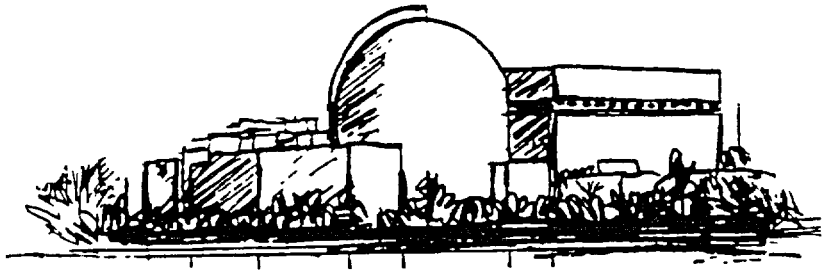
Seabrook Steam Generator Tube Assessment Project

November 14, 2002

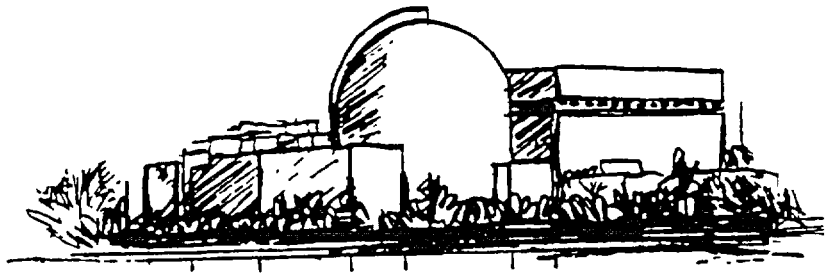
FPL Energy Seabrook



Enclosure 2

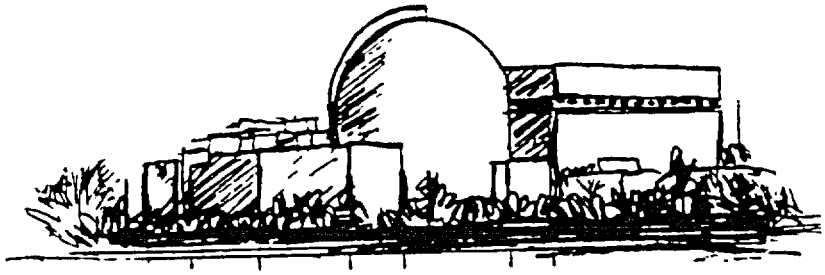
Meeting Objectives

- Present Root Cause Evaluation Results for Axial Indications Identified in May, 2002 Inspection
- Address NRC Staff Questions
- Reach Agreement on Extent of Condition



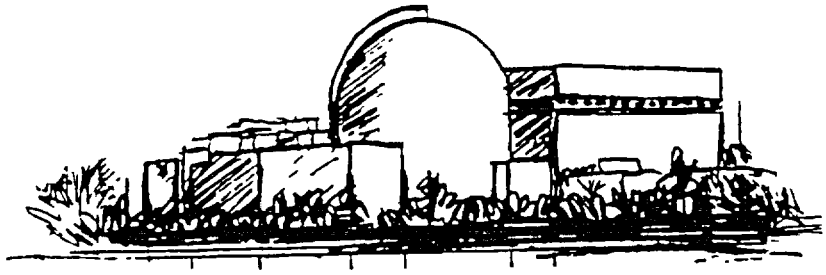
Regulatory/Industry Reporting

- Results Discussed With NRC In August 2002, and October 2002
- I&E Notice Issued By NRC
- INPO Event Report Issued
- Informed Plants With Fall 2002 Inspections Of Residual Stress Signal Characteristic
- Today's Public Meeting With NRC



Investigation Process Summary

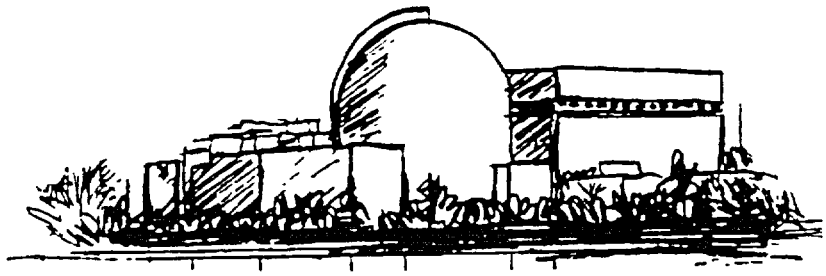
- Removed Two Degraded Tubes For Lab Testing
- Convened A Team Of Experts for Root Cause
- Identified The Root Cause
  - *High Residual Stress Caused By Manufacturing Process In A Small Subset Of Tubes*
- Identified Extent Of Condition At Seabrook
- Degradation Mechanism Is Not A New Generic Issue In Thermally Treated Tubing and is not an Active Damage Mechanism at Seabrook.



