PWROG Flaw Tolerance Evaluation of CE and B&W Pump Nozzle DM Welds

Warren Bamford

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Why We are Here

- To discuss the issue of large diameter cold leg nozzles
- To explain the results of this program, to address those issues
- To gain NRC feedback on the program, so changes can be made, if needed, before completion
- To describe our plans to revise N-770, and obtain NRC feedback on our approach

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Presentation Outline

- Inspection Challenges for CE Large Diameter Nozzles
- Phase 1: Flaw Tolerance Feasibility Study
- CE RC Pump and SI Nozzle Weld Flaw Tolerance Results for Phase 1
- B&W Design RCP Flaw Tolerance Study (Ongoing)
- Phase 2 set up for RCP nozzles only
- Status of Phase 2 of the PWROG program

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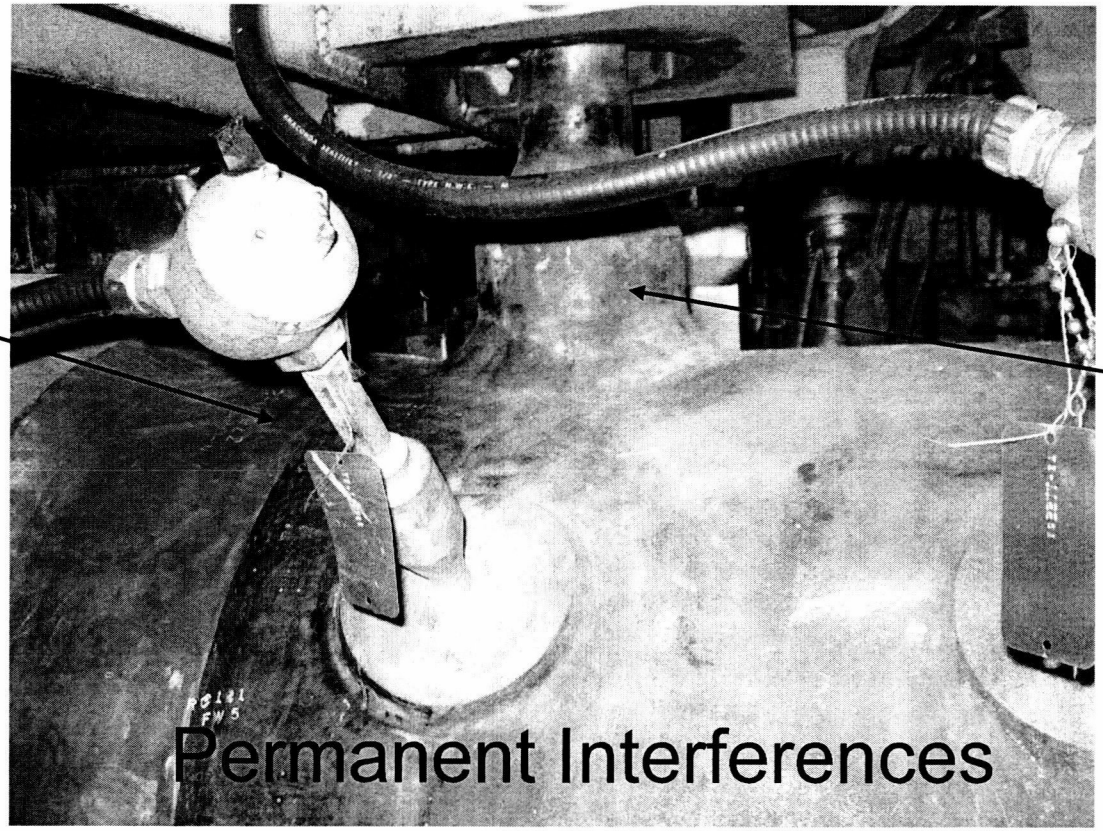
CE Reactor Coolant Pump Nozzle Weld Inspection Issues: an Example

