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

H. B. ROBINSON UNIT NO. 2

AUGUST 1981 STEAM GENERATOR INSPECTION

SAFETY EVALUATION REPORT

MATERIALS ENGINEERING BRANCH
INSERVICE INSPECTION SECTION

Introduction

H. B. Robinson Unit No. 2 was shut down on July 30, 1981 after the detection of a primary-to-secondary leak of 0.301 gpm in steam generator B. This leakage rate was less than the Unit's technical specification limit of 0.35 gpm per steam generator. The resultant inspection of the unit revealed that two leaking tubes existed on the hot leg side of steam generator B. Carolina Power and Light Company (the licensee) has performed corrective actions and propose to continue operation of H. B. Robinson until the next refueling outage. On August 21, 1981, the licensee submitted an SER to support continued operation until the next refueling outage (approximately 260 equivalent 50% power days of operation).

Background

Plant performance at H. B. Robinson Unit 2 has been closely monitored by NRC for the past two years. The facility has had defects at U-bends, at or above support plates, inside tubesheet, at top of tubesheet, and above the top of the tubesheet. The degradation above the tubesheet and at or slightly above the support plates is believed to be phosphate induced thinning. Robinson Unit 2 is one of two PWR units which continues to operate with phosphate secondary water chemistry control. The degradation within the tubesheet is believed to be intergranular corrosion phenomenon which has been observed at other units. Two tube specimens containing U-bend indications were removed during the August 1980 outage. Laboratory examination indicates that the U-bend defects were the result of corrosion induced thinning.

The steam generators at H. B. Robinson Unit 2 were inspected in May 1981. One hundred eight-two (182) tubes were plugged as a result of the May 1981 inspection. The unit returned to operation on June 12, 1981. A primary-to-secondary leak occurred within 48 days from the May 1981 outage. At the time of the shutdown, H. B. Robinson was operated at a power level of approximately 95%.

Discussion

Inspection Results

The August 1981 eddy current inspection program was performed using multi-frequency bobbin probe eddy current techniques. One hundred percent of the unplugged steam generator tubes were inspected from the Steam Generator A inlet, Steam Generator B inlet and outlet, and Steam Generator C inlet and outlet. Tables 1 through 3 summarize the August 1981 inspection results for Steam Generator B inlet and outlet and Steam Generator C inlet legs. The data for Steam Generator A inlet and Steam Generator C outlet is in the process of being tabulated.

A novel design eddy current probe, designated the "5x5", was used to check the bobbin probe results. The design of this probe consists of two banks of series wired, surface-riding pancake coils differentially coupled, and thereby provides the sensitivity of surface-riding pancake coil in a straight-pull (as opposed to rotating) mode of test. A sample of 22 tubes in Steam Generator B and 54 tubes in Steam Generator C were tested with the 5x5 probe. The results of this verification test were consistent with those found by the bobbin probe.

Laboratory Examinations

Two tube sections were pulled during the August 1981 outage from the hot leg side of Steam Generator B for detailed non-destructive and destructive examination. The first tube examined, R36C37, was identified as a leaker reportedly containing a through-wall eddy current indication at 1" to 1 1/2" above the secondary side of the tube sheet. The second tube, R37C38, was reportedly a sound tube, free of eddy current indications. The results of the examination, which consisted of visual, radiographic, eddy current and micro-analytical non-destructive evaluation and optical and scanning electron microscopy revealed the following:

1. The cause of the leakage and reported through-wall eddy current signals in tube R36C37 were clearly due to the axial stress corrosion crack(s) above the tube sheet surface.

2. The intergranular nature of these cracks in tube R36C37 as well as the general IGA observed in the tube sheet crevice are consistent with previously observed metallographic evidence of caustic related attack.

3. Tube R37C38 was judged free of indications based on double wall radiography and eddy current testing.

Table 1

DISTRIBUTION OF EDDY CURRENT INDICATIONS

LOCATION	PERCENTAGE OF WALL PENETRATION												
	DS	<20	20-26	27-33	34-40	41-47	48-54	55-61	62-68	69-75	76-82	83-89	90-96
BELOW THE TUBE SHEET	8	0	0	0	0	0	0	2	2	2	4	12	8
AT THE TUBE SHEET	1	475	135	98	55	17	20	4	12	14	20	13	2
AT THE SUPPORT PLATES	0	4	4	4	5	1	0	1	0	0	0	0	0
IN THE UBEND	0	28	13	10	5	3	0	0	0	0	0	0	0
TOTALS	9	507	152	112	65	21	20	7	14	16	24	25	10

