VIRGINIA ELECTRIC AND POWER COMPANY

RICHMOND, VIRGINIA 23261

November 13, 1989

United States Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555

Serial No. 89-006B
PES/AVB:hts:584 R8
Docket Nos. 50-280
50-281
License Nos. DPR-32
DPR-37

Gentlemen:

VIRGINIA ELECTRIC AND POWER COMPANY
SURRY POWER STATION UNITS 1 AND 2
RESPONSE TO NRC BULLETIN NO. 88-11
PRESSURIZER SURGE LINE THERMAL STRATIFICATION

Virginia Electric and Power Company submitted a response (Serial No. 89-006A) to NRC Bulletin 88-11 on May 3, 1989, for Surry and North Anna Power Stations.

Upon further review, we have found it necessary to revise and clarify Surry Power Station's Summary Evaluation (Attachment 2) with respect to the analytical evaluations, visual inspections of the pressurizer surge line, and analysis of data collected during recent operations.

Enclosed is the revised Attachment 2 with highlighted changes to the document. The previous conclusions of our evaluation remain unchanged.

The information provided in this transmittal is true and accurate to the best of my knowledge.

Very truly yours,

W L Stewart

W. L. Stewart
Senior Vice President - Power

Attachment

cc: United States Nuclear Regulatory Commission
Region II
101 Marietta Street, N. W.
Suite 2900
Atlanta, Georgia 30323

Mr. J. L. Caldwell
NRC Senior Resident Inspector
North Anna Power Station

Mr. W. E. Holland
NRC Senior Resident Inspector
Surry Power Station

IE30
1/1

COMMONWEALTH OF VIRGINIA)
)
COUNTY OF HENRICO)

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by W. L. Stewart who is Senior Vice President - Power, of Virginia Electric and Power Company. He is duly authorized to execute and file the foregoing document in behalf of that Company, and the statements in the document are true to the best of his knowledge and belief.

Acknowledged before me this 13 day of November, 1989.

My Commission Expires: February 25, 1990.

Vicki L. Hull
Notary Public

(SEAL)

ATTACHMENT 2

SURRY POWER STATION UNITS 1 AND 2

SUMMARY OF THE EVALUATION OF
PRESSURIZER SURGE LINE THERMAL STRATIFICATION
IN RESPONSE TO NRC BULLETIN 88-11

September 1989

PRESSURIZER SURGE LINE THERMAL STRATIFICATION

BACKGROUND

NRC Bulletin 88-11, "Pressurizer Surge Line Thermal Stratification," requested holders of operating licenses to establish and implement a program to confirm pressurizer surge line integrity with respect to thermal stratification and striping concerns.

The specific actions requested by the Bulletin are as follows:

a. Conduct a visual inspection to identify any gross discernible distress or structural damage in the entire surge line including piping, supports, whip restraints, and anchor bolts.

b. Demonstrate that the surge line meets the applicable design codes (fatigue analysis to be performed per the latest ASME requirements) for the life of the plant, considering thermal stratification and striping.

c. Instrument pressurizer surge line as an alternative to obtain plant specific data for analysis.

d. Update the stress and fatigue analysis to show code compliance incorporating any observations from the visual inspection.

PROGRAM

A detailed program has been established to confirm the integrity of the pressurizer surge line. As part of the program, the following actions have been implemented.

1. Perform visual inspection (VT-3) of the entire surge line. Two inspections were performed on each unit with the surge line at ambient temperature. The first walkdown was performed with the insulation still on the pipe, and the second walkdown was performed with the surge line at ambient conditions and the insulation removed from accessible portions of the piping.

   The purpose of the first walkdown was to inspect for any binding or interference with the movement of the surge line as may be evidenced by dented or crushed insulation.

   The second walkdown involved:

   a. inspection for any gross discernible marks on the pipe that may evidence distress or damage.

   b. inspection of any damage to the supports, rupture restraints, and anchor bolts.

   c. measurement of actual current settings on spring hangers.

2. Perform plant specific detailed ASME III Class 1 stress and fatigue analysis in accordance with the latest ASME requirement incorporating high cycle fatigue and considering both thermal stratification and thermal striping.

