Reactor Pressure Vessel Head Degradation

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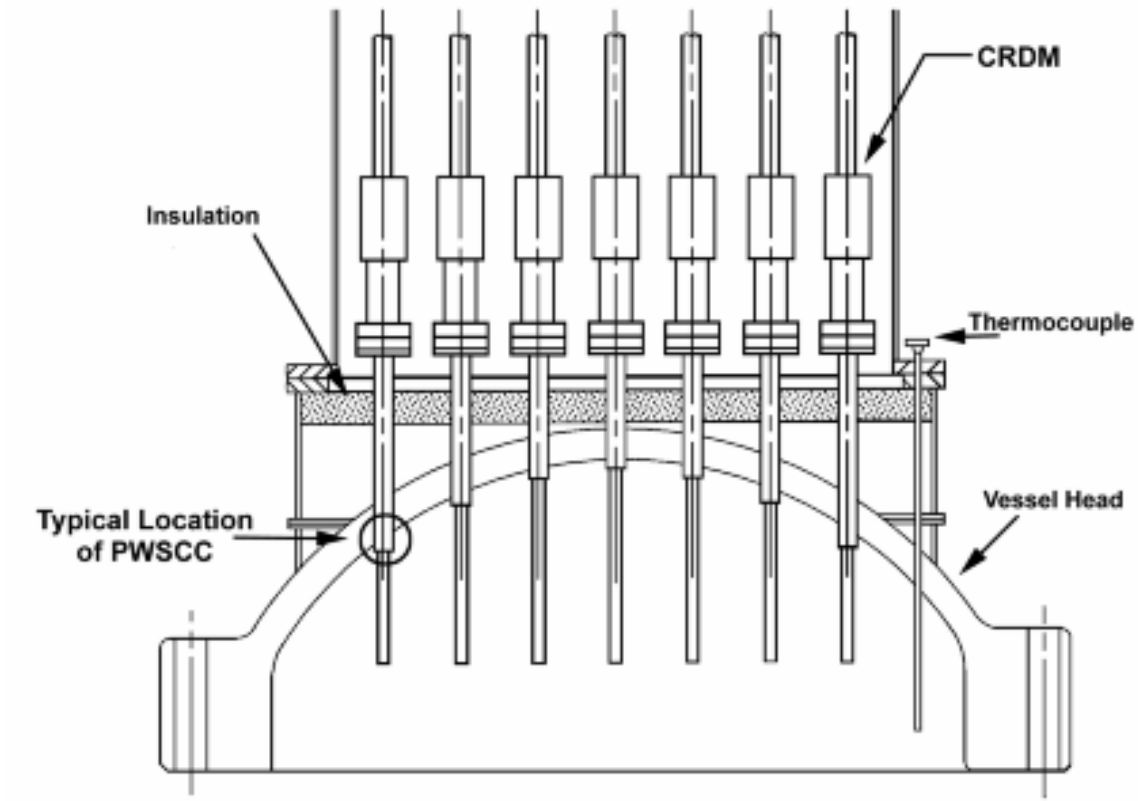
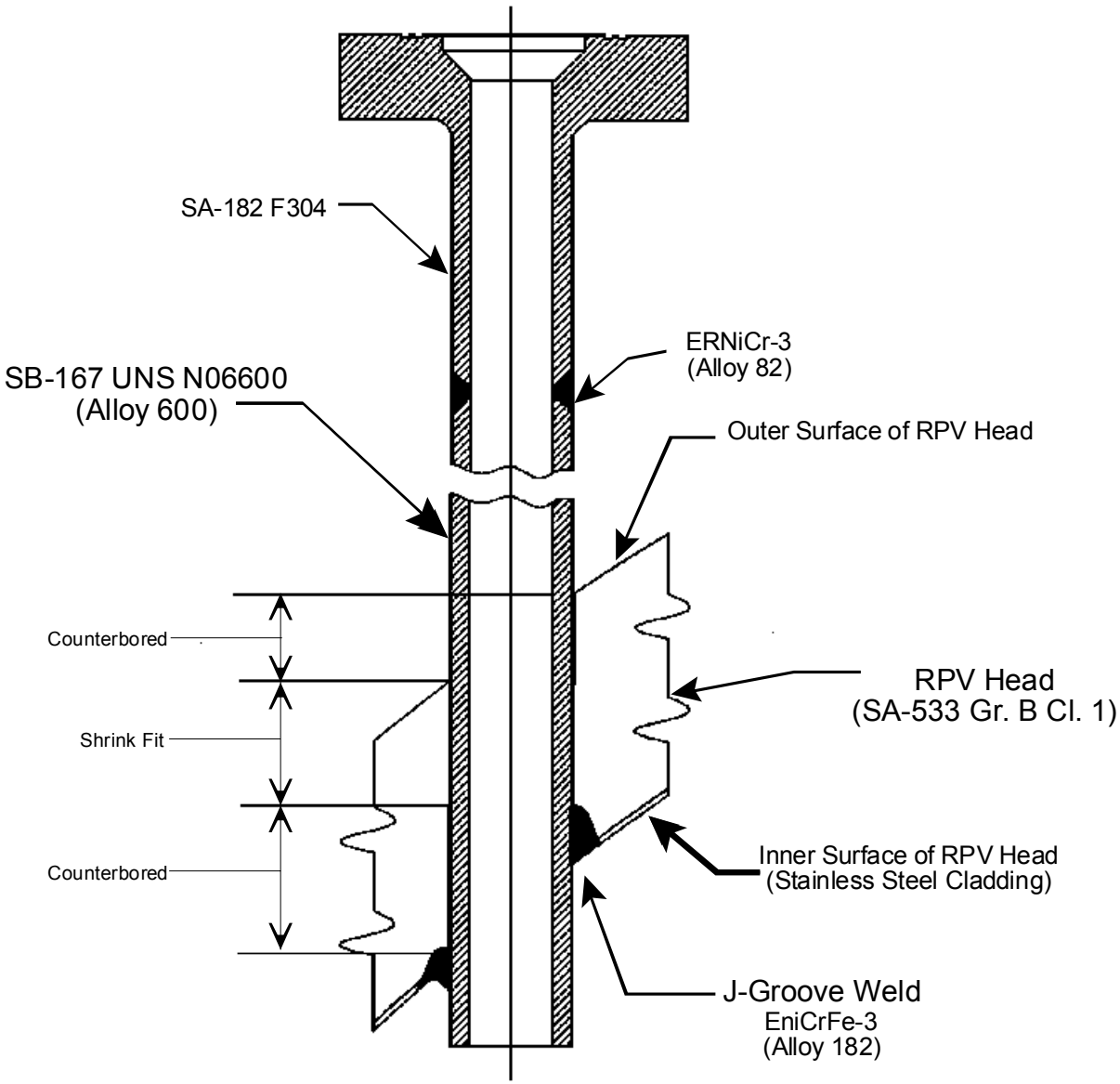
Background

