

## **Bottom Mounted Instrument Penetration Tube Condition Update**



6/5/03

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## **STP Participants**

Tom Jordan	VP, Engineering & Tech Services
Mark McBurnett	Manager, Quality & Licensing
Steve Thomas	Manager, Plant Design
Rick Gangluff	Manager, Chemistry
Michael Lashley	Test Engineering Supervisor
Bill Humble	NSSS Supervisor
Ron Baker	Materials Specialist
Wayne Harrison	Licensing Engineer
Ulhas Patil	Design Engineer
Steve Hunt	Dominion Engineering
John Broussard	Dominion Engineering
Chong Chiu	Performance Improvement Intl.
Ron Latanision	Exponent Failure Analysis Assoc.
John Hall	Westinghouse/CE

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# **INTRODUCTORY REMARKS**

**Mark McBurnett**  
**Manager, Quality & Licensing**

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## **Agenda**

<b>Introductory Remarks</b>	<b>Mark McBurnett</b>
<b>Progress Summary</b>	<b>Tom Jordan</b>
<b>NDE Activities</b>	<b>Michael Lashley</b>
<b>Cause Analysis and Status</b>	<b>Steve Thomas</b>
<b>Repair Plan</b>	<b>Steve Thomas</b>
<b>Corrosion Assessment</b>	<b>Rick Gangluff</b>
<b>Concluding Remarks</b>	<b>Mark McBurnett</b>

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## **Desired Meeting Outcomes**

- NDE results and cause analysis are understood
- Future NDE and testing is understood
- Supporting analyses and schedule are understood
- Documents provided for submittal and inspection are understood
- Future NRC / STP meetings are identified
- NRC questions and needs are clearly understood

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## **PROGRESS SUMMARY**

**Tom Jordan  
Vice President,  
Engineering & Technical Services**

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## Summary

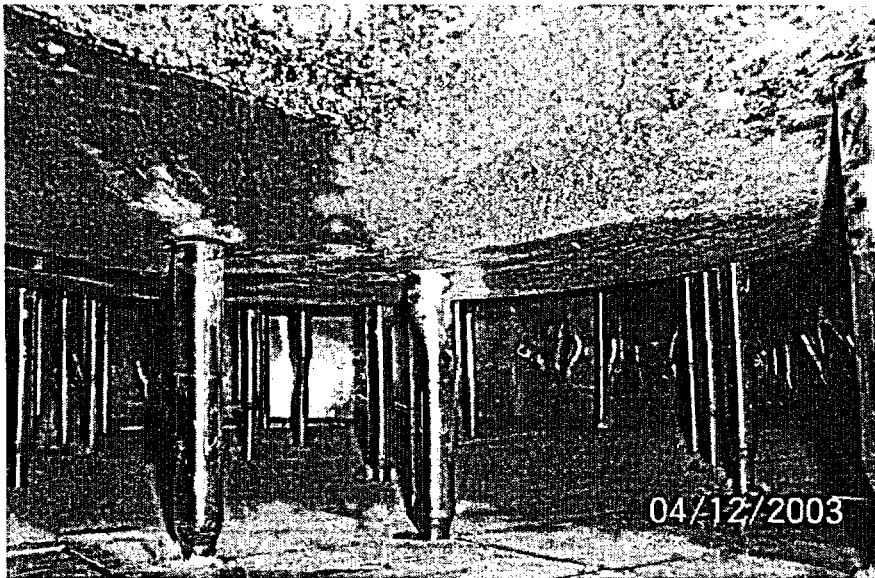
Found residue on two BMI penetrations on April 12

~150 mg of residue on Penetration #1

~ 3 mg of residue on Penetration #46

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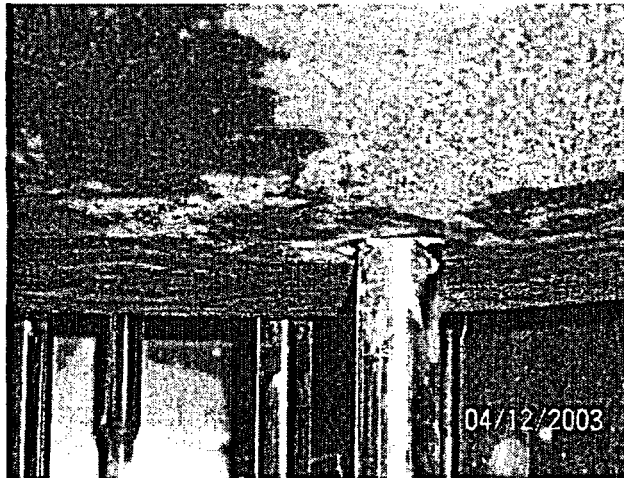
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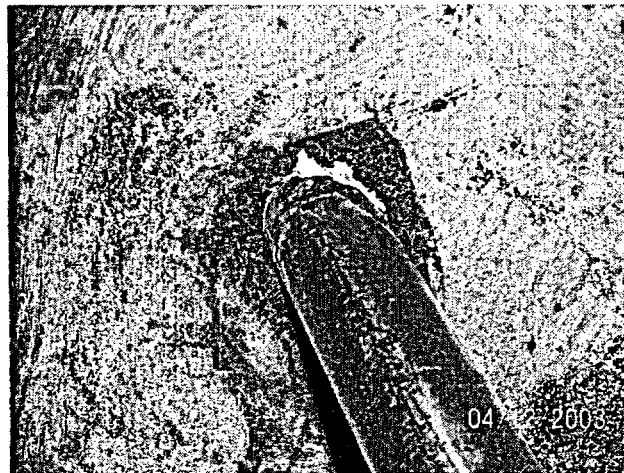
## Penetration #1



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## Penetration #46



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## **Efforts to Date**

- Completed inside vessel NDE
- Selected vendor; commenced design and preparations for half-nozzle repair
- Established cause investigation team using EPRI MRP FMEA technique
- Continuing with activities under the vessel

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## **Overview of NDE Results**

- UT and ECT revealed small axial cracks in #1 and #46, which confirmed leakage path
- No cracks found in other penetration tubes
- No surface breaking indication in any J-groove weld

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## **Planned Activities**

- Additional inspection
- Design and repair activities
- Sample removal and analysis
- NRC review
- Cause analysis

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## **Key Points**

- Careful, deliberate process
- NDE campaign successful
- Condition / repair scope known
- Repairs enable safe return to operation
- Close cooperation with industry and NRC on cause analysis

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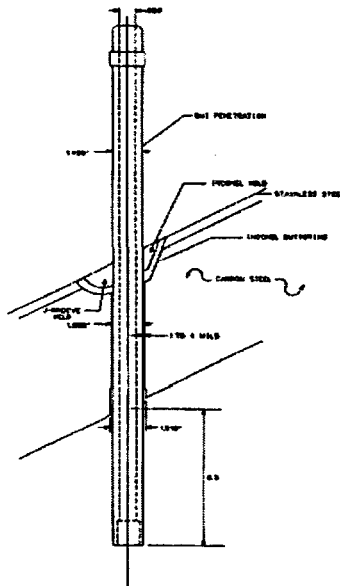
# NDE ACTIVITIES

Michael Lashley  
Test Engineering Supervisor

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## BMI Guide Tube Penetration



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## **Base Inspections Scope**

- **Penetration 1 & 46**
  - UT from penetration tube ID
  - Enhanced visual exam of J-groove weld surface
  - Volumetrically interrogate vessel base metal for wastage
- **Remaining penetrations**
  - UT from the penetration tube ID
  - Enhanced visual exam of J-groove weld surface

