Bottom Mounted Instrument Penetration Tube Condition Update

NUCLEAR OPERATING COMPANY

STP

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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 Intnl.
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

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

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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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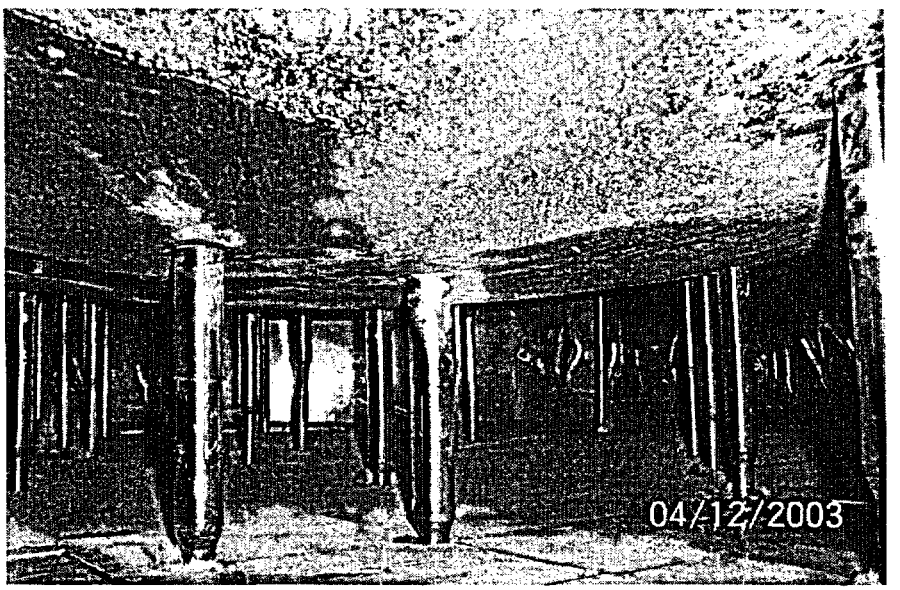

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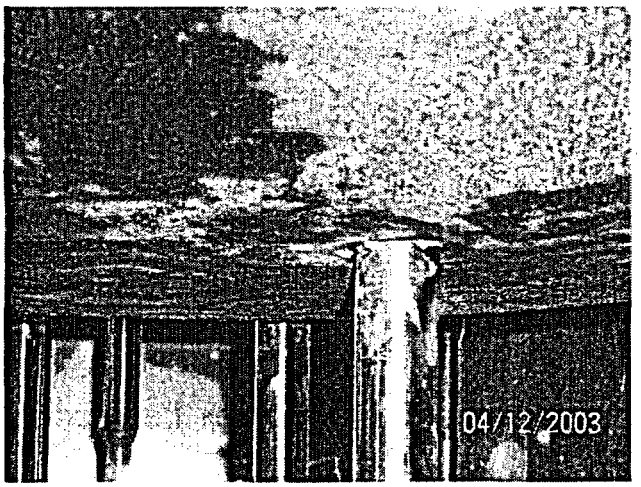
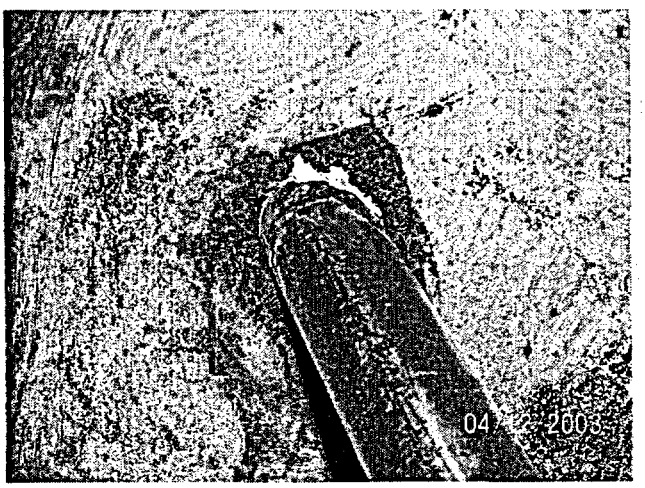
Penetration #1



Penetration #46



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

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

Planned Activities

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

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

NDE ACTIVITIES

Michael Lashley
Test Engineering Supervisor

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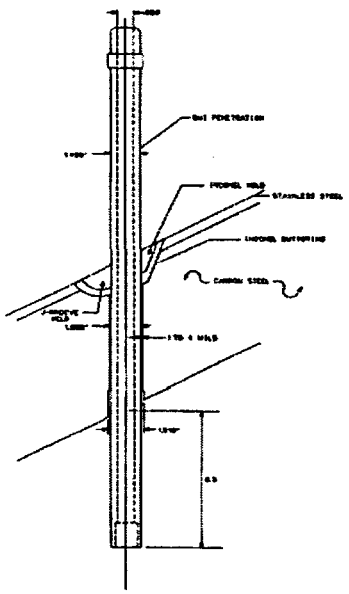
BMI Guide Tube Penetration



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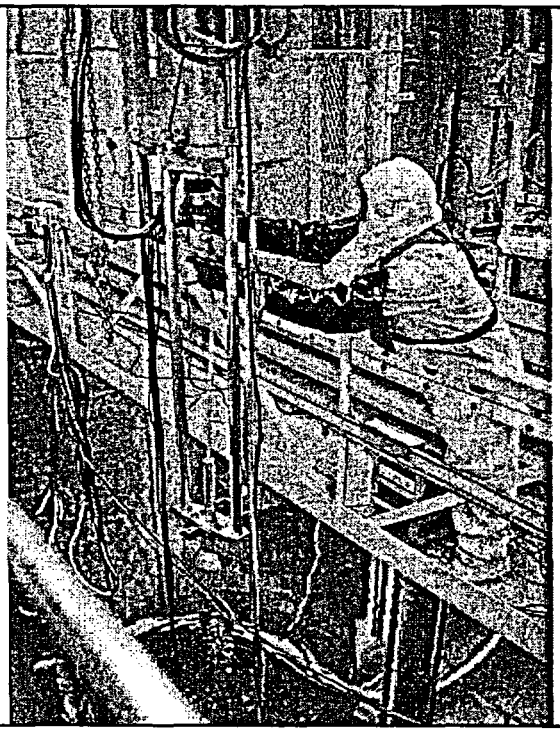
Base Inspections Scope

