UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

September 8, 2009

LICENSEE: Exelon Generation Company, LLC

FACILITY: Byron Station, Unit No. 2

SUBJECT: SUMMARY OF SEPTEMBER 2, 2009, POST-SUBMITTAL PUBLIC MEETING WITH EXELON GENERATION COMPANY, LLC, TO DISCUSS BYRON STATION, UNIT NO. 2, RELIEF REQUEST FOR ALTERNATE EXAMINATION FREQUENCY UNDER ASME CODE CASE N-729-1 FOR REACTOR VESSEL HEAD PENETRATION WELDS (TAC NO. ME1066)

On September 2, 2009, a Category 1 public meeting was held between the U.S. Nuclear Regulatory Commission (NRC) and representatives of Exelon Generation Company, LLC (the licensee) at the NRC Headquarters, One White Flint North, 11555 Rockville Pike, Rockville, Maryland. The purpose of the meeting was to discuss Byron Station (Byron), Unit No. 2, Relief Request (RR) I3R-16, submitted for NRC staff review on April 2, 2009, for an alternative examination frequency under American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) Code Case N-729-1 for reactor vessel head penetration welds. A list of attendees is provided as Enclosure 1.

The licensee's presentation (See Enclosure 2) elaborated on the technical justification submitted in the April 2, 2009, RR. The presentation provided background on the issue, inspection results, industry operating experience, boat sample results of a flaw found in a Byron, Unit No. 2 reactor vessel head penetration (Penetration 68), growth projections for the flaw, and a probabilistic assessment pertaining to the RR. The licensee also discussed the uniqueness of the occurrence of primary water stress-corrosion cracking in Penetration 68 based on the inspection results and boat sample evaluations, in support of the requested proposed alternative inspection frequency.

Members of the public were not in attendance. Public Meeting Feedback forms were not received.

Please direct any inquiries to me at 301-415-1547, or marshall.david@nrc.gov.

Sincerely,

Marshall David, Project Manager
Plant Licensing Branch III-2
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-455

Enclosures:
1. List of Attendees
2. Licensee Handout

cc w/encl: Distribution via ListServ

LIST OF ATTENDEES

SEPTEMBER 2, 2009, MEETING WITH EXELON GENERATION COMPANY, LLC, TO DISCUSS BYRON STATION, UNIT NO. 2, RELIEF REQUEST FOR ALTERNATE EXAMINATION FREQUENCY UNDER ASME CODE CASE N-729-1 FOR REACTOR VESSEL HEAD PENETRATION WELDS

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R. Hardies	NRC/NRR/ADES/DCI	301-415-5802
T. Chan	NRC/NRR/ADES/DCI/CPNB	301-415-2768
J. Tsao	NRC/NRR/ADES/DCI/CPNB	301-415-2702
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J. Cirilli	Exelon/Senior Staff Engr - Corp Asset Mgmt	610-765-5966
G. DeBoo	Exelon/Senior Staff Engr - Corp Asset Mgmt	630-657-3828
S. Koernschild	Exelon/Senior Staff Eng Analyst - Byron Progs Eng	815-406-4006
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W. Bamford	Westinghouse	412-374-5858
B. Bishop	Westinghouse	412-374-4636
J. Brihmadesam	Westinghouse	662-320-3944
J. Lareau	Westinghouse	860-731-1605

Enclosure 1

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Exelon Nuclear Post Submittal Meeting

Proposed Relief Request from

ASME Code Case N-729-1 Inspection Frequency

Byron Station Unit 2

September 2, 2009

Enclosure 2

Agenda

Introduction – Patrick Simpson

Background and Inspection Results – Scot Greenlee

Industry Operating Experience
and Boat Sample Results – Jim Cirilli

Growth Projections and Probabilistic
Assessment – Guy DeBoo

Closing Remarks – Scot Greenlee

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Introduction

Patrick Simpson

Manager - Licensing

Meeting Purpose

- ✓ Present technical basis for Exelon Nuclear's Byron 2 Relief Request for alternate examination frequency under ASME Code Case N-729-1

- ✓ Obtain NRC feedback

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Technical Basis Conclusions

- ✓ Byron 2 reactor pressure vessel (RPV) head Penetration 68 flaw required welding defects, present from fabrication, to initiate primary water stress corrosion cracking (PWSCC) in the tube
- ✓ PWSCC growth studies determined a minimum of 9 years or 6 fuel cycles is needed for a postulated flaw like the one found in Penetration 68 to initiate a leak path
- ✓ The proposed inspection technique and frequency is sufficient to detect flaws prior to initiating a leak path
- ✓ 2008 head inspections demonstrate no additional PWSCC in Byron 2
- ✓ No similar issues identified in Byron 1 or Braidwood 1 & 2

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Request for Relief

- ✓ Relief requested with a proposed alternative inspection frequency based on the uniqueness of the occurrence of PWSCC in Penetration 68, specifically:
  - Perform volumetric and/or surface examinations of all penetrations as identified by Table 1 of ASME Code Case N-729-1 at a frequency of once every 4th refueling outage or 6 calendar years, whichever is less
  - Except for Penetration 68, which will be volumetrically and/or surface examined each refueling outage
  - In addition, bare metal visual (BMV) examinations of the RPV head will occur every 3rd refueling outage or 5 calendar years, whichever is less
- ✓ Approval is requested before April 2, 2010 outage

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Background and Inspection Results

Scot Greenlee

Byron Station Engineering Director

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Byron 2 Background

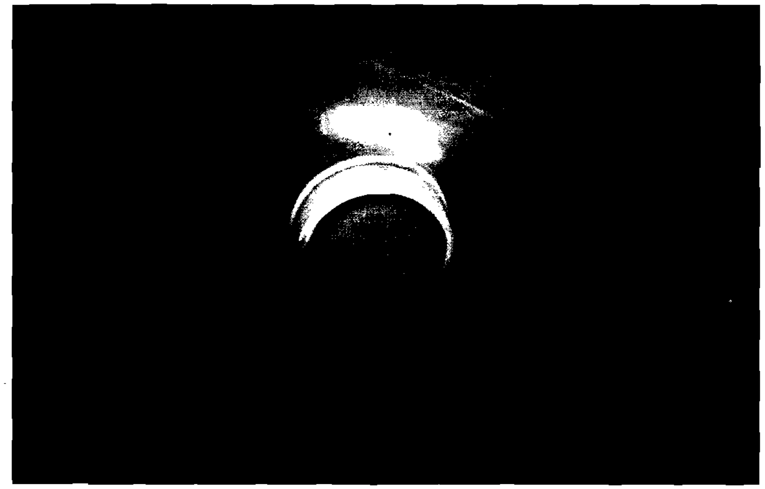
- ✓ Westinghouse 4-loop NSSS design
  - RPV head penetration nozzles were provided by B&W Tubular Products
  - RPV head fabrication and penetration nozzle installation were by B&W
- ✓ Commercial operation – August 1987
- ✓ T-Cold Head (<550°F)
  - 2.2 Effective Degradation Years (EDY) at time of 2007 inspection
- ✓ Prior to the Spring 2007 refueling outage (B2R13), BMV examinations were performed in:
  - Fall 2002 (B2R10)
  - Fall 2005 (B2R12)

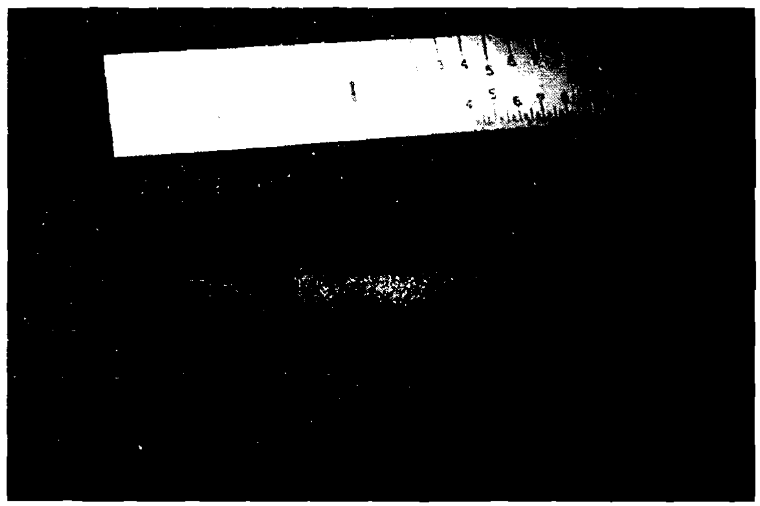
Spring 2007 Byron 2 Inspection Results

✓ Penetration 68 results – Spring 2007

- 100% volumetric ultrasonic testing (UT)
- UT exam revealed 50% through-wall axial indication ~0.52" long
- Subsequent dye penetrant (PT) exam of J-groove weld identified one rounded and one linear indication
- Leak path assessment did not detect any leaks

2007 Inspection Results – Byron 2





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Fall 2008 Inspection at Byron 2

✓ Inspected in Fall 2008 (B2R14)

✓ In accordance with NRC Order EA-03-009, volumetric examination of all 79 penetrations

- Leak path assessment of the RPV penetration to RPV low-alloy steel annulus
- Surface examination (dye penetrant) examination of the Penetration 68 weld overlay
- 100% BMV of the external RPV head surface

✓ No indications

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Summary

- ✓ Byron and Braidwood Stations – Overall Inspection Results
  - 100% BMV – no indications in Byron 1 or Braidwood 1 & 2 and no additional indications in Byron 2
  - 100% Volumetric Inspection – no indications in Byron 1 or Braidwood 1 & 2 and no additional indications in Byron 2
    - UT and eddy current exam methods employed
- ✓ Inspection results support uniqueness of Byron 2 RPV head Penetration 68 indication
- ✓ Industry operating experience (international and domestic) also supports conclusions

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Industry Operating Experience and Boat Sample Results

