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RECIP.NAME RECIPIENT AFFILIATION

SUBJECT: LER 98-015-00:on 981104,ISI found that 75 tubes in SG A & 40 tubes in SG B which were considered defective.Caused by IGA & IGSCC.All defective tubes were plugged or repaired. With 981204 ltr.

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December 4, 1998

10 CFR 50.73

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D.C. 20555

Ladies/Gentlemen:

Docket 50-305
Operating License DPR-43
Kewaunee Nuclear Power Plant
Reportable Occurrence 1998-015-00

In accordance with the requirements of 10 CFR 50.73, "Licensee Event Report System," the attached Licensee Event Report (LER) for reportable occurrence 1998-015-00 is being submitted.

Sincerely,

Mark L. Marchi
Site Vice President-Kewaunee Plant

TPO/jmf

Attach.

cc - INPO Records Center
US NRC Senior Resident Inspector
US NRC, Region III

NRC FORM 366 (6-1998) U.S. NUCLEAR REGULATORY COMMISSION

LICENSEE EVENT REPORT (LER)

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APPROVED BY OMB NO. 3150-0104 EXPIRES 06/30/2001

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TITLE (4)

Intergranular Attack & Intergranular Stress Corrosion Cracking of Tubes in Both Steam Generators Results in Category C-3

EVENT DATE (5)			LER NUMBER (6)			REPORT DATE (7)			OTHER FACILITIES INVOLVED (8)	
MONTH	DAY	YEAR	YEAR	SEQUENTIAL NUMBER	REVISION NUMBER	MONTH	DAY	YEAR	FACILITY NAME	DOCKET NUMBER
11	04	1998	1998	-- 015 --	00	12	04	1998	N/A	05000
									FACILITY NAME	DOCKET NUMBER
										05000

		THIS REPORT IS SUBMITTED PURSUANT TO THE REQUIREMENTS OF 10 CFR §: (Check one or more) (11)					
OPERATING MODE (9)	N		20.2201(b)		20.2203(a)(2)(v)		50.73(a)(2)(i)		50.73(a)(2)(viii)
POWER LEVEL (10)	000		20.2203(a)(1)		20.2203(a)(3)(i)	X	50.73(a)(2)(ii)		50.73(a)(2)(x)
			20.2203(a)(2)(i)		20.2203(a)(3)(ii)		50.73(a)(2)(iii)		73.71
			20.2203(a)(2)(ii)		20.2203(a)(4)		50.73(a)(2)(iv)	X	OTHER
			20.2203(a)(2)(iii)		50.36(c)(1)		50.73(a)(2)(v)		Specify in Abstract below or in NRC Form 366A
			20.2203(a)(2)(iv)		50.36(c)(2)		50.73(a)(2)(vii)		

LICENSEE CONTACT FOR THIS LER (12)

NAME	TELEPHONE NUMBER (Include Area Code)
TP Olson	920-388-8443

COMPLETE ONE LINE FOR EACH COMPONENT FAILURE DESCRIBED IN THIS REPORT (13)

CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO EPIX	CAUSE	SYSTEM	COMPONENT	MANUFACTURER	REPORTABLE TO EPIX
B	AB	SG	W120	Y					

SUPPLEMENTAL REPORT EXPECTED (14)			EXPECTED SUBMISSION DATE (15)	MONTH	DAY	YEAR
	YES (If yes, complete EXPECTED SUBMISSION DATE).	X NO				

ABSTRACT (Limit to 1400 spaces, i.e., approximately 15 single-spaced typewritten lines) (16)

On November 5, 1998, with the plant in refueling shutdown, the 1998 in-service inspection of Steam Generator (SG) tubes was completed. The in-service inspection found 75 tubes in SG A, and 40 tubes in SG B which were considered defective. In accordance with the Kewaunee Nuclear Power Plant (KNPP) technical specifications (TSs), both SGs were categorized as C-3. This Licensee Event Report provides the required 30 day written report to the Nuclear Regulatory Commission.