- 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

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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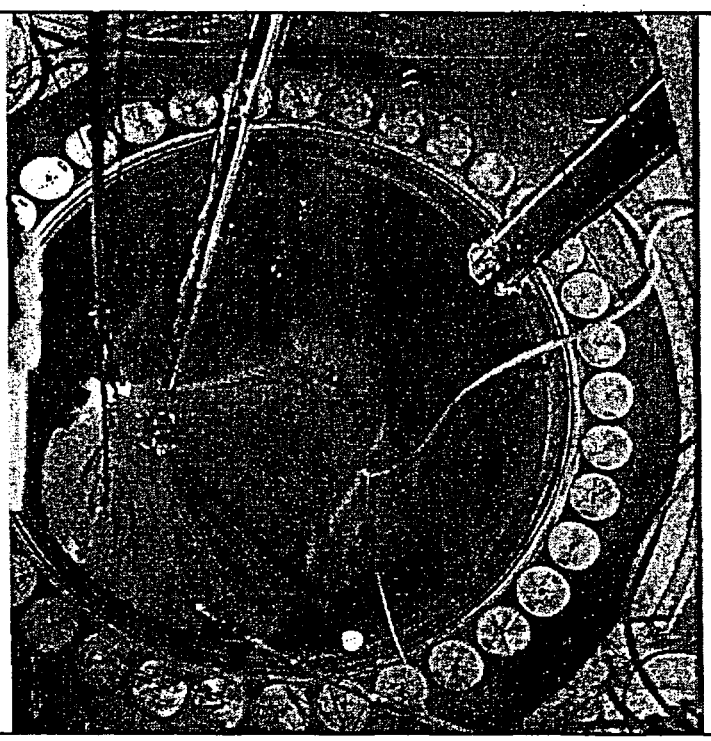

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Confirmatory Inspection Scope

- 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

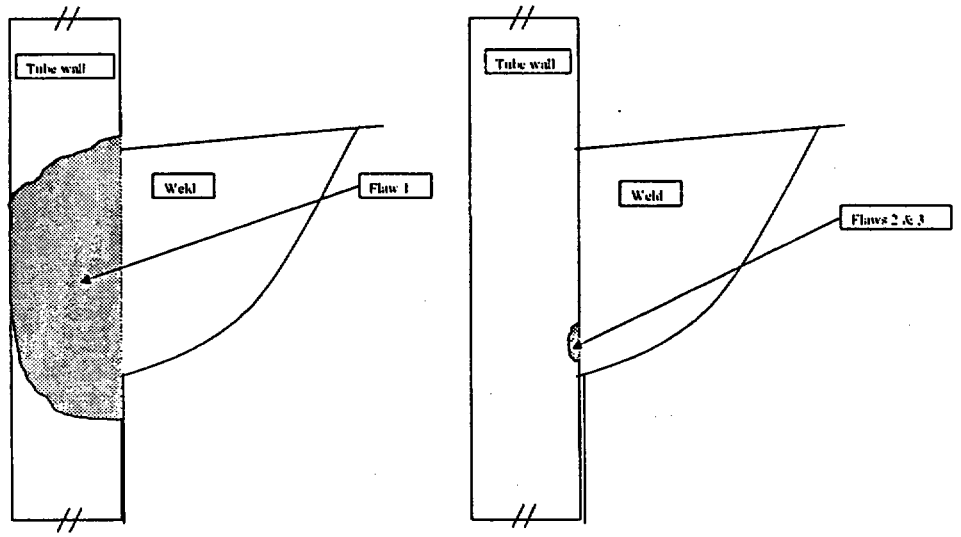
- Mockup fabrication (CIP samples & full scale mockup)
- NRC presentation
- Demonstration / vendor selection
- Demonstration / equipment checkout
- Base scope inspections
- Confirmatory Inspections

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

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

Penetration #1



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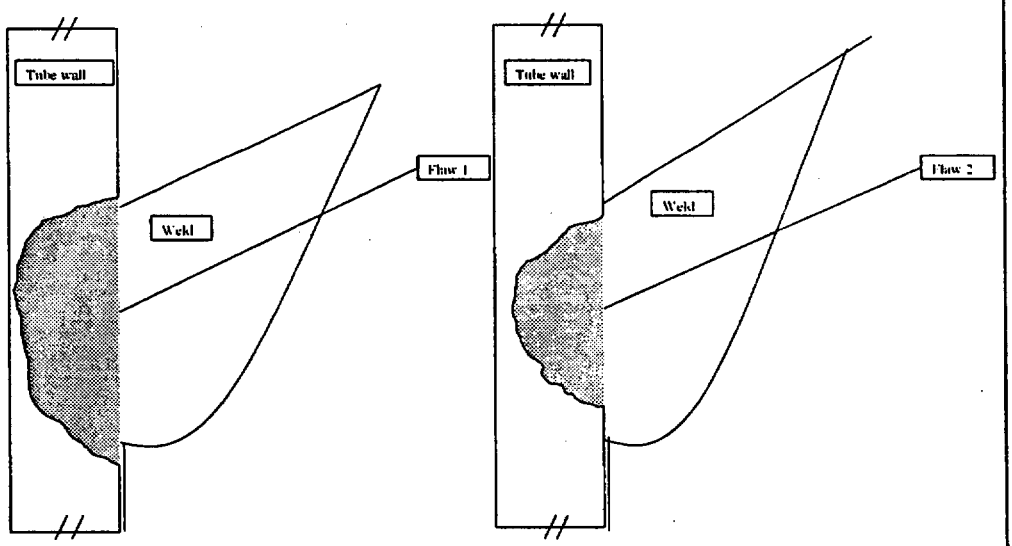
Penetration #46



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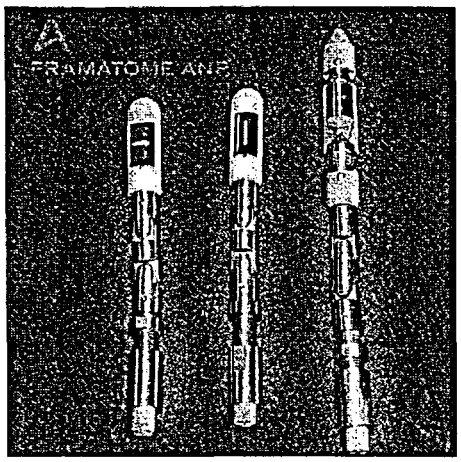
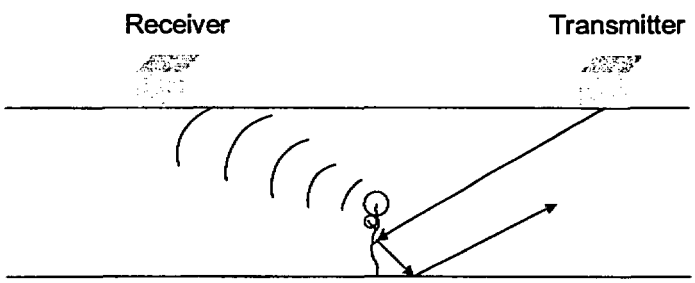
UT Examination Probes



