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82-06 #3

November 1, 1982

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MIDLAND NUCLEAR COGENERATION PLANT
MIDLAND DOCKET NOS 50-329, 50-330
B&W STEAM GENERATOR AUXILIARY
FEEDWATER HEADER DESIGN CHANGE
FILE: 0.4.9.62, 0505.2 SERIAL: 19403

REFERENCE: (1) J W COOK LETTER TO J G KEPPLER
SERIAL: 17504, DATED MAY 26, 1982
(2) J W COOK LETTER TO J G KEPPLER
SERIAL 17560, DATED AUGUST 6, 1982
(3) T M NOVAK LETTER TO J W COOK
DATED AUGUST 11, 1982

ENCLOSURE: (1) B&W CODE ANALYSIS OF THE STABILIZED
INTERNAL AFW HEADER

This letter provides another interim 50.55(e) report concerning the B&W steam generator auxiliary feedwater header. Consumers Power Company and B&W are in the process of implementing the design modifications as designed and presented in an earlier 50.55(e) report, reference 2.

This report is an attempt to fulfill the Mechanical Engineering Branch Request For Additional Information attached to reference 3. Enclosure 1 is a summary of the B&W analysis performed to assure the structural integrity of the stabilized internal header. An ASME code analysis was performed using conservative weld assumptions. The results indicate that the stress intensities are within the applicable code allowables for the different ASME service level load combinations. The Midland design details of the AFW header requested by MEB were sent by reference 2 while reference 3 from the NRC was enroute.

We believe the information attached as enclosure 1 of this report and the information attached as enclosures of our previous report, reference 2,

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responds to the MEB requests for additonal information. Should other information or a meeting on the subject be required to complete the license review process, please notify us so that this outstanding issue can be closed.

Another report, either interim or final, will be sent on or before February 28, 1982.

JWC/WJC/bjb

James W. Cook

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DJudd, B&W, w/o

BCC JLBacon, M-1085A, w/o
RCBauman, P-14-312B, w/a
WRBird, P-14-418A
NRC Correspondence File, P-24-517, w/a
LHCurtis, Bechtel, Ann Arbor, w/o
LEDavis, Bechtel-Midland, w/o
MADietrich, Bechtel-Midland, w/o
GREagle, CPCo, Ann Arbor, w/o
BWMarguglio, Midland, w/o
DBMiller, Midland (3), w/a
JAMooney, P-14-115A, w/o
JARutgers, Bechtel, Ann Arbor, w/o
REWhitaker, Midland, w/a
MLCurland, Midland, w/o
DMTurnbull, Midland, w/a
MEGibbs, IL&B, w/o
FDField, Union Electric, w/o
RAWells, P-14-113A, w/o
FCWilliams, IL&B, Washington, w/o
PSteptoe, IL&B, Chicago, w/o
RWHuston, Washington, w/a
DTPerry, P-14-300, w/o
WJCloutier, P-24-505, w/o
DMBudzik, P-24-517A, w/o
FJLevandoski, B&W, Lynchburg, w/a
EMHughes, Bechtel, Ann Arobr, w/o
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CONSUMERS POWER COMPANY
Midland Units 1 and 2
Docket No 50-329, 50-330

Letter Serial 19403 Dated November 1, 1982

At the request of the Commission and pursuant to the Atomic Energy Act of 1954, and the Energy Reorganization Act of 1974, as amended and the Commission's Rules and Regulations thereunder, Consumers Power Company submits 50.55(e) report concerning the B&W steam generator auxiliary feedwater header.

CONSUMERS POWER COMPANY

By J W Cook
J W Cook, Vice President
Projects, Engineering and Construction

Sworn and subscribed before me this 3 day of November, 1982

Barbara Townsend
Notary Public
Jackson County, Michigan

My Commission Expires September 8, 1984

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ENCLOSURE I

B&W CODE ANALYSIS OF THE INTERNAL AFW HEADER

Answer to Question 3

1.0 Summary

Analyses were performed to determine the adequacy of the header attachment design and the header structure. A three dimensional finite element model was utilized. Loads were combined according to ASME Code Criteria and applied to the structure. The resulting stresses were compared to allowables also in accordance with the ASME Code. The conclusion drawn from this analysis is that the header attachment design is adequate for all anticipated loads and that the header structure has sufficient margin to accommodate a substantial amount of weld cracks or degradation.

