ENCLOSURE 2

M200117

Presentation Slides for Pre-Application Meeting for Planned Submittal of GE-Hitachi BWRX-300 Selected Topical Report

Non-Proprietary Information - Class I (Public)

IMPORTANT NOTICE

This is a non-proprietary version of the Presentation Slides for Pre-Application Meeting for Planned Submittal of GE-Hitachi BWRX-300 Selected Topical Report, from which the proprietary information has been removed. The footer of each page in this enclosure that originally contained proprietary information of GEH carries the notation "Non-Proprietary Information." Portions of the enclosure that have been removed are indicated by an open and closed bracket as shown here [[ ]].

Pre-Submittal Meeting For GE Hitachi (GEH) BWRX-300 Licensing Topical Report (LTR)

NEDC-33922P
BWRX-300 Containment Evaluation Method

August 26, 2020

Pre-Submittal Meeting For GE Hitachi (GEH) BWRX-300 Licensing Topical Report (LTR)

NEDC-33922P
BWRX-300 Containment Evaluation Method

Open Session

Agenda

Open Session

BWRX-300 Design Overview

Overview of Containment Design and Features Relevant to Evaluation Method

Licensing Topical Report Purpose and Scope

Containment Design and Licensing Basis Events

Analysis Methodology for Reactor Pressure Vessel and Containment Response

- Evaluation Method
- Overview of Containment Application Method
- TRACG Mass and Energy Release Method
- Evaluation Method – Isolation Condenser Performance
- GOTHIC Evaluation Method – Containment Response

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Agenda

- Containment Phenomena Importance Definition
- GOTHIC Evaluation Method – Uncertainties
- GOTHIC Evaluation Method - Benchmarking

