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50-001-001	32-1128224-02	Revised HPI Nozzle Usage Factor	S	N	N/A

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TYPE: ___ RESEARCH & DEVELOPMENT ___ SAFETY ANALYSIS REPORT ___ NUC. SERV. INPUT ___ DESIGN RQMT. X DESIGN VERIF. ___ OTHER

TITLE Revised HPI Nozzle Usage Factor

PREPARED BY [illegible] REVIEWED BY RR Schaefer

TITLE Engineer [illegible] DATE [illegible] TITLE Engineer IV DATE 8/31/82

PURPOSE:

The purpose of this analysis is to justify, by analysis, the operational events for the HPI nozzle. The operational events include 40 test transient cycles, 240 heatup and cooldown cycles, 40 rapid depressurization cycles, 650 OBE cycles and 70 additional HPI manual actuation cycles following a reactor trip.

Revision 1 - Incorporated revised HPI flow rates and pressure.

Revision 2 - Revised Ref. 1 to the appropriate RCS Functional Specification for the AOTC program upgrade.

SUMMARY OF RESULTS (INCLUDE DOC. ID'S OF PREVIOUS TRANSMITTALS & SOURCE CALCULATIONAL PACKAGES FOR THIS TRANSMITTAL)

The HPI nozzle can withstand the 40 cycles of test transient, 240 cycles of heatup and cooldown transient, 40 rapid depressurization cycles, 650 OBE cycles and 70 additional HPI manual actuation cycles following a reactor trip.

Total Usage Factor = U = 0.74

Revision 2 of this document completely supersedes revision 1.

Source Reference: 1. B&W Doc. No. 18-1130828-01.

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GENERAL CALCULATIONS

TABLE OF CONTENTS

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1.0 INTRODUCTION

Following each reactor trip, additional make-up flow must be obtained to prevent loss of indicated pressurizer level during the transient. All four of the high pressure injection (HPI) nozzles, located in the cold legs on the discharge side of the pumps, have been used for these occurrences. The three nozzles which do not have continuous make-up flow to the system receive a thermal shock from the cold BWST (borated water storage tank) water. The operational events for the HPI nozzle analysis included 40 test transient cycles, 40 rapid depressurization transient cycles, 240 heatup and cooldown cycles and 650 OBE cycles. An additional 70 cycles of HPI manual actuation following a reactor trip is being added, Ref. 6. The purpose of this report is to justify, by analysis, the operational events for the HPI nozzle following a reactor trip. The analysis method utilized will be the simplified elastic-plastic discontinuity analysis in Ref. #2.

3.0 Conclusion and Results

Primary + Secondary Stress Intensity Range

40 Cycles of Rapid Depressurization Transient

$\bar{\sigma}$ Primary + Secondary Range = 122.5 KSI > 3Sm = 51.3 KSI

40 Cycles of Test Transient

$\bar{\sigma}$ Primary + Secondary Range = 97.2 KSI > 3Sm = 51.3 KSI

240 Cycles of Heat-up and Cool-down Transient

$\bar{\sigma}$ Primary + Secondary Range = 18.4 KSI < 3Sm = 51.3 KSI

30 Cycles of HPI Actuation With Inclusion of ± OBE Stresses

$\bar{\sigma}$ Primary + Secondary Range = 129.4 KSI >3Sm = 51.3 KSI

40 Cycles of HPI Actuation Without Inclusion of ± OBE Stresses

$\bar{\sigma}$ Primary + Secondary Range = 126.9 KSI > 3Sm = 51.3 KSI

650 Cycles of ± OBE Stresses

$\bar{\sigma}$ Primary + Secondary Range = 2.43 KSI < 3Sm = 51.3KSI

Total number of cycles in which the primary + secondary stress intensity range exceeded 3Sm is 40+40+30+40 = 150 < 250. Therefore, an elastic plastic fatigue analysis was performed.

USAGE FACTOR

U_1 = Usage Factor For 40 Rapid Depressurization Transient Cycles = 0.22

U_2 = Usage Factor For 40 Test Transient Cycles = 0.05

U_3 = Usage Factor For 240-40 = 200 Heat-Up and Cool-Down Transient Cycles = 0.0

U_4 = Usage Factor For 30 HPI Manual Actuation Cycles (With Inclusion of ± OBE Stresses) = 0.21

U_5 = Usage Factor For 40 HPI Manual Actuation Cycles (Without Inclusion of ± OBE Stresses) = 0.26

U_6 = Usage Factor For Remainder of ± OBE Stress Cycles = 0.0

$\bar{U}$ = Total Usage Factor

$$\bar{U} = U_1 + U_2 + U_3 + U_4 + U_5 + U_6$$

$$\bar{U} = 0.22 + 0.05 + 0.0 + 0.21 + 0.26 + 0.0$$

$$\bar{U} = 0.74 < 1$$

In conclusion, the HPI nozzle can withstand the operational events of 40 rapid depressurization, 40 test, 240 heat-up and cool-down, 650 OBE and 70 HPI actuation transient cycles.

3.0 Discussion and Method of Analysis

This analysis calculates the additional fatigue usage factor on the HPI/Makeup Nozzles resulting from seventy additional HPI actuations following a reactor trip. The method of analysis utilizes the thermal/mechanical stresses calculated in the original stress report. The following discussion is provided as background information to the methods used in the original HPI analysis. The discussion will address three topics; 1) thermal analysis, (2) structural model and 3) stress analysis.

Thermal Analysis

A two-dimensional heat transfer analysis utilizing B&W computer code P91167, reference #3, was performed to obtain the temperature distribution in the nozzle and local shell region. A model of the nozzle and local shell region is shown in Figure 1. The nozzle and shell components are represented by a system of blocks with a nodal point at the center of each block. Program P91167 solves a heat balance equation between each block and the four adjacent blocks.

The following transients were selected for thermal analysis, because these transients either contribute significantly to the usage factor or are of short duration and have larger temperature differences than other transients.

(1) Heatup and cooldown (Transient 1A or 1B)
(2) Power loading and unloading (Transients 2A, 2B, 3 and 4)
(3) Rapid Depressurization (Transient 9)
(4) Test transient-HPI system (Transient 22)

The heat transfer boundary conditions consist of convective heat transfer at the inside surfaces of the nozzle and shell. The HPI nozzle contains a thermal sleeve (see Figure 2). There is an enclosed water gap between the thermal sleeve and the nozzle inside surface. The cut-off surfaces of the nozzle and shell are assumed insulated. Also, the outer surfaces of the nozzle and shell are considered

3.0 Discussion and Method of Analysis - Continued

insulated.

The results of this thermal analysis consist of temperature at each nodal point of the grid thermal model, Figure 1. Several nodes and pairs of nodes representing critical locations of the nozzle are selected to evaluate the radial and axial thermal gradients resulting from the application of each transient condition. These thermal gradients for each selected node are plotted. From these plots, selection of critical transient times for subsequent stress evaluation was made.

Structural Model

The thermal stress calculations were performed utilizing B&W Computer Programs P91206 and P91032, References #4 & #5 respectively Program P91206 uses the virtual work method to solve axisymmetric shells of revolution (see Figure 3). Program P91032 is a general thermal motion and stress program solving for various shapes using appropriate classical theory. The portion used in this analysis is the opening in a cylinder using flat plate theory modified to account for curvature in the circumferential direction.

The stresses were generated by inputting appropriate temperatures and geometry into the programs assuming no reactions at the nozzle to shell intersection. A two element discontinuity analysis was then performed and forces and moments generated were then superimposed on the thermal stresses to give a total thermal stress picture.

Stress Analysis

Several computer runs were made to obtain the stresses in the nozzle resulting from the application of selected transients. The loads for each selected critical transient time consisted of the temperature distribution, operating pressure at that transient time and the nozzle to shell interaction loads. The pressure was

Stress Analysis - Continued

applied at the inside surfaces of the nozzle and the shell.

The resulting stresses in the elements included stress concentration effects at structural discontinuities. Stress concentration factors were obtained by using the indices of USAS B31.7, "Nuclear Power Piping", 1968 Draft, and other sources. Program P91206 also output primary plus secondary stresses. The range of these linearized stresses was then compared to the associated 3Sm stress limit. The peak stresses and associated usage factors were determined for the selected critical locations in the nozzle and the shell.

In the calculations following, some of the inherent conservatism in the original stress calculations is removed. The tabulation for primary plus secondary stresses (Table 1), external load and peak stresses (Table 2) are taken directly from the original stress report.

The required thermal analysis for the HPI transient following a reactor trip is performed using temperature distribution program P91232, Reference #11. This program calculates the temperature distribution through the thickness of a cylinder as a function of time by solving one dimensional heat transfer equations. This program also determines the linear and non-linear portions of the radial temperature gradient and the associated stresses. This program was run for various types of transients to develop a simplified "temperature gradient/stress" ratio method to determine stresses for the added reactor trip HPI actuation transient.

This simplified stress ratio method utilizes the stresses in the original design analysis for the rapid depressurization transients to obtain stresses for the added reactor trip transients. The stresses and the associated cycles for the reactor trip transients were used in conjunction with the stresses and cycles in the original design analysis for the test and rapid depressurization transients to determine a total usage factor.

Stress Analysis - Continued

To conservatively analyze earthquake stresses, the following was used. There are 650 OBE cycles to consider consisting of 30 separate earthquake events, with each event having approximately 22 cycles. The full range of OBE stress was added to the thermal, pressure and thermal expansion stresses for a HPI transient following a reactor trip. This stress range was evaluated for 30 cycles. The 620 (650-30) remaining cycles of full range of OBE stress (± OBE) were analyzed separately.

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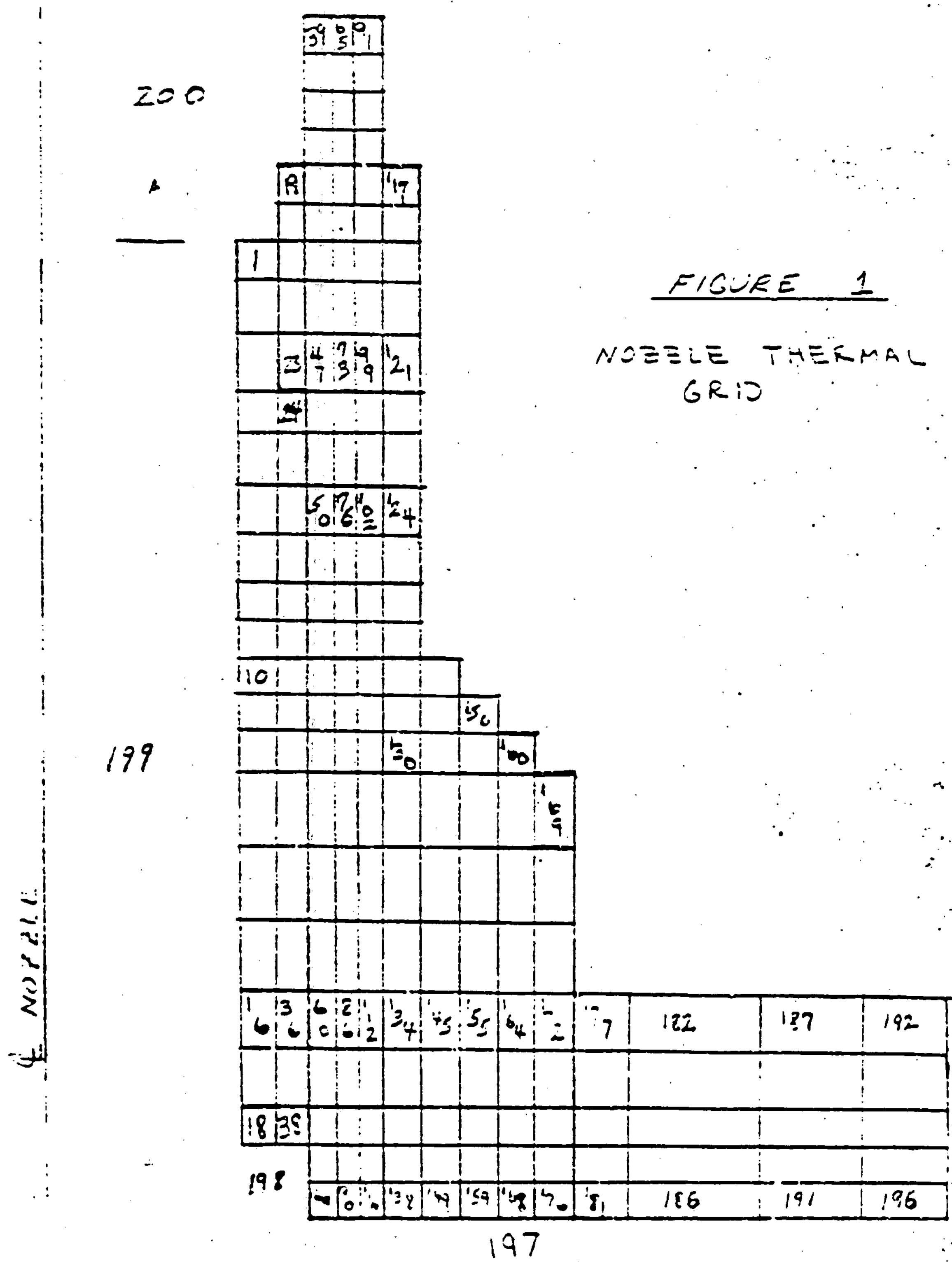

