Davis Besse Lessons Learned – Session H4

How NRC's Office of Nuclear Regulatory Research Played A Role

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DB LLTF Recommendations
NRC's Office of Nuclear Regulatory Research

RES considered DB Challenges As Emerging Issues and Instituted the Following Strategies:

Short-Term Response

- Identify and Mobilize Technical Expertise
- Establish technical basis for near-term regulatory decisions based on current technology
- Provide technical assistance for assessment (e.g., SDP, AIT, NDE, other)

Long-Term Response

- Continue to develop and refine risk assessment tools for passive component degradation and evaluate risk significance
- Develop technical basis for long-term programs and generic implementation
- Monitor effectiveness of technical solutions to DBLLTF lessons learned recommendations and refine process as needed

DB LLTF Recommendations
NRC's Office of Nuclear Regulatory Research

RES has a role in all of the DB Action Plans

Significant Contributions Are:

- Conducted Detailed Risk Assessment – Accident Sequence Precursor (ASP) Analysis
- Led and Executed Action Plan efforts on Barrier Integrity
- Provided active support on
  - Operating Experience Task Force
  - Boric Acid Corrosion
  - CRDM Nozzle Cracking Susceptibility Due to Primary Water Stress Corrosion Cracking (PWSCC)

DB LLTF Recommendations
NRC's Office of Nuclear Regulatory Research

Examples of Use of Research Information

Product	Regulatory Application
1. Boric Acid Corrosion Technical Reports	Consideration of additional inspections of dissimilar metal welds and high nickel alloy components for addressing PWSCC and for precluding SAC as a result of through-wall leakage.
2. Technical reports on Nozzle Cracking Susceptibility of Vessel Head Penetration Materials	Affirmed the adequacy of the RVHP susceptibility model for prioritizing RVHP inspections and provided technical information for inspection requirements in Order EA-03-009.

DB LLTF Recommendations
NRC's Office of Nuclear Regulatory Research

Examples of Use of Research Information (Continued)

Product	Regulatory Application
3. Technical report on leak monitoring systems and requirements	Provided technical basis for potential improvements to reactor coolant system (RCS) unidentified leakage requirements
4. Revision to M.D. 6.4, "Generic issues Program"	Specific revisions enhance and simplify the process for submitting candidate generic issues.
5. Technical report on adequacy of risk assessment of passive components (in-progress)	Improved risk assessment methods for better guidance on inservice inspection (ISI) and subsequent regulatory decision-making.

DB LLTF Recommendations
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Challenges:

- Defining the scope influenced by
  - Resources (Internal, National Laboratories, International Cooperative Research Programs)
  - Timeliness
  - Quality of data and Information
- Complexity of technical issues
- Availability of information relevant to current need
- Identification of technical information gaps
- Recommendation of future research to address technical gaps
- Dissemination of research information to public

DB LLTF Recommendations
NRC's Office of Nuclear Regulatory Research

Some of the Lessons Learned For RES Are:

- Continue to foster research culture to expect the "unexpected" or "non-obvious" situations in nuclear plant operations
- Continue to be proactive in formulating, championing, acquiring the resources, and conducting needed high-quality research to address safety issues on "unexpected" or "non-obvious" challenges
- Continue to be responsive to feedback from stakeholders to reprioritize research to be more timely to provide regulatory safety technical information
- Be more aggressive in educating stakeholders to be more realistic in resources and time needs for generating high-quality data for difficult and complex technical safety issues for regulatory decision making.

NRC Office of Research LLTF Recommendations Follow-through – New Activities

- Assemble information on foreign & domestic findings
  - Boric acid corrosion
  - Alloy 600 cracking
- Evaluate uncertainties in SCC models
- Evaluate adequacy of plant-based boric acid programs, and develop plan for periodic evaluation of those programs
- Encourage ASME code changes for bare-metal nozzle inspection
- Review procedures for dissemination of relevant information
- Ensure that inspector training includes corrosion & PWSCC
- Improve requirements related to unidentified leakage
  - Determine whether plants should install on-line leakage monitors
- Improve risk assessment for passive component degradation

NRC Research Directions to Address CRDM Cracking and Leaking, and Davis-Besse Issue in Particular

