APS/NRC Meeting
July 20, 2004

Discussion of A600 Repair/Inspection issues and associated relief requests

Mike Winsor
Director, Nuclear Engineering
Arizona Public Service Co

Purpose

- Discuss CE plant alliance efforts to develop a methodology for replacement of pressurizer heater sleeves and provide information to the NRC on needed relief requests.

- Provide additional information on Palo Verde RR #25 "Palo Verde CEDM inspection"

- Provide additional information on Palo Verde RR #24 "Removal of RV head vent orifice"

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Agenda

Background and Alliance Efforts – Mike Winsor

- Overview of A600 Replacement Program
- Pressurizer heater sleeve repair/replacement history
- Cooperative efforts between APS, Entergy, and SCE to develop a mid-wall heater sleeve replacement option

Pressurizer Modification using the Mid Wall technique

Rex Meeden

Palo Verde CEDM Nozzle Inspection RR #25

Mike Melton

Palo Verde Reactor Head Vent Orifice Relocation

Mark Radspinner

Palo Verde A600 Replacement Program

- **Aggressive and Systematic Replacement Program based on relative susceptibility (temperature and yield strength)**

- **Initiated Replacement Program in Fall 1991 with Unit 2 Hot Leg Instrument Nozzles (75 ksi Yield Strength)**

A600 Nozzle Replacements

A600 Nozzle Replacements

Nozzle Location	# of Nozzles/Unit	Completion Date
Pressurizer Instrument Nozzles	7	Unit 1 Spring 1992
	7	Unit 3 Fall 1992
	7	Unit 2 Spring 1993
Hot Leg Instrument/Sampling Nozzles	8 1	Unit 2 Fall 1991 Unit 2 Fall 2000
	9	Unit 3 Fall 2001
	9	Unit 1 Spring 2001
Hot Leg Spare RTD Nozzles	8	Unit 2 Fall 2000
	8	Unit 1 Spring 2001
	8	Unit 3 Fall 2001
Hot Leg Inservice RTD Nozzles	10	Unit 1 Fall 2002
	10	Unit 3 Spring 2003
	10	Unit 2 Scheduled for Completion Spring 2005
Pressurizer Heater Sleeves	36	Unit 2 Fall 2003
	36	Unit 3 Scheduled for Completion Fall 2004
	36	Unit 1 Scheduled for Completion Fall 2005
Red indicates Half-nozzle Repairs, Black indicates Full Nozzle (no remnant) Repairs		

A600 Nozzle Replacements

- Replacement of Unit 1 Pressurizer Heater Sleeves scheduled for Fall 2005 will complete nozzle replacement plan for all A600 nozzles/penetrations at Hot Leg Temperature or above
- Strategically plan for upper head replacement and dissimilar butt weld examinations and mitigation techniques

Palo Verde Pzr Heater Sleeve Repair/Replacement Program

- Pressurizer heater sleeve status
  - Unit 2 completed replacement in Fall 2003 using pad repair
    - 36 day installation duration
    - 32 REM installation dose
- Original schedule for Palo Verde heater sleeve replacement
  - Unit 1 scheduled for Fall 2005
  - Unit 3 scheduled for Fall 2007

Alliance Efforts to Address PZR Heater Sleeves

- **Arizona Public Service Co., Entergy Nuclear Inc., and Southern California Edison Co., agreement to support development of a mid-wall heater sleeve replacement technique**

- **Develop a common replacement technique to leverage licensing, developmental, training, and tooling costs**

- **Welding Services Inc and Structural Integrity to provide technical and field services**

- **Began in spring of 2004 following Palo Verde U3 February SNO outage**

Pressurizer Heater Sleeve Replacement Schedule

- **Palo Verde will be the lead plant with its 3R11 Fall 2004 outage and U1R12 Fall 2005 outage**
- **Waterford 3 Spring 2005**
- **SONGS 2 Fall 2005, SONGS 3 Spring 2006**

Palo Verde Unit 1 and 3 Pressurizer Heater Sleeve Repair And Remnant Sleeve Flaw Evaluation

NRC Presentation

Rex Meeden

July 20, 2004

Pressurizer Heater Sleeve Repair

Agenda

- Pro-Active Strategy
- Pad Repair
- Midwall Repair
  - Concept (Rex Meeden)
  - Relief Requests #28 & #29 (Rex Meeden)
  - Design and Analysis (Dick Mattson)
  - Tooling (Pedro Amador)
  - Welding Development Program (Pedro Amador)
  - NDE (Michael Lashley)
  - Triple Point Flaw Evaluation (Pete Riccardella)
- Conclusions

Pressurizer Heater Sleeve Original Strategy

- February 2004: Implement pad repair during replacement steam generator outages
  - Unit 2 – pad repair complete fall 2003
  - Unit 1 – fall 2005
  - Unit 3 – fall 2007
- MNSA contingency
  - 2 Mechanical Nozzle Seal Assemblies (MNSAs) installed, U3R10 (Spring 2003)
  - Relief Request #17 granted 2 cycles of operation
- Plan supported by failure rate analysis
  - Yield strength of material
  - Industry experience

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Pressurizer Heater Sleeve Revised Strategy

- March 2004 – Unit 3 forced outage
  - BMV identified 1 leaking heater sleeve
- Installed MNSA - third MNSA in unit 3
  - Radiological exposure of 3 REM
- Management decision to accelerate unit 3 repair from fall 2007 to fall 2004
  - Planned repair of 36 heater sleeves
  - Remove 3 MNSAs
  - No need to exercise 2nd cycle of operation granted in RR #17

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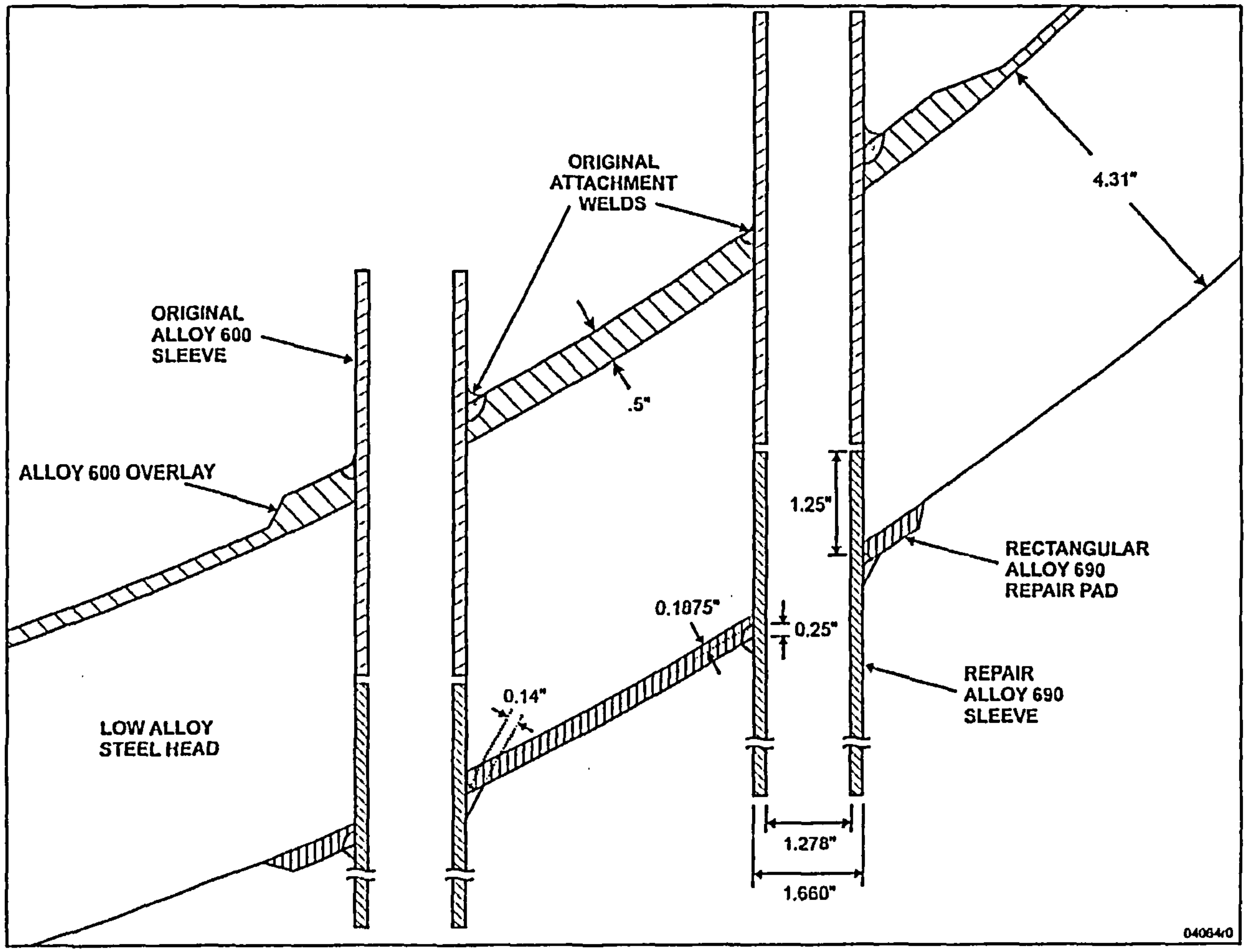
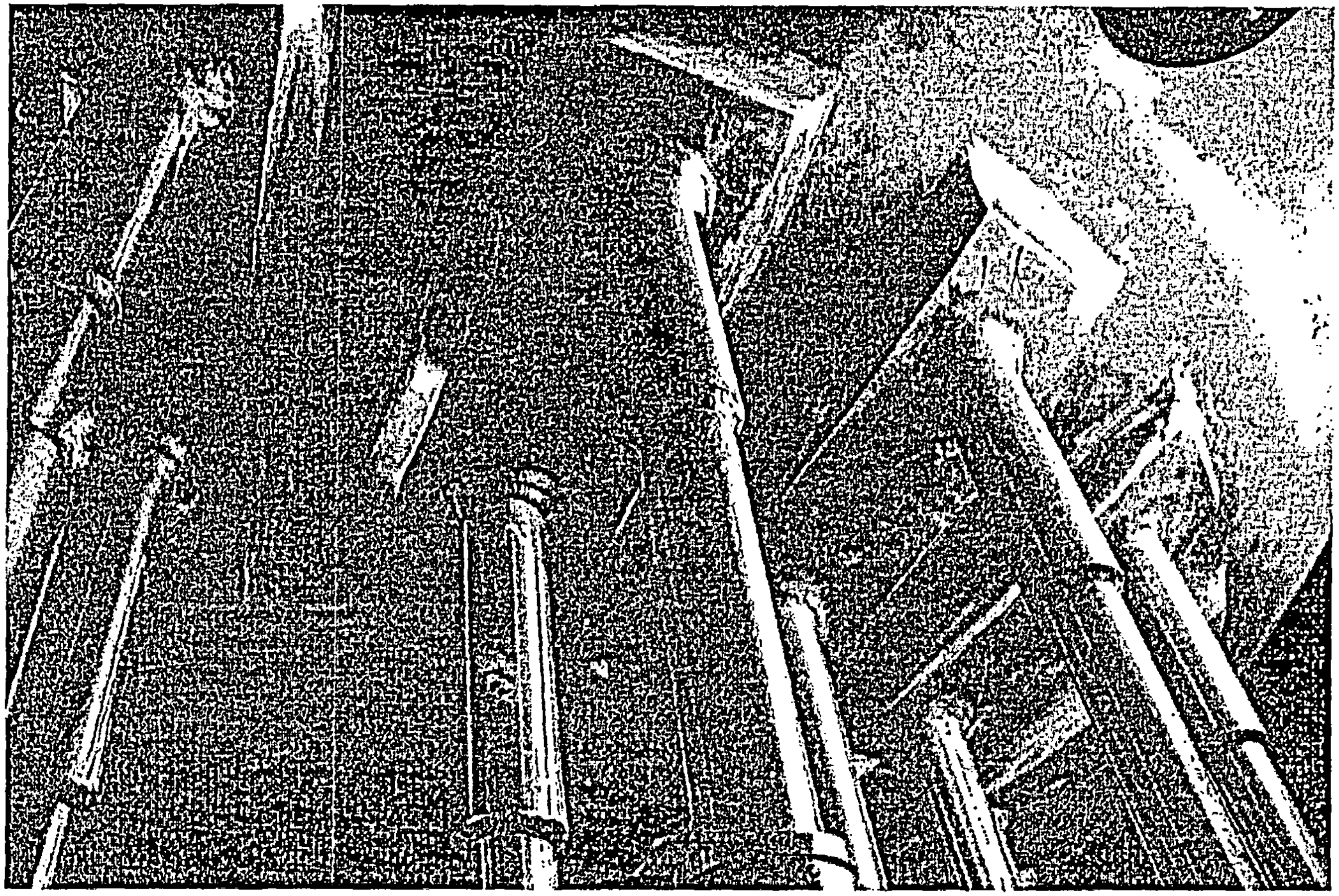
Pressurizer Heater Sleeve Repair

Pad Repair



Pressurizer Heater Sleeve Repair

Pad Repair



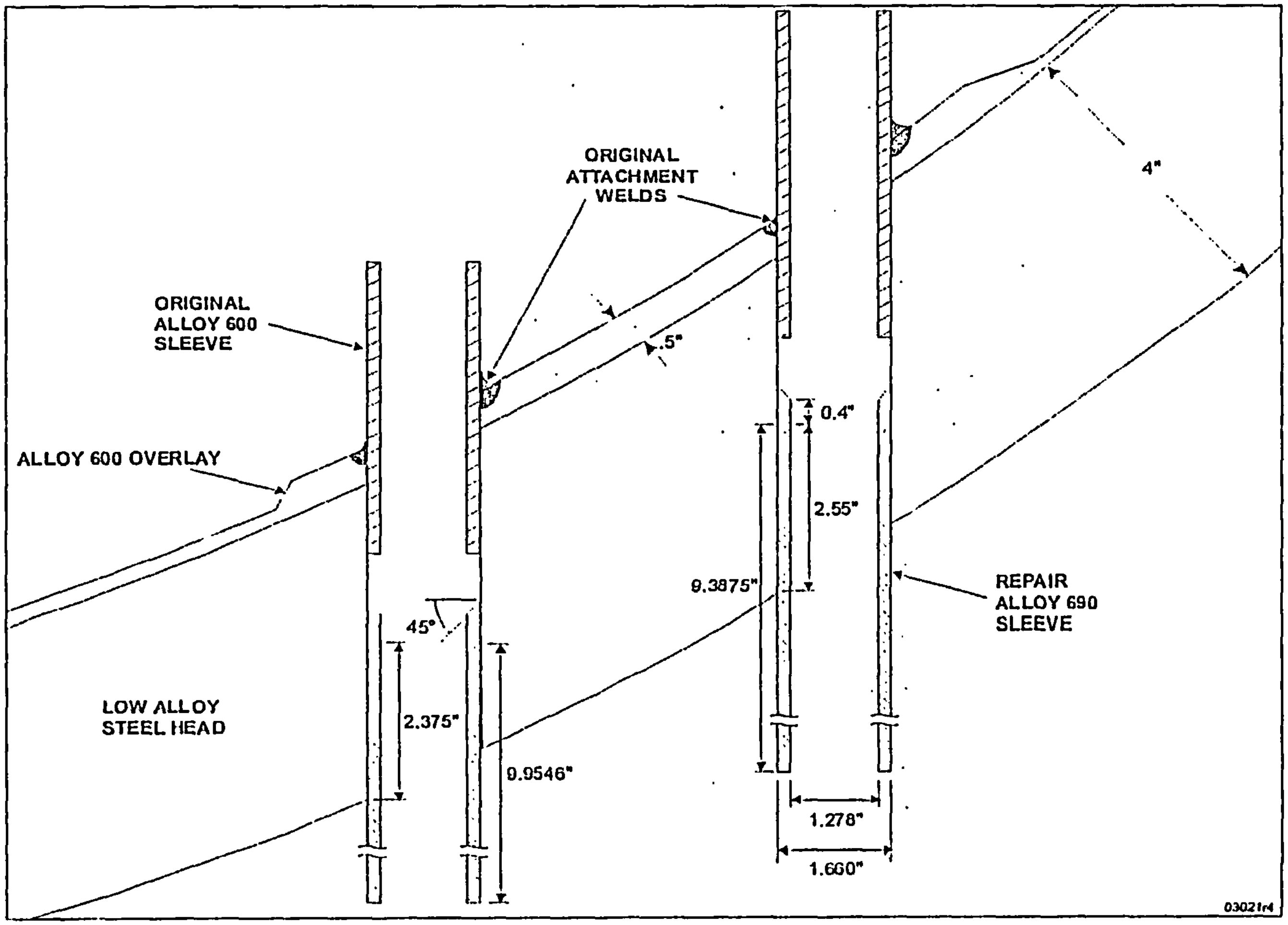
Pressurizer Heater Sleeve Repair

Pad Repair

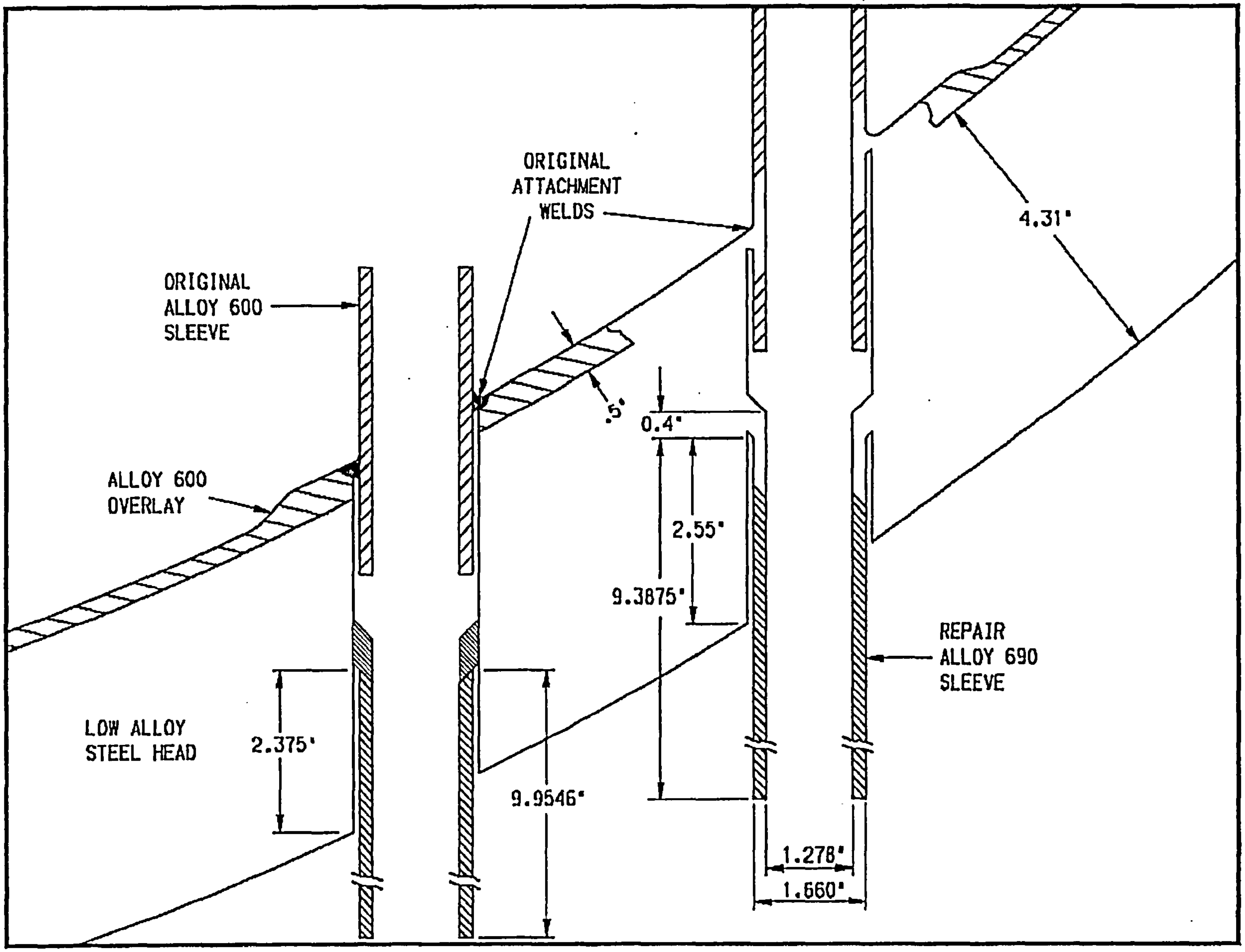
- Unique concentric ring configuration favors rectangular pad
- Installation dose - 32 REM
- Installation duration - approximately 36 days
- Other utilities likely to incur more dose due to different sleeve configuration

