VIRGINIA ELECTRIC AND POWER COMPANY

RICHMOND, VIRGINIA 23261

May 3, 1989

United States Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, D. C. 20555

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Gentlemen:

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

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.

In response to the Action Item 1.a of the bulletin, Virginia Electric and Power Company conducted visual inspections of the pressurizer surge lines at Surry Units 1 and 2, and North Anna Unit 2. No discernible distress or damage attributable to thermal stratification was identified for the surge line piping, supports, restraints, or anchor bolts. In addition, ultrasonic examination of the pressurizer surge line welds adjacent to the reactor coolant hot leg piping was performed and no relevant indications in Surry Units 1 and 2, and North Anna Unit 2 surge lines were observed. The non-destructive examination (NDE) of North Anna Unit 1 pressurizer surge line is in progress. The results of the NDE to date are discussed in Attachments 1 and 2.

This letter also provides the results of the pressurizer surge line stress and fatigue analysis performed for both Surry and North Anna Power Stations in response to the Action Item 1.b of the bulletin. A stress and fatigue analysis considering the effects of thermal stratification and thermal striping was performed in accordance with the latest ASME Code (1986 Edition with addenda through 1987) for both Surry and North Anna Power Stations. The results of this analysis demonstrate that the pressurizer surge lines at each station meet the applicable ASME code requirements.

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The analysis was performed using the worst case anticipated thermal stratification and striping and indicated that no hardware modifications were required on pressurizer surge lines at Surry Units 1 and 2, and North Anna Unit 1. However, the North Anna Unit 2 pressurizer surge line required a modification to one spring support to allow greater than anticipated deflection of the line. This modification has been made.

Under worst anticipated thermal stratification, the calculated loads at the pressurizer nozzle are within the allowable loads specified by the equipment manufacturer for Surry Units 1 and 2 and North Anna Unit 1. However, on the North Anna Unit 2 pressurizer nozzle, the calculated loads exceed the allowable loads specified by the equipment manufacturer. These new loads are currently being reviewed by the equipment manufacturer. However, our review of the North Anna Unit 2 pressurizer nozzle loads shows no significant safety concern. There is no impact on the pressurizer, pressurizer nozzle and pressurizer supports based on our independent assessment and no significant usage factor will be added during the next operating cycle to the cumulative fatigue. We expect the manufacturer's review of the new nozzle loads to be completed by July 15, 1989.

Attachments 1 and 2 of this letter provide separate evaluation summaries for the pressurizer surge lines at North Anna and Surry Power Stations, respectively. Attachment 1 also details our assessment of the pressurizer nozzle loads for North Anna Unit 2 and the basis for continued operation pending final review of the nozzle loads.

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

Very truly yours,

for W. L. Stewart
Senior Vice President-Power

Attachments
1. North Anna Evaluation Summary
2. Surry Evaluation Summary

cc: United States Nuclear Regulatory Commission
Region II
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Mr. J. L. Caldwell
NRC Senior Resident Inspector
North Anna Power Station

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

COMMONWEALTH OF VIRGINIA)
)
COUNTY OF HENRICO)

The foregoing document was acknowledged before me, in and for the County and Commonwealth aforesaid, today by J. L. Wilson who is Assistant Vice President - Nuclear, 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 3 day of May, 1989.

My Commission Expires: February 25, 1990.

Vicki L. Hull
Notary Public

(SEAL)

ATTACHMENT 1

NORTH ANNA POWER STATION UNITS 1 AND 2

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

April 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 Unit 2, the first was performed during plant cooldown 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 (a) to inspect for any binding or interference with the movement of the surge line as may be evidenced by dented or crushed insulation and (b) to measure the travel of spring hangers and snubbers at various temperatures during cooldown.

   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 and snubbers.

   d. measurement of actual current gaps between the pipe and rupture restraints.

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 loadings including thermal stratification and thermal striping. These NDE locations were later adjusted based on stress and fatigue analysis (including thermal stratification and striping) and accessibility, where necessary.

4. As an additional measure, provisions have been made to instrument the surge line to detect temperature distribution and thermal movements. Engineering packages have been prepared to install thermocouples and displacement monitors on the surge line with the objective of obtaining plant specific data on thermal stratification, thermal striping, and line deflections. The installation of thermocouples and displacement monitors is expected to be completed during the ongoing outages. The measured temperatures and deflections will be used to confirm the results of the analysis.

INSPECTION RESULTS

(a) North Anna Unit 2

a.1) The initial inspection involved a series of recordings of snubber and spring hanger travel and load set during plant cooldown in the recent outage, as well as measurement of the gap on rupture restraints. The temperature of the pressurizer was noted for each set of recordings. These were 653°F, 435°F, 255°F and 115°F. The corresponding hot leg temperatures were 540°F, 113°F, 118°F, and 113°F, respectively.

