February 12, 1997

LICENSEE: Southern Nuclear Operating Company, Inc.

FACILITY: Farley Nuclear Plant, Units 1 and 2

SUBJECT: MEETING SUMMARY - DIRECT TUBE REPAIR METHOD OF STEAM GENERATOR REPAIR AND PROPOSED TECHNICAL SPECIFICATION AMENDMENT REQUEST SUBMITTAL SCHEDULE

Reference: Meeting Notice by J. I. Zimmerman, January 27, 1997

On February 5, 1997, the staff met with Southern Nuclear Operating Company, Inc. (SNC), and Westinghouse Electric Corporation for initial discussion of SNC's plans and schedule for submitting a proposed Technical Specification amendment request regarding the use of Direct Tube Repair in the repair of steam generator tubes. Enclosure 1 is a list of the meeting participants. Enclosure 2 is a copy of the material presented by SNC and discussed during the meeting.

Original signed by:

Jacob I. Zimmerman, Project Manager
Project Directorate II-2
Division of Reactor Projects - I/II
Office of Nuclear Reactor Regulation

Docket Nos. 50-348 and 50-364

Enclosures: 1. List of participants
2. Material presented

cc w/encls: See next page

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

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Joseph M. Farley Nuclear Plant

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LIST OF PARTICIPANTS

MEETING ON FARLEY DIRECT TUBE REPAIR OF STEAM GENERATORS

ONE WHITE FLINT NORTH, 0-1-F-5

FEBRUARY 5, 1997

Name	Organization
Jacob Zimmerman	NRC
Edmund Sullivan	NRC
Geoff Hornseth	NRC
Phil Rush	NRC
John Tsao	NRC
Cheryl Beardslee	NRC
Robert Hermann	NRC
John Garlington	SNC
Mark Ajluni	SNC
Brad Moore	SNC
Rick Mullins	SNC
Bala Nair	Westinghouse
Gary Pierini	Westinghouse
Bill Cullen	Westinghouse
Boyd Radford	Baltimore Gas & Electric
Jeffrey Poehler	Baltimore Gas & Electric
Lynn Connor	***Doc-Search Associates

Enclosure 1

Direct Tube Repair

of

Steam Generator Tubes

NRC Staff/Southern Nuclear Meeting

Wednesday, February 5, 1997
One White Flint North
Rockville, MD

Enclosure 2

Agenda

Introduction
John Garlington, SNC

Why direct tube repair?
Brad Moore, SNC

DTR Process/Corrosion Process
Bala Nair, West

Structural Evaluation
Bill Cullen, West

NDE Concept
Gary Pierini, West

Schedule
Mark Ajluni, SNC

Discussion - All

Why direct tube repair (DTR)?

- Inability to repair flaws above sleeves
- Efficient use of resources
  - Potentially quicker
  - Less complicated
  - Reduced radiation exposure
- Less impact
  - Heat transfer
  - Flow resistance

LASER WELDED DIRECT TUBE REPAIR

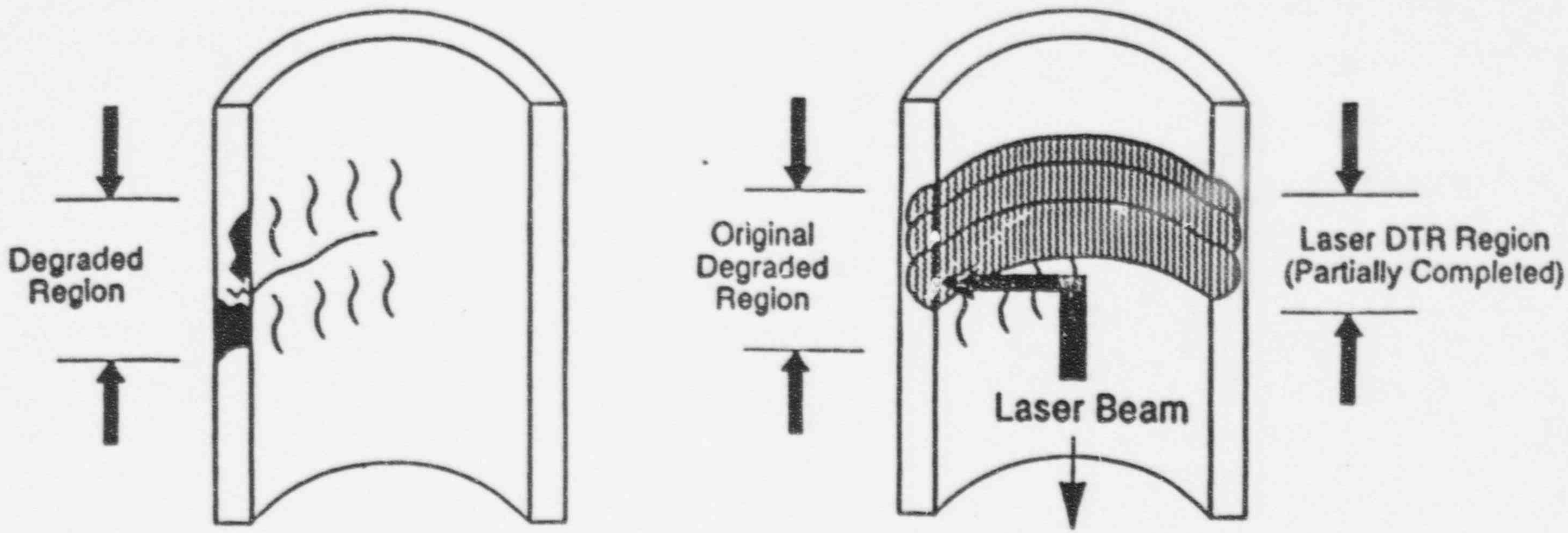
WPF2685:49/020397-1

Objectives of the Direct Tube Repair Program

- Restore the structural integrity of degraded tubing which exceed the repair criteria

