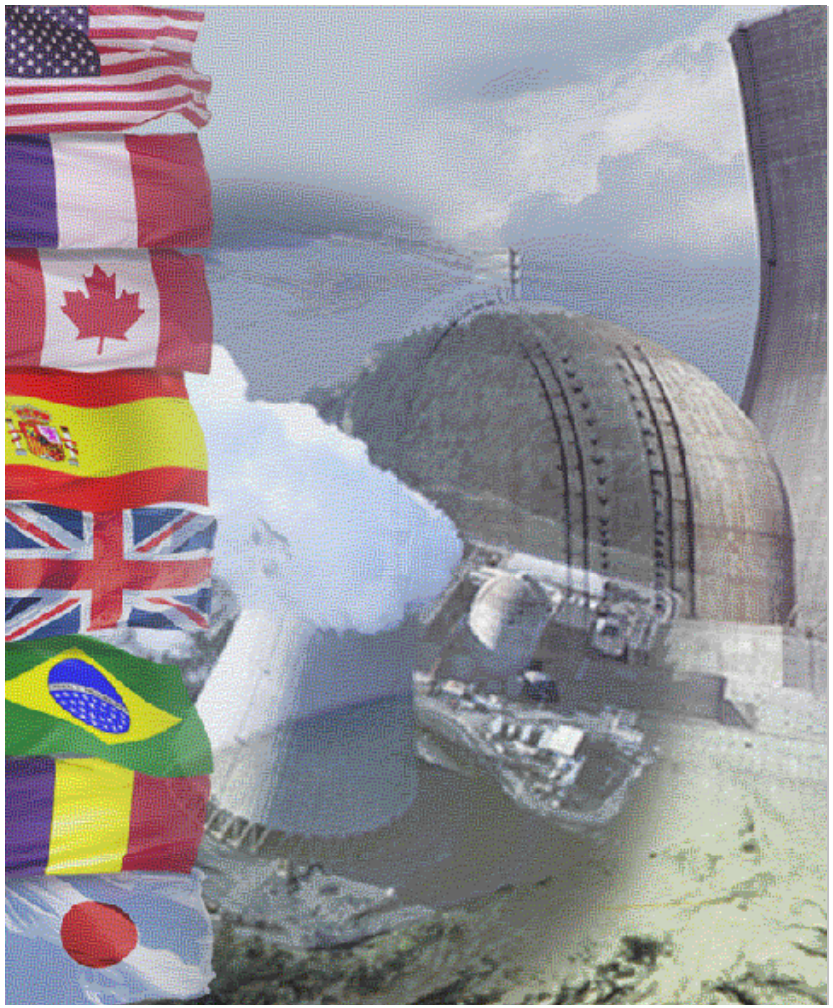


Bottom Mounted Nozzle Strategic Plan

Garry Randolph, AmerenUE

Chair, PMMP Steering Committee

Larry Mathews, Southern Nuclear

Chair, MRP Alloy 600 ITG

Mel Arey, Duke Energy

MRP Alloy 600 ITG

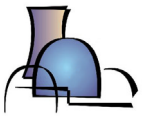
November 25, 2003

Rockville, MD

EPRI

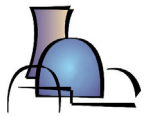
Meeting Agenda

- Short Term
  - BWOG LOCA Evaluation
  - WOG Reasonable Assurance of Safe Operation
  - MRP Visual Examination Recommendations
- Long Term Strategic Plan
  - NDE Demonstration Program
  - Bottom Mounted Nozzle Assessment Plan
  - Industry Integrated Inspection Plan
  - Bottom Mounted Nozzle Repairs
- Summary/Schedule



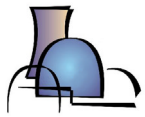
Short Term Industry Evaluations

- Because of the STP-1 event and the possible BMN leakage at Davis-Besse, several short term actions in the industry were undertaken.
  - BWOG performed LOCA analysis work in 2002.
  - WOG completed a “Reasonable Assurance of Safe Operation”
  - MRP issued recommendations for visual examinations to the PWR fleet.
- OG evaluations confirmed that the ECCS systems would allow for safe shutdown in the event of catastrophic failure.



