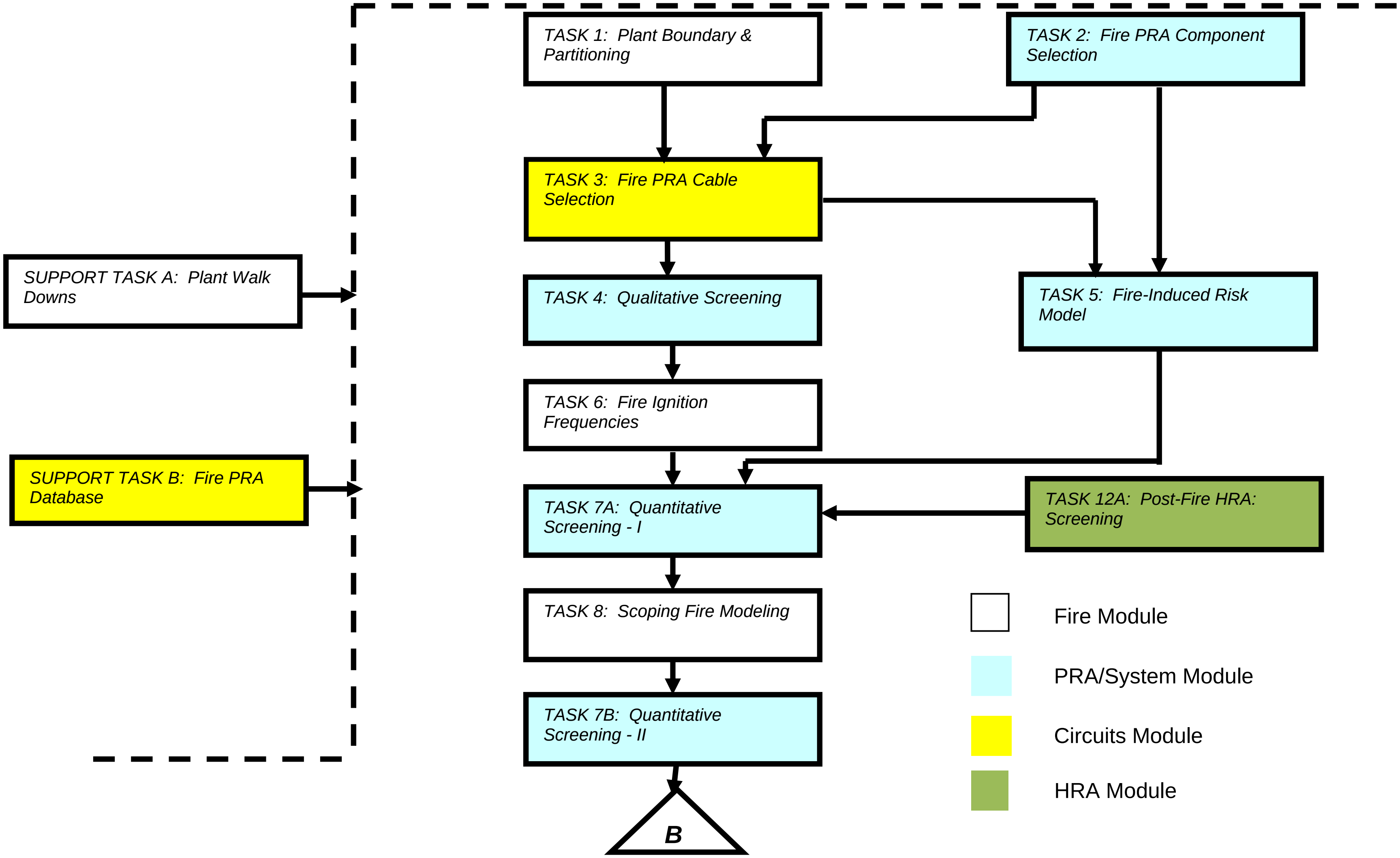
This package is intended to provide the background information necessary to perform some of the problem sets of the Course/Seminar. Please note:

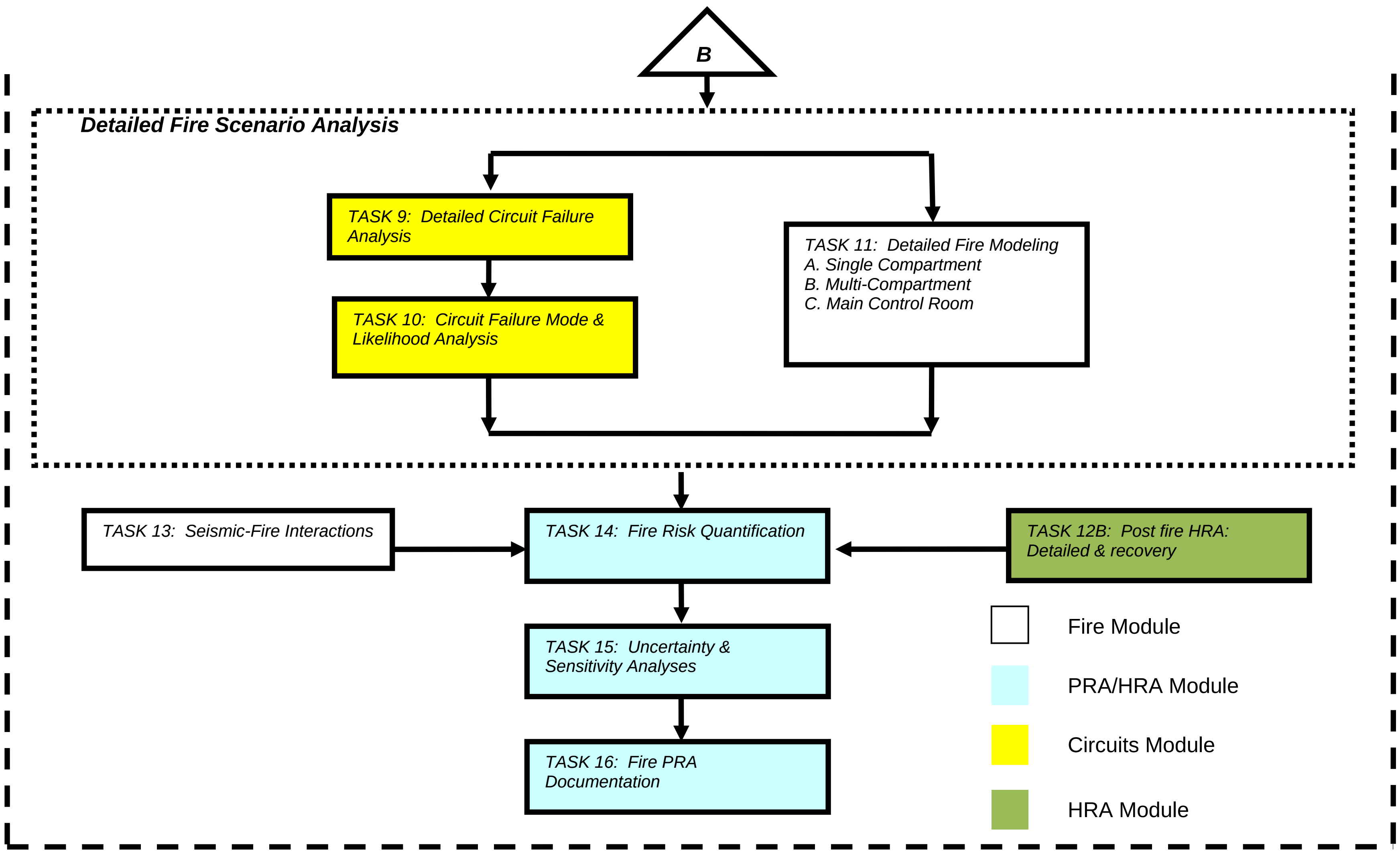
1. All Course/Seminar attendees are expected to review Section 2 of this document and become familiar with the power plant defined in that section.
2. The instructors of each module will provide questions or case study problem sets and will guide the attendees to sections relevant to each specific problem set. Attendees will be expected to review those relevant sections and use the information or examples provided in those sections to complete the assigned problem set.
3. Do not make any additional assumptions in terms of equipment, systems, or plant layout other than those presented in the problem package without consulting the instructor.

1.3 References

1. EPRI 1011989, NUREG/CR-6850, *EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities*, September 2005.

2. EPRI 1019196, NUREG-1921, *EPRI/NRC-RES Fire Human Reliability Analysis Guidelines – Draft Report for Comment*, Technical Update, November 2009.


TASK 1: Plant Boundary & Partitioning
TASK 2: Fire PRA Component Selection
TASK 3: Fire PRA Cable Selection
SUPPORT TASK A: Plant Walk Downs
TASK 4: Qualitative Screening
TASK 5: Fire-Induced Risk Model
TASK 6: Fire Ignition Frequencies
SUPPORT TASK B: Fire PRA Database
TASK 7A: Quantitative Screening - I
TASK 12A: Post-Fire HRA: Screening
TASK 8: Scoping Fire Modeling
TASK 7B: Quantitative Screening - II
B
Fire Module
PRA/System Module
Circuits Module
HRA Module


B
Detailed Fire Scenario Analysis
TASK 9: Detailed Circuit Failure Analysis
TASK 10: Circuit Failure Mode & Likelihood Analysis
TASK 11: Detailed Fire Modeling
A. Single Compartment
B. Multi-Compartment
C. Main Control Room
TASK 13: Seismic-Fire Interactions
TASK 14: Fire Risk Quantification
TASK 12B: Post fire HRA: Detailed & recovery
TASK 15: Uncertainty & Sensitivity Analyses
TASK 16: Fire PRA Documentation
Fire Module
PRA/HRA Module
Circuits Module
HRA Module

2
EXAMPLE CASE PLANT - GENERAL INFORMATION

2.1 Overall Plant Description

This chapter provides background information about the fictitious plant used in the hands-on problem sets of Modules 1, 2 and 3. Note that the examples used in Module 4 (HRA) are not based on the example case plant.