2.0 Method of Analysis

The stabilized header is subjected to loads which cannot be simulated using axisymetric models. To provide adequate accuracy, the header, eight attachment points and an attenuation length of the shroud were modeled as a three dimensional structure using the ANSYS Finite Element Code. The header was modeled using quadrilateral plate elements to represent the four sides of the header. The circumference of the header was divided into 54 elements with nodes separated by an average of 6.7^{0}. The shroud was also modeled using quadrilateral plate elements and included one dimensional elements at eight node points around the circumference to simulate the alignment pins and their interaction with the steam generator shell. The two structures are connected at eight locations by the use of tie-nodes to represent the welded attachments. In order to avoid excessive computer time the shroud was treated as a super element and thus specific results are not available for it. Figure 1 shows the full 360^{0} model which was used.

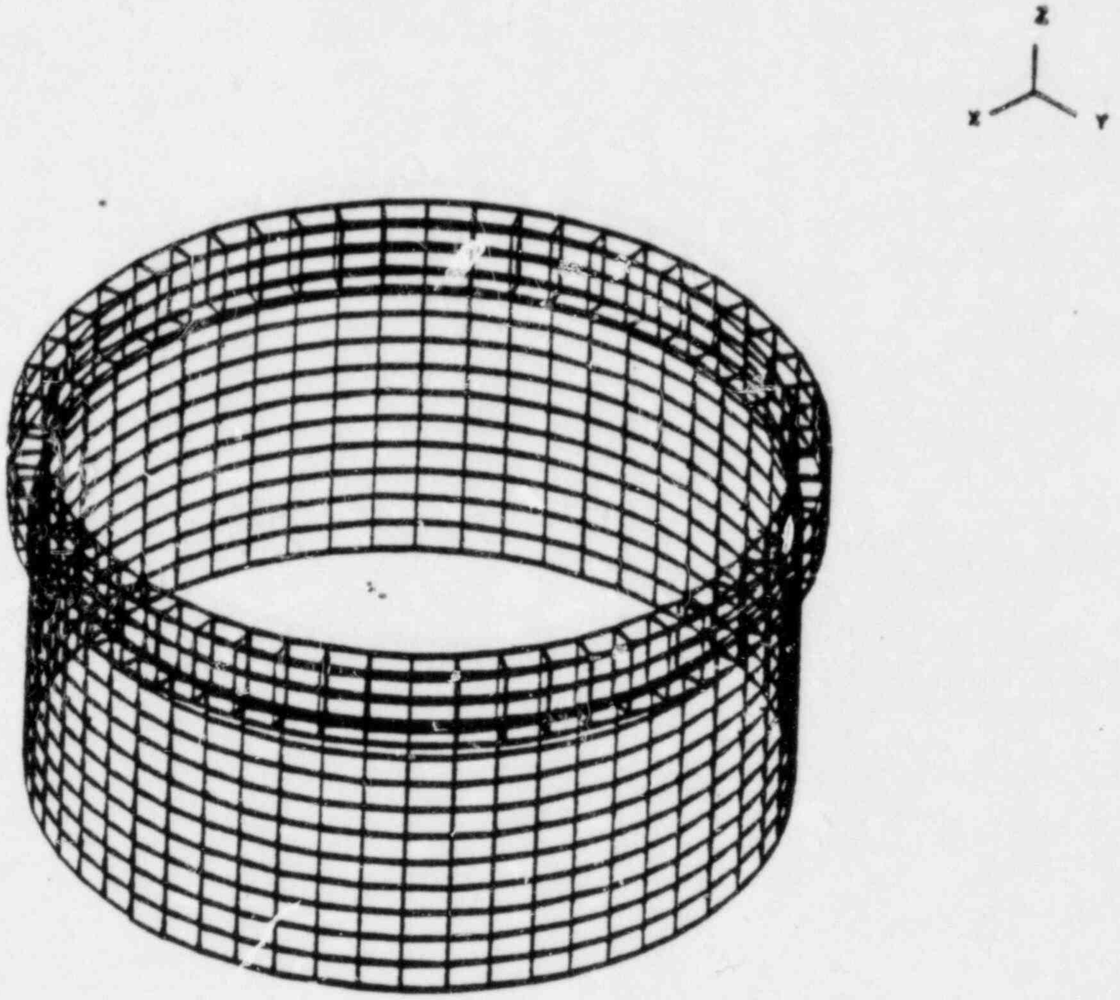

FIG. 1 COMPLETE 360° F.E. MODEL

3.0 Attachment Weld Analysis

3.1 Attachment Design

The internal header attachment design provides eight attachment points between the header and shroud. Each of the attachment points is located near one of the shroud alignment pins. The attachment is provided by a large fillet weld between the shroud and header in the corner formed by the two parts. In addition, a gusset plate is welded between the bottom of the header and the side of the shroud. The attach ent design is shown in Figure 2.

3.2 Assumptions

The model was created primarily to determine the loads imposed on the re-designed connections between the header and shroud. Because of the geometry of the welded attachment, shown in Figure 2, the calculation of the stress intensities from the load and moment vectors required assumptions as to the way the welded attachments would carry the load.

1. Radial Horizontal Load

   Because the gusset is relatively flexible in this direction compared to the fillet weld it was conservatively assumed that only the fillet weld would carry this load in shear.

2. Circumferential Horizontal Load

   Both the gusset and fillet welds share this load in shear.

