Portland General Electric Company

April 11, 1990

Trojan Nuclear Plant
Docket 50-344
License NPF-1

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington DC 20555

Dear Sirs:

Nuclear Regulatory Commission Bulletin (NRCB) 88-11,
"Pressurizer Surge Line Thermal Stratification"

Nuclear Regulatory Commission (NRC) Bulletin 88-11 requested that operating nuclear plant licensees establish and implement a program to confirm pressurizer surge line integrity in view of the occurrence of thermal stratification. By letter dated April 20, 1989, Portland General Electric Company (PGE) summarized our actions to address the specific items requested in the bulletin. As committed in our letter of April 20, 1989, this letter is notification that PGE has completed the open Requested Actions, Numbers 1.b and 1.d, and that the results of our testing and analyses are available for your inspection.

Based on the current understanding of the thermal stratification phenomenon, it is concluded that thermal stratification does not affect the integrity of the pressurizer surge line of the Trojan Nuclear Plant for its design life of 40 years. A description of the analytical approaches used in reaching our conclusion and a summary of the results are provided as the attachment.

Furthermore, proprietary (WCAP-12456) and nonproprietary (WCAP-12457) versions of a report entitled "Evaluation of Thermal Stratification for the Trojan Nuclear Plant Pressurizer Surge Line" are enclosed providing detailed information concerning the analyses. Since WCAP-12456 contains information proprietary to Westinghouse Electric Corporation, also enclosed is Westinghouse Authorization Letter CAW-90-009, a Proprietary Information Notice, and accompanying Affidavit CAW-88-129. The affidavit signed by Westinghouse, the owner of the information, sets forth the basis on which the information may be withheld from public disclosure by the Commission and addresses with specificity the considerations listed in Title 10 of the Code of Federal Regulations, Section 2.790, Paragraph (b)(4) [10 CFR 2.790(b)(4)]. Accordingly, it is respectfully requested that the

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information which is proprietary to Westinghouse be withheld from public disclosure in accordance with 10 CFR 2.790. Correspondence with respect to the proprietary aspects of the application for withholding or the supporting Westinghouse affidavit should reference CAW-90-009 and should be addressed to R. A. Wiesemann, Manager of Regulatory & Legislative Affairs, Westinghouse Electric Corporation, PO Box 355, Pittsburgh, Pennsylvania, 15230-0355.

Sincerely,

T. D. Walt
Acting Vice President, Nuclear

Attachment
Enclosures

c: Mr. John B. Martin
Regional Administrator, Region V
U.S. Nuclear Regulatory Commission

Mr. David Stewart-Smith (w/o WCAPs)
State of Oregon
Department of Energy

Mr. R. C. Barr (w/o WCAPs)
NRC Resident Inspector
Trojan Nuclear Plant

Subscribed and sworn to before me this 11th day of April 1990.

Notary Public of Oregon

My Commission Expires: March 27, 1994

EVALUATION OF THERMAL STRATIFICATION FOR THE TROJAN NUCLEAR PLANT PRESSURIZER SURGE LINE

Nuclear Regulatory Commission (NRC) Bulletin 88-11, "Pressurizer Surge Line Thermal Stratification", requested that operating nuclear plant licensees establish and implement a program to confirm pressurizer surge line integrity in view of the occurrence of thermal stratification. The analysis required to satisfy Requested Actions 1.b and 1.d of the Bulletin has been completed by the Trojan Plant Nuclear Steam Supply System (NSSS) vendor. From the analysis it is concluded that, based on the current understanding of the phenomenon, thermal stratification does not affect the integrity of the pressurizer surge line for the 40-year design life of the Plant. Requested Action 1.b is restated below, followed by a description of the analytical approaches used and a summary of the results that led to our conclusion. The stress and fatigue analyses have been updated to ensure compliance with applicable American Society of Mechanical Engineers (ASME) Code requirements in accordance with Requested Action 1.d.