- Circumferential probe
- Axial probe
- 0-degree mapping

Time of Flight Diffracted (TOFD)



Low-amplitude, secondary wave generated by excitation of flaw

TOFD

Samp001.exe

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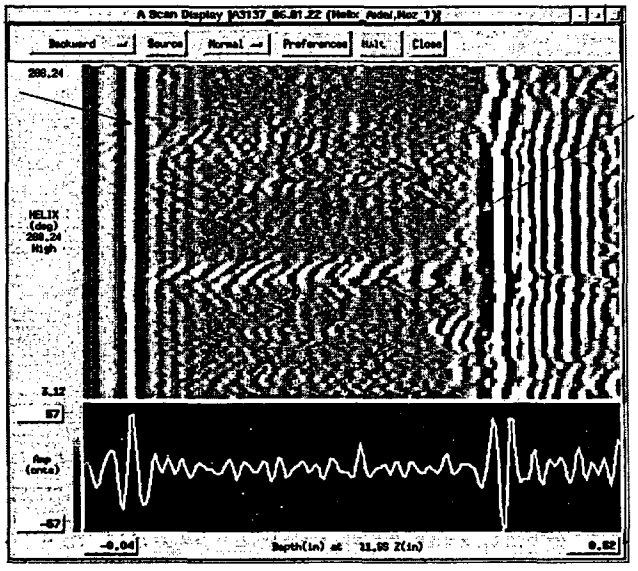
Penetration #1 Axial Probe

Tube ID



Tube OD

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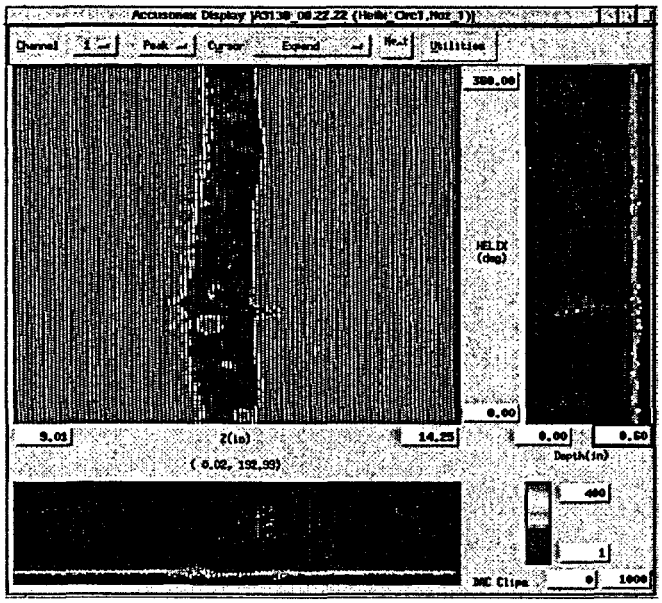
Penetration #1 Weld Profile



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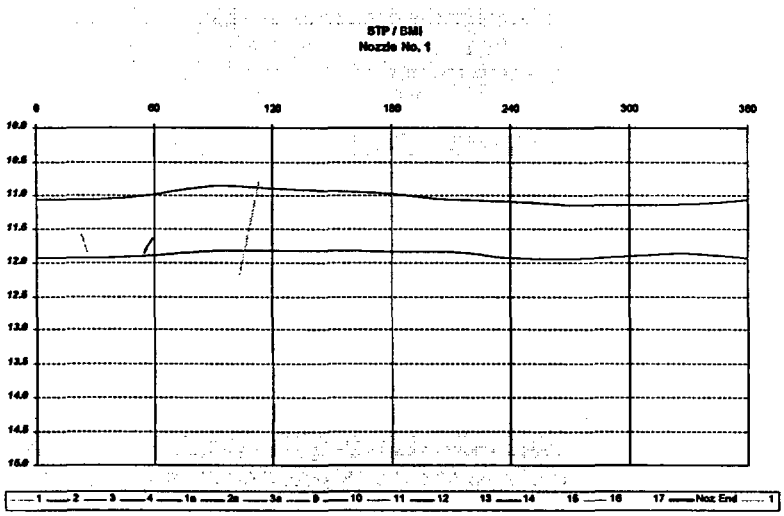
Penetration #1 Leak Path



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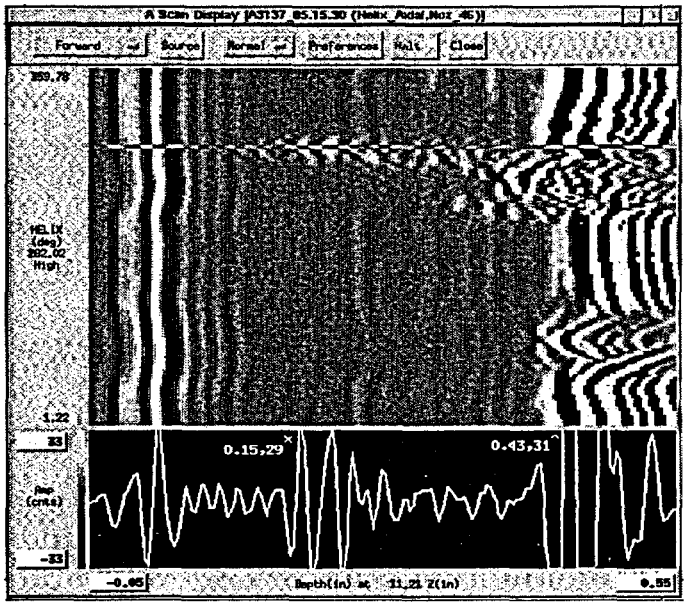
Penetration #46 Axial Scan



