## ArevaEPRDCPEm Resource

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**Subject:** AREVA U.S. EPR Fukushima Technical Approach Slide Presentation - GoToMeeting with NRC November 8, 2012
**Attachments:** Fukushima Technical Approach meeting with NRC NOV 8 2012.pdf

Amy,

Attached is the slide presentation that we used during the Go To Meeting with NRC staff on Nov. 8th regarding the assumptions/inputs to be used for our Fukushima response thermal hydraulic analyses. As discussed at the DCWG meeting Nov. 13th, AREVA agreed to provide these slides and request feedback from NRC staff.

These slides are not proprietary and are not SUNSI.

Thanks,
Dennis

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# Technical Approach on U.S. EPR Fukushima Response - Thermal-Hydraulic Analyses

## Go-To-Meeting November 8, 2012

EPR™ by AREVA

AREVA

# Agenda

- U.S. EPR Fukushima Response Basic Overview
- Secondary Side Feed and Bleed Analysis in Modes 1 - 4 (RELAP5)
- Core Cooling in Modes 5 & 6
- Containment Heatup Analysis (GOTHIC)
- Summary

# U.S. EPR™ Fukushima Mitigation Strategy Basic Overview

- **U.S. EPR™ Fukushima Mitigation Strategy was presented to NRC on September 19, 2012 in Rockville, MD.**
- **The U.S. EPR™ mitigation strategy for Recommendation 4.2 will conform with Order EA-12-049, JLD-ISG-2012-01 and NEI 12-06, "*Diverse and Flexible Coping Strategies (FLEX) Implementation Guide*"**
  - **Order requires a three phase approach:**
    - Phase 1: The initial phase requires the use of installed equipment and resources to maintain or restore core cooling, containment and spent fuel pool (SFP) cooling capabilities.
    - Phase 2: The transition phase requires providing sufficient, portable, onsite equipment and consumables to maintain or restore these functions until they can be accomplished with resources brought from off site.
    - Phase 3: The final phase requires obtaining sufficient offsite resources to sustain those functions indefinitely.

# U.S. EPR™ Fukushima Mitigation Strategy Basic Overview (continued)

- The DC applicant will address Phase 1 event mitigation and will add permanent plant connections (as needed) and identify performance requirements for portable equipment to support long-term event mitigation (interface provisions for Phase 2 and 3 actions).
- Implement strategies in all modes
- Assumes the unavailability of ac sources -- grid, EDGs, and SBO DGs. Only dc batteries available (capacity to be extended by load shedding).

# Analysis Required

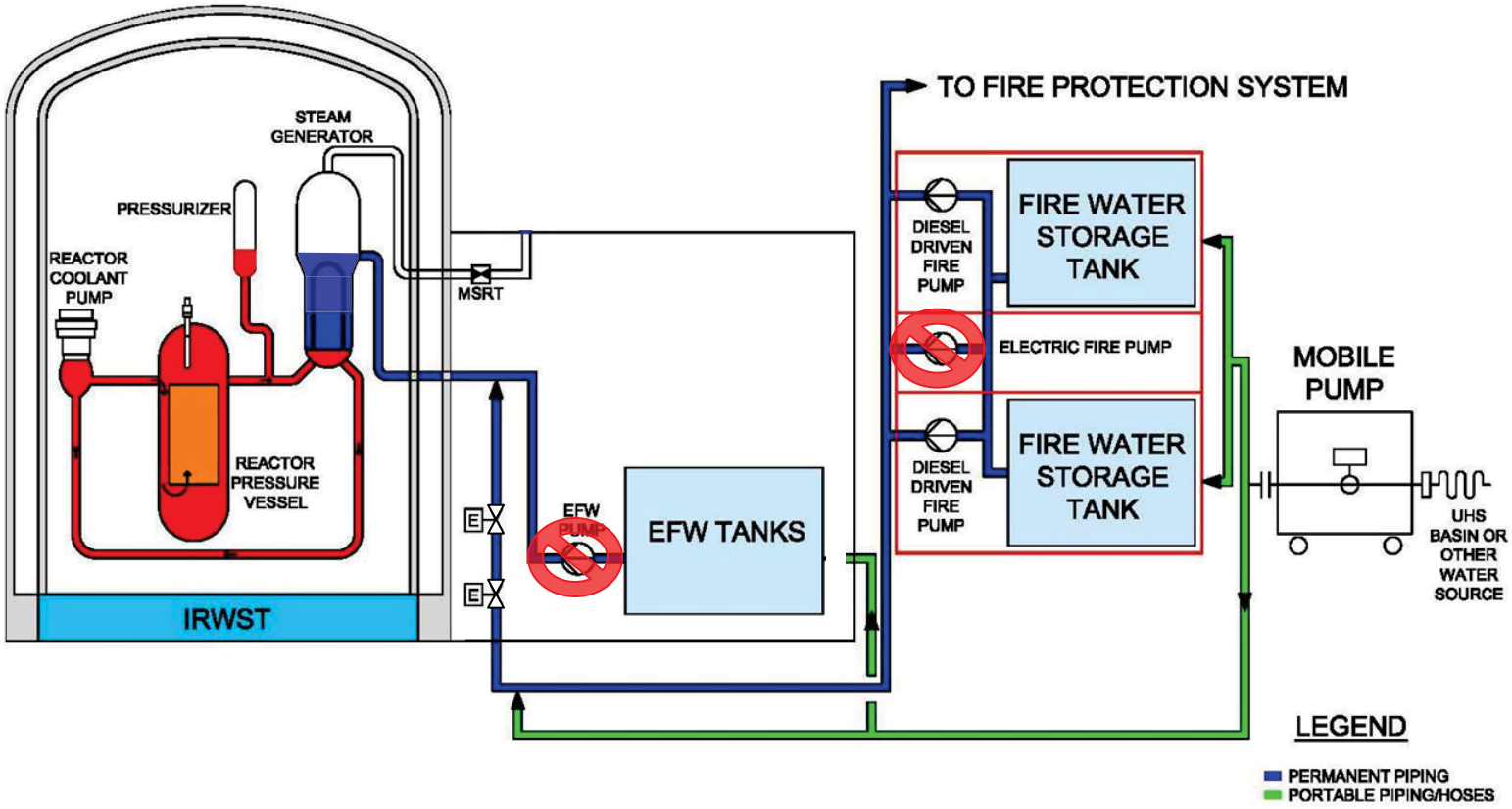
- **From NEI 12-06 Section 11.2.1:**
  - *Design requirements and supporting analysis should be developed for portable equipment that directly performs a FLEX mitigation strategy for core, containment, and SFP that provides the inputs, assumptions, and documented analysis that the mitigation strategy and support equipment will perform as intended.*
- **Objective: Confirm required operator actions, timing, and indications (e.g., initiate secondary side depressurization, control depressurization rate, control final SG pressure) to meet acceptance criteria (e.g., core cooling & long term subcriticality).**