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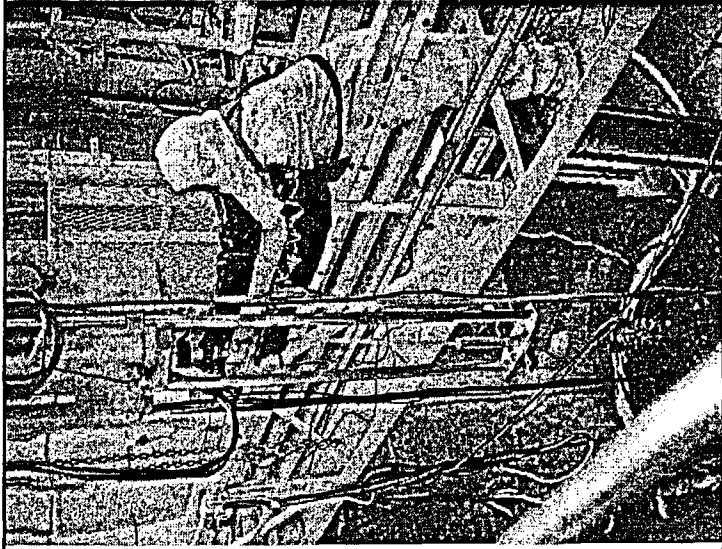
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## **STP BMI Approach follows EPRI MRP CRDM Approach**

- **Define NDE objectives**
  - Identify relevant flaw mechanisms
  - Define inspection locations and volumes
  - Define range of flaws to address
- **Mockup design and procurement**
- **Demonstration protocol and schedule**
  - Non-blind / blind
  - Detection / sizing / location
  - False calls

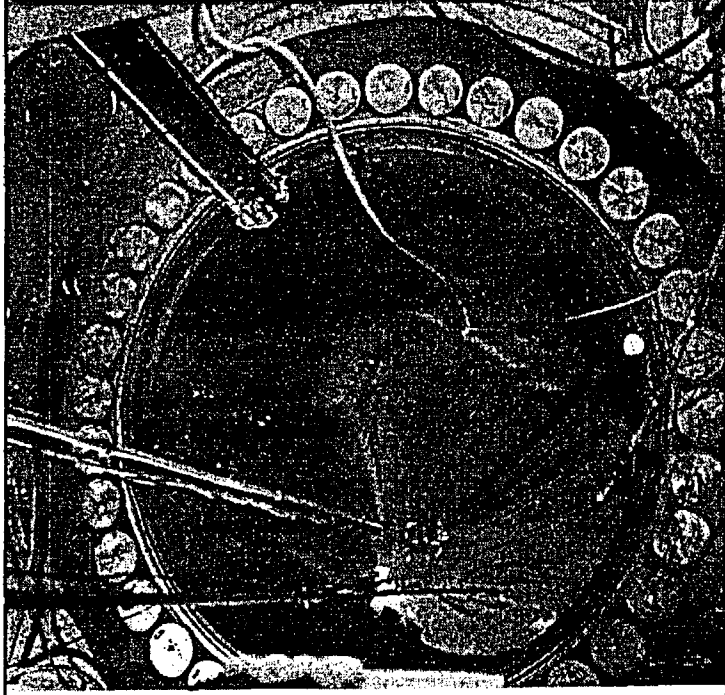
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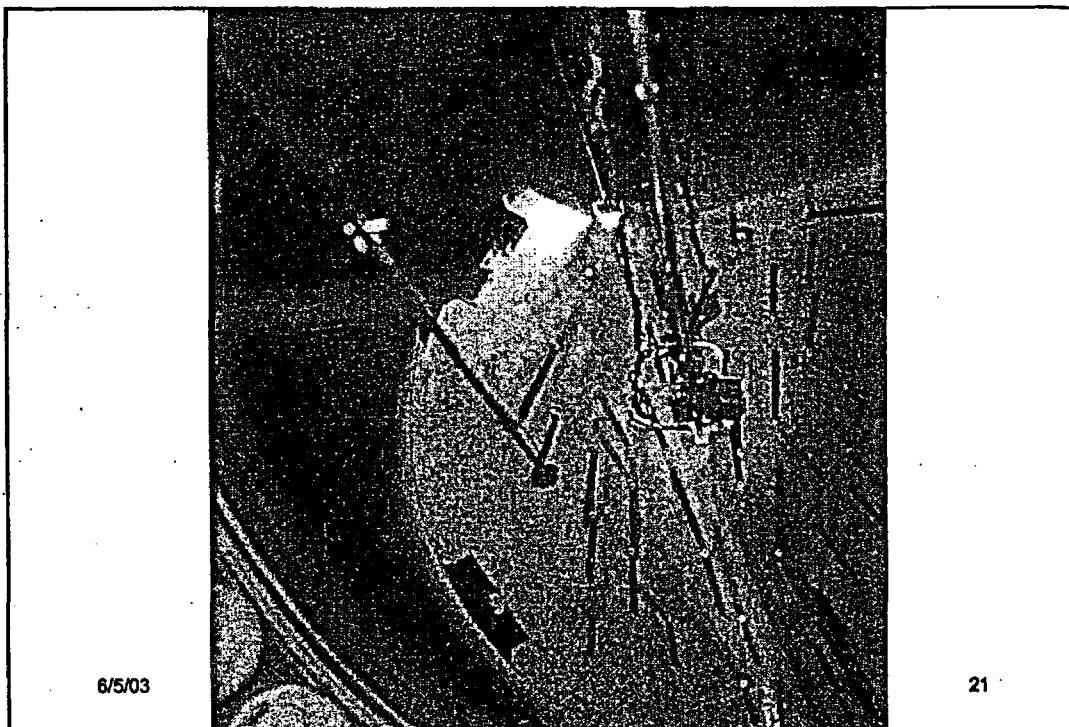
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## Confirmatory Inspection Scope

- Penetration 1 & 46
  - ET from penetration tube ID
  - ET of J-groove weld surface
- Remaining penetrations
  - ET from the penetration tube ID of two other penetrations (2 & 6)
  - ET of J-groove weld surface of six other penetrations (9, 12, 33, 34, 38 & 41)

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## **Activities April 21 – May 26**

- Mockup fabrication (CIP samples & full scale mockup)
- NRC presentation
- Demonstration / vendor selection
- Demonstration / equipment checkout
- Base scope inspections
- Confirmatory Inspections

Demonstrations, base scope inspections, and confirmatory inspections were witnessed by NRC Inspection Team

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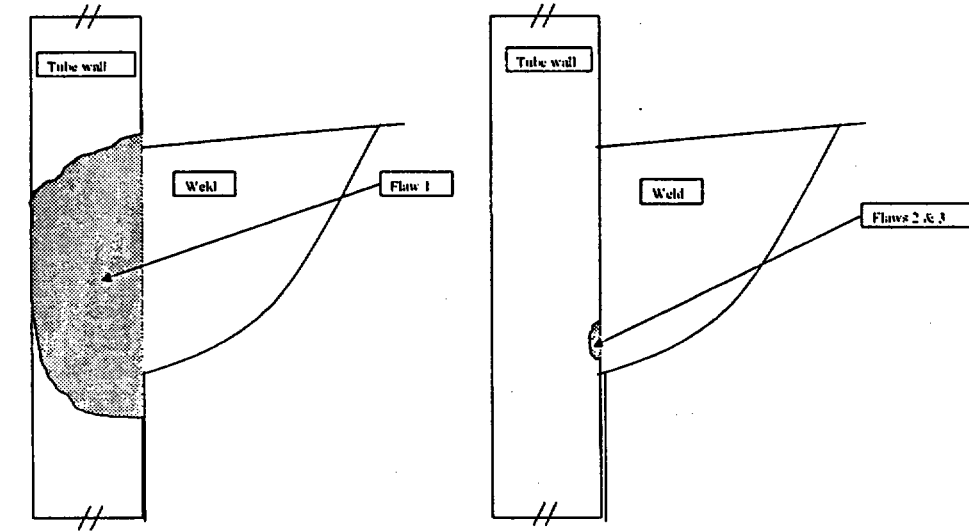
## **Summary of Results**

