AP1000

AP1000 Draft Safety Evaluation Report LBB Open Items

Presentation to NRC Staff
Rockville, MD

July 11, 2003

BNFL Westinghouse

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AP1000 Draft Safety Evaluation Report

- **Two DSER Open Items Related to LBB**
  - 3.6.3.4-1 - PWSCC
  - 3.6.3.4-2 - TGSCC
- **PWSCC Open Item**
  - Requests W to include Combined Operating License applicant commitment to implement inspection plans, evaluation criteria, and other types of measures imposed on or adopted by operating PWRs with currently approved leak-before-break (LBB) applications as part of the resolution of concerns regarding the potential for PWSCC in those units
  - Westinghouse has incorporated the COL item in the AP1000 DCD

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- **TGSCC Open Item**
  - Identifies TGSCC as a possible failure mechanism for AP1000 piping systems
  - If TGSCC crack morphology parameters are assumed, LBB bounding curves would be impacted, and it will be more difficult to demonstrate that AP1000 piping systems meet LBB
  - Requests W to perform piping stress analysis and perform sensitivity analysis for 5 piping systems to demonstrate that AP1000 piping systems can meet LBB

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W Position on TGSCC Open Item

- **W does not agree that TGSCC is a possible degradation mechanism for AP1000 piping systems**
  - AP1000 Bounding Analysis Curves as currently constructed are appropriate
  - Fundamental requirement for LBB application is that stress corrosion cracking does not exist
    - VC Summer experience with PWSCC does not apply to AP1000
    - Assuming TGSCC crack morphology parameters as a surrogate for PWSCC is not consistent with LBB approach
  - Therefore W will provide information to demonstrate that PWSCC and TGSCC do not apply to AP1000 LBB piping systems

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Alloy 690, Alloy 52, Alloy 152 in AP1000

- In view of the continuing occurrence of primary water stress corrosion cracking [PWSCC] of Alloy 600, and its associated welds Alloys 82 and 182, the decision was taken to preclude use of these materials in the AP1000 design
- The materials selected for these applications are Alloys 690, 52 and 152, respectively
- The recent cracking experiences in Alloy 600 and associated welds in operating PWRs therefore have no relevance to the AP1000

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Alloy 690 - Historical Perspective

- Thermally treated Alloy 690 [A690 TT] was adopted as the preferred alloy for SG heat transfer tubing applications in 1986
- A690 TT also began service as mechanical SG tube plugs at approximately the same time
- Since the initial replacement SG startup at D.C. Cook Unit 2 in May 1989, A690 TT is now in service at more than fifty PWRs worldwide
- Applications of A690 TT have since been extended to include SG divider plates, pressurizer heater sleeve penetrations, RV head penetrations (including CRDM pipes), and other small-bore instrument penetrations

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Alloy 690 - Experience (Cont'd.)

- Several of the CE-repaired components, with A690 TT as the replacement material, have been in service since approximately 1989
- With over fourteen years of SG operating experience, at temperatures exceeding 328°C [622.4°F], and nearly sixteen years in pressurizer penetration applications at 343°C [650°F] there has not been a single incidence of environmental degradation of A690 TT

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Alloys 52 and 152

- With the extension of A690 TT applications to SG divider plates, RV and pressurizer penetrations, and other applications requiring welding, the A690 weld metal analogs Alloys 52 and 152 have been widely deployed
- Alloy 52 is used for gas-tungsten-arc [GTA] or gas-metal-arc [GMA] welding; Alloy 152 is the stick electrode composition used for shielded metal-arc welding [SMAW]
- Alloys 52 and 152 contain the same nominal concentrations of Cr and Fe, with slightly less Ni - relative to Alloy 690

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A52 and A152 - Applications in PWRs

- The earliest application of these weld metal alloys was in CE pressurizers in which partial penetration welds were used to complete the repairs; these applications extend as far back as early 1989
- Westinghouse replacement SGs at N. Anna 1 and V. C. Summer were the first units to employ large-scale use of A52 and A152
- These SG applications included safe end-to-nozzle welds, and welding of the divider plate and stub runner to the channel head
- The initial SG applications went into service in late 1993, accruing nearly ten years of service since that time

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Alloy 52 & Alloy 152 - SCC Resistance

- Owing primarily to high Cr content, Alloys 690, 52, and 152 exhibit apparent immunity to primary water stress corrosion cracking (PWSCC)
- Service experience with Alloy 690 in SG heat transfer tubing applications, and Alloys 52/152 as buttering, cladding and weld filler materials has been exemplary, with no reported degradation
- Laboratory testing of each of these materials endorse the exceptional corrosion resistance - no known incidence of crack initiation or crack propagation in primary water environments in any of these materials

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Alloys 52 & 152 - SCC Resistance (Cont'd.)

