TRTOPE

Enclosure

SAFETY EVALUATION REPORT
ON THE
WESTINGHOUSE OWNERS GROUP PRESSURIZER SURGE LINE THERMAL STRATIFICATION GENERIC DETAILED ANALYSIS
WCAP-12639

1.0 INTRODUCTION

NRC Bulletin No. 88-11 requested all PWR licensees to establish and implement a program to confirm pressurizer surge line integrity in view of the occurrence of thermal stratification and inform the staff of the actions taken to resolve this issue. Licensees of operating PWR's were requested to take the following actions:

Action 1.a - Perform a visual inspection walkdown (ASME Section XI, VT-3) at the first available cold shutdown which exceeds seven days.

Action 1.b - Perform a plant specific or generic bounding analysis to demonstrate that the surge line meets applicable design codes and other FSAR and regulatory commitments for the design life of the plant. The analysis is requested within four months for plants in operation over ten years and within one year for plants in operation less than ten years. If the analysis does not demonstrate compliance with these requirements, submit a justification for continued operation (JCO) and implement actions 1.c and 1.d below.

Action 1.c - Obtain data on thermal stratification, thermal striping, and line deflections either by plant specific monitoring or through collective efforts among plants with a similar surge line design. If through collective efforts, demonstrate similarity in geometry and operation.

Action 1.d - Perform detailed stress and fatigue analyses of the surge line to ensure compliance with applicable code requirements incorporating any observations from 1.a. The analysis should be based on the applicable plant specific or referenced data and should be completed within two years. If the detailed analysis is unable to show compliance, submit a JCO and a description of corrective actions for effecting long term resolution.

Although not required by the Bulletin, licensees were encouraged to work collectively to address the technical concerns associated with this issue. In response, the Westinghouse Owners Group (WOG) implemented two programs to address the issue of surge line stratification in Westinghouse plants. In the first program, a generic bounding evaluation was performed to satisfy Bulletin Action 1.b. Since the results of this evaluation provided less than full design life verification, this report was used later by each of the WOG plants as technical basis for justifying continued operation (JCO). Based on the evaluation, it was deemed acceptable for all WOG plants to continue power operation for at least ten additional heatup/cooldown cycles. The bounding analysis methods and results were summarized in a Westinghouse topical report, WCAP-12277, which was submitted to the staff in June 1989. The staff reviewed the report and concluded that the bounding evaluation provided a sound technical basis for justifying continued operation until completion of the Bulletin requested action 1.d by the end of 1990. This report, combined with acceptable plant specific visual inspection results, satisfied Bulletin Actions 1.a and 1.b for all Westinghouse plants.

The second WOG program was implemented to develop a detailed analysis of the surge line to demonstrate Code compliance for the design life of plants and satisfy Bulletin Actions 1.c and 1.d. The program provided ASME stress and fatigue evaluations based on individual detailed analyses of groups of plants. The methodology and results of the generic detailed analysis were summarized in WCAP-12639 which was submitted to NRC in June 1990. The staff reviewed the WOG report and conducted an audit at Westinghouse offices in November 1990. The following section summarizes the staff evaluation of the program.

2.0 STAFF EVALUATION

The WOG generic detailed analysis was applicable to 43 of the 55 Westinghouse plants. Plant specific analyses had been previously performed for the other 12 plants. In order to reduce the analytical efforts, the 43 plants were categorized into 17 analysis groups based on their similarity of response to thermal stratification. The WOG program involved the development of updated design transients to account for stratification and striping, and the analysis of each structural group for global and local stresses for verifying ASME Code compliance in stress and fatigue. The individual licensees are responsible for demonstrating applicability of the WOG generic analysis to their specific plant. The major areas of staff review and evaluation are summarized below.

2.1 Update of Design Transients

Westinghouse updated their design transients for the pressurizer surge line to reflect stratification effects. Two major categories of transients were considered: heatup and cooldown transients and normal and upset transients. For each design transient, the original uniform temperature distribution was modified to a stratified distribution with a corresponding number of cycles. In addition, Westinghouse developed a new set of transients for thermal striping.