The following notes generally describe the example case plant, including its layout:

1. The plant is a Pressurized Water Reactor (PWR) consisting of one Primary Coolant Loop, which consists of one Steam Generator, two Reactor Coolant Pumps and the Pressurizer. A Chemical Volume Control System and multiple train High Pressure Injection system, as well as a single train Residual Heat Removal system interface with the primary system
2. The secondary side of the plant contains a Main Steam and Feedwater loop associated with the single Steam Generator, and a multiple train Auxiliary Feedwater System to provide decay heat removal.
3. The operating conditions and parameters of this plant are similar to that of a typical PWR. For example, the primary side runs at about 2,200 psi pressure. The steam generator can reject the decay heat after a reactor trip. There is a possibility for feed and bleed.
4. It is assumed that the reactor is initially at 100% power.
5. The plant is laid out in accordance with Figures 1 through 9. The plant consists of a Containment Building, Auxiliary Building, Turbine Building, Diesel Generator Building and the Yard. All other buildings and plant areas are shown but no details are provided.

2.2 Systems Description

This section provides a more detailed description of the various systems within the plant and addressed in the case studies. Each system is described separately.

2.2.1 Primary Coolant System

The following notes and Figure 10 define the Primary Coolant System:

1. The Primary Coolant Loop consists of the Reactor Vessel, two Reactor Coolant Pumps, and one Steam Generator and the Pressurizer, along with associated piping.

2. The Pressurizer is equipped with a normally closed Power Operated Relief Valve (PORV), which is an air operated valve (AOV-1) with its pilot solenoid operated valve (SOV-1). There is also a normally open motor operated block valve (MOV-13) upstream of the PORV.
3. The Pressure Transmitter (PT-1) on the pressurizer provides the pressure reading for the Primary Coolant Loop and is used to signal a switch from Chemical Volume Control System (CVCS) to High Pressure Injection (HPI) configuration. That is, PT-1 provides the automatic signal for high pressure injection on low RCS pressure. It also provides the automatic signal to open the PORV on high RCS pressure.
4. A nitrogen bottle provides the necessary pressurized gas to operate the PORV in case of loss of plant air but does not have sufficient capacity to support long-term operation.

2.2.2 Chemical Volume Control and High Pressure Injection Systems

The following notes and Figure 10 define the shared CVCS and HPI System:

1. The CVCS normally operates during power generation.
2. Valve type and position information include:

Valve	Type	Status on Loss of Power (or Air as applicable)	Position During Normal Operation	Motor Power (hp)
AOV-2	Air Operated Valve	Fail Closed	Open	N/A
AOV-3	Air Operated Valve	Fail Open	Open	N/A
MOV-1	Motor Operated Valve	Fail As Is	Closed	>5
MOV-2	Motor Operated Valve	Fail As Is	Open	<5
MOV-3	Motor Operated Valve	Fail As Is	Closed	<5
MOV-4	Motor Operated Valve	Fail As Is	Closed	<5
MOV-5	Motor Operated Valve	Fail As Is	Closed	<5
MOV-6	Motor Operated Valve	Fail As Is	Closed	>5
MOV-9	Motor Operated Valve	Fail As Is	Closed	>5

3. One of the two HPI pumps runs when the CVCS is operating.
4. One of the two HPI pumps is sufficient to provide all injection needs after a reactor trip and all postulated accident conditions.
5. HPI and CVCS use the same set of pumps.

6. On a need for safety injection, the following lineup takes place automatically:
   - AOV-3 closes
   - MOV-5 and MOV-6 open
   - MOV-2 closes.
   - Both HPI pumps receive start signal, the stand-by pump starts and the operating pump continues operating.
   - MOV-1 and MOV-9 open.
7. HPI is used for re-circulating sump water after a Loss of Coolant Accident (LOCA). For recirculation, upon proper indication of low RWST level and sufficient sump level, the operator manually opens MOV-3 and MOV-4, closes MOV-5 and MOV-6, starts the RHR pump, and aligns CCW to the RHR heat exchanger.
8. RWST provides the necessary cooling water for the HPI pumps during injection. During the recirculation mode, HPI pump cooling is provided by the recirculation water.
9. There are level indications of the RWST and containment sump levels that are used by the operator to know when to switch from high pressure injection to recirculation cooling mode.
10. The Air Compressor provides the motive power for operating the Air Operated Valves but the detailed connections to the various valves are not shown.

2.2.4 Residual Heat Removal System

The following notes and Figure 10 define the Residual Heat Removal (RHR) System:

1. The design pressure of the RHR system downstream of MOV-8 is low.
2. Valve type and position information include:

Valve	Type	Status on Loss of Power	Position During Normal Operation	Motor Power (hp)
MOV-7	Motor Operated Valve	Fail As Is	Closed (breaker racked out)	>5
MOV-8	Motor Operated Valve	Fail As Is	Closed	>5
MOV-20	Motor Operated Valve	Fails As Is	Closed	>5

3. Operators have to align the system for shutdown cooling, after reactor vessel de-pressurization from the control room by opening MOV-7 and MOV-8, turn the RHR pump on and establish cooling in the RHR Heat Exchanger.

2.2.5 Auxiliary Feedwater System

The following notes and Figure 11 define the Auxiliary Feedwater (AFW) System:

1. One of three pumps of the AFW system can provide the necessary secondary side cooling for reactor heat removal after a reactor trip.
2. Pump AFW-A is motor-driven, AFW-B is steam turbine-driven, and AFW-C is diesel-driven.
3. Valve type and position information include:

Valve	**Type**	**Status on Loss of Power**	**Position During Normal Operation**	**Motor Power (hp)**
MOV-10	Motor Operated Valve	Fail As Is	Closed	>5
MOV-11	Motor Operated Valve	Fail As Is	Closed	>5
MOV-14	Motor Operated Valve	Fail As Is	Closed	<5
MOV-15	Motor Operated Valve	Fail As Is	Closed	<5
MOV-16	Motor Operated Valve	Fail As Is	Closed	<5
MOV-17	Motor Operated Valve	Fail As Is	Closed	<5
MOV-18	Motor Operated Valve	Fail As Is	Closed	>5
MOV-19	Motor Operated Valve	Fail As Is	Closed	<5

4. Upon a plant trip, Main Feedwater isolates and AFW automatically initiates by starting AFW-A and AFW-C pumps, opening the steam valves MOV-14 and MOV-15 to operate the AFW-B steam-driven pump, and opening valves MOV-10, MOV-11, and MOV-18.
5. The CST has sufficient capacity to provide core cooling until cold shutdown is achieved.
6. The test return paths through MOVs-16, 17, and 19 are low flow lines and do not represent significant diversions of AFW flow even if the valves are open
7. There is a high motor temperature alarm on AFW pump A. Upon indication in the control room, the operator is to stop the pump immediately and have the condition subsequently checked by dispatching a local operator.
8. The atmospheric relief valve opens, as needed, automatically to remove decay heat if/should the main condenser path be unavailable.
9. The connections to the Main Turbine and Main Feedwater are shown in terms of one Main Steam Isolation Valve (MSIV) and a check valve. Portions of the plant beyond these interfacing components will not be addressed in the course.

10. Atmospheric dump valve AOV-4 is used to depressurize the steam generator in case of a tube rupture.

2.2.6 Electrical System

Figure 12 is a one-line diagram of the Electrical Distribution System (EDS). Safety related buses are identified by the use of alphabetic letters (e.g., SWGR-A, MCC-B1, etc.) while the non-safety buses use numbers as part of their designations (e.g., SWGR-1 and MCC-2).

The safety-related portions of the EDS include 4160 volt switchgear buses SWGR-A and SWGR-B, which are normally powered from the startup transformer SUT-1. In the event that off-site power is lost, these switchgear receive power from emergency diesel generators EDG-A and EDG-B. The 480 volt safety-related load centers (LC-A and LC-B) receive power from the switchgear buses via station service transformers SST-A and SST-B. The motor control centers (MCC-A1 and MCC-B1) are powered directly from the load centers. The MCCs provide motive power to several safety-related motor operated valves (MOVs) and to DC buses DC BUS-A and DC BUS-B via Battery Chargers BC-A and BC-B. The two 125 VDC batteries, BAT-A and BAT-B, supply power to the DC buses in the event that all AC power is lost. DC control power for the 4160 safety-related switchgear is provided through distribution panels PNL-A and PNL-B. The 120 VAC vital loads are powered from buses VITAL-A and VITAL-B, which in turn receive their power from the DC buses through inverters INV-A and INV-B.