- Slow or stop the progression of active degradation

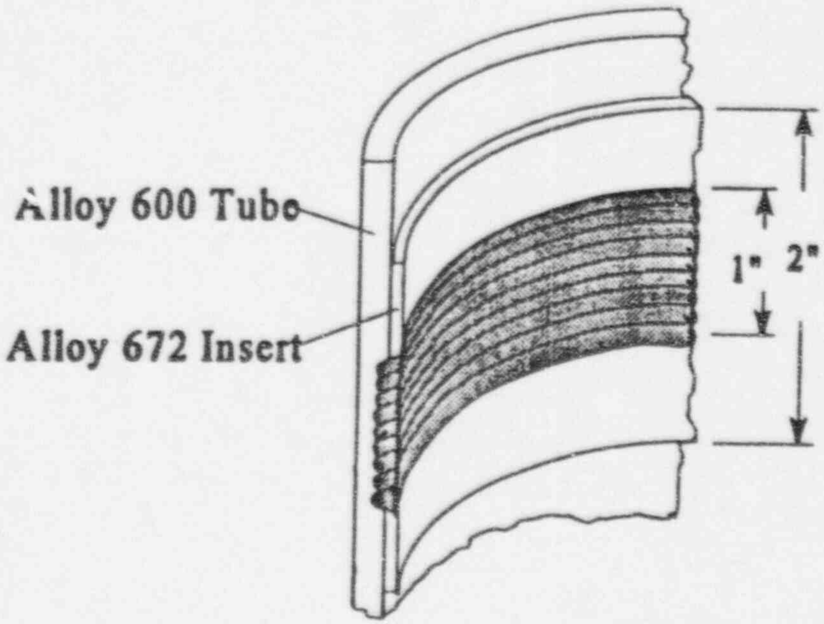
Initial Focus of Development Was on a Single Pass Autogenous Process



a) Degraded Tube

b) DTR In Progress

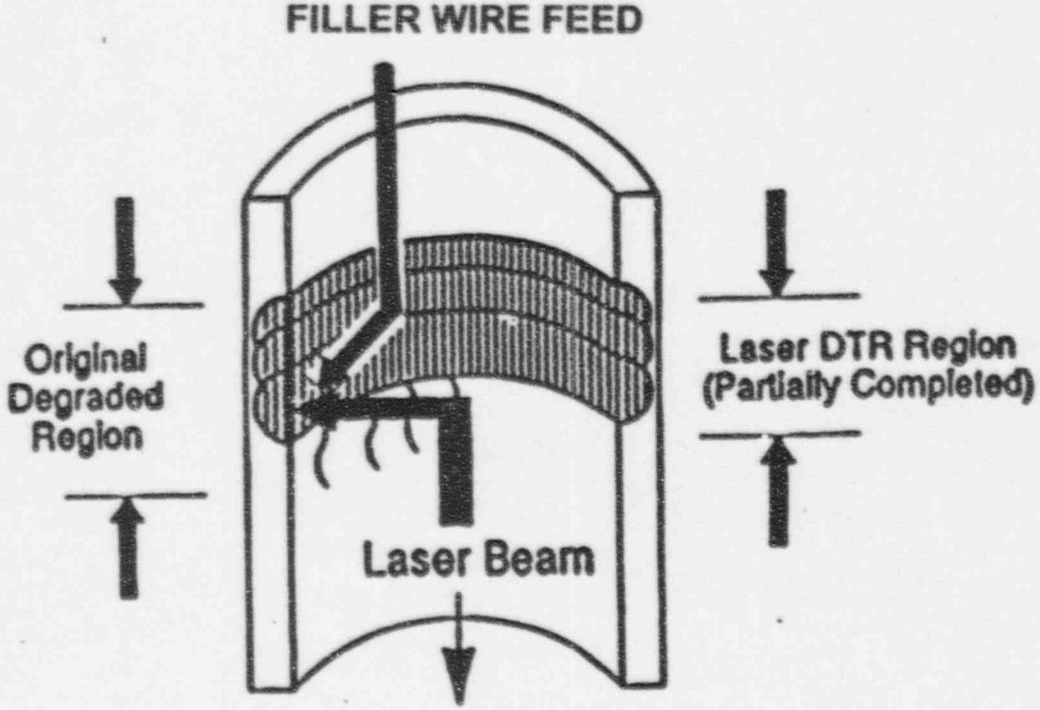
DTR - Filler Insert Approach



Focus in 1994 Was On a Process That Modified Weld Chemistry Through Addition of Filler Metal

