ENCLOSURE

SAFETY EVALUATION
ON THE
BABCOCK & WILCOX OWNERS GROUP PRESSURIZER SURGE LINE THERMAL STRATIFICATION GENERIC DETAILED ANALYSIS
BAW - 2127

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 Babcock & Wilcox Owners Group (B&WOG) developed and implemented a program to address the issue of surge line stratification in B&W plants. The first part of the program was documented in an interim report, BAW-2085 dated May 1989. Based on preliminary bounding calculations, B&W concluded that all B&W plants can continue operating safely in the near term until the final analyses could be completed. The staff reviewed the interim evaluation and identified several concerns but concluded that it was sufficient to be used as the technical basis for justification for continued operation for all B&W plants until the final analysis is completed by the end of 1990. The interim report, combined with acceptable plant specific visual inspection results, satisfied Bulletin Actions 1.a and 1.b for all B&W plants.

The B&W final analysis was completed in 1990. The summary and results of the program were documented in report BAW-2127, dated December 1990. The report summarized the work performed to satisfy the remaining NRC Bulletin Action items including the monitoring program and the final ASME Code stress and fatigue evaluations. It covered all B&W lowered loop plants: Arkansas Nuclear One Unit 1, Crystal River Unit 3, Oconee Units 1, 2, and 3, and Three Mile Island Unit 1. The remaining B&W plant, Davis-Besse Unit 1, is a raised loop plant and is undergoing a plant specific evaluation which will be reported in a future supplement to the report.

The staff reviewed the final report and conducted an audit at B&W offices in February 1991. The following sections summarize the staff evaluation of the program.

2.0 STAFF EVALUATION

The B&WOG Program for evaluation of the lowered loop plants was divided into two basic sections: thermal-hydraulics and stress analysis. The thermal-hydraulics portion developed a revised set of surge line design basis transients that account for thermal stratification and thermal striping. It involved the instrumentation and monitoring of surge line temperature and displacement data from a representative plant (Oconee Unit 1). It included an assessment of operating procedures and review of historical plant data from all B&W plants. The stress analysis portion involved the development of structural mathematical models of the surge line and associated equipment. Structural loading analysis was performed using the revised thermal-hydraulic design basis. Stress and fatigue evaluations were performed in accordance with the 1986 Edition of the ASME Code Section III requirements. The major areas of staff review and evaluation are summarized below.

2.1 Development of Revised Design Transients

The development of the revised design basis transients involved the monitoring of surge line data at Oconee Unit 1, the development of surge line thermal stratification and thermal striping correlations, the review of operational histories, and the formulation of revised transients. Based on comparisons of dimensions of the lowered loop surge line plants, B&WOG concluded that a single plant could be instrumented to provide typical thermal stratification data. Oconee Unit 1 was selected and instrumented with 54 thermocouples and 14 displacement instruments affixed to various parts of the lines. The instrumentation package was installed during the January 1989 refueling outage. Temperature measurements were recorded at either 20 second or one minute intervals during heatup, cooldown, and various power operation conditions. The measured data was processed and used to develop correlations to predict surge line temperature versus time based on global plant conditions including pressurizer and hot leg temperature, surge line flow rate, and reactor coolant pump and spray valve status. Prediction correlations were developed for stratification temperatures in the horizontal piping as well as for temperatures at the nozzles. The stratification correlations were used in conjunction with the synthesized plant transients to develop temperature profiles for use in the stress analysis.

B&W developed thermal striping correlations based on experimentally observed striping data. Based on a review of the literature on striping experiments, B&W found that experiments performed in the HDR facility at Battelle Institute, Karlsruhe, FRG were conducted under conditions that most closely matched those of the pressurizer surge lines. The HDR tests were performed in a large-diameter (15.6 inch), insulated metal pipe using plant-typical fluid conditions. The pipe was extensively instrumented with fast-response thermocouples. B&W obtained the complete set of measurements from the "PWR" subseries of tests. The data was processed to determine interface characteristics as well as striping frequencies and amplitudes. B&W used the ordered overall range method to count striping cycles and to develop distributions of cumulative frequencies of occurrence versus striping amplitude. The maximum striping amplitude for each test was compared and correlated with the governing fluid conditions. The maximum striping amplitudes of the final correlation were increased by 10% to allow for uncertainties.

