United States Nuclear Regulatory Commission Official Hearing Exhibit

In the Matter of: Entergy Nuclear Operations, Inc.
(Indian Point Nuclear Generating Units 2 and 3)

ASLBP #: 07-858-03-LR-BD01
Docket #: 05000247 | 05000286
Exhibit #: RIV00052C-00-BD01
Identified: 10/15/2012
Admitted: 10/15/2012
Withdrawn:
Rejected:
Stricken:
Other:

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

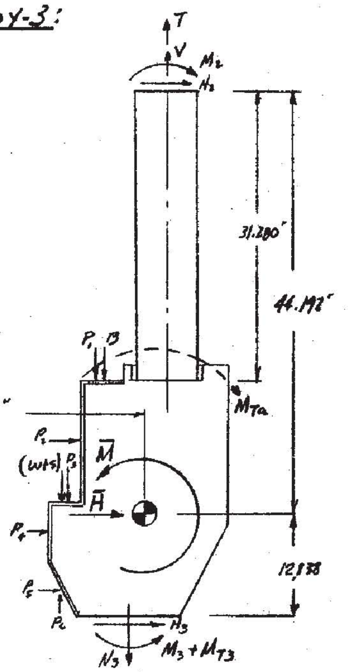
NUMBER S-151-P | A-65
SHEET 14 OF 51
CHARGE NO.
DATE 5-12-66 BY COCKRELL
DESCRIPTION FATIGUE EVALUATION OF HEAD FLANGE VESSEL FLANGE AND CLOSURE STUDS
CHECK DATE 5-12-66 BY ALEXANDER

5. DETAILED ANALYSIS:

d. DEVELOPMENT OF CONTINUITY EQUATIONS:

2. MOVEMENTS DUE TO LOADS:

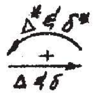
BODY-3:



$I = 20945 \text{ IN}^4$
$A = 378.957 \text{ IN}^2$
$\frac{R^2}{I} = 0.41409$
$\frac{R^2}{A} = 22.9367$

$$\bar{H} = 1.0290 H_2 + 0.9764 H_3 + 23.7340 P$$

$$\bar{M} = -45.4751 H_2 - 1.0290 M_2 - 1.0136 M_{Ta} + 12.5351 H_3 + 0.9765(M_3 + M_{T3}) + 7.1372(T+V) + 7.8499(w+s) - 79.8729 P$$



DISPLACEMENTS DUE TO REDUNDANT FORCES:

$$E\Delta_{32} = \frac{R^2}{A}\bar{H} - h_i \frac{R^2}{I}\bar{M} = 1919.0093 H_2 + 69.7697 M_2 - 207.4870 H_3 - 17.9066 M_3 - 130.8923 V$$

$$E\Delta^*_{32} = \frac{R^2}{I}\bar{M} = -69.7697 H_2 - 3.6815 M_2 + 5.2019 H_3 + 0.4052 M_3 + 2.9619 V$$

$$E\Delta_{33} = \frac{R^2}{A}\bar{H} - h_i \frac{R^2}{I}\bar{M} = -218.6730 H_2 - 5.4818 M_2 + 89.1774 H_3 + 5.2020 M_3 + 38.0249 V$$

$$E\Delta^*_{33} = \frac{R^2}{I}\bar{M} = -18.8717 H_2 - 0.4270 M_2 + 5.2019 H_3 + 0.4052 M_3 + 2.9619 V$$

$$E V_{33} = 6.936 \frac{R^2}{I}\bar{M} = -130.8941 H_2 - 2.9617 M_2 + 36.0804 H_3 + 2.8105 M_3 + 30.1982 V$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO. __________
DESCRIPTION Fatigue Evaluation Of Head Flange Vessel Flange And Closure Studs

NUMBER 5-151-P | A 66
SHEET 15 **OF** 51
DATE 5-12-66 **BY** Cockrell
CHECK DATE 5-12-66 **BY** Alexander

5- DETAILED ANALYSIS:

d- DEVELOPMENT OF CONTINUITY EQUATIONS:

2- MOVEMENTS DUE TO FORCES:

DISPLACEMENTS DUE TO APPLIED FORCES:

$$E\delta_{32} = \frac{R^2}{A}\bar{H} - h_j\frac{R^2}{I}\bar{M} = \underline{-130.8923T - 143.9612(W+S) + 2009.1897P}$$

$$E\delta^*_{32} = \frac{R^2}{I}\bar{M} = \underline{2.9619T + 3.2576(W+S) - 33.1465P}$$

$$E\delta_{33} = \frac{R^2}{A}\bar{H} - h_j\frac{R^2}{I}\bar{M} = \underline{38.0249T + 41.8215(W+S) + 118.8449P}$$

$$E\delta^*_{33} = \frac{R^2}{I}\bar{M} = \underline{2.9619T + 3.2576(W+S) - 33.1465P}$$

$$E v_{32} = 6.936\frac{R^2}{I}\bar{M} = \underline{-229.9041P}$$

DISPLACEMENTS DUE TO THERMPL EFFECTS:

$$E\delta_{32T} = R_3 E\alpha(T_m - 70) - R_3 h_1 E\alpha\left(\frac{\Delta T}{\Delta X}\right)_{eq} - h_j\frac{R^2}{I}\bar{M} =$$

$$= \underline{93.231E\alpha(T_m - 70) - 4120.064E\alpha\left(\frac{\Delta T}{\Delta X}\right)_{eq} - 17.9066M_{T3} + 18.5485M_{Ta}}$$

$$E\delta^*_{32} = R_3 E\alpha\left(\frac{\Delta T}{\Delta X}\right)_{eq} + \frac{R^2}{I}\bar{M} = \underline{93.231E\alpha\left(\frac{\Delta T}{\Delta X}\right)_{eq} + 04052M_{T3} - 0.41972M_{Ta}}$$

$$E\delta_{33T} = R_4 E\alpha(T_{beq} - 70) + h_j\frac{R^2}{I}\bar{M} = \underline{91.031E\alpha(T_{beq} - 70) + 5.2020M_{T3} - 5.3884M_{Ta}}$$

$$E\delta^*_{33T} = R_3 E\alpha\left(\frac{\Delta T}{\Delta X}\right)_{eq} + \frac{R^2}{I}\bar{M} = \underline{93.231E\alpha\left(\frac{\Delta T}{\Delta X}\right)_{eq} + 0.4052M_{T3} - 0.41972M_{Ta}}$$

$$E v_{32T} = \ell_B E\alpha(T_B - 70)\frac{E\alpha_B}{E\alpha_{193}} + 6.936\frac{R^2}{I}\bar{M} =$$

$$= \underline{30.5221E\alpha(T_B - 70) + 646.6502E\alpha\left(\frac{\Delta T}{\Delta X}\right)_{eq} + 2.8105M_{T3} - 2.9112M_{Ta}}$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER S-151-D A67
SHEET 16 OF 51
CHARGE NO.
DATE 5-12-66 BY COCKRELL
DESCRIPTION FATIGUE EVALUATION OF HEAD FLANGE VESSEL FLANGE AND CLOSURE STUDS
CHECK DATE 5-12-66 BY ALEXANDER

5. DETAILED ANALYSIS:

d. DEVELOPMENT OF CONTINUITY EQUATIONS:

2. MOVEMENTS DUE TO FORCES:

$T_{a_{eq}}$, $T_{b_{eq}}$, AND $\left(\frac{\Delta T}{\Delta X}\right)_{eq}$ FOR THE VESSEL FLANGE ARE OBTAINED BY THE METHOD AS ILLUSTRATED ON SHEETS-11 & 12 AND ARE LISTED BELOW.

TRANSIENT		T_M	$(E\alpha)_i$	M_T	$\left(\frac{\Delta T}{\Delta X}\right)_{eq}$	T_a	T_b	T_B (BOLT)
HEATUP	4.00 HRS	296	196	-2682806	6.539	211.0	381.0	172
	4.25	315	198	-2838430	6.848	226.0	404.0	183
	4.35	323	198	-2896055	6.987	232.2	413.8	187
	4.47	334	199	-2986356	7.169	240.8	427.2	194
	5.00	368	202	-3007646	7.113	275.5	460.5	220
STEADY STATE		533	212	-471993	1.064	519.2	546.8	532
COOLDOWN	4.00 HRS	336	199	2325354	-5.582	408.6	263.4	459
	4.25	317	198	2424287	-5.849	393.0	241.0	449
	4.35	309	197	2469749	-5.989	386.9	231.1	444
	4.47	299	196	2523836	-6.151	379.0	219.0	437
	5.00	263	193	2448075	-6.059	341.8	184.2	411

SUBSTITUTING VALUES INTO EQUATIONS AS GIVEN ON SHEET-15, WE GET THE FOLLOWING VALUES FOR DISPLACEMENTS AND ROTATIONS OF BODY-3 AT CUTS-2 & 3.

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

NUMBER 5-151-P | A 68
SHEET 17 OF 51
DATE 5-12-66 BY COCKRELL
CHECK DATE 5-12-66 BY ALEXANDER

DESCRIPTION FATIGUE EVALUATION OF HEAD FLANGE, VESSEL FLANGE AND CLOSURE STUDS

5- DETAILED ANALYSIS:

d- DEVELOPMENT OF CONTINUITY MATRIX:

2- MOVEMENTS DUE TO LOADS:

TRANSIENT		(T_m-70)	$(E\alpha)_m$	(T_b-70)	$(E\alpha)_m$	(T_B-70)	$(E\alpha)_m$	$\left(\frac{\Delta T}{\Delta X}\right)_{eq}$	M_{T3}	M_{Ta}	$E\delta_{32T}$	$E\delta^*_{32T}$	$E\delta_{33T}$	$E\delta^*_{33T}$	$E\nu_{32T}$
HEATUP	4.00 HRS	226	183	311	184	102	180	6.539	453071	1023212	9702229	-132289	2078537	-132289	-338472
	4.25	215	184	334	185	113	180	6.848	461449	1069229	10581097	-144324	2263799	-144324	-356069
	4.35	253	184	343.8	185	117	180	6.987	462890	1101081	11177955	-154725	2264701	-154725	-405380
	4.47	264	184	357.2	186	124	180	7.169	464736	1134218	11810278	-164762	2353930	-164762	-435043
	5.00	298	184	390.5	186	150	181	7.113	361170	1176806	15080433	-225563	2149524	-225563	-703782
STEADYSTATE		463	186	476.8	186	462	186	1.064	17291	361003	13599949	-126063	6217775	-126063	1833059
COOLDOWN	4.00 HRS	266	184	193.4	182	389	186	-5.582	-402539	-726730	2523090	46158	5026108	46158	2599787
	4.25	247	184	171	182	379	186	-5.849	-406478	-774763	1579158	60142	4893324	60142	2638176
	4.35	239	183	161.1	181	374	186	-5.989	-408144	-796483	1128053	66740	4823010	66740	2654639
	4.47	229	183	149	181	367	185	-6.151	-410452	-821931	648890	73722	4748762	73722	2662044
	5.00	193	182	114.2	180	341	185	-6.059	-304752	-842210	-2346516	127197	4824103	127197	2880580

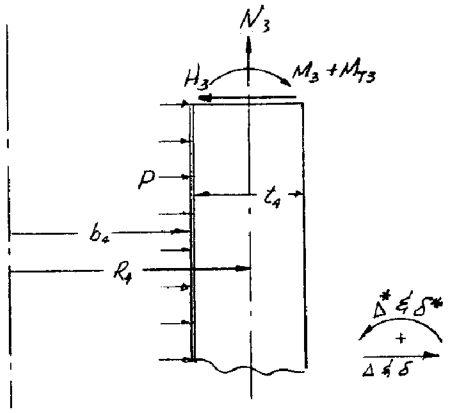
NUMBER 5-151-P | A 69
SHEET 18 OF 51
DATE 5-12-66 BY COCKRELL
CHARGE NO.
CHECK DATE 5-12-66 BY ALEXANDER
DESCRIPTION FATIGUE EVALUATION OF HEAD FLANGE, VESSEL FLANGE AND CLOSURE STUDS

5. DETAILED ANALYSIS:

d. DEVELOPMENT OF CONTINUITY EQUATIONS:

2. MOVEMENTS DUE TO FORCES:

BODY-4:



$R_4 = 91.031''$

$b_4 = 85.437''$

$t_4 = 10.75''$

$$\beta^4 = \frac{3(1-\nu^2)}{R^2t^2}$$

$\beta = 0.04108$

$$D = \frac{Et^3}{12(1-\nu^2)} = 113.76345E$$

DISPLACEMENTS DUE TO REDUNDANT FORCES:

$$E\Delta_{43} = \frac{E}{2\beta^2 D}\left[-\frac{1}{\beta}H_3 + M_3\right] = \underline{-63.2918H_3 + 2.6006M_3}$$

$$E\Delta^*_{43} = -\frac{E}{2\beta^2 D}\left[-H_3 + 2\beta M_3\right] = \underline{2.6006H_3 - 0.2137M_3}$$

DISPLACEMENTS DUE TO APPLIED LOADS:

$$E\delta_{43} = \frac{b_4^2}{t_4}\left(\frac{R_4}{b_4} - \frac{\nu}{2}\right)P = 621.6238P$$

$$E\delta^*_{43} = 0$$

DISPLACEMENTS DUE TO THERMAL EFFECTS:

$$E\delta_{43T} = R_4 E\alpha(T_{43} - 70) + \frac{E}{2\beta^2 D}M_{T3} = \underline{91.031E\alpha(T_{43} - 70) + 2.6006M_{T3}}$$

$$E\delta^*_{43T} = R_4 E\alpha\left(\frac{\Delta T}{\Delta X}\right)_{43} - \frac{E}{\beta D}M_{T3} = \underline{91.031E\alpha\left(\frac{\Delta T}{\Delta X}\right)_{43} - 0.2137M_{T3}}$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION FATIGUE EVALUATION OF HEAD FLANGE, VESSEL FLANGE AND CLOSURE STUDS

NUMBER S-151-P | A 70
SHEET 19 OF 51
DATE 5-12-66 BY COCKRELL
CHECK DATE 5-12-66 BY ALEXANDER

5. DETAILED ANALYSIS:

d. DEVELOPMENT OF CONTINUITY EQUATIONS:

2. MOVEMENTS DUE TO FORCES:

SUBSTITUTING VALUES INTO DISPLACEMENTS AS GIVEN ON SHEET-18, WE GET THE FOLLOWING VALUES FOR DISPLACEMENTS AND ROTATIONS OF BODY-4 AT CUT-3.

TRANSIENT		T_{43}	$(E\alpha)_m$	$\left(\frac{\Delta T}{\Delta X}\right)_{43}$	M_{T3}	$E\delta_{43T}$	$E\delta^*_{43T}$
HEATUP	4.00 HRS	391	185	2.800	458071	6597135	-50736
	4.25	413	185	2.800	461449	6976416	-51458
	4.35	423	186	2.800	462890	7180705	-51511
	4.47	435	186	3.200	464736	7388687	-45132
	5.00	466	186	3.00	361170	7644238	-26387
STEADY STATE		544	186	0.200	17291	8070624	-309
COOLDOWN	4.00 HRS	253	182	-2.600	-402539	1985035	42947
	4.25	230	181	-2.600	-406478	1579171	43788
	4.35	221	181	-2.700	-408144	1426549	42733
	4.47	209	180	-2.500	-410452	1210175	46750
	5.00	177	180	-2.900	-304752	960719	25801

3. CONTINUITY MATRIX AND LOADING VECTORS:

THE MATRIX FOR THE SOLUTION FOR THE THERMAL LOADINGS WILL BE ARRANGED AS SHOWN BELOW

$$E\Delta_{11} - E\Delta_{21} = E\delta_{21T} - E\delta_{11T}$$
$$E\Delta^*_{11} - E\Delta^*_{21} = E\delta^*_{21T} - E\delta^*_{11T}$$
$$E\Delta_{22} - E\Delta_{32} = E\delta_{32T} - E\delta_{22T}$$
$$E\Delta^*_{22} - E\Delta^*_{32} = E\delta^*_{32T} - E\delta^*_{22T}$$
$$E\Delta_{33} - E\Delta_{43} = E\delta_{43T} - E\delta_{33T}$$
$$E\Delta^*_{33} - E\Delta^*_{43} = E\delta^*_{43T} - E\delta^*_{33T}$$
$$EV_{22} - EV_{32} = Ev_{32T} - Ev_{22T}$$

THE SOLUTION FOR THE APPLIED LOADS WERE DETERMINED IN THE MECHANICAL ANALYSIS (S-150-P).

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION Fatigue Evaluation Of Head Flange, Vessel Flange And Closure Studs

NUMBER 5-151-P | A71
SHEET 20 **OF** 51
DATE 5-12-66 **BY** Cockrell
CHECK DATE 5-12-66 **BY** Alexander

5- Detailed Analysis

d- Development Of Continuity Equations:

3. Continuity Matrix And Loading Vectors:

Substituting The Deflections And Rotations In The Compatibility Equations As Given On Sheet -19 And Writing In Matrix Form Yields The Following Matrix And Loading Vectors:

$$\begin{bmatrix} 162.1377 & 2.2709 & 82.6039 & 3.9830 & 0 & 0 & -27.6228 \\ 2.2709 & 0.9094 & -5.0262 & -0.3190 & 0 & 0 & 2.2123 \\ -72.3659 & 4.4028 & -2018.0589 & -74.7959 & 207.4870 & 17.9066 & 165.7537 \\ 3.4890 & -0.2794 & 74.7959 & 4.0005 & -5.2019 & -0.4052 & -5.1742 \\ 0 & 0 & -218.6730 & -5.4818 & 152.4692 & 2.6013 & 38.0249 \\ 0 & 0 & -18.8717 & -0.4270 & 2.6013 & 0.6189 & 2.9619 \\ 24.1997 & -1.9379 & 165.7558 & 5.1743 & -36.0804 & -2.8105 & -48.1249 \end{bmatrix} \begin{bmatrix} H_1 \\ M_1 \\ H_2 \\ M_2 \\ H_3 \\ M_3 \\ V \end{bmatrix} =$$

Heat up					Steady State
T=4.00 HRS	T=4.25	T=4.35	T=4.37	T=5.00	
-2212,270	-2296,590	-2331,160	-2367,380	-2105,180	-12,000
-236,050	-234,790	-234,080	-233,770	-165,500	-4,810
3833,219	4366,047	4835,205	5267,348	8313,263	5097,179
-44,929	-56,284	-66,435	-76,072	-158,163	-121,723
4518,598	4712,617	4916,004	5034,757	5494,714	1852,849
31,550	92,860	103,220	119,630	199,170	125,750
-1182,842	-1304,099	-1391,680	-1481,383	-2079,022	-866,841

Cool down				
T=4.00 HRS	T=4.25	T=4.35	T=4.47	T=5.00
2096,790	2137,860	2167,270	2181,990	1958,810
195,740	197,030	196,920	196,960	134,550
-709,320	-1292,952	-1599,907	-1849,120	-4630,996
-26,902	-13,648	-7,340	-808	72,437
-3041,073	-3314,153	-3396,461	-3538,587	-3863,384
-3,210	-16,350	-24,010	-26,970	-101,400
671,377	820,286	880,239	953,544	1478,570

5- DETAILED ANALYSIS:

d- DEVELOPMENT OF CONTINUITY EQUATIONS:

4. REDUNDANT LOAD VALUES:

SOLVING THE MATRIX ON SHEET - 20 WITH THE GIVEN LOADING VECTORS FOR THE HEATUP, STEADYSTATE AND COOLDOWN CONDITIONS, WE GET THE FOLLOWING REDUNDANT FORCES. THE VALUES OF THE REDUNDANT FORCES FOR BOLT-UP, CORE SUPPORT WEIGHT, CORE HOLDDOWN SPRING FORCE AND INTERNAL PRESSURE ARE TAKEN FROM CALCULATION NO. 5-150-P. THE VALUES OF THE REDUNDANT FORCES FOR INTERNAL PRESSURE ARE LEFT IN TERMS OF PRESSURE SINCE THE ACTUAL PRESSURE DURING THE TRANSIENT WILL BE USED.

TRANSIENT		H_1	M_1	H_2	M_2	H_3	M_3	V
BOLT-UP ONLY		23.2120	-329.4526	3.3876	-19.1672	-18.2221	-391.0394	—
CORE SUPPORT WEIGHT		-0.0112	0.0771	0.0550	-0.7267	-0.2172	-4.5965	—
CORE HOLDOWN SPRING		0.2130	-3.0406	0.0426	-0.3261	-0.2134	-4.5652	—
INTERNAL PRESSURE		-0.04139P	-8.38228P	-1.09028P	19.09019P	1.22229P	9.64912P	3.90667P
HEATUP	4.00 HRS	-7.6782	-275.2274	2.6804	-13.3455	28.4550	-3.7709	18.4845
	4.25	-7.9770	-275.9300	2.5753	-10.9385	29.2191	3.6531	19.8155
	4.35	-8.1679	-275.0594	2.5149	-8.9711	30.2851	13.9666	20.0634
	4.47	-8.4331	-273.9405	2.6621	-10.3082	30.7298	41.7267	20.1573
	5.00	-6.8833	-213.1766	2.2308	-4.5564	30.5946	141.8189	24.2974
STEADY STATE		0.8837	-17.3723	-0.1853	-1.7866	8.5167	144.3207	3.8965
COOLDOWN	4.00 HRS	8.0529	224.1142	-2.3640	7.7285	-20.5951	92.0124	-16.1701
	4.25	7.7977	231.9945	-2.4440	7.8418	-21.7476	85.5139	-18.7298
	4.35	7.87722	232.8309	-2.3687	6.2381	-21.9726	77.8335	-19.2652
	4.47	7.5940	237.8749	-2.3461	5.6215	-22.5571	84.3951	-21.0675
	5.00	6.4418	179.6201	-1.8011	-2.0546	-21.7719	-13.7274	-24.0173

UNITS ON FORCES:

FOR H's KIPS PER INCH OF CIRCUMFERENCE
M's IN-KIP PER INCH OF CIRCUMFERENCE
V's KIPS PER INCH OF CIRCUMFERENCE
} APPLIED AT THEIR RESPECTIVE RADII.

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT. CHATTANOOGA. TENN.

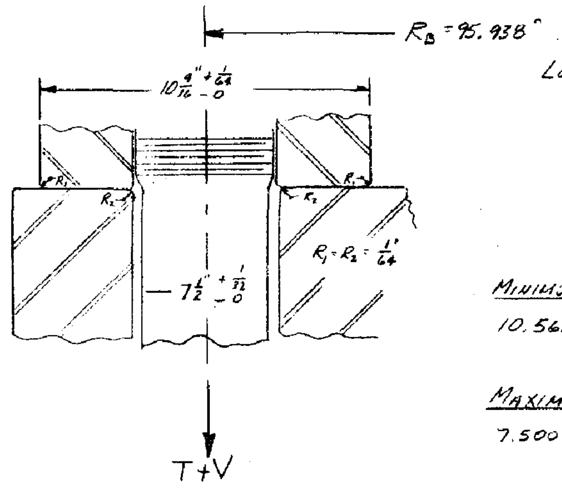
CHARGE NO.

NUMBER 5-151-P | A 73
SHEET 22 OF 51
DATE 5-12-66 BY COCKRELL
CHECK DATE 5-12-66 BY ALEXANDER

DESCRIPTION FATIGUE EVALUATION OF HEAD FLANGE VESSEL FLANGE AND CLOSURE STUDS

5. DETAILED ANALYSIS:
e. STRESSES:
1. UNCONCENTRATED:

CONSIDER THE BEARING STRESS BETWEEN THE STUD WASHER AND CLOSURE HEAD. AT THE END OF THE HEATUP TRANSIENT, THE AXIAL LOAD ON THE CLOSURE STUD WILL BE THE GREATEST; HENCE, THE BEARING STRESS BETWEEN THE STUD WASHER AND CLOSURE HEAD WILL BE THE GREATEST. NOTE THAT THE CHANGE IN BOLT LOAD, OVER THE INITIAL COLD BOLT-UP LOAD, IS APPROXIMATELY 28 % TOTAL FOR BOTH PRESSURE AND THERMAL EFFECTS.