- Penetration #1
  - Three axial indications, one leak path
  - No crack-like indications on J-Groove weld
  - Visual grinding marks in side of tube
- Penetration #46
  - Two axial indications, one leak path
  - No crack-like indications on J-Groove weld

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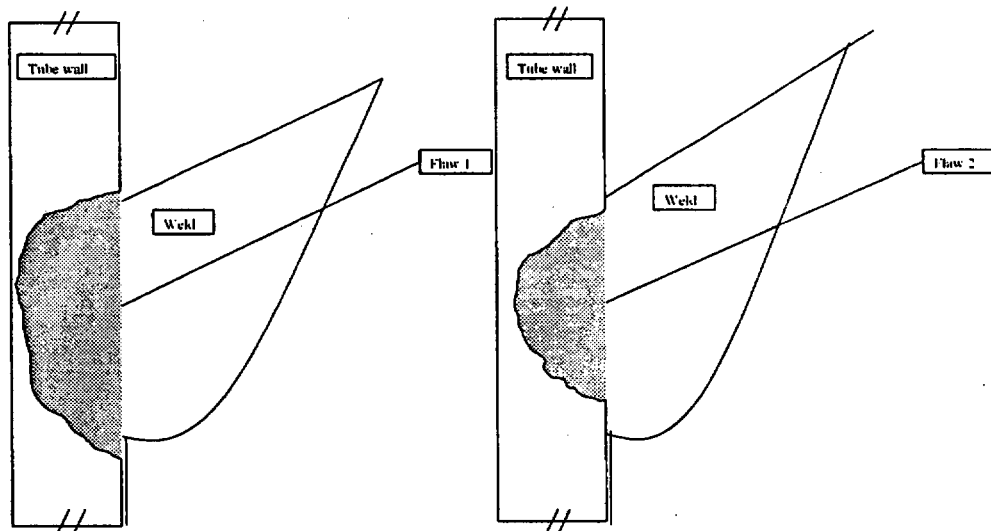
## Penetration #1



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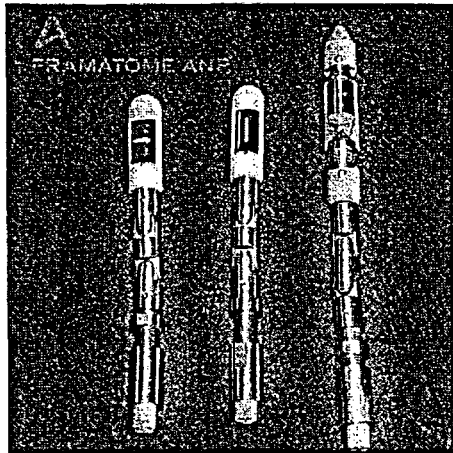
## Penetration #46



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## UT Examination Probes

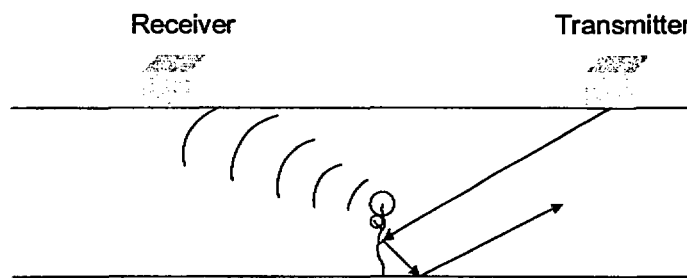


- Circumferential probe
- Axial probe
- 0-degree mapping

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## Time of Flight Diffracted (TOFD)



Low-amplitude, secondary wave generated by excitation of flaw

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# TOFD

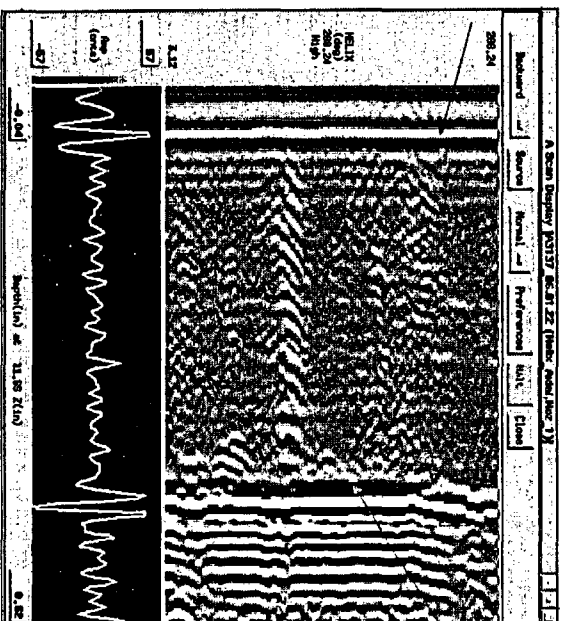


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## Penetration #1 Axial Probe

Tube ID

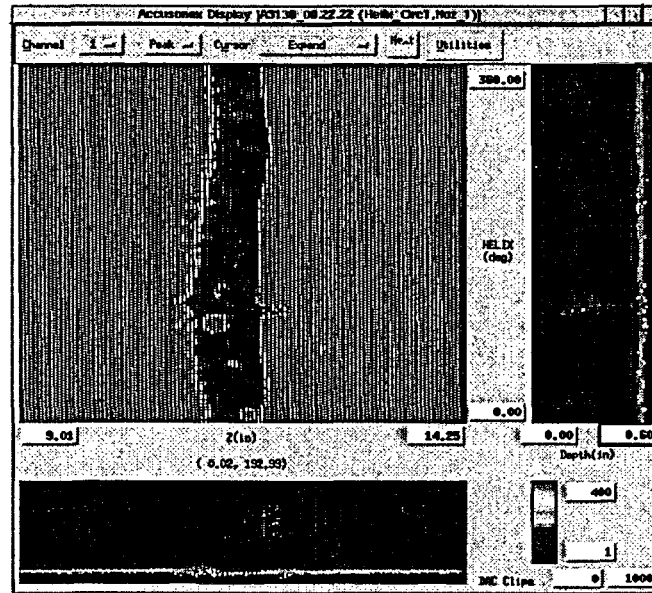


Tube OD

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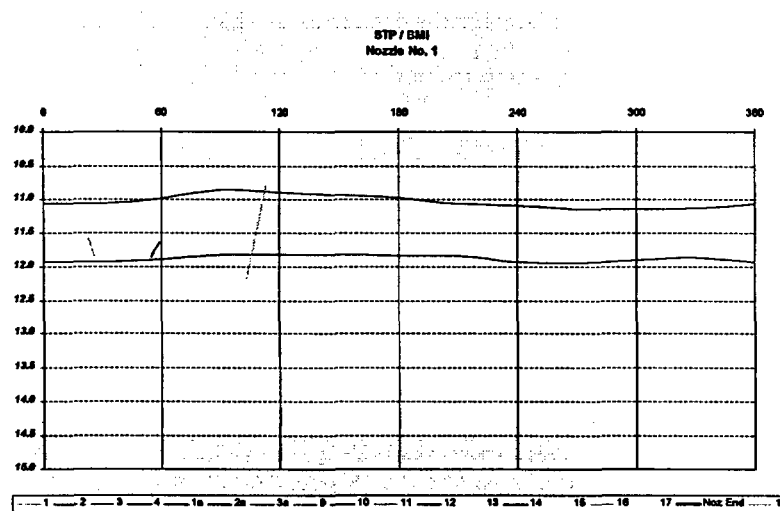
## Penetration #1 Weld Profile