FIGURE 1

NOZZLE THERMAL GRID

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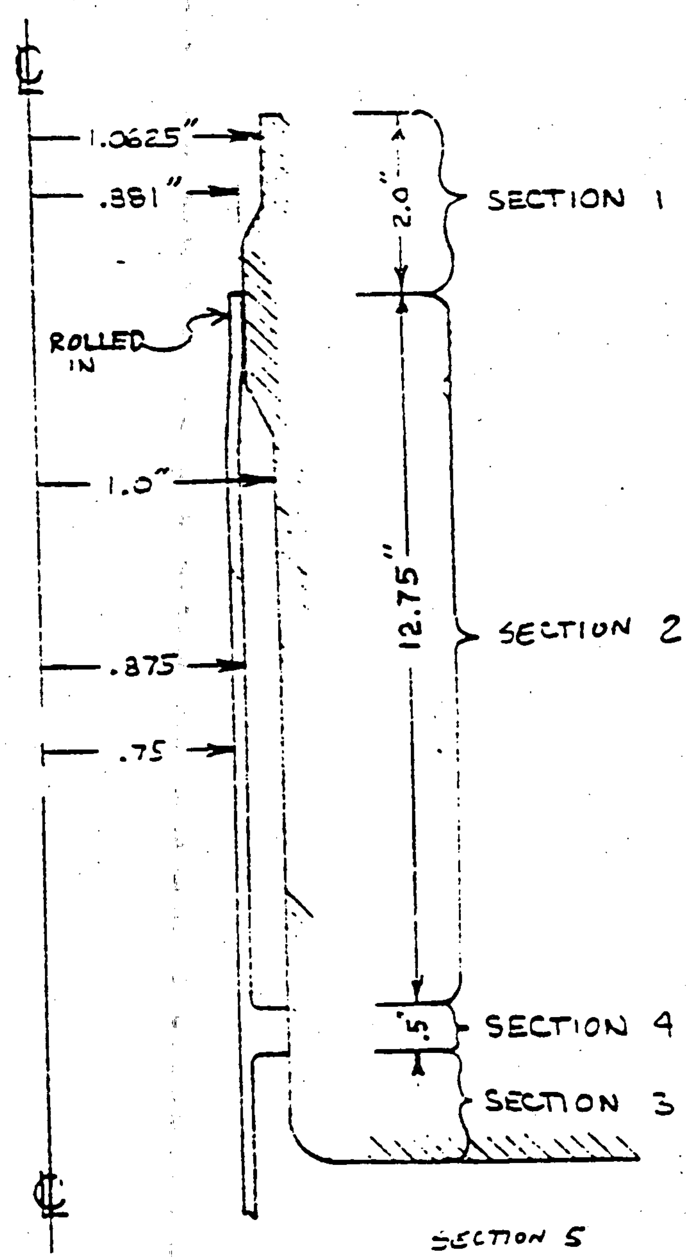

FIGURE 2
THERMAL SLEEVE GEOMETRY

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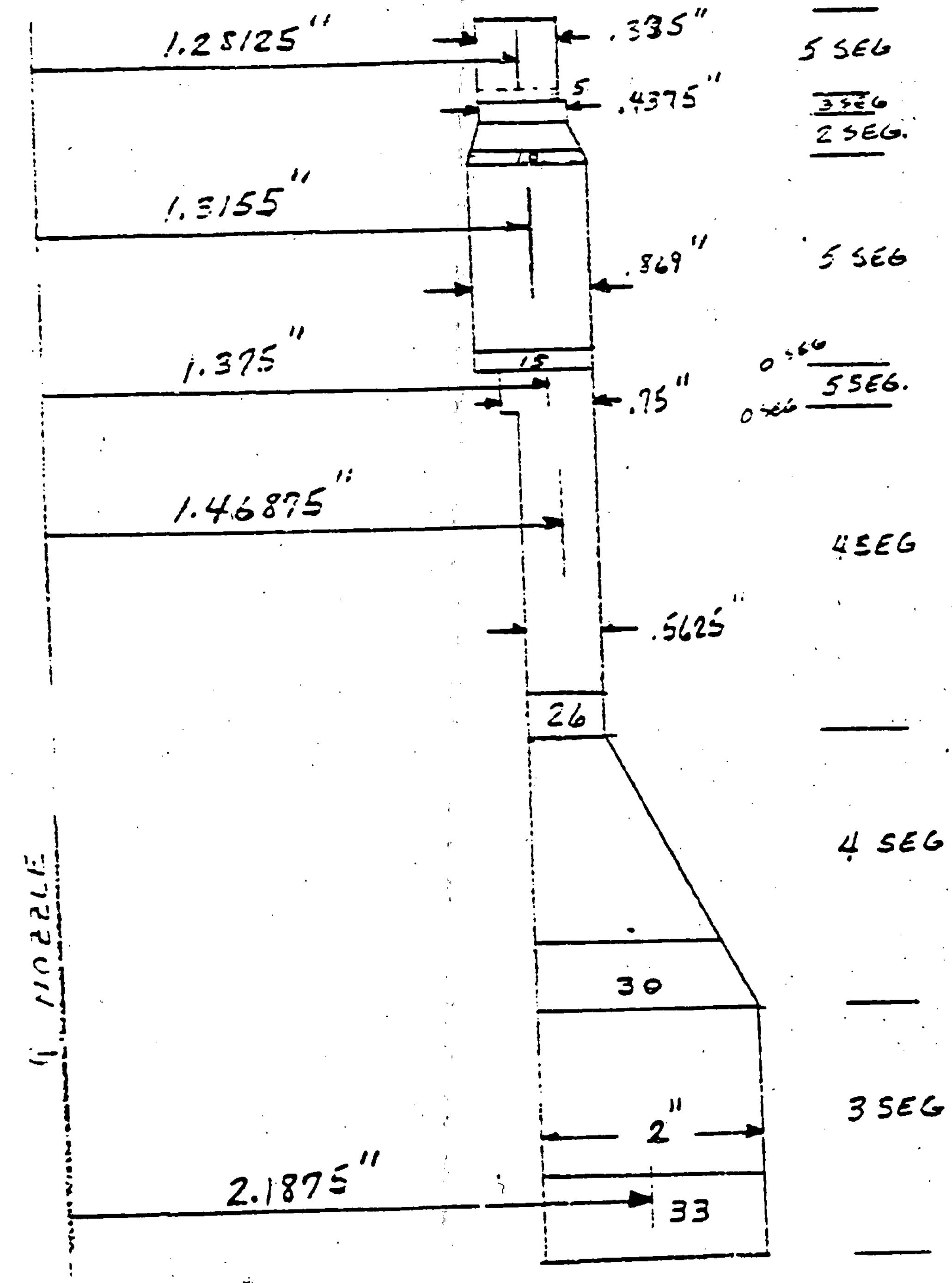

FIGURE 3

NOZZLE AXISYMMETRIC MODEL

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4.0 Description of Transients

The temperature transient for the 40 cycles of test and 40 cycles of rapid depressurization is shown in Figure 4. The test transient starts at a temperature of 550°F and a pressure of 2200 psi, drops down to 50°F and ends at a temperature of 550°F and a pressure of 2200 psi. This transient lasts for 10 seconds. The rapid depressurization transient starts at a temperature of 550°F and a pressure of 2200 psi, drops down to 60°F for 45 seconds, drops down to 40°F and ends at a temperature of 500°F and a pressure of 600 psi. This transient lasts for 15 minutes.

The temperature transient for the 70 cycles of HPI manual actuation is shown in Figure 5. The transient starts at a temperature of 579°F and a pressure of 1600 psi, drops down to 60°F for 45 seconds, drops down to 40°F and ends at a temperature of 558.[illegible]°F and a pressure of 1100 psi, References #8 and #9. This transient lasts for 15 minutes. The maximum flow rate through each nozzle is 335 gpm.

The temperature transient for heat-up and cool-down consists of heat-up from 70°F to 550° and 2200 psi and cool-down to 70°F. This transient occurs at a temperature change rate of 100 degrees per hour.