LOAD PER STUD $= \frac{2\pi R_B(T+V)}{54}$

SEE SHEET 23 FOR VALUES OF T+V

$$= \left[\frac{116.532 + 3.90667P + 24.297}{54}\right] 2\pi R_B$$

$$= 1670.2 \text{ KIPS.}$$

MINIMUM O.D. OF WASHER:

$10.5625 - 0.0313 = 10.5312"$

MAXIMUM DIA. OF STUD HOLE:

$7.500 + 0.0625 = 7.5625"$

BEARING AREA PER STUD $= \frac{\pi}{4}\left[\overline{10.5312}^2 - \overline{7.5625}^2\right] = 42.19 \text{ in}^2$

$$\sigma_B = \frac{T+V}{A_B} = \frac{1670.2}{42.19} = \underline{\underline{39.6 \text{ ksi}}}$$

ALLOWABLES	FLANGE:	$1.5S_m = 40$ ksi
SEE CRITERION	WASHER:	$1.5S_m = 59.2$ ksi
5-C-1	BOTH AT	550°F (ACTUAL TEMP.)

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.

NUMBER S-151-P | A 74
SHEET 23 **OF** 51
DATE 5-12-66 **BY** COCKRELL
CHECK DATE 5-12-66 **BY** ALEXANDER

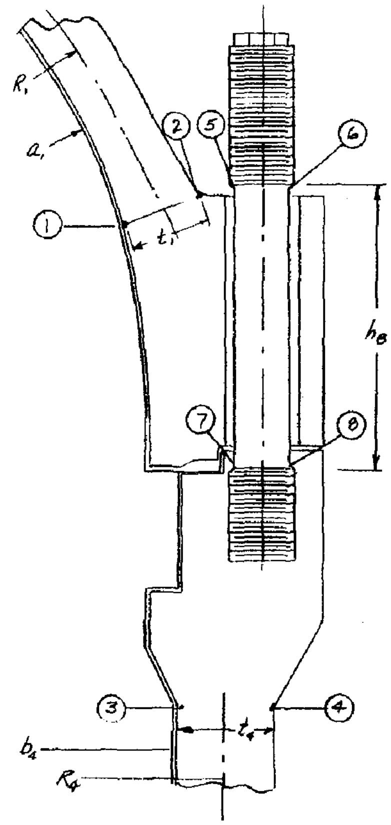
DESCRIPTION FATIGUE EVALUATION OF HEAD FLANGE, VESSEL FLANGE AND CLOSURE HEAD

5- DETAILED ANALYSIS:

e- STRESSES:

1- UNCONCENTRATED:

STRESSES WILL BE CALCULATED AT THE LOCATIONS AS SHOWN BELOW.



POINTS 1 & 2:

$$\sigma_x = \pm\frac{6}{t_1^2}(M_1+M_{T1}) + \frac{H_1\cos\theta}{t_1} + \frac{a_1^2P}{2R_1t_1} + \frac{E\alpha}{(1-\nu)}(T_{m1}-70)$$
$$= \underline{\pm 0.06783(M_1+M_{T1}) + 0.03654H_1 + 4.3709P}$$
$$\underline{+1.42857E\alpha(T_{m1}-70)}$$

$$\sigma_\theta = \pm\frac{\nu 6}{t_1^2}(M_1+M_{T1}) + \frac{\nu H_1\cos\theta}{t_1} + \frac{E\Delta_{11}+E\delta_{11T}}{R_1\sin\theta} \pm \frac{t_1\cos\theta(E\Delta_{11}^*+E\delta_{11T}^*)}{2R_1\sin\theta}$$
$$+\frac{a_1^2P}{2R_1t_1} + \frac{E\alpha(T_{m1}-70)}{(1-\nu)} - E\alpha(T_{m1}-70) = \underline{\pm 0.02035(M_1+M_{T1})}$$
$$\underline{+0.01096H_1 + 0.01189(E\Delta_{11}+E\delta_{11T}) \pm 0.01922(E\Delta_{11}^*+E\delta_{11T}^*)}$$
$$\underline{+4.3709P + 1.42857E\alpha(T_{m1}-70) - E\alpha(T_m-70)}$$

POINTS 3 & 4:

$$\sigma_x = \pm\frac{6}{t_4^2}(M_3+M_{T3}) + \frac{b_4^2P}{2R_4t_4} + \frac{E\alpha}{(1-\nu)}(T_{m4}-70)$$
$$= \underline{\pm 0.05191(M_3+M_{T3}) + 3.7296P + 1.42857E\alpha(T_{m4}-70)}$$

$$\sigma_\theta = \pm\frac{\nu 6}{t_4^2}(M_3+M_{T3}) + \frac{EM_{T3}}{2R_4\beta_4^2D_4} + \frac{E\Delta_{43}}{R_4} + \frac{b_4P}{t_4}$$
$$+\frac{E\alpha}{(1-\nu)}(T_{m4}-70) = \underline{\pm 0.01557(M_3+M_{T3}) + 0.02860M_{T3}}$$
$$\underline{+0.01098E\Delta_{43} + 7.94762P + 1.42857E\alpha(T_{m4}-70)}$$

POINTS 5 & 6:

$$\sigma_x = \frac{\bar{T}+\bar{V}}{A} \pm \frac{\bar{M}c}{I} = \underline{0.31631(T+V) \pm 0.36236M_2}$$

POINTS 7 & 8:

$$\sigma_x = \frac{\bar{T}+\bar{V}}{A} \pm \frac{(\bar{M}+\bar{H}\ell_B)c}{I} = \underline{0.31631(T+V) \pm 0.36236M_2 \pm 11.33489H_2}$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER 5-151-P | A 75
SHEET 24 OF 51
CHARGE NO.
DATE 5-12-66 BY Cockrell
DESCRIPTION Fatigue Evaluation Of Head Flange, Vessel Flange And Closure Studs
CHECK DATE 5-12-66 BY Alexander

5- Detailed Analysis:

e- Stresses:

1- Unconcentrated:

The Following Tables Give The Mechanical And Thermal Stresses, The Total Stress, And Stress Intensities At The Locations As Shown On Sheet-23. Stresses For The Mechanical Loads And For The Heatup And Cooldown Cycles Were Calculated By Using The Stress Expressions As Given On Sheet-23 And The Values Of The Redundant Forces Listed On Sheet-21. Thermal Stresses For All Other Transient Conditions Were Conservatively Calculated By Treating The Change In Reactor Coolant Temperature As A Skin Effect On The Inside Surface Of The Vessel. This Method Was Used Since The Mean Temperature Of The Vessel Wall Will Not Deviate Appreciably From The Mean Temperature Existing At Steady State And Because The Transients Are Of Short Duration. The Stress At The Inside Surface Will Be Calculated Assuming That The Surface Will Be At A Temperature Equal To The Reactor Coolant Temperature And Is Calculated From The Expression:

$$\sigma_x = \sigma_\theta = \frac{E\alpha}{1-\nu}(T_m - T)$$

Where,

T = Reactor Coolant Temperature

T_m = Mean Temp. Of Vessel At The Location Of Interest

$E\alpha$ = Young's Modulus Times Coefficient Of Thermal Expansion

ν = Poisson's Ratio

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.________

DESCRIPTION Fatigue Evaluation of Head Flange Vessel Flange And Closure Studs

NUMBER 5-151-P | A 76
SHEET 25 OF 51
DATE 5-12-66 BY Cockrell
CHECK DATE 5-12-66 BY Alexander

5- Detailed Analysis:

e- Stresses:

1- Unconcentrated:

Location 1

Transient		Internal Pressure ksia	(T_m-T) °F	Thermal Stress		Pressure Stress			Total Stress			Stress Intensity		
				σ_x	σ_θ	σ_x	σ_θ	σ_r	σ_x	σ_θ	σ_r	$\sigma_x-\sigma_\theta$	$\sigma_x-\sigma_r$	$\sigma_\theta-\sigma_r$
Cold Bolt Up		0	0	0	0	-21.50	-2.51	0	-21.50	-2.51	0	-18.99	-21.50	-2.51
Bolt Up + 2500 psia		2.5	0	0	0	-11.99	6.17	-2.50	-11.99	6.17	-2.50	-18.16	-9.49	8.67
a Heatup	4.00 hrs.	1.882		-17.50	-26.63	-14.35	4.02	-1.88	-31.85	-22.61	-1.88	-9.24	-29.97	-20.73
	4.25	2.078		-18.38	-27.98	-13.60	4.70	-2.08	-31.98	-23.28	-2.08	-8.70	-29.90	-21.20
	4.35	2.156		-18.37	-28.19	-13.31	4.97	-2.16	-31.68	-23.22	-2.16	-8.76	-29.52	-21.06
	4.47	2.250		-18.61	-28.73	-12.95	5.30	-2.25	-31.56	-23.43	-2.25	-8.13	-29.31	-21.18
	5.00	2.250		-13.80	-22.43	-12.95	5.30	-2.25	-26.75	-17.13	-2.25	-9.62	-24.50	-14.88
Steady State		2.250		-1.23	-0.59	-12.95	5.30	-2.25	-14.18	4.71	-2.25	-18.89	-11.93	6.96
b Cooldown	4.00 hrs.	0.315		14.96	24.85	-20.30	-1.42	-0.32	-5.34	23.43	-0.32	-28.77	-5.02	23.75
	4.25	↓		16.29	25.49	↓	↓	↓	-4.01	24.07	-0.32	-28.08	-3.69	24.39
	4.35			16.43	25.74				-3.87	24.32	-0.32	-28.19	-3.55	24.64
	4.47			16.80	25.89				-3.50	24.47	-0.32	-27.97	-3.18	24.79
	5.00			11.69	19.66				-8.61	18.24	-0.32	-26.85	-8.29	18.56
c	20 min	2.250	-7.8	-3.63	-2.99	-12.95	5.30	-2.25	-16.58	2.31	-2.25	-18.89	-14.33	4.56
d	20 min	2.250	7.8	1.17	1.81	-12.95	5.30	-2.25	-11.78	7.11	-2.25	-18.89	-9.53	9.36
e	100 sec.	2.110	11.2	2.21	2.35	-13.37	4.92	-2.14	-11.16	7.77	-2.14	-18.93	-9.02	9.91
	225 sec.	2.275	1.7	-0.71	-0.07	-12.85	5.38	-2.28	-13.56	5.31	-2.28	-18.87	-11.28	7.59

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.
DESCRIPTION Fatigue Evaluation Of Head Flange
Vessel Flange And Closure Studs

NUMBER 5-151-P | A 77
SHEET 26 OF 51
DATE 5-12-66 BY [illegible]
CHECK DATE 5-12-66 BY Alexander

5. Detailed Analysis:
C. Stresses:
1. Unconcentrated:

LOCATION - 1

Transient		Internal Pressure KSIA	(T_m-T) °F	Thermal Stress		Pressure Stress			Total Stress			Stress Intensity		
				σ_x	σ_θ	σ_x	σ_θ	σ_r	σ_x	σ_θ	σ_r	$\sigma_x-\sigma_\theta$	$\sigma_x-\sigma_r$	$\sigma_\theta-\sigma_r$
f	40sec	2.320	-9.3	-4.09	-3.45	-12.68	5.54	-2.32	-16.77	2.09	-2.32	-18.86	-14.45	4.41
	100sec	2.260	-13.3	-5.31	-4.67	-12.91	5.33	-2.26	-18.22	0.66	-2.26	-18.88	-15.96	2.92
	260sec	2.140	-1.3	-1.63	-0.99	-13.37	4.92	-2.14	-15.00	3.93	-2.14	-18.93	-12.86	6.07
g	2 min	2.370	-12.0	-4.92	-4.28	-12.49	5.71	-2.37	-17.41	1.43	-2.37	-18.84	-15.04	3.80
	3.2 min	2.350	-15.0	-5.84	-5.20	-12.57	5.64	-2.35	-18.41	0.44	-2.35	-18.85	-16.06	2.79
	10.4 min	2.150	0	-1.23	-0.59	-13.33	4.95	-2.15	-14.56	4.36	-2.15	-18.92	-12.41	6.51
h	10 sec	2.220	-9.5	-4.15	-3.51	-13.06	5.19	-2.22	-17.21	1.68	-2.22	-18.89	-14.99	3.90
	65sec	1.910	8.5	1.38	2.02	-14.24	4.12	-1.91	-12.86	6.14	-1.91	-19.00	-10.95	8.05
i	220 min	3.125	0	0	0	-9.62	8.33	-3.13	-9.62	8.33	-3.13	-17.95	-6.49	11.46
j	HEATUP 3.5 hrs	1.250		-18.61	-28.73	-16.75	1.83	-1.25	-35.36	-26.90	-1.25	-8.46	-34.11	-25.65
	S.S.	2.500		-1.23	-0.59	-11.99	6.17	-2.50	-13.22	5.58	-2.50	-18.80	-10.72	8.08
	COOLDOWN 3.5 hrs	0.315		16.80	25.89	-20.30	-1.42	-0.32	-3.50	24.47	-0.32	-27.97	-3.18	24.79
k	~	2.350	6.0	0.61	1.25	-12.57	5.64	-2.35	-11.96	6.89	-2.35	-18.85	-9.16	9.24
	~	2.150	-6.0	-3.07	-2.43	-13.33	4.95	-2.15	-16.40	2.52	-2.15	-18.92	-14.25	4.64
l	12sec	2.250	33.3	9.00	9.64	-12.95	5.30	-2.25	-3.95	14.94	-2.25	-18.89	-1.70	17.19
m	10 sec	2.760	-30.2	-10.51	-9.87	-11.01	7.07	-2.76	-2152	-2.80	-2.76	-18.72	-18.76	-0.04
	28 sec	2.120	-41.2	-13.88	-13.24	-13.44	4.85	-2.12	-27.32	-8.39	-2.12	-18.93	-25.20	-6.27
	160sec	1.440	4.8	0.24	0.88	-16.03	2.49	-1.44	-15.79	3.37	-1.44	-19.16	-14.35	4.81
n	33sec	0.300	117	34.71	35.35	-20.36	-1.47	-0.30	14.35	33.88	-0.30	-19.53	14.65	34.18
	54 sec	0.700	197	59.28	59.92	-18.84	-0.08	-0.70	40.44	59.84	-0.70	-19.40	41.14	60.54

$S.I._{\substack{MAX \\ RANGE}} = (\sigma_\theta - \sigma_r) = 50.40 ksi < 3S_m = 80.1 ksi$ Criterion 5-C-2

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION Fatigue Evaluation Of Head Flange Vessel Flange And Closure Studs

NUMBER 5-151-P 1A78
SHEET 27 OF 51
DATE 5-12-66 BY Cockrell
CHECK DATE 5-12-66 BY Alexander

5. Detailed Analysis:

e. Stresses:

1. Unconcentrated:

Location 2

Transient		Internal Pressure ksia	(T_m-T) °F	Thermal Stress		Pressure Stress			Total Stress			Stress Intensity		
				σ_x	σ_θ	σ_x	σ_θ	σ_r	σ_x	σ_θ	σ_r	$\sigma_x-\sigma_\theta$	$\sigma_x-\sigma_r$	$\sigma_\theta-\sigma_r$
Cold Bolt Up		0	0	0	0	23.20	13.74	0	23.20	13.74	0	9.46	23.20	13.74
Bolt Up + 2500 psia		2.5	0	0	0	35.54	23.80		35.54	23.80		11.74	35.54	23.80
a Heatup	4.00 hrs.	1.882		12.25	8.53	32.49	21.31		44.74	29.84		14.90	44.74	29.84
	4.25	2.078		13.09	9.06	33.46	22.10		46.55	31.16		15.39	46.55	31.16
	4.35	2.156		13.04	9.00	33.85	22.41		46.89	31.41		15.48	46.89	31.41
	4.47	2.250		13.54	7.20	34.31	22.79		47.85	29.99		17.86	47.85	29.99
	5.00	2.250		10.91	6.72	34.31	22.79		45.22	29.51		15.71	45.22	29.51
Steady State		2.250		0.99	0.29	34.31	22.79		35.30	23.08		12.22	35.30	23.08
b Cooldown	4.00 hrs.	0.315		-9.74	-6.60	24.76	15.01		15.02	8.41		6.61	15.02	8.41
	4.25	↓		-10.83	-7.35	↓	↓		13.93	7.66		6.27	13.93	7.66
	4.35			-10.45	-6.89				14.31	8.12		6.19	14.31	8.12
	4.47			-10.87	-7.23				13.89	7.78		6.11	13.89	7.78
	5.00			-9.36	-5.71				15.40	9.30		6.10	15.40	9.30
c	20 min	2.250	0	0.99	0.29	34.31	22.79		35.30	23.08		12.22	35.30	23.08
d	20 min	2.250	↓	↓	↓	34.31	22.79		35.30	23.08		12.22	35.30	23.08
e	100 sec	2.140				33.77	22.35		34.76	22.64		12.12	34.76	22.64
	225 sec	2.275	↓	↓	↓	34.43	22.89	↓	35.42	23.18	↓	12.24	35.42	23.18

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER 5-151-P | A-79
SHEET 28 OF 51
DATE 5-12-66 BY Gockel
CHECK DATE 5-12-66 BY Alexander
CHARGE NO.
DESCRIPTION Fatigue Evaluation Of Head Flange Vessel Flange And Closure Studs

5- Detailed Analysis:

e- Stresses:

1- Unconcentrated:

LOCATION - 2

Transient		Internal Pressure KSIA	$(T_m - T)$ °F	Thermal Stress		Pressure Stress			Total Stress			Stress Intensity		
				σ_x	σ_θ	σ_x	σ_θ	σ_r	σ_x	σ_θ	σ_r	$\sigma_x - \sigma_\theta$	$\sigma_x - \sigma_r$	$\sigma_\theta - \sigma_r$
f	40 sec	2.320	0	0.99	0.29	34.66	23.07	0	35.65	23.36	0	12.29	35.65	23.36
	100 sec	2.260				34.36	22.83		35.35	23.12		12.23	35.35	23.12
	260 sec	2.140				33.77	22.35		34.76	22.64		12.12	34.76	22.64
g	2 min	2.370				34.90	23.28		35.89	23.57		12.32	35.89	23.57
	3.2 min	2.350				34.80	23.19		35.79	23.48		12.31	35.79	23.48
	10.4 min	2.150				33.82	22.39		34.81	22.68		12.13	34.81	22.68
h	10 sec	2.220				34.16	22.67		35.15	22.96		12.19	35.15	22.96
	65 sec	1.910				32.63	21.42		33.62	21.71		11.91	33.62	21.71
i	220 min	3.125		0	0	38.63	26.31		38.63	26.31		12.32	38.63	26.31
j	Heatup 3.5 hrs	1.250		13.54	7.20	29.37	18.77		42.91	25.97		16.94	42.91	25.97
	S.S.	2.500		0.99	0.29	35.54	23.80		36.53	24.09		12.44	36.53	24.09
	Cooldown 3.5 hrs	0.315		-10.87	-7.23	24.76	15.01		13.89	7.78		6.11	13.89	7.78
k	~	2.350	0	0.99	0.29	34.80	23.19		35.79	23.48		12.31	35.79	23.48
	~	2.150				33.82	22.39		34.81	22.68		12.13	34.81	22.68
l	12 sec	2.250				34.31	22.79		35.30	23.08		12.22	35.30	23.08
m	10 sec	2.760				36.83	24.84		37.82	25.13		12.69	37.82	25.13
	28 sec	2.120				33.67	22.27		34.66	22.56		12.10	34.66	22.56
	160 sec	1.440				30.31	19.53		31.30	19.82		11.48	31.30	19.82
n	33 sec	0.300				24.68	14.95		25.67	15.24		10.43	25.67	15.24
	54 sec	0.700				26.66	16.56		27.65	16.85		10.80	27.65	16.85

$S.I._{\substack{max \\ range}} = (\sigma_x - \sigma_r) = 47.85$ ksi $< 3S_m = 80.1$ ksi (Criteria 5-C-2

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION Fatigue Evaluation Of Head Flange Vessel Flange And Closure Studs

NUMBER 5-151-P A80
SHEET 29 OF 51
DATE 5-12-66 BY Cockrell
CHECK DATE 5-12-66 BY Alexander

5. Detailed Analysis:
e. Stresses:
1- Unconcentrated:

Location 3

Transient		Internal Pressure ksia	(T_m-T) °F	Thermal Stress		Pressure Stress			Total Stress			Stress Intensity		
				σ_x	σ_θ	σ_x	σ_θ	σ_r	σ_x	σ_θ	σ_r	$\sigma_x-\sigma_\theta$	$\sigma_x-\sigma_r$	$\sigma_\theta-\sigma_r$
Cold Bolt Up		0	0	0	0	-20.30	-4.59	0	-20.30	-4.59	0	-15.71	-20.30	-4.59
Bolt Up + 2500 psia		2.5	0	0	0	-9.72	14.22	-2.50	-9.72	14.22	-2.50	-23.94	-7.22	16.72
a Heatup	4.00 hrs.	1.882		-3.10	-26.39	-12.34	9.57	-1.19	-15.44	-16.82	-1.19	1.38	-14.25	-15.63
	4.25	2.078		-3.09	-27.00	-11.51	11.04	-2.08	-14.60	-15.96	-2.08	1.36	-12.52	-13.88
	4.35	2.156		-2.61	-27.35	-11.18	11.63	-2.16	-13.79	-15.72	-2.16	1.93	-11.63	-13.56
	4.47	2.250		-1.67	-26.94	-10.78	12.34	-2.25	-12.45	-1460	-2.25	2.15	-10.20	-12.35
	5.00	2.250		5.31	-19.85	-10.78	12.34	-2.25	-5.47	-751	-2.25	2.04	-3.22	-5.26
Steady State		2.250		7.48	0.30	-10.78	12.34	-2.25	-3.30	12.64	-2.25	-15.94	-1.05	14.89
b Cooldown	4.00 hrs.	0.315		8.42	25.13	-18.97	-2.22	-0.32	-10.55	22.91	-0.32	-33.46	-10.23	23.23
	4.25	↓		7.90	25.49	↓	↓	↓	-11.07	23.27	-0.32	-34.34	-10.75	23.59
	4.35			7.55	25.38				-11.42	23.16	-0.32	-34.58	-11.10	23.48
	4.47			8.18	26.38				-10.79	24.16	-0.32	-34.95	-10.47	24.48
	5.00			1.27	18.87				-17.70	16.65	-0.32	-34.35	-17.38	16.97
c	20 min	2.250	-7.8	5.08	-2.10	-10.78	12.34	-2.25	-5.70	10.24	-2.25	-15.94	-3.45	12.49
d	20 min	2.250	7.8	9.88	2.70	-10.78	12.34	-2.25	-0.90	15.04	-2.25	-15.94	1.35	17.29
e	100 sec	2.110	11.2	10.92	3.74	-11.25	11.51	-2.14	-0.33	15.25	-2.14	-15.58	1.81	17.39
	225 sec	2.275	1.7	8.00	0.82	-10.68	12.53	-2.28	-2.68	13.35	-2.28	-16.03	-0.40	15.63

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION Fatigue Evaluation Of Head Flange
Vessel Flange And Closure Studs

NUMBER 5-151-P | A 91
SHEET 30 OF 51
DATE 5-12-66 BY [illegible]
CHECK DATE 5-12-66 BY Alexander