- The laboratory tests of these weld metals continues to support the concept of "immunity" to PWSCC
- Even specimens precracked in fatigue will not propagate; details of these tests have been provided in the Revision 1 response to RAI 251.004
- Alloys 52 & 152 have been used in operating PWRs for RV nozzle repairs at V.C. Summer and Ringhals 3 & 4
- The use of Alloy 52 for an embedded flaw weld repair of CRDM pipe degradation at N. Anna Unit 1 was approved in late 1992, and generically approved in July 2003.

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Alloys 52 & 152 - Conclusions

- There is no technical basis to judge that Alloy 52 & Alloy 152 will not preclude the occurrence of environmental degradation in PWR primary water environments

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TGSCC Issues

- PWR experience with austenitic stainless steel has been excellent
- After more than 3000 reactor years of service, no TGSCC has occurred in piping
- TGSCC has occurred in other geometries, and these will be reviewed briefly
- The key requirements for TGSCC are high stress, high Oxygen content, and impurities such as Chlorides
- AP1000 builds on this extensive successful experience

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TGSCC Cracking Experience

- Palisades CEDM housings
  - Summer 2001 was the most recent occurrence
  - Earlier, CEDM seal housings had shown cracking
  - These housings have a large volume of stagnant water, not vented
- Other Occurrences of TGSCC in Austenitic SS
  - Canopy Seal Weld Region Cracks – Numerous Occurrences
  - EdF Auxiliary Lines, Drain Lines (stagnant, High O_2, with chlorides)
- **Common Theme** – High Residual Stresses, Stagnant or Semi-Stagnant Flow Conditions, High Oxygen, Some Level of Cl

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How does AP1000 Ensure that TGSCC does not Occur?

- Dissolved Oxygen levels are kept to near zero, by a hydrogen overpressure, which scavenges all oxygen out of the water
- Chlorides are kept to extremely low levels by careful chemistry control at all times
- These controls, on both oxygen and Chlorides, have been used in the commercial PWR business since its beginning over thirty years ago, with great success
- Controlling to these low levels ensures that TGSCC cannot occur, as seen in the next slide

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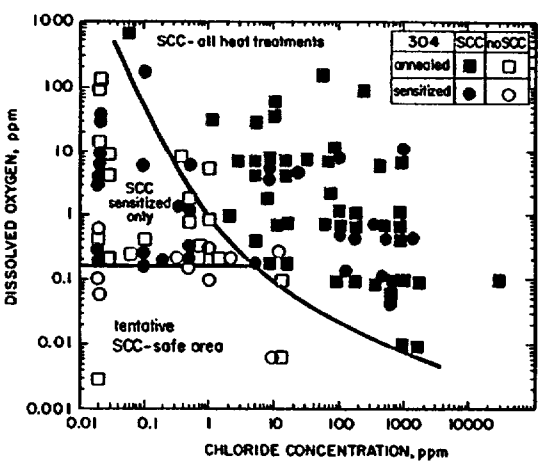
Dissolved Oxygen and Chlorides that may lead to SCC in Stainless Steel



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Open Item 3.6.3.4-1 [PWSCC] - Conclusions

- Alloys 52 and 152 have been shown to exhibit excellent resistance to PWSCC, both in lab and field experience
- However, Westinghouse recognizes the reservations expressed by the NRC with respect to the limited [ca. 9.5 years] field experience
- Continued field experience - and laboratory evaluations currently underway - will accrue prior to final operation of AP1000
- Westinghouse remains confident this experience will validate the decision to extensively deploy these materials in the AP1000 primary system

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Open Item 3.6.3.4-2 [TGSCC] - Conclusions

- TGSCC is a well known cracking mechanism in austenitic stainless steels
- However, as the direct consequence of the design and operation of the AP1000 primary system, the environmental conditions necessary for its occurrence (high O_2, chlorides) will not exist
- Therefore, it is concluded that there is no phenomenological basis to conclude that TGSCC will represent a failure mechanism in the AP1000 LBB piping systems - and leak-before-break is applicable