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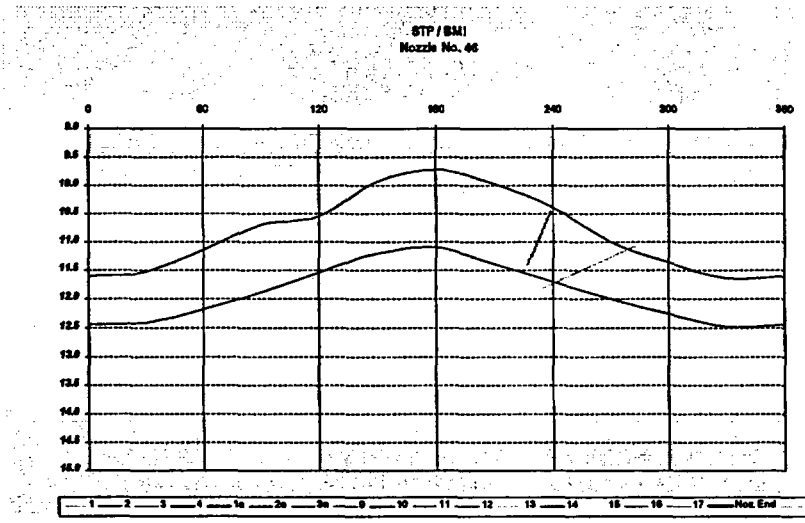
Penetration #46 Leak Path



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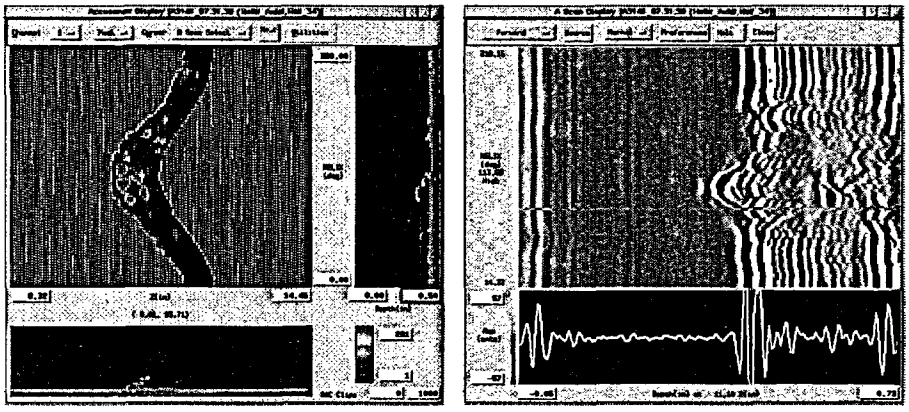
Penetration #34 Fabrication Discontinuity



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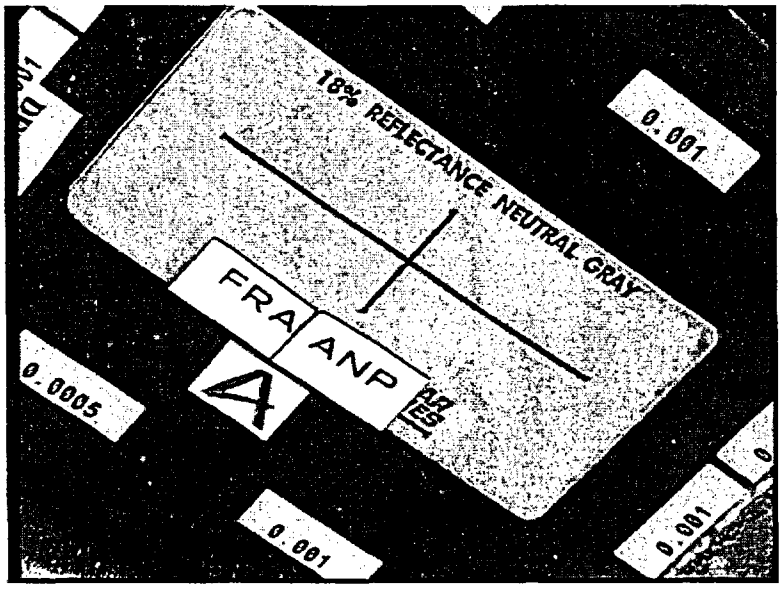
Enhanced Visual



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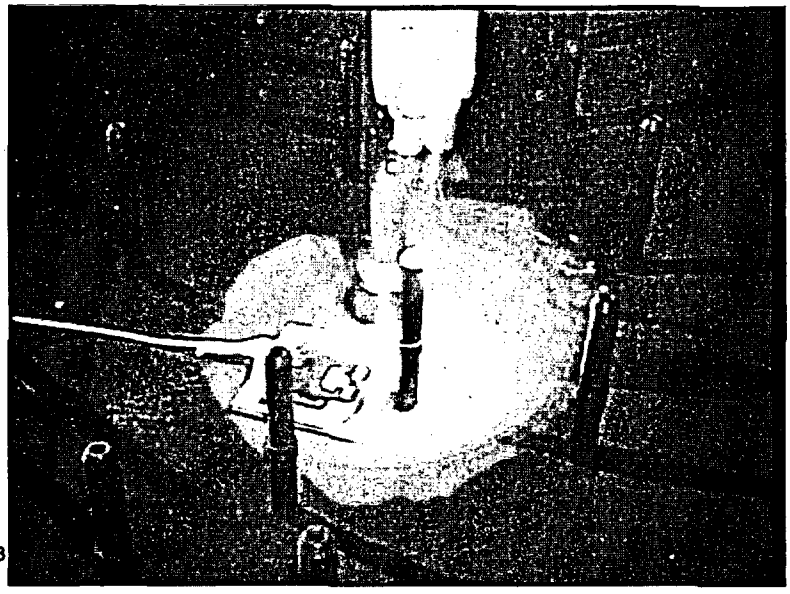
Penetration Overview



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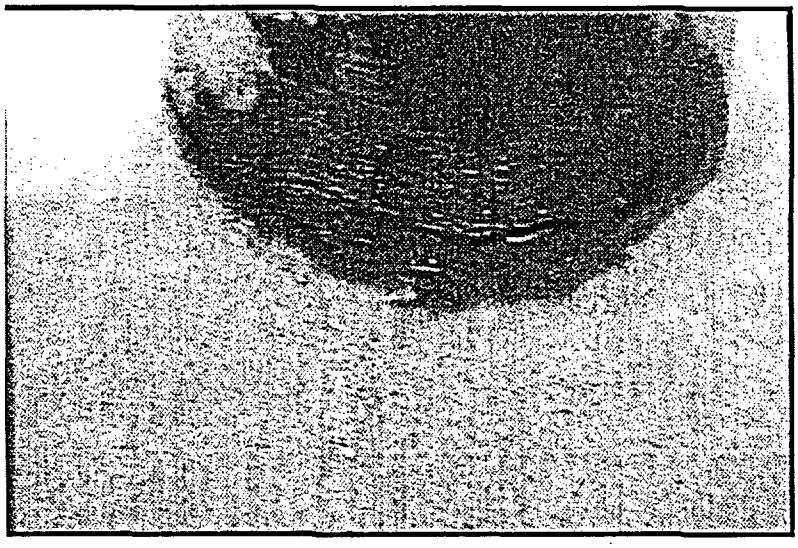
Penetration #1 Visual



