



UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

September 10, 1992

Docket No. 50-368

LICENSEE: Entergy Operations, Inc.

FACILITY: Arkansas Nuclear One, Unit 2 (ANO-2)

SUBJECT: SUMMARY OF MEETING ON AUGUST 27, 1992, CONCERNING
THE STEAM GENERATORS AT ANO-2

On August 27, 1992, representatives of Entergy Operations, Combustion Engineering, and Dominion Engineering briefed the NRC staff on the ANO-2 steam generator (SG) pulled-tube analysis and their inspection plans for the upcoming refueling outage (2R9), currently scheduled to begin on September 4, 1992. Meeting attendees are listed in Enclosure 1. A handout that was presented by Entergy during the meeting is in Enclosure 2.

The licensee presented background information and a review of the forced-outage activities of March-April 1992 as a result of a SG tube leak. Four hundred eighty-eight SG tubes were sleeved or plugged during this forced outage, and five tubes were pulled for further analysis. The licensee stated that its criteria for repairing tubes was very conservative (all potential circumferential cracks were repaired).

Laboratory examination showed that the circumferential tubesheet indications in the pulled tubes were all outside diameter (OD) initiated and a result of stress corrosion cracking. The average depth of attack ranged from 88-94% through-wall (TW), with 100% TW penetration over 100 degrees. Based on the Regulatory Guide (RG) 1.121 analysis, the circumferential defects failed to meet the margins allowed for under design-basis conditions.

Axial eggcrate indications in the pulled tubes were also all OD-initiated stress corrosion cracks with only limited intergranular attack found. The axial indications averaged in depth between 36 and 41% TW; however, the burst strength significantly exceeded the RG 1.121 requirements.

For tubesheet indications, motorized rotating pancake coil (MRPC) examination showed excellent correlation with the metallography results for average TW depth. For axial indications, both bobbin and MRPC examination showed excellent correlation with the metallography results for average TW penetration. Ultrasonic (UT) examination consistently undersized the average depth of the tubesheet indications and failed to detect the presence of tube support plate axial indications.

150047

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The inspection plans for 2R9 include 100% hot-leg MRPC examination on both SGs, 20% cold-leg MRPC examination on both SGs, and 100% full-length bobbin examination on both SGs. Selected tube support plate locations will also be subjected to MRPC examination. The eddy current analysis will include revised analyst guidelines, a performance demonstration program, and an independent company for secondary eddy current analysis. It was noted that establishing the rate of degradation would be an important aspect of the inspection.

The operational strategy for the upcoming cycle includes a proceduralized administrative shutdown limit for SG leakage of 0.1 gallons per minute (gpm) (the technical specification limit is 0.5 gpm), and the use of a dedicated control room alarm, "SECONDARY SYSTEMS RADIATION HIGH." Planned modifications include in-line ion chromatography, N16 gamma-specific monitors, morpholine injection, and T-hot reduction of the reactor coolant system.

Throughout the licensee's presentation, the NRC staff asked for clarifications or for more details. The staff plans to use the information from the presentation to support issuance of a future information notice.

The licensee concluded that it has committed to do, and is currently doing, all that is necessary to support safe operation of the plant with respect to the SGs. The staff indicated that the licensee's plans and actions appeared to be comprehensive.

Original signed by:

Thomas W. Alexion, Project Manager
Project Directorate IV-1
Division of Reactor Projects - III/IV/V
Office of Nuclear Reactor Regulation

Enclosures:

1. List of meeting attendees
2. Information Update on the ANO-2 SGs

cc w/enclosures:

See next page

DISTRIBUTION:

Docket File	NRC & Local PDRs	B. D. Liaw
PD4-1 Reading	TMurley/FMiraglia	M. Hum
JPartlow	BBoger	E. Hackett
MVirgilio	JLarkins	ACRS (10)
TAlexion	RYoung	SShankman
PNoonan	OGC	ABBeach
EJordan	JStrosnider	HConrad
GJohnson	EMurphy	LCampbell

OFC	LA:PD4-1	PM:PD4-1	PE:PD4-1	BC:EMCB	D:PD4-1
NAME	PNoonan	TAlexion	RYoung	JStrosnider	JLarkins
DATE	9/2/92	9/7/92	9/4/92	9/9/92	9/10/92

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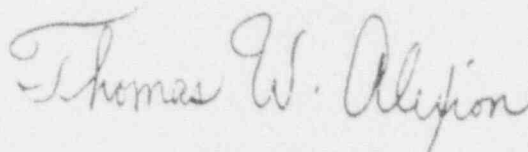
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Division of Reactor Projects - III/IV/V
Office of Nuclear Reactor Regulation

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See next page

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ANO-2 STEAM GENERATOR MEETING

AUGUST 26, 1992

<u>NAME</u>	<u>ORGANIZATION</u>
T. Alexion	NRC/NRR/PDIV-1
J. Larkins	NRC/NRR/PDIV-1
B. Boger	NRC/NRR/DRPW
J. Strosnider	NRC/NRR/EMCB
B. D. Liaw	NRC/NRR/DET
M. Hum	NRC/NRR/EMCB
H. Conrad	NRC/NRR/EMCB
G. Johnson	NRC/NRR/EMCB
E. Hackett	NRC/RES/MEB
L. Campbell	NRC/NRR/RVIB
R. Young	NRC/NRR/PDIV-1
D. Harrison	ANO/SG Engineer
C. Eubanks	ANO/Supervis.-Eng. Prog's
R. Edington	ANO/Plant Manager-Unit 2
R. Fenech	ANO/General Manager
J. Piscaro	ANO/Director-Licensing
W. Eater	ANO/Director-Design Eng.
W. McKelvy	ANO/Chemistry Superint.
D. Moore	ANO/SG Tech. Specialist
R. Maurer	ABB/Combustion Engineering
G. Fink	ABB/Combustion Engineering
J. Hall	ABB/Combustion Engineering
M. Partridge	Dominion Engineering, Inc.

**INFORMATION UPDATE
CONCERNING THE
ANO-2 STEAM GENERATORS**

AUGUST 26, 1992

AGENDA

INFORMATION UPDATE CONCERNING THE ANO-2 STEAM GENERATORS

- | | | |
|------|-------------------------|----------------|
| I. | INTRODUCTIONS | J. J. FISICARO |
| II. | OPENING REMARKS | R. A. FENECH |
| III. | BACKGROUND | R. K. EDINGTON |
| IV. | FORCED OUTAGE | C. EUBANKS |
| V. | PULLED TUBE ANALYSIS | D. F. HARRISON |
| VI. | FUTURE PLANS | |
| | A. 2R9 INSPECTION PLANS | D. F. HARRISON |
| | B. GROWTH ASSESSMENT | D. F. HARRISON |
| | C. STRATEGY | R. K. EDINGTON |
| VII. | CLOSING REMARKS | R. A. FENECH |