In developing the revised design basis transients, B&W considered past operational information. An information base of plant operating data, operating procedures, surveillance procedures, and operational limits was collected from utility and B&W records. Discussions with plant operators provided additional information. The revised surge line design basis transients were based on the original design basis transients with some modifications and additions. For all transients, the surge line conditions were redefined to include stratification and striping. The most significant transients which produce the largest top to bottom temperature difference and contribute most to the cumulative fatigue in the surge line are plant heatup and cooldown. These transients were completely redefined. Heatups were categorized into five transients with three representing past operations and two representing future operations. Hot leg and pressurizer temperature versus time plots were developed for each heatup transient. The transients varied in terms of pressurizer to hot leg differential temperature with the most severe transient based on the pressure-temperature limits which satisfy the vessel fracture toughness requirements of 10CFR50 Appendix G at two effective full power years. The number of occurrences for each type of heatup transient was determined by reviewing plant data and taking conservative estimated fractions of the most severe heatups to total number of heatups. For each heatup, operational events that effect surge line flow were identified by a review of plant data and procedures. The number of events per transient was based on the reviews with additional random flow events added. The thermal stratification and thermal striping correlations were used to generate the surge line thermal response to the events. For the most severe heatup transient, B&W estimated a maximum pressurizer to hot leg temperature differential of 400°F. The maximum value of stratification (top to bottom surge line temperature difference) was 397°F. B&W followed similar procedures to redefine the cooldown and other design basis transients. The final results of this effort provided the input for the stress and fatigue analysis of the surge line for each lowered loop plant.

The staff reviewed the methodology described in the BAW-2127 report and raised several questions which were discussed during the February 1991 audit. B&W provided copies of detailed calculations on thermal stratification and striping correlations for review. From the information provided, it was clear that the B&W effort was extensive and thorough. Although the staff did not check the calculations in detail, the overall approach was found to be reasonable and conservative. Comparisons of predicted stratification to plant measurements showed the prediction correlations to conservatively overpredict stratification response. The striping correlations were based on an envelope of test results and striping amplitudes were further increased by 10% to account for uncertainties. The development of the revised design basis transients considered bounding operating limits as well as typical conditions observed during plant operation.

2.2 Stress and Fatigue Evaluation

The stress analysis effort involved the development of structural mathematical models of the surge line and nozzles, the loading of the models to generate the internal forces, moments and stresses for the thermal stratification conditions and a stress and fatigue evaluation which considered appropriate combinations of stresses generated by other loads to demonstrate compliance with ASME Code Section III requirements.

The ANSYS computer program was used to develop an "extended" mathematical piping model of the pressurizer surge line. The model included the pressurizer, surge line, hot leg, reactor vessel, and steam generator. The attached equipment was included so that correct anchor movements and component flexibility would be correctly simulated. The ANSYS program was chosen because of its capability to analyze a piping system with a top-to-bottom temperature variation in the piping elements. Since the variation can only be applied linearly, however, B&W developed "equivalent linear temperature profiles" to represent the nonlinear profiles indicated by plant measurements. Nonlinearity coefficients were developed to generate equivalent linear temperature profiles which give the same pipe cross-section rotation as the nonlinear profile. The nonlinearity coefficient was found to be a function of top and bottom temperatures and fluid interface elevation. B&W developed a mathematical formula for nonlinearity coefficient as a function of these variables.

Using the extended mathematical piping model and calculating the nonlinearity coefficients for the Oconee data, a verification run was performed. The measured temperatures were applied to the model and displacements were determined. The comparison of calculated to measured displacements showed very good agreement. B&W stated that this verified the accuracy of the model and the nonlinearity correction method.

B&W used this model to analyze the three most critical thermal stratification conditions that occur during the most severe heatup transient. Top-to-bottom temperature differences were 397°F, 393°F, and 386°F. Additional analyses were performed for seven other thermal stratification conditions plus the unstratified 100% power condition. With these 11 sets of internal forces and moments, B&W was able to set up an interpolation scheme to determine internal forces and moments everywhere in the surge line for all temperature conditions.