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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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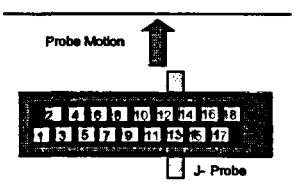
Eddy Current Probe Operation

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



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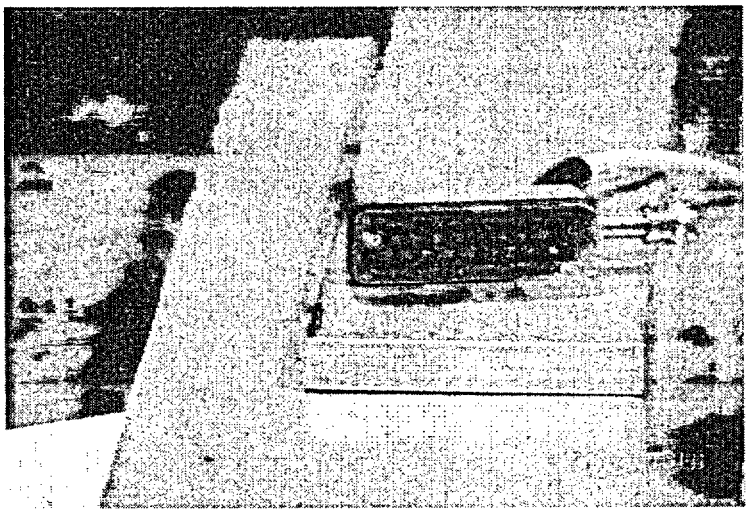
Eddy Current Probe



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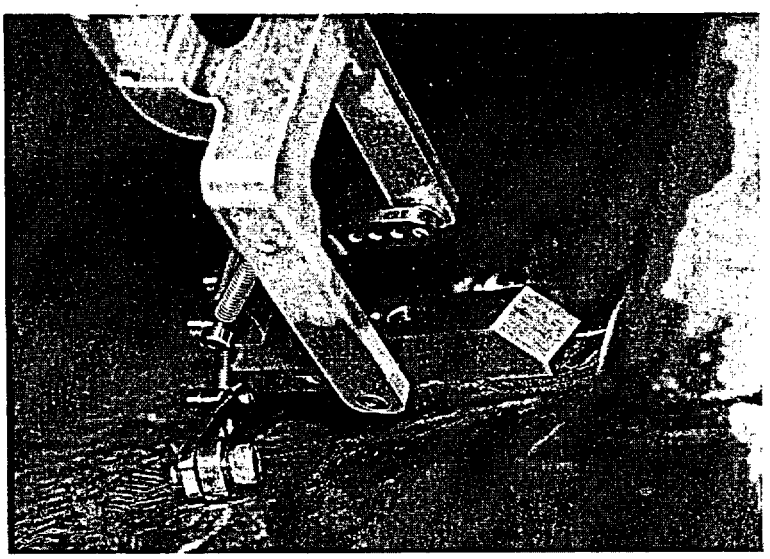
Eddy Current J-Groove Probe



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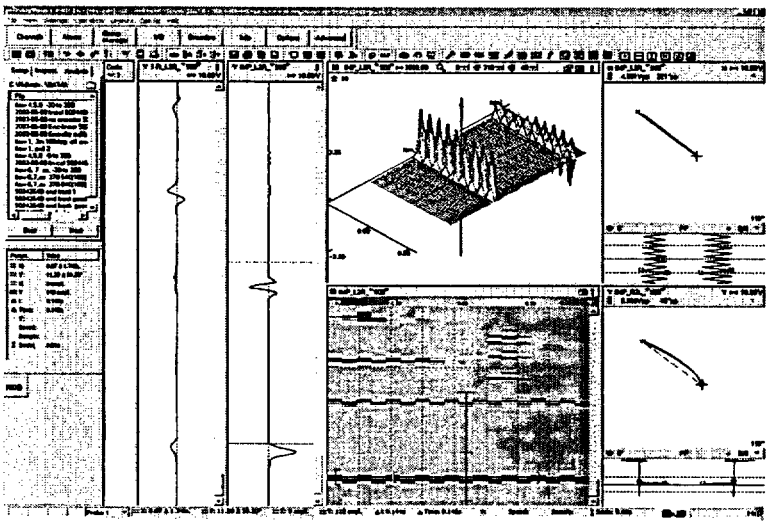
Calibration Setup



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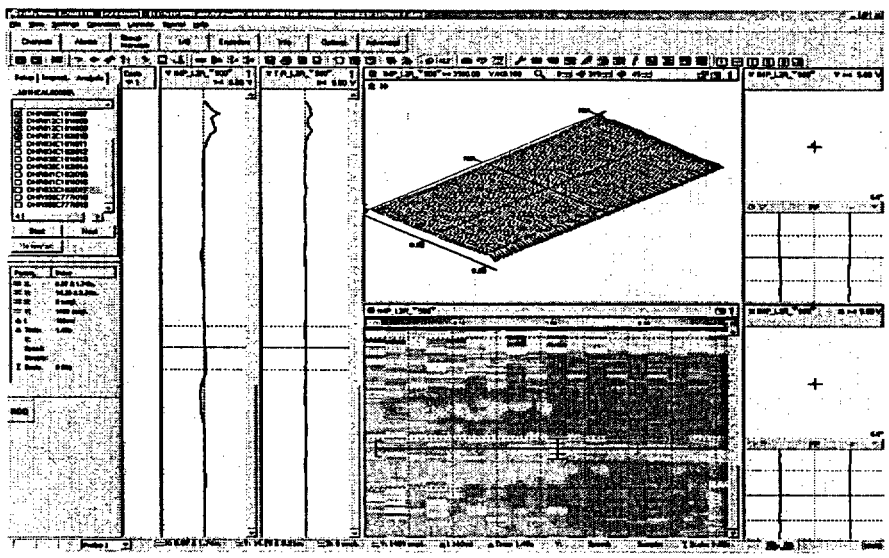
Penetration 33 J-Groove exam