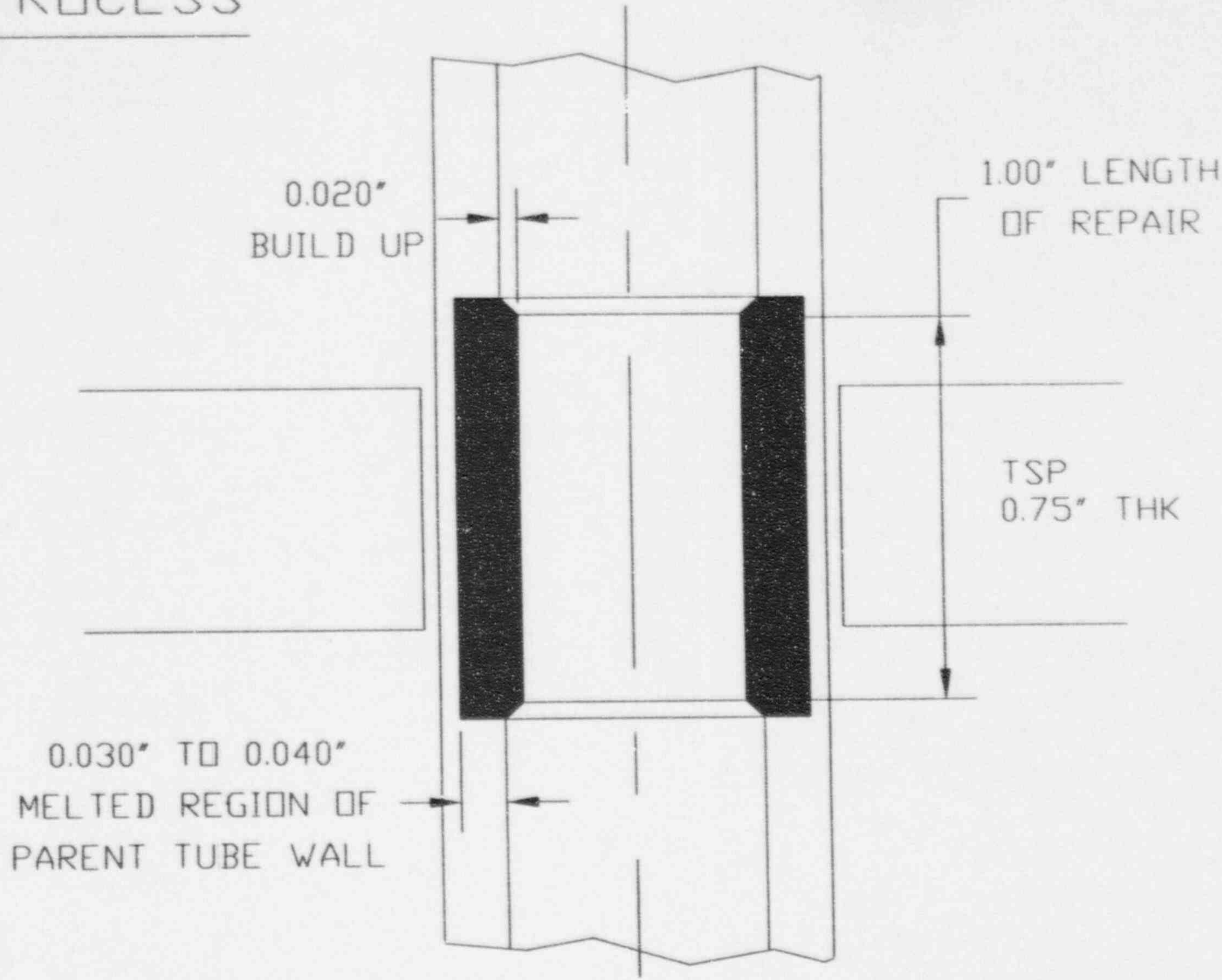
- Filler metal-based process using consumable insert developed
- Parent tube penetration limited to about 35 percent, with 0.020 inch buildup
- Corrosion tests yielded excellent results
- Tensile and burst tests showed no significant difference from virgin tubes
- Good low and high cycle fatigue test results