The insulation along the entire line was also inspected and showed no signs of being scratched, broken, misaligned, or twisted.

a.2) The final inspection walkdown was performed at shutdown conditions with the insulation removed. Spring hanger and snubber settings were recorded, and the gaps on rupture restraints were also measured. Accessible portions of the piping and every pipe support, rupture restraint, and anchor bolt were visually inspected. No gross discernible distress or structural damage to any components was observed.

a.3) The ultrasonic examination of the pressurizer surgeline welds adjacent to the reactor coolant system piping resulted in no relevant indications.

(b) North Anna Unit 1

Visual inspection and ultrasonic examination of the surge line for Unit 1 will be performed prior to restart. The results of this inspection will be submitted in accordance with the requirements of the bulletin.

STRESS & FATIGUE ANALYSIS

Separate analyses were performed for Unit 1 and for Unit 2 since the configuration of the surge line for each unit is unique. The analysis for each unit 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 through 1987) incorporating high cycle fatigue as required by NRC Bulletin 88-11.

The results of a detailed Class 1 stress and fatigue analysis for each unit considering thermal stratification and striping demonstrate that the surge line at each unit meets ASME code requirements. The analysis also incorporates the as-built conditions on North Anna Unit 2. North Anna Unit 1 as-built information will be reconciled with the analysis upon completion of "as-built" verification.

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

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. A detailed review and comparison of these transients to Westinghouse System Description Document 1.3, Rev. 1, which was used in the original analysis has been performed. It has been concluded that the thermal transients used in the analysis are conservative for evaluating fatigue of the surge line. No other transients as described in the above documents significantly affect the fatigue of the Pressurizer Surge Line.

(c) Thermal Stratification Profile

c.1) The Pressurizer Surge Line for North Anna 2 consists of two horizontal legs, at different elevations, where stratification may occur. For analysis purposes, several stratification profiles were considered in order to bound the possible scenarios of stratification of each leg. A maximum differential temperature of 300°F was considered between top and bottom surfaces of the pipe during heat up. The entire length of one or both horizontal legs is considered stratified for analysis purposes. The maximum forces and bending moments generated from the assumed stratification profiles are then appropriately combined with the other loading conditions described above. The effect of potential closure of gaps at rupture restraints and of bottoming out of spring hangers due to the conservatively assumed stratification profiles was also considered although no gap closure was observed during walkdown.

c.2) The Pressurizer Surge Line for North Anna 1 has one horizontal leg where stratification may occur. The entire horizontal length was assumed stratified. A maximum differential temperature of 300°F was considered between top and bottom surfaces of the pipe during heat up. The forces and bending moments generated from the stratification profile are then combined with the other loading conditions described above.

It is intended that the stratification profile will be determined from the recorded temperatures and displacements subsequent to plant start up. This will provide confirmation that the observed profile is enveloped by the stratification profiles used in the analysis.

(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 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
   200°F stratification for 600 cycles
   150°F stratification for 200 cycles
   100°F stratification for 1,400 cycles

2. Other hot conditions

   74°F stratification for 29,470 cycles

A review of the records of operating history indicates that North Anna Units 1 and 2 have undergone a total of 54 and 38 heatup and cooldown cycles respectively with up to a maximum observed 260°F differential temperature between the pressurizer and reactor coolant hot leg during each heat-up and cooldown.

(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.

For North Anna 2, 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 austenitic stainless steel SA376 TP 316.

Max. Stress Range = 51,792 psi
Equation 12 Allowables (3 Sm) = 53,237 psi (calculated as the mean Sm between 425°F and 673°F per NB-3200)

For North Anna 1, the maximum stress range occurs at the elbow below the pressurizer nozzle. The surge line material is austenitic stainless steel SA 376, TP 316.

Max. Stress Range - 52,591 psi
Equation 12 Allowables (3 Sm) = 53,237 psi (calculated as the mean Sm between 425°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 and due to the fluctuating fluid temperature depends on the velocity of flow the frequency and amplitude of temperature fluctuations. The local stress 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 70 gpm) localized in 20% of the pipe cross-sectional area.

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.

For North Anna 2, the maximum usage factor was calculated to be 0.968 at the taper transition of the surge line to the hot leg RCL nozzle.

For North Anna 1, the maximum usage factor was calculated to be 0.990 at the location of lug attachments for axial snubbers.

(h) Rachet Ratio

The results of the rachet check are as follows:

For Unit 2, the maximum rachet ratio is 0.808 at the elbow between the top horizontal leg and the vertical riser to the bottom horizontal leg.

For Unit 1, the maximum rachet ratio is 0.926 at the elbow below the pressurizer nozzle.

(i) Pressurizer Nozzle

i.1) North Anna 1

For Unit 1, 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.

i.2) North Anna 2

For Unit 2, nozzle loads were generated from the same conservatively assumed combination of thermal stratification profiles and scenarios used in the qualification of the line. These nozzle loads which exceed the allowable loads specified by the equipment manufacturer have been reviewed for their impact on the junction between the nozzle and the pressurizer and for the impact on the pressurizer shell and supports. The following assessment has been made:

1. There is no impact to the pressurizer supports since the design of these supports is governed by much higher rupture and valve discharge loads.

2. The stresses generated in the pressurizer shell in the area of the surge line nozzle due to internal pressure and mechanical piping loads including stratification are much lower than the allowable stress for the pressurizer shell material.