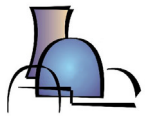
BWOG LOCA Evaluation

- Framatome ANP performed two small break LOCA analyses for B&W 177 Fuel Assembly (FA) plants:
  - Lowered Loop (ONS-1, ONS-2, ONS-3, CR-3, TMI-1, and ANO-1)
  - Raised-Loop (Davis-Besse)
- Each plant type was evaluated for a break area of:
  - The inside diameter of the BMN tube with the incore detector ejected (0.0021 ft^2)
  - The reactor vessel BMN bore diameter with the incore detector ejected and nozzle not obstructing the break flow area (0.0060 ft^2).
- Work completed using an Appendix K methodology



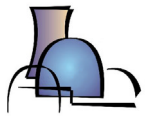
BWOG LOCA Evaluation Conclusions

- Generic 0.0021-ft^2 break
  - No core uncovering for either plant design
    - Minimum RCS level remained within the hot legs.
- Generic 0.0060-ft^2 break
  - 177 FA raised loop plant
    - No core uncovering
      - Minimum RV level was ~2 ft above top of the heated core region.
  - 177 FA lowered loop plants
    - Some core uncovering
      - Minimum RV level was ~4 ft below the top of the heated core region.
    - Bounding peak cladding temperature (PCT) of 1346 F
      - 10 CFR 50.46 criteria for PCT is 2200 F.



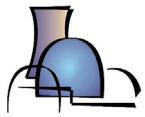
BWOG LOCA Evaluation Conclusions cont'd

- **Any break of a single bottom mounted nozzle at any B&W operating (177 FA) plant would be mitigated by the ECCS systems and allow for safe shutdown preventing fuel damage.**
- Observation
  - Operator initiated steam generator cooldown improves ECCS delivery. This increases the minimum core mixture level (decrease PCT) for the largest bottom mounted nozzle break.



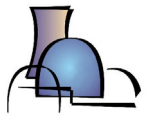
WOG Reasonable Assurance of Safe Operation

- Potential failures modes of BMN tubes were examined:
  - Axial cracking
    - Expected that leakage would be detectable by inspection before failure would occur.
  - Circumferential cracking below the weld
    - ID of BMN penetration
      - 0.6 inches (0.002 sq ft area) for W NSSS
      - 0.75 inches (0.003 sq ft area) for CE System 80 NSSS
    - Expected that leakage would be detectable by inspection before failure would occur.
  - Complete loss of weld integrity.
    - Ejection of BMN penetration tube not credible.



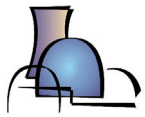
WOG Reasonable Assurance of Safe Operation Conclusions

- **Assessment concludes BMN ID failure mitigated by ECCS without crediting operator action to initiate RCS cooldown and depressurization.**
- Observations
  - Existing Emergency Procedure Guidance directs RCS cooldown and depressurization using steam generators. This is beneficial for BMN event mitigation.



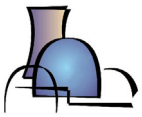
MRP Visual Examination Recommendations

- June 2003, MRP letter to all PWR Owners recommending:
  - Perform bare metal examination of any Alloy 600 nozzles on bottom head
    - Current or next outage
    - Perform expedited modifications (if necessary) to allow examination at earliest possible scheduled outage
  - Non-visual NDE may ultimately be a prudent and necessary component in a comprehensive inspection plan

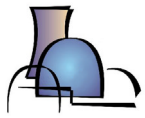


Boric Acid Deposit Sampling and Analysis

- White Paper was provided to MRP members September 2003
  - Provides cautions, recommendations and experiences from various plants
  - Describes visual examination of deposit, sampling techniques, types of analyses that may be useful, typical aging equations, etc.
  - Identifies that each situation is somewhat unique and guidance must be adapted
- Currently evaluating need for formal document

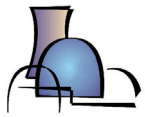


Bottom Mounted Nozzle Strategic Plan



Bottom Mounted Nozzle Strategic Plan

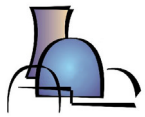
- NDE Demonstration Program
  - MRP Alloy 600 ITG
- BMN Assessment Plan
  - MRP Alloy 600 ITG lead, supported by BWOG, WOG
- Integrated Industry Inspection Plan
  - MRP Alloy 600 ITG and PWR Owners
- BMN Repairs
  - MRP Alloy 600 ITG