Schematic of Filler Wire Feed DTR Process

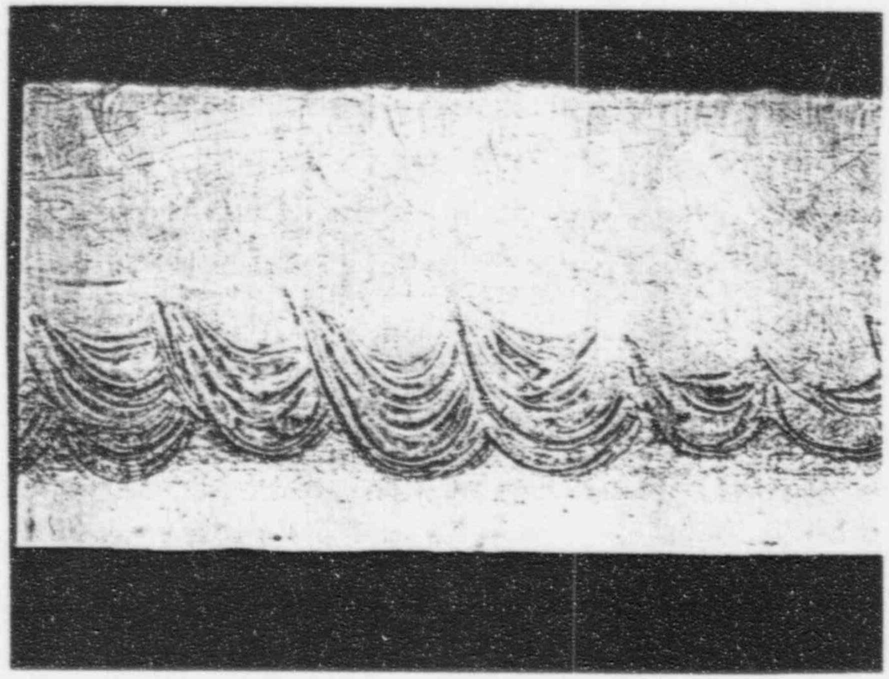


b) DTR In Progress

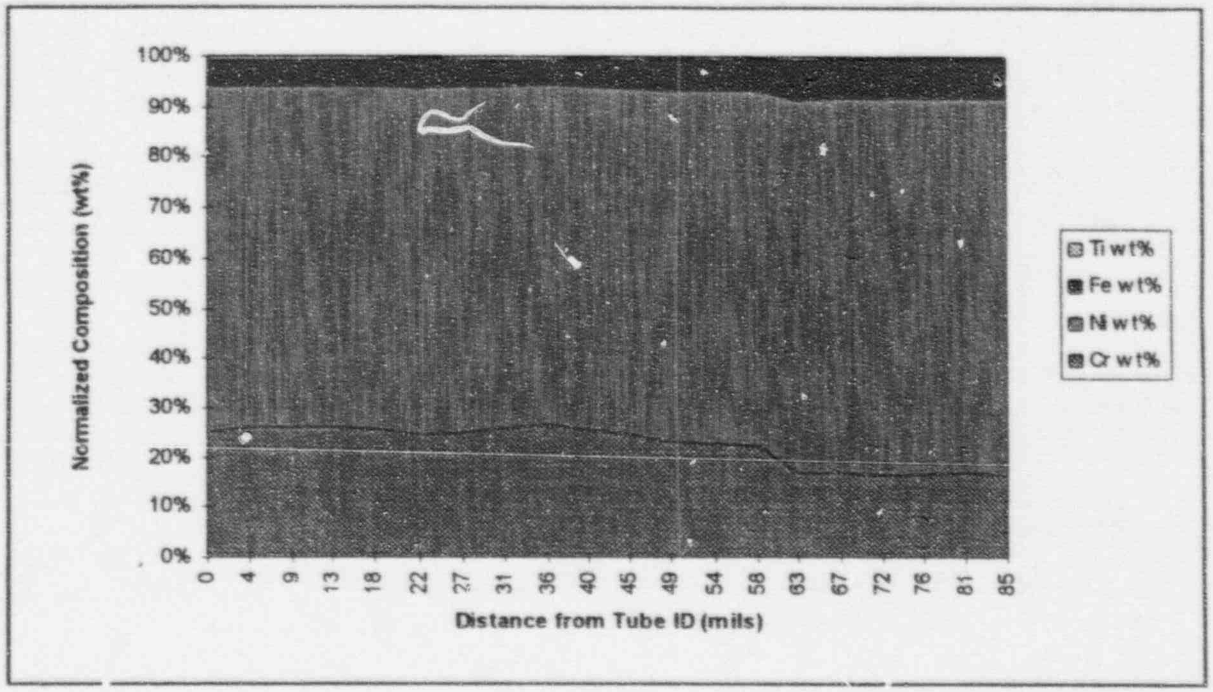
DTR PROCESS


0.020"
BUILD UP
1.00" LENGTH
OF REPAIR
TSP
0.75" THK
0.030" TO 0.040"
MELTED REGION OF
PARENT TUBE WALL

Filler Wire Based DTR Weld Cross-Section



As-Measured Chemistry of Filler Wire Based DTR Weld



Summary of DTR Weld Microprobe Chemistry Analysis

Elem.	Alloy 600		Alloy 672	DTR Insert		DTR Wire Feed		Alloy 690
	Ht 8161	Ht 7368		Ht 8161	Ht 7368	HT 8161	Ht 7368	
Ni	76.17	76.21	55.81	66.11	65.35	70.2	69.7	58.00
Cr	15.59	14.87	43.11	29.19	29.97	23.4	24.0	27.31
Fe	7.62	7.98	0.23	4.12	4.11	5.7	5.7	7.11
Ti			0.59	0.58	0.57	0.6	0.5	

Post Weld Stress Relief Heat Treatment Qualified for DTR Process is Same as for Laser Welded Sleeving

- Range of 1250°F to 1600°F for 5 minutes
- Target temperature of 1400°F

Comprehensive Accelerated Corrosion Testing Performed with Two Heats of Alloy 600 MA Tubing

- Heats known to have high susceptibility to SCC
- Five different types of DTR specimens
  - Pre-degraded tubes
  - EDM notched specimens
  - Thinned tubes
  - Pre-dented tubes (TSP simulation with packed crevice)
  - Base tubes
- Control specimens
  - Pre-degraded tubes without DTR for OD exposure tests
  - Roll transitions for ID exposure tests
- DTR specimens stress relieved by heat treatment

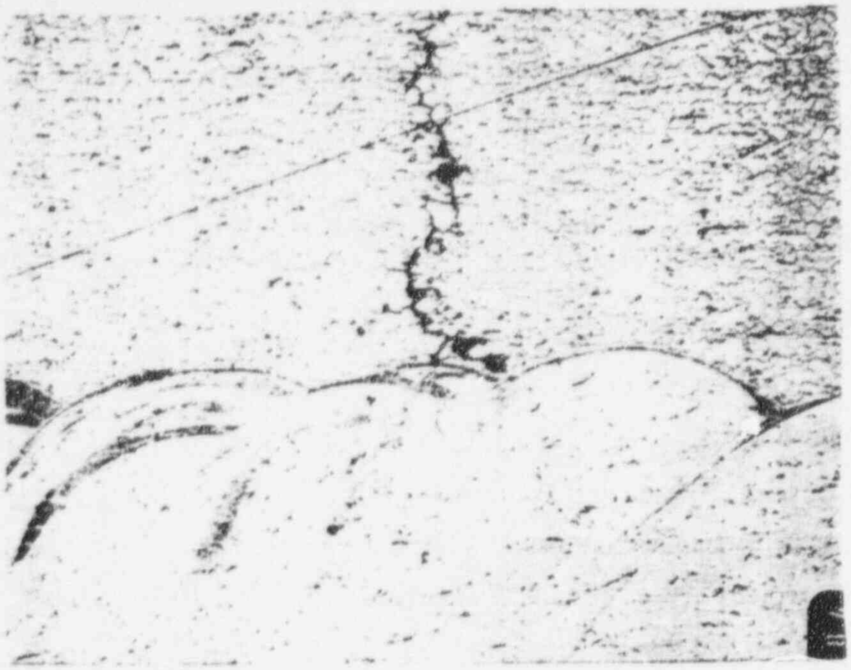
Accelerated Corrosion Testing was Performed with Both Doped Steam and Caustic Environments

- ID and OD doped steam tests at 750°F, 100 PPM concentration

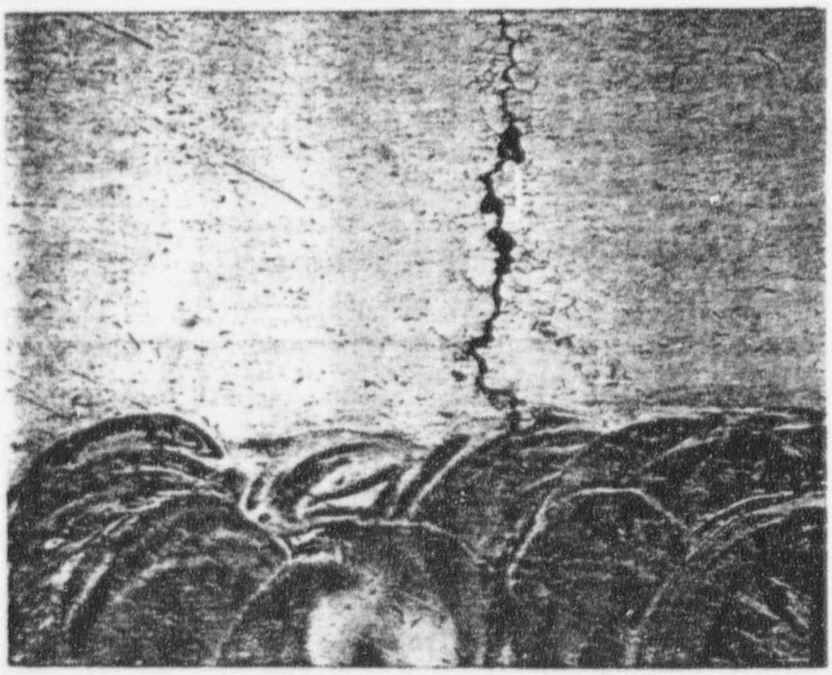
- OD caustic testing at 662°F, 10 percent NaOH solution