Table 2

DISTRIBUTION OF EDDY CURRENT INDICATIONS

LOCATION	PERCENTAGE OF WALL PENETRATION												
	DS	<20	20-26	27-33	34-40	41-47	48-54	55-61	62-68	69-75	76-82	83-89	90-96
BELOW THE TUBE SHEET	0	0	0	0	0	0	0	0	0	0	0	0	0
AT THE TUBE SHEET	0	31	25	21	31	15	2	0	0	0	0	0	0
AT THE SUPPORT PLATES	0	0	2	3	0	1	0	0	0	0	0	0	0
IN THE UBEND	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	0	31	27	24	31	16	2	0	0	0	0	0	0

Table 3

DISTRIBUTION OF EDDY CURRENT INDICATIONS

Location	Percentage of Wall Penetration												
	DS	<20	20-26	27-33	34-40	41-47	48-54	55-61	62-68	69-75	76-82	83-89	90-96
Below the Tube Sheet	2	0	1	0	0	2	1	0	1	0	0	0	0
At the Tube Sheet	1	177	80	63	30	8	1	3	7	6	14	8	2
At the Support Plates	0	2	1	1	1	0	1	0	0	0	0	0	0
In the U Bend	0	1	2	3	2	0	1	0	0	0	0	0	0

Tube Plugging

The August 1981 steam generator inspections revealed a total of 212 tubes with eddy current indications in excess of the 47% plugging limit or distorted signals below the tube sheet (crevice region). These tubes were plugged. A hydrostatic pressure test was conducted after the eddy current inspection. As a result, a leaking tube was discovered in Steam Generator C outlet (R5-C28). Eddy current data from this and the immediate surrounding tubes were reviewed. No signal was found that could be related to the leak. Subsequently, this tube was tested with the 5x5 probe which revealed an indication above the top of the tube sheet. Therefore, a total of 213 tubes were plugged as a result of the eddy current and leakage observations. The plugging totals in each of the elevations (regions) are as follows:

H. B. ROBINSON #2
TUBE PLUGGING DISTRIBUTION
AUGUST 1981 INSPECTION

	S/G A		S/G B		S/G C		
REGION	INLET	OUTLET	INLET	OUTLET	INLET	OUTLET	TOTAL
Above the Tubesheet	28	-	73	2	39	1	143
Top of the Tubesheet	1	-	16	0	3	-	20
Crevice	9	-	36	0	4	-	49
Tube Support Plants	0	-	1	0	0	-	1
U-Bend	0	-	0	0	0	-	0
TOTALS	38	-	126	2	46	1	213

A comparison of the August 1981 plugging totals with the total tubes plugged prior to that date is as follows:

ROBINSON #2 8/81
STEAM GENERATOR TUBE PLUGGING

	8/81	PRIOR
SG/A	38	302
SG/B	128	321
SG/C	46	234
TOTAL	212	857
CUMULATIVE	1068	10.92%

Corrective Actions

The licensee has proposed the following program to provide additional assurance of continued safety:

a. A primary to secondary pressure test at approximately 1900 psi differential will be performed after operation at power levels such that estimated corrosion is equivalent to or less than that of 24 effective full power days operation as shown in figure 4.3.3 in Attachment B of CP&L's letter of August 21, 1981. A period of seven additional calendar days is permitted for flexibility in scheduling the test (e.g. if the unit operated at a constant power level of 100% (2300 MWt), then the pressure test would be required prior to 24 + 7 calendar days, if the unit operated at 50% power level constantly, then the pressure test would be required prior to 112 + 7 calendar days. For operation at power levels between 50% and 100%, the calendar days equivalency is determined from Figure 4.3.3. Thus, at a power level of 75%, the amount of calendar days between pressure tests would be: [Corrosion Allowance factor at 100% ÷ Corrosion Allowance Factor at 75%] X 24 = 45 + 7 calendar days.

b. At the end of core life (approximately 260 equivalent 50% power days of operation) of the present cycle, an eddy current examination shall be performed. The scope of this inspection will be submitted to the NRC for approval at least 45 calendar days prior to this end of core life inspection.

c. During the remainder of the cycle 8 operations, the following steam generator tube leakage criteria shall be in effect. Specifically, the plant shall be shutdown if the verified primary to secondary leakage in one steam generator exceeds any of the following:

   1. A sudden increase of 0.1 gallon per minute (gpm) if the total leakage rate in that steam generator exceeds 0.2 gpm.

   2. If the leakage rate in that steam generator exceeds 0.2 gpm and an upward trend in leakage rate in excess of 0.02 gpm per day is verified. This trend will be established using at least five valid consecutive daily samples.

d. Should the plant be required to shut down to repair a steam generator tube leak as indicated in item (c) above, an inspection shall be performed as mutually agreed upon by the NRC Staff and CP&L.

e. The NRC Staff shall be provided with a summary of the results of the eddy current examination performed under item (b) above.