Jim Cirilli

Senior Staff Engineer

Corporate Asset Management

Industry Operating Experience

✓ Domestic Operating Experience

- All RPV upper heads inspected (hot & cold)
  - Represents over 3000 cold head penetrations inspected
  - No defects found in cold heads
    - o Byron 2 Penetration 68 is the only domestic cold head penetration with PWSCC
- PWSCC flaws found in high temperature upper heads
- Greater than 1000 RPV bottom mounted penetrations inspected
- Operating experience related to weld defects
  - Fall 2008 - SONGS 3 Penetration 64 indication found in embedded repair weld metal
  - South Texas Project bottom mounted penetrations - Initiated from pre-existing weld defect, similar to Byron 2 Penetration 68

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Industry Operating Experience (continued)

- ✓ International Operating Experience
  - EdF reported cracks in CRDM nozzles with first at Bugey 3 in 1991
  - Zorita (Spain) reported intergranular cracking due to high sulfate levels in 1994 (not PWSCC)
  - OHI 3 CRDM indication (2004) – surface preparation issue
  - Greater than 1600 bottom mounted penetrations inspected
- ✓ Sources: EPRI, Westinghouse, AREVA

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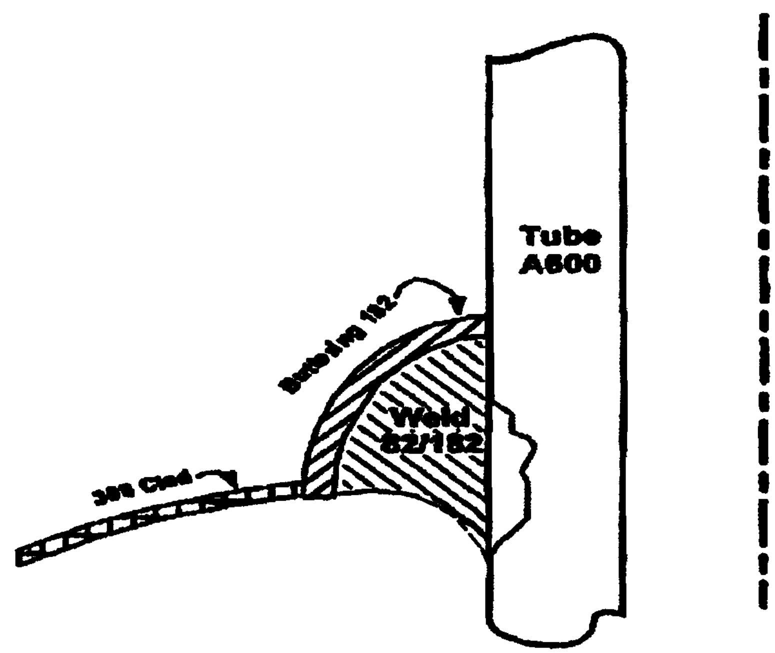
Boat Sample Results - Background



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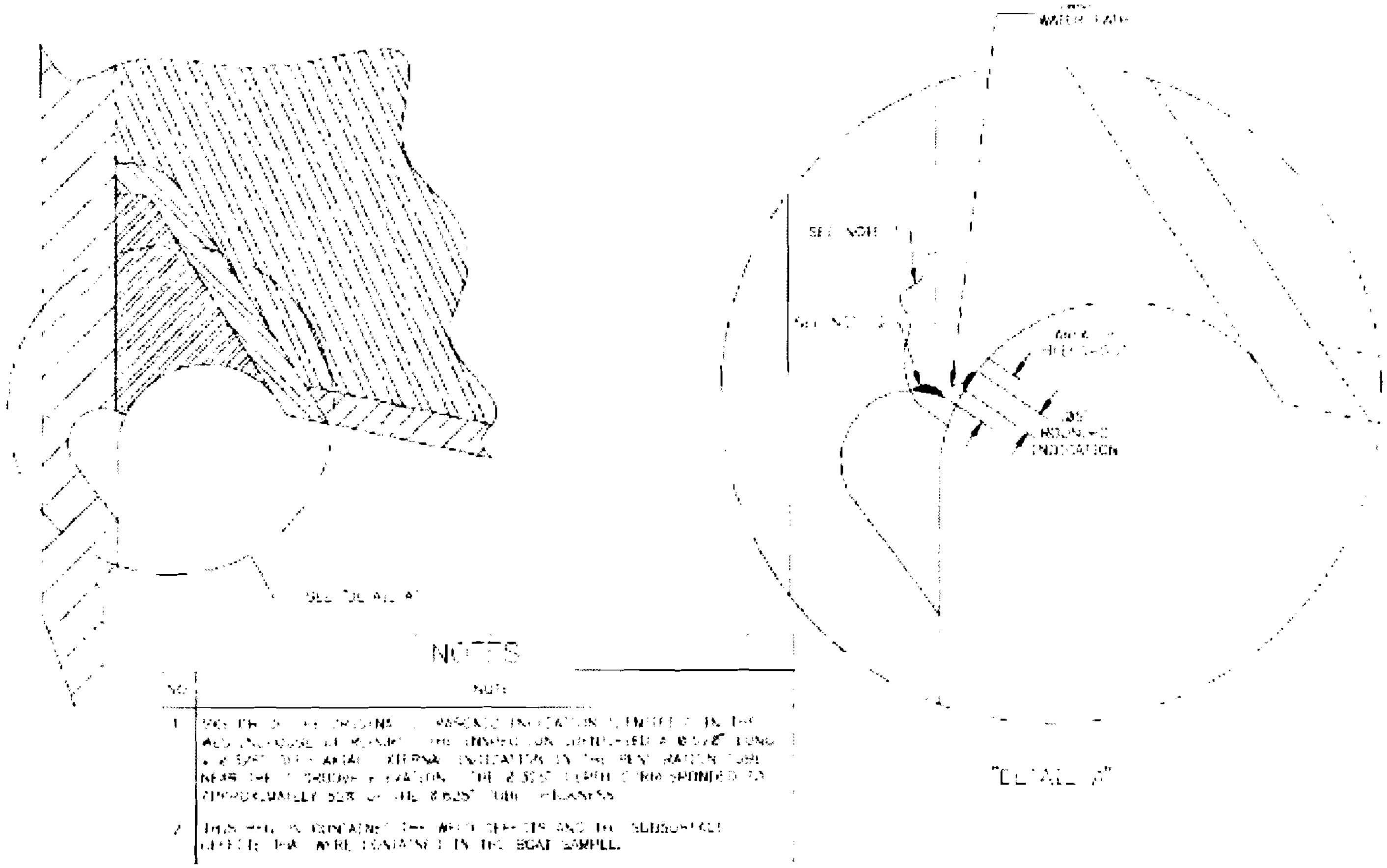
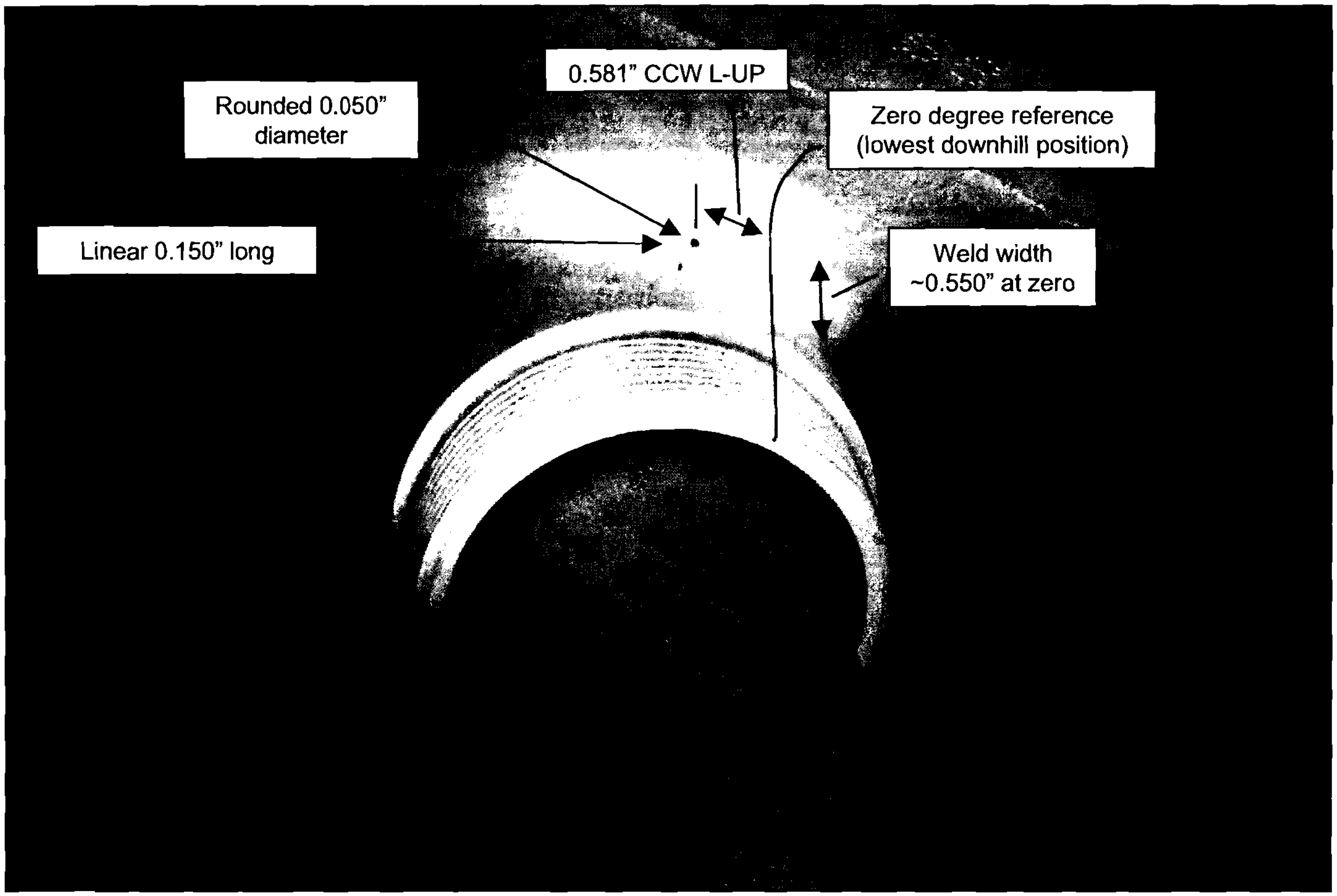
Boat Sample Results