EPRI

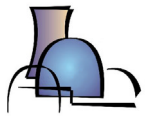
NDE Demonstration Program

- Purpose: to demonstrate NDE technologies and techniques for use in the industry to effectively inspect RV bottom head nozzles
- The program has the following characteristics:
  - Blind
    - Supported by non-blind preparation phases
  - Procedure demonstration
    - No acceptance criteria
  - Measurements of flaw detection capability and limits
    - No acceptance (pass-fail) criteria



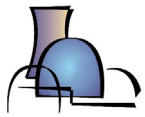
NDE Demonstration Program

- BMN NDE mockup design criteria completed
  - Similar to recommendations for upper head mockups
    - Demonstrate basic flaw detection and sizing capability
    - Assume PWSCC is the operative damage mechanism
    - Include axial, circumferential flaw orientations/ OD and ID of tube
    - Include weld flaws



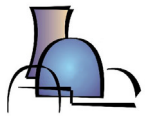
NDE Demonstration Program
Existing Mockups

- One partial-scale mockup of the B&W design
  - Conventional EDM notches that could be used for scanner and equipment development and examination coverage
- Two full-scale mockups of the Westinghouse Design.
  - Conventional EDM notches that could be used for scanner and equipment development and examination coverage
  - Contains simulation of wastage
- Two tube-only mockups of the Westinghouse Design
  - Processed EDM notches whose flaw responses would be considered representative.
  - Although the tube mockups are not welded into plate material, when used in combination with the full-scale mockups, enhance the assessment of procedure capability.



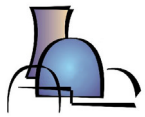
NDE Demonstration Program – New Mockup Fabrication

- Two mockups of the B&W design geometry and two mockups of the Westinghouse design.
  - Full-scale tubes welded into 6” to 7” thick vessel plate material
  - The nozzle/head geometry, weld prep geometry, and welding processes are based on original drawings or information obtained from participating utilities.
  - Fabrication processes are selected to simulate the original fabrication process as closely as practical.
  - The mockups will also contain lack-of-fusion (LOF) and grinding marks.



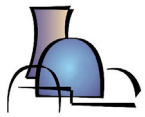
NDE Demonstration Program – New Mockup Fabrication (Continued)

- The mockups contain simulated flaws manufactured using isostatic processed electro-discharged machining (EDM) notches.
- Deeper flaws are comprised of multiple processed notches to simulate flaw branching.
- Shallow flaws are in some cases single processed notches with no branching, which simulate findings from destructive sectioning of field-removed flaws.



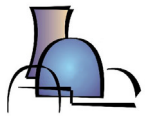
Bottom Mounted Nozzle Assessment Plan

- Purpose
  - Demonstrate safety of operation
  - Demonstrate continued compliance with all applicable regulatory requirements
  - Define the inspection requirements
  - Develop inspection and evaluation guidelines necessary to assure continued safe and reliable operations



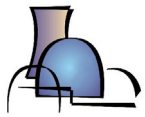
Bottom Mounted Nozzle Assessment Plan

- Purpose (continued)
  - Provide inspection, monitoring, and repair guidance that ensures low probabilities of failure and high margins of safety
  - Demonstrate low probabilities of leakage



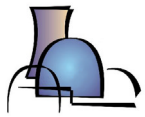
Industry BMN Assessment Plan

- Coordinated effort between MRP, BWOG, and WOG
  - Industry has committed funds through WOG and BWOG to complete the Assessment Plan
  - Tasks are already underway
- Final Management Plan will be consolidated by MRP

