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# AP1000 COL Piping Analysis, Hazard Evaluation, and LBB Evaluation

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# Piping Load and Analysis Requirements

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- **3.9.1 Special Topics for Mechanical Components**
  - Piping analysis will be performed using only specific software (PIPESTRESS, WECAN, ANSYS, GAPPIPE)
  - Piping benchmark program required for other than above
  - Design transients defined for service levels A, B, C, D and testing conditions

# Piping Load and Analysis Requirements

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- **3.9.3 ASME Code Classes 1,2,3 components / supports**
  - Piping evaluation to 1989 Edition, 1989 addendum of ASME Code
  - 60 year design life – 40 year initial license
  - Fatigue evaluation for class 1 piping
  - Environmental fatigue not a commitment at present (will need to address at license renewal)
  - Thermal stratification, cycling and striping (TASCS) included in evaluation for:
    - **Cold leg, surge line, ADS stage 4, RNS suction, and PRHR return lines**

# Piping Analysis Approach

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- **Piping Seismic Analysis**

- Analysis methods, damping values, modal combinations, high frequency modes, seismic anchor motions covered in DCD 3.7
- OBE is not a design basis event
- Pipe supports for seismic
  - Snubber vs limit stop
  - Support stiffness and gap
  - Seismic self-weight excitation

# Piping Analysis Approach

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- **Address Piping COL Commitments**

- ASME design specifications and design reports
- Surge line thermal monitoring program
- Piping benchmark program
- Process followed basic SRP/ASME/Industry requirements and was acceptable to NRC reviewers in FSER

- **No Design ITAACs**

# Piping Analysis Progress

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- 29 Class 1, 175 Class 2, 95 Class 3 packages
  - Many of the large bore packages have been started
  - Several packages have spec, report and support designs
  - Fatigue analysis for class 1 by Spring 2007 (exclude env fatigue)
- Class 1 and Class 2/3 piping design specification
  - Class 1 spec issued for review

# Piping COL Information Items

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- **Design Specifications and Reports**

- Section 3.9.8.2
- Combined License applicants referencing the AP1000 design will have available for NRC audit the design specifications and design reports prepared for ASME Section III components. Combined License applicants will address consistency of the reactor vessel core support materials relative to known issues of irradiation-assisted stress corrosion cracking or void swelling (see subsection 4.5.2.1). *[The design report for the ASME Class 1, 2, and 3 piping will include the reconciliation of the as-built piping as outlined in subsection 3.9.3. This reconciliation includes verification of the thermal cycling and stratification loadings considered in the stress analysis discussed in subsection 3.9.3.1.2.]\**

# Piping COL Information Items

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- **COL Information Item 3.9-2**

- Technical report for as-designed (summer 2007)
- Detailed design efforts
- Component design reports addressed separately
- As-built aspect identified as post-COL item
- Reactor internals addressed separately

# Piping COL Information Items

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- **Surge Line Thermal Monitoring**

- Section 3.9.8.5
- A monitoring program will be implemented by the combined license holder at the first AP1000 to record temperature distributions and thermal displacements of the surge line piping as outlined in subsection 3.9.3.1.2.
- COL information item 3.9-5.
- Input technical report provided to NuStart.

# Piping COL Information Items

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- **Piping Benchmark Program**

- Section 3.9.8.6
- The combined license applicant will implement a benchmark program as described in subsection 3.9.1.2 if a piping analysis computer program other than one of those used for design certification is used. The piping benchmark problems identified in Reference 20 for the Westinghouse AP600 are also representative for the AP1000 and can be used for the AP1000 piping benchmark program if required.