- 1988—NRC Generic Letter 88-05 requests licensees to monitor, inspect, and prevent boric acid corrosion on pressure boundary surfaces
- 1991--First cracking of CRDM nozzles identified in an international nuclear plant
- 1997—NRC Generic Letter 97-01 requests
  - Description/plans of CRDM nozzle inspection and results
  - Analysis if augmented inspection is not performed
  - Description of any resin intrusions that exceeded EPRI primary water chemistry guidelines


CRDM
Insulation
Thermocouple
Typical Location
of PWSCC
Vessel Head


SA-182 F304
ERNiCr-3
(Alloy 82)
SB-167 UNS N06600
(Alloy 600)
Outer Surface of RPV Head
Counterbored
Shrink Fit
Counterbored
RPV Head
(SA-533 Gr. B Cl. 1)
Inner Surface of RPV Head
(Stainless Steel Cladding)
J-Groove Weld
EniCrFe-3
(Alloy 182)

Background

- **February 2001—Oconee Unit 3 CRDM nozzle inspection per NRC Generic Letter 97-01**
  - **Discovers 9 cracked & leaking CRDM nozzles**
  - **Circumferential cracks in 3 of the 9 degraded nozzles**
  - **2 cracks are 165 degrees in circumferential extent and through-wall**

- **April 2001—Oconee Unit 2 CRDM nozzle inspection**
  - **Discovers 4 cracked & leaking CRDM nozzles**
  - **Circumferential crack in 1 of the 4 degraded nozzles**

- **All Oconee cracks were repaired**

Background

- **August 2001--NRC Bulletin 2001-01 requests:**
  - **Susceptibility ranking of vessel head penetration nozzles from all plants**
  - **Inspection plans for vessel head penetration nozzles on the basis of susceptibility ranking**
  - **Description of post-inspection vessel head penetration nozzle leakage and cracking**