Demonstration Cases

Conformance with Regulatory Guidance

Closed Session

Containment Evaluation Method GEH Proprietary Information

Demonstration Cases: Base Cases and Conservative Cases

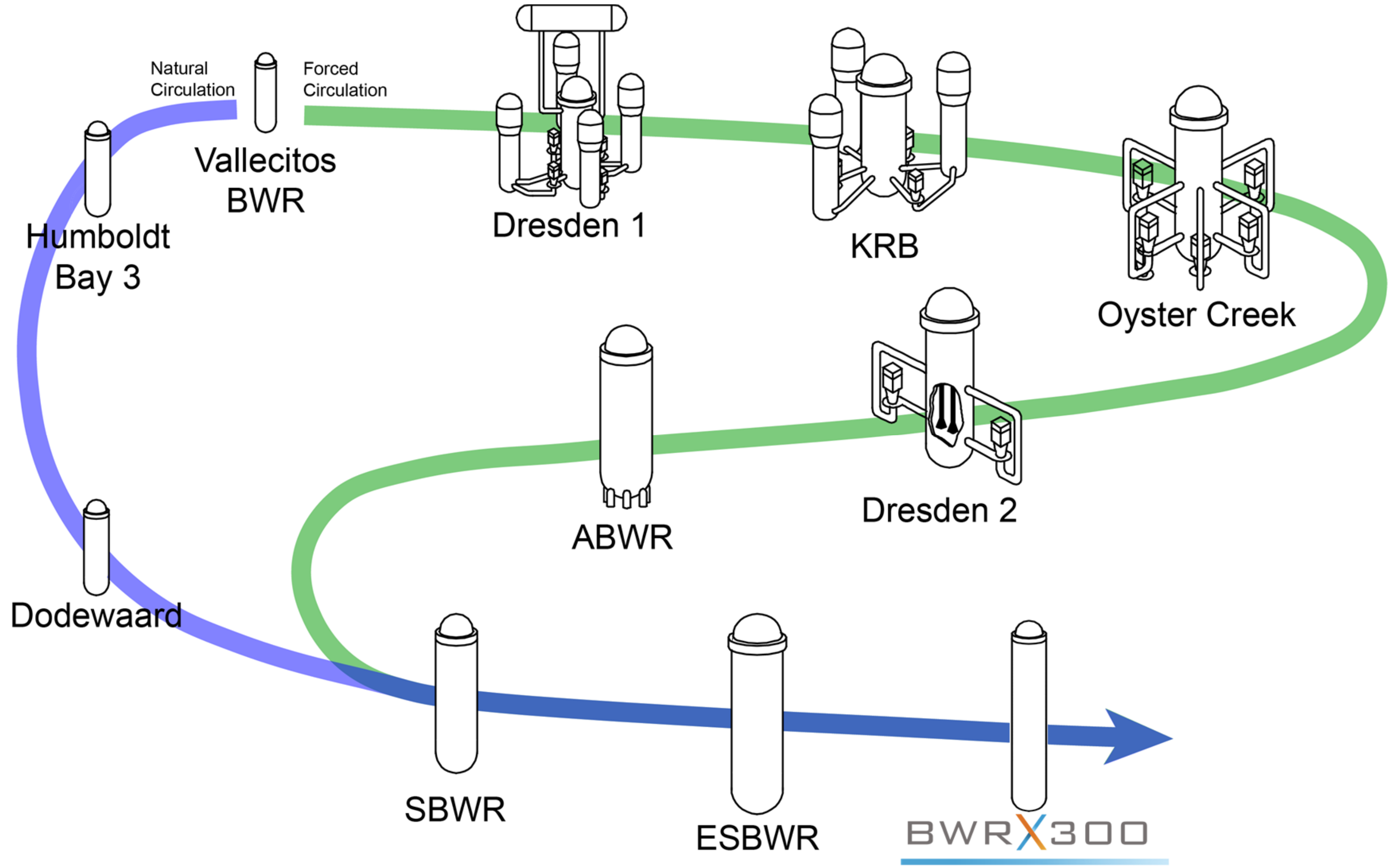
Containment Evaluation Method Summary

Questions and Comments

Schedule and Scope of Future Licensing Topical Reports

BWRX-300 Design Overview

Boiling Water Reactor Evolution



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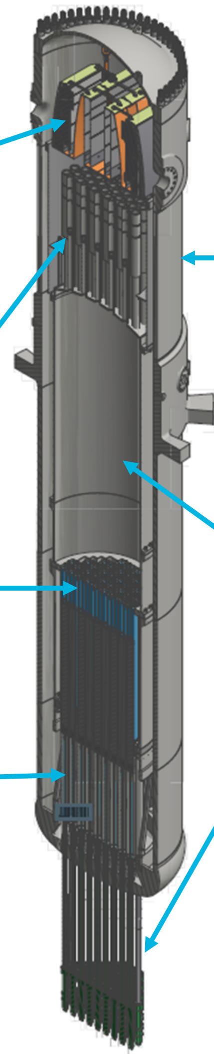
Proven Reactor Technology

BWRX300



Dryer:
Same features as ABWR* & ESBWR …
Same as upgrades for existing fleet …
Size nearly identical to KKM**

Steam Separators:
Same as ABWR* & ESBWR …
Similar to others in the BWR fleet

GNF2 Fuel:
18,500+ bundles delivered …
Utilized by ~70% of BWR fleet

Control Rod Blades:
Same as ABWR* …
Longer than ESBWR …
Almost identical to latest design for BWR fleet

