Palo Verde Unit 3
Bottom-Mounted Instrument (BMI)
Relief Request 52
Pre-submittal Meeting

April 2, 2014

Palo Verde Participants/Attendees

Ken House*	Director, Design Engineering
Tom Weber*	Department Leader, Nuclear Regulatory Affairs
Mike Hooshmand	Department Leader, Mechanical/Civil Design Engineering
Doug Hansen	Senior Consulting Engineer, Program Engineering/Principal Level III
Winston Borrero	Senior Consulting Engineer, Design Engineering
Ed Fernandez*	Senior Metallurgist, Engineering Programs / EPRI MRP Inspection Chairman
Gene Montgomery*	Senior Engineer, Design Engineering (Mechanical NSSS)
Doug Killian	Technical Consultant, AREVA
Ashok Nana	Supervisory/Advisory Engineer, AREVA
Delbert Elkinton	Senior Regulatory Affairs Consultant

NOTE: * identifies presenters

Introduction

Tom Weber
Department Leader
Nuclear Regulatory Affairs

Agenda

- Introduction ..... Tom Weber
- Testing/Examination Results ..... Ed Fernandez
- Summary of Analyses ..... Gene Montgomery
- Relief Request #52 ..... Tom Weber
- Closing Comments ..... Ken House

Desired Meeting Outcomes

- Awareness/understanding of:
  - Actions completed since RR#51
    - Repair of nozzle
    - Destructive examination and metallurgical results
    - Engineering analyses
  - Relief Request #52

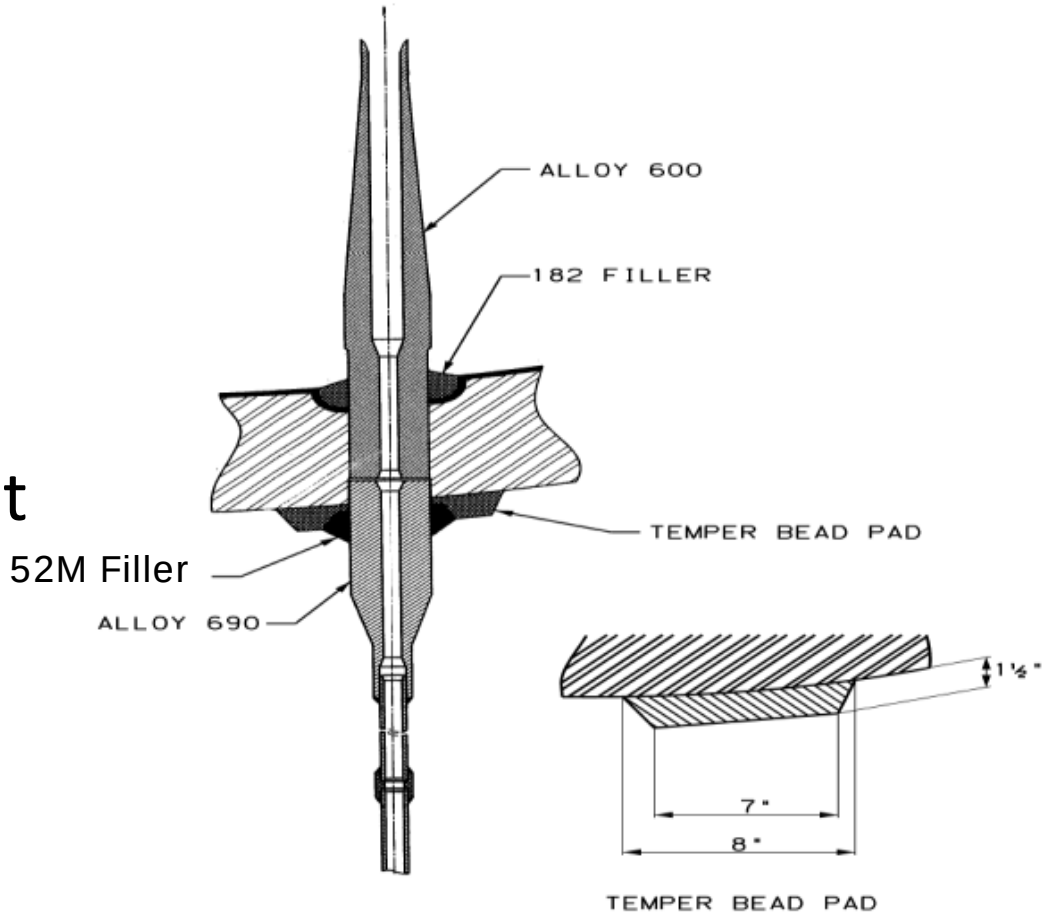
- APS/Palo Verde understands NRC questions related to this issue

Unit 3 Reactor Vessel BMI Nozzle #3

2010	2013 As Found	2013 As Left
		

Half-Nozzle Repair

- Industry proven permanent repair
- Weld pad with new A690 nozzle
- ASME Code compliant
- Relocated pressure boundary



APS Approach

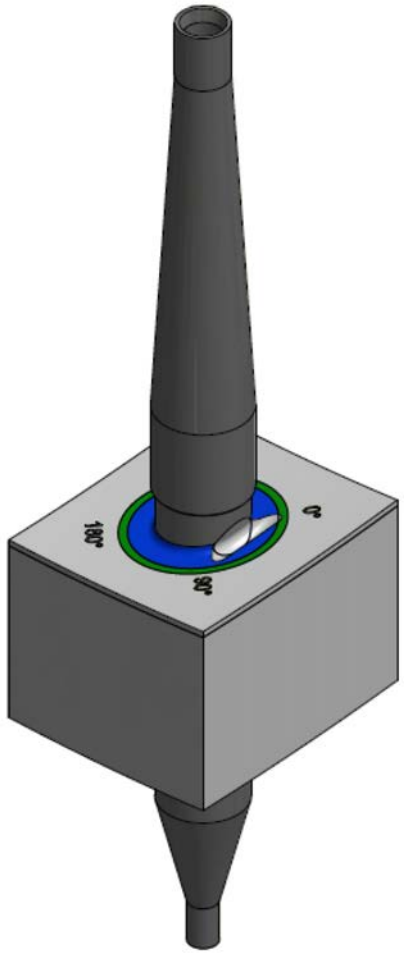
- Two separate relief requests
  - RR#51 for one operating cycle
  - Boat sample results not available
  - Plant specific analysis not available
- NRC verbal approval on November 21
- RR#52 planned for May 2014

