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Containment Systems

May 22, 2013

(Redacted Version)

This is a pre-application document and includes preliminary design or design supporting information and is subject to further internal review, revision, or verification.

Objectives

Meeting objective:

- To provide information to the NRC regarding the current state of containment functional design and several associated systems

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Agenda

- Introduction
- Plant Layout
- Containment Functional Design
- Systems
  - Containment Isolation System
  - Combustible Gas Control System
  - Containment Leak Rate Testing
- Mass and Energy Release Analysis
- Containment Heat Removal
- Containment P/T Analysis

Introduction

Design Evolution of the Reactor Containment Vessel:

- Initially a steel-lined concrete containment; currently a free-standing steel containment
- Passively cooled
- Containment diameter and height recently adjusted
- Equipment layout optimized for refueling and operation

Plant Layout

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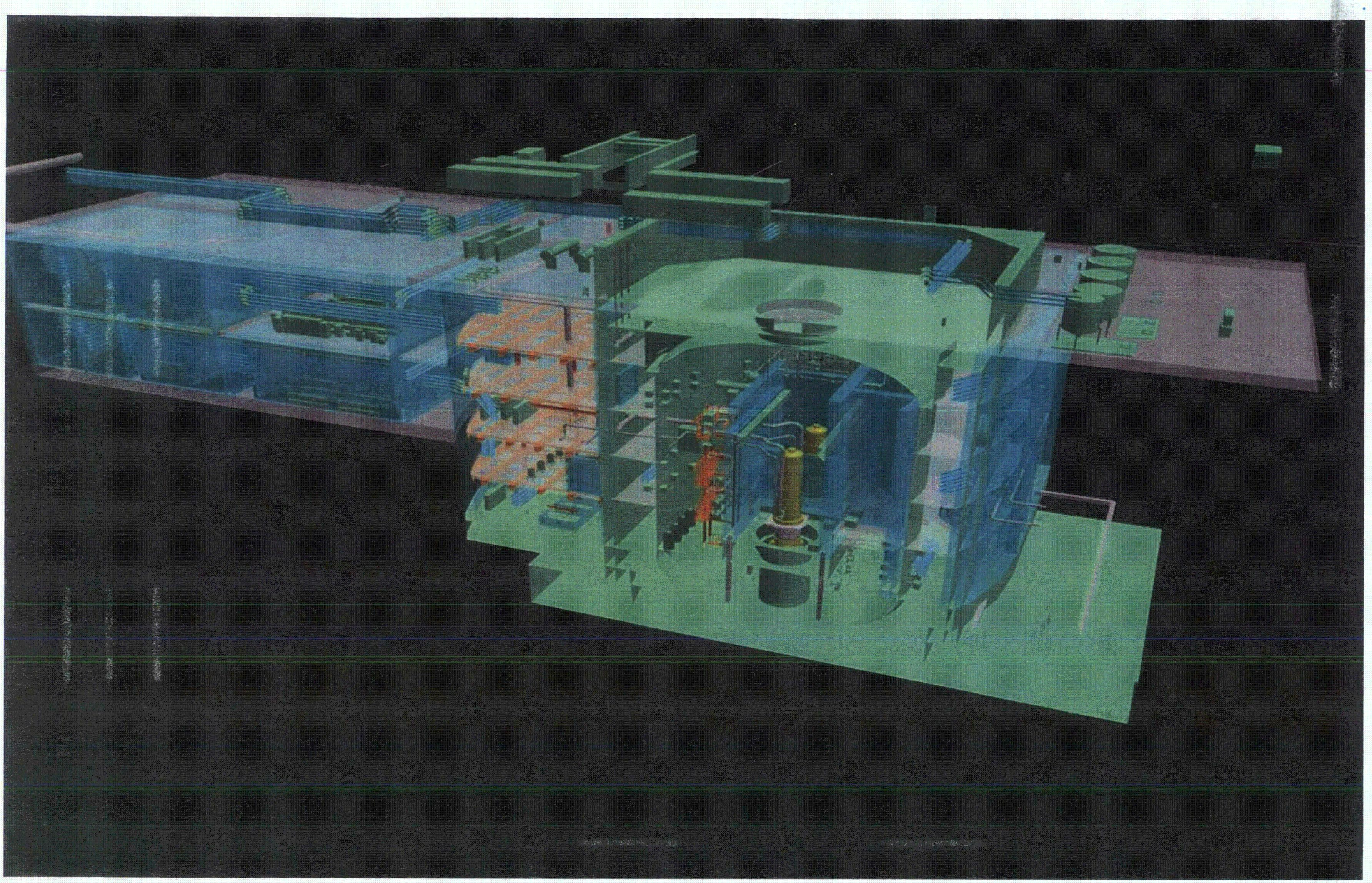
Cutaway of RSB & Reactor Containment