The development of updated transients used information from an operational study and results of several plant monitoring programs. In the operational study, Westinghouse reviewed heatup and cooldown procedures as well as historical records from several plants. Heatup and cooldown operation was of primary concern because the maximum ΔTs between the pressurizer and hot leg occur during these modes. In addition, Westinghouse conducted interviews with reactor operators and shift supervisors at a representative sample of plants to gain additional insight into the variation of operating methods.

Based on a review of WOG plant geometries and earlier monitoring experience gained in plant specific programs, Westinghouse provided recommendations regarding the need for additional monitoring data to cover all variations of WOG plants. Westinghouse received surge line monitoring data from a total of 21 domestic plants. Typical monitoring programs involved the installation of temporary sensors on the surge line piping. Externally mounted RTD's or thermocouples were attached to the outside surface of the pipe at various circumferential and axial locations. These sensors provided data on the top to bottom temperature distribution along the longitudinal axis of the pipe. Several plants also installed sensors to detect vertical and horizontal movements at locations along the pipe axis. Data was typically collected at frequent intervals during heatups and cooldowns when system ΔT was high. Data was also collected during steady state operation but at a reduced frequency. In addition, existing plant instrumentation was used to record various system parameters for correlation of plant operation actions with stratification in the surge line. The data was typically provided to Westinghouse in tabular form or in time history plots.

In updating the heatup and cooldown transients, the total number of heatup-cooldown cycles remained unchanged (200). However, sub-events and the associated number of occurrences were redefined based on historical records and monitoring data. Westinghouse reviewed operating records from 10 plants to determine a conservative distribution of maximum system ΔT ranges to be used over the design life. Monitoring data from 10 plants was analyzed to develop a bounding distribution of cycles at various ranges of

relative strength of stratification (ratio of pipe ΔT to system ΔT). The information was used to develop a table of numbers of cycles at various maximum stratification ΔT values for heatup/cooldown for the design life of the plant.

In updating the normal and upset transients, Westinghouse redefined the thermal fluid conditions based on the existing design transient system parameters and the knowledge gained from the monitoring programs. The redefined thermal fluid conditions conservatively accounted for thermal stratification. The result of this effort was a table of maximum stratification ΔT values and corresponding cycles for all normal and upset transients. Westinghouse reviewed the monitoring data to verify that all recorded normal or upset transient data was enveloped by the updated design transients.

Westinghouse developed a new set of transients for thermal striping. The frequency of fluid oscillation was conservatively derived from various experimental studies referenced in WCAP-12639. Westinghouse assumed that each stratification transient would initiate striping oscillations. The differential temperature was assumed to be the full ΔT which would decrease with time because of conduction between the hot and cold layers of fluid. The attenuation of thermal striping was factored into the amount of time that each level of ΔT was assumed. The end result was a table of striping transients shown as numbers of initiation cycles for several ΔT levels.

The staff reviewed the methodology and raised several questions which were discussed during the November 1990 audit at Westinghouse offices. During the audit, the staff also reviewed some of the monitoring data and other related documentation. Based on the review of the information provided during the audit, all questions were adequately resolved. The staff found the methodology used by Westinghouse to update design transients acceptable. Westinghouse used conservative methods and assumptions to incorporate stratification into their normal and upset transients. To the extent possible, monitoring data was used to confirm the conservatism of the revised normal and upset transients. The definition of thermal striping transients was based on conservative application of experimental data and anticipated stratification conditions in the surge line. The development of updated heatup and cooldown transients relied heavily on plant monitoring data, procedural limits and historical data. By considering distributions of maximum system ΔT and relative strengths of stratification observed in several plants, Westinghouse developed a reasonably conservative table of numbers of cycles at corresponding maximum stratification ΔT values for heatups and cooldowns during the life of a plant. To provide additional confidence, each licensee will be required to review their operating records and procedures to verify that the input and assumptions of the generic analysis are applicable to their specific plant.

2.2 Pipe Stress Analysis

In order to minimize the number of analyses, Westinghouse divided the 43 plants into 17 analysis groups based on similarity of design and response to stratification. The three major parameters considered in establishing the groups were structural layout and support design configuration, axial temperature profile distribution, and thermal transients from plant operation. During the audit, the staff reviewed the guidelines for defining enveloping design configurations and found them to be conservative.