# Acceptance Criteria

| FUNCTION | ACCEPTANCE CRITERIA |
|---|---|
| Core Cooling | Fuel in core remains covered – no fuel damage<br>Criticality - Maintain core subcritical in the long term |
| Spent Fuel Cooling | Fuel in spent fuel pool remains covered – no fuel damage |
| Containment Integrity | Containment pressure remains below containment ultimate pressure capacity limits |

# Secondary Side Feed and Bleed Analysis Modes 1 - 4

# Secondary Side Feed and Bleed



# Secondary Side Feed and Bleed Analysis

- **Applicable for Modes 1 – 4**
- **Goal: Core Cooling Sustainable via SG Feed & Bleed**
  - **Remain in Mode 4 (Hot Shutdown)**
  - **Transition to Phases 2 & 3 using portable equipment**
- **Principal Analysis Code: S-RELAP5**
  - **Best Estimate SBLOCA Model with:**
    - Non-Safety System Capabilities
    - EOC kinetics
    - Best Estimate Decay Heat
    - No Stuck Rods
    - No Single Failures / no Equipment out of service
- **Acceptance Criteria:**
  - **Fuel in core remains covered – no fuel damage**
  - **Criticality - Maintain core subcritical in the long term**

# Secondary Side Feed and Bleed Analysis

## Key Inputs and Assumptions

- **Loss of Offsite Power with common cause failure of EDGs and SBO Diesels as initiating event, followed by Extended Loss of AC Power (ELAP)**
- **Rx/Turbine Trip, Loss of RCPs, no FW, no EFW, no MHSI/LHSI**
- **Initial RCP Seal Leakage at 2 minutes (25 gpm/pump + 11 gpm misc RCS leakage)**
- **RCP Standstill Seal System activation at 15 minutes (RCP leakage reduced to 0.5 gpm/pump, or 13 gpm total RCS leakage)**
- **Secondary Side controlled depressurization using Main Steam Relief Trains (MSRTs)**
- **Initiate SG cooling via MSRTs (bleed) and Diesel Driven Fire Water Pump connected to EFW header as soon as SG pressure permits (feed)**
- **RCS Makeup via:**
  - Accumulator Injection
  - May require opening PSRV to partially depressurize RCS

# Secondary Side Feed and Bleed Analysis

## Critical Times to be Determined

- Time to SG dryout and when to begin depressurizing with MSRTs
- Time to core uncovery if SG inventory is NOT resupplied
- Time to core uncovery (with SG cooling) if RCS makeup is not available.
- Time at which Fire Water Storage Tanks must be replenished (extrapolation of feed usage rate)
- Time accumulators inject and when accumulators must be isolated or vented.