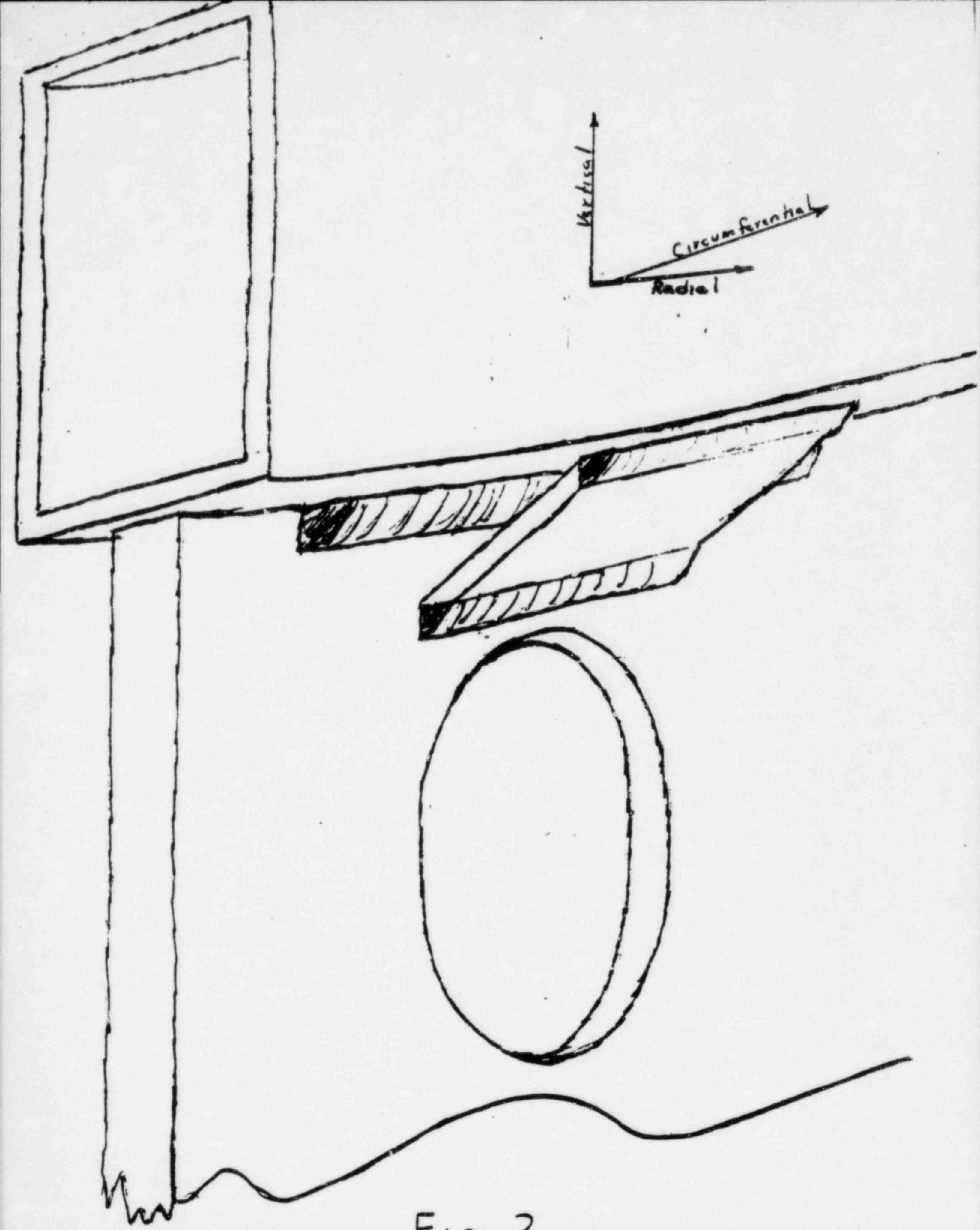

Fig. 2

3. Vertical Load

Both the gusset and fillet welds share this load.

4. Moment about Radial Axis

Both the gusset and fillet welds share this moment with the centroid being at the center of the welds.

5. Moment about Circumferential Axis

The gusset and fillet take this moment as a vertical couple. The centroid is between the two welds.

6. Moment about Vertical Axis

The gusset and fillet weld share this moment with the centroid being between the welds at the center of the welds.

7. All stresses were converted to stress intensities.

The weld area of the fillet weld is taken to be the theoretical throat times the length. The weld area of the gusset welds is taken to be the thickness times the length. For both welds a weld quality factor of 0.5 is used as is recommended for a fillet weld in Section III Subsection NB paragraph 3356 of the ASME Code 1977 Edition, Summer of 1978 Addenda.

The analysis of the welds in the header itself used a weld quality factor of 1 since these were designed as full penetration welds. The model is constructed such that the full stiffness of these corner welds is used. In considering the stresses in the corner welds the use of the full stiffness is conservative since it maximizes the predicted loads on the weld.

3.3 Load Combinations and Results

Level A & B

This analysis was performed for the combined Loads of Deadweight, Flow Induced Vibration, Operating Basis Earthquake and thermal transients. Flow induced vibration due to random excitation was calculated and found not to exceed peak loads of 2880 lbs. horizontal and 77.4 lbs vertical once in 40 years. Flutter and Vortex Shedding were considered and found to be negligible. The steady state drag load created a net downward force of less than 1700 lbs. and a horizontal radial load of less than 60 lbs. The operating base earthquake for Rancho Seco, the plant with highest seismic loads, resulted in acceleration levels of 1.3g's horizontal and .2g's vertical*. All of these loads result in low stresses in the header although they were added into the load combinations. Two transient normal operating conditions have been analyzed, secondary side heatup and initiation of auxiliary feedwater. Both of these are thermal transients which create secondary stresses in the shroud and header. All of the other transients considered did not result in a sufficient change in temperature in the generator to produce significant stresses. In a like manner the stresses in the attachment welds might be considered secondary; however to be conservative the stresses in these welds were treated as primary stresses.

*These are the accelerations for the internal header due to steam generator motions calculated using lumped mass dynamic models.