- Developed Short-term Plans to Re-direct Applicable Aspects of Existing Programs to Focus on Boric Acid Corrosion and Structural Integrity
- Founded an International Cooperative Group on PWSCC of Nickel-base Alloys, Including Inspection and Repair Techniques
- Held an International Workshop in March 2003 to Discuss Issues of PWSCC in Nickel-Base Alloys

NRC Research Programs Related to CRDM & Alloy 600

- Modeling of Residual Stresses
- Improved Probabilistic Model for tf from Leakage of Circumferential Cracks
- Summary Report on Leakage from CRDMs
- Continue Testing SCC Growth Rates of Alloys 600 & 690
  - Supplemented D-B materials (A600, A182) into on-going program
- Parts of D-B Head to be removed, saved for later failure analyses
- Industry saving parts of North Anna #2 head for later failure analyses (Head taken offsite 11/02, harvested early ’03)

Two New Programs Emerged from Davis-Besse Challenges

- **Structural Integrity Assessment of DB Cavity - ORNL**
  - **Determined failure time for continued cavity growth**
  - **Evaluated the effect of cladding flaws on structural properties**
  - **Estimated model uncertainties using combined analytical and experimental techniques**

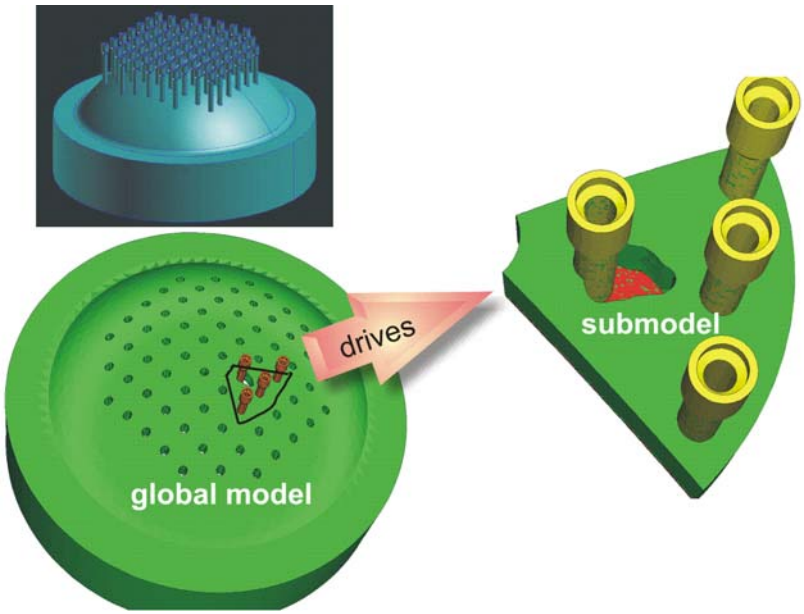
- **Head Degradation Due to Concentrated Boric Acid Corrosion - ANL**
  - **Aims to determine fundamental processes of boric acid corrosion**
  - **Includes probabilistic evaluation of inspection intervals**

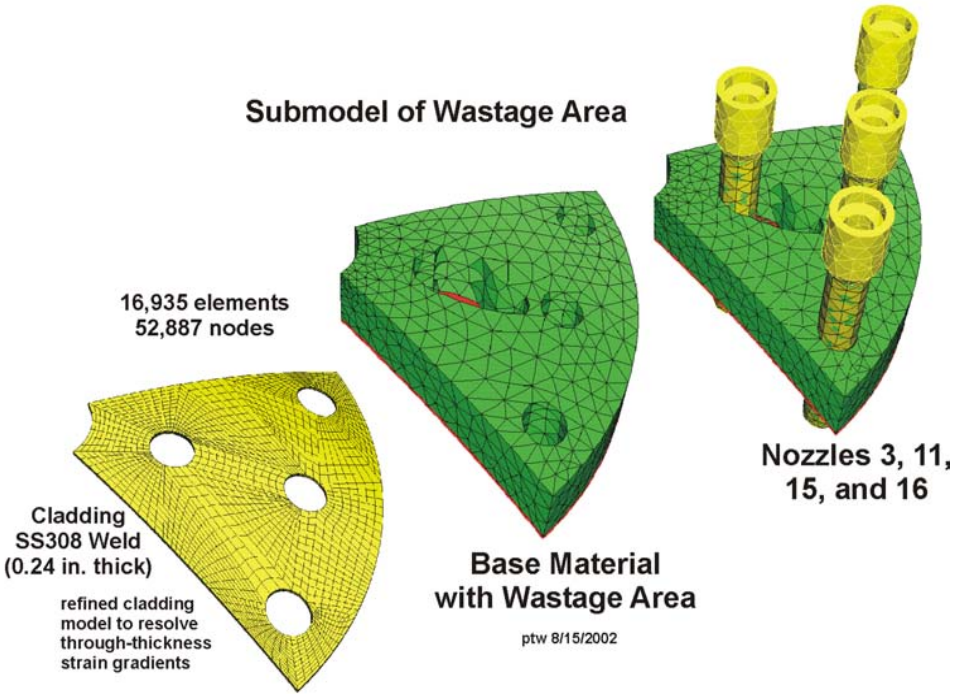
Ongoing Davis-Besse Structural Integrity Assessment