CRDM 68 PT Results - Before Boat Sample



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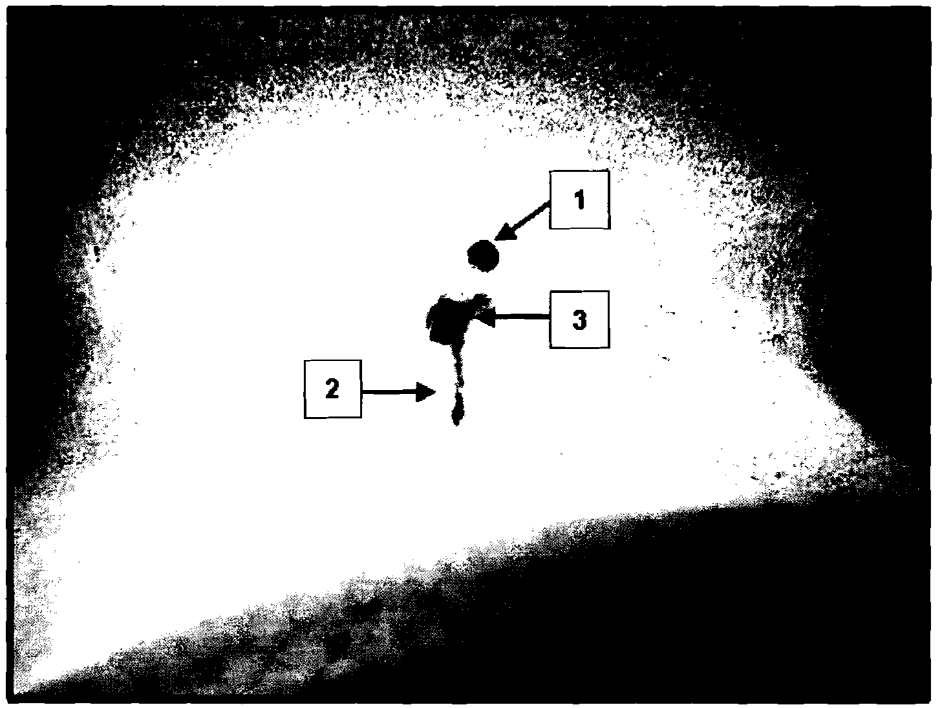
CRDM 68 PT Results – After Boat Sample

- ✓ Subsurface linear defect is connected to the lack-of-fusion defect
- ✓ Evidence indicates a high probability that the rounded PT indication not captured by the boat sample was connected below the surface to the lack-of-fusion defect
- ✓ A surface flaw the size of the rounded indication would have been considered acceptable by ASME Code of fabrication for Byron Station
- ✓ Heavy grinding in this area may have masked the indication during fabrication exams



1. Rounded PT indication
2. Subsurface portion of axial indication
3. Subsurface linear defect connected to lack of fusion

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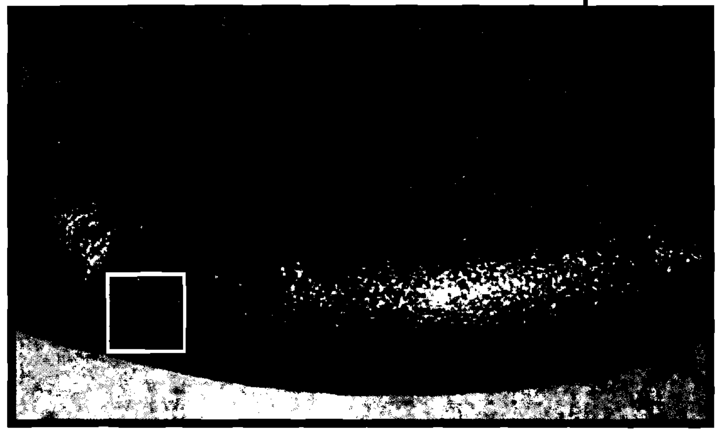
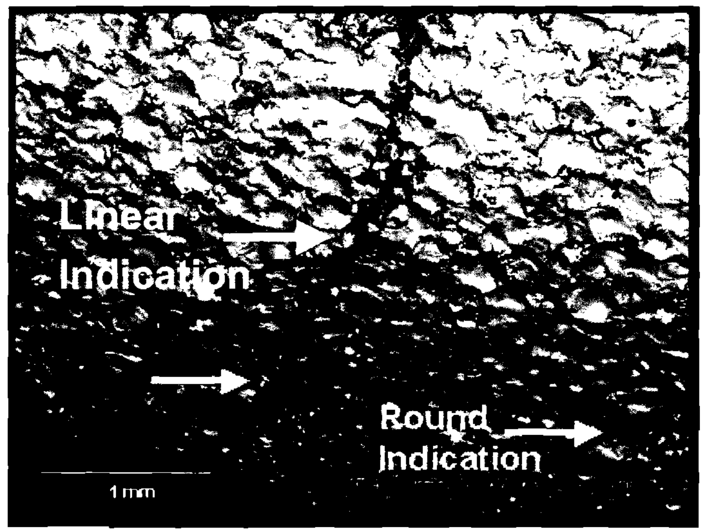
Boat Sample Results - Summary

- ✓ Rounded subsurface defect captured by the boat sample identified as lack of fusion between the weld and tube surfaces
  - Incipient cracks were observed emanating from the defect
  - Weld defect produced during original fabrication process
- ✓ Linear indication exhibited multiple defect/crack morphologies including lack of fusion, hot cracking, and PWSCC
  - In the weld, the direction of PWSCC propagation was from the subsurface location toward the wetted surface
  - In the tube material, none of the PWSCC was connected to the outer surface of the tube below the J-groove and/or fillet weld

Cut surface of boat sample





SEM Image of inset area above

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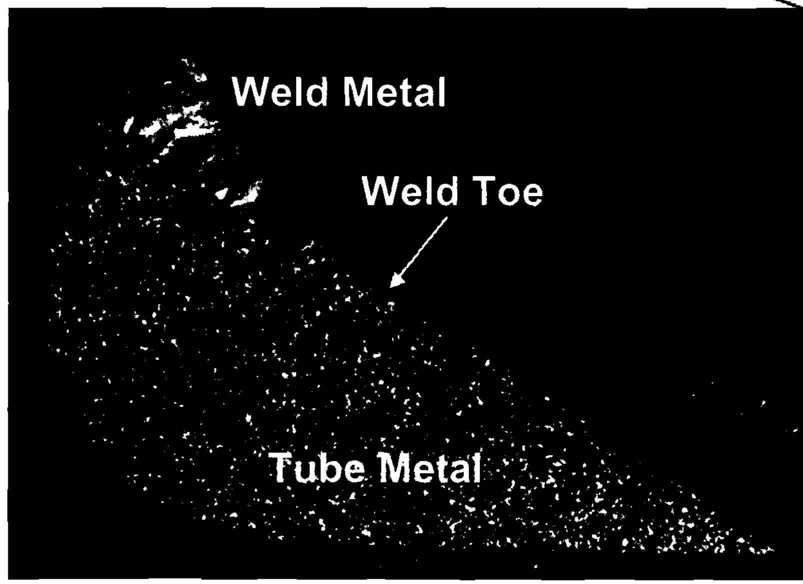
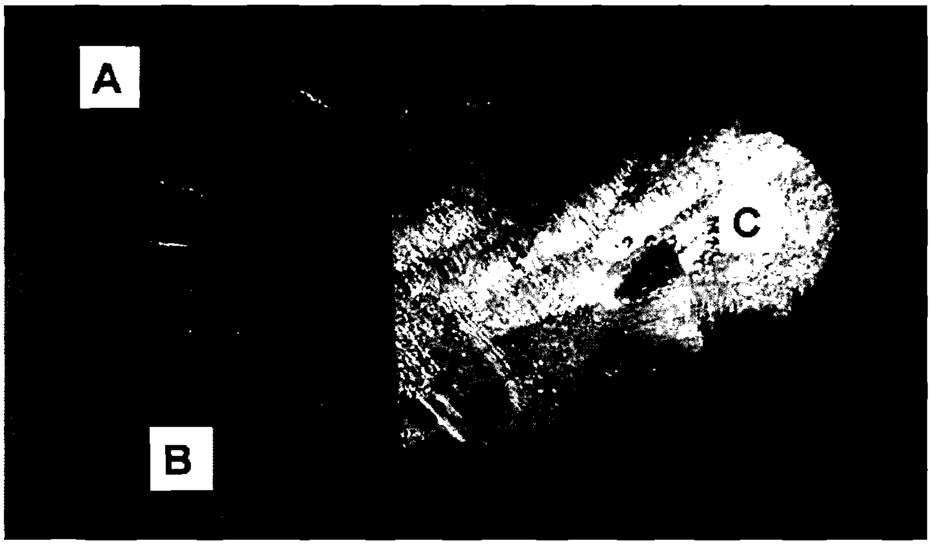
Section C