Reevaluation of the surge line for thermal stratification involved satisfying ASME Code Section III NB-3600 allowable stress limits for primary plus secondary stress intensity range (Equation 10) and cumulative fatigue usage limits for peak stress intensity range (Equation 11). For the most critical thermal stratification cycles, the Equation 10 stress limit of $3S_m$ was exceeded. As an alternative, the Code permits a simplified elastic-plastic fatigue analysis by applying a penalty factor, Ke, to the peak stress (Equation 14) provided that the load sets meet the stress limits of Equation 12 and 13 of NB-3653.6 and the thermal stress ratcheting equation of NB-3653.7. B&W was able to demonstrate compliance with Equation 13 (primary plus secondary stress intensity excluding thermal expansion) and thermal stress ratcheting, but was not able to meet the Equation 12 (secondary stress range due to thermal expansion) limit of $3S_m$ in the elbows using the simplified formulas and stress indices given in the Code. B&W then attempted to remove the conservatism in the Code stress indices by developing new C_2 and K_2 stress indices for the surge line elbows based on finite element analysis. The computer program ABAQUS was used to generate an elasto-plastic finite element model of the elbows and apply in-plane and out-of-plane bending moments. Using the definitions of secondary and peak stresses and taking the higher of the two loading conditions, B&W defined generic stress indices of $C_2 = 1.58$ and $K_2 = 1.47$ compared to values of $C_2 = 2.33$ and $K_2 = 1.0$ from formulas given in Table NB-3685.1-2 of the Code.

Using the internal forces and moments from the most severe thermal stratification conditions and the redefined generic elbow stress indices, three of the four surge line elbows still exceeded the Equation 12 stress allowable. B&W then applied these forces directly to the elasto-plastic finite element model and used the same method to calculate maximum secondary stress as was used to generate the C_2 stress index. The resulting calculated secondary stresses were shown to be less than the $3S_m$ allowable.

For the ASME Code fatigue evaluation, B&W considered the stresses due to stratification induced moment loadings as well as localized peak stresses induced by through-wall temperature gradients ΔT_1 and ΔT_2 due to fluid flow, thermal striping, and nonlinear temperature profiles. Peak stresses due to thermal striping were determined from the striping temperature data given in the design basis transients. The temperature distribution through the wall thickness was determined from an ANSYS finite element model. The time-dependent wall temperature was simulated as a "cut-sawtooth" wave. From the experimental data, B&W determined that the fluctuations have a period of approximately 1.0 seconds. To cover a range of periods which could be expected, thermal analyses were performed with periods of 0.5, 1.0, 2.0 and 4.0 seconds. For each period, the extreme temperature profiles were determined and the linear and nonlinear through-wall temperature gradients were calculated, leading to the maximum peak stress intensity range.

Peak stresses due to the nonlinearity of the temperature profile are the result of the difference between the actual nonlinear and the "equivalent linear" temperature profiles used in the structural loading analysis. B&W referred to this temperature difference as ΔT_4. An ABAQUS finite element analysis was performed for the two most severe measured top-to-bottom temperature profiles. The analyses indicated that the maximum peak stress intensity occurs at the inside radius of the pipe cross section. From these results, B&W developed a correlation to calculate ΔT_4 as a function of top-to-bottom temperature difference and fluid interface elevation, and give the maximum peak stress intensity in the pipe as a function of ΔT_4, top-to-bottom temperature difference and fluid interface elevation.

B&W performed a fatigue analysis in accordance with the 1986 Edition of ASME Section III NB-3600 as required by Bulletin 88-11. Since all plants had been designed to earlier Code Editions, a Code reconciliation was performed. The findings indicated that for the 1986 Code: 1) more sophisticated formulas are used for stress indices, 2) allowables are equal to or smaller than the earlier allowables, 3) the fatigue curves go up to 10^{11} cycles compared to earlier curves which only went up to 10^6 cycles.

B&W calculated the "main fatigue usage" which they defined as the usage factor due to all thermal stratification conditions which are characterized by a top-to-bottom temperature difference. The absolute values of the peak stress ranges from the following contributions were added:

1. Moment loading range due to thermal stratification.
2. Moment loading range for the 30 occurrences of OBE.
3. Internal pressure range.
4. Additional localized peak stress due to nonlinearity of the top-to-bottom temperature profile (ΔT_4).
5. Maximum stress between the peak stress due to thermal striping and the one due to fluid flow (through-wall temperature gradients ΔT_1 and ΔT_2).

B&W performed a sort of all the total peak stress intensity values and built a selection table for the combination of the thermal stratification peaks and valleys into pairs in such a way that stress ranges were maximized. For each pair of conditions, the alternating stress intensity was calculated as a function of the peak stress intensity range and of the Equation 10 primary plus secondary stress intensity range. The usage factor associated with each alternating stress intensity value was calculated in accordance with the 1986 ASME Code extended fatigue curves (up to 10^{11} cycles). The summation of all usage factors for each pair gave the total "main fatigue usage."