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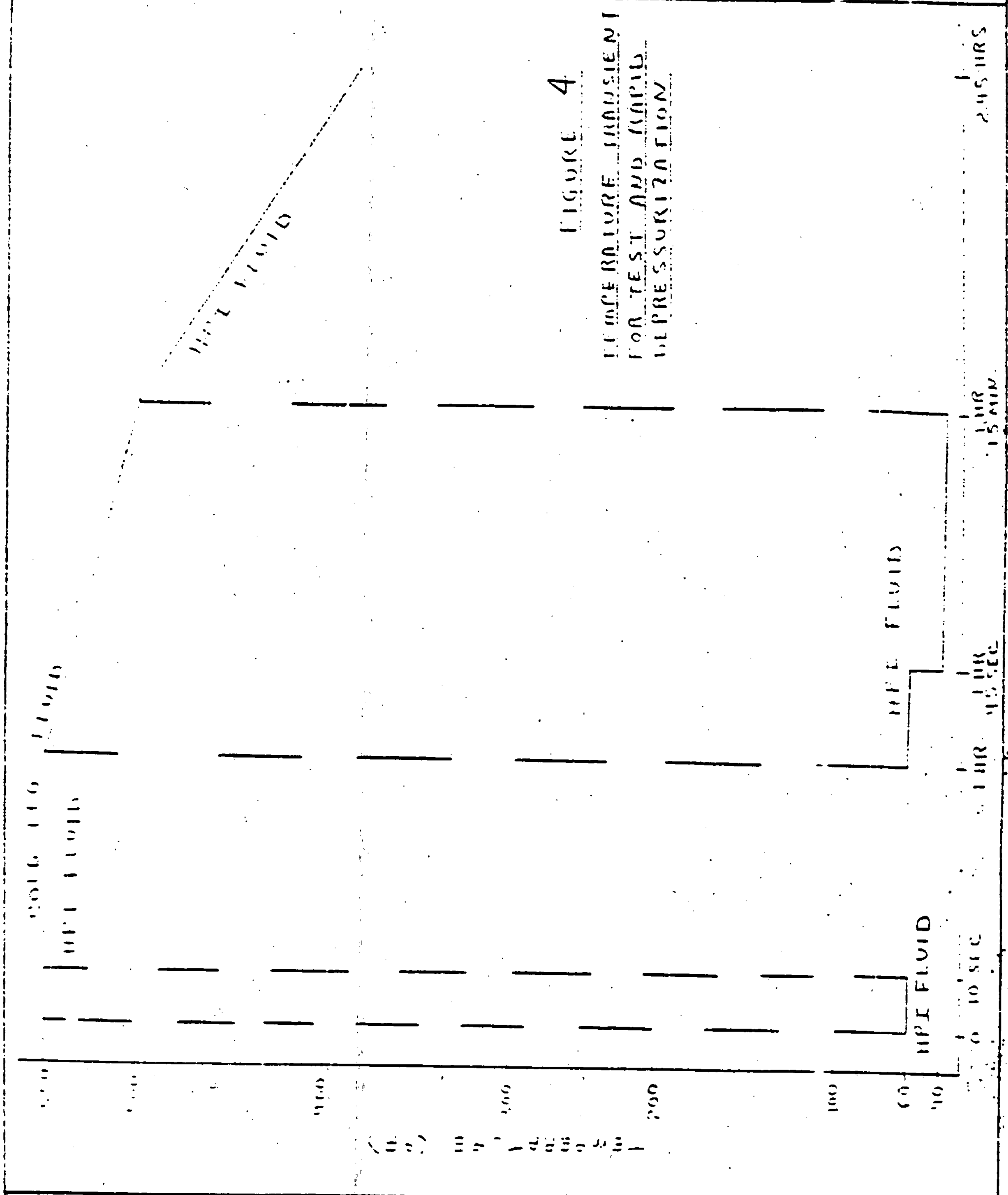

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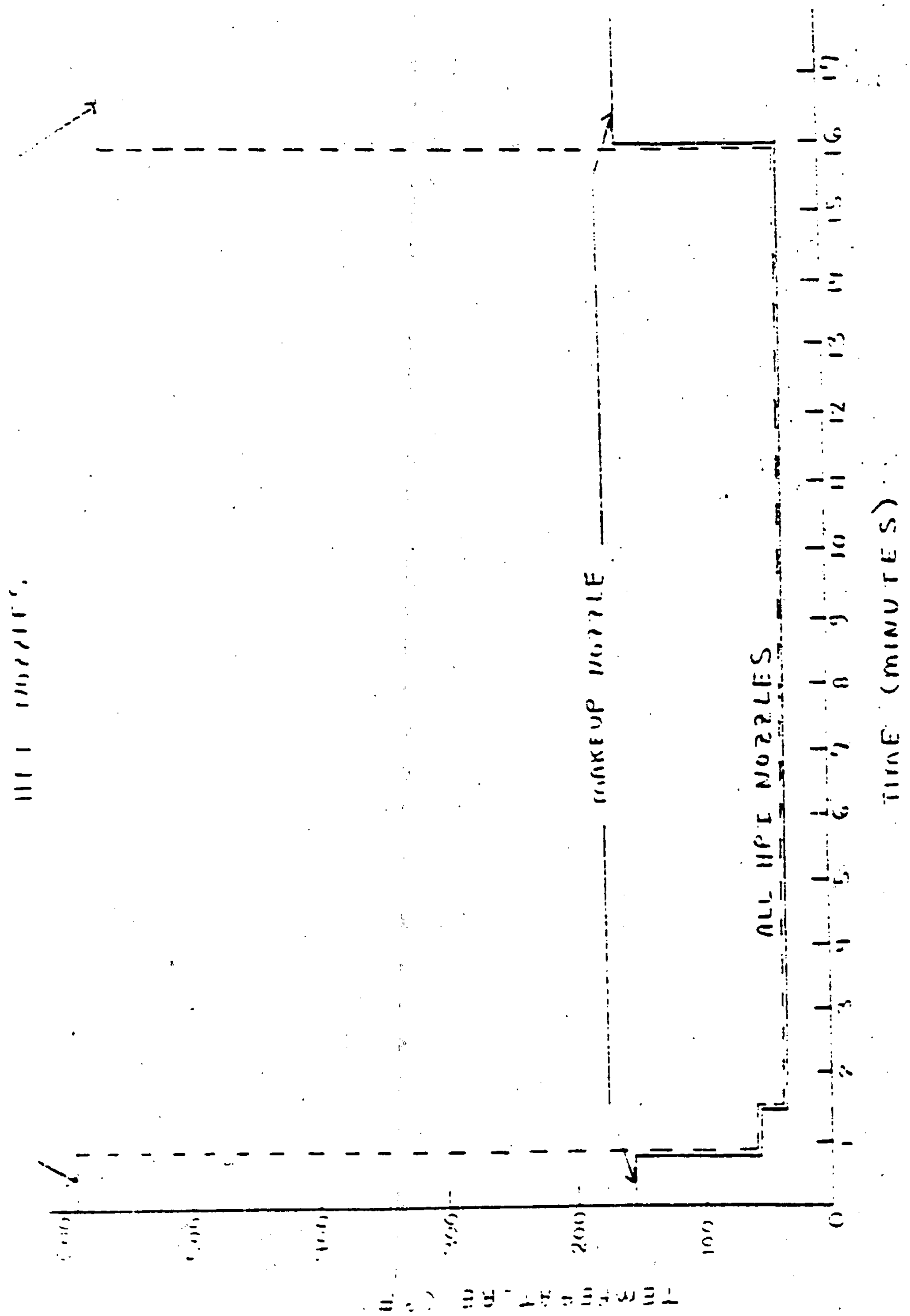

FIGURE 5

TEMPERATURE TRANSIENT FOR HPI MANUAL ACTIVATION

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5.0 Thermal Parameters

On Page 4-2 of Reference #6, the film coefficient values used in the analysis for the rapid depressurization transient were calculated. This film coefficient calculation assumed a flow rate of 425 GPM through each nozzle. The actual flow is a maximum of 335 GPM per nozzle, References #8 and #9. The actual film coefficient that should have been used is calculated below:

In Branch (Per Page 4-2, Reference 6)

The film coefficients were calculated from equation (VIII-1), Ref. #10, Page 139:

$$h = 0.023\left(\frac{k}{D}\right)\left(\frac{DG}{\mu}\right)^{0.8}\left(\frac{\mu C_p}{k}\right)^{0.4}$$

Where:
- h = Film coefficient, BTU/HR-FT^2-^{o}F,
- k = Thermal Conductivity, BTU/HR-FT - ^{o}F,
- D = Diameter Of Pipe, FT,
- G = Rate Of Flow/Unit Area, LBm/FT^2 - HR,
- μ = Dynamic Viscosity, LBm/FT - HR,
- C_p = Specific Heat, BTU/LBm - ^{o}F,

All at the fluid temperature. The properties will be evaluated at 60^{o}F since the highest stresses developed occurred over the first 45 seconds, at which time the temperature was 60^{o}F.

FOR 60°F WATER, [REF. #6, PAGE 4-2]

C_p = 1.0 Btu/Lbm-°F k = 0.344 Btu/hr-ft-°F

ρ = 62.34 Lbm/ft^3 D = 0.177 ft

μ = 2.71 Lbm/ft-hr A = 0.0246 ft^2

$$G = \frac{(335\ \text{gal}/\text{min})(60\ \text{min}/\text{hr})(0.1337\ \text{ft}^3/\text{gal})(62.34\ \text{Lbm}/\text{ft}^3)}{0.0246\ \text{ft}^2}$$

G = 6,810,99.9 Lbm/ft^2-hr

5.0 Thermal Parameters-Continued

$$h = 0.023\left(\frac{0.344}{0.199}\right)\left[\frac{(0.199)(6{,}810{,}188.9)}{(2.91)}\right]^{0.8}\left[\frac{(2.91)(1.0)}{(0.344)}\right]^{0.4}$$

$h = 3368.3$ Btu/hr - ft^2 - °F

A film coefficient of 4100 BTU/HR - FT^2 - °F for the rapid depressurization transient was used in Reference #6. The film coefficient used in Reference #6 for the test transient is 1300 BTU/HR - FT^2 - °F. This film coefficient was calculated using the correct flow rate.

On page 31 of this calculation package, it has been determined that with a film coefficient value of 4100 BTU/HR - FT^2 - °F, the same ΔT and stress ratios were computed as with a film coefficient value of 1300 BTU/HR - FT^2 - °F. Therefore, it has been concluded that using a film coefficient value of 3368.3 BTU/HR - FT^2 - °F would give the same ΔT and stress ratios. Therefore, no adjustment needs to be made during the ratio method of analysis.

6.2 Thermal Discontinuity

The thermal discontinuity effects would also be lower if the lower film coefficient value of 3368.3 BTU/HR - FT^2 - ^oF for the rapid depressurization transient was used. With a lower film coefficient value, the metal temperatures would change at a slower rate, thus decreasing the axial ΔT temperature at the time point being evaluated. Therefore, using a film coefficient value of 4100 BTU/HR - FT^2 - ^oF produces a desired conservatism in the analysis.

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GENERAL CALCULATIONS

TO HPI NOZZLE LOADS AND STRESSES

THERMAL EXPANSION LOADS (PER REF. #13)

F_x = -255 LBS M_x = 2226 FT-LB
F_y = -365 LBS M_y = -914 FT-LB
F_z = -.11 LBS M_z = -1043 FT-LB

R_i = 1.0625" D_i = 2.125"
R_o = 1.5" D_o = 3.0"

$I = \pi/64 (D_o^4 - D_i^4) = 2.98 \ IN^4$

$\sigma = C_2 D M_I / 2I$

WHERE: $C_2 = 1.2$ {REF. 2, TABLE D-201, TAPERED TRANSITION JOINT}

$M_I = (M_x^2 + M_y^2 + M_z^2)^{1/2} + VL$

$V = (F_y^2 + F_z^2)^{1/2}$

L = 0.0833 FT = DISTANCE TO JUNCTURE #8

INSIDE

$$\sigma_i^i = \frac{1.2(2.125)(12)\{(2226^2 + 914^2 + 1043^2)^{1/2} + (365^2 + .11^2)^{1/2}(.0833)\}}{2(2.98)}$$

σ_i^i = 13.6 KSI

$\sigma_i^o = 13.6 (3.0/2.125) = 19.2$ KSI

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DEADWEIGHT - OBE (PER REF. #13)

F_x = 3 LB M_x = 186 FT-LB
F_y = -264 LB M_y = 161 FT-LB
F_z = 73 LB M_z = -106 FT-LB

FOR CONSERVATISM DEADWEIGHT + OBE WILL BE USED AS OBE SINCE OBE IS NOT SPECIFIED SEPARATELY.

$S = B_2 D M_I / 2I$ WHERE: $B_2 = 1.0$ (REF. 13, PG. B-52.5)

INSIDE (OBE)

$$S_L = \frac{1.0(2.125)(12)\left[(186^2 + 161^2 + 106^2)^{1/2} + (264^2 + 73^2)^{1/2}(.0833)\right]}{2(2.08)}$$

S_L = 1.24 KSI

OUTSIDE (OBE)

$S_L = 1.24(3.0/2.125) = $ 1.75 KSI

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GENERAL CALCULATIONS

5.0 Primary + Secondary Stress Intensities

Tabulated on page 22 are the primary + secondary stress intensities at juncture #8 for the HPI nozzle. Juncture #8 is the most critical location in the HPI nozzle.

