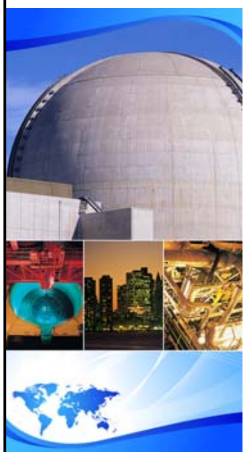


EPRI/NRC-RES FIRE PRA METHODOLOGY

Module I-1: Fire Risk Requantification Project

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

Joint RES/EPRI Fire PRA Workshop
June 22 -26 and October 12 – 16, 2009

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
  - Volunteer pilot NPPs, peer review by industry participants
  - Public review and comment
- Formal process to resolve technical disputes within NUREG/CR-6850 (EPRI 1011989) team
- Improvements made in areas important to fire risk
  - Means to advance range from consolidating existing research to developing new approaches

Uses Of Methodology

- Support for new rule 10CFR50.48c implementation
  - NFPA pilot 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)
- Basis for review guidance that RES developed for NFPA 805 related changes
- 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, 2008
• EPRI 1011999/NUREG-1824	2007
• Fire HRA Methodology Development	Mar 2010
• Fire Modeling User's Guide	Mar 2010
• FAQ Support	Ongoing
• Fire Modeling Training	Ongoing
• Low Power/Shutdown Fire PRA Methods	NRC

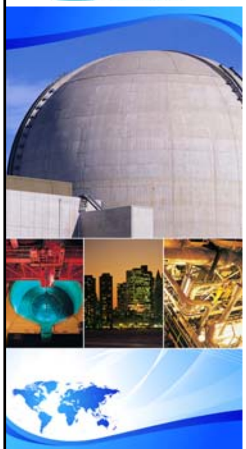
- Current Course also being offered on Oct 12 -16 in VA

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

EPRI | Electric Power Research Institute

Sandia National Laboratories

SAIC Science Applications International Corporation



EPRI/NRC-RES FIRE PRA METHODOLOGY

Introduction and Overview: the Fire PRA Methodology and Course Structure

Bijan Najafi - Science Applications International Corp.
Steve Nowlen - Sandia National Laboratories

Joint RES/EPRI Fire PRA Training Workshop
June 22-26, 2009, Palo Alto, CA and
October 12-16, Richmond VA

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

Overview

I. An Overview of the EPRI/NRC-RES Fire PRA Methodology
   – Fire PRA Course
II. EPRI and NRC-RES Fire Research Activities Related to Fire PRA
   – CAROLFIRE, RES project
   – ANS Fire PRA Standard
   – Fire Model V&V, joint EPRI & RES project
   – Fire HRA, joint EPRI & RES project

PART I

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

&

The Fire PRA Course

BACKGROUND

- Prior to IPEEE; Mostly simple approximate method for order-of-magnitude assessment of fire risk, e.g. NUREG/CR-2258, Fire Risk Analysis for Nuclear Power Plants.
- 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

- 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

- 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

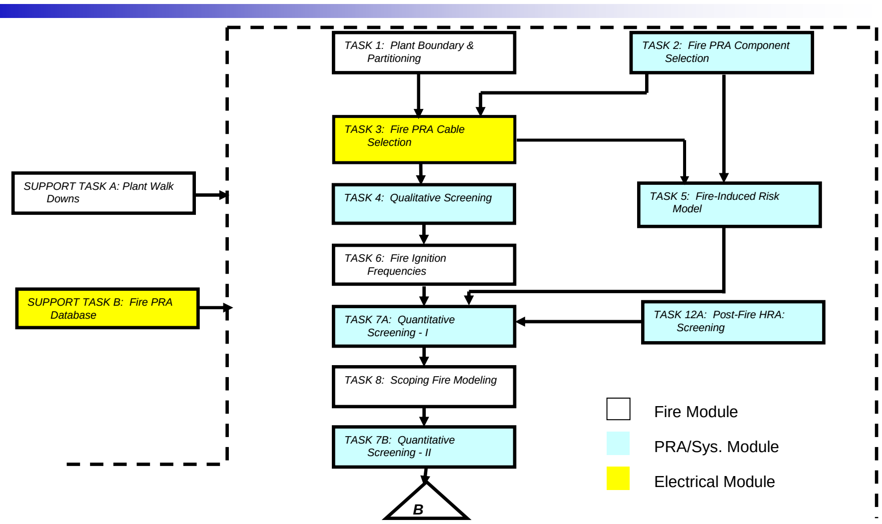
1. Purpose
2. Scope
3. Background information: General approach and assumptions
4. Interfaces: Input/output to other tasks, plant and other information needed, walk-downs
5. Procedure: Step-by-step instructions for conduct of the technical task
6. References

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

Course Structure

- Three parallel modules:
  – PRA/Systems Analysis (including HRA)
  – Fire Analysis
  – Electrical Analysis
- General structure for each module:
  – PowerPoint presentations designed to convey key concepts and the general “how to” of each task
  – An example problem designed to illustrate key elements of the procedures (more on this shortly)

OVERVIEW OF FIRE PRA PROCESS AND MODULE STRUCTURE

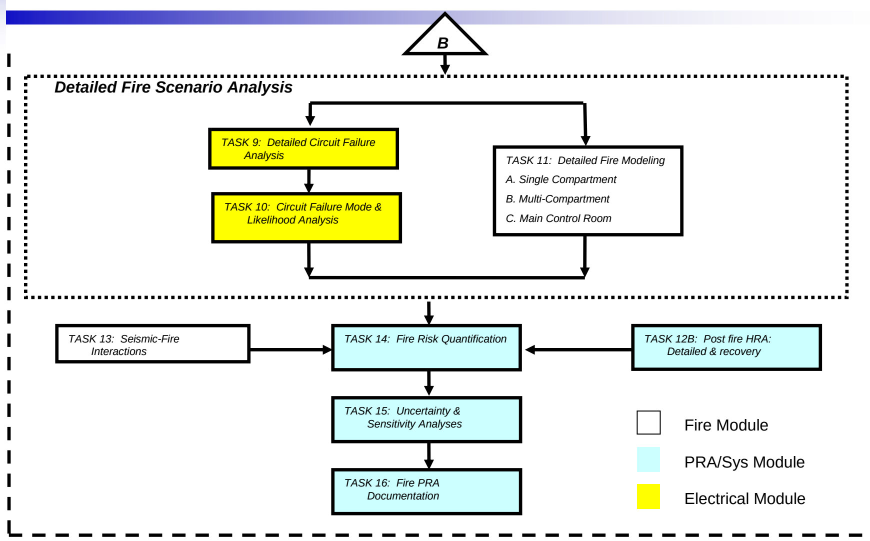


Fire PRA Training, 2009
Introduction and Overview

Slide 9

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

OVERVIEW OF FIRE PRA PROCESS AND MODULE STRUCTURE (2)



Fire PRA Training, 2009
Introduction and Overview

Slide 10

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

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 at a higher level of detail than provided via the previous "roll-out" workshops
  - To illustrate and demonstrate key aspects of the procedures
- We expect and want significant participant interaction
  - Class size was limited specifically to 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

Training Objective (3 of 3)

- This training is about NUREG/CR-6850, EPRI TR-1011989 and the EPRI/RES teams' intent for implementation of that method
  - It is not about regulatory compliance (talk to NRR about that)
  - It is not about alternative methods, NFPA-805, or the ANS FPRA standard and its "Capability Categories"
  - We cannot cover areas that are outside the scope of the document (e.g., detailed HRA)
- Your next step:
  - You should not expect to come out of this training an "instant expert"
  - We do expect that after the training you will possess the fundamental knowledge needed to "hit the ground running" and to implement the method or to review an application involving the method
  - Ultimately, you learn by doing, so get out there and do it!

What's next:

- The rest of these introductory slides will provide a short overview of each of the three modules
- Intent is to ensure that those of you in one module are aware of what is being covered in the other two modules
- FPRA requires a team effort and integration is critical to success
- That will close out the introductions, and then you will be breaking up and going to your individual modules

Module 1: PRA/Systems Analysis

- This module will cover all aspects of the plant systems accident response modeling, human reliability analysis, 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 12: Human Reliability Analysis (HRA)
  - Task 15: Risk Quantification
  - Task 16: Uncertainty Analysis

Task 2: Equipment Selection (1 of 3)

- Objective: To decide what subset of the plant equipment will be modeled in the FPRA
- FPRA equipment will draw 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 3)

- Many choices to be made in this task, many factors will influence these decisions
  - Fire-induced failures that might cause and 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

Task 2: Equipment Selection (3 of 3)

- Choices are important in part because “selecting” equipment implies a burden to *Identify and Trace* cables
  - Cable selection is covered in Module 2 (Electrical) but can represent a significant commitment of time and effort to the FPRA

Task 4: Qualitative Screening (1 of 2)

- 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)

- Criteria are established that 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 (1 of 2)

- Objective: To construct the FPRA plant response model
  - Functional relationships among selected equipment
  - Equipment failure modes (including spurious actuation)
  - Human Failure Events (HFEs)

Task 5: Fire-Induced Risk Model (2 of 2)

- Covers both CDF and LERF
  - Builds on/from the internal events model but more than just a "tweak"
  - Adds fire unique equipment
  - Adds fire-specific equipment failure modes (e.g., spurious actuations)
  - Adds fire-specific operator actions

Task 7: Quantitative Screening (1 of 2)

- 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)

- 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)

Post-fire Human Reliability Analysis

- Objective: To assess Human Error Probabilities (HEPs) for the Human Failure Events (HFEs) included in the FPRA plant response model
  - For those already in the level 1 PRA, and
  - Those to be added specific to post-fire condition considerations
- You will hear about HRA based mainly on the ongoing RES/EPRI collaboration
  - A draft for public comment of the project report has been issued
  - Updates and expands on information in NUREG/CR-6850, EPRI 1011989
    - Updates the rules-based screening approach
    - Details approaches for more detailed quantification of HEP values not treated in 6850/1011989
  - Presentations Thursday PM and Friday AM will focus on recommended approaches per the draft for public comment

Task 14: Fire Risk Quantification

- 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

- 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?