Boat Sample Destructive Exam (DE) and Metallurgical Results

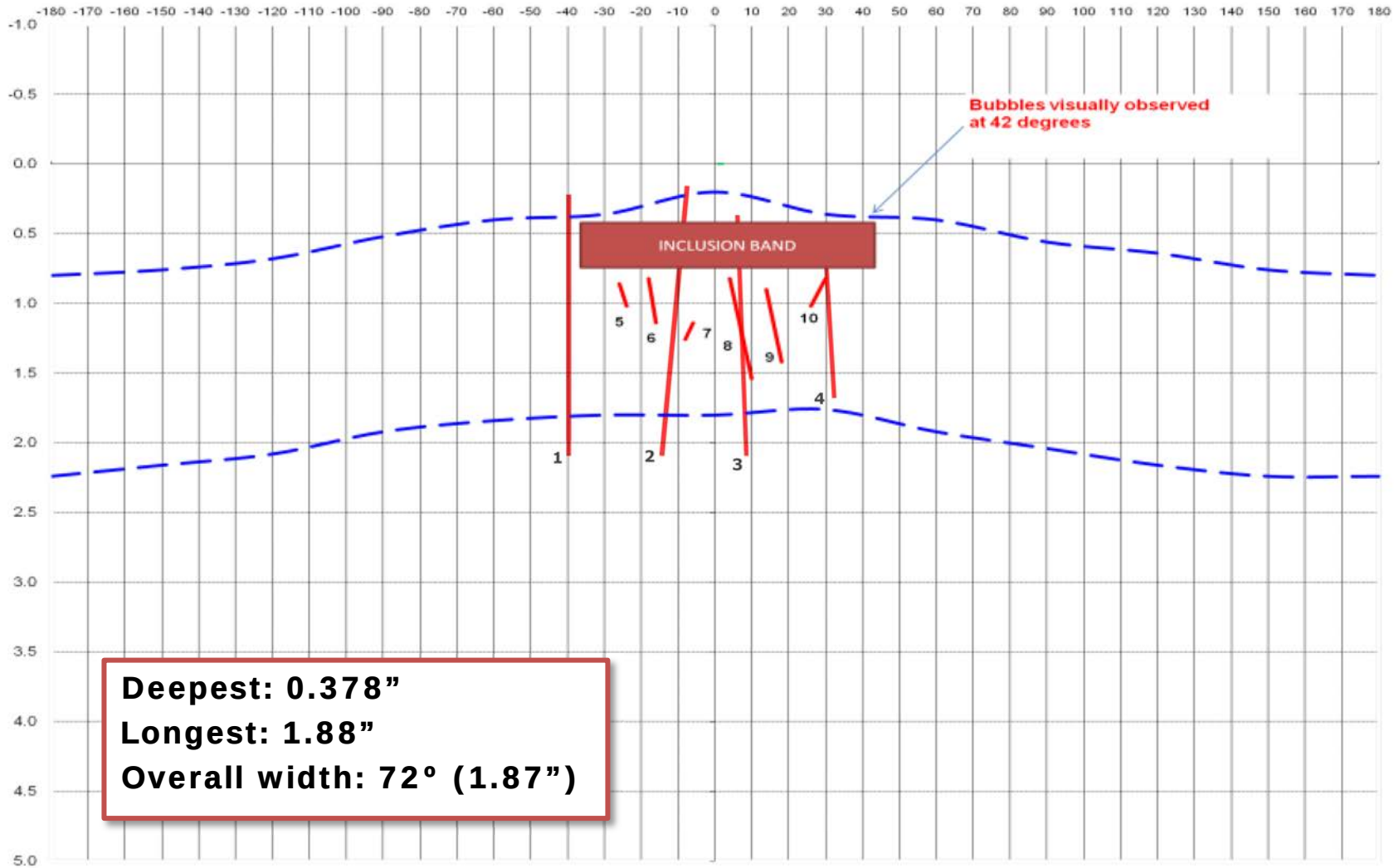
Ed Fernandez
Senior Metallurgist, Engineering Programs
EPRI MRP Inspection TAC
Chairman

Collection of Boat Sample

- Targeted Areas
  - RCS leak entrance point
  - Weld defect
  - Axial crack
  - Area of high reflectivity
  - Unaffected Alloy 600 and 182 material



BMI Nozzle #3


Bubbles visually observed at 42 degrees
INCLUSION BAND
1
2
3
4
5
6
7
8
9
10
Deepest: 0.378”
Longest: 1.88”
Overall width: 72° (1.87”)