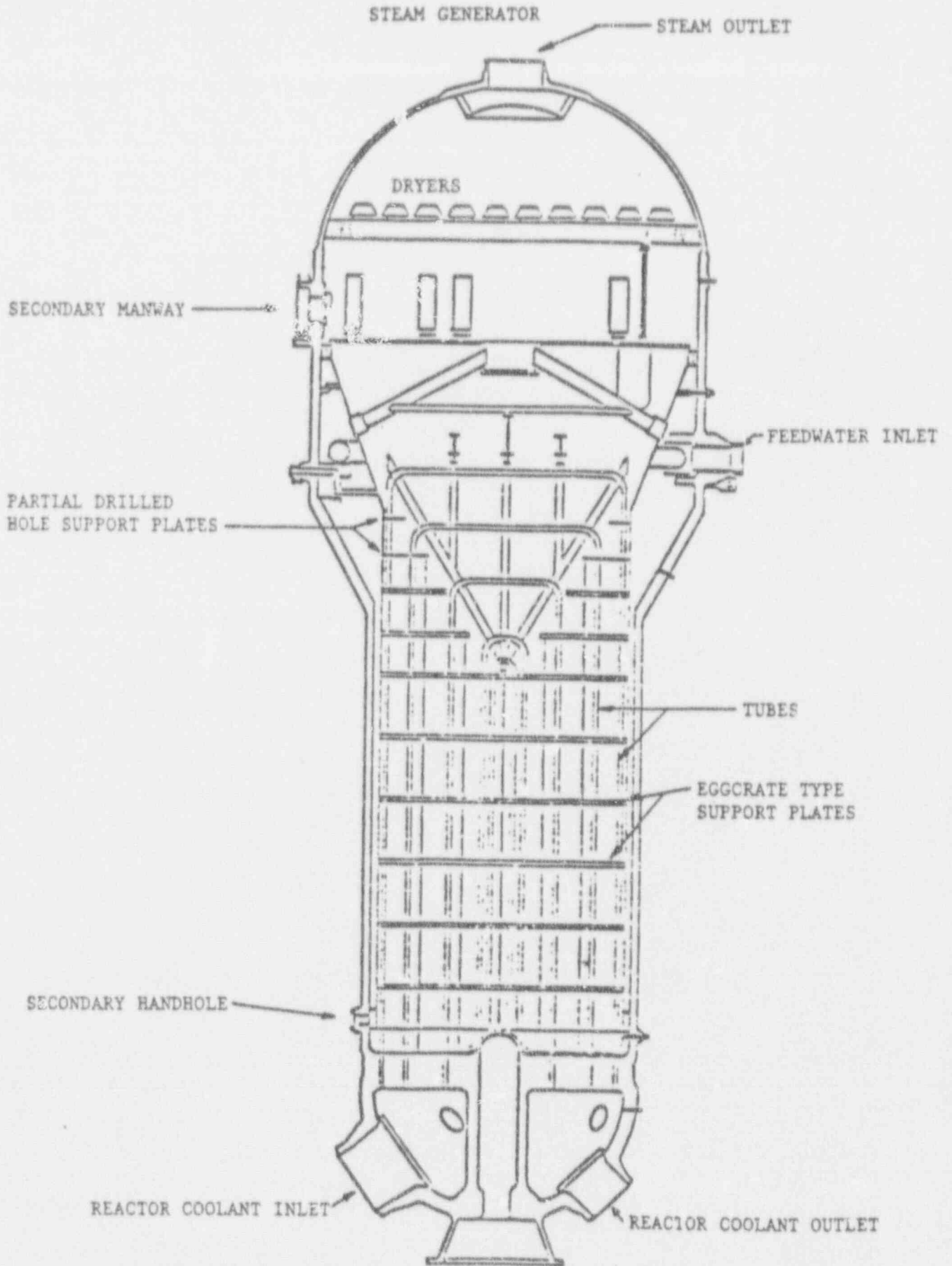
OPENING REMARKS

BACKGROUND

STEAM GENERATOR SPECIFICS

- MODEL - COMBUSTION ENGINEERING 2815
- TUBING MATERIAL - INCONEL 600 MILL ANNEALED (HIGH TEMPERATURE), 3/4 INCH OD, 0.048 INCH WALL
- 7 FULL EGGCRATE (EC), 2 PARTIAL EC, 2 DRILLED SUPPORT PLATES, AND 5 BATWING SUPPORTS
- NUMBER OF TUBES PER STEAM GENERATOR - 8411
- TUBESHEET EXPANSION - FULL DEPTH EXPLOSIVELY EXPANDED
- DATE OF INITIAL COMMERCIAL OPERATION - MARCH 1980
- CURRENT FUEL CYCLE - 9 (8.5 EFY)
- NEXT SCHEDULED REFUELING OUTAGE - CURRENTLY SCHEDULED TO COMMENCE ON SEPTEMBER 4, 1992
- DEFECT MECHANISMS - DENTING, BATWING WEAR, VERTICAL STRAP WEAR (CS) - IGA AND SCC AT THE TUBE SUPPORT PLATES
- SECONDARY CHEMISTRY - AVT (BORIC ACID ADDITION COMMENCED IN 1983 TO ARREST DENTING)
- SLUDGE LANCING EACH OUTAGE
- NUMBER OF TUBES PLUGGED PRIOR TO CURRENT OUTAGE - 15 IN "A" AND 109 IN "B"
- T HOT - 607 DEGREES F

ARKANSAS NUCLEAR ONE UNIT TWO



REVIEW OF PREVIOUS INSPECTION DATA

- 3% INSPECTION SAMPLES (BOBBIN) THROUGH 2R7 (1980 - 1989)
- REPAIRS THROUGH 2R7 (1989) WERE ASSOCIATED WITH PRESERVICE REPAIRS AND WEAR AT THE BATWING SUPPORTS (15 IN "A" AND 36 IN "B")
- INSPECTIONS DURING 2R8 (1991)
 - BEGAN WITH 3% IN EACH STEAM GENERATOR
 - FOUND TUBE SUPPORT PLATE (TSP) DAMAGE IN "B" (BELIEVED TO BE OD - IGA AND SCC)
 - EXPANDED TO 100% IN "B" AND 9% IN "A"
 - 73 TUBES REPAIRED IN "B" AND 0 IN "A" (ALL PLUGGED)
 - SMALL NUMBER OF TSP INTERSECTIONS PROPED WITH MRPC
- PLANS WERE TO DO 100% BOBBIN AND 20% MRPC AT THE TOP OF THE TUBESHEET IN BOTH STEAM GENERATORS DURING 2R9 (1992)
- PLANS WERE BASED ON:
 - 2R8 "B" BOBBIN RESULTS
 - INDUSTRY ISSUE WITH CIRCUMFERENTIAL CRACKING
 - NOZZLE DAMS

MARCH 9, 1992 STEAM GENERATOR LEAK

- STEP CHANGE IN "A" STEAM GENERATOR LEAKAGE - MARCH 9, 1992
- LEAK RATE OF 0.25 GPM ESTIMATED - CONFIRMED BY THREE DIFFERENT METHODS - ARGON, TRITIUM, AND RCS INVENTORY BALANCE
- TECHNICAL SPECIFICATION LIMIT OF 0.5 GPM
- PREVIOUSLY ESTABLISHED ADMINISTRATIVE LIMIT OF 0.1 GPM. WHEN THIS WAS EXCEEDED THE UNIT WAS TAKEN OFF LINE

FORCED OUTAGE

- HELIUM TEST PERFORMED TO FIND LEAK
- LEAK LOCATED ON HOT LEG SIDE OF "A" STEAM GENERATOR IN TUBE 67-109. CONFIRMED WITH BOTH BOBBIN AND MRPC AS CIRCUMFERENTIAL CRACKING AT THE TOP OF THE TUBESHEET
- PLUGGED AND STABILIZED TUBE 67-109
- ANOTHER HELIUM TEST WAS PERFORMED TO LOCATE ANY ADDITIONAL TUBE LEAKS. NONE WERE FOUND
- ANO EDDY CURRENT ANALYSIS GUIDELINES
 - PRIOR TO FORCED OUTAGE
 - * ANO SPECIFIC EDDY CURRENT TESTING (ECT) GUIDELINES ESTABLISHED IN 1989
 - * BASED ON EPR1 / INDUSTRY, UPGRADES TO ANO SPECIFIC GUIDELINES WERE INITIATED IN OCTOBER 1991
 - * UPGRADE WAS COMPLETED FOR ANO-1 PRIOR TO 1R10 AND WAS SCHEDULED FOR COMPLETION FOR ANO-2 PRIOR TO 2R9
 - * THE UPGRADES ALSO INCLUDE SPECIFIC ECT ANALYST TRAINING AND PERFORMANCE DEMONSTRATION

- ANO EDDY CURRENT ANALYSIS GUIDELINES
(CONTINUED)

- FORCED OUTAGE

- BWNS SELECTED TO PERFORM ANO-2 FORCED OUTAGE STEAM GENERATOR WORK DUE TO HAVING PERSONNEL AND EQUIPMENT ALREADY ONSITE
- WRITTEN GUIDELINES WERE PREPARED FOR THE ANO-2 FORCED OUTAGE WITH INPUT FROM ABB-CE, BWNS, AND ENTERGY ECT PERSONNEL
- THE GUIDELINES WERE FULLY PROCEDURALIZED AND APPROVED BY THE PLANT SAFETY COMMITTEE
- THE GUIDELINES DID NOT INCLUDE PERFORMANCE DEMONSTRATIONS, HOWEVER, ANO DID BRING IN INDUSTRY EXPERTISE IN ANALYSIS OF MRPC AND CIRCUMFERENTIAL CRACKS
- WITH EACH ANALYST, THE LEAD ANALYST REVIEWED THE FAILED TUBE SIGNATURE AND GAVE SPECIFIC INSTRUCTIONS ON ANALYSIS OF TUBESHEET CIRCUMFERENTIAL INDICATIONS
- ADDITIONALLY MANY OF THE BWNS ANALYSIS PERSONNEL USED FOR THE ANO-2 WORK HAD COMPLETED THE ANALYSIS TRAINING AND PERFORMANCE DEMONSTRATION ON ANO-1

• REVIEW OF 2R8 DATA

- REVIEW OF DATA REVEALED THAT A DISTORTED TUBESHEET INDICATION (DTI) WAS PRESENT IN TUBE 67-109
- WESTINGHOUSE REANALYZED ALL 2R8 DATA THAT THE SAME ANALYSTS HAD REVIEWED. SIX ADDITIONAL TUBES SHOULD HAVE BEEN CALLED DTI
- BOBBIN COIL USED IN 2R8. THIS TECHNIQUE IS NOT GOOD FOR IDENTIFYING CIRCUMFERENTIAL CRACKING
- ISSUE OF MISSED DTI'S WAS RELATED TO BOBBIN COIL ANALYSIS AT EXPANSION TRANSITION ZONE IN TUBESHEET IN THE PRESENCE OF OD DEPOSITS
- MISSED CALL DID NOT ALTER ANO'S ANALYSIS PHILOSOPHY DURING THE FORCED OUTAGE. UPGRADE OF ANALYSIS GUIDELINES HAD ALREADY BEGUN FOR ANO-2 AND WERE COMPLETED FOR ANO-1

