Florida
Power
CORPORATION

December 18, 1989
3F1289-06

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555

Subject: Crystal River Unit 3
Docket No. 50-302
Operating License No. DPR-72
Additional Response to Bulletin 88-11

References:

1. B&W Owners Group Letter OG-854 to the NRC, dated September 29, 1989
2. B&W Owners Group Letter OG-606 to the NRC, dated November 27, 1989

Dear Sir:

Florida Power Corporation's (FPC) June 1, 1989, letter provided the response to Bulletin 88-11, Pressurizer Surge Line Thermal Stratification, by submitting B&W Owners Group (B&WOG) Report BAW-2085. The NRC provided comments on the report to the B&WOG in an August 17, 1989 letter. The reference letters provided responses to the NRC comments.

FPC is submitting a copy of each of the referenced letters for the docket. FPC concurs with the B&WOG answers provided to the NRC. The B&WOG will submit its topical report describing the comprehensive program for Bulletin 88-11 in December 1990.

Sincerely,

Ken Wilson

Ken R. Wilson, Manager
Nuclear Licensing

KRW/JWT/sdr

Enclosure

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PDR ADOCK 05000302
Q PDC

xc: Regional Administrator, Region II
Senior Resident Inspector

IE30

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STATE OF FLORIDA

COUNTY OF CITRUS

Ken R. Wilson states that he is the Manager, Nuclear Licensing for Florida Power Corporation; that he is authorized on the part of said company to sign and file with the Nuclear Regulatory Commission the information attached hereto; and that all such statements made and matters set forth therein are true and correct to the best of his knowledge, information, and belief.

Ken Wilson

Ken R. Wilson, Manager
Nuclear Licensing

Subscribed and sworn to before me, a Notary Public in and for the State and County above named, this 18th day of December 1989.

Susan D. Weinfurter

Notary Public

Notary Public, State of Florida at Large,

My Commission Expires: NOTARY PUBLIC, STATE OF FLORIDA. MY COMMISSION EXPIRES: AUG. 30, 1993. BONDED THRU NOTARY PUBLIC UNDERWRITERS.

THE B&W OWNERS GROUP

Arkansas Power & Light Company — ANO-1
Duke Power Company — Oconee 1, 2, 3
Florida Power Corporation — Crystal River 3
GPU Nuclear Corporation — TMI-1
Sacramento Municipal Utility District — Rancho Seco
Toledo Edison Company — Davis Besse
Tennessee Valley Authority — Bellefonte 1,2
Babcock & Wilcox Company

Working Together to Economically Provide Reliable and Safe Electrical Power

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September 29, 1989
OG-854

Mr. Terence L. Chan, Senior Project Manager
Project Directorate V
Division of Reactor Projects - III,
IV, V and Special Projects
Office of Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Babcock & Wilcox Owners Group Response to NRC Bulletin 88-11, "Pressurizer Surge Line Thermal Stratification"

Reference: NRC Letter, Terence L. Chan to Daniel F. Spond, "NRC Bulletin 88-11, 'Pressurizer Surge Line Thermal Stratification,'" dated August 17, 1989

Dear Mr. Chan:

The reference letter documented the NRC's request for additional information regarding the B&W Owners Group (B&WOG) report BAW-2085, Submittal in Response to Nuclear Regulatory Commission Bulletin 88-11 "Pressurizer Surge Line Thermal Stratification," dated May 1989. The purpose of this letter is to provide formal B&WOG responses to your questions. Responses have been provided to all of the NRC questions with the exception of Question 9 on Section 5 of BAW-2085. We have not yet completed the analysis necessary to respond to this question and respectfully request a delay in our response to this question until November 30, 1989. Should our analysis be completed earlier than currently anticipated, our submittal will be made earlier.

The B&WOG is also providing a status report on our continuing evaluation of the thermal striping phenomena. Our submittal, therefore, provides the following two attachments to this letter:

Attachment 1 - B&W Owners Group Responses to NRC Questions on BAW-2085, September 1989

Attachment 2 - B&W Owners Group Status Report on Thermal Striping Evaluation, September 1989

8910050157 2pp.

As you know, the original intent of the B&WOG was to provide a submittal in response to NRC Bulletin 88-11, Item 1.b, in May 1989 which would not include an evaluation of thermal striping. An additional submittal to address thermal striping was planned for October 1989. However, in an April 7, 1989 meeting with the B&WOG the NRC requested that an evaluation of thermal striping, based on information available at that time, be included in our May 1989 submittal. In compliance with this request, the B&WOG submitted BAW-2085 which includes comparisons of plant surge line geometries, preliminary evaluation of thermal stratification (including thermal striping), and fatigue analyses. Therefore, an October 1989 submittal on thermal striping, as part of the bounding analysis in response to Item 1.b of NRC Bulletin 88-11, is no longer necessary. However, Attachment 2 is provided to keep you informed of the status of our continuing evaluation.

The intent of BAW-2085 was to report a preliminary evaluation of this issue by presenting bounding analyses. BAW-2085 supports continued plant operation while the B&WOG continues with our comprehensive evaluation program which was developed to fully respond to NRC Bulletin 88-11. Based on the interim results presented in BAW-2085, it was shown that the B&WOG plants can continue to safely operate in the near term while the comprehensive evaluation program continues. The B&WOG will document the results of our comprehensive evaluation program in a topical report which is scheduled for submittal in December 1990. This submittal will meet the technical and schedule requirements of NRC Bulletin 88-11.

Individual licensees will submit or reference the material provided by this letter so that it is appropriately docketed. In addition, the B&WOG is prepared to meet with you to discuss our responses and to provide you with the details of our comprehensive program. Should you require any further information, please contact me at (501) 377-3865 or contact the B&W Owners Group Project Manager, W. R. Gray, at (804) 385-2783.

Very truly yours,

Daniel F. Spond

Daniel F. Spond, Chairman
B&WOG Materials Committee

DFS/leh

Attachment

cc: W. T. O'Connor - TE
R. B. Borsum - B&W

bcc: Materials Committee

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R. J. McGoey - GPUN
R. Schrauder - TE

ATTACHMENT 1

B&W Owners Group Responses to
NRC Questions on BAW-2085

September 1989

INTRODUCTION

Attachment 1 responds to the NRC letter: Terence L. Chan to Daniel F. Spond, "NRC Bulletin 88-11, 'Pressurizer Surge Line Thermal Stratification,'" dated August 17, 1989. This letter requested additional information on BAW-2085, the B&WOG interim submittal on surge line stratification. The responses are organized by first stating the NRC question and then following the question with the B&WOG response. The sections noted in each question refer to sections of BAW-2085. Two separate submittals to the NRC are referred to in these responses, i.e.:

a. "BAW-2085" refers to B&WOG report BAW-2085, Submittal in Response to Nuclear Regulatory Commission Bulletin 88-11" Pressurizer Surge Line Thermal Stratification," dated May 1989

b. The "Toledo Edison submittal" refers to the Toledo Edison specific document for Davis-Besse on Docket No. 50-346, Serial No. 1671, dated June 2, 1989

GENERAL QUESTIONS

GENERAL - QUESTION 1 (G.1)

Provide a comparison of calculated surge line thermal displacements with the measured Oconee data to demonstrate the validity and conservatism of the bounding analysis.