✓ Section C – Mounted along vertical cut face

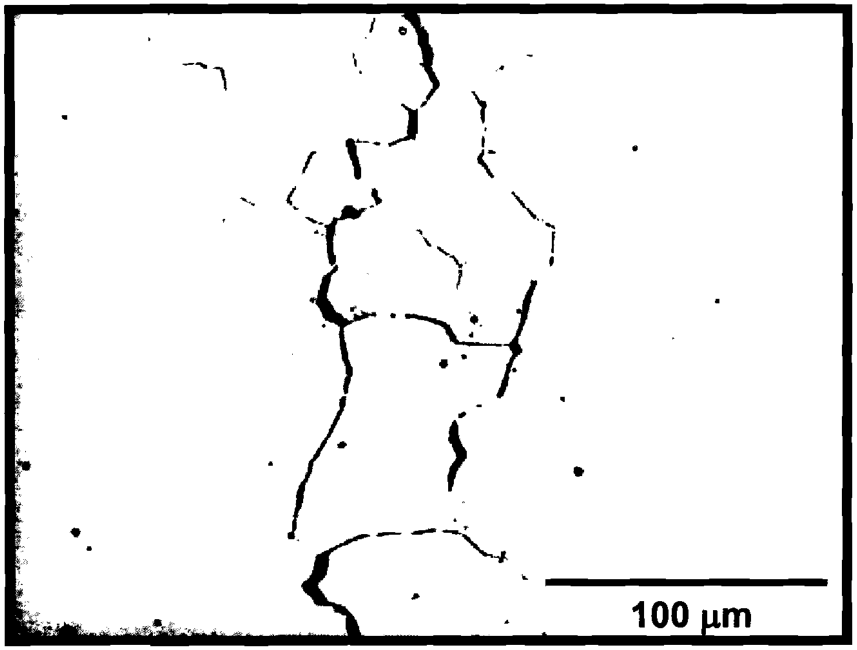
- Boat sample contains tube material and last two weld passes
- Composition of Alloy 600 tube material and Alloy 182 weld metal consistent with specifications

Section B

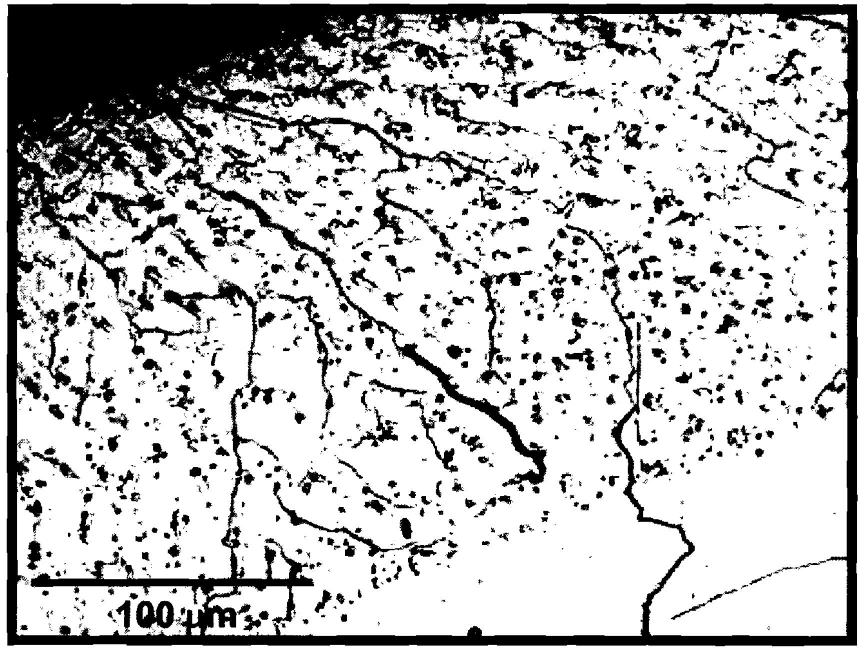


Section B Mounted along Horizontal Cut Face

Section B -- Metallography



Intergranular Cracking in Tube Metal
(Unetched)



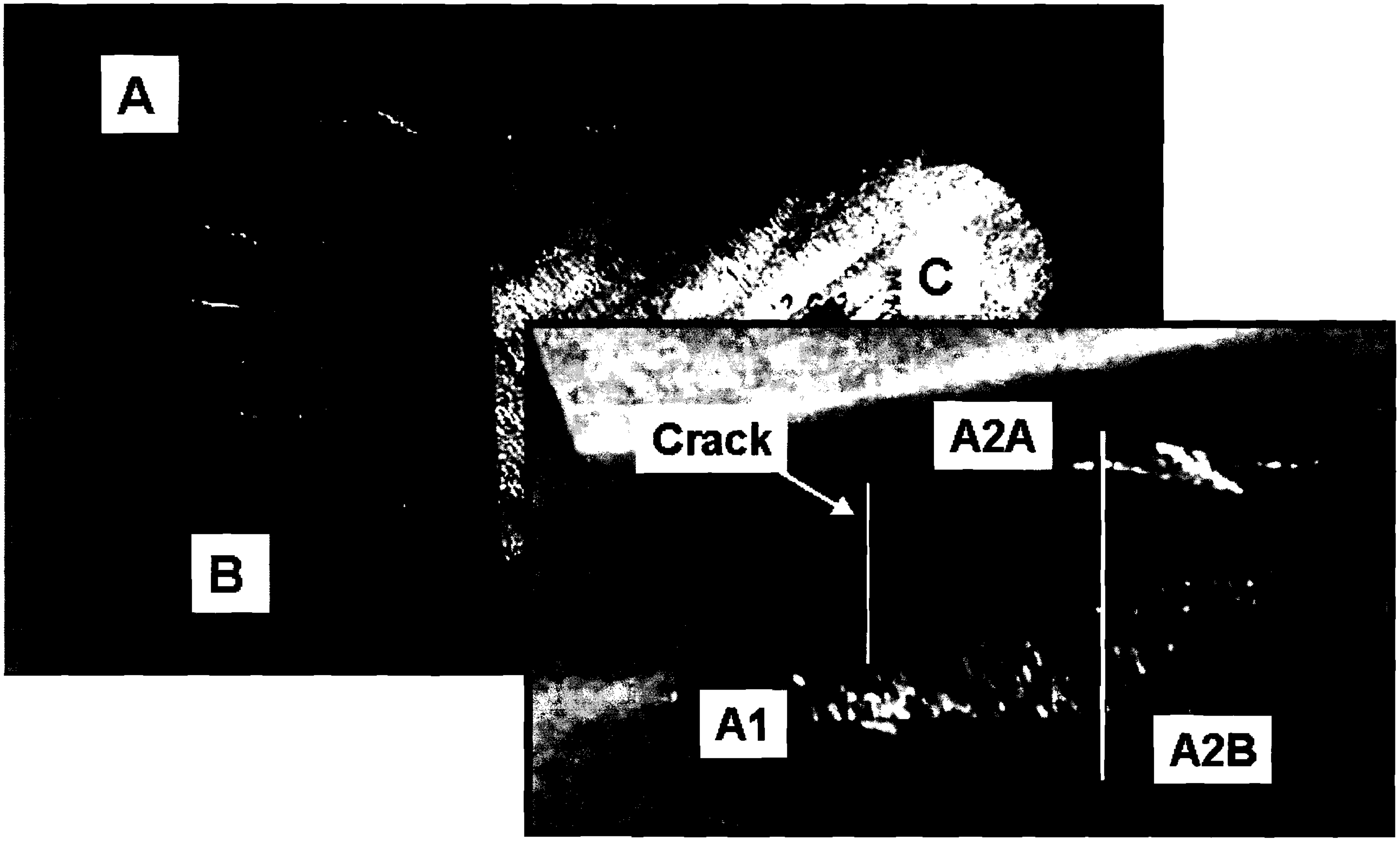
Intergranular Cracking
in Tube and Weld Metals
(Electrolytic Phosphoric-Nital Dual Etch)

Section B -- Metallography

Intergranular Cracking in Tube Metal
(Electrolytic Phosphoric-Nital Dual Etch)

Susceptibility of Alloy 600 MA Tube Material
(Electrolytic Phosphoric Etch)

