ATTACHMENT 1 TO AEP:NRC:1166AI

COOK STEAM GENERATOR U1R97

CONDITION MONITORING AND OPERATIONAL ASSESSMENT

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1.0 Introduction

The Cook Unit 1 steam generators were inspected with various types of eddy current testing methods at the EOC-15 1997 scheduled outage. The inspection was the most thorough ever performed at Cook Unit 1, and included the following for each steam generator:

- 100% full length BC
- 100% full depth hot leg tubesheets from TEH to TSH + 3" with RPC
- 20% full depth cold leg tubesheets from TEC to TSC + 3" with RPC
- 100% U-bend exam of rows 1 and 2 (expanded to row 3 in one SG) with RPC
- Inspection of distorted or non-quantifiable BC signals with RPC
- Inspection of all dents at support plates with bobbin voltage > 5.0 volts
- Inspection of all support plate residuals that could mask a BC signal
- 100% plus point inspection of all inservice HEJ sleeves

2.0 Executive Summary

A number of different tube degradation mechanisms were identified and characterized by the ECT methods utilized during the inspection. In some cases, a non-qualified sizing technique may have been utilized to aid in the characterization of the indications for in-situ selection processes and verification of tube integrity. Results of the ECT and this assesment noted no indications were of such severity that the steam generators would not have maintained tube integrity for the EOC-15, based upon RG 1.121 requirements. The evaluation for tube integrity mainly focused on leakage, as the location of the majority of the indications within the tubesheet eliminated the tube rupture concern. Based upon the in-situ testing performed during the U1R97, the steam generator tubes maintained adequate margin against tube rupture under bounding conditions and also against the allowable leakage under postulated accident conditions for cycle 15 operation.

Based upon the results of in-situ testing, the population of indications at EOC-15, historical review of past ECT data, and evaluations presented in this report, the Unit 1 steam generator tubes will maintain adequate margin against tube rupture and accident leakage requirements specified in RG 1.121 through the end of the current cycle (cycle 16).

3.0 Secondary Side Pressure Test at EOC-15

Based upon the shutdown leakage values that were calculated by plant monitoring equipment, a secondary side pressure test was performed on all four steam generators to pinpoint primary-secondary side leakage identified during operation. The testing was performed by holding a nitrogen overpressure on the secondary side which created a delta P of approximately 400 psi. The estimated breakdown of the leak rates prior to shutdown, was as follows:

- SG 11 - 25.63 gpd
- SG 12 - 0.59 gpd
- SG 13 - 2.31 gpd
- SG 14 - 1.13 gpd

The results of the test were consistent with the calculated leak rates obtained during operation, in that most leakage observed during the test was observed in SG 11. The following table is a summary of the leaking locations and the status of the tubes during cycle 15 operation.

Table 3-1
Identified Leaking Locations During
Secondary-Primary Pressure Testing

SG	Row	Column	Leak Evaluation	Tube Status/Likely Source
11	16	27	Dripping	HEJ Sleeve/Trapped residual water
	18	37	Dripping Hard	Rerolled 1995/Reroll Joint
	31	37	Dripping	HEJ Sleeve/Trapped residual water
	20	41	Dripping	Rerolled 1995/ODSCC TSH
	1	47	Dripping *	Inservice Tube/PWSCC U-bend
	5	54	Dripping	Rerolled 1995/Reroll Joint
	20	71	Dripping	Rerolled 1995/Reroll Joint
13	8	31	Moist	Rerolled 1995/Reroll Joint
	4	44	1 drip/25 sec.	Rerolled 1995/Reroll Joint
	4	50	1 drip/3 min.	Rerolled 1995/Reroll Joint
14	29	19	1 drip	Inservice Tube/ODSCC TSH
	26	48	1 drip/2 min.	Inservice Tube/ODSCC TSH
	30	49	1 drip/6 min.	Inservice Tube/ODSCC TSH

* - Location was dripping from C/L only.

4.0 Evaluation of Tube Degradation at EOC-15

4.1 PWSCC in U-bends

The original U1R97 scope for the U-bend inspection was a 100% inspection of rows 1 and 2 in SG 11. During the previous outage, a sample inspection was conducted in one SG (SG 14) for U-bend PWSCC, using a rotating coil technique. No indications were detected at that time.

Based upon the detection of axial and circumferential indications in row 1 of SG 11, the U1R97 scope was expanded to encompass 100% of the row 1 and 2 U-bends in the remaining steam generators. This inspection identified six, eight, and eight tubes with indications in SGs 11, 12, and 13, respectively. No indications were detected in SG 14, which was consistant with inspection results from the previous outage.

SG 11 also had two detected indications in the row 2 U-bend, therefore, the scope of the inspection was conservatively expanded in that steam generator to 100% of row 3 tubes. As expected, no row 3 indications were detected in the U-bend region. No other SGs contained row 2 U-bend indications.

The following table summarizes the information pertaining to the PWSCC indications that were detected in the low row U-bend region.

Table 4-1
U-bend Indication Data

SG	Row	Column	Location of Indication	Orientation of Indication	RPC Voltage	Size of Indication
11	1	47	07C + 5.06"	Circumferential	17.71	0.84"/111°
	1	43	07H + 8.86"	Circumferential	4.32	0.54"/71°
	1	45	07H + 5.22"	Circumferential	2.80	0.55"/72°
	1	84	07H + 10.2"	Circumferential	7.89	0.65"/86°
	2	69	07H + 14.1"	Axial	2.06	0.22"
	2	86	07H + 6.06"	Axial	2.84	0.28"
12	1	72	07H + 9.81"	Circumferential	2.58	0.35"/46°
	1	73	07H + 10.02" 07H + 10.68"	Axial Circumferential	1.61 2.27	0.33" 0.35"/46°
	1	79	07H + 9.75"	Axial	1.24	0.45"
	1	80	07H + 4.20"	Axial	3.42	0.40"
	1	82	07H + 9.12"	Axial	3.82	0.33"
12	1	84	07H + 8.81"	Axial	.79	0.27"
	1	85	07H + 8.74" 07H + 9.56"	Axial Axial	.66 1.62	0.30" 0.30"
	1	86	07H + 8.60" 07H + 9.37"	Axial Axial	.89 1.57	0.27" 0.30"
13	1	21	07H + 4.32"	Circumferential	9.00	0.85"/112°
	1	23	07H + 9.66"	Circumferential	3.27	0.48"/63°
	1	27	07H + 4.34"	Circumferential	8.90	0.77"/102°
	1	31	07H + 4.19"	Axial	6.34	0.50"
	1	40	07H + 3.80"	Circumferential Same plane	16.30 21.20	0.68"/89° 0.73"/96°
	1	77	07H + 6.99"	Circumferential	5.06	0.60"/79°
	1	81	07H + 10.95"	Circumferential	11.32	0.78"/102°
	1	86	07H + 10.49"	Axial	18.09	0.64"