RESPONSE (G.1)

Direct comparisons of displacements will be performed in the detailed analysis program which is scheduled for submittal in December 1990. Thermal stratification causes rotation at the location of occurrence. These rotations cause displacements along the surge line. Thus, the observed displacements are very sensitive to the local top-to-bottom stratification (i.e., rotations). Displacement comparisons at higher Delta Ts than the actual Delta Ts (top-to-bottom temperature differences) could be misleading, even though the moments are very conservative. Please see the response to Question 4.1 for additional information on this topic.

GENERAL - QUESTION 2 (G.2)

Discuss the B&WOG's efforts regarding the effects and generic implications of potential thermal stratification on other lines which may be susceptible to this phenomenon.

RESPONSE (G.2)

This B&WOG program and the material provided in BAW-2085 are directed to the subject of pressurizer surge line thermal stratification (see NRC Bulletin 88-11). For information regarding other piping, it is suggested that the Staff review individual licensee responses to NRC Bulletin 88-08.

QUESTIONS ON SECTION 4

SECTION 4 - QUESTION 1 (4.1)

How do the monitoring results for displacements and temperatures compare with analysis results? What are the values at the critical locations?

RESPONSE (4.1)

The calculated surge line thermal displacements have not been compared with actual displacement data for the reactor vessel (RV) skirt supported (Oconee type) plants. This is not considered a priority because:

a. Restraints which would be thermally active (gapped whip restraints or rigid supports) do not exist on any of the RV skirt supported plant surge lines,

b. The observed displacements at Oconee and the calculated displacements are well within any limits for snubber travel.

The displacements in the piping are a function of not only the top-to-bottom temperature difference, but also the average temperature and the temperature change along the length of the surge line. Until actual temperatures are analyzed, the only comparison which would be valid would be general deformation plots. A point for point comparison could be misleading prior to analysis of as measured data. A comparison between calculated surge line thermal displacements and actual displacement data will be performed for the final report which is scheduled for submittal in December 1990.

Critical locations should be at gapped restraint locations. The RV skirt supported plant surge lines have no gapped restraints. The nozzle supported plant (Davis-Besse) has already presented the data requested at the restraint locations. Visual inspection of the surge line has already been performed for some of the plants and is planned for the next shutdown for the remaining plants.

For Davis-Besse, Unit 1, transverse piping deflections were measured during the heatup after the 5th Refueling Outage as a cross-check on the deflection analyses. Twelve lanyard potentiometers were installed at seven pipe whip restraint locations. The measured deflections for the bounding transients fell within the values derived from the analyses used as input for the bounding fatigue analysis.

The analysis results and measured deflections are described and illustrated in the Toledo Edison submittal in Attachment I, "Davis-Besse Pressurizer Surge Line Thermal Stratification-Phase I Program," Section III.H.3.

SECTION 4 - QUESTION 2 (4.2)

Since no upsets or cooldowns have occurred yet, what were the assumptions/inputs used in the analysis? How was the worst case determined?

RESPONSE (4.2)

The stratification load cases which cause the highest stress are those where the pressurizer is hot and the hot leg is cold. Plant heatup is the operational condition expected to produce the largest temperature difference across the surge line. For the bounding analysis the assumed temperature differences during heatup are based on the Muelheim-Kaerlich (M-K) data; these temperature differences were much larger than the temperature differences observed at Oconee 1. Similarly, the number and magnitude of thermal cycles occurring during a cooldown are based on M-K data.

The reactor coolant system (RCS) Functional Specifications for the 177 fuel assembly plants show that changes in the pressurizer pressure (and therefore in the pressurizer temperature) lead changes in the RCS temperature during heatups and cooldowns. Therefore, the pressurizer temperature to loop temperature difference is larger during a heatup than during a cooldown. Plant trips which do not result in a plant cooldown do not exhibit as large a degree of stratification as that which exists during normal plant cooldown conditions. If a cooldown does result from a plant trip, the cooldown is procedurally controlled as a normal cooldown and falls within the limits of the normal design cooldown.

The Functional Specifications provide temperature and pressure curves for piping and components for anticipated transients. A review of these documents indicates that the largest temperature difference during trips is about 100°F between the pressurizer and the hot leg. If this temperature difference is assumed between the top and bottom of the surge line, no significant additional fatigue usage occurs.

QUESTIONS ON SECTION 5

SECTION 5 - QUESTION 1 (5.1)

What are the key assumptions/inputs provided by Toledo Edison to B&W for the fatigue analysis of Davis-Besse?

RESPONSE (5.1)

Toledo Edison provided the stratification temperature ranges considered likely to occur during heatup and cooldown at Davis-Besse to B&W. These temperature ranges are tabulated on page 5-5 of BAW-2085. They are derived from the temperatures measured on the surge line at M-K and were modified to account for Davis-Besse operating parameters. This was basically done by reviewing the normal heatup and cooldown transients for the Davis-Besse plant and fitting the M-K data in the envelope between the pressurizer temperature and the hot leg temperature. Toledo Edison furnished a transient plot of the heatup and cooldown transients from M-K, showing the number of occurrences for each stratification load case. For each case, Toledo Edison also provided the moments in the surge line and in the nozzles at each end. This input aided B&W in associating the correct parameters to be combined with the stratifications for the fatigue evaluation.

All other inputs for the fatigue evaluation were available from the latest Davis-Besse stress report (pressure ranges, thermal expansion moments, seismic moments). The evaluation furnished in Appendix B concluded that the transients used in the bounding analysis (as described above) was in fact bounding.

SECTION 5 - QUESTION 2 (5.2)

What are the specific differences between the Muelheim-Kaerlich (M-K) plant and the domestic plants?

RESPONSE (5.2)

The M-K plant is a two-loop pressurized water reactor (PWR) with two cold legs in each loop, each with its own reactor coolant pump. The plant employs a pressurizer and associated spray line and surge line functionally similar to typical U.S. PWRs.

The M-K plant's surge line dimensions and configuration are somewhat different from the domestic 177 fuel assembly plants' surge lines. BAW-2085 includes the specific information for the dimensions and configuration of the domestic plant surge lines. Figure 1 shows the M-K surge line configuration. The total line length at M-K is approximately 78 feet compared to about 50 feet for the domestic plants. The M-K configuration also contains a vertical rise in the line about 16 feet away from the pressurizer, somewhat similar to the configuration at the Davis-Besse plant. However, the upper horizontal run at M-K is significantly longer than its counterpart at Davis-Besse.

The surge line inside diameter at M-K is approximately 15.7 inches versus 8.75 inches on the domestic plants. The straight pipe wall thickness at M-K is 1.8 inches versus the domestic plant value of 1 inch. M-K has removable stainless steel insulation on the surge line similar to that manufactured by B&W and used on most of the domestic surge lines.

The M-K plant's basic thermal-hydraulic performance and system operations are similar to the domestic plants'. Plant startup requires an initial pressurization of the RCS after fill and venting steps are completed. This is done in conjunction with venting of the nitrogen bubble from the pressurizer. This step is followed by increased pressurization of the RCS in order to establish the minimum NPSH for running the reactor coolant pumps. During this initial pressurization phase, the largest pressurizer to loop temperature differential exists. This is similar to the domestic plants. With the heatup of the RCS, the pressurizer-loop temperature differential decreases as the plant approaches the hot zero power condition. It continues to decrease with power escalation.