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Containment Looking East

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[CCI per Affidavit 4(a)-(d)]

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Containment Looking North

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[CCI per Affidavit 4(a)-(d)]

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Containment Plan at Elevation [ ]'

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[CCI per Affidavit 4(a)-(d)]

Containment Plan at Elevation [ ]'

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[CCI per Affidavit 4(a)-(d)]

Containment Plan at Elevation [ ]'

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[CCI per Affidavit 4(a)-(d)]

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Containment Plan at Elevation [ ]’

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[CCI per Affidavit 4(a)-(d)]

Containment Physical Description

- Reactor Containment Vessel (RCV) is free-standing steel
- [ ]
- [ ]
- Inner diameter ~ [ ] feet
- Overall height ~ [ ] feet
- [ ] Equipment Hatches [ ]
- Personnel Airlocks [ ] & Emergency Airlocks [ ]
- Fuel Transfer Tube [ ]
- [ ] process penetrations

[CCI per Affidavit 4(a)-(d)]

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[CCI per Affidavit 4(a)-(d)]

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Containment Physical Description

- Reactor Containment Vessel (RCV) supported by Reactor Service Building (RSB) foundation
- RSB protects RCV from wind, tornadoes, hurricanes, and snow
- Located below grade – no physical damage from aircraft impact event
- Structural steel platforms located around the RCV provide access to the upper levels and support to utilities (HVAC, Feedwater, Main Steam, Electrical)

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RCV Looking East

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Containment Functional Design

Containment Functional Design

10CFR50 Appendix A, General Design Criteria

- GDC 2 – Design Bases for Protection Against Natural Phenomena
- GDC 4 – Environmental and Dynamic Effects Design Bases
- GDC 13 – Instrumentation and Control
- GDC 16 – Containment Design
- GDC 38 – Containment Heat Removal
- GDC 39 – Inspection of Containment Heat Removal System
- GDC 40 – Testing of Containment Heat Removal System
- GDCs 41, 42, and 43 – Containment Atmosphere Cleanup, Inspection, Testing
- GDC 50 – Containment Design Basis
- GDC 64 – Monitoring Radioactivity Releases

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Containment Functional Design

Regulatory Guides

- RG 1.4 – Assumptions Used for Evaluating the Potential Radiological Consequences of Loss-of-Coolant Accident for Pressurized Water Reactors
- RG 1.97 – Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants
- RG 1.157 – Best Estimate Calculations of ECCS Performance
- RG 1.183 – Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Plants
- RG 1.195 – Methods and Assumptions for Evaluating Radiological Consequences of DBAs at Light-Water Nuclear Power Reactors

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Containment Functional Design

- Peak pressure ~ [ ] psia
  - Preliminary analysis peak pressure from LOCA
- Peak temperature ~ [ ] F
  - Preliminary peak temperature from MSLB
- Ultimate capacity pressure (ASME Service Level C limit) of containment will be above the pressure for limiting severe accident conditions calculated using the Adiabatic Isochoric Complete Combustion model
- Containment will provide a barrier against uncontrolled release of fission products

[CCI per Affidavit 4(a)-(d)]

Containment Functional Design

- Designed to withstand the seismic, environmental and dynamic effects associated with both normal plant operation and postulated accidents (GDC 2 and GDC 4)
- Containment and associated systems form a barrier against the uncontrolled release of radioactivity to the environment and incorporate sufficient design margin so that conditions important to safety are not exceeded as long as postulated accident conditions require (GDC 16)

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Containment Functional Design

- Design development includes consideration of SRP Section 6.2.1.1.A (GDC 13).

  Instrumentation and Control design includes:
  - Containment instrumentation capable of monitoring variables and systems over anticipated ranges for all normal operations, anticipated operational occurrences, and accident conditions.
  - Appropriate controls maintain these variables and systems within prescribed operating ranges

Containment Functional Design

- Design development includes consideration of SRP Section 6.2.1.1.A (other GDCs) including:
  - GDC 50 – Containment Design Basis
  - GDC 64 – Monitoring Radioactivity Releases
- Simplified lumped parameter model and analyses are prepared in support of DCD Chapter 6 functional design.
- Chapter 6 analysis is based on loads from the DCD Chapters 15 and 19 Evaluation Model and Assessment Process (EMDAP) methodology.