The non-safety portions of the EDS reflect a similar hierarchy of power flow. There are important differences however. For example, 4160 volt SWGR-1 and SWGR-2 are normally energized from the unit auxiliary transformer (UAT-1) with backup power available from SUT-1. A cross-tie breaker allows one non-safety switchgear bus to provide power to the other. Non-safety load centers LC-1 and LC-2 are powered at 480 volts from the 4160 volt switchgear via SST-1 and SST-2. These load centers provide power directly to the non-safety MCCs. The non-vital DC bus (DC BUS-1) can be powered from either MCC via an automatic transfer switch (ATS-1) and battery charger BC-1 or directly from the 125 volt DC battery, BAT-1.

2.2.7 Other Systems

The following systems and equipment are mentioned in the plant description but not explicitly included in the fire PRA:

- Component Cooling Water (CCW) – provides cooling to Letdown Heat Exchanger and the RHR Heat Exchanger– assumed to be available at all times.
- It is assumed that the control rods can successfully insert and shutdown the reactor under all conditions.
- It is assumed that the ECCS and other AFW related instrumentation and control circuits (other than those specifically noted in the diagrams) exist and are perfect such that in all cases, they would sense the presence of a LOCA or otherwise a need to trip the plant and provide safety injection and auxiliary feedwater by sending the proper signals to the affected components (i.e., close valves and start pumps, insert control rods, etc.).

- Instrument air is required for operation of AOV-1, AOV-2, AOV-3, and AOV-4.

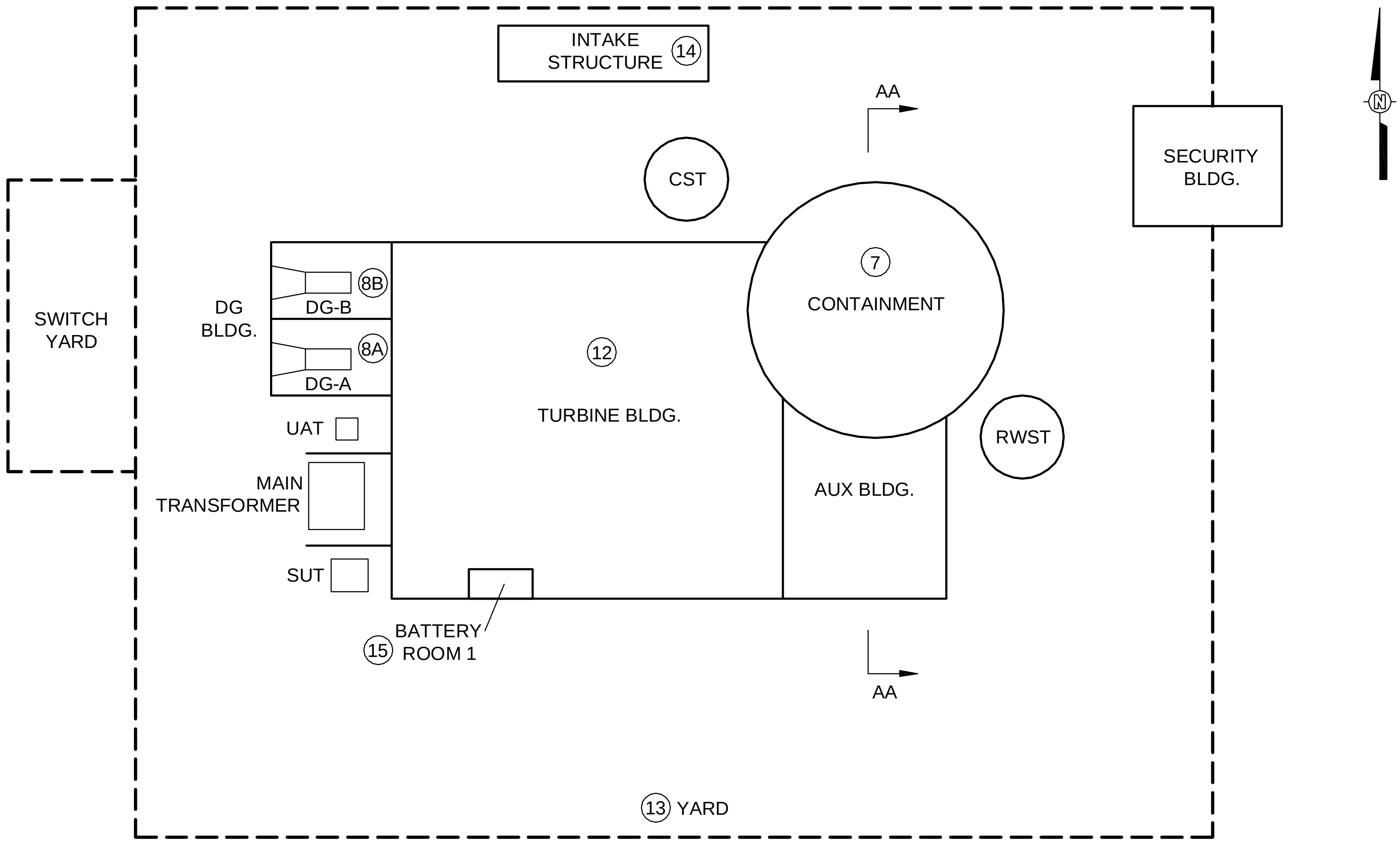
2.3 Plant Layout

The following notes augment the information provided in Figures 1 through 9 (Drawings A-01 through A09):

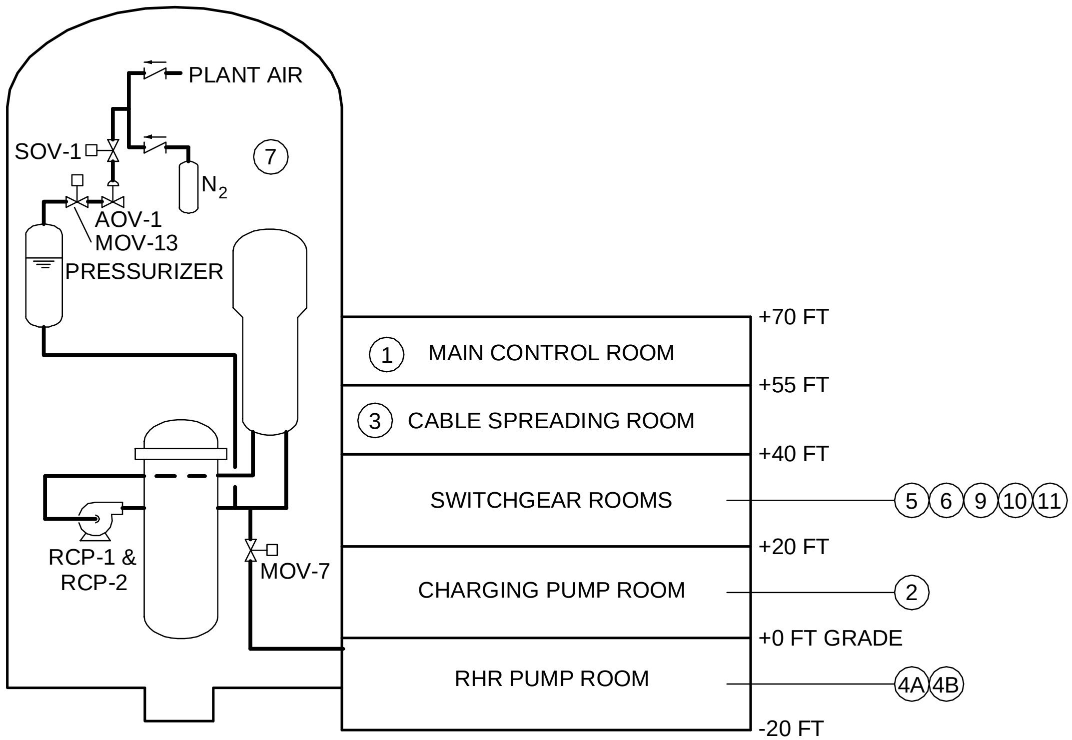
- The main structures of the plant are as follows:
  - Containment
  - Auxiliary Building
  - Turbine Building
  - Diesel Generator Building
  - Intake Structure
  - Security Building
- In Figure 1 (Drawing A-01), the dashed lines represent the fence that separates two major parts: the Yard and Switchyard.
- Switchyard is located outside the Yard with a separate security access.
- CST, RWST, UAT, Main Transformer and SUT are located in the open in the Yard.
- All walls shown in Figures 1 through 8 (Drawings A-01 through A-08) should be assumed as fire rated.
- All doors shown in Figures 1 through 8 (Drawings A-01 through A-08) should be assumed as fire rated and normally closed.
- Battery rooms A and B are located inside the respective switchgear rooms with 1-hour rated walls, ceilings and doors.
- All cable trays are open type. Vertical cable trays are designated as VCBT and horizontal cable trays as HCBT. For horizontal cable trays, the number following the letters indicate the elevation of the cable tray. For example, HCBT+35A denotes a horizontal cable tray at elevation +35 ft.
- The stairwell in the Aux. Building provides access to all the floors of the building. The doors and walls are fire rated and doors are normally closed.