# Piping COL Information Items

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- **COL Information Item 3.9-6**

- Technical report 15 (APP-GW-GLR-006) issued March, 2006
  - No benchmark program required
  - No programs used that have not been benchmarked

# Protection against Pipe Break Hazards

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- **Protection Against the Dynamic Effects Associated with the Postulated Rupture of Piping**
  - Satisfy GDC 4, BTP MEB 3-1
  - Redundancy, routing for separation, analysis for dynamic effects, protection with barriers or PWRs
  - RCS, PXS, CVS, and SGS is where the action is
  - Break exclusion zone (BEZ)
  - Leak-before-break (LBB)

# Pipe Break Hazard Evaluation

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- **Pipe Break Hazard Evaluation**

- Identify high energy piping ( $T > 200\text{F}$  or  $P > 275$  psi)
- Postulate break locations
  - Terminal ends
  - Locations of high stress (OBE not included) or usage factor
- Calculate pipe whip plastic hinges and jets associated with breaks
- Identify rooms, breaks, and safety-related targets
- Identify what equipment is required for each break
- Identify how to protect equipment from break effects (whips and jets)
  - Analyze
  - Separate
  - Protect (barriers, restraints)
- Design pipe whip restraints

# Pipe Break Hazard Evaluation

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- **Break Exclusion Zone Piping**

- High energy piping in containment penetration area
- Cannot meet containment isolation with single active failure
- Main steam, main feedwater, startup feedwater, SG blowdown, and CVS makeup have been identified as BEZ piping
- Additional ISI requirements
- Special requirements for MSIV compartment adjacent to MCR
  - Floor and wall evaluated for pipe whip and jet impingement for worst case break in MSL or FWL

# Pipe Break Hazard Evaluation Progress

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- AP600 hazard evaluation did not design whip restraints
- AP1000 hazard evaluation will repeat AP600 work and design whip restraints
- AP1000 layout is similar to AP600 layout
- Pipe breaks and safety targets are similar
- Pipe break evaluation and sample of whip restraint design will be completed by end of 2006