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

Task 3: Cable Selection (1 of 2)

- Objectives:
  - To identify/select cables whose fire-induced failure could adversely effect the operation of selected equipment
  - To locate selected cables
- Cables may include Power, Control/Indication, and Instrumentation

Task 3: Cable Selection (2 of 2)

- Selected cables need to be routed/located
- 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

Support Task B: FPRA Database (1 of 2)

- Objective: Develop a database to support query needs of the FPRA
- FPRA will ask: "if a fire damages everything within some spatial region, what equipment and cables are lost?"
  - The regions is defined by the fire scenarios (this is covered in Module 3)
  - The region may be as large as a combination of two or more fire areas or as small as a single raceway
- Because cables tend to be the primary driver, the FPRA Database is covered in the electrical module

Support Task B: FPRA Database (2 of 2)

- The electrical module will describe the needs served by the database:
  - Database functionality needs
  - How to assess capability of exiting systems
  - How to implement a structured process to obtain required capability
  - Some discussion of the potential role of new software and data management tools

Task 9: Detailed Circuit Failure Analysis (1 of 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)

- 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)

- 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)

- 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

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

Task 1: Plant Partitioning (1 of 3)

- Objectives:
  - To define the global analysis boundary of the FPRA
  - To divide the areas within the global analysis boundary into fire compartments
- The fire compartments become the "basic unit" of analysis
  - Generally we screen based on fire compartments
  - Risk results are often rolled up to a fire compartment level

Task 1: Plant Partitioning (2 of 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)

- 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 6: Fire Ignition Frequency (1 of 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 levels of resolution:
  - An entire fire area
  - A fire compartment
  - 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)

- 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)

- 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 8: Scoping Fire Modeling (1 of 2)

- 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)

- 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 11: Detailed Fire Modeling (1 of 3)

- Objective: To identify and analyze specific fire scenarios

- Divided into three sub-tasks:
  - 12a: General fire compartments (as individual risk contributors)
  - 12b: Main Control Room analysis
  - 12c: Multi-Compartment fire scenarios

Task 11: Detailed Fire Modeling (2 of 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)

- 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 13: Seismic/Fire Interactions

- 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)

Sample Problems / Sample Plant

- All modules will involve hands-on exercises
  - Intent: To illustrate *key aspects* of the methodology through a cohesive set of sample problems
- All exercises are built around a common sample plant – the SNPP
- The exercises are designed such that taking all modules together presents a fairly complete picture of the FPRA methodology
  - Not every task is covered by the SNPP sample problems
  - Not every aspect of covered tasks are illustrated

The SNPP: Intent and Approach

- The SNPP is not intended to reflect either regulatory compliance or good engineering practice
  - It is purely an imaginary construct intended to highlight key aspects of the methodology – nothing more!
- The SNPP has been kept as simple as possible while still serving the needs of the training modules
- Aspects of the plant are assumed for purposes of the training exercises, e.g.:
  - BOP equipment not covered in detail
  - Some systems are assumed to remain available
  - Details will be provided in each module

PART II

EPRI and RES Fire Research Activities Relevant to Fire PRA

RES Direct Current Electrical Shorting In Response to Exposure-Fire

DESIREE-FIRE

NRC-RES DESIREE Fire Project

- An RES project with EPRI collaboration is underway to follow-up on the CAROLFIRE project (NUREG/CR-6931)
  - CAROLFIRE focused on A/C control circuits
  - DESIREE fire is focusing (mainly) on DC control circuits
- Objective: Develop a basis for extending circuit failure mode and likelihood analysis methods to DC circuits
  - Nearly all of the available circuit failure modes and likelihood information has been based on testing and analysis of AC control circuits
  - Validity of extrapolating AC results to DC circuits has not been established and Duke tests indicate extrapolation may not be valid
  - Test data is being gathered to characterize and quantify behavior of DC control circuits given fire-induced cable failures
  - Overall approach is similar to CAROLFIRE

The Testing Approach

- Two Scales of testing are being pursued
  - Small-scale radiant heating experiments
  - Intermediate-scale open burn tests
- A representative set of battery cells was provided to the project via EPRI collaboration
  - Set of large UPS cells being removed from service at North Anna
  - 60 cells create a nominal 125VDC battery bank
  - Nominal dead-short currents of up to 13,000A are possible
- Testing a broad range of cable products

Testing Approach (cont.)

- Tests will monitor response of a range of DC control circuits using actual components:
  - Large (15kV) switchgear breaker DC control circuit
  - Small pilot solenoid valves
  - 1" solenoid valve (e.g., head vent valve)
  - Large coil (e.g., direct acting PORV or other large valve)
  - DC MOV reversing motor starter set
- Inter-cable DC shorting configurations
  - e.g., cable bundles monitored for plus-plus, minus-minus concurrent shorts
- Testing surrogate instrument circuits

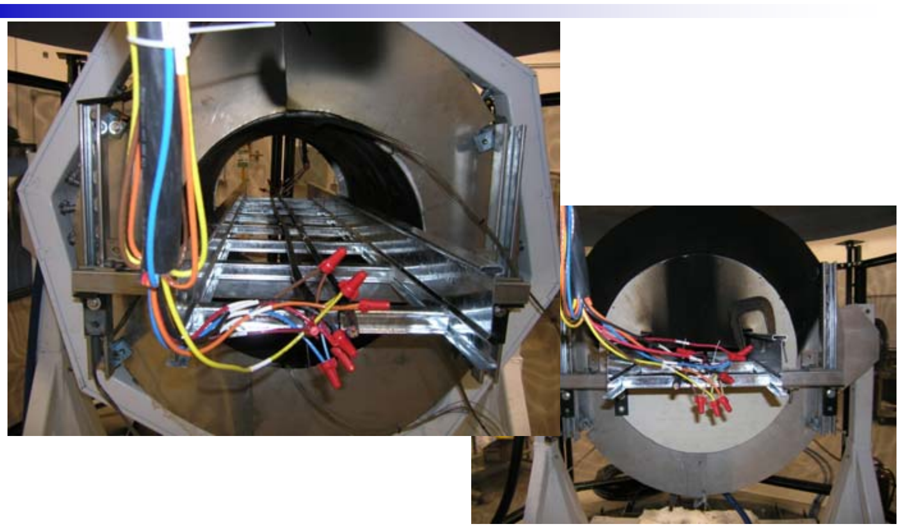
Cable Types Being Tested
Represent Wide Range of NPP Products

- Same cable set as used for CAROLFIRE
  - Range of Thermoset and Thermoplastic insulated cables
  - Not every CAROLFIRE cable will be tested again, but primary types will all be tested (EPR, XLPE, PVC, PE…)
- Plus a limited supply of armored cables provided by industry through EPRI collaboration
- Plus Kerite FR and Kerite HTK also provided by industry through EPRI collaboration

Small Scale Tests

- ***Penlight*** heats target cables via grey-body radiation from a heated shroud
- Well controlled, well instrumented tests
- Allows for many experiments in a short time
- Thermal response and failure for single cables and small cable bundles (up to six cables)
- Cable trays, air drops, conduits

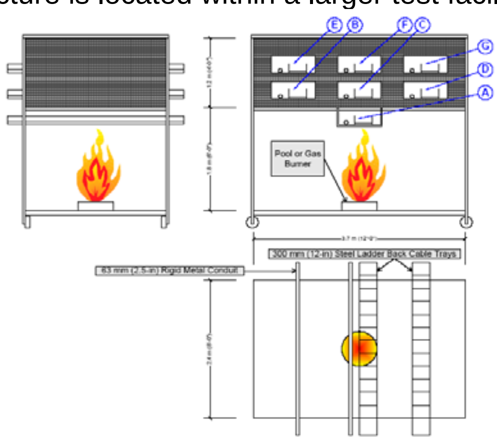
Typical Penlight setup



Intermediate-Scale Tests

Layout of the intermediate-scale test structure.

Structure is located within a larger test facility.



Locations B&D will not be used

Intermediate-Scale Tests

- Less controlled, but a more realistic testing scale
- Hood is roughly the size of a typical ASTM E603 type room fire test facility (more open to allow for ready access)
- Propane burner fire source (200 kW typical)
- Cables in trays, conduits and air drop

DESIREE Fire: Summary

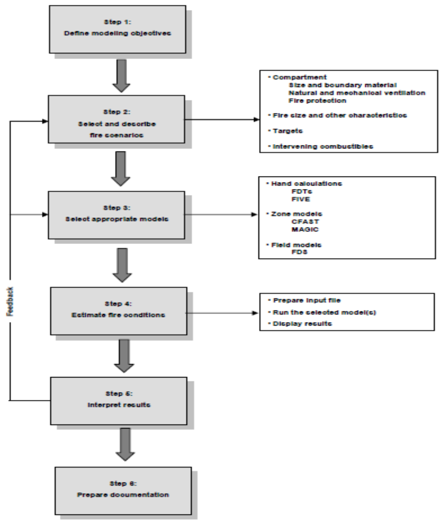
- A follow on to CAROLFIRE to address the current lack of DC circuit data
- Status:
  - Testing through Summer 2009
  - Final reports to be drafted this fall, finalized in the winter/spring

Joint EPRI & NRC-RES Fire Model User's Guide

Fire Model User's Guide

- Purpose
  - To revise *Fire Modeling Guide for Nuclear Power Plant Applications,* EPRI 1002981 to
    - Reflect the results of the V&V of selected fire models when used for typical nuclear power plant fire scenarios (NUREG-1824, EPRI 1011999)
    - Develops a method for quantification of confidence on the fire model prediction
    - Support application of fire modeling in Fire PRAs, or independently, for 805, OMA, MSO, etc.
- Tasks
  - Development of the Guidance
  - Independent Technical Review
  - Documentation/Review (Industry, NRR, ACRS)/Publication
- A joint EPRI/NRC-RES Project in partnership with NIST