2.4 SNPP Drawings

The following 12 pages (pages 2-7 through 2-18) provide schematic drawings of the SNPP. Drawings A-01 through A-09 are general physical layout drawings providing plan and elevation views of the plant. These drawings also identify the location of important plant equipment. Drawing A-10 provides a piping and instrumentation diagram (P&ID) for the primary coolant system, and drawing A-11 provides a P&ID for the secondary systems. Drawing A-12 is a simplified one-line diagram of the plant power distribution system.



SNPP PLANT LAYOUT GENERAL	Drawing No.: A-01
	Date: 6/22/09
	Revision No.: 1



SNPP PLANT LAYOUT SECTION AA	Drawing No.: A-02
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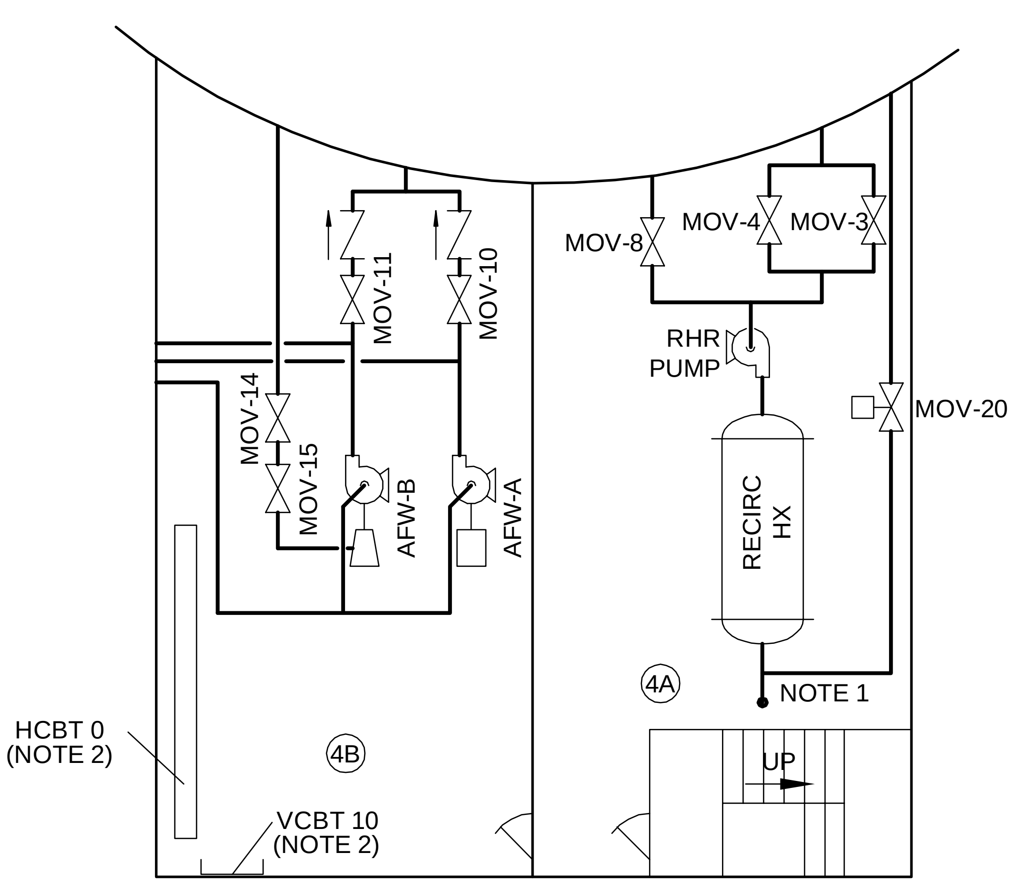
	Revision No.: 1



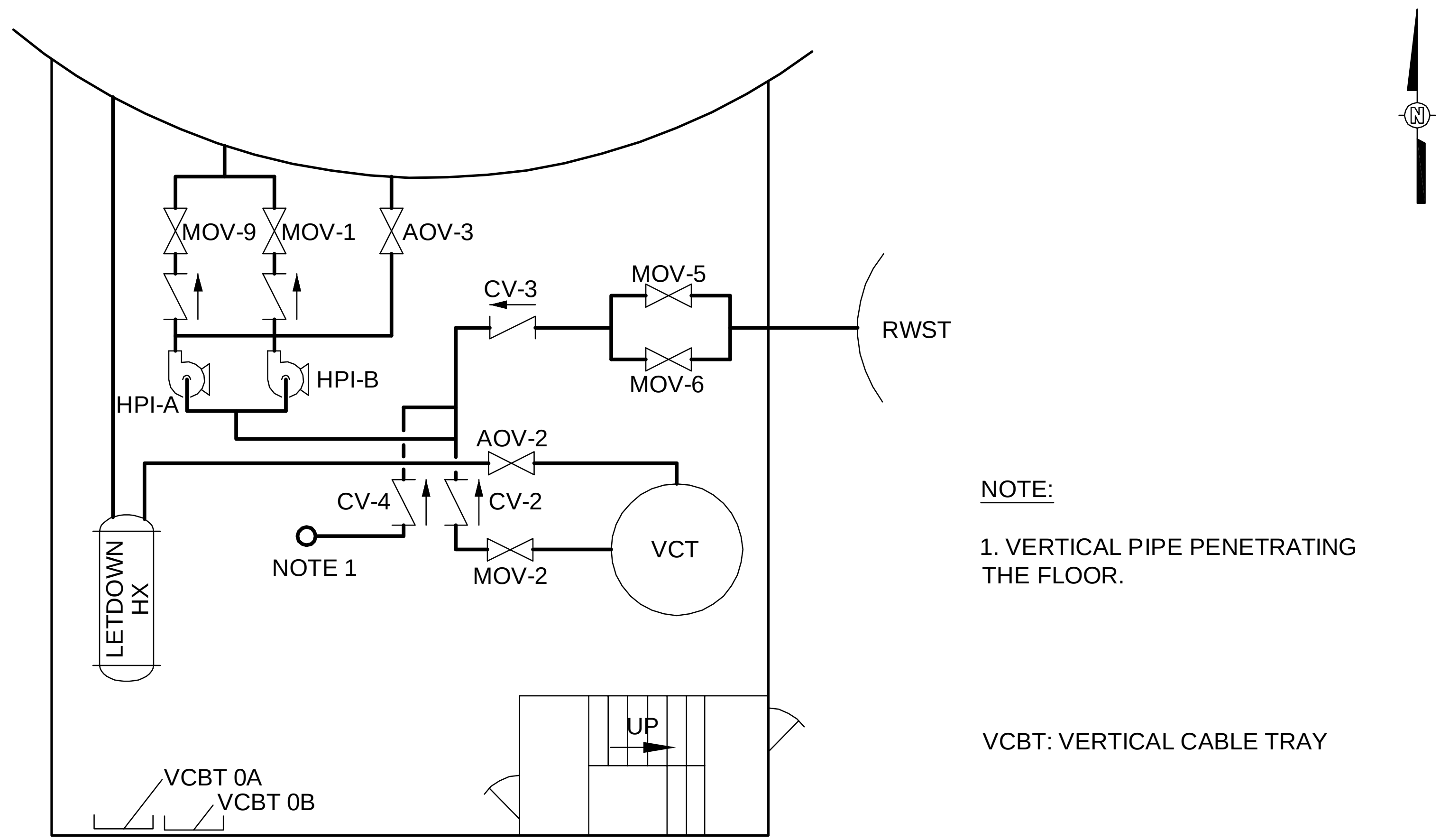
NOTES:

1. VERTICAL PIPE PENETRATION TO UPPER ELEVATION.

2. PENETRATION TO UPPER FLOOR IS SEALED.

HCBT: HORIZONTAL CABLE TRAY
VCBT: VERTICAL CABLE TRAY

SNPP AUX BLDG EL. - 20FT	Drawing No.: A-03
	Date: 6/22/09
	Revision No.: 1

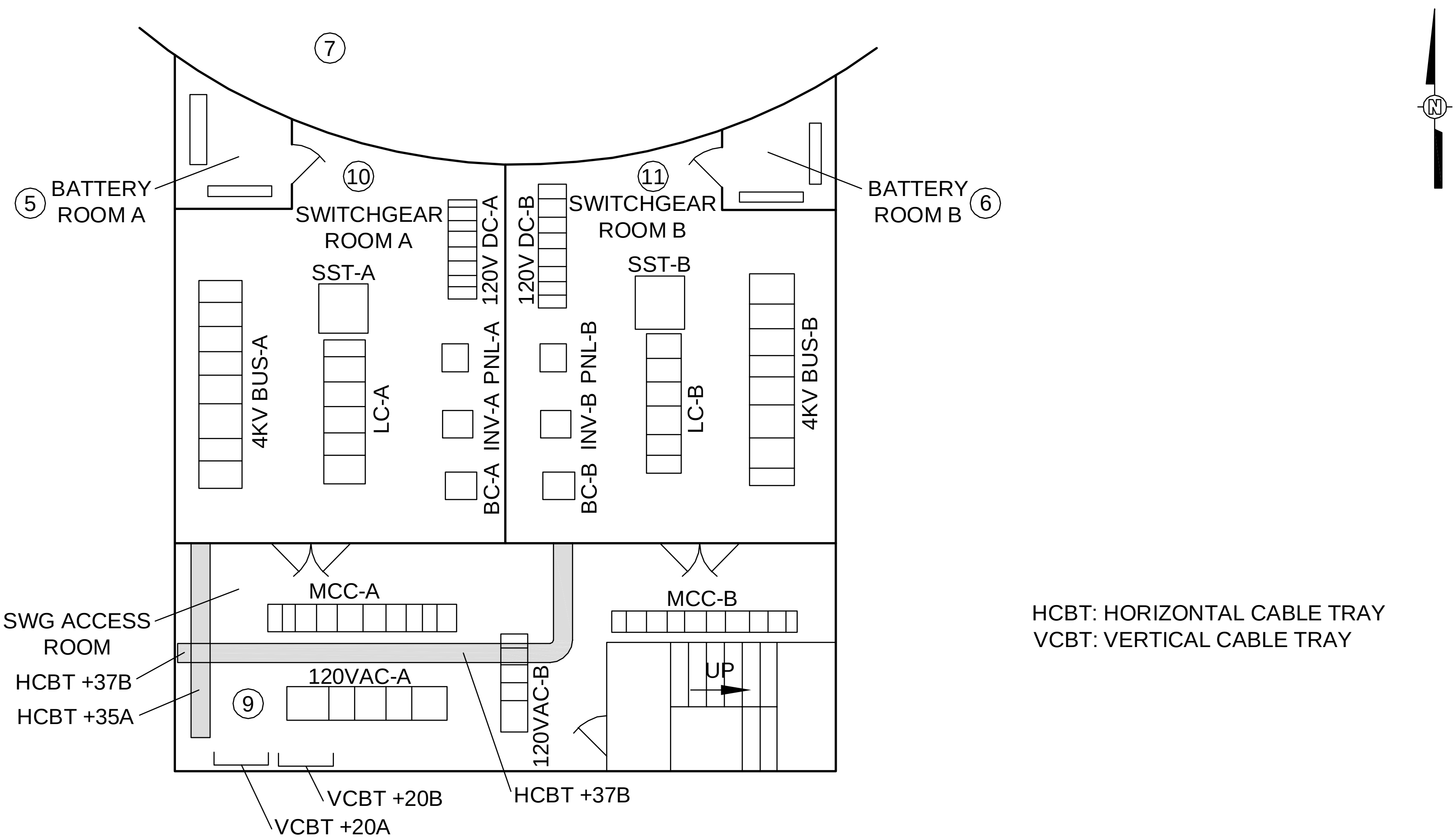


NOTE:

1. VERTICAL PIPE PENETRATING THE FLOOR.

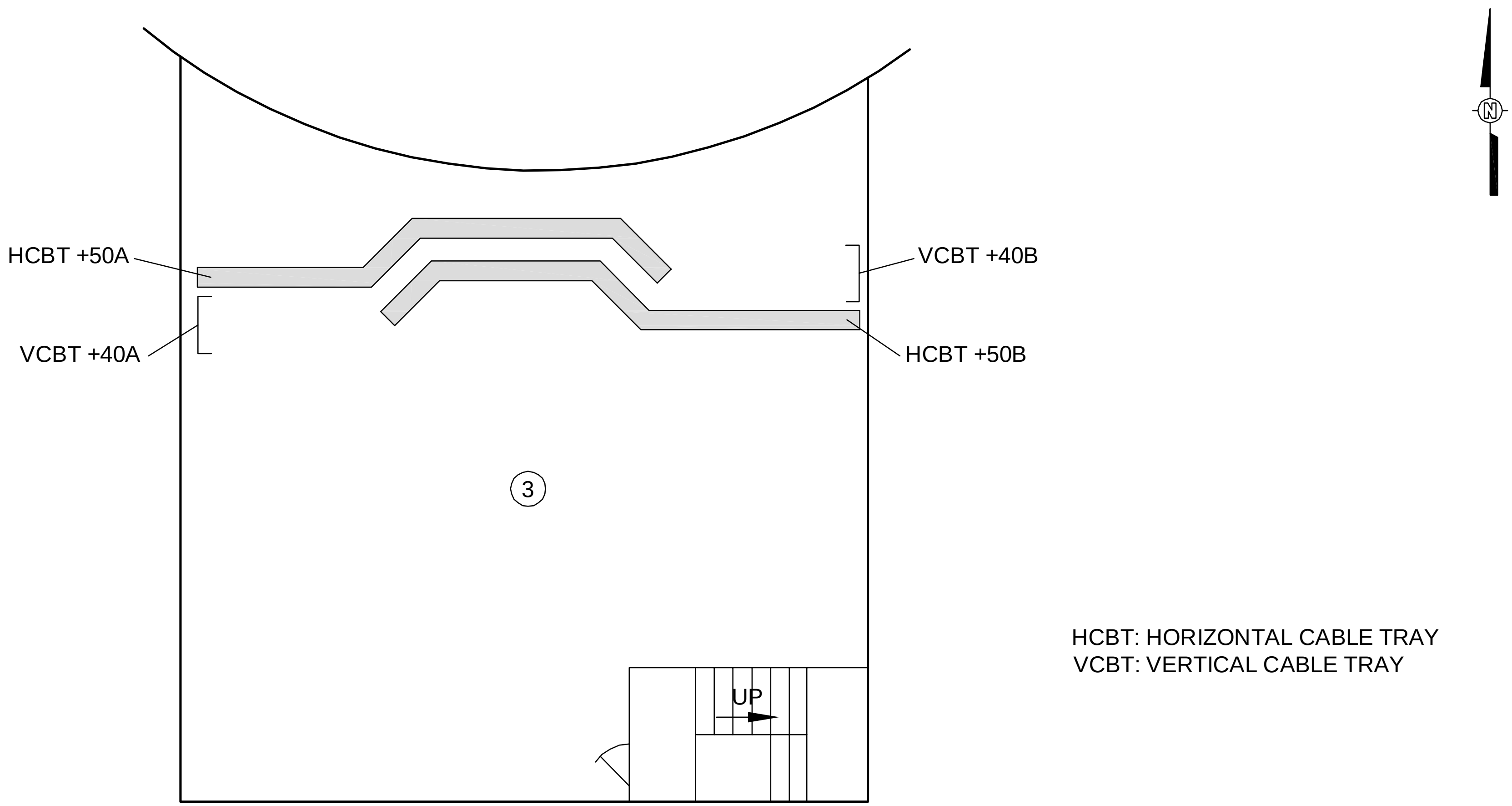
VCBT: VERTICAL CABLE TRAY

SNPP	Drawing No.: A-04
AUX BLDG	Date: 6/22/09
EL. 0FT	Revision No.: 1



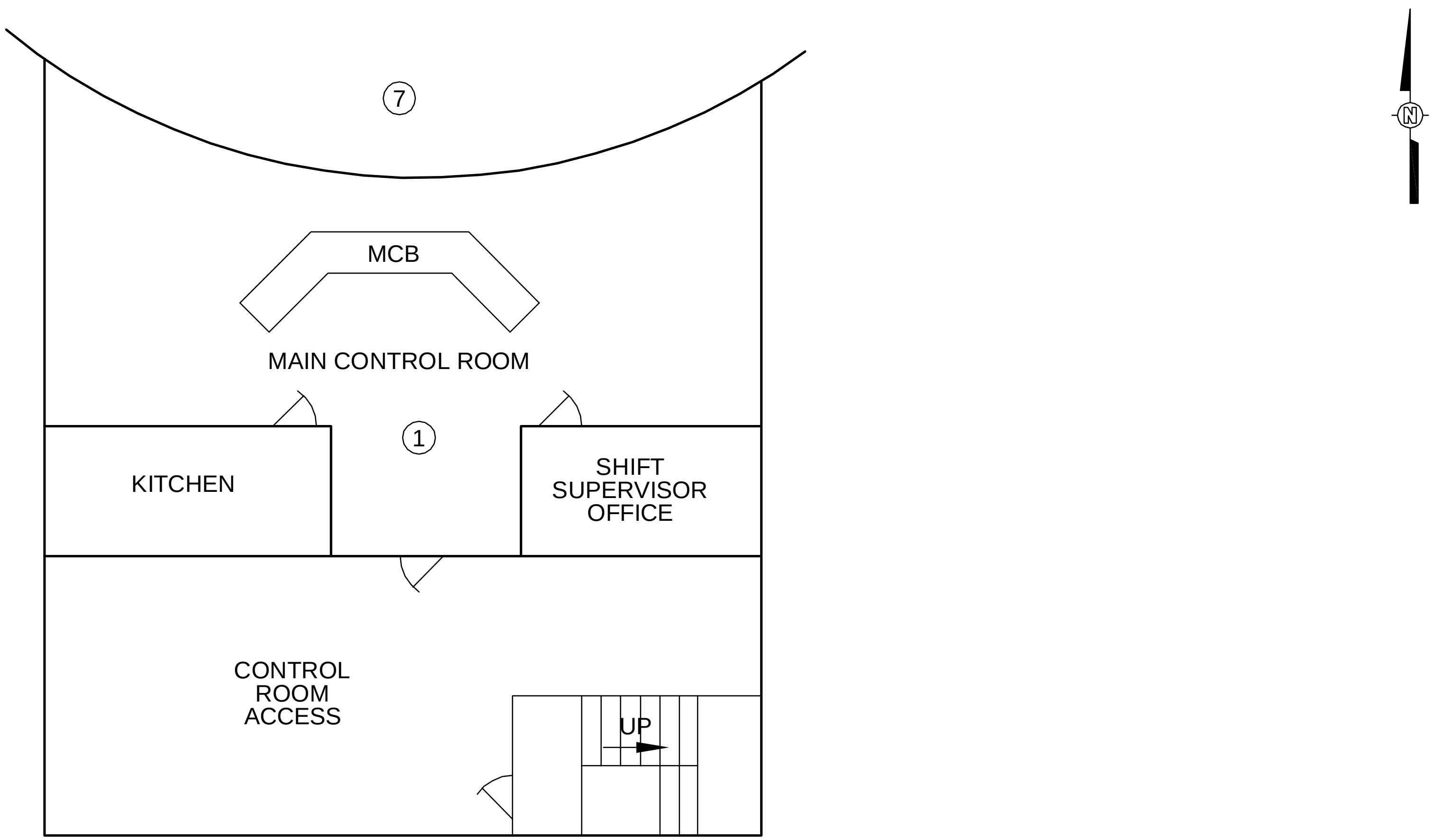
HCBT: HORIZONTAL CABLE TRAY
VCBT: VERTICAL CABLE TRAY

SNPP	Drawing No.: A-05
AUX BLDG	Date: 6/22/09
EL. +20FT	Revision No.: 1



HCBT: HORIZONTAL CABLE TRAY
VCBT: VERTICAL CABLE TRAY

SNPP AUX BLDG EL. +40FT CABLE SPREADING ROOM	Drawing No.: A-06
	Date: 6/22/09
	Revision No.: 1



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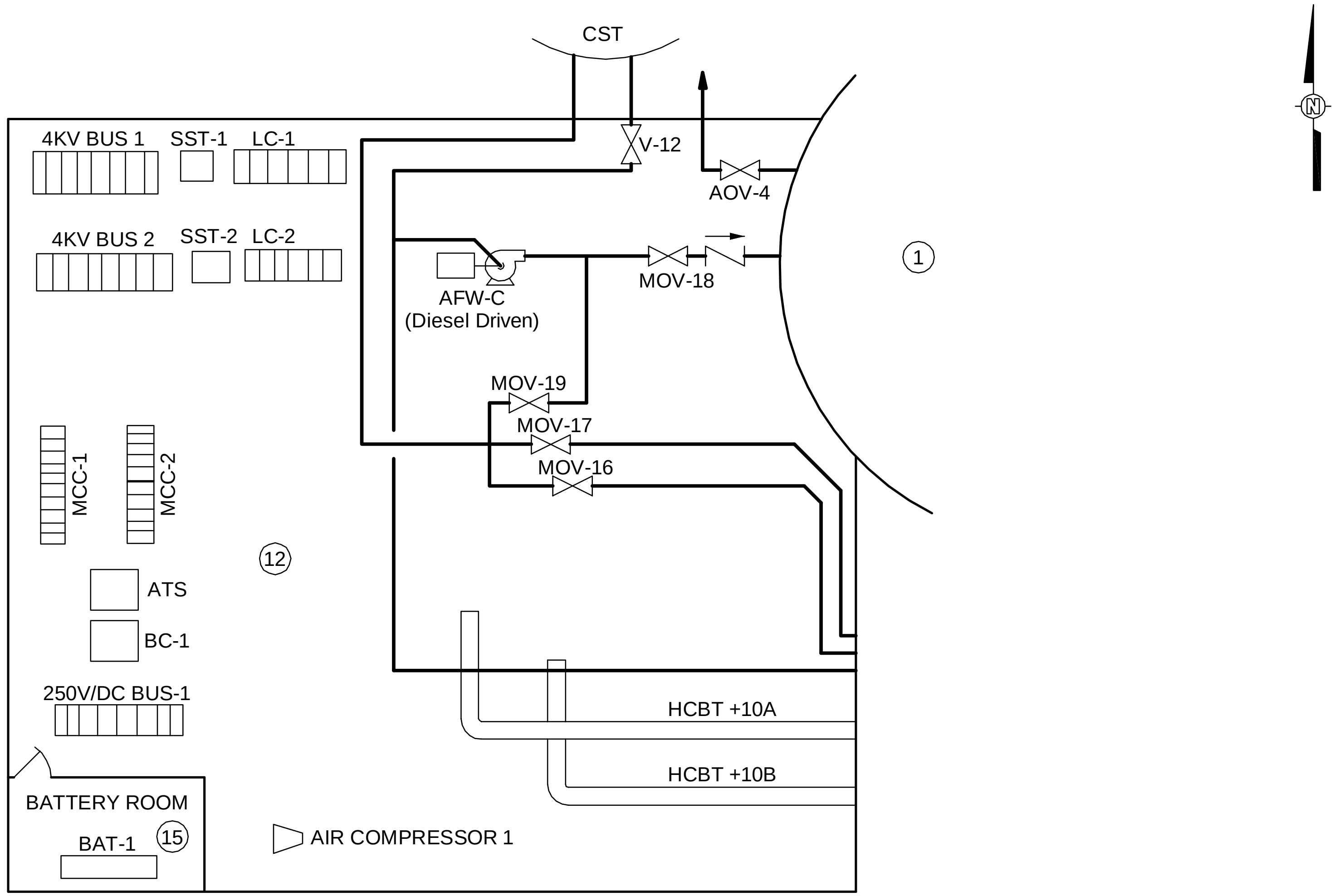
AUX BLDG	Date: 6/22/09
MAIN CONTROL ROOM	Revision No.: 1



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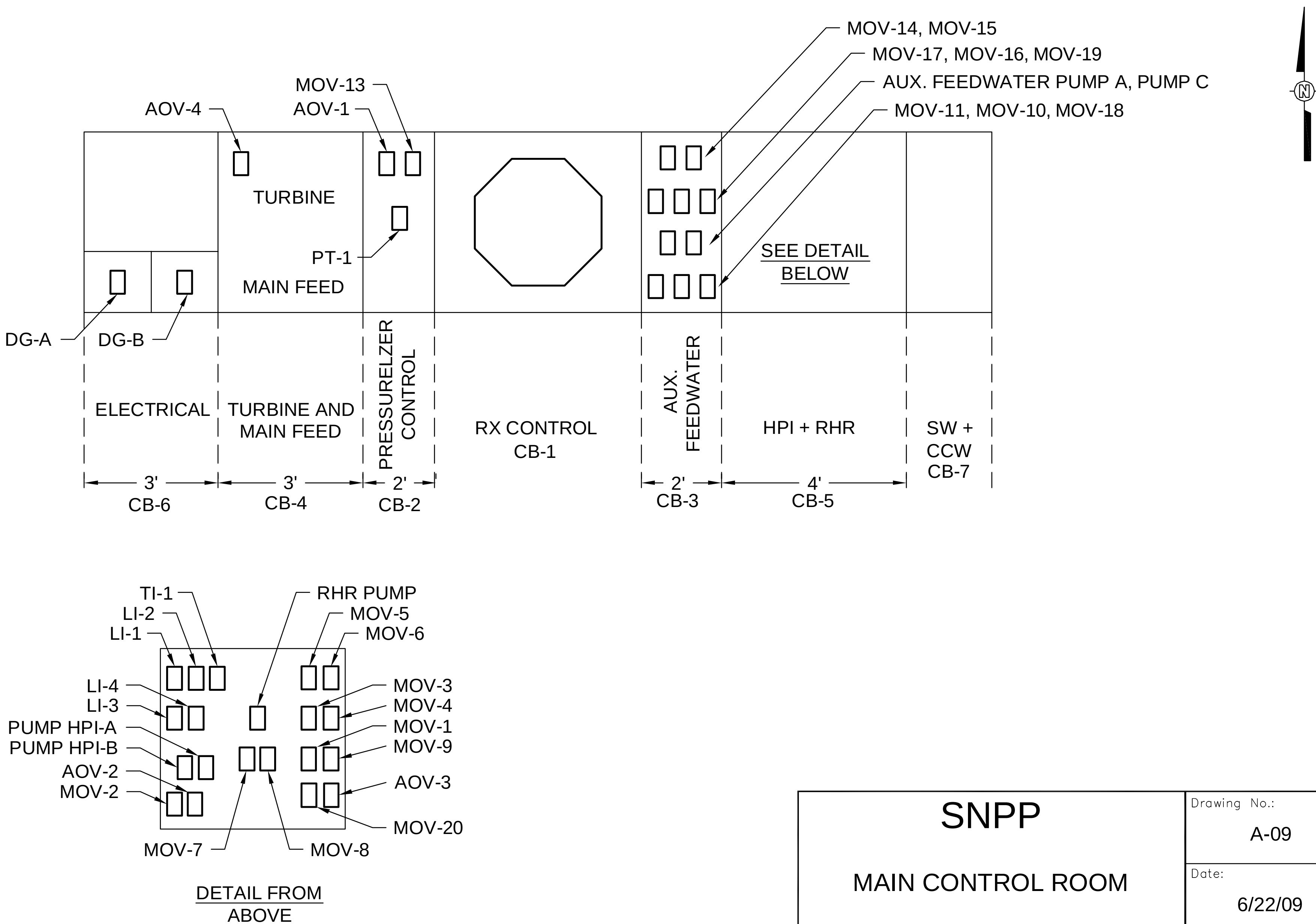