Pressurizer Heater Sleeve Repair

Midwall Repair



Pressurizer Heater Sleeve Repair Midwall Repair



Midwall Sleeve Repair

- Relatively small weld volume, increased effective throat
- Extensive welding development program conducted
- Qualified NDE procedure to support repair
- Future ISI per Section XI and NRC Bulletin 2004-01
- Projected installation dose – 23.5 vs. 32 REM
- Projected installation duration – 20 vs. 36 days
- 8.5 REM savings/PV Unit (2 Units to do)
- Potential savings for 5 CE alliance Units approximately 50 REM

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Pressurizer Heater Sleeve Repair

Relief Request #28

- Ambient temperature temper bead versus preheat/post weld soak temper bead welding
- GTAW versus SMAW
- Code Case N-638-0 used as a guide (included in Regulatory Guide 1.147) – minimal changes
- Ultrasonic examination in place of radiography required by section XI ('92 Edition '92 Addenda)
- Liquid penetrant examination of midwall weld area prior to welding and final weld surface/heat affected zone after welding
- Relief Request #28 is similar to Relief Request #23 (previously approved for Unit 2 pad repair)

Pressurizer Heater Sleeve Repair

Relief Request #29

- Leave postulated flaws in remnant sleeve and J-Weld w/o full characterization or successive examinations
- Section XI flaw evaluation complete; worst case flaw modeled
  - Linear elastic fracture mechanics (LEFM) and elastic plastic fracture mechanics (EPFM) utilized
  - EPFM precedence established by Entergy for reactor head
- Corrosion analysis
  - WCAP-15973-P Rev.1 demonstrates that the limiting CE plant lifetime following half sleeve repair is194 years

ASME Code Evaluations

- ASME Code, Section III evaluations
- ASME Code, Section XI evaluations
- Elastic-Plastic Fracture Mechanics evaluations

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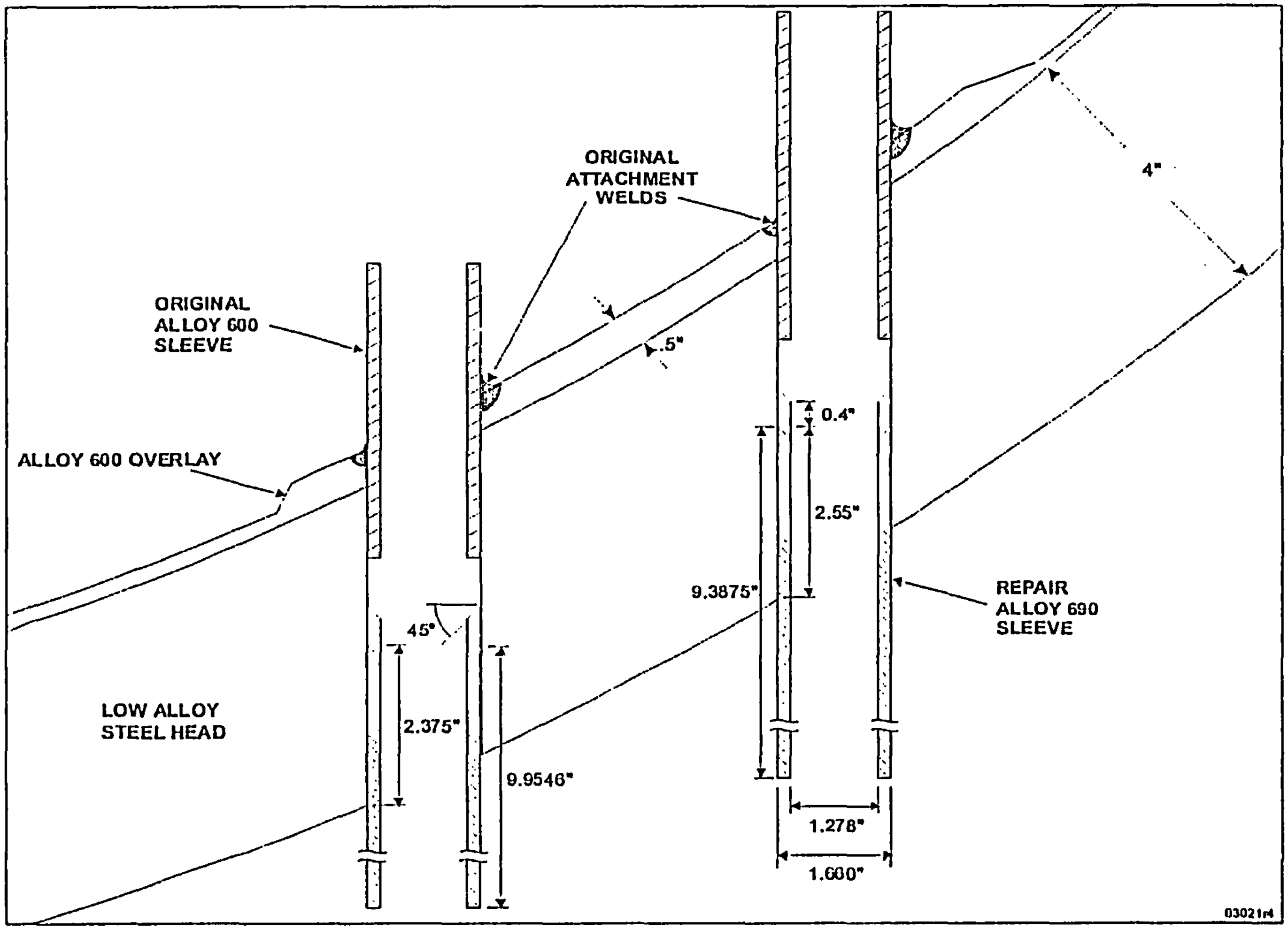
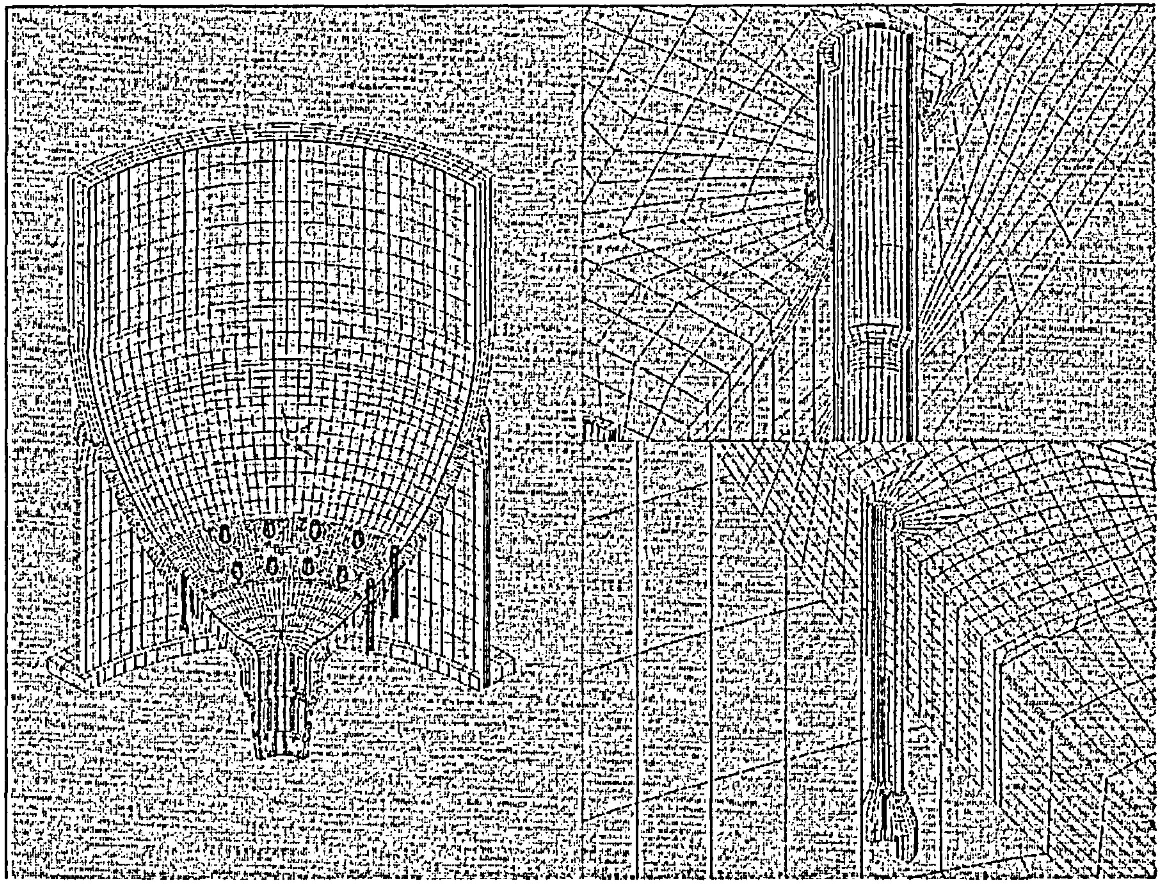
Pressurizer Heater Sleeve Mid-wall Repair Concept



Section III Evaluations

- Load Definition
  - Original design basis (pressure/thermal transients)
- Stress Analysis
  - Three-dimensional finite element analysis
  - 90° model with appropriate boundary conditions
- Section III Evaluations
  - Stress criteria
  - Fatigue evaluation (60 years of extrapolated 40 year cycles)
  - Attachment mid-wall weld is the controlling location

Finite Element Model



Section XI Evaluations

- Postulated axial flaw in sleeve, overlay, and J-groove weld
- Stresses extracted from Section III analyses
- Linear elastic fracture mechanics (LEFM) techniques utilized
- Residual stress analyses for similar plant
- Fatigue crack growth analyses
- Limited life based upon LEFM analyses
- Acceptability to end-of-life (including 20 year license renewal period) demonstrated utilizing elastic-plastic fracture mechanics (EPFM) techniques

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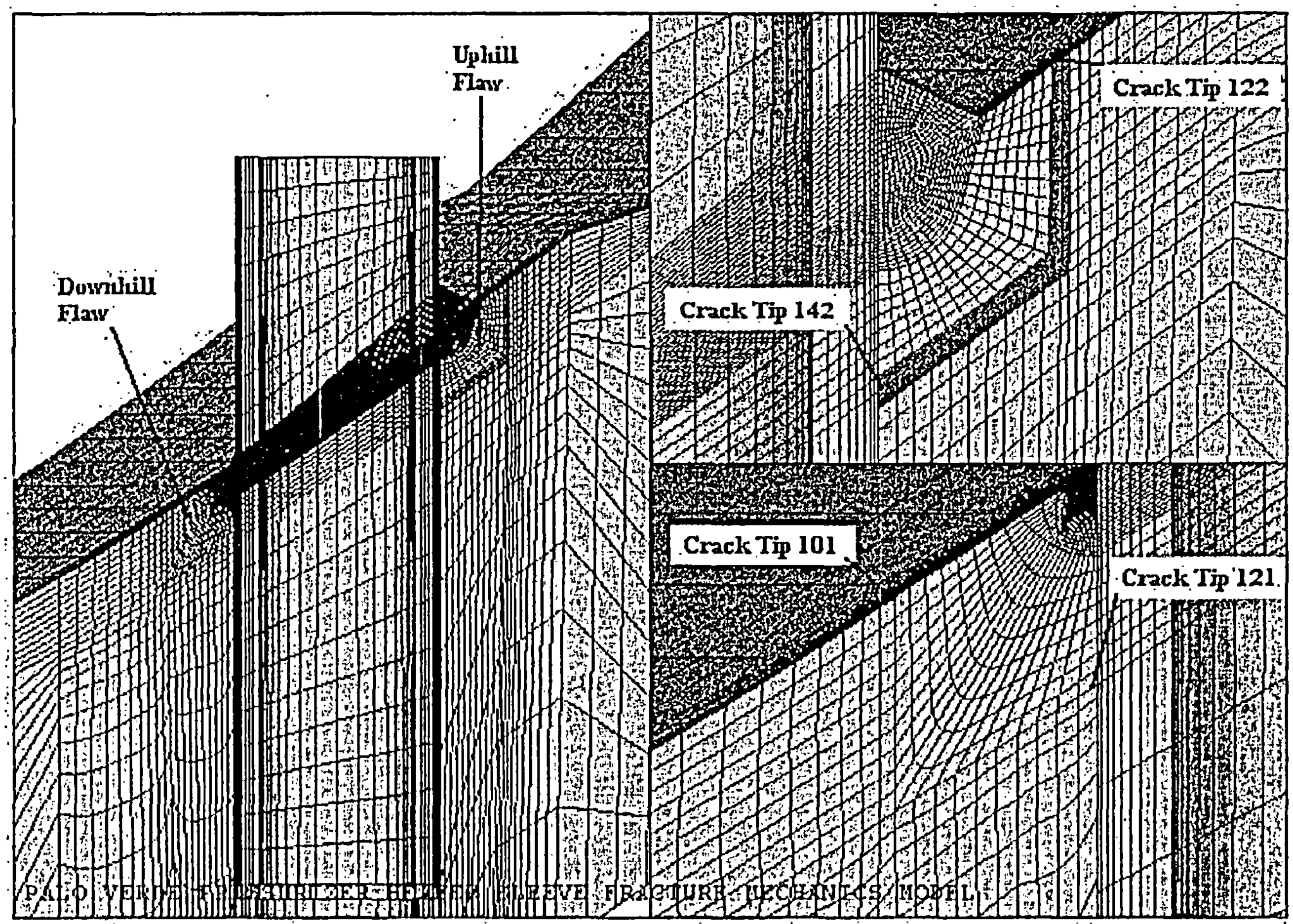
Fracture Mechanics Finite Element Model



Basis for EPFM Approach

- Controlling transients occur at operating temperature
  - Well above upper shelf on Charpy impact energy curve
  - Pressurizer material possesses considerable ductility in this regime
- EPFM is the more appropriate technology for ductile materials (such as the Palo Verde pressurizer at upper shelf)
- Ample precedent exists in ASME Code, Section XI for the use of EPFM and appropriate treatment of safety factors
  - Appendix C for Flaws in Austenitic Piping
  - Appendix H for Flaws in Ferritic Piping
  - Appendix K for Assessment of RPVs with Low Upper Shelf Toughness
- These code appendices all specify reduced safety factors (SFs) for secondary (strain controlled) loading conditions, and permit EPFM instability analysis

ASME Code Evaluation Conclusions

- Proposed mid-wall repair concept is acceptable because:
  - Design meets ASME Code, Section III criteria
  - Remaining postulated defect in Alloy 600 material is acceptable for life of plant plus life extension