• MRPC

- INSPECTED 100% OF BOTH HOT LEGS AND 20% OF SLUDGE PILE REGION IN COLD LEG OF "A" STEAM GENERATOR
- THE RESULTS OF THE COLD LEG SIDE INSPECTIONS
- NO DEFECTS
- TESTING WAS PERFORMED USING SAME PARAMETERS AS WAS USED AT MAINE YANKEE AND MILLSTONE

- ANO DECIDED SLEEVING TO BE THE BEST REPAIR METHOD, BASED ON THE NATURE OF THE DEFECT, LOCATION AND PLUGGING MARGIN
- PRIOR TO SLEEVING TUBES WITH TOP OF TUBESHEET CRACKS, FULL LENGTH BOBBIN COIL ECT WAS PERFORMED ON THOSE TUBES TO ENSURE THE TUBE WOULD NOT REQUIRE PLUGGING DUE TO TUBE SUPPORT PLATE FLAW
- INSPECTIONS RESULTED IN REPAIRS TO 488 TOTAL TUBES

	<u>SG "A"</u>	<u>SG "B"</u>
NUMBER PLUGGED	29	11
NUMBER SLEEVED	<u>392</u>	<u>56</u>
TOTAL	421	67

- REPAIR LIST WAS BASED ON VERY CONSERVATIVE EDDY CURRENT ANALYSIS. ALL POTENTIAL CIRCUMFERENTIAL CRACKS WERE REPAIRED
- ALSO, BASED ON GOOD EXPERIENCE FROM ANOTHER PLANT, UT WAS PERFORMED ON 85 TUBES
- AS STATED IN ANO'S APRIL 16, 1992, PRESENTATION, THE INTENDED USE FOR UT WAS FOR DEFECT CHARACTERIZATION AND MORE ACCURATE SIZING OF DEFECTS DURING UPCOMING OUTAGES, IF REASONABLE CORRELATION TO TUBE PULL DESTRUCTIVE ANALYSIS WAS OBTAINED

- ORIGINALLY ANO EVALUATED THE USE OF UT TO HELP DISPOSITION SMALL POTENTIAL DEFECTS IDENTIFIED BY MRPC. UPON FURTHER EVALUATION, ANO DECIDED NOT TO USE UT TO REMOVE QUESTIONABLE INDICATIONS FROM THE REPAIR LIST
- AS WAS DURING THE APRIL 16, 1992, PRESENTATION, REGULATORY GUIDE 1.121 ANALYSIS WAS PERFORMED, UTILIZING FLAW SIZES BASED ON THE UT DATA. ANALYSIS CONCLUDED THAT ANO DID NOT EXCEED THE REGULATORY GUIDE MARGINS, BASED ON THE UT DATA
- IN ORDER TO BETTER UNDERSTAND ANO-2'S DAMAGE MECHANISMS AND TO ASSESS SAFETY SIGNIFICANCE, IT WAS DECIDED TO PULL FIVE TUBES; THREE WITH CIRCUMFERENTIAL DEFECTS AND TWO WITH AXIAL DEFECTS
- REVERSE PRESSURE TEST WAS PERFORMED AFTER REPAIRS WERE COMPLETE. EIGHTEEN SLEEVES LEAKED UNDER THIS CONDITION. THESE TUBES WERE PLUGGED
- FORCED OUTAGE ACTIONS WERE APPROPRIATE AND CONSERVATIVE
 - 100% MRPC OF HOT LEGS
 - 20% SAMPLE OF COLD LEGS
 - ALL POTENTIAL CIRCUMFERENTIAL DEFECTS REPAIRED
 - REVERSE PRESSURE TEST PERFORMED ON THE SECONDARY SIDE
- IN RETROSPECT, ANO-2 WOULD NOT CHANGE ANY ACTIONS TAKEN DURING THE FORCED OUTAGE
- ANO-2 LEFT THE STEAM GENERATORS IN AS GOOD A CONDITION AS POSSIBLE

PULLED TUBE ANALYSIS

EXAMINATION OBJECTIVES

- CONFIRM THE NATURE OF THE INDICATIONS IDENTIFIED BY ECT AT THE TOP OF THE TUBESHEET AND EGGCRATES
- DETERMINE THE EXTENT AND DEPTH OF THE DEFECTS
- DETERMINE THE RELATIONSHIP BETWEEN THE DEFECTS AND THE TUBE PROPERTIES
- DETERMINE THE ABILITY OF FIELD BOBBIN COIL AND MRPC ECT TECHNIQUES TO ACCURATELY CHARACTERIZE THE DEPTH AND EXTENT OF THE DEFECTS
- DETERMINE THE CAUSATIVE CHEMICAL SPECIES OR CHEMISTRY CONDITIONS UNDER WHICH THE DEFECTS INITIATED OR PROPAGATED
- DETERMINE THE EFFECT OF THE DEFECTS ON THE BURST STRENGTHS OF THE TUBES AND ASSESS THE POSSIBLE SAFETY ISSUES

METHODOLOGY

- VISUAL EXAMINATION OF AS RECEIVED CONDITION
- DIMENSIONAL CHARACTERIZATION
- DOUBLE WALL RADIOGRAPHY
- LIGHT OPTICAL MICROSCOPIC EXAMINATION
- DETAILED TUBE EXAMINATION MAPS
- SCANNING ELECTRON MICROSCOPE
- AUGER ELECTRON SPECTROSCOPY
- X-RAY PHOTOELECTRON SPECTROSCOPY
- SECONDARY ION MASS SPECTROSCOPY
- TUBE DEPOSIT ANALYSIS
- TENSILE TESTING
- MICROHARDNESS TESTING
- TUBE MATERIAL CHEMICAL ANALYSIS
- SENSITIZATION TESTING
- DEFECT LEAK RATE TESTING
- DEFECT BURST TESTING
- MULTEQ EVALUATION

DESCRIPTION OF SPECIMENS

STEAM GENERATOR "A"

<u>TUBE LOCATION</u>	<u>DEFECTS OF INTEREST</u>
ROW 13 LINE 147	94% AVERAGE THROUGHWALL (TW) CIRCUMFERENTIAL INDICATION AT THE TUBESHEET INTERFACE
ROW 55 LINE 63	88% AVERAGE TW CIRCUMFERENTIAL INDICATION AT THE TUBESHEET INTERFACE

STEAM GENERATOR "B"

<u>TUBE LOCATION</u>	<u>DEFECTS OF INTEREST</u>
ROW 36 LINE 130	88% AVERAGE TW CIRCUMFERENTIAL INDICATION AT THE HOT LEG TUBESHEET AT A DENT 4.5 INCH UN-EXPANDED TUBESHEET CREVICE
ROW 96 LINE 116	A SINGLE BOBBIN INDICATION OF 59% TW AT EGGCRATE #2, WHICH MRPC IDENTIFIED AS A SINGLE AXIAL FLAW 0.5 INCH IN LENGTH A CLEAN HOT LEG TUBESHEET INTERFACE A CLEAN EGGCRATE #1

DESCRIPTION OF SPECIMENS
(CONTINUED)

STEAM GENERATOR "B"

TUBE LOCATION

DEFECTS OF INTEREST

ROW 19 LINE 55

5 SMALL CIRCUMFERENTIAL INDICATIONS AT THE TOP OF THE TUBESHEET NOTED BY UT (ECT NOTED NO DEFECT AT THIS LOCATION)

A SMALL VOLUME (0.56V) ECT BOBBIN INDICATION NOTED 1.55 INCHES ABOVE THE TUBESHEET AND ESTIMATED AT 31% TW

A DISTORTED BOBBIN INDICATION AT EGGCRATE #1 WHICH MRPC CALLED AS A SINGLE AXIAL INDICATION 0.72 INCHES LONG

AN MRPC INDICATION 26% TW FLAW AT EGGCRATE #2 IDENTIFIED AS MULTIPLE AXIAL INDICATIONS WITH A LENGTH OF 0.57 INCH

CIRCUMFERENTIAL INDICATIONS

- ALL OD INITIATED
- ALL STRESS CORROSION CRACKING
- SUPERFICIAL OR NO IGA PRESENT
- NO EVIDENCE OF TRANSGRANULAR CRACKING
- NO EVIDENCE OF PWSCC
- AVERAGE DEPTH OF ATTACK RANGED FROM 88-94% TW
- ATTACK EXTENDED 360 DEGREES AROUND THE TUBES WITH 100% TW FOR 110-150 DEGREES OF THE CIRCUMFERENCE
- ATTACK APPEARED TO BE A COMBINATION OF INDEPENDENT CRACKS JOINED TOGETHER
- NO EVIDENCE OF PITTING OR ANY OTHER DAMAGE MECHANISM
- ATTACK LIMITED TO THE STRESSED EXPANSION REGION
- SLUDGE PILE IMPURITIES, INCLUDING LEAD AND SULFUR, ASSOCIATED WITH THE DEFECTS