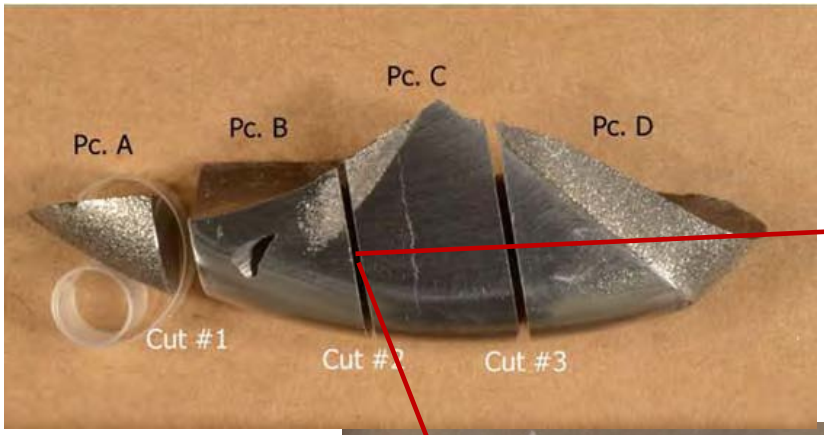
Destructive Evaluation Plan

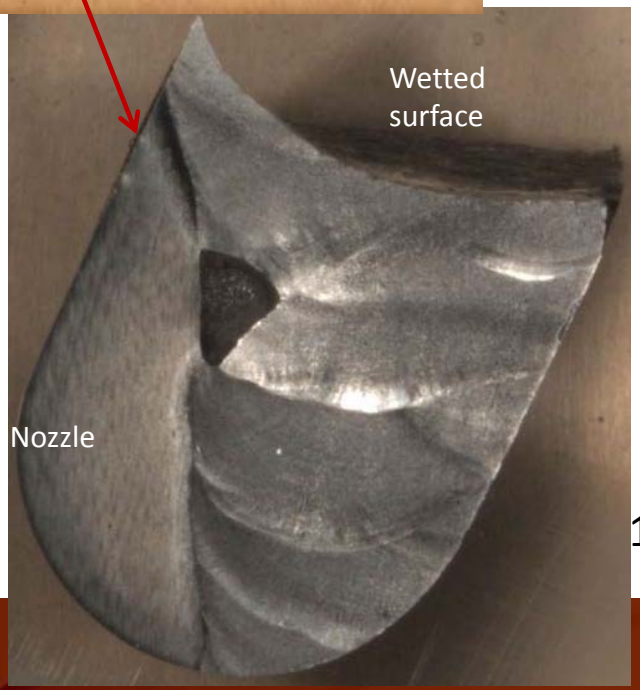
Boat Sample

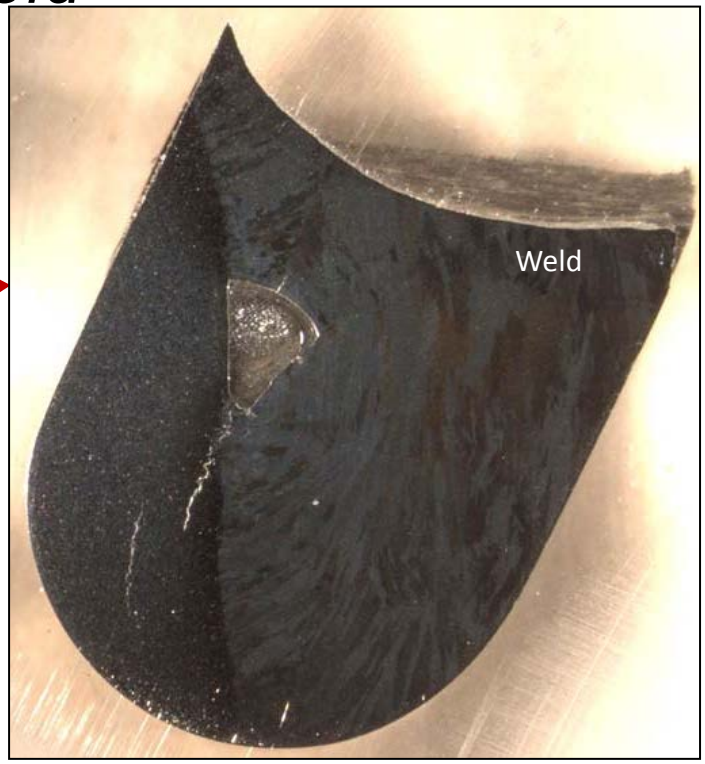
- How did cracking begin?
- Propagation mechanism(s) of the observed cracks?
- Nature, extent, and role of the weld inclusion zone?
- Assembled Industry Team
  - EPRI, Westinghouse, AREVA, Industry Peers
- Metallurgical Analysis
  - Visual inspections
  - X-ray radiography
  - High Resolution Replication
  - Scanning Electron Microscopy (SEM)
  - Energy Dispersive Spectroscopy (EDS)
  - Metallography

Sectioning (Piece B)

Boat Sample – Investigate Void







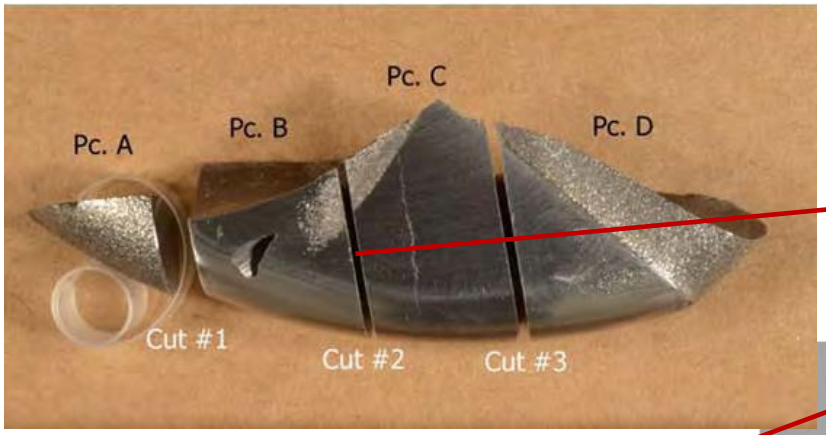
Piece B
Cut #2

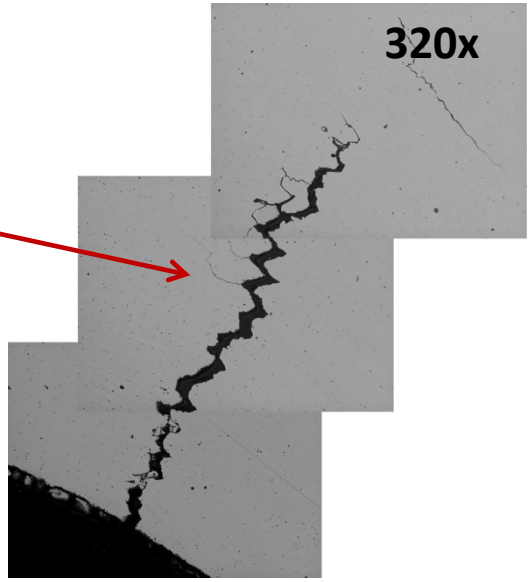
As-polished

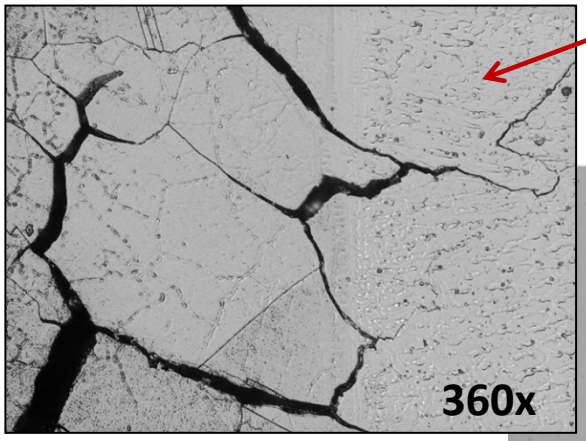
10% oxalic etch

Sectioning (Piece B)