Section A



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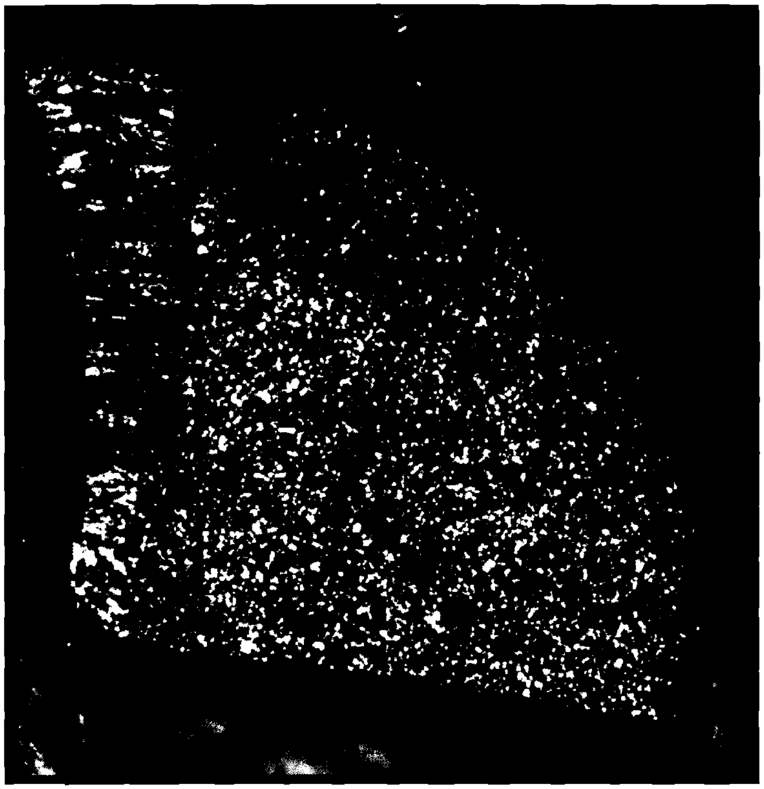
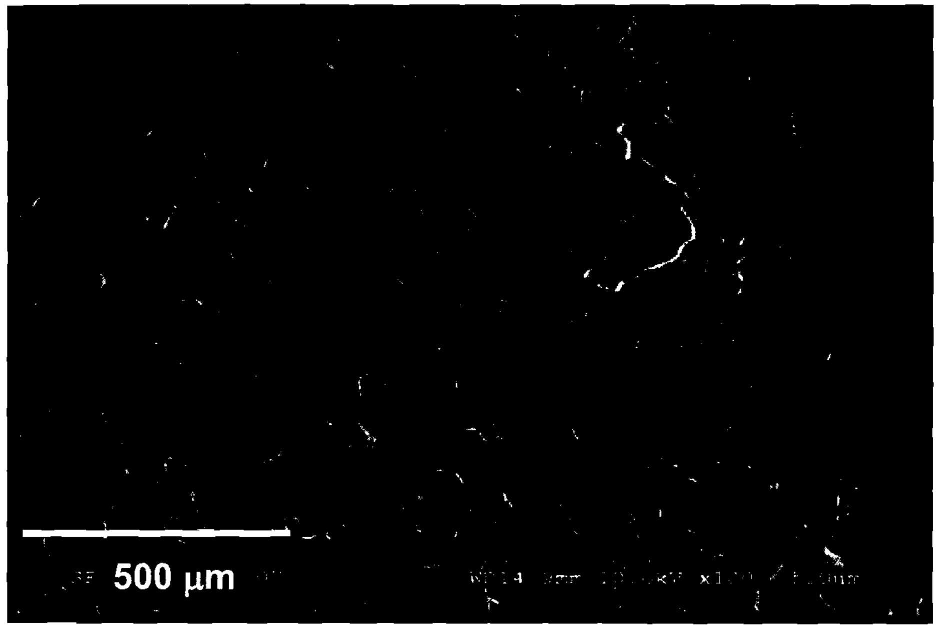
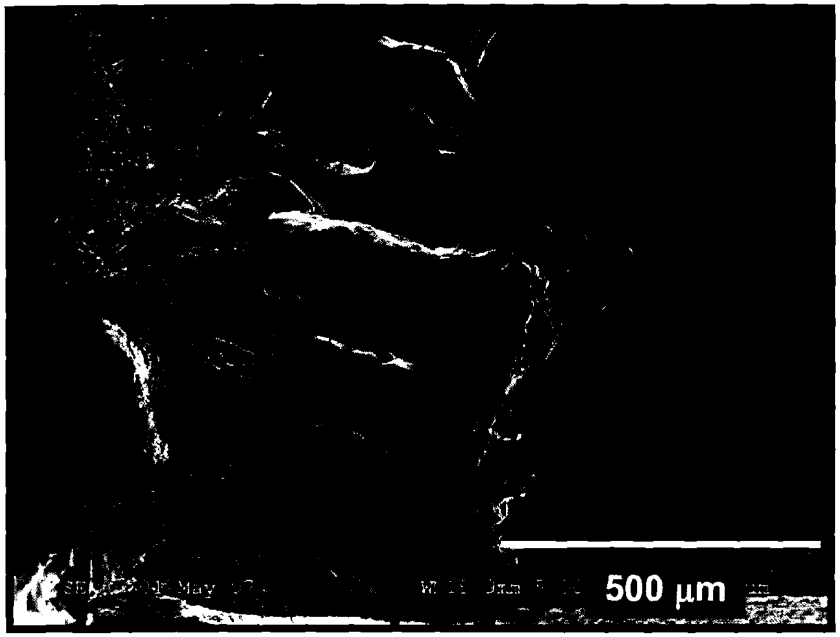
Section A1 -- Crack Surface



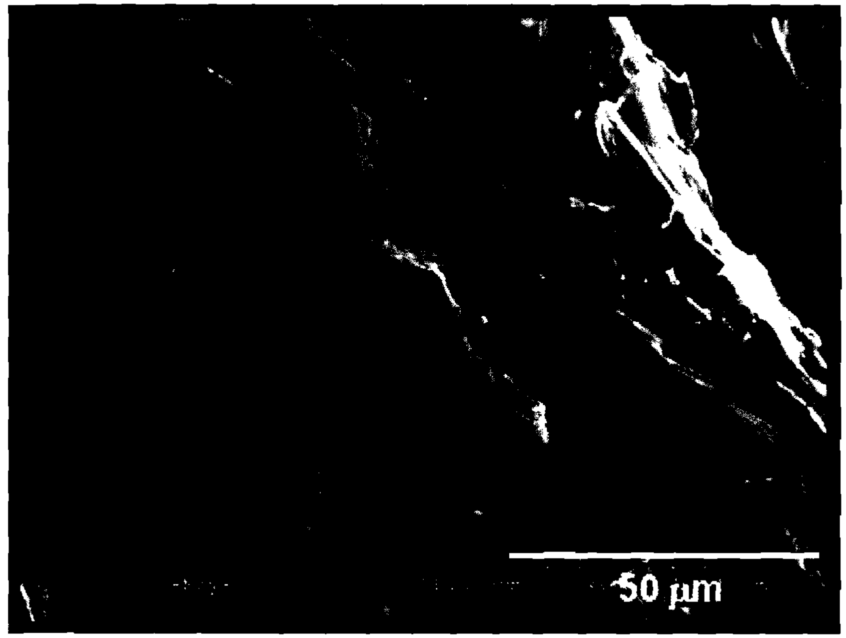


Intergranular Cracking in Tube Metal

Section A1 -- Crack Surface



Ductile Tearing at Wetted Surface



Hot Cracking in Weld

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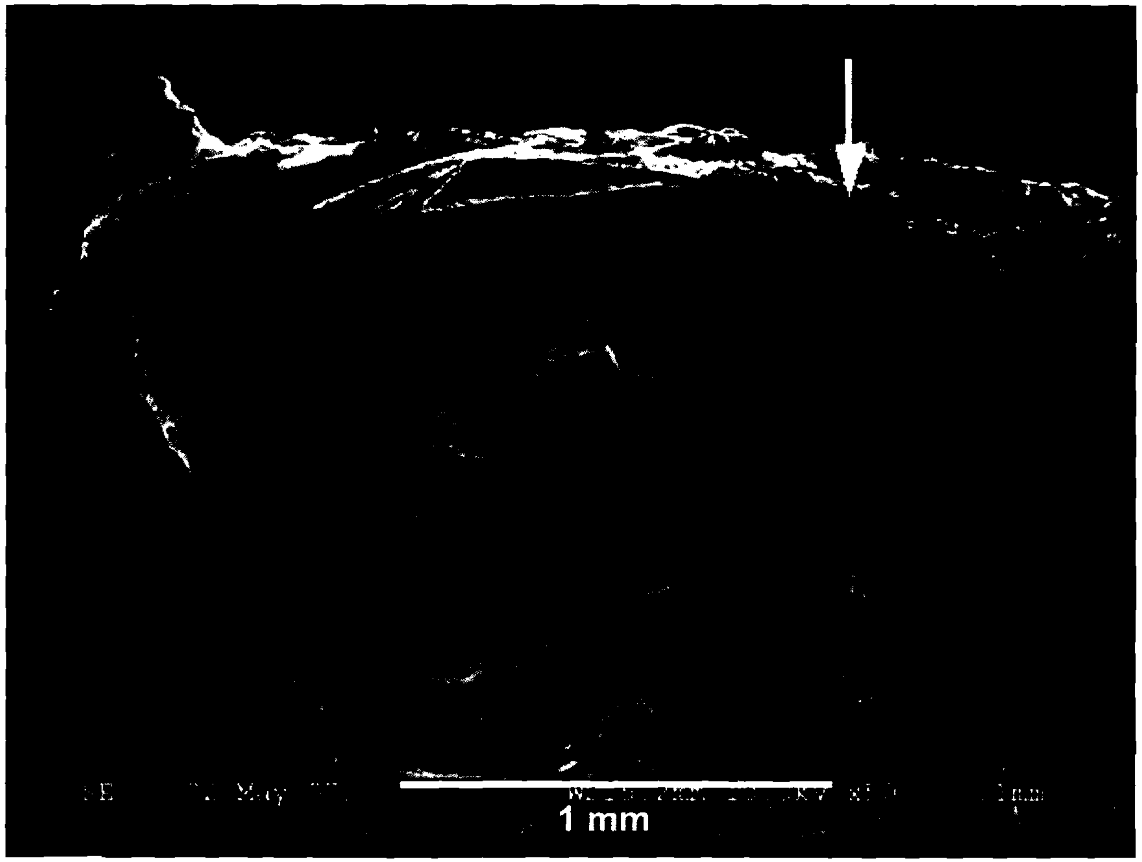
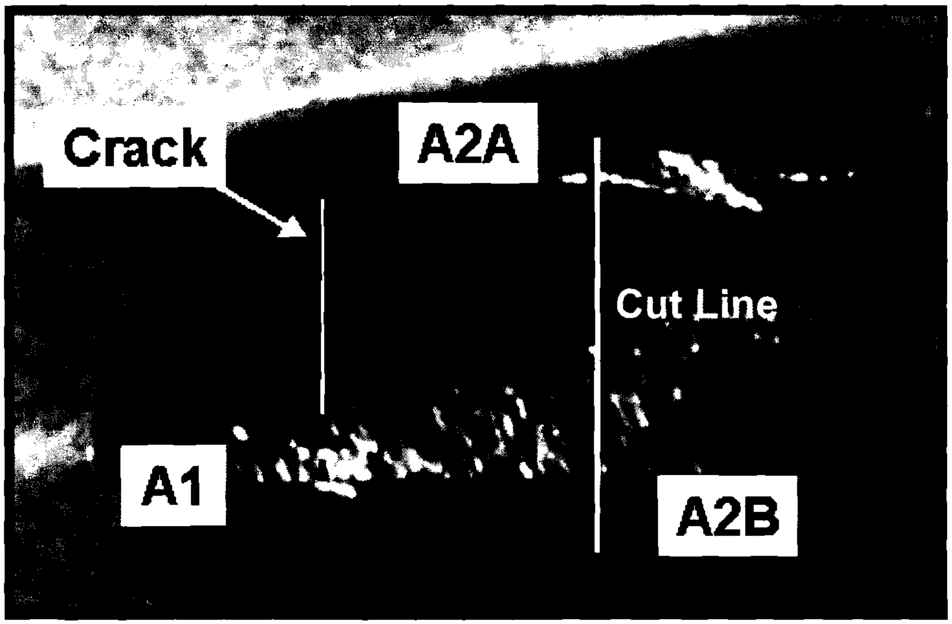
Section A1 -- Crack Surface