In addition to the main usage factor, B&W evaluated the additional fatigue contributions due to the highly cyclic thermal striping ranges, the additional OBE ranges not associated with stratification, and the additional fluid flow conditions not associated with stratification. Contributions due to OBE and fluid flow were found to be very small. Fatigue usage due to thermal striping was found to be in the range of 0.10 and 0.15 depending on the specific plant. B&W combined the main usage factor with the additional fatigue usage contributions to calculate the total cumulative usage factor for each of the six B&W lowered loop plants. The values were different for each plant because the number of occurrences of the events in the design basis transients is unique to each plant. The results showed that all cumulative usage factors were below their allowable of 1.0. The highest usage factor was 0.82 and occurred in the vertical elbow at the bottom of the surge line riser to the hot leg in Oconee Unit 2.

In addition to the piping analysis, B&W performed detailed stress analyses of the pressurizer and hot leg nozzles. For both nozzles, axisymmetric thermal and thermal stress analyses were performed using the ANSYS finite element computer code. The loadings consisted of thermal gradients, internal pressure, and external piping loads. Since the pressurizer nozzle is vertical, there were no significant thermal stratification loads. The hot leg nozzle is horizontal and is subject to direct thermal stratification which produces circumferential temperature gradients. The stresses due to these gradients were determined by the use of the ANSYS harmonic element STIF 25 which can handle an axisymmetric structure with nonaxisymmetric loading. The nozzles were evaluated in accordance with the requirements for Class 1 components of the ASME Code, Section III, 1986 Edition. For both nozzles the linearized primary-plus-secondary stress intensities exceeded the $3S_m$ limit. However, the Code requirements were satisfied by performing a "simplified elastic-plastic analysis" as defined in NB-3228.5. Cumulative fatigue usage factors were calculated for each plant. All plants met the 1.0 allowable for both nozzles. The highest usage factors in the pressurizer nozzle was 0.41 in Oconee Units 2 and 3. In the hot leg nozzle, the highest usage factor was 0.62 in TMI Unit 1, Crystal River Unit 3, and ANO Unit 1.

The staff reviewed the stress analysis and Code evaluation methodology and results described in the BAW-2127 report and raised a number of questions which were discussed during the February 1991 audit. B&W provided copies of the detailed calculations on the piping and nozzle stress analyses for review. The staff reviewed selected portions of the piping stress analysis in detail. Based on the review, the staff found the B&W stress reevaluation effort to be comprehensive and complete. All known thermal stratification effects including global bending stresses, local stresses due to the nonlinear temperature profiles, and cyclic stresses due to thermal striping were considered. Calculations were found to be clear and well organized. Assumptions were reasonable and generally conservative. The accuracy of the mathematical piping model was checked against data taken at Oconee and showed good agreement in predicting displacements. The fatigue analysis considered stress intensity ranges due to all global and local stratification loads as well as other cyclic design loads. Absolute values of peak stresses due to different loads were combined by conservatively assuming that maximum stresses occur at the same location on the pipe cross-section.

There is, however, one significant issue that is currently unresolved. The staff disagreed with the B&W methodology for calculating a revised C_2 stress index for the surge line elbows. The methodology was discussed with B&W during the February 1991 audit and calculations were further reviewed in detail. The analysis involved the application of in-plane and out-of-plane bending moments to ABAQUS elastic and elasto-plastic finite element models of the surge line elbows. Based on the results of these analyses, new elbow stress indices were calculated as follows:

For peak stress:

K_2C_2 = Maximum stress anywhere in the elbow divided by the nominal (straight pipe) stress at the surface.

For secondary stress:

C_2 = Maximum stress at mid-thickness in the elbow divided by the corresponding nominal (straight pipe) stress at mid-thickness.

