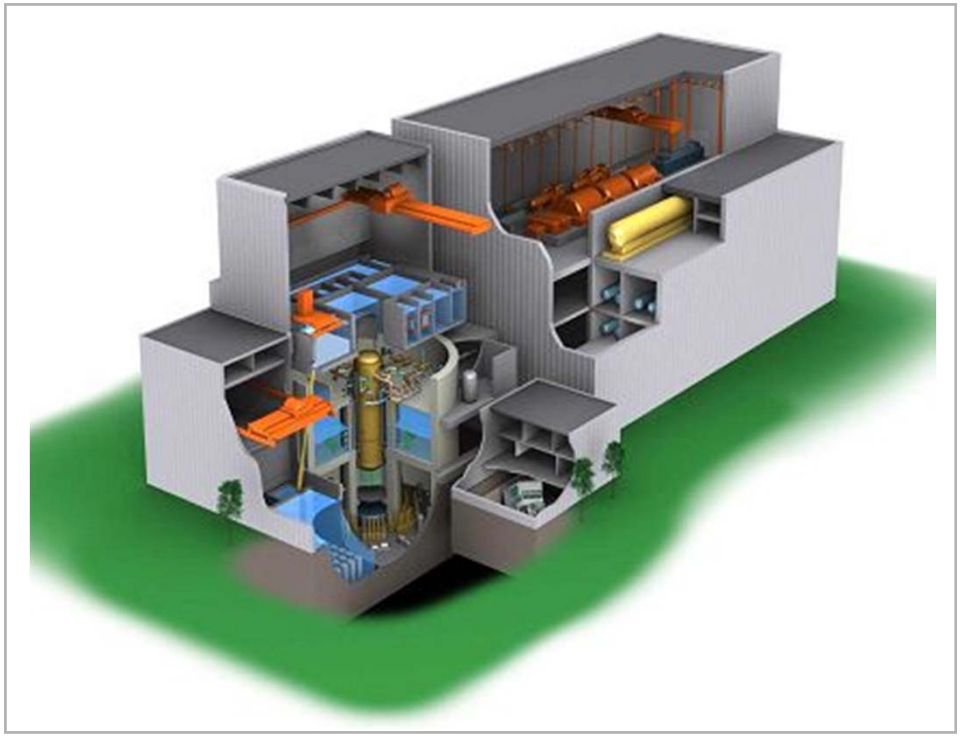
GE Hitachi Nuclear Energy

ESBWR Steam Dryer Meeting



Open Session

January 31, 2012

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Outline

- Introductions and Opening Statements
- History of BWR Steam Dryers
  - Basic Hood Designs
  - Relative Stress on Dryer Hood
- NRC Regulatory Guidance for Steam Dryers
- ESBWR Design Certification
  - Steam Dryer Design and Programmatic Elements for Assuring Structural Integrity
  - ESBWR Steam Dryer Design Overview
  - ESBWR Reactor Vessel
  - Existing Regulatory Elements in ESBWR Steam Dryer Program
  - NRC Issues Identified in 01/19/2012 Letter
  - Implications for Rulemaking

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Introductions and Opening Statements

Opening Statements

- Brian Johnson – Vice President, GEH New Plant Projects

Presenters

- Glen Watford – Vice President – GEH Services Engineering
- Daniel Pappone – Chief Consulting Engineer
- Scott Bowman – Services Engineering Manager
- Gerald Deaver – ESBWR Engineering Manager

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History of BWR Steam Dryers

- BWR Steam Dryer removes moisture from steam exiting the reactor by vanes and perforated plates
  - Ensures higher steam "quality" for turbine cycle
  - BWR Steam Dryer is a crucial component for power generation efficiency
- BWR Steam Dryer performs *no safety* function
  - Designed to maintain structural integrity to avoid generating loose parts that may interfere with ability to shut down reactor, provide core cooling, or isolate main steam lines

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History of BWR Steam Dryers (continued)