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## Penetration #1 Leak Path

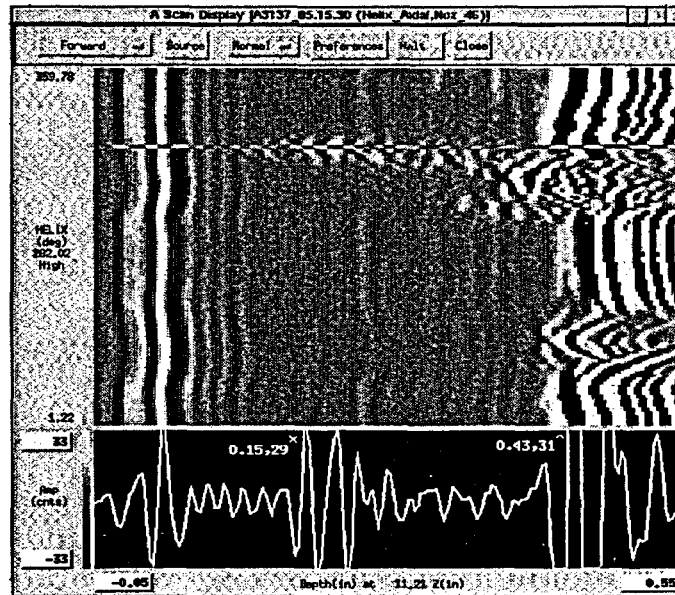


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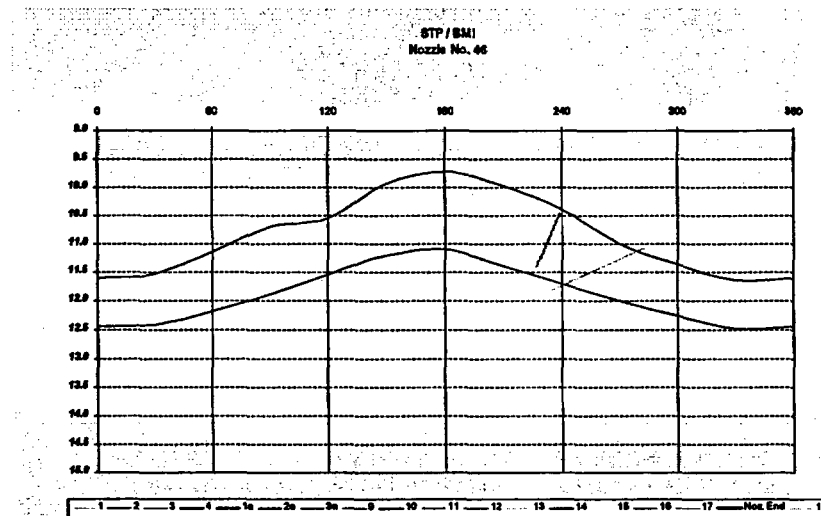
## Penetration #46 Axial Scan



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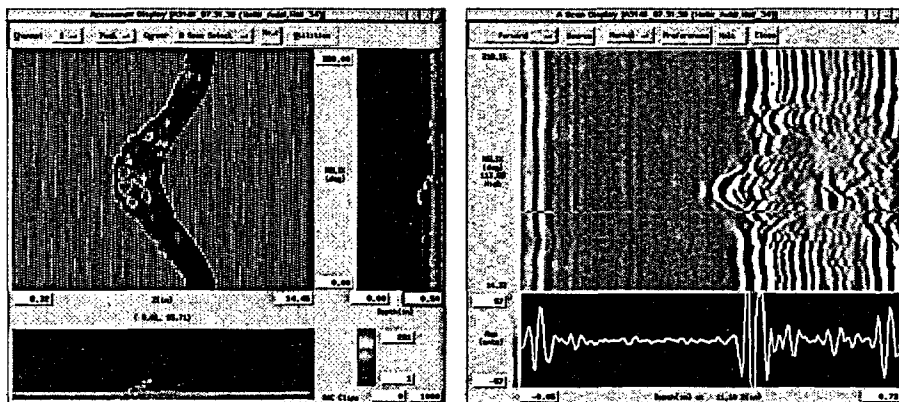
## Penetration #46 Leak Path



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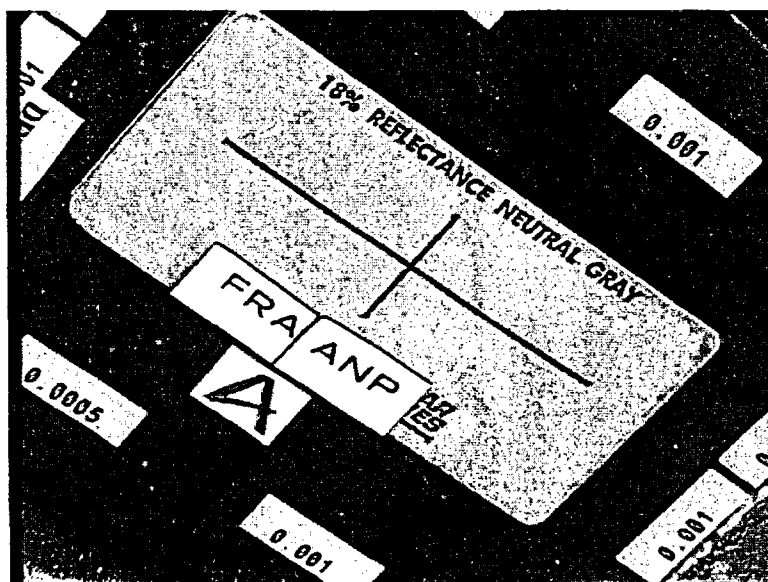
## Penetration #34 Fabrication Discontinuity



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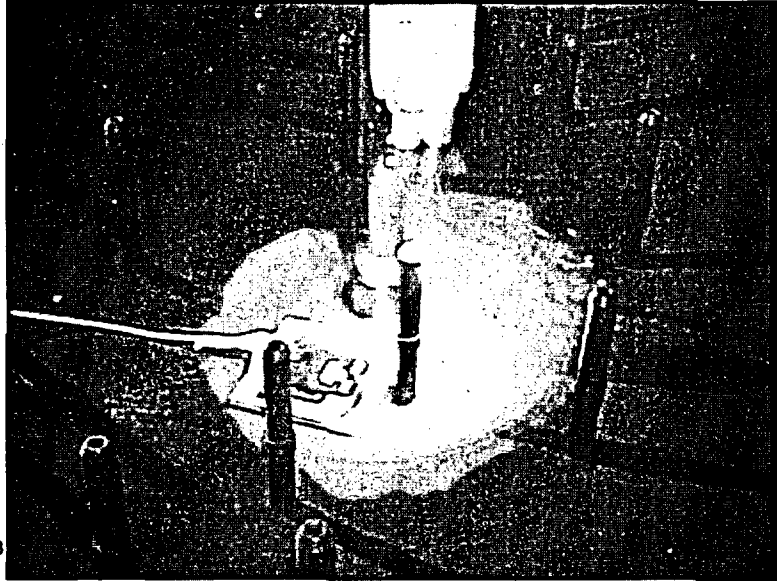
## Enhanced Visual