Reference #2, paragraph F-104.4, gives the primary plus secondary stress intensity range limit as 3 Sm. If the 3 Sm limit is exceeded, then an elastic-plastic fatigue analysis must be performed in accordance with Ref. #2, paragraph F-105.2.7. (The 3 Sm value at the critical location, Juncture #8, is 51.3 ksi, Ref. #6). This fatigue method is valid only if the number of cycles that exceed 3 Sm are less than 250. The number of cycles that exceed 3 Sm are determined on page 27.

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GENERAL CALCULATIONS

Table 1
Primary + Secondary Stress Intensities
At Juncture #8 (L-R Intensity)#

L - Longitudinal
R - Radial

Table references and explanations are included on the following page.

Iteration	Pressure	Pressure Stress (ksi)[1]		Thermal Expansion Stress (ksi)[2]		Stress Report Thermal Stress (ksi)[3]		Total Stress Intensity (ksi)[7]	
		Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
3	2200	4.84	1.32	13.6	19.2	63.7	-58.2	82.1	-37.7
6	2200	4.84	1.32	13.6	19.2	77.5	-70.8	95.9	-50.3
8	2200	4.84	1.32	13.6	19.2	78.8	-71.9	97.2	-51.4
15	2200	4.84	1.32	13.6	19.2	69.3	-63.0	87.7	-42.5
30	2200	4.84	1.32	13.6	19.2	7.7	- 6.9	26.1	13.6
1211	2200	4.84	1.32	13.6	19.2	-0.4	0.3	18.0	20.8
1491	2200	4.84	1.32	13.6	19.2	0.0	- 0.0	18.4	20.5
42021	2200	4.84	1.32	13.6	19.2	0.0	0.0	18.4	20.5
27976	2200	4.84	1.32	13.6	19.2	-0.7	0.6	17.7	21.1
5072	2200	4.84	1.32	13.6	19.2	86.0	-78.3	104.4	-57.8
5060	2200	4.84	1.32	13.6	19.2	73.1	-66.8	91.5	-46.3
5063	2200	4.84	1.32	13.6	19.2	97.9	-89.3	116.3	-68.8
5124	2100	4.62	1.26	13.6	19.2	33.0	-29.7	51.2	-9.2
5237	1800	3.96	1.08	13.6	19.2	11.5	-10.4	29.1	9.9
6059	1000	2.2	0.6	13.6	19.2	0.4	- 0.4	16.2	19.4
6307	800	1.76	0.48	0.0*	0.0*	0.4	- 0.4	2.2	0.1
6338	700	1.54	0.42	0.0*	0.0*	-7.7	7.0	-6.2	7.4
6850	600	1.32	0.36	0.0*	0.0*	-3.5	3.1	-2.2	3.5
A(4)	1500	3.3	0.9	13.6	19.2	103.7	-94.6	120.6	-74.5
B(4)	1100	2.4	0.7	0.0*	0.0*	-8.7	7.9	-6.3	8.6
OBE[6]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.24	1.75
2(OBE)[5]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.48	3.5

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Table References and Explanations

1. In the Stress Report, Ref. #6, Iteration 1 was run of pressure only on the nozzle at a pressure of 1000 psi. Therefore, pressure stresses are obtained by multiplying the pressure stresses from Ref. #6, page 5-17 times the ratio of actual pressure/1000 psi.

2. Thermal expansion stresses are calculated on page 19 of this analysis.

3. Stress Report Thermal Stresses are from Ref. #6, Page 5-17. These thermal stresses are conservative since they were calculated with a flow rate of 425 gpm instead of the new flow rate of 335 gpm (Ref. #8 and 9). Therefore, the film coefficient were higher than necessary, thus increasing the thermal stresses.

4. Transient A is the start of the 70 cycles of HPI manual actuation. Transient B is the end of the 70 cycles of HPI manual actuation. This transient occurs following a reactor trip transient. The pressure stresses are calculated according to Note 1 above. The thermal expansion and thermal stresses are calculated using iterations 5060 and 6338, and adjusting the stresses using a ΔT ratio. These calculations are presented in Section 8.2 of this analysis.

5. Full range OBE (2 x OBE) stresses are calculated on page 20 of the analysis for juncture #8. This is the stress range for a cold earthquake.

6. Hot earthquake stresses and cycles will be applied and analyzed for in the primary + secondary and peak stress intensity range sheets in this calculation package. OBE stresses are calculated on page 20 of this analysis.

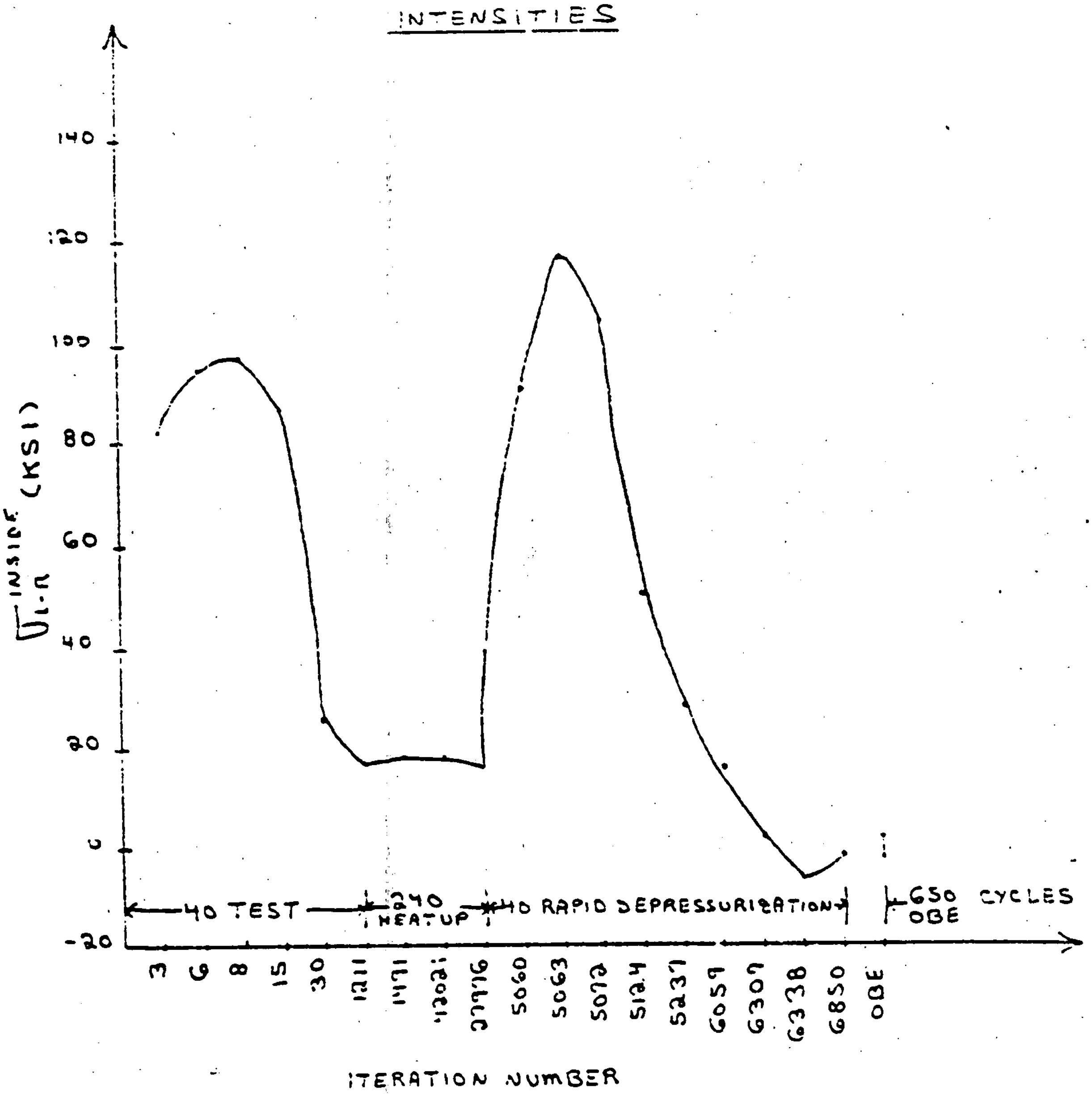
7. Total stress intensity is obtained by adding pressure stress + thermal expansion stress + stress report thermal stress.

* Note - A value of 0.0 ksi is used to approximate the range of thermal expansion stress at the HPI nozzle end due to the change in temperature of the HPI line.

- The cross-section position that experiences positive thermal expansion stresses is used to maximize the inside intensity which is the critical intensity.

- A graph of the L-R inside intensities is shown on page 25 of this calculation package to aid in determining ranges for maximum and minimum intensity values.

FIGURE 6
PRIMARY + SECONDARY STRESS
INTENSITIES



8.1 <u>40 Test, 240 Heatup and Cooldown, and 40 Rapid Depressurization Transient Cycles</u>

The primary + secondary stress intensity range will now be calculated for the 40 cycles of test transient, 240 cycles of heatup and cooldown transient, and 40 cycles of rapid depressurization transient. The temperature transient for these cycles is shown in Figure #1, Ref. #6. The stress intensities are tabulated on page 22 and shown in graphic form on page 25 of this analysis.

Maximum Primary + Secondary Stress Intensity Range

This range is comprised of |(Iteration 5063) - (Iteration 6338)|.
It occurs during rapid depressurization and can occur for 40 cycles.

$\sigma_{pri + sec \; range} = |116.3 - (-6.2)| = 122.5$ ksi > 3 Sm = 51.3 ksi

2nd Maximum Primary + Secondary Stress Intensity Range

This range is comprised of |(Iteration 3) - (Zero Stress State)|.
It occurs during testing and can occur for 40 cycles.

$\sigma_{pri + sec \; range} = |97.2 - 0.0| = 97.2$ ksi > 3 Sm = 51.3 ksi

3rd Maximum Primary + Secondary Stress Intensity Range

This range is comprised of |(Iteration 42021) - (Zero Stress State)|.
It occurs during heatup and can occur for 240-40 = 200 cycles.

$\sigma_{pri + sec \; range} = |18.4 - 0.0| = 18.$ ksi < 3 Sm = 51.3 ksi

The number of cycles in which the primary plus secondary stress intensity range exceeds 3 Sm is 80.

8.2 70 Cycles of HPI Actuation and OBE Cycles

The 70 additional cycles of HPI actuation following a reactor trip undergo a different temperature transient. (Ref. #8). The transient starts at a temperature of 579°F and a pressure of 1600 psig, drops to 50°F during the next 45 seconds and then drops to 40°F. The transient ends at a temperature of 555.0°F and a pressure of 1100 psig. The maximum flow rate is 335 gpm per nozzle. (References 8 and 9) These additional 70 cycles will be justified by adjusting the stress intensity ranges calculated on the preceding pages for the rapid depressurization transient.

To justify the analysis of the 70 additional cycles for the higher starting temperature (579°F versus 550°F), three (3) analogous thermal stress runs were made using B&W computer program P91232. Using this slab temperature program, the HPI test and rapid depressurization transients were analyzed as to their effect on the nozzle end thermal stress without discontinuity effects. The results of this analysis are contained in Reference #7, Microfiche AC3IMJU.