Location 1-47 in SG 11 was selected as a in-situ test candidate because it was a known leaking location and offered an indication with a (relatively) high voltage magnitude and length. Location 1-40 in SG 13 was selected for in-situ testing because it was the next bounding indication for characterization of leakage through a U-bend circumferential indication. The axial indications, locations 1-86 in SG 13 and 1-80 in SG 12 were

selected as the bounding axial indications in the U-bend, based upon voltage and length. The following table represents the locations tested and the results of the testing.

Table 4-2
Results of U-bend In-situ Testing

SG	Row	Column	Indication	Pressure Test Results (gpd)		
				NOP	MSLB	3 x NOP
11	1	47	Circ.	0.0	0.71	13.56
12	1	80	Axial	0.0	0.0	0.0
13	1	40	Circ.	0.0	0.0	0.0
	1	86	Axial	11.84	44.84	628.9

Based upon these results, all of the indications met the structural requirements of RG 1.121, with respect to tube burst. In order to address accident leak rates at EOC-15, all of the U-bend circumferential indications were conservatively assigned an accident leak rate of 0.71 gpd, even though location 1-40 had zero leakage and bounded the remaining population of circumferential indications. The U-bend axial indications were assigned a conservative leak rate of 44.84 gpd for each indication, except for location 1-80, where testing showed zero leakage, and bounded the remaining population of axial indications.

4.2 PWSCC in OEM Roll Transition

The TSH inspection included all of the inservice OEM roll transition regions of the tubes in the hot leg. The inspection detected a total of 635 tubes with axial PWSCC type indications, distributed as follows: 171 in SG 11, 128 in SG 12, 248 in SG 13, and 88 in SG 14.

The number of indications was much larger than expected. This is attributed to the enhanced ECT inspection technique utilized in the current outage and the previously identified issues with the analysis of the Cecco-5 data in the previous inspection. The indications were typical in size and characterization to those previously detected in the Unit 1 steam generators. No indications were characterized as being of sufficient severity to potentially not meet the leakage requirements of RG 1.121, nor were they expected to be, based upon in-situ testing at other PWR SGs and laboratory testing. However, due to the sheer magnitude of the population of tubes affected and as a baseline for Unit 1, in-situ test candidates were chosen based upon the largest voltage, axial length and location within the roll transition. These indications are not a concern for rupture due to confinement within the tubesheet but two indications were conservatively selected for in-situ testing to quantify the population's leakage

contribution during accident conditions. The following table provides the indications and the results of the testing.

Table 4-3
Results of PWSCC in Roll Transition In-situ Testing

SG	Row	Column	Location of Indication	RPC Voltage	Length	Results of In-situ Testing		
						NOP	MSLB	3 x NOP
11	3	59	BRT + 0.14"	8.39	0.41"	0.0	0.0	N/A
	25	64	BRT + 0.19"	4.97	0.45"	0.0	0.0	N/A

Based upon the results of the in-situ testing performed on axial PWSCC in OEM roll transitions, no leakage at EOC-15 is attributed to these types of indications. This further supports the industry's data that these indications are very tight and leakage of this type is very minute.

4.3 PWSCC in Reroll Roll Transition

The RPC inspection of inservice rerolled tubes identified a total of 55 locations that developed new axial PWSCC in the reroll roll transition. The appearance of this damage mechanism is not unexpected due to the increased stress applied to the tube during the process. It also confirms the need for continuing inspection of rerolled tubes in future inspections.

The breakdown of the locations is as follows: 16 in SG 11, 4 in SG 12, 29 in SG 13, and 6 in SG 14. These indications were screened utilizing voltage, length and proximity to the roll transition as criteria for selection of in-situ pressure testing. The majority of the population had very small lengths and the voltages were < 1.5 volts from RPC. Locations 11-35 in SG 11 and 21-25 in SG 12 were selected as the best in-situ candidates based upon the aforementioned screening criteria. These indications bounded the remaining population of tubes with this type of degradation.

Table 4-4
Results of PWSCC in Reroll Roll Transition In-situ Testing

SG	Row	Col	Location of Indication	RPC Voltage	Length	Results of In-situ Testing		
						NOP	MSLB	3 x NOP
11	11	35	BRT + 0.34"	5.52	0.21"	0.0	4.2	N/A
12	21	25	BRT + 0.12"	11.16	0.36"	0.0	0.0	N/A

Based upon the results of the in-situ testing performed on axial PWSCC in reroll roll transitions, a conservative accident leak rate of 4.2 gpd is applied to these indications detected at EOC-15, even though the testing of location 21-25 bounded the remaining population of indications.

4.4 ODSCC in Crevice/TTS

During the full depth inspection of the hot leg tubesheet region, indications were also identified at or near the secondary face of the tubesheet by both bobbin coil and RPC techniques. Some of these indications were large in signal voltage response from both examinations. These indications were assessed to determine their impact on SG tube integrity for the last cycle. The total number of tubes with indications detected was 829, with 245 in SG 11, 99 in SG 12, 206 in SG 13, and 287 in SG 14.