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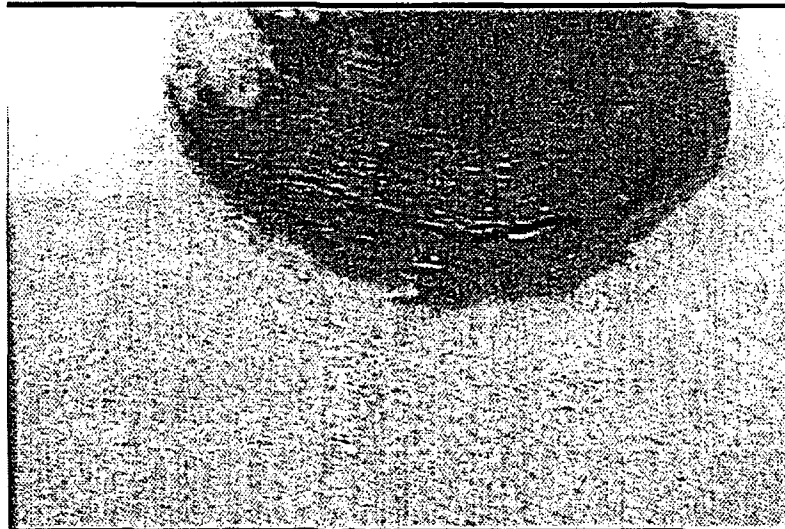
## Penetration Overview



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## Penetration #1 Visual



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## Confirmatory Examinations

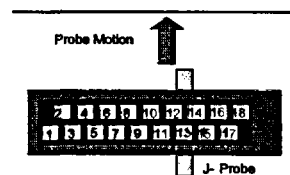
- Bobbin coil eddy current on penetration ID
  - Penetration #1 displayed a tube ID surface-breaking flaw
  - Penetration #46 displayed a tube ID sub-surface flaw
  - Two other reference penetrations displayed no flaws
- Array coil eddy current on J-Groove weld
  - Penetration 1, 46, 33 & 5 others scanned
  - No flaws identified

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## Eddy Current Probe Operation

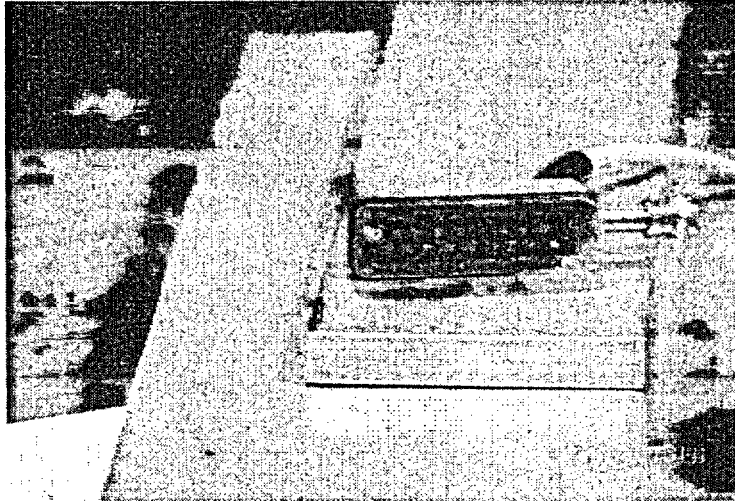
- 18 coil array
- X coil windings
- 2 rows of 9 coils
- 1.6" coverage



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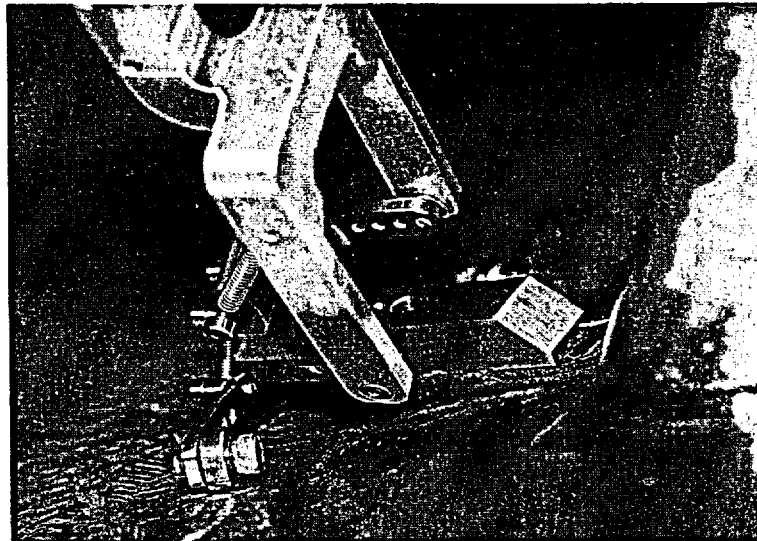
## Eddy Current Probe



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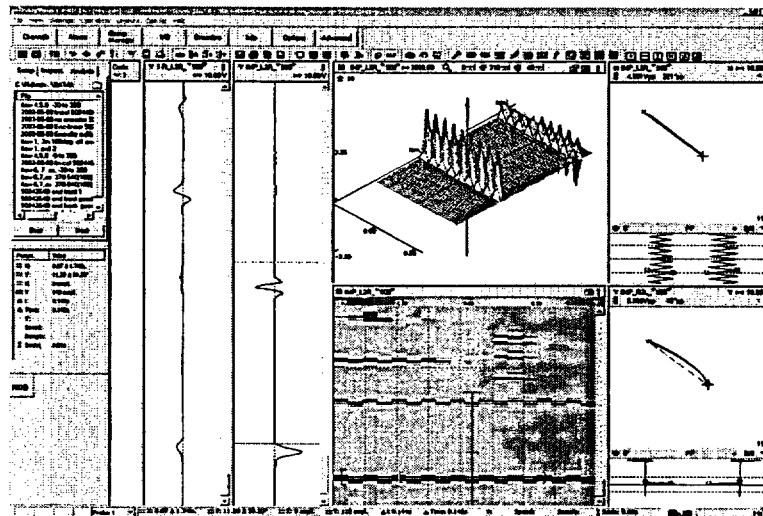
## Eddy Current J-Groove Probe



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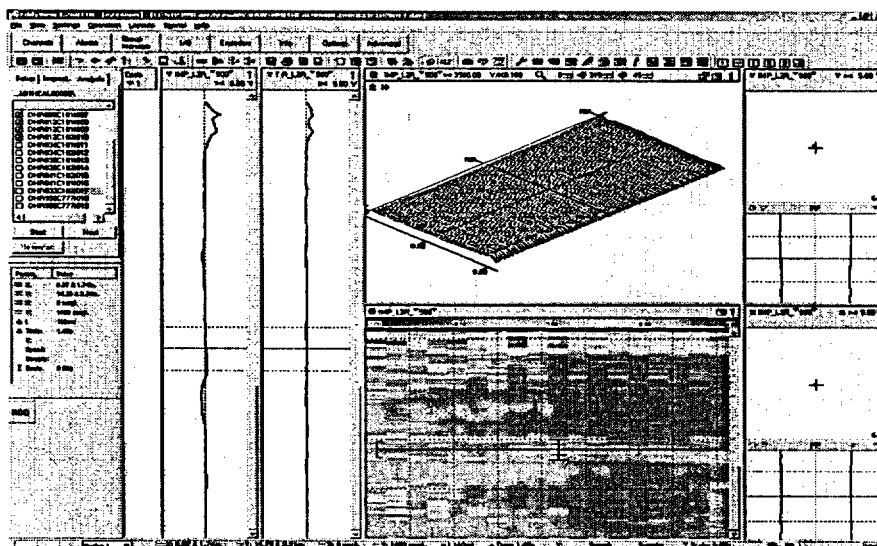
## Calibration Setup



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## Penetration 33 J-Groove exam