- Operating Experience of Steam Dryers
  - Loose parts generated in Quad Cities 1 and 2 (see NRC IN 2002-26 and its supplements) attributed to high-cycle fatigue and significant acoustic resonance in steam lines at extended power uprate operation
  - Industry actions taken to prevent recurrence include improved mechanical designs, development of advanced acoustical methods for predicting loads, detailed structural evaluations, monitoring of main steam lines, and rigorous inspection programs
  - Steam dryer designs have improved over time as operating experience has been gained and replacement dryer designs are more robust and less likely to experience structural failure
    - See graphics on following slides (reference ML032390172)
    - OE is an ongoing process (*e.g.*, *see* response to NRC Reactor Internals Audit Item 1, MFN 09-621, Oct. 8, 2009)

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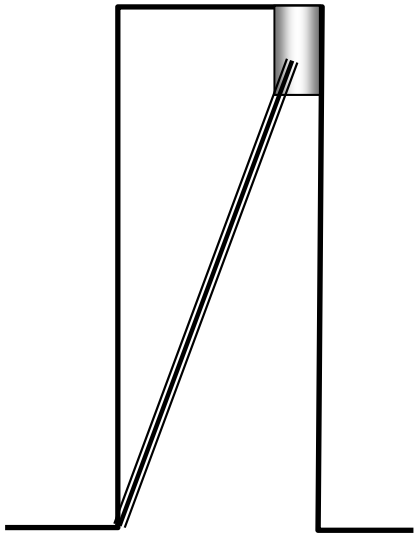
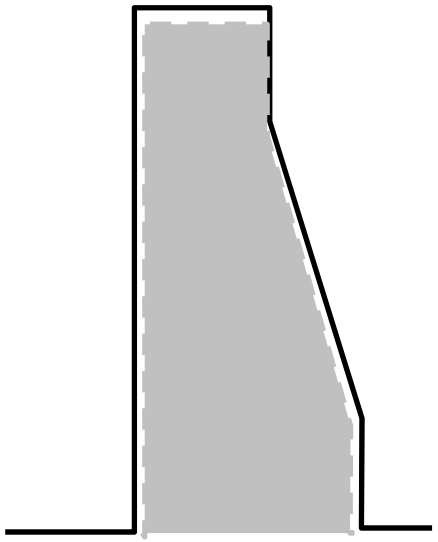
Basic Hood Designs



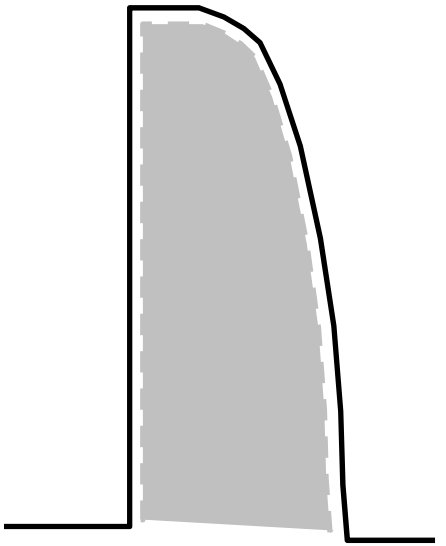
Square hoods

- BWR/3 Style Dryer
- Earliest Design
- Localized Top Hood Stress



Slanted hoods

- Early BWR/4 Style Dryer
- Improved
  - Better Steam Flow
  - Reduced Stress Concentration



Curved hoods

- BWR/4 and Later
- Optimized for Steam Flow

Source: ML032390172

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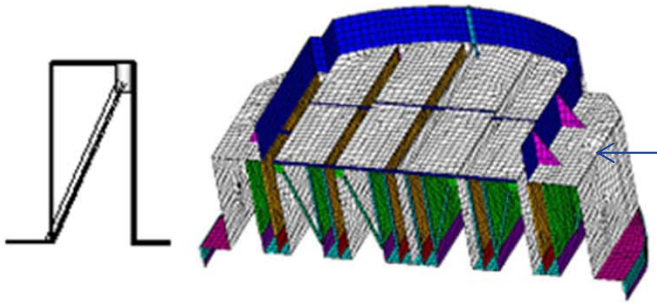
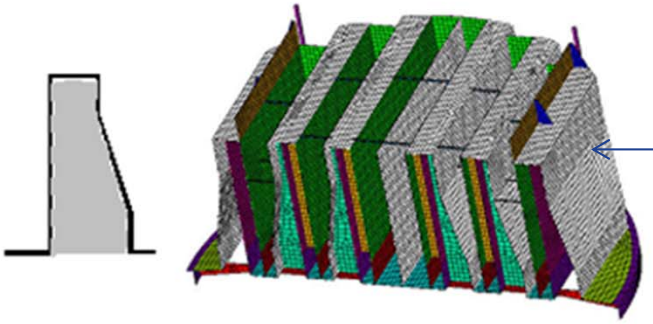
Relative Stress on Dryer Hood