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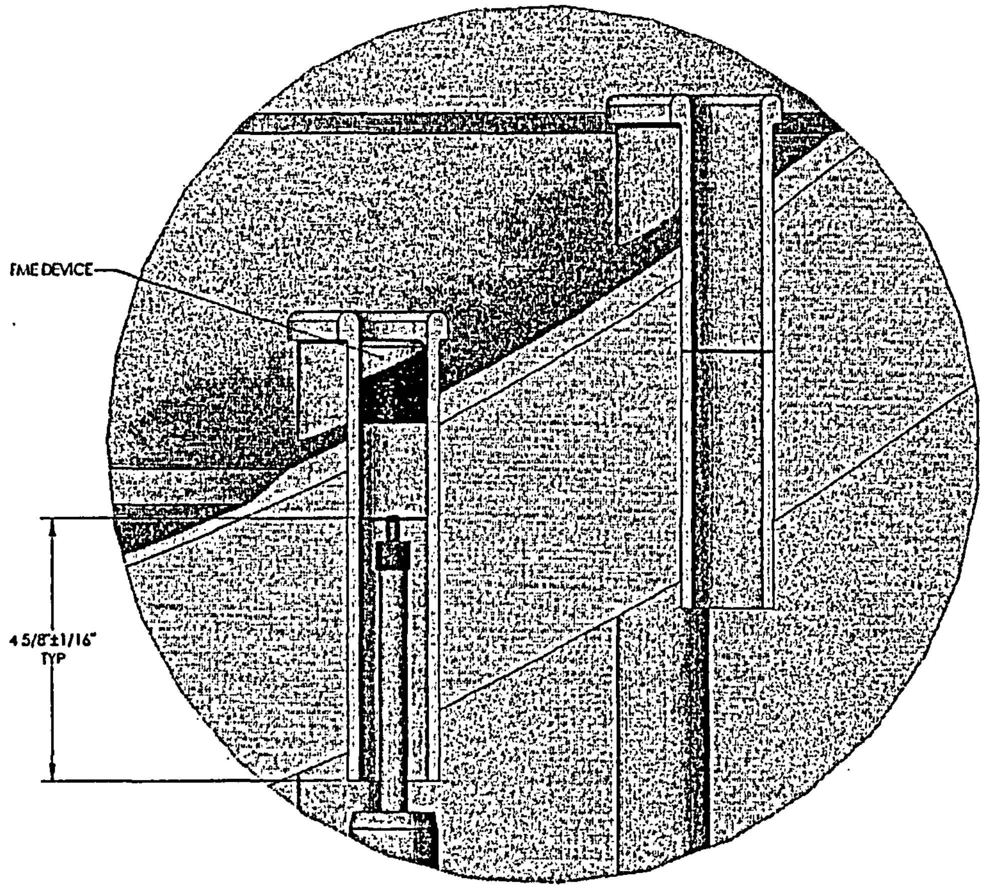
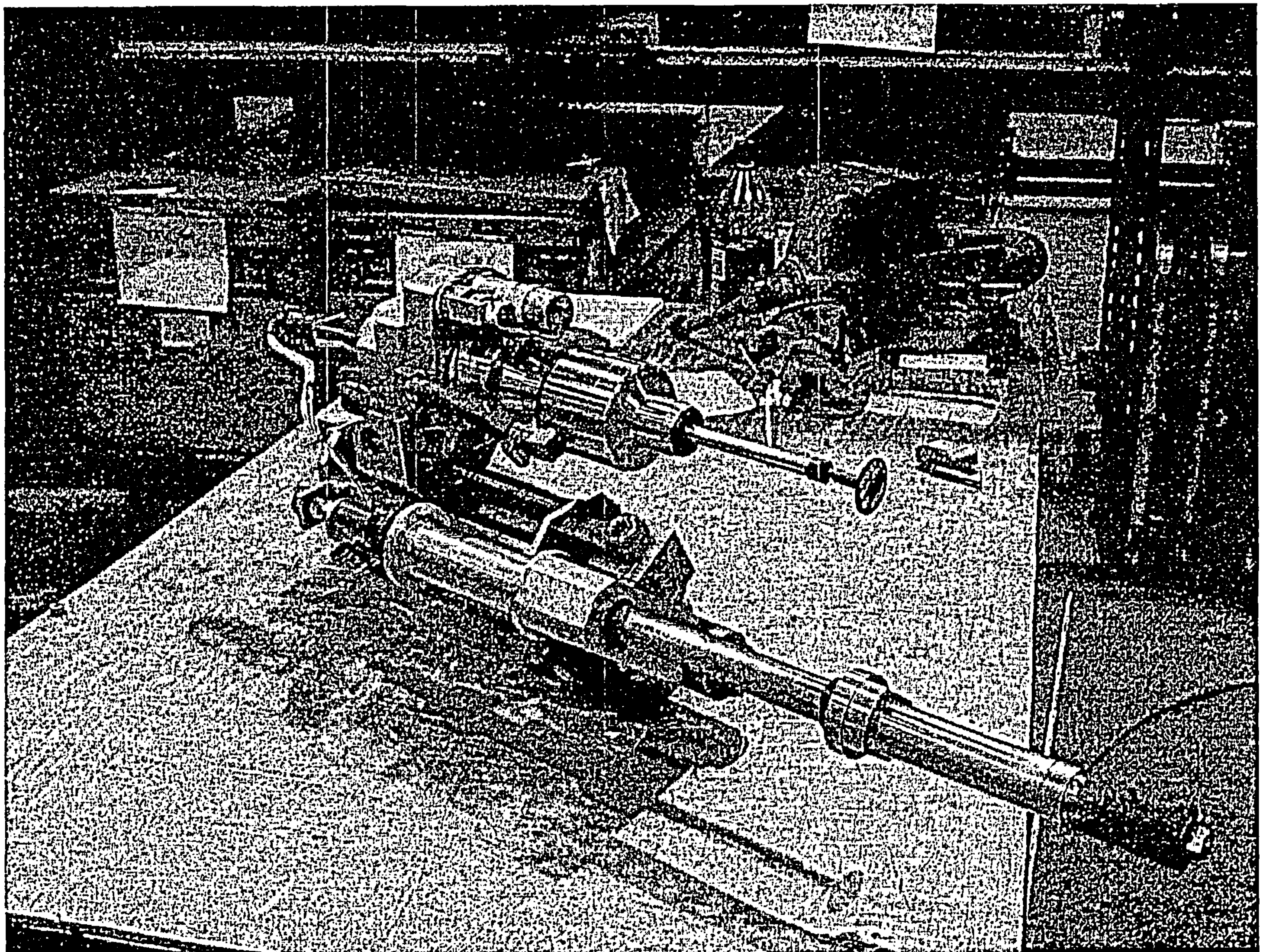
Sequential Repair Procedure

- ID Sleeve Sever
  - WSI Nozzle Severing Tool
  - Depth of cut selected to maximize weld area work envelope



ID Sever Tool with Articulating Arm



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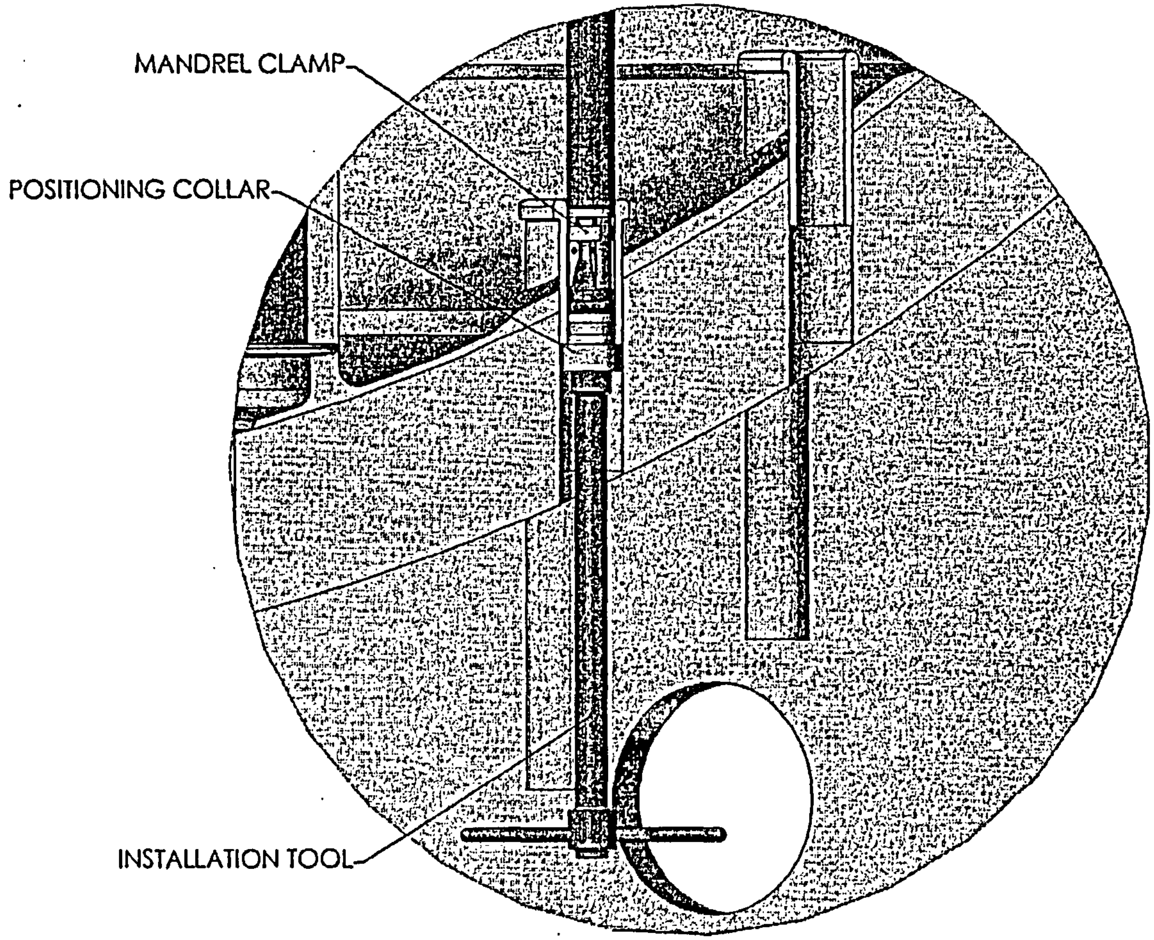
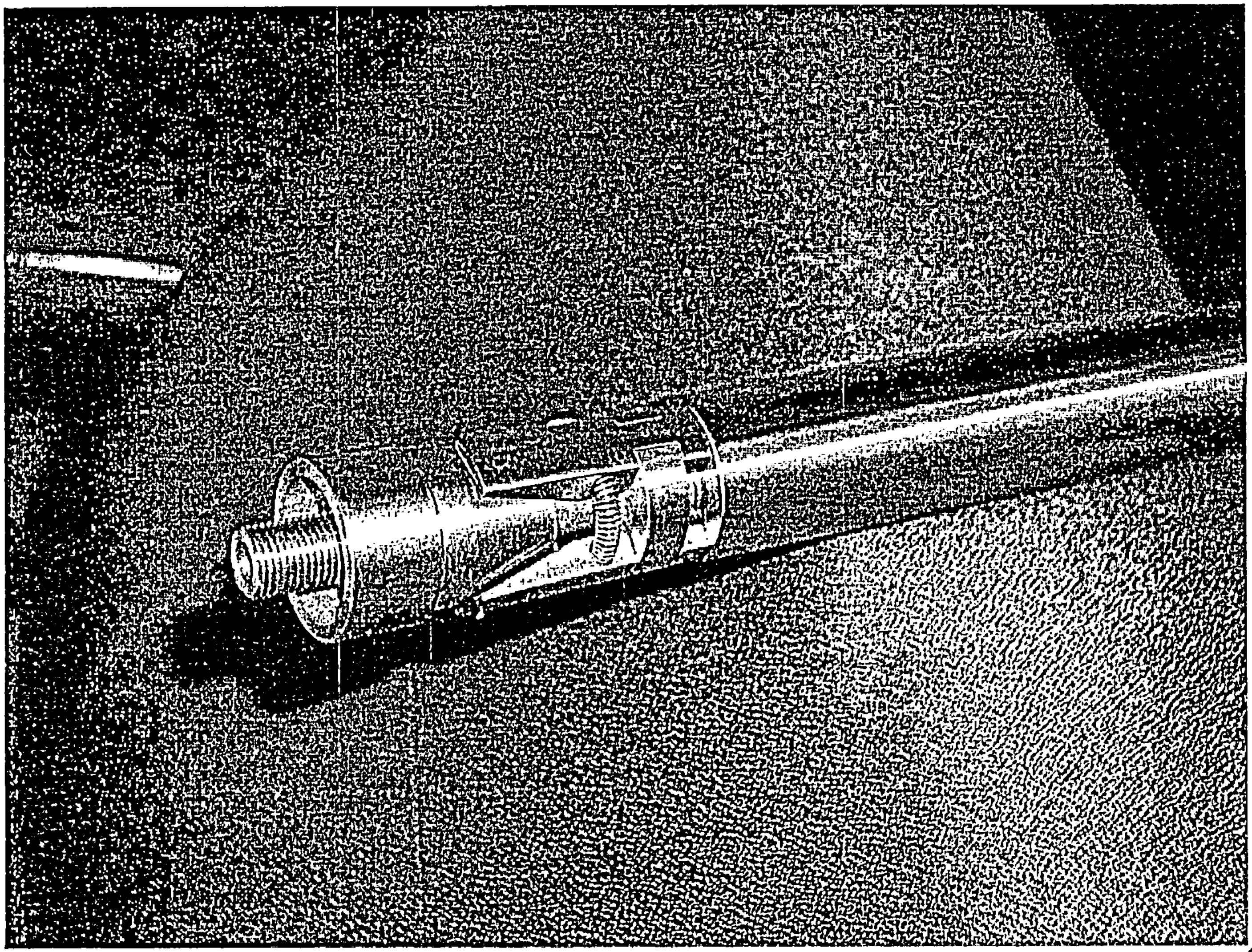
Sequential Repair Procedure

- SSAT Tool Installation
  - Positioning Collar Locates Axially
  - Self Centering Feature Locates Radially
  - Tool Extends through the first Heater Tray