M-K operates with an average reactor coolant temperature of 595.4°F above 15% full power. Normal RCS pressure at hot zero power and for the whole power range is 2189 psig. Corresponding values for the domestic plants are 579°F (582°F for the 2772 MWt plants) and 2155 psig. Hence, at power, the domestic plants have a somewhat larger pressurizer to hot leg temperature differential than at M-K.

SECTION 5 - QUESTION 3 (5.3)

What is the basis for loading case 1 to occur three times? (Ref. page 5-2.)

RESPONSE (5.3)

M-K measurements show load case 1 occurs three times during plant heatup, with a maximum top-to-bottom temperature difference of 330°F. When the Oconee 1 bounding fatigue analysis was performed, the M-K measurements were the only ones available. Review and preliminary evaluation of the actual Oconee 1 measurements showed this assumption to be conservative, i.e. the assumed number of cycles and the assumed temperature difference produced more fatigue than actual Oconee 1 measurements.

SECTION 5 - QUESTION 4 (5.4)

What are the usage factor values at critical locations

a. due to stratification loadings?

b. due to other loadings?

RESPONSE (5.4)

The most straightforward response is to review the fatigue in accordance with the conditions listed at the bottom of page B-3 of Appendix B. (Since the present interim report does not attempt to justify forty years of plant operation, the conditions are given as a percentage of the total usage factor.) Table 1 shows the usage factors for the most critical location of the Oconee 1 surge line (drain line nozzle).

Table 2 shows the usage factors for the most critical location of the Davis-Besse 1 surge line (hot leg/surge line nozzle material discontinuity).

In each Table, Items 1 and 2 cover total peak stress ranges due to thermal stratification during heatup and cooldown, respectively.

SECTION 5 - QUESTION 5 (5.5)

How are the usage factors combined at critical locations

a. linearly?

b. enveloped?

RESPONSE (5.5)

The stresses for an operating condition are calculated via ASME Section III NB-3600. Each operating condition is considered in calculating stress ranges (stress reversals are considered). The components of stress are superimposed to obtain the stress for a condition to be ranged with either zero or another condition. These stress ranges are used to calculate the usage factors. Each range is carried through the number of cycles that the pipe is expected to see with each heatup and cooldown based on the Oconee 1 data, Functional Specifications, and the M-K cooldown.

A usage factor is calculated for each stress range and all the usage factors are summed (each is positive) to obtain total cumulative damage per the ASME Code.

SECTION 5 - QUESTION 6 (5.6)

How are the values for the allowable number of cycles shown on page 5-4 determined? Do they include striping effects? If not, what is the impact?

RESPONSE (5.6)

The drain nozzle is the most critical location in the Oconee 1 surge line. At that location, the cumulative usage factor is equal to 0.752 for 105 heatup and cooldown cycles. Therefore, the allowable number of heatup and cooldown cycles is 105 divided by 0.752 = 139 (rounded down to 135 on page 5-4). In the bounding analysis, extremely conservative through-wall radial gradients were combined with stratification stresses to allow for striping. The Appendix B radial gradients were taken from the preliminary analysis provided in Subsection 7.3 which includes high cyclic striping.

Table 1 shows the effects of striping in both the Oconee 1 Bounding Fatigue and the Oconee 1 Verification of Appendix B (one striping cycle combined with each stratification cycle, and the remaining striping cycles considered separately to add thermal striping fatigue). In the Oconee 1 Bounding Fatigue, the number of heatup and cooldown cycles required to obtain a usage factor of 1.0 is 135. The percentages of the cumulative usage factor are given in Table 1 for both the Oconee 1 Bounding Fatigue and the Oconee 1 Verification of Appendix B.

SECTION 5 - QUESTION 7 (5.7)

What type of adjustments and for which data were made to the M-K plant to account for the differences of Davis-Besse?

RESPONSE (5.7)

The temperature ranges for the analysis used in the fatigue evaluation were derived for Davis-Besse from the temperatures measured on the surge line at M-K. Modifications to the upper bounds of these temperatures were made to account for Davis-Besse plant operating limits. These were derived from a review of the Davis-Besse heatup procedure. For example, the maximum of 409°F, occurring early in the heatup, results from the maximum pressurizer temperature permitted to prevent exceeding the decay heat removal loop pressure limit.

A more complete description of the review of plant operation, and the basis for the modifications to tailor the M-K data for conditions at Davis-Besse are given in the Toledo Edison submittal in Attachment I, "Davis-Besse Pressurizer Surge Line Thermal Stratification - Phase I Program," Section III.E.

SECTION 5 - QUESTION 8 (5.8)

What are the maximum values and worst case location for ASME III NB-3600 equations 9 through 14? What is the effect if 3Sm allowable value is used?

RESPONSE (5.8)

For the Oconee 1 Bounding Fatigue, thermal stratification load case 2 is the most critical load case (top-to-bottom temperature difference equal to 422°F). For that load case, the highest stresses occur at the lowest point on the vertical elbow from the pressurizer, where the Equation 12 thermal stress range is equal to 92.3 Ksi, using stress index C2 = 2.65 from the ASME Code. The Oconee 1 bounding fatigue analysis replaces the 3*Sm allowable value by the 2*Sb limit (93.9 Ksi), as justified by Appendix C. Note, however, that the verification performed in Appendix B uses the 3*Sm allowable value in Equation 10 to compute fatigue reduction for the Equation 14 alternating stress, Sa, to be used in fatigue usage calculation.

The Equation 9 results are within code limits, but are not altered by thermal stratification. Therefore, they are available in the original stress report and are not part of this program. Equation 13 stresses are also within code limits, since they are not impacted by thermal stratification. Equation 10 stresses are used in Appendix B (and compared to 3*Sm) to calculate fatigue reduction and otherwise are moot (Equations 12 and 13).

The analysis performed here is a preliminary analysis which shows that fatigue usage is within the allowable limit. In the final analysis (to be documented in the final report scheduled for submittal in December 1990), a detailed elbow stress evaluation will be performed to show that Equation 12 thermal stress range is within the ASME Code allowable of 3*Sm.

For the Davis-Besse 1 Bounding Fatigue, all maximum stress values (for Equation 10 or Equation 12 stress ranges) are within the 3*Sm limit of USA Standard B31.7 based on Certified Materials Test Reports.

SECTION 5 - QUESTION 9 (5.9)

The use of twice "strain-hardened" yield strength in place of the 3Sm limit required by the ASME Code may be non-conservative. The acceptable interim limit is twice yield strength based on CMTR values.

RESPONSE (5.9)

As noted in the transmittal letter, a response to this question will be provided by November 30, 1989.

Figure 1

Muelheim - Kaerlich Surge Line Configuration

Note: Dimensions are in millimeters unless otherwise noted.