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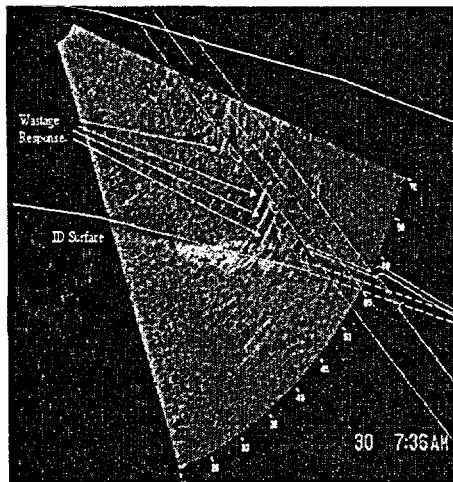
## Additional Confirmatory Inspections and Tests

- Wastage UT (phased array)
- Other
  - Rod test
  - Bubble test
  - Profilometry
  - Visual of tube ID
  - Visual of vessel bore
  - Metallurgical sample
  - Boat sample

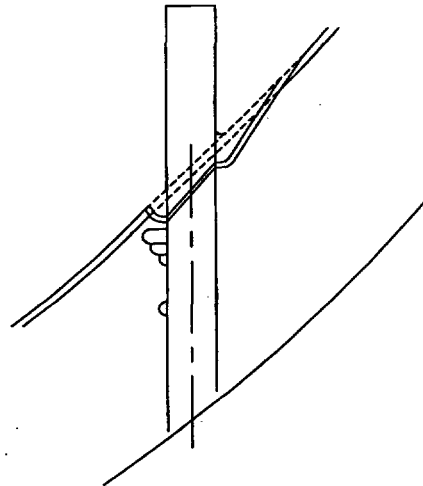
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## Developing Technology to Identify Wastage



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# **CAUSE ANALYSIS and STATUS**

**Steve Thomas  
Manager, Plant Design**

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## **What Was Found**

- Residue on two nozzles
- Total of five flaws in the two nozzles
- One flaw in each nozzle provides a leak path
  - Only one flaw fully penetrated nozzle
- Three embedded flaws
- Discontinuities
- Grinding marks

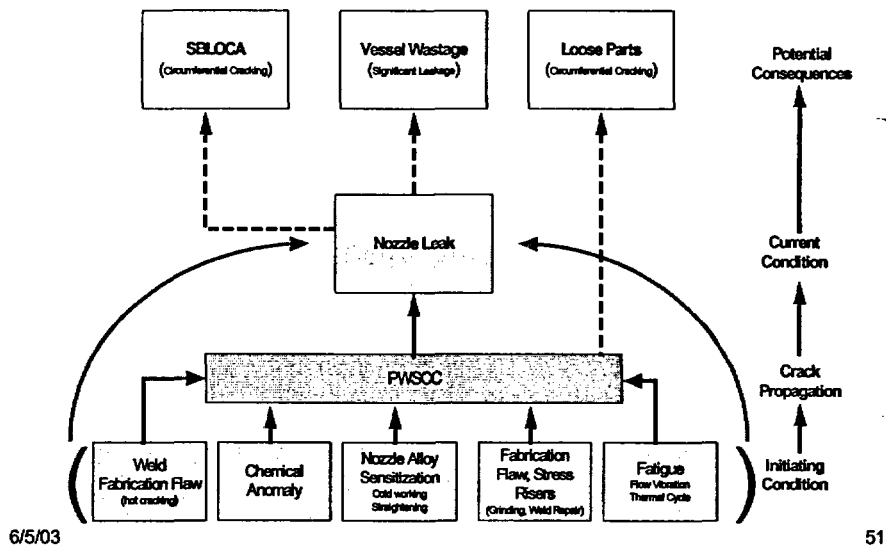
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## PWSCC May Not Be the Cause



## Tube Coldworking Not a Likely Contributor

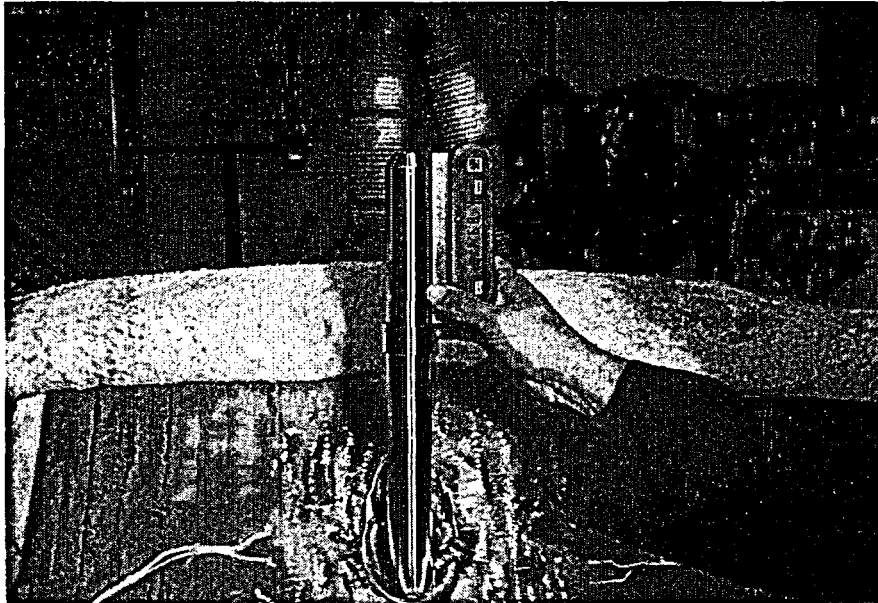
1976 Combustion Engineering Nuclear Fabrication Practice 101-3-0 states:

5.8.1 REMINDER: Use the bull's eye level and alternate welds as necessary to insure alignment

5.8.4 Cold straighten, as necessary, all tubes which are out of alignment

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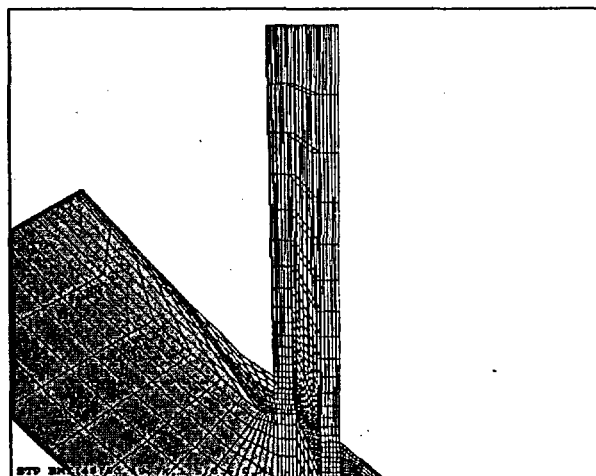
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## Analysis Shows Minimal Displacement During Welding



MESH 8.7  
 MAY 10 2003  
 11:03:26  
 FLOT NO. 8  
 DISPLACEMENT  
 TIME=7000  
 RAY=0  
 DMX =.021614  
 DISPLACEMENT  
 TIME=7000  
 RAY=0  
 DMX =.04614  
 \*DCR=1  
 TV =1  
 \*DIST=7.25  
 \*XF =-8.02  
 \*YF =66.127  
 \*ZF =53.045  
 A=25+90  
 PRECISE HIDE