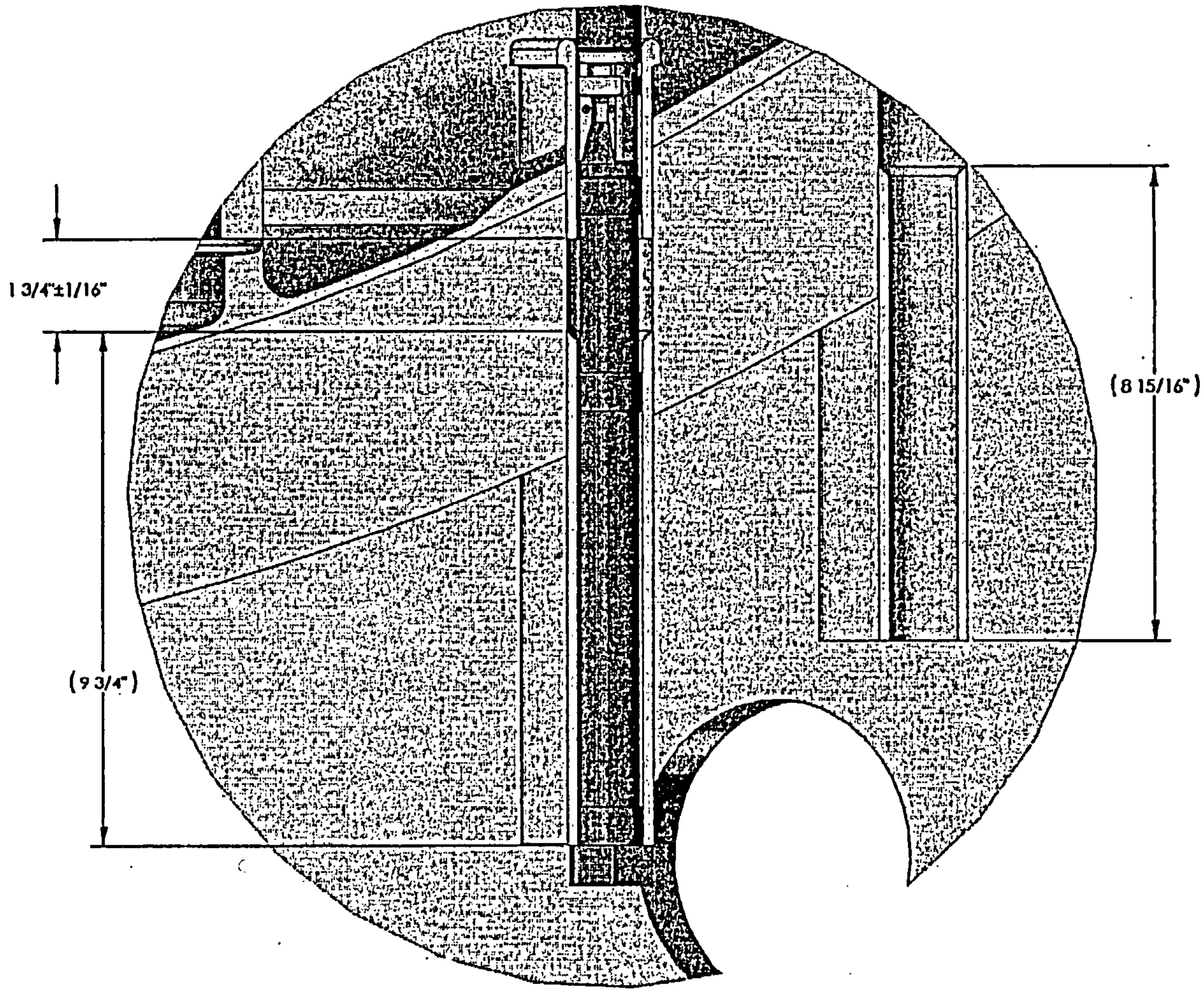


Sequential Repair Procedure

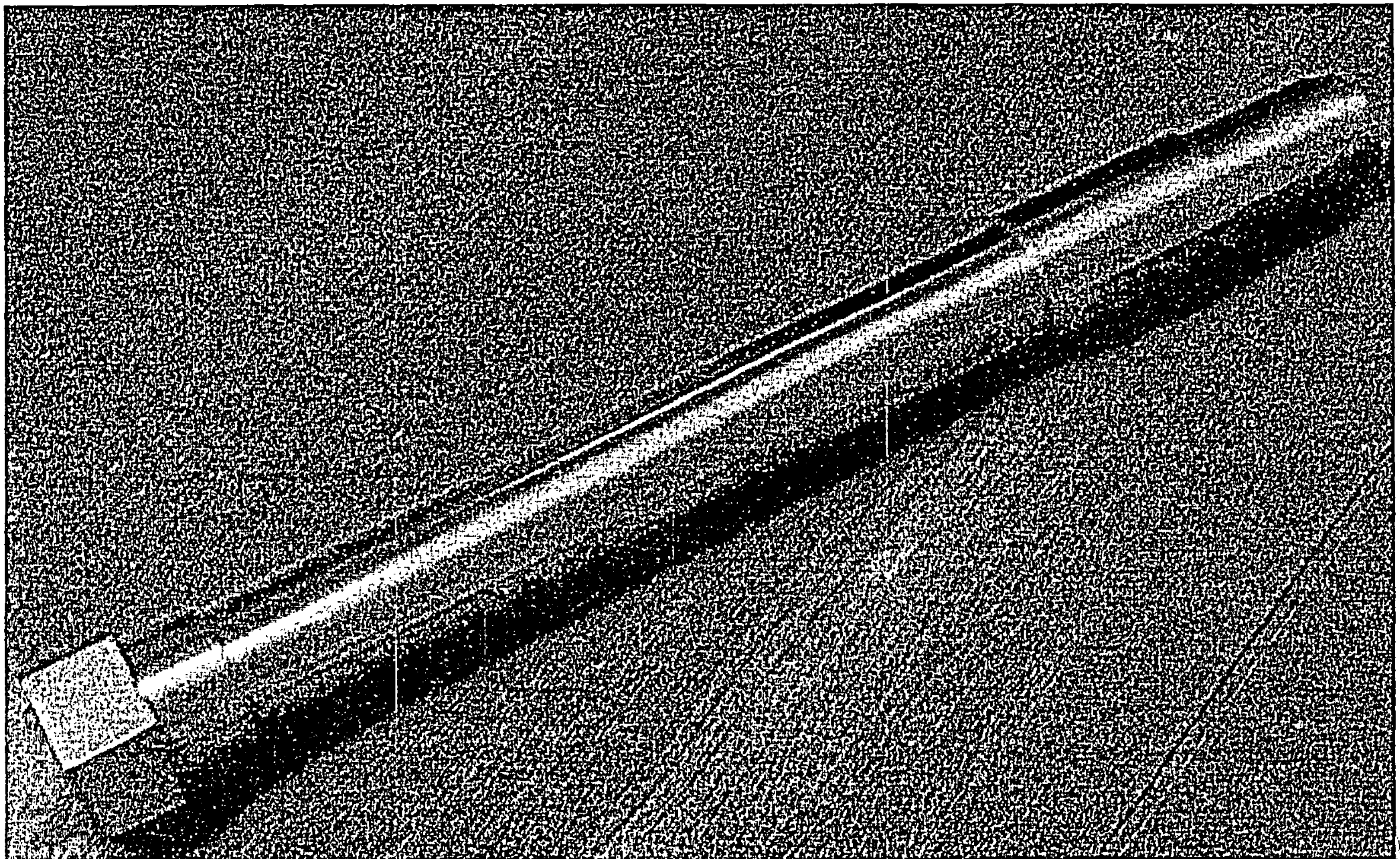


Sequential Repair Procedure

- SSAT with Replacement Sleeve and Alignment Shaft
  - Piloted in SSAT

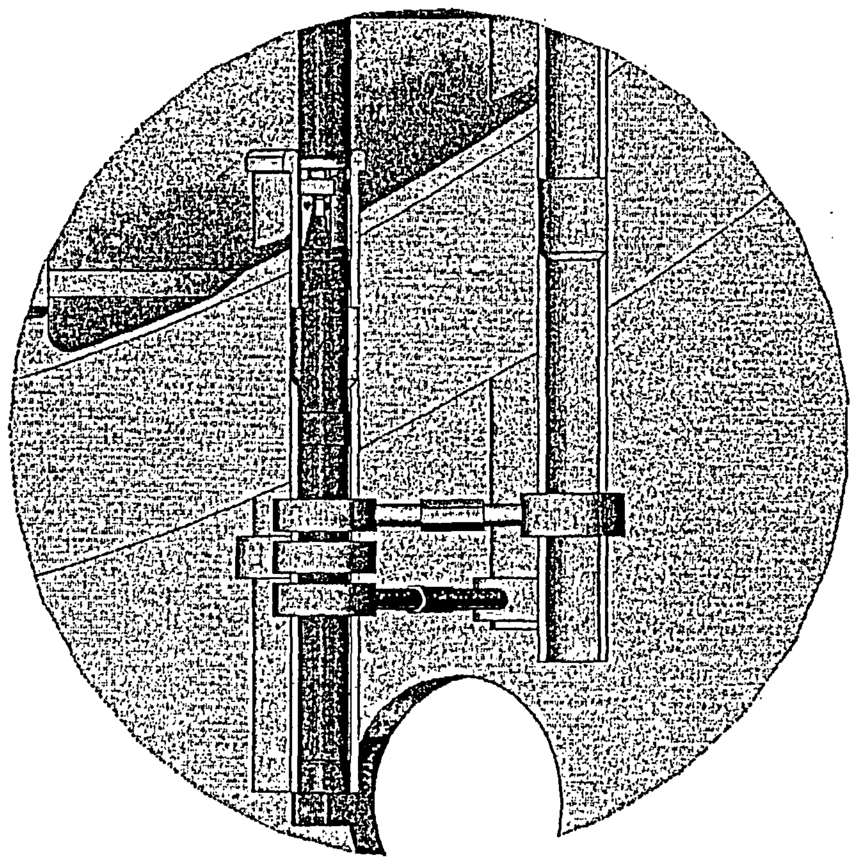


Internal Alignment Tool

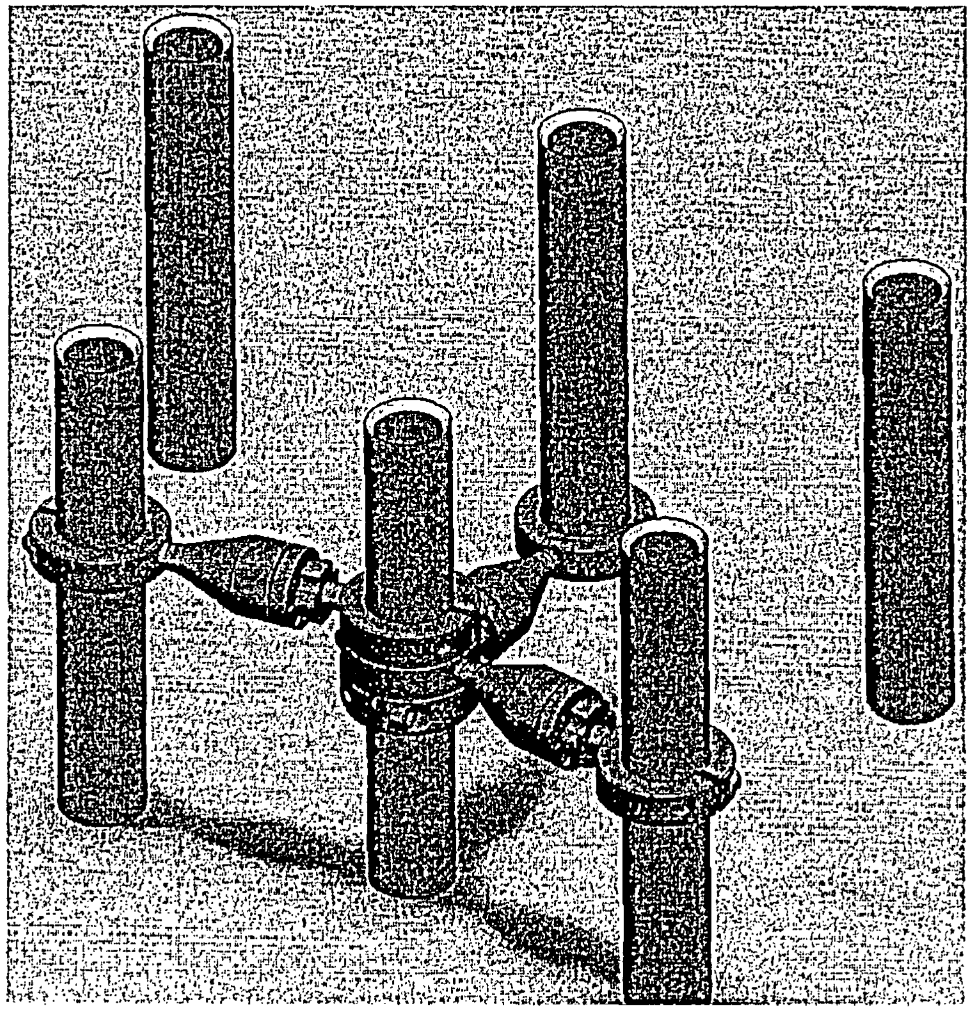


Sequential Repair Procedure

- Sleeve External Alignment Tool
  - Shims installed
  - Clamping Device Installed
- Tool is Mandrel or OD Mounted to two or three adjacent penetrations

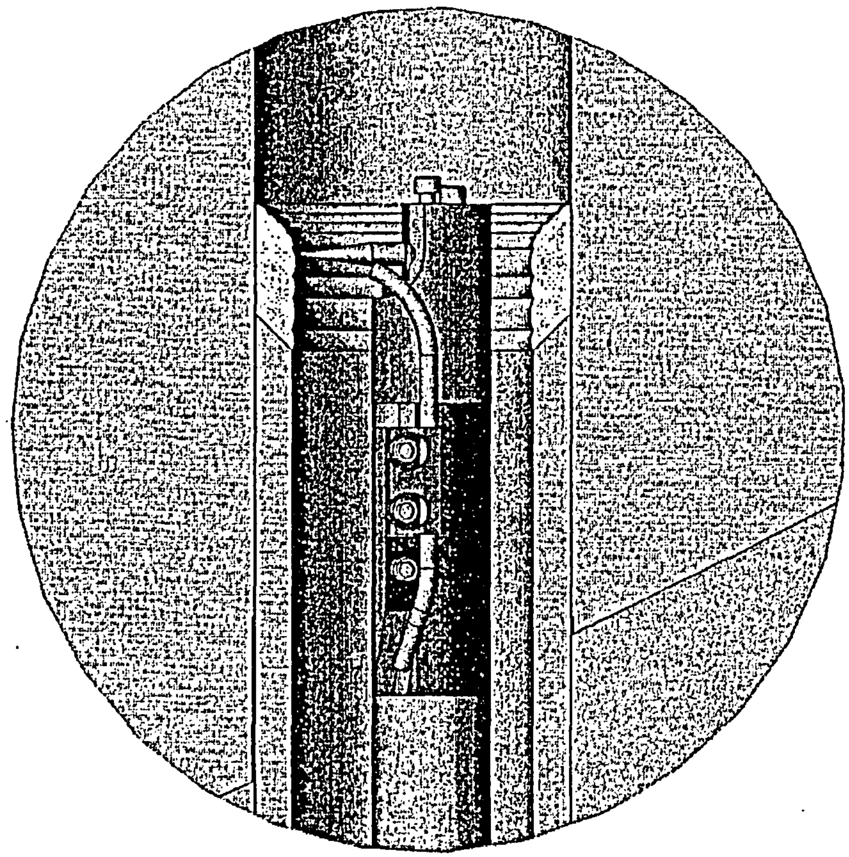


Zero Force Clamp Installation

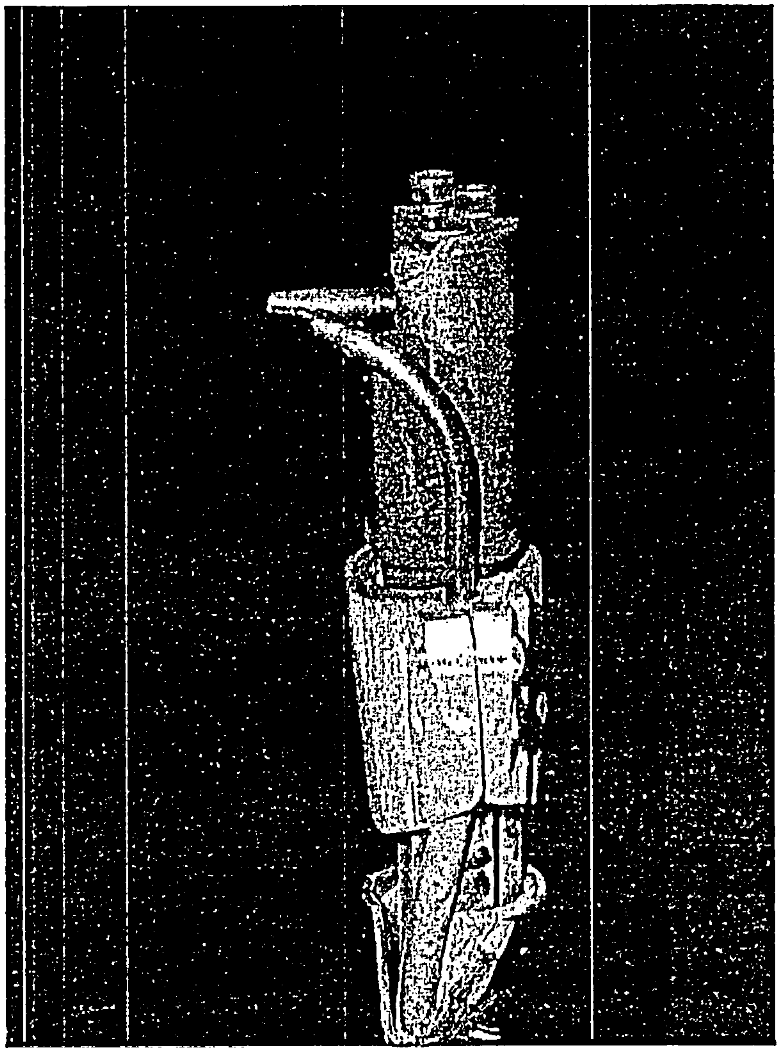


Sequential Repair Procedure

- Mid-Wall Weld Head Front-End
  - Video
  - Wire Feed
  - Inert Gas Delivery
  - Water Cooled

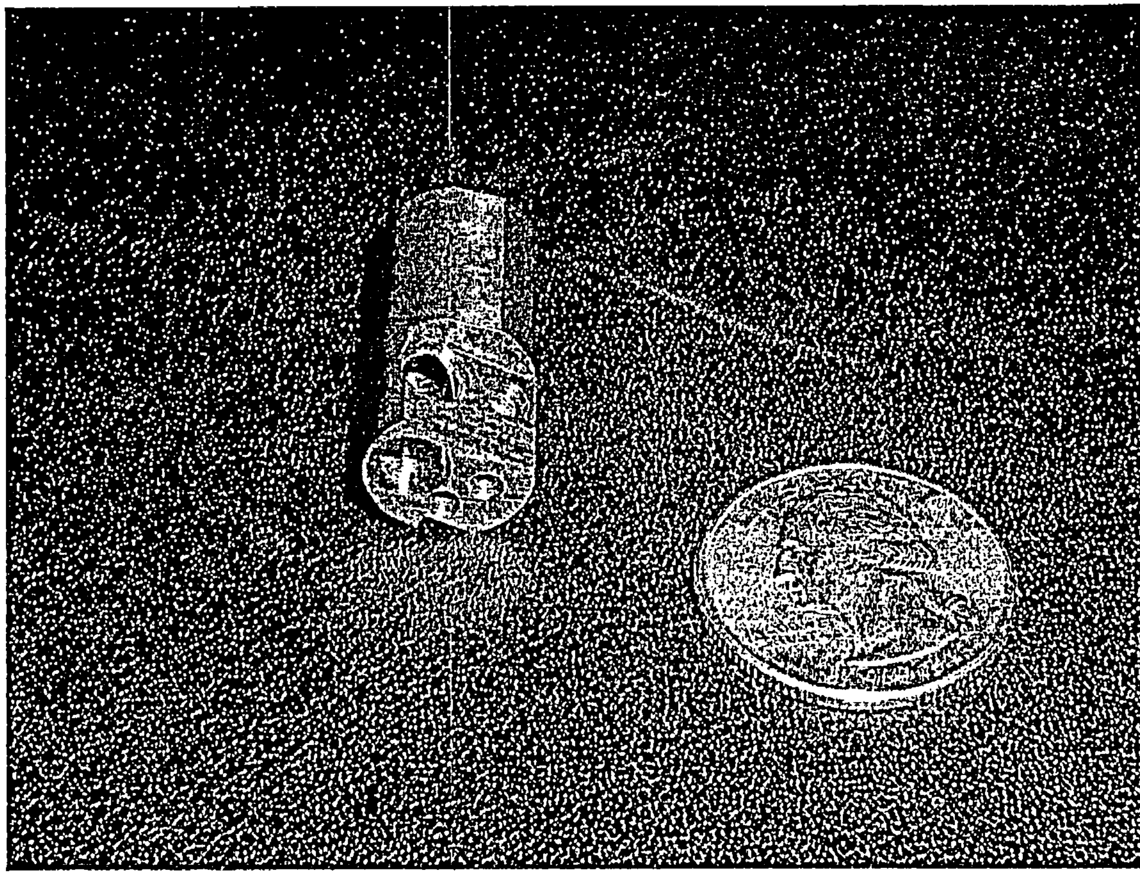


Sequential Repair Procedure

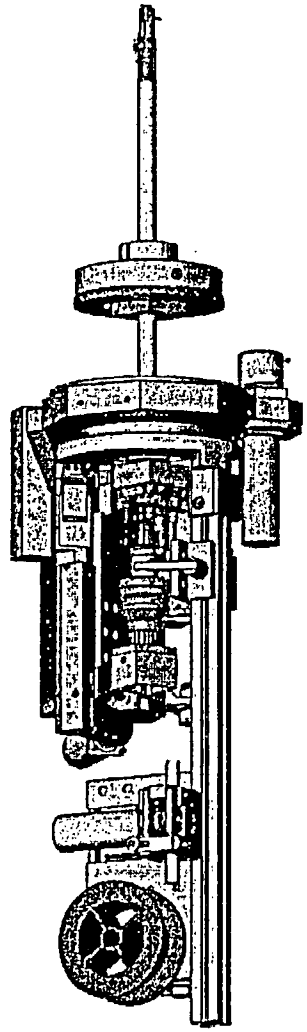


Sequential Repair Procedure

- Mid-Wall Weld
  - Water Cooled Copper Front End Piece after Machining
  - Core component of torch assembly