Boat Sample – Investigate Void





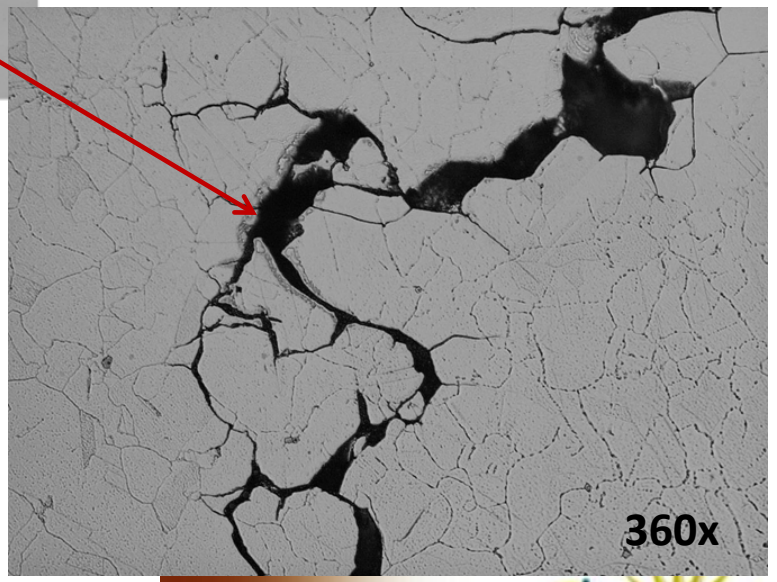


Tube

Weld

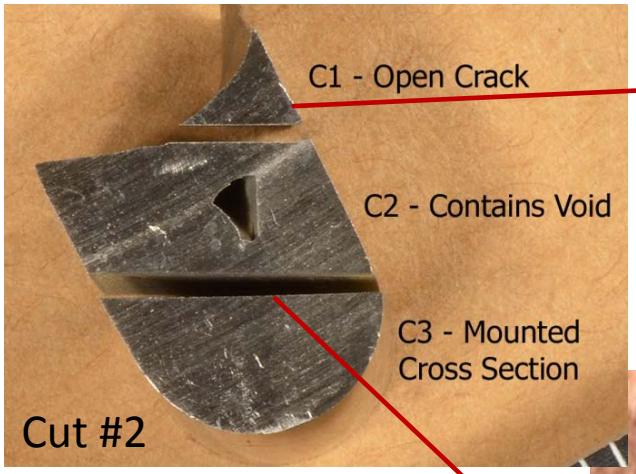
25x

Piece B
Cut #2

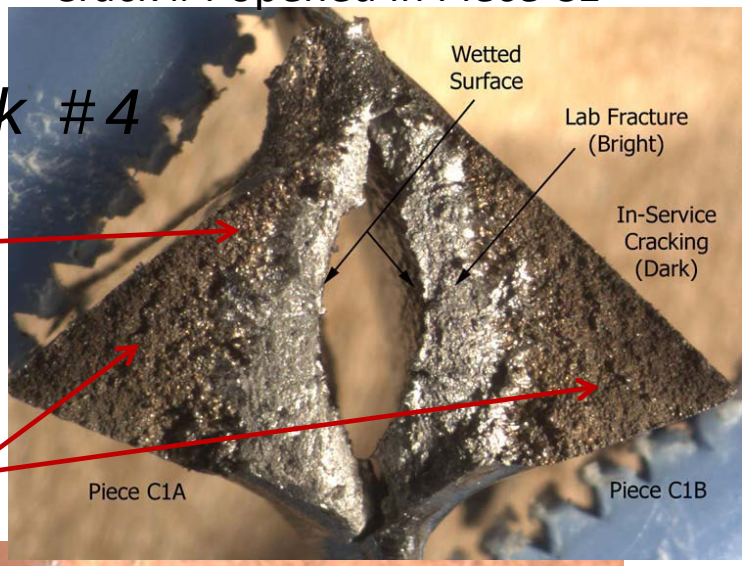


Sectioning (Piece C)

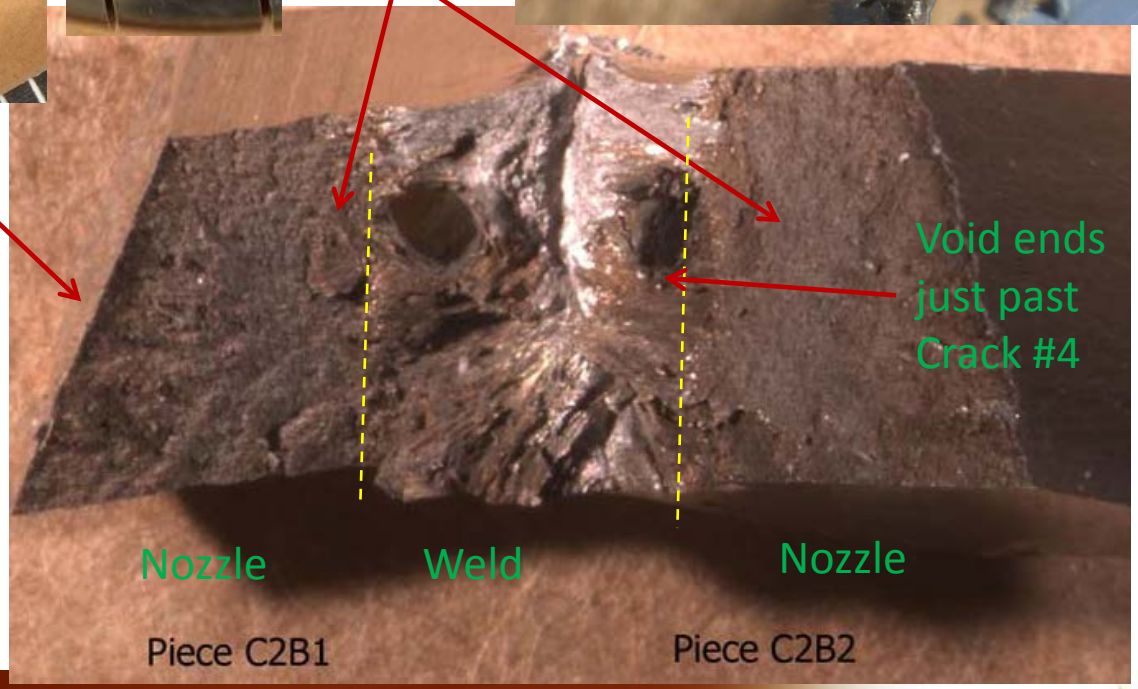
Boat Sample – Investigate Crack #4



Crack #4 opened in Piece C1



PWSCC



Destructive Exam - *Observations*

- Two crack types identified
  - Single weld solidification crack - in top of void
  - All other observed cracks are characteristic of PWSCC
- All cracks were found to be associated with the void
- Wetted-surface-connected crack not found in boat sample
- No detrimental residual chemicals