Seabrook Steam Generators

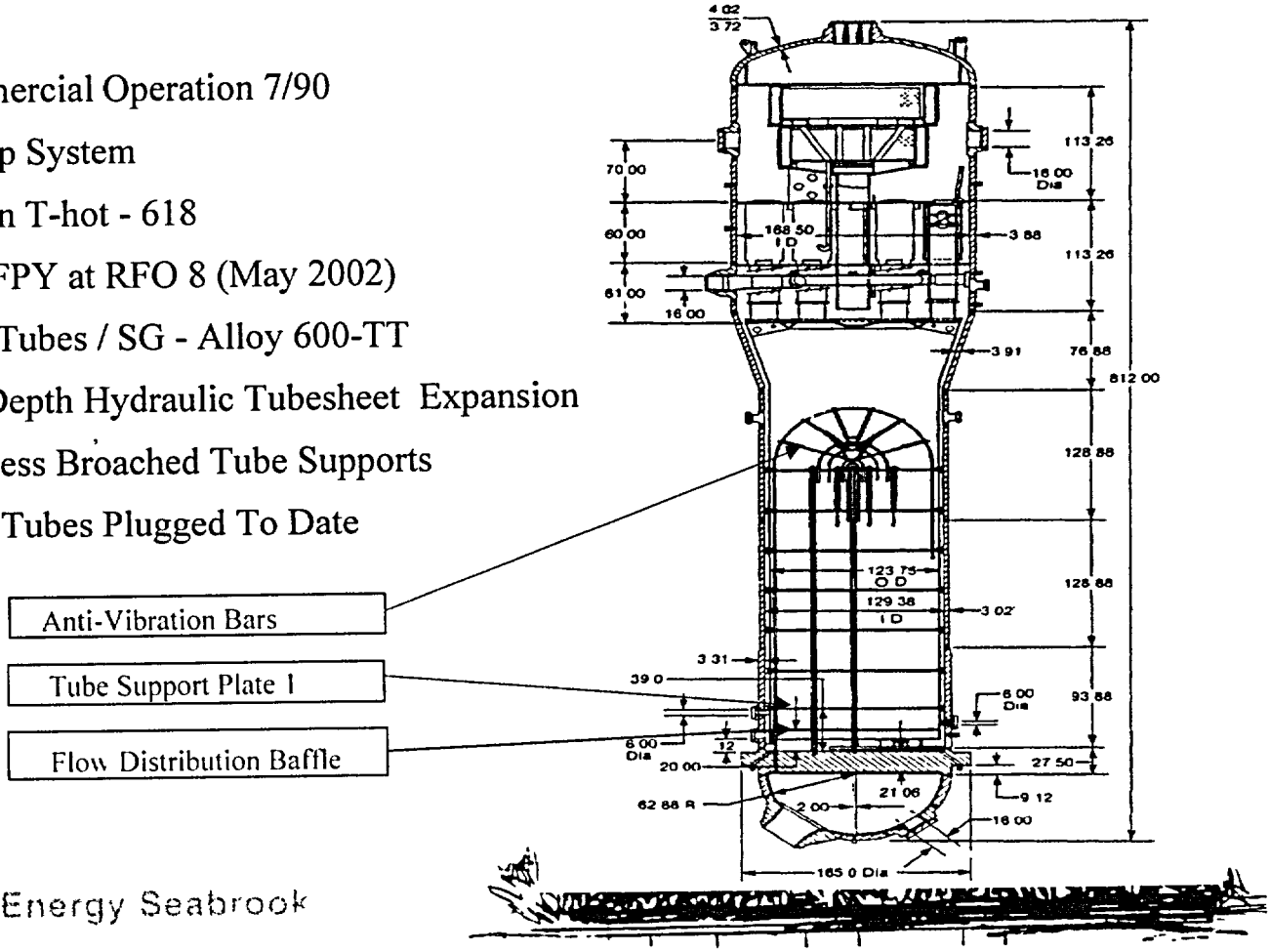
- Model F
  - Thermally Treated Alloy 600 Tubing
- Recognized Industry Leader
  - Primary/Secondary Side Chemistry
  - Life Cycle Management Strategies

- Design Margin Strategies
  - 8% tube plugging vs. 0.5% plugged



Seabrook Model F Steam Generator

- Commercial Operation 7/90
- 4 Loop System
- Design T-hot - 618
- 9.7 EFPY at RFO 8 (May 2002)
- 5626 Tubes / SG - Alloy 600-TT
- Full Depth Hydraulic Tubesheet Expansion
- Stainless Broached Tube Supports
- 0.5% Tubes Plugged To Date



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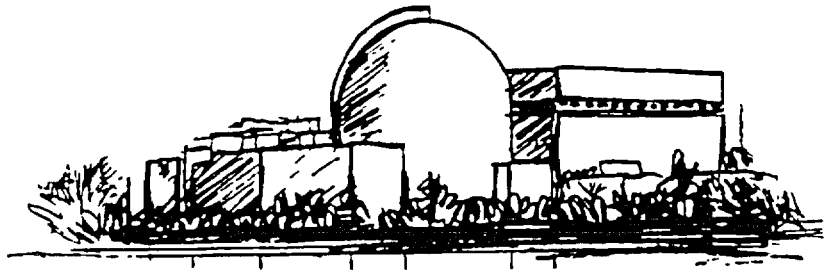
Manufacturing Process Timeframe

- Seabrook Tubes Manufactured between April 1980 and June 1980
- Seabrook Tubes Manufactured From 376 Heats
- Each Heat Contains Between 3,000 and 5,000 Tubes
- Eight Other Plants Had Tubes Manufactured In Same Timeframe

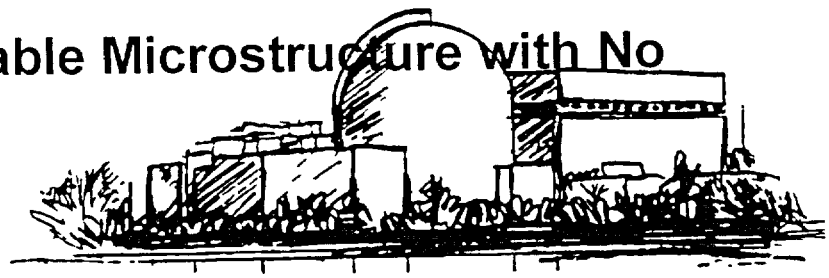


Key Elements Of Manufacturing Process

- Tube Manufactured To Specification (0.69" OD x .040" wall)

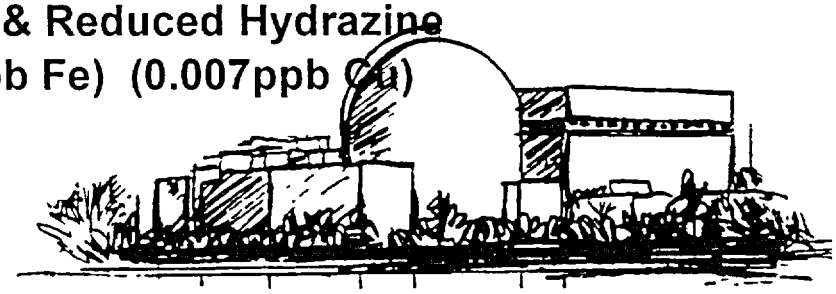
■ Final Mill Anneal	1950 F for 3 min
■ Straightening and Polishing	
■ Thermal Treatment	1320 F for 10 hrs
■ U-Bending	All Rows
■ Stress Relief	1320 F for 2 hrs (rows 1-10)

- Desired Result – Favorable Microstructure with No Residual Stress



Steam Generator Program Meets NEI 97-06

- **Primary Side Inspections**
  - Starting In RFO 5- Inspect 100% Of Two Steam Generators At Each RFO
    - "D" Generator Last Inspected RFO 6 May, 1999
- **Secondary Side Work**
  - Sludge Lance / FOSAR at Each RFO
  - Extensive Hydraulic Cleaning
    - UBIB, UBHB, CECIL, Pressure Pulse
- **Progressive Chemistry Program**
  - Elevated pH, ETA, MPA & Reduced Hydrazine
  - Final Feedwater (1.4ppb Fe) (0.007ppb Cu)



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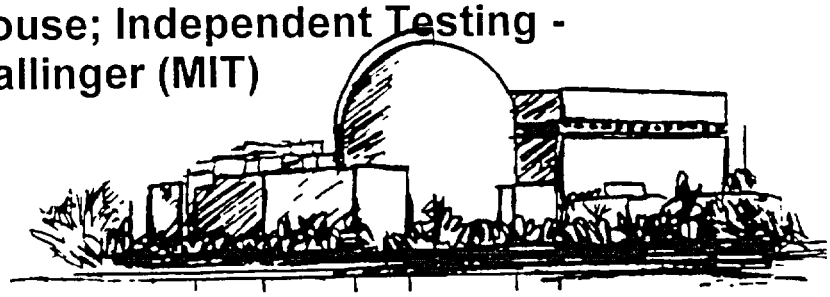
OR08 Inspection Results