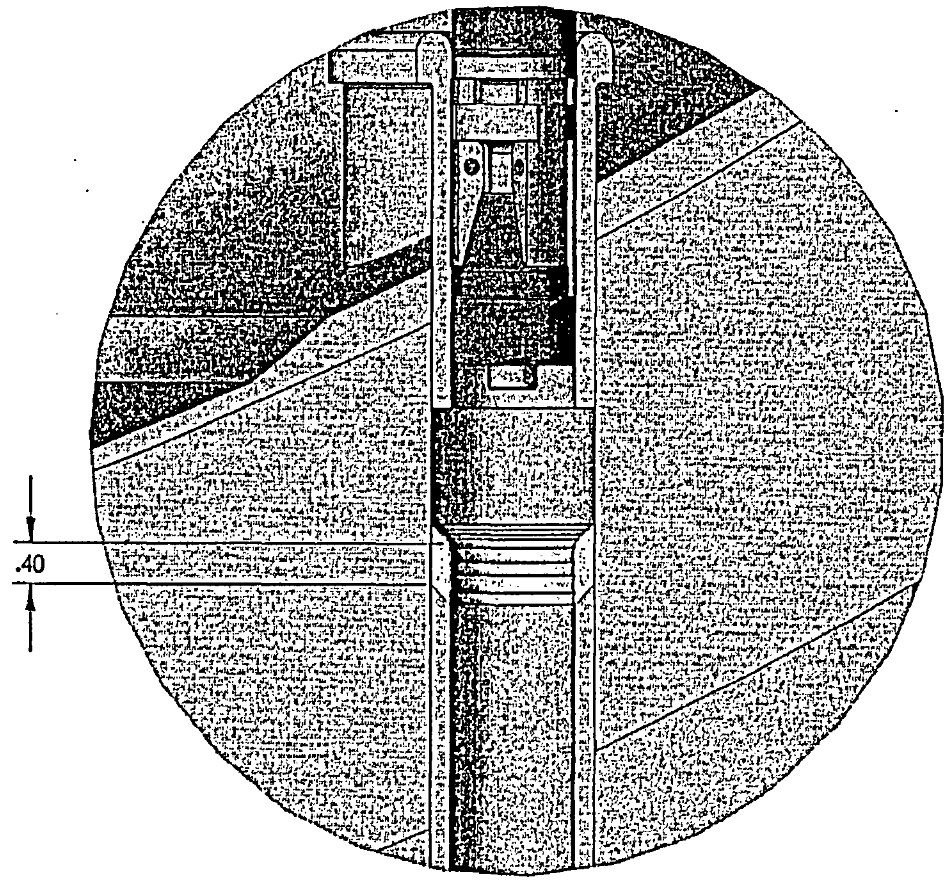


Sequential Repair Procedure



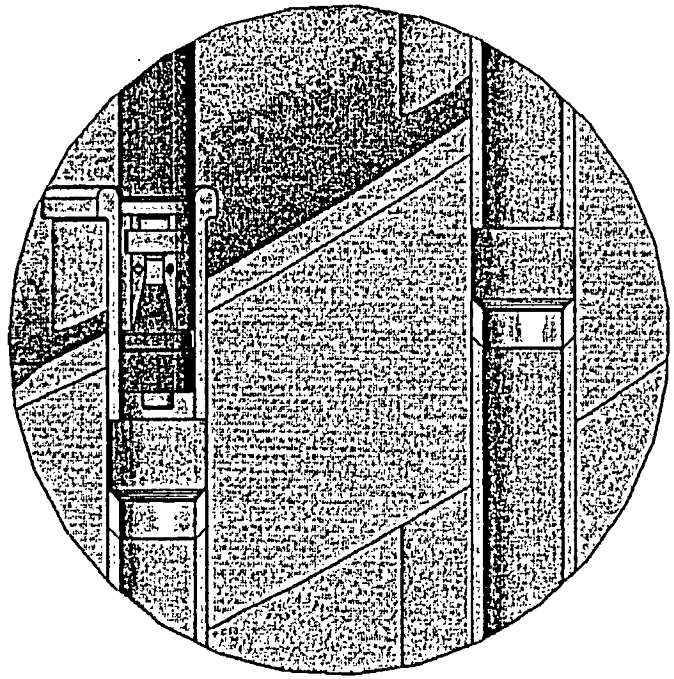
Sequential Repair Procedure

- As Welded Configuration
  - Minimum three layers and 1/8" weld deposit
  - Minimal build-up beyond sleeve wall thickness

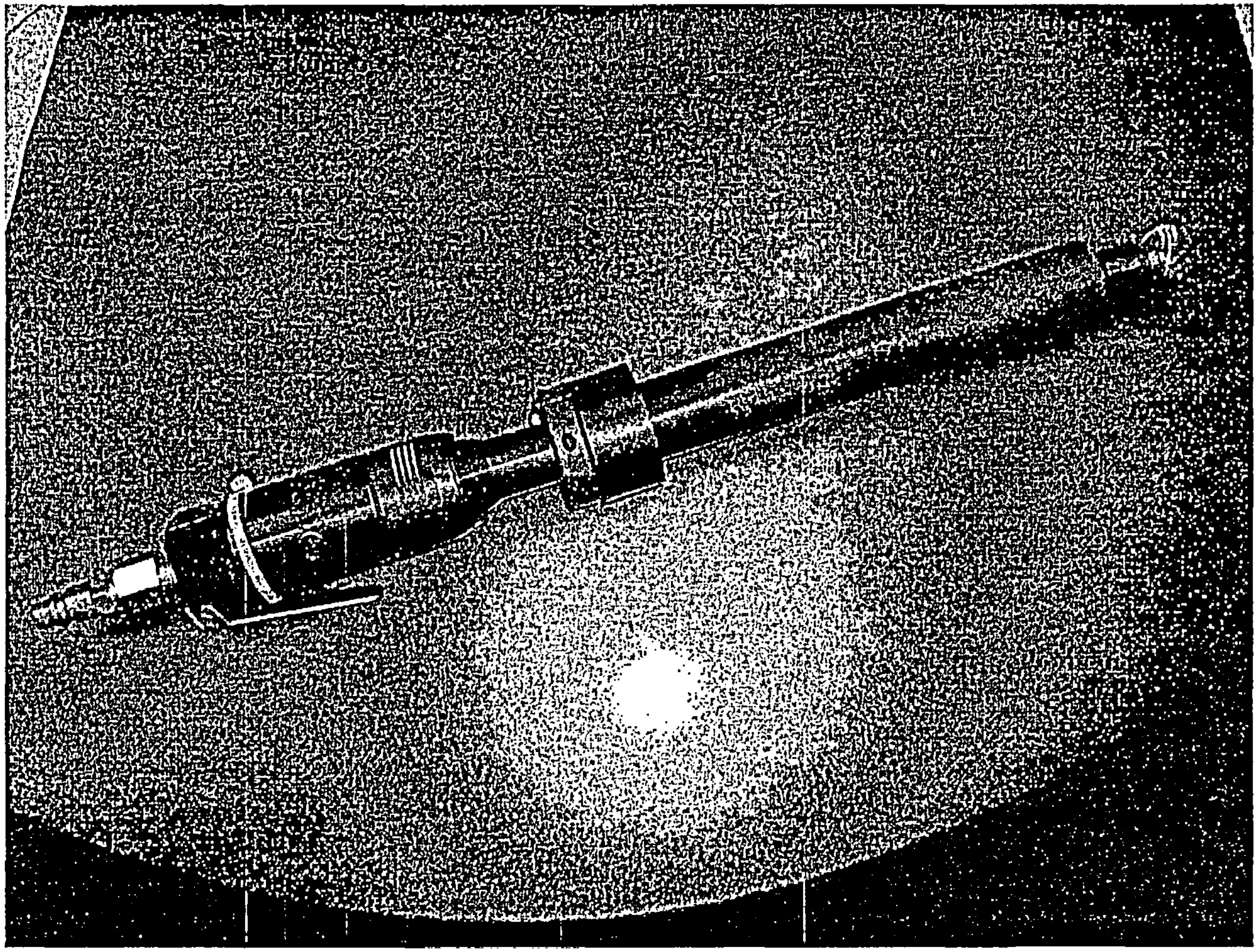


Sequential Repair Procedure

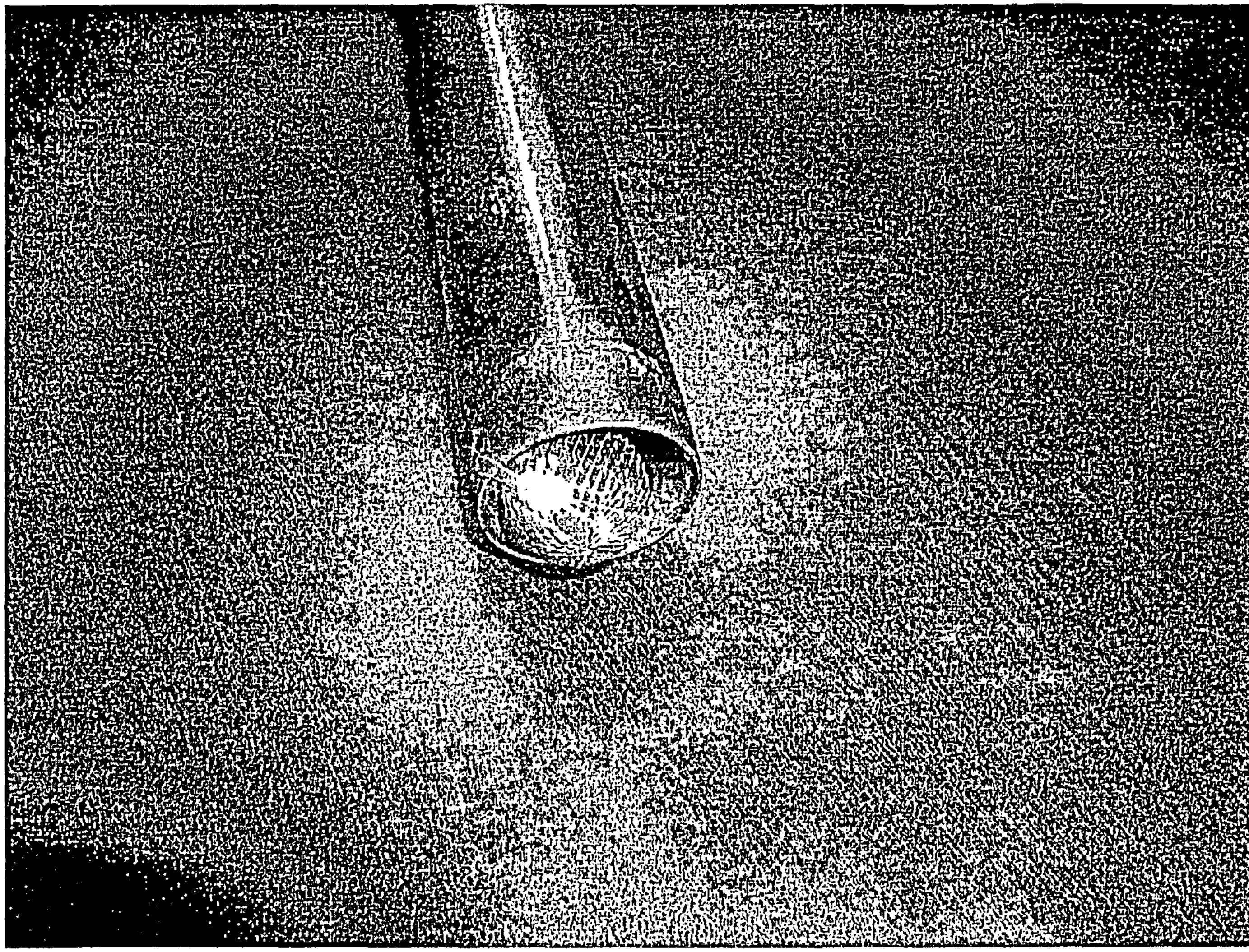
- Post Weld Clean-Up
  - Grind/abrade surface of weld to:
    - Remove any build-up beyond bore ID
    - Prepare weld surface for final NDE



