VIRGINIA ELECTRIC AND POWER COMPANY

RICHMOND, VIRGINIA 23261

August 31, 1979

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
Attn: Mr. Albert Schwencer, Chief
Operating Reactors Branch 1
Division of Operating Reactors
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Serial No. 492C
PO/DLB:baw
Docket No. 50-280
License No. DPR-32

Dear Mr. Denton:

Subject: Feedwater System Piping Inspections
Surry Power Station Unit No. 1

The attached report provides the results of the recently completed feedwater line inspections, a feedwater line stress analysis summary, a tabulation of feedwater chemistry history and the results to date of the feedwater reducers metallurgical examination on Surry Unit 1. The remainder of the metallurgical examination results will be forwarded as soon as they are available.

Very truly yours,

W L Proffitt

C. M. Stallings
Vice President-Power Supply
and Production Operations

cc: Mr. James P. O'Reilly

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Report of Feedwater System Piping Inspections
Surry Power Station Unit No.1

Introduction

In response to IE Bulletin 79-13, "Cracking in Feedwater System Piping", all feedwater nozzle-to-pipe weld areas and all feedwater pipe weld areas inside containment have been inspected on Surry Unit No. 1. The three Unit No. 1 feedwater reducers have been replaced and the old reducers have been shipped to the NSSS vendor for metallurgical evaluations. In addition, the NSSS vendor has performed stress analyses on the Unit No. 1 feedwater line configuration in an effort to determine the mechanism causing the observed cracking. The onsite inspections and the stress analyses have been completed. The metallurgical examination of the Loop B reducer has been completed. The results of these inspections, feedwater chemistry history, and corrective actions are discussed below.

Inspection Results

Onsite Inspections

Radiography of Surry Unit No. 1 steam generator feedwater nozzles and reducers revealed circumferential crack indications in the base metal at the nozzle to reducer counterbore regions of all three steam generators. One weld metal crack was also revealed. Detailed descriptions of the cracks found in Loop B are discussed below under metallurgical examination results. Additional information on Loop A and C indications will be forwarded following completion of the metallurgical examinations.

All feedwater pipe weld areas inside containment have been inspected with the following results:

Steam Generator "A": Seventeen welds total. No cracking as was reported in the nozzle area was noted. Two welds could not be radiographed due to the presence of water in the lines. These two welds were ultrasonically examined and found to be acceptable. Four welds were rejected as follows:

- W#3 Small area of rejectable porosity, (reported to NRC 7-16-79).
- W#4 Two small linear indications in the root area, (reported to NRC 7-16-79).
- W#5 Small area, lack of fusion - reject (reported to NRC 7-23-79).
- W#13 Small areas of rejectable incomplete fusion (reported to NRC 7-12-79).

Steam Generator "B". Eleven welds total. No cracking as was reported in the nozzle areas was noted. One weld's total surface was only inspected 60% due to a saddle support for snubbers covering the remainder of the weld. Two welds were rejected as follows:

W#1 Small area of rejectable porosity, (reported to NRC 7-12-79).

W#10 Small area of slag/incomplete fusion - reject (reported to NRC 7-24-79).

Steam Generator "C". Fourteen welds total. No cracking as was reported in the nozzle area was noted. Six welds were rejected as follows:

W#5 Small area of rejectable porosity, (reported to NRC 7-16-79).

W#6 Small area of rejectable incomplete fusion, (reported to NRC 7-16-79).

W#11 Small area of rejectable incomplete fusion, (reported to NRC 7-16-79).

W#9 Small area of rejectable incomplete fusion, (reported to NRC 7-23-79).

W#13 Small area of slag - reject (reported to NRC 7-23-79).

W#14 Small areas of slag/incomplete fusion - reject (reported to NRC 7-23-79).

Auxiliary Feedwater Connections

The 3 inch auxiliary feedwater connections on all three main feedwater lines were magnetic particle inspected. The results of these inspections were acceptable.

Metallurgical Evaluations

All Surry Unit No. 1 feedwater reducers were shipped to the NSSS vendor for evaluation. To date, only the Loop B reducer examination has been completed. Evaluation results for Loops A and C will be forwarded as soon as they are available.