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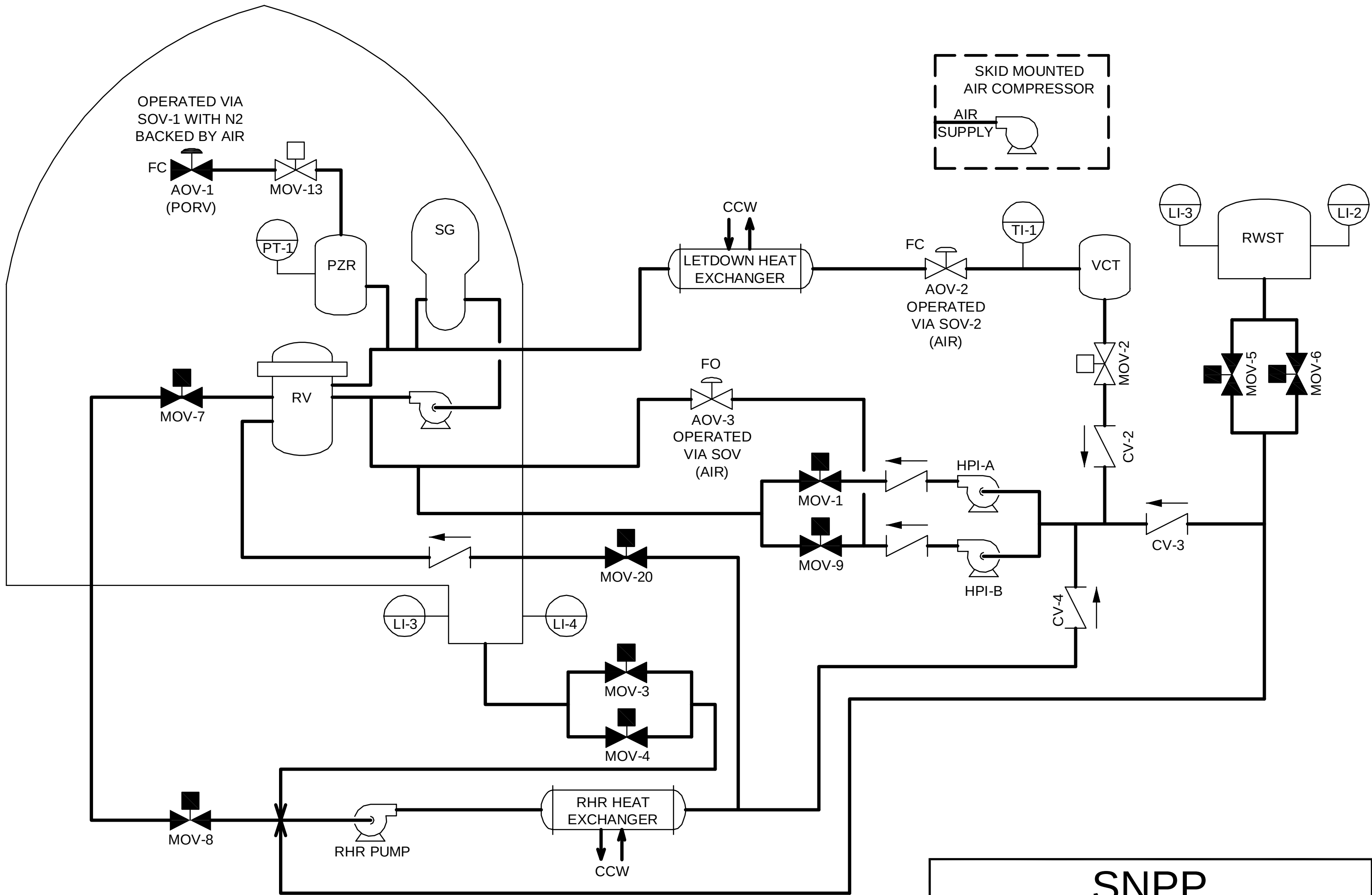
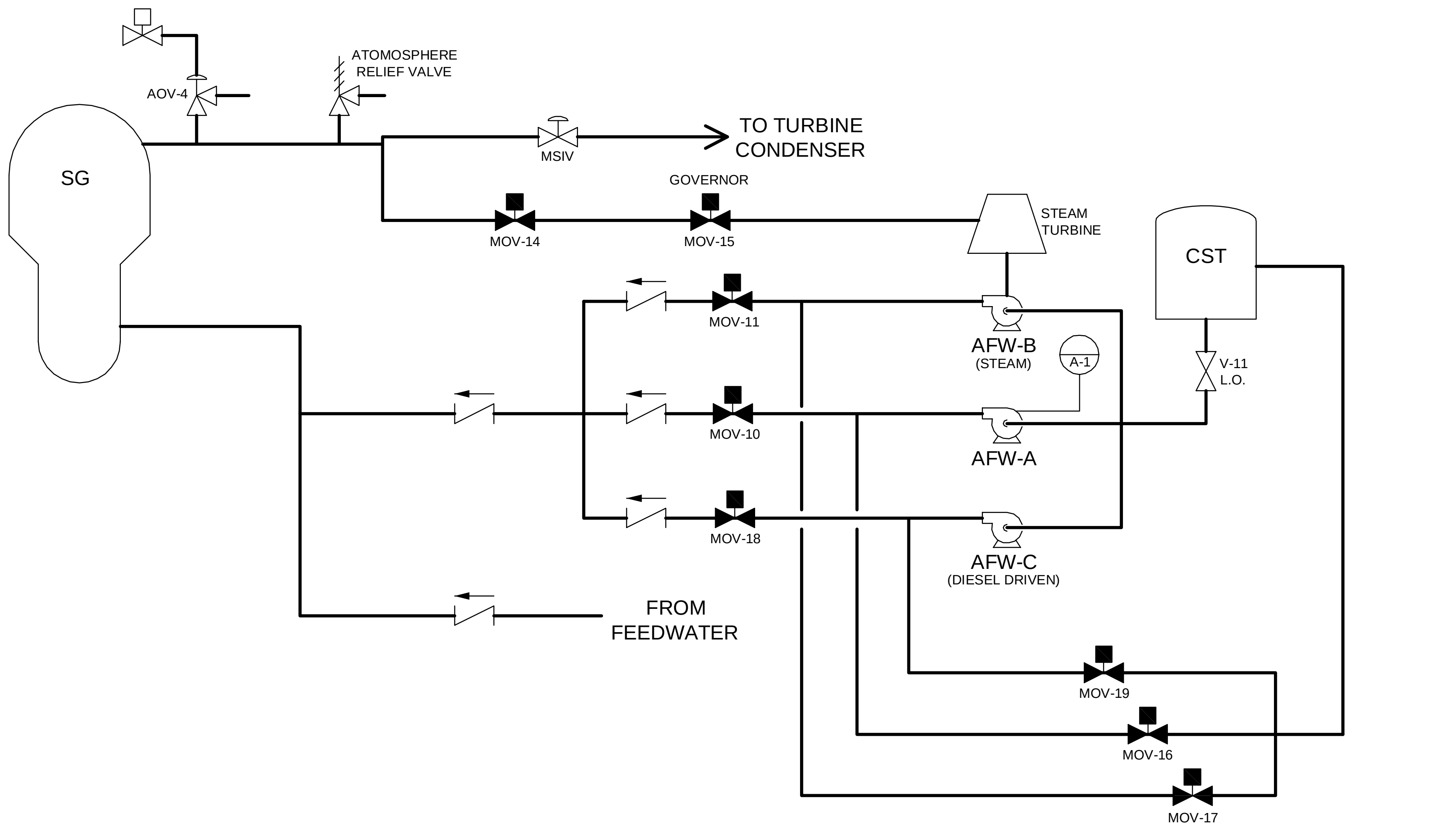