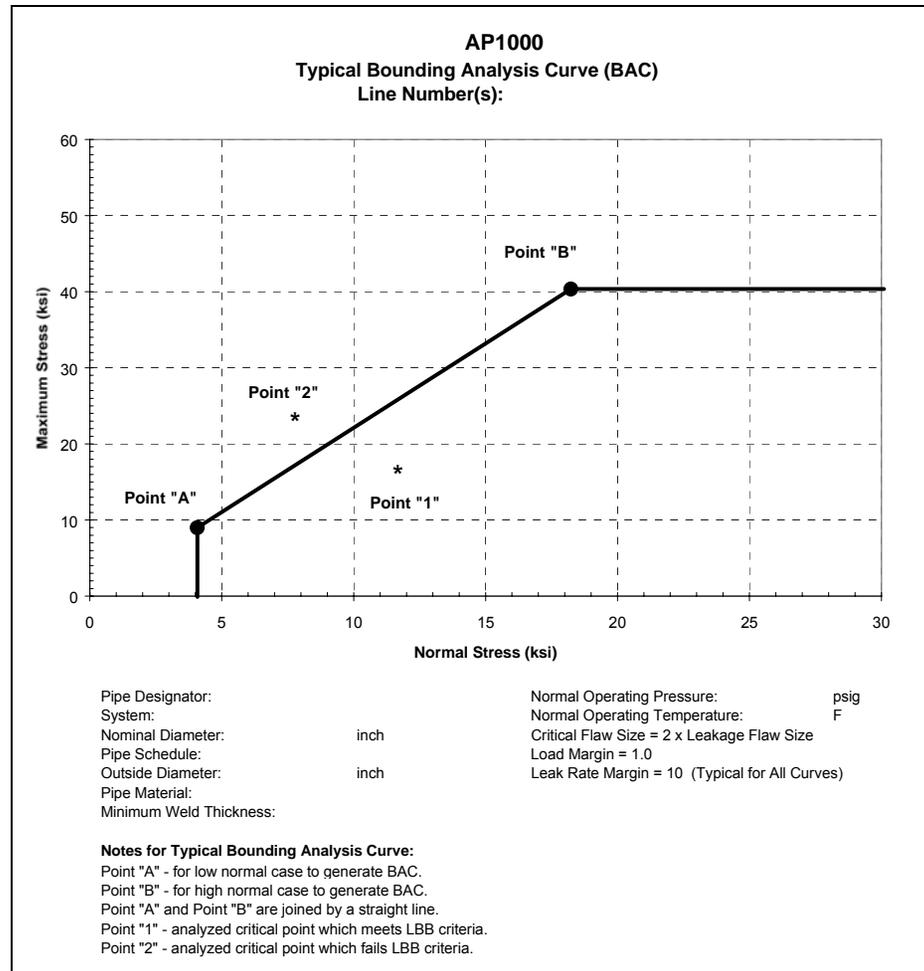
# Leak-Before-Break

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- **Leak-Before-Break (LBB)**

- GDC 4 changed to allow design to exclude dynamic effects from pipe rupture if:
  - Stability analysis of critical circ thru-wall crack for normal & SSE
  - Leakage analysis for crack that gives 10x detectable leak rate
  - Critical crack size is 2x of leakage crack size
- Bounding analysis curve (BAC)
  - A BAC generated for each line size, temp, press, material
  - AP1000 has LBB for the HEL inside containment  $\geq 6$ "
  - LBB not granted for MFW and SUF lines
  - Normal stress vs. max stress
  - Total moment used instead of bending moment
  - If critical stress is at/or below curve, piping meets LBB

# Leak-Before-Break



# Leak-Before-Break

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- LBB not applied to piping susceptible to degradation mechanisms
  - Waterhammer, creep damage, erosion, corrosion, fatigue etc.
- Evaluation specifically addresses SCC, thermal aging, and thermal stratification (goes beyond explicit guidance in draft SRP 3.6.3)
- Evaluation assumes GTAW
- Leak detection systems inside containment found acceptable
  - 0.25 gpm capability may be required for some systems
  - NRC satisfied that capability exists for AP1000
- One portion of LBB line is class 3
  - ISI requirement for line makes equivalent to class 2 (volumetric)

# LBB and Hazard COL Information Items

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- **COL commitment for Section 3.6**
  - As-built pipe rupture hazards analysis report
  - As-designed leak-before-break evaluation report
  - As-built leak-before-break evaluation report
  - Primary system inspection program for leak-before-break piping
  - Process followed basic SRP requirements and was acceptable to NRC reviewers in FSER
  
- **No design ITAACs**

# Pipe Break Hazard COL Information Items

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- **COL Information Item 3.6-1**

- Section 3.6.4.1
- Combined License applicants referencing the AP1000 certified design will complete the final pipe whip restraint design and address as built reconciliation of the pipe break hazards analysis in accordance with the criteria outlined in subsections 3.6.1.3.2 and 3.6.2.5. The as-built pipe rupture hazard analysis will be documented in an as-built Pipe Rupture Hazards Analysis Report.

# Pipe Break Hazard COL Information Items

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- **COL Information Item 3.6-1**

- As-built aspect to be identified as post-COL item
- Input technical report addressing pipe whip restraints to be provided to NuStart January 2007
- Detailed design efforts

# LBB COL Information Items

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- **COL Information Item 3.6-2**
  - **Section 3.6.4.2**
  - **Combined License applicants referencing the AP1000 certified design will complete the leak-before-break evaluation by comparing the results of the as-designed piping stress analysis with the bounding analysis curves documented in Appendix 3B. The Combined License applicant may perform leak-before-break evaluation for a specific location and loading for cases not covered by the bounding analysis curves. Successfully satisfying the bounding curve limits in Appendix 3B may necessitate lowering the detection limit for unidentified leakage in containment from 0.5 gpm to 0.25 gpm. If so, the Combined License applicant shall provide a leak detection system capable of detecting a 0.25 gpm leak within one hour and shall modify appropriate portions of the DCD including subsections 5.2.5, 3.6.3.3, 11.2.4.1, Technical Specification 3.4.7 (and bases), Technical Specification Bases B3.4.9, and Technical Specification 3.7.8 (and Bases). The leak-before-break evaluation will be documented in a leak-before-break evaluation report.**