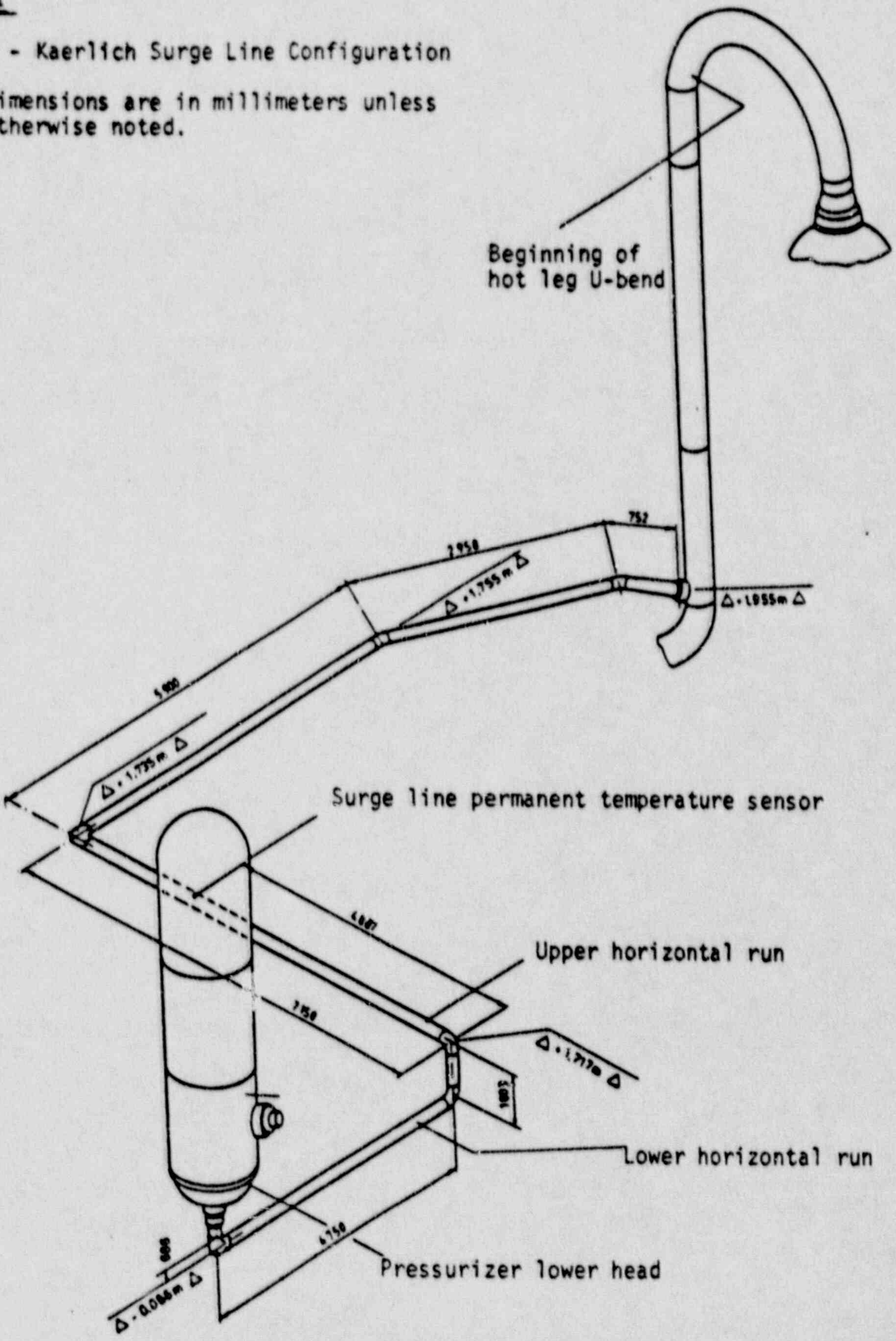

TABLE 1
Oconee 1 Surge Line
(Drain Line Nozzle)

	LOADINGS	BOUNDING FATIGUE (Subsection 5.1)	VERIFICATION (Appendix B)	
1	Heatup	66%	56%	including striping
2	Cooldown	5%	5%	including striping
3	Stress Report	29%	32%	stress same in both
4	Thermal Striping	0%	7%	
	TOTAL	100% (135 heatup and cooldown cycles)	100%	(91% of BOUNDING FATIGUE TOTAL)

TABLE 2
Davis-Besse Surge Line
(Hot Leg/Surge Line Nozzle Material Discontinuity- Carbon Steel)

	LOADINGS	BOUNDING FATIGUE (Subsection 5.2)	VERIFICATION (Appendix B)	
1	Heatup	32%	53%	
2	Cooldown	1%	1%	
3	Stress Report	67%	46%	stress same in both
4	No Thermal Striping present at this location			
	TOTAL	100% (57 heatup and cooldown cycles)	100%	(73% of BOUNDING FATIGUE TOTAL)

QUESTIONS ON SECTION 6

SECTION 6 - QUESTION 1 (6.1)

Are the snubbers shown on Figs. 6.1 and 6.2 the only supports in the entire PSL? If not, provide type and location of other supports.

RESPONSE (6.1)

The Oconee type plants have no supports which resist thermal motion (e.g., only snubbers and dead weight hangers). Each utility confirmed this early in this program. Each plant has a slightly different support configuration but none of the Oconee type plants have rigid or gapped supports which could resist thermal motion even though it is radically different from the original calculated thermal motions. Thus, the detailed support configurations for each of these plants are of no interest for thermal expansion type calculations.

For Davis-Besse, the configuration shown in Figure 6.2 illustrates the three hydraulic snubbers, R1, R2 and R3 and the single spring hanger, H1, which provide support for the surge line under various loading conditions considered in the design basis. The locations for these supports are correctly reflected in Figure 6.2.

In addition to these supports, there are eight fixed pipe whip restraints which are not in contact with the pipe during normal operations. Four of these are located along the upper horizontal run, three are spaced along the lower horizontal run, and one is located at the mid-point of the connecting vertical riser. The whip restraints on the horizontal runs are spaced approximately equally along the runs. Typically the pipe whip restraints are of I-beam, box-type construction that are bolted to poured concrete walls. At each whip restraint location, an impact collar which acts as a spacer is affixed to the pressurizer surge line. Free movement of the pressurizer surge line is determined by preset gaps between shims, applied to the inside of the whip restraint, and the pressurizer surge line collar.

A more detailed discussion of the supports and their interaction with the surge line is contained in the Toledo Edison submittal in Attachment I, "Davis-Besse Pressurizer Surge Line Thermal Stratification - Phase I Program," Sections II, III.A, B, C, D., and III.I.

QUESTIONS ON SECTION 7

SECTION 7 - QUESTION 1 (7.1)

How will the measurement program from Oconee provide input to the striping effects? (Temperatures at the inside face of the pipe wall can't be measured unless they are of a large amplitude and a long period.)

RESPONSE (7.1)

We agree with the Staff's observation that the Oconee data cannot adequately measure striping temperature oscillations in the surge line fluid. As noted in BAW-2085, the approach employed for the submittal involved use of the Oconee data to determine the cumulative time that the surge line experienced various degrees of stratification. Since the gross stratification changed very slowly, there is reasonable confidence that the measurements provide good resolution for the top-to-bottom temperature difference. This information was then combined with the estimated striping characteristics, as determined from the literature, to yield a conservative estimate of the number and amplitude of the striping oscillations that occurred in the surge line.