The indications were axial in nature, except for four indications that were reported as circumferential in SG 12. This is not believed to truly be the case, as there is no stress in the unexpanded portion of the tubes to initiate a circumferential indication, as well as no denting in these locations. Based upon previous tube pull specimen metallography from Unit 1 for OD degradation in this region, axial indications closely lined up and extending around the circumference of the tube can appear to be a circumferential indication by ECT techniques. In addition, these four indications exhibited the same type ECT signal identified with the tube pull specimens.

A historical review of the largest indications from 1995 bobbin inspection has shown that these indications were present, but were not confirmed by the Cecco probe inspection performed at that time. A re-analysis of the Cecco data from the EOC-14 was conducted during the current inspection using improved analysis techniques. The re-analysis identified that a large number of indications were not confirmed or detected during the previous inspection. The largest indications were also traced back to the 1994 RPC inspection (0.080" coil). Most had a very small ECT response which is believed to be the precursor to the indications that were detected during the current inspection. This investigation confirms that these indications do not have a significant growth rate and the majority are considered "two-cycle" indications. The data is contained in Table 4-5.

Location 20-41 in SG 11, and locations 26-48, 29-19, and 30-49 in SG 14 were selected for in-situ testing based upon the results of the secondary side hydro test, RPC voltage response, axial length, and their proximity to the top of the secondary face of the tubesheet. Additional indications, 16-8, and 14-40 in SG 12 and 9-71 in SG 13 were selected and tested to bound the results obtained from the leaking tubes. These tubes were also selected based upon the size of the indications, voltage response, magnitude, size in length, and proximity to the top of the tubesheet.

Table 4-5
Largest ODSCC Indications in TS/Crevice Region

SG	Row	Col	Location of Indication	Orientation of Indication	RPC Voltage	1997 RPC Size of Indication	1997 Bobbin Voltage and Call	1995 Bobbin Historical Review	1995 Cecco 5 Re-analysis	1994 RPC Historical Review (0.080" coil)
11	12	55	TSH - 5.08"	Axial	9.70	0.63"	NDD	NDD	Flaw Present w/ deposit influences	NDD
	12	56	TSH - 3.06"	Axial	14.83	.0.49"	NDD	NDD	Flaw Present	NDD
	13	57	TSH - 7.41" TSH - 6.26"	Axial Axial	13.98	1.74" 0.62"	NDD	NDD	Flaws Present w/ deposit influences	NDD
	14	29	TSH - 0.27"	Axial	2.66	0.97"	DTI 1.29 volts	Flaw Present	Flaw Present	Flaw Present
	20	41	TSH - 0.51"	Axial	9.03	0.84"	DTI 5.32 volts	Flaw Present	Flaw Present	Flaw Present
12	14	40	TSH + 0.00"	Circ.	1.33	2.1"/273°	NDD	Flaw Present	Flaw Present	0.43"/57°
	12	42	TSH + 0.00"	Circ.	1.62	1.69"/221°	NDD	Flaw Present	Flaw Present	0.92"/121°
	12	34	TSH - 3.96"	Axial	2.22	0.4"/0.53"	NDD	NDD	Flaw Present	NDD
	16	8	TSH - 0.67"	Axial	2.94	0.80"	DTI 4.16 volts	Flaw Present	Flaw Present	Flaw Present
	16	45	TSH - 1.69" TSH - 2.38"	Axial	2.69 2.89	0.76" 0.79"	DTI 1.23 volts	NDD	Flaw Present	NDD
	38	31	TSH - 0.81"	Axial	2.12	0.44"	NQI 1.35 volts	Flaw Present	Flaw Present w/ deposit influences	NDD
13	3	69	TSH - 0.41"	Axial	3.51	0.94"	NDD	Flaw Present	Flaw Present	NDD
	4	28	TSH - 1.08"	Axial	2.15	1.65"	NQI 0.96 volts	Flaw Present	Flaw Present	NDD
	9	71	TSH - 1.80"	Axial	2.19	4.11"	NDD	Flaw Present	Flaw Present	NDD
14	8	16	TSH - 0.80"	Axial	2.91	0.43"	NQI 1.97 volts	Flaw Present	Flaw Present w/ deposit influence	Flaw Present
	8	17	TSH - 0.92"	Axial	3.62	1.03"	NQI 4.37 volts	Flaw Present	Flaw Present w/ deposit influence	Flaw Present
	8	61	TSH - 0.58"	Axial	2.03	0.52"	NDD	Flaw Present	Flaw Present w/ deposit influence	Flaw Present
	10	17	TSH - 0.79"	Axial	2.41	0.75"	NQI 4.08 volts	Flaw Present	Flaw Present w/ deposit influence	Flaw Present
	11	19	TSH - 0.69"	Axial	2.48	1.01"	DTI 9.90 volts	Flaw Present	Flaw Present w/ deposit influence	Flaw Present
	15	11	TSH - 1.03"	Axial	4.97	0.54"	NQI 3.38 volts	Flaw Present	Flaw Present	Flaw Present
	16	32	TSH + 0.24"	Axial	4.18	0.37"	NDD	Flaw Present	Flaw Present w/ deposit influence and distorted by dent	Flaw Present
	17	31	TSH - 2.94"	Axial	2.38	0.83"	NDD	NDD	Flaw Present	NDD
	21	34	TSH - 0.56"	Axial	5.01	0.71"	DTI 3.78 volts	Flaw Present	Flaw Present w/ deposit influence	Flaw Present
	24	31	TSH - 1.01"	Axial	13.6	1.10"	NQI 5.02 volts	NDD	Flaw Present	Flaw Present
	26	48	TSH - 0.96"	Axial	8.29	1.20"	NQI 3.56 volts	Flaw Present	Flaw Present	Flaw Present
	29	19	TSH - 1.00"	Axial	3.22	1.23"	NQI 6.15 volts	Flaw Present	Flaw Present w/ deposit influence	Flaw Present
	30	49	TSH - 0.80"	Axial	3.22	0.84"	NQI 4.42 volts	Flaw Present	Flaw Present	Flaw Present
	30	56	TSH - 0.85"	Axial	5.52	0.96"	DTI 4.41 volts	Flaw Present	Flaw Present w/ deposit influence	Flaw

The results of the testing, contained in the Table 4.6 below, bound the large population of indications that were detected at EOC-15 in this region. For axial indications with RPC voltages >3 volts, a conservative leak rate of 7.5 gpd is assigned to each indication, for those indications < 3 volts, based upon the testing, a leak rate of zero was assigned. Additionally, for circumferentially oriented indications, no leak rate is assigned, based upon the testing performed. The leak rates are factored into the total steam generator leakage based upon the population of indications and their voltage, for each steam generator.