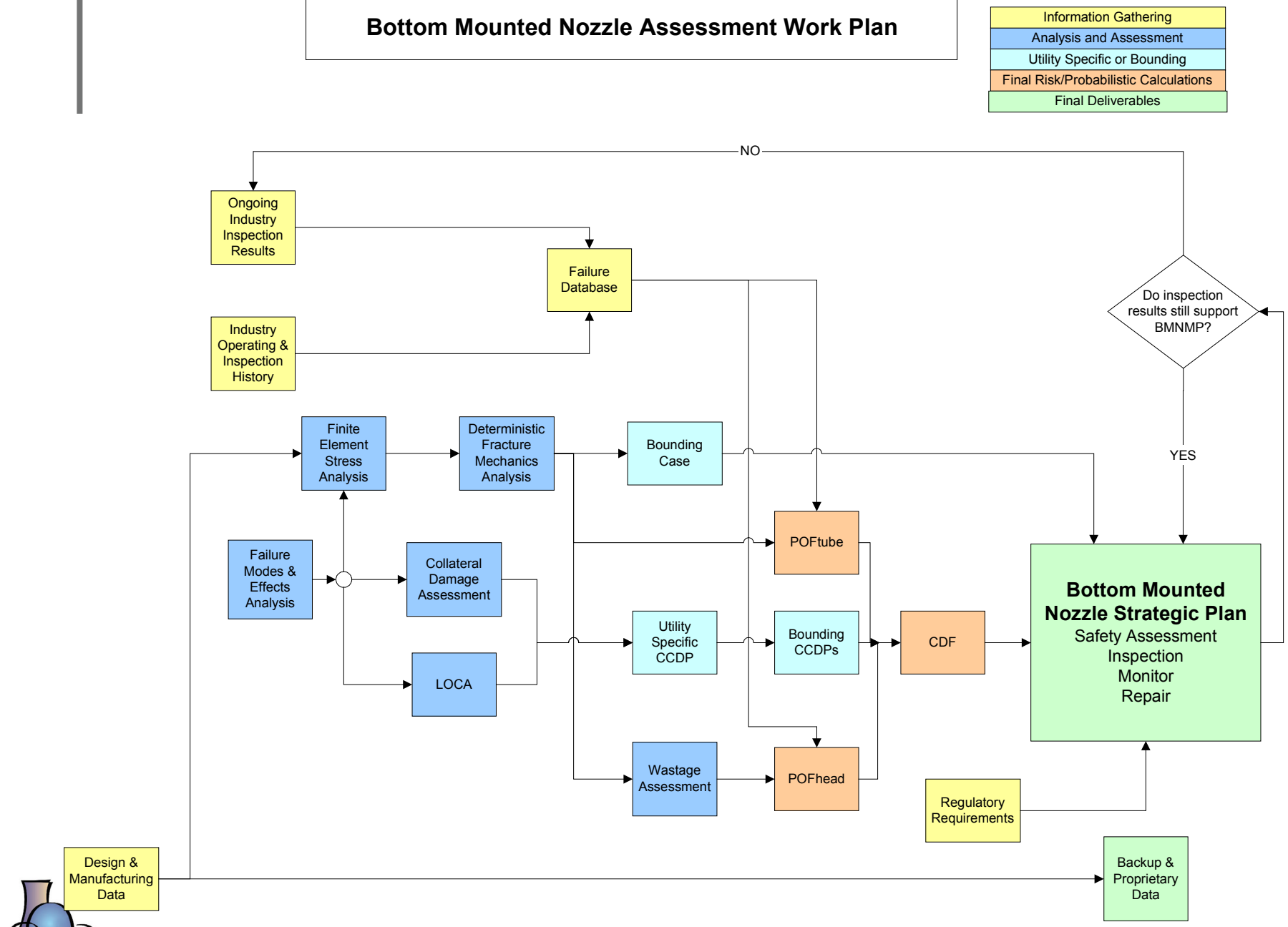


Industry BMN Assessment Plan

- Primary Elements of Plan
  - Failure Modes and Effects Analysis
  - Review of Design and Manufacturing Data
  - LOCA Analysis
  - Stress Analysis & Fracture Mechanics Analysis
  - Collateral Damage Assessment
  - Wastage Assessment
  - Inspection History and Ongoing Results
  - Core Damage Frequency
  - Long Term Inspection Recommendations
  - Repair Recommendations



Bottom Mounted Nozzle Assessment Work Plan

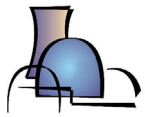


Elements of BMN Assessment Plan

– Failure Modes and Effects Analysis

- To identify all potential failure modes for BMN nozzles

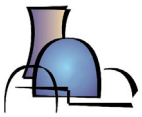
- Provide the cause, effect, detection capability and frequency of occurrence for the failure modes identified in step one.



Elements of BMN Assessment Plan

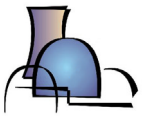
- Review of Design and Manufacturing Data
  - Collect information for subsequent analyses for inspections, repair, and analysis.
    - Examples of information being collected: cold leg temperature, vessel manufacturer, material properties, manufacturing steps, joint design and weld configuration, vessel design and bounding operating loads

- LOCA Analysis
  - Determine the plant response due to loss of a nozzle
  - Subsequently, review whether Emergency Operating Procedures (EOP) should be enhanced.