This same general approach is expected to be used in the final striping analysis, however, two refinements will be made. First, an evaluation of the domestic plant operating history and procedures will result in a better estimate for typical and bounding stratification conditions in the surge line. The result of this evaluation is expected to supersede the Oconee 1 data for cumulative time at various levels of stratification. Secondly, the conservative estimates for the striping phenomenon itself, i.e., the frequency and amplitude based on the percentage of the gross surge line stratification, will be replaced with data from experiments that closely simulate the B&W surge line conditions.

In neither the interim report nor in the final report, will the Oconee surge line data be interpreted to yield a direct temperature oscillation in the metal wall or in the fluid.

SECTION 7 - QUESTION 2 (7.2)

Why are 240 cycles used for Davis-Besse instead of 360?

RESPONSE (7.2)

The original design basis for all domestic B&W plants included 240 heatup and cooldown cycles. Duke Power later requested an upgrade for the Oconee units to 360 cycles for these two transients. The number of design heatup and cooldown cycles is a factor in two sections of BAW-2085. The first is in Section 5 where estimates of remaining life are made for the surge line.

Subsection 5.1 addresses the lowered-loop plants to which the Oconee units belong. Once the fatigue impact was determined for a single heatup and cooldown cycle, the total allowable cycles was calculated (i.e., the number of cycles that would yield a fatigue usage of 1.0). As shown on the table at the top of page 5-4, the limiting location is the surge line drain nozzle with a total of 135 allowable cycles. Given that the unit with the largest number of heatups is Oconee Unit 2 with 96, the remaining years of useful life were simply estimated by using the design basis of 360 cycles for the 40 year life of the plant. Hence, the result is the reported value of about five years of remaining life. this is quite conservative given that the Oconee units in the past few years have heated up and cooled down much less frequently than nine times per year. The same type of evaluation is performed in Subsection 5.2 for Davis-Besse although its 240 cycle design basis is not explicitly stated. (It can be backed out from the quoted six cycles per year specified in its design basis.)

Section 7 also makes reference to a design number of heatup and cooldown cycles (page 7-18). In this context, the number of design heatup and cooldowns is being used to estimate the total lifetime impact of striping. 240 cycles was used because it is the design basis for all B&W units except the three Oconee units. The calculated striping usage factor (0.10) was modified appropriately in Appendix B to the number of cycles justified for each plant in Section 5.

SECTION 7 - QUESTION 3 (7.3)

In ref. to Table 7-2

a. Does the temperature range account for insulation

b. What kind of stress concentration/indices are used

RESPONSE (7.3)

The temperature data used to prepare Table 7-2 takes into account insulation on the pipe. The insulation was removed, the thermocouples were fastened to the surge line, and then the insulation was replaced.

The calculation of Sa from the piping equations in the ASME Code considers the stress indices for as-welded butt welds (K3 = 1.7).

QUESTIONS ON APPENDIX A

APPENDIX A - QUESTION 1 (A.1)

Need clarification for first paragraph of page A-4.

RESPONSE (A.1)

Page A-4 of BAW-2085 contains a typographical error. The sentence which begins on line 3 of page A-4 should read:

> "This result is derived using the relationship sigma = 1.43*E*alpha*(Delta T2) and an endurance limit of 16,500 psi at 1.0 E+11 cycles."

This is from the Code stress equation E * alpha (Delta T2) / (1-poisson's ratio). In this case, (Delta T2) is equal to 45°F (rounded down) to achieve a stress range of 16500 psi. From the fatigue curves in the ASME Code, this yields 1.0 E+11 cycles.

QUESTIONS ON APPENDIX B

APPENDIX B - QUESTION 1 (B.1)

What is the % difference; and what are the values for displacements, reactions and stresses, when the non-linear vs. equivalent linear temperature profiles F.E. models are compared?

RESPONSE (B.1)

To study the effect of a non-linear temperature profile, a finite element model (with enough circumferential elements to represent the measured data) of a statically determinate cantilever beam was chosen. The cross-section of that beam is the one of the surge line. The temperature profile in each cross-section of the beam was first given as a linear top-to-bottom temperature profile, and the transverse displacement at the end of the beam was calculated.

When giving the non-linear top-to-bottom temperature profile using the circumferential elements, the transverse displacement at the end of the beam increased by 24% (assumed as 25% in Appendix B). Since the rotation is equal to the displacement divided by the length of the beam, the same percentage increase is valid for the rotations. Since this analysis is purely elastic, the reactions and the axial stress to be used in the piping analysis have the same percentage increase.

In reality, the multiplication factor should be smaller than 1.25 since the portion of the peak stress range which results from the classical thermal expansion of the surge line (with average temperature on the pipe cross-section) is the same whether accompanied by a linear or a non-linear temperature profile. Therefore, the 1.25 factor applied to the total peak stress range is conservative.

APPENDIX B - QUESTION 2 (B.2)

How are the peak stress ranges scaled down to match the actual data from the Oconee measurements?

RESPONSE (B.2)

The thermal expansion/stratification analysis is linear. Thus, the peak stress ranges are scaled down linearly. They are multiplied by the ratio between the measured top-to-bottom temperature differences and the ones considered in the Bounding Fatigue Analyses. Scaling down the peak stresses linearly by the ratio of the temperature differences is reasonable, as they are then multiplied by 1.25 in the following step to conservatively obtain a representation of the non-linear temperature profile.

Please see the answer to Question B.1 for further information on this topic.

APPENDIX B - QUESTION 3 (B.3)

What is the usage factor contribution from each item (1-4) described on page B-3?

RESPONSE (B.3)

Tables 1 and 2 furnish the requested data. Since the interim bounding analysis is not intended to represent 40 years of plant operation, the information is furnished as percentages of the total fatigue. The Appendix B analysis verifies that the bounding analysis is bounding for fatigue.

ATTACHMENT 2

B&W Owners Group Status Report on Thermal Striping Evaluation

September 1989

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INTRODUCTION

Since the May submittal of the interim report (BAW-2085), the B&WOG surge line thermal stratification program has proceeded with its comprehensive evaluation program which will culminate in a Topical Report submittal to the NRC in December 1990. A key element of this program is the complete treatment of thermal striping. BAW-2085 was supported by an extensive review of the literature. As a result of the literature review, the B&WOG procured relevant portions of the experimental thermal striping data taken by Battelle-Frankfurt and is currently processing this data. The data processing includes the following six steps: conversion, subdivision, wave resynthesis, cycle counting, analysis of results, and correlation. These data processing steps are described in this status report.

DATA ANALYSIS

The B&WOG acquired the complete Battelle-Frankfurt data for each test which simulated pressurized water reactor surge line conditions. One of these tests (No. 33.25) consisted of three distinct subtests, making a total of nine available test conditions for analysis. The initial step in data processing was the conversion of the taped data to accessible files and the rudimentary checking of the supplied data. The signals of each instrument were screened to uncover invariant signals and, for each of the 119 temperature measurements, to flag readings which appeared erroneous. The few identified data anomalies were of no consequence to the application of this data to the characterization of thermal striping.