For thermal stratification loading, the piping analysis was divided into two parts. The global piping system analysis addressed the restraint effects from pipe supports on the piping system. The local stress analysis considered the effects of the non-linear temperature gradient in the pipe at several locations including structural discontinuities. In the global analysis, a piping model which typically included pipe, elbow, linear and non-linear support elements was prepared for each of the 17 analysis groups. Bounding thermal stratification loadings were defined and applied. The results provided maximum pipe loads at critical locations for each group.

The local stress analysis determined the local axial stresses which result from the step change in temperature that occurs at the hot-to-cold interface along the pipe including the structural discontinuity stresses in the nozzle transition region. Westinghouse developed detailed finite element models of the surge line piping and hot leg nozzles to calculate these local thermal stresses. A number of stratification load cases were defined and analyzed to determine temperature and stress distribution. The results of the global and local stress analyses were combined as needed to perform the ASME Code evaluation.

Stresses and fatigue usage due to thermal striping were evaluated separately. The fluid ΔT and corresponding number of cycles of striping initiation transients were developed from design transients and plant monitoring data. Initially, the striping differential temperature was assumed to be the full ΔT but decreasing with time because of conduction between the hot and cold layers of fluid. A striping attenuation curve was developed, and for each striping initiation cycle, the ΔT was assumed to follow this curve in five degree temperature steps. The total numbers of striping cycles at each five degree step were determined by multiplying the number of striping initiation cycles which have a temperature step at that level, by the frequency of striping oscillation and amount of time that the ΔT was determined to be at that step. The frequency of oscillation was based on values observed in water model flow tests performed for the Liquid Metal Fast Breeder Reactor and in experimental studies of thermal striping which were performed in Japan by Mitsubishi Heavy Industries. Thermal striping stresses were determined by finite

element analysis and by a Westinghouse computer program STRFAT2. Stresses were intensified by the appropriate ASME Code stress indices for peak stress.

During the Westinghouse audit, the staff reviewed sample calculations covering key analysis methods and assumptions. This included the methodology for heat transfer and stress analysis, calculations for determining film coefficients for stratification and striping, models used in the striping analysis and the technical basis for the attenuation curve used in the striping analysis. The staff found the methodology and assumptions to be reasonably conservative and acceptable.

2.3 ASME Code Evaluation and Results

The stress and fatigue evaluation was based on ASME Code, Section III, 1986 Edition. Westinghouse generally applied the methods of NB-3200 to evaluate the surge line components and reported the results in terms of the NB-3650 piping stress equations. Stresses were classified in accordance with Code guidelines using stress indices from NB-3680 where appropriate. Stresses due to pressure, moments, and thermal loads were combined for checking against the limits of Code Equations 12 and 13, cumulative fatigue usage and thermal stress ratchet requirements.

The results of the evaluation were presented in WCAP-12639. Westinghouse concluded that all analysis groups met the thermal stress ratchet requirements. However, only 15 plants in five groups met the Equation 12 and cumulative fatigue usage factor limits. For Equation 13 qualification, Westinghouse determined limiting values for the resultant moments due to deadweight and OBE for the plant groups that met the other limits. Therefore, each of the 15 plants must demonstrate that their plant specific OBE and deadweight moments in the surge line are enveloped by values used by Westinghouse.

The staff reviewed the Code evaluation results and agreed that they provide an acceptable basis for qualification of the surge lines for the 15 plants subject to plant specific verification of applicability of the generic analysis and completion of additional plant specific evaluations needed to address items not covered by the generic analysis.

2.4 Applicability Demonstration

For the 15 plants which were found acceptable by the WOG generic detailed analysis, Westinghouse provided guidelines regarding additional work that licensees should perform to verify applicability of the generic analysis for their specific plant and to complete additional evaluations which were outside of the scope

of the WOG generic analysis. These guidelines are summarized below.