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GENERAL CALCULATIONS

The pertinent results are tabulated below:

Case	Initial Temp. (°F)	ΔT (T-60) °F	Film Coeff. ($BTU/HR\text{-}FT^2\text{-}°F$)	ΔT Ratio (1)	Linear Thermal Stress (PSI)	Stress Ratio (2)
1	550	490	4100	1.00	73106	1.00
2	570	510	4100	1.04	76023	1.04
3	585	525	4100	1.07	78204	1.07
4	550	490	1300	1.00	57131	1.00
5	570	510	1300	1.04	59350	1.04
6	585	525	1300	1.07	61005	1.07

Notes - (1) ΔT Ratio = $\Delta T/\Delta T_1$ = ΔT/490

(2) Stress Ratio = S_2 or $_3/S_1$ for Cases 1, 2, 3

Stress Ratio = S_5 or $_6/S_4$ for Cases 4, 5, 6

To justify the analysis of the 70 additional cycles for a higher return temperature (558.2°F versus 500°F), the following results from B&W computer program P91232 are tabulated below. These results are from Reference #7, Microfiche A0BIMJU.

Case	Return Temp. (°F)	ΔT (T-40) °F	Film Coeff. ($BTU/HR\text{-}FT^2\text{-}°F$)	ΔT Ratio (1)	Linear Thermal Stress (PSI)	Stress Ratio (2)
1	550	510	35	1.00	-5653	1.00
2	570	530	35	1.04	-5876	1.04
3	585	545	35	1.07	-6039	1.07

Notes - (1) ΔT Ratio = $\Delta T/\Delta T_1$ = ΔT/510

(2) Stress Ratio = S_2 or $_3/S_1$

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From the tabulations on the preceding pages, one can see that the ΔT ratio is the same as the stress ratio for each case. Therefore, there is sufficient justification for using a ΔT ratio method to justify the different temperature transient from Reference #8 versus the test and rapid depressurization transient from Ref. #6, Page 4-4.

In order to calculate a stress intensity range for the reactor trip followed by HPI Manual actuation, the following method will be utilized: Thermal gradient stresses from the rapid depressurization transient will be multiplied by the ΔT ratio to obtain the thermal gradient stresses for the HPI manual actuation transient. Pressure stresses for the HPI manual actuation transient will be similarly adjusted. Thermal expansion stresses will not be ratioed because these stresses are due to the temperature in the HPI Line, and the only transient that changed was the cold leg temperature.

The following calculations apply to the 70 additional cycles of HPI actuation following a reactor trip. Two cases will be analyzed during these 70 additional cycles; one with the inclusion of 30 ± OBE stresses and the other without the inclusion of ± OBE stresses. The number of ± OBE cycles analyzed is 650 - 30 = 620.

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GENERAL CALCULATIONS

MAXIMUM PRIMARY + SECONDARY STRESS INTENSITY (INSIDE)

[illegible] NO. 2

PRESSURE STRESS = (4.84 KSI) $\left(\frac{1500\ PSI}{2200\ PSI}\right)$ = 3.3 KSI

THERMAL EXPANSION STRESS = 13.6 KSI

THERMAL STRESS = (97.9 KSI) $\left(\frac{579°F - 60°F}{550°F - 60°F}\right)$ = 103.7 KSI

TOTAL STRESS = 3.3 + 13.6 + 103.7 = 120.6 KSI

[illegible] NO. 3

PRESSURE STRESS = (1.54 KSI) $\left(\frac{1100\ PSI}{700\ PSI}\right)$ = 2.4 KSI

THERMAL EXPANSION STRESS = 0.0 KSI

THERMAL STRESS = -7.7 KSI $\left(\frac{553.2°F - 40°F}{500°F - 40°F}\right)$ = -8.7 KSI

TOTAL STRESS = 2.4 + 0.0 - 8.7 = -6.3 KSI

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GENERAL CALCULATIONS

<u>MAXIMUM PRIMARY-SECONDARY STRESS INTENSITY (OUTSIDE)</u>

<u>[illegible] ON A</u>

PRESSURE STRESS = $(1.32 \text{ KSI})\left(\frac{1500 \text{ PSI}}{2200 \text{ PSI}}\right) = 0.9$ KSI

THERMAL EXPANSION STRESS = 19.2 KSI

THERMAL STRESS = $(-89.3 \text{ KSI})\left(\frac{579°F - 60°F}{550°F - 60°F}\right) = -94.6$ KSI

TOTAL STRESS = 0.9 + 19.2 − 94.6 = −74.5 KSI

<u>[illegible] ON B</u>

PRESSURE STRESS = $(0.42 \text{ KSI})\left(\frac{1100 \text{ PSI}}{700 \text{ PSI}}\right) = 0.7$ KSI

THERMAL EXPANSION STRESS = 0.0 KSI

THERMAL STRESS = $(6.6 \text{ KSI})\left(\frac{582°F - 70°F}{500°F - 70°F}\right) = 7.9$ KSI

TOTAL STRESS = 0.7 + 0.0 + 7.9 = 8.6 KSI

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Case 1 - Primary + Secondary Stress Intensity Range w/Inclusion of ± OBE Stresses

The maximum primary + secondary stress intensity range is comprised of |(Iteration A + OBE) - (Iteration B - OBE)| and can occur for 30 cycles.

$\overline{\sigma}_{\substack{pri + sec \\ range}}$ (inside) = |(120.6 + 1.24) - (-6.3 - 1.24)| = 129.4 KSI
> 3Sm = 51.3 ksi

$\overline{\sigma}_{\substack{pri + sec \\ range}}$ (outside) = |(-74.5 - 1.75) - (8.6 + 1.75)| = 86.6 KSI
> 3 Sm = 51.3 ksi

Case 2 - Primary + Secondary Stress Intensity Range w/o ± OBE Stresses

$\overline{\sigma}_{\substack{pri + sec \\ range}}$ (inside) = |120.6 - (-6.3)| = 126.9 KSI

$\overline{\sigma}_{\substack{pri + sec \\ range}}$ (outside) = |(-74.5 - 8.6)| = 83.1 ksi > 3 Sm = 51.3 ksi

This range of stresses can occur for 70 - 30 = 40 cycles

OBE Primary + Secondary Stress Intensity Range (inside)

This range is comprised of ± OBE and can occur for the remainder of the earthquake cycles = 650 - 30 = 620.

$\overline{\sigma}_{\substack{pri + sec. \\ range}}$ (inside) = |1.24 + 1.24| = 2.48 KSI

The number of cycles in which the primary plus secondary stress intensity range exceeds 3 Sm is 70.

The total number of cycles during the operational events in which the primary plus secondary stress intensity range exceeds 3 Sm is 80 + 70 = 150 < 250. Therefore, the elastic-plastic fatigue analysis is valid.

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GENERAL CALCULATIONS

9.0 Peak Stress Intensities

Following is a tabulation of the peak stress intensities at juncture #5 of the HPI nozzle. Only the stresses at the inside of segment #8 will be tabulated as they are the most critical.

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L - Longitudinal
R - Radial

Table 2

Peak Stress Intensities

At Juncture #8, L-R Inside*

*Table references and explanations are included on following page.

Iteration	Pressure (psi)	Pressure Stress (ksi)[1]	Thermal Expansion Stress (ksi)[2]	Stress Report Thermal Stress (ksi)[3]	Total Stress (ksi)[6]
3	2200	5.5	17.4	109.0	131.9
6	2200	5.5	17.4	115.0	137.9
9	2200	5.5	17.4	113.3	136.2
15	2200	5.5	17.4	95.0	117.9
30	2200	5.5	17.4	8.7	31.6
1211	2200	5.5	17.4	- 0.4	22.5
1491	2200	5.5	17.4	0.0	22.9
42027	2200	5.5	17.4	0.0	22.9
27976	2200	5.5	17.4	-0.8	22.1
5060	2200	5.5	17.4	147.4	170.3
5063	2200	5.5	17.4	143.3	166.2
5072	2200	5.5	17.4	117.3	140.2
5134	2100	5.25	17.4	39.9	62.6
5237	1800	4.5	17.4	14.2	36.1
6059	1000	2.5	17.4	0.5	20.4
6307	800	2.0	0.0*	0.5	2.5
6338	700	1.75	0.0*	-9.6	-7.9
6950	600	1.5	0.0*	-1.3	0.2
1(4)	1500	3.8	17.4	156.24	177.3
2(4)	1100	2.75	0.0*	-10.81	-8.0
OBE	0.0	0.0	0.0	0.0	[illegible]1.6
210BE	0.0	0.0	0.0	0.0	3.2

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GENERAL CALCULATIONS

Table References and Explanations

1. Pressure Stresses are obtained by multiplying the peak pressure stress from Ref. #6, Page 5-17 (Iteration #1) times the ratio of actual pressure/1000 psi.

2. Thermal expansion stresses are from page 19 of this calculation package for juncture #8, multiplied by the bending stress concentration factor from Ref. #6, Page 1-4 (KB = 1.28).

3. Stress Report thermal stresses are from Ref. #6, page 5-17.

4. Transient A is the start of the 70 cycles of HPI manual actuation. Transient B is the end of the 70 cycles of HPI manual actuation. This transient occurs following a reactor trip. The pressure stresses are calculated according to note (1). The thermal expansion and thermal stresses are calculated using iterations 5060 and 6338, and adjusting the stresses using a ΔT ratio. These calculations are presented in Section 10.2 of this analysis.

5. Full range OBE (2xOBE) stresses are from page 20 of this calculation package multiplied times the bending stress concentration factor from Ref. #6, page 1-4 (KB=1.28). This is the range for a cold earthquake.

6. Total stress intensity is obtained by adding pressure stress + thermal expansion stress + stress report thermal stress.

* Note - A value of 0.0 ksi is used to approximate the range of thermal expansion stress at the HPI nozzle end due to the change in temperature of the HPI line.