For non-sleeved tubes, the predominant degradation mode is outside diameter (OD) intergranular attack and OD intergranular stress corrosion cracking. For degradation occurring in the hybrid expansion joint (HEJ) sleeves, the predominant degradation mode is circumferential stress corrosion cracking initiated on the inside diameter (ID) of the parent tube. In accordance with KNPP's TS, all defective tubes were plugged or repaired. The secondary side boric acid and Morpholine (or alternative amine) addition programs and molar ratio control will continue during the next operating cycle to reduce the caustic environment and corrosion/erosion of the secondary side components.

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TEXT *(If more space is required, use additional copies of NRC Form 366A)* (17)

Description of Event

On November 5, 1998, with the plant in refueling shutdown, the in-service inspection of steam generator [SG] tubes [TBG] was completed for the 1998 refueling outage.

The Kewaunee Nuclear Power Plant (KNPP) steam generators (SG) are Westinghouse model 51. The tubes are constructed of mill-annealed inconel 600 and are partially rolled for a length of 1.5 to 2.5 inches into the tubesheet. As a result of tube degradation, significant plugging, sleeving and sleeve repair efforts have been required in each SG. Prior to the 1998 refueling outage, SG A contained 839 plugged tubes and 1669 sleeved tubes (850 Westinghouse mechanical sleeves, 381 Westinghouse laser weld repaired mechanical sleeves, and 438 ABB Combustion Engineering welded sleeves). SG B contained 785 plugged tubes and 1625 sleeved tubes (1329 Westinghouse mechanical sleeves, 292 Westinghouse laser weld repaired mechanical sleeves, and 4 ABB Combustion Engineering welded sleeves). The combined equivalent plugging percent for the two SGs was 26.07 percent.

The KNPP 1998 SG eddy current examination program for each SG was:

1. A 100% bobbin coil examination through the entire length of all tubes not previously plugged or sleeved.
2. A 100% bobbin coil examination of all sleeved tubes, from the top of the sleeve, around the U-bend to the end of the tube.
3. A 20% rotating probe examination of inservice ABB Combustion Engineering welded sleeves, from two inches above the top of the sleeve to the bottom of the sleeve.
4. A 100% rotating probe examination of all inservice Westinghouse mechanical sleeve upper expansion joints, from two inches above the top of the sleeve to approximately six inches below the top of the sleeve.
5. A 20% rotating probe examination of all inservice Westinghouse mechanical sleeves, from two inches above the top of the sleeve to the bottom of the sleeve.
6. A 100% rotating probe examination of all open row 1 and row 2 U-bends and 20% of the row 3 U-bends, from the seventh hot leg tube support plate to the seventh cold leg tube support plate.

7. A 100% rotating probe examination of all non-sleeved hot leg tubes, from the end of the tube to approximately four inches above the secondary face of the tubesheet.
8. A 20% rotating probe examination of cold leg tubes, from the end of the tube to approximately four inches above the secondary face of the tubesheet.
9. A 100% rotating probe examination of all inservice Westinghouse mechanical sleeve laser weld repairs, from two inches above the top of the sleeve to approximately six inches below the top of the sleeve.
10. A 20% rotating probe examination of inservice Westinghouse mechanical sleeve laser weld repairs, from two inches above the top of the sleeve to the bottom of the sleeve.
11. A 20% ultrasonic examination of in service Westinghouse mechanical sleeve laser weld repairs.

Based on the above listed examination scope, KNPP Technical Specification (TS) 4.2.b.2 requirements were satisfied.

1998 Inspection Results

During the course of the 1998 eddy current examination of the KNPP SGs, it was identified that greater than 1% of the tubes in each steam generator were classified as defective. Since greater than 1% of the examined tubes were considered defective (categorized as C-3), the Nuclear Regulatory Commission (NRC) was notified at 1354 hours on November 4, 1998 as required by KNPP TS 4.2.b.7.c and 10 CFR 50.72(b)(2)(i). The eddy current examinations were completed on November 5, 1998. A total of 75 tubes in SG A and 40 tubes in SG B met the KNPP TS definition of defective. These tubes were either removed from service via plugging or repaired via tubesheet sleeving in accordance with TS 4.2.b.4.a. No tubes were removed for destructive analysis. A total of 83 tubes in SG A and 87 tubes in SG B were recovered. As a result of tube plugging, repairs and recovery, the combined equivalent tube plugging percentage is 24.62%.