Prior to return to power, the licensee also proposes to sludge lance all three steam generators and thus remove solid steam generator deposits. After sludge lancing operation, the licensee proposes to use Crevice/Sludge Flushing technique to remove additional potentially aggressive chemicals remaining in the steam generators.

Evaluation

The licensee has inspected 100% of the Steam Generators B and C tubes, and a 100% of the inlet leg of the Steam Generator A tubes, using the multi-frequency eddy current technique with the standard bobbin probe. To supplement the standard bobbin probe, a portion of the tubes in Steam Generators B and C were also inspected by an advanced "5 x 5" probe. The results from the supplement inspections have verified the results obtained by the standard bobbin probe. Furthermore, examinations of the two pulled tubes also verified the results obtained by the standard bobbin probe. Therefore, we believe that the August 1981 inspection has identified all tubes with significant defects which would jeopardize tube integrity during normal operation or postulated accident conditions. These defective tubes have been plugged in accordance with existing criteria.

At the request of the staff, the licensee has agreed to perform a primary to secondary hydrostatic test to monitor the tubes' ability to maintain their integrity under 1900 psi differential pressure loading every 24 effective full power days (EFPD). The actual number of calendar days in this period is a function of power level and corrosion rate, i.e., 75 or 112 calendar days if the plant operated at 63% or 50% power, respectively. The relationship between corrosion rate and power (temperature of the primary coolant) is based on data provided by Westinghouse. We agree that hydrostatic pressure tests periodically will provide a positive indication and increased confidence in steam generator tube integrity. At the end of core life (approximately 260 equivalent 50% power days of operation) an eddy current inspection shall be performed on 100% of the tubes in all three steam generators. This will provide adequate assurance that a large number of tubes will not simultaneously reach a point of incipient failure.

The licensee has also proposed the following restrictions on steam generator tube leakage which would apply in addition to the current 0.35 gpm (500 gpd) Technical Specification limit, beyond which the plant would be required to shutdown:

1) an upward trend in leakage rate in excess of 0.02 gpm per day if the leakage rate in that steam generator exceeds .2 gpm. This trend will be established using at least five valid consecutive daily samples. (The licensee has stated that 0.2 gpm is the minimum threshold value beyond which leak rate trends or step changes can be reliably established).

2) a sudden increase in leakage of 0.1 gpm if the total leakage rate in that steam generator exceeds 0.2 gpm.

The 0.35 gpm Technical Specification limit was developed to assure that any individual through-wall crack will not result in a tube burst (gross tube failure) under loads associated with either normal operation or a postulated accident. The proposed additional restrictions on leak rate provides some additional assurance that if a leak should develop, timely plant shutdown and corrective actions can be taken.

Regarding the sludge lancing and the crevice/sludge flushing procedure proposed by the licensee, residual sodium and phosphate in the tubesheet crevice region and sludge will be removed by flushing. This should help minimize further tube degradation in the deep crevice of the tubesheet and areas where sludge tends to build up.

The licensee also has committed to discuss steam generator inspection plans in the event that reactor shutdown is required due to the above leak rate criteria. We believe that until the next ECT inspections are performed, the inspections to be performed during any plant shutdown to repair a steam generator leak should be discussed with the staff.

Conclusions

Based upon the above evaluation, the staff has concluded the following:

1. The plugging of the identified pluggable tubes, the validation of the ECT technique by the tube pulls and the bundle pressure tests demonstrate the integrity of the tube bundle in its present condition.

2. The proposed hydrostatic pressure tests during operation will identify any significant defects in the steam generator tubes.

3. The proposed primary to secondary leak rate restrictions in excess of Technical Specification requirements provide additional assurance that timely plant shutdown and corrective action can be taken prior to gross tube failure.

4. A maximum of 260 equivalent 50% power days of operation prior to the next ECT inspection will provide adequate assurance that a large number of tubes will not simultaneously reach a point of incipient failure.

5. Crevice/sludge flushing procedure proposed by the licensee will minimize further tube degradation.

6. If the plant is shutdown to repair a steam generator tube leak prior to performing the 100% eddy current inspection; the steam generators should be inspected as agreed upon by the NRC staff and the licensee.