Subsequent analyses focused on the 26 measurements of inside pipe wall temperature. Temperatures measured at discrete times do not always capture the extremes of the temperature fluctuations. Because these extreme temperatures were key to the determination of the amplitude of striping, each extreme was numerically reconstructed. A third-order fit was applied to the three measured temperatures which included and bracketed each temperature-versus-time reversal. This technique is illustrated in Figure 1. The solid trace depicts the measured temperatures; the asterisks are the calculated extreme temperatures. These calculated extremes were used in the subsequent analyses. As demonstrated in Figure 1, the experimental data, which was taken at 10 Hz, was wholly adequate to quite accurately reconstruct the actual waveforms--there were generally several measurements during each temperature undulation. Cycles were counted using the ordered overall range method. Counting was performed for each of the nine test conditions for the 26 different temperature measurements. Counting was performed using amplitude windows of 5% of the imposed temperature difference. For example, if the amplitude of the maximum temperature reversal of a particular test was between 50% and 55% of the imposed temperature difference, the counting was initiated with a threshold amplitude of 50%, counting was then repeated with a threshold of 45%, then with a threshold of 40%, and so on until all reversals had been counted. The resulting numbers of reversals are those having amplitudes greater than the corresponding threshold. These cumulative numbers of reversals were converted to a cumulative frequency of occurrence. The counting results are illustrated in Figure 2.

PRELIMINARY RESULTS

The observed striping characteristics will be generalized by correlating them to the non-dimensional governing conditions, such as the Reynolds, Grashof, and Richardson Numbers. This generalized correlation will then be used to predict striping at plant conditions. However, estimates of striping characteristics for experimental conditions, rather than their non-dimensional counterparts, are an intermediate result of this work. The data shows that the maximum striping amplitude varies approximately linearly with the pipe mass flow rate. The cumulative frequency of occurrence of temperature oscillations less than the maximum varies approximately linearly with the logarithm of the amplitude of the temperature oscillation. This observation holds for amplitudes greater than 10% of the maximum.

These preliminary observations show that the striping frequency distributions derived from the tests are characterized by relatively rare load cycles of a magnitude as large as 50% of the overall imposed top-to-bottom temperature difference. The bulk of the oscillations tended to occur at much lower amplitudes. As an example, for a pressurizer level change occurring at two inches/minute (a surge line flow rate of roughly 45 gpm), a frequency of occurrence versus amplitude table can be constructed as follows:

Amplitude Percent of imposed delta T	Frequency of occurrence, Hz
Greater than 40%	0
35 to 40%	0.010
30 to 35%	0.011
25 to 30%	0.013
20 to 25%	0.016
15 to 20%	0.021
10 to 15%	0.029

A pressurizer level rate of change of two inches/minute bounds the level changes observed at Oconee 1 during the heatup recorded in February 1989. The frequency versus amplitude relationship, when coupled with the estimates for the plant surge line conditions during various modes of operation, will result in revised fatigue analysis inputs for thermal striping.

Although final fatigue analysis for striping has yet to be done, some comparison of the assumed thermal striping characteristics used in BAW-2085 can be made to the preliminary results from the Battelle-Frankfurt data. In BAW-2085, thermal striping was assumed to occur at a constant 45% of the top-to-bottom temperature difference at a frequency of 0.25 Hz. This assumption was maintained over the entire range of the surge line flow conditions and temperature differences. In contrast, the Battelle-Frankfurt data shows a highly skewed distribution occurring for every test with only a few large amplitude cycles. There is a significant difference between these assumptions. Since the fatigue impact of a thermal cycle diminishes rapidly with decreases in cycle magnitude, the fatigue impact is also expected to be significantly decreased. The thermal striping fatigue usage factor reported in BAW-2085 was 0.10 for 240 cycles of plant heatup and cooldown. The final fatigue impact resulting from the characteristics derived from the Battelle-Frankfurt data has yet to be determined, but it appears that the derived distribution frequency will reduce the overall fatigue usage to the surge line.

The final fatigue analysis for thermal striping is dependent not only on the striping correlation information, but also on the actual surge line thermal stratification assumed to occur in the plants. A review of plant historical data and operating procedures is in progress to supplement the Oconee 1 data taken as part of this program. This review will provide representative times for plant heatups and cooldowns and will characterize the pressurizer to hot leg temperature difference necessary to make the final determination of fatigue impact for thermal stratification and striping. An essential part of this task is the correlation of gross plant parameters to the surge line stratification conditions. Oconee 1 data will form the basis for this correlation which will relate surge line end point temperatures and pressurizer level changes to the thermal stratification cycles that occur in the surge line and give rise to thermal striping. Other parameters needed in the correlation, such as reactor coolant pump operation, will be included as necessary.

SUMMARY

The B&WOG program to evaluate surge line thermal stratification and thermal striping in response to NRC Bulletin 88-11 continues to move to closure. Preliminary results from the evaluation of the Battelle-Frankfurt striping experiments support the conclusion that the assumptions used to assess thermal striping in BAW-2085 were quite conservative. Therefore, thermal striping is not expected to be a major contributor to the overall usage factor at any location in the surge line. The bounding calculations made for striping in BAW-2085 are adequate to justify continued plant operation until the more comprehensive issue of thermal stratification is completely addressed. Final resolution of thermal stratification is expected to occur in the December 1990 Topical Report submittal by the B&W Owners Group.