Bulletin 2001-01: Susceptibility Criteria

- **Plants with CRDM nozzle cracking or leakage: expected to perform qualified volumetric exam by end of 2001**
- **Plants with High Susceptibility (within 5 EFPY of Oconee 3): expected to perform qualified visual exam by end of 2001**
- **Plant with Moderate Susceptibility (5 to 30 EFPY of Oconee 3): expected to perform effective visual exam at the next refueling outage**
- **Plant with Low susceptibility (more than 30 EFPY of Oconee 3): no additional actions required**

INSPECTION RESULTS: CRACKING/LEAKAGE HISTORY AND HIGH SUSCEPTIBILITY PLANTS (4/24/02)

Plants	Most Recent Inspection					
	Date	Method & Scope	Summary of Cracked or Leaking CRDM Nozzles			
			Leaking	Cracked	Circumferential Nozzle Cracks	Number Repaired
Oconee 1	11/2000	Qualified Visual - 100%	1★	1★	0	1
Oconee 3	02/2001	Qualified Visual - 100%	9	9	3	9
ANO-1	03/2001	Qualified Visual - 100%	1	1	0	1
Oconee 2	04/2001	Qualified Visual - 100%	4	4	1	4
Robinson	04/2001	Qualified Visual - 100%	0	0	0	0
North Anna 1	09/2001	Qualified Visual - 100%★★	0	8	0	0
Crystal River 3 ★★★	10/2001	Qualified Visual - 100%★★	1	1	1	1
TMI-1	10/2001	Qualified Visual - 100%	5★	8★	0	6
Surry 1	10/2001	Qualified Visual - 100%★★	(4)	10	0	6
North Anna 2	10/2001	Qualified Visual - 100%★★	3	3	0	3
Surry 2	11/2001	Qualified Visual - 100%★★	0	0	0	0
Oconee 3	11/2001	Qual. Visual - 100% (UT of 100%)	5	7	1	7
D. C. Cook 2	1/2002	Qual. Visual, ECT, UT - 100%	0	0	0	0
Millstone 2 ★★★	2/2002	UT Examination - 100%	0	3	0	3
Davis-Besse	2/2002	UT Examination - 100%	3	5	1	3 (5)
Oconee 1	3/2002	Qualified Visual - 100%	1	2	0	2

★ Thermocouple nozzles also cracked/leaking: Oconee 1 (5 out of 8), TMI 1 (8 out of 8)

★★ Pending acceptability of licensee's supplemental response

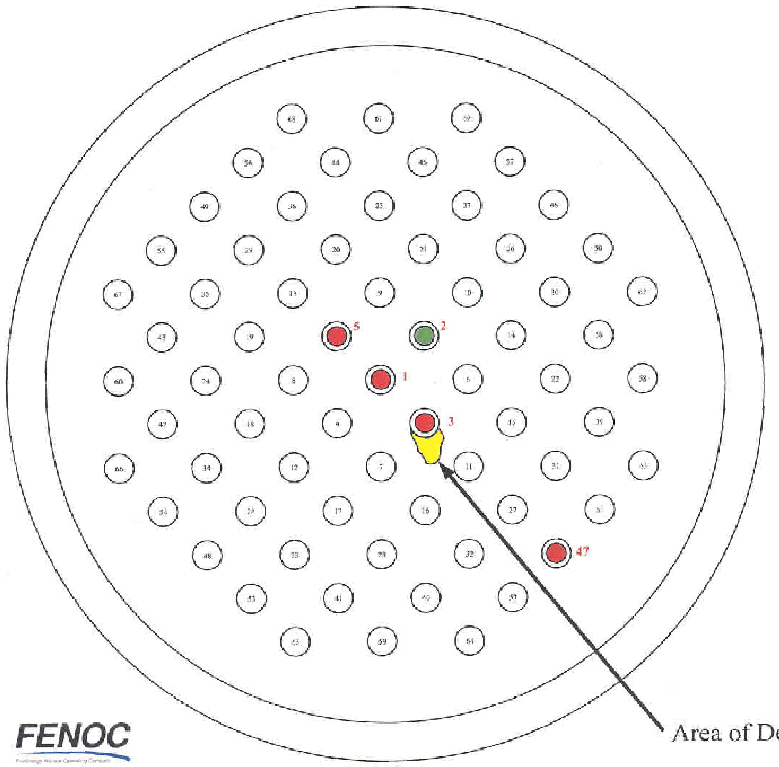
★★★ MODERATE susceptibility plants.