3. Perform non-destructive examination of critical locations on the surge line. These locations were pre-selected based on anticipated high stress and usage factors under the combined effect of loading including thermal stratification and thermal striping. These NDE locations were confirmed based on stress and fatigue analysis (including thermal stratification and striping).

4. As an additional measure, provisions have been made to instrument the surge line to detect temperature distribution and thermal movements. Thermocouples and displacement monitors have been installed on the surge line with the objective of obtaining plant specific data on thermal stratification, thermal striping, and line deflections.

INSPECTION RESULTS

The insulation along the entire line for both units was inspected during the initial walkdown, and showed no signs of being dented, broken, misaligned, or twisted.

The final inspection walkdown on each unit was performed at shutdown condition with the insulation removed. The settings on the spring hangers that support the line and the rupture restraints were recorded. The piping, pipe supports, rupture restraints, and anchor bolts were visually inspected. No gross discernible distress or structural damage was observed on the pipe.

The surge line is supported with spring hanger assemblies at two locations. Each spring hanger assembly consists of two cans. The rupture restraint assembly consists of five radial fingers tied to a center location. Each finger and the center location is supported from the top with a spring hanger (total of six spring hangers).

Inspections on the Unit 1 surge line revealed no significant observations. However, on Unit 2, the following was observed:

1. On one of the spring hanger assemblies supporting the surge line, the two spring cans were found not to be carrying balanced proportions of the load, resulting in a cocked configuration for the spring hanger.

2. The rod of the spring hanger supporting the middle finger of the rupture restraint assembly was found to be discernibly bent. The rod of an adjacent spring hanger was found to be slightly bent.

3. Three of the spring hangers on the rupture restraint fingers were about 2" out of plumb.

4. Loose nuts were noted on the inside of one whip restraint.

The above conditions on Unit 2 result in a redistribution of load sharing between the spring hangers. We have analyzed the as-found condition and concluded that this redistribution in load sharing has no adverse effect on the pipe. The impact of these conditions is to redistribute the load sharing between the spring hangers without any adverse effect to the pipe.

Actions were taken to replace the two bent spring hanger rods, readjust the position of three spring hangers to make them completely plumb, and reset ten spring hanger cans to allow for unrestricted movement of the surge line. The loose nuts noted on the inside of one whip restraint were tightened.

We believe that the observed conditions may be attributed to the original cold sets of the springs or slight repositioning of the surge line due to normal thermal expansion and contraction during the prior years of operation. Unit 2 operation along with the surge line piping and support configuration are very similar to Unit 1, yet the same conditions were not observed on the Unit 1 spring hangers. However, for Unit 1, some markings on the pipe were found at the point of contact with the rupture restraints. No similar markings were found on Unit 2. The analysis for thermal stratification does not indicate that movement of the surge line due to stratification can lead to the conditions observed on the Unit 2 rupture restraint spring hangers. In addition, ultrasonic examinations of the pressurizer surge line welds adjacent to the reactor coolant system piping were performed and no relevant indications were found.

STRESS & FATIGUE ANALYSIS

Since the configuration of the surge line at Surry 1 and 2 is similar, a bounding analysis of the surge line was performed to cover both units. The analysis addresses the qualification of critical points on the surge line, the intersection point of the RCL hot leg and the surge line, as well as the nozzle to the pressurizer. The analysis has been performed in accordance with the latest ASME Code (1986 with addenda thru 1987) incorporating high cycle fatigue as required by NRC Bulletin 88-11.

The results of a detailed Class 1 stress and fatigue analysis for both units considering thermal stratification and striping demonstrate that the surge line at each unit meets the applicable code requirements. The analysis incorporates the as-built conditions on both units.

The stress and fatigue analysis is based on conservative assumptions which are highlighted below:

(a) Methodology

A piping model using the STRUDL computer program was used to generate the forces and moments due to various conservatively assumed combinations of stratification profiles and scenarios. This was done by imposing different temperatures on the top and bottom of the piping surfaces. Potential bottoming out of spring hangers and closure of gaps at rupture restraints under each of the assumed stratification scenarios were also simulated in the model.