5. Detailed Analysis:
e. Stresses:
1. Unconcentrated:

Location - 3

Transient		Internal Pressure KSIA	$(T_m - T)$ °F	Thermal Stress		Pressure Stress			Total Stress			Stress Intensity		
				σ_x	σ_θ	σ_x	σ_θ	σ_r	σ_x	σ_θ	σ_r	$\sigma_x-\sigma_\theta$	$\sigma_x-\sigma_r$	$\sigma_\theta-\sigma_r$
f	40sec	2.320	-9.3	4.62	-2.56	-10.49	12.87	-2.32	-5.87	10.31	-2.32	-16.18	-3.55	12.63
	100sec	2.260	-13.3	3.40	-3.78	-10.74	12.41	-2.26	-7.34	8.63	-2.26	-15.97	-5.08	10.89
	260sec	2.140	-1.3	7.08	-0.10	-11.25	11.51	-2.14	-4.17	11.41	-2.14	-15.58	-2.03	13.55
g	.2 min	2.370	-12.0	3.79	-3.39	-10.27	13.24	-2.37	-6.48	9.85	-2.37	-16.33	-4.11	12.22
	3.2 min	2.350	-15.0	2.97	-4.31	-10.36	13.09	-2.35	-7.49	8.78	-2.35	-16.27	-5.14	11.13
	10.4 min	2.150	0	7.48	0.30	-11.20	11.59	-2.15	-3.72	11.89	-2.15	-15.61	-1.57	14.04
h	10 sec	2.220	-9.5	4.56	-2.62	-10.91	12.11	-2.22	-6.35	9.49	-2.22	-15.84	-4.13	11.71
	65sec	1.910	8.5	10.09	2.91	-12.22	9.78	-1.91	-2.13	12.69	-1.91	-14.82	-0.22	14.60
i	220 min	3.125	0	0	0	-7.08	18.92	-3.13	-7.08	18.92	-3.13	-26.00	-3.95	22.05
j	HEATUP 3.5 hrs	1.250		-1.67	-26.94	-15.01	4.82	-1.25	-16.68	-22.12	-1.25	5.44	-15.43	-20.87
	S.S.	2.500		7.48	0.30	-9.72	14.22	-2.50	-2.24	14.52	-2.50	-16.56	0.26	17.02
	COOLDOWN 3.5 hrs	0.315		8.18	26.38	-18.97	-2.22	-0.32	-10.79	24.16	-0.32	-34.95	-10.47	24.48
k	~	2.350	6.0	9.32	2.14	-10.36	13.09	-2.35	-1.04	15.23	-2.35	-16.27	1.31	17.58
	~	2.150	-6.0	5.64	-1.54	-11.20	11.59	-2.15	-5.56	10.05	-2.15	-15.61	-3.41	12.20
l	12sec	2.250	33.3	17.71	10.53	-10.78	12.34	-2.25	6.93	22.87	-2.25	-15.94	9.18	25.12
m	10 sec	2.760	-30.2	-1.80	-9.98	-8.62	16.18	-2.76	-10.42	7.20	-2.76	-17.62	-7.66	9.96
	29 sec	2.120	-41.2	-5.17	-12.35	-11.33	11.36	-2.12	-16.50	-0.99	-2.12	-15.51	-14.39	1.13
	160sec	1.440	4.8	8.95	1.77	-14.21	6.24	-1.44	-5.26	8.01	-1.44	-13.27	-3.92	9.45
n	33sec	0.300	117	43.42	36.24	-19.03	-2.33	-0.30	24.39	33.91	-0.30	-9.52	24.69	34.21
	54sec	0.700	197	67.99	60.91	-17.34	0.68	-0.70	50.65	61.49	-0.70	-10.84	51.35	62.19

$S.I._{\substack{max \\ RANGE}} = (\sigma_\theta - \sigma_r) = 45.35$ ksi < 80.1 Ksi Criteria 5-C-2

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.______

DESCRIPTION Fatigue Evaluation of Head Flange
Vessel Flange And Closure Studs

NUMBER 5-151-P | A 82
SHEET 31 OF 51
DATE 5-12-66 BY Cockrell
CHECK DATE 5-17-66 BY Alexander

5- Detailed Analysis:
e- Stresses:
1- Unconcentrated:

Location-4

Transient		Internal Pressure ksia	(T_m-T) °F	Thermal Stress		Pressure Stress			Total Stress			Stress Intensity		
				σ_x	σ_θ	σ_x	σ_θ	σ_r	σ_x	σ_θ	σ_r	$\sigma_x-\sigma_\theta$	$\sigma_x-\sigma_r$	$\sigma_\theta-\sigma_r$
Cold Bolt Up		0	0	0	0	20.30	7.59	0	20.30	7.59	0	12.71	20.30	7.59
Bolt Up + 2500 psia		2.5	0	0	0	28.37	25.65	↓	28.37	25.65	↓	2.72	29.37	25.65
a Heatup	4.00 hrs.	1.882		-7.92	1.81	26.38	21.18		18.46	22.99		-4.53	18.46	22.99
	4.25	2.078		-8.04	1.86	27.01	22.60		18.97	24.46		-5.49	18.97	24.46
	4.35	2.156		-8.27	1.65	27.26	23.16		18.99	24.81		-5.82	18.99	24.81
	4.47	2.250		-9.52	2.02	27.56	23.84		19.04	25.86		-7.82	18.04	25.86
	5.00	2.250		-13.04	-1.64	27.56	23.84		14.52	22.20		-7.68	14.52	22.20
Steady State		2.250		-7.78	-3.21	27.56	23.84		19.78	20.63		-0.85	19.78	20.63
b Cooldown	4.00 hrs.	0.315		1.78	-4.08	21.32	9.87		23.10	5.79		17.31	23.10	5.79
	4.25	↓		1.93	-3.81	↓	↓		23.25	6.06		17.19	23.25	6.06
	4.35			2.49	-3.70				23.81	6.17		17.64	23.81	6.17
	4.47			2.62	-2.89				23.94	6.98		16.96	23.94	6.98
	5.00			5.37	-0.18				26.69	9.69		17.00	26.69	9.69
c	20 min	2.250	0	-7.78	-3.21	27.56	23.84		19.78	20.63		-0.85	19.78	20.63
d	20 min	2.250	↓	↓	↓	27.56	23.84		19.78	20.63		-0.85	19.78	20.63
e	100 sec	2.140				27.21	23.05		19.43	19.84		-0.41	19.43	19.84
	225 sec	2.275				27.65	24.02		19.87	20.81		-0.94	19.87	20.81

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION Fatigue Evaluation Of Head Flange Vessel Flange And Closure Studs

NUMBER 5-151-P | A 83
SHEET 32 OF 51
DATE 5-12-66 BY [illegible]
CHECK DATE 5-12-66 BY Alexander

5. Detailed Analysis:

e- Stresses:

1- Unconcentrated:

Location - 4

Transient		Internal Pressure KSIA	$(T_m - T)$ °F	Thermal Stress		Pressure Stress			Total Stress			Stress Intensity		
				σ_x	σ_θ	σ_x	σ_θ	σ_r	σ_x	σ_θ	σ_r	$\sigma_x-\sigma_\theta$	$\sigma_x-\sigma_r$	$\sigma_\theta-\sigma_r$
f	40sec	2.320	0	-7.78	-3.21	27.79	24.35	0	20.01	21.14	0	-1.13	20.01	21.14
	100sec	2.260				27.60	23.92		19.82	20.71		-0.89	19.82	20.71
	260sec	2.140				27.21	23.05		19.43	19.84		-0.41	19.43	19.84
g	2 min	2.370				27.95	24.71		20.17	21.50		-1.33	20.17	21.50
	3.2 min	2.350				27.89	24.57		20.11	21.36		-1.25	20.11	21.36
	10.4 min	2.150				27.24	23.12		19.46	19.91		-0.45	19.46	19.91
h	10 sec	2.220				27.47	23.63		19.69	20.42		-0.73	19.69	20.42
	65sec	1.910				26.47	21.39		18.69	18.18		0.51	18.69	18.18
i	220 min	3.125		0	0	30.39	30.16		30.39	30.16		0.23	30.39	30.16
j	HEATUP 3.5 hrs	1.250		-9.52	2.02	24.34	16.62		14.82	18.64		-3.82	14.82	18.64
	S.S.	2.500		-7.78	-3.21	28.37	25.65		20.59	22.44		-1.85	20.59	22.44
	COOLDOWN 3.5 hrs	0.315		2.62	-2.89	21.32	9.87		23.94	6.98		16.96	23.94	6.98
k	~	2.350	0	-7.78	-3.21	27.89	24.57		20.11	21.36		-1.25	20.11	21.36
	~	2.150				27.24	23.12		19.46	19.91		-0.45	19.46	19.91
l	12sec	2.250				27.56	23.84		19.78	20.63		-0.85	19.78	20.63
m	10 sec	2.760				29.21	27.53		21.43	24.32		-2.89	21.43	24.32
	29 sec	2.120				27.14	22.90		19.36	19.69		-0.33	19.36	19.69
	160 sec	1.440				24.95	19.99		17.17	16.78		0.39	17.17	16.78
n	33 sec	0.300				21.27	9.76		13.49	6.55		6.94	13.49	6.55
	54 sec	0.700				22.56	12.65		14.78	9.44		5.34	14.78	9.44

$SI_{MAX\ RANGE} = \sigma_x - \sigma_r = 3039$ ksi $<$ 80.1 ksi Criterion 5-C-2

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER 5-151-P | A 84
SHEET 33 OF 51
CHARGE NO.
DATE 5-12-66 BY Cockrell
DESCRIPTION Fatigue Evaluation Of Head Flange Vessel Flange And Closure Studs
CHECK DATE 5-12-66 BY Alexander

5- Detailed Analysis:

e- Stresses

1- Unconcentrated:

Transient		Internal Pressure KSIA	Location-5			Location-6			Location-7			Location-8		
			Mechanical Stress σ_x	Thermal Stress σ_x	Total Stress σ_x	Mechanical Stress σ_x	Thermal Stress σ_x	Total Stress σ_x	Mechanical Stress σ_x	Thermal Stress σ_x	Total Stress σ_x	Mechanical Stress σ_x	Thermal Stress σ_x	Total Stress σ_x
Cold Bolt Up		0	29.91	0	29.91	43.81	0	43.81	68.31	0	68.31	5.41	0	5.41
Bolt up + 2500 psi		2.500	50.29	0	50.29	29.61	0	29.61	57.80	0	57.80	22.10	0	22.10
a Heatup	4.00 hrs	1.882	45.25	1.01	46.26	34.12	10.68	44.80	60.40	31.39	91.79	17.97	-19.70	-1.73
	4.25	2.078	46.95	2.45	49.30	32.00	10.09	42.09	59.57	31.64	91.21	19.28	-19.10	0.18
	4.35	2.156	47.49	3.10	50.59	31.56	9.60	41.16	59.24	31.61	90.85	19.80	-18.91	0.89
	4.47	2.250	48.25	2.64	50.89	31.03	10.11	41.14	58.85	32.81	91.66	20.43	-20.06	0.37
	5.00	2.250	48.25	6.03	54.28	31.03	9.34	40.37	58.85	31.32	90.17	20.43	-15.95	4.48
Steady State		2.250	48.25	0.59	48.84	31.03	1.88	32.91	59.95	-1.51	57.34	20.43	3.98	24.41
b Cooldown	4.00 hrs	0.315	32.49	-2.31	30.17	42.02	-7.91	34.11	66.99	-29.11	37.88	7.54	18.89	26.43
	4.25	↓	↓	-3.08	29.40	↓	-8.77	33.25	↓	-30.78	36.21	↓	18.93	26.47
	4.35	↓	↓	-3.83	28.65	↓	-9.35	33.67	↓	-30.68	36.31	↓	18.50	26.04
	4.47	↓	↓	-4.63	27.85	↓	-8.70	33.32	↓	-31.22	35.77	↓	17.89	25.43
	5.00	↓	↓	-8.34	24.14	↓	-6.35	35.17	↓	-29.76	38.23	↓	13.57	21.11
c	20 min	2.250	48.25	0.59	48.84	31.03	1.88	32.91	58.95	-1.51	57.34	20.43	3.98	24.41
d	20 min	2.250	48.25	↓	48.84	31.03	↓	32.91	58.95	↓	57.34	20.43	↓	24.41
e	100 sec	2.140	47.36	↓	47.95	31.65	↓	33.53	59.31	↓	57.80	19.70	↓	23.68
	225 sec	2.275	48.46	↓	49.05	30.88	↓	32.76	59.74	↓	57.23	20.60	↓	24.58

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION FATIGUE EVALUATION OF HEAD FLANGE VESSEL FLANGE AND CLOSURE STUDS

NUMBER 5-151-P |A85
SHEET 34 **OF** 51
DATE 5-12-66 **BY** COCKRELL
CHECK DATE 5-12-66 **BY** ALEXANDER

5. DETAILED ANALYSIS:
e. STRESSES:
1. UNCONCENTRATED:

			LOCATION-5			LOCATION-6			LOCATION-7			LOCATION-8		
TRANSIENT		INTERNAL PRESSURE	MECHANICAL STRESS	THERMAL STRESS	TOTAL STRESS	MECHANICAL STRESS	THERMAL STRESS	TOTAL STRESS	MECHANICAL STRESS	THERMAL STRESS	TOTAL STRESS	MECHANICAL STRESS	THERMAL STRESS	TOTAL STRESS
		KSIA	σ_x	σ_x	σ_x	σ_x	σ_x	σ_x	σ_y	σ_x	σ_y	σ_x	σ_x	σ_x
f	40sec	2.320	48.83	0.59	49.42	30.63	1.88	32.51	58.55	-1.51	57.04	20.90	3.98	24.88
	100sec	2.260	4934	↓	48.93	30.97	↓	32.85	58.81	↓	57.30	20.50	↓	24.48
	260sec	2.140	47.36	↓	47.95	31.65	↓	33.53	59.31	↓	57.80	19.70	↓	23.68
g	2 min	2.370	49.23	↓	49.82	30.34	↓	32.22	58.34	↓	56.83	21.23	↓	25.21
	3.2 min	2.350	49.07	↓	49.66	30.46	↓	3234	58.43	↓	56.92	21.10	↓	25.08
	10.4 min	2.150	47.44	↓	48.03	31.59	↓	33.47	59.27	↓	57.76	19.76	↓	23.74
h	10 sec	2.220	49.01	↓	48.60	31.20	↓	33.08	58.97	↓	57.46	20.23	↓	24.21
	65 sec	1.910	45.48	↓	46.07	32.96	↓	34.84	60.28	↓	58.77	18.16	↓	22.14
i	220 min	3.125	55.39	0	55.39	26.05	0	26.05	55.17	0	55.17	26.27	0	26.27
j	HEATUP 3.5hrs	1.250	40.10	2.64	42.74	36.70	10.11	46.81	63.06	32.81	95.87	13.76	-20.26	-6.50
	S.S.	2.500	50.29	0.59	50.88	29.61	1.88	31.49	57.80	-1.51	56.29	22.10	3.98	26.08
	COOLDOWN 3.5hrs	0.315	32.48	-4.63	27.85	42.02	-8.70	33.32	66.99	-31.22	35.77	7.54	17.89	25.43
k	~	2.350	49.07	0.59	49.66	30.46	1.88	32.34	58.43	-1.51	56.92	21.10	3.98	25.08
	~	2.150	47.44	↓	48.03	31.59	↓	33.47	59.27	↓	57.76	19.76	↓	23.74
l	12sec	2.250	48.25	↓	48.84	31.03	↓	32.91	59.85	↓	57.34	20.43	↓	24.41
m	10sec	2.760	52.41	↓	53.00	28.13	↓	30.01	56.70	↓	55.19	23.84	↓	27.82
	28sec	2.120	47.19	↓	47.78	31.76	↓	3364	59.40	↓	57.89	19.56	↓	23.54
	160sec	1.440	41.65	↓	42.24	35.63	↓	37.51	62.25	↓	60.74	15.02	↓	19.00
n	33sec	0.300	32.32	↓	32.91	42.10	↓	43.98	67.05	↓	65.54	7.41	↓	11.39
	54sec	0.700	35.62	↓	36.21	39.82	↓	41.70	65.37	↓	63.86	10.08	↓	14.06

$S.I._{max}$ = 95.87 ksi < 110.2 ksi CRITERIA 5-C-2

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION FATIGUE EVALUATION OF HEAD FLANGE, VESSEL FLANGE AND CLOSURE STUDS

NUMBER 5-151-P | A 86
SHEET 35 **OF** 51
DATE 5-12-66 **BY** COCKRELL
CHECK DATE 5-12-66 **BY** ALEXANDER

5- DETAILED ANALYSIS:

e. STRESSES:

2. CONCENTRATED :

FOR THE PURPOSE OF THE FATIGUE ANALYSIS, THE FOLLOWING STRESS EXPRESSIONS WILL BE USED TO CALCULATE PEAK STRESSES AT THE EIGHT LOCATIONS AS SHOWN ON SHEET-23.

POINTS 1 & 2:

$$\sigma_X = \pm\frac{6}{t_1^2}(M_1+M_{T1})K_B + \frac{H_1\cos\theta}{t_1}K_T + \frac{a_1^2P}{2R_1t_1}K_T + \frac{E\alpha}{(1-\nu)}(T_{m1}-70)K_T$$
$$= \pm 0.06783(M_1+M_{T1})K_B + 0.03654H_1K_T + 4.3709PK_T + 1.42857(T_{m1}-70)K_T$$

$$\sigma_\theta = \pm\frac{\nu 6}{t_1^2}(M_1+M_{T1})K_B + \frac{\nu H_1\cos\theta}{t_1} + \frac{E\Delta_{11}+E\delta_{11T}}{R_1\sin\theta} \pm \frac{t_1\cos\theta(E\Delta_{11}^*+E\delta_{11T}^*)}{2R_1\sin\theta} + \frac{a_1^2P}{2R_1t_1} + \frac{E\alpha}{(1-\nu)}(T_{m1}-70) - E\alpha(T_{m1}-70)$$
$$= \pm 0.02035(M_1+M_{T1})K_B + 0.01096H_1 + 0.01189(E\Delta_{11}+E\delta_{11T}) \pm 0.01922(E\Delta_{11}^*+E\delta_{11T}^*) + 4.3709P$$
$$+ 1.42857(T_{m1}-70) - E\alpha(T_{m1}-70)$$

POINTS 3 & 4:

$$\sigma_X = \pm\frac{6}{t_4^2}(M_3+M_{T3})K_B + \frac{b^2P}{2R_4t_4}K_T + \frac{E\alpha}{(1-\nu)}(T_{m4}-70)K_T$$
$$= \pm 0.05191(M_3+M_{T3})K_T + 3.7296PK_T + 1.42857(T_{m4}-70)K_T$$

$$\sigma_\theta = \pm\frac{\nu 6}{t_4^2}(M_3+M_{T3})K_B + \frac{EM_{T3}}{2R_4\beta_4^2D_4} + \frac{E\Delta_{43}}{R_4} + \frac{b_4P}{t_4} + \frac{E\alpha}{(1-\nu)}(T_{m4}-70)$$
$$= \pm 0.01557(M_3+M_{T3})K_B + 0.02860M_{T3} + 0.01098E\Delta_{43} + 7.94762P + 1.42857E\alpha(T_{m4}-70)$$

POINTS 5 & 6:

$$\sigma_X = \left(\frac{\bar{T}+\bar{V}}{A}\right)K_T \pm \frac{\bar{M}c}{I}K_B = 0.31631(T+V)K_T \pm 0.36236M_2K_B$$

POINTS 7 & 8:

$$\sigma_X = \left(\frac{\bar{T}+\bar{V}}{A}\right)K_T \pm \frac{(\bar{M}+\bar{H}\ell_B)c}{I}K_B = 0.31631(T+V)k_T \pm 0.36236M_2K_B \pm 11.33489H_2K_B$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION *FATIGUE EVALUATION OF HEAD FLANGE VESSEL FLANGE AND CLOSURE STUDS*

NUMBER 5-151-P | A 87
SHEET 36 OF 51
DATE 5-12-66 BY COCKRELL
CHECK DATE 5-12-66 BY ALEXANDER

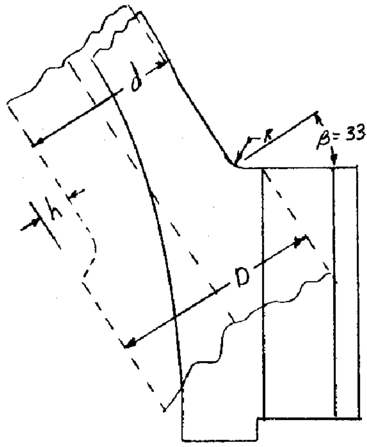
5. DETAILED ANALYSIS:
e. STRESSES:
2. CONCENTRATED:

DETERMINATION OF STRESS CONCENTRATION FACTORS:

POINT - 1

$K_T = K_B = 1$

POINT - 2



$h = 2.181''$ $R = 1.875''$

$D = 11.586''$

$d = 9.405''$

$\Delta = \frac{D}{d} = 1.232$

FROM REFERENCE - 4, WE HAVE

FOR TENSION

$$K_0 = 1 + \left[\frac{1}{2.8\Delta - 2}\left(\frac{h}{R}\right)\right]^{0.65} = 1 + \left[\frac{1}{2.8(1.232)-2}\left(\frac{2.181}{1.875}\right)\right]^{0.65}$$

$$= 1.866$$

$$K_T = 1 + (K_0 - 1)\left[1 - \left(\frac{\beta}{90}\right)^{1+2.4\sqrt{R/h}}\right]$$

$$= 1 + (1.866 - 1)\left[1 - \left(\frac{33}{90}\right)^{1+2.4\sqrt{\frac{1.875}{2.181}}}\right]$$

$$= \underline{\underline{1.833}} \longleftarrow$$

FOR BENDING:

$$K_0 = 1 + \left[\frac{1}{5.37\Delta - 4.8}\left(\frac{h}{R}\right)\right]^{0.85} = 1 + \left[\frac{1}{5.37(1.232) - 4.8}\left(\frac{2.181}{1.875}\right)\right]^{0.85} = 1.685$$

$$K_B = 1 + (K_0 - 1)\left[1 - \left(\frac{\beta}{90}\right)^{1+2.4\sqrt{R/h}}\right] = 1 + (1.685 - 1)\left[1 - \left(\frac{33}{90}\right)^{1+2.4\sqrt{\frac{1.875}{2.181}}}\right] = \underline{\underline{1.659}} \longleftarrow$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION FATIGUE EVALUATION OF HEAD FLANGE, VESSEL FLANGE AND CLOSURE STUDS

NUMBER 5-151-P | A 88

SHEET 37 **OF** 51

DATE 5-12-66 **BY** COCKRELL

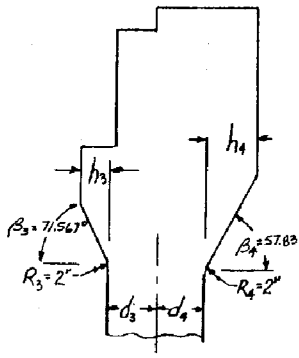
CHECK DATE 5-12-66 **BY** ALEXANDER

5. DETAILED ANALYSIS:

e. STRESSES:

2. CONCENTRATED:

POINT - 3:



$h_3 = 1.906"$ $h_4 = 6.094"$

$D_3 = 7.281"$ $D_4 = 11.469"$

$d_3 = 5.375"$ $d_4 = 5.375"$

$\Delta_3 = \frac{D_3}{d_3} = 1.355$ $\Delta_4 = \frac{D_4}{d_4} = 2.134$

FROM REF. 4, WE HAVE

FOR TENSION

$$K_o = 1 + \left[\frac{1}{2.8\Delta_3 - 2}\left(\frac{h_3}{R_3}\right)\right]^{0.65} = 1 + \left[\frac{1}{2.8(1.355) - 2}\left(\frac{1.906}{2}\right)\right]^{0.65} = 1.663$$

$$K_T = 1 + (K_o - 1)\left[1 - \left(\frac{\beta_3}{90}\right)^{1+2.4\sqrt{\frac{R}{h}}}\right] = 1 + (1.663 - 1)\left[1 - (0.795)^{1+2.4\sqrt{\frac{2}{1.906}}}\right] = \underline{\underline{1.363}} \longleftarrow$$