Eddy Current Examination of Tube Support Plates - The 2 volt alternate repair criteria (ARC) was applied to indications (attributable to Outside Diameter Stress Corrosion Cracking (ODSCC)) found within the tube support plates. The ARC was implemented in accordance with TS 4.2.b.5. The eddy current examination of

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the tube support plates found 305 indications in SG A, and 763 indications in SG B. Of these, 0 indications in SG A and 1 indication in SG B did not satisfy the ARC (due to the inability to inspect with the required 0.720 inch diameter bobbin probe). This tube was removed from service. The average voltage was 0.52 volts for SG A and 0.58 volts for SG B, which is consistent with previous inspections in which the 2 volt ARC was implemented. Augmented testing included plus point examinations of all dents greater than 5 volts, rotating pancake coil (RPC) testing of all indications with a phase angle corresponding to a depth >50% through wall and large mix residual signals. There were no indications reported in the dented tube intersections or in the large mix residuals. For those tubes RPC tested based on phase, all but one tube location in SG B were reported containing indications suggestive of ODSCC, in which the 2 volt alternate repair criteria could be applied. The one tube location in which ODSCC could not be confirmed was removed from service.

Plus Point Probe Inspection of Upper and Lower Hybrid Expansion Joints (HEJs) of the Westinghouse Sleeves - Eddy current examination results of the sleeve upper HEJs found 3 tubes in SG A and 5 tubes in SG B with circumferential indications in the parent tube at the lower transition of the upper roll expansion within the pressure boundary defined in TS 4.2.b.4.c. TS 4.2.b.4.c defines the pressure boundary for parent tube indications within the HEJ region in terms of a minimum non-degraded (i.e., no detectable degradation in the parent tube) hardroll length of 0.95 inch (inclusive of NDE uncertainty) as measured from the bottom of the hardroll upper transition. As these indications were within the pressure boundary, they were classified as defective and were removed from service. No degradation was detected in the sleeve lower joint or the sleeve straight length.

Plus Point Probe Inspection of ABB Combustion Engineering Welded Sleeves - This sleeve population included both 27 inch tubesheet sleeves and 39 inch tubesheet sleeves installed in 1997 as part of the resleeving effort. No degradation was reported in the welded sleeves as a result of this inspection.

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The Plus Point Probe Inspection of Row 1, 2 and 3 U-Bend Regions - Two indications of Primary Water Stress Corrosion Cracking (PWSCC) were detected in the low row U-bend region in SG A, one axial and one circumferentially oriented. Both indications were in row 1 tubes. These tubes were removed from service.

RPC Probe Inspection of Hot Leg Open Tubesheet Crevice Regions - Examination of the hot leg crevices in SG A (880 tubes) identified 45 tubes containing single or multiple axial indications. Examination of the hot leg crevices in SG B (978 tubes) identified 28 tubes containing single or multiple axial indications. Of the 45 tubes considered defective in SG A, 30 were repaired by sleeving in accordance with TS 4.2.b.4.a. The remaining 15 were removed from service. Of the 28 tubes considered defective in SG B, 22 were repaired by sleeving in accordance with TS 4.2.b.4.a. The remaining 6 were removed from service. The number of indications reported in the hot leg tubesheet crevice region is consistent with the two previous inspections.

RPC Probe Inspection of Cold Leg Open Tubeshcet Crevice Regions - One tube in SG A contained an indication at the top of the cold leg tubesheet. This indication was volumetric in nature and was sized at less than 50% through wall in previous inspections dating back to 1994. No attempt to size this indication was made during the 1998 inspection. This tube was removed from service. No other degradation in the cold leg tubesheet crevice region was reported.