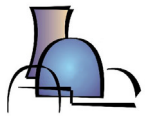
Elements of BMN Assessment Plan (cont'd)

- Stress Analysis & Fracture Mechanics Analysis
  - Determine the level and distribution of stresses that might act to initiate and drive cracking
  - Deterministic Fracture Mechanics will develop an understanding of the flaw tolerance of this component.
  - The fracture mechanics analyses will provide bounding flaw size and the probabilities of tube and head failure



Elements of BMN Assessment Plan (cont'd)

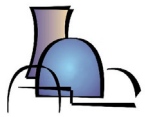
- Collateral Damage Assessment
  - Assuming a BMN failure, determine if damage to adjacent equipment will prevent or hinder safe shutdown of the reactor during this LOCA
    - Various plant layouts will be reviewed to determine what types of equipment can be damaged.
    - Issues to be considered include cavity pressure effects under the vessel, effect of ejection on adjacent nozzles, etc.



Elements of BMN Assessment Plan (cont'd)

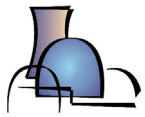
– Wastage Assessment
  - To understand the rate of corrosion associated with leakage due to PWSCC degradation
  - Based on the calculated corrosion rates, inspection requirements will be identified

– Inspection History and Ongoing Results
  - Consolidate information to understand the type and frequencies of BMN inspections worldwide
  - Provide input to the failure database – information will be used to evaluate probability of tube and head failure



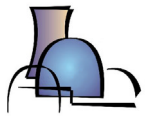
Elements of BMN Assessment Plan (cont'd)

- Core Damage Frequency
  - Consolidate the probability of head failure, probability of tube failure, and the bounding CCDPs to determine the change in core damage frequency due to PWSCC degradation of BMN nozzles
- Long Term Inspection Recommendations
  - Develop a BMN inspection strategy to ensure continued safe operation



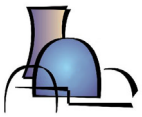
Integrated Industry Inspection Plan

- Purpose
  - Perform selected volumetric inspections while the work progresses to determine long term inspection and monitoring strategy.
  - Gather additional data on extent of the problem.
  - Develop a proactive industry management program that assures safe and reliable operation.



Integrated Industry Inspection Plan

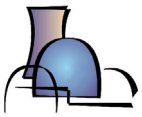
- Multiple plants over several years
  - Spring 2004 to Fall 2005
- Broad cross section of plants
  - No susceptibility ranking for initial choices
  - Based on manufacturer of lower vessel head, NSSS vendor, date of commercial operation
  - 10 year Vessel Examination Schedules



EPRI

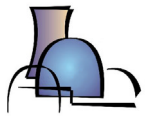
Integrated Industry Inspection Plan

- Potential Inspection Requirements:
  - BMV of lower vessel head
  - UT of nozzle
  - Enhanced visual of j-groove weld
  - ECT of j-groove weld
- As inspection results come in, results will be reviewed to determine if a susceptibility model could/should be developed
- Develop a BMN inspection strategy to ensure continued safe operation



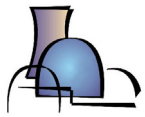
Bottom Mounted Nozzle Repairs

- Define the attributes of an ideal repair.
- Evaluate the current repair options with respect to ideal attributes and define/discuss the various strengths and areas for improvement of each repair technique available.
- Develop new repair technology, if necessary.
- Provide resources for repair technique development efforts as appropriate.



Project Activities

- Spring 2004
  - Visual Exam Results from Fall 2003 Outages
  - First NDE Demonstration Program Results
  - Volunteers identified for Integrated Industry Inspection Plan
- Summer 2004
  - LOCA Analysis
  - Wastage Assessment
- Fall 2004
  - Failure Modes and Effects Analysis
- Spring 2005 – Spring 2006
  - Fracture Mechanics and Deterministic Calculations
  - Core Damage Frequency
  - Final BMN Inspection Strategy
  - Final BMN Assessment



Summary

- Bare metal visual examinations are on-going.
- Multiple volumetric examinations to be completed over next 4 outage seasons.
- NDE Demonstrations are underway
- BMN assessment is progressing
- Propose meeting in March 2004 to review project status and any preliminary results.

- **No immediate safety concern.**