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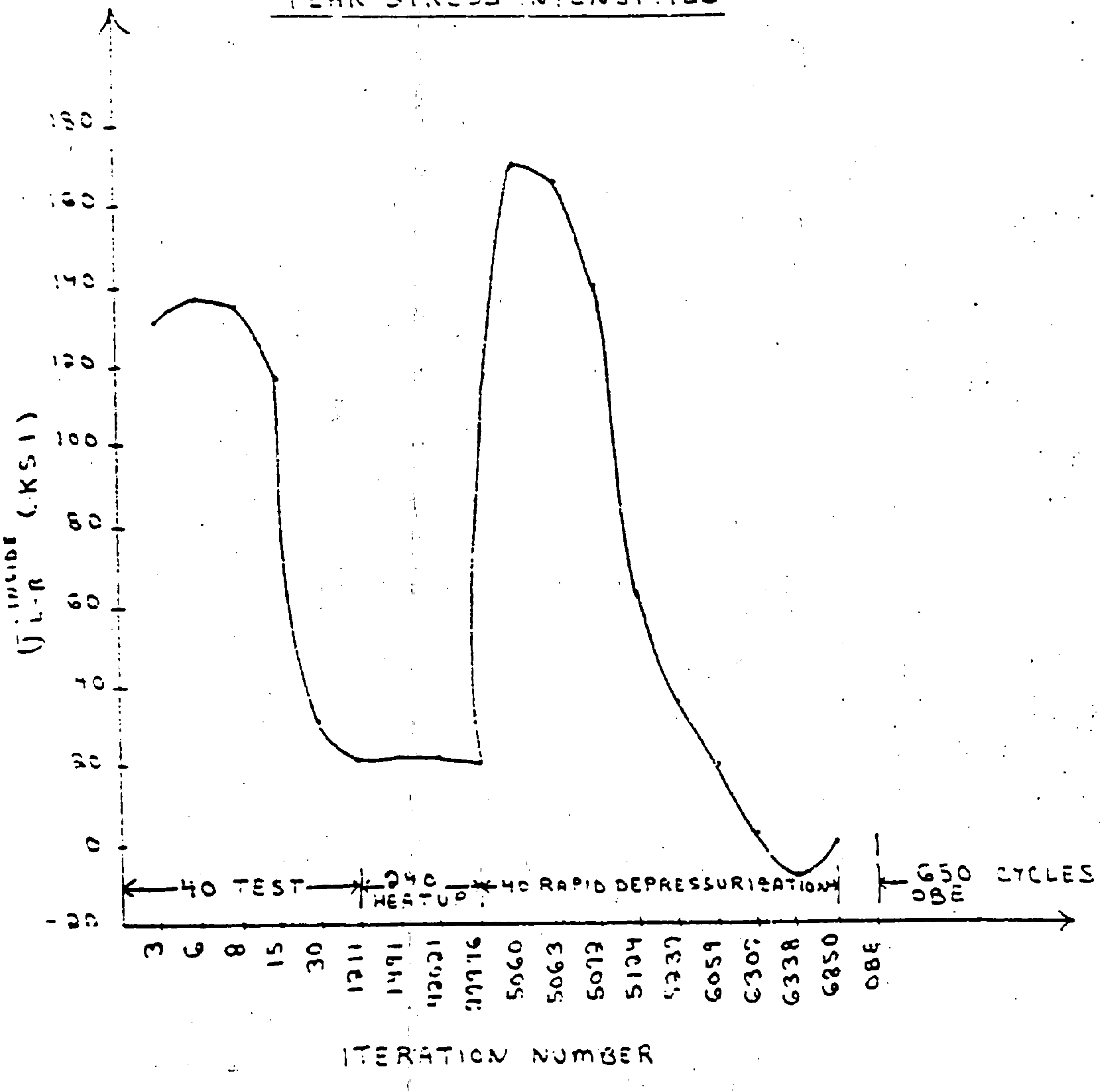
- The cross sectional position that experiences positive thermal expansion stresses is used to maximize the critical inside intensity.

- A graph of the L-R inside peak stress intensities is shown on the following page to aid in determining ranges for maximum and minimum intensity values.

FIGURE 7

PEAK STRESS INTENSITIES



10.0 Fatigue Analysis

The fatigue analysis is performed in accordance with paragraph F-[illegible]05.2.7 of Ref. #2, "Simplified Elastic-Plastic Discontinuity Analysis." The peak stress intensities and cycles are presented in graphic form on page 36. These are used to determine maximum peak stress intensity ranges and cycles used in the usage factor calculations. Actual peak stress intensity values can be obtained from the tabulation on page 35. Primary + Secondary stress intensities are also used in the fatigue analysis: these values are obtained from the tabulation on page 22.

3. 40 TEST, 240 HEAT-UP AND COOL-DOWN AND 40 RAPID DEPRESSURIZATION TRANSIENT CYCLES

MAXIMUM PEAK STRESS INTENSITY RANGE

THIS RANGE IS COMPRISED OF |(ITERATION 5060) - (ITERATION 6338)|. IT OCCURS DURING RAPID DEPRESSURIZATION AND CAN OCCUR FOR 40 CYCLES.

$\sigma_{PEAK\ RANGE} = |(170.3) - (-7.9)| = 178.2$ KSI

THE PRIMARY - SECONDARY STRESS INTENSITY RANGE ASSOCIATED WITH THESE TRANSIENTS = 122.5 KSI > $3S_m$ = 81.3 KSI (ITERATIONS 5063 AND 6338). THEREFORE, AN ELASTIC-PLASTIC ANALYSIS MUST BE PERFORMED FOR THESE 40 CYCLES FOLLOWING THE PROCEDURE OF REF. #2 PARAGRAPH F-65.2.7. THE FINAL PEAK ALTERNATING STRESS INTENSITY, S_{alt}, IS:

$$S_{alt} = \frac{1}{2} K_f K_e S_{n_3}$$

WHERE $K_f = K_A - A(K_A - 1)$ = OVERALL FATIGUE STRENGTH REDUCTION FACTOR

$$K_e = \frac{S_p}{S_{n_3}} = \frac{\text{PEAK STRESS INTENSITY RANGE}}{\text{PRIMARY - SECONDARY STRESS INTENSITY RANGE}}$$

= OVERALL EFFECTIVE STRESS CONCENTRATION FOR THE CYCLIC LOADING
q = 0.7 FOR STAINLESS STEEL A-376, TP316 FROM FIG. D-201(c), REF #2

[illegible],

$$K_t = \frac{178.2}{122.5} = 1.45$$

$$\therefore K_f = 1.45 + 0.7(1.45 - 1.0) = 1.77$$

K_e IS DETERMINED FROM FIG. F-105(a).

FOLLOWING IS THE CALCULATION OF THE PARAMETERS NECESSARY TO OBTAIN K_e:

$$\frac{S_n}{3S_m} = \frac{\text{PRIMARY + SECONDARY STRESS INTENSITY RANGE}}{3S_m}$$

$$\frac{S_n}{3S_m} = \frac{122.5}{3 \times [illegible] \text{ KSI}} = 2.39$$

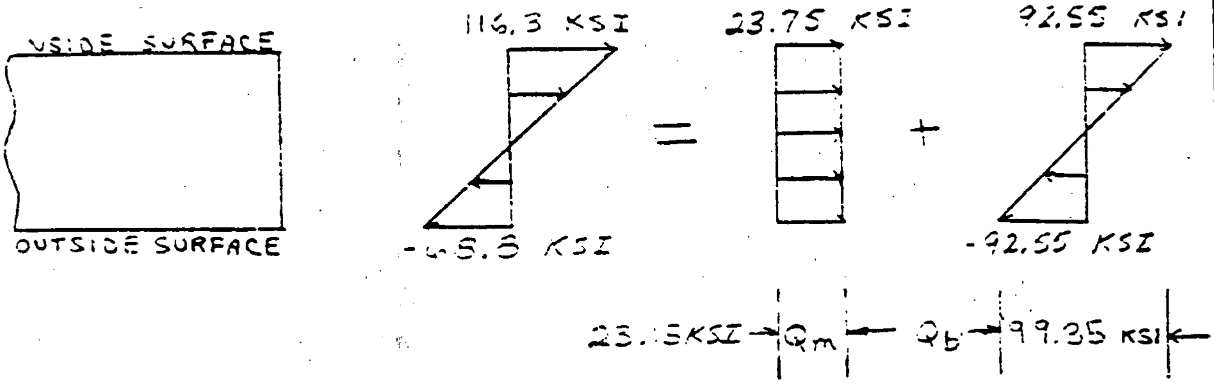
$S_m / [S_m - S_b]$ IS DETERMINED NEXT, WHERE:

S_m IS THE MAGNITUDE OF PRIMARY + SECONDARY MEMBRANE STRESS INTENSITY RANGE AVERAGED THROUGH THE THICKNESS OF THE SECTION

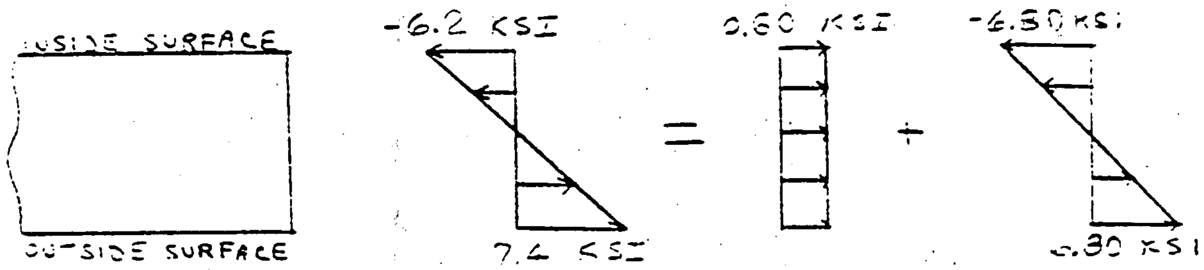
S_b IS THE MAGNITUDE OF PRIMARY + SECONDARY BENDING STRESS INTENSITY RANGE

AVERAGED THROUGH THE THICKNESS OF THE SECTION.

(CONDITION 1a = ITERATION 5063)



(CONDITION 1b = ITERATION 6338)



$$\frac{Q_m}{Q_m + Q_b} = \frac{23.15}{23.15 + 99.35} \text{ KSI} = 0.19$$

FROM FIG. F-105(a) REF. #2,

$$K_E \approx 1.75$$

$$T_{ALT} = \tfrac{1}{2} K_S K_E S_{range}^{(n)}$$

$$T_{ALT} = \tfrac{1}{2}(\ldots)(\ldots 55)/122.5) = 200.6 \text{ KSI}$$

TO TAKE INTO ACCOUNT THE EFFECT OF ELASTIC MODULUS, MULTIPLY S_{ALT} BY THE RATIO OF THE MODULUS OF ELASTICITY GIVEN ON THE DESIGN FATIGUE CURVE TO THE VALUE OF THE MODULUS OF ELASTICITY USED IN THE ANALYSIS. DURING THE RAPID DEPRESSURIZATION TRANSIENT, THE TEMPERATURE VARIES FROM 550°F TO 40°F. AT AN AVERAGE TEMPERATURE OF

$$\frac{550°F + 40°F}{2} = 295°F,$$

$$E = 27.13 \times 10^6 \text{ PSI} \qquad [\text{REF. \#2}]$$

$$\therefore S_a = 200.6\left(\frac{26 \times 10^6}{27.13 \times 10^6}\right) = 192.2 \text{ KSI}$$

[THE DESIGN FATIGUE CURVE USED IS FIG. F-106(b), REF. #2 $E_{CURVE} = 26 \times 10^6$ PSI.]

FROM FIG. F-106 (b), REF. #2,

N = ALLOWABLE CYCLES = 90

$$U = \text{USAGE FACTOR} = \frac{\text{NO. OF REQ'D CYCLES}}{\text{NO. OF ALLOWABLE CYCLES}}$$

$U_1 = \frac{40}{30} = 0.22$

2nd MAXIMUM PEAK STRESS INTENSITY RANGE

THIS RANGE IS COMPRISED OF |(ITERATION 6) - (ZERO STRESS STATE)|. IT OCCURS DURING TESTING AND CAN OCCUR FOR 40 CYCLES.