- Analytical Calculations
  - Evaluate effect of thermal gradient-induced stresses on rupture pressure.
  - Develop alternative failure model based on tearing initiation of representative cladding flaw distribution.
    - Determine cladding toughness resistance.
    - Develop crack driving force curves for relevant flaw depths and length.
  - Extend model to predict failure time probabilities at operating pressure using Monte Carlo analysis from flaw size, wastage rate, material toughness, and burst pressure distributions.
  - Quantify uncertainty due to geometric, material, and failure model uncertainties.

- Experimental Program
  - Conduct material property testing of surrogate cladding material (PVRUF).
  - Perform burst tests on simple, circular or elliptical cavity geometries.
    - Unflawed specimens
    - Flawed specimens with various relevant flaw depths and shapes
  - Compare results with analytical model predictions to determine model accuracy.

Full 3D FE Model *(ORNL)*



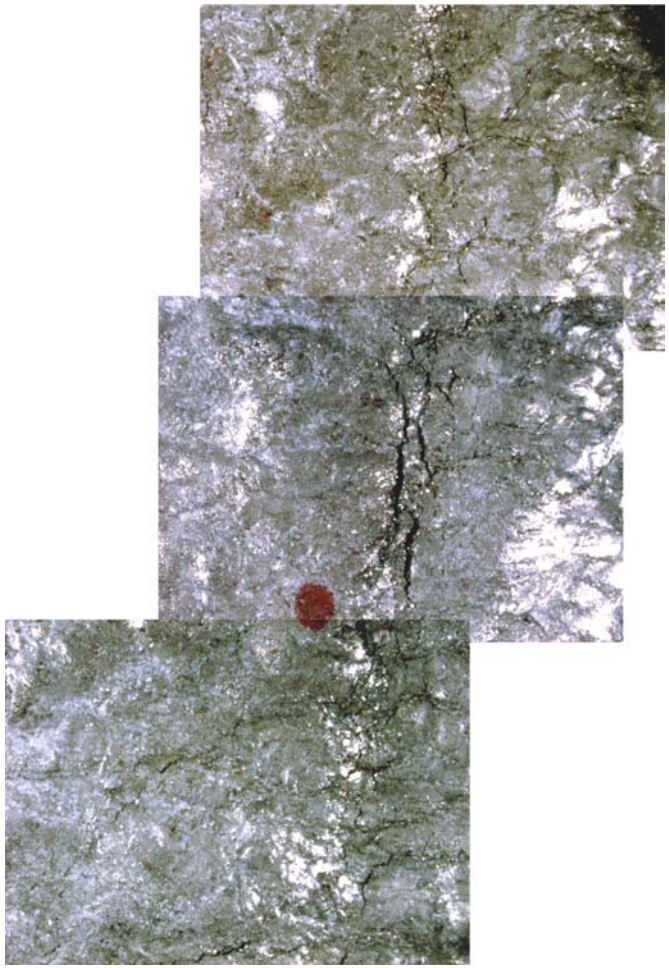


- Most realistic and tractable representation of the geometry of both the wastage area and the overall head design

17 in. diam plug removed from head by water jet cutting. Three CRDM housings also removed.

Analysis of deposits, exact measurements of cavity dimensions, stress-corrosion crack growth rate tests of Alloy 600 CRDM & weld materials are planned for near future.