Licensees should review past operating records to verify that system ΔT values have not exceeded the maximum system ΔT used in the analysis. They should verify that the operational method used in the WOG generic analysis is applicable to their plant. It is expected that system ΔT will be controlled in the future by plant operations procedures to avoid the possibility of having to reconcile the effects of exceeding these values. WCAP-12639 provided a list of operational recommendations to minimize the chances for exceeding these values in the future.

Each plant must demonstrate adequacy of pipe supports and acceptability of piping displacements. Additional plant specific piping analysis may be needed to determine these loads and displacements. Licensees must verify that seismic OBE moments assumed in the fatigue analysis are applicable or conservative. Allowable resultant moments values for combined deadweight and OBE at the hot leg nozzle safe end weld must be checked.

The WOG generic detailed analysis did not address the effects of thermal stratification on stress and fatigue at integral welded attachments (lugs, plates, etc.) or on the pressurizer nozzle. Plant specific evaluations of these areas are needed to complete the surge line qualification.

Plant specific detailed analysis must be performed for all plants that were not shown acceptable under the generic analysis. For some plants, modifications may be necessary.

The staff reviewed the above plant specific applicability requirements and agreed with the Westinghouse recommendations.

3.0 CONCLUSIONS

Based on the review of the WCAP-12639 and additional information provided by Westinghouse during the November 1990 audit, the staff concludes that the WOG methodology for evaluation of stress and fatigue effects on the surge line due to thermal stratification and thermal striping is acceptable. The WOG generic detailed analysis demonstrated acceptable ASME Section III NB-3650 Equation 12 stress and fatigue usage in the surge line and reactor coolant loop nozzle for the following 15 plants:

Zion 1 & 2	Haddam Neck
Salem 1 & 2	Millstone 3
McGuire 1 & 2	Ginna
Catawba 1 & 2	San Onofre 1
Prairie Island 2	Wolf Creek
Callaway	

For these plants, the WOG generic detailed analysis program results can be used to satisfy the requirements of NRC Bulletin 88-11, Actions 1.c and 1.d, provided that plant specific applicability is demonstrated and additional evaluations which were not included as part of the WOG program are performed.

Applicability requirements include:

- o Review of operating records to ensure that system ΔT limits assumed in the analysis were not exceeded

- o Verification of operational methods to ensure that they are consistent with the methods assumed in the analysis. Limits on system ΔT for future operation are recommended.

- o Verification of applicability of seismic OBE bending moments used in the fatigue analysis and combined deadweight and OBE moments at the hot leg nozzle.

Additional plant specific evaluations to be performed include:

- o Evaluation of adequacy of pipe support loads and pipe displacements.

- o Evaluation of effects of stratification on stress and fatigue at integral welded attachments (lugs, plates, etc.)

- o Evaluation of effects of stratification on stress and fatigue of the pressurizer nozzle.

. A total of 28 Westinghouse plants could not be shown acceptable by the WOG generic analysis. They include the following plants:

D.C. Cook 1 & 2	Indian Point 2 & 3
Farley 1 & 2	Turkey Point 3 & 4
H.B. Robinson 2	Kewaunee
Shearon Harris	Yankee Rowe
Byron 1 & 2	V.C. Summer
Braidwood 1 & 2	Sequoyah 1 & 2
Watts Bar 1 & 2	North Anna 1 & 2
Surry 1 & 2	Point Beach 1 & 2
Prairie Island 1	

This group of plants will require plant specific analysis to demonstrate Code compliance. It is anticipated that some of these plants can be shown acceptable by removing some of the conservatisms inherent in the generic approach. It is likely, however, that some of these plants will require modifications.

A central radiation safety training session is being planned for the very near future for all of those who may be found to be deficient in training. You will be notified as soon as the date of the session is finalized.

Another area of discrepancy which must be corrected immediately is the presence of food, beverages, coffee pots, smoking materials, eating utensils, etc., in laboratories where licensed activities are performed. All of these materials must be immediately removed and prohibition enforced.

Your written response containing the required information described in this memo must be provided on or before November 30, 1987, to the following:

Thomas A. Bozich
Security & Environmental Affairs
Room 202, Quail Building

Any questions should also be directed to Mr. Bozich on x2906.

APL/cu

cc: T. A. Bozich
R. B. Adams
Applicable Chairmen