FOR BENDING:

$$K_o = 1 + \left[\frac{1}{5.37\Delta_3 - 4.8}\left(\frac{h_3}{R_3}\right)\right]^{0.85} = 1 + \left[\frac{1}{5.37(1.355) - 4.8}\left(\frac{1.906}{2}\right)\right]^{0.85} = 1.444$$

$$K_B = 1 + (K_o - 1)\left[1 - \left(\frac{\beta_3}{90}\right)^{1+2.4\sqrt{\frac{R}{h}}}\right] = 1 + (1.444 - 1)\left[1 - (0.795)^{1+2.4\sqrt{\frac{2}{1.906}}}\right] = \underline{\underline{1.243}} \longleftarrow$$

POINT - 4:

FOR TENSION:

$$K_o = 1 + \left[\frac{1}{2.8\Delta_4 - 2}\left(\frac{h_4}{R_4}\right)\right]^{0.65} = 1 + \left[\frac{1}{2.8(2.134) - 2}\left(\frac{6.094}{2}\right)\right]^{0.65} = 1.841$$

$$K_T = 1 + (K_o - 1)\left[1 - \left(\frac{\beta_4}{90}\right)^{1+2.4\sqrt{\frac{R}{h}}}\right] = 1 + (1.841 - 1)\left[1 - (0.643)^{1+2.4\sqrt{\frac{2}{6.094}}}\right] = \underline{\underline{1.547}} \longleftarrow$$

FOR BENDING:

$$K_o = 1 + \left[\frac{1}{5.37\Delta_4 - 4.8}\left(\frac{h_4}{R_4}\right)\right]^{0.85} = 1 + \left[\frac{1}{5.37(2.134) - 4.8}\left(\frac{6.094}{2}\right)\right]^{0.85} = 1.515$$

$$K_B = 1 + (K_o - 1)\left[1 - \left(\frac{\beta_4}{90}\right)^{1+2.4\sqrt{\frac{R}{h}}}\right] = 1 + (1.515 - 1)\left[1 - (0.643)^{1+2.4\sqrt{\frac{2}{6.094}}}\right] = \underline{\underline{1.335}} \longleftarrow$$

POINTS 5, 6, 7, & 8:

$K_T = K_B = \underline{\underline{4}} \longleftarrow$ (FROM PAR. N-416.4, SECTION III NUCLEAR CODE)

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION Fatigue Evaluation of Head Flange Vessel Flange And Closure Studs

NUMBER 5-151-P | A 89
SHEET 38 OF 51
DATE 5-12-66 BY Cockrell
CHECK DATE 5-12-66 BY Alexander

5. Detailed Analysis:
e- Stresses:
2- Concentrated:

Location -1

Transient		Internal Pressure ksia	(T_m-T) °F	Thermal Stress		Pressure Stress			Peak Stress			Stress Intensity		
				σ_x	σ_θ	σ_x	σ_θ	σ_r	σ_x	σ_θ	σ_r	$\sigma_x-\sigma_\theta$	$\sigma_x-\sigma_r$	$\sigma_\theta-\sigma_r$
Cold Bolt Up		0	0	0	0	-21.50	-2.51	0	-21.50	-2.51	0	-18.99	-21.50	-2.51
Bolt Up + 2500 psia		2.5	0	0	0	-11.99	6.17	-2.50	-11.99	6.17	-2.50	-18.16	-9.49	8.67
a Heatup	4.00 hrs.	1.882		-17.50	-26.63	-14.35	4.02	-1.88	-31.85	-22.61	-1.88	-9.24	-29.97	-20.73
	4.25	2.078		-18.38	-27.98	-13.60	4.70	-2.08	-31.98	-23.28	-2.08	-8.70	-29.90	-21.20
	4.35	2.156		-18.37	-28.19	-13.31	4.97	-2.16	-31.68	-23.22	-2.16	-8.76	-29.52	-21.06
	4.47	2.250		-18.61	-28.73	-12.95	5.30	-2.25	-31.56	-23.43	-2.25	-8.13	-29.31	-21.18
	5.00	2.250		-13.80	-22.43	-12.95	5.30	-2.25	-26.75	-17.13	-2.25	-9.62	-24.50	-14.88
Steady State		2.250		-1.23	-0.59	-12.95	5.30	-2.25	-14.18	4.71	-2.25	-18.99	-11.93	6.96
b Cooldown	4.00 hrs.	0.315		14.96	24.85	-20.30	-1.42	-0.32	-5.34	23.43	-0.32	-28.77	-5.02	23.75
	4.25	↓		16.29	25.49	↓	↓	↓	-4.01	24.07	-0.32	-28.08	-3.69	24.39
	4.35			16.43	25.74				-3.87	24.32	-0.32	-28.19	-3.55	24.64
	4.47			16.80	25.89				-3.50	24.47	-0.32	-27.97	-3.18	24.79
	5.00			11.69	19.66				-8.61	18.24	-0.32	-26.85	-8.29	18.56
c	20 min	2.250	-7.8	-3.63	-2.99	-12.95	5.30	-2.25	-16.58	2.31	-2.25	-18.89	-14.33	4.56
d	20 min	2.250	7.8	1.17	1.81	-12.95	5.30	-2.25	-11.78	7.11	-2.25	-18.89	-9.53	9.36
e	100 sec	2.110	11.2	2.21	2.85	-13.37	4.92	-2.14	-11.16	7.77	-2.14	-18.93	-9.02	9.91
	225 sec	2.275	1.7	-0.71	-0.07	-12.85	5.38	-2.28	-13.56	5.31	-2.28	-18.87	-11.28	7.59

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION Fatigue Evaluation Of Head Flange Vessel Flange And Closure Studs

NUMBER 5-151-P A 90
SHEET 39 **OF** 51
DATE 5-12-66 **BY**
CHECK DATE 5-12-66 **BY** Alexander

5- Detailed Analysis:

e- Stresses

2- Concentrated:

LOCATION - 1

Transient		Internal Pressure KSIA	$(T_m - T)$ °F	Thermal Stress σ_x	Thermal Stress σ_θ	Pressure Stress σ_x	Pressure Stress σ_θ	Pressure Stress σ_r	Peak Stress σ_x	Peak Stress σ_θ	Peak Stress σ_r	Stress Intensity $\sigma_x - \sigma_\theta$	Stress Intensity $\sigma_x - \sigma_r$	Stress Intensity $\sigma_\theta - \sigma_r$
f	40 sec	2.320	-9.3	-4.09	-3.45	-12.68	5.54	-2.32	-16.77	2.09	-2.32	-18.86	-14.45	4.41
	100 sec	2.260	-13.3	-5.31	-4.67	-12.91	5.33	-2.26	-18.22	0.66	-2.26	-18.86	-15.96	2.92
	260 sec	2.140	-1.3	-1.63	-0.99	-13.37	4.92	-2.14	-15.00	3.93	-2.14	-18.93	-12.86	6.07
g	2 min	2.370	-12.0	-4.92	-4.28	-12.49	5.71	-2.37	-17.41	1.43	-2.37	-18.84	-15.04	3.80
	3.2 min	2.350	-15.0	-5.84	-5.20	-12.57	5.64	-2.35	-18.41	0.44	-2.35	-18.85	-16.06	2.79
	10.4 min	2.150	0	-1.23	-0.59	-13.33	4.95	-2.15	-14.56	4.36	-2.15	-18.92	-12.41	6.51
h	10 sec	2.220	-9.5	-4.15	-3.51	-13.06	5.19	-2.22	-17.21	1.68	-2.22	-18.89	-14.99	3.90
	65 sec	1.910	8.5	1.38	2.02	-14.24	4.12	-1.91	-12.86	6.14	-1.91	-19.00	-10.95	8.05
i	220 min	3.125	0	0	0	-9.62	8.33	-3.13	-9.62	8.33	-3.13	-17.95	-6.49	11.46
j	HEATUP 3.5 hrs	1.250		-18.61	-28.73	-16.75	1.83	-1.25	-35.36	-26.90	-1.25	-8.46	-34.11	-25.65
	S.S.	2.500		-1.23	-0.59	-11.99	6.17	-2.50	-13.22	5.58	-2.50	-18.80	-10.72	8.08
	COOLDOWN 3.5 hrs	0.315		16.80	25.89	-20.30	-1.42	-0.32	-3.50	24.47	-0.32	-27.97	-3.18	24.79
k	~	2.350	6.0	0.61	1.25	-12.57	5.64	-2.35	-11.96	6.89	-2.35	-18.85	-9.16	9.24
	~	2.150	-6.0	-3.07	-2.43	-13.33	4.95	-2.15	-16.40	2.52	-2.15	-18.92	-14.25	4.67
l	12 sec	2.250	33.3	9.00	9.64	-12.95	5.30	-2.25	-3.95	14.94	-2.25	-19.89	-1.70	17.19
m	10 sec	2.760	-30.2	-10.51	-9.87	-11.01	7.07	-2.76	-21.52	-2.90	-2.76	-18.72	-18.76	-0.04
	28 sec	2.170	-41.2	-13.88	-13.24	-13.44	4.85	-2.12	-27.32	-9.39	-2.12	-18.93	-25.20	-6.27
	160 sec	1.490	4.8	0.24	0.88	-16.03	2.49	-1.44	-15.79	3.37	-1.44	-19.16	-14.35	4.81
n	33 sec	0.300	117	34.71	35.35	-20.36	-1.47	-0.30	14.35	33.88	-0.30	-19.53	14.65	34.18
	54 sec	0.700	197	59.28	59.92	-18.84	-0.08	-0.70	40.44	59.84	-0.70	-19.40	41.14	60.54

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.
DESCRIPTION Fatigue Evaluation of Head Flange Vessel Flange And Closure Studs

NUMBER 5-151-P | A91
SHEET 40 OF 51
DATE 5-12-66 BY Cockrell
CHECK DATE 5-12-66 BY Alexander

5. Detailed Analysis:
e. Stresses:
2. Concentrated:

LOCATION -2

Transient		Internal Pressure ksia	(T_m-T) °F	Thermal Stress		Pressure Stress			Peak Stress			Stress Intensity		
				σ_x	σ_θ	σ_x	σ_θ	σ_r	σ_x	σ_θ	σ_r	$\sigma_x-\sigma_\theta$	$\sigma_x-\sigma_r$	$\sigma_\theta-\sigma_r$
Cold Bolt Up		0	0	0	0	38.63	18.16	0	38.63	18.16	0	20.47	38.63	18.16
Bolt Up + 2500 psia		2.5	0	0	0	61.01	28.50		61.01	28.50		32.51	61.01	28.50
a Heatup	4.00 hrs.	1.882		23.13	7.76	55.48	25.94		78.61	33.70		44.91	78.61	33.70
	4.25	2.078		24.68	8.27	57.23	26.75		81.91	35.02		46.89	81.91	35.02
	4.35	2.156		24.62	8.19	57.93	27.08		82.55	35.27		47.28	82.55	35.27
	4.47	2.250		25.57	6.36	58.77	27.47		84.34	33.83		50.51	84.34	33.83
	5.00	2.250		20.54	6.09	58.77	27.47		79.31	33.56		45.75	79.31	33.56
Steady State		2.250		1.65	0.48	58.77	27.47		60.42	27.95		32.47	60.42	27.95
b Cooldown	4.00 hrs.	0.315		-18.62	-5.72	41.45	19.46		22.83	13.74		9.09	22.83	13.74
	4.25			-20.56	-6.54				20.89	12.92		7.97	20.89	12.92
	4.35			-19.87	-6.08				21.58	13.38		8.20	21.59	13.38
	4.47			-20.61	-6.46				20.84	13.00		7.84	20.84	13.00
	5.00	↓		-17.70	-5.10				23.75	14.36		9.39	23.75	14.36
c	20 min	2.250	0	1.65	0.48	58.77	27.47		60.42	27.95		32.47	60.42	27.95
d	20 min	2.250				58.77	27.47		60.42	27.95		32.47	60.42	27.95
e	100 sec.	2.110				57.79	27.01		59.44	27.49		31.95	59.44	27.49
	225 sec	2.275	↓	↓	↓	59.00	27.57	↓	60.65	28.05	↓	32.60	60.65	28.05

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION Fatigue Evaluation Of Head Flange Vessel Flange And Closure Studs

NUMBER 5-151-P 1A 92
SHEET 41 OF 51
DATE 5-12-66 BY [illegible]
CHECK DATE 5-12-66 BY Alexander

5. Detailed Analysis:
e. Stresses:
2. Concentrated:

Location - 2

Transient		Internal Pressure KSIA	$(T_m - T)$ °F	Thermal Stress		Pressure Stress			Peak Stress			Stress Intensity		
				σ_x	σ_θ	σ_x	σ_θ	σ_r	σ_x	σ_θ	σ_r	$\sigma_x - \sigma_\theta$	$\sigma_x - \sigma_r$	$\sigma_\theta - \sigma_r$
f	40 sec	2.320	0	1.65	0.48	59.40	27.75	0	61.05	28.23	0	32.82	61.05	28.23
	100 sec	2.260				58.86	27.50		60.51	27.98		32.53	60.51	27.98
	260 sec	2.140				57.79	27.01		59.44	27.49		31.95	59.44	27.49
g	2 min	2.370				59.85	27.96		61.50	28.44		33.06	61.50	28.44
	3.2 min	2.350				59.67	27.88		61.32	28.36		32.96	61.32	28.84
	10.4 min	2.150				57.88	27.05		59.33	27.53		32.00	59.53	27.53
h	10 sec	2.220				58.50	27.34		60.15	27.82		32.33	60.15	27.82
	65 sec	1.910				55.73	26.06		57.38	26.54		30.84	57.38	26.54
i	220 min	3.125		0	0	66.61	31.08		66.61	31.08		35.53	66.61	31.08
j	HEATUP 3.5 hrs	1.250		25.57	6.36	49.82	23.33		75.39	29.69		45.70	75.39	29.69
	S.S.	2.500		1.65	0.48	61.01	28.50		62.66	28.98		33.68	62.66	28.98
	COOLDOWN 3.5 hrs	0.315		-20.61	-6.46	41.45	19.46		20.84	13.00		7.84	20.84	13.00
k	~	2.350	0	1.65	0.48	59.67	27.88		61.32	28.36		32.96	61.32	28.36
	~	2.150				57.88	27.05		59.53	27.53		32.00	59.53	27.53
l	12 sec	2.250				58.77	27.47		60.42	27.95		32.47	60.42	27.95
m	10 sec	2.760				63.34	29.57		64.99	30.05		34.94	64.99	30.05
	28 sec	2.120				57.61	26.93		59.26	27.41		31.85	59.26	27.41
	160 sec	1.440				51.52	24.12		53.17	24.60		28.57	53.17	24.60
n	33 sec	0.300				41.32	19.40		42.97	19.88		23.09	42.97	19.88
	54 sec	0.700				44.90	21.06		46.55	21.54		25.01	46.55	21.54

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.______

DESCRIPTION Fatigue Evaluation of Head Flange Vessel Flange And Closure Studs

NUMBER 5-151-P | A93
SHEET 42 OF 51
DATE 5-12-66 BY Cockrell
CHECK DATE 5-12-66 BY Alexander

5-Detailed Analysis:
e. Stresses:
2. Concentrated:

Location -3

Transient		Internal Pressure ksia	(T_m-T) °F	Thermal Stress σ_x	Thermal Stress σ_θ	Pressure Stress σ_x	Pressure Stress σ_θ	Pressure Stress σ_r	Peak Stress σ_x	Peak Stress σ_θ	Peak Stress σ_r	Stress Intensity $\sigma_x-\sigma_\theta$	Stress Intensity $\sigma_x-\sigma_r$	Stress Intensity $\sigma_\theta-\sigma_r$
Cold Bolt up		0	0	0	0	-25.23	-6.07	0	-25.23	-6.07	0	-19.16	-25.23	-6.07
Bolt up + 2500 psia		2.5	0	0	0	-10.93	12.83	-2.50	-10.96	12.83	-2.50	-23.79	-9.46	15.33
a Heatup	4.00 hrs.	1.832		-7.05	-24.67	-14.49	8.16	-1.88	-21.54	-16.51	-1.88	-5.03	-19.66	-14.63
	4.25	2.078		-7.12	-25.24	-13.37	9.64	-2.08	-20.49	-15.60	-2.08	-4.89	-19.41	-13.52
	4.35	2.156		-6.54	-25.55	-12.93	10.23	-2.16	-19.47	-15.32	-2.16	-4.15	-17.31	-13.16
	4.47	2.250		-5.43	-25.02	-12.39	10.94	-2.25	-17.82	-14.08	-2.25	-3.74	-15.57	-11.83
	5.00	2.250		4.10	-17.95	-12.39	10.94	-2.25	-8.29	-7.01	-2.25	-1.28	-6.04	-4.76
Steady State		2.250		9.18	0.41	-12.39	10.94	-2.25	-3.21	11.85	-2.25	-15.06	-0.96	14.10
b Cooldown	4.00 hrs.	0.315		13.41	23.95	-23.43	-3.69	-0.32	-10.01	20.26	-0.32	-30.28	-9.70	20.58
	4.25			12.76	24.28				-10.67	20.59	-0.32	-31.26	-10.35	20.91
	4.35			12.35	24.13				-11.08	20.44	-0.32	-31.52	-10.76	20.76
	4.47			13.19	25.15				-10.24	21.46	-0.32	-31.70	-9.92	21.78
	5.00	↓		3.72	17.67			↓	-19.71	13.98	-0.32	-33.69	-19.39	14.30
c	20 min	2.250	-7.8	4.79	-3.48	-12.39	10.94	-2.25	-7.60	7.46	-2.25	-15.06	-5.35	9.71
d	20 min	2.250	7.8	13.57	5.30	-12.39	10.94	-2.25	-1.18	16.24	-2.25	-15.06	3.43	18.49
e	100 sec	2.110	11.2	15.49	7.22	-13.02	10.11	-2.14	2.47	17.33	-2.14	-14.86	4.61	19.47
	225 sec	2.275	1.7	10.14	1.87	-12.25	11.13	-2.28	-2.11	13.00	-2.28	-15.11	0.17	15.28

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER 5-151-1 | A 94
SHEET 43 OF 51
CHARGE NO.
DATE 5-12-66 BY [illegible]
DESCRIPTION Fatigue Evaluation Of Head Flange Vessel Flange And Closure Studs
CHECK DATE 5-17-66 BY [illegible]

5- Detailed Analysis:

e- Stresses:

2- Concentrated:

Location - 3

Transient		Internal Pressure KSIA	(T_m-T) °F	Thermal Stress σ_x	Thermal Stress σ_θ	Pressure Stress σ_x	Pressure Stress σ_θ	Pressure Stress σ_r	Peak Stress σ_x	Peak Stress σ_θ	Peak Stress σ_r	Stress Intensity $\sigma_x-\sigma_\theta$	Stress Intensity $\sigma_x-\sigma_r$	Stress Intensity $\sigma_\theta-\sigma_r$
f	40sec	2.320	-9.3	3.94	-4.33	-11.94	11.47	-2.32	-8.05	7.14	-2.32	-15.19	-5.73	9.46
	10sec	2.260	-13.3	1.69	-6.58	-12.33	11.02	-2.26	-10.64	4.44	-2.26	-15.08	-8.38	6.70
	260sec	2.140	-1.3	8.45	0.18	-13.02	10.11	-2.14	-4.57	10.29	-2.14	-14.86	-2.43	12.43
g	2 min	2.370	-12.0	2.42	-5.85	-11.71	11.85	-2.37	-9.29	6.00	-2.37	-15.29	-6.92	8.37
	3.2 min	2.350	-15.0	0.74	-7.53	-11.82	11.70	-2.35	-11.08	4.17	-2.35	-15.25	-8.73	6.52
	10.4 min	2.150	0	9.18	0.91	-12.96	10.19	-2.15	-3.78	11.10	-2.15	-14.88	-1.63	13.25
h	10 sec	2.220	-9.5	3.93	-4.44	-12.56	10.71	-2.22	-8.73	6.27	-2.22	-15.00	-6.51	8.49
	65sec	1.910	3.5	13.97	5.70	-14.33	9.37	-1.91	-0.36	14.07	-1.91	-14.43	1.55	15.98
i	220 min	3.125	0	0	0	-7.40	17.56	-3.13	-7.40	17.56	-3.13	-24.96	-4.27	20.69
j	Heatup 3.5 hrs	1.250		-5.43	-25.02	-19.10	3.38	-1.25	-23.53	-21.64	-1.25	-1.89	-22.29	-20.39
	S.S.	2.500		9.18	0.91	-10.93	12.33	-2.50	-1.75	13.74	-2.50	-15.49	0.75	16.24
	Cooldown 3.5 hrs	0.315		13.19	25.12	-23.43	-3.69	-0.32	-10.24	21.46	-0.32	-31.70	-9.92	21.78
k	~	2.350	6.0	12.56	4.29	-11.82	11.70	-2.35	0.74	15.99	-2.35	-15.25	3.09	18.34
	~	2.150	-6.0	5.90	-2.47	-12.96	10.19	-2.15	-7.16	7.72	-2.15	-14.88	-5.01	9.87
l	12sec	2.250	33.3	27.43	19.66	-12.39	10.94	-2.25	15.54	30.60	-2.25	-15.06	17.79	32.85
m	16 sec	2.760	-30.2	-7.82	-16.09	-9.48	14.80	-2.76	-17.30	-1.29	-2.76	-16.01	-14.54	1.47
	29 sec	2.120	-41.2	-14.02	-22.29	-13.13	9.96	-2.12	-27.15	-12.33	-2.12	-14.82	-25.03	-10.21
	160 sec	1.440	4.8	11.88	3.61	-17.01	4.82	-1.44	-5.13	8.43	-1.44	-13.56	-3.69	9.87
n	33 sec	0.300	117	75.05	66.78	-23.52	-3.80	-0.30	51.53	62.98	-0.30	-11.45	51.83	63.28
	54 sec	0.700	197	120.09	111.82	-21.24	-0.78	-0.70	99.85	111.04	-0.70	-12.19	99.55	111.74

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.
DESCRIPTION Fatigue Evaluation of Head Flange Vessel Flange And Closure Studs

NUMBER 5-151-P | A 95
SHEET 44 OF 51
DATE 5-12-66 BY Cockrell
CHECK DATE 5-12-66 BY Alexander

5. Detailed Analysis:
e. Stresses:
2. Concentrated:

Location - 4

Transient		Internal Pressure ksia	(T_m-T) °F	Thermal Stress		Pressure Stress			Peak Stress			Stress Intensity		
				σ_x	σ_θ	σ_x	σ_θ	σ_r	σ_x	σ_θ	σ_r	$\sigma_x-\sigma_\theta$	$\sigma_x-\sigma_r$	$\sigma_\theta-\sigma_r$
Cold Bolt Up		0	0	0	0	27.10	9.63	0	27.10	9.63	0	17.47	27.10	9.63
Bolt Up + 2500 psia		2.5	0	0	0	39.55	27.56	↓	39.55	27.56	↓	11.99	39.55	27.56
a Heatup	4.00 hrs.	1.892		-7.25	-0.56	36.48	23.13		29.23	22.57		6.66	29.23	22.57
	4.25	2.078		-7.31	-0.57	37.45	24.54		30.14	23.97		6.17	30.14	23.97
	4.35	2.156		-7.55	-0.84	37.84	15.47		30.29	24.25		6.04	30.29	24.25
	4.47	2.250		-9.14	-0.62	38.31	25.77		29.17	25.15		4.02	29.17	25.15
	5.00	2.250		-14.63	-4.26	38.31	25.77		23.68	21.51		2.17	23.68	21.51
Steady State		2.250		-10.26	-4.05	38.31	25.77		28.05	21.72		6.33	28.05	21.72
b Cooldown	4.00 hrs.	0.315		-0.66	-2.46	28.67	11.89		28.01	9.43		18.59	28.01	9.43
	4.25	↓		-0.55	-2.14	↓	↓		28.12	9.75		18.37	28.12	9.75
	4.35			0.21	-1.96				28.88	9.91		19.97	28.88	9.91
	4.47			0.45	-1.19				29.12	10.70		18.42	29.12	10.70
	5.00			4.90	1.48				33.47	13.37		20.10	33.47	13.37
c	20 min	2.250	0	-10.26	-4.05	38.31	25.77		28.05	21.72		6.33	28.05	21.72
d	20 min	2.250	↓	↓	↓	38.31	25.77		28.05	21.72		6.33	28.05	21.72
e	100 sec	2.140				37.76	24.98		27.50	20.93		6.57	27.50	20.93
	225 sec	2.275				38.43	25.95		28.17	21.90		6.27	28.17	21.90