Table 4-6
Results of ODSCC in Tubesheet Region In-situ Testing

SG	Row	Col	Location of Indication	RPC Voltage	Length	Results of In-situ Testing		
						NOP	MSLB	3 x NOP
11	20	41	TSH - 0.51"	9.03	0.84"	1.7	7.5	317.3
12	16	8	TSH - 0.67"	2.94	0.80"	0.0	0.0	0.0
	14	40	TSH - 0.00"	1.62	1.03"/154°	0.0	0.0	0.0
13	9	71	TSH - 1.80"	2.19	4.11"	0.0	0.0	0.0
14	26	48	TSH + 0.29"	1.35		-	-	-
			TSH - 0.96"	8.19	1.20"	0.0	0.0	0.0
	29	19	TSH - 1.00"	3.22	1.23"	0.0	0.0	0.0
	30	49	TSH - 0.80"	3.22	0.84"	0.0	0.0	0.4

4.5 ODSCC at TSPs

The required calculations for the as-found conditions of the steam generators, with respect to the population of ODSCC type indications at hot leg support plate intersections, was performed. The calculated probability of burst is well below the required 1×10^{-2} threshold. Additionally, the associated leak rates are consistent with previous calculations performed for Unit 1 and are also well below the allowable 8.4 gpm limit. The largest bobbin coil indication at a TSP detected during the inspection was 1.73 volts. The calculated leak rates were factored into the total limiting steam generator for EOC-15 leakage evaluation. The results of the calculations are contained in Table 4-7 below.

Table 4-7
Results of TSP ODSCC ARC Calculations for EOC-15

SG	Number of Indications	Conditional Leak Rate Results (gpd)	Probability of Burst Results
11	369	607.5	1.56×10^{-5}
12	169	361.5	9.72×10^{-6}
13	160	164.4	6.02×10^{-6}
14	355	583.8	1.56×10^{-5}

4.6 Cold Leg Thinning

Based upon the size of the detected cold leg thinning during U1R97, no indications were a concern with respect to tube integrity requirements. No contribution to leakage at EOC-15 is attributed to this type of tube degradation.

4.7 AVB Wear

Based upon the size of the detected AVB wear during U1R97, no indications were a concern with respect to tube integrity requirements. No contribution to leakage at EOC-15 is attributed to this type of tube degradation.

4.8 HEJ Sleeves

4.8.1 Sleeves with Indications

Sleeves that had indications detected by the plus point above the hard roll region of the HEJ were also considered as potential candidates for in-situ pressure testing. The indications at the upper expansion transition are of particular interest because of the potentially short leak path through the top of the sleeve through the flaw and into the secondary side. A summary of the indications that were detected in the HEJs above the hard roll region of the HEJ joint and were considered as in-situ candidates, is contained in Table 4.8. Two locations were selected for in-situ pressure testing. Tubes 33-23 and 17-31 in SG 13 were tested based upon the relative size, type, and location of the indications within the upper region of the joint.

Table 4-8
HEJ Sleeve Indication Data

SG	Row	Col	Location	'97 +Pt Voltage	Orientation	Size	CECCO-5 1995 Review
11	6	31	UEZ	1.06	Circ.	0.29"/46°	NDD
	19	27	UUE	1.64	Axial	.30"	NDD
	20	44	UUE	4.74	Circ.	.44"/77°	NDD
	20	51	URT	1.92	Circ.	.15"/27°	NDD
	29	36	UUE	3.04	Circ. Circ.	.31"/42° .23"/30°	PTI PTI
	33	20	UUE	1.66	Circ.	.44"/77°	NDD
	38	64	UEZ	1.61	Circ.	.25"/46°	NDD
12	15	24	UUE	2.49	Circ. Axial	.24"/38° .14"	NDD NDD
	16	29	UUE	3.24	Circ.	.44"/77°	NDD
	16	49	UUE	5.30	Axial	.26"	NDD
	16	78	UUE	4.56	Circ. Circ.	.28"/38° .44"/78°	NDD NDD
	20	43	UUE	2.18	Circ.	.28"/38°	NDD
	20	44	UUE	0.67	Circ.	.19"/25°	NDD
	21	24	UUE	2.41	Circ.	.25"/46°	NDD

Table 4-8
HEJ Sleeve Indication Data
(cont.)

SG	Row	Col	Location	'97 +Pt Voltage	Orientation	Size	CECCO-5 1995 Review
13	5	22	UUE	1.62	Circ.	.50"/66°	NDD
	5	53	URT	1.53	Circ.	.44"/58°	NDD
					Circ.	.26"/ 35°	NDD
	11	53	URT	1.81	Circ.	.26"/35°	NDD
	15	54	UUE	5.77	Axial	.44"	NDD
	17	31	UUE	31.37	Circ.	.41"/54°	NDD
	22	65	URT	0.77	Circ.	.35"/46°	NDD
	23	45	URT	1.62	Circ.	.17"/23°	NDD
	33	23	URT	0.96	Circ.	.23"/31°	NDD

Neither of the locations developed any leakage during the pressure testing, which included equivalent pressures for NOP, MSLB, and 3 x NOP conditions. Based upon these results, the sleeves with indications were conservatively assigned a leak rate for EOC-15 equivalent to the licensing basis leak rate for a HEJ sleeve, or 0.0046 gpd per sleeve.