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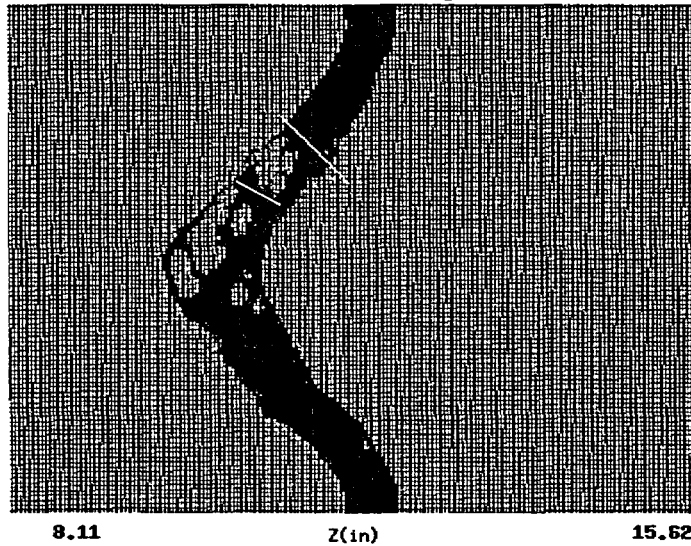
## Conclusion

Coldworking is not a significant contributing factor

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## Axial Scan of Penetration 46 with Flaws Overlayed



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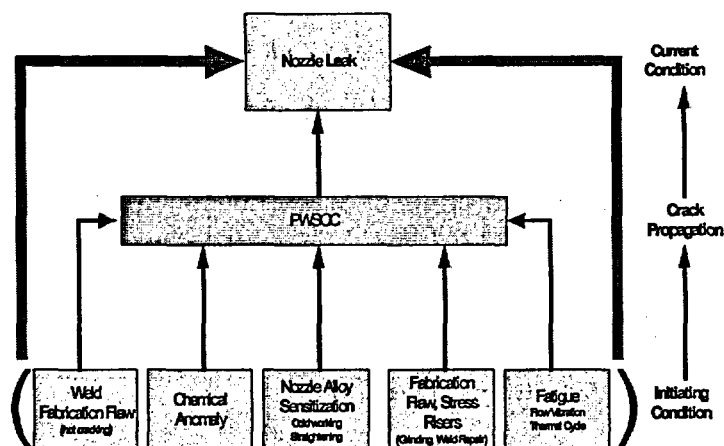
## Most Likely Causes

- Residual fabrication stresses
  - J-groove weld grinding, welding, welding rework
- Lack of J-groove weld fusion to nozzle OD
- Weld cracking; fabrication defects / contaminants
- Combination of one or more with PWSCC

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## Root Cause Focus



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## **Planned Additional Testing**

- Volumetric UT of vessel around #1 and #46
- Helium test for #1 and #46 annulus
- Visually examine inside bore #1 and #46
  - Perform after nozzle capped and separated
  - Possibly detect irregularities
  - Look for known through-wall flaw in #1

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## **Planned Additional Testing (cont'd)**

- Eddy current profilometry of #1 and #46
  - Performed from the bottom after nozzle is capped and separated from guide tube
  - Captures data on ID characteristics like ovalization at J-groove weld zone
- Visual exam of vessel at #1 and #46 after portion of old nozzle removed

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## **Planned Additional Testing (cont'd)**

- Metallurgical analyses of removed nozzle ends
- Boat samples from #1 and #46 flaw zones

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## **Repair and Startup Are Safe**

- Inspections limit repair scope to the two leaking nozzles
  - Extensive NDE reveals no flaws in other nozzles

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## **Repair and Startup Are Safe (cont'd)**

- Regardless of final root cause, half-nozzle repair is the appropriate corrective action
  - Bounds potential causes
  - Establishes new ASME Code pressure boundary
  - Utilizes proven industry process
  - Upgrades material to Alloy 690

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## **Repair and Startup Are Safe (cont'd)**

- Evaluation of evidence indicates minor nozzle leakage is worst potential consequence

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## Severe Consequences Not Likely

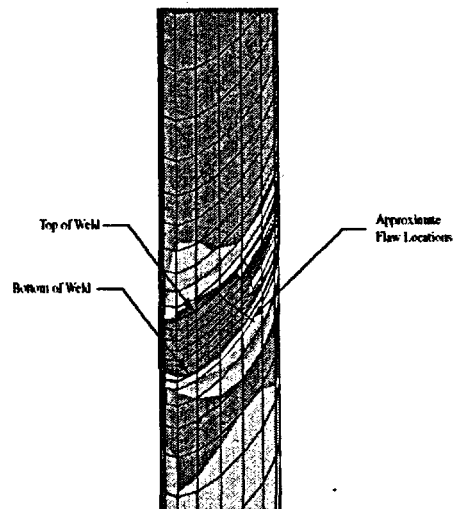
### Small Break Loss of Coolant Accident (SBLOCA)

- Residual stresses favor axial crack orientation
- No circumferential cracks

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## Flaw Locations and Stresses



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Nozzle Alone, Showing Approximate Flow Locations and Stresses in the Direction Parallel to the Plane of the Weld

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## Severe Consequences Not Likely (cont'd)

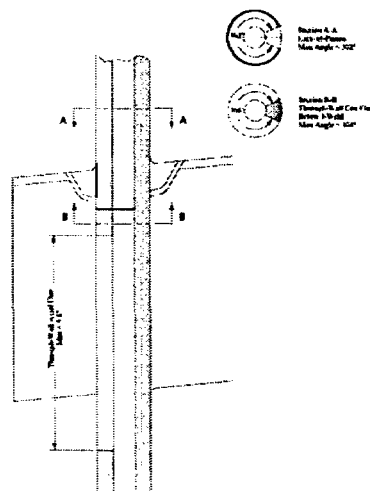
### Small Break Loss of Coolant Accident (SBLOCA)

- Residual stresses favor axial crack orientation
- No circumferential cracks
- Robust design
- Limiting flaw size

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## Limiting Flaw Size



Locations of Analyzed Axial and Circumferential Flaws

Figure 5-1

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## **Severe Consequences Not Likely (cont'd)**

### **Small Break Loss of Coolant Accident (SBLOCA)**

- Residual stresses favor axial crack orientation
- No circumferential cracks
- Robust design
- Limiting flaw size
- Very large safety factor
- Bare metal inspection
- Leak before break

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## **Severe Consequences Not Likely (cont'd)**

### **No evidence of vessel wastage**

- No significant iron in residue
- No wastage residue
- No visual indication
- Confirmed by UT

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## **Severe Consequences Not Likely (cont'd)**

### **Loose Parts**

- No flaws above weld
- No circumferential flaw
- Residual stresses favor axial crack orientation

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## **Conclusions**

- We have good data
- Repair scope limited to #1 and #46
- Repair bounds likely causes
- Root cause will determine monitoring plan

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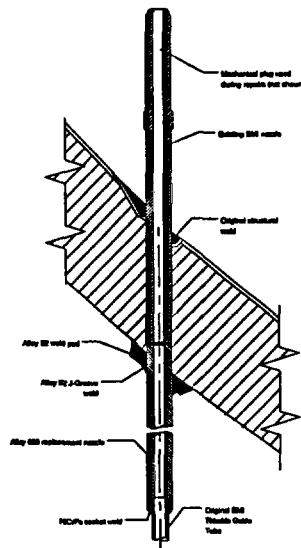
# REPAIR PLAN

Steve Thomas  
Manager, Plant Design

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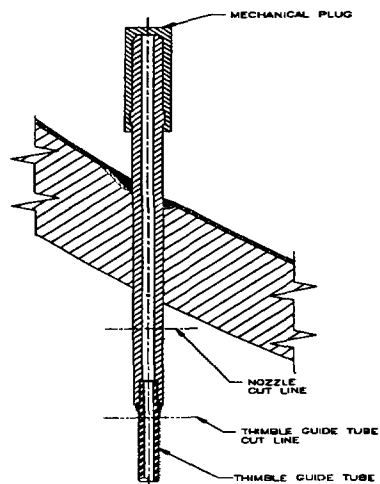
## Half-Nozzle Repair