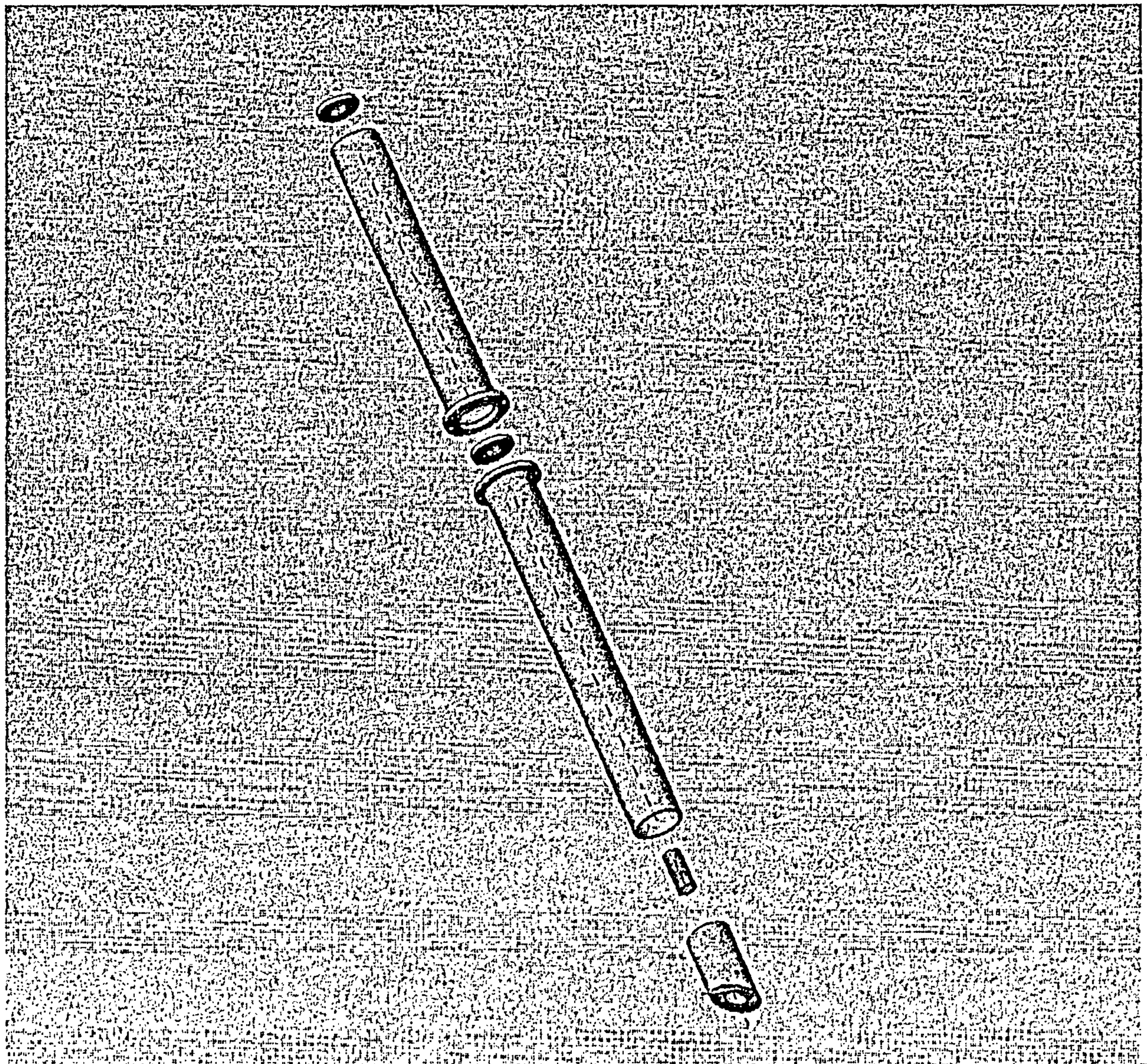
Sequential Repair Procedure



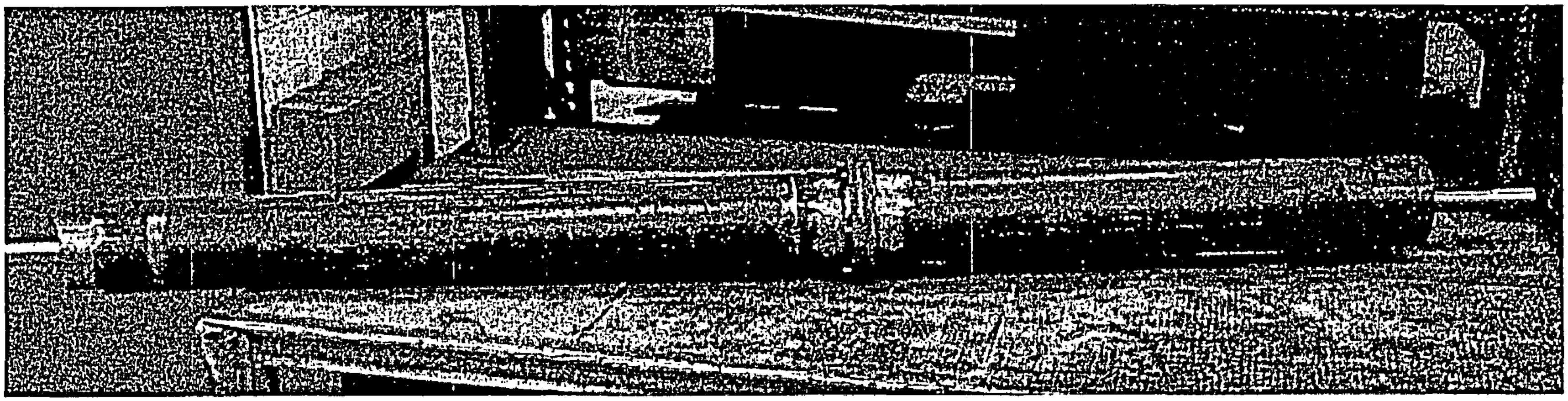
Sequential Repair Procedure



PZR "Bazooka" Mockup



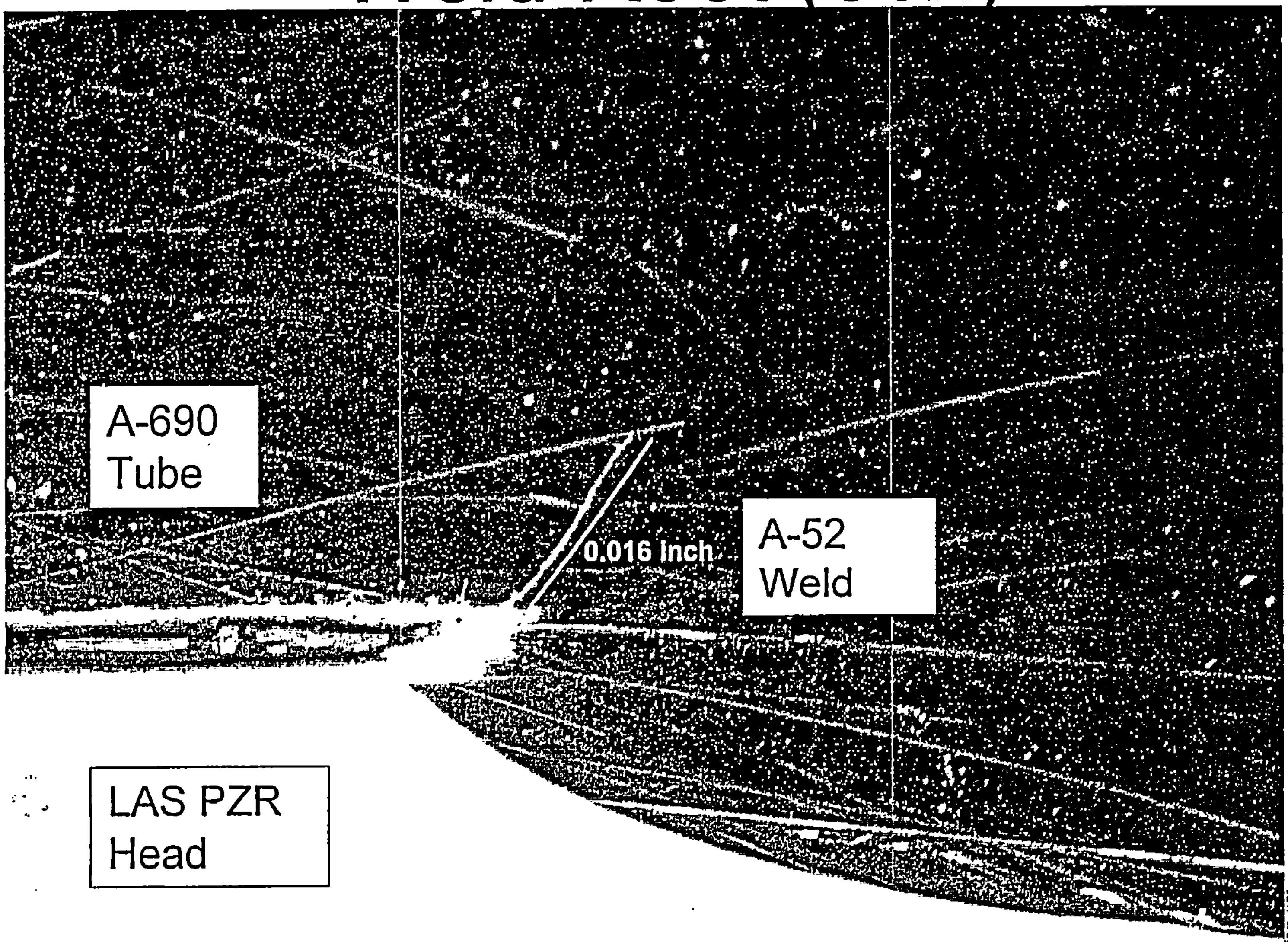
PZR "Bazooka" Mockup



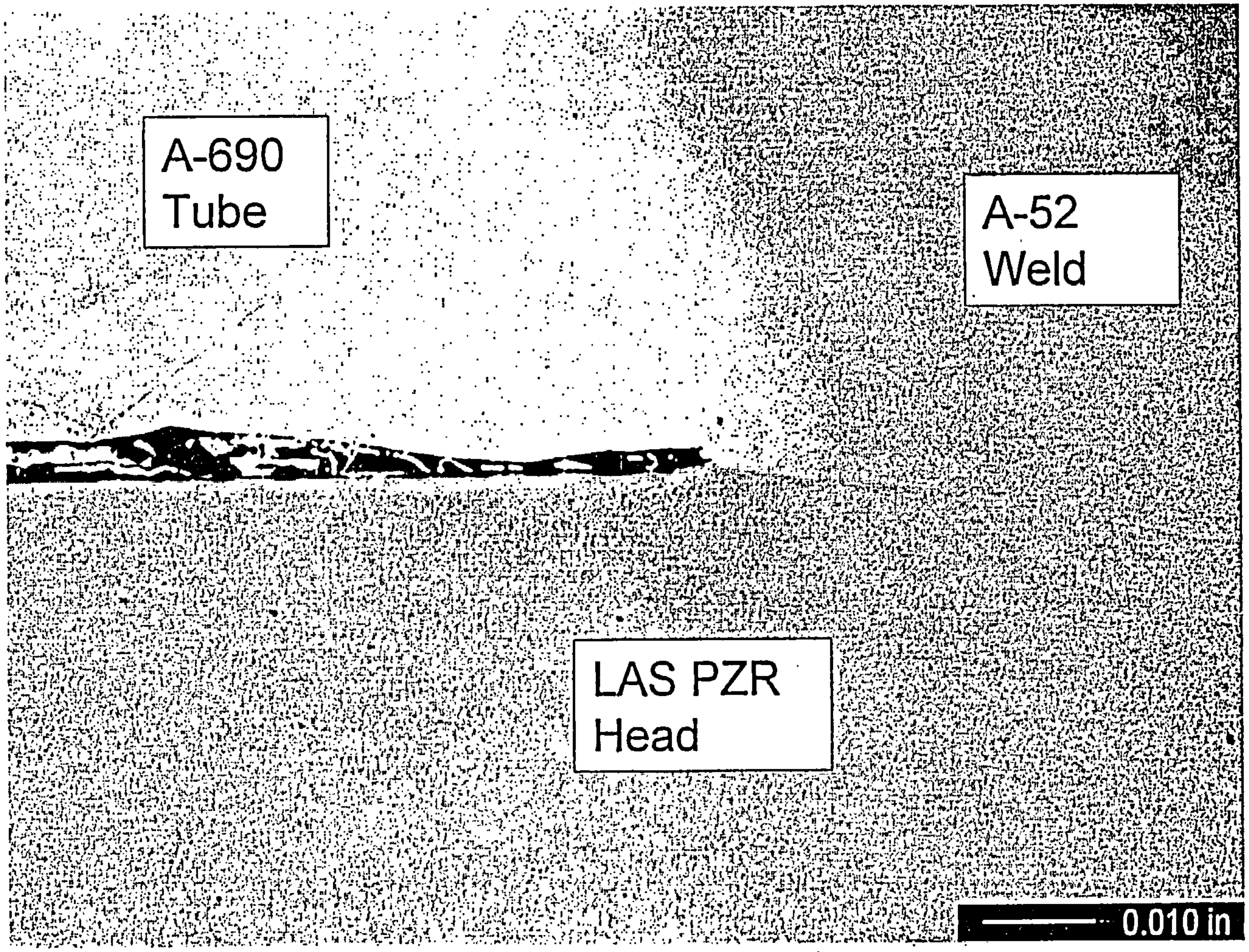
Welding Development Program

- Extensive welding development program conducted to address potential triple point / welding solidification anomaly
  - Over 13 weld samples produced to date
  - Triple point cross sections examined at high magnification
  - Welding parameters refined & improved
- Demonstrated ability to repeatedly produce defect-free welds with no solidification anomalies at the weld root

Early Sample with Cracking at Weld Root (50x)



Recent Weld Sample (50x)
(Typical of 6 production welds produced)



Weld Process Conclusions

- OE and initial shop trials produced cracks at weld root
- Further process variable changes were able to reliably resolve the "triple point" issue
- Process has been refined to produce reliable and repeatable high quality welds

Mid-Wall Repair NDE

- PVNGS is committed to the '92 Edition/'92 Addenda of ASME Code, Section XI
- IWA-4170(b) requires repairs and replacements to be performed in accordance with the Construction Code, or all or part of later editions and addenda thereof, and code cases
- Weld to be examined per Section III NB-5000, guidance to be taken from N-638-0
  - PT of pressurizer bore before welding
  - Final PT of weld surface and adjacent base metal
  - Volumetric examination with straight beam and angle beam transducers

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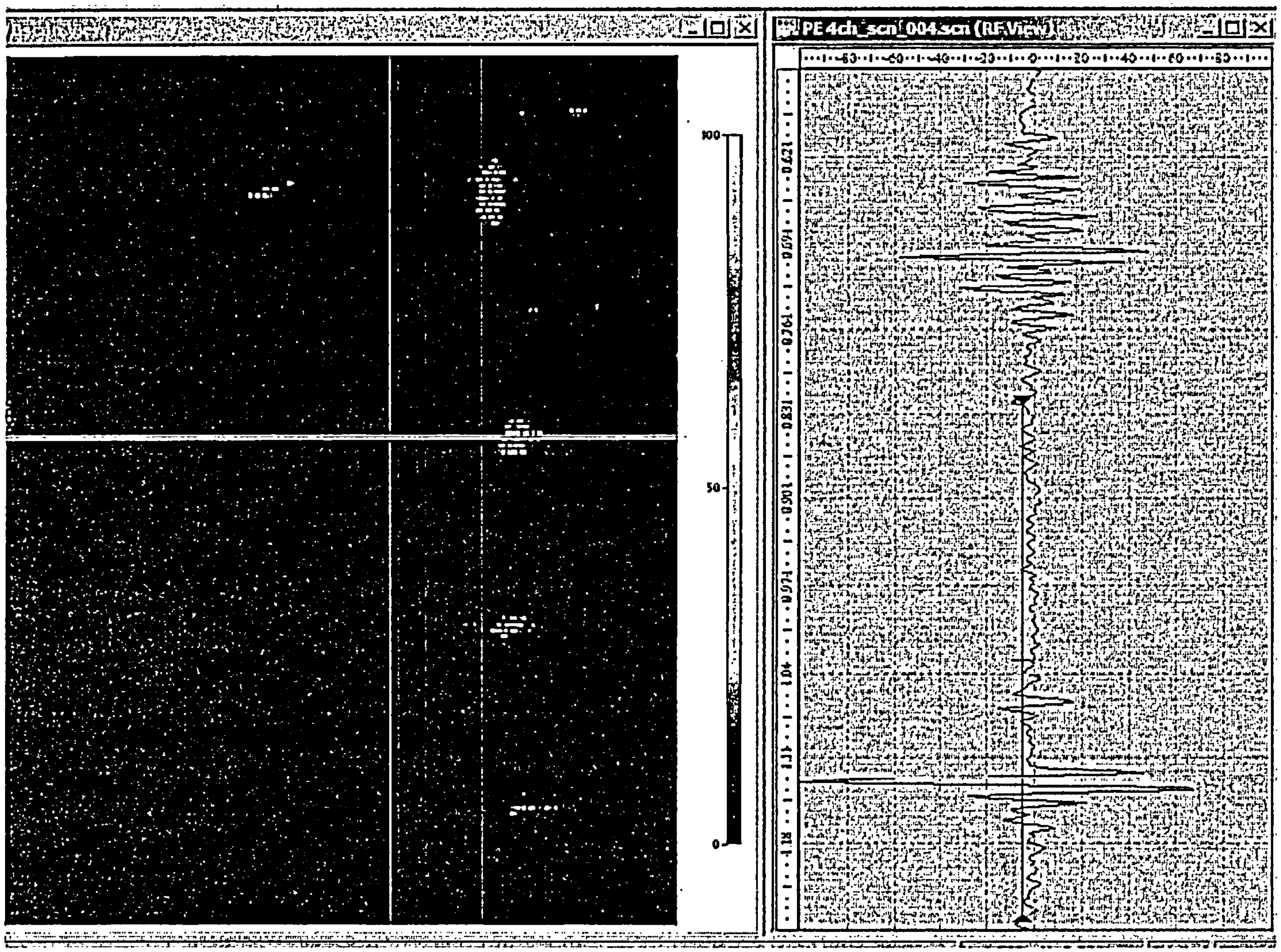
Midwall Repair NDE

- Surface Examination
  - PT examination prior to welding to ensure surface is free of defects
  - Final PT examination of weld surface and adjacent base metal
- Volumetric Examination
  - Straight beam examination to a depth of 0.25”
    - Surface of weld and adjacent heater sleeve to ensure no lack of bond or lack of fusion and to detect any reflectors that could interfere with the angle beam examination
  - Angle beam examination to a depth of 0.25”
    - Scanning looking in both direction for axial reflectors
    - Scanning looking in both direction for circumferential reflectors

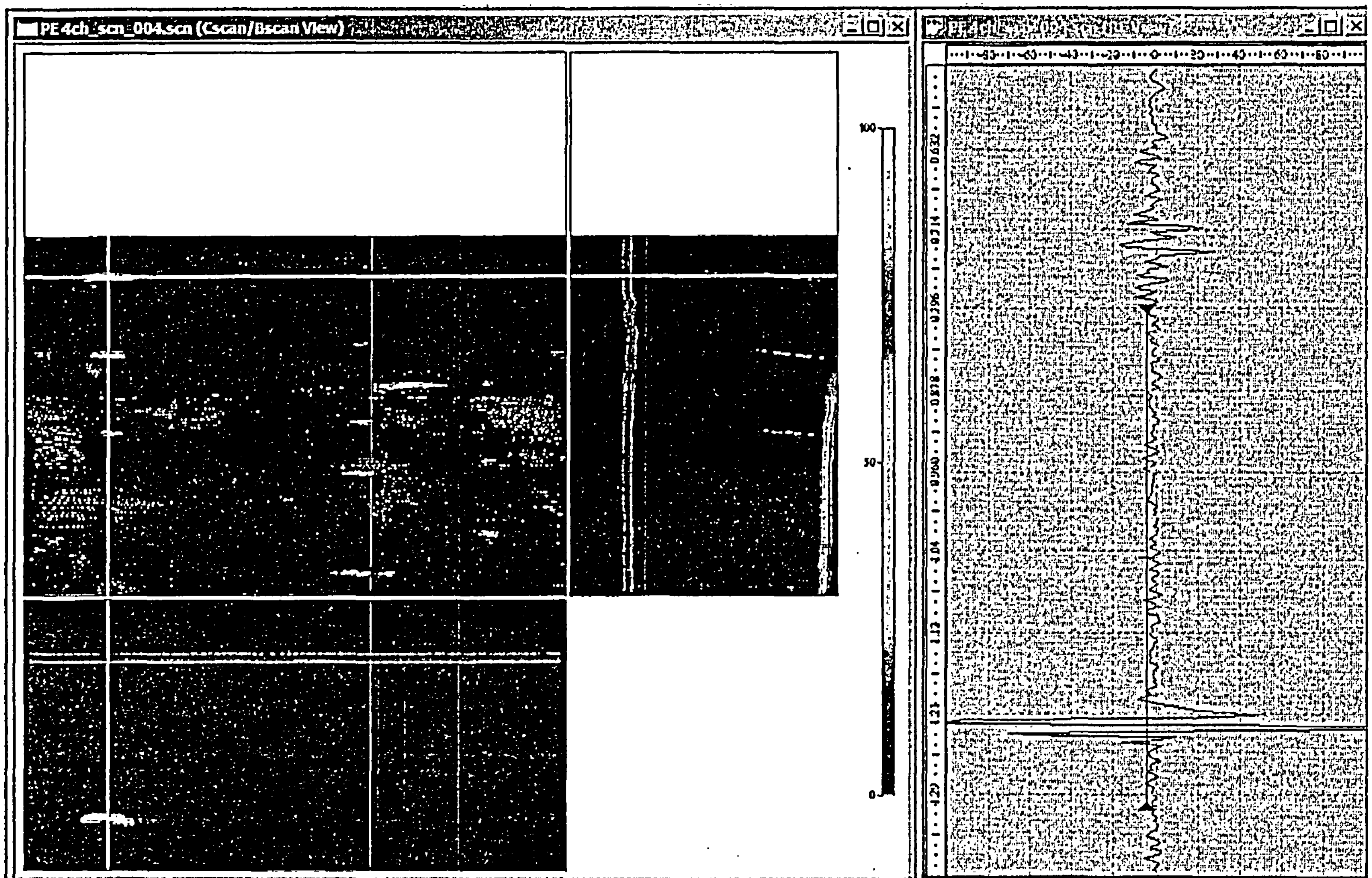
Mid-Wall Repair NDE

- Demonstration of Midwall Repair NDE
  - Volumetric Examination
    - Straight beam examination
      - Welded mockup with flat bottom holes
    - Angle beam examination
      - Welded mockup with OD/ID circumferential and axial EDM notches and end drilled holes