Fire Model User’s Guide Overview



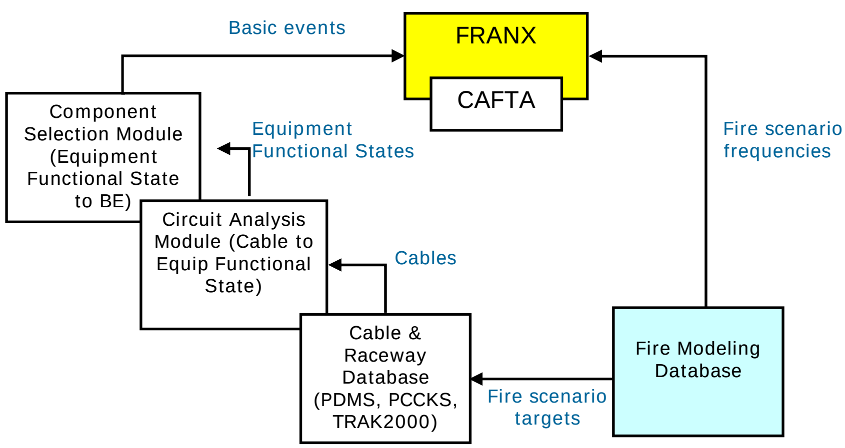
Fire Model User’s Guide

- Status/Schedule

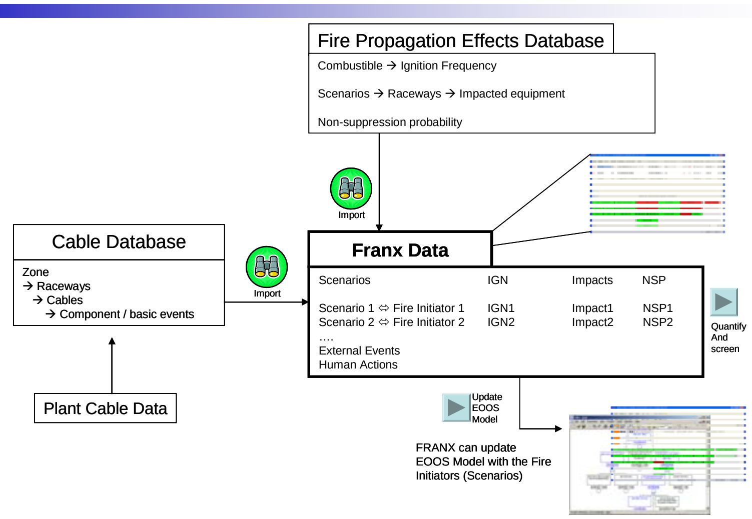
– 1st Draft	Apr 09
– Independent Review	July/Aug 09
– Draft for Public Comment	Oct 09
– Completion of ACRS Review	1st Qtr 10 (est.)
– Publication	2nd Qtr 10 (est.)

Automation; EPRI Fire Software

Functional Overview

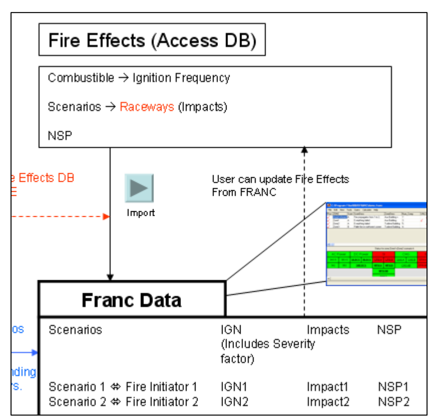


Software Integration Diagram



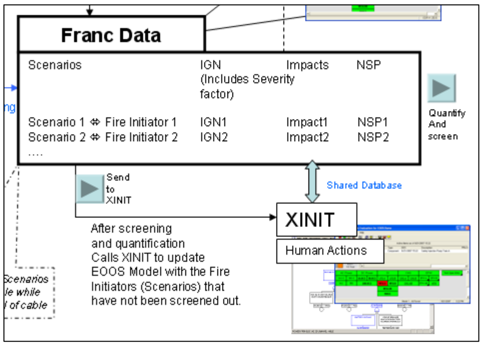
Fire Effects

- Calculates Ignition Frequency and non-suppression probability
- Calculates fire progression and subsequent Equipment Impacts
- Import then into FRANX Scenario Quantification



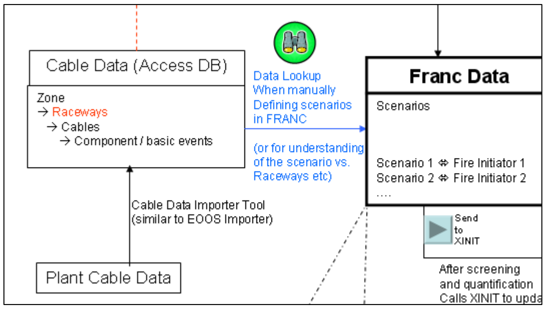
Integration with Risk Monitor

- New PRA model is constructed that includes fire initiators and scenario information (human actions, NSP, etc.)
- Allows simultaneous calculation of all fire impacts
- Model can be used with real-time model in risk monitors such as EOOS



Interface to Cable Data

- FRANX mapping database
- Import from more sophisticated database
- Plant Raceway/Cable Data
- Cable/BE Data



Future work

2009 Products

- FRANX Scenario Quantification Module (Beta currently available, Final version Summer 2009)
  - Import cable data
  - Import Fire initiator frequencies

2010 Activities

Fire Propagation Model

- Incorporate simple calculations of fire frequencies and damage effects

Other External Events

- Incorporate additional flood & seismic specific features

Future (TBD)

Configuration Risk Management Improvements

- Track status of fire barriers, suppression systems, etc.
- Ability to change the status of barriers etc.. (not possible now)

- Questions before we break up?

EPRI/NRC-RES Fire PRA Course

June 2009
September 2009

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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.

A Fire PRA Course has been put together to train interested parties in the application of this methodology. The Course is provided in three parallel parts: (1) PRA/HRA, (2) Electrical Analysis and (3) Fire Analysis. For each part a one-day seminar is provided initially on the first day that covers fundamental concepts. Starting with the second day of the Course, detailed presentations and discussions focus on the methodology covering the following topics and report sections:

- Module 1: PRA/HRA - This module covers the technical tasks for development of the system and operator response to a fire. Specifically, this module covers EPRI 1011989, NUREG/CR-6850, Volume 2, Sections 2, 4, 5, 7, 12, 14, and 15. Post-Fire Human Reliability Analysis (HRA) in the context of fire risk is addressed separately based on EPRI/NRC joint project on this topic.
- 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 EPRI 1011989, NUREG/CR-6850, Volume 2, Sections 3, 9, and 10.
- 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 EPRI 1011989, NUREG/CR-6850, Volume 2, sections 1, 6, 8, 11, and 13.

Integral to the Course 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 needed as input to the Fire PRA. The instruction package for specific technical tasks is provided in Sections 3, 4 and 5 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.

- ***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 estimating screening human error probabilities (HEPs) before detailed fire modeling results (e.g., fire growth and damage behaviors) or detailed circuit analyses (e.g., can the circuit spuriously actuate as opposed to simply assuming it can) have necessarily been developed. Estimating HEP values with high confidence is critical to the effectiveness of screening in a Fire PRA. This report does not develop a detailed fire HRA methodology. There are a number of HRA methods that can be adopted for fire with appropriate additional instructions that superimpose fire effects on any of the existing HRA methods, such as THERP, CBDT, ATHEANA, etc. This would improve consistency across analyses i.e., fire and internal events PRA.

  Module 1b of this course has been added to provide a discussion on the ongoing EPRI/NRC Fire HRA project. Module 1b is intended as added information for the attendees. A formal training of the topic is being considered by EPRI/NRC once the project is completed early 2010.
- ***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).