Fig. 1 Test 33.25 Of Battelle Data -- Resynthesized Extreme Values

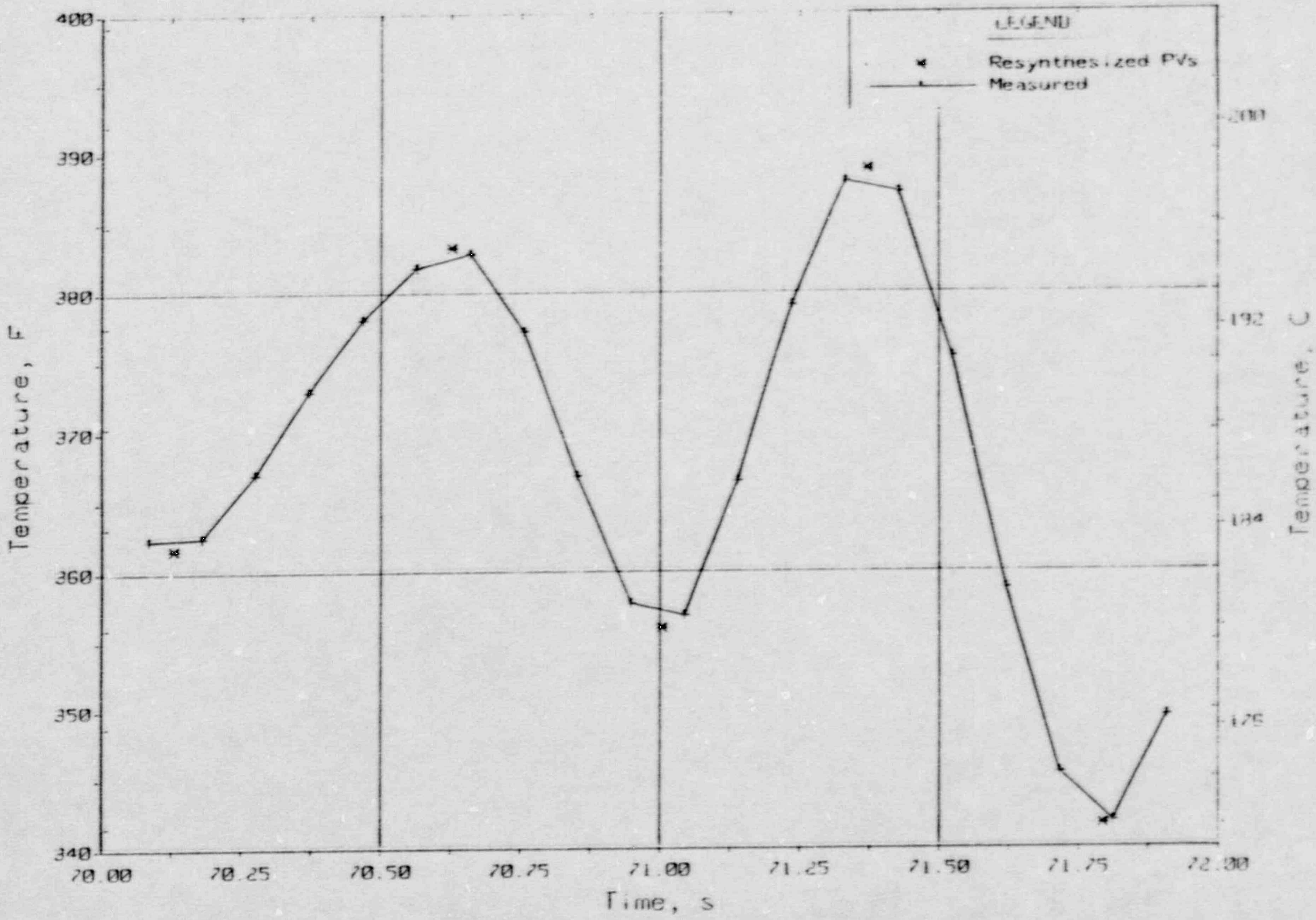
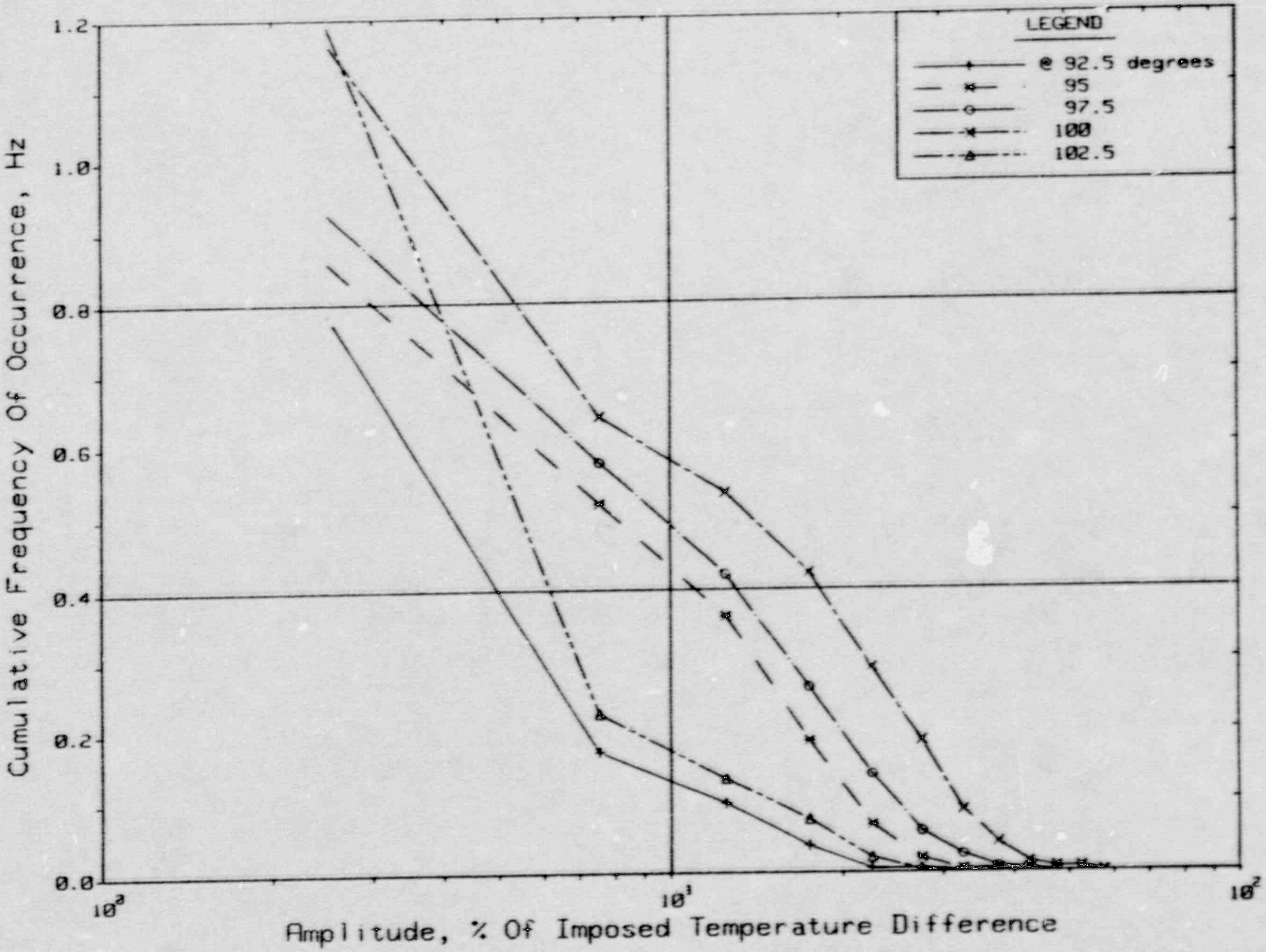


Fig. 2 Test 33.25 -- Results Of Ordered Overall Range Counting



THE B&W OWNERS GROUP

Arkansas Power & Light Company ANO-1
Duke Power Company Oconee 1, 2, 3
Florida Power Corporation Crystal River 3
GPU Nuclear Corporation TMI-1

Sacramento Municipal Utility District Rancho Seco
Toledo Edison Company Davis Besse
Tennessee Valley Authority Bellefonte 1,2
Babcock & Wilcox Company

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November 27, 1989
OG-606

Mr. Terence L. Chan, Senior Project Manager
Project Directorate V
Division of Reactor Projects - III,
IV, V and Special Projects
Office of Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Babcock & Wilcox Owners Group Response to NRC Bulletin 88-11, "Pressurizer Surge Line Thermal Stratification"

References:

1) NRC Letter, Terence L. Chan to Daniel F. Spond, "NRC Bulletin 88-11, 'Pressurizer Surge Line Thermal Stratification,'" dated August 17, 1989

2) B&WOG Letter, Daniel F. Spond to Terence L. Chan, "Babcock & Wilcox Owners Group Response to NRC Bulletin 88-11, 'Pressurizer Surge Line Thermal Stratification,'" dated September 29, 1989, OG-854

Dear Mr. Chan:

Reference 1 documented the NRC's request for additional information regarding the B&W Owners Group (B&WOG) report BAW-2085, Submittal in Response to Nuclear Regulatory Commission Bulletin 88-11 "Pressurizer Surge Line Thermal Stratification," dated May 1989. Reference 2 provided the B&WOG's response to the Staff's request for additional information with the exception of Question 9 on Section 5 (Q5.9) of BAW-2085. Reference 2 provided the following information:

Attachment 1 - B&W Owners Group Responses to NRC Questions on BAW-2085, September 1989

Attachment 2 - B&W Owners Group Status Report on Thermal Striping Evaluation, September 1989

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The purpose of this letter is to provide the Staff with the B&WOG's response to Q5.9 of Reference 1. Our response is provided as an attachment to this letter in the same format as Attachment 1 of Reference 2.