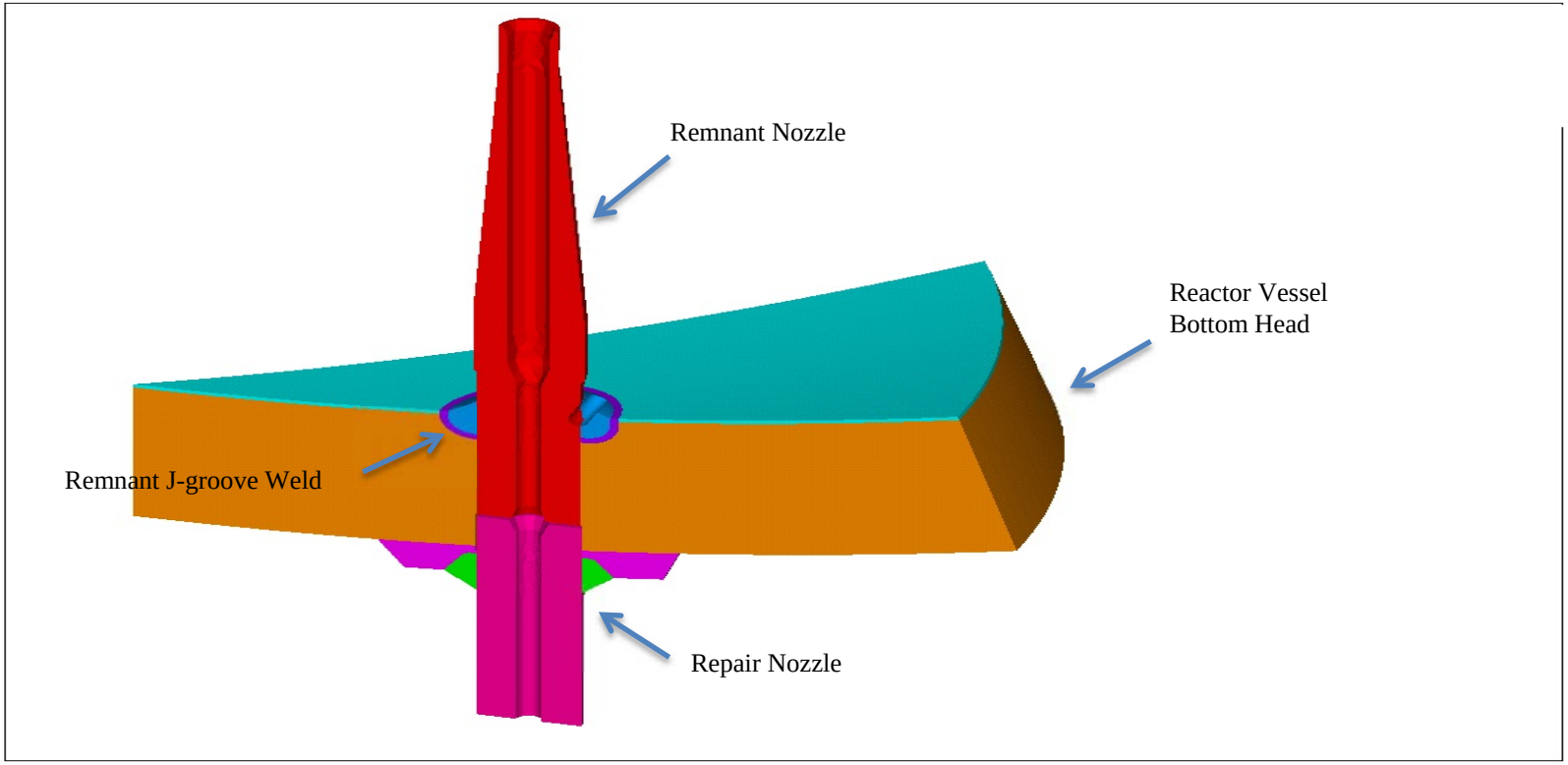
Stress and Supporting Analyses

Gene Montgomery
Sr. Engineer, Design Engineering

Unit 3 BMI Nozzle #3 Repair Analyses and Reports

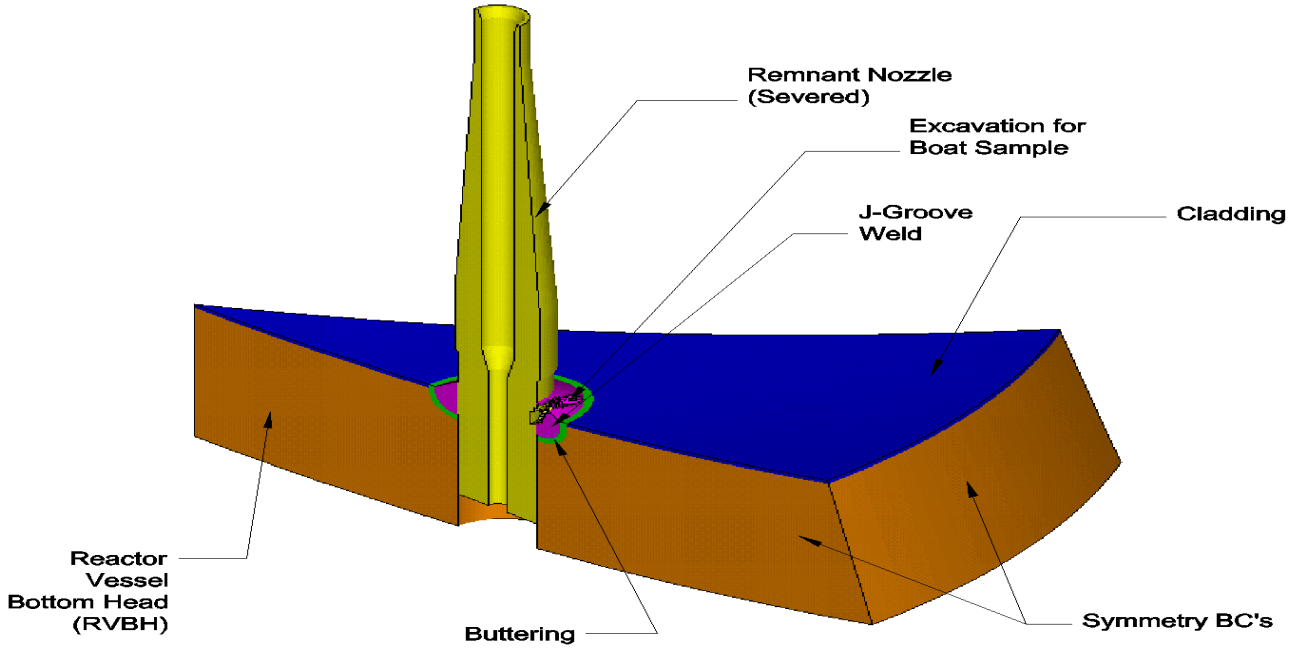
- ASME Code Section III analysis
- Welding residual stress analysis
- RPV shell J-groove weld crack growth analysis
- Remnant nozzle crack growth analysis
- Remnant nozzle structural & frequency analysis
- Corrosion assessment report
- Loose parts evaluation report