The reducer section of Loop B feedwater pipe of Surry Unit 1 was examined using ultrasonic inspection techniques, metallography and fractography. The reducer was examined ultrasonically from the cut face through the weldment. The deepest penetrations were estimated at 64° (∿ 2:00 position) and at 121° (∿ 4:00). Cross sections at these positions showed the deepest penetrations to be located at a section change in the feedwater reducer where the Schedule 80 reducer had been counterbored to match the Schedule 60 nozzle. The crack at the 121° position was 0.08 inches deep and at the 64° position 0.04 inches deep. Smaller cracks were found along the tapered section. The microscopic tests revealed a few beachmarks. The cracks were transgranular in nature and showed no side branching. From metallographic and fractographic observations the conclusion is that the cracking was the result of corrosion assisted fatigue. Further fractographic observations are in progress.

The ID of the reducer exhibited a large number of machining grooves. Most cracks were tight, showing only an oxide spike. The larger of the cracks were relatively straight and filled with gray oxide. Opened and cleaned (deoxidized) cracks showed a relatively rough topography near the crack tip.

Mechanical testing (Charpy and Tensile) and chemical analysis of the reducer material are in progress.

Stress Analysis Results

Stress analyses were performed on the Surry Unit No. 1 feedwater line configuration in an effort to determine the mechanism causing the observed cracking. The analyses were broken into three parts:

(1) Structural analyses of the feedwater line including the effects of thermal, deadweight and pressure.

(2) 2D finite element fatigue analysis of the feedwater nozzle/elbow configuration.

(3) Frequency analyses of the feedwater line.

The structural analysis was performed using a 3D finite element model of the feedwater line with anchors included at the steam generator (SG) and containment penetration and the vertical and horizontal thermal growth of the SG applied at the feedwater nozzle. The WESTDYN7 computer code was used for the analysis. The geometry generally consists of the feedwater nozzle with a 16" Schedule 60 end prep, which is connected to a 16" x 14" reducer. Each 14" piping run then travels horizontally from a loop seal arrangement to an approximately 30' vertical drop, then horizontally ∿ 8 feet to the containment penetration. Supports consist of deadweight spring hangers, and dynamic snubbers only.

Two thermal conditions were run. The first with the SG at ∿ 550°F and the feedwater line at ∿ 437°F representing normal operation. The second with the SG at ∿ 550°F and the feedwater line cold representing the hot shutdown condition. The analyses results show a maximum thermal stress of approximately 7 ksi at the nozzle to pipe junction. The maximum deadweight and pressure stresses were 3 ksi and 7 ksi respectively. These stresses are below code allowable values.

The second analysis performed was a detailed 2D finite element fatigue analysis of the most severe thermal transient, which occurred during hot shutdown, in the region of the feedwater nozzle to short radius elbow junction. The analysis used the WECAN computer code and the rules of ASME Section III, NB-3200. The model used constant strain quadrilateral elements with a minimum of 8 nodes through the wall and ran from the SG shell to 10" beyond the nozzle to elbow weld. The transient analyzed consisted of a ramp change in temperature from ∿ 550°F to 60°F in 9 seconds followed by a period of constant 60°F operation, flow velocity .38 ft/sec. This represents the injection of auxiliary feedwater into the feedwater nozzle/ elbow junction, which has been heated by the SG during the hot standby condition. When the auxiliary feedwater is terminated, a step change in temperature is assumed from 60°F to ∿ 550°F. This represents the conservative assumption of a leaking check valve in the feedwater system, which allows water to flow from the SG to the feedwater line and assumes no mixing of auxiliary feedwater with water in the SG. The maximum peak stress range obtained from this transient was 60 ksi which is then multiplied by a conservative factor of 1.7 to account for the detailed affect of the "notch" at the elbow counter bore. This peak stress range of 102 ksi yields an allowable 5000 cycles using the ASME Section III S/N curves. The design transients given in the SG E-Spec has shown acceptable values of usage factors for the feedwater nozzle. Correspondingly, analysis of the nozzle to elbow junction will have an acceptable value of usage factor since the thermal transient stresses are lower at this junction than in the nozzle.

The final analysis performed was a frequency analysis of the feedwater line. Table 1 summarizes the line frequencies less than 10 Hz. These frequencies are in the same range as those found in the SG in the reactor coolant loops of other Westinghouse plants. W testing of other plants has shown that the SG vibrates in its fundamental modes due to flow in the reactor coolant loop. While resonance between the feedwater line and steam generator is a possiblity, it is considered extremely unlikely based on previous feedwater testing and analysis.