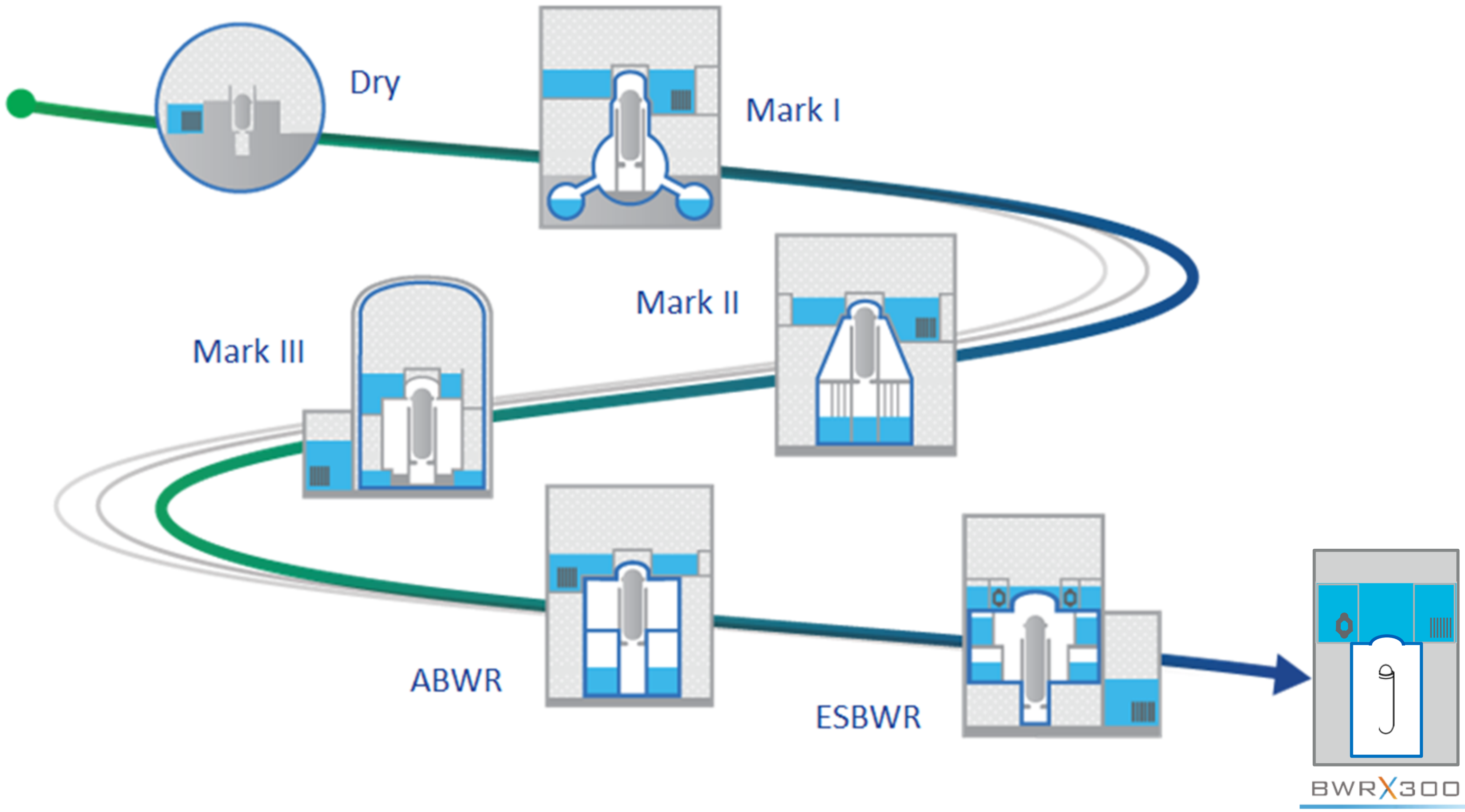
Reactor Pressure Vessel:
Same material and fabrication processes as ABWR*, ESBWR and many of the BWR fleet …
Diameter almost identical to KKM**

Chimney:
Uses ESBWR and Dodewaard*** technology …
Simplified

Fine Motion Control Rod Drives:
Same as ABWR* & ESBWR

* Advanced Boiling Water Reactor (ABWR) fleet has combined 22+ years of operating experience
** Kernkraftwerk Mühleberg (KKM): 355 MWe BWR/4 in operation since 1972
*** Dodewaard: 58MWe natural circulation BWR, 1969 ~ 1997

BWR Evolution



Containment Design Development

Design features based upon BWR experience and performance include:

- Containment size comparable to a BWR drywell
- Containment peak accident pressure and temperatures within existing BWR experience base
- Containment loads simplified as compared to conventional BWRs
- Nitrogen-inerted containment, same as conventional BWRs
- Pressure and temperature during normal operation are maintained using fan coolers like existing BWRs
- Upon loss of active containment cooling, heat removal is achieved by passive containment cooling system (PCCS)

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Overview of Containment Design and Features Relevant to Evaluation Method

Design Features Addressing Design Basis Events

- Underground primary containment vessel
- Dry containment with no suppression pool
- Nitrogen-inerted containment
- Passive containment heat removal by PCCS
- No subcompartments with large bore high energy lines
- Design features for mitigation of Beyond Design Basis Events (BDBEs) per 10 CFR 50.34(i) are to be addressed by LTR NEDC-33921P, BWRX-300 Severe Accident Management