Discovery of Cracks in Exposed Cladding

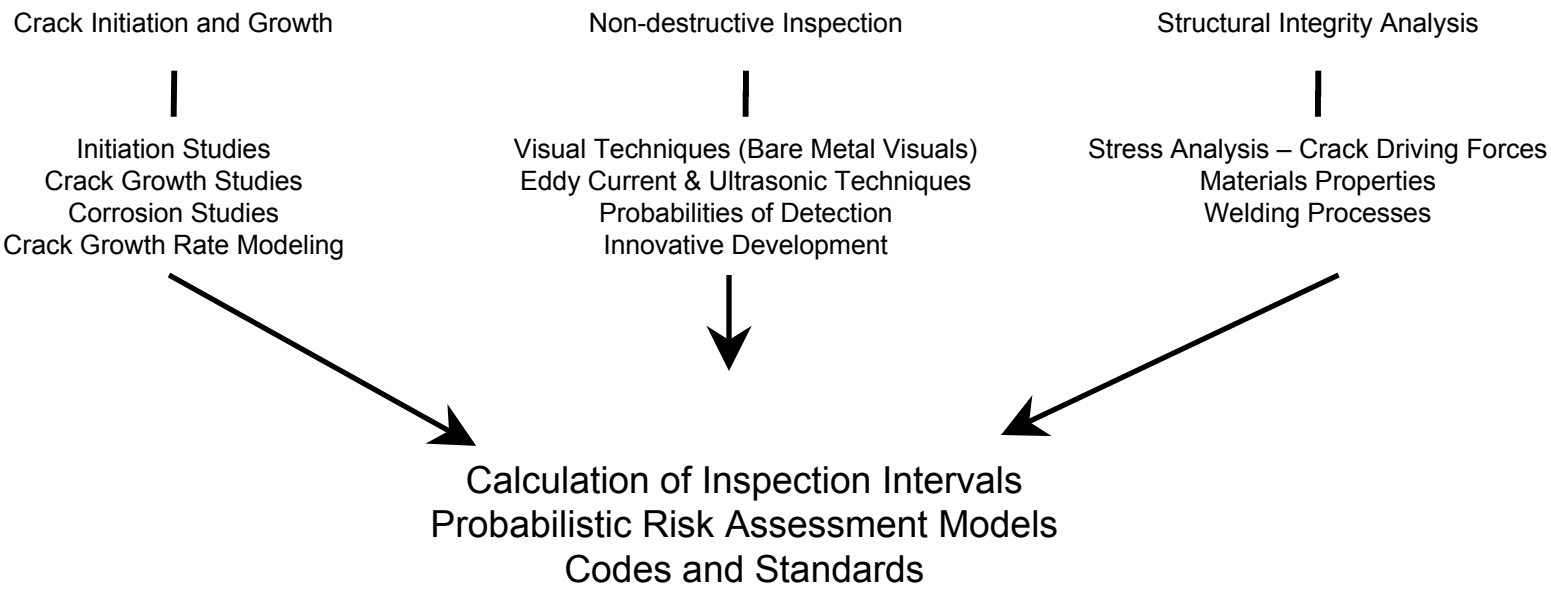


Cracks appear to be associated with seams between cladding strips. May be shallow, limited to dilution zone. Cracks are most open at maximum bulge (red dot).

Content of New Boric Acid Corrosion Research Program

- Crack Growth Rates of Alloys 600 & 182 from Davis-Besse Head
- Computational Model, Based on Probabilistic Assessment of:
  - Probability of Detection & Accuracy of Sizing
  - Crack Growth Rate Variations
  - Stress Intensity Factor Gradients (Residual Stress, Interferences)
  - Critical Crack Sizes, Including Factor of Safety
- Electrochemical Potential and Polarization Measurements of Low-Alloy Steel, Alloys 600 & 182 in Concentrated Boric Acid Solutions
- Mockup to Simulate Cavity Growth in Davis-Besse
  - Simulate Initial, Intermediate and Final Stages of Cavity Development
  - Examine Nozzle #2 cavity from Davis-Besse Head

Integrated Approach to CRDM/Vessel Head Inspection Issue



March ’03 Conference on CRDM and related Issues (Including safe ends, ICI penetrations, coolant loop repairs, etc.)

- In Washington, DC area
- March 24 – 26
- ~ 150 or more attendees & participants
- Three main session topics
  - Inspection technologies, disposition & sizing of flaws, new developments
  - Crack growth rates for relevant nickel-base alloys & welds
  - Repair technologies, success rate, component replacement, future topics, including replacement component fabrication procedures