4.8.2 Sleeves with No Indications

Based upon the results of the secondary side hydro testing, the two sleeved locations in SG 11 that were identified as having minimal leakage (Table 1-1), were in-situ pressure tested to verify integrity of the joints within the sleeve. Both tubes were full tube tested to a room temperature pressure equivalent to 3 x NOP at temperature, with no signs of leakage during any portion of the test. Based upon these results, the assumed leakage for these two locations during a MSLB for EOC-15 is assumed to be the licensed leak rate of 0.0046 gpd per sleeve.

4.9 Rerolled Tubes Exhibiting Leakage

Three in service re-rolled locations were noted as leaking during the secondary side hydro test. These locations were in-situ pressure tested to quantify the leak rate during postulated accident conditions. The locations and the results of the test are noted in Table 4-9. Tube 18-37 in SG 11 exhibited significantly more leakage during both the pressure and in-situ tests than the other re-roll leaking tubes. Additional review was performed to account for this difference. A review of 1995 ECT and reroll data noted tube 18-37 had a typical size flaw prior to re-roll operations. Post reroll ECT indicated that the re-roll operations had increased the flaw size. 1997 ECT data noted that the flaw size had again increased during the previous cycle to the point of being throughwall. Reroll installation data confirmed that the tube had a marginally acceptable diametrical expansion that was unable to provide a leaktight seal. Comparisons between tube 18-37 and the other leaking

locations determined that tube 18-37 had less expansion than the other two tubes. ECT results noted this indication also had a much larger voltage than the other leaking locations. It is believe that the combination of these factors account for the higher leakrate observed from tube 18-37.

A review of the diametrical expansion data of all previously installed rerolls was performed. 119 locations were identified as having marginal expansion and were re-rerolled. Additionally, an ECT review was conducted to identify any similar indications to tube 18-37. This review identified two other tubes with similar ECT indications, but which had exhibited no leakage during the hydro test. These tubes were selected for in-situ testing in order to verify the integrity of the remaining population of rerolled tubes. Post reroll leak testing was also performed to assure the success of the reroll process. No leaking tubes were found during this test.

Table 4-9
Summary of Rerolled Tubes In-situ Tests

SG	Row	Col	Type	Location	Voltage	Pressure Test Results (gpd)		
						NOP	MSLB	3 x NOP
11	18	37	LRT	SAI @ BRT - 1.67"	18.91	100.7	196.6	N/A
				Re-test	-	37.8	58.1	N/A
13	4	44	LRT	MAI @ BRT - 1.67"	14.40	0.9	1.7	N/A
	8	31	LRT	MAI @ BRT - 1.74"	7.60	0.0	0.0	N/A
	24	24	RT	MAI @ BRT - 1.67"	8.09	0.0	0.0	0.0
	3	70	RT	MAI @ BRT - 1.98"	14.83	0.0	0.0	0.0

Based upon these results, a conservative leak rate of 196.6 gpd was assigned to reroll locations that were leaking during the secondary side hydro test, except for those that have specific in-situ test results. The remaining reroll indications were bounded by the testing of locations 24-24 and 3-70 in SG 13, which exhibited zero leakage during both pressure tests. The licensed accident leak rate value of 0.000423 gpd per in service reroll location was applied to the remaining population of rerolled tubes at EOC-15.

5.0 Tube Integrity Evaluation at EOC-15

5.1 Burst Capability

The indications evaluated against the tube rupture requirements of RG 1.121 were in-situ tested up to bounding equivalent pressures of 3 x NOP. These indications were in the U-bend region and at the top of the hot leg tubesheet. None of the indications tested ruptured during the test, and those that leaked during the test did not leak beyond the capacity of the test system (1 gpm @ MSLB equivalent) and are classified as not ruptured. Therefore, at EOC-15, there were no tubes that would have ruptured under postulated accident conditions, nor under bounding 3 x NOP conditions. Therefore, the Unit 1 steam generators met the requirements of RG 1.121 for tube integrity for cycle 15.

5.2 Total Leakage Evaluation

The total leakage evaluation is based upon a cumulative assessment approach that assigns conservative leak rates based upon in-situ pressure test results to each damage mechanism, or licensed non-leak tight repair technique (HEJs and rerolled tubes). Tables 5-1 through 5-4 itemize the leak rates for each steam generator during EOC-15. The bounding steam generator was SG 11 with a postulated leak rate under accident conditions of 0.69 gpm, well within the allowable 8.4 gpm 10CFR100 limits. Table 5-5 is a compilation of all in-situ testing performed and the results of each test.

Table S-1 SG 11 EOC-15 Cumulative Leakage Summary				
CATEGORY	Number of Locations	Leak Rate (gpd)	Leak Rate Total per Type	Category Total
Tubes with HEJ sleeves (826 tubes)				
• Sleeves In-situ Tested	2	0.00	0.00	
• Sleeves w/ Ind. above Hard Roll Region	7	0.0046	0.03	
• Remaining Sleeves	817	0.0046	3.76	3.79
Tubes Previously Rerolled (245 tubes)				
• RR w/ OEM RT Indications > 14 volts	3	58.10	174.30	
• RR w/ OEM RT Indications 8-14 volts	3	1.70	5.10	
• Remaining Rerolled Tubes	223	0.000423	0.09	
• New Indications in Reroll RT	16	4.20	67.2	246.69
PWSCC in OEM RT (174 ind. in 171 tubes)				
• Indications In-situ Tested	2	0.00	0.00	
• Remaining RT Indications	172	0.00	0.00	0.00
ODSCC at TSPs	369	Calculated per GL 95-05		607.50
U-bend PWSCC (6 ind. in 6 tubes)				
• Circumferential Indications	4	0.80	3.20	
• Axial Indications In-situ Tested	2	44.80	89.60	
• Remaining Axial Indications	0	0.00	0.00	92.80
TTS ODSCC (263 ind. in 245 tubes)				
• Circ. Oriented Indications	0	0.00	0.00	
• Axial Indications > 3 volts	5	7.50	37.50	
• Axial Indications < = 3 volts	258	0.00	0.00	37.50
Cold Leg Thinning (100 ind. in 80 tubes)	100	0.00	0.00	0.00
AVB Wear (8 ind. in 5 tubes)	8	0.00	0.00	0.00
Steam Generator Total (gpd)				988.28
Steam Generator Total (gpm)				0.69