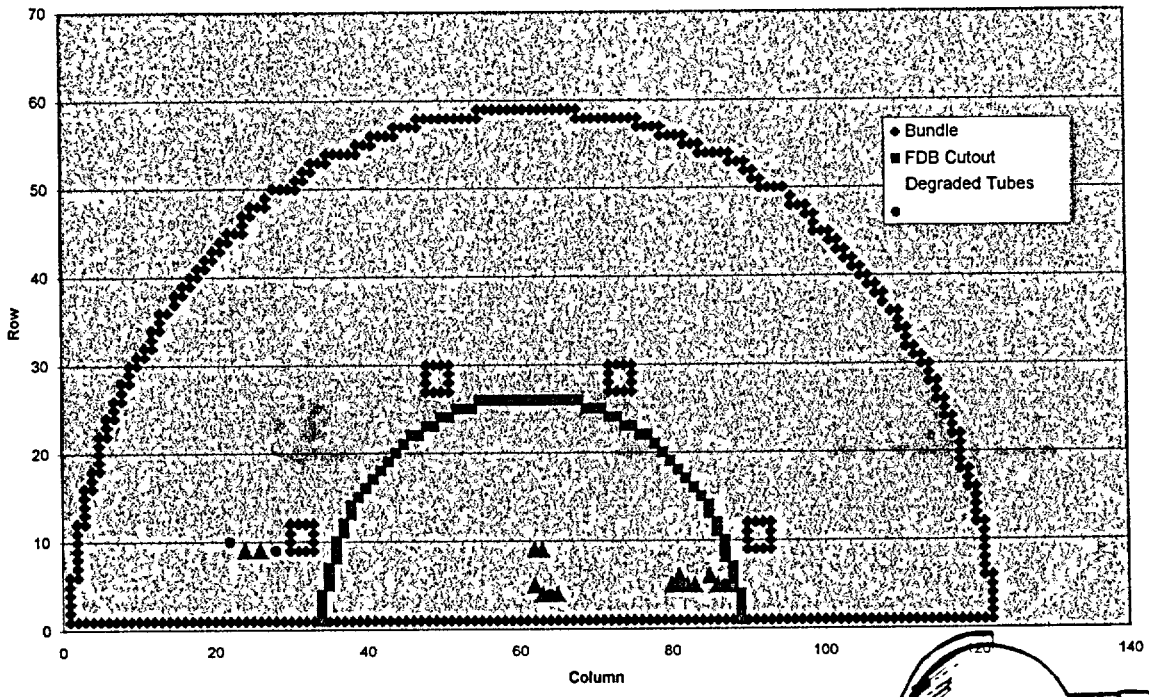
- **A Generator-** 100 % E/C Inspection
  - \ AVB wear-normal mechanism in model F

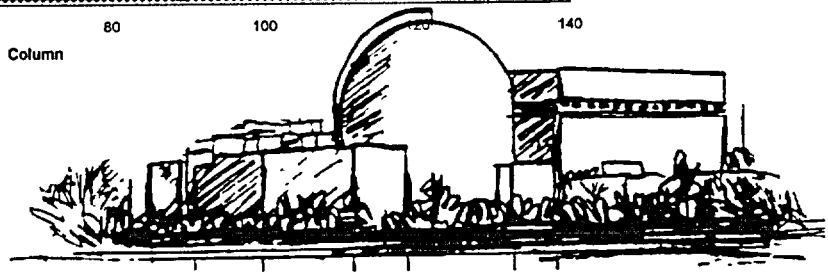
- **D Generator-** 100% E/C Inspection
  - \ 15 tubes with 42 indications - all at TSPs intersections
  - \ All indications confined to first ten rows
  - \ Indicative Of OD Stress Corrosion Cracking
  - \ Confirmed by Plus Point & Ultrasonics
  - \ Two Tubes Removed - Fourteen Segments Available

- **Root Cause Team Formed**
  - Lead Test Lab- Westinghouse; Independent Testing - Altran + Professor Ron Ballinger (MIT)



Location of Degraded Tubes





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Pulled Tube Testing Summary

- Two Pulled Tubes Available For Testing (both from Heat 1374)
- Lab test confirmed field E/C data - Tubes have Micro Cracks
- Burst Test confirmed tube structural capability (i.e. Large Safety Margin)
  - Most Deeply Flawed Segment Tested To 7,000 psi- No leakage
  - Non Flawed Segments Burst Tested To 13,000 psi
- Tube Chemical and Mechanical Properties Consistent w/ spec
- Fractography Confirms Cracking Mechanism Is Stress Corrosion

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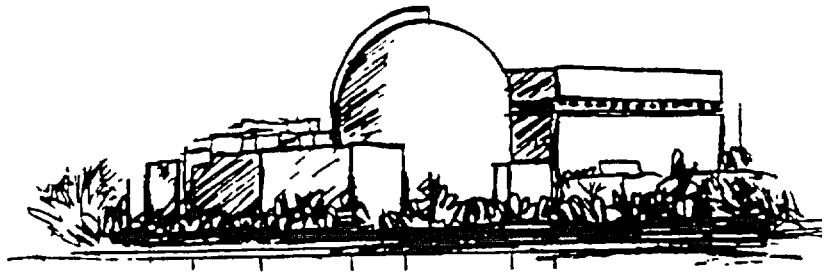
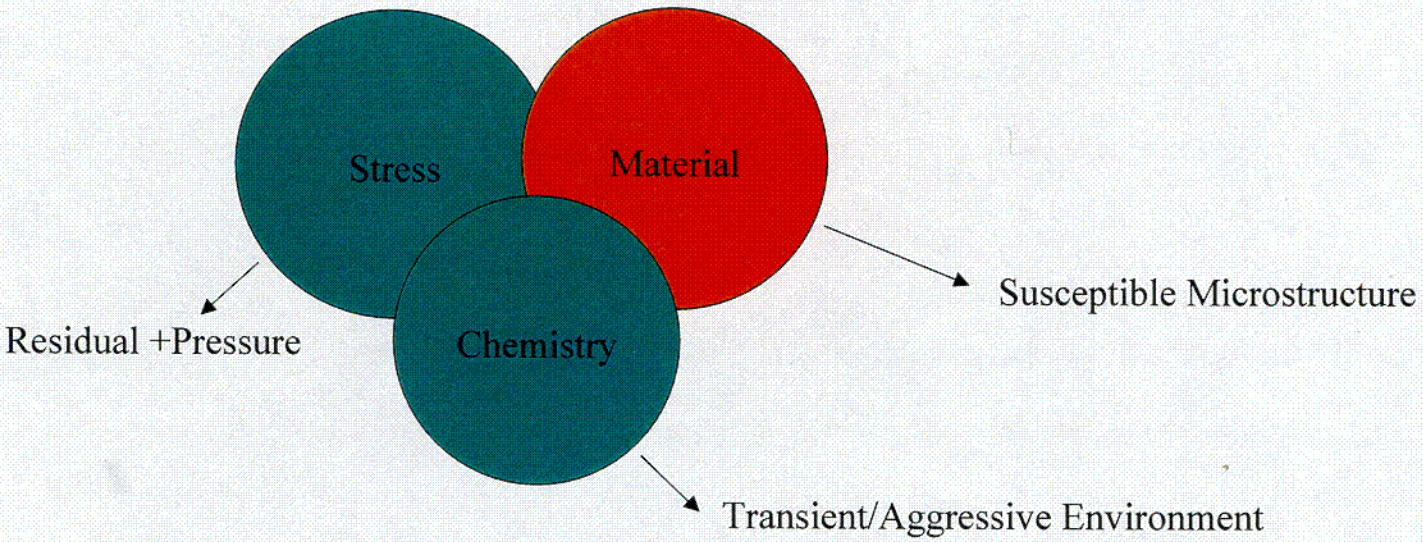