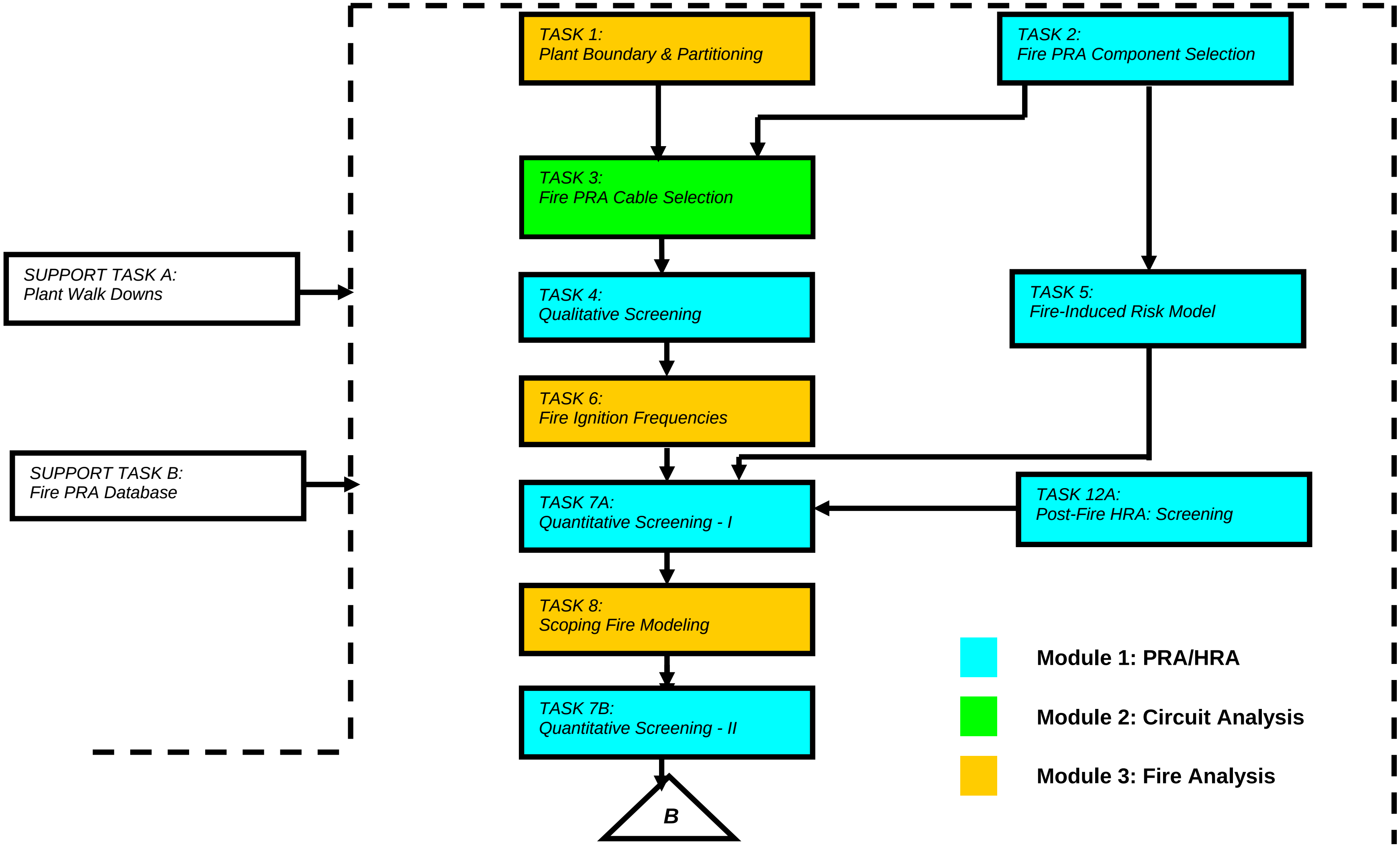
1.2 How to Use this Package

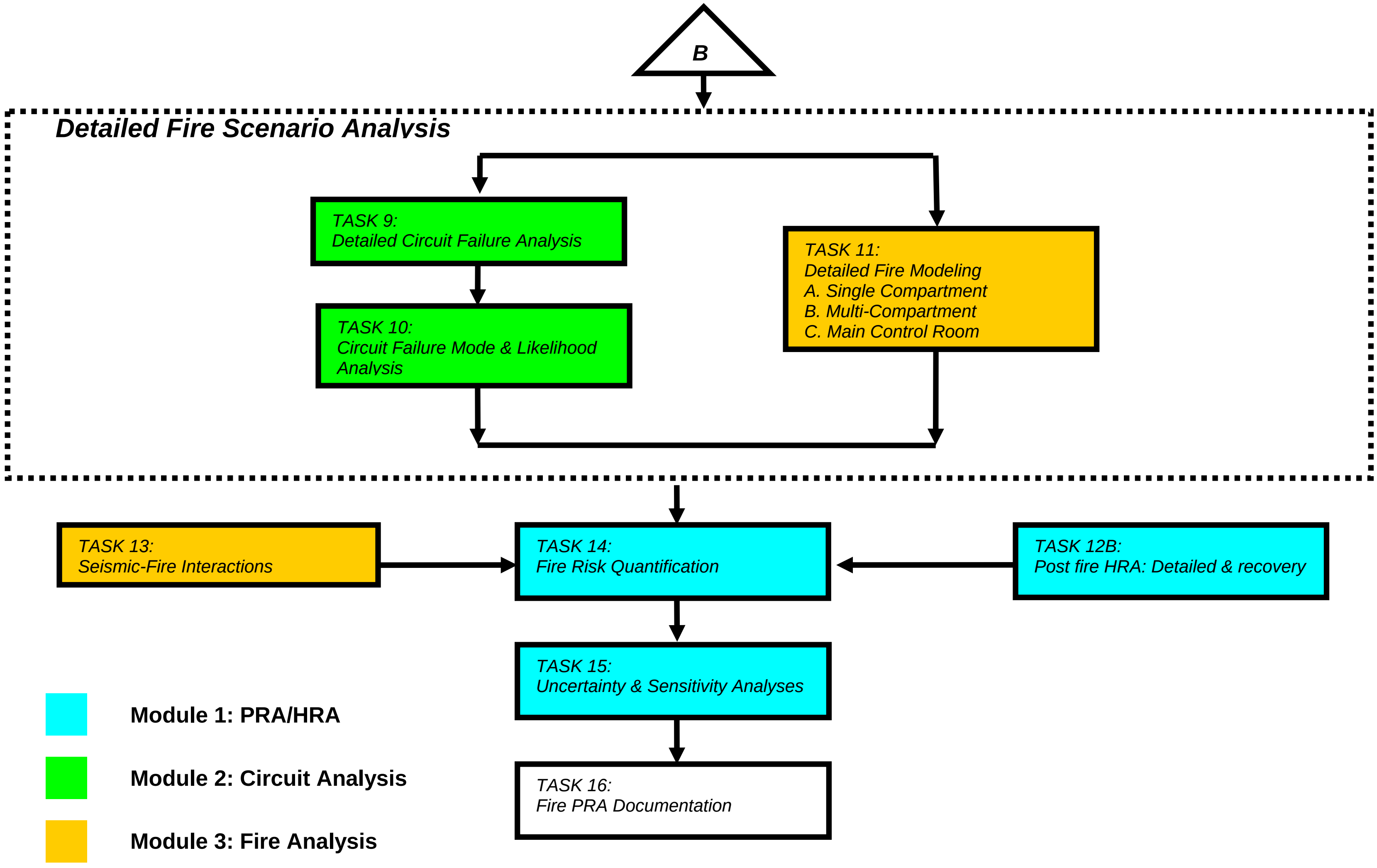
This package is intended to provide the background information necessary to perform some of the problem sets of the Course/Seminar. Please note:

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. Note that Fire HRA Module 1b presented in this course is not intended as training at this time, as it is based on work in progress expected to be completed for publication early 2010.
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.


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
Module 1: PRA/HRA
Module 2: Circuit Analysis
Module 3: Fire Analysis
TASK 7B:
Quantitative Screening - II
B


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
Module 1: PRA/HRA
Module 2: Circuit Analysis
Module 3: Fire Analysis

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 all three parallel modules.

The following notes generally describe the 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.
4. A nitrogen bottle provides the necessary pressurized gas to operate the PORV in case of loss of plant air.

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. The HPI is used for re-circulating sump water after a Loss of Coolant Accident (LOCA) using the pathway involving MOV-3 and MOV-4. For recirculation, the operator manually opens MOV-3 and MOV-4 and closes MOV-5 and MOV-6 upon proper indication of low RWST level and sufficient sump level.
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.).

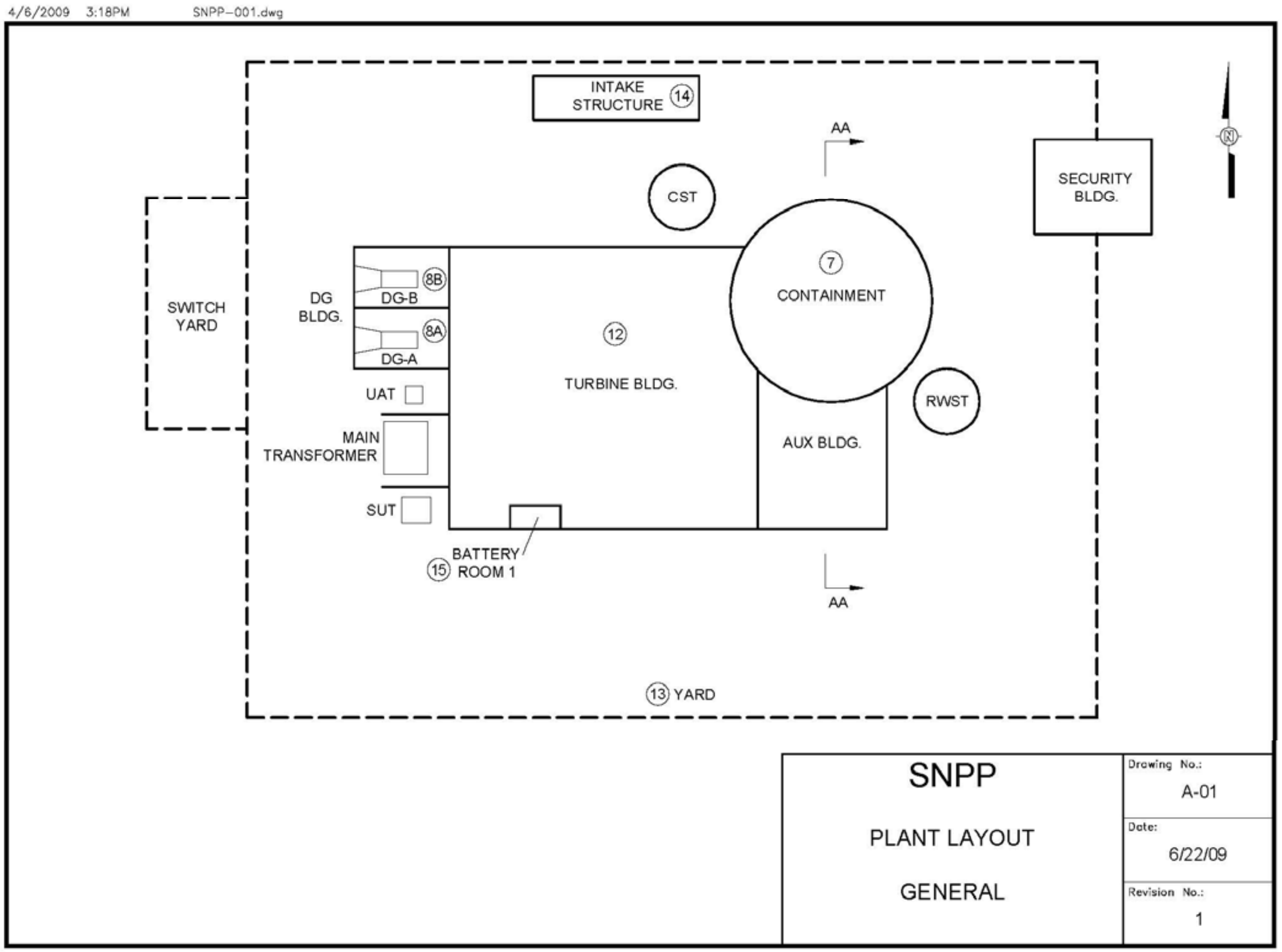
- Instrument air is required for operation of AOV-1, AOV-2, AOV-3, and AOV-4.