Table S-2 SG 12 EOC-15 Cumulative Leakage Summary				
CATEGORY	Number of Locations	Leak Rate (gpd)	Leak Rate Total per Type	Category Total
Tubes with HEJ sleeves (180 tubes)				
• Sleeves w/ Ind. above Hard Roll Region	7	0.0046	0.03	
• Remaining Sleeves	173	0.0046	0.80	0.83
Tubes Previously Rerolled (117 tubes)				
• RR w/ OEM RT Indications > 14 volts	0	58.10	0.00	
• RR w/ OEM RT Indications 8-14 volts	1	1.70	1.70	
• RR w/ OEM RT Indication In-situ Tested	1	0.00	0.00	
• Remaining Rerolled Tubes	110	0.000423	0.05	
• New Ind. in Reroll RT In-situ Tested	1	0.00	0.00	
• Remaining New Ind. in Reroll RT	4	4.20	16.80	18.55
PWSCC in OEM RT (128 ind. in 128 tubes)				
• RT Indications	128	0.00	0.00	0.00
ODSCC at TSPs	169	Calculated per GL 95-05		361.50
U-bend PWSCC (10 ind. in 8 tubes)				
• Circumferential Indications	1	0.80	0.80	
• Axial Indications In-situ Tested	1	0.00	0.00	
• Remaining Axial Indications	8	44.80	358.40	359.20
TTS ODSCC (99 ind. in 91 tubes)				
• Circ. Oriented Indications In-situ Tested	1	0.00	0.00	
• Remaining Circ. Oriented Indications	3	0.00	15.00	
• Axial Indications > 3 volts	0	7.50	0.00	
• Axial Indications < = 3 volts	95	0.00	0.00	0.00
Cold Leg Thinning (89 ind. in 74 tubes)	89	0.00	0.00	0.00
AVB Wear (29 ind. in 21 tubes)	29	0.00	0.00	0.00
Steam Generator Total (gpd)				740.08
Steam Generator Total (gpm)				0.51

Table 5-3 SG 13 EOC-15 Cumulative Leakage Summary				
CATEGORY	Number of Indications	Leak Rate (gpd)	Leak Rate Total per Type	Category Total
Tubes with HEJ sleeves (459 tubes)				
• Sleeves In-situ Tested	2	0.00	0.00	
• Sleeves w/ Ind. above Hard Roll Region	8	0.0046	0.04	
• Remaining Sleeves	449	0.0046	2.07	2.11
Tubes Previously Rerolled (493 tubes)				
• OEM RT Indications In-situ Tested	3	0.00	0.00	
• RR w/ OEM RT Indications > 14 volts	0	58.10	0.00	
• RR w/ OEM RT Indications 8-14 volts	5	1.70	8.50	
• Remaining Rerolled Tubes	456	0.000423	0.19	
• New Indications in Reroll RT	29	4.20	121.80	130.49
PWSCC in OEM RT (251 ind. in 248 tubes)				
• RT Indications	251	0.00	0.00	0.00
ODSCC at TSPs	160	Calculated per GL 95-05		164.40
U-bend PWSCC (9 ind. in 8 tubes)				
• Circ. Indications In-situ Tested	1	0.00	0.00	
• Remaining Circ. Indications	6	0.80	4.80	
• Axial Indications In-situ Tested	1	0.00	0.00	
• Remaining Axial Indications	1	44.80	44.80	49.60
TTS ODSCC (231 ind. in 206 tubes)				
• Circ. Oriented Indications	0	0.00	0.00	
• Axial Indications In-situ Tested	1	0.00	0.00	
• Axial Indications > 3 volts	3	7.50	30.00	
• Axial Indications < = 3 volts	227	0.00	0.00	30.00
Cold Leg Thinning (61 ind. in 55 tubes)	61	0.00	0.00	0.00
AVB Wear (66 ind. in 40 tubes)	66	0.00	0.00	0.00
Steam Generator Total (gpd)				376.60
Steam Generator Total (gpm)				0.26

Table 5-4 SG 14 EOC-15 Cumulative Leakage Summary				
CATEGORY	Number of Locations	Leak Rate (gpd)	Leak Rate Total per Type	Category Total
Tubes with HEJ sleeves (374 tubes)				
• Sleeves w/ Ind. above Hard Roll Region	0	0.0046	0.00	
• Remaining Sleeves	374	0.0046	1.72	1.72
Tubes Previously Rerolled (109 tubes)				
• RR w/ OEM RT Indications > 14 volts	0	58.1	0.00	
• RR w/ OEM RT Indications 8-14 volts	1	1.70	1.70	
• Remaining Rerolled Tubes	102	0.000423	0.04	
• New Indications in Reroll RT	6	4.20	25.2	26.94
PWSCC in OEM RT (88 ind. in 88 tubes)				
• RT Indications	88	0.00	0.00	0.00
ODSCC at TSPs	355	Calculated per GL 95-05		583.80
U-bend PWSCC				
• Circ. Indications	0	0.80	0.00	
• Axial Indications	0	44.80	0.00	0.00
TTS ODSCC (300 ind. in 287 tubes)				
• Circ. Oriented Indications	0	0.00	0.00	
• Axial Indications In-situ Tested	3	0.00	0.00	
• Axial Indications > 3 volts	6	7.50	45.00	
• Axial Indications <= 3 volts	291	0.00	0.00	45.00
Cold Leg Thinning (74 ind. in 69 tubes)	74	0.00	0.00	0.00
AVB Wear (23 ind. in 13 tubes)	23	0.00	0.00	0.00
Steam Generator Total (gpd)				657.43
Steam Generator Total (gpm)				0.45