Stress Corrosion Cracking



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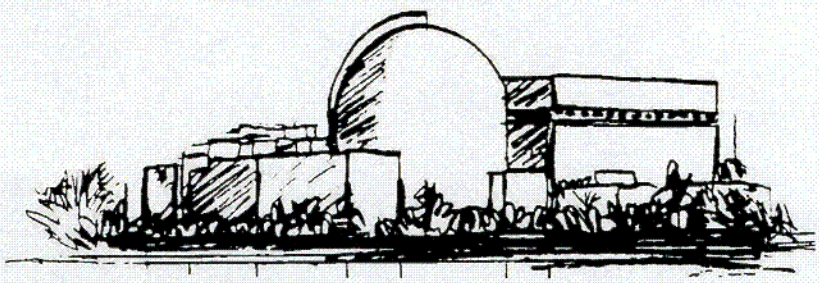

C 01

Material Susceptibility

- Material Is Not Sensitized As Defined By Industry Standards
- 13 of15 Tubes Are From Heat 1374 (.048% C)
- Two Tubes From Lower Carbon Heats (.032%C) - Heats 1456 & 1457
- Pulled Tube Micro Structure not typical of Optimum Thermally Treated Tubes
  - Grain Structure
  - Carbide Distribution
- In-Service Performance Of This Microstructure Has Been Excellent

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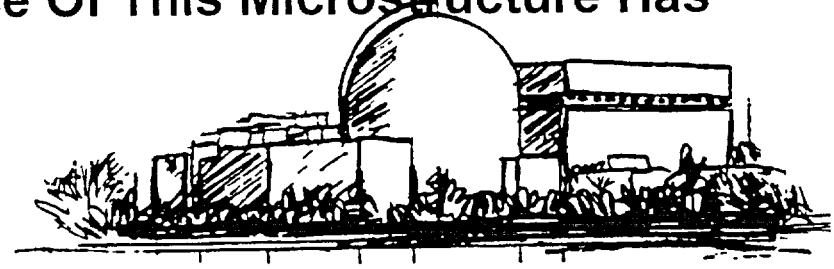
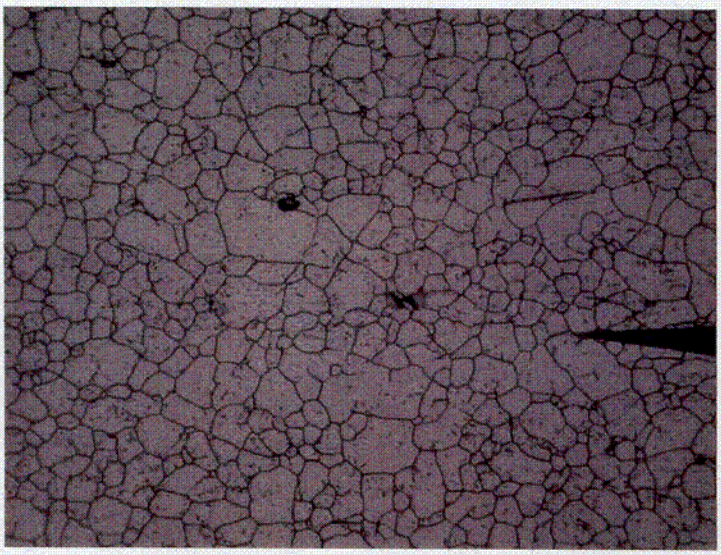
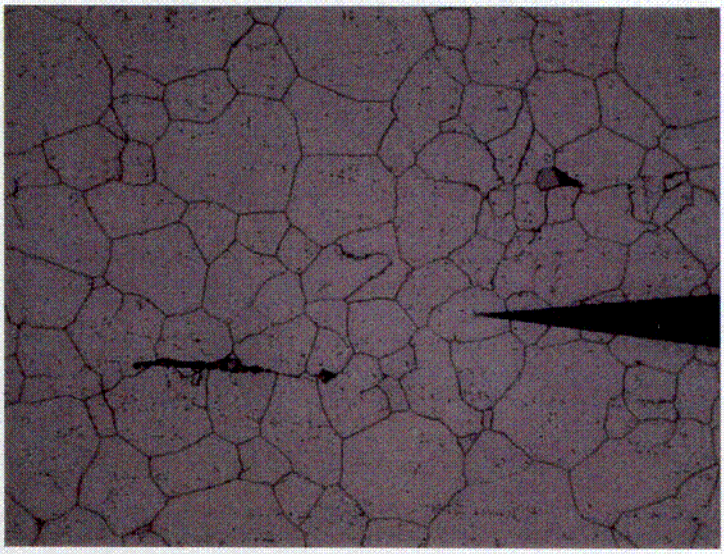


Pulled Tube Heat 1374
Grain Boundary Etch

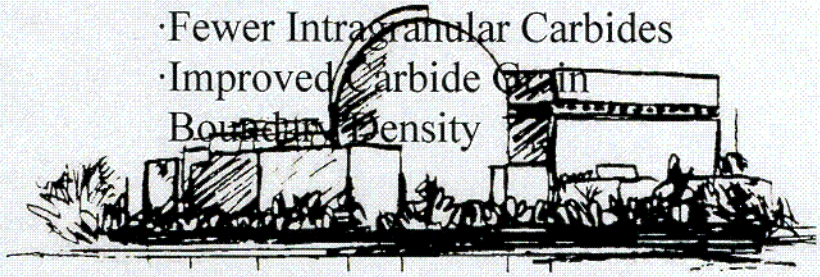


·ASTM Grain Size 10-12
·Intragranular Carbides
·Low Carbide Density On The Grain Boundaries