The K_2C_2 value was based on an elastic analysis while the C_2 value was based on an elasto-plastic analysis with a correction factor for displacement-controlled loading. B&W took the larger of the in-plane and out-of-plane stress index values and obtained $C_2 = 1.58$, $K_2C_2 = 2.33$ (or $K_2 = 1.47$). Using ASME Code tables, these values would be $C_2 = 2.33$ and $K_2 = 1.0$. The B&W indices, therefore, would predict significantly lower secondary stresses but the same peak (equation 11) stresses. In differentiating between secondary and peak stresses, B&W referred to the Code definition of peak stress (NB-3213.11) as "that increment of stress which is additive to the primary plus secondary stresses by reason of local discontinuities or local thermal stress including the effect of stress concentrations. The basic characteristic of a peak stress is that it does not cause any noticeable distortion and is objectionable only as a possible source of a fatigue crack." B&W also noted that Figure NB-3222-1 defines a "secondary" expansion stress intensity P_e as "stresses which result from the constraint of free end displacement. Considers effects of discontinuities but not local stress concentration." B&W argued that the maximum stress in the elbow has all the characteristics of a local stress concentration. Their review of the stress analysis results around the circumference and through the elbow thickness indicated that the highest stress intensity was highly localized. B&W also stated that the elbow behaved in a linear fashion after the highest stressed locations entered the plastic domain and that these stresses had a negligible impact on elbow distortion. B&W therefore felt justified in treating surface stresses as peak stresses and the average through-wall stresses (mid-thickness stresses) as secondary stresses.

With the redefined "generic" C_2 stress index, three of the four elbows still did not meet the equation 12 stress allowable. B&W performed additional elasto-plastic finite element analyses for the critical loading case to demonstrate that the elbows meet the expansion stress intensity limit. These analyses took advantage of the lower stress indices for in-plane bending (1.30) and torsion (1.0) and demonstrated acceptable results. However, the basic definitions of secondary and peak stresses were the same as discussed above. Secondary expansion stress intensity was based on mid-thickness stress.

The staff disagreed with the B&W interpretation of the definition of secondary and peak stress in an elbow. The Code (NB-3682) defines the C stress index as the <u>maximum</u> stress intensity due to load L divided by the nominal stress intensity due to load L. This presumably means maximum stress intensity anywhere in the cross-section, not a mid-thickness stress intensity. The B&W definition of secondary stress completely neglects the circumferential bending stresses that develop in an elbow. These stresses are considered only as peak stresses by B&W. It does not appear that the circumferential bending stresses in the elbow walls should be considered peak stresses. Peak stresses are generally associated with localized geometric or material discontinuities that effect the stress distribution through a fractional part of the wall thickness or with local thermal stresses that produce no significant distortion. In the case of elbows, the circumferential bending stresses affect the entire wall thickness and produce distortion (ovalization) of the elbow cross-section. NB-3222.3 defines expansion stress intensity as "the highest value of stress, neglecting local structural discontinuities, produced <u>at any point across the thickness of a section</u> by the loadings that result from restraint of free end displacement." The Code stress index tables (NB-3681(a)-1 and NB-3685.1-2) provide further evidence that the maximum elbow stresses should be treated as secondary stresses. The C_2 value of 2.31 computed from the table formulas agrees exactly with the B&W finite element model maximum stress at the elbow surface. The K_2 value of 1.0 indicates that no stress concentration factor needs to be applied to elbows for determining peak stress.

The potential consequences of this unresolved issue are as follows:

1. If Code stress indices are used, for the most severe thermal stratification load conditions, the range of thermal expansion stress intensity will exceed the $3S_m$ limit (Equation 12).

2. Higher C_2 stress indices will increase the primary plus secondary stress intensity value calculated in Equation 10. For severe load sets, which require the simplified elastic-plastic analysis method of NB-3653.6, the penalty factor, Ke, which is based on Equation 10 stress will increase. This will result in larger alternating stresses (Equation 14) and higher fatigue usage with potential for exceeding the 1.0 allowable.

Further staff discussions with an ASME Code expert indicated that the Equation 12 $3S_m$ allowable may have significant margin. Various tests have shown that piping systems can have substantial fatigue capacity even if Equation 12 is not met. Nevertheless, since meeting the $3S_m$ expansion stress limit is a current Code requirement, the staff recommends that B&W initiate an ASME Code inquiry to determine whether the Code Committee either agrees with the B&W interpretation of C_2 stress index or permits a higher Equation 12 allowable for this particular application.

The fatigue usage allowable of 1.0 for the life of the plant must be met. The staff recommends that B&W reevaluate fatigue usage using the Code table stress indices. If the allowable is exceeded, B&W should investigate alternate approaches to demonstrate that Code requirements for fatigue and expansion stress are met.

2.3 Plant Specific Applicability of B&WOG Analysis

The BAW-2127 report identified the conditions upon which the generation of the revised design basis transients and the thermal stratification fatigue stress analysis of the surge line were based.