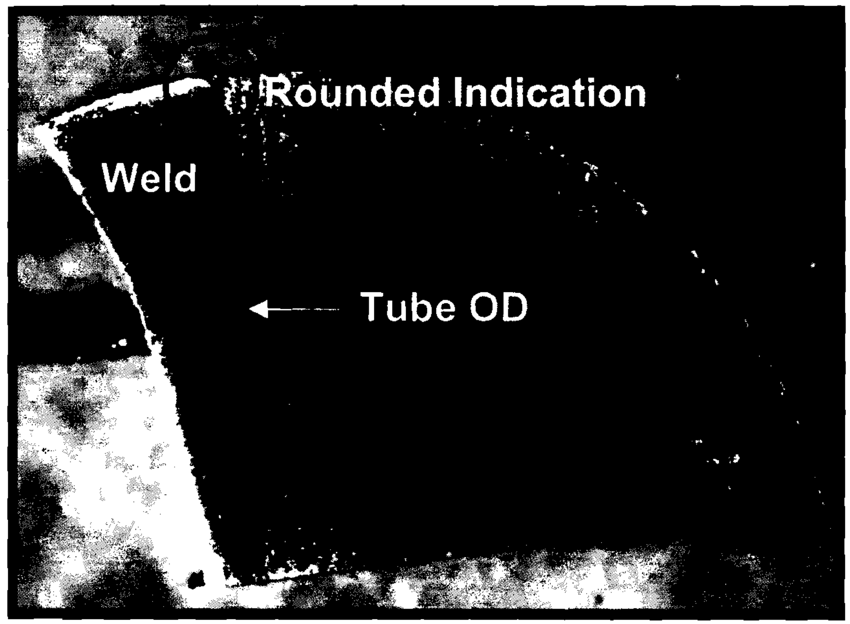


Lack of Fusion between Weld Passes

Section A2 -- Cut Surface



Cut Line Located Adjacent to Rounded Indication on EDM Surface



Section A2A Ground to Reveal Rounded Indication

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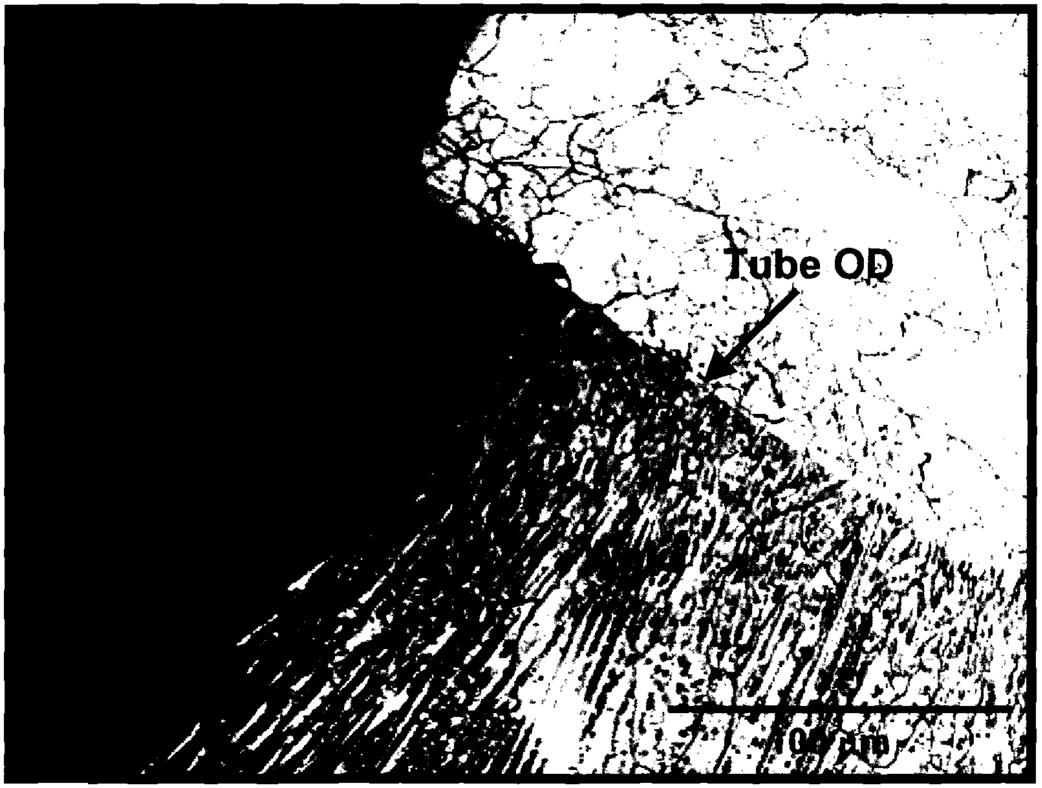
Section A2A -- Weld Defect



Lack-of-Fusion Defect

(Electrolytic Phosphoric-Nital Dual Etch)

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Section A2A -- Defect and Inclusion

Inclusion Revealed after Polishing

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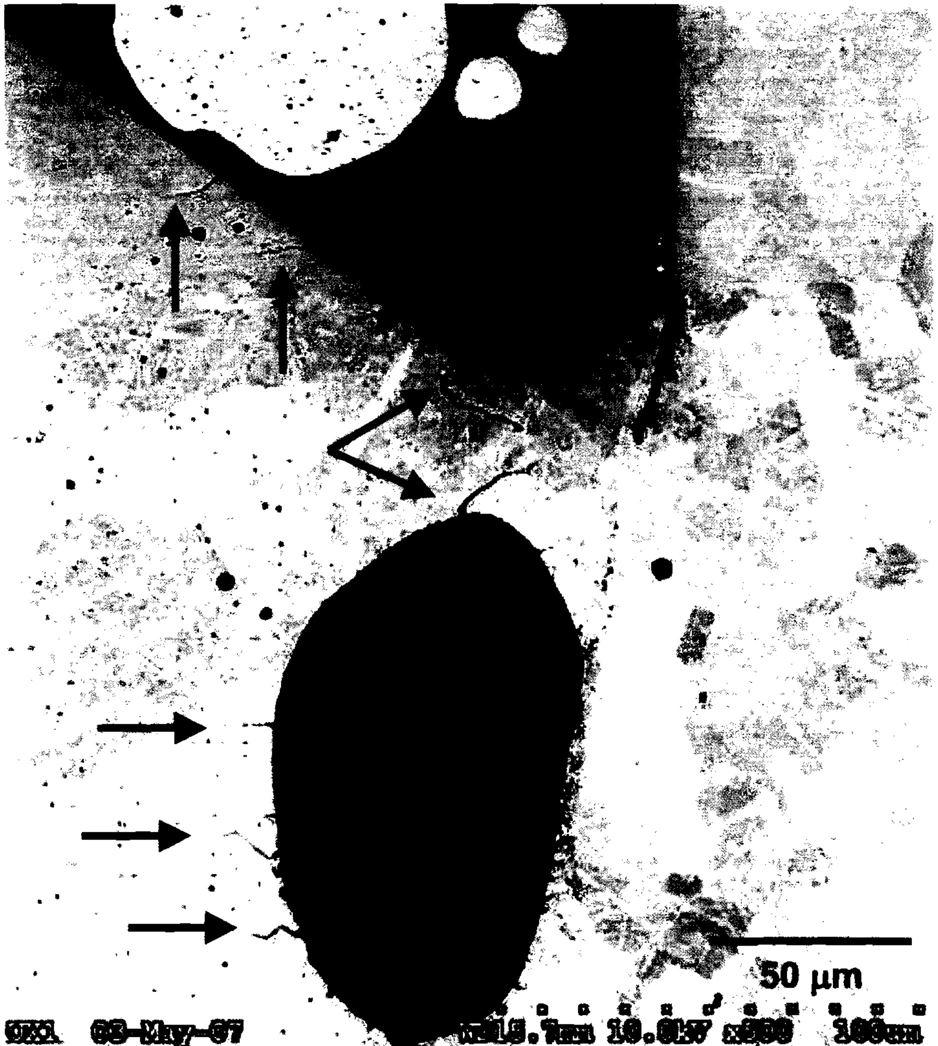
Section A2A -- Defect and Inclusion



- ✓ Inclusions contained Ti, N, and O
- ✓ Crevice contained oxidized W, Fe, Ni, Cr, and Nb
- ✓ Cracks contained Inconel 182 oxidation products
- ✓ No measurable fluorine or other corrosive elements

Incipient Cracks shown by Arrows

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Boat Sample Results

- ✓ Rounded subsurface defect captured by the boat sample identified as lack of fusion between the weld and tube surfaces
  - Incipient cracks were observed emanating from the defect
  - Weld defect produced during original fabrication process
- ✓ Linear indication exhibited multiple defect/crack morphologies including lack of fusion, hot cracking, and PWSCC
  - In the weld, the direction of PWSCC propagation was from the subsurface location toward the wetted surface
  - In the tube material, none of the PWSCC was connected to the outer surface of the tube below the J-groove and/or fillet weld
- ✓ No initiation in the penetration tube material