The first condition, heatup, causes stress because of the interaction of the shroud alignment pins with the shell. During heatup the shroud and header follows the steam temperature more closely than the shell resulting in a maximum Δt of $70^{o}F$. The shroud attempts to expand radially but is prevented by the alignment pins which contact the shell. The shroud deflects into an eight lobed shape. The header which is also at the steam temperature tends to remain round. The analysis was performed by imposing the calculated radial displacement caused by $70^{o}F$ Δt, .026 inches, inward on the shroud at the eight alignment pin locations. The maximum stress resulting in the most highly stressed bracket from this load combination was 9,600 psi compared to an allowable of 10,000 psi. The allowable stress intensity is S_m (Level A & B primary allowable) times a 0.5 weld quality factor or .5 S_m.

The second transient condition, initiation of auxiliary feedwater, causes stress by cooling the shroud by splash-back from the nozzle discharge. The splashback causes local cooling of the shroud at the 6 or 8 nozzle locations. The header is not cooled and tends to remain round thereby imposing loads on the attachments. The maximum stress intensity resulting from the load combination including this transient is 6,920 psi compared to 7,900 psi allowable. The allowable is lower than the heatup case because of the higher temperature.

A fatigue analysis of the Level A & B conditions shows that the header attachment welds are adequate for 360 heatup transients 29,000 initiation of a AFW transients and the full compliment of all other transient listed for the plant. A fatigue stress concentration factor of 4 was used in the analysis.

Level C

Level C analysis was performed considering Dead Weight, Flow Induced Vibration, Thermal Transients and Safe Shutdown Earthquake. All conditions for Level C are the same as analyzed for Levels A & B with the exception of the Safe Shutdown Earthquake which has acceleration levels twice that of the Operating Basis Earthquake. The additional stress due to SSE is small resulting in the Level A&B margins being limiting.

Level D

Two Load Combinations were considered: (1) Dead Weight, LOCA, and Safe Shutdown Earthquake; (2) Dead Weight, Main Steam Line Break (MSLB) and Safe Shutdown Earthquake. The limiting case is the combination including Main Steam Line Break because of the lateral load resulting from the unsymetric steam flow caused by the break. The lateral load was obtained from an analysis performed on a model representing a steam generator with a tall shroud rather than the combination of shroud and header. The side load taken from that analysis was a distributed pressure loading which when integrated over the header area yielded a load of 23,500 lbs. The header, because it reduces the steam annulus has a higher pressure drop than the tall shroud. A study was performed to assess the effect this would have on the MSLB load. It was determined that a factor of 10 would conservatively bound the effect of the different geometry. This yielded a load of 235,000 lbs. The application of this load plus deadweight and SSE yielded a stress intensity of 20,500 in the most highly stressed attachment weld. This compares to an allowable of 21,000 psi which is equal to .35 Su or 0.7 Su times a 0.5 weld quality factor.

The load combination including LOCA is not limiting because the LOCA accelerations of 13.75g's horizontal and 8.25 vertical do not produce significant stresses due to the relatively low mass of the header. The stress in the most highly stressed attachment weld is 2,100 psi compared to 20,000 psi allowable.

3.4 Conclusion

The header attachment welds are adequate for all anticipated loads. The requirement for these attachments is to hold the header in place atop the shroud and for Level A, B or C Conditions to prevent contact between the header and tubes. The attachments provide sufficient rigidity to satisfy this requirement. For Level D, the requirement is no tube rupture. The attachments by preventing the header from breaking loose avoid any potential for the header to cause tube rupture.

4.0 Header Weld Analysis

The same set of analyses was performed on the welds at the corners of the header. Because these were designed as full penetration welds the analysis was performed using a weld quality factor of one. For Level A, B or C the significant stresses are primary plus secondary stresses where the peak stress intensity in any weld is 11,480 psi compared to an allowable of 47,400 psi which is equal to $3S_m$. This yields a safety factor of 4.1.

For the Level D loads the combination including Main Steam Line Break is most limiting. The most highly stressed of any of the welds has a stress intensity of 17,200 compared to an allowable of 37,920 psi which yields a safety factor of 2.2.

The fatigue analysis for the welds was performed using a stress concentration factor of 4 which is appropriate if cracks are present. (A stress concentration factor of 1.0 would normally be used.) This analysis yielded a fatigue usage factor of .86 for 360 heatup cycles and 29,000 AFW initiation cycles.