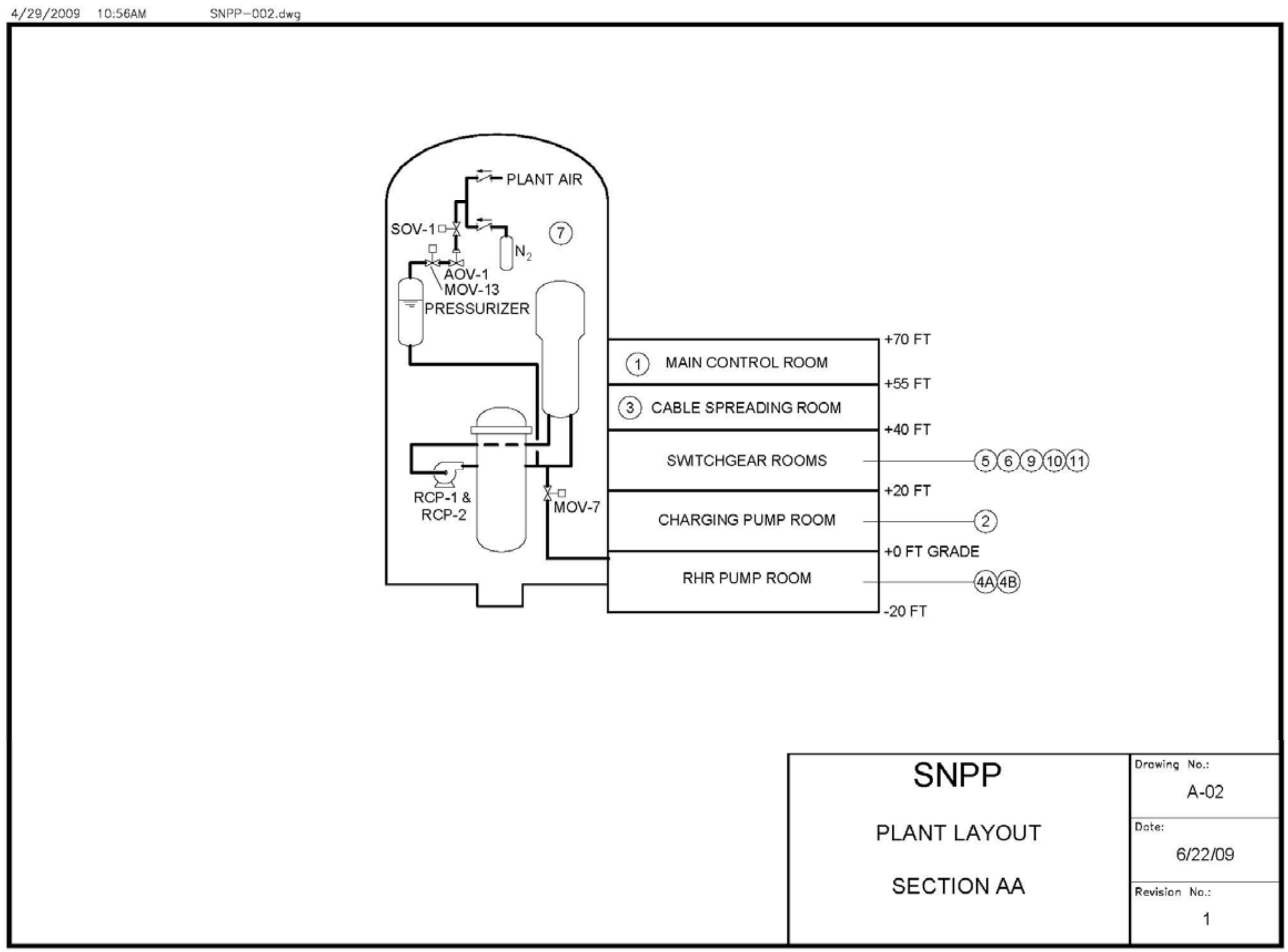
2.3 Plant Layout

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.

Figures 1 through 9
SNPP General Layouts

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RCP-2
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+55 FT
3 CABLE SPREADING ROOM
+40 FT
SWITCHGEAR ROOMS
5 6 9 10 11
+20 FT
CHARGING PUMP ROOM
2
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RHR PUMP ROOM
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6/22/09
Revision No.:
1

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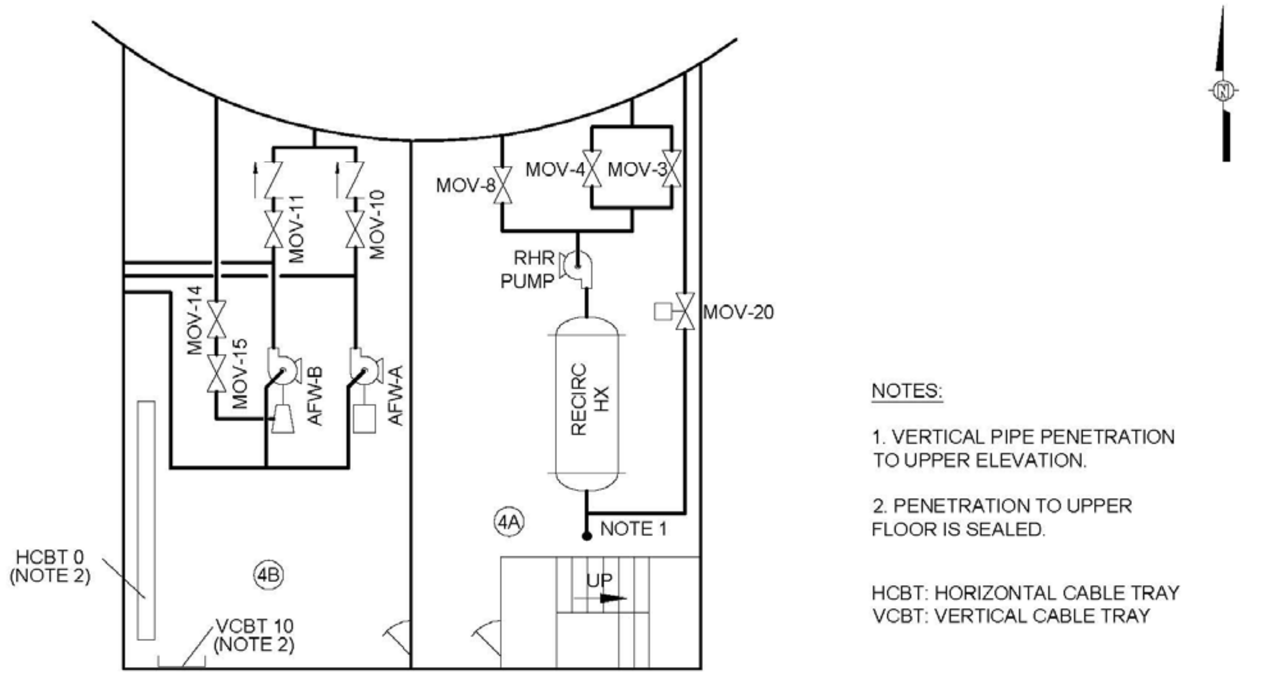


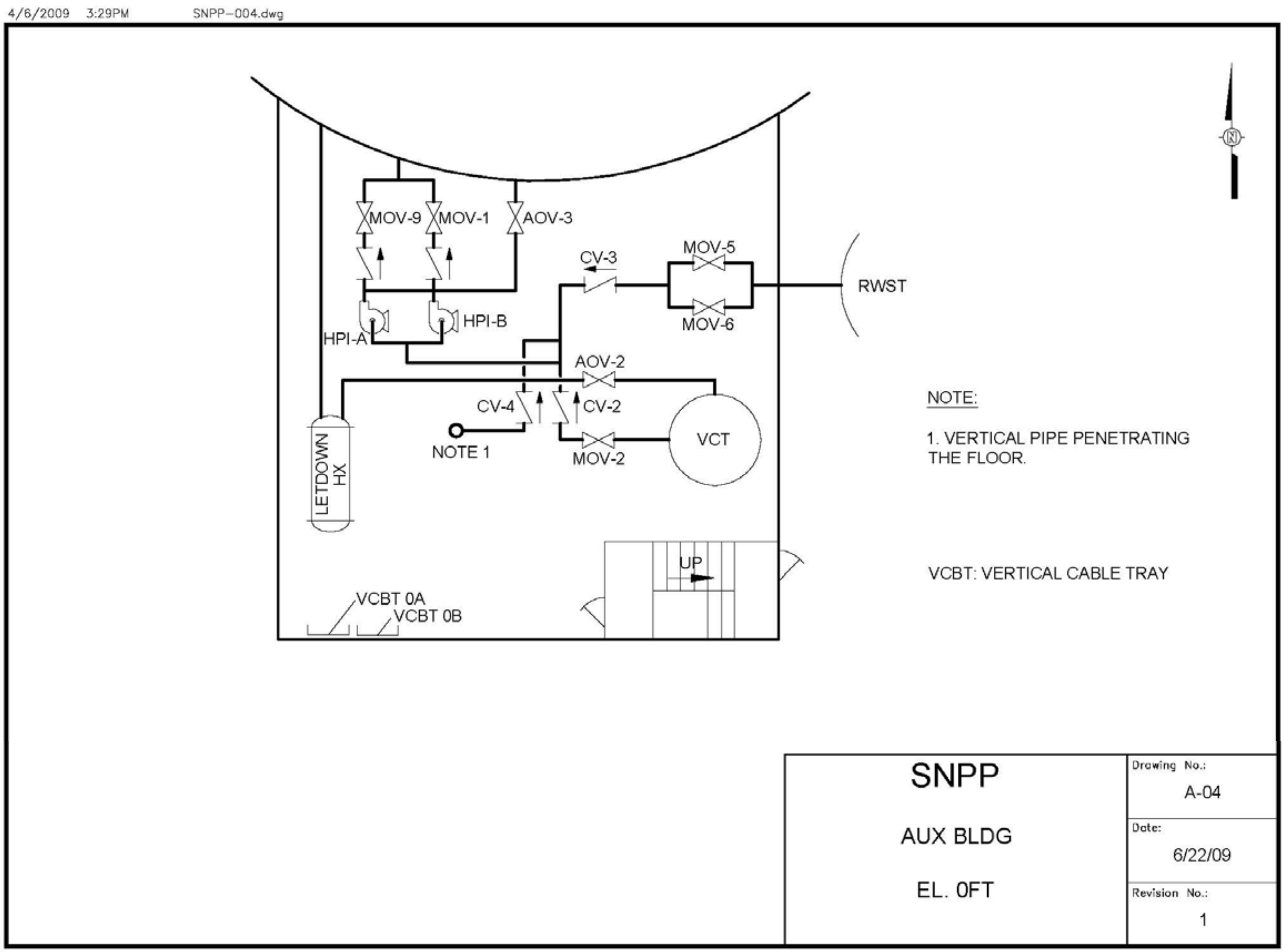
NOTES:

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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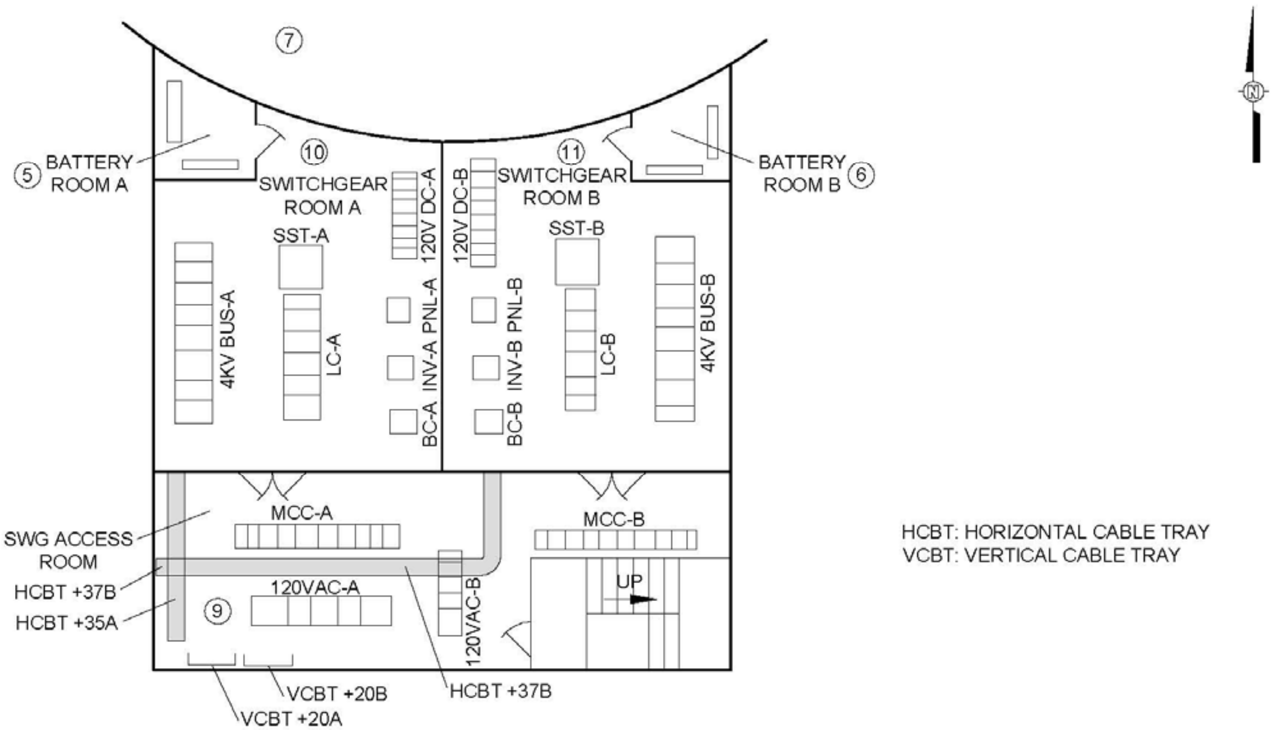
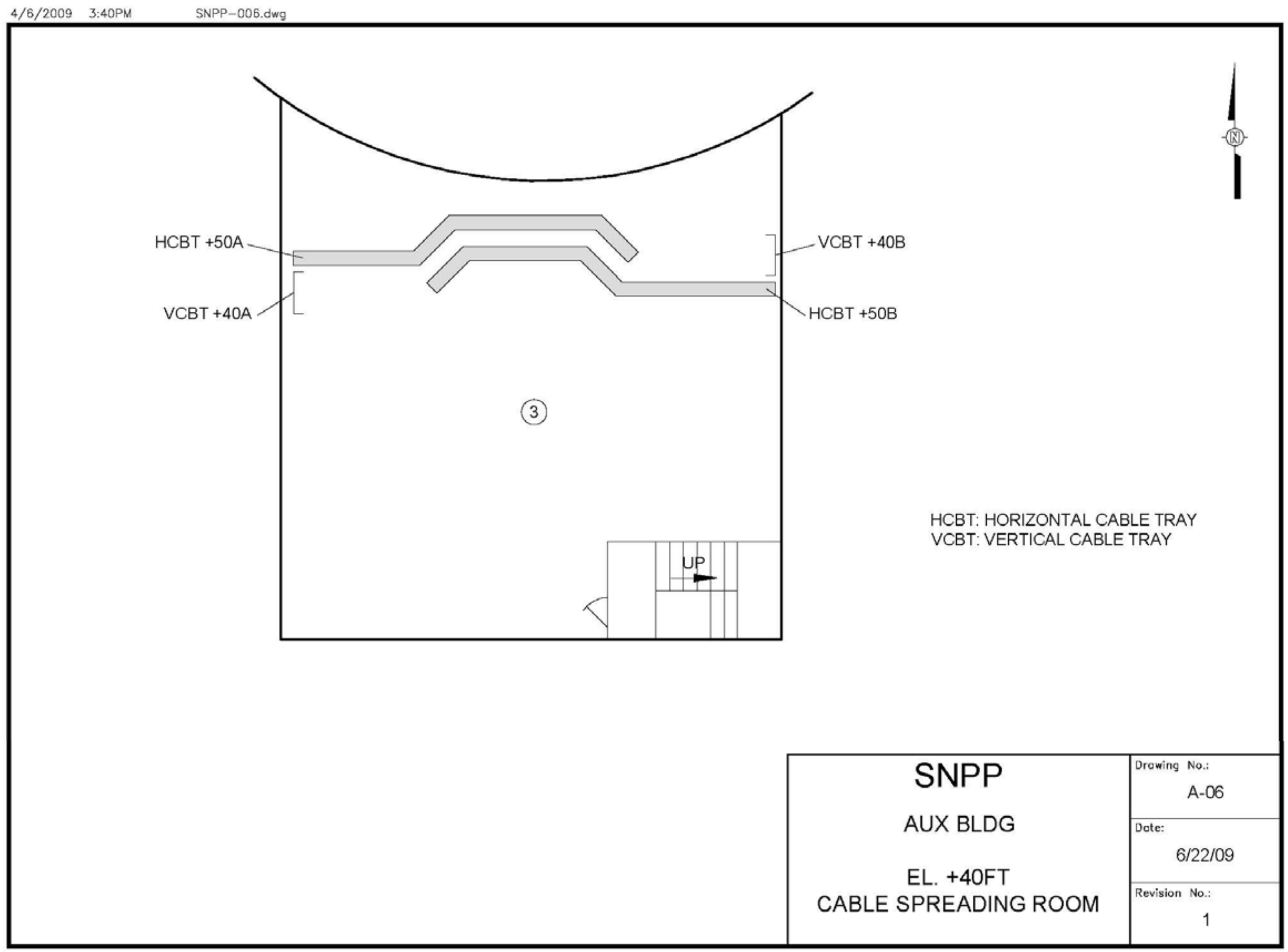
MOV-9
MOV-1
AOV-3
CV-3
MOV-5
RWST
MOV-6
HPI-B
HPI-A
AOV-2
CV-4
CV-2
VCT
NOTE 1
MOV-2
LETDOWN HX
UP
VCBT 0A
VCBT 0B
NOTE:
1. VERTICAL PIPE PENETRATING THE FLOOR.
VCBT: VERTICAL CABLE TRAY
SNPP
AUX BLDG
EL. 0FT
Drawing No.:
A-04
Date:
6/22/09
Revision No.:
1

4/29/2009 10:29AM SNPP-005.dwg



HCBT: HORIZONTAL CABLE TRAY
VCBT: VERTICAL CABLE TRAY

SNPP	Drawing No.: A-05	
AUX BLDG	Date: 6/22/09	
EL. +20FT	Revision No.: 1	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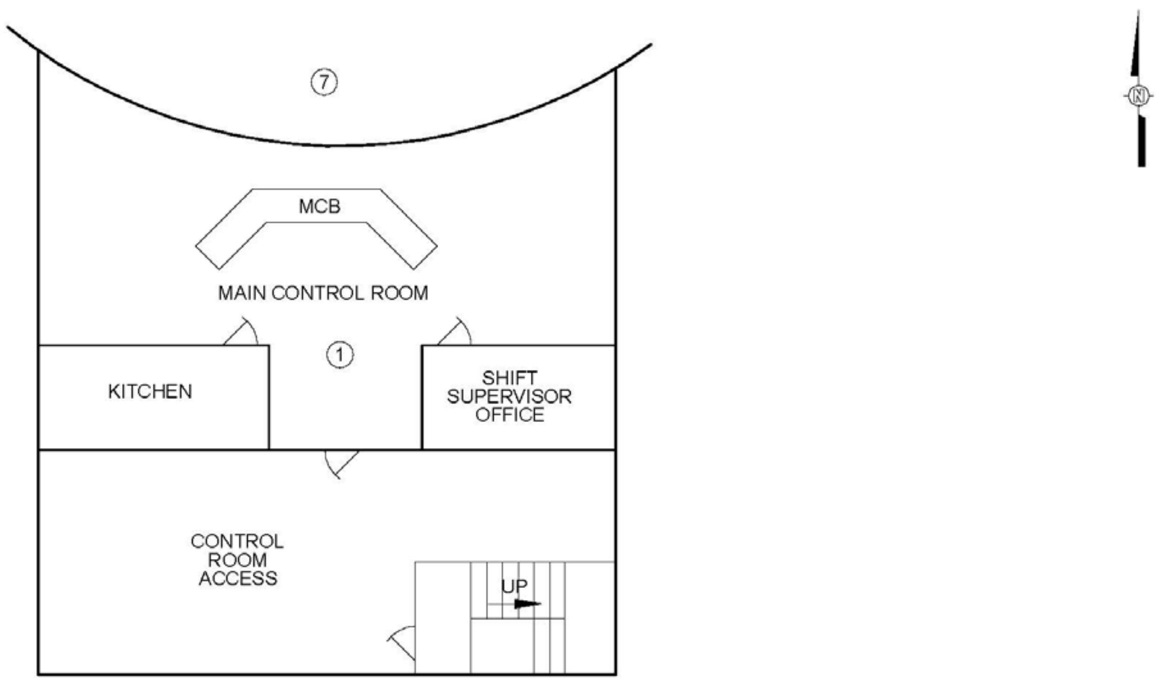
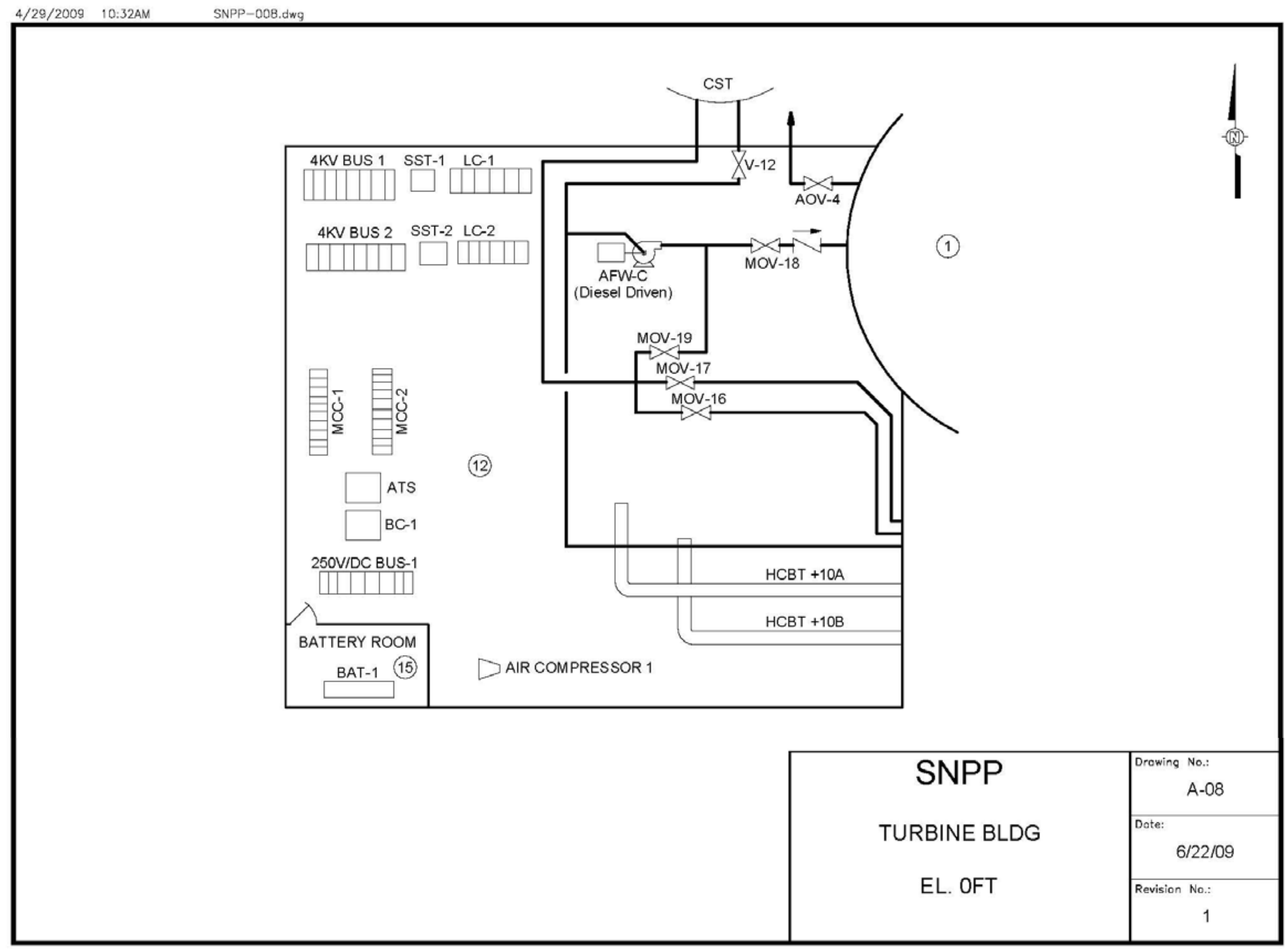
HCBT +50A
VCBT +40A
VCBT +40B
HCBT +50B
3
UP
HCBT: HORIZONTAL CABLE TRAY
VCBT: VERTICAL CABLE TRAY
SNPP
AUX BLDG
EL. +40FT
CABLE SPREADING ROOM
Drawing No.:
A-06
Date:
6/22/09
Revision No.:
1