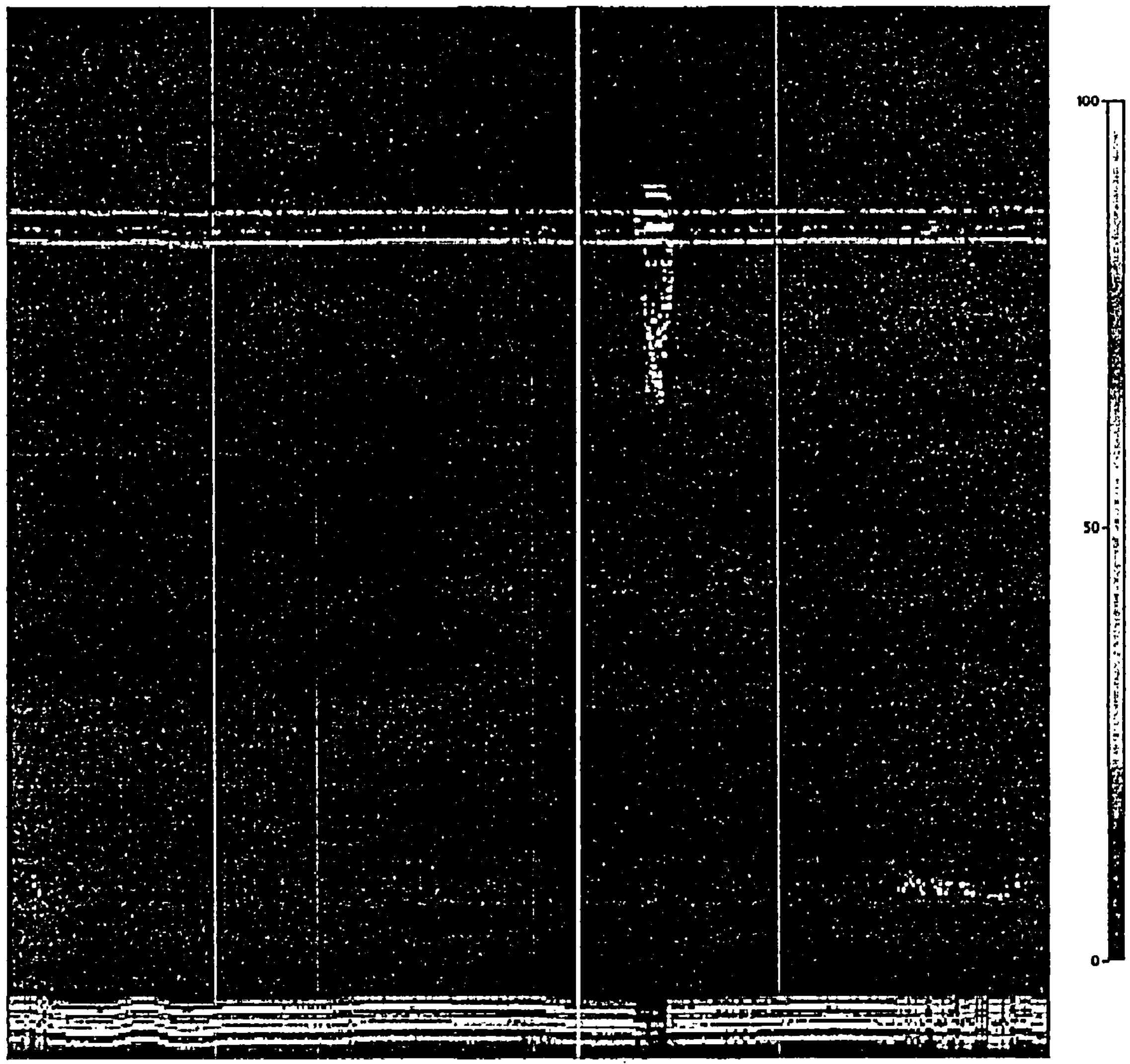
NDE of OD Axial EDM Notched Sleeve



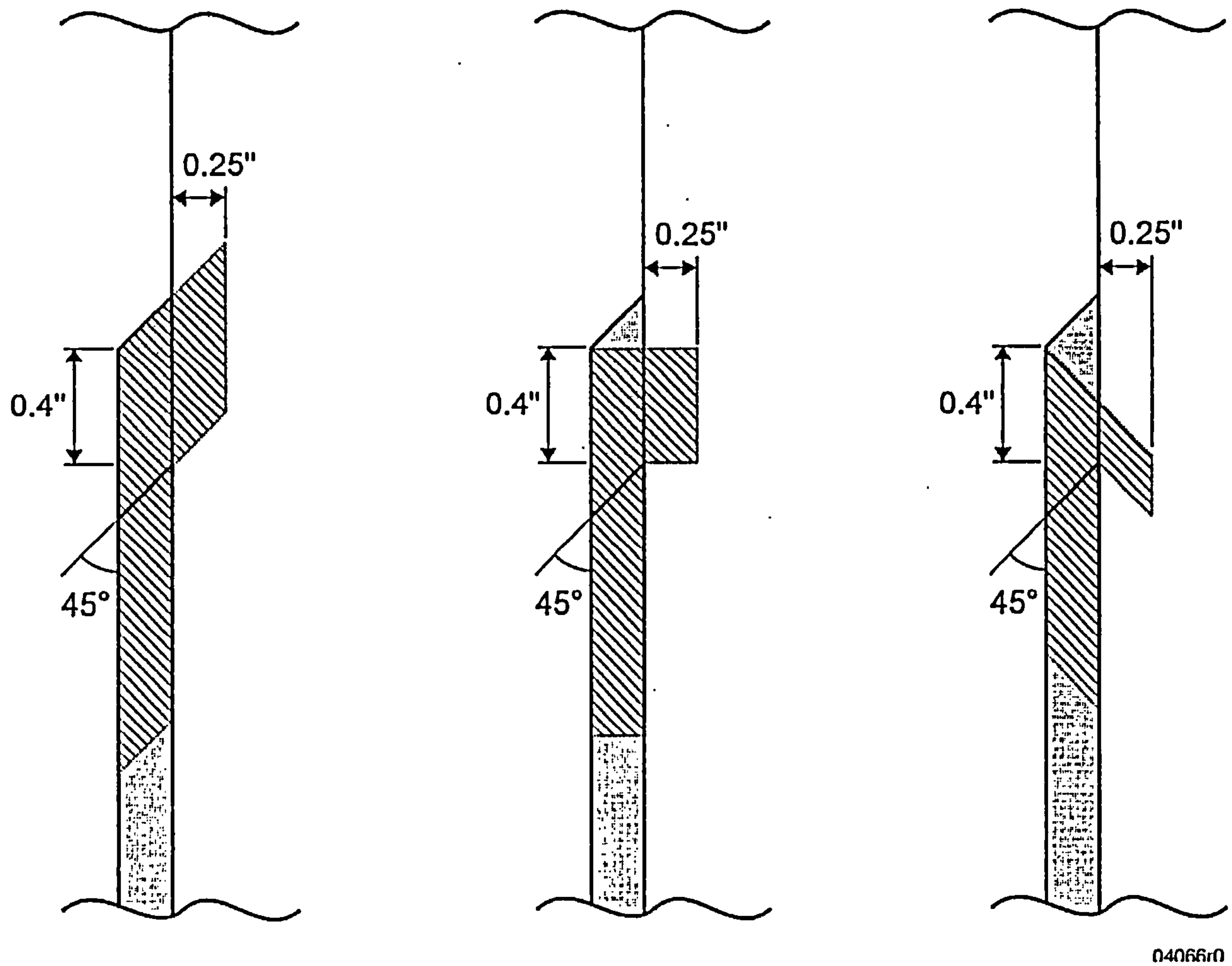
NDE of OD Circumferential EDM Notched Sleeve



NDE of ID Circumferential EDM Notched Sleeve



Pressurizer Mid-Wall Repair UT Inspection Coverage



Pressurizer Heater Sleeve Repair

Midwall Repair NDE Timeline

Completed Items

- Review applicable codes and standards to define inspection requirements
- Design and fabricate calibration standard and preliminary test samples
- Design/build/test development scanner
- Design, procure, and machine prototype probes/heads/wedges
- Perform preliminary examination on test samples

Scheduled Items

- Design and fabricate final demonstration blocks – 7/30
- Perform technique demonstration – 8/5 and 8/6
- Finalize NDE procedure – 8/17
- Compile demonstration package and procedure qualification – 8/20
- NDE personnel training – 8/23

Mid-Wall Repair NDE

- NDE meets applicable ASME Code requirements (Section XI, III, and V)
- Technique will be Demonstrated on a Mid-wall Welded Mockup

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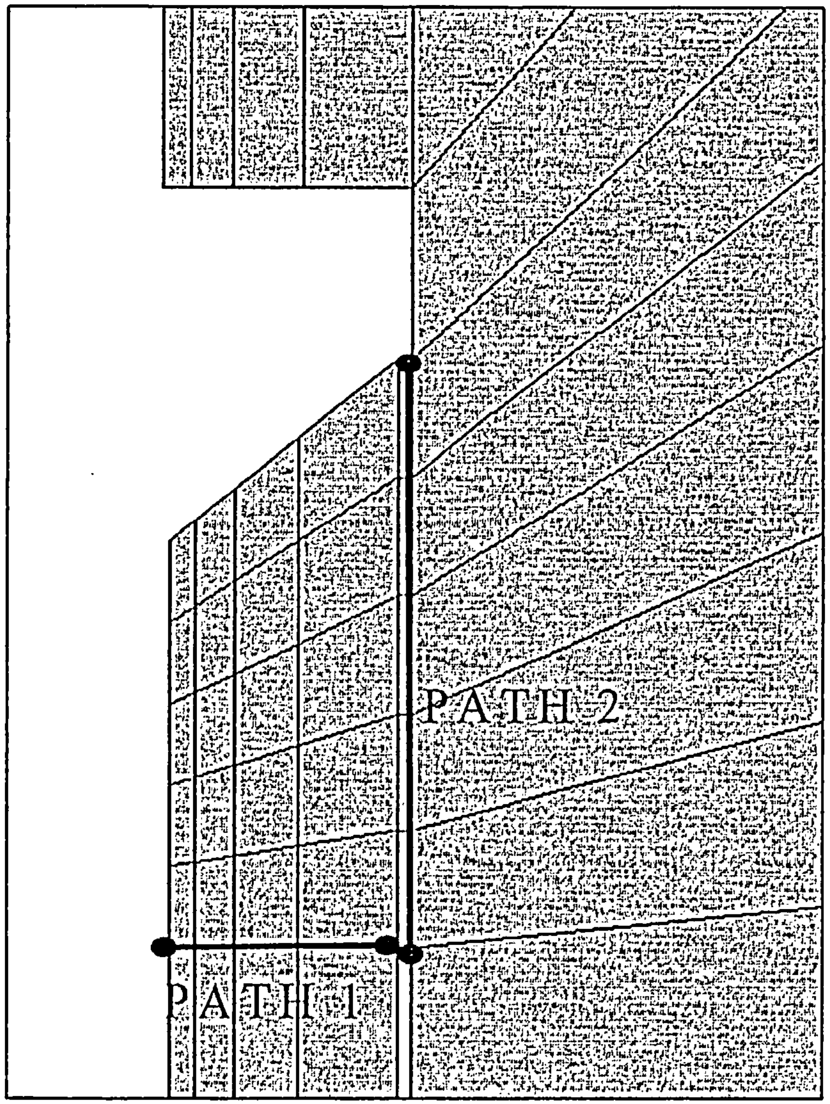
Triple Point Flaw Evaluation

- Although triple point flaws not expected, ASME Section XI applied to establish NDE detection and acceptance criteria, considering:
  – Flaw Acceptance Standards (IWB-3500)
  – Fracture Mechanics Flaw Evaluation Criteria (IWB-3600)

ASME Section XI
Allowable Flaw Standards

- Allowable flaw sizes in accordance with Section XI Pre-service Inspection Standards
  - IWB-3514.3, Austenitic Piping
  - IWB-3514.4, Dissimilar Metal Welds
- Established for Paths 1 and 2 (see Figure)
- Applicable to austenitic piping, including wrought stainless and Ni-Cr-Fe piping material and associated weldments
- If no indications are detected that exceed these limits:
  - welds are considered clean in accordance with ASME Section XI, IWB-3112, and
  - no successive examinations, in accordance with ASME Section XI, IWB-2420 are required

Triple Point Flaw Evaluation Paths



ASME Section XI
Fracture Mechanics Flaw Evaluation

- Employ Fracture Mechanics principles to determine crack growth rates and end of life allowable flaw sizes
  - Strictly applicable only to Inservice (not Pre-service) Inspections
  - When employed, introduce requirement for successive examinations per IWB-2420
- Applied to mid-wall triple point evaluation to demonstrate conservatism of Section XI Standards

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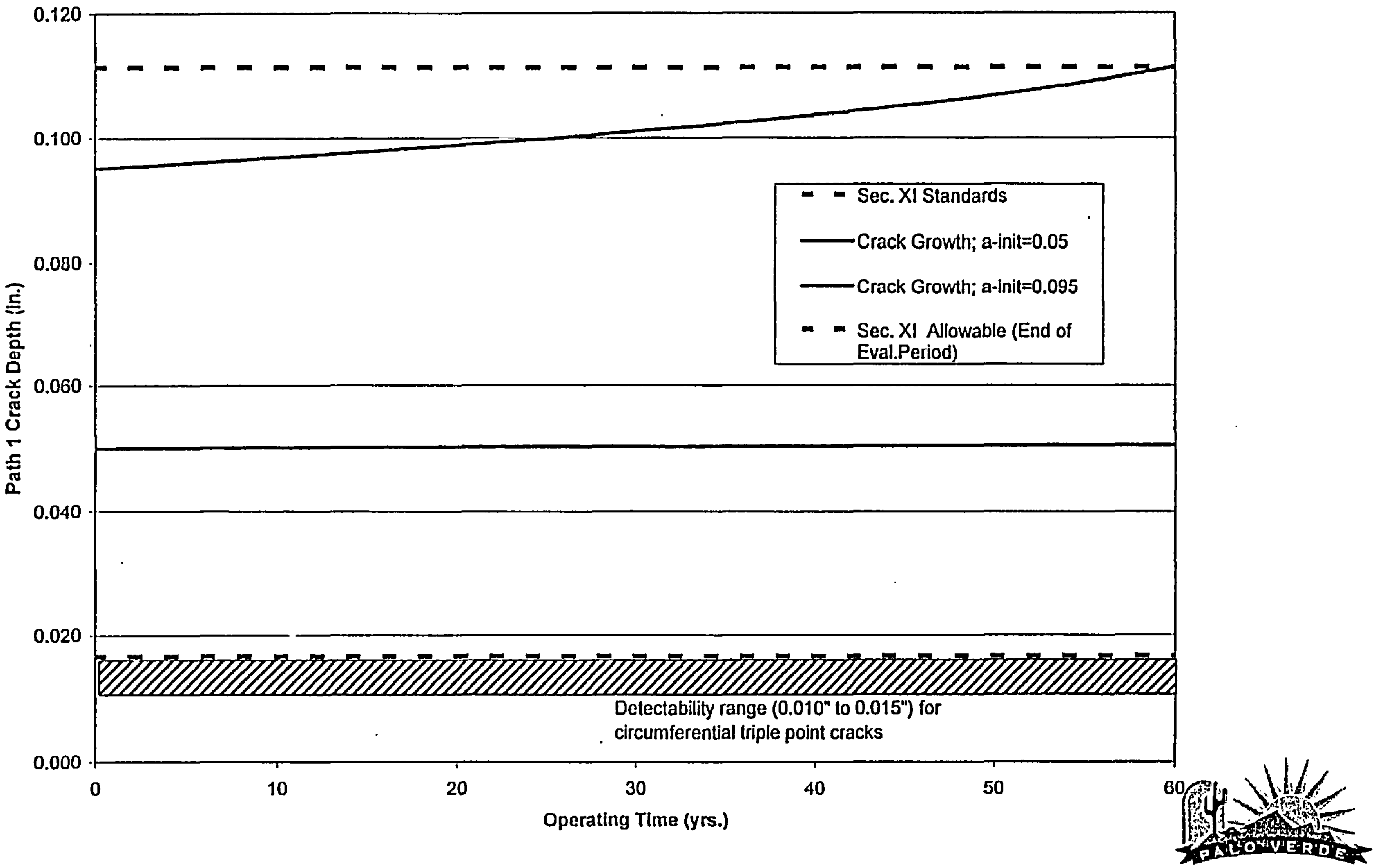
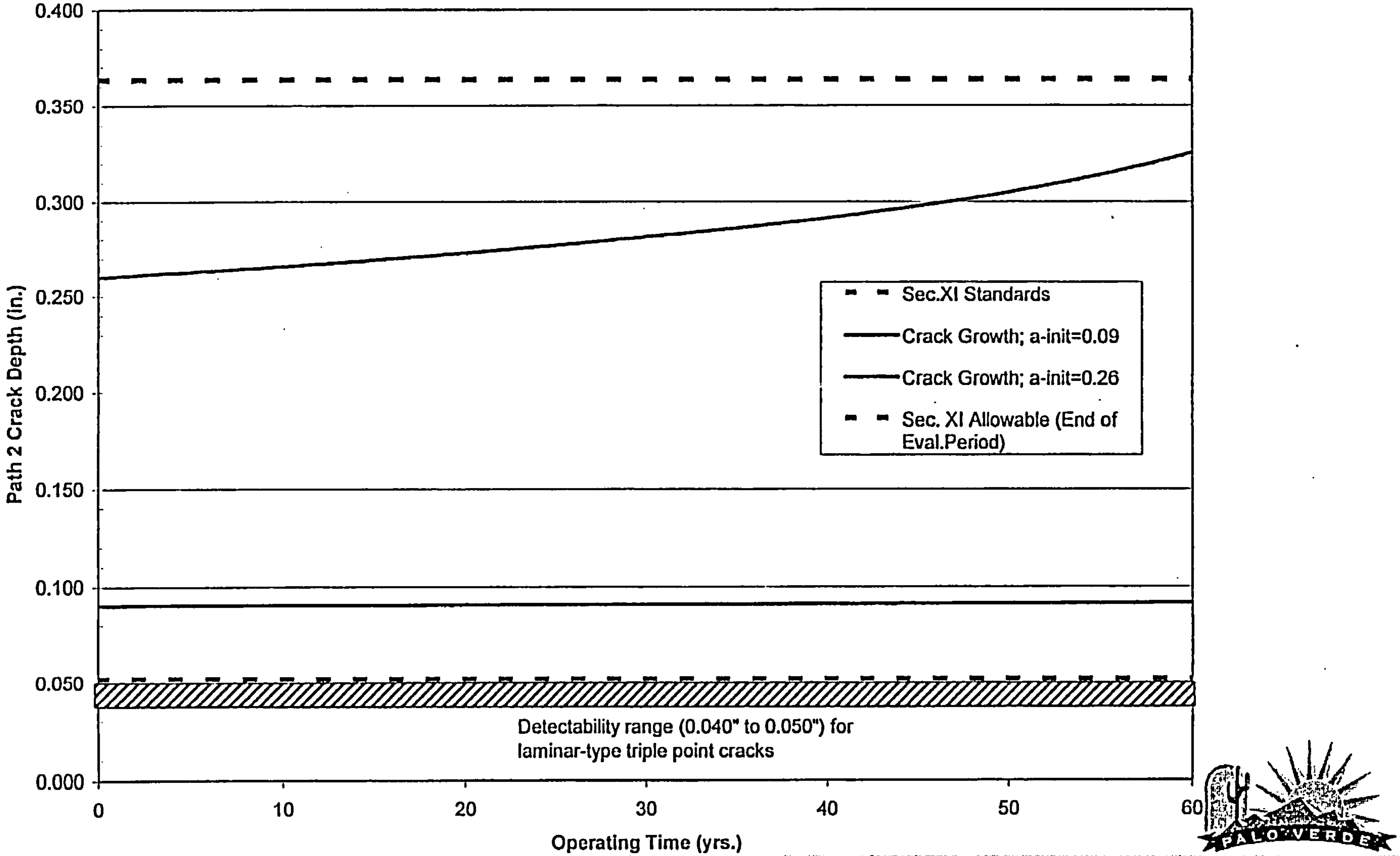
Evaluation Results for Postulated Path 1 Flaw



Evaluation Results for Postulated Path 2 Flaw



Summary of Triple Point Flaw Evaluation Results

Postulated Flaw Location	Allowable Flaw Sizes per Section XI Standards	Allowable Flaw Sizes per Fracture Mechanics Evaluation	
		Initial Flaw Size*	End-of-Evaluation Period
Path 1	0.0166”	0.095”	0.112”
Path 2	0.0522	0.26”	0.36”

*Approximate flaw size that would grow to End-of-Evaluation Period Allowable in sixty years.