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Containment Functional Design

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Systems

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Containment Isolation System

Containment Isolation System

10CFR50 Appendix A, General Design Criteria

- GDC 1 – Quality Standards and Records
- GDC 2 – Design Bases for Protection Against Natural Phenomena
- GDC 4 – Environmental and Dynamic Effects Design Bases
- GDC 16 – Containment Design
- GDC 50 – Containment Design Basis
- GDC 52 – Capability for Containment Leakage Rate Testing
- GDC 53 – Provisions for Containment Testing and Inspection

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Containment Isolation System

10CFR50 Appendix A, General Design Criteria (cont'd)

- GDC 54 – Systems Penetrating Containment
- GDC 55 – Reactor Coolant Pressure Boundary Penetrating Containment
- GDC 56 – Primary Containment Isolation
- GDC 57 – Closed Systems Isolation Valves

10CFR50 Appendix J, Primary Reactor Containment Leakage Testing for Water-Cooled Power Reactors

Containment Isolation System

Regulatory Guides

- RG 1.11 – Instrument Lines Penetrating Primary Reactor Containment
- RG 1.26 – Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants
- RG 1.29 – Seismic Design Classification
- RG 1.141 – Containment Isolation Provisions for Fluid Systems
- RG 1.155 – Station Blackout

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Containment Isolation System

[ ] containment penetrations consisting of:

- Process piping line penetrations [ ]
- Standard pressurized electrical penetrations [ ] – Diameter [ ] in
- HVAC penetrations [ ]
- Sampling lines [ ]
- Personnel airlocks [ ] – Diameter [ ] ft
- Emergency personnel airlocks [ ] – Diameter [ ] ft
- Equipment hatches [ ] – Diameter [ ] ft
- Fuel Transfer Tube [ ] – Diameter [ ] ft

[CCI per Affidavit 4(a)-(d)]

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Containment Isolation System

Valves close on Containment Isolation Signal:

- High Containment pressure
- Containment isolation signal [

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Containment Isolation System

- Air-operated Containment Isolation Valves (CIVs) fail closed on loss of control air
- Automatic CIV positions are indicated in Main Control Room except check valves applied as inside-containment automatic CIVs
- Provisions for Local Leak Rate Tests (LLRTs) of CIVs.
- Type A Integrated Leak Rate Test (ILRT) addresses each steam generator secondary side line that is closed system inside containment, with a single automatic CIV outside containment

Component Cooling Water

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Floor and Equipment Drains

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Containment Purge Duct

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Combustible Gas Control System

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Combustible Gas Control System

- ~~10CFR50.44, Combustible Gas Control~~
- 10CFR50 Appendix A, General Design Criteria
  - GDC 41 – Containment Atmosphere Cleanup
  - GDC 42 – Inspection of Containment Atmosphere Cleanup Systems
  - GDC 43 – Testing of Containment Atmosphere Cleanup Systems
- RG 1.7, Control of Combustible Gas Concentrations in Containment
- RG 1.216, Containment Structural Integrity Evaluation for Internal Pressure Loadings Above Design-Basis Pressure

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Combustible Gas Control System

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- H_2 Igniters
  - [

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Combustible Gas Control System

- Combustible Gas Control System (CGCS) promotes a well-mixed atmosphere with containment (10CFR50.44(c)(1)).
- MAAP5 analyses will be performed to model H_2 generation rate timeline, assess containment H_2 concentrations over time, and demonstrate natural circulation mixing.
- CGCS limits overall H_2 concentration to less than 10% by volume during and following an accident that results in a fuel cladding-coolant reaction involving 100% of the cladding surrounding the active fuel region (10 CFR 50.44(c)(2)).

Combustible Gas Control System

- Containment pressure and temperature effects associated with hydrogen burn-off are considered (10CFR50.44(c)(3)).
- Loads generated from normal flame deflagration will be conservatively estimated by evaluating the combustion reaction assuming isochoric, complete combustion with no external heat loss Adiabatic Isochoric Complete Combustion (AICC) Model.
- CGCS remains functional during and after exposure to accident environmental conditions (10CFR50.44(c)(3)).
- Monitoring instruments measure H_2 concentration in containment during and after accident; and remain functional during and after exposure to accident environmental conditions (10CFR50.44(c)(4)(ii)).