SNPP

PRIMARY SYSTEM
P & I D

Drawing No.:	A-10
Date:	6/22/09
Revision No.:	1



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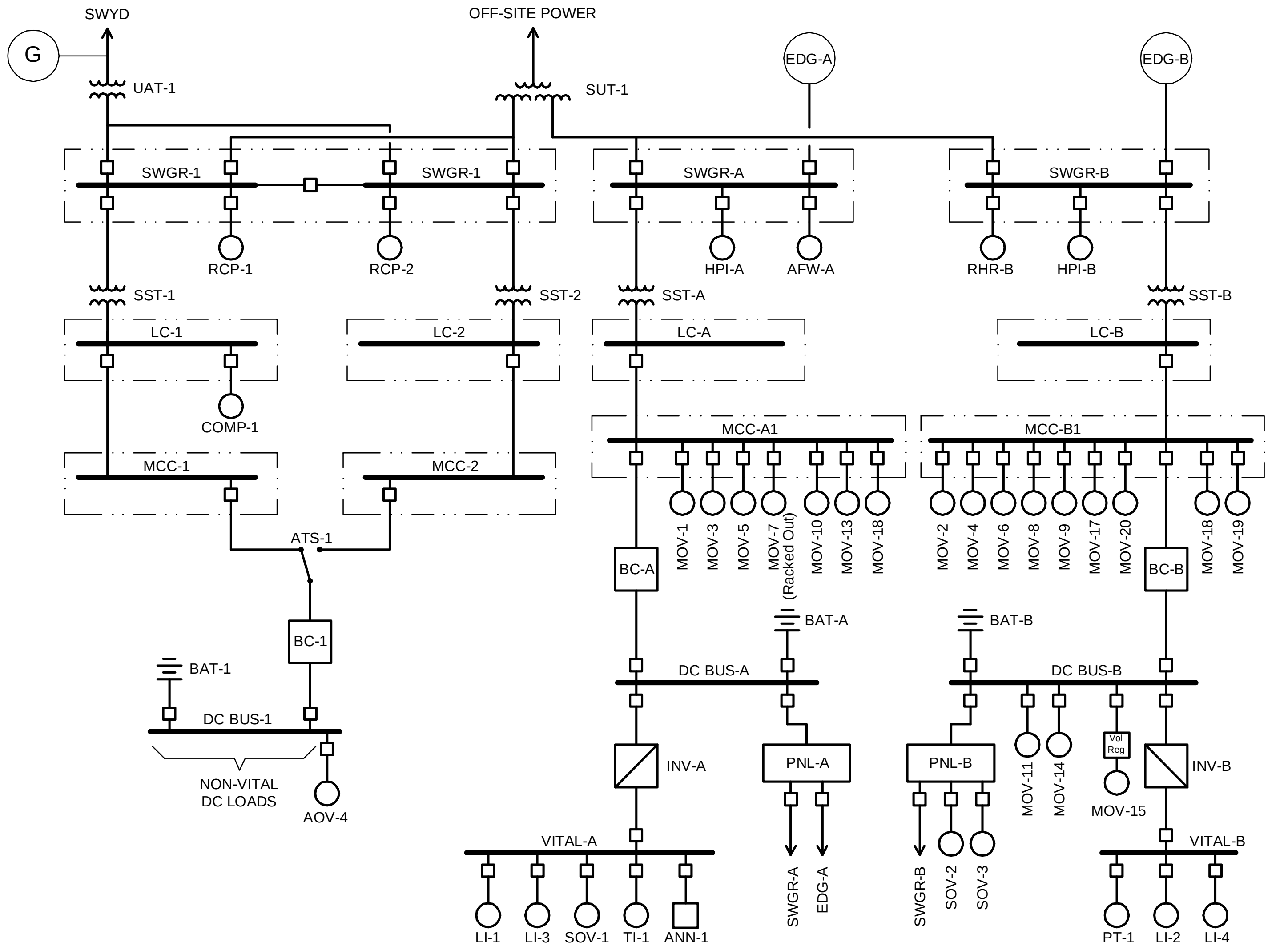
	Date: 6/22/09
	Revision No.: 1



SNPP ELECTRICAL ONE-LINE DIAGRAM	Drawing No.: A-12
	Date: 6/22/09
	Revision No.: 1

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MODULE 1: PRA/SYSTEMS

The following is a short description of the Fire PRA technical tasks covered in this module. For further details, refer to the individual task descriptions in Volume 2 of EPRI 1011989, NUREG/CR-6850.

- ***Fire PRA Component Selection (Task 2).*** The selection of components that are to be credited for plant shutdown following a fire is a critical step in any Fire PRA. Components selected would generally include many components credited in the 10 CFR 50 Appendix R post-fire SSD analysis. Additional components will likely be selected, potentially including any and all components credited in the plant's internal events PRA. Also, the proposed methodology would likely introduce components beyond either the 10 CFR 50 Appendix R list or the internal events PRA model. Such components are often of interest due to considerations of multiple spurious actuations that may threaten the credited functions and components.
- ***Qualitative Screening (Task 4).*** This task identifies fire analysis compartments that can be shown to have little or no risk significance without quantitative analysis. Fire compartments may be screened out if they contain no components or cables identified in Tasks 2 and 3, and if they cannot lead to a plant trip due to either plant procedures, an automatic trip signal, or technical specification requirements.
- ***Plant Fire-Induced Risk Model (Task 5).*** This task discusses steps for the development of a logic model that reflects plant response following a fire. Specific instructions have been provided for treatment of fire-specific procedures or preplans. These procedures may impact availability of functions and components, or include fire-specific operator actions (e.g., self-induced-station-blackout).
- ***Quantitative Screening (Task 7).*** A Fire PRA allows the screening of fire compartments and scenarios based on their contribution to fire risk. This approach considers the cumulative risk associated with the screened compartments (i.e., the ones not retained for detailed analysis) to ensure that a true estimate of fire risk profile (as opposed to vulnerability) is obtained.
- ***Post-Fire Human Reliability Analysis (Task 12).*** This task considers operator actions for manipulation of plant components. Task 12 is covered in **limited detail** in the PRA/Systems module. In particular, those aspects of Task 12 that deal with identifying and incorporating human failure events (HFEs) into the plant response model are discussed. Methods for quantifying human error probabilities (HEPs) are deferred to Module 4.
- ***Fire Risk Quantification (Task 14).*** The task summarizes what is to be done for quantification of the fire risk results.
- ***Uncertainty and Sensitivity Analyses (Task 15).*** This task describes the approach to follow for identifying and treating uncertainties throughout the Fire PRA process. The treatment

may vary from quantitative estimation and propagation of uncertainties where possible (e.g., in fire frequency and non-suppression probability) to identification of sources without quantitative estimation. The treatment may also include one-at-a-time variation of individual parameter values or modeling approaches to determine the effect on the overall fire risk (sensitivity analysis).

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MODULE 2: ELECTRICAL ANALYSIS

The following is a short description of the Fire PRA technical tasks covered in this module. For further details, refer to the individual task descriptions in Volume 2 of EPRI 1011989, NUREG/CR-6850.

- ***Fire PRA Cable Selection (Task 3).*** This task provides instructions and technical considerations associated with identifying cables supporting those components selected in Task 2. In previous Fire PRA methods (such as EPRI FIVE and Fire PRA Implementation Guide) this task was relegated to the SSD analysis and its associated databases. This document offers a more structured set of rules for selection of cables.
- ***Detailed Circuit Failure Analysis (Task 9).*** This task provides an approach and technical considerations for identifying how the failure of specific cables will impact the components included in the Fire PRA SSD plant response model.
- ***Circuit Failure Mode Likelihood Analysis (Task 10).*** This task considers the relative likelihood of various circuit failure modes. This added level of resolution may be a desired option for those fire scenarios that are significant contributors to the risk. The methodology provided in this document benefits from the knowledge gained from the tests performed in response to the circuit failure issue.

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MODULE 3: FIRE ANALYSIS

The following is a short description of the Fire PRA technical tasks covered in this module. For further details, refer to the individual task descriptions in Volume 2 of EPRI 1011989, NUREG/CR-6850.

- ***Plant Boundary Definition and Partitioning (Task 1).*** The first step in a Fire PRA is to define the physical boundary of the analysis, and to divide the area within that boundary into analysis compartments.
- ***Fire Ignition Frequency (Task 6).*** This task describes the approach to develop frequency estimates for fire compartments and scenarios. Ignition frequencies are provided for 37 item types that are categorized by ignition source type and location within the plant. For example, ignition frequencies are provided for transient fires in the Turbine Buildings and in the Auxiliary Buildings. A method is provided on how to specialize these frequencies to the specific cases and conditions.
- ***Scoping fire Modeling (Task 8).*** Scoping fire modeling is the first task in the Fire PRA framework where fire modeling tolls are used to identify ignition sources that may impact the fire risk of the plant. Screening some of the ignition sources, along with the applications of severity factors to the unscreened ones, may reduce the compartment fire frequency previously calculated in Task 6.
- ***Detailed Fire Modeling (Task 11).*** This task describes the method to examine the consequences of a fire. This includes consideration of scenarios involving single compartments, multiple fire compartments, and the main control room. Factors considered include initial fire characteristics, fire growth in a fire compartment or across fire compartments, detection and suppression, electrical raceway fire barrier systems), and damage from heat and smoke. Special consideration is given to turbine generator (T/G) fires, hydrogen fires, high-energy arcing faults, cable fires, and main control board (MCB) fires.
- ***Seismic Fire Interactions (Task 13).*** This task is a qualitative approach for identifying potential interactions between an earthquake and fire.

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MODULE 4: HUMAN RELIABILITY ANALYSIS

The following is a short description of the Fire PRA technical tasks covered in this module. For further details relative to this technical task, refer to the individual task descriptions in Volume 2 of EPRI 1011989, NUREG/CR-6850.

- ***Post-Fire Human Reliability Analysis (Task 12).*** This task considers operator actions for manipulation of plant components. The analysis task procedure provides structured instructions for identification and inclusion of these actions in the Fire PRA. The procedure also provides instructions for incorporating human error probabilities (HEPs) into the fire PRA analysis.

Note that NUREG/CR-6850, EPRI 1011989 did not develop a detailed fire HRA methodology. Training module 4 is instead based on a joint EPRI/RES project as documented in NUREG-1921, EPRI 1019196, *EPRI/NRC-RES Fire Human Reliability Analysis Guidelines – Draft Report for Comment.* Publication of the final report remains pending. The training materials presented here are based on the draft guidance including consideration of public review comments received and the team's response to those comments.