$\sigma^{PEAK}_{RANGE} = |(137.9) - (0.0)| = 137.9$ KSI

THE PRIMARY + SECONDARY STRESS INTENSITY RANGE ASSOCIATED WITH THESE TRANSIENTS IS 97.2 KSI > $3S_m$ = 51.3 KSI. [ITERATIONS 8 AND ZERO STRESS STATE] THEREFORE, AN ELASTIC-PLASTIC FATIGUE ANALYSIS MUST BE PERFORMED FOR THESE 40 CYCLES. FOLLOWING THE PROCEDURE OF REF. #2, PARAGRAPH F-105.2.7, THE FINAL PEAK ALTERNATING STRESS INTENSITY, σ_{ALT}, IS:

$$\sigma_{ALT} = 1/2\ K_2\ K_e\ S^{(n)}_{rng},$$

WHERE $K_2 = K_t + A(K_t - 1.0)$

$$K_t = \frac{S_{ri_2}^{(P)}}{S_{ri_2}^{(S)}} = \frac{137.9}{97.2} = 1.42$$

λ = 0.7 FOR STAINLESS STEEL A-376, TP316, FROM FIG. D-201 (C), REF. #2

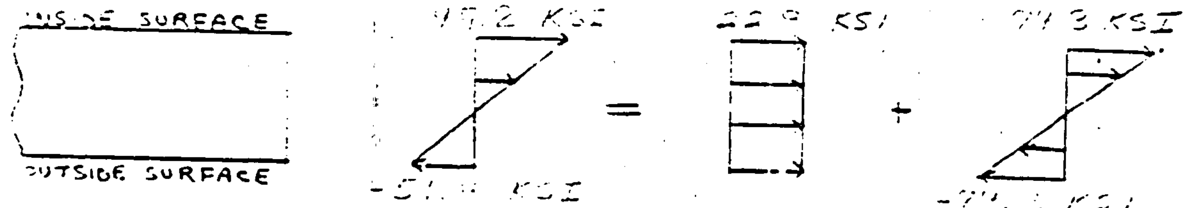
$$\therefore K_e = 1.42 + 0.7(1.42 - 1.0) = 1.71$$

Ke IS DETERMINED FROM FIG. F-105 (a). FOLLOWING IS THE CALCULATION OF THE PARAMETERS NECESSARY TO OBTAIN Ke

$$\frac{S_n}{3S_m} = \frac{97.2 \text{ KSI}}{51.3 \text{ KSI}} = 1.89$$

$|Q_m| / [|Q_m| + |Q_b|]$ IS DETERMINED BELOW:

(CONDITION 2a = ITERATION 8)



(CONDITION 2b = ZERO STRESS STATE)

$\therefore Q_m$ = 22.[illegible] KSI

Q_b = [illegible] KSI

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GENERAL CALCULATIONS

$$\frac{Q_m}{Q_m + Q_b} = \frac{22.9}{22.9 + 74.3} = 0.24$$

FROM FIG. F-105(a), REF. #2,

$K_E \approx$ [illegible]

$T_{ALT} = 1/2 \, K_2 K_E S_{rij}^{(n)}$

$T_{ALT} = 1/2$ [illegible] (.71) (97.2) = 122.2 KSI

DURING THE TESTING TRANSIENT, THE TEMPERATURE VARIES FROM 550°F TO 60°F. AT AN AVERAGE TEMPERATURE OF $\frac{550°F + 60°F}{2} = 305°F$,

$E = 27.08 \times 10^6$ PSI [REF. #2]

$S_A = $ [illegible] $\left(\frac{26 \times 10^6}{27.08 \times 10^6}\right) = $ [illegible] KSI

FROM FIG. F-106(b), REF. #2,

N = ALLOWABLE CYCLES = 7E5 CYCLES

U_2 = USAGE FACTOR = $\frac{40}{7E5}$ = 0.05

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3rd MAXIMUM PEAK STRESS INTENSITY RANGE

THIS RANGE IS COMPRISED OF |(ITERATION 42021) - (ZERO STRESS STATE)|. IT OCCURS DURING HEAT-UP AND COOL-DOWN AND CAN OCCUR FOR 240 - 40 = 200 CYCLES.

$\sigma^{PEAK}_{RANGE} = |(22.9 - 0.0)| = 22.9$ KSI

THE PRIMARY + SECONDARY STRESS INTENSITY RANGE ASSOCIATED WITH THESE TRANSIENTS IS 18.4 KSI < $3S_m$ = 51.3 KSI. [ITERATIONS 42021 AND ZERO STRESS STATE]. THEREFORE, THE FINAL PEAK ALTERNATING STRESS INTENSITY RANGE, σ_{ALT}, IS:

$\sigma_{ALT} = 1/2\ \sigma^{PEAK}_{RANGE} = 1/2\ (22.9) = 11.45$ KSI

DURING THE HEAT-UP AND COOL-DOWN TRANSIENT, THE TEMPERATURE VARIES FROM 550°F TO 70°F. AT AN AVERAGE TEMPERATURE OF $\frac{550°F + 70°F}{2}$ = 310°F,

$E = 27.05 \times 10^6$ PSI [REF. #2]

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GENERAL CALCULATIONS

$$S_2 = 11.45 \left(\frac{26 \times 10^6}{27.05 \times 10^6} \right) = 11.01 \text{ KSI}$$

FROM FIG. F-106 (b), REF. #2

N = ALLOWABLE CYCLES = ∞

U_3 = USAGE FACTOR = 200/∞ = 0.0

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GENERAL CALCULATIONS

10.2 70 CYCLES OF HPI ACTUATION AND OBE CYCLES

THE PEAK STRESSES ARE NOW CALCULATED FOR THE 70 CYCLES OF HPI MANUAL ACTUATION FOLLOWING A REACTOR TRIP. THESE 70 CYCLES UNDERGO A DIFFERENT TEMPERATURE TRANSIENT THAN FOR THE 40 CYCLES OF TEST TRANSIENT AND 40 CYCLES OF RAPID DEPRESSURIZATION TRANSIENT. THUS, THE PEAK STRESSES WILL BE ADJUSTED USING A ΔT RATIO METHOD.

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MAXIMUM PEAK STRESS INTENSITY (INSIDE)

ITERATION A

PRESSURE STRESS = 5.5 (1500/2200) = 3.8 KSI

THERMAL EXPANSION STRESS = 17.4 KSI

THERMAL STRESS = $147.4 \left(\frac{579 - 60}{550 - 60} \right) = 156.1$ KSI

TOTAL STRESS = 3.8 + 17.4 + 156.1 = 177.3 KSI

ITERATION B

PRESSURE STRESS = .78 (1100/700) = 2.8 KSI

THERMAL EXPANSION STRESS = 0.0 KSI

THERMAL STRESS = $-9.6 \left(\frac{558.2 - 40}{500 - 40} \right) = -10.8$ KSI

TOTAL STRESS = 2.8 - 0.0 + (-10.8) = -8.0 KSI

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GENERAL CALCULATIONS

THE FOLLOWING CALCULATIONS APPLY TO THE 70 CYCLES OF HPI MANUAL ACTUATION. TWO CASES WILL BE ANALYZED DURING THE 70 ADDITIONAL CYCLES; ONE WITH THE INCLUSION OF ± OBE STRESSES AND THE OTHER WITHOUT THE INCLUSION OF ± OBE STRESSES. THE NUMBER OF ± OBE STRESS CYCLES ANALYZED IS 650 - 30 = 620.

CASE 1 - PEAK STRESS INTENSITY RANGE WITH INCLUSION OF ± OBE STRESSES

THE MAXIMUM PEAK STRESS INTENSITY RANGE IS COMPRISED OF |(ITERATION A + OBE) - (ITERATION B - OBE)| AND CAN OCCUR FOR 30 CYCLES.

$$\sigma_{\text{PEAK RANGE}} = |(177.3 + 1.6) - (-3.0 - 1.6)| = 183.5 \text{ KSI}$$

THE PRIMARY + SECONDARY STRESS INTENSITY RANGE ASSOCIATED WITH THIS TRANSIENT IS 129.4 KSI $> 3S_m = 51.3$ KSI. [ITERATIONS A AND B ± OBE].

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THEREFORE, AN ELASTIC-PLASTIC FATIGUE ANALYSIS MUST BE PERFORMED FOR THESE 30 CYCLES.

FOLLOWING THE PROCEDURE OF REF. #2, PARAGRAPH F-105.2.7, THE FINAL PEAK ALTERNATING STRESS INTENSITY, σ_{ALT}, IS:

$$\sigma_{ALT} = 1/2 \, K_f K_\varepsilon S_{rig}^{(n)} ,$$

WHERE: $K_f = K_t + A(K_t - 1.0)$

$$K_t = \frac{S_{rig}^{(p)}}{S_{rig}^{(n)}} = \frac{188.5 \text{ KSI}}{129.4 \text{ KSI}} = 1.46$$

$A = 0.7$ FOR STAINLESS STEEL A-376, TP316, FROM FIG. D-201(c), REF. #2

$\therefore K_f = 1.46 + 0.7(1.46 - 1.0) = 1.78$

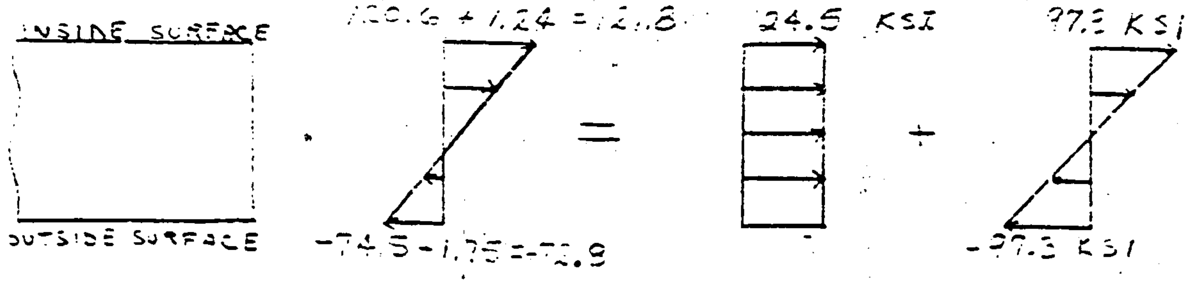
K_ε IS DETERMINED FROM FIG. F-105(a). FOLLOWING IS THE CALCULATION OF THE PARAMETERS NECESSARY TO OBTAIN K_ε.

$$\frac{S_n}{2S_m} = \frac{129.4 \text{ KSI}}{51.3 \text{ KSI}} = 2.52$$

$|Q_m| / [|Q_m| + |Q_b|]$ IS DETERMINED NEXT:

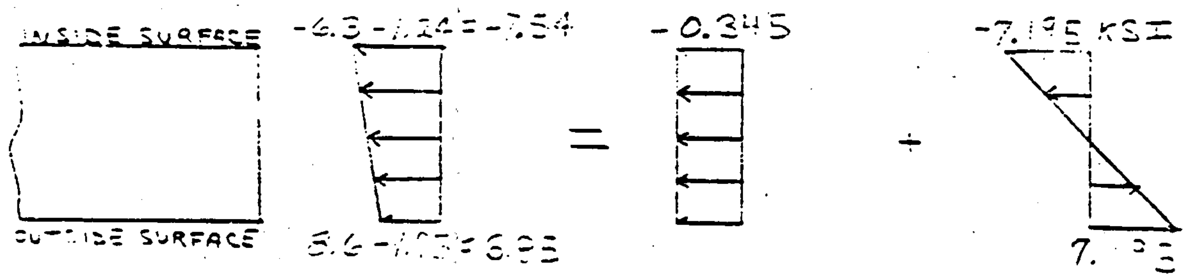
GENERAL CALCULATIONS

(CONDITION 2 = ITERATION 4 + OBE)



$Q_m \rightarrow$ 24.85 $\leftarrow$ $Q_b \rightarrow$ 104.50 $\leftarrow$

(CONDITION 15 = ITERATION 3 - OBE)



$$\frac{Q_m}{Q_m + Q_b} \quad \frac{24.85}{24.85 + 104.50} = 0.19$$

FROM FIG. F-105 (a), REF. #2,

$$K_\epsilon \approx 1.50$$

$$T_{ALT} = 12\, K_f\, K_\epsilon\, S^{(n)}_{ALT}$$

T_{ALT} = 12 [illegible] = 217.7 KSI

DURING THE HPI MANUAL ACTUATION TRANSIENT, THE

TEMPERATURE VARIES FROM 579°F TO 40°F. AT AN AVERAGE TEMPERATURE OF $\frac{579°F + 40°F}{2} = 309.5°F$,

$E = 27.05 \times 10^6$ PSI [REF. #2]

$S_a = 217.7 \left(\frac{26 \times 10^6}{27.05 \times 10^6}\right) = 209.2$ KSI

FROM FIG. F-106(b), REF. #2,

N = ALLOWABLE CYCLES = 145 CYCLES

U_4 = USAGE FACTOR = $\frac{30}{145} = 0.21$.