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Passive Containment Cooling System

PCCS design is based upon proven concepts:

- Heat is rejected to the reactor cavity pool above containment by natural circulation using water jackets covering sections of the containment shell or concentric pipes
- Heat transfer from the containment to PCCS is by natural convection and condensation

No Subcompartments With Large Bore High Energy Lines

The containment subcompartments include:

- Volume below the reactor pressure vessel (RPV)
- Space between the RPV and the biological shield
- Containment head area above the refueling bellows

No large bore high energy lines within these subcompartments

Subcompartments contain only small diameter pipes such as fine motion control rod drive (FMCRD) hydraulics lines and instrument lines

Combustible gas control is not required because the containment atmosphere, including subcompartments, is inerted

Line breaks both inside and outside the subcompartments do not create significant pressure differentials across subcompartment walls

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Licensing Topical Report Purpose and Scope

Licensing Topical Report Purpose and Scope

The Containment Evaluation Method LTR requests NRC approval for:

- Application of the previously approved TRACG methodology with identified changes for mass and energy release from the BWRX-300 Reactor Pressure Vessel
- Application of the methodology using GOTHIC for the BWRX-300 containment thermal-hydraulic pressure and temperature response
- Appropriateness of the methodology for use in evaluating containment response to design basis accidents (DBAs, including loss-of-coolant accidents (LOCAs)), transient events (AOOs), station blackout, and Anticipated Transient Without Scram (ATWS)

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Containment Design and Licensing Basis Events

Design and Licensing Basis Events

Large break LOCAs (large steam and liquid pipe breaks) are limited by closure of RPV isolation valves

Small break LOCAs (unisolated small steam and liquid pipe breaks) are limited by the isolation condenser system (ICS) depressurizing the RPV to minimize break flow

For any LOCA, containment pressure and temperature response is limited by condensation on containment walls, RPV heat removal by ICS, and containment heat removal by PCCS

For RPV Isolation and Station Blackout events, containment pressure and temperature response is limited by RPV heat removal by ICS and containment heat removal by PCCS

Containment Response To Design Basis Accidents

Large break LOCA is the limiting DBA with respect to containment pressure and temperature

- Break isolation and condensation limit peak pressure
- PCCS reduces the containment accident pressure to half of its peak value within 24 hours

Containment accident temperature response has spatial variation

- Peak airspace temperature can be high for a short duration near the break location
- Shell, structure and equipment temperatures remain well within GEH experience base

Unisolated small break LOCAs are not limiting for containment peak accident pressure or temperature

Decay heat is removed by ICS and PCCS

Response to a Large Break LOCA

Break flow terminated when RPV isolation valves close and steam in piping is depleted

Most limiting break is double-ended guillotine break of a main steam pipe

- Break flows from both ends of the break are included
- Containment isolation valve is assumed to remain open to maximize the break flow from intact steam line

Sufficient ICS capacity to accommodate single failure concurrent with any pipe break

Containment pressure peak is reached at the time RPV isolation valves are closed

After closure of RPV isolation valves, core decay heat is rejected to the ICS pools and does not add to the containment heat load except a small amount through the RPV and hot piping wall insulation

Containment pressure and temperature start decreasing after RPV isolation valve closure by PCCS heat removal and heat loss through drywell head

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Response to a Small Break LOCA

Some small break LOCAs may remain unisolated

RPV nozzles, including instrument pipe connections, are well above the top of active fuel

Most limiting small break LOCA with respect to the RPV inventory and fuel heat up is a liquid line break

Most limiting small break LOCA with respect to containment pressure and temperature is a steam pipe break

Containment peak pressure is reached within a few hours after a break

Peak pressure and temperatures for small breaks are well below those from large steam pipe breaks

ICS depressurizes the RPV in a few hours making break flow very small

- Break flow is down to normal RPV leakage levels within 3 days, without accounting for containment back pressure

Response to AOOs, Station Blackout and ATWS Events

- Stored energy and decay heat are removed by ICS
- Only sources of heat load to containment are RPV leakage and heat losses through insulation of the RPV and hot piping
- ICS depressurizes RPV in a few hours to decrease the RPV temperature, thereby reducing heat load to containment
- Normal RPV leakage is much less than the leakage in conventional BWRs because there are no relief valves, and no recirculation pumps or other rotating equipment with seals that are prone to leakage
- AOOs and isolation events have a similar containment response
- ATWS events produce the limiting RPV pressure that remains higher for a longer duration resulting in larger heat loads on containment
- AOOs, Station Blackout, and ATWS events are bounded by small breaks that are bounded by large break LOCA events