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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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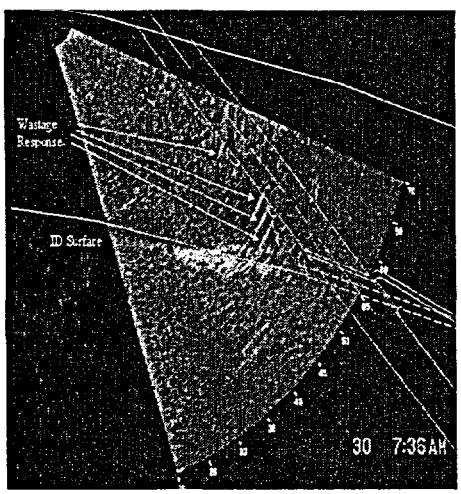
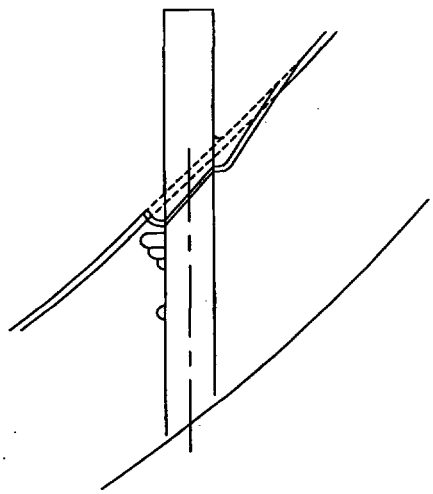
Developing Technology to Identify Wastage





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CAUSE ANALYSIS and STATUS

Steve Thomas
Manager, Plant Design

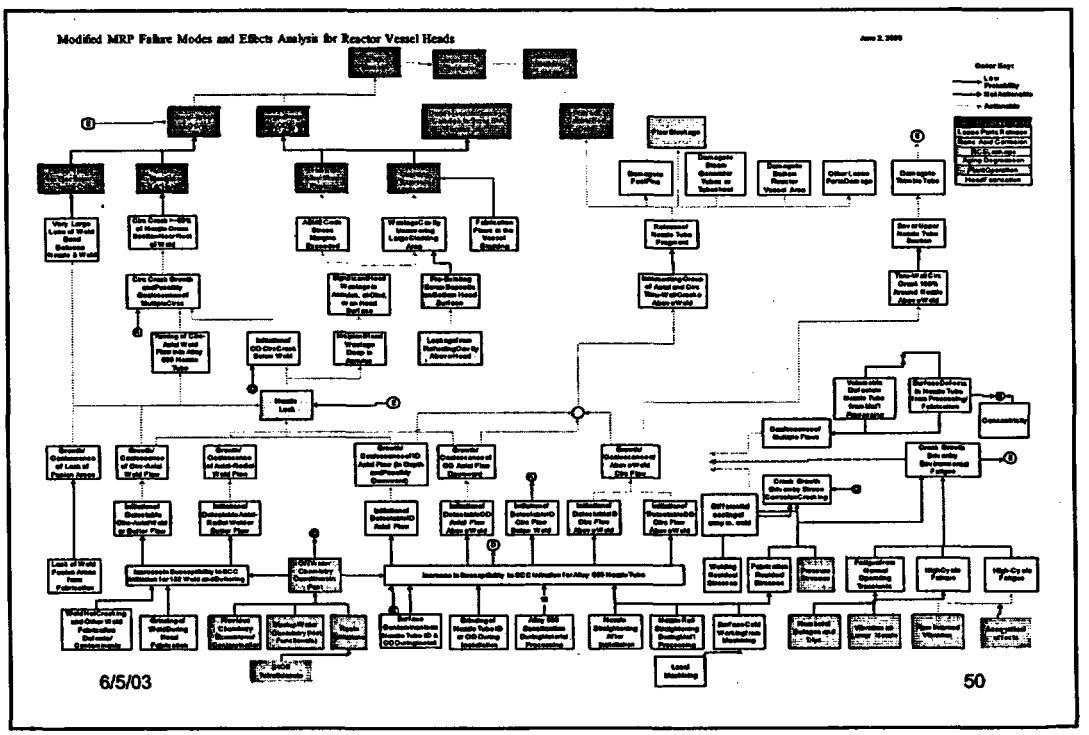
What Was Found

- 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

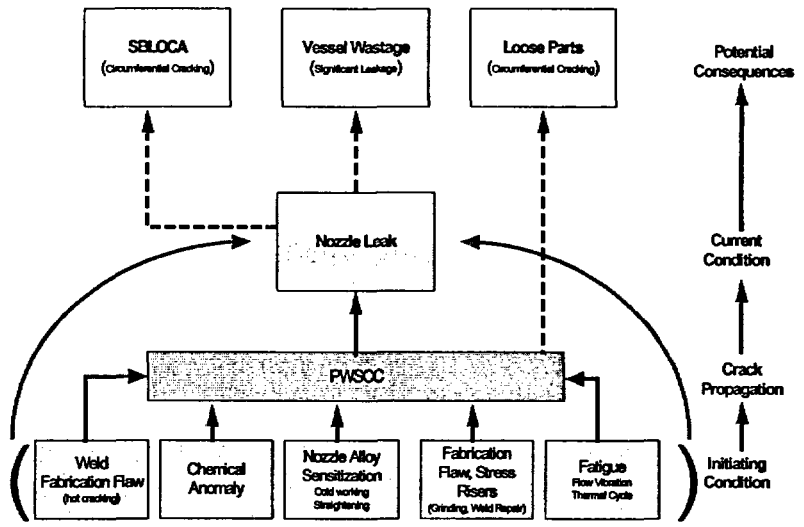
Other Observations

- No flaws in the 55* other nozzles
- No evidence of circumferential cracks
- No evidence of ID initiated cracks