- Non-fixed DTR specimens (no axial stress)

- Fixed-fixed DTR specimens (thermally induced axial stress maintained during corrosion testing)



907 Hours in Caustic Tests Environment;
Specimen No. 530



923 Hours in Doped Steam Environment;
Specimen No. 507

OD Corrosion Crack Terminating at DTR Weld

Corrosion Test Results Support Life Expectation for DTR Process

- ID doped steam test data shows repair life 10 to 15 times that of roll transitions
- OD doped steam and caustic test data project even better performance
- DTR life estimated to be in excess of 20 years

Tensile Tests Showed That Properties of DTR Weld Metal Exceed ASME Code Allowables

	RT Yield Strength (ksi)	RT Ultimate Strength (ksi)	600 deg F Yield Strength (ksi)	600 deg F Ultimate Strength (ksi)
Base Tube Metal				
Ht. 7368	65.2	104.8	55.8	98.3
Ht. 8161	46.4	106.7	43.1	96.6
DTR Weld Metal				
Ht. 7368	56.4	105.3	47.7	86.8
Ht. 8161	52.0	100.9	44.3	83.6

ASME Code Requirement = 35 ksi Yield, 80 ksi Ultimate @ 600°F

Burst Properties of DTR Welded Tubing Are Approximately Equivalent To Those Of As-Received Tubing

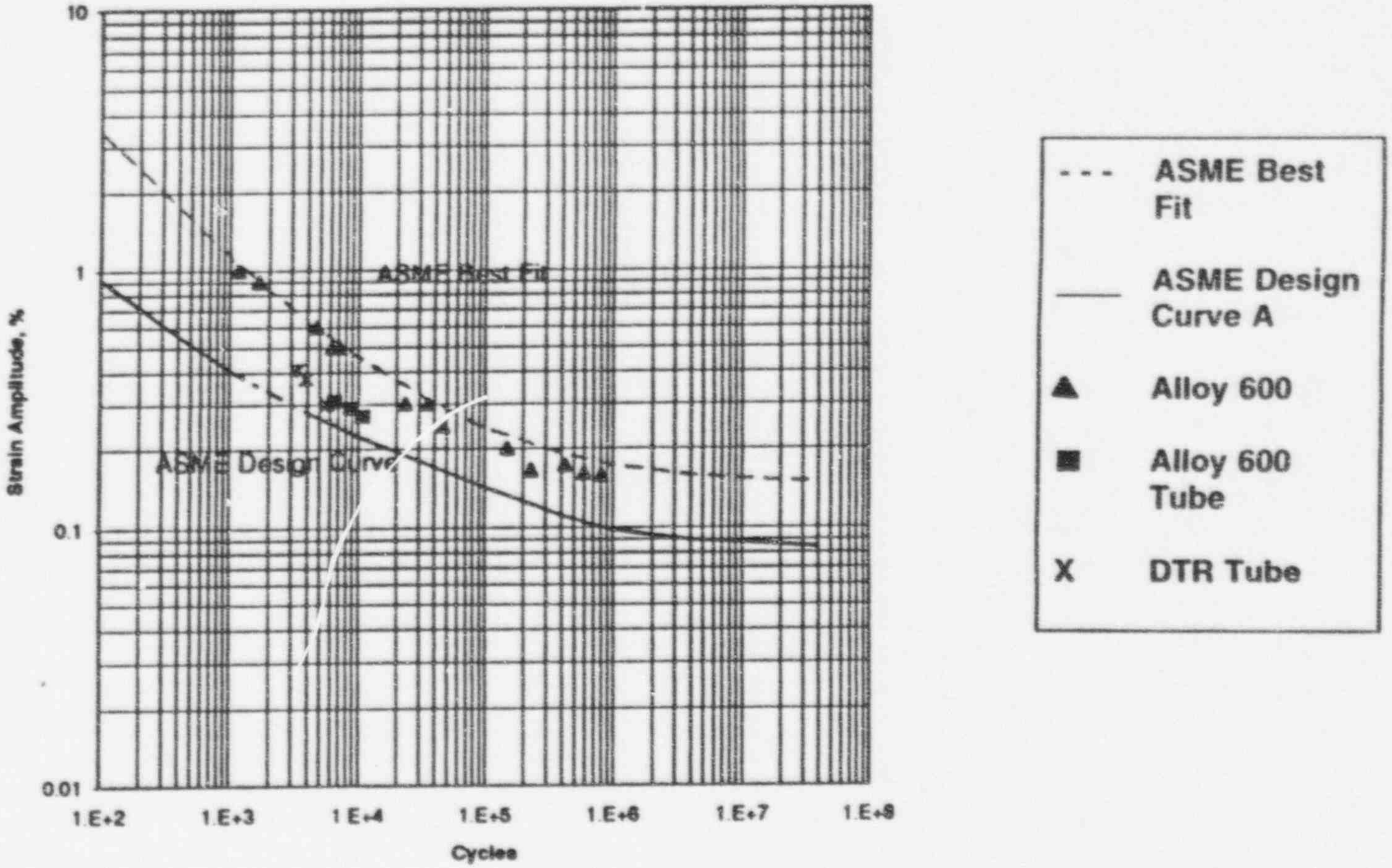
ROOM TEMPERATURE PROPERTIES

DTR Sample	Tubing Heat Number	OD (in.)	ID (in.)	Burst Pressure (ksi)	Tube Wall (in.)	Burst Stress (ksi)	Press. Rate (psi/s)
Base Tubes							
A129	7368	0.8742	0.7699	11.65	0.0522	91.7	N/A
A130	7368	0.8742	0.7699	11.72	0.0522	92.3	N/A
B131	8161	0.8764	0.7769	11.35	0.0498	94.2	N/A
B132	8161	0.8764	0.7700	11.42	0.0532	88.4	N/A
Freespan DTR Welds							
610	7368	0.8069	0.7370	10.00	0.0350	110.3	1400
611	7368	0.8065	0.7309	10.80	0.0378	109.8	1300
613	8161	0.8068	0.7420	8.81	0.0324	105.3	1300
615	8161	0.8074	0.7340	10.14	0.0367	106.5	1300
Clamped DTR Welds							
556	8161	0.8037	0.7620	11.35	0.0389	111.6	1200
557	8161	0.8025	0.7290	11.07	0.0367	115.5	1200
558	8161	0.8054	0.7260	11.51	0.0397	111.0	1200
560	8161	0.8052	0.7230	11.80	0.0411	109.7	1100