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Pressurizer Heater Sleeve Repair

Conclusions

- Midwall repair requires less machining and significantly less welding than pad repair
- Palo Verde would save 8.5 REM per unit by implementing the midwall repair in lieu of the pad repair
- Other utilities would likely incur more dose than Palo Verde by implementing pad repair due to sleeve configuration

Pressurizer Heater Sleeve Repair

Conclusions Cont'd

- Requesting relief to utilize GTAW ambient temperature temper bead process for midwall repair (RR28)
- Requesting relief to leave the postulated flaw in place w/o full characterization and successive exams (RR29)
- Requesting relief to utilize EPFM for flaw evaluation

Pressurizer Heater Sleeve Repair

Conclusions Cont'd

- Successive volumetric examinations in addition to Section XI/NRCB 2004-01 exams are not required
  - Qualified welds
  - ASME flaw margin demonstrated
- Successive volumetric examinations would eliminate CE alliance dose reduction benefit
- NRC concurrence needed to support Unit 3 fall 2004 outage

Relaxation Request No. 25 on Inspection Coverage for Palo Verde Unit 1

NRC Presentation

Mike Melton

July 20, 2004

Background

- Arizona Public Service Company (APS) requested relaxation from the requirements of first revised order EA-03-009, section IV.C.(5)(b).
- The NRC requested analysis be performed to substantiate inspection coverage below the weld for Unit 1 CEDM Nozzles 84, 87 and 93 were acceptable.
- APS has completed an additional finite element analysis (FEA) of CEDM Nozzles 84, 87 and 93 using the as-built J-weld configuration for these nozzles.
- APS recently submitted revised analysis

Actual Inspection Coverage

Penetration No.	Nozzle Angle (°)	Proposed Inspection Coverage in Relaxation Request	ID Distance Covered by UT Below Weld	OD Distance Covered by PT Below Weld
84	35.7	0.40"	0.28"	1.0 "
87	51.5	0.35"	0.20"	0.8 "
93	35.7	0.40"	0.36"	0.7 "

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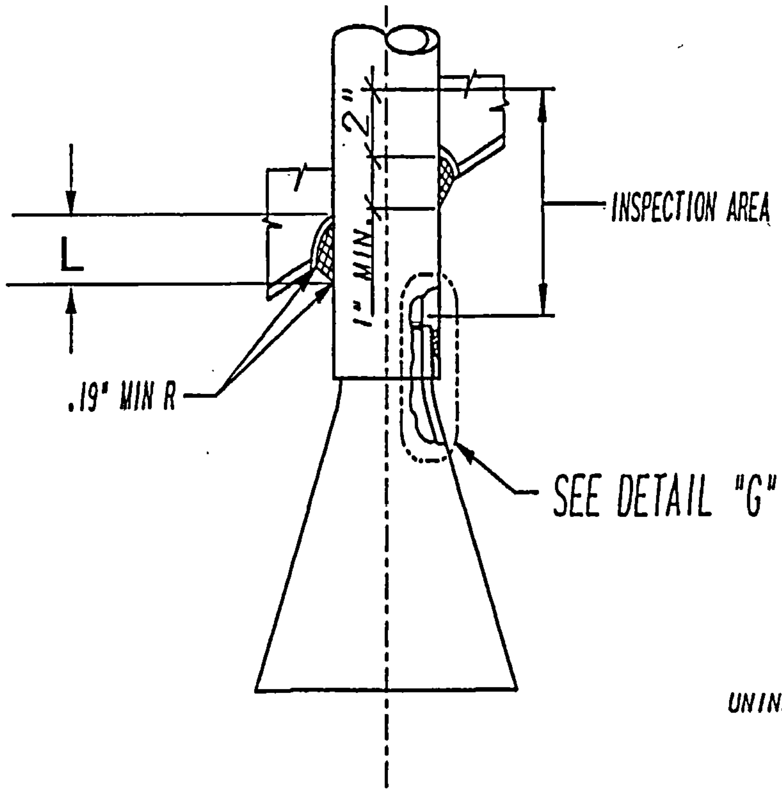
As Built J-Weld Configuration (penetration No. 84, 87 and 93)



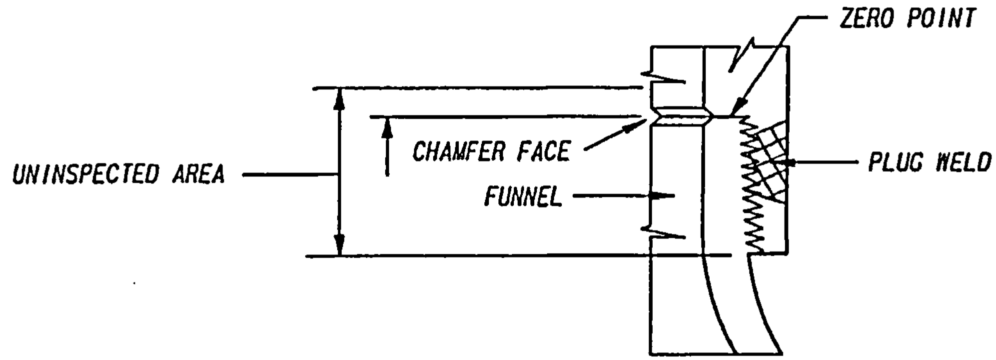
TYPICAL PENETRATION NO'S 1 THRU 97

L = As-Built J-Weld Heights

Nozzle 84 = 2.24"

Nozzle 87 = 2.62"

Nozzle 93 = 1.76"



DETAIL "G"

PALO VERDE

Revised Stress Analysis

- Hoop stress distribution for as-built J-weld configuration
- Methodology same as discussed in relaxation request (letter 102-05075-CDM/SAB/RJR, dated March 19, 2004.)
- Accounted for instrumentation measurement uncertainty

PALO VERDE

Crack Growth Calculation

- For the three penetrations with incomplete coverage, a through-wall axial flaw was postulated
- The upper end of the flaw was located at the location where inspection coverage stopped
- The lower end of the flaw was located where the stresses dropped to zero
- Maximum stresses anywhere along the crack were used to calculate the stress Intensity factor
- Crack growth model of MRP-55 used

Conclusions

- No crack growth below the weld for any undetected flaws in penetration No. 84,87 and 93
- Undetected flaws will not reach weld bottom before next inspection
- Provides an acceptable level of quality and safety for a full operation cycle

Follow-up Requested

- APS has submitted the analysis and revised table for Unit 1 to support a full cycle of operation
  - Currently under 7.7 month limited operation
- The relaxation for Unit 3 CEDM inspection coverage was previously submitted and needs NRC approval for the 2004 fall outage
  - Outage start October, 2004

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Reactor Vessel Head Vent Line Orifice Relocation

PALO VERDE

NRC Presentation
Mark Radspinner
July 20, 2004

Relief Request 24

- APS requested relief from Order requirement IV.C.(1)(b) for the head vent line nozzle with integral orifice
- Either
  - UT of each nozzle ID and an assessment to determine if leakage has occurred into the interference fit zone OR
  - ET or PT of wetted surface

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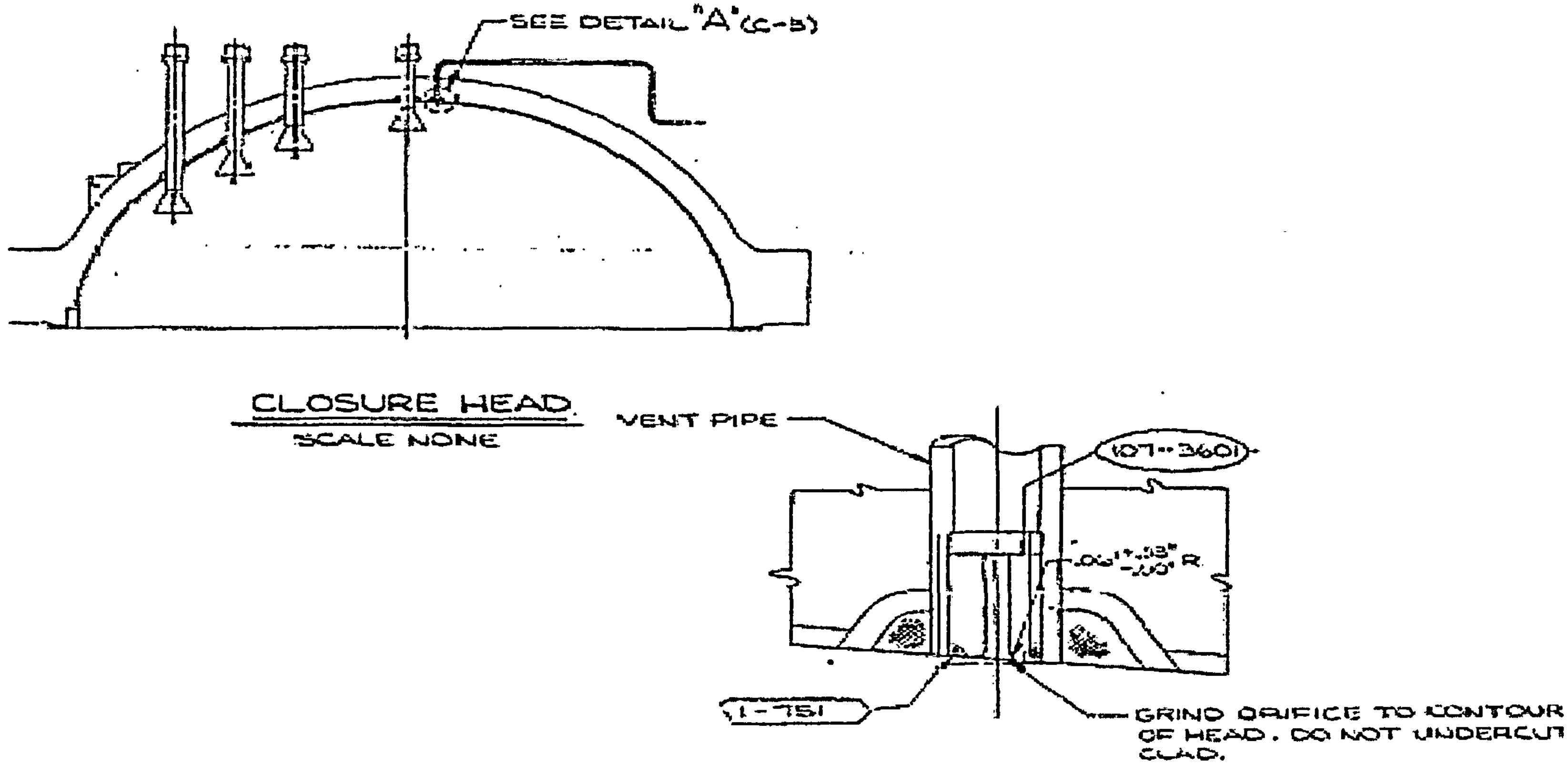
Vent Line and Orifice



Vent Line Orifice

- NUREG 0737 Item II.B.1 Requirement
  - Remotely operated RCS vent system
  - Stipulated must not lead to an unacceptable increase in the probability of a LOCA
    - Meet 10CFR50.46 acceptance criteria and General Design Criteria
  - Palo Verde construction status allowed optimal orifice location

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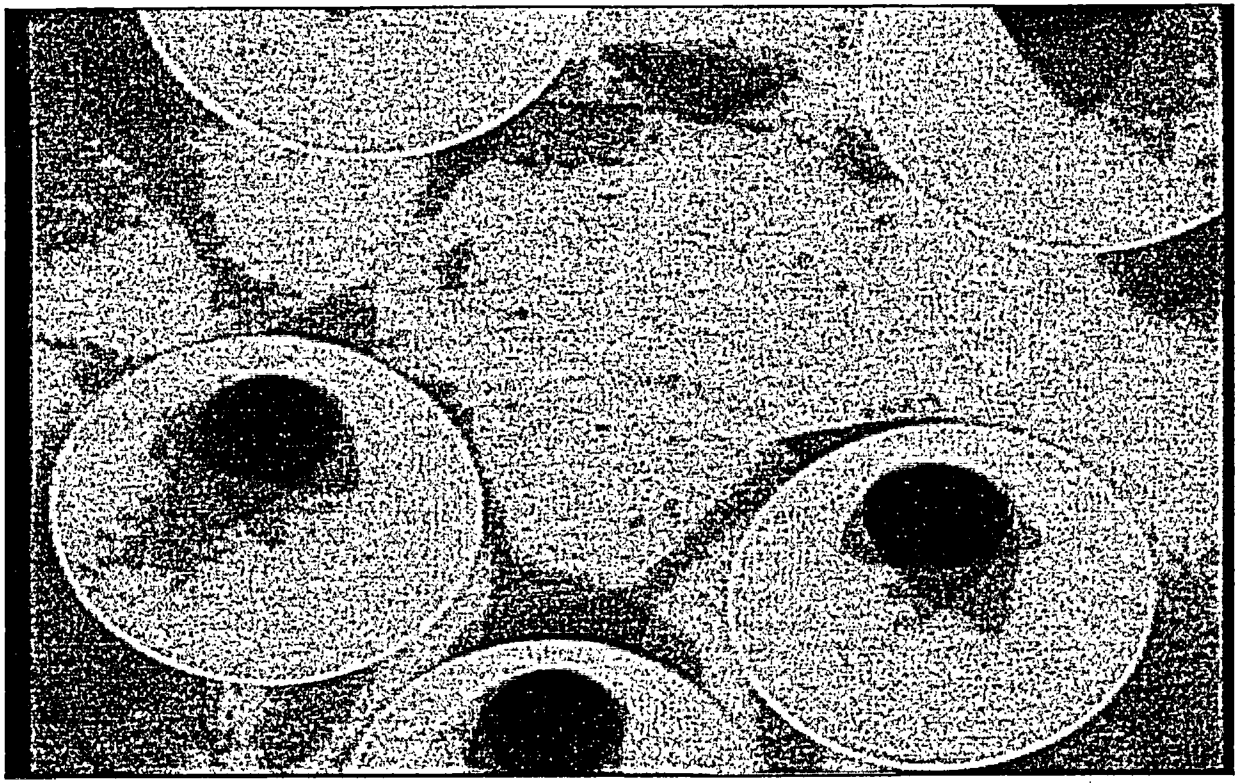
Vent Line and Orifice



Relief Request 24

- Proposed alternative of surface exam of vent nozzle J-groove weld and orifice attachment weld
- Combined with IV.C.(1)(a)-required bare metal visual exam, felt to provide acceptable level of quality and safety

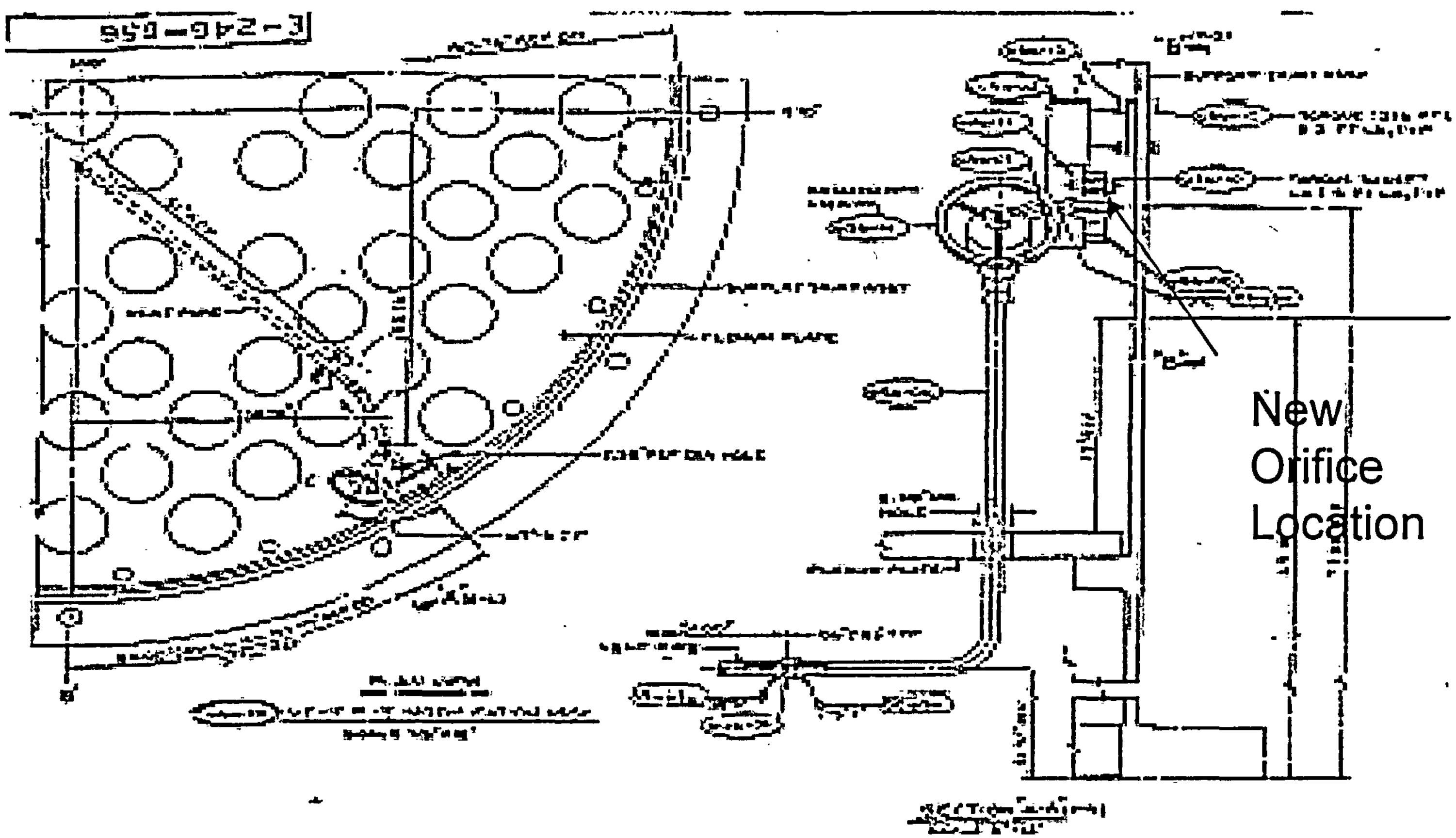
NRC SER

- Relief granted for one cycle, Unit 1 only, in recognition of magnitude of radiation exposure (hardship) that would be incurred considering lack of developed tooling and methods to remove orifice

Unit 3 Preparation Status

- Developing remote tooling for orifice removal
- Developing orifice relocation package
  - ASME Code Class Break reconciliation
    - Will require PT of one existing butt weld to meet Class 1 requirements
  - Design and licensing basis reconciliation
    - NUREG 0737 and GDC requirements met

Orifice Relocation



10CFR50.59

- Meets NUREG 0737 Requirements
- Will meet ASME Class 1 Requirements
- Meets GDC Requirements
- No/minimal increase in frequency of occurrence or consequences of accident or malfunction

Expectation

- Full compliance with Order requirements
- Developed methods and tooling to minimize radiation exposure (basis for granting of Relief Request)