The generation of the revised design basis transients for future events was based on the incorporation of operational guidelines which:

- limit the pressurizer to RCS temperature difference during plant heatups and cooldowns (imposed with pressure/temperature limits)
- prevent surveillance tests that cause rapid additions of water to the RCS from being performed with pressurizer to RCS temperature difference greater than 220°F

Pressurizer/temperature limits for future heatup and cooldown operations were included as Figure 8-1 of BAW-2127. In order to meet the pressure limit specified for heatup in the 70°F to 150°F temperature range, B&W recommended preheating the RCS. For heatups involving pressurization at lower RCS temperatures, a less restrictive limit was included in Figure 8-1. The fatigue evaluation was based on the assumption that 85% of the heatups for the remainder of plant life meet the recommended limit shown by path CDEN of Figure 8-1, and 15% of future heatups meet the less restrictive path ABEN.

The thermal stratification fatigue analysis was based on the following assumptions:

- o no interference of the surge line with any other structure
- o surge line movement within the travel range of each snubber
- o surge line movement within the travel range of each hanger
- o branch moments at the surge line drain nozzle connection within their respective maximum allowables (for deadweight, OBE and thermal stratification)

The staff discussed the conditions of applicability with licensee representatives present at the February 1991 audit. They indicated that the requirements were understood. They agreed to follow the B&W proposed operational guidelines. Operating procedures will be revised to reflect these limits. Licensees have received the maximum surge line displacements from B&W and are checking for interferences and for travel limits on hangers and snubbers. Each licensee will be responsible for reevaluating the drain line piping and nozzle. Plants with welded attachments (Crystal River and Davis-Besse) will evaluate them on a plant specific basis. The licensee representatives indicated that no problems have been identified to date. The staff found the licensee responses acceptable, but may verify licensee programs and activities in future plant specific audits.

3.0 CONCLUSIONS

Based on the review of BAW-2127 and additional information provided during the February 1991 audit, the staff concludes that B&W has defined and implemented a comprehensive program to address the pressurizer surge line thermal stratification concerns discussed in NRC Bulletin 88-11. The program is applicable to the six B&W lowered loop plants:

Arkansas Nuclear One Unit 1
Crystal River Unit 3
Oconee Units 1, 2, 3
Three Mile Island Unit 1

Licensees are responsible for verifying plant-specific applicability of the B&WOG program and results. This will include verification of analysis assumptions, qualification of supports and attached piping, and revision of operating procedures as indicated in BAW-2127. The remaining B&W plant, Davis-Besse Unit 1 is a raised loop plant which is undergoing a plant specific evaluation. The results of that evaluation will be reported in a future supplement to BAW-2127.

The B&WOG program developed a revised set of design transients which incorporated thermal stratification and thermal striping. The program included instrumentation and monitoring of surge line temperature and displacement data from a representative plant. The stress and fatigue analysis involved the development of structural mathematical models to analyze the global and local stresses resulting from stratified conditions in the line. Structural loading was performed using the revised design transients. Stress and fatigue evaluations were performed in accordance with the requirements of ASME Code Section III, 1986 Edition.

The staff review found the B&W effort to be quite extensive, thorough and of high quality. Assumptions were found to be reasonable and generally conservative. The staff found the methodology acceptable with one significant exception. B&W did not use the ASME Code stress indices as defined in Table NB-3685.1-2, but instead performed a finite element analysis to redefine lower stress indices for the surge line elbows. Although the Code permits stress indices to be defined by analysis, the staff disagrees with the B&W interpretation of the secondary stress index (C_2) for an elbow. The C_2 index was based on the maximum stress at the mid-thickness of the elbow wall. The staff believes that the C_2 index should be based on maximum stress anywhere in the elbow. This definition is consistent with the values obtained from the Code table.

The use of Code table stress indices for surge line elbows may have a significant adverse impact on the results of the B&W evaluation. It is highly probable that the surge line would not meet the Code limits on thermal expansion stress ($3S_m$) and fatigue usage (1.0). The staff, therefore, recommends the following actions:

1. Reevaluate the surge line to all Code requirements using the Code table stress indices for elbows.
2. If thermal expansion stress limits are exceeded, initiate an ASME Code Inquiry to determine whether the Code Committee agrees with the B&W interpretation of C_2 stress index or permits a higher Equation 12 allowable for this particular application.
3. If fatigue usage factor exceeds 1.0, investigate alternate approaches to demonstrate that Code fatigue requirements and expansion stress limits are met.

Date: February 21, 1992