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER 5-151-P | A-96
SHEET 45 OF 51
CHARGE NO.
DATE 5-12-66 BY Geller
DESCRIPTION Fatigue Evaluation Of Head Flange Vessel Flange And Closure Studs
CHECK DATE 5-12-66 BY Alexander

5. Detailed Analysis:
e. Stresses:
2. Concentrated:

Location – 4

Transient		Internal Pressure KSIA	(T_m-T) °F	Thermal Stress		Pressure Stress			Peak Stress			Stress Intensity		
				σ_x	σ_θ -	σ_x	σ_θ	σ_r	σ_x	σ_θ	σ_r	$\sigma_x-\sigma_\theta$	$\sigma_x-\sigma_r$	$\sigma_\theta-\sigma_r$
f	40sec	2.320	0	-10.26	-4.05	38.66	26.27	0	28.40	22.22	0	6.18	28.40	22.22
	100sec	2.260	↓	↓	↓	38.36	25.84	↓	28.10	21.79	↓	6.31	29.10	21.79
	260sec	2.140	↓	↓	↓	37.76	24.98	↓	27.50	20.93	↓	6.57	27.50	20.93
g	2 min	2.370	↓	↓	↓	38.91	26.63	↓	28.65	22.58	↓	6.07	28.65	22.58
	3.2 min	2.350	↓	↓	↓	38.91	26.49	↓	28.55	22.44	↓	6.11	28.55	22.44
	10.4 min	2.150	↓	↓	↓	37.81	25.05	↓	27.55	21.00	↓	6.55	27.55	21.00
h	10sec	2.220	↓	↓	↓	38.16	25.55	↓	27.90	21.50	↓	6.40	27.90	21.50
	65sec	1.910	↓	↓	↓	36.16	23.33	↓	26.35	19.28	↓	7.07	26.35	19.28
i	220 min	3.125	↓	0	0	42.67	32.05	↓	42.67	32.05	↓	10.62	42.67	32.05
j	HEATUP 3.5 hrs	1.250	X	-9.14	-0.62	33.33	18.59	↓	24.19	17.97	↓	6.22	24.19	17.97
	S.S.	2.500		-10.26	-4.05	39.55	27.56	↓	29.29	23.51	↓	5.78	29.29	23.51
	COOLDOWN 3.5 hrs	0.315		0.45	-1.19	29.67	11.89	↓	29.12	10.70	↓	18.42	29.12	10.70
k	~	2.350	0	-10.26	-4.05	38.81	26.49	↓	28.55	22.44	↓	6.11	28.55	22.44
	~	2.150	↓	↓	↓	37.81	25.05	↓	27.55	21.00	↓	6.55	27.55	21.00
l	12sec	2.250	↓	↓	↓	38.31	25.77	↓	28.05	21.72	↓	6.33	28.05	21.72
m	10 sec	2.760	↓	↓	↓	40.85	29.43	↓	30.59	25.38	↓	5.21	30.59	25.38
	29 sec	2.170	↓	↓	↓	37.66	24.84	↓	27.40	20.79	↓	6.61	27.40	20.79
	160 sec	1.440	↓	↓	↓	34.27	19.96	↓	24.01	15.91	↓	8.10	24.01	15.91
n	33 sec	0.300	↓	↓	↓	28.59	11.78	↓	18.33	7.73	↓	10.60	18.33	7.73
	54 sec	0.700	↓	↓	↓	30.59	14.65	↓	20.33	10.60	↓	9.73	20.33	10.60

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER 5-151-P | A 97
SHEET 46 OF 51
CHARGE NO.
DATE 5-12-66 BY Cockrell
DESCRIPTION Fatigue Evaluation Of Head Flange Vessel Flange And Closure Studs
CHECK DATE 5-12-66 BY Alexander

5. Detailed Analysis:
e. Stresses:
2 Concentrated:

Transient		Location-5	Location-6	Location-7	Location-8
		σ_x	σ_x	σ_x	σ_x
Cold Bolt-Up		119.64	175.24	273.24	21.64
Bolt-Up + 2500 psi		201.16	118.44	231.20	88.40
a Heatup	4.00 hrs	185.04	179.20	367.16	-6.92
	4.25 hrs	197.20	168.36	364.84	0.72
	4.35	202.36	164.64	363.40	3.56
	4.47	203.56	164.56	366.64	1.48
	5.00	217.12	161.48	360.68	17.92
Steady State		195.36	131.64	229.36	97.64
b Cooldown	4.00 hrs	120.68	136.44	151.52	105.72
	4.25	117.60	133.00	144.84	105.88
	4.35	114.60	134.68	145.24	104.16
	4.47	111.40	133.28	143.08	101.72
	5.00	96.56	140.68	152.92	84.44
c	20 min	195.36	131.64	229.36	97.64
d	20 min	195.36	131.64	229.36	97.64
e	100 sec	191.80	134.12	231.20	94.72
	225 sec	196.20	131.04	228.92	98.32

Transient		Location-5	Location-6	Location-7	Location-8
		σ_x	σ_x	σ_x	σ_x
f	40sec	197.68	130.04	228.16	99.52
	100sec	195.72	131.40	229.20	97.92
	260sec	191.80	134.12	231.20	94.72
g	2 min	199.28	128.88	227.32	100.84
	3.2 min	198.64	129.36	227.68	100.32
	10.4 min	192.12	133.88	231.04	94.96
h	10 sec	192.80	132.32	229.84	96.84
	65sec	184.28	139.36	235.08	88.56
i	220min	221.56	104.20	220.68	105.08
j	Heatup 3.5 hrs	170.96	187.24	383.48	-26.00
	S.S.	203.52	125.96	225.16	104.32
	Cooldown 3.5hrs	111.40	133.28	143.08	101.72
k	~	198.64	129.36	227.68	100.32
	~	192.12	133.88	231.04	94.96
l	12sec	195.36	131.64	229.36	97.64
m	10sec	212.00	120.04	220.76	111.28
	28sec	191.12	134.56	231.56	94.16
	160sec	168.96	150.04	242.96	76.00
n	33sec	131.64	175.92	262.16	45.56
	54sec	144.84	166.80	255.44	56.24

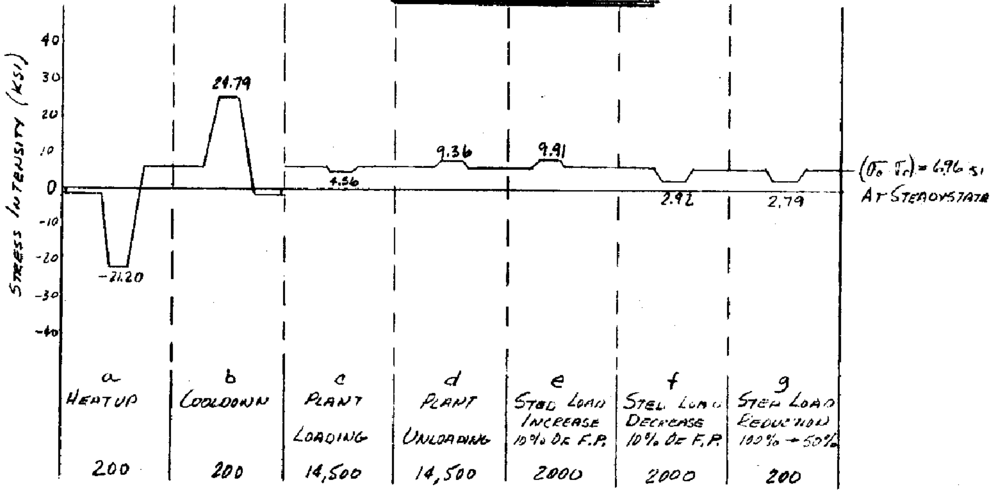
COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION Fatigue Evaluation Of Head Flange Vessel Flange And Closure Studs

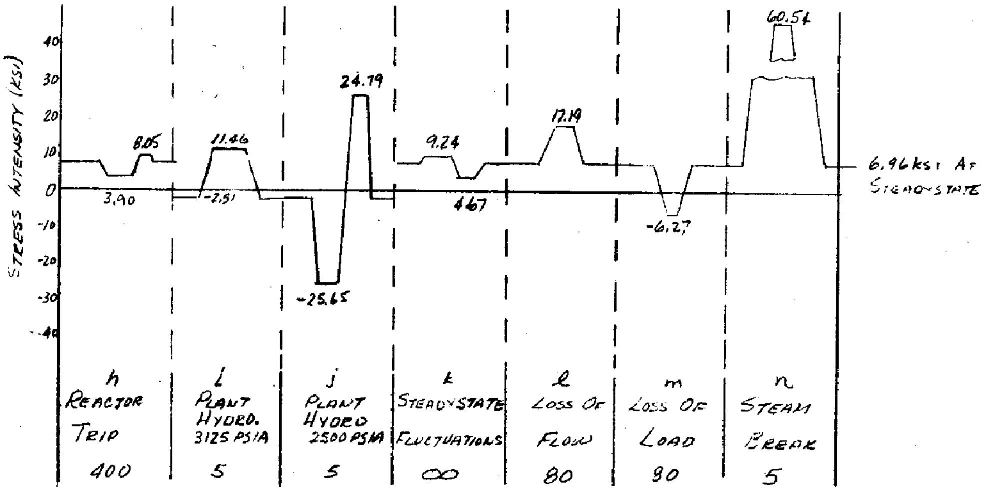
NUMBER 5-151-P | A98
SHEET 47 OF 51
DATE 5-12-66 BY Cockrell
CHECK DATE 5-12-66 BY Alexander

5. DETAILED ANALYSIS:

f. FATIGUE EVALUATION:

$(\sigma_\theta - \sigma_r)$ AT LOCATION - 1





S_{MAX}	S_{MIN}	Number Of Occurrences	S_{ALT}	N^*	U
60.54	-25.65	5	43.1	6600	0.00075
24.79	-21.20	195	23.0	56000	0.00348
17.19	-6.27	80	11.7	∞	0

* From Fig. N-415(A) Reference 1

$U_{OVERALL} = 0.00423$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO. ______

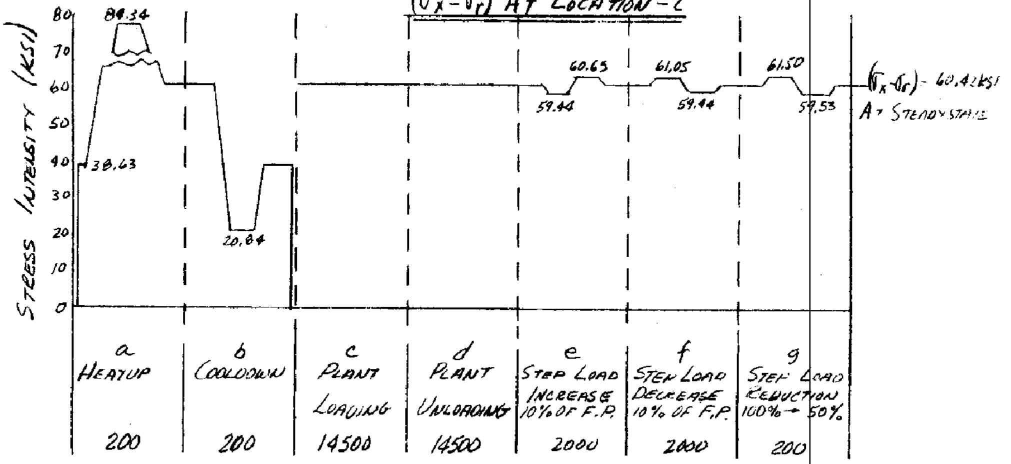
DESCRIPTION *Fatigue Evaluation Of Head Flange Vessel Flange And Closure Studs*

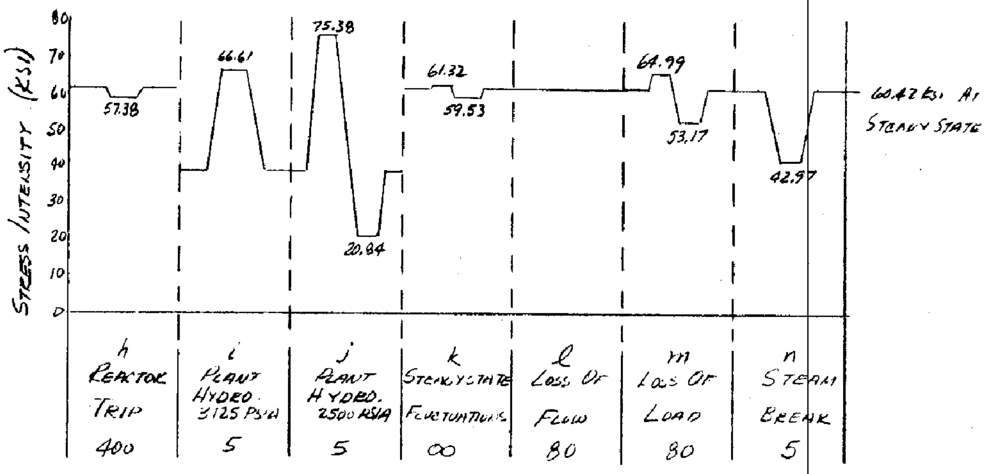
NUMBER *5-151-P* | *A 99*
SHEET *48* OF *51*
DATE *5-12-66* BY *Cockrell*
CHECK DATE *5-12-66* BY *Alexander*

5. Detailed Analysis:

f. Fatigue Evaluation:

$(\sigma_x - \sigma_r)$ At Location-2





S_{MAX}	S_{MIN}	Number of Occurrences	S_{ALT}	N^*	U
84.34	0	40	42.2	7000	0.00571
84.34	20.84	160	31.8	18000	0.00888
75.38	20.84	5	27.3	30000	0.00016
66.61	38.63	5	14.0	600000	0.00001
64.99	42.97	5	11.0	∞	0

* From Fig. N-415(A) Reference 1

$U_{OVERALL} = 0.01476$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT. CHATTANOOGA. TENN.

CHARGE NO.

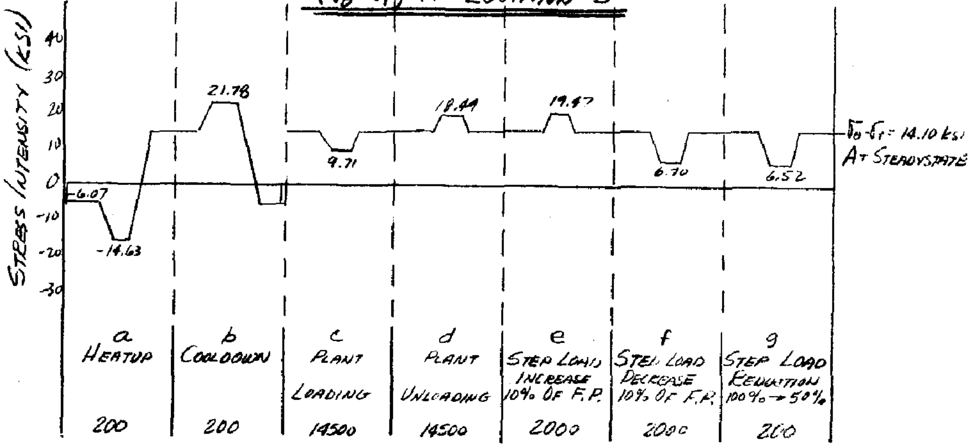
DESCRIPTION Fatigue Evaluation Of Head Flange Vessel Flange And Closure Studs

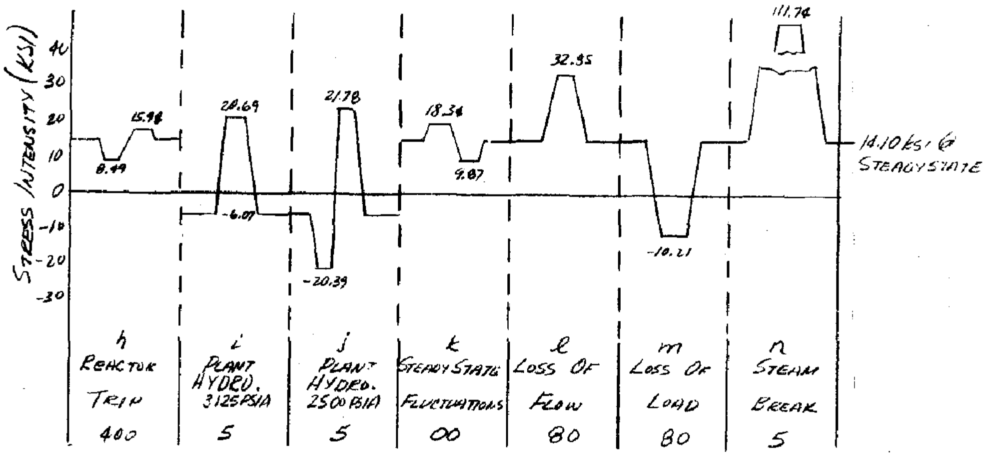
NUMBER S-151-P | A100
SHEET 49 OF 51
DATE 5-12-66 BY Cockrell
CHECK DATE 5-12-66 BY Alexander

5- Detailed Analysis:

f- Fatigue Evaluation:

$(\sigma_b \cdot \sigma_r)$ At Location 3





S_{max}	S_{min}	Number Of Occurrences	S_{alt}	N*	U
111.74	-20.39	5	66.1	2000	0.00250
32.85	-14.63	80	23.7	51000	0.00156
21.78	-14.63	115	18.2	140000	0.00082
19.47	-10.21	80	14.8	400000	0.00020
20.69	-6.07	5	13.4	800000	0.00001
19.47	6.52	200	6.5	∞	0

* From Fig. N-415(A) Reference 1

$U_{overall} = 0.00508$

RIV000052C
Submitted: December 22, 2011

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

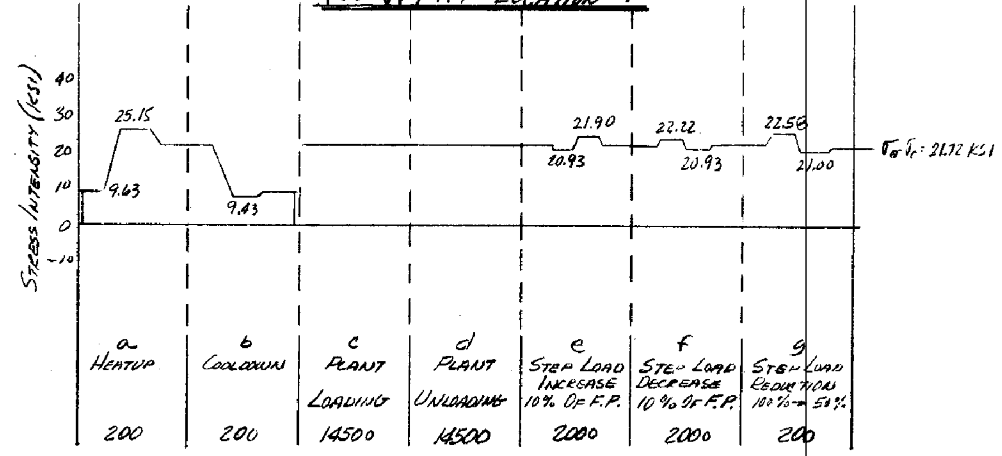
NUMBER S-151-P | A 101
SHEET 50 OF 51
DATE 5-12-66 BY COCKRELL
CHECK DATE 5-12-66 BY ALEXANDER

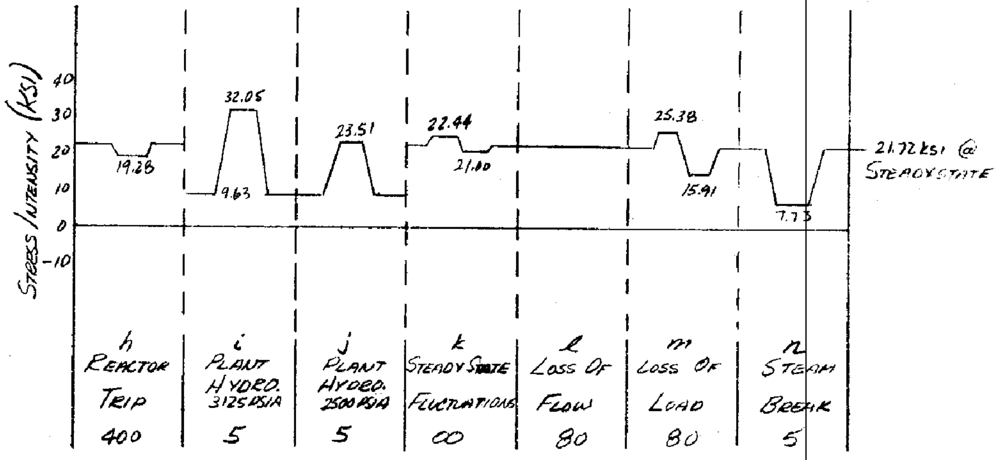
DESCRIPTION FATIGUE EVALUATION OF HEAD FLANGE VESSEL FLANGE AND CLOSURE STUDS

5. DETAILED ANALYSIS:

f. FATIGUE EVALUATION:

$(\sigma_\theta - \sigma_r)$ AT LOCATION-4





S_{MAX}	S_{MIN}	NUMBER OF OCCURRENCES	S_{ALT}	N^*	U
32.05	0	5	16.1	260000	0.00002
25.38	0	80	12.7	∞	0

* FROM FIG. N-415(A) REFERENCE 1

$U_{OVERALL} = 0.00002$

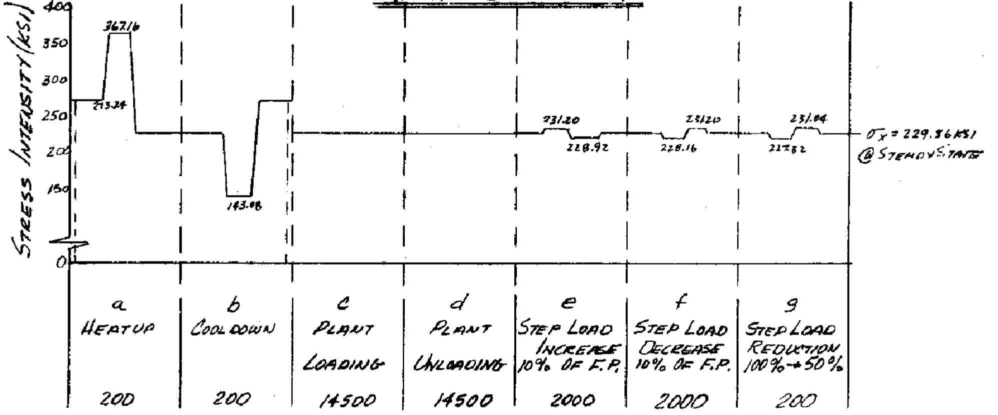
COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT. CHATTANOOGA. TENN.
CHARGE NO.
DESCRIPTION Fatigue Evaluation Of Head Flange Vessel Flange And Closure Studs