REQUESTED ACTION 1.b

Demonstrate that the pressurizer surge line meets the applicable design codes (fatigue analysis should be performed in accordance with the latest ASME Section III requirements incorporating high-cycle fatigue) and other Final Safety Analysis Report and regulatory commitments for the licensed life of the plant, considering the phenomenon of thermal stratification and thermal striping in the fatigue and stress evaluations.

DESCRIPTION OF ANALYTICAL APPROACHES USED

Evaluation of thermal stratification for the Trojan Nuclear Plant pressurizer surge line consisted of four major parts which are discussed below.

1.0 Temperature and Displacement Monitoring

By letter dated September 27, 1988, Portland General Electric Company (PGE) provided the NRC staff with a description of this program.

2.0 Update of Design Transients

Modification of the pressurizer surge line transients to account for thermal stratification was accomplished by replacing the existing heatup and cooldown transients with a new set of transients that were based on actual monitoring data from several plants. In order to assure conservative design, it was necessary to not only replace the existing heatup and cooldown transients, but to modify the existing normal and upset transients to account for the effects of stratification. Modification of the existing normal and upset transients was accomplished by interpreting the previously defined transients in terms of the types of stratification phenomena they are expected to produce.

In the way of clarification, the maximum temperature difference permitted between the pressurizer and the hot leg by Trojan Technical Specification (TTS) 3/4.4.9.2, "Pressurizer Pressure/Temperature Limits", is 320°F. Verification that this limitation is not exceeded during heatup, cooldown, or pressurizer bubble formation or collapse is accomplished through use of an operating procedure which requires hourly determination and recording of the temperature difference.

3.0 Stress Analyses

This section describes the procedure to determine the effects of thermal stratification on the pressurizer surge line based on transients developed as described in Section 2.0 above. These effects were divided into three separate areas, which are discussed in detail below.

3.1 Structural or Global Effects

Analytical studies using several computer codes have confirmed the validity of using an equivalent linear diametric temperature profile to represent the thermal stratification for displacement and loads. Comparison between the analysis results and the plant measured displacement was performed and showed good agreement. Eleven cases of thermal stratification were analyzed by computer for the Trojan surge line. Results for all other cases of stratification were obtained by interpolation. The resulting loads on the pressurizer and hot leg nozzles are acceptable. The surge line pipe stress satisfies the ASME Section III, Subarticle NB-3600 Equation 12 limits.

3.2 Local Stress Due to Nonlinear Thermal Gradient

Local axial stresses develop due to the restraint of axial expansion or contraction. This restraint is provided by the material in the adjacent beam cross sections. For a linear top-to-bottom temperature gradient, the local axial stresses would not exist. Finite element methods were used to evaluate local stresses in the surge line pipe wall and the hot leg nozzle.

3.3 Thermal Striping

At the time when the feedwater line cracking problems in pressurized water reactors (PWRs) were first discovered, it was postulated that thermal oscillations (striping) may significantly contribute to the fatigue cracking problems. These oscillations were thought to be due to either mixing of hot and cold fluid, or turbulence in the hot-to-cold stratification layer from strong buoyancy forces during low flow rate conditions. Thermal striping was verified to occur during subsequent flow model tests. Results of the flow model tests were used to establish boundary conditions for the stratification analysis and to provide striping oscillation data for evaluating high-cycle fatigue.

Thermal striping was also examined during water model flow tests performed for the Liquid Metal Fast Breeder Reactor primary pipe loop. The stratified flow was observed to have a dynamic interface region which oscillated in a wave pattern. These dynamic oscillations were shown to produce significant fatigue damage (primary crack initiation). The flow model test results were used to obtain frequency and duration parameters which were used in the striping evaluation. A conservative amplitude of fluid delta temperature for the Trojan surge line was assumed.

The peak stress range and stress intensity was calculated from a two-dimensional finite element analysis. The methods used to determine alternating stress intensity are defined in ASME Section III. Several locations were evaluated in order to determine the location where stress intensity was a maximum. The worst piping elements were the butt weld and the tapered transition. The fatigue usage factors due to striping alone were then calculated.