Plus Point Probe Inspection of Laser Weld Repair Region in Westinghouse Sleeves - Fourteen tubes in SG A and 5 tubes in SG B contained an obstruction in which the eddy current probe was not able to transverse. Subsequent visual examinations revealed the sleeve had dented, preventing passage of the probe. These tubes were removed from service. In addition, 9 tubes in SG A and 0 tubes in SG B contained indications in the laser weld, and 2 tubes in SG A and 0 tubes in SG B contained indications in the sleeve. The weld indications were identified with the high frequency plus point coil, which is indicative of inside diameter (ID) cracking. The low frequency plus point coil was unable to detect these indications. As this is the first inspection using a high frequency plus point coil specifically to identify ID weld cracking, it is likely these ID cracks resulted from installation and were not service induced. The sleeve indications are most likely scratches or other

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"tooling marks" resulting from the original sleeve installation. However, for these two locations these indications could not be traced back to the original baseline data. All tube locations with indications in the weld or sleeve as described above were removed from service. Ultrasonic examinations were acceptable, with little to no change from the baseline ultrasonic data.

The overall examination results for 1998 outage found 75 tubes (2.94 percent of tubes inspected) in SG A and 40 tubes (1.54 percent of tubes inspected) in SG B which met the KNPP definition of defective. According to the KNPP TS 4.2.b.7.a, following each in-service inspection, the number of tubes which require plugging or repairing shall be reported to the NRC within 30 days. The C-3 category requires:

1. Prompt notification of the NRC (TS 4.2.b.7.c).
2. A written follow-up to the NRC (TS 4.2.b.7.c).
3. Plugging or repair of all defective tubes (Table TS 4.2-2).
4. An examination of additional tubes in the affected areas if the sample size is less than 100 percent in the affected area (Table TS 4.2-2).
5. Increasing the required SG inspection frequency to once per twenty months (TS 4.2.b.3.b).

The NRC was notified at 1354 hours on November 4, 1998, upon identification of the C-3 classification. This Licensee Event Report satisfies the 30 day reporting requirement of KNPP TS 4.2.b.7.a and TS 4.2.b.7.c. All defective tubes have been plugged or repaired. The affected area resulting in the C-3 classification was degradation in the hot leg tubesheet crevice region in each SG. Since 100% of the affected population was examined, no sample expansion was necessary. As KNPP plans on replacing its SGs in April 2000, no subsequent scheduled in service examination of the existing SGs will be performed. In the event SG replacement is delayed, KNPP will re-evaluate the need to perform a subsequent inservice examination in accordance with TS 4.2.b.3.b.

A tube recovery program was also initiated to regain additional plugging margin. As part of this effort, plugs were removed from previously plugged Westinghouse HEJ sleeves and the sleeve reinspected to the TS 4.2.b.4.c revised pressure boundary definition. A total of 83 tubes in SG A and 49 tubes in SG B were returned to service. In addition, tubes previously plugged for indications in the tubesheet crevice region in SG B were removed and tubesheet sleeves installed in accordance with TS 4.2.b.4.a. A total of 38 tube locations were sleeved and returned to service in SG B.

Cause of Event

The majority of the SG tube degradation in the non-sleeved locations is most likely due to outside diameter intergranular attack and outside diameter intergranular stress corrosion cracking (IGA/IGSCC). This assumption is based on the analysis of: two tubes pulled from the KNPP SG's during the 1990 outage, three tubes pulled during the 1993 outage, eddy current signals, and industry experience with similar SGs. Outside diameter IGA/IGSCC is usually associated with a restricted geometry; e.g., the tubeshcet crevice, tube support plate crevice or a sludge pile, and with a caustic environment; i.e., a pH greater than ten.

During the 1995 refueling outage, portions of 3 sleeved tubes were extracted from the B SG. These tubes were examined by non-destructive and destructive examination techniques to determine actual tube/sleeve joint condition relative to eddy current results and degradation mode. The results of this examination concluded that the parent tube cracking in the upper sleeve joint was circumferential PWSCC on the inner diameter of the parent tube. The parent tube cracking was most likely caused by high residual stresses as a result of the sleeve installation process.