SNPP	Drawing No.: A-07
AUX BLDG	Date: 6/22/09
MAIN CONTROL ROOM	Revision No.: 1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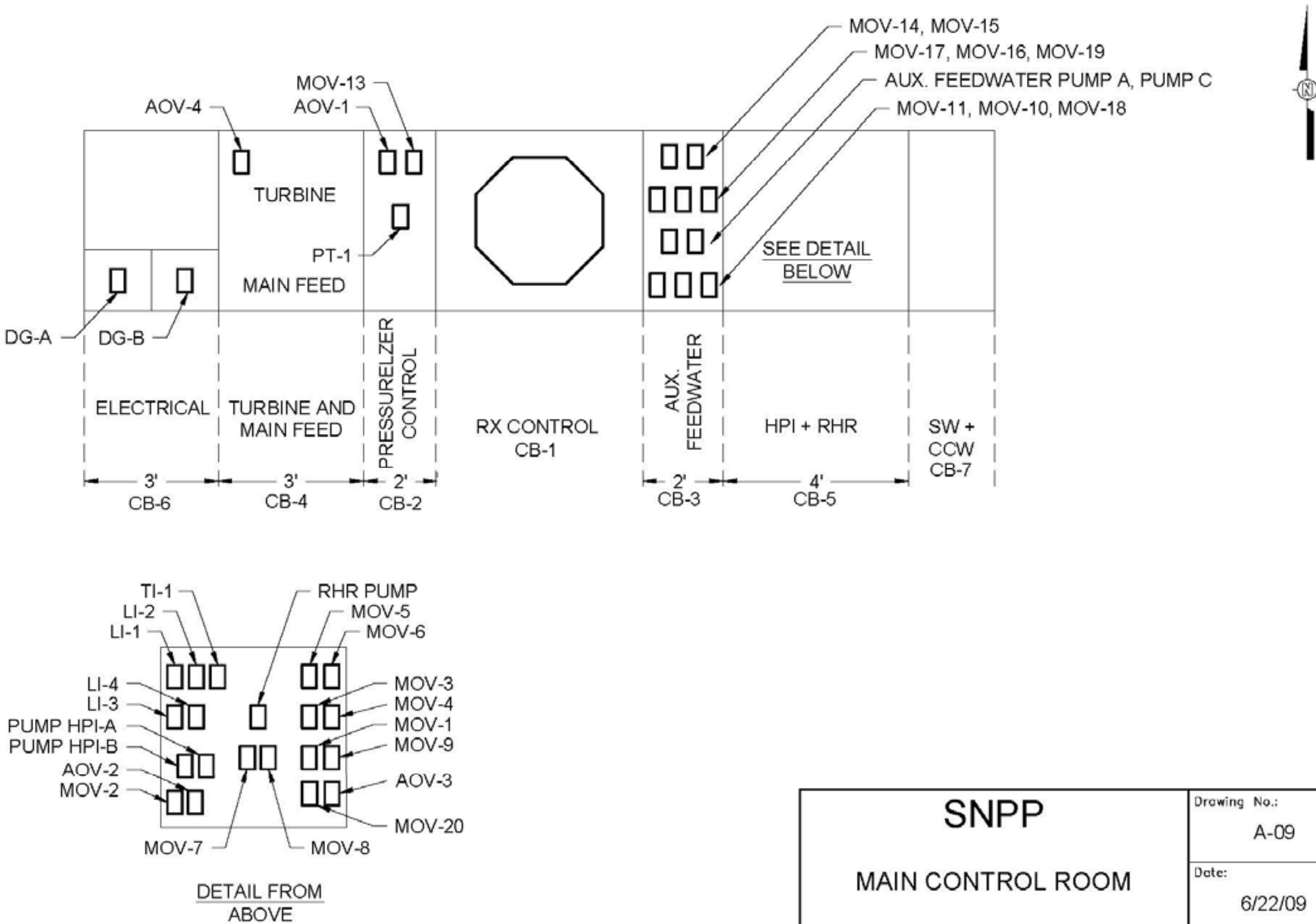
CST
V-12
AOV-4
4KV BUS 1
SST-1
LC-1
4KV BUS 2
SST-2
LC-2
AFW-C
(Diesel Driven)
MOV-18
1
MOV-19
MOV-17
MOV-16
MCC-1
MCC-2
12
ATS
BC-1
250V/DC BUS-1
HCBT +10A
HCBT +10B
BATTERY ROOM
BAT-1
15
AIR COMPRESSOR 1
SNPP
TURBINE BLDG
EL. 0FT
Drawing No.:
A-08
Date:
6/22/09
Revision No.:
1

4/6/2009 3:48PM SNPP–009.dwg



SNPP MAIN CONTROL ROOM MAIN CONTROL BOARD	Drawing No.: A-09
	Date: 6/22/09
	Revision No.: 1