Maximum forces and moments resulting from the assumed stratification profiles were generated at a number of critical locations along the surge line.

The local effects of gross discontinuities, linear and non-linear temperature gradients for significant thermal transients were determined using the one-dimensional HTLOAD computer program.

The forces and moments (from STRUDL analysis) were then appropriately combined with other mechanical loads (i.e,. seismic, deadload, and thermal expansion) and with local effects of thermal and pressure transients (from HTLOAD analysis) to calculate fatigue usage factors using the NUPIPE computer program.

(NOTE: STRUDL and NUPIPE models were compared to each other for typical loads to ensure consistency in stiffness modeling).

(b) Thermal Transients

The pressurizer surge line was originally designed in accordance with ANSI B.31.1 code and therefore no thermal transients were defined and considered in the analysis. In order to analyze for thermal stratification and striping in combination with other transients, the transients were defined as follows:

Significant transients that affect the surge line have been considered. These transients were extracted from Westinghouse System Description Document 1.3, Rev. 2, and 1.3X, Rev. 0. It has been concluded that the thermal transients used in the analysis are conservative for evaluating fatigue of the surge line. No transients other than as described in the above documents significantly affect the fatigue of the Pressurizer Surge Line.

(c) Thermal Stratification Profile

The configuration of the pressurizer surge line for Surry 1 and Surry 2 is similar having one horizontal leg where stratification could occur. The entire horizontal length was assumed stratified from the pressurizer end to a distance of two pipe diameters from the RCL hot leg. A maximum differential temperature of 300°F was originally considered between top and bottom surfaces of the pipe during heatup. The effect of potential bottoming or topping out of spring hangers was also considered. The forces and moments generated from the assumed stratification profiles were then appropriately combined with the other loading conditions.

During the recent heatup of Unit 1, the differential temperature between the pressurizer and the RCL hot leg may have been as high as 320°F based on temperature in the RCS hot leg and pressurizer. This higher than previously assumed temperature was due to the extended outage and corresponding load decay heat input during startup. The actual maximum temperature differential recorded by the newly installed surge line thermocouples during the recent startups of Units 1 and 2 was 203°F. To ensure that the recorded conditions are bounded by analysis, three additional conservative upper bound scenarios were evaluated.

The first evaluation was performed by assuming a temperature differential of 345°F between the top and bottom of the surge line pipe for the length of pipe between the pressurizer and the approximate point instrumented with thermocouples. A temperature differential of 225°F between top and bottom of the pipe was assumed over the remaining surge line pipe length to a distance of two pipe diameters from the RCL hot leg, and the rest of the piping being at the RCL temperature. The second evaluation is similar to the first, except that a 300°F differential temperature was assumed for the portion from the point instrumented to a distance of two pipe diameters from the RCL hot leg instead of 225°F. The third evaluation was performed by assuming a temperature differential of 320°F between the top and bottom of the surge line pipe for the length of pipe between the pressurizer and the approximate point instrumented with thermocouples. A temperature differential of 280°F between top and bottom of pipe was assumed over the remaining surge line pipe length to a distance of two pipe diameters from the RCL hot leg, and the rest of the pipe being at the RCL temperature.

The following is a summary of the results of the evaluations:

1. Piping stresses and fatigue usage factors are based on the maximum loads generated by any of the stratification profiles considered in the analysis.

2. Pressurizer nozzle loads are enveloped by the calculation of record for the unstratified condition.

3. Fatigue analysis of the surge line has been performed assuming the above scenarios over a 40-year life of the plant, and the results continue to indicate the cumulative usage factor is still below the ASME Code allowable of 1.0.

(d) Stratification Cycles

A full stratification moment cycle (fully stratified to fully destratified condition) has been conservatively considered to occur during the stratification phenomenon.