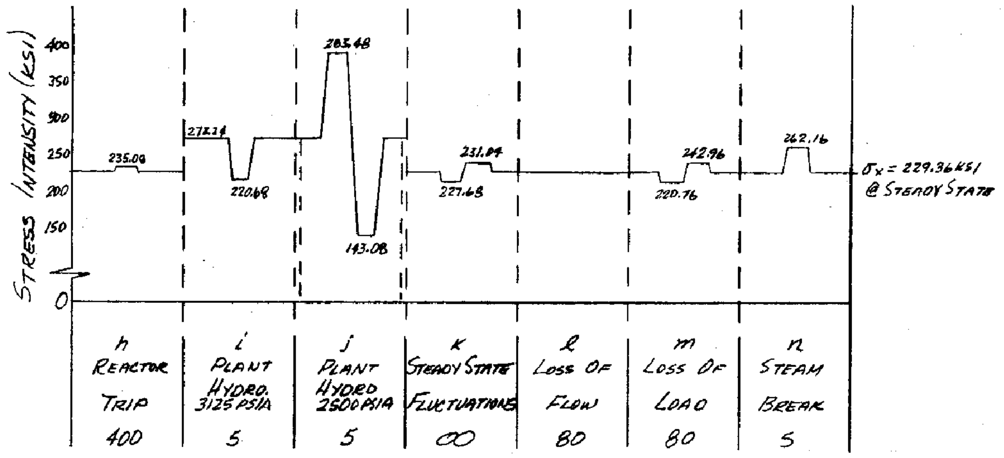
NUMBER S-151-P | A 102
SHEET 51 **OF** 51
DATE 5-12-66 **BY** Cockrell
CHECK DATE 5-12-66 **BY** Alexander

5- Detailed Analysis:

f- Fatigue Evaluation:

σ_x At Location-7





S_{MAX}	S_{MIN}	S_{ALT}	S_{eq}	Number Of Occurrences	N	U
383.48	0	191.74	191.74	5	218	0.02294
367.16	0	183.58	183.58	35	246	0.14228
367.16	143.08	112.04	112.04	165	1140	0.14473
273.24	220.68	26.28	92.31	5	2450	0.00204
262.16	220.76	20.70	62.61	5	12960	0.00038
242.96	220.76	11.10	42.86	75	122426	0.00061
235.08	227.32	7.76	33.16	200	∞	0

$$*\ N=\frac{1}{5.7}\left[\frac{10^4}{2S_{eq.}-10^2}\right]^2$$

For $S_{eq.} > 78$ ksi

$$N=\left[\frac{10^4}{3S_{eq.}-10^2}\right]^2$$

For $S_{eq.} \leq 78$ ksi

See N-416.2 Of Ref. 1

$U_{overall} = 0.31298$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION Nozzle Code Calculation

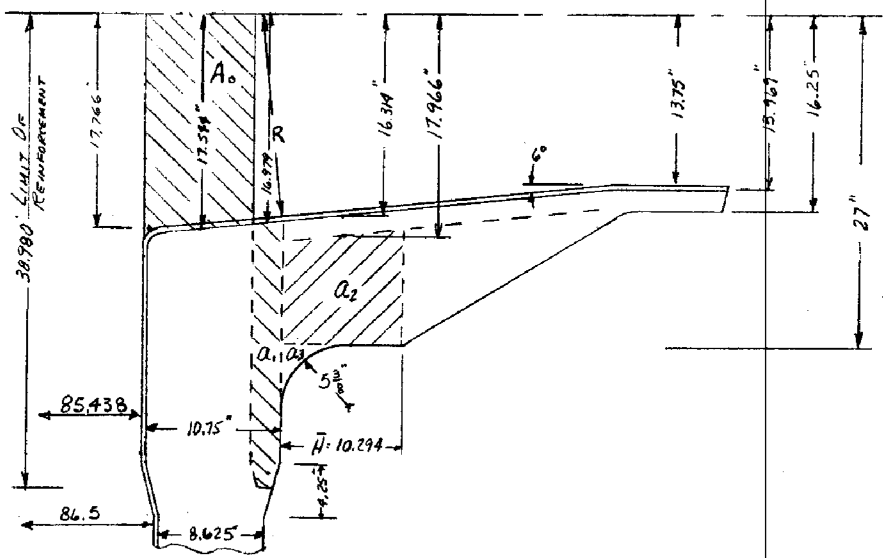
NUMBER S-210-P | A 103
SHEET 4 **OF** 14
DATE 10-15-65 **BY** Cockrell
CHECK DATE 10-20-65 **BY** Ferguson

5- DETAILED ANALYSIS:

a. REINFORCEMENT CALCULATIONS:

1- INLET NOZZLE:

A CROSS-SECTION OF THE INLET NOZZLE IS SHOWN BELOW. CERTAIN DIMENSIONS ARE GIVEN TO FACILITATE THE ANALYSIS



THE GENERAL PROCEDURE FOR INSURING ADEQUATE REINFORCEMENT IS OUTLINED IN PARAGRAPHS N-451 THRU N-456 OF THE SECTION III NUCLEAR CODE

THE MINIMUM REQUIRED SHELL THICKNESS IS:

$$t_{REQ} = \frac{PR}{S_m - 0.5P} = \frac{2.5(85.438)}{26.7-1.25} = \underline{\underline{8.393''}}$$

THE REQUIRED NOZZLE THICKNESS IS:

$$R = \frac{17.766 - 10.75 \tan 6^\circ}{\cos 6^\circ} = \frac{17.766 - 10.75(0.1051)}{0.99452} = 16.728'$$

$$t_{REQ} = \frac{PR}{S_m - 0.5P} = \frac{2.5(16.728)}{26.7-1.25} = \underline{\underline{1.643''}}$$

SEE ARTICLE I-110 OF APPENDIX I OF SECTION III

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION Nozzle Code Calculation

NUMBER S-210-P | A 104
SHEET 5 **OF** 14
DATE 10-15-65 **BY** Campbell
CHECK DATE 10-20-65 **BY** Ferguson

5. Detailed Analysis:

a - Reinforcement Calculation:

1- Inlet Nozzle:

From Paragraph N-452, The Area Removed Is Given By:

$$A_o = d\,t_r\,F = 2(17.544)(8.393)(1) + \left[(1.75)^2\left(1 - \frac{\pi}{4}\right)\right]2 = 295.81\ in^2$$

Where:

d = Average Dia. Of Hole Thru Code Thickness Of Shell
t_r = Code Thickness Of Shell
F = See Figure 452 Of Section III

Consider The Limits Of Compensation As Outlined In N-454:

The Limit Of Reinforcement Along The Vessel Wall Is The Larger Of:

1- The Diameter Of The Opening In The Corroded Condition = 35.088"

2- The Sum Of The Finished Corroded Radius, The Actual Base Metal Vessel Shell Thickness, And The Thickness Of The Nozzle Wall = 17.544 + 10.75 + 10.686 = $\underline{38.980"}$ ← Use

The Limit Of Reinforcement Measured Normal To The Vessel Shall Be Equal To,

$$\bar{H} = 0.5\sqrt{r_m t} + 0.5\,R_2 = 0.5\sqrt{(21.657)(10.686)} + 0.5(5.375)$$

$$= \underline{10.294"}$$

r_m = Mean Nozzle Radius = $\frac{16.314 + 27}{2}$ = 21.657"
t = Nominal Nozzle Wall Thickness = 10.686"
R_2 = Transition Radius Between Nozzle & Vessel Wall = 5.375"

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.
DESCRIPTION Nozzle Code Calculations

NUMBER 5-210-P | A 105
SHEET 6 **OF** 14
DATE 10-16-65 **BY** Cockrell
CHECK DATE 10-20-65 **BY** Ferguson

5- DETAILED ANALYSIS:

a. REINFORCEMENT CALCULATIONS:

1- INLET NOZZLE:

THE TOTAL AREA OF REINFORCEMENT CONSISTS OF THE THREE AREAS DESIGINATED a_1, a_2, AND a_3 ON SHEE-4.

$$a_1 = 2(38.980 - 16.979)(2.357) - (2.23)(0.853) = 101.81 \text{ in}^2$$
$$a_2 = 2(27 - 17.966)(10.294) = 185.99 \text{ in}^2$$
$$a_3 = 2(5.375)^2(1 - \frac{\pi}{4}) = 12.40 \text{ in}^2$$
$$a_{TOTAL} = 300.20 \text{ in}^2$$

$a_{TOTAL} = 300.2 > 295.8$ ∴ ADEQUATE REINFORCEMENT IS PROVIDED

NOTE THAT 2/3 OF THE REQUIRED REINFORCEMENT MUST BE WITHIN THE LIMIT,

$$r + 0.5\sqrt{Rt}$$

WHERE:

R = THE MEAN SHELL RADIUS = 91.032"
t = THE NIMINAL VESSEL THICKNESS = 10.75"
r = THE INSIDE NOZZLE RADIUS = 16.314"

$$r + 0.5\sqrt{Rt} = 16.314 + 0.5\sqrt{(91.032)(10.75)} = 31.955"$$

AREA OUTSIDE LIMIT $= 2(38.980 - 31.955)(2.357) - (2.23)(0.853)$
$= 31.21 \text{ in}^2$

$\frac{31.21}{300.20} = 0.10$ ∴ LESS THAN 1/3 OF REINFORCEMENT IS OUTSIDE OF THE LIMIT - REQUIREMENT SATISFIED,

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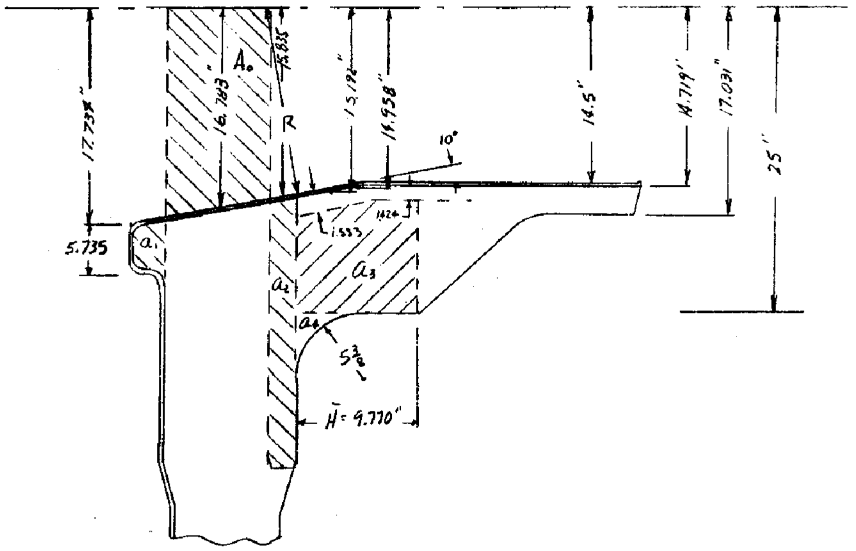
CHARGE NO.
DESCRIPTION *Nozzle Code Calculations*

NUMBER 5-210-P | A 106
SHEET 7 OF 14
DATE 10-15-65 BY Cockrell
CHECK DATE 10-20-65 BY Ferguson

5- Detailed Analysis:
a- Reinforcement Calculations:
2- Outlet Nozzle:

A Cross Section Of The Outlet Nozzle Is Shown Below. Certain Dimensions Are Given To Facilitate The Analysis.



THE MINIMUM REQUIRED SHELL THICKNESS IS:

$t_{REQ} = 8.393''$

THE REQUIRED NOZZLE THKKNESS IS:

$$R_1 = \frac{17.734 - 13.403 \tan 10^\circ}{\cos 10^\circ} = \frac{17.734 - 13.403(.17633)}{0.98481} = 15,607''$$

$$t_{REQ.1} = \frac{PR_1}{S_m - 0.5P} = \frac{2.5(15,607)}{26.7 - 1.25} = 1.533''$$

$$t_{REQ.2} = \frac{PR_2}{S_m - 0.5P} = \frac{2.5(14.5)}{26.7 - 1.25} = 1.424''$$

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CHARGE NO.
DESCRIPTION NOZZLE CODE CALCULATION

NUMBER S-210-1P | A 107
SHEET 8 OF 14
DATE 10-15-65 BY COCKRELL
CHECK DATE 10-20-65 BY FERGUSON

5- DETAILED ANALYSIS:
a. REINFORCEMENT CALCULATIONS:
2. OUTLET NOZZLE:

AREA REMOVED:

$$A_o = d\,t_r\,F = 2(16.783)(8.393)(1) = 281.72\ in^2$$

LIMIT OF REINFORCEMENT:

1- ALONG VESSEL WALL (LARGER OF):

a - DIAMETER OF OPENING IN THE CORRODED CONDITION
= 33.566 "

b - FINISHED CORRODED RADIUS + VESSEL THICKNESS +
NOZZLE WALL THICKNESS = 16.783 + 10.75 + 10.042
= 37.575 " ⟸ USE

2. NORMAL TO VESSEL WALL:

$$\bar{H} = 0.5\sqrt{r_m t} + 0.5R_2 = 0.5\sqrt{(19.979)(10.042)} + 0.5(5.375)$$

$$= 9.770\ ''$$

AREA OF REINFORCEMENT:

$$a_1 = 2\left[(2.438)(5.297) - (1.094)^2\left(1 - \tfrac{\pi}{4}\right)\right] = 25.31$$
$$a_2 = 2(37.575 - 15.835)(2.357) - (.825)(.315) = 102.48$$
$$a_3 = 2(4.937)(25 - 16.749) + 2(4.823)(25 - 16.143) = 167.08$$
$$a_4 = 2(5.375)^2\left(1 - \tfrac{\pi}{4}\right) = 12.40$$
$$307.27\ in^2$$

$$a_{TOTAL} = 307.27\ in^2 > 281.72\ in^2 \therefore \text{ADEQUATE REINFORCEMENT}$$

2/3 AREA REQUIREMENT

$LIMIT = r + 0.5\sqrt{Rt} = 30.599\ in$

AREA OUTSIDE LIMIT = 32.625

$$\frac{32.625}{307.27} = 0.11 \therefore \text{REQUIREMENT SATISFIED}$$

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CHARGE NO.

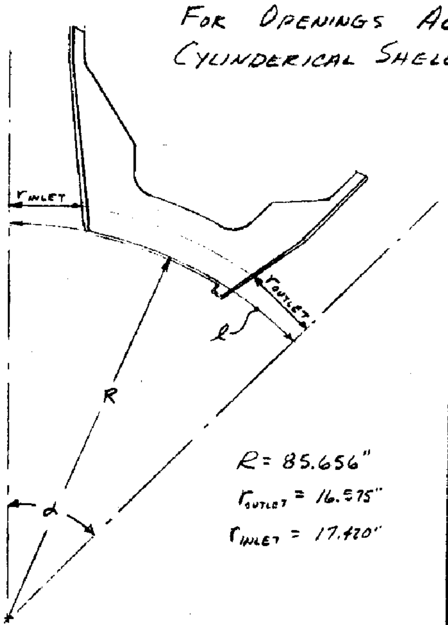
DESCRIPTION NOZZLE CODE CALCULATION

NUMBER S-210-P | A 108
SHEET 9 OF 14
DATE 10-15-65 BY COCKRELL
CHECK DATE 10-20-65 BY FERGUSON

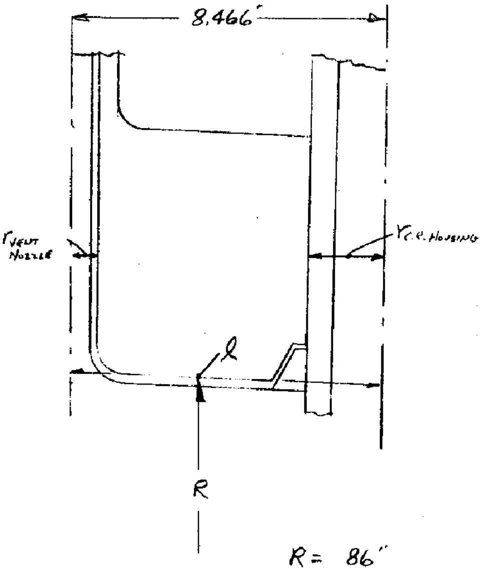
5- DETAILED ANALYSIS:
b- NOZZLE SPACING:
INLET, OUTLET, & VENT NOZZLES:

IN ORDER TO USE THE STRESS INDEX METHOD OF STRESS EVALUATION, THE REQUIREMENTS OF ARTICLE I-6, I-613 MUST BE SATISFIED. THE APPLICABLE PORTIONS OF SECTION I-613 ARE CONSIDERED BELOW.

I-613-b: STATES THAT THE ARC DISTANCE MEASURED BETWEEN THE CENTER LINES OF ADJACENT NOZZLES MEASURED ALONG THE INSIDE SURFACE OF THE SHELL SHALL NOT BE LESS THAN
1- THREE TIMES THE SUM OF THEIR INSIDE RADII FOR OPENINGS IN A HEAD,
2- TWO TIMES THE SUM OF THEIR INSIDE RADII FOR OPENINGS ALONG THE CIRUMFERENCE OF A CYLINDERICAL SHELL.



INLET & OUTLET NOZZLES



VENT NOZZLE

$R = 86''$
$r_{CR\ HOUSING} = 2''$
$r_{VENT\ NOZ.} = 0.781''$

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CHARGE NO.
DESCRIPTION Nozzle Code Calculation

NUMBER S-210-P | A 109
SHEET 10 **OF** 14
DATE 10-15-65 **BY** Cockrell
CHECK DATE 10-20-65 **BY** Ferguson

5. Detailed Analysis:
b. Nozzle Spacing
Inlet, Outlet & Vent Nozzles:

I-613-b (Cont'd):

	α (Actual)	α^* (Required)
2 Inlet Nozzles	46°	46.609°
2 Outlet Nozzles	44°	44.348°
1 Inlet 1 Outlet	45°	45.479°
Vent Noz. C.R. Housing	5.622°	5.059°

$$^*\alpha \geqq \frac{2(r_1+r_2)}{R}\left(\frac{180}{\pi}\right)$$ (For Inlet & Outlet Nozzles)

$$\alpha \geqq \frac{3(r_1+r_2)}{R}\left(\frac{180}{\pi}\right)$$ (For Vent Nozzle)

We See From This Table That All Nozzles Meet The Spacing Requirement Except By A Negligible Amount (Less Than 1°).

I-613-c: States That,

1- The Ratio Of The Inside Shell Diameter To The Shell Thickness Shall Not Exceed (a) 100 For Cylinderical Shells And (b) 100 For Spherical Shells
2- The Ratio Of The Inside Nozzle Diameter To The Inside Shell Diameter Shall Not Exceed 0.5

	Condition 1	Condition 2
Inlet Nozzle	15.9 < 100	0.203 < 0.5
Outlet Nozzle	15.9 < 100	0.194 < 0.5
Vent Nozzle	24.6 < 100	0.006 < 0.5

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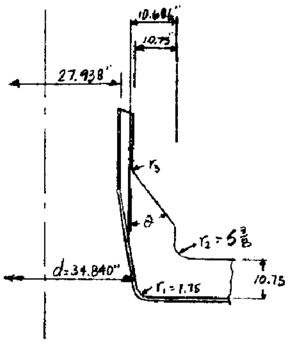
CHARGE NO.
DESCRIPTION Nozzle Code Calculations

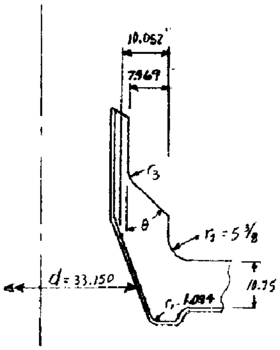
NUMBER S-210-P | A 110
SHEET 11 **OF** 14
DATE 10-15-65 **BY** Cockrel
CHECK DATE 10-20-65 **BY** Ferguson

5 - Detailed Analysis:
b - Nozzle Spacing:
Inlet, Outlet & Vent Nozzle:

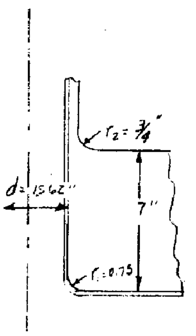
Shown Below Are Certain Dimensions For The Inlet, Outlet And Vent Nozzles Which Must Meet Certain Values In I-613-d → f.



Inlet Nozzle



Outlet Nozzle



Vent Nozzle

I-613-d States That r_1 Must Be Between 0.1 And 0.5 Times The Shell Thickness

Nozzle	r_1 (Actual)	r_1 (Req)
Inlet	1.75	$1.08 \leq r_1 \leq 5.39$
Outlet	1.094	$1.08 \leq r_1 \leq 5.38$
Vent	0.75	$0.7 \leq r_1 \leq 3.5$

$0.1t \leq r_1 \leq 0.5t$

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CHARGE NO.
DESCRIPTION Nozzle Code Calculation

NUMBER 5-210-P | A-111
SHEET 12 **OF** 14
DATE 10-15-65 **BY** Cockrell
CHECK DATE 10-20-65 **BY** Ferguson

5- Detailed Analysis:

6- Nozzle Spacing:

Inlet, Outlet & Vent Nozzle:

I-613-e States That r_2 Should Be Large Enough To Provide A Smooth Transition Between Nozzle And Shell. In Addition, If The Opening Diameter Is Greater Than 1½ Times The Shell Thickness For Cylinderical Shells And 3 Times The Shell Thickness For Spherical Shells, Then r_2 Shall Be Equal To Or Greater Than The Larger Of The Nozzle Or Shell Thickness.

Nozzle	r_2 (Actual)	r_2 (Req'd)
Inlet	5.375	5.375
Outlet	5.375	5.375

$r_{2\,req'd} = 0.5\ t_n$ or $0.5\ t_s$

Note That The Diameter Of The Vent Nozzle Is Less Than $3\ t_{shell}$; Hence r_2 Is Not Limited To $0.5\ t_n$ Or $0.5\ t_s$.

I-613-f States That r_3 Must Be Equal To Or Greater Than The Larger Of $0.002\ D_o$ Or $2\,(\sin\theta)^3\,(\text{Offset})$, Where D_o = Outside Dia Of Noz.

Nozzle	r_3 (Actual)	r_3 (Req'd)
Inlet	3.219	3.203
Outlet	5.408	5.381

$$r_3(\text{req'd}) \geq 0.002\,D_o \quad \text{or} \quad \geq 2\,(\sin\theta)^3(\text{Offset})$$

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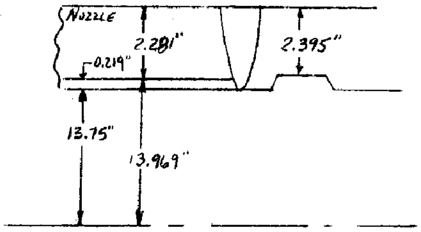
CHARGE NO.
DESCRIPTION NOZZLE CODE CALCULATIONS

NUMBER 5-210-P | A-112
SHEET 13 **OF** 14
DATE 5-15-65 **BY** COCKRELL
CHECK DATE 5-20-65 **BY** FERGUSON

5. DETAILED ANALYSIS:
b- NOZZLE SPACING:
INLET, OUTLET & VENT NOZZLE:

FROM THE RESULTS AS GIVEN ON SHEETS 9 – 12, WE SEE THAT THE INLET AND OUTLET NOZZLES DO NOT MEET ALL THE REQUIREMENTS OF I-6, I-613; HENCE, THE STRESS INDEX METHOD OF STRESS EVALUATION CANNOT BE USED. SINCE THIS IS THE CASE, AN INTERACTION ANALYSIS OF THE NOZZLE TO VESSEL JUNCTURE WILL HAVE TO BE PERFORMED. WE SEE, HOWEVER, THAT THE VENT NOZZLE DOES MEET ALL THE REQUIRMENTS OF I-6, I-613, THEREFORE, THE STRESS INDEX METHOD CAN BE USED FOR THE VENT NOZZLE.

c- NOZZLE AND SAFE END CODE SIZING:
1- INLET NOZZLE:



NOZZLE:
SA-336 $S_m = 26.7$ ksi @ 650°F

SAFE END:
SA-182-F-316 $S_m = 16.7$ ksi @ 650°F

FOR THE NOZZLE END FROM I-110 OF SECTION III:

$$t_{MIN,REQ} = \frac{PR}{S_m - 0.5P} = \frac{2.5(13.750)}{26.7 - 1.25} =$$

$$= \underline{1.351"} \quad (\text{Use } 2.281" \text{ min})$$

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CHARGE NO.