RCP Outlet Nozzle DM Weld



Spray Nozzle

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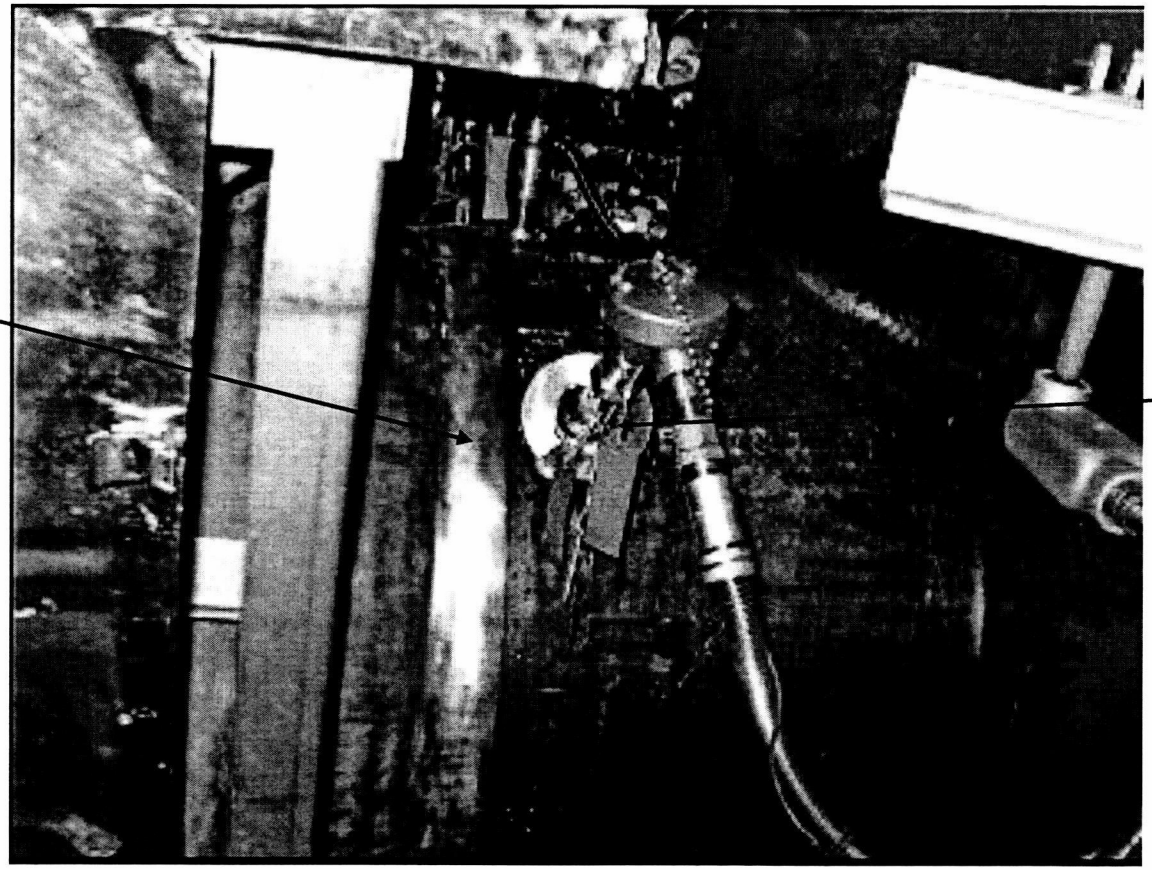
CE Reactor Coolant Pump Nozzle Weld Inspection Issues: another Example

RCP Outlet Nozzle DM Weld



Instrument Nozzle

Permanent Interferences

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Reactor Coolant Pump Nozzle Weld Inspection Issues

- Cast Stainless Steel Safe End (One-side Inspection for CE Nozzles)
- Weld Contour/Nozzle Configuration Limit Inspection
- No Effective Mitigation Solution for large diameter Low Susceptibility Nozzles

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Objectives of Phase 1 Studies

- Low Cold Leg Temperature Results in:
  - Lower probability of crack initiation
  - Slower PWSCC growth rate
- How Flaw Tolerant Are These Nozzle Welds?
  - CE & B&W RC Pump
  - CE Safety Injection
  - B&W High Pressure Injection
- Can one Cycle of operation be justified, if an indication were to be found?