Filler Based DTR Fatigue Tests

- Low cycle fatigue tests
  - Alloy 600 MA and DTR tubes
  - Room temperature
  - Strain controlled, strain rate of 0.0001/sec
- High cycle fatigue tests
  - Cyclic rate of 20 Hz
  - Room temperature
  - Half sinusoidal cycle stress wave form (0 to max stress)
  - Runout for 10^6 cycles without failure

Low Cycle Fatigue Test Results



ASME BPVC Section XI Code Case Inquiry was Approved by Main Committee in 1996

- Reviewed by various Working Groups, Sub-Groups, and Sub-Committees in December
- Approved by Main Committee
- Confirmed by letter ballot with no negative votes

Supplementary Testing and Qualifications Planned for This Year

- Weld process testing with prototype wire feed weld head
- Accelerated doped steam PWSCC tests under approximately 100 percent preload locked tube conditions
- ASME Code weld process qualification
- EPRI Appendix H qualification of NDE process

DTR Structural Integrity Evaluation

W. K. Cullen

Westinghouse NSD

prepared by: A. L. Thurman

Westinghouse NSD

Introduction

- Provide analytical justification for DTR repaired tubes in 44 and 51 S/G's
  - Bounding set of generic load conditions
- Summary
  - Strength properties adjusted based on tests
  - Meets ASME Code requirements
    - Primary stresses
    - Primary + secondary stress intensity range
    - Fatigue

Assumed Degradation Profile

- Axial cracks for entire non-welded DTR region length
- Non-welded tube wall in DTR region assumed to have zero structural strength
- Pressure boundary at DTR region

Finite Element Model

- 2-D axisymmetric
- Symmetric about center of weld
- Degraded tube properties behind weld
  - Zero strength (wall thinning)
  - Zero hoop strength (axial cracks)
  - Results approximately the same for both cases

DTR Weld Metal Properties

- Alloy 690 mechanical and thermal properties
- Alloy 600 MA yield strength appropriate
- DTR ultimate strength reduced
  - Data points for 600F at low end of Alloy 600 distribution (but greater than Code minimum values)
  - Performed statistical analysis

DTR Weld Metal Properties (cont)

- S_m= lesser of 2/3 yield or 1/3 ultimate
- ASME design fatigue curve with allowable cycles reduced based on fatigue test results
- Maximum stress concentration factors applied based on geometry

ASME Code evaluation

- Primary stress evaluations

Condition	Calculated/Allowable
Design	0.66
Faulted	0.53
Upset	0.65
Test	0.90

ASME Code evaluation (cont.)

- Maximum range of primary plus secondary stress intensity = 0.59 of allowable
- Maximum fatigue usage = 0.72

Minimum wall thickness

- ASME Code pressure stress equation
- TPS proximity, unwelded tube material neglected
- Limiting t_{min} determined from Normal conditions
  - P_i=2250, P_o=720; ΔP=1530 psi
  - $P_m < S_u/3$; t_{min}=0.0267 in.
- Upset and accident conditions resulted in lower calculated minimum thickness

Summary

- ASME Code limits are satisfied
- Minimum required wall thickness for plugging limit determination = 0.0267 in.
  - Conservative based on in-situ conditions
- DTR weld structurally acceptable

Direct Tube Repair
Non-Destructive Evaluation

Presentation to the NRC

5 February 1997

Westinghouse Electric Corporation
Nuclear Services Division

Outline

- Program Objectives
- Current Work
- Eddy Current Techniques
- Qualification Program
- Proposed Eddy Current Technique
- Summary

Program Objectives

- Pre-Service Process Acceptance
  - Verify Location and Extent of Repair
  - Detect Unacceptable Process Anomalies
  - Verify Presence of Heat Treatment
  - Verify Sound Wall Thickness
- In-Service Inspection
  - Detection of Unacceptable Crack Penetration
    - Growth of Remnant Crack
    - Presence of New Repairable Indications

Program Objectives (cont.)

- Present Section XI Requirements for S/G Tubes
  - Volumetric Examination with UT or ECT (IWB-2500)
  - Re-Examinations Same As Original
  - ECT Method Capable of Finding 20% Thru Wall Indication (Section V, Article 8, Appendix II)
  - Acceptance Criteria:
    - 40% Thru Wall OD Flaw (IWB-3521), or
    - Analysis of Other Flaw Types/Sizes (IWB-3630)

Program Objectives (cont.)

- Code Case Requirements
  - UT
    - Minimum Total Thickness, ±10%
    - Minimum Deposit Axial Length
    - Lack of Fusion (≥ 0.125 inch in width or length)
    - Volumetric Examination of LBW Deposit Per Modified NB-2552 (Reference notches 20% thru wall)

Program Objectives (cont.)