# LBB COL Information Items

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- **COL Information Item 3.6-2**
  - Revised technical report issued July 2006
    - Description of methodology
    - BACs for all systems covered
    - Documents as-designed LBB analysis

# LBB COL Information Items

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- **COL Information Item 3.6-3**
  - **Section 3.6.4.3**
  - **Combined License applicants referencing the AP1000 certified design will address: 1) verification that the as-built stresses, diameter, wall thickness, material, welding process, pressure, and temperature in piping excluded from consideration of the dynamic effects of pipe break are bounded by the leak-before-break bounding analysis; 2) a review of the Certified Material Test Reports of Certifications from the Material Manufacturer to verify that the ASME Code, Section III strength and Charpy toughness requirements are satisfied; and 3) complete the leak-before-break evaluation by comparing the results of the final piping stress analysis with the bounding analysis curves documented in Appendix 3B. The leak-before-break evaluation will be documented in a leak-before-break evaluation report.**

# LBB COL Information Items

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- **COL Information Item 3.6-3**

- As-built aspect identified as post-COL item
- Parts 1) and 2) are required before 3) can be completed.

# LBB COL Information Items

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- **COL Information Item 3.6-4**
  - Section 3.6.4.4
  - Combined License applicants referencing the AP1000 certified design will develop an inspection program for piping systems qualified for leak-before-break. The inspection program will consider the operating experience of the materials used in the AP1000 piping systems qualified for leak-before-break, and will include augmented inspection plans and evaluation criteria consistent with those measures imposed on or adopted by operating PWRs as part of the ongoing resolution of concerns regarding the potential for PWSCC in operating plants. The AP1000 inspection program will be consistent with the inspection program adopted for operating PWRs that use Alloy 690, 52, and 152 in approved leak-before-break applications.

# LBB COL Information Items

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- **COL Information Item 3.6-4**

- Westinghouse and Enercon share COL information item technical lead
- Westinghouse is developing a technical report due September 2006 that will contain inspection locations. Enercon will need to review report for consistency with Section XI / utility requirements.
- Investigating the use of RI-ISI

# Comparison of AP600 to AP1000

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- **Analysis Level of detail**

- Piping analysis for AP1000  $\geq$  detail for AP600
- Pipe supports were not designed for AP600 but have detail designs for AP1000
- Piping design specification much more detailed for AP1000

- **Completion rate**

- AP600 had more “completed” packages than AP1000
- AP1000 has the same type of packages analyzed as AP600, just not as many
- AP1000 analysis packages have more detail (see above)

# Piping Design Acceptance Criteria

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- **Piping design acceptance criteria (DAC) appears in introduction to DCD**
- **The piping DAC includes AP1000 piping design analysis methods, design procedures, and acceptance criteria that are to be used for completion of the AP1000 piping design**
- **Table 1-2 in the DCD introduction references portions of the DCD that define methods and criteria.**
- **AP1000 FSER section 3.12 addresses DAC**

# Piping Design Acceptance Criteria

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- **Design Work Completion to Close Piping DAC**
  - The evaluations/reports provide evidence of meeting the DAC
  - NRC review of ongoing work attests to meeting the DAC
  - NRC can start checking off DAC commitments during this audit
  - By the time the NRC has reviewed the piping technical reports, including the on-site reviews, the DAC should be able to be closed
- **Objective is to close DAC with this detailed design/analysis**
- **NRC action going forward: Establish how DAC closure will be documented**

# Piping Generic Code Design Report

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- **Piping Covered**

- Significant number of class 1, class 2, and class 3 piping analyses/calculations will be available for NRC review by spring 2007
- Will include all LBB lines
- Will include all large bore class 1
- Will include at least one of each large bore class 2/3 that have a unique function (e.g. one of two blowdown lines)
- Will include piping qualification and pipe support qualification for all piping packages completed