Table 5-5
Summary of All In-situ Tests by Damage Mechanism
Cook 1 U1R97

SG	Row	Col	Location	Reason for Test	Pressure Test Results (gpd)		
					NOP	MSLB	3 x NOP
11	1	47	U-Bend	U-Bend PWSCC, leaker*	0.0	0.8	13.6
13	1	40	U-Bend	U-Bend PWSCC	0.0	0.0	0.0
					0.0	0.0	0.0
13	1	86	U-Bend	U-Bend PWSCC	11.8	44.8	628.9
12	1	80	U-Bend	U-Bend PWSCC	0.0	0.0	0.0
11	16	27	Sleeve	Apparent leaker*	0.0	0.0	0.0
11	31	37	Sleeve	Apparent leaker*	0.0	0.0	0.0
13	33	23	Sleeve	PTI @ HEJ sleeve	0.0	0.0	0.0
13	17	31	Sleeve	PTI @ HEJ sleeve	0.0	0.0	0.0
11	20	41	TTS	ODSCC @ TSH, leaker*	1.7	7.5	317.3
12	16	8	TTS	ODSCC @ TSH	0.0	0.0	0.0
12	14	40	TTS	ODSCC @ TSH	0.0	0.0	0.0
14	26	48	TTS	ODSCC @ TSH, leaker*	0.0	0.0	0.0
					0.0	0.0	0.0
14	29	19	TTS	ODSCC @ TSH, leaker*	0.0	0.0	0.0
14	30	49	TTS	ODSCC @ TSH, leaker*	0.0	0.0	0.4
13	9	71	TTS	ODSCC @ TSH	0.0	0.0	0.0
11	18	37	RT	Leaking rerolled tube*	100.7	196.6	N/A
				Retest	37.8	58.1	N/A
13	4	44	RT	Leaking rerolled tube*	0.9	1.7	N/A
13	8	31	RT	Leaking rerolled tube*	0.0	0.0	N/A
13	24	24	RT	Similar signal to 11-R18C37	0.0	0.0	N/A
13	30	70	RT	Similar signal to 11-R18C37	0.0	0.0	N/A
11	11	35	RRT	New PWSCC in RRT	0.0	4.2	N/A
12	21	25	RRT	New PWSCC in RRT	0.0	0.0	N/A
11	3	59	RT	PWSCC in OEM RT	0.0	0.0	N/A
11	25	64		PWSCC in OEM RT	0.0	0.0	N/A

* - Observed Leaking Under Hydro Test

6.0 Cycle 16 Operability Review

6.1 Assessment of Tube Rupture at EOC-16

Based upon the results of the ECT inspection performed during U1R97, tube burst under bounding worst case conditions at EOC-16 is not a concern.

Based upon the types and characteristics of the indications detected during the EOC-15 inspection, it is expected that the population of indications, as well as the severity of the indications, will bound future cycles at Unit 1. The majority of all large flaws (most of which are not a concern for tube burst due to location) are classified as "two-cycle" flaws, based upon review of historical data and the fact that the U-bends that had indications had not previously been inspected with a rotating technique. Therefore, the growth rate of the most limiting indications is based upon two cycles of operation and is not considered a concern for one cycle.

Due to the enhanced techniques utilized during the most recent inspection, and reanalysis of historical data from previous inspections, the indications detected at EOC-15 should bound any indications found in future inspections at Unit 1. The probability of detection is also increased due to the use of the enhanced ECT techniques and analyst site specific testing/training, both of which contribute to decreasing the likelihood of returning a significant indication to service for cycle 16.

The bounding indications for tube burst (U-bend PWSCC and TTS ODSCC) were in-situ tested to the room temperature equivalent bounding pressure differentials and did not rupture. Therefore, the likelihood of tube rupture under bounding RG 1.121 pressures (3 x NOP), is not a concern for these types of indications at EOC-16, and future inspections.

6.2 Assessment of Projected Leakage at EOC-16

Using the results of the ECT inspection performed at EOC-15, as well as the results from the in-situ pressure testing, an evaluation was performed for estimated leakage under postulated accident conditions on the last day of cycle 16. The leakage assessment uses the information obtained at EOC-15 to conservatively bound the leakage. Tables 6-1 through 6-4 provide the overall summary of the cumulative estimated leak rates for each steam generator at EOC-16, during MSLB conditions. The estimates show that SG 11 is the bounding steam generator.

Results show that the estimated cumulative leak rates for each steam generator are limited to well below the primary-to-secondary technical specification limit (8.4 gpm in a faulted loop during a potential steam line break event).

HEJ Sleeve Contribution

Based upon the results of the in-situ pressure testing of HEJ sleeves at EOC-15, the projected contribution of HEJ sleeves to the leak rate is based on the number of in service sleeves and the licensed accident leak rate of 0.000423 gpd per sleeve.

Rerolled Tubes

Based on the results of the ECT inspection and the re-evaluation of suspect rerolled tubes, the EOC-16 projected contribution to accident leakage is based on the number of rerolled tubes returned to service and the associated licensed leak rate value. Because there are two different types of in service rerolls (Westinghouse and FTI), the more conservative higher FTI leak rate will be used for all rerolled tubes left in service for cycle 16. This leak rate is 0.001081 gpd per reroll.

PWSCC in OEM Roll Transition

Because of the results of the ECT inspection, and the continuing progression of this tube degradation on Unit 1, it is anticipated that as many as 300 new indications may be present at EOC-16, with 75 in each SG. However, based on the testing performed at EOC-15 on the largest indications, the associated accident leak rate is zero. Additionally, based upon the ECT techniques used at EOC-15 compared to those used in past inspections, it is judged that the worst indications were present at EOC-15. Because of the increased probability of detection of both large and smaller flaws at EOC-15, the indications expected to be seen at EOC-16 will be bounded by those at EOC-15 which when in-situ tested, exhibited zero leakage.

ODSCC at Tube Support Plate Intersections

The required calculations were performed for both the probability of tube burst and accident leak rate, in accordance with GL 95-05 and WCAP 14277. The results are contained within the following tables. These results are consistent with previous Unit 1 analyses and are well within the allowable limits. The leak rates calculated as part of this evaluation are the largest contributor to the total projected leak rate at EOC-16. This is mostly due to the fact that the correlation between bobbin coil voltage response and predicted leak rate does not meet the 5% criteria. If such a correlation existed, the leak rates would be expected to be a fraction of the values currently calculated.