Combustible Gas Control System

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Containment Leakage Testing System

Containment Leakage Testing System

10CFR50 Appendix A, General Design Criteria

- GDC 52 – Capability for Containment Leakage Rate Testing
- GDC 53 – Provisions for Containment Testing and Inspection
- GDC 54 – Systems Penetrating Containment

Containment Leakage Testing System

10CFR50 Appendix J, Option A or Option B

- NEI 94-01, Guidelines for Implementing Appendix J, Option B
- ANSI/ANS 56.8-2002, Containment System Leakage Testing Requirements
- Branch Technical Position 6-3, Determination of Bypass Leakage Paths in Dual Containment Plants

Regulatory Guides

- RG 1.11, Instrument Lines Penetrating Primary Reactor Containment
- RG 1.163, Performance-Based Containment Leak-Test Program

Containment Leakage Testing System

Plant design supports Type A, B and C leak rate testing per 10CFR50 Appendix J, Option B, and RG 1.163:

- Type A Test – Containment – overall pneumatic pressure test of containment
- Type B Test – Penetrations through Containment
  - Local leak rate test – calculated peak accident pressure P_a applied
  - Pneumatic pressure test of pressure-retaining boundaries incorporating seal design and lock space between doors, e.g., airlocks and access hatches
- Type C Test – Local isolation valves
  - Local leak rate test – calculated peak accident pressure P_a applied
  - Closed SG secondary side systems (steam, feedwater, blowdown) are included in Type A test

Sample lines are not local leak-rate tested – (i) less than one inch in diameter and (ii) not considered a major leakage pathway. Hence it will be covered under Type A test.

Containment Leakage Testing System

Traditional Type A pneumatic pressure test on containment

- Temporary pressurization equipment

Option B test frequency

- ILRT design supports implementation of performance-based option from RG 1.163 (full consideration of RG 1.163 Rev. 1 and referenced NEI 94-01 Rev. 3A).

Containment Leakage Testing System

Traditional Type B pneumatic pressure tests

- Seals, bellows, hatches, airlocks
- Plant air is used for tests

Option B test frequency

- LLRT design supports implementation of performance-based option from RG 1.163 for Type B testing for penetrations other than airlocks and hatches
- LLRT design Type B testing for airlocks and hatches in accordance with 10 CFR 50 Appendix J, including guidance from RG 1.163

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Containment Leakage Testing System

Traditional Type C pneumatic leak-rate tests

- Isolation valves
- Plant air is used for tests

Traditional non-pneumatic leak-rate tests

- Water-filled lines during accident

Option B test frequency

- Type C test design supports implementation of performance based option from RG 1.163

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Mass and Energy Release

Break Locations

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] [CCI per Affidavit 4(a)-(d)]

Mass and Energy Release

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Mass and Energy Release

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Mass and Energy Release

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Mass and Energy Release

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Mass and Energy Release

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Containment Heat Removal

Containment Heat Removal

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Containment Heat Removal

10CFR50 Appendix A, General Design Criteria

- GDC 38 – Containment Heat Removal
- GDC 39 – Inspection of Containment Heat Removal System
- GDC 40 – Testing of Containment Heat Removal System
- GDC 50 – Containment Design Basis

10CFR50 Appendix K, ECCS Evaluation Models

Regulatory Guides

- RG 1.97, Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants

Containment Pressure/Temperature Analysis

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Containment Accident Heat Removal – Analysis

B&W mPower requirements presented in MPWR-TECR-005013

- SRP 6.2.1.3 Mass and Energy Release for LOCA
  - [ ]
- SRP 6.2.1.4 Mass and Energy Release for secondary system pipe ruptures
  - Similar to conventional PWRs

Parametric treatments compliant with SRP

- Loss of offsite power
- Most severe single failure in the [ ]
- Most sources of mass and energy biases applicable to B&W mPower

Codes to be used:

- LOCA mass and energy release rates
  - Short-term – RELAP5
  - Long-term – GOTHIC

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Containment Accident Heat Removal – Analysis

- GOTHIC Version 8.0 will be used for containment pressure/temperature analysis

- Blowdown to be obtained from RELAP5

- Analyses to be performed
  MSLB cases
  LOCA cases

Containment Accident Heat Removal – Analysis

GOTHIC Model Comparison

- The GOTHIC containment analysis results will be compared with results using RELAP5 computer program
- RELAP5 confirmatory model is recognized as a best-estimate solution
- GOTHIC and RELAP5 containment models use the same nodalization
- The [ ] is to be modeled in RELAP5

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GOTHIC Model With Containment (Ctmt) and RWST Volumes and Major Heat Sinks

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Total Decay Power Curve

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Compartment Mixing in Containment

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[CCI per Affidavit 4(a)-(d)]

Preliminary MSLB Case

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Preliminary MSLB Case

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Preliminary LOCA Case

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Looking Ahead

- Plan in place and being executed to deliver high quality DC application
- Active and frequent engagement with the NRC staff will continue
- Important for NRC staff to continue to be well engaged in pre-application efforts
- Objective to inform the DC application and ensure success paths for key licensing topics

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Questions