ASME Section III Class 1 Stress Analysis



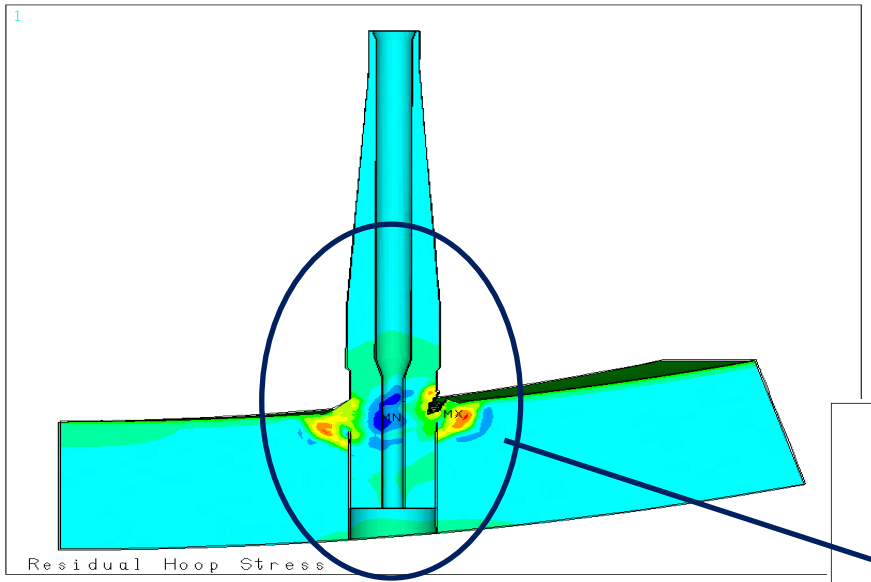
- All ASME Section III Class 1 stress and fatigue requirements are met for the new primary pressure boundary repair nozzle
- Results from operating transient cycles applied to this model are input into the remnant J-groove weld crack & remnant nozzle crack growth analysis

Welding Residual Stress Analysis



- Boat sample removal, remnant nozzle severance, and a hypothetical repair weld sequence in accordance with MRP-287 are included in the model
- Welding residual stresses are input to the remnant J-groove weld crack & remnant nozzle crack growth analysis

Residual Hoop Stress (PSI) at 70° F



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JAN 17 2014
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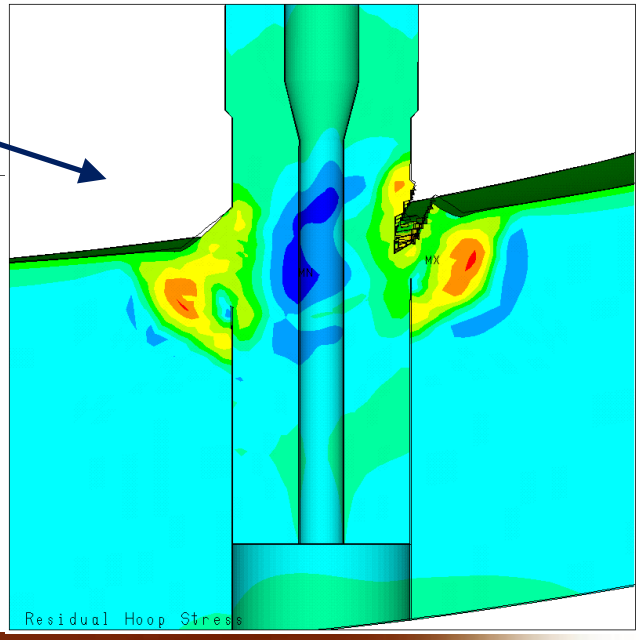

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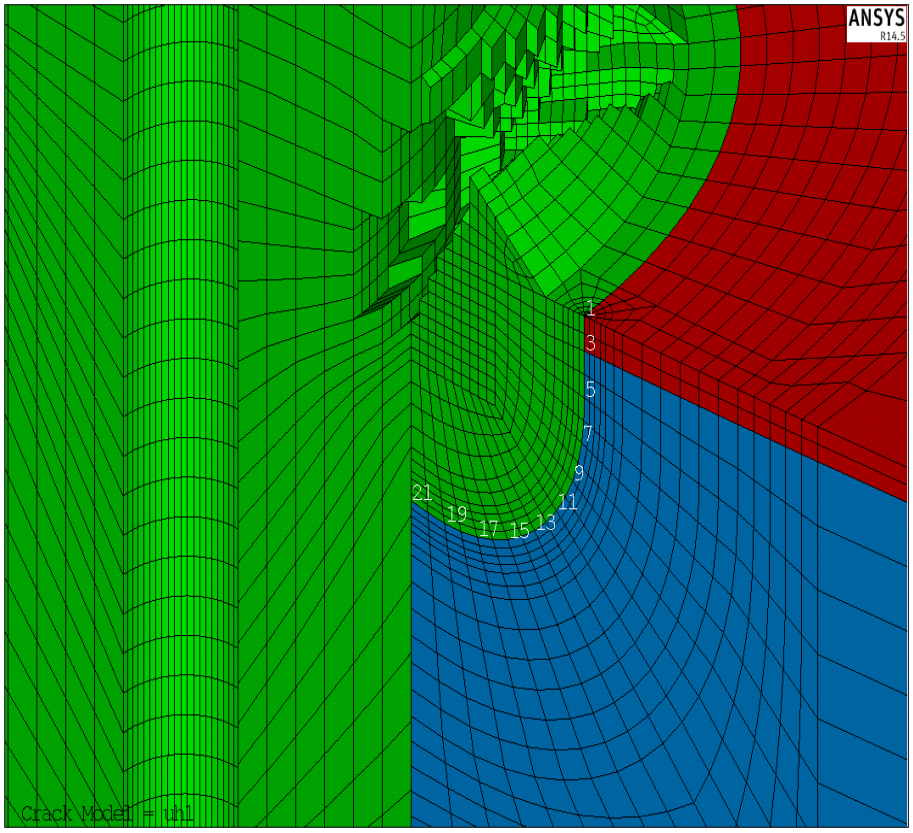
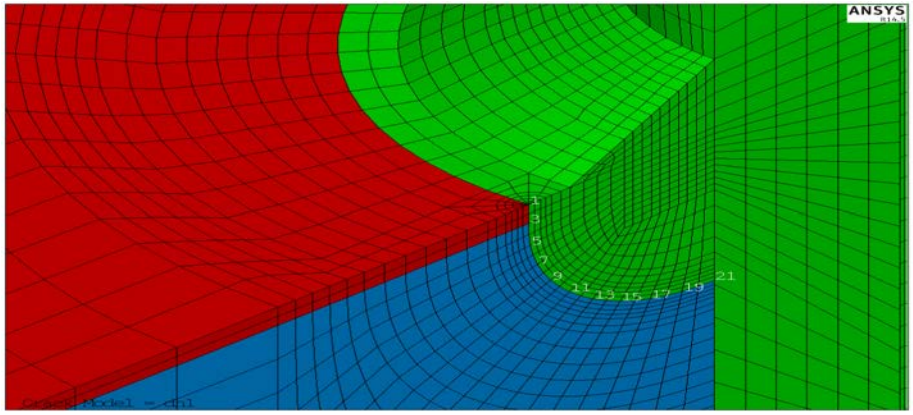
-10614
414
11441
22469
33496
44524
55551
66579