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Break

Analysis Methodology for Reactor Pressure Vessel and Containment Response

Evaluation Method

The evaluation method development utilizes the graded approach to qualification described in Code Scaling, Applicability and Uncertainty (CSAU), NUREG/CR-5249 and Regulatory Guide (RG) 1.203

RG 1.203 includes specifying:

- Analysis Purpose – Identification of 10 CFR 50 containment pressure and temperature margin to design containment pressure and temperature, and 10 CFR 50 Appendix A GDC 38 rapid containment pressure reduction compliance
- Transient Class – Design and Licensing Basis Events
- Power Plant Class – BWRX-300
- Figures of Merit – Containment pressure and temperature
- Evaluation Model – Mass and energy release from the RPV using TRACG and containment response using GOTHIC

Overview of Containment Application Methodology

RPV mass and energy release calculated by TRACG is used as a boundary condition for the GOTHIC containment model

RPV fluid temperature calculated by TRACG is also used by GOTHIC in calculating the heat transfer to the containment through the RPV and piping wall and insulation

Containment response is calculated by using GOTHIC

Because containment back pressure is not credited in calculating break flows, it is not necessary to iterate between the TRACG and GOTHIC calculations

Two sets of results are generated: base case and conservative case

- Base case uses the nominal initial conditions, inputs and correlations
- Conservative case uses biased initial conditions (such as initial power, relative humidity, containment pressure), inputs (such as loss coefficients) and correlations to bound uncertainties in each of these parameters
- This accounting method for uncertainties compounds conservatisms, making overall results bounding

TRACG Mass and Energy Release Method

The approved TRACG mass and energy release method (NEDE-33083P-A) has been developed using the same guidance

The evaluation method developed for the ESBWR mass and energy release is applicable to BWRX-300 RPV because:

- BWRX-300 RPV is a scaled version of the ESBWR RPV
- Both ESBWR and BWRX-300 are natural circulation plants
- Nozzles for large pipes are at a much higher elevation than the top of active fuel

BWRX-300 design minimizes mass and energy releases from a pipe break, making the evaluation simpler than ESBWR

The LTR includes the ESBWR application of the TRACG mass and energy release models with identified differences for BWRX-300 application

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Evaluation Method – Isolation Condenser Performance

Isolation condensers used in BWRX-300 are the same as ESBWR

- Because of BWRX-300 lower thermal power, each isolation condenser can remove a larger fraction (~ five times) of the rated thermal power in BWRX-300 than in ESBWR

Isolation condensers have been qualified against the PANTHERS and PANDA tests

- A minimum isolation condenser capacity has been established for ESBWR based on the test data
- TRACG models were qualified for isolation condenser performance

A single isolation condenser is sufficient to remove decay heat and depressurize the RPV after a steam pipe break is isolated

H_2 and O_2 generated from radiolysis over 3 days corresponds to a small volume compared to steam volume

- Degradation of ICS performance due to non-condensables is minimal and has been included

Isolation condenser qualification includes build up of non-condensable gases in a much larger range of non-condensable concentrations

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GOTHIC Evaluation Method – Containment Response

An expert panel comprised of experienced individuals from GEH and MIT who have participated in prior PIRT expert panels was formed to develop the Phenomena Identification and Ranking Table (PIRT)

Phenomena included in the expert panel's consideration were primarily drawn from:

- NEDE-33083P-A, TRACG Application for ESBWR
- NEA/CSNI/R(2014)3, Containment Code Validation Matrix (OECD)
- NRC SMSAB-02-02, An Assessment of CONTAIN 2.0: A Focus on Containment Thermal Hydraulics

Panel members provided their rationale for rankings and held a series of meetings to reconcile their rankings

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Containment Phenomena Importance Definition

Importance	Definition
High (H)	Phenomenon has controlling impact on Containment Pressure and Temperature
Medium (M)	Phenomenon has moderate impact on Containment Pressure and Temperature
Low (L)	Phenomenon has low impact on Containment Pressure and Temperature
Not Applicable / Not Relevant (N/A)	Phenomenon has no, or insignificant impact on Containment Pressure and Temperature for the design and licensing basis events.