Summary

- ✓ Three elements must be present simultaneously for PWSCC initiation
  - Susceptible Metallurgical Condition
    - Susceptibility is related to grain boundary carbide coverage (GBCC)
    - Penetration 68 Heat 80054 considered to have good GBCC - 29 other nozzles from the same heat have been inspected with no indications
  - Tensile Stress
    - Includes residual welding stresses and operating pressures
    - Byron 2 Penetration 68 is not the location of highest stress
  - Critical Corrosive Environment
    - PWSCC has strong temperature dependence
    - Below 570°F (as in Byron 2), PWSCC initiation and growth are very slow processes
- ✓ Necessary conditions for the initiation of PWSCC would not have been simultaneously met without the presence of the original fabrication weld defects, which created a critical corrosive environment
- ✓ PWSCC initiated at pre-existing weld defect, not penetration tube material

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Growth Projections and Probabilistic Assessment

Guy DeBoo
Senior Staff Engineer
Corporate Asset Management

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Probabilistic Assessment

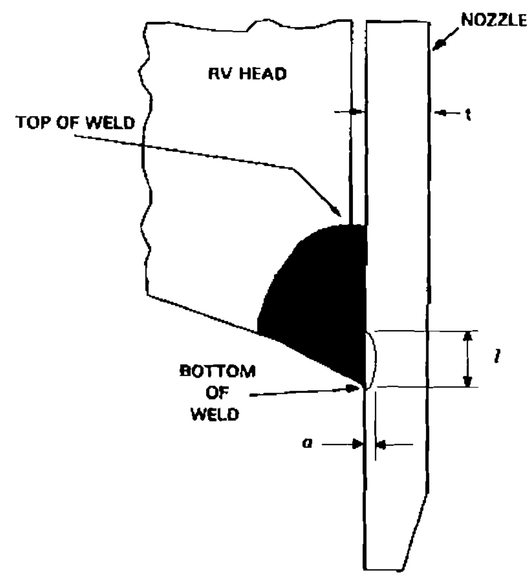
Probabilistic evaluations using industry inspection results with Weibull analyses and Monte Carlo simulations determined:

- ✓ Probability of a 50% throughwall crack occurring in Byron 2 after 20 years of service is three orders of magnitude below the probability expected for flaw initiation and growth due to typical PWSCC
- ✓ The observed flaw did not occur in the most susceptible Byron 2 penetration location (i.e., Penetration 72 is 4 to 6 times more likely to initiate a flaw)
- ✓ The flaw in Penetration 68 is not due to typical flaw initiation and growth by PWSCC in the Alloy 600 base metal
  - Although fabrication weld defects may exist in other nozzles, Penetration 68 is the only cold head nozzle found with a flaw in the US

Growth Projections

✓ Performed analyses to determine the PWSCC project growth rates for RPV head penetrations

- Tube OD axial flaw growth studies for five RPV head penetration groups (0°, 25.4°, 42.8°, 43.8° and 47°)
- Growth based on operational plus weld residual stresses
- PWSCC growth rates per MRP-55 Rev 1 for Alloy 600 tube material
- Postulated initial flaw sized at the limit of UT detection, 0.075" by 0.150"
- Postulated flaw located at highest stressed locations on the uphill and downhill sides of the penetration
- Growth limited to the top of the J-groove weld where pressure boundary leak would initiate



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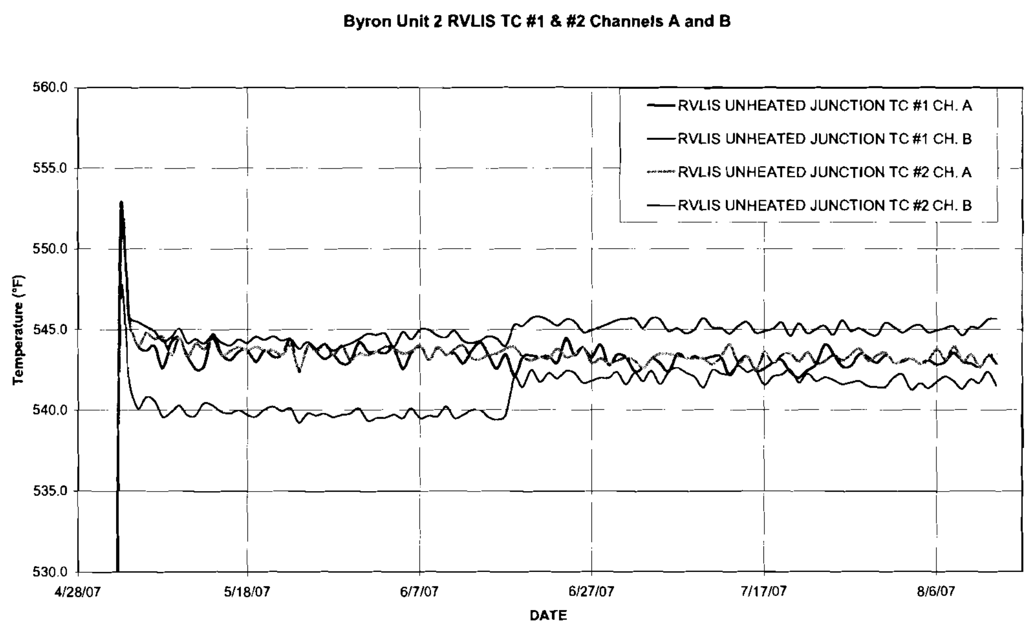
Growth Projections (continued)

✓ Byron 2 RPV head operating temperature for Cycle 14 indicates head temperature is typically 545°F



✓ Postulated flaw growth projections were based on 558°F

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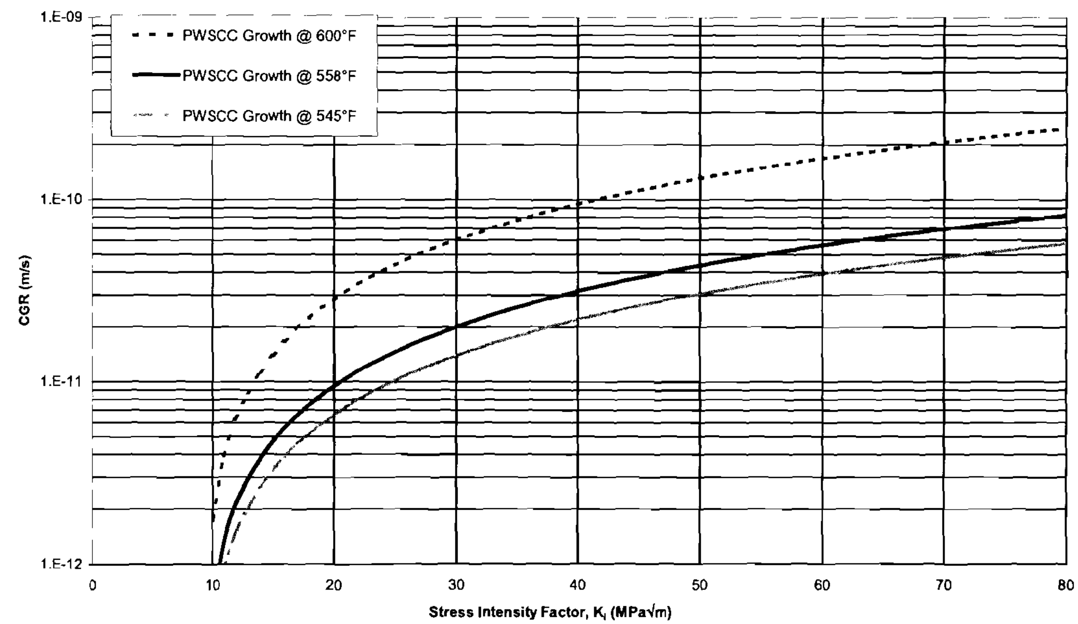
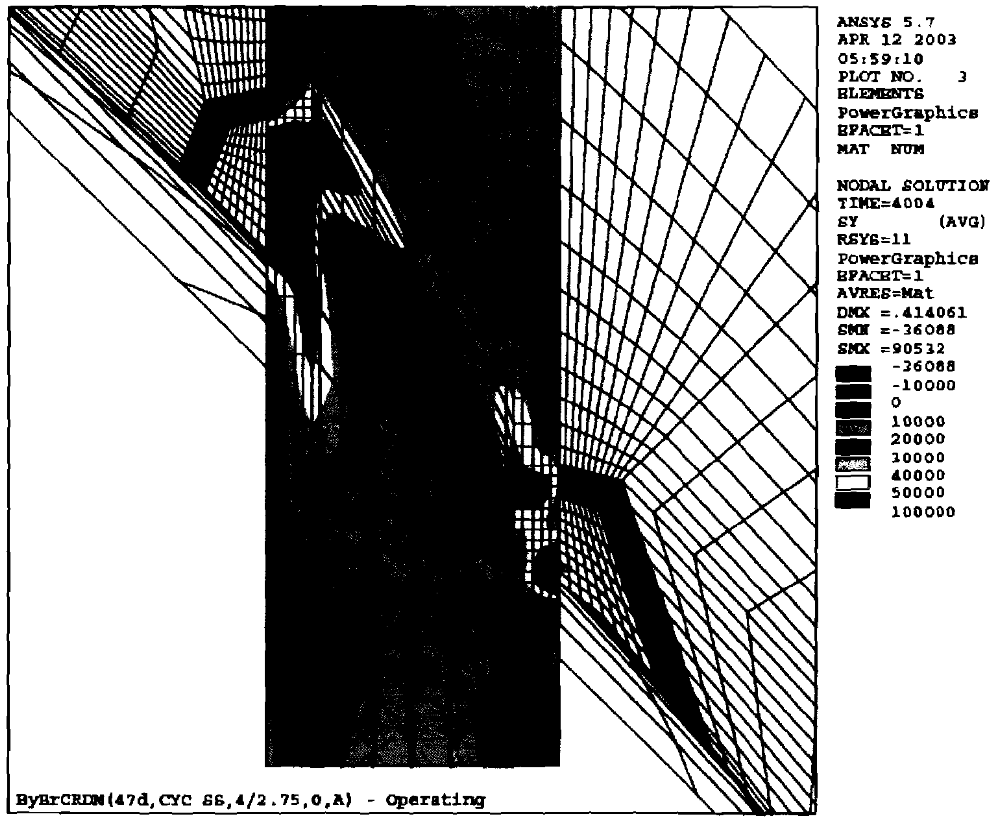
Growth Projections (continued)