Square Hood



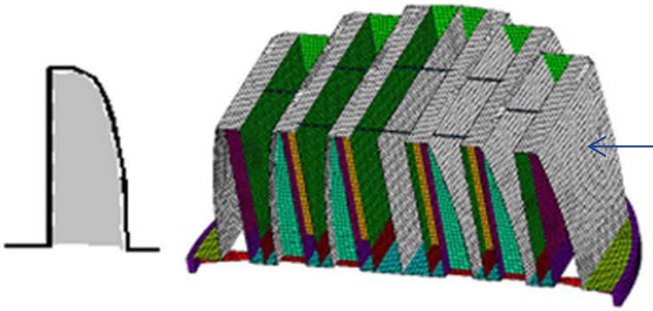
14160 psi

Slanted Hood



3860 psi

Curved Hood



2650 psi

Source: ML032390172

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NRC Regulatory Guidance for Steam Dryers

- NRC Standard Review Plan Guidance (March 2007)
  - SRP 3.9.2, "Dynamic Testing and Analysis of Systems, Structures, and Components," identifies BWR steam dryer assembly for including in dynamic analysis of structural components with reactor vessel
  - SRP 3.9.5, "Reactor Pressure Vessel Internals," provides guidance for NRC review of potential adverse flow effects of flow-excited vibrations and acoustic resonances on plant systems and components (including nonsafety-related steam dryer) and elements of design, data collection, and monitoring
- Regulatory Guide (RG) 1.20, "Comprehensive Vibration Assessment Program for Reactor Internals During Preoperational and Initial Startup Testing" (March 2007), describes a methodology NRC staff considers acceptable for preoperational and initial startup testing for verifying structural integrity of reactor internals for flow-induced vibrations prior to commercial operation

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ESBWR Design Certification

Steam Dryer Design and Programmatic Elements for Assuring Structural Integrity

- ESBWR Design Control Document, Tier 1, and Tier 2 (Sections 3.9, Appendix 3L), with supporting Licensing Topical Reports NEDE-33312P, NEDE-33313P, NEDC-33408, and NEDC-33408, Supplement 1, provide information on Steam Dryer:
  - Steam Dryer is not ASME *Boiler and Pressure Vessel (B&PV) Code* component, but design complies with requirements of ASME B&PV Code, Subsection NG-3000 (except for weld quality and fatigue factors)
  - First ESBWR Steam Dryer will be a prototype in accordance with RG 1.20 guidance, is included in overall reactor internals vibration assessment program in accordance with RG 1.20, will be fully instrumented during initial startup testing, and ESBWR-specific load definition will be established following startup testing

Steam Dryer Design and Programmatic Elements for Assuring Structural Integrity (continued)

- As explained in ESBWR DCD:
  - ***ESBWR steam dryer design is based on ABWR steam dryer design***, with in-plant, on-dryer measurements to define load, and further improved the basic load definition through comparison with testing and operating experience gained from GEH Extended Power Uprates (EPUs) conducted on several operating plants
  - ***ESBWR dryer design specifically eliminates acoustic loads identified through operating experience*** (Safety Relief Valve (SRV) standpipes and main steam line branch lines designed to preclude SRV/branch line resonances that could be a significant contributor to steam dryer loading at normal operating conditions – *see* Table 2.1.2-3, ITAAC #36)
  - ***ESBWR prototype dryer load definitions to be confirmed by on-dryer measurements*** with additional MSL measurements to support subsequent dryers with external measurements only (testing and instrumentation during plant startup – *see* Table 2.1.1-3 ITAAC 8a, 8b, 12, 13, 14 and COL Information Item 3.9.9-1-A)