CASE 2 - PEAK STRESS INTENSITY RANGE WITHOUT ±OBE STRESSES

THE MAXIMUM PEAK STRESS INTENSITY RANGE IS COMPRISED OF |(ITERATION A) - (ITERATION B)| AND CAN OCCUR FOR 40 CYCLES.

$T_{PEAK\ RANGE}$ = | 177.3 - (-8.0) | = 185.3 KSI

THE PRIMARY + SECONDARY STRESS INTENSITY RANGE ASSOCIATED WITH THIS TRANSIENT IS 126.? KSI > 3Sm = 51.3 KSI. [ITERATIONS A AND B ± OBE].

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THEREFORE AN ELASTIC-PLASTIC FATIGUE ANALYSIS MUST BE PERFORMED FOR THESE 40 CYCLES.

FOLLOWING THE PROCEDURE OF REF. #2, PARAGRAPH F-105.2.7, THE FINAL PEAK ALTERNATING STRESS INTENSITY, σ_{ALT}, IS:

$$\sigma_{ALT} = 1/2\, K_f\, K_E\, S_{rig}^{(n)},$$

WHERE $K_f = K_t + A(K_t - 1.0)$

$$K_t = \frac{S_{rig}^{(p)}}{S_{rig}^{(n)}} = \frac{185.3 \text{ KSI}}{126.9 \text{ KSI}} = 1.46$$

$A = 0.7$ FOR STAINLESS STEEL A-376, TP316, FROM FIG. D-201(c), REF. #2

$\therefore\ K_f = 1.46 + 0.7(1.46 - 1.0) = 1.78$

K_E IS DETERMINED FROM FIG. F-105(a). FOLLOWING IS THE CALCULATION OF THE PARAMETERS NECESSARY TO OBTAIN K_E.

$$\frac{S_n}{3S_m} = \frac{126.9 \text{ KSI}}{51.3 \text{ KSI}} = 2.47$$

$|Q_m| / [\,|Q_m| + |Q_b|\,]$ IS DETERMINED NEXT.

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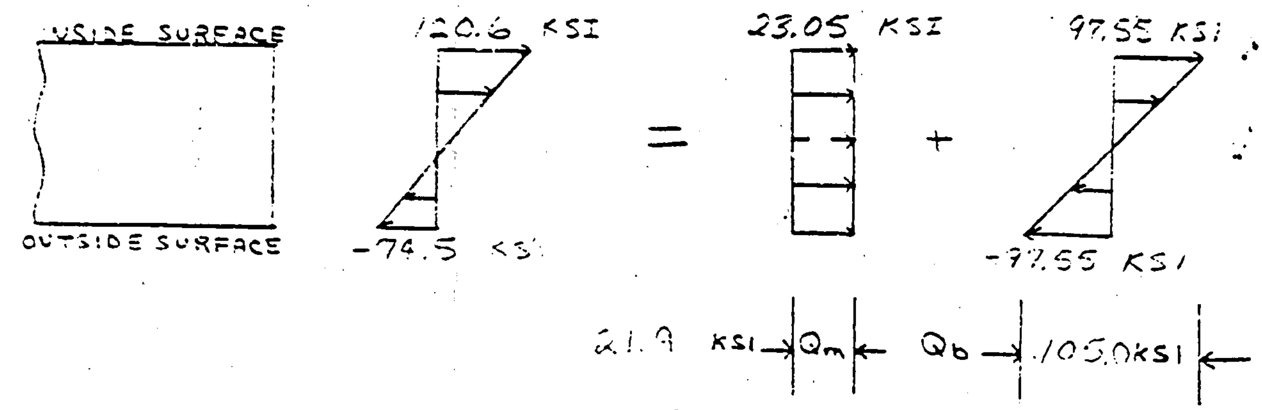
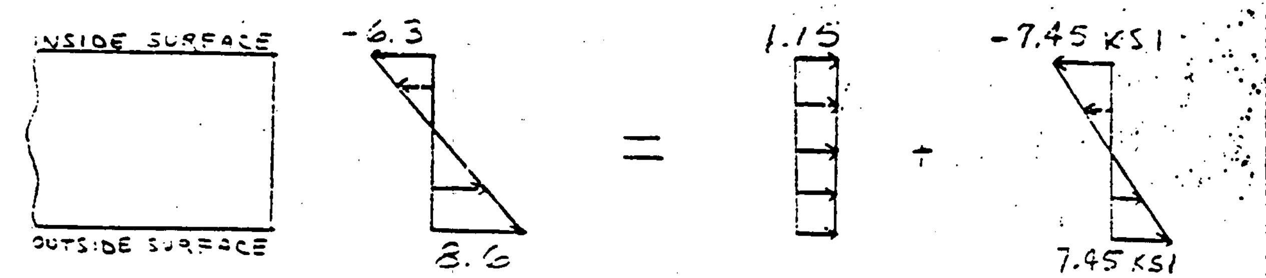
(CONDITION 2a = ITERATION A)



(CONDITION 2b = ITERATION B)



$$\frac{Q_m}{Q_m - Q_b} = \frac{21.9}{21.9 + 105.0} = 0.17$$

FROM FIG F-105(a), REF. #2,

$$K_E \approx 1.55$$

$$T_{ALT} = 1/2\, K_f\, K_E\, S^{(n)}_{r-z}$$

T_{ALT} = 1/2 ([illegible].75)(1.55)(126.9) = 208.9 KSI

DURING THE HPI MANUAL ACTUATION TRANSIENT,

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THE TEMPERATURE VARIES FROM 579 °F TO 40 °F AT AN AVERAGE TEMPERATURE OF (579 + 40)/2 = 309.5 °F.

$E = 27.05 \times 10^6$ PSI (REF. #2)

$S_{\_} = 208.9\ (26/27.05) = 200.8$ KSI

FROM FIG. F-106 (b), REF. #2

N = ALLOWABLE CYCLES = 155

$U_5 = 40/155 = 0.26$

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OBE PEAK STRESS INTENSITY RANGE

THIS RANGE IS COMPRISED OF I OBE AND CAN OCCUR FOR THE REMAINDER OF THE EARTHQUAKE CYCLES, THAT IS, 650 - 30 = 620 CYCLES.

$$\sigma^{PEAK}_{RANGE} = | 1.6 - (-1.6) | = 3.2 \text{ KSI}$$

THE PRIMARY + SECONDARY STRESS INTENSITY RANGE ASSOCIATED WITH THIS TRANSIENT IS 2.43 KSI < 3Sm = 51.3 KSI. THEREFORE, THE FINAL PEAK ALTERNATING STRESS INTENSITY RANGE, σ_{ALT}, IS:

$$\sigma_{ALT} = \frac{1}{2} \sigma^{PEAK}_{RANGE} = \frac{1}{2} (3.2) = 1.6 \text{ KSI}$$

THE REMAINDER OF THE EARTHQUAKE CYCLES OCCUR DURING STEADY-STATE CONDITIONS. THEREFORE, AT A TEMPERATURE OF 550°F,

$$E = 25.73 \times 10^6 \text{ PSI} \quad \text{[REF. \# 2]}$$

$S_a = 1.6\,(26/25.75) = 1.62$ KSI

FROM FIG. F-106 (b), REF. #2

N = ALLOWABLE CYCLES = ∞

$U_6 = 0.0$

11.0 TOTAL USAGE FACTOR

$U_T = U_1 + U_2 + U_3 + U_4 + U_5 + U_6$

$U_T = 0.22 + 0.05 + 0.0 + 0.21 + 0.26 + 0.0$

$U_T = 0.74 \leq 1.0$ ALLOWABLE USAGE FACTOR

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GENERAL CALCULATIONS

12.0 References

1. B&W General Functional Specification for Reactor Coolant System, 18-1130828-01, Duke Power Company.
2. Nuclear Power Piping Code, USAS B31.7 - Draft 1968.
3. B&W Computer Code P91167
4. B&W Computer Code P91206
5. B&W Computer Code P91032
6. B&W Doc. "Stress Report for Reactor Coolant Piping", B&W Contract No. 620-0009-50, Design Analysis Report No. 7, "Thermal-Mechanical Analysis of 2½ Sch. 160 Make-up and HPI Nozzle, Microfilm rolls 79-472 and 473.
7. Microfiche AC3IMJU, "Reactor Trip w/HPI Nozzle". (attached)
8. See Reference #1.
9. See Reference #1.
10. JAKOB + Hawkins, "Elements of Heat Transfer, 3rd Edition, Wiley and Sons, Inc. 1957.
11. B&W Computer Code P91232.
12. B&W Drawing No. 1:0156, Rev. 7, "Assembly and Detail for 2½" "Pressure Injection Nozzle".
13. B&W Doc., "Stress Report for Reactor Coolant Piping", B&W Contract No. 620-0003-50, Revision 1, Design Analysis Report No. 4, "Piping Reactions", Microfilm roll 79-479.

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REVIEWED BY R R Schaefer DATE 8/31/82

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GENERAL CALCULATIONS

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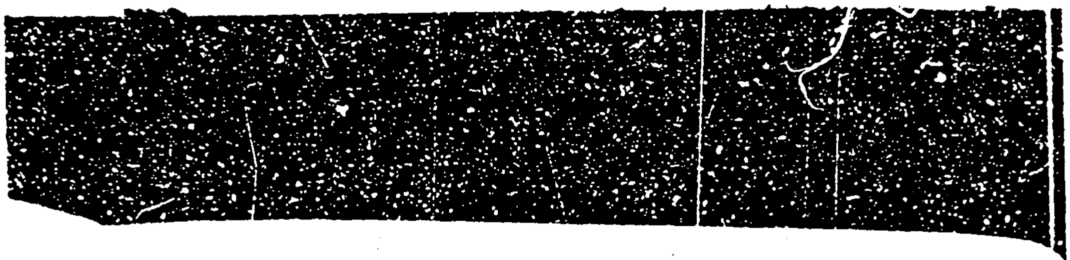

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REVIEWED BY [illegible] DATE [illegible]

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RECORD OF REVIEW

ADDENDUM TO CALCULATION PACKAGE 32 - 1128224 — 02

Serial — Revision

1. Calculation file not reviewed since it is deemed as: ☐ Obsolete ☐ Non-Safety

2. All present source references on calculation file source reference list are acceptable. ☐ Yes

3. Reference provides only assumptive, background, procedural or methods information (i.e., "FOR INFO ONLY")

REF. NO.	INFORMATION TYPE	REF. NO.	INFORMATION TYPE
2.4.5	BACKGROUND		

4. The following reference changed in this calculation file, as indicated:

REF. NO.	CORRECTED REFERENCE INFORMATION
11	ADD: VERSION 1.0

5. The following references require special disposition as indicated:

REF. NO.	METHOD OF DISPOSITION

Preparer of Record of Review (Signature) (Name) James G. Tilley — 2/15/88 Date

Reviewer of Record of Review (if item 4 or 5 applied) (Signature) (Name) James R. [illegible] — 3/2/88 Date

cc: Section Coordinator