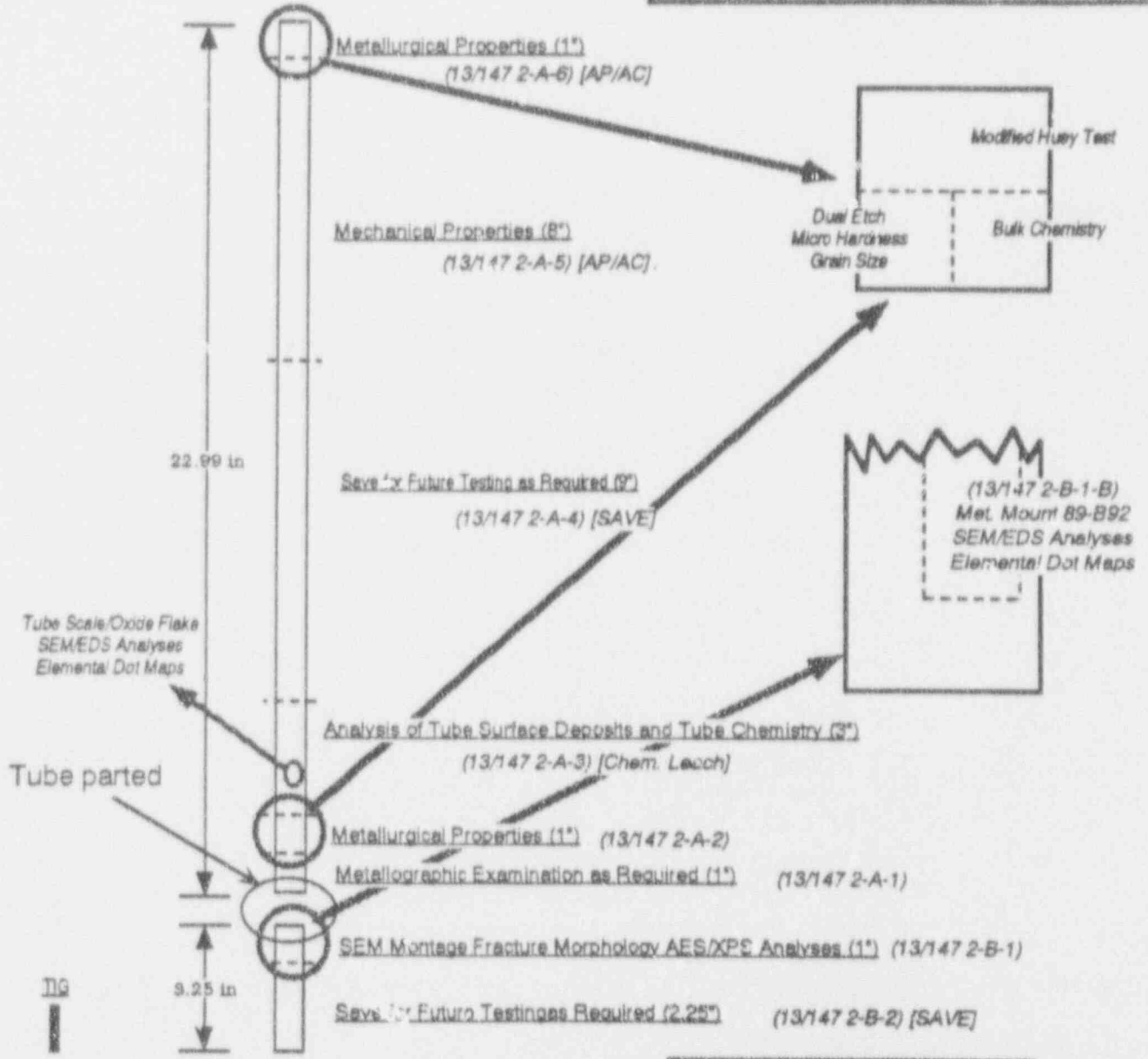
CIRCUMFERENTIAL INDICATIONS (CONTINUED)

- COPPER DEPOSITS FOUND, BUT NOT ASSOCIATED WITH THE DAMAGE
- LOW NICKEL/CHROMIUM RATIO, LEAD, AND SULFUR SUGGEST ACIDIC ATTACK
- NO EVIDENCE OF CAUSTIC INDUCED ATTACK

**Tube 13/147
Section 2**

X-RAY "A"

X Ray - Part A Upper part, Distorted crack edge, some secondary cracks from lower part.
Part B Lower part, many secondary cracks



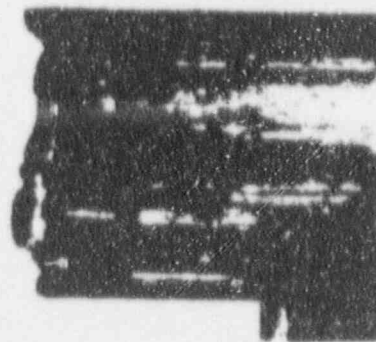
ECT Data:
 • MRPC 89% average TW
 80V Circ. Crack 360°
 • UT Average 61% TW
 with 100% TW

Figure 9-1. Sectioning Diagram for Steam Generator A Tube R13L147 Section 2.

Upper Part



Lower Part

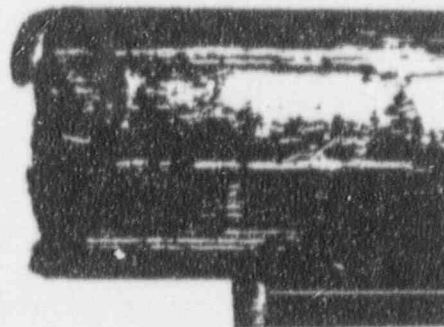


0°

Upper Part



Lower Part



90°

Upper Part

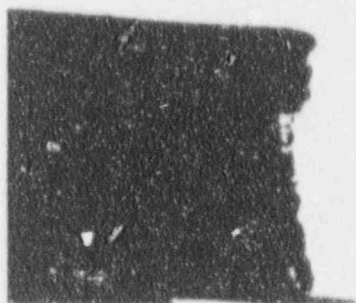


Lower Part

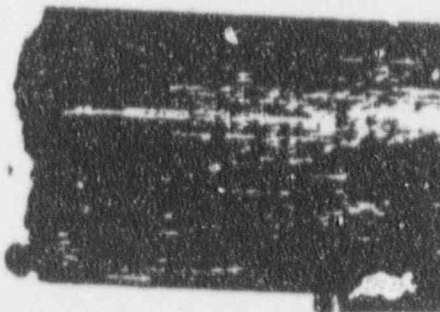


180°

Upper Part



Lower Part



270°

Figure 6-18. Photographs of Steam Generator A Tube R11147 at the Top of the Tubesheet (2X).