These analyses can be used to show that substantial margin exists to encompass the existence of cracks in the weld. To meet the code limits for faulted condition only 45.4% of the weld would be required even if all of the weld were stressed at this peak value. For this to be true any cracks would have to be interspersed around the circumference. A reasonably conservative inference would be that 25% of any weld could be fully degraded or cracked if the condition was intermittently distributed.

The stress averaged around the circumference for the corner welds due to the main steam line break is much less than the peak values given. An analysis has been performed using the Main Steam Line

Break Load assuming a 28 inch crack to exist in a inner corner weld to determine its effect on the header stress pattern. The result of the analysis was that the crack does cause a slight increase in local stresses in the corner welds but has no significant impact on the stresses elsewhere in the header. This leads us to conclude that the existence of some cracks does not invalidate the analysis reported here and supports the above conclusions.

MINIMUM REQUIRED TUBE CLEARANCE

The minimum required clearance between the steam generator tubes and the header was first arrived at in a qualitative manner. There is a .250 inch clearance between steam generator tubes which has proved through many reactor years of operation to be adequate to prevent tube damage. The minimum tube to header gap was set at one-half this or .125 inches.

Qualitative analysis for Level A, B and C conditions have been performed to assure that the predicted tube and header motion is less than this minimum clearance of .125 inches and thus no contact will occur.

During Level A and B conditions the effects of dead weight, flow induced vibration, operating base earthquake, and thermal transients have been considered. Deadweight is not significant. Flow Induced vibration of the tubes has been addressed in analysis and test. The lane tube which is known to vibrate the most, has a vibratory amplitude of less than .015 inches. For OBE tube vibration is calculated to be 3×10^{-6} inches which is negligible. The header sees such small loads due to both FIV and OBE that its motion is less than .001 inches. During the heatup transient the shroud is restricted by the shell while the tubes move with the tubesheet which can result in a maximum radial relative motion of .026". This is the maximum shroud deflection and is a conservative estimate for the header. If these motions are assumed to occur simultaneously the total would be 0.042 inches which is approximately 1/3 the .125 inch requirement.

Level C conditions again vary only in that Safe Shutdown Earthquake is considered. The additional transients listed are either not significant in that they do not affect secondary side temperatures or they are similar to the transients considered for Level A & B. The doubling of the acceleration level for SSE has no significant effect on either tube or header relative motion.

There are two conditions considered for Level D conditions LOCA and

Main Steam Line Break. For both of these conditions the requirements is that steam generator tubes not rupture. For LOCA, the accelerations do not cause sufficient motion to cause the tube to touch the header. The tube motion is calculated to be 1×10^{-5} inches and the header motion to be .002 - .005 inches. For the main steam line break the drag force from the high velocity steam blowing across the tubes may be sufficient to cause the tubes to contact the header. This is acceptable because of the high ductility of the inconel tube which can accommodate as much as 50% strain without rupture. The plastic strain which would result if the tube were to deflect sufficiently to touch the header is less than 5%. This leaves a large margin of ductility to accommodate any local denting which might occur because of contact with the corner of the header.

Question 2. Provide a commitment to prepare the ASME Section III required Design Reports for the modified steam generators and auxiliary feedwater piping systems.

Response: The Stress Report issued when the steam generators were fabricated is what is now called the Design Report. The Field Change Authorization (FCA) revising this report to incorporate the changes to the header is being prepared for each licensee by Babcock & Wilcox.

Question 4. Since the inlet opening to the internal headers will not be closed, provide assurance that steam pockets cannot still be trapped in the header and cause additional damage in the event of their collapse.

Response: Although the 6" inlet hole and the 60 1½" holes remain in the internal header, a steam condensation problem is not anticipated because of the absence in the header of water below saturation temperature. Auxiliary Feedwater will now be injected into the tube bundle below the bottom of the header. This will prevent any cold water from entering the internal header and thus prevent steam condensation pressure fluctuations.