A total of 32,070 significant stratification cycles have been considered by design to occur during the following events:

a. Spray initiation during heat-up and cooldown
b. Loop out of service
c. Steam dump
d. Feedwater cycling at shutdown
e. Spray during boron equalization
f. Loss of load, loss of power, and loss of flow in a single loop
g. Reactor trips
h. RCS depressurization
i. Inadvertent safety injection
j. Turbine roll test
k. Drawing a bubble during heat-up

These cycles account for known in-surges and out-surges from the pressurizer as well as steady state conditions. The cycles are bounded by the following groupings:

1. Heatups and Cooldowns

300°F stratification for 400 cycles (maximum loads are used based on 300°F over the entire length or 345°F over a portion of the line with the rest at 300°F)
200°F stratification for 600 cycles (considered to generate 2/3 of the loads of the first case)

150°F stratification for 200 cycles (considered to generate 1/2 of the loads of the first case)

100°F stratification for 1,400 cycles (considered to generate 1/3 of the loads of the first case)

2. Other hot conditions

74°F stratification for 29,470 cycles

A review of the records of the outage logs indicates that Surry Units 1 and 2 have undergone less than 100 heat up and cooldown cycles for each unit. An administrative limit will be implemented to limit the differential temperature between the pressurizer and the RCS hot leg for future heatup/cooldown cycles.

(e) Thermal Stress Range

Forces and moments resulting from stratification were combined with those due to thermal expansion to determine ASME Equation 12 thermal stress range levels.

The maximum stress range occurs at the taper junction of the surge line to the nozzle attached to the RCL hot leg. The material of the surge line is austenetic stainless steel SA376 TP 316.

Max. Stress Range = 53,352 psi
Equation 12 Allowables (3 Sm) = 54,774 psi (calculated as the mean Sm between 200°F and 673°F per NB - 3200)

(f) Thermal Striping

Thermal striping is the rapid oscillation of the thermal boundary interface along the piping inside surface occurring during stratified flow conditions. It is a localized phenomenon which creates thermal stresses in the pipe wall. Striping, by itself, does not result in change to the moment level in the pipe.

The response of the inside temperature of the pipe due to the fluctuating fluid temperature depends on the velocity of flow and the frequency and amplitude of temperature fluctuations. The local stresses generated at the pipe wall are caused by the linear and non-linear temperature gradients through the pipe wall thickness.

Based on a survey of available literature (e.g. General Electric BWR Feedwater nozzle/sparger report NEDE-21821-02 and work performed for other utilities obtained in owner's group meetings), assumed frequencies between 10 and 0.03 hz for thermal striping are considered conservative. At higher frequencies, there is no sufficient soak time for the pipe wall to respond to the imposed fluctuating fluid temperature. In addition, it is not possible for a sinusoidal wave to maintain its full peak at lower frequencies, especially in conjunction with an assumed local fluid velocity of 1.8 ft./sec. The local fluid velocity was conservatively calculated by assuming a spray flow of 10% of the pressurizer water volume (or approximately 80 gpm) localized in 20% of the pipe inside diameter.

The stress levels associated with striping were determined using stress indices for a girth butt weld. Oscillations are evaluated for 300°F sine-wave temperature variations. These variations are conservatively considered to occur with frequencies between 10.0 and 0.03 hz. The local effects due to striping were calculated using simplified heat transfer models. The hotter fluid is assumed to act at a point on the inside surface of the pipe within a cooler two-dimensional boundary which conservatively represents the pipe. The actual pipe boundary is hotter than that assumed in the model because the heat transfer is along the pipe surface in addition to the pipe wall thickness. A hotter pipe boundary tends to relax the stress field predicted by the model. Therefore, the use of simplified time dependent heat transfer gives more conservative results. In addition, the resulting stress is conservatively assumed to exist for the duration of each heatup or cooldown spray modes where the Pressurizer to Hot Leg temperature difference exceeds 100°F and also for two hours during each heatup while the pressurizer steam bubble is being drawn. Heatup to cooldown is considered to occur 200 times over the lifetime of the plant. The usage factors for these cases are determined by utilizing the calculated peak stress range, the total time, the frequency, and the fatigue curve.

Additionally, the 100°F thermal striping case is evaluated by using 1/3 of the stress determined for the 300°F case and considering it to exist constantly for the entire 40 year plant life.