ANC Steam Generator "A"
Tube R13-L147
Through Wall Crack

Average Penetration 94%

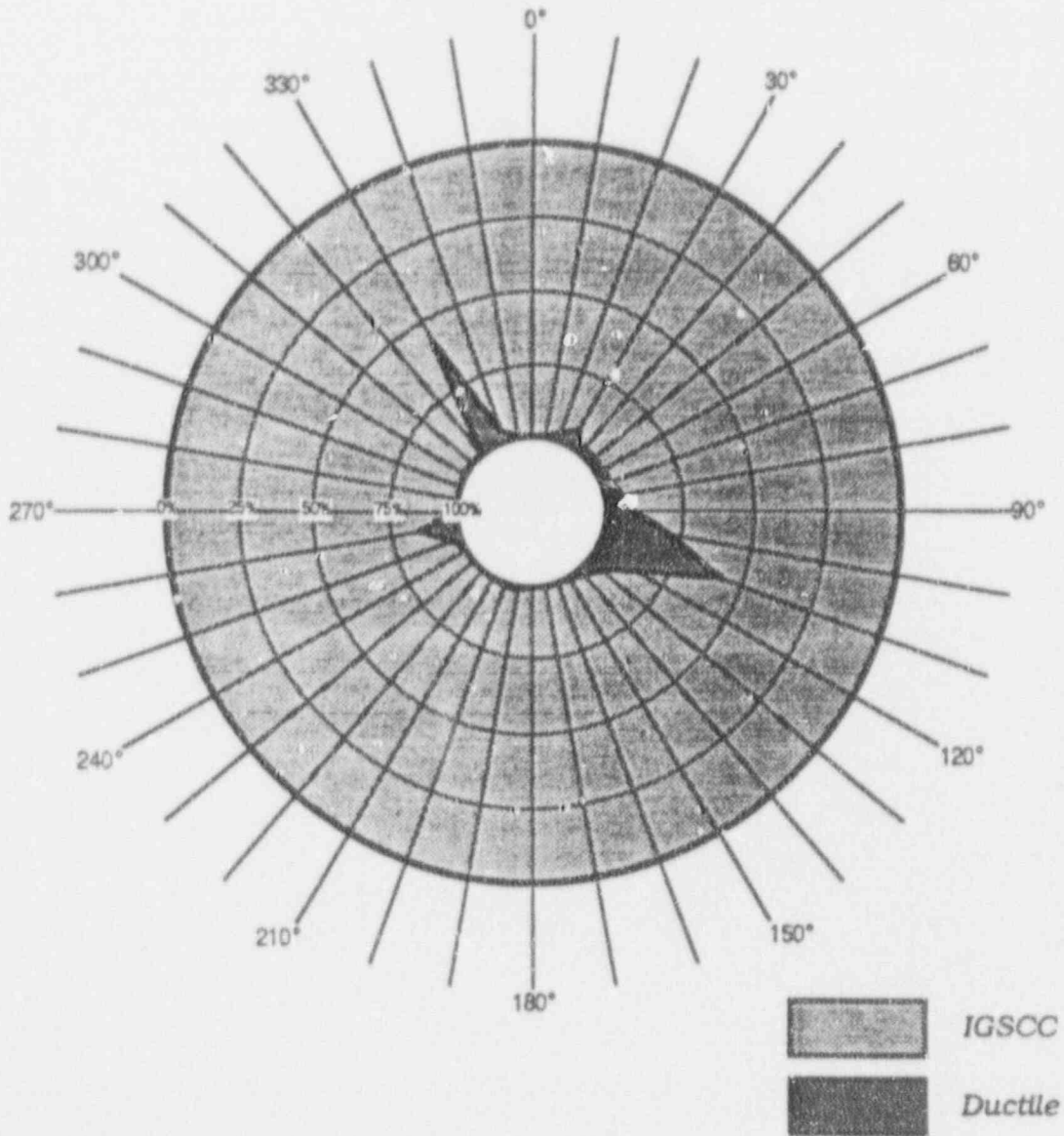
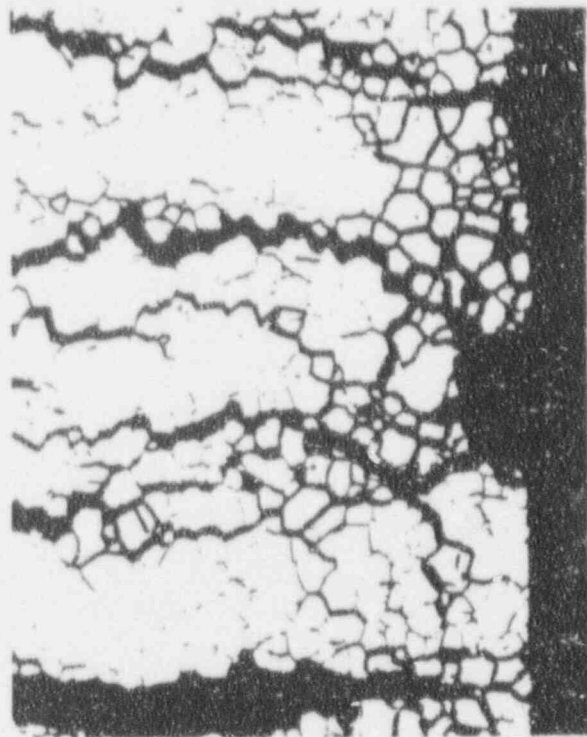


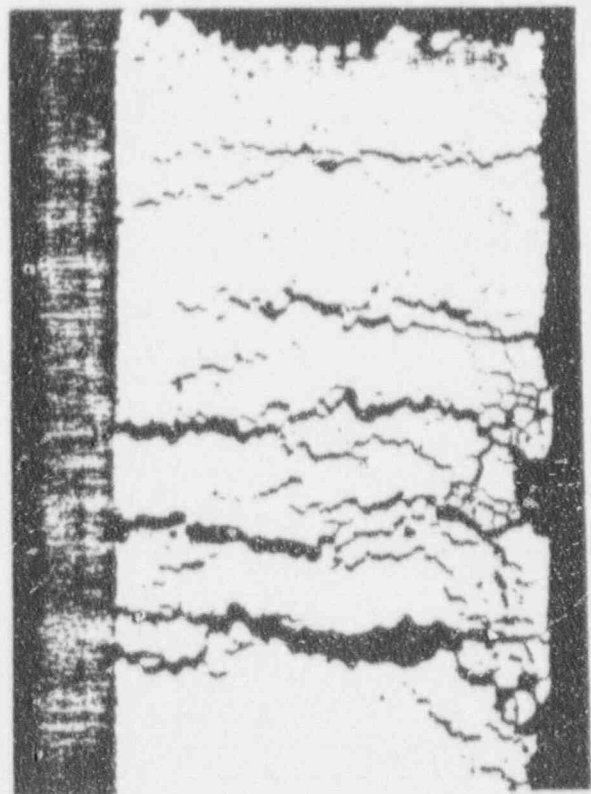
Figure 10-1. Degradation as a Function of Circumferential Location for Tube R13L147.



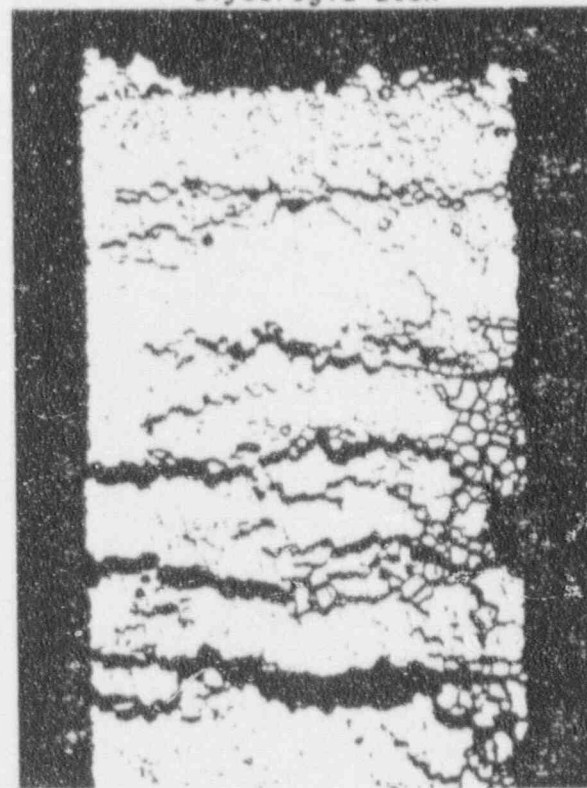
102061 100X
As Polished



102347 100X
Glyceregia Etch



102064 50X
As Polished



102346 50X
Glyceregia Etch

Figure 11-1. Light Photomicrograph of Seam Generator A Tube R13L147
Near the Fracture (Longitudinal View).