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GOTHIC Evaluation Method – Uncertainties

The same expert panel also assessed the knowledge level for each of the phenomena identified in PIRT to determine if sufficient knowledge exists to quantify uncertainties

- Concluded that BWRX-300 containment does not have any novel features for the phenomena

Sensitivity analyses were performed to further evaluate the importance of some phenomena

GOTHIC offers choices of correlations that have been benchmarked extensively against separate effects tests

- Correlations that gave the best benchmarking to data were selected

Uncertainties in high-ranking phenomena were evaluated

- Expertise from academia (MIT faculty) was also utilized to quantify the uncertainties in the most significant phenomena, namely condensation and convection

Nodalization studies show convergence of the calculated results

Evaluation Method - Benchmarking

The Carolina Virtual Test Reactor (CVTR) test was performed for a dry containment that is of a similar size, few subcompartments or internal structures like the BWRX-300 containment, a similar magnitude of pressure range, and similar stratification magnitude expected in the BWRX-300 containment

- Test is well-instrumented, providing quality data for code benchmarking

The evaluation method using the inputs and correlation without bias was used to benchmark the model to the CVTR test and very good agreement was obtained

- This test is also in the qualification basis of the BWRX-300 GOTHIC code

The biases in the correlations were applied to the same benchmark cases

- Predicted peak pressure is approximately 15% higher than the base case, and the test data are bounded at and after the peak, even without additional conservatisms in the mass and energy release calculations

Demonstration Cases

Evaluation Method – Demonstration Cases

The BWRX-300 TRACG / GOTHIC evaluation method was used for containment response to large and small break cases using nominal inputs and correlations to form the base case

Initial conditions, input parameters, such as loss coefficients, and modeling parameters used in the correlations were biased to obtain the results for the conservative cases

The results include:

- Containment pressure and steam / air temperature, structure temperature
- Pressure differential across the boundaries of the subcompartments
- Combustible gas accumulation in the subcompartments

Conclusion: containment pressure and temperature are well within the experience base of typical BWRs

- Pressure differential across the boundaries of subcompartments are very small due to large openings
- Combustible gas concentrations in the dome region are far below the flammable limit