* Penetration #31 will be examined during repair



PWSCC May Not Be the Cause



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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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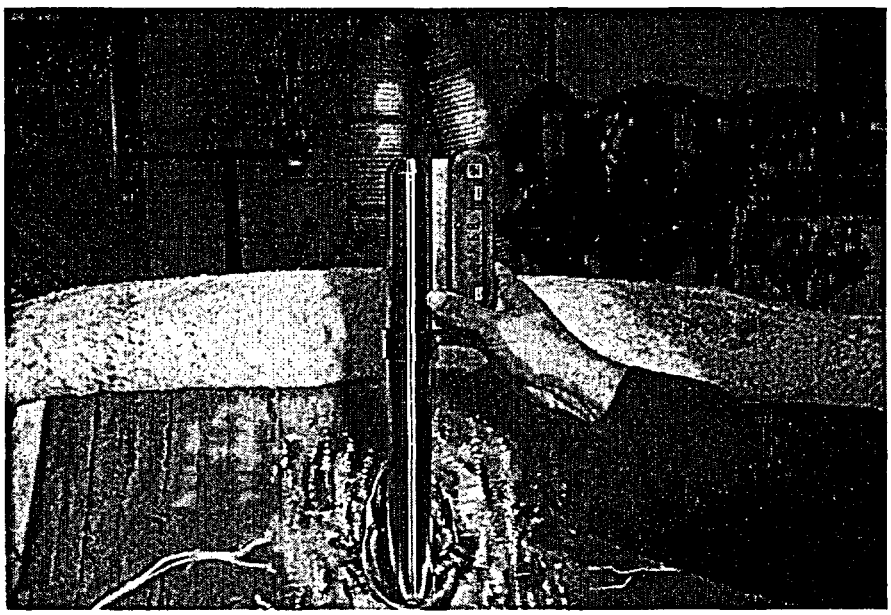
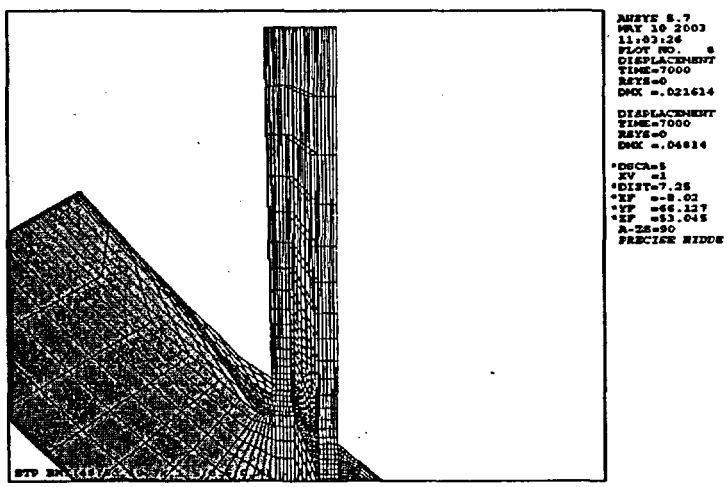


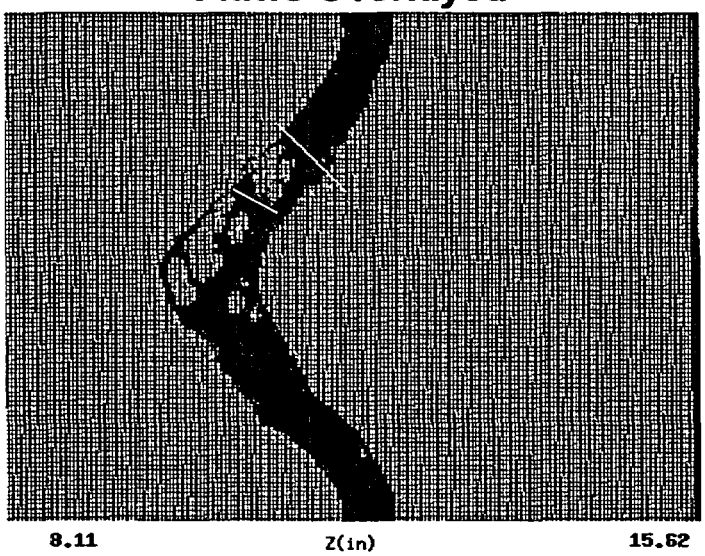
Analysis Shows Minimal Displacement During Welding



Conclusion

Coldworking is not a significant contributing factor

Axial Scan of Penetration 46 with Flaws Overlayed



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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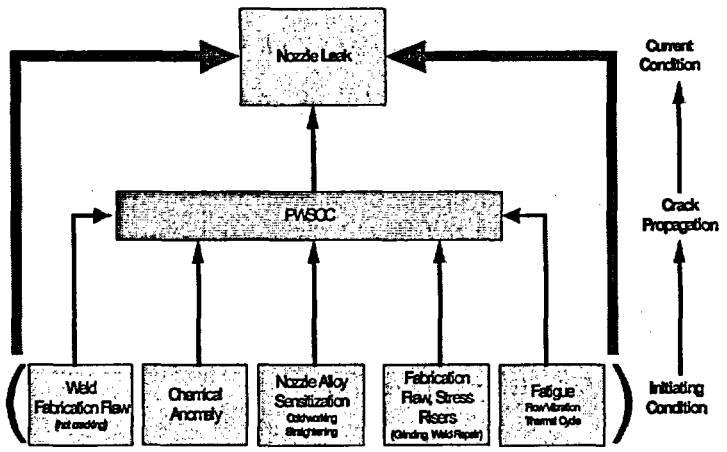
Root Cause Focus



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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

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

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

Repair and Startup Are Safe (cont'd)

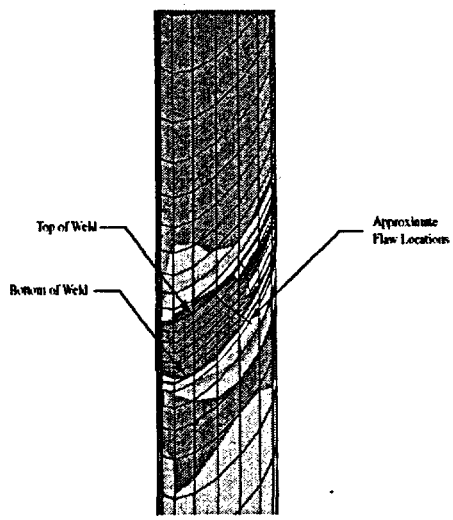
- Evaluation of evidence indicates minor nozzle leakage is worst potential consequence

Severe Consequences Not Likely

Small Break Loss of Coolant Accident (SBLOCA)

- Residual stresses favor axial crack orientation
- No circumferential cracks

Flaw Locations and Stresses



Nozzle Alone, Showing Approximate Flaw Locations and Stresses In the Direction Parallel to the Plane of the Weld

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

Limiting Flaw Size

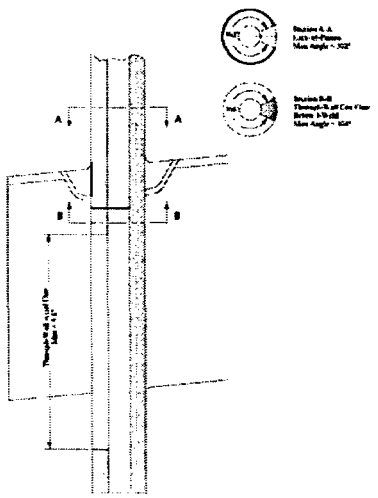


Figure 5-1

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

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

Severe Consequences Not Likely (cont'd)