DESCRIPTION NOZZLE CODE CALCULATIONS

NUMBER 5-210-P | A113
SHEET 14 OF 14
DATE 5-15-65 BY COCKRELL
CHECK DATE 5-20-65 BY FERGUSON

5- DETAILED ANALYSIS:

C- NOZZLE AND SAFE END CODE SIZING:

1- INLET NOZZLE:

THE NOZZLE SAFE END IS CLASSIFIED AS PIPING IN PARAGRAPH N-150 OF SECTION III. IT THEREFORE MUST BE SIZED BY THE CODE FOR PRESSURE PIPING, SEE REFERENCE 8, WHICH DEFINES THE THICKNESS BY

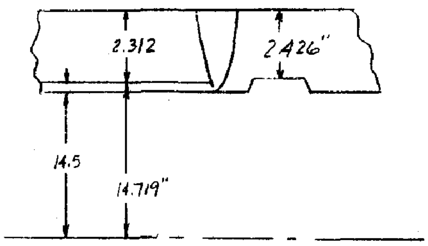
$$t_{MIN.} = \frac{PD}{2S+2yP} + C$$

$$= \frac{(2.5)(32.5)}{2(16.7)+2(0.4)(2.5)}$$

$$= \underline{\underline{2.295'' \quad (USE\ 2.395'')}}$$

WHERE: P IS THE DESIGN PRESS OF 2.5 ksi
D IS THE O.D. OF PIPE = 32.5"
S IS THE ALLOWABLE OF MATERIAL - TAKEN AS S_m FOR SA-182-F-316 FROM SECTION III @ 650°F, S_m = 16.7 ksi
$y = 0.4$, $C = 0$ } FROM REF. 8

2- OUTLET NOZZLE:



FOR NOZZLE END:

$$t_{MIN.\ REQ'D} = \frac{PR}{S_m - 0.5P} = \frac{2.5(14.5)}{26.7-1.25} = \underline{\underline{1.424'' \quad USE\ 2.312''}}$$

FOR SAFE END:

$$t_{MIN\ REQ'D} = \frac{PD}{2S+2yP} + C = \frac{2.5(34.062)}{2(16.7)+2(0.4)(2.5)} = \underline{\underline{2.406'' \quad USE\ 2.426''}}$$

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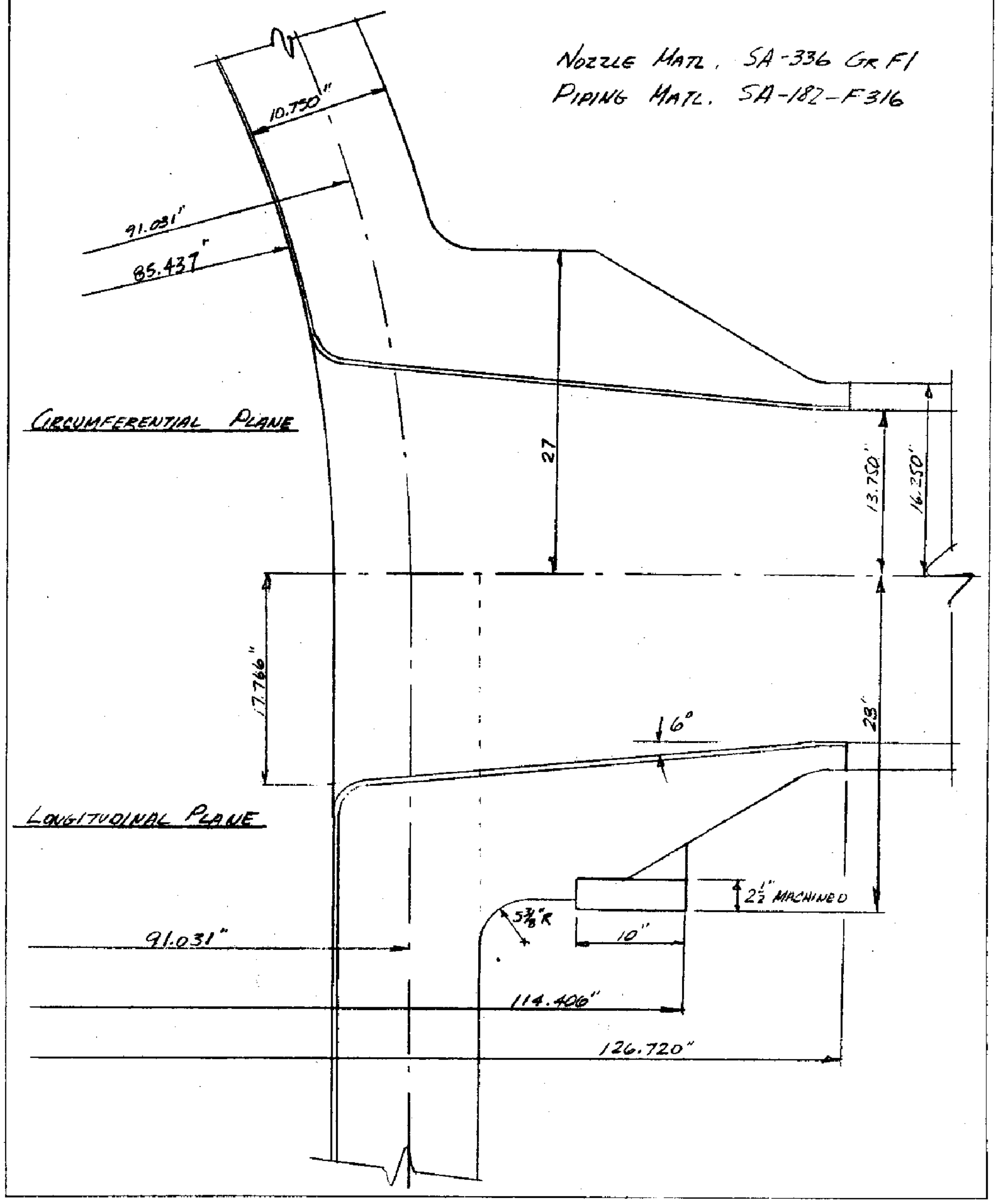
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

NUMBER 5-211-P | A114
SHEET 6 OF 69
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5. DETAILED ANALYSIS:

a - SYSTEM GEOMETRY:



COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION Structural And Fatigue Evaluation Of Inlet Nozzle – Vessel Support

NUMBER 5-211-P | A 115
SHEET 7 OF 69
DATE 4-22-68 BY Cockrell
CHECK DATE 4-22-68 BY Heilker

5. Detailed Analysis:

b. System Allowables:

1- The Stress Intensity In The Reinforcement Portion Of The Nozzle Resulting From Design Pressure And From External Load Or Moment Shall Not Exceed S_m At Design Temp.

2- The Stress Intensity Derived From The Average Primary Plus The Local Primary Stress Shall Not Exceed $1.5 S_m$ At Design Temp.

3- The Stress Intensity Around The Nozzle To Shell Juncture Resulting From Internal Pressure, Pipe Loads, Weight Of Vessel And Reactions From External Loads Shall Not Exceed $1.5 S_m$ At Design Temp.

4- The Stress Intensity In The Nozzle Outside Of The Reinforcement Portion Of The Nozzle And The Safe End Resulting From Design Pressure And From Design Seismic Load Or Moment Shall Not Exceed $1.5 S_m$ At Design Temp.

5- The Range Of Primary Plus Secondary Stress Intensity Resulting From Mechanical Or Thermal Loads Shall Not Exceed $3 S_m$ At Operating Pressure And Temp.

6- Show That Each Point Meets The Requirements For Peak Stress Intensity Given In N-414.5 Of The ASME Code. The Procedure Will Be As Outlined In N-415.2 Of Sect. III.

Note That For The Consideration Of "No Loss Of Function" Seismic Nozzle Loads, The Above Allowables (Where Applicable) Will Be Increased By A Factor Of 1.2.

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ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION Structural And Fatigue Evaluation Of Inlet Nozzle – Vessel Support

NUMBER 5-211-P | A 116
SHEET 8 **OF** 69
DATE 4-22-68 **BY** Cockrell
CHECK DATE 4-22-68 **BY** Heilker

5. Detailed Analysis:

c. System Loading:

1. Internal Pressure:

The Inlet Nozzle And The Vessel Wall In The Vicinity Of The Nozzle Will Be Investicated For The Design Pressure Where Applicable And The Operating Pressures During The Transients Listed In 5.C.2. The Stresses Resulting From Internal Pressure Are Determined From An Interaction Analysis And Are Presented In 5.e. The Peak Stresses Due To Internal Pressure At The Juncture Of The Nozzle To Vessel Shell Will Be Taken As Given In I-610 Of The ASME Code Sect. III.

2. Thermal Transients:

The Inlet Nozzle And The Vessel Wall Will Be Analyzed For The Following Transient Conditions.

Transient	Number Of Occurrences
a. Plant Heatup At 100°F Per Hour	200
b. Plant Cooldown At 100°F Per Hour	200
c. Plant Loading At 5% Of Full Power Per Min.	14500
d. Plant Unloading At 5% Of Full Power Per Min.	14500
e. Step Load Increase Of 10% Of Full Power But Not To Exceed Full Power	2000
f. Step Load Decrease Of 10% Of Full Power From 100% Power	2000
g. Step Load Reduction From 100% To 50% Full Power	200
h. Reactor Trip From Full Power	400
i. Plant Hydrostatic Test Of 3125 PSIA At Room Temp.	5
j. Plant Hydrostatic Test Of 2500 PSIA Up To 400°F.	5
k. Steadystate Fluctuations Of ± 6°F And ± 100 PSI Per Min.	∞
l. Loss Of Flow, One Pump	80
m. Loss Of Load	80
n. Steam Break	5

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CHARGE NO.

DESCRIPTION Structural And Fatigue Evaluation Of Inlet Nozzle – Vessel Supports

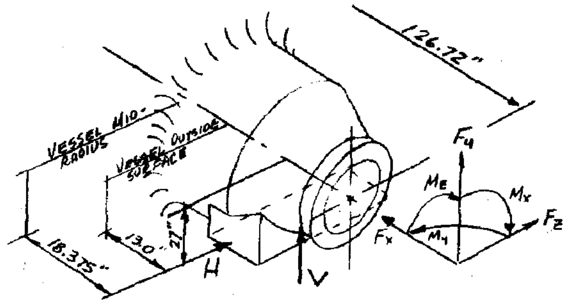
NUMBER 5-211-P 1 A 117
SHEET 9 OF 69
DATE 4-22-68 BY Cockrell
CHECK DATE 4-22-68 BY Heilker

5. Detailed Analysis:

c. System Loading:

3. Thermal Induced Pipe Reactions:

The Following Figure Shows The Inlet Nozzle With The Positive Directions. The Pipe Reactions Are Applied At The Small End Of The Nozzle.



$F_x = 14.8$ kips
$F_y = -92.0$ kips
$F_z = 27.5$ kips
$M_x = -3783$ in-kips
$M_y = 4499$ in-kips
$M_z = 7441$ in-kips

4. Seismic Pipe Reactions:

The Following Pipe Reactions Due To Seismic Conditions Will Be Combined With The Thermal Pipe Reactions In The Worst Possible Combination When Analyzing The Nozzle And Supports. To Determine The Maximum Effect Of The Seismic Pipe Reactions On The Nozzle To Vessel Juncture And The Support Pad, It Is Necessary To Determine The Worse Combination Of Forces. This Has Been Done And The Forces Resulting Are Labeled H And V. Note That The Effect Of Two Of The Inlet And Outlet Nozzle Seismic Reactions Must Be Taken By The Inlet And Outlet Nozzles Which Support The Vessel. The Following Are The Pipe Reactions.

Design Seismic Loading	No Loss Of Function Seismic Loading
$F_x = \pm$ 57.9 kips	$F_x = \pm$ 81.9 kips
$F_y = \pm$ 67.0 kips	$F_y = \pm$ 111.0 kips
$F_z = \pm$ 132.9 kips	$F_z = \pm$ 262.0 kips
$M_x = \pm$ 982 in-kips	$M_x = \pm$ 2800 in-kips
$M_y = \pm$ 12972 in-kips	$M_y = \pm$ 23655 in-kips
$M_z = \pm$ 9910 in-kips	$M_z = \pm$ 10005 in-kips

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION Structural And Fatigue Evaluation Of Inlet Nozzle - Vessel Support

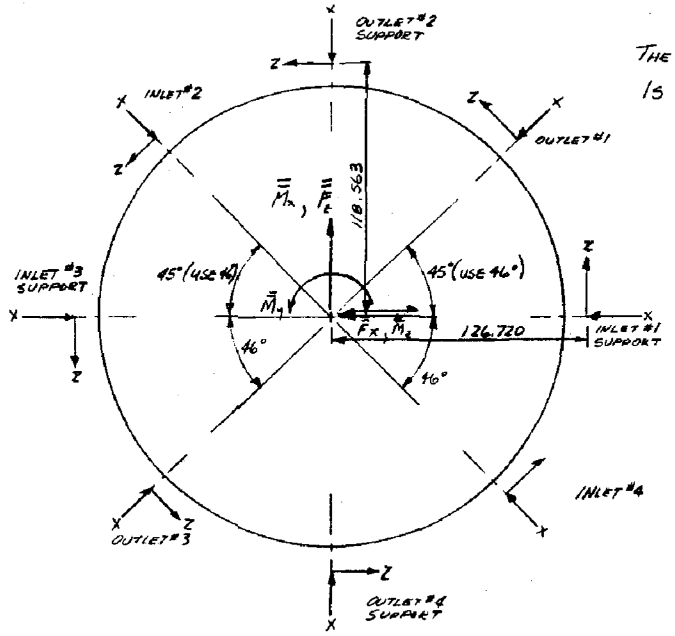
NUMBER S-211-P | A118
SHEET 10 OF 69
DATE 4-22-68 BY Cockrell
CHECK DATE 4-22-68 BY Heilker

5- Detailed Analysis:

c- System Loading:

4- Seismic Pipe Reactions:

As Can Be Seen From The Table On Sheet 9, There Are Many Combinations Of Forces. Since The Seismic Forces Can Alternate, It Will Be Necessary To Determine The Combination Of Forces Which Produce The Maximum And Minimum Stresses At Cut-4. This Will Occur When The Values For $\bar{F}_x$, $\bar{F}_y$, $\bar{F}_z$, $\bar{M}_x$, $\bar{M}_y$, & $\bar{M}_z$ As Given On Sheets 41 & 46 Are Solved To Give Maximum And Minimum Values. The Method Used To Determine This Is As Follows: (1) The Loads On The Individual Nozzles Are Transferred To The C.G. Of The Reactor Vessel, (2) The Forces H And V Are Determine In Relation To The Loads At The ℄ Of The Vessel, And (3) Taking The Combination Of Seismic Loads Given On Sheet 9 To Give The Maximum And Minimum Values Of H & V.



The Positive Y Direction Is Out Of The Paper

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ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION Structural And Fatigue Evaluation Of Inlet Nozzles – Vessel Supports

NUMBER 5-211-P | A119
SHEET 11 OF 69
DATE 4-22-68 BY Cockrell
CHECK DATE 4-22-68 BY Heilker

5. Detailed Analysis:

c. System Loading:

4. Seismic Pipe Reactions:

(1) Forces At ℄ Of Vessel:

$$\overline{\overline{F}}_x = (F_{x_{IN\#1}} - F_{x_{IN\#3}}) + (-F_{x_{IN\#2}} + F_{x_{IN\#4}})\cos 46^\circ + (F_{z_{IN\#2}} - F_{z_{IN\#4}})\sin 46^\circ + (F_{x_{OUT\#1}} - F_{x_{OUT\#3}})\cos 46^\circ$$

$$+ (F_{z_{OUT\#1}} - F_{z_{OUT\#3}})\sin 46^\circ + (F_{z_{OUT\#2}} - F_{z_{OUT\#4}})$$

$$\overline{\overline{F}}_y = (F_{y_{IN\#1}} + F_{y_{IN\#2}} + F_{y_{IN\#3}} + F_{y_{IN\#4}}) + (F_{y_{OUT\#1}} + F_{y_{OUT\#2}} + F_{y_{OUT\#3}} + F_{y_{OUT\#4}})$$

$$\overline{\overline{F}}_z = (-F_{x_{IN\#2}} + F_{x_{IN\#4}})\sin 46^\circ + (F_{z_{IN\#1}} - F_{z_{IN\#3}}) + (-F_{z_{IN\#2}} + F_{z_{IN\#4}})\cos 46^\circ + (-F_{x_{OUT\#1}} + F_{x_{OUT\#3}})\sin 46^\circ$$

$$+ (-F_{x_{OUT\#2}} + F_{x_{OUT\#4}}) + (F_{z_{OUT\#1}} - F_{x_{OUT\#3}})\cos 46^\circ$$

$$\overline{\overline{M}}_x = (-F_{y_{IN\#2}} + F_{y_{IN\#4}})126.72\sin 46^\circ + (M_{x_{IN\#1}} - M_{x_{IN\#3}}) + (-M_{x_{IN\#2}} + M_{x_{IN\#4}})\cos 46^\circ + (M_{z_{IN\#2}} - M_{z_{IN\#4}})\sin 46^\circ$$

$$+ (-F_{y_{OUT\#1}} + F_{y_{OUT\#3}})118.563\sin 46^\circ + (-F_{y_{OUT\#2}} + F_{y_{OUT\#4}})118.563 + (M_{x_{OUT\#1}} - M_{x_{OUT\#3}})\cos 46^\circ$$

$$+ (M_{z_{OUT\#1}} - M_{z_{OUT\#3}})\sin 46^\circ + (M_{z_{OUT\#2}} - M_{z_{OUT\#4}})$$

$$\overline{\overline{M}}_y = (F_{z_{IN\#1}} + F_{z_{IN\#2}} + F_{z_{IN\#3}} + F_{z_{IN\#4}})126.72 + (M_{y_{IN\#1}} + M_{y_{IN\#2}} + M_{y_{IN\#3}} + M_{y_{IN\#4}})$$

$$+ (F_{z_{OUT\#1}} + F_{z_{OUT\#2}} + F_{z_{OUT\#3}} + F_{z_{OUT\#4}})118.563 + (M_{y_{OUT\#1}} + M_{y_{OUT\#2}} + M_{y_{OUT\#3}} + M_{y_{OUT\#4}})$$

$$\overline{\overline{M}}_z = (-F_{y_{IN\#1}} + F_{y_{IN\#3}})126.72 + (F_{y_{IN\#2}} - F_{y_{IN\#4}})126.72\cos 46^\circ + (-M_{x_{IN\#2}} + M_{x_{IN\#4}})\sin 46^\circ$$

$$+ (M_{z_{IN\#1}} - M_{z_{IN\#3}}) + (-M_{z_{IN\#2}} + M_{z_{IN\#4}})\cos 46^\circ + (-F_{y_{OUT\#1}} + F_{y_{OUT\#3}})118.563\cos 46^\circ$$

$$+ (-M_{x_{OUT\#1}} + M_{x_{OUT\#3}})\sin 46^\circ + (-M_{x_{OUT\#2}} + M_{x_{OUT\#4}}) + (M_{z_{OUT\#1}} - M_{z_{OUT\#3}})\cos 46^\circ$$

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ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO. ____________
DESCRIPTION Structural And Fatigue Evaluation Of Inlet Nozzle - Vessel Supports

NUMBER S-211-P | A 120
SHEET 12 OF 69
DATE 4-22-68 BY Cockrell
CHECK DATE 4-22-68 BY Heilker

5- DETAILED ANALYSIS:

C- SYSTEM LOADING:

4. SEISMIC PIPE REACTIONS:

(2) FORCES ON SUPPORTS:

$$H = \mp \frac{\bar{\bar{F}}_z}{2} - \frac{\bar{\bar{M}}_y}{4(109.406)}$$

$$V = - \frac{\bar{\bar{F}}_y}{4} \pm \frac{\bar{\bar{M}}_z}{2(109.406)}$$

NOTE HERE THAT THE TOP SIGN IS FOR INLET NOZZLE #1 AND THE BOTTOM SIGN IS FOR INLET NOZZLE #3. HOWEVER, WITH SUBSITUTION OF FORMULAS ON SHEET 11 & SOLVING WILL YIELD THE SAME RESULTS.

(3) VALUES OF FORCES ON SUPPORTS:

WITH THE ABOVE EXPRESSIONS FOR H & V AND THE EXPRESSIONS FOR $\bar{\bar{F}}_y$, $\bar{\bar{F}}_z$, $\bar{\bar{M}}_y$, AND $\bar{\bar{M}}_z$ GIVEN ON SHEET 11, WE GET THE FOLLOWING.

$$H = 0.35967\left(F_{x_{IN\#2}} - F_{x_{IN\#4}}\right) - 0.78956 F_{z_{IN\#1}} + 0.05777 F_{z_{IN\#2}} + 0.21044 F_{z_{IN\#3}} - 0.63689 F_{z_{IN\#4}}$$
$$- 0.002285\left(M_{y_{IN\#1}} + M_{y_{IN\#2}} + M_{y_{IN\#3}} + M_{y_{IN\#4}}\right) + 0.35967\left(F_{x_{OUT\#1}} - F_{x_{OUT\#3}}\right) + 0.5\left(F_{x_{OUT\#2}} - F_{x_{OUT\#4}}\right)$$
$$- 0.61825 F_{z_{OUT\#1}} - 0.27092\left(F_{z_{OUT\#2}} + F_{z_{OUT\#4}}\right) + 0.07641 F_{z_{OUT\#3}} - 0.002295\left(M_{y_{OUT\#1}} + M_{y_{OUT\#2}} + M_{y_{OUT\#3}} + M_{y_{OUT\#4}}\right)$$

$$V = -0.8291 F_{y_{IN\#1}} + 0.15229 F_{y_{IN\#2}} + 0.32912 F_{y_{IN\#3}} - 0.65229 F_{y_{IN\#4}} + 0.00329\left(-M_{x_{IN\#2}} + M_{x_{IN\#4}}\right)$$
$$+ 0.00457\left(M_{z_{IN\#1}} - M_{z_{IN\#3}}\right) + 0.00317\left(-M_{z_{IN\#2}} + M_{z_{IN\#4}}\right) - 0.6264 F_{y_{OUT\#1}}$$
$$+ 0.25\left(-F_{y_{OUT\#2}} - F_{y_{OUT\#4}}\right) + 0.12640 F_{y_{OUT\#3}} + 0.00329\left(-M_{x_{OUT\#1}} + M_{x_{OUT\#3}}\right)$$
$$+ 0.00457\left(-M_{x_{OUT\#2}} + M_{x_{OUT\#4}}\right) + 0.00317\left(M_{z_{OUT\#1}} - M_{z_{OUT\#3}}\right)$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

NUMBER S-211-P | A 121
SHEET 13 OF 69
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

C- SYSTEM LOADING:

4- SEISMIC PIPE REACTIONS:

WITH THE ABOVE EQUATIONS AND THE FOLLOWING VALUES FOR THE SEISMIC PIPE REACTIONS, THE VALUES FOR H & V ARE DETERMINED THAT WILL GIVE THE MAXIMUM AND MINIMUM STRESSES AT CUT-4.