The B&WOG is continuing work on its comprehensive program in response to NRC Bulletin 88-11. The B&WOG will document the results of this program in a topical report which is scheduled for submittal in December 1990. This submittal will meet the technical and schedule requirements of NRC Bulletin 88-11.

Individual licensees will submit or reference the material provided by this letter so that it is appropriately docketed. Should you require any further information, please contact me at (501) 377-3865 or contact the B&W Owners Group Project Manager, W. R. Gray, at (804) 385-2783.

Very truly yours,

Daniel F. Spond

Daniel F. Spond, Chairman
B&WOG Materials Committee

DFS/leh

Attachment

cc: W. T. O'Connor - TE
R. B. Borsum - B&W

bcc: <u>Materials Committee</u>

M. C. Snow - AP&L
M. A. Haghi - DPCo
D. N. Miskiewicz - FPC
T. Dempsey - GPUN
R. J. Gradomski - TE
F. R. Burke - BWNS

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B&W OWNERS GROUP RESPONSE TO NRC QUESTION 5.9 ON BAW-2085

SECTION 5 - QUESTION 9 (5.9)

The use of twice "strain-hardened" yield strength in place of the 3Sm limit required by the ASME Code may be non-conservative. The acceptable interim limit is twice yield strength based on CMTR values.

RESPONSE (Q5.9)

In order to be responsive to the Staff's question (above), additional stress analyses have been performed for comparison with the 3Sm limit.

SUMMARY OF RESULTS

A more detailed stress analysis of the surge line elbows has been performed to demonstrate compliance with the ASME Code (Eq. 12) based on a 3Sm limit. This analysis was limited to the elbows since the simplified Eq. 12 piping stress is well within Code allowables for the surge line straight piping. This analysis was performed for the worst Oconee 1 measured stratification temperature differential.

The resultant Eq. 12 stress was found to be lower than the 3Sm value, based on CMTR yield strength. The resultant fatigue usage factor remains bounded by that which is reported in BAW-2085.

Background information on the bounding analysis and the verification analysis (which utilized Oconee data) is summarized in the last section of this response.

SUPPLEMENTARY STRESS ANALYSIS

The analyses performed in response to Q5.9 made use of CMTR values to adjust the surge line elbow Code allowables. The CMTR values for both the yield strength and the ultimate tensile strength are a minimum of 10% higher than the Code allowables for any 177 FA plant. Therefore, the 3Sm Code limit, adjusted for the minimum CMTR values, is 66.0 Ksi (1.10*60.0). The stress was then calculated using Table NB-3685.1-2 of the ASME Code and the moments resulting from the most critical Oconee 1 measured top-to-bottom thermal stratification (delta T=280F). The maximum calculated stress was determined to be 65.4 Ksi occurring in the second elbow from the hot leg. This is less than the adjusted Code allowable. The thermal expansion stress range of 65.4 Ksi is a "Tresca" stress intensity using the maximum difference between the principal stresses. As a point of comparison, the maximum thermal expansion stress range using the "von Mises" criterion was determined to be 57.7 Ksi ("von Mises stress intensity").

In addition, an elastic finite element stress analysis of each elbow has been performed using the loadings from the maximum measured temperature difference, assuming the surge line boundaries are rotationally rigid, and applying a 25% increase to the thermal expansion stress range for non-linearity. The finite element analysis achieved approximately a 10% reduction in the stresses calculated above using Table NB-3685.1-2 of the ASME Code. This 10% reduction applies to both the "Tresca" and "von Mises" stress intensity values shown above.

USAGE FACTOR

The following table summarizes the contributions to the cumulative usage factor at the most critical elbow location:

	LOADINGS	FATIGUE CONTRIBUTION	
1.	Heatup	36%	(including striping)
2.	Cooldown	24%	(including striping)
3.	Stress report	32%	(stress same as bounding fatigue analysis)
4.	Thermal striping	8%	
	TOTAL	100%	(89% of bounding fatigue analysis presented in BAW-2085)

This table is presented in accordance with the conditions listed in Appendix B of BAW-2085 and is similar to Tables 1 and 2 of the B&WOG's September 29, 1989 submittal of responses to the other Staff questions on BAW-2085. For each condition, a percentage of the total cumulative usage factor is provided. The verification of the bounding fatigue analysis was performed using the ASME Code stress indices (Table NB-3681(a)-1), Oconee data for the heatup, the most critical heatup thermal stratification cycle (280F) for the cooldown, and the 3Sm Code allowable to calculate the penalty factor, Ke, for each thermal stratification cycle. The Eq. 10 and Eq. 11 stresses do not utilize the more detailed stress analysis discussed above for Eq. 12; and Eq. 13 remains well within its allowable value. As noted in the above table, the cumulative usage factor determined in this manner is 11% smaller than that calculated in the bounding fatigue analysis. Therefore, the fatigue results using the Oconee 1 measured data are enveloped by the fatigue results of the bounding analysis.

The foregoing discussion applies to all 177FA plants except Davis-Besse, since the Davis-Besse surge line meets the stress criteria of USA-Standard B31.7.

BACKGROUND

Section 5.1 of BAW-2085 documents the bounding fatigue analysis which calculated an Eq. 12 elbow stress of 92.3 Ksi. This was compared to the cyclically strain-hardened yield (2Sb) as described in Appendix C of BAW-2085. A further review of published literature, performed as a result of this question, indicates that the 2Sb limit could be a reasonable replacement for 3Sm. The bounding analysis used conservative inputs, i.e., 422F stratification, rigid rotational boundaries, simplified Eq. 12 stress, and no credit for CMTR values.

The fatigue was verified to be conservative (the Oconee verification analysis) by using the as-measured Oconee data (280F worst case thermal stratification). The highest Eq. 12 stress for this evaluation was 76.9 Ksi and the comparison to 2Sb was retained. Conservative assumptions were also input to this analysis, i.e., rigid rotational boundaries, simplified Eq. 12 stress, no credit for CMTR values, and a 25% increase in the total thermal expansion stress to account for the non-linearity of the temperature profile.

The more detailed analysis presented in this response utilizes the Oconee 1 as-measured data since it is considered to be representative of the 177 FA plants. As reported above, the equivalent Eq. 12 stress for this more detailed analysis was determined to be 65.4 Ksi which is lower than the 3Sm value based on CMTR yield strength.