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AP1000 Piping Systems Designed for LBB

- **AP1000 LBB Piping Systems are the same as those designed for AP600**
  - Some line sizes increased
  - Line routings the same
  - Stress analyses completed for AP600 demonstrate the feasibility that the AP1000 piping systems can be designed to meet bounding analysis curves
- **AP1000 LBB Piping System isometric / layout drawings were reviewed by NRC in September 2002**

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AP1000 Piping Systems Designed for LBB

- **Reactor Coolant Loop**
- **Pressurizer Surge Line**
- **Direct Vessel Injection Lines A & B**
- **Core Makeup Tank Inlet Lines A & B**
- **Passive RHR HX Return Lines**
- **ADS-1/2/3 Piping**
- **ADS-4 Piping A & B**
- **Normal RHR Piping**
- **Main Steam Lines A & B**

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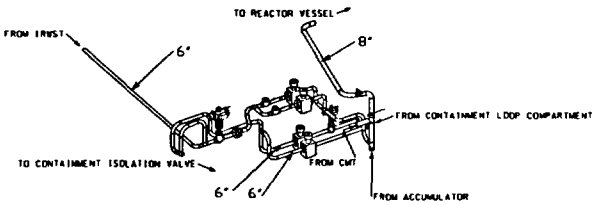
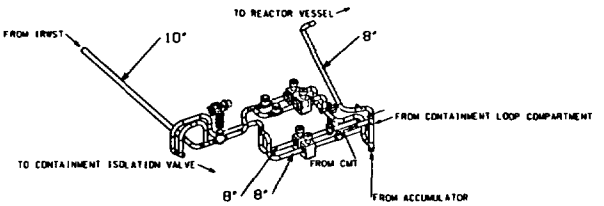
Comparison of IRWST Injection/DVI Line



DVIA-AP600



DVIA-1000

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AP1000 Piping Analysis Methodology

- **AP1000 Piping Design Criteria Document (APP-GW-P1-001)**
  - Defines Mandatory Analysis Requirements for AP1000 Piping Systems
  - Applicable Loadings and Loading Combinations
  - Methods of Analysis
  - Acceptance Criteria
- **Consistent with AP1000 DCD Sections 3.7 and 3.9**
- **Criteria Reviewed by NRC Staff at Westinghouse Office in September 2002**

AP1000 Piping Analysis Methodology (Continued)

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- **Pipe Rupture Protection Design Criteria Document (APP-GW-N1-001)**
  - Defines Mandatory Requirements for AP1000 Pipe Rupture Protection
  - Leak-Before-Break Bounding Analysis Methods
    - Bounding Analysis Curve Margins
      - Margin of 10 on leak detection capability
      - Margin of 2 on flaw size
      - Margin of 1 on load by using absolute summation method of maximum loads combination
  - Consistent with AP1000 DCD Appendix 3B
- **Criteria Reviewed by NRC Staff at Westinghouse Office in September 2002**

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AP1000 Preliminary Stress Analysis

- **Piping stress analysis for AP1000 candidate system in-progress**
- **DVI-A Piping Analysis Package**
  - Selected based on our experience with AP600
    - Difficult to qualify
  - Complicated piping system
  - Some piping sizes were changed
  - Contains smallest piping line qualified for LBB
  - Subcompartment pressurization impacts if line would not meet LBB criteria

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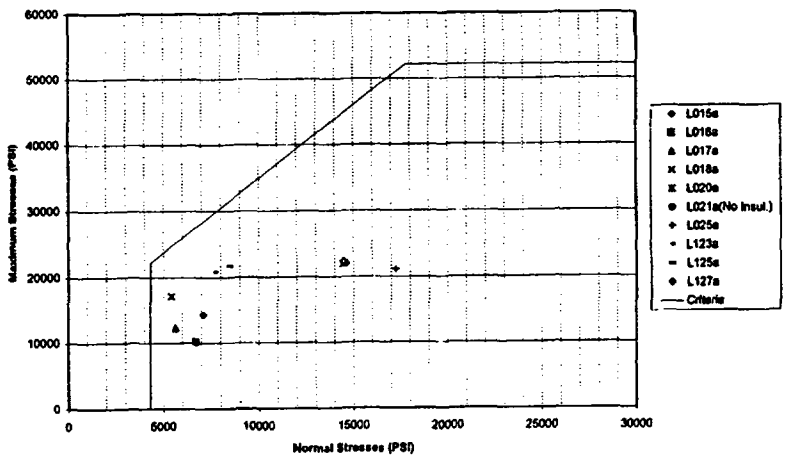
Preliminary Results