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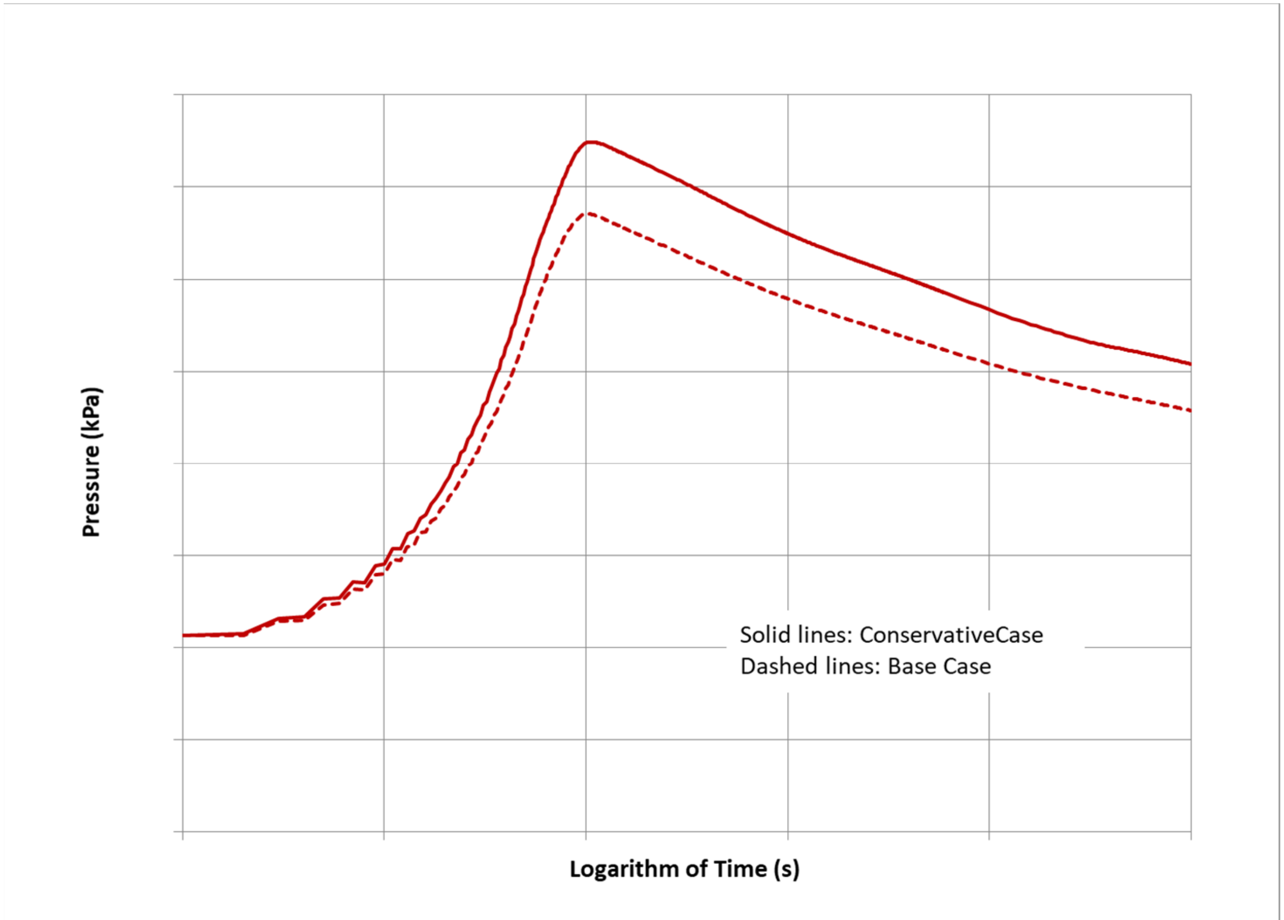
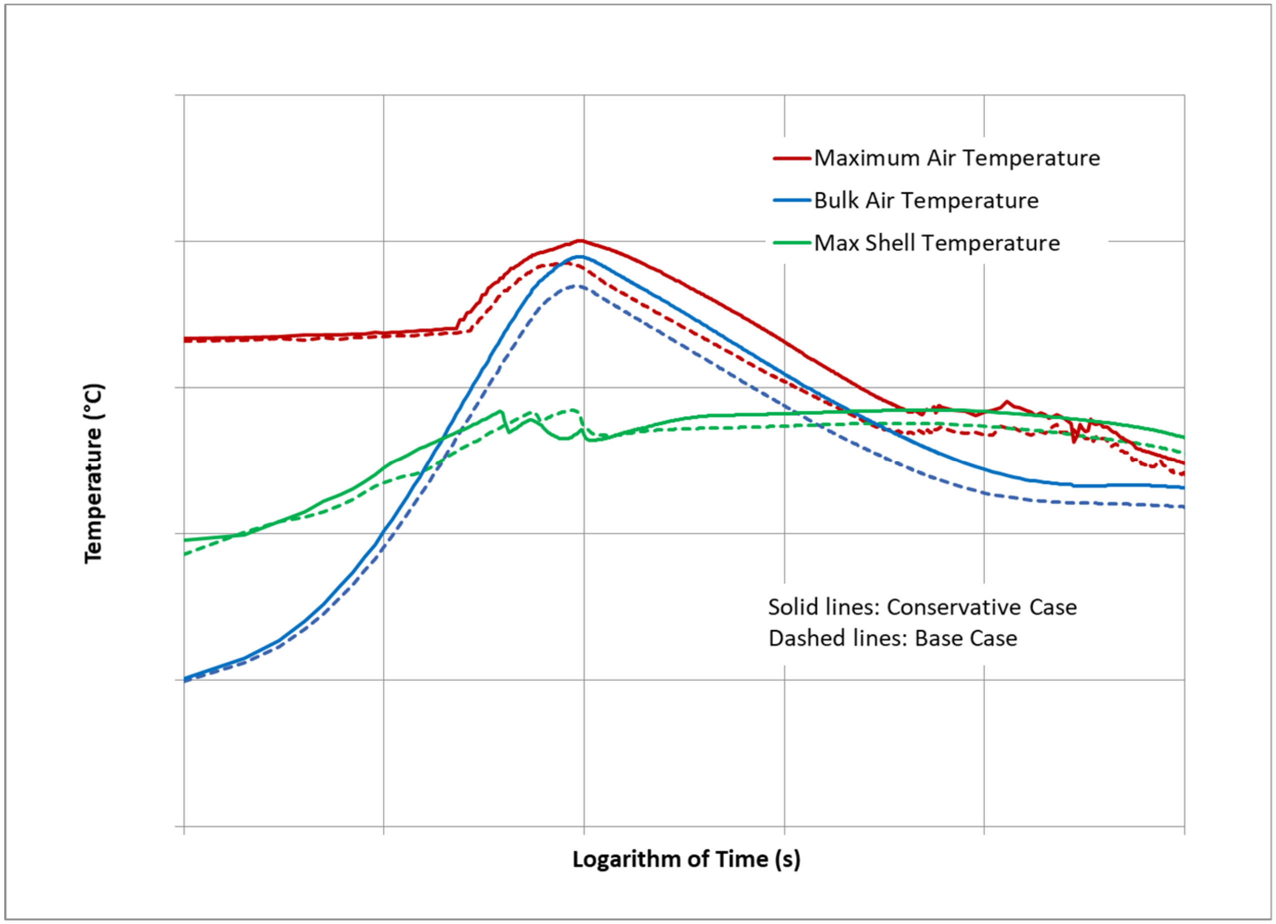
Containment Pressure Response to LB-LOCA, Steam Pipe