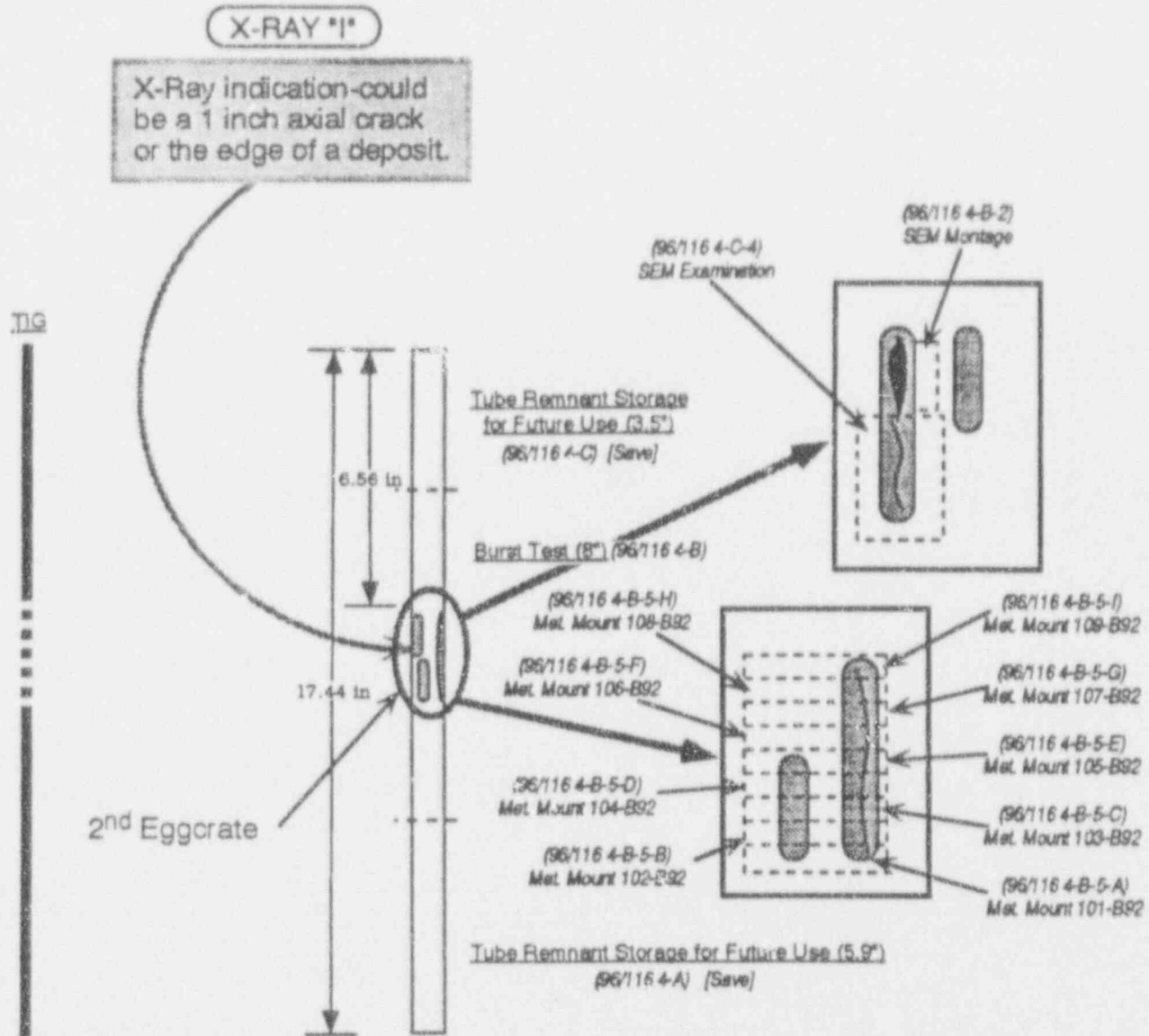
AXIAL INDICATIONS

- ALL OD INITIATED
- ALL FLAWS WERE AXIALLY ORIENTATED STRESS CORROSION CRACKS
- THE AVERAGE DEPTH OF THE CRACKS RANGED BETWEEN 36-41%TW
- THE DEEPEST CRACK WAS <59% TW
- ONLY LIMITED AND VER? SUPERFICIAL IGA WAS FOUND
- THE CRACKS WERE ALL LOCATED WITHIN THE TUBE TO TUBE SUPPORT CONTACT REGIONS
- NO CRACKS EXTENDED BEYOND THE TUBE SUPPORT REGION
- NO EVIDENCE OF ANY OTHER DAMAGE MECHANISM WAS FOUND
- THE TUBE SURFACES WERE COVERED BY A UNIFORM TUBE SCALE CONSISTING MAINLY OF MAGNETITE
- ELEMENTAL COPPER WAS FOUND, BUT DID NOT APPEAR TO BE ASSOCIATED WITH THE DAMAGE MECHANISM
- THE ACTUAL TUBE TO TUBE SUPPORT INTERFACE WAS CLEAN RELATIVE TO TUBE DEPOSITS
- SULFUR AND LEAD APPEAR TO BE ASSOCIATED WITH THE DAMAGE MECHANISM

AXIAL INDICATIONS (CONTINUED)

- THE DAMAGE MECHANISM APPEARS TO BE ACIDIC RATHER THAN CAUSTIC
- WHILE THE FLAWS APPEAR TO BE INITIATED BY CHEMICAL ATTACK, PROPAGATION APPEARS TO BE DRIVEN BY PRIMARY SIDE HOOP STRESSES

Tube 96/116 Section 4



ECT Data:

- Bobbin Coil 1% TW 0.99 V
0.44 in. above Support CL
- MRPC Axial Indication 30% TW
0.51 in. long

This section of the tube was TIG Relaxed for removal from the S/G. The area of the support only a single vertical TIG pass was applied.

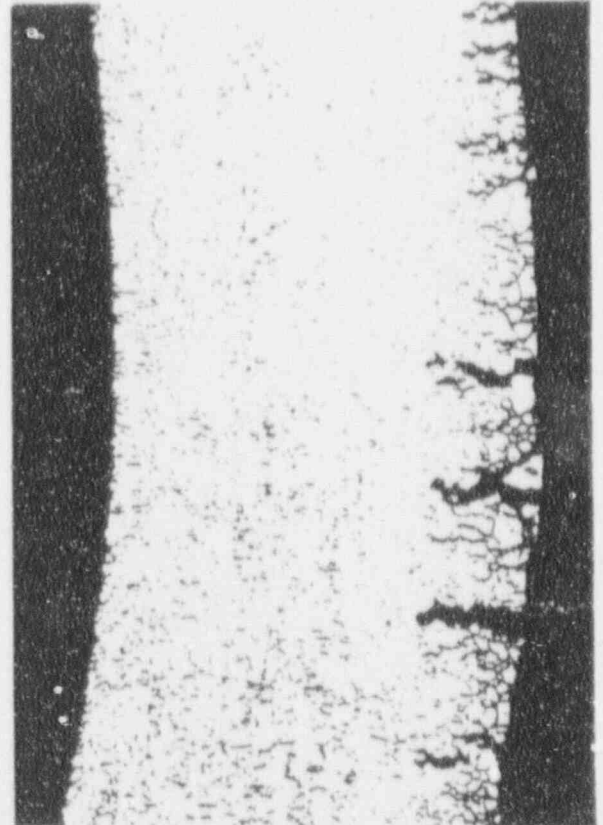
Figure 9-9. Sectioning Diagram for Steam Generator B Tube R96L116 Section 4.



R96/116 4-B-5-C)
Mat. Mount 103-B92



102667 50X
As Polished
Mount 103-B92



102769 50X
Nital Etch
Mount 103-B92

Figure 11-15. Light Photomicrographs of Steam Generator A Tube R96L116 at EC 2. IGSCC in Area of Contact with 2 inch Support Strap (Transverse View).

TUBE PROPERTIES

- THE MICROSTRUCTURE ANALYSIS OF THE FIVE PULLED TUBES IS CONSISTENT WITH THAT OBSERVED FROM OTHER CE STEAM GENERATORS, INDICATING THAT THE TUBES ARE HIGH TEMPERATURE MILL ANNEALED
- MODIFIED HUEY TESTS INDICATE THAT THE TUBES ARE NOT SENSITIZED
- MICROHARDNESS TEST RESULTS ARE CONSISTENT WITH THOSE FROM OTHER CE PLANTS
- TENSILE TEST RESULTS ARE WITHIN THE ORIGINAL PROCUREMENT REQUIREMENTS
- THE CHEMICAL COMPOSITION OF THE FIVE ANO-2 TUBES CONFORM TO THE REQUIREMENTS OF THE ORIGINAL SPECIFICATION
- NO SIGNIFICANT ABNORMALITIES WERE OBSERVED IN ANY OF THE TUBE MATERIAL TESTING

EDDY CURRENT / MRPC CORRELATION

- FOR TUBESHEET INDICATIONS, MRPC VERSUS METALLOGRAPHY SHOWS EXCELLENT CORRELATION FOR AVERAGE THROUGHWALL DEPTH
- FOR AXIAL INDICATIONS, BOTH SCUBBIN AND MRPC SHOW EXCELLENT CORRELATION WITH THE METALLOGRAPHY RESULTS FOR AVERAGE THROUGHWALL PENETRATION
- IT CONSISTENTLY UNDERSIZED THE AVERAGE DEPTH OF THE TUBESHEET INDICATIONS BASED ON TIME OF FLIGHT. AMPLITUDE DATA CORRELATED REASONABLY WELL
- UT FAILED TO DETECT THE PRESENCE OF THE TUBE SUPPORT PLATE AXIAL INDICATIONS

ANO-2 SG TUBE PULL SAMPLE NDE

<u>SG</u>	<u>Row</u>	<u>Line</u>	<u>Location</u>	<u>Pre-Pull Bobbin</u>	<u>Pre-Pull MRPC</u>	<u>Pre-Pull UT</u>	<u>Metallography</u>
A	13	147	TSH + 0.17"	DTI	SCI @ 80 Volts 89% Thru-Wall 360 Degrees	Multiple Circ 100% Max 61% Avg 347 Degrees	360 Degree 100% Max 94% Avg
A	55	63	TSH + 0.16"	DTI	SCI @ 40 Volts 88% Thru-Wall 360 Degrees	Multiple Circ 100% Max 49% Avg 289 Degrees	360 Degree 100% Max 88% Avg
B	19	55	TSH + 0.41"	DTI	NDD	5-20% Max Depth Circ Cracks	NDD
			TSH + 1.55"	31% Thru-Wall 0.56 Volts	NDD	NDD	NDD
			01H + 0.68"	DSI 0.26 Volts	SAI @ 0.77 Volts 46% Thru-Wall 0.72" Long	NDD	Max 52% Avg 36%
			02H + 0.70"	26% Thru-Wall 0.68 Volts	SAI @ 0.84 Volts 26% Thru-Wall 0.57" Long	NDD	Max 49% Avg not available
B	96	116	02H + 0.42"	41% Thru-Wall 0.99 Volts	SAI @ 2.05 Volts 39% Thru-Wall 0.51" Long	NDD	Max 59% Avg 41%
B	36	130	TSH + 0.06"	DTI	SCI @ 7 Volts 80% Thru-Wall 360 Degrees	Wrong location tested	360 Degree 100% Max 88% Avg