TABLE 1

SUMMARY OF FEEDWATER LINE FREQUENCIES < 10 HZ (W/SNUBBERS)

LINE	FREQUENCIES (HZ)
Loop 1	2.79, 2.98, 3.97, 5.48, 5.76, 8.38, 9.16, 9.41
Loop 2	3.07, 7.16
Loop 3	3.17, 3.87, 8.13

SUMMARY OF FEEDWATER LINE FREQUENCIES < 10 HZ (W/O SNUBBERS)

LINE	FREQUENCIES (HZ)
Loop 1	.83, .93, 1.69, 2.78, 2.94, 3.03, 3.94 4.92, 5.62, 7.38, 8.41, 9.75
Loop 2	1.57, 2.59, 3.08, 6.59, 7.22
Loop 3	1.63, 3.24, 3.42, 7.29, 8.24

Corrective Actions

All feedwater reducers and spoolpieces have been replaced in accordance with the following sequence:

1) Machined off 1/2" of nozzle removing all suspect metal and re-prepped to original configuration.

2) Liquid penetrant examination of nozzle ID and OD.

3) Radiographed final machined nozzle.

4) Installed new reducer and spool piece in accordance with B31.1 1977 winter addendum. All joints were consumable insert using 7018 filler metal.

5) All welds were stress relieved at 1150°F for one hour and then final radiographed.

6) Performed baseline U.T. of nozzle to reducer welds.

The replacement configuration is identical to the original configuration and therefore does not represent a change to station design.

Repairs to feedwater line weld areas have been completed. A total of twelve welds were repaired. In repairing W#4, "A", S.G., the linear indications originally reported (7-16-79) were removed by grinding through the entire weld. The P.T. prior to weld repair revealed rejectable porosity on the elbow side of the remaining weld material. Continued grinding carried into the base metal of the elbow without eliminating the porosity and also revealed 5 minute linear indications. Further grinding did not eliminate any of the rejectable indications. It was decided to replace the elbow since the indications could not be removed within allowable code limits for amount of elbow material removed for repair welding.

Feedwater Chemistry History

Information regarding feedwater chemistry control for Surry Unit No. 1 was submitted in our letters of June 20, 1979 (Serial No. 492) and August 9, 1979 (Serial No. 492B). Surry Unit No. 1 changed from phosphate to AVT chemistry control in January, 1975. A summary of feedwater chemistry history for Surry Unit No. 1 is included in Table 2.

TABLE 2

FEEDWATER CHEMISTRY HISTORY
SURRY UNIT NO. 1

1974 Average pH = 9.50± .2; maximum pH = 10.20
Average conductivity = 10.0 umhos/cm
Na, ppb 0-10, 50% of time
10-100, 45% of time
>100, 5% of time
Dissolved oxygen, < .005 ppm
Corrosion inhibitors used: cyclohexcylamine, hydrazine, phosphate

1975	Average pH = 8.80± .2, maximum pH = 9.60 Average conductivity = 5.0 umhos/cm Na. ppb 0 - 10, 50% of time 10-100, 45% of time >100, 5% of time Dissolved oxygen < .005 ppm Corrosion inhibitors used: ammonium hydraxide, hydrozine	
1976	Average pH = 9.5± .2; maximum pH = 10.20 Average conductivity = 10.0 umhos/cm Na, ppb 0-10, 50% of time 10-100, 49% of time >100, 1% of time Dissolved oxygen <.005 ppm Corrosion inhibitors used: cyclohexcylamine, hydrazine	
1977	Average pH = 9.1 ±.2; maximum pH = 10.10 Average conductivity = 5.0 umhos/cm Na, ppb 0-10 65% of time 10-100 34% of time >100 1% of time Dissolved oxygen, <.005 ppm Corrosion inhibitors used: cyclohexcylamine, morpholine, hydrazine	
1978	Average pH = 8.9±.2; maximum pH = 9.60 Average conductivity = 4.0 umhos/cm Na, ppb 0-10, 75% of time 10-100, 24% of time >100, 1% of time Dissolved oxygen, <.005 ppm Corrosion inhibitors used: morpholine, hydrazine	

Conclusion

All feedwater line reducers and spoolpieces have been replaced. All feed line weld defects will be repaired prior to startup.

Approximately seven months of operation of Surry Unit No. 1 remains in the current fuel cycle. Following this seven months of operation, Unit 1 will be shutdown for steam generator replacement.

Surry Unit No. 1 has operated for seven years prior to these inspections. The cracks which developed during that time were not through-wall, and were of limited penetration. It is, therefore, unlikely that cracks will develop and propogate to a level of consequence during the next seven months of operation. We, therefore, conclude that the continued operation of Surry Unit No. 1 until the steam generator replacement outage is acceptable.