Analysis of Event

The eddy current examination results were reviewed to determine the structural significance of all of the indications that were detected, relative to the requirements of the KNPP TS, NRC Regulatory Guide 1.121, NRC Generic Letter 95-05, the Draft SG Rule, and the EPRI SG In-Situ Pressure Test Guidelines.

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For the as-found tube support plate indications, the end of cycle probability of burst was calculated to be $1.83x10^{-5}$ for SG A and $2.10x10^{-5}$ for SG B. These values are significantly less than the limitmg probability of burst ($1.0x10^{-2}$) stated in NRC Generic Letter 95-05. The as-found conditional leak rate under a postulated steam line break was determined to be 0.195 gpm for SG A and 0.670 gpm for SG B, significantly less than the Kewaunee allowable of 9.85 gpm.

Of the HEJ sleeved tubes containing indications within the parent tube pressure boundary as defmed by TS 4.2.b.4.c, tube burst is precluded by the presence of the undegraded sleeve. Tube leakage under a postulated steam line break event is conservatively bounded at 1.0 gpm. Includmg the leakage from tube support plate indications left in service as a result of application of the 2 volt ARC, the total allowable leakage remains well below the Kewaunee allowable of 9.85 gpm.

Of the tubes containing indications in the hot leg tubesheet crevice, a small number (6) contained indications above the secondary tubesheet interface. The balance of the indications were contained within the tubesheet crevice, where burst is precluded by the presence of the tubesheet. Those indications above the tubesheet interface were compared to the limiting crack length of 0.38 inches (for free span, axially oriented indications, a through wall crack of 0.38 inches satisfies the 3 delta P limit at Kewaunee). All but 2 of the indications were sized less than this limit. For the 2 locations whose length exceeded the 3 delta P allowable, the maximum depth of the indications was evaluated to determine if in-situ pressure testmg was required. The maximum depths obtained were $<40\%$ through wall using a non-qualified depth sizing technique, which is less than the 75% depth threshold for in-situ pressure testing. Therefore, these indications would be expected to meet the requirements for free span burst under bounding design basis conditions. All indications reported within or above the tubesheet crevice were either plugged or sleeved.

The u-bend indications were evaluated against burst under bounding conditions. The 2 indications were indicative of PWSCC in the highly stressed region of the row 1 bends of the tubes. The axial indication, which measured 0.43 inches in length by a non-qualified ET technique, was evaluated against an assumed

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through wall crack of 0.55 inches for an axial u-bend flaw, which would be expected to fail under 3 delta P conditions. The circumferential indication was also characterized in order to evaluate its structural significance. The circumferential extent was measured at 42 degrees and compared to a structural limit of 229 degrees. As both indications were measured less than the bounding values, no in-situ pressure testing was performed for structural concerns. The tubes with u-bend indications were removed from service.

Some laser weld repaired sleeved tube locations could not be inspected due to the presence of an obstruction in the sleeve. Subsequent visual examinations revealed an area of the sleeve that was bulged inward. The only plausible mechanism for the occurrence of the bulge is that the annulus between the sleeve and tube filled with or essentially filled with water at low temperature and was unable to escape the annulus as the plant heated up. The expanding water generated stresses that caused the partial collapse of the sleeve. Testing performed by Westinghouse has shown that even in the event a sleeve totally collapsed, the resulting stresses generated would not be enough to separate the weld. Therefore, structural integrity is not a concern. Although uncommon, similar experiences have been reported at other plants containing both Westinghouse and ABB Combustion Engineering welded sleeves. These tubes were removed from service.