Figure 10
PRIMARY SYSTEM P & ID

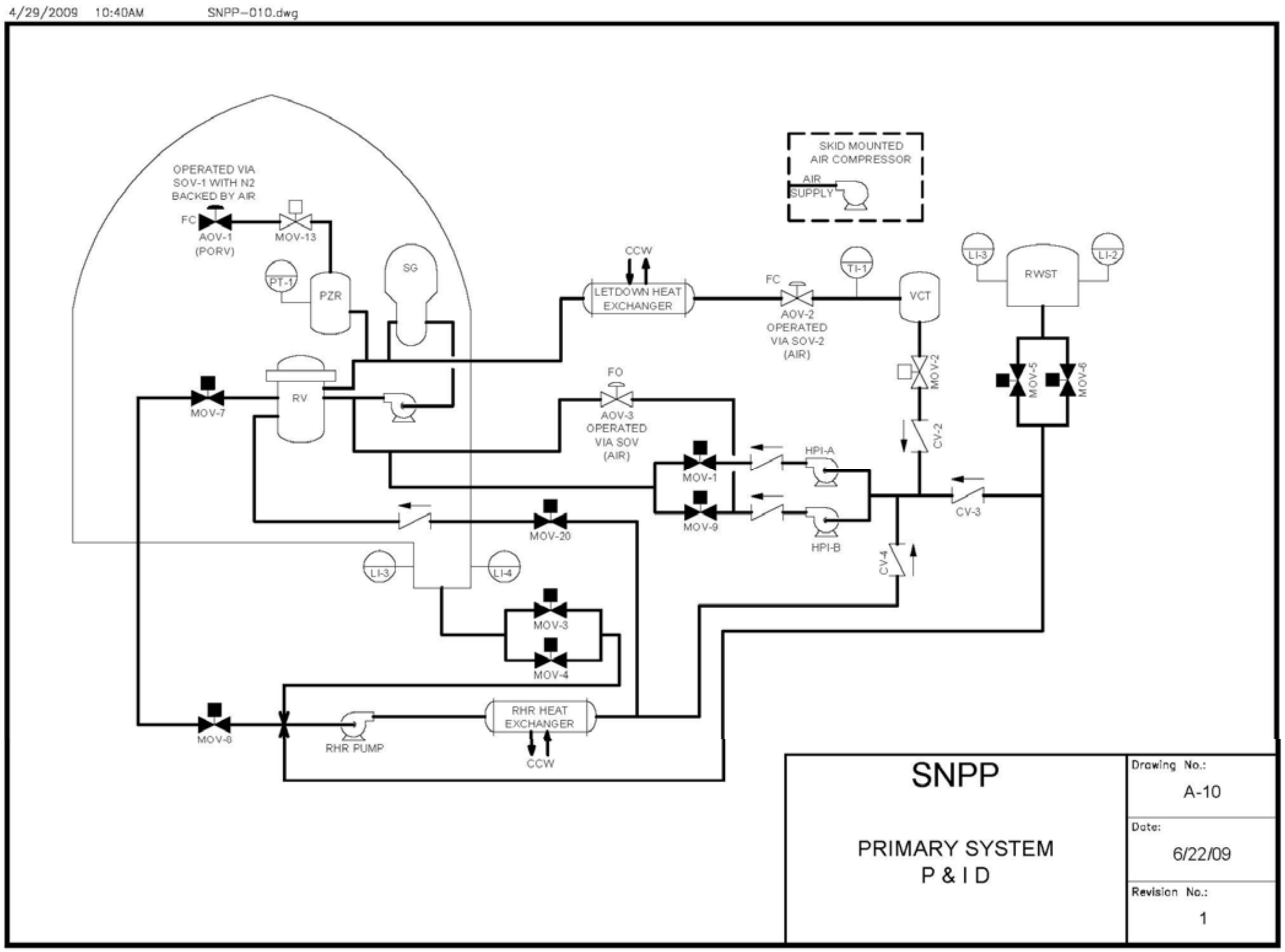


Figure 11
SECONDARY SYSTEM P & ID

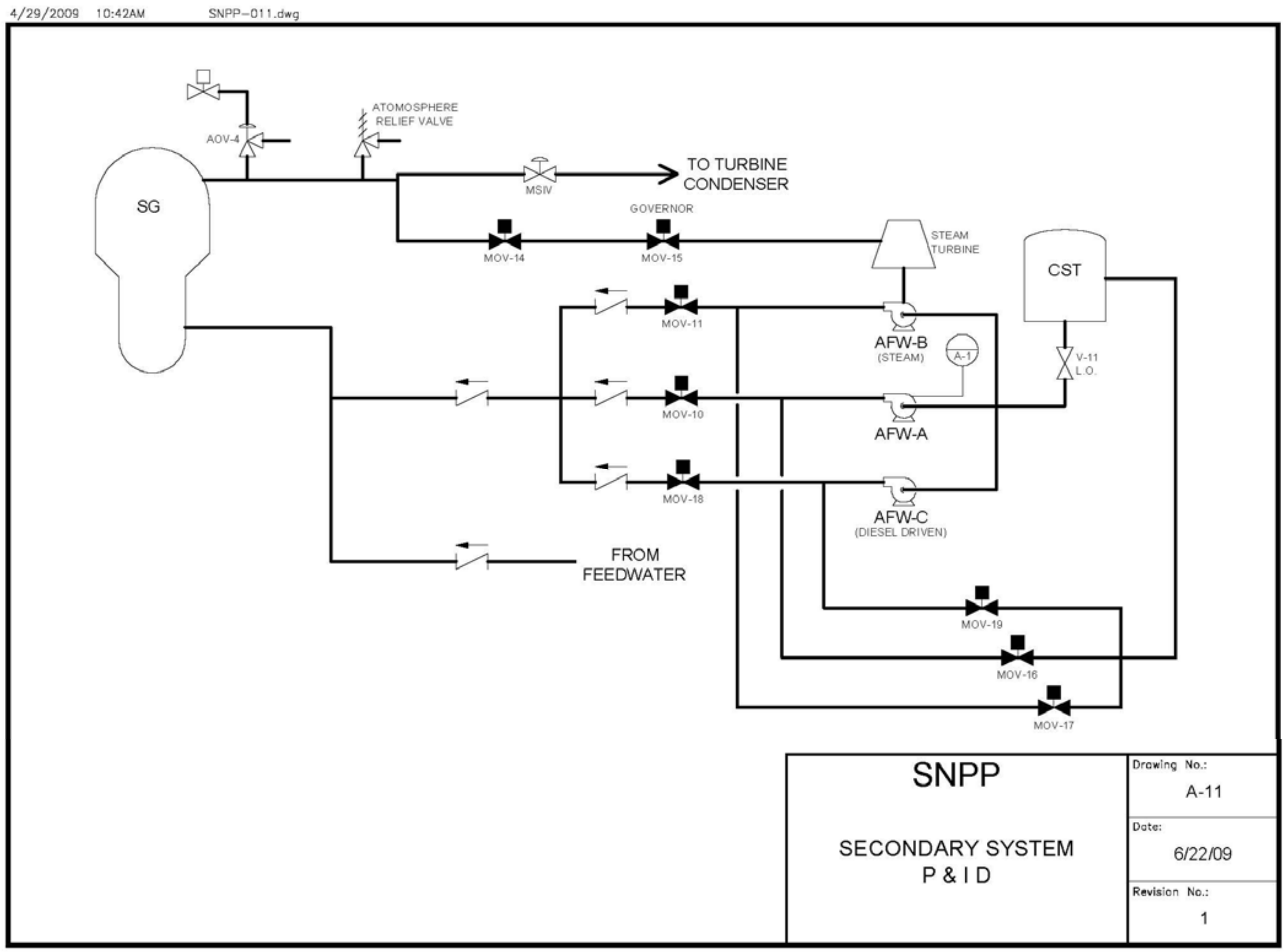
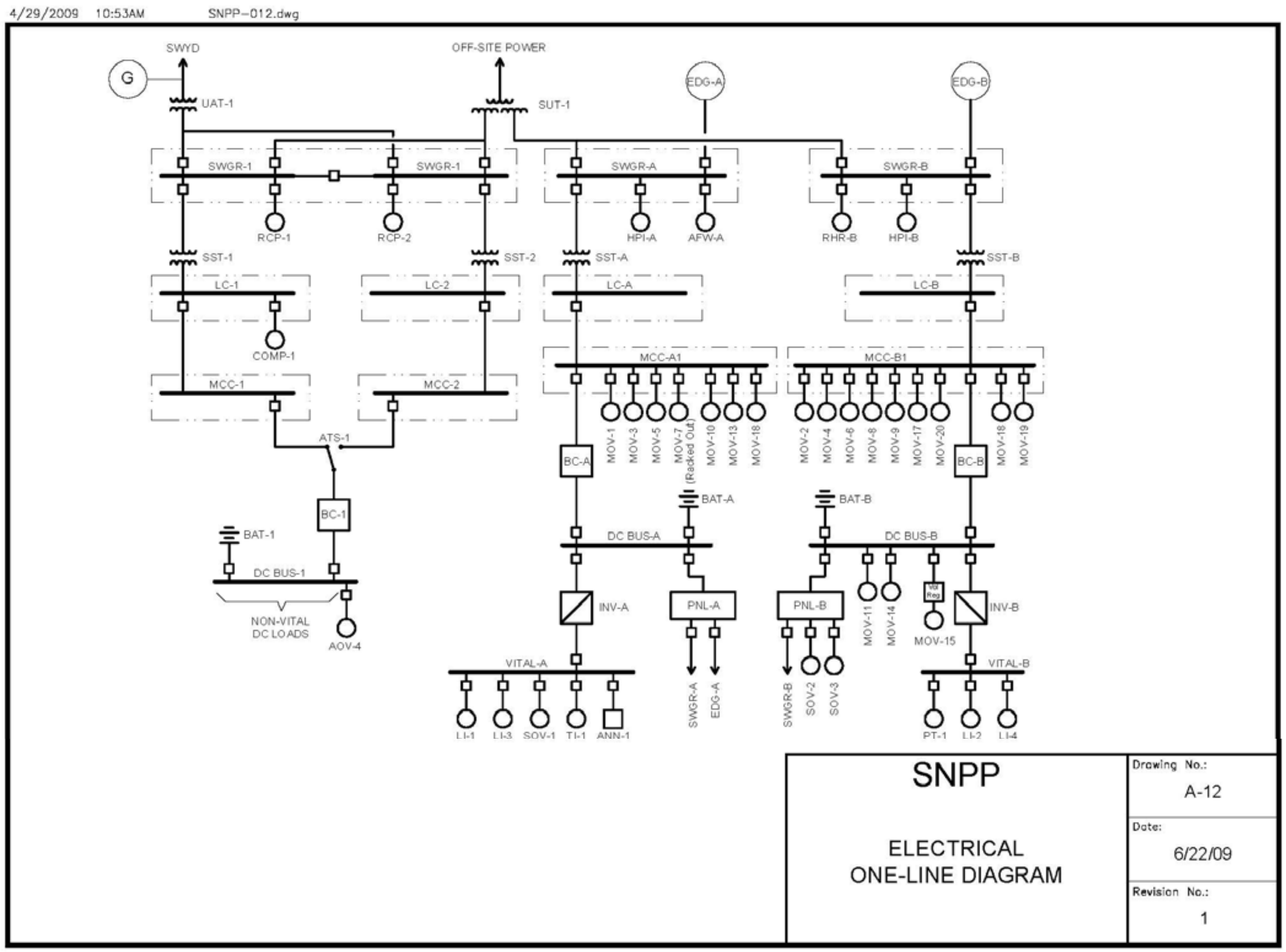


Figure 12
ELECTRICAL DISTRIBUTION SYSTEM - SIMPLIFIED ONE-LINE DIAGRAM



3
MODULE 1: PRA/HRA

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. The analysis task procedure provides structured instructions for identification and inclusion of these actions in the Fire PRA. The procedure also provides instructions for estimating screening human error probabilities (HEPs) before detailed fire modeling results (e.g., fire growth and damage behaviors) have been developed. Estimating HEP values with high confidence is critical to the effectiveness of screening in a Fire PRA. This report does not develop a detailed fire HRA methodology. There are a number of HRA methods that can be adopted for fire with appropriate additional instructions that superimpose fire effects on any of the existing HRA methods, such as SHARP,

ATHEANA, etc. This would improve consistency across analyses i.e., fire and internal events PRA.

As noted above, Module 1B of this course has been added to provide a discussion on the ongoing EPRI/NRC Fire HRA project. Module 1B is intended as added information for the attendees. A formal training of the topic is being considered by EPRI/NRC once the project is completed early 2010.

- ***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.