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General Methodology for Phase 1

- Ignore Fatigue Crack Growth Due to Short Duration of service considered (18-24 Months)
- Various circ. extent flaws considered
- Axial Flaw (Aspect Ratio of 2)
- Residual Stress With and Without Inside Surface Weld Repair

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Allowable ASME End-of-Evaluation Period Flaw Depths (% Wall Thickness): CE Design Pumps

Flaw Orientation	Pump Suction and Discharge
Axial	75
Circumferential	73 to 75

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Allowable ASME End-of-Evaluation Period Flaw Depths (% Wall Thickness): B&W Design Pumps

Flaw Orientation	Pump Suction and Discharge
Axial	75
Circumferential ($2\theta = 60°$)	70 to 75

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Maximum ASME End-of-Evaluation Period Flaw Depths: CE Design SI Nozzles

Flaw Orientation	SI Nozzles
Axial	75%
Circumferential	66 to 75%

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Maximum ASME End-of-Evaluation Period Flaw Depths: B&W Design HPI Nozzles

Flaw Orientation	HPI Nozzles
Axial	67 to 75%
Circumferential ($2\theta = 60°$)	75%

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Maximum Acceptable Initial Flaw Depths: CE Designs, Accounting for SCC for one Cycle

		Plant Operation Duration	
		18 Months	24 Months
Nozzle	Flaw Orientation	Acceptable Initial Inside Surface Flaw Size (% through-wall)	Acceptable Initial Inside Surface Flaw Size (% through-wall)
RCP Suction & Discharge Nozzles (with residual stresses and ID weld repair)	Axial	54	48
	Circumferential	57	53
SI Nozzle (with residual stresses and ID weld repair)	Axial	49	41
SI Nozzle (No Inside Surface Weld Repairs)	Circumferential	42	37
SI Nozzle (With Inside Surface Weld Repairs)	Circumferential	12 - 22	5.4 - 11

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Summary: Phase 1

- Large Diameter Cold Leg Nozzles are Highly Flaw Tolerant: supports one cycle of operation with code margins
- Smaller diameter nozzles are not so flaw tolerant, and are also more amenable to mitigation
- Therefore, further work was planned for only the pump nozzles
- Results May Vary somewhat:
  - Residual Stress With and Without Weld Repairs
  - Nozzle Specific Loads

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Summary: Phase 1 (cont.)

- Flaw Tolerance Is A Viable Approach
  - Justify Reduced Examination Coverage and/or larger Inspection Intervals
  - Justify Continued Operations/Delay Repairs
- Beneficial to Low Susceptibility Large Diameter Nozzles With No Effective Mitigation Options
- PWROG is now funding Phase 2, for Pump nozzles only

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Background: Phase 2

Purpose:

- Provide justification for potential changes in inspection requirements for large diameter low-susceptibility nozzles
- Such changes could be made to Code Case N-770
- This would make it consistent with MRP Butt Weld Inspection and Evaluation Guidelines (MRP-139, Rev. 1)
- Provide a basis for continued operation for a period of time, to allow repair methods to be developed as needed

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Project Scope Overview: Phase 2

- Scope:
  - Task 1: Deterministic Fracture Mechanics Analysis
  - Task 2: Advanced Finite Element Crack Growth Analysis
  - Task 3: Fatigue Crack Growth Analysis
  - Task 4: Probabilistic Analysis
  - Task 5: Review of Results with Industry and NRC, and revision of N-770 to be consistent with MRP-139 Rev. 1.

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Flaw Tolerance Option of MRP-139 Rev. 1

- For Circumferential Flaws, If inspection coverage < 90%, and is a result of permanent obstructions, the following requirements ensue, per Section 5.1:
  - For Cold Leg locations, with diameters >14 inches, achieve maximum coverage possible, and perform a flaw tolerance evaluation
- Axial Flaws: Achieve maximum coverage possible, and document the limitations, provided 90% Circ. coverage is achieved

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Option added to MRP-139 Rev. 1: Circumferential Flaw Tolerance

- Assume a through-thickness flaw for the area not inspected (or part through flaw if justified)
- Calculate the critical flaw size for the location
- Show that the time to reach critical flaw size is greater than the time to the next inspection, or adjust the inspection accordingly
- Perform VT-2 Exams of the region every refueling outage
- Evaluate the risk of leakage occurring between inspections, and document leakage monitoring action levels

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Project Activities: Phase 2

- Recently Completed Activities:
  - Kick-off meeting for program held March 12
  - Letter sent to owners requesting leak detection capabilities and details of obstructions
  - FEA Crack computer program additional license obtained (30 March)
  - Database of observed cracking events developed and verified, for probabilistic task
- Project expected to be complete in August 2009

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Summary

- Introduced the issue of large diameter cold leg nozzles
- Explained the goals of the program, to address those issues
- Described our plans to revise N-770
- What is your feedback on the program?
- Comments on our approach to dealing with this issue in the Code?

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