This report is being submitted in accordance with KNPP TS 4.2.b.7.a which requires a report to be submitted to the NRC within thirty days of completing the in-service inspection of the SGs. The following table provides a historical summary of the number of the SG tubes plugged and sleeved each year:

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	Steam Generator A						Steam Generator B					
	Plugged Tubes		Recovered Tubes			Repaired Tubes	Plugged Tubes		Recovered Tubes			Repaired Tubes
	Un-Sleeved (A)	Sleeved (B)	Unplugged & Sleeved (C)	Unplugged (non- sleeved) (D)	Unplugged (sleeved) (E)	Sleeved Tubes (F)	Un-Sleeved (A)	Sleeved (B)	Unplugged & Sleeved (C)	Unplugged (non- sleeved) (D)	Unplugged (sleeved) (E)	Sleeved Tubes (F)
1983	23						50					
1984	9						17					
1985	26						22					
1986	26						46					
1987	44						79					
1988	17					990	26					950
1989	21					883	31					815
1990	114	8					103	6				
1991	63	11	150			172	77	8	246			122
1992	17	13				12	19	16				4
1993	6	3					7	5				
1994	21	56					9	19				
1995	46	433		17	19		40	229		29	16	
1996	35	370	62		275		22	352			107	
1998	17	28			83	30	7	11	38		49	22
Total Tubes Plugged (1)	801						716					
Total Tubes Sleeved (2)		1754						1723				

Notes: 1. Total Tubes Plugged = $\sum(A) + \sum(B) - \sum(C) - \sum(D) - \sum(E)$
2. Total Tubes Sleeved = $\sum(C) + \sum(E) + \sum(F) - \sum(B)$

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Corrective Actions

In accordance with KNPP's TS, all tubes classified as defective were plugged or repaired.

Sludge lancing was conducted during the 1998 refueling outage to reduce the amount of sludge and to remove contaminants from the tubesheet. A secondary side boric acid addition program continues to be implemented to reduce the caustic environment in the tube crevices and prevent tube support plate denting. The program includes boric acid soaks at low power levels and on line boric acid addition at normal power levels. Evidence indicates that boric acid may reduce the crack growth rate. Also, a secondary side morpholine addition (or alternative amine) program continues to be implemented. Morpholine addition minimizes the corrosion/erosion in the two-phase steam piping. Sludge (corrosion product) transport into the steam generators is thereby minimized and results in a decreased sludge pile.

A molar ratio control program is also used at KNPP. This is accomplished by adding ammonium chloride to the secondary side to control the molar ratio. This is designed to maintain a neutral pH in the tubesheet crevice environment.

Additional Information

Equipment Failure: Westinghouse Model 51 steam generator tubes. The tubing is mill annealed Inconel 600.

Similar Events:

1. LER 96-006-01, Intergranular Attack and Intergranular Stress Corrosion Cracking of Tubes in Both Steam Generators Results in Category C-3.
2. LER 95-001, Intergranular Attack and Intergranular Stress Corrosion Cracking of Tubes in Both Steam Generator Results in Category C-3.
3. LER 94-004, Intergranular Attack and Intergranular Stress Corrosion Cracking Result in Defective Steam Generator Tubes.

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4. LER 93-004, Intergranular Attack and Intergranular Stress Corrosion Cracking Results in Both Steam Generators Being Categorized as C-2.
5. LER 92-006, Intergranular Attack and Intergranular Stress Corrosion Cracking Results in Both Steam Generators Being Categorized as C-3.
6. LER 91-005, Intergranular Attack and Intergranular Stress Corrosion Cracking Results in Both Steam Generators Being Categorized as C-3.
7. LER 90-005, Intergranular Attack and Intergranular Stress Corrosion Cracking Result in Defective Steam Generator Tubes.
8. LER 89-007, Intergranular Attack and Intergranular Stress Corrosion Cracking Result in Defective Steam Generator Tubes.
9. LER 88-003, Intergranular Attack and Intergranular Stress Corrosion Cracking Result in Defective Steam Generator Tubes.
10. Letter from D.C. Hintz (WPSC) to G.E. Lear (NRC) dated April 23, 1986.
11. LER 85-06, Steam Generator Tube Plugged in Incorrect Location.
12. Letter from C.W. Giesler (WPSC) to S.A. Varga (NRC) dated May 1, 1984.