CAUSATIVE CHEMICAL SPECIES

- SULFUR AND LEAD WERE ASSOCIATED WITH ALL OF THE MAJOR DEFECT REGIONS
- COPPER, WHILE PRESENT IN NOTABLE AMOUNTS, DID NOT APPEAR TO BE ASSOCIATED WITH THE DEFECTS
- SILICA AND, TO A LESSER DEGREE, CHLORIDES WERE ALSO FOUND IN MANY LOCATIONS
- CAUSTIC SPECIES SUCH AS SODIUM AND POTASSIUM WERE NOT FOUND IN SIGNIFICANT AMOUNTS
- NICKEL DEPLETION IN THE OXIDES AND THE LOW NI/CR RATIO FOUND IN THE DEFECT REGIONS IS CONSISTENT WITH A POSTULATED ACIDIC ENVIRONMENT

THE PRESENCE OF LEAD AND ABSENCE OF TRANSGRANULAR ATTACK IS CONSISTENT WITH AN ACIDIC ENVIRONMENT

- THE PRESENCE OF COPPER, BUT THE LACK OF PITTING, SUGGESTS THAT THE ENVIRONMENT WITHIN THE CREVICES IS ONLY SLIGHTLY ACIDIC
- REANALYSIS OF MULTEQ DATA SUGGESTS THAT THE STEAM GENERATOR BULK WATER HAS REMAINED SLIGHTLY ALKALINE TO NEUTRAL SINCE 1986. THIS SUGGESTS THAT THE ACIDIC ENVIRONMENT WHICH INITIATED THE DAMAGE MECHANISM OCCURRED PRIOR TO 1986, A TIME WHEN CONDENSER INTEGRITY AND HIGH AIR IN-LEAKAGE WERE MAJOR PROBLEMS

LEAK RATE / BURST TEST RESULTS

- CIRCUMFERENTIAL CRACKS
 - BY ANALYTICAL CALCULATIONS WOULD HAVE FAILED TO MEET THE MINIMUM ACCEPTABLE BURST PRESSURE OF 3 TIMES DELTA P OR 4,050 PSIG
- AXIAL CRACKS
 - LEAK RATE
 - * NO LEAKAGE WAS DETECTED IN EGGCRATE #2 FROM TUBE R96/L116 AT 588 DEGREES AND 4450 PSIG. THIS EGGCRATE SAMPLE CONTAINED A 41% TW ECT AXIAL INDICATION
 - * NO LEAKAGE WAS DETECTED IN EGGCRATE #1 FROM TUBE R19/L55 AT ROOM TEMPERATURE AND 4450 PSIG. THIS EGGCRATE SAMPLE CONTAINED A 0.26 VOLT BOF BIN COIL DISTORTED INDICATION
 - BURST TEST
 - A FREE SPAN SECTION, KNOWN TO BE DEFECT FREE, WAS BURST TESTED AT ROOM TEMPERATURE. FINAL BURST PRESSURE WAS >10,836 PSIG. WHEN CORRECTED FOR AN OPERATING TEMPERATURE OF 607 DEGREES, THIS EQUALED 9,286 PSIG

LEAK RATE / BURST TEST RESULTS

- AXIAL CRACKS

- BURST TEST (CONTINUED)

- * EGGCRATE #2 FROM TUBE R96/L116 BURST AT A ROOM TEMPERATURE PRESSURE OF 8,123 PSIG. THIS CORRELATES TO A BURST PRESSURE OF 6,961 PSIG AT 607 DEGREES.
- * EGGCRATE #1 FROM TUBE R19/L55 BURST AT A ROOM TEMPERATURE PRESSURE OF 9,810 PSIG. THIS CORRELATES TO A BURST PRESSURE OF 8,407 PSIG AT 607 DEGREES.
- * IN THE EGGCRATE SAMPLES, THE FAILURES ALL OCCURRED AT THE 2 INCH TUBE TO TUBE SUPPORT CONTACT POINT
- * NUMEROUS SMALL SECONDARY CRACKS PARALLEL TO THE FAILURE WERE OBSERVED. ALL CRACKS REMAINED WITHIN THE TUBE TO TUBE SUPPORT CONTACT REGION, WITH THE MAXIMUM EXTENT BEING 1.905 INCHES

LEAK RATE AND BURST TEST RESULTS

Specimen	Leak Test Temp. °F	Leak Rate GPM	Burst Test Temp. °F	Burst Pressure PSI	Burst Crack Length, in.
R19L55 Free Span	77	0	77	10,836	0.085
R96L116 EC2	588	0	77	8,123	0.659
R19L55 EC1	77	0	77	9,810	0.658

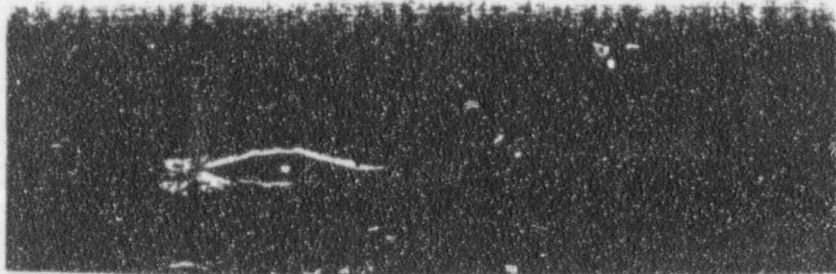
ADJUSTED BURST TEST RESULTS

Specimen	Operating Temperature, °F	Adjusted Burst Pressure, psi
R19L55 Free Span	607	9286
R96L116 EC2	607	6961
R19L55 EC1	607	8407



102469

1.5X



102460

5X

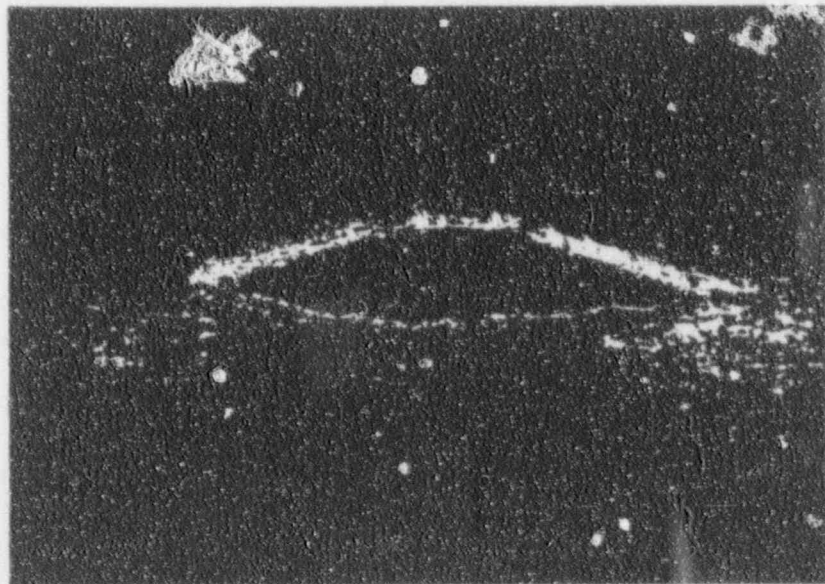


Figure 8-2. Tube R96L116 EC2 Burst Test Specimen After Test.