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ESBWR Steam Dryer Design Overview

- ESBWR geometries are similar to ABWR
  - RPV diameters are the same except main flange is slightly larger (LTR NEDE 33259P-A Table 2)
  - Steam Lines increase from 28" to 30" to compensate for steam flow increase (ESBWR DCD Tier 2, Table 5.4-1)
  - ESBWR uses a steam dryer design patterned after the ABWR DCD (ESBWR DCD Tier 2, Appendix 3L, Section 3L.2.1)
  - Steam Dryer Bank flow area sized to match increased flow rate
  - Eliminates most partial penetration welds and incorporates latest design improvements
- Testing of the Prototype ABWR Steam Dryer produced very low vibration loads
- SRV/SV branch piping geometry precludes first and second shear layer wave acoustic resonance conditions from occurring and avoids pressure loads on the steam dryer (Table 2.1.2-3 ITAAC #36)
- Designed to meet ASME code NG-3000

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ESBWR Reactor Vessel

Steam Dryer

Steam Separator

Chimney

Core

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Existing Regulatory Elements in ESBWR Steam Dryer Program

- Tier 1 Inspections, tests, analyses, and acceptance critical (ITAAC): To verify that the ESBWR steam dryers are designed, fabricated, and installed in accordance with the licensing basis, the ESBWR DCD Tier 1 includes:
  - ITAAC directed toward assuring structural integrity of reactor internals (including the steam dryer) (Table 2.1.1-3, ITAAC #8a and #8b)
  - ITAAC with acceptance criteria for installing sensors for startup testing and monitoring (Table 2.1.1-3, ITAAC #12, #13, and #14)
  - ITAAC acceptance criteria for verifying main steam lines and safety/relief valves system geometry to avoid acoustic resonance frequencies (Table 2.1.2-3, ITAAC #36)

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Existing Regulatory Elements in ESBWR Steam Dryer Program (continued)

- Tier 2* Information in ESBWR Design Control Document, Section 3.9.2.3, "Dynamic Response of Reactor Internals Under Operational Flow Transients and Steady-State Conditions"
  - Predictive evaluations
  - Fatigue analysis and fatigue limits
  - FIV load definition is defined from the recorded dryer pressure or dryer pressure and steam line data
  - Load definition bias and uncertainty is benchmarked against the dryer pressure sensor data. A structural assessment is performed to benchmark the FE model strain and acceleration predictions against the measured data.
  - Subsequent ESBWR steam dryers includes dryer FIV monitoring via main steam line instruments

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Existing Regulatory Elements in ESBWR Steam Dryer Program (continued)

- In accordance with RG 1.20, the steam dryer is included in the reactor internals vibration analysis, measurement, and inspection program, which is addressed in ESBWR COL Information Item 3.9.9-1-A

"3.9.9 COL Information

3.9.9-1-A Reactor Internals Vibration Analysis, Measurement and Inspection Program

The COL Applicant will classify its reactor per the guidance in RG 1.20 and provide a milestone for submitting a description of the inspection and measurement programs to be performed (including measurement locations and analysis predictions) and the results of the vibration analysis, measurement and test program."

NOTE: RG 1.20 guidance suggests a time period that allows for NRC staff's review of vibration measurement and inspection program.

NRC Issues Identified in 01/19/2012 Letter

1. Mesh sizing
2. Main steam line area modeled versus actual
3. Model inconsistencies
4. Alternate benchmarking results
5. Strain gage measurement accuracies

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Implications for Rulemaking

- ESBWR rulemaking need not be delayed while addressing NRC issues for the following reasons:
  - NRC conclusions in FSER remain valid (i.e., significance of issues not expected to affect ESBWR dryer design)
  - Adequate regulatory oversight is in place for verifying adequacy of ESBWR Steam Dryer structural integrity through ITAAC and vibration assessment program
  - GEH continues to incorporate improvements and lessons learned into reactor internals/steam dryer designs

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