4.0 ASME Section III Fatigue Usage Factor Evaluation

This section describes the evaluation results of the ASME Section III fatigue life of the surge line subject to all design transients plus the effects of stratification.

4.1 Code and Criteria

Fatigue usage factors for the Trojan surge line were evaluated based on the requirements of ASME Section III (1986 Edition), Subarticle NB-3600, for piping components. The more detailed techniques of Subarticle NB-3200 were employed, as allowed by Subparagraph NB-3611.2. The cases selected in the fatigue analysis were the in-line component in each profile region with the highest C and K stress indices defined by ASME Section III.

4.2 Previous Design Methods

Previous methods of surge line piping fatigue evaluation used the ASME Section III, Paragraph NB-3653 techniques, but with thermal transients based upon the assumption that the fluid surges sweep the surge line piping. Effects of stratification were not included in previous design analyses, which produced usage factors for the line components.

4.3 Analysis for Thermal Stratification

With thermal transients redefined to account for thermal stratification, the stresses in the piping components were established and new fatigue usage factors were calculated. Due to the nonaxisymmetric nature of the stratification loading, stresses due to all loadings were obtained from finite element analysis and then combined on a stress component basis.

4.3.1 Stress Input

Stresses in the pipe wall due to internal pressure, moments, and thermal stratification loadings were obtained from the analyses of 14 inch, Schedule 160 and Schedule 140 pipes. For a given load condition, the total stress in the pipe was determined by superposition of stresses due to pressure, moment, and local stratification effects. The stresses in the finite element model due to each of these types of loading were first determined for nominal values of load. Scale factors were then developed for each load condition based on actual pressure, moment, and stratification loading for each condition and stress indices for the component being evaluated. The total stresses at each node point in the finite element model were then determined by superposition of the individual contributions. After determining the total stress components for each load condition, the fatigue evaluation was performed conservatively considering stress concentration effects by applying the maximum peak stress index for the component being evaluated to the total stress.

4.3.2 Classification and Combination of Stresses

As described in Section 4.3.1 above, the total stress in the pipe wall was determined for each transient load case. For the hot leg nozzle, the primary plus secondary stresses were determined for transients with stratification in the nozzle, including appropriate stress intensification. Peak stresses, including the total surface stress from all loadings - pressure, moment, stratification - were then calculated for each transient.

4.3.3 Cumulative Fatigue Usage Factor Evaluation

The primary plus secondary stress and peak stress calculated for each transient were then used with the latest ASME Section III requirements relating to high-cycle fatigue to determine usage factors at selected node points in the finite element model on the pipe wall surface, corresponding to the analysis cross sections. These node points were selected based on review of the local stress profiles and previous analysis results where maximum usage factors were calculated. The maximum usage factor was then reported for the global location.

4.3.4 Simplified Elastic-Plastic Analysis

When the primary plus secondary stress exceeded three times the allowable design stress, a simplified elastic-plastic analysis was performed per ASME Section III, Subparagaph NB-3653.6.

4.3.5 Fatigue Usage Results

The maximum usage factors were determined to be at the hot leg nozzle safe-end and at the long radius elbow underneath the pressurizer, and found to be less than the ASME Section III allowable of 1.0.

The usage factor included the effects of striping. The nature of striping damage is at a much higher frequency, varies in location due to fluid level changes, and is maximized at a different location than the ASME Section III usage factor caused by the global bending and local transient effects of thermal stratification.

SUMMARY OF RESULTS

1. Based on plant monitoring results from several Westinghouse PWR plants (including Trojan) and flow stratification test data, the thermal design transients for the surge line have been updated to incorporate the effects of stratification.

2. The structural global and local stresses and loads in the surge line piping and support system meet ASME Section III allowables. The maximum cumulative fatigue usage factor including the effects of striping, for 40 year design life, is less than the ASME Section III allowable of 1.0.

In summary, based on the current understanding of the thermal stratification phenomenon, it is concluded that thermal stratification does not affect the integrity of the pressurizer surge line of the Trojan Nuclear Power Plant. The design life (40 years) and ASME Section III compliance are not affected.