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## Deploy Plug; Cut Guide Tube / Nozzle

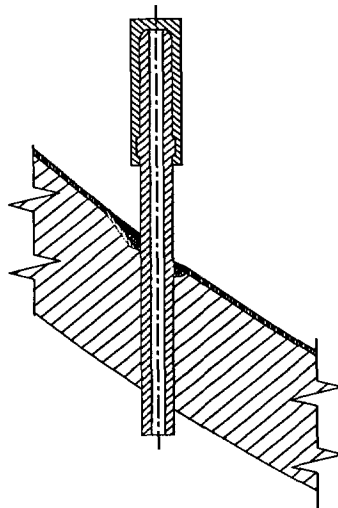


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STEP 1  
DEPLOY MECHANICAL PLUG  
SEVER THIMBLE GUIDE TUBE  
INITIAL NOZZLE CUT

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## Inspect for Leaks

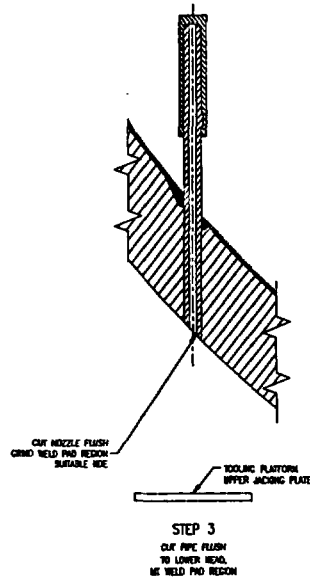


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STEP 2  
INSPECT FOR LEAKS

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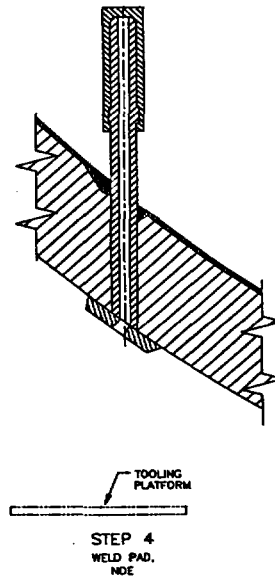
## Cut Nozzle Flush with Head



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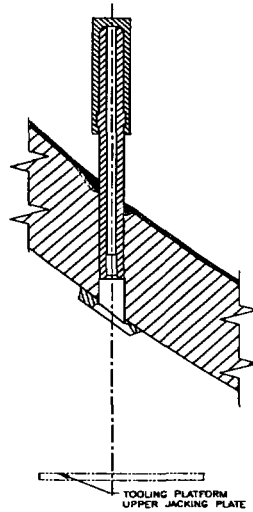
## Form Weld Pad and NDE



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## Machine Bore and Form Weld Prep

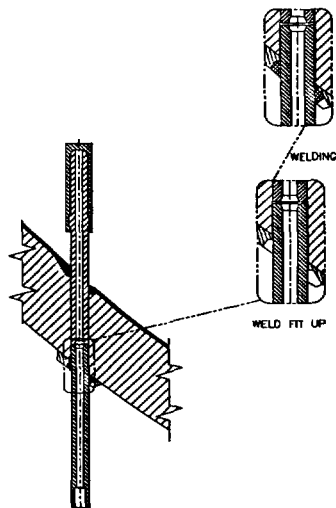


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STEP 5  
MACHINE BORE  
FORM WELD PREP

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## Install Nozzle; Weld; NDE



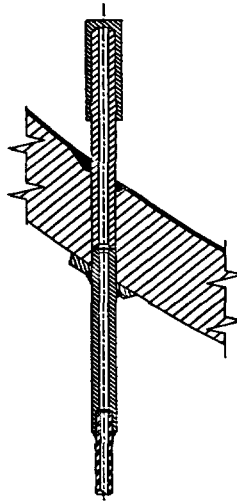
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STEP 6  
INSTALL REPLACEMENT NOZZLE,  
WELD, NDE

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## Install Tube; Weld; NDE; Remove Plug

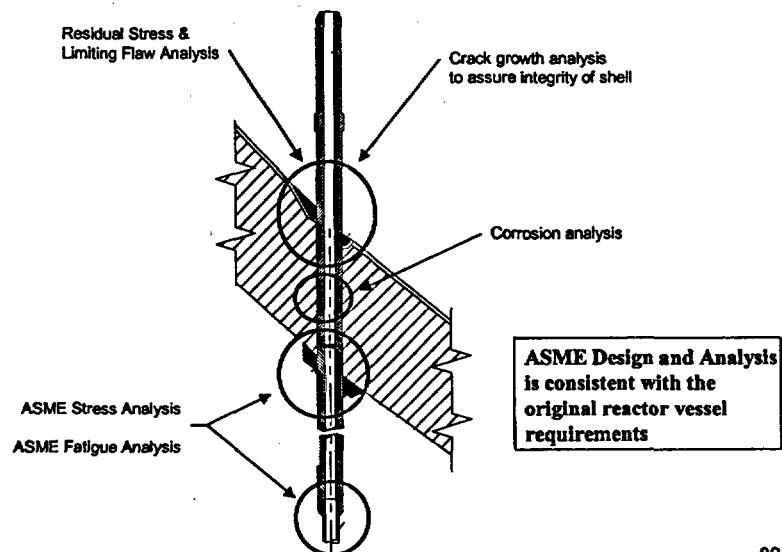


STEP 7  
INSTALL THERMOCouple GUIDE TUBE,  
WELD, NDE, REMOVE MECHANICAL  
PLUG

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## Analyses Supporting Repair



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# **CORROSION ASSESSMENT**

**Rick Gangluff**  
**Manager, Chemistry**

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## **Half-Nozzle Replacement Corrosion Assessment**

- Small gap between Alloy 600 remnant and new Alloy 690 nozzle
- Carbon steel (SA 533B) in annulus region exposed to primary coolant
- No mechanism to concentrate boric acid
- Corrosion rates are very low (~1.5 mil/yr)

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## **Corrosion Rates Addressed by CEOG for Nozzle Replacement**

- SER issued for Rev. 0 of CEOG Report
- NRC found CEOG report methods and analyses to be acceptable
- STP plant-specific analyses in accordance with SER nearing completion

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## **BMI General Corrosion Acceptable**

- Corrosion rate identified in report acceptable for STP based on projected capacity factors
- Lifetime increase in diameter
  - 24 years     0.073"
  - 44 years     0.135"
  - Less than most limiting nozzle

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# CONCLUDING REMARKS

**Mark McBurnett**  
**Manager, Quality & Licensing**

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## Deliverables

Nozzle finite element stress analysis	Avail.
Flaw size limits to prevent net section collapse	Avail.
NRC site review visit	TBD
Submit LER	6-12
NDE inspection report	6-14
Design change (Section III, Section XI, corrosion)	6-14
Annulus dilation analysis	6-15
Submit temper bead relief request	6-17
Nozzle inservice acceptability analysis	6-30

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## **Deliverables (cont'd)**

Preliminary cause report (FMEA summary, bounding cause, safety significance, corrective action, monitoring plan)	<b>7-12</b>
Rockville meeting (cause report)	-
Public meeting at STP	-
Relief request approval	-
Half-nozzle lab analysis report	9-21
Boat sample analysis report	9-21
Submit LER supplement (final cause report summary)	<b>10-12</b>

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## **Conclusions**

- NDE campaign successful
- Condition/repair scope known
- Repairs enable safe return to operation
- Continued close cooperation with industry and NRC on cause analysis

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