Archive Heat 1457
Grain Boundary Etch



·ASTM Grain Size 5-7
·Fewer Intragranular Carbides
·Improved Carbide Grain Boundary Density



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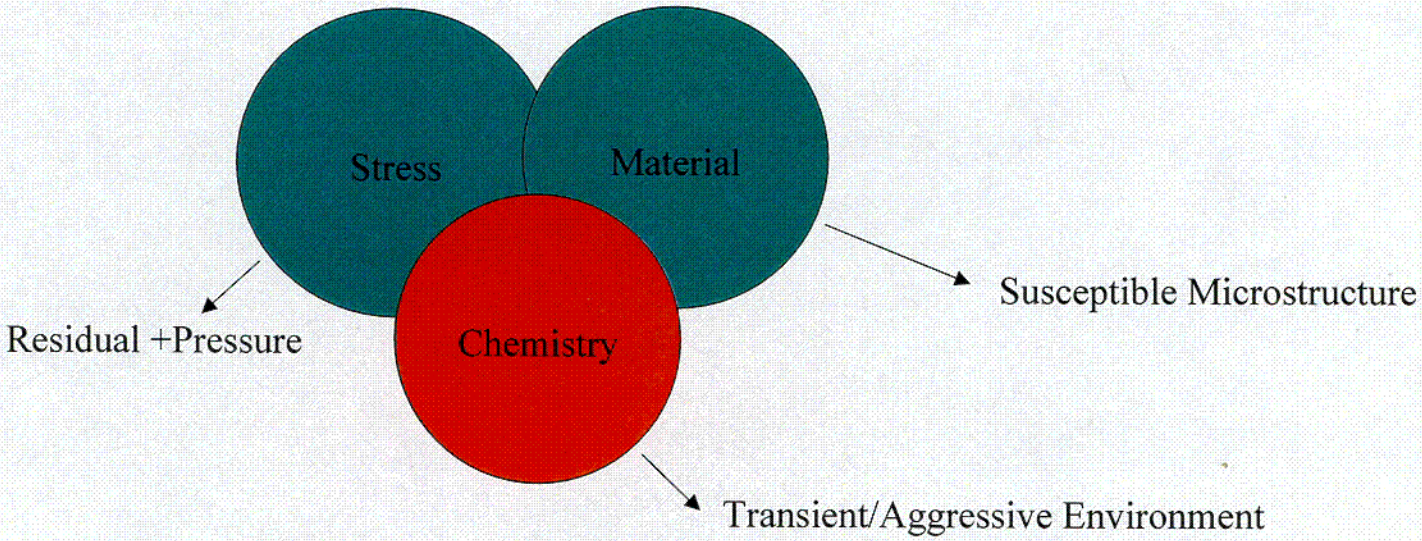
C02

Stress Corrosion Cracking



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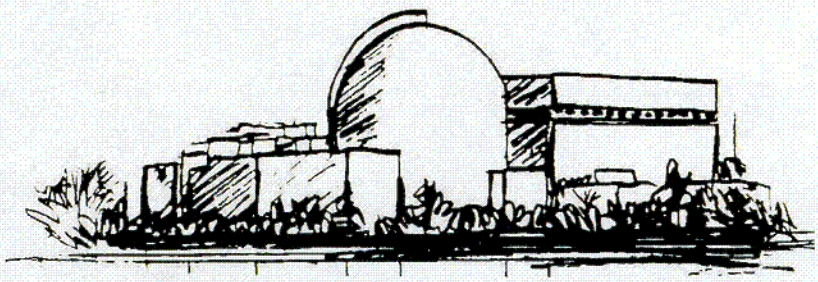
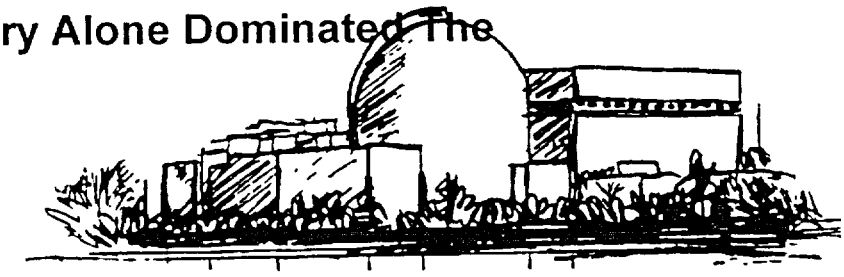


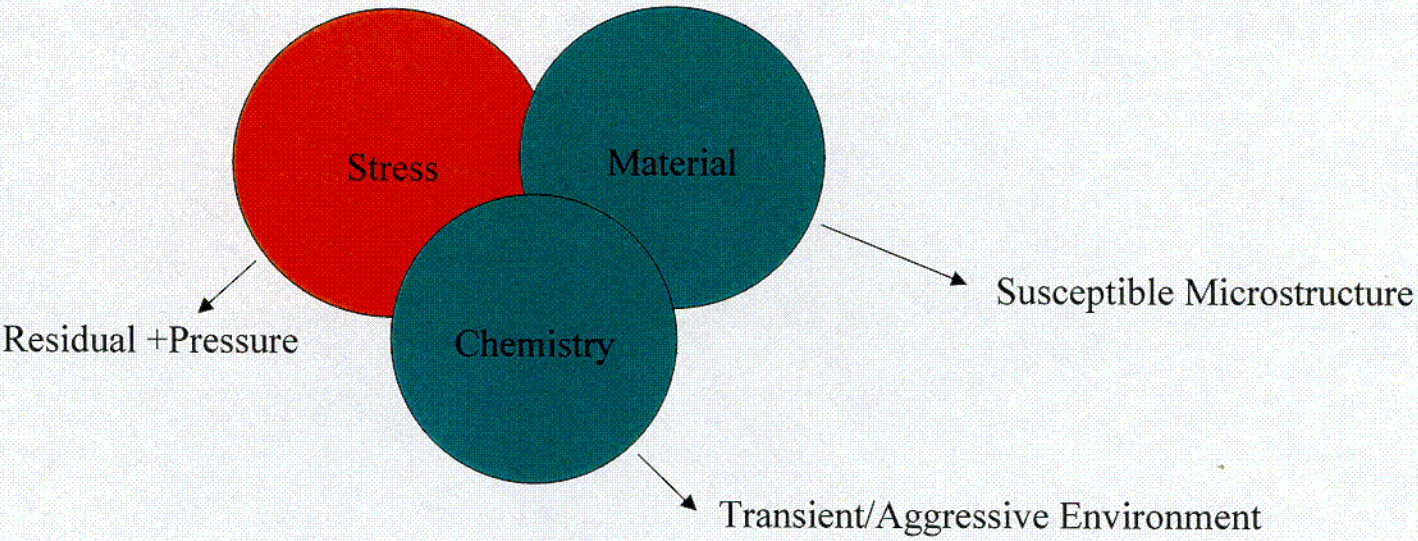
C03

Deposit Chemistry

- Surface Deposits From TSP Land Areas and Crack Tip Constituents Were Analyzed
- Deposits Contained Expected Constituents -
  - Very Low Concentrations Of Copper Oxide and Lead Were Present In A Limited Number Of Samples
  - Tight Crevice Between TSP Land and Tube Will Concentrate Contaminants
- No Evidence That Chemistry Alone Dominated The Cracking Process