3. The nozzle and the pressurizer are thicker than the surge line. Since the nozzle is located close to the pressurizer supports, there are no additional mechanical loads (e.g. seismic) that the pressurizer shell will be subjected to in the area of the surge line nozzle.

Moreover, pending final review of the nozzle loads continued operation of North Anna Unit 2 is justified for the following reasons:

1. The stratification profiles that generate the maximum nozzle loads are associated primarily with heatup and cooldown. No significant usage factor will be added during the next operating cycle to the cumulative fatigue since only 38 out of 400 heatup and cooldown cycles under worst anticipated differetial temperature of 300°F have been used.

2. The results of the visual inspection of most of the surge line confirm that there is no gross discernible distress or structural damage to any piping components, pipe supports, whip restraints and anchor bolts. The results of additional visual inspection performed during and after the last plant cooldown confirms that the insulation showed no signs of being scratched, broken, misaligned, or twisted.

3. North Anna Unit 2 obtained its low power license after January 1, 1979. In accordance with action (1.b) requested in NRC Bulletin 88-11, the licensee must complete the analysis within one year from receipt of the bulletin (i.e. January 1990). The pressurizer nozzle loads which exceed the allowable loads are being reviewed by the equipment manufacturer to independently verify the adequacy of the pressurizer design. The piping analysis has been completed and the results of the pressurizer nozzle load analysis will be completed and reported to NRC by July 15, 1989.

4. In accordance with action (1.c) requested in NRC Bulletin, if the analysis does not show compliance with the requirements stated in the bulletin for the duration of the operating license, then the licensee is requested to obtain plant specific data by installing instruments to detect temperature distribution and thermal movements. Plant specific thermal stratification and pipe movement data will be obtained during the next operating cycle.

Even though nozzle on the pressurizer is not a safety concern based on our review, we still intend to confirm the analysis by using recorded data. Twelve thermocouples and two displacement positioners have been installed on the surge line at Unit 2 for that purpose.

(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

(a) North Anna Unit 2

Under the worst case stratification scenario, the analysis indicates the potential for a spring hanger to bottom out. The resulting forces and moments have been adequately accounted for in the stress and fatigue analysis. Nevertheless, it was decided that it is preferable to substitute the existing spring hanger with one that can accommodate calculated travel. This modification has been made.

(b) North Anna Unit 1

The analysis considers the effect of potential closure of rupture restraint gaps. Additionally, spring hangers and snubbers have adequate travel to accommodate the anticipated surge line movements. Therefore, no modifications are required on North Anna 1.

DATA COLLECTION

For the purpose of further verification, instruments have been installed on the surge line on Unit 2 to detect temperature distribution and thermal movements. Instruments will be installed on Unit 1 similarly during the ongoing outage.

For Unit 2, thermocouples have been placed at one location on the upper horizontal leg and one location on the lower horizontal leg. At each location, six thermocouples were placed around half a pipe circumference. 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. In addition, two displacement positioner devices have been placed at one location on the surge line to detect vertical and horizontal deflections.

For Unit 1, six thermocouples will be placed at one location on the surge line. The thermocouples will be equally spaced along half a pipe circumference from top to bottom. 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 thermal stratification effect on the fatigue of safety injection lines (NRCB-88-08).

REVISIONS TO TECHNICAL SPECIFICATION

According to the Technical Specification 3.4.9.2, 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 assumed was 300°F. North Anna currently administratively limits the differential temperature to 260°F. These administrative limits will remain in effect. The need to revise Technical Specification 3.4.9.2 is under evaluation.

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

April 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. However, on Unit 2, loose nuts were noted on the inside of one whip restraint, one restraint had a bent rod, and two other spring can rods were offset approximately three inches from plumb. The discoveries are not attributable to thermal stratification. The only impact from this condition is to redistribute the weight of the rupture restraint to other spring hangers. The appropriate hangers were replaced and reset as required. There is no other impact to the surge line. In addition, ultrasonic examination of the pressurizer surge line welds adjacent to the reactor coolant system piping resulted in no relevant indications.

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 each unit 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. A maximum differential temperature of 300°F was 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.

It is intended that the stratification profile will be determined from the recorded temperatures and displacements subsequent to plant start up. This will provide confirmation that the observed profile is enveloped by the stratification profiles used in the analysis.

(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
   200°F stratification for 600 cycles
   150°F stratification for 200 cycles
   100°F stratification for 1,400 cycles

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. Administrative limits will be implemented to limit the differential temperature between the pressurizer surge line and RCS hot leg to 260°F.

(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 = 50,634 psi
Equation 12 Allowables (3 Sm) = 53,237 psi (calculated as the mean Sm between 425°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 occuring 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 ampitude of temperature fluctuations. The local stress 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 70 gpm) localized in the 20% of the pipe cross-sectional area.

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 0.961 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 provide 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 assumed was 300°F. Surry will implement adminstrative controls to limit the differential temperature to 260°F. The need to revise Technical Specification 3.1.B.3 is under evaluation.