- ✓ Using MRP-55 Rev 1 formulation growth rates for a typical hot head at 600°F, are compared to the evaluation temperature of 558°F and the typical Byron 2 head temperature of 545°F
- ✓ At 30 ksi√in (33 MPa√m), margin factors of 1.4 from 545°F to 558°F and 4.4 from 545°F to 600°F are seen

Growth Projections (continued)

- ✓ Typical operating plus weld residual hoop stress field used for crack growth – RPV head 47° nozzle (psi)
- ✓ Comparison studies performed by D. Rudland and J. Broussard and reported in ASME PVP2007-26045 demonstrated the methodology used to define the hoop welding residual stresses was conservative



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Growth Projections (continued)

- ✓ Postulated flaw initially 0.075" by 0.150" located in the tube outer surface at the center of the J-groove weld

Table 5-1 Operating Time for a Postulated Axial Flaw at the J-groove Weld to Grow Its Limit	
Nozzle Group & Location	**Available Operating Window (Fuel Cycles)[1]**
0.0° Nozzle	7.30
25.4° Nozzle; Downhill	9.05
25.4° Nozzle; Uphill	6.06
42.8° Nozzle; Downhill	11.69
42.8° Nozzle; Uphill	6.37
43.8° Nozzle; Downhill	12.26
43.8° Nozzle; Uphill	6.42
47.0° Nozzle; Downhill	13.75
47.0° Nozzle; Uphill	6.67

Note 1. A fuel cycle was assumed to be 18 months with a 98% capacity factor. Hot operating time conversion is 1.5 years/fuel cycle.

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Growth Projections (Axial Tube ID)

- ✓ PWSCC growth projections for an inside surface, axially oriented flaw on the uphill side at the J-groove weld with initial depth of 0.075" and fixed aspect ratio of 6
- ✓ Maximum flaw depth is projected to be 30% throughwall after 6 years of operation or 4 fuel cycles – providing additional margin to ASME Code structural limit of 75% wall depth

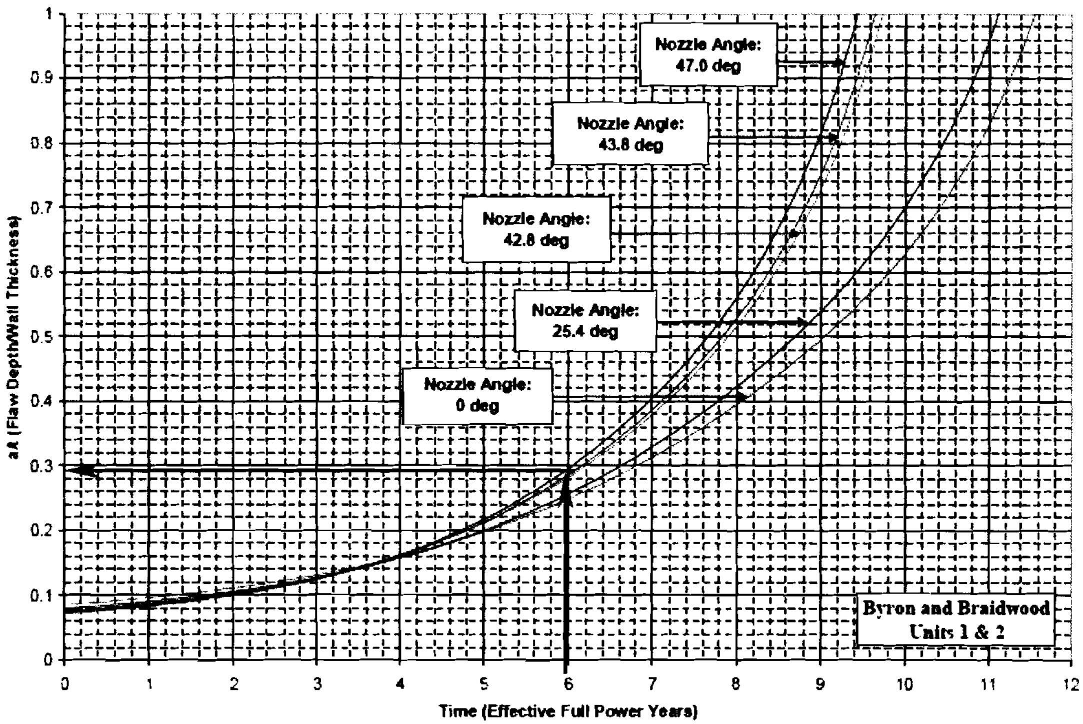

Figure 5-7: PWSCC Growth Projections for an Inside Surface, Axially Oriented Flaw on the Uphill Side at the J-groove Weld

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Growth Projections (Circumferential OD)

- ✓ PWSCC growth projections for an outside surface, circumferentially oriented flaw on the downhill side at the J-groove weld with initial depth of 0.075" and fixed aspect ratio of 6
- ✓ Maximum flaw depth is projected to be 56% throughwall after 6 years of operation or 4 fuel cycles – providing additional margin to ASME Code structural limit of 75% wall depth

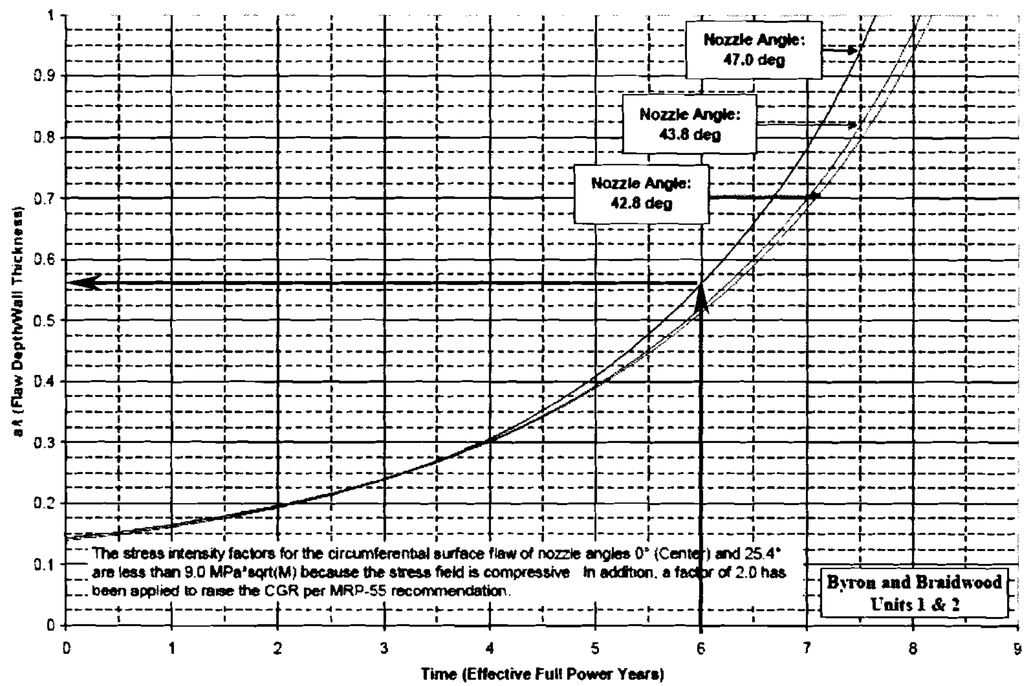

Figure 5-8: PWSCC Growth Projections for an Outside Surface, Circumferentially Oriented Flaw on the Downhill Side Above the J-groove Weld

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Growth Projections (Summary)

- ✓ After 4 fuel cycles or 6 years of operation postulated flaw sizes are significantly smaller than their structural and leakage size limits

- ✓ An inspection interval of 4 fuel cycles or 6 years of operation for Byron 2 (not every refueling outage) provides adequate time to detect and repair flaws prior to initiating a leak path through the tube

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Evaluation Conclusions

- ✓ Byron 2 head penetration flaw required welding defects, present from fabrication, to initiate PWSCC in the tube
- ✓ UT examinations demonstrate any potential flaws in other Byron 2 penetrations are less than the threshold of detection
- ✓ PWSCC growth studies determined a minimum of 9 years or 6 fuel cycles is needed for a postulated flaw like the one found in Penetration 68 to initiate a leak path
- ✓ An inspection frequency of 4 fuel cycles (6 years of hot operation) provides additional flaw detection margin prior to initiating a leak path through the tube

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Proposed Relief Request

✓ Relief requested with a proposed alternative inspection frequency based on the uniqueness of the occurrence of PWSCC in Penetration 68, specifically:

- Perform volumetric and/or surface examinations of all penetrations as identified by Table 1 of ASME Code Case N-729-1 at a frequency of once every 4^{th} refueling outage or 6 hot operating years whichever is less
- Except for Penetration 68, which will be volumetrically and/or surface examined each refueling outage
- In addition, BMV examinations of the RPV head will occur every 3^{rd} refueling outage or 5 calendar years, whichever is less

Exelon Nuclear

Closing Remarks

Scot Greenlee

Byron Station Engineering Director

Exelon. Nuclear

Closing Remarks

✓ Byron 2 RPV head Penetration 68 indication is unique
  - Inspection results
  - Boat sample evaluations

✓ 2008 head inspections demonstrate no additional PWSCC in Byron 2 and no similar issues in Byron 1 or Braidwood 1 & 2

✓ Proposed inspection frequency appropriate for Byron 2 RPV head consistent with intent of CC N-729-1

Please direct any inquiries to me at 301-415-1547, or marshall.david@nrc.gov.

Sincerely,

/RA/

Marshall David, Project Manager
Plant Licensing Branch III-2
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-455

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2. Licensee Handout

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DATE	09/8/09	09/8/09	09/8/09	09/8/09

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