Stress Corrosion Cracking



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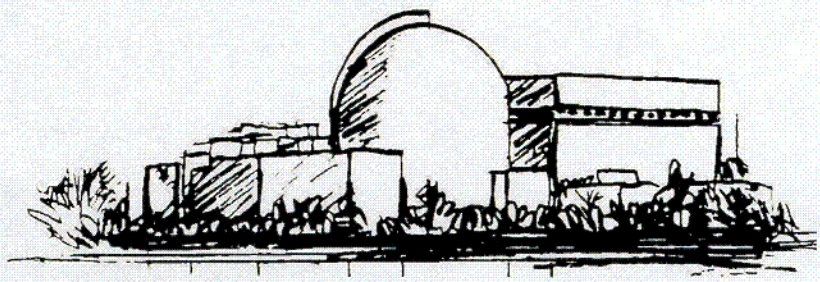
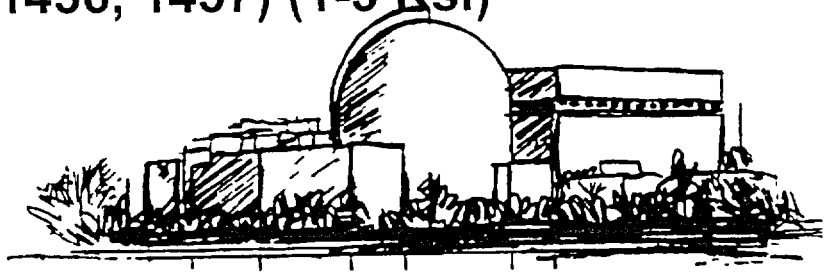


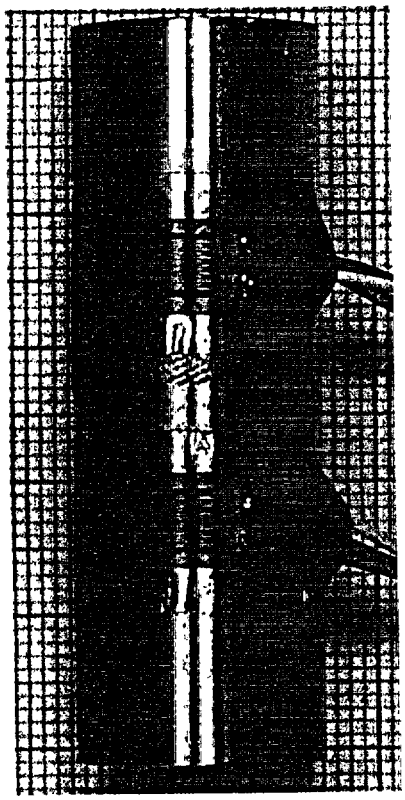
C04

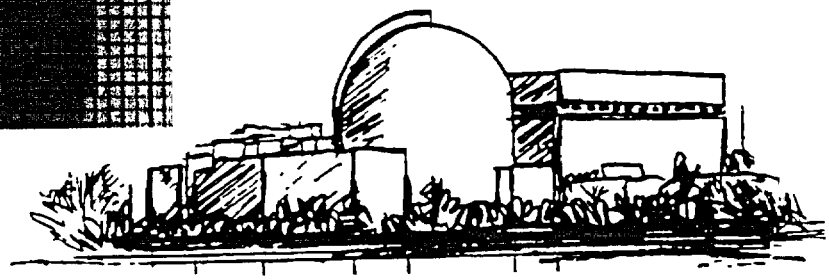
Operating and Residual Stress

- Operating Stress - 10 Ksi (Pressure+Thermal)
- Both Pulled Tubes Have An Unexpectedly High Measured Residual Hoop Stress (16-26 Ksi vs 2 Ksi)
- OD Surface Residual Is Up To 2 times Higher
- Low Residual Stress In Archived Tubes From The Affected Heats (1374, 1456, 1457) (1-3 Ksi)



Residual Stress Split Ring Test Specimen





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Residual Hoop Stress Results

Sample	Description	Residual Hoop Strain (με)		Calculated Residual Hoop Stress (psi)		Average Residual Stress (psi)
		Gage 1	Gage 2	Gage 1	Gage 2	
Heat 1638	MA		-240		7,464	7,464
Heat 1638	MA	-378	-218	11,756	6,780	9,268
Heat 96845	MA	-358	-167	11,134	5,194	8,164
Heat 96845	TT	-56	-121	1,742	3,763	2,752
Pulled Tube R9C63	AR	-926	-762	28,799	23,698	26,248
PulledTube TR9C63	AR	-610	-496	18,971	15,426	17,198

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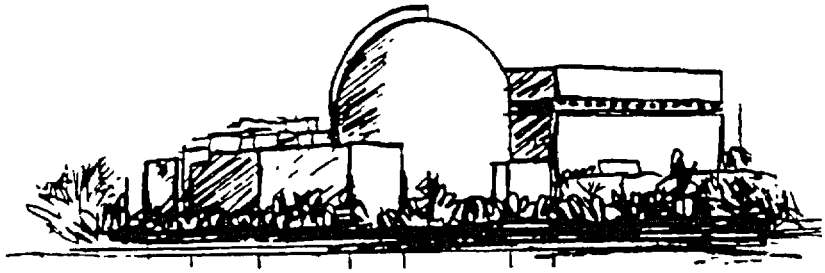
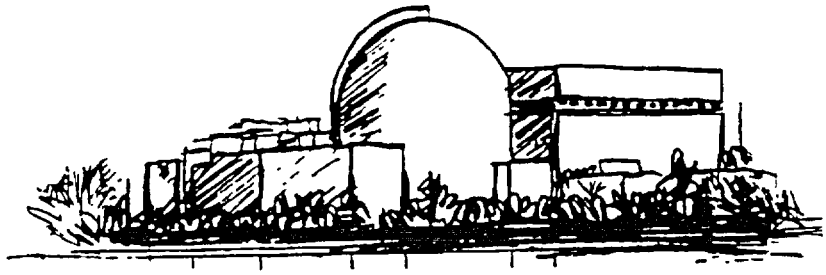