Preliminary, Unverified Demonstration Case

Containment Temperature Response to LB-LOCA, Steam Pipe



Preliminary, Unverified Demonstration Case

Conformance with Regulatory Guidance

Conformance with Regulatory Guidance

NUREG-0800 Standard Review Plan for the Review of Safety Analysis Reports for Plants: LWR Edition Applicability

- SRP 6.2.1.5 Minimum Containment Pressure Analysis for Emergency Core Cooling System Performance Capability Studies, Revision 3, March 2007 – Design does not incorporate the use of any ECCS system to actively remove heat or pressure within containment, and utilizes passive heat removal through the use of heat pipes or water jackets by convection or condensation heat removal to the reactor cavity pool above (see NEDC-33911P, Section 5.3.9 for compliance to the guidance), and no minimum containment pressure analysis is necessary for the BWRX-300
- SRP 6.2.5 Combustible Gas Control in Containment, Revision 3, March 2007 – Design does not require the use of any combustible gas control measures for design and licensing basis events with the nitrogen-inerted containment (see NEDC-33911P, Section 5.3.13 for compliance to the guidance)

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Break

Pre-Submittal Meeting For GE Hitachi (GEH) BWRX-300 Licensing Topical Report (LTR)

NEDC-33922P
BWRX-300 Containment Evaluation Method

Closed Session

Containment Evaluation Method GEH Proprietary Information

Containment Layout

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Passive Containment Cooling System (PCCS)

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TRACG Model of RPV

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TRACG Model of ICS Loop A

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Containment Phenomena Importance Ranking Table

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GOTHIC Correlations and Biases

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GOTHIC Inputs and Biases

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GOTHIC Model

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Demonstration Cases: Base Case and Conservative Case

LB-LOCA, Steam Pipe Break Flow - Base Case

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LB-LOCA, Steam Pipe Break, RPV Pressure - Base Case

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LB-LOCA, Steam Pipe Break, RPV Level - Base Case

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LB-LOCA, Steam Pipe Break Flow - Conservative Case

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LB-LOCA, Steam Pipe Break, RPV Pressure - Conservative Case

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LB-LOCA, Steam Pipe Break, RPV Level - Conservative Case

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Containment Pressure Response to LB-LOCA, Steam Pipe

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Containment Temperature Response to LB-LOCA, Steam Pipe

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Containment Evaluation Method Summary

Summary

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Questions and Comments

Schedule and Scope of Future Licensing Topical Reports

BWRX-300 Licensing Topical Reports

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BWRX-300 Licensing Topical Reports

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Closing Remarks and Questions