Examination of Dissimilar Metal Welds and Alloy 600 CRDM Head Penetrations---US Industry Update

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Background

- 1984 - DM weld leak at Pilgrim Station (NRC Issued IN-84-41)
- 1991 - CRDM penetration crack at Bugey in France
- 1994 - US industry effort to manage cracking in Alloy 600 CRDM head penetrations based on discovery of cracking in European plants
- 1997 - NRC GL 97-01 Requesting industry response to CRDM cracking
Background (continued)

- 1999 - Formal Qualification for DM Welds Addressed in Rule-Making
- 2000 - Leaks discovered in DM welds in PWRs in Sweden and US due to PWSCC in Alloy 182/82
- 2000-2001 - Discovery of circumferential cracking above the weld in CRDM head penetrations
- 2000-2001 - EPRI MRP program realigned to address PWSCC in head penetrations and PWR pipe butt welds (182/82)
- 2001 - MRP issues guidance for spring 2001 butt weld examinations
- 2002 - Rulemaking takes effect for demonstration of DM weld examinations
The Challenge - Dissimilar Metal Welds

- Complex Configurations
- Metallurgical Interfaces
- Grain Growth Patterns
- Geometry
Dissimilar Metal Weld

τ BWR Core Spray Nozzle-to-Safe End Weld

Field-Fabricated Alloy 600 Safe End
Approx. 0.85"

Alloy 600 Field-Fabricated Safe End
Approx. 1.25" Thick

Alloy 82 Root Pass
Possibly Removed during Repair Welding

Possible Remnants of Shop-Fabricated
Type 304 Safe End, Filler Metal, and Buttering
Attached to an SA-508 Nozzle Forging

SA-508 Nozzle Forging

2.1"

Shop-Fabricated Stainless Steel Clad
VC Summer Hot Leg Weld PWSCC

- Nozzle (SA-508)
- Pipe (304SS)
- Intersecting circumferential crack
- Inconel butter
- Inconel weld
- Weep hole
- Extent of axial crack
IGSCC Examination Approach Not Generally Applicable to DM Weld Examination

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Successful Dissimilar Metal Weld Examinations

- Have required documentation available on-site
- Knowledgeable/Skilled Examiners
- Optimize techniques using mock-ups
- Utilize automated techniques where practical
  - Probe offsets critical
- Compare Examination results
- Independent Data Review
DM Weld Qualification Sample Selection Basis

Issue
- Many different configurations in service
- Neither possible nor necessary to mockup every configuration

Approach
- Include representative configurations, materials, flaw types in a standard set
- Specific situations addressed with additional samples

Sample selection based on
- Number and types of configurations in service
- Experience gained from recent events (e.g., Ringhals, VC Summer)
- Vendor and utility participation in design
- EPRI personnel experience gained from support of spring examinations funded by MRP
- Perceived degree of difficulty
- Essential features evaluated on recently purchased samples
PWR Sample Standard Configurations--Example

Outlet Field Weld Configuration
PWR Sample Standard Configurations--Example

Outlet Shop Weld Configuration
Other Sample Design Features

- Fabricated in similar fashion as the field components (e.g. welding type, weld direction, repair processes)
- Weld repair areas included with and without flaws associated with them
- Flaw fabrication methods in use to date have been shown to produce realistic flaws in most cases, especially for flaw detection
  - Efforts underway to evaluate alternative flaw implantation processes such as HIP (Hot Isostatic Pressing) to provide more flexibility
  - Responses of fabricated and actual cracks are compared as opportunities are presented to evaluate and improve flaw fabrication processes
- The flaws/samples are being designed specifically to qualify procedures and personnel for ultrasonic examination and may not be appropriate for qualification of other methods
Results of DM Weld Sample Evaluations

- Safe-end material and nozzle material have very little effect on sensitivity of examination (508, 316, 304 or Alloy 600)
  - Greater effects noted if beam is initiated on top of weld material versus base material
- Orientation of flaw has much greater effect than base material type
- External taper that precludes the beam from reaching the examination volume has significant effect
- Procedure parameters (e.g., instrument settings, search unit selection and other essential parameters) did not vary greatly and can be defined in a criteria based procedure
  - Not many options to choose from
- Site Specific Mock-Ups will be required, but can be limited in number
CRDM Head Penetrations

† Recent significant events
  – Leaking penetrations discovered in 2000 & 2001 produced small amounts of boric acid deposits on top of the head
  – OD, circumferential cracking detected above the weld
  – Requires revisiting industry position developed in response to GL 97-01

† NRC Bulletin 2001-01 August 3, 2001 requests plants to provide information on how they intend to address the structural integrity of head penetrations

† EPRI MRP Program is taking the industry lead in addressing this issue
The Challenge - CRDM Head Penetrations

- Qualification program in place since 1994 for ID flaws
- OD flaws are different
- Flaw shape/orientation/location
- Presence of weld

Pulse-echo (PE) UT Method
CRDM Head Penetrations

τ EPRI MRP Inspection Committee tasks

– Develop visual inspection training package
  • Awareness that small amounts of boric acid can be expected
  • Examples of results from Oconee and ANO inspections
  • Procedure linked to still photos and videos to illustrate what to expect and how to discriminate leak sources

– Develop volumetric examination qualification program
  • Step 1 - Fall 2001 demonstrations
    – Detection of large flaws in the base metal
    – Weld metal NDE under evaluation
  • Step 2 - 2002 inspections
    – Flaw sizing
    – Wider range of flaw types and inspection volumes
Conclusions

Recent industry events are setting priorities for NDE development and demonstration activities
- Alloy 600 CRDM head penetration cracking
- Alloy 182/82 PWSCC in PWR piping
- Rulemaking for qualification of dissimilar metal weld ISI