Loose Parts

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

Conclusions

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

REPAIR PLAN

Steve Thomas
Manager, Plant Design

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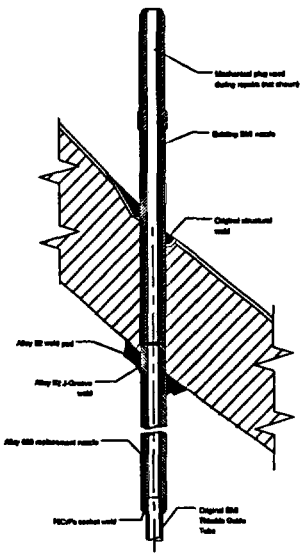
Half-Nozzle Repair



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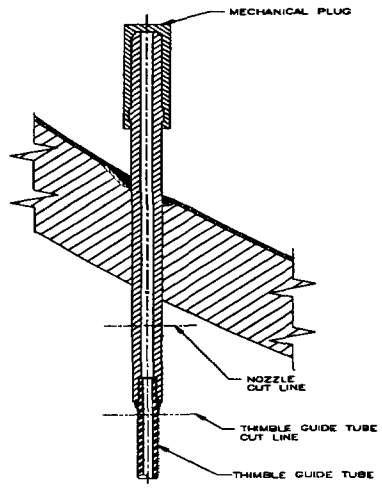
Deploy Plug; Cut Guide Tube / Nozzle



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

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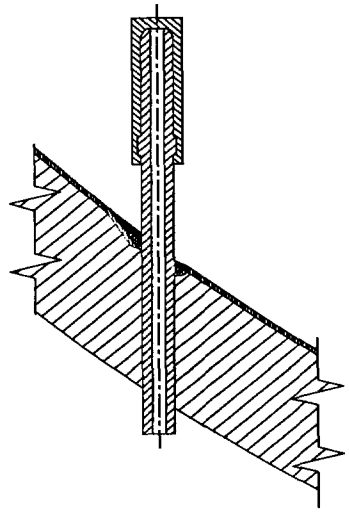
Inspect for Leaks



STEP 2
INSPECT FOR LEAKS

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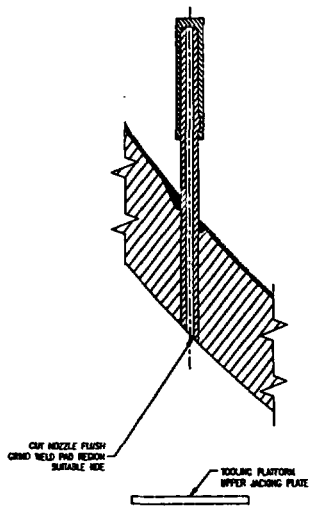
Cut Nozzle Flush with Head



STEP 3
CUT PIPE FLUSH
TO LOWER HEAD,
NE WELD PAD REGION

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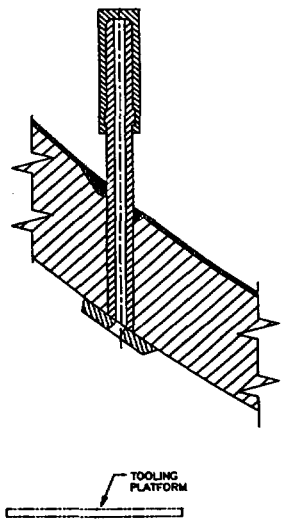
Form Weld Pad and NDE



STEP 4
WELD PAD,
NDE

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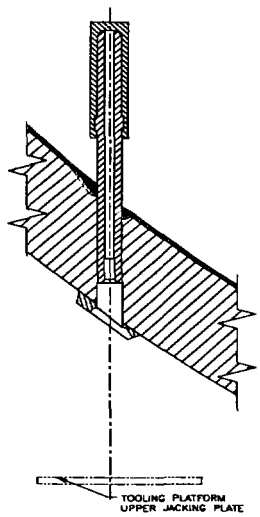
Machine Bore and Form Weld Prep



STEP 5
MACHINE BORE
FORM WELD PREP

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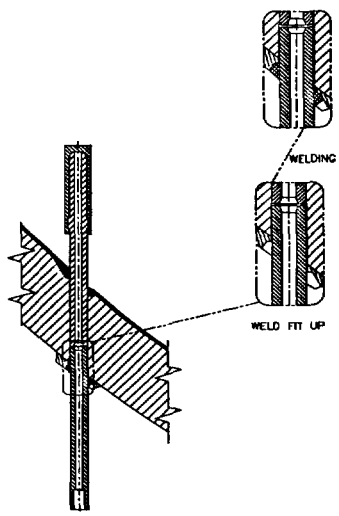
Install Nozzle; Weld; NDE



STEP 6
INSTALL REPLACEMENT NOZZLE,
WELD, NDE

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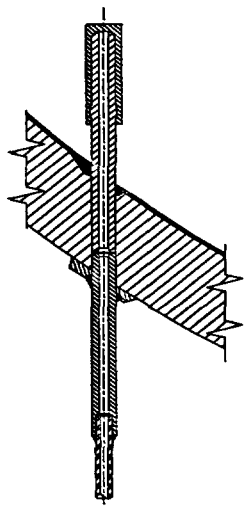
Install Tube; Weld; NDE; Remove Plug



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

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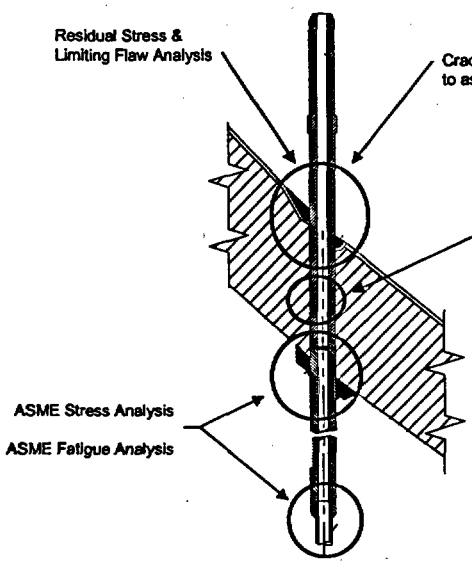
Analyses Supporting Repair



ASME Design and Analysis is consistent with the original reactor vessel requirements

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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

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

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)	**7-12**
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)	**10-12**

Conclusions

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