- Code Case Requirements (cont.)
  - ECT
    - Amended IWB-3521: OD Indications in the LBW Deposit of ≤ 20% of Original Tube Wall Are Acceptable (Reference notches in deposit used as a comparitor)
    - Alternate Acceptance Per IWB-3132 May Be Established
    - Detection of Existing Parent Tube Defect or Support Plate to Verify Location of LBW Deposit
    - Qualification of Technique Shall Include Flawed Samples

Current Work

- UT of Clad Tubes Demonstrated Capability to Find:
  - Lack of Fusion < 0.125 inch in Diameter
  - Thickness Within 10%
  - Axial 0.010 inch Deep Notch, ID and OD
  - Circumferential 0.010 inch Deep Notch, ID and OD
  - Location of Original Flaw in LBW Deposit
- ECT of Clad Tubes Demonstrated Capability to Find:
  - Location of Original Flaw or Structure (Lower frequencies)
  - Acceptance of Repair Possible By Adjusting Frequency Such That Rejectable Conditions (i.e. Insufficient LBW Deposit Thickness) Are Detectable
  - Flaw (0.029 Inch Deep From OD - 18% Penetration Into Repair) Within 0.050 inch LBW Deposit Detectable

Eddy Current Techniques

- Different Eddy Current Methods for Different Applications
  - Bobbin for H/T Presence, Detection of Some Anomalies and Repair Location and Extent
  - Rotating Coil for Verification of Adequate Repair Penetration and Unacceptable Anomalies
  - Cecco-5 for Verification of Adequate Repair Penetration and Unacceptable Anomalies

Qualification Program

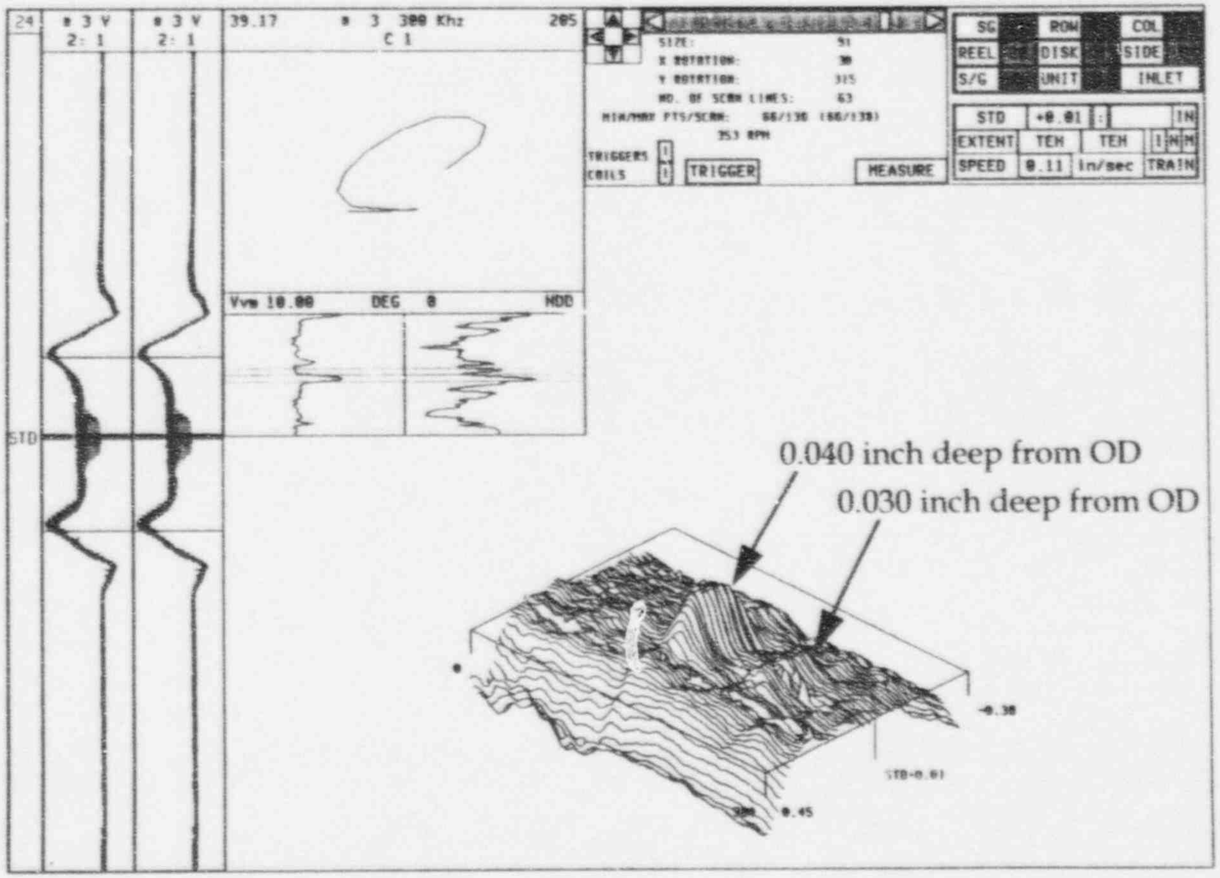
- Designed in Accordance with EPRI ISI Guideline, Appendix H
  - Assure Detection of Unacceptable Condition
  - Statistical Basis - 80% POD at 90% Confidence
  - Depth Sizing - 25% RMSE
- Process Verification Qualification
- Sample Design
  - Process Samples
  - Degraded Samples
  - Simulations

Proposed Eddy Current Technique

- Based Upon Structural Requirements
- Challenges
  - Surface Condition Makes Depth Sizing Difficult
  - NDE Error/Repeatability
  - Acceptable But Detectable Remnant Indications
- Ease of Interpretation
  - 'Go/No-Go' Test for Most Repairs Based Upon Frequency Gating
  - Amplitude Based Acceptance of Remnant Indications