Major Contributor to Cracking

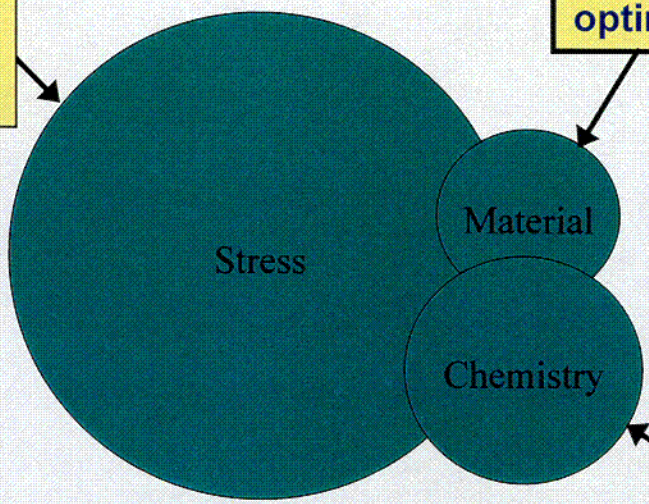
- **Residual Hoop Stress**
  - Need > 40ksi To Initiate Cracking In TT Material
  - High Residual + Operating Stress Exceeds 40 ksi on Tube Surface
  - Potential Sources
    - Cold Work After Final TT
    - Improper Heat Treatment Including Stress Relief



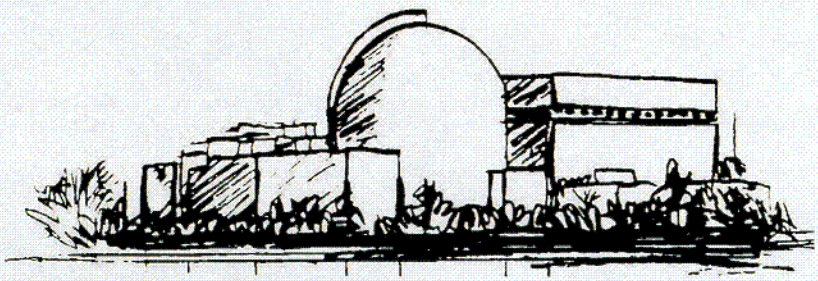
Root Cause

Operating +Residual Stress Exceeds 40 Ksi On Tube Surface

Microstructure not optimum, but acceptable

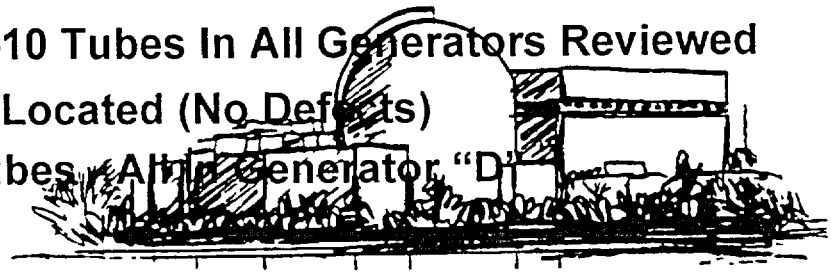


Chemistry Concentrated at TSP lands but not unusual

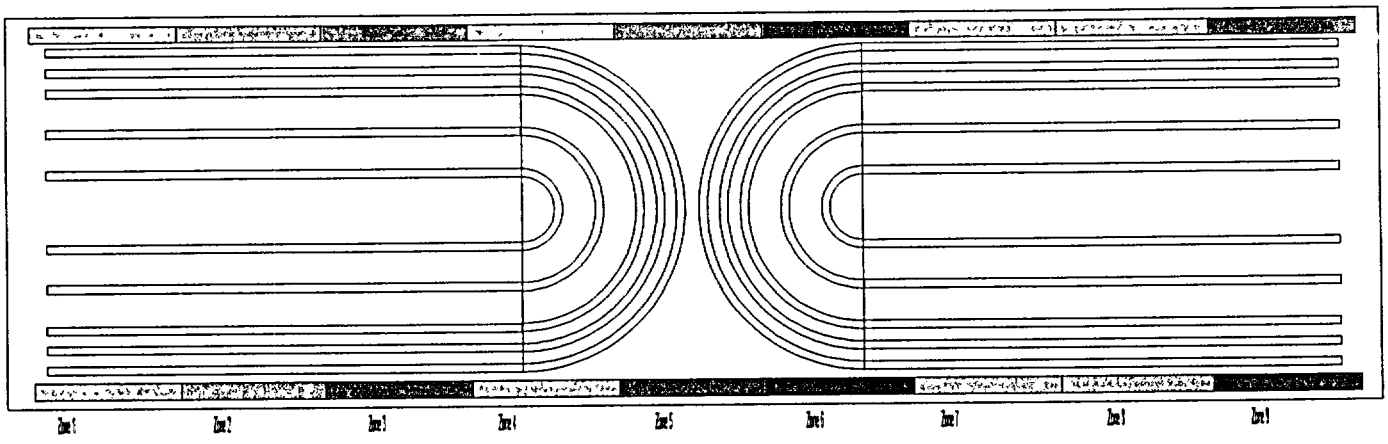


Assessment Of Extent Of Condition

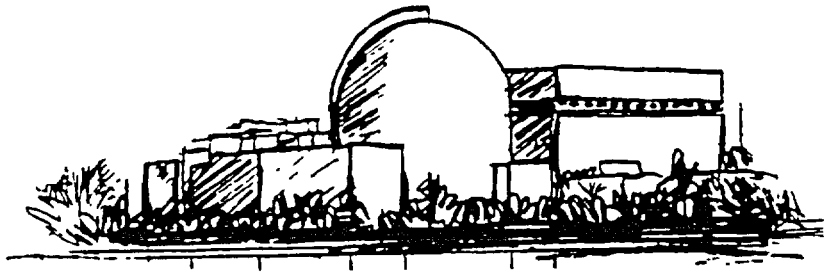
- Established EPRI Eddy Current To Stress Correlation Technique Used To Characterize Residual Stress In Rows 1-10
  - Eddy Current Measures Change In Conductivity Induced By Cold Work In The Material
  - Process Is Well Established For Rows 1-10
  - Distintinctive Eddy Current Offset Signal Exists In All 15 Degraded Tubes
  - ECT Data for All Row 1-10 Tubes In All Generators Reviewed
    - 6 Additional Tubes Located (No Defects)
    - 21 Total Affected Tubes In Steam Generator "D"



U-bend Stress Relief Furnace Loading



Zones 1 through 9 are heating zones in the furnace. Only zones 4, 5 and 6 were activated for stress relief of the u-bends.