# Secondary Side Feed and Bleed Analysis

## Additional Highlights:

- **Diesel Fire Pump is presently rated for 2,500 gpm at 185 psi – sufficient flow, but low head – analysis will determine if delivery pressure needs to be increased**
- **Controlled SG depressurization via MSRTs**
  - MSRT "Partial Cooldown" mode of ~180 °F/hr Tavg reduction is target initial depressurization rate – analysis will determine if depressurization rate is acceptable
  - Final SG pressure – analysis will determine acceptable range of final SG pressures
- **Active valves, such as PSRVs, MSRTs, and accumulator isolation/vent valves, will be operable using DC power – separate DC load shedding analysis will demonstrate that required loads are powered**

# Secondary Side Feed and Bleed Analysis

## Summary

- Core Cooling via Natural Circulation to SGs (Mode 4)
- SG cooling via MSRTs (bleed) and Diesel Driven Fire Water Pump connected to EFW pump discharge header (feed)
- Confirm acceptability of Diesel Fire Water Pump characteristics or define new characteristics
- RCP Standstill Seal System limits seal leakage to 0.5 gpm/pump
- RCS Makeup via Accumulators
- Interface requirement for Phase 2 and Phase 3 –
  - RCS makeup flow rate for RCP seal leakage and Tech Spec leakage
  - Secondary inventory delivery requirements

# Core Cooling in Modes 5 and 6

# Core Cooling in Modes 5 & 6

- **Applicable for Modes 5 & 6**
- **Goal: Determine primary side makeup for core cooling in Modes 5 & 6**
  - **Utilize installed / onsite equipment**
  - **Determine interface requirements for Phase 2 & 3 core cooling with portable equipment**
- **Principal Analysis Tool: Hand Calculation**
- **Acceptance Criteria:**
  - **Fuel in core remains covered – no fuel damage**
  - **Criticality - Maintain core subcritical in the long term**

# Core Cooling Modes 5 and 6

- Mode 5 (RCS < 200 ºF and between 14.7 psia and 370 psia and Keff < .99)
- Mode 6 (one or more RV closure bolts less than fully tensioned)

| MODE | VENTING | RCS MAKEUP |
|---|---|---|
| 5 | Pressurizer Safety Relief Valve(s) | Borated Makeup |
| 6 | Pressurizer Safety Relief Valve(s) | Borated Makeup |
| 6 | RCS Vented | Borated Makeup |

# Core Cooling Modes 5 and 6

- Core cooling equivalent to keeping core covered with borated water
- Core cooling requirements (make-up) in mode 5 and 6 derived with a hand calculation

# Core Cooling Modes 5 and 6

## Hand Calculation

$Q = W (h_o – h_i)$

Where: Q = decay heat

W = injection flow rate required

$h_o$ = core exit enthalpy of saturated steam

$h_i$ = injection flow enthalpy

Solving for the injection flow rate required, W

$W = Q/(h_o – h_i)$

# Core Cooling Modes 5 and 6

## Key Inputs and Assumptions

- **RCS adequately vented at time of make-up**
  - PSRVs or reactor vessel head removed
- **Initial conditions span Mode 5 and 6**
  - Pressure 14.7 psia – 370 psia
  - Temperature ≤ 200 º F
- **Best Estimate Decay Heat**
- **Flow requirements derived for range of injection temperatures**

# Core Cooling Modes 5 and 6

## Summary

- Primary side make-up and venting using installed equipment (Phase 1) and available upon ELAP
- Make-up flow requirements determined with hand calculation for all three Phases
- Best estimate decay heat assumed
- Full range of conditions evaluated to bound Mode 5 and 6
- Keeping the core covered provides adequate core cooling

# Containment Heatup Analysis

# Containment Heatup Analysis
## Overview

- **Applicable for Modes 1 – 4 and 5 & 6**
- **Goal: Establish Requirements Necessary to Maintain Containment Integrity**
  - **Determine duration of the containment heat up and pressurization in Phase 1 before portable equipment can be utilized in Phase 2/3**
  - **Determine interface requirements for Phase 2/3 event mitigation**
- **Principal Analysis Code: GOTHIC**
  - **Multi-node EPR containment model with:**
    - Subdivided dome region
    - Best estimate containment conditions
    - RCS leakage / venting
    - Sensible energy addition from equipment / piping
- **Acceptance Criteria**
  - **Maximum containment pressure of 118 psig**

# Inputs
## Containment

- **Containment parameters (best estimate)**
  - **Free Volume - 2,827,498 ft³**
  - **Initial pressure - 14.7 psia**
  - **Initial containment temperature - 86°F**
  - **Relative humidity - 50%**
- **Containment cooling methods**
  - **Active containment cooling not credited during Phase 1**