RPV Shell J-Groove Weld Crack Growth Analysis

- 3-D explicit ANSYS finite element radial-axial crack tip models
- Flaw Stability and Crack Driving Force EPFM criteria are met using lower bound J-R curve (from RG 1.161) and safety factors consistent with RR 51.

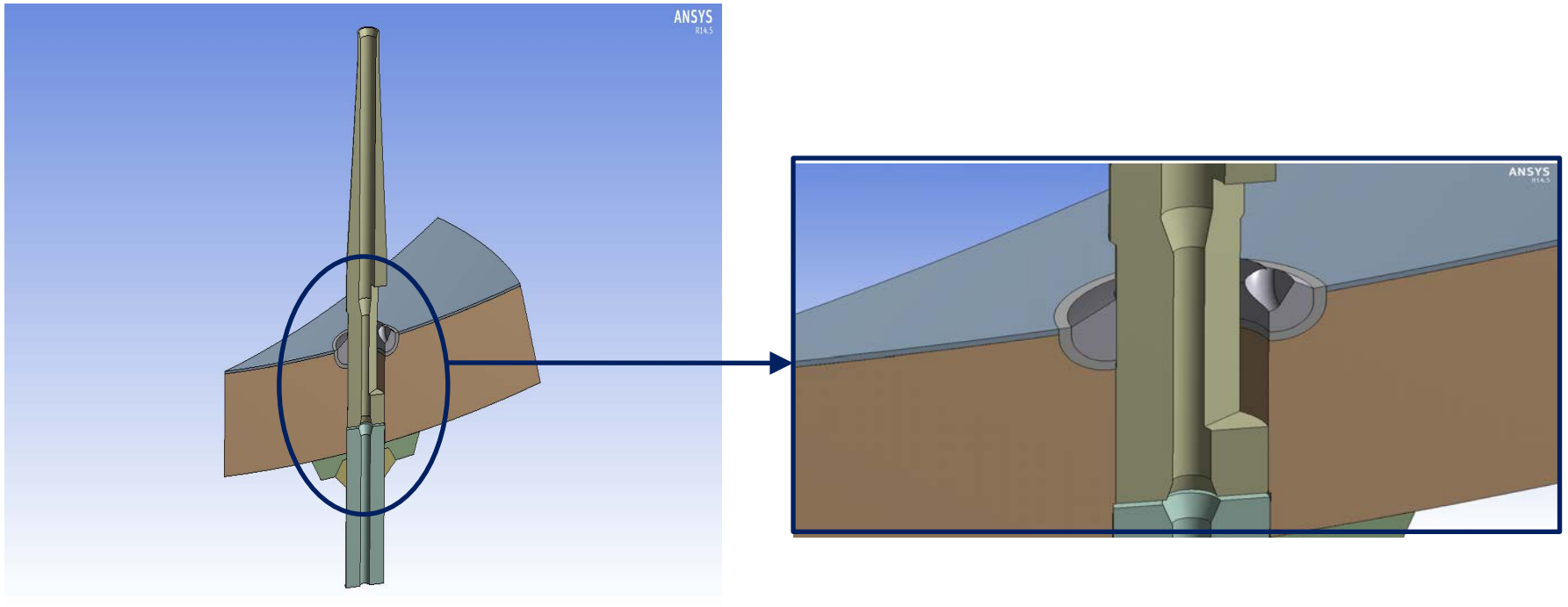
Uphill Crack Model





Downhill Crack Model

Remnant Nozzle Structural Integrity and Frequency Analysis

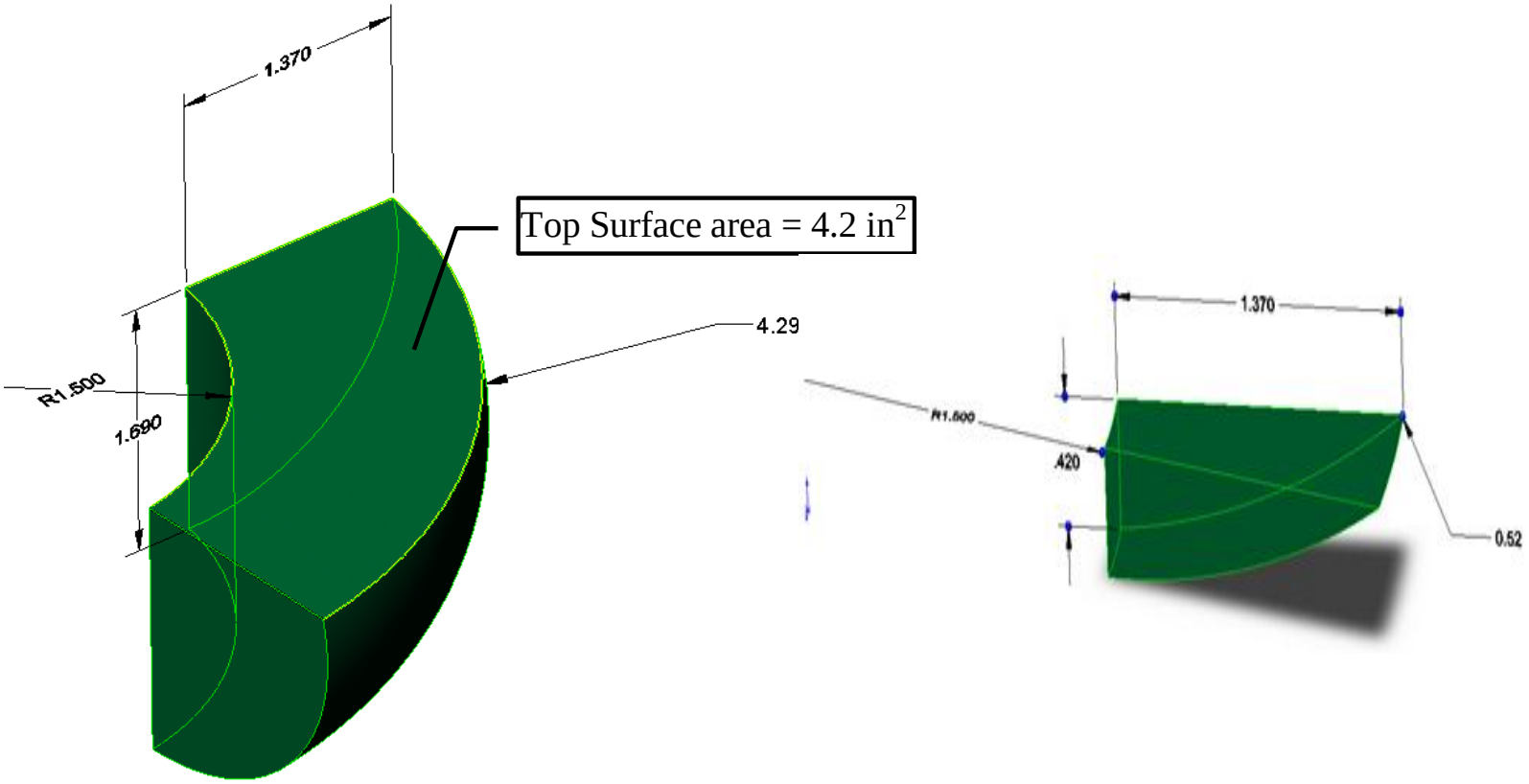


- Limit Load analysis demonstrates structural integrity of the remnant nozzle by showing the nozzle remains intact under primary loads
- Natural frequency remains above excitation frequency for vortex shedding
- Longitudinal crack growth analysis demonstrates the remnant nozzle will remain intact

Corrosion Assessment

- Small gap exists between original Alloy 600 nozzle and new Alloy 690 nozzle following repair
- Low-alloy steel corrosion rate due to interaction with primary coolant in operating reactors has proven to be extremely small
- WCAP-15973 documents method for evaluating corrosion of low alloy steel following half-nozzle repairs
- Palo Verde plant-specific analyses followed the WCAP methodology and demonstrated that long term corrosion of the low-alloy steel has a negligible impact on the BMI repair design with 0.072” radial bore corrosion in 40 years

Loose Parts Evaluation



Assumed Maximum/Minimum potential J-groove weld material loose parts from BMI Nozzle #3 used by Westinghouse to assess impact on fuel assemblies and RCS flow paths

Summary and Conclusions

- Palo Verde implemented a half-nozzle repair on Unit 3, Nozzle #3
  - Code compliant repair with PWSCC resistant material (Alloy 690)
  - Permanent repair backed by extensive industry experience
- Plant specific analyses account for BMI design inputs in geometry, materials, operating transients and design conditions
- Detailed finite element models were used to define the internal J-groove welding residual stresses and the operating stresses in the ASME III analysis
- Results from the ASME III analysis, the remnant RPV J-groove weld crack growth analysis and the remnant nozzle crack growth analysis justify operation through the end of licensed operating life

Relief Request #52

Tom Weber
Department Leader, Nuclear Regulatory Affairs

Palo Verde Applicable ASME Codes

- Design Code for reactor vessel
  - ASME III 1971 Edition, Winter 1973 Addenda
- Construction Code
  - ASME III 1974 Edition, Winter 1975 Addenda
- Repairs/Replacements
  - ASME XI 2001 Edition, 2003 Addenda
- Palo Verde 3rd ISI Interval
  - Unit 1 thru 7-17-2018
  - Unit 2 thru 3-17-2017
  - Unit 3 thru 1-10-2018

APS Approach