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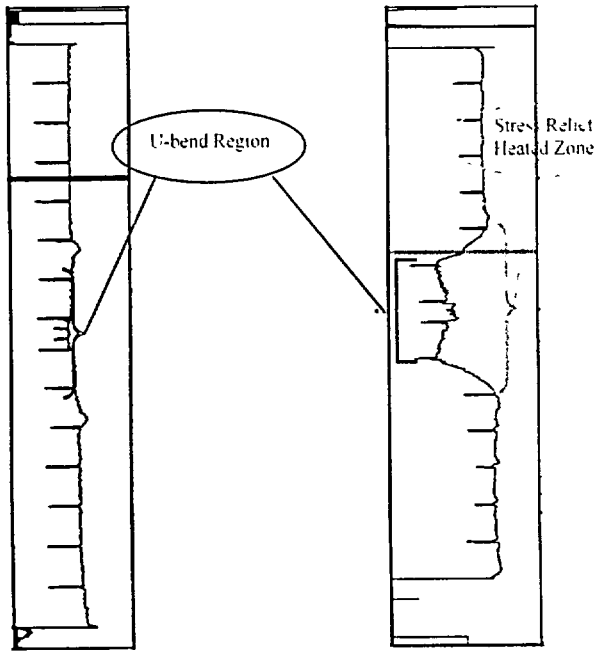
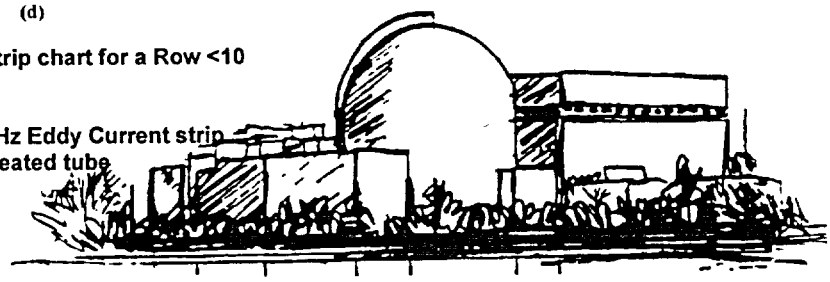
Row 1-10 150 Hz Eddy Current Signal Traces



(a) (d)

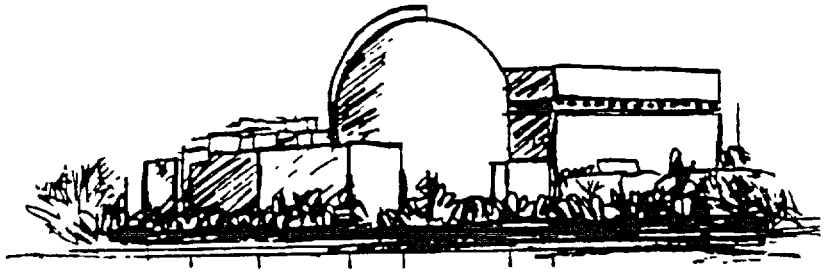
(a) Normal 150 kHz Eddy Current strip chart for a Row <10 thermally treated tube

(b) Seabrook degraded tube, 150 kHz Eddy Current strip chart for a Row <10 thermally treated tube

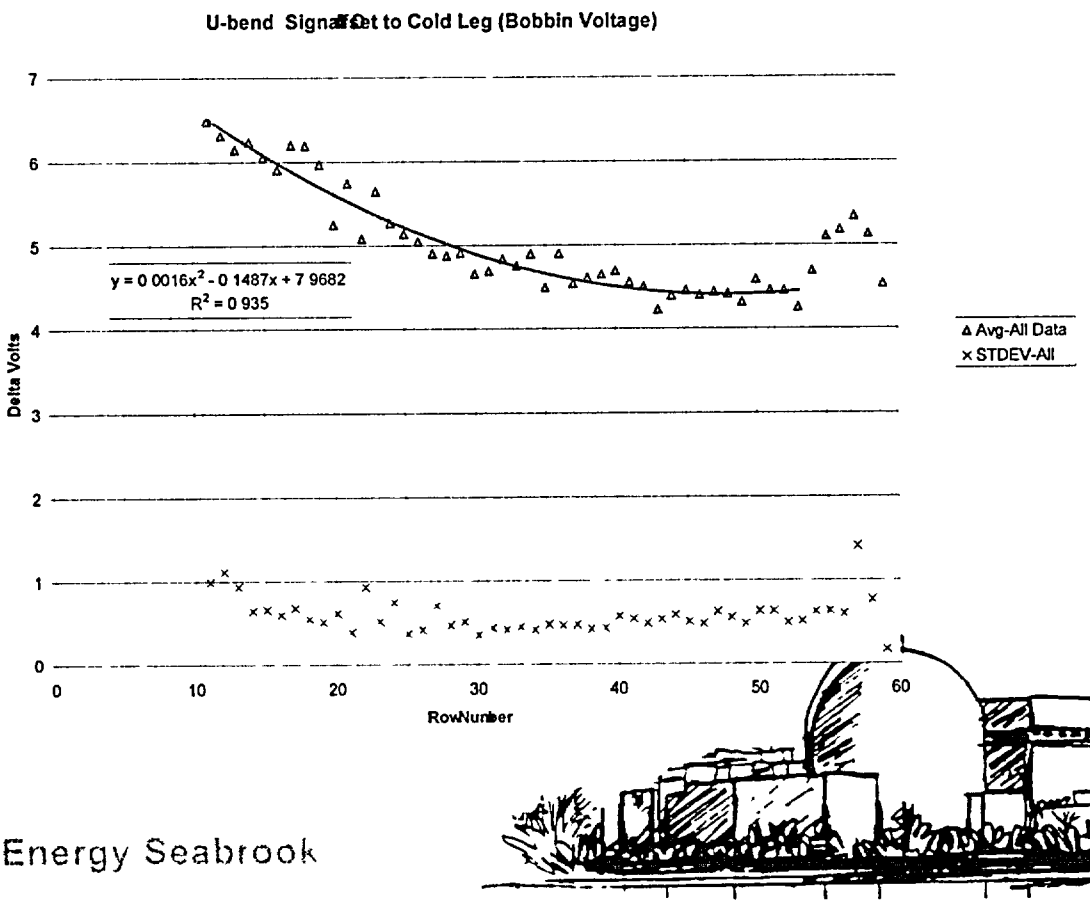


Extent Of Condition In Rows 11- 59

- Applying The Process To Rows > 10 Is Similar
  - Eddy Current Offset Values Provide Excellent Correlation With Bend Radius
  - Tubes With High Residual Stress In The Straight Length Would Be Apparent
  - There Are No Outliers – No Signal Reversals
  - Correlation Between Degraded Tubes And Offset Signal Is 100% In Rows < 10
- Absence Of Observed Corrosion In Outer Rows Indicates That No Tubes Are Susceptible



U-bend Bobbin Signal Offset -CL



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Root Cause Summary

- The Root Cause Of The Tube Cracking In Seabrook Steam Generator "D" At RFO8 Is High Residual Stress In A Subset Of Tubes Caused By Manufacturing Process
- The Extent Of Condition Is Defined
- Degradation Mechanism Is Not A New Generic Issue In Thermally Treated Tubing and is not an Active Damage Mechanism at Seabrook.