Moderate susceptibility plants with no evidence of boric acid deposits: ANO 2, Beaver Valley 1 & 2, Calvert Cliffs 1, Farley 1, Kewaunee, Palo Verde 2, Point Beach 2, Prairie Island 2, Salem 2, St. Lucie 2, Turkey Point 3 & 4, and Waterford 3

Davis Besse RPV Head Inspection

- **February 2002---Davis Besse visual inspection of RPV head per NRC Bulletin 2001-01**
- **UT inspection of all 69 CRDM nozzles**
  - **5 nozzles with indications (3 with throughwall cracks)**
  - **Cavity found adjacent to nozzle #3**
  - **Degraded area near nozzle #2**
  - **Significant boron and corrosion deposits on the RPV head**

Findings



Framatome ANP Inc. completed UT examination on all 69 CRDM nozzles using the under-head circumferential probe and subsequent confirmatory testing using the top-down UT on suspect nozzles

Nozzle with Axial Indication -

Nozzle with Axial and Circumferential Indication –

FENOC

6

NRC Bulletin 2002-01

- March 2002---NRC Bulletin 2002-01
- Within 15 days--
  - Summarize RPV head inspection and maintenance program
  - Evaluate potential degradation conditions
  - Plan for future inspections
  - Justify continued operation
- Within 30 days after inspection—submit results of inspection
- Within 60-days– submit boric acid corrosion prevention program

Responses to Bulletin 2002-01

- **General observations:**
  - **Most licensees correct leaks**
  - **Most licensees do inspections under insulation following "significant" leakage**
  - **No one is in same category as Davis-Besse**
  - **Many licensees have performed bare metal inspections**
  - **Almost all licensees have left minor debris and isolated chunks of boron deposit on the RPV head**

NRC Augmented Inspection Team Findings at Davis Besse

- **Containment Air Cooler Clogging**
  - **Increase in boron deposit on cooling coils**
  - **Change in boron deposit color**
- **Containment Radiation Monitor Filters**
  - **Filters clogged with corrosion products from reactor coolant leakage**
- **Boric Acid Corrosion**
  - **Nozzle flange leakage**
  - **RPV head boron and corrosion deposit not removed**

Root Cause Investigation

- Sequence of events leading to 2002
- Contributors to degradation
- Crack propagation
- Leak rates through crack
- Boric acid corrosion and corrosion rate

Contributors to Degradation

- **Degradation caused by primary water stress corrosion cracking (PWSCC)**
  - **Susceptible material-- Alloy 600 in nozzles and Alloy 82/182 in J-groove welds**
  - **Affected nozzles fabricated from heat M3935**
  - **High tensile stress adjacent to J-groove weld**
  - **Aggressive environment—high head operating temperature**

NRC's Actions

- **Augmented Inspection Team at Davis Besse**
- **Davis-Besse Lessons Learned Task Force**
- **Inspection Manual Chapter 0350 Panel**
- **Review licensee's root cause analysis**
- **Review responses to NRC Bulletin 2002-01**

Current status of Davis Besse

- The licensee decided to use RPV head from Midland plant
- Certify Midland RPV head per NRC regulation and industry codes
- Framatome is studying degraded section of original RPV head
- NRC Region III followup inspections
- NRC Manual Chapter 0350 Restart panel formed

Generic Implications

- **Davis Besse root cause evaluation provided qualitative assessment of probable corrosion mechanisms and sequence of events**

- **Did not provide quantitative information regarding when and under what conditions a through-wall leak would lead to vessel head corrosion**

Generic Implications

- **Is there a period of time following initiation of a through-wall leak in which NRC can be assured no unacceptable reactor vessel head corrosion will occur?**

- **Without knowing this, NRC has no assurance that visual inspections for through-wall leaks will prevent unacceptable reactor vessel head corrosion**

- **What is an acceptable amount of reactor vessel head corrosion?**

Generic Implications

- **Industry needs to provide NRC with sufficient information to justify why visual inspection methods and inspection intervals will assure no unacceptable reactor vessel head corrosion**
- **Until that information is received, NRC staff is reevaluating acceptability of visual inspections to detect CRDM nozzle cracking**
- **NRC staff is preparing further guidance**

Website of Presentation Slides

- www.nrc.gov/reactors/operating/ops-experience/vessel-head-degradation/public-meetings.html
- **Or,**
- **Go to www.nrc.gov**
- **Click on Nuclear Reactors (top of the page)**
- **Click on Operating Reactors (scroll down)**
- **Click on Operational Experience (scroll down)**
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