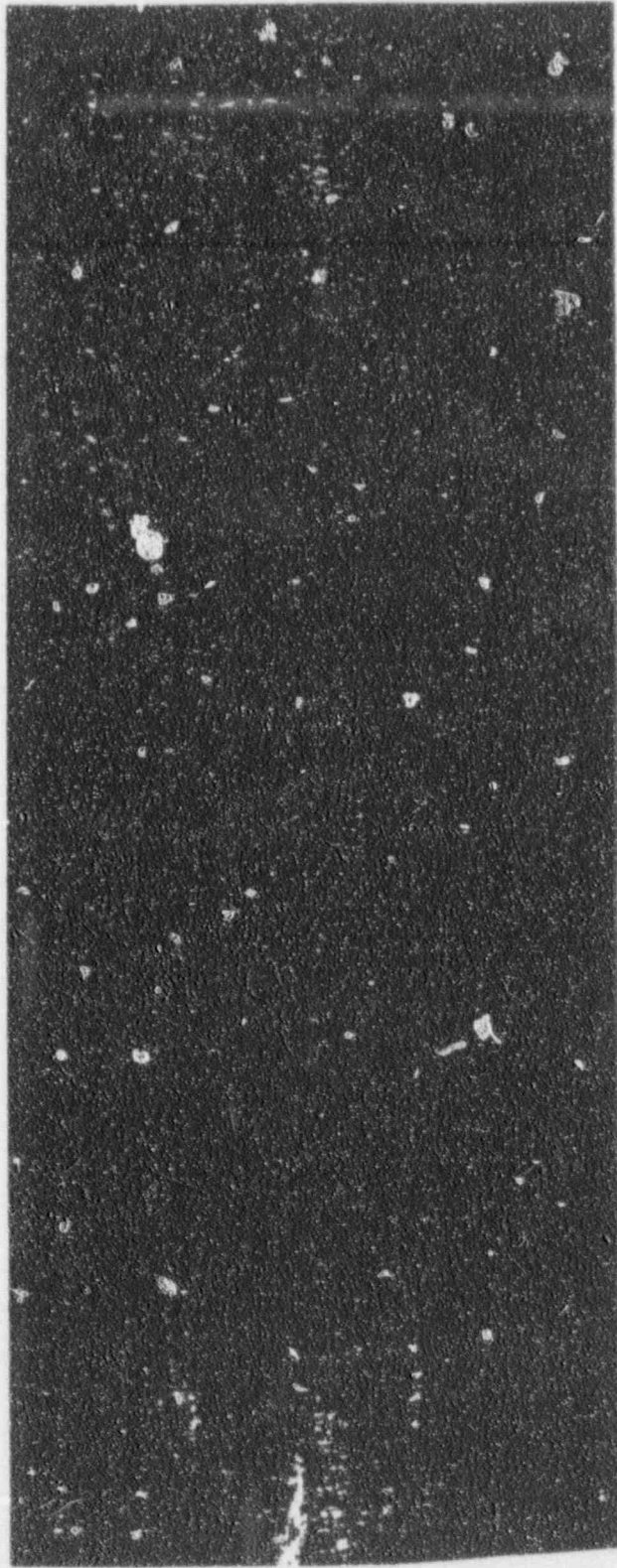


Figure 8-5. Secondary Cracks Near the Burst Failure in the Tube R96L116 EC2 Specimen (5X).

CONCLUSIONS

- CIRCUMFERENTIAL CRACKS

- THE TUBESHEET INDICATIONS WERE DEEP, CIRCUMFERENTIAL, OD INITIATED STRESS CORROSION CRACKS, LOCATED WITHIN THE STRESSED TUBESHEET EXPANSION REGION. INTERGRANULAR ATTACK DOES NOT APPEAR TO BE A MAJOR CONTRIBUTOR TO THE CRACKING.
- THE CIRCUMFERENTIAL CRACKS AVERAGED BETWEEN 88 AND 94% THROUGHWALL, WITH 100% THROUGHWALL PENETRATION OVER 100 DEGREES.
- BASED ON REGULATORY GUIDE 1.121 ANALYSIS, THE THREE CIRCUMFERENTIAL DEFECTS FAILED TO MEET THE MARGINS ALLOWED FOR UNDER DESIGN BASIS CONDITIONS.

- AXIAL CRACKS

- THE AXIAL INDICATIONS AT THE EGGCRATES WERE OD INITIATED STRESS CORROSION CRACKS WITH ONLY LIMITED INTERGRANULAR ATTACK FOUND.
- THE AXIAL CRACKS AVERAGED IN DEPTH BETWEEN 36 AND 41% THROUGHWALL.
- THE BURST STRENGTHS OF THE AXIAL FLAWS SIGNIFICANTLY EXCEEDED THE REGULATORY GUIDE 1.121 REQUIREMENTS, WITH NO AT TEMPERATURE LEAKAGE FOUND.

CONCLUSIONS

- AXIAL CRACKS (CONTINUED)
 - PROPAGATION OF THE AXIAL DEFECTS IS STRESS DRIVEN AND LIMITED TO THE CONTACT AREA BETWEEN THE TUBE AND TUBE SUPPORT.
- CIRCUMFERENTIAL / AXIAL CRACKS
 - THE MOST LIKELY CHEMICAL CONTRIBUTORS TO BOTH THE CIRCUMFERENTIAL AND AXIAL DEFECT INITIATION ARE SULFUR, LEAD OR A COMBINATION OF BOTH IN AN ACIDIC CREVICE ENVIRONMENT.

FUTURE PLANS

2R9 INSPECTION PLANS

- INSPECTION SCOPE
 - 100% HOT LEG MRPC ON BOTH STEAM GENERATORS
 - 20% COLD LEG MRPC ON BOTH STEAM GENERATORS
 - 100% FULL LENGTH BOBBIN ON BOTH STEAM GENERATORS
 - SELECTED TUBE SUPPORT PLATE LOCATIONS TESTED WITH MRPC
 - IF ANY CIRCUMFERENTIAL CRACKS ARE IDENTIFIED, A TUBE PULL WILL BE PERFORMED

- EDDY CURRENT ANALYSIS
 - REVISED ANALYST GUIDELINES
 - PERFORMANCE DEMONSTRATION PROGRAM
 - * TWO DAYS OF CLASSROOM AND ANALYST TRAINING
 - * ONE DAY PERFORMANCE DEMONSTRATION TESTING

 - INDEPENDENT COMPANY FOR SECONDARY ECT ANALYSIS

GROWTH RATE EVALUATION

- GROWTH RATE
 - REVIEW HISTORICAL TUBESHEET INDICATIONS
 - COMPARE TUBE-TO-TUBE DATA
 - EVALUATE TOTAL POPULATION OF INDICATIONS
 - PERFORM DEGRADATION ANALYSIS
 - * INDUSTRY DATA
 - * VENDOR SPECIFIC
 - PERFORM TUBE PULL ANALYSIS
- PERFORM LEAK RATE ASSESSMENT
 - PROJECT DISTRIBUTION OF END OF CYCLE INDICATIONS
 - DETERMINE LEAK RATE VERSUS CIRCUMFERENTIAL CRACK LENGTH UNDER STEAM LINE BREAK AND NORMAL OPERATING CONDITIONS
 - DETERMINE BURST STRENGTH VERSUS CIRCUMFERENTIAL CRACK LENGTH
- DEVELOP DEGRADATION PROJECTIONS
 - PROJECT NUMBER OF ANTICIPATED INDICATIONS
 - ASSESS IMPACT OF T HOT REDUCTION

STEAM GENERATOR STRATEGY

- PROCEDURALIZED ADMINISTRATIVE SHUTDOWN LIMIT FOR STEAM GENERATOR LEAKAGE OF LESS THAN OR EQUAL TO 0.1 GPM. THE TECHNICAL SPECIFICATION LIMIT IS 0.5 GPM
- DEDICATED CONTROL ROOM ALARM 2K11 B-3 "SECONDARY SYSTEMS RADIATION HIGH"-COLOR CODED
- DEDICATED CONTROL ROOM TREND RECORDERS
 - STEAM GENERATOR BLOWDOWN LIQUID MONITORS FOR BOTH STEAM GENERATORS
 - MAIN STEAM LINE RADIATION MONITORS FOR BOTH STEAM GENERATORS
 - CONDENSER VACUUM PUMP DISCHARGE MONITOR
- PROCEDURALIZED VARIABLE ALARM SETPOINTS
 - STEAM GENERATOR BLOWDOWN LIQUID MONITORS FOR BOTH STEAM GENERATORS
 - CONDENSER VACUUM PUMP DISCHARGE MONITOR
- MONITORING / TRACKING
 - CHEMISTRY MONITORING / GRAPHS (ARGON, TRITIUM)
 - OPERATOR LOGS / INDICATIONS
- SPECIFIC SIMULATOR TRAINING
 - SMALL LEAKS
 - TUBE RUPTURES

STEAM GENERATOR STRATEGY (CONTINUED)

- ANO INSPECTION PHILOSOPHY
 - CURRENT WITH INDUSTRY STANDARDS AND CAPABILITIES
 - ACTIVE DAMAGE MECHANISM - THOROUGH, AGGRESSIVE INSPECTION PLANS TO PRECLUDE EXCEEDING STRUCTURAL OR TUBE LEAKAGE DESIGN BASIS CONDITIONS (I.E., CURRENT 100% MRPC OF TUBESHEET REGION ON BOTH STEAM GENERATOR'S HOTLEGS)
 - POTENTIAL DAMAGE MECHANISM - REPRESENTATIVE AND STATISTICALLY ACCEPTABLE MONITORING PROGRAMS (I.E., CURRENT 20% MRPC OF SLUDGE PILE REGION FOR STEAM GENERATOR'S COLD LEGS)

- MODIFICATIONS
 - IN-LINE ION CHROMATOGRAPHY
 - N16 GAMMA SPECIFIC MONITORS
 - MORPHOLINE INJECTION
 - T HOT REDUCTION

- CORPORATE STEAM GENERATOR POSITION ESTABLISHED

- STEAM GENERATOR INTEGRITY COMMITTEE (SGIC) IS IN PLACE TO ADDRESS STEAM GENERATOR ISSUES

- STEAM GENERATOR OVERSIGHT COMMITTEE, COMPRISED OF MANAGEMENT PERSONNEL WAS RECENTLY FORMED TO REVIEW SGIC ACTIONS AND PROVIDE RECOMMENDATIONS FOR LONG TERM ACTIVITIES

CLOSING REMARKS