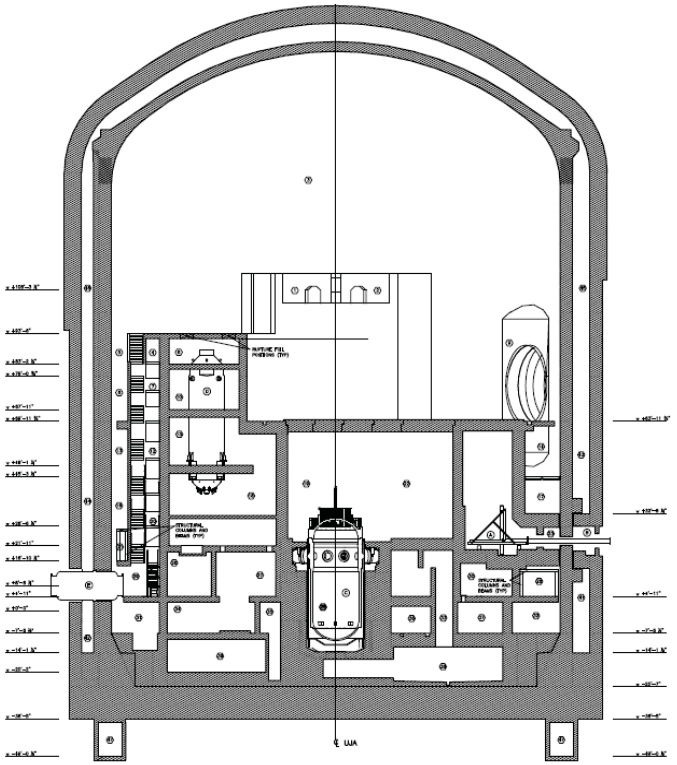


Figure 3.8-13—Reactor Building Section C-C

# Inputs
## Mass and Energy Release - Mode 1

- **RCS Leakage**
  - **RCS leakage - 11 gpm (10 gpm of identified leakage and 1 gpm of unidentified)**
  - **RCP seal integrity compromised at 2 minutes (RCP seal leakage is 25 gpm/pump)**
  - **RCP Standstill Seal System actuated 15 minutes into the event, (RCP seal leakage to 0.5 gpm/pump)**
- **Other potential sources**
  - **Venting of the primary system may become necessary**
  - **Integrated with feed and bleed analysis**

# Inputs
## Mass and Energy Release - Mode 5 and 6

- **Mass flow rates**
  - **Release either from venting out of the PSRV (Mode 5) or the open head (Mode 6)**
  - **Release of RCS venting into containment will be based on calculations from Modes 5 and 6 core cooling analysis**
- **Enthalpy values based on saturated steam conditions**

# Inputs
## Sensible Energy – Mode 1 (1/2)

- **Primary Side**
  - **Modeled as a control volume with heat conductors inside of the GOTHIC model**
  - **Best estimate nominal RCS conditions and inventory**
- **Secondary side**
  - **Modeled as a control volume with heat conductors inside of the GOTHIC model**
  - **Control volume will represent all of the FW and steam piping inside the reactor building, secondary side of the SGs.**

# Inputs
## Sensible Energy – Mode 1 (2/2)

- **Other equipment heat load**
  - **Heat load modeled with heater components**
  - **Total sensible energy addition including primary side, secondary side and other equipment based on HVAC internal heat load design**

# Inputs
## Sensible Energy – Mode 5 and 6

- **Primary and secondary side**
  - **Utilize control volumes and conductors created for mode 1**
  - **Control volume conditions based on results from core cooling analyses**
- **Other equipment loads**
  - **Utilize heaters created for mode 1**
  - **The heat addition values based on available equipment in Modes 5 & 6**

# Summary

- **GOTHIC multi-node model**
  - **Best estimate nominal conditions**
  - **Sensible energy**
    - NSSS control volumes at constant conditions with conductors
    - Heat addition from other equipment to be modeled as a heater
    - Model refinements may be necessary to support acceptance criteria
- **Mass and energy release**
  - **RCS leakage and primary side venting**
- **Goals:**
  - **Determine duration of the containment heat up and pressurization in Phase 1 before portable equipment can be utilized in Phase 2/3**
  - **Determine interface requirements for Phase 2/3 event mitigation**

# General Summary

- **Thermal/hydraulic analyses will confirm required operator actions, timing, and indications to meet acceptance criteria (e.g., core cooling, long term subcriticality).**
  - **Demonstrate achievement of core cooling and containment functions**
  - **Establish functional requirements for Phase 1 event mitigation**
  - **Establish interfacing functional requirements for Phase 2/3 event mitigation**
- **Questions?**