The film coefficient used in the analysis is based on the local fluid velocity of 1.8 ft/sec. This velocity is sufficiently high to envelop the events under consideration.

The maximum usage factor due to thermal striping was determined to be 0.1.

(g) Usage Factors

Loadings due to stratification, striping, thermal expansion, thermal transients, and seismic load were combined to determine usage factors.

The maximum usage factor was calculated to be 0.861 at the taper transition of the surge line to the hot leg RCL nozzle.

(h) Rachet Ratio

The results of the rachet check are as follows:

The maximum rachet ratio is 0.528 at the taper transition of the surge line to the pressurizer.

The second highest rachet ratio is 0.505 at the taper transition between the surge line and the hot leg RCL nozzle.

(i) Pressurizer Nozzle

For Surry, the forces and moments generated at the pressurizer nozzle due to thermal stratification counteract those due to thermal expansion. The combined thermal loads at the pressurizer nozzle due to thermal stratification and thermal expansion are lower than those due to thermal expansion alone. Therefore, the original analysis performed without thermal stratification bounds the results of the analysis that considers stratification, and provides the acceptance basis for the nozzle loads.

(j) Computer Programs

j.1) NUPIPE-SW

NUPIPE-SW is a finite element computer program which performs a linear elastic analysis of three dimensional piping system subject to static, thermal and dynamic loads. The program performs code compliance check to the requirements of ASME III Class 1, 2 and 3 and ANSI B.31.1 Piping. This is a proprietary version of NUPIPE which is a public domain computer code.

j.2) HTLOAD

HTLOAD is a one dimensional heat transfer program which determines the thermal response of a piping system with or without a thermal sleeve, due to the temperature, velocity and/or the state change of the inside fluid. The program lists as output, the time dependent linear pipe wall temperature gradient (ΔT_1), the non-linear temperature gradient (ΔT_2), and the discontinuity stress that are used in the calculation of piping stress in accordance with ASME Section III, Subsection NB.

j.3) STRUDL-SW

STRUDL-SW is a structural analysis computer program, which is applicable to a wide range of structural problems. This program analyzes the support structure (generally, 2 or 3 dimensional frames, trusses) with specified loadings for stress values in each member, reactions at attachment points, internal reactions at joints, displacements at loading points, and local buckling of members.

j.4) FAST2

"FAST2" is a computer code for the analysis of stresses and deflections at vessel-nozzle intersections. FAST2 is applicable to a cylindrical vessel or spherical head with a cylindrical pipe intersecting the wall.

HARDWARE MODIFICATIONS

The spring hangers supporting the surge line and the rupture restraints on both units have been reset to allow for unrestricted movement of the line. In addition, the spring hangers rejected during the visual inspections performed on Unit 2 were replaced.

DATA COLLECTION

For the purpose of further verification, instruments have been installed on the surge line for both Units 1 and 2 to detect temperature distribution and thermal movements.

For each unit, six thermocouples have been placed at one location on the surge line. The thermocouples are equally spaced along half a pipe circumference from top to bottom. The top and bottom thermocouples are intended to detect stratification, and the four thermocouples on the side of the pipe are intended to detect striping. A displacement positioner has also been placed at the same location to detect vertical deflections.

These instruments will provide plant specific data on thermal stratification, thermal striping, and line deflections. This will corroborate that the analysis bounds the recorded data.

A recording and evaluation procedure has been prepared to systematically record data for pressure surge line and safety injection lines. Evaluation of data is specifically geared towards evaluating the thermal stratification effect on the fatigue of safety injection lines (NRCB-88-08).

REVISIONS TO TECHNICAL SPECIFICATION

According to the Technical Specification 3.1.B.3, the pressurizer temperature is limited such that the differential temperature between pressurizer and spray water will not exceed 320°F. As stated in the previous summary of analysis results, the maximum differential temperature previously assumed was 300°F over the entire horizontal length. Based on recent, more conservative analytical assessments of maximum differential temperature, administrative controls are being reassessed including effects of instrument error. Surry will implement administrative controls to limit the differential temperature following completion of this re-evaluation. The need to revise Technical Specification 3.1.B.3 is under evaluation.