Figure 8.6.1 AP1000 Bounding Analysis Curve for 8" CMT, DVI,IRWST
(Line Numbers: L015A,016A,018A,020A,021A-No Insul.,025A,125A,127A)



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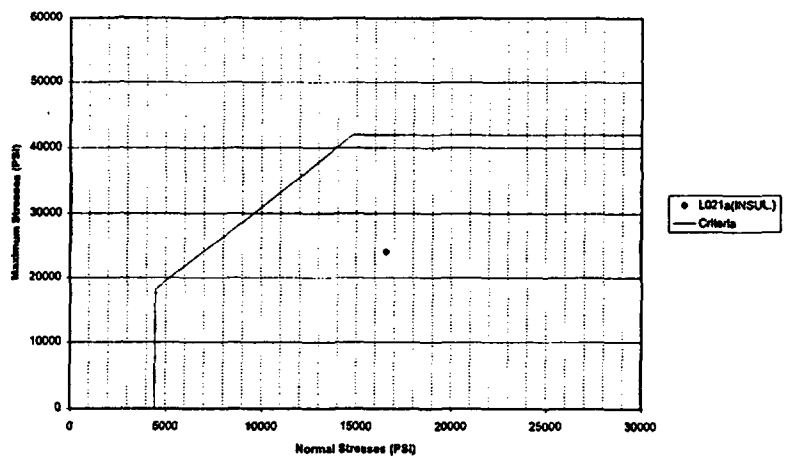
Preliminary Results

Figure 8.6.2 AP1000 Bounding Analysis Curve for 8" DVI Cold Trap to RV
(Line Number: L021A-Insul.)



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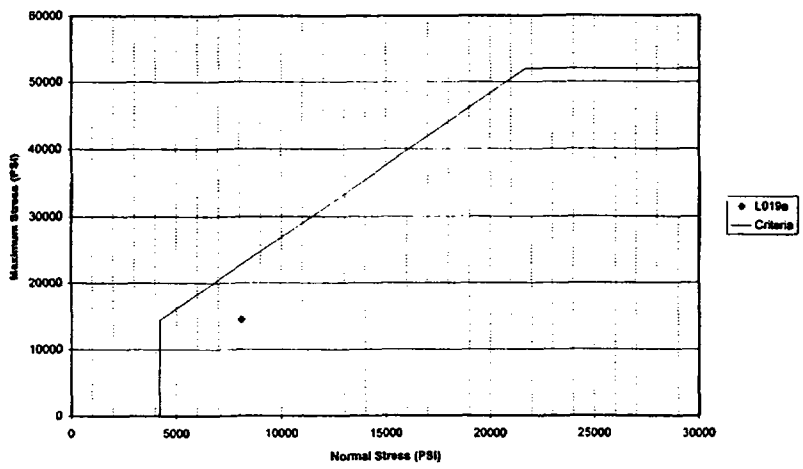
Preliminary Results

Figure 8.6.3 AP1000 Bounding Analysis Curve for RNS Discharge
(Line Number:L019A)



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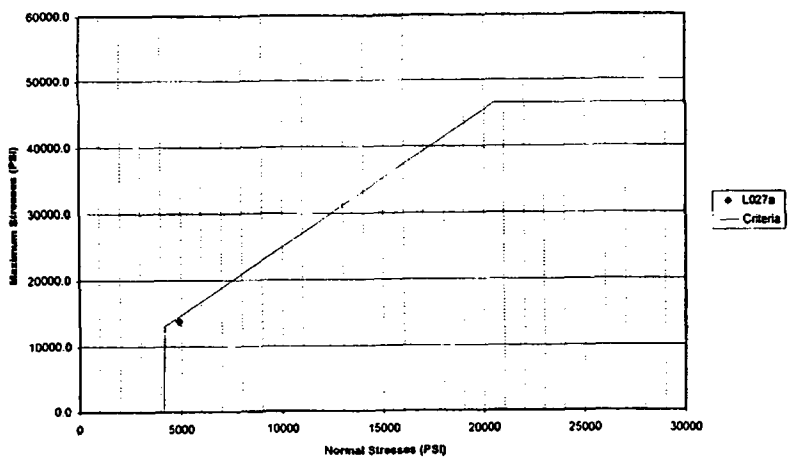
Preliminary Results