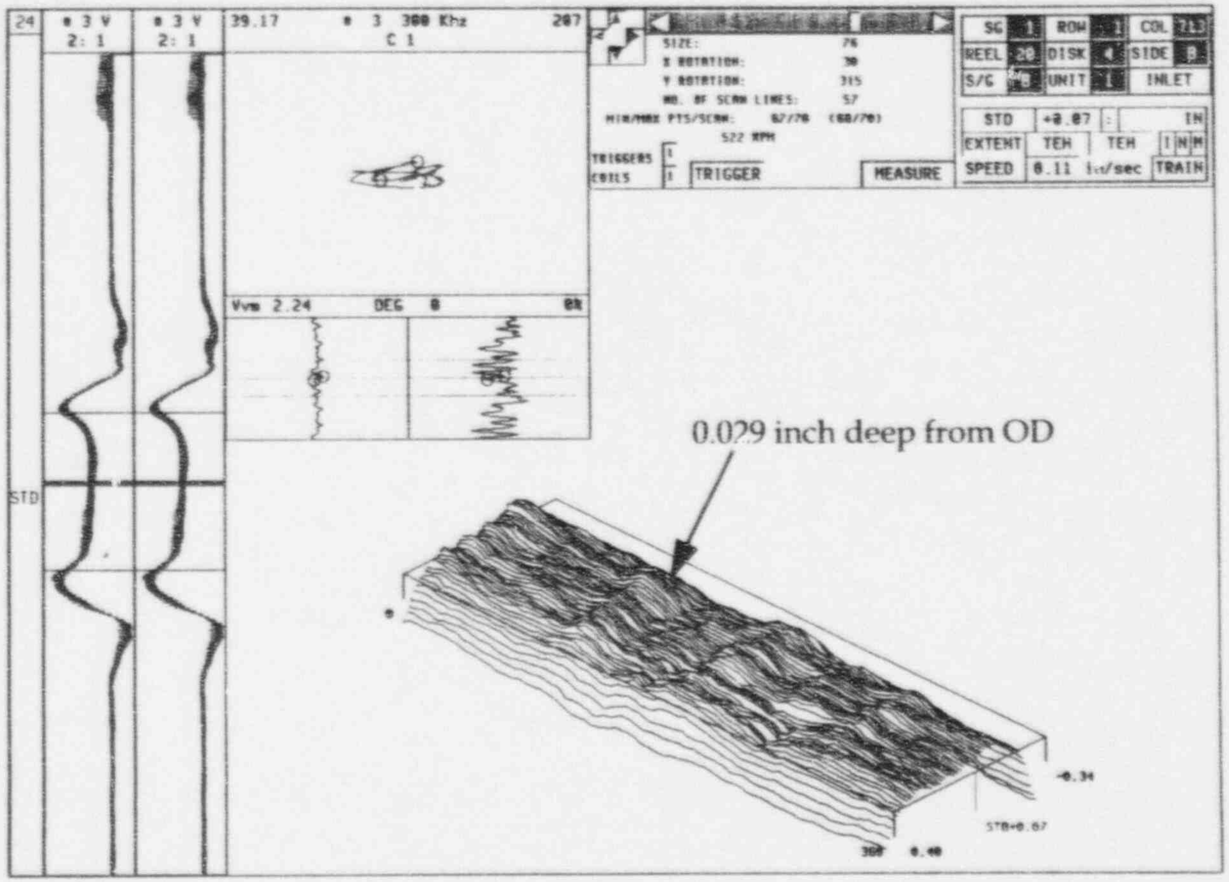
Proposed Eddy Current Technique (cont.)

- EDM Sample



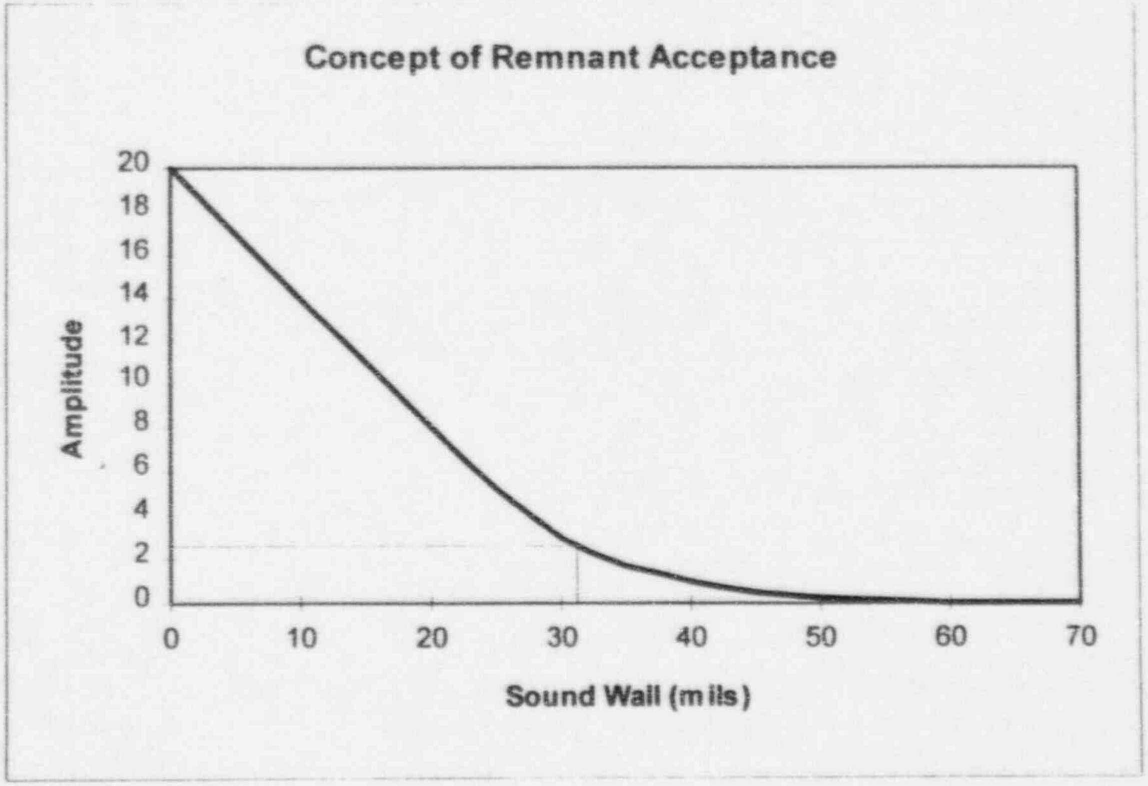
Proposed Eddy Current Technique (cont.)

- Crack Sample 713



Proposed Eddy Current Technique (cont.)

- Concept of Amplitude Based Acceptance



Summary

- DTR Inspectability by UT and Eddy Current is Feasible
- Depth Sizing of Remnant Flaws Difficult
- Possible to Use Threshold of Detection to Determine Acceptability
- Qualification of Eddy Current Technique - Will Meet EPRI Appendix H Criteria for Detection
- Detectable Remnants May Be Left In Service - Criteria Must Be Established and Verified

Schedule

March 1997 - Technical specification amendment submittal to NRC

June 1997 - Eddy current qualification report submittal to NRC

June 1997 - Corrosion Qualification Report-PWSCC submittal to NRC

March 1998 - Implement in Farley Unit 2 outage

October 1998 - Implement in Farley Unit 1 outage