U-bend PWSCC

Due to the results of the U1R97 inspection and the industry's experience with this type of tubing degradation, it is expected that some small population of indications will exist at EOC-16. However, based upon the inspection techniques used at EOC-15, the fact that these indications were the first ever detected at Unit 1, and that the U-bends had not been previously examined with a rotating technique, the indications at EOC-15 should bound future populations of indications with respect to structural integrity. As a conservative measure, numbers of indications were postulated at EOC-16 to provide additional leakage to the projected cumulative leak rate.

ODSCC at Tubesheet Secondary Face

Based upon the results of the U1R97 inspection and plant specific experience with this type of tubing degradation, it is expected that a population of indications will exist at EOC-16. However, due to the inspection techniques used at EOC-15, the projected indications should be bounded by the largest detected at EOC-15 that were also traceable to the 1994 RPC inspection. As a conservative measure, numbers of indications were postulated at EOC-16 to provide additional leakage to the projected cumulative leak rate for each steam generator.

Assessment at EOC-16

Based upon the requirements of RG 1.121 and the Draft Reg. Guide for Condition Monitoring and Operational Assessments, a similar assessment will be performed at the EOC-16 for the conditions of the steam generators. It is the intent to apply the results of the in-situ testing at EOC-15 to the indications detected at EOC-16 for evaluation of both the need to in-situ test, as well as the structural implications of different types of tubing degradation that will be detected at EOC-16. Similar ECT techniques and ranking of indication severity will be employed to ensure that proper comparisons and inferences can be made.

Table 6-1 SG 11 EOC-16 Cumulative Leakage Estimation				
CATEGORY	Number of Locations	Leak Rate (gpd)	Leak Rate Total per Type	Category Total
Tubes with HEJ sleeves				
• Inservice Sleeves	817	0.0046	3.76	3.76
Tubes with Reroll Repair				
• Inservice Rerolls (Westinghouse + FTI)	331	0.001081	0.36	
• Estimated New Indications in Reroll RT	22	4.20	92.4	92.76
PWSCC in OEM RT				
• Projected Indications	75	0.00	0.00	0.00
ODSCC at TSPs	575	Calculated per GL 95-05		1386.86
U-bend PWSCC				
• Circ. Indications Expected	4	0.80	3.20	
• Axial Indications Expected	2	44.80	89.60	92.80
TTS ODSCC				
• Circ. Oriented Indications Expected	0	0.00	0.00	
• Axial Indications > 3 volts Expected	5	7.50	37.50	
• Axial Indications < = 3 volts Expected	258	0.00	0.00	37.50
Steam Generator Total (gpd)				1613.68
Steam Generator Total (gpm)				1.12

Table 6-2 SG 12 EOC-16 Cumulative Leakage Estimation				
CATEGORY	Number of Locations	Leak Rate (gpd)	Leak Rate Total per Type	Category Total
Tubes with HEJ sleeves				
• Inservice Sleeves	173	0.0046	0.80	0.80
Tubes with Reroll Repair				
• Inservice Rerolls (Westinghouse + FTI)	224	0.001081	0.24	
• Estimated New Indications in Reroll RT	8	4.20	33.60	33.84
PWSCC in OEM RT				
• Projected Indications	75	0.00	0.00	0.00
ODSCC at TSPs	259	Calculated per GL 95-05		681.11
U-bend PWSCC				
• Circ. Indications Expected	1	0.80	0.80	
• Axial Indications Expected	9	44.80	403.20	404.00
TTS ODSCC				
• Circ. Oriented Indications Expected	0	0.00	0.00	
• Axial Indications > 3 volts Expected	0	7.50	0.00	
• Axial Indications <= 3 volts Expected	95	0.00	0.00	0.00
Steam Generator Total (gpd)				1119.75
Steam Generator Total (gpm)				0.78

Table 6-3 SG 13 EOC-16 Cumulative Leakage Estimation				
CATEGORY	Number of Locations	Leak Rate (gpd)	Leak Rate Total per Type	Category Total
Tubes with HEJ sleeves				
• Inservice Sleeves	449	0.0046	2.07	2.07
Tubes with Reroll Repair				
• Inservice Rerolls (Westinghouse + FTI)	596	0.001081	0.64	
• Estimated New Indications in Reroll RT	35	4.20	147.00	147.64
PWSCC in OEM RT				
• Projected Indications	75	0.00	0.00	0.00
ODSCC at TSPs	247	Calculated per GL 95-05		345.24
U-bend PWSCC				
• Circ. Indications Expected	7	0.80	5.60	
• Axial Indications Expected	2	44.80	89.60	95.20
TTS ODSCC				
• Circ. Oriented Indications Expected	0	0.00	0.00	
• Axial Indications > 3 volts Expected	3	7.50	22.50	
• Axial Indications < = 3 volts Expected	227	0.00	0.00	22.50
Steam Generator Total (gpd)				612.65
Steam Generator Total (gpm)				0.43

Table 6-4 SG 14 EOC-16 Cumulative Leakage Estimation				
CATEGORY	Number of Locations	Leak Rate (gpd)	Leak Rate Total per Type	Category Total
Tubes with HEJ sleeves • Inservice Sleeves	374	0.0046	1.72	1.72
Tubes with Reroll Repair • Inservice Rerolls (Westinghouse + FTI) • Estimated New Indications in Reroll RT	146 8	0.001081 4.20	0.16 33.60	33.78
PWSCC in OEM RT • Projected Indications	75	0.00	0.00	0.00
ODSCC at TSPs	526	Calculated per GL 95-05		1243.63
U-bend PWSCC • Circ. Indications Expected • Axial Indications Expected	5 4	0.80 44.80	4.00 179.20	183.20
TTS ODSCC • Circ. Oriented Indications Expected • Axial Indications > 3 volts Expected Axial Indications < = 3 volts Expected	0 9 291	0.00 7.50 0.00	0.00 67.50 0.00	67.50
Steam Generator Total (gpd)				1529.83
Steam Generator Total (gpm)				1.06