Figure 8.6.4 AP1000 Bounding Analysis Curve for Accumulator after Isolation Valve
(Line Number : L027A)



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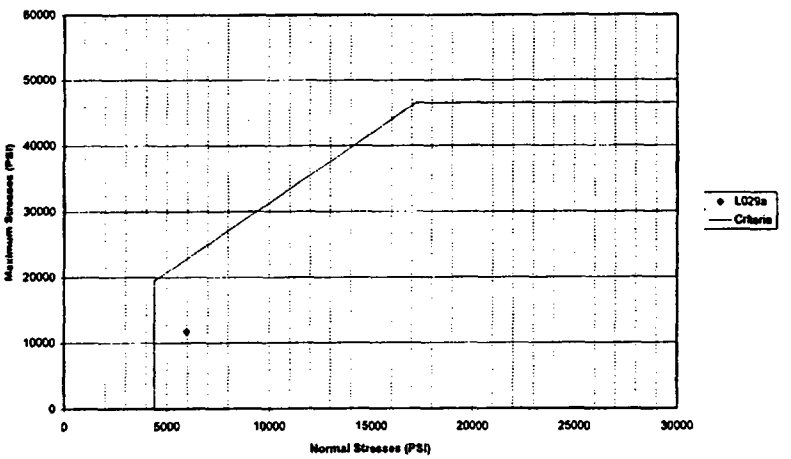
Preliminary Results

Figure 9.8.5 AP1000 Bounding Analysis Curve for 6" Accumulator to Isolation Valve
(Line Number : L029A)



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AP1000 Use of Design Acceptance Criteria

BACKGROUND

- **Westinghouse introduced AP1000 at a meeting with NRC in April 2000**
  - Identified the need for Westinghouse to use Design Acceptance Criteria (DAC) in lieu of detailed piping design and analysis
  - Basis:
    - Previous certified designs used Piping DAC
      - NRC can make safety determination without detailed piping design during Design Certification
    - Piping design and analysis can be deferred to COL applicant
    - Final piping design and analysis verified during ITAAC

Four Main Issues Addressed in Pre-Certification Review

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- Applicability of AP600 Test Program to AP1000
- Applicability of AP600 Safety Analysis Codes to AP1000
- **Defer Detailed Engineering using Design Acceptance Criteria**
- Applicability of AP600 Exemptions to 10CFR50

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AP1000 Pre-Certification Review

- **WCAP-15614, "AP1000 Seismic and Structural Design Activities"**
  - Report submitted to NRC in 1/2001 outlines proposed DAC approach
    - Piping design
    - Structural design
    - Included preliminary seismic analysis results
- **NRC staff raised issues with our approach**
  - Westinghouse agreed to revise DAC approach for AP1000
    - Drop DAC approach for seismic / structural
    - Use DAC approach for piping

AP1000 Pre-Certification Review Conclusions

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- **SECY-02-0059**
  - Use of DAC Acceptable for AP1000 piping
    - The use of DAC will not affect the staff's ability to make necessary safety determination
      - Contingent on ability to agree to an adequate piping DAC
      - Some reliance on similarities of AP600 and AP1000
      - Identified LBB as an issue to be resolved
- **ACRS Endorsed Use of DAC for AP1000**
  - Piping DAC could have been approved without reliance on similarities to AP600
  - Degree of design detail at DC stage is a business decision for the applicant, provided safety determination can be made

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Westinghouse Position on LBB Issues

- **SCC is not an issue for AP1000 LBB Piping Systems**
  - AP1000 materials not susceptible to SCC
  - COL Item incorporated to address resolution of industry issue for LBB
  - Significant additional operating experience with AP1000 materials will be realized prior to first AP1000 is deployed
- **BAC provided in DCD contain recommended LBB margins and are valid for AP1000**

Westinghouse Position on LBB Issues (Continued)

AP1000

- **SECY-02-0059 Approved DAC Approach for Piping**
  - Design Acceptance Criteria in lieu of detailed piping design and analysis
- **W approach specifies that piping stress analysis be completed as part of COL application**
- **AP600 piping stress analyses can be used to demonstrate feasibility for AP1000**
- **AP1000 piping stress analysis for DVI-A further demonstrates feasibility**
- **No additional piping analysis required**