- Two separate relief requests
  - Relief Request #51 - Restart analysis
    - Duration of current operating cycle #18
    - Verbally approved on November 21, 2013
  - Relief Request #52 - Long-term evaluation
    - Detailed analysis including fatigue crack growth
    - Operation through remainder of licensed operating life (November 25, 2047)

Relief from ASME Code

- Removal of defects
  - IWA 4421, “Defects shall be removed or mitigated in accordance…”
  - IWA 4422.1a, “A defect is considered removed when it has been reduced to an acceptable size…”
  - IWA 4422.1b, “Alternately, the defect removal area and any remaining portion of the defect may be evaluated and the component accepted in accordance with the appropriate flaw evaluation provisions of Section XI…”

Relief from ASME Code

- Characterization of flaws in J-groove weld
  - IWA 3100(a), “Evaluation shall be made of flaws detected during an inservice examination as required by IWB-3000 for Class 1 pressure retaining components…”
  - IWA 3300(b), “Flaws shall be characterized in accordance with IWA-3310 through IWA-3390…”
  - IWA 3420, “Each detected flaw or group of flaws shall be characterized by the rules of IWA-3300 to establish the dimensions of the flaws. These dimensions shall be used in conjunction with the acceptance standards of IWB-3500.”

Relief from ASME Code

- Successive examinations
  - IWB 2420(b), “If a component is accepted for continued service in accordance with IWB-3132.3 or IWB-3142.4, the areas containing flaws or relevant conditions shall be reexamined during the next three inspection periods listed in the schedule of the inspection program of IWB-2400…”

Proposed Alternative per 10 CFR 50.55a(a)(3)(i)

- Completed ASME Code compliant repair on external surface of Unit 3 reactor vessel
- Relocated pressure boundary weld
- Analyzed a postulated maximum flaw in remnant J-groove weld

Basis for Relief Request

- ASME Code compliant half-nozzle repair
- No demonstrated technology available for characterization of flaws in J-groove weld
- Analysis of postulated maximum flaw demonstrates remnant flaw remains acceptable for remainder of licensed operating life

Relief Request Summary

- Proposed ASME Code alternative provides an acceptable level of quality and safety
- Analyses of BMI nozzle support the relief request such that nozzle is acceptable for the remainder of the licensed operating life
- RR#52 submittal planned for May, 2014
- Needed for restart following 18th refueling outage, Spring 2015

Closing Comments

Ken House
Director, Design Engineering

We SAFELY and *efficiently* generate electricity for the *long term*