FOR DESIGN SEISMIC:

NOZZLE	PIPE REACTION					
	F_x	F_y	F_z	M_x	M_y	M_z
INLET #1	-57.9	-67	132.9	-982	12972	9910
2	57.9	-67	132.9	982	-12972	9910
3		-67	132.9		-12972	9910
4	-57.9	67	-132.9	-982	-12972	-9910
OUTLET #1	122	90	-71	1572	-11248	-7282
2	122	90	-71	1572	-11248	
3	-122	-90	71	-1572	-11248	7282
4	-122	90	-71	-1572	-11248	

$H = 516.5$ KIPS
$V = -273.2$ KIPS

REVERSING SIGNS GIVES
$H = -516.5$ KIPS
$V = 273.2$ KIPS

FOR NO LOSS OF FUNCTION SEISMIC:

NOZZLE	PIPE REACTION					
	F_x	F_y	F_z	M_x	M_y	M_z
INLET #1	-81.9	- 111	262	- 2800	23655	10005
2	81.9	- 111	262	2800	- 23655	10005
3		- 111	262		- 23655	10005
4	-81.9	111	-262	-2800	- 23655	- 10005
OUTLET #1	122	162	- 124	2830	- 19569	- 13200
2	122	162	- 124	2830	- 19569	
3	- 122	- 162	124	-2830	- 19569	13200
4	- 122	162	- 124	-2830	- 19569	

$H = 738.9$ KIPS
$V = -446.5$ KIPS

REVERSIGING SIGNS GIVES,
$H = -738.9$ KIPS
$V = 446.5$ KIPS

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION Structural And Fatigue Evaluation Of Inlet Nozzle - Vessel Support

NUMBER 5-211-P | A122
SHEET 14 **OF** 69
DATE 4-22-69 **BY** Cockrell
CHECK DATE 4-22-68 **BY** Heilker

5- Detailed Analysis:

c. System Loading:

5- Static Loading Through Supports:

The Following Is The Overall Weight And C.G. For The Vessel And Contents. The Dynamic Load Of The Scrammed Control Rods Will Be Added Where It Gives Higher Stresses.

Item	Description	Weight (kips)	Distance To C.G. From ℄ Of Nozzles
a	Weight Of Core And Core Support Structure	675	100.8 Below
b	Dynamic Load Of Tripped Control Rods	112.8	~
c	Weight Of Water Contained Within The Reactor Vessel And Head	375	79.6 Below
d	Weight Of Reactor Vessel & Closure Head	866	41.2 Below
e	Weight Of Insulation On Vessel & Closure Head	12	80 Below
f	Weight Of Vessel Head Lifting Rig And Ventilating Shroud	60	330.0 Above
g	Weight Of Control Rod Drive Mechanisms	161.5	260.3 Above
h	Partial Weight Of Reactor Coolant Piping	95	@ ℄ Of Nozzles

Total Static Load $= \Sigma W = 2244.5$ kips

C.G. Of System $= \frac{\Sigma W d}{\Sigma W} = \underline{32.6}''$ Below ℄ Of Nozzles

Static Load Per Support $= \underline{561.1 \text{ kips}}$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION Structural And Fatigue Evaluation Of Inlet Nozzle - Vessel Supports

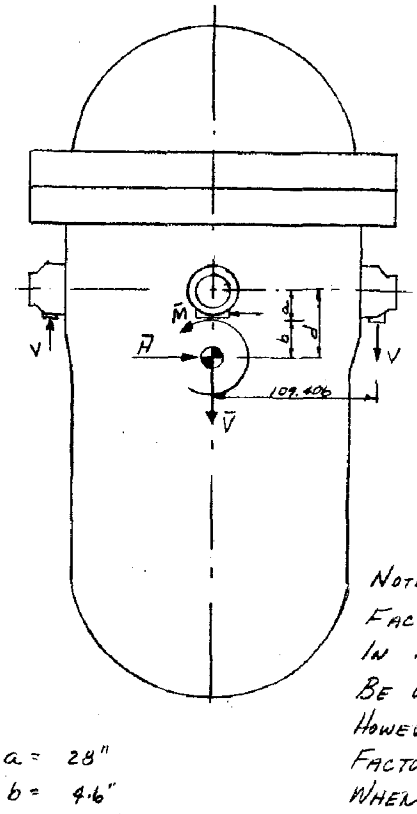
NUMBER S-211-P | A123
SHEET 15 OF 69
DATE 4-22-68 BY Cockrell
CHECK DATE 4-22-68 BY Heilker

5. Detailed Analysis:

c. System Loading:

6. Earthquake Loading Through Supports:

During An Earthquake, The Supports Must Resist The Vertical And Horizontal Forces Applied Through The C.G. Of The Vessel Due To The Earthquake Shock Forces. Since The Bottom Of The Vessel Supports Is At A Different Elevation Than The C.G. Of The Vessel, An Overturning Moment Due To The Horizontal Shock Force Results And Must Be Resisted By The Supports. The Following Figure Illustrates The Method For Determining The Forces On The Pads.



$$V = \pm \frac{\bar{V}}{4} \pm \frac{\bar{M}}{2(109.406)}$$

$$H = \pm \frac{\bar{H}}{2}$$

Direction	Earthquake Factors	
	Design	No Loss Of Function
Horizontal	0.3 g	0.6 g
Vertical	0.2 g	0.4 g

Force	Design Earthquake	No Loss Of Function Earthquake
H	± 336.7	± 673.4
V	± 126.4	± 252.8

a = 28"
b = 4.6"
c = 32.6"

Note Here That The Above Seismic Shock Factors Are Larger Than Those Listed In Ref. 9. The Above Factors Will Be Uses When Calculating Stresses; However, The Specified Seismic Shock Factors Given In Ref. 9 Will Be Used When Determining The Maximum Forces On The Pad, See Sheet 57.

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT. CHATTANOOGA, TENN.

CHARGE NO. ____________
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORT

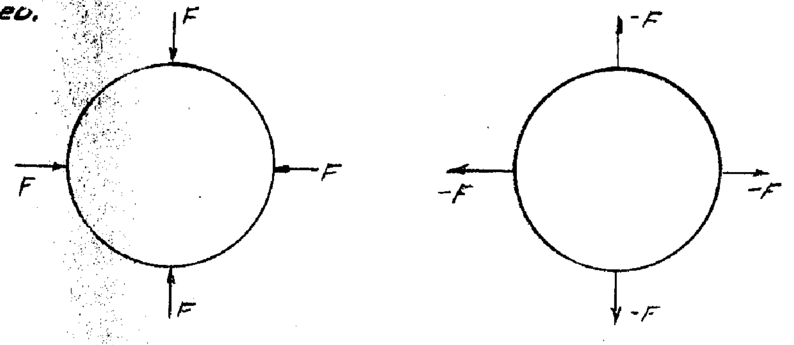
NUMBER 5-211-P | A 124
SHEET 16 OF 69
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

c- SYSTEM LOADING:

7- DUE TO THERMAL EXPANSION & CONTRACTION:

DURING THE HEATUP AND COOLDOWN TRANSIENT THE VESSEL WILL EXPAND OR CONTRACT RADIALLY, THUS CREATING RADIAL FORCES IN THE HORIZONTAL PLANE DUE TO FRICTION BETWEEN THE SUPPORT PADS ON THE NOZZLES AND THE BEARING PLATES ON THE SUPPORT LEDGE OF THE CONCRETE ENCLOSURE. IN CALCULATING THESE FRICTIONAL FORCES, A COEFFICIENT OF STATIC FRICTION OF $\mu = 0.3$ IS ASSUMED.



FORCES DUE TO HEATUP

FORCES DUE TO COOLDOWN

THE MAXIMUM RADIAL FORCE ON ONE LUG DUE TO FRICTION IS,

$$F = \frac{\mu W}{4} = \frac{0.3(2244.5)}{4} = 168.3 \text{ KIPS}$$

IN DETERMINING THE ABOVE FRICTIONAL FORCE, ONLY THE STATIC WEIGHT OF THE VESSEL AND COMPONENTS IS CONSIDERED BECAUSE THE FRICTIONAL FORCE WOULD BE DESTROYED DURING AN EARTHQUAKE SHOCK. THIS FRICTIONAL FORCE WILL BE CONSIDERED WHERE APPLICABLE.

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORT

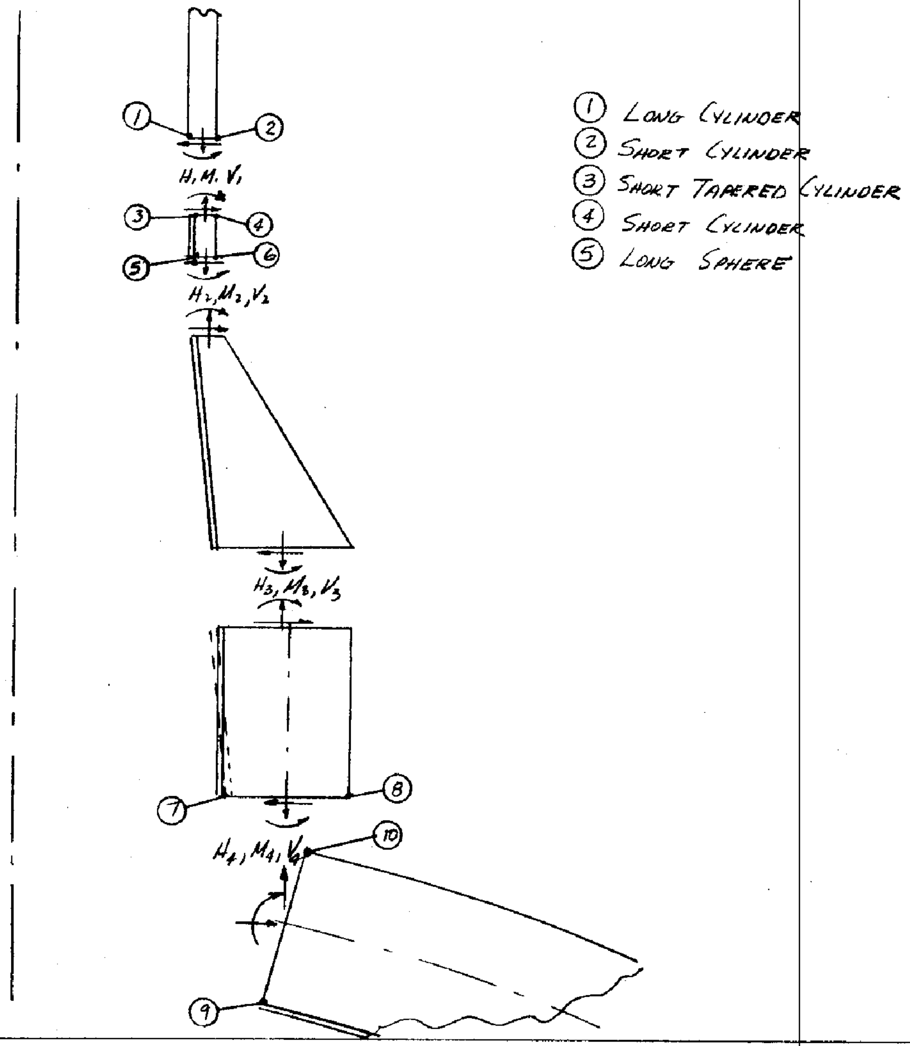
NUMBER S-211-P | A 125
SHEET 17 OF 69
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-66 BY HEILKER

5- DETAILED ANALYSIS:

d- PRESSURE AND THERMAL INTERACTION:

1- ANALYTICAL MODEL:

THE ACTUAL STRUCTURE AS SHOWN ON SHEET 16 IS DIVIDED INTO THE FOLLOWING ANALYTICAL MODEL TO FACILITATE THE ANALYSIS. THE ASSUMED DIRECTION OF THE REDUNDANT FORCES IS ILLUSTRATED.



COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION Structural And Fatigue Evaluation Of Inlet Nozzle - Vessel Support

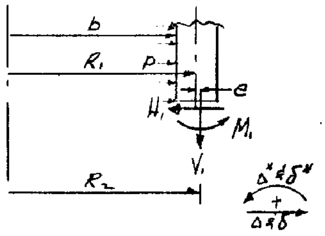
NUMBER S-211-P | A 126
SHEET 18 **OF** 69
DATE 4-22-69 **BY** Cockrell
CHECK DATE 4-22-69 **BY** Heilker

5- Detailed Analysis:

d- Pressure And Thermal Interaction:

1- Deflections:

Body-1



$R_1 = 15.000''$
$b_1 = 13.750''$
$t_1 = 2.500''$
$R_2 = 15.110''$
$e = 0.110$

$\beta^4 = \frac{3(1-\nu^2)}{R_1^2 t_1^2}$
$\beta = 0.20991$

$D = \frac{Et^3}{12(1-\nu^2)} = 1.43086\, E_{316}$
$\frac{E_{316}}{E_{316}} = 1$

Displacements Due To Redundant Forces:

$$E\Delta_{11} = -\frac{E}{2\beta^3 D}\left[\frac{1}{\beta}H_1 - M_1\right]\frac{R_2}{R_1}\frac{E_{302B}}{E_{316}} = -\underline{38.0602 H_1 + 7.9891 M_1}$$

$$E\Delta^*_{11} = -\frac{E}{2\beta^2 D}\left[H_1 - 2\beta M_1\right]\frac{R_2}{R_1}\frac{E_{302B}}{E_{316}} = -\underline{7.9891 H_1 + 3.3539 M_1}$$

Displacements Due To Applied Forces:

$$E\delta_{11} = \frac{b_1^2}{t_1}\left(\frac{R_1}{b_1} - \frac{\nu}{2}\right)p\,\frac{E_{302B}}{E_{316}} - \frac{E}{2\beta^2 D}(V_1 e)\frac{R_2}{R_1}\frac{E_{302B}}{E_{316}} = \underline{65.6583 P}$$

$$E\delta^*_{11} = -\frac{E}{\beta D}(V_1 e)\frac{R_1}{R_2}\frac{E_{302B}}{E_{316}} = -\underline{2.3081 P}$$

Displacements Due To Thermal Effects:

For Range Of Stress	For Peak Stress
$E\delta_{11T} = R_2 E\alpha_m (T_{11} - 100)\frac{E_{302B}}{E_{316}}$	$= R_2 E\alpha_m (T_{11} - 100)\frac{E_{302B}}{E_{316}} + \frac{E}{2\beta^2 D}\frac{R_2}{R_1}\frac{E_{302B}}{E_{316}} M_{1T}$
$= \underline{15.110 E\alpha_m (T_{11} - 100)}$	$= \underline{15.110 E\alpha_m (T_{11} - 100) + 7.9891 M_{1T}}$
$E\delta^*_{11T} = R_1 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{11}\frac{E_{302B}}{E_{316}}$	$= R_1 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{11}\frac{E_{302B}}{E_{316}} + \frac{E}{\beta D}\frac{R_2}{R_1}\frac{E_{302B}}{E_{316}} M_{1T}$
$= \underline{15.000 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{11}}$	$= \underline{15.000 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{11} + 3.3539 M_{1T}}$

RIV000052C
Submitted: December 22, 2011

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

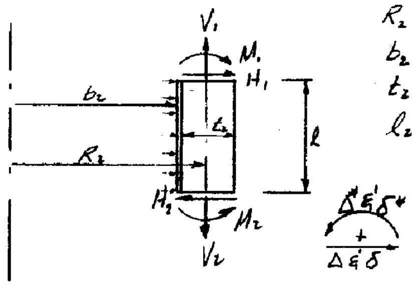
NUMBER 5-211-P | A127
SHEET 19 OF 69
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5. DETAILED ANALYSIS:

d. PRESSURE AND THERMAL INTERACTION:

2 - DEFLECTIONS:

BODY-2



$R_2 = 15.110''$
$b_2 = 13.750''$
$t_2 = 2.281''$
$l_2 = 2.923''$

$\beta^4 = \frac{3(1-\nu^2)}{R_2^2 t_2^2}$
$\beta = 0.21895$
$D = \frac{Et^3}{12(1-\nu^2)} = 1.0868E$

FOR $\beta l = 0.64$

$B_{11} = 3.1300$	$G_{11} = -1.5588$
$B_{12} = 7.3671$	$G_{12} = -7.2989$
$B_{22} = 23.3633$	$G_{22} = -22.7239$

DISPLACEMENTS DUE TO REDUNDANT FORCES

$$E\Delta_{21} = \frac{E}{2\beta^2 D}\left[\frac{1}{\beta}B_{11}H_1 + B_{12}M_1 - \frac{1}{\beta}G_{11}H_2 + G_{12}M_2\right]$$

$$= \underline{137.1918\,H_1 + 70.7010\,M_1 + 68.3242\,H_2 - 70.0465\,M_2}$$

$$E\Delta_{21}^* = \frac{E}{2\beta^2 D}\left[-B_{12}H_1 - \beta B_{22}M_1 + G_{12}H_2 - \beta\,G_{22}M_2\right]$$

$$= \underline{-70.7010\,H_1 - 49.0918\,M_1 - 70.0465\,H_2 + 47.7482\,M_2}$$

$$E\Delta_{22} = \frac{E}{2\beta^2 D}\left[\frac{1}{\beta}G_{11}H_1 + G_{12}M_1 - \frac{1}{\beta}B_{11}H_2 + B_{12}M_1\right]$$

$$= \underline{-68.3242\,H_1 - 70.0465\,M_1 - 137.1918\,H_2 + 70.7010\,M_2}$$

$$E\Delta_{22}^* = \frac{E}{2\beta^2 D}\left[G_{12}H_1 + \beta G_{22}M_1 - B_{12}H_2 + \beta B_{22}M_2\right]$$

$$= \underline{-70.0465\,H_1 - 47.7482\,M_1 - 70.7010\,H_2 + 49.0918\,M_2}$$

CHARGE NO.

NUMBER S-211-P | A128
SHEET 20 OF 69
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

5. DETAILED ANALYSIS:

d- PRESSURE AND THERMAL INTERACTION:

2- DEFLECTIONS:

DISPLACEMENTS DUE TO APPLIED FORCES

$$E\delta_{21} = E\delta_{22} = \frac{b_i^2}{t_2}\left(\frac{R_2}{b_2} - \frac{\nu}{2}\right)P = \underline{78.6511P}$$

$$E\delta_{21}^* = E\delta_{22}^* = 0$$

DISPLACEMENTS DUE TO THERMAL EFFECTS:

FOR RANGE OF STRESS	FOR PEAK STRESS
$E\delta_{21T} = R_2 E\alpha_m (T_{21} - 100)$	$= R_2 E\alpha_m (T_{21} - 100) + \frac{E}{2\beta^2 D}\left[B_{12} M_{1T} + G_{12} M_{2T}\right]$
$= \underline{15.110 E\alpha (T_{21} - 100)}$	$= \underline{15.110 E\alpha (T_{21} - 100) + 70.7010 M_{1T} - 70.0465 M_{2T}}$
$E\delta_{21T}^* = R_2 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{21}$	$= R_2 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{21} + \frac{E}{2\beta^2 D}\left[-\beta B_{22} M_{1T} - \beta G_{22} M_{2T}\right]$
$= \underline{15.110 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{21}}$	$= \underline{15.110 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{21} - 49.0918 M_{1T} + 47.7482 M_{2T}}$
$E\delta_{22T} = R_2 E\alpha_m (T_{22} - 100)$	$= R_2 E\alpha_m (T_{22} - 100) + \frac{E}{2\beta^2 D}\left[G_{12} M_{1T} + B_{12} M_{2T}\right]$
$= \underline{15.110 E\alpha_m (T_{22} - 100)}$	$= \underline{15.110 E\alpha_m (T_{22} - 100) - 70.0465 M_{1T} + 70.7010 M_{2T}}$
$E\delta_{22T}^* = R_2 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{22}$	$= R_2 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{22} + \frac{E}{2\beta^2 D}\left[\beta G_{22} M_{1T} + \beta B_{22} M_{2T}\right]$
$= \underline{15.110 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{22}}$	$= \underline{15.110 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{22} - 47.7482 M_{1T} + 49.0918 M_{2T}}$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

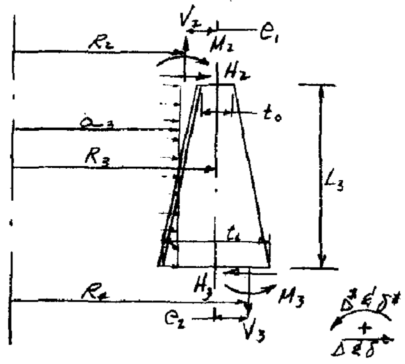
NUMBER S-211-P | A129
SHEET 21 **OF** 69
DATE 4-22-69 **BY** COCKRELL
CHECK DATE 4-22-69 **BY** HEILKER

5- DETAILED ANALYSIS:

d- PRESSURE & THERMAL INTERACTION:

2- DEFLECTIONS:

BODY-3:



$R_2 = 15.110''$
$R_3 = 18.383''$
$R_4 = 21.657$
$a_3 = 14.922$
$t_0 = 2.281''$
$t_L = 10.686''$
$L_3 = 17.077''$
$e_1 = 3.273''$
$e_2 = 3.274$

$\lambda = \frac{1}{L_3}(t_L - t_0) = 0.49218$

THE INFLUENCE COEFFICIENTS FOR A SHORT TAPERED CYLINDER ARE CALCULATED BY THE METHOD OUTLINED ON PAGES 488 → 492 OF REF 12 AND ARE PRINTED OUT ON C.E.'S COMPUTER PROGRAM AS FOLLOWS.

DISPLACEMENTS DUE TO REDUNDANT FORCES:

$$E\Delta_{32} = \phi_{11} H_2 \frac{R_2}{R_3} + \phi_{12} M_2 \frac{R_2}{R_3} + \phi_{13} H_3 \frac{R_4}{R_3} + \phi_{14} M_3 \frac{R_4}{R_3}$$

$$= \underline{20.9248 H_2 + 3.3409 M_2 + 6.5006 H_3 - 1.2909 M_3}$$

$$E\Delta^*_{32} = \phi_{21} H_2 \frac{R_2}{R_3} + \phi_{22} M_2 \frac{R_2}{R_3} + \phi_{23} H_3 \frac{R_4}{R_3} + \phi_{24} M_3 \frac{R_4}{R_3}$$

$$= \underline{-3.3342 H_2 - 1.4814 M_2 - 0.7004 H_3 + 0.0605 M_3}$$

$$E\Delta_{33} = \phi_{31} H_2 \frac{R_2}{R_3} + \phi_{32} M_2 \frac{R_2}{R_3} + \phi_{33} H_3 \frac{R_4}{R_3} + \phi_{34} M_3 \frac{R_4}{R_3}$$

$$= \underline{-4.5532 H_2 - 0.4916 M_2 - 12.0860 H_3 + 1.4232 M_3}$$

$$E\Delta^*_{33} = \phi_{41} H_2 \frac{R_2}{R_3} + \phi_{42} M_2 \frac{R_2}{R_3} + \phi_{43} H_3 \frac{R_4}{R_3} + \phi_{44} M_3 \frac{R_4}{R_3}$$

$$= \underline{-0.9061 H_2 - 0.0425 M_2 - 1.4262 H_3 + 0.2817 M_3}$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

NUMBER 5-211-P | A130
SHEET 22 OF 69
DATE 4-22-69 BY COCKRELL
CHECK DATE 4-22-69 BY HEILKER

5. DETAILED ANALYSIS:

d. PRESSURE AND THERMAL INTERACTION:

2. DEFLECTIONS:

DISPLACEMENTS DUE TO APPLIED FORCES:

$$E\delta_{32} = Pa_3^2\left(\frac{R_3}{a_3} - \frac{\nu}{2}\right)\left[(\phi_{12}+\phi_{14})\frac{-\lambda^2}{6(1-\nu^2)} + \frac{1}{t_o}\right] + \phi_{12} V_2 e_1 \frac{R_2}{R_3} - \phi_{14} V_3 e_2 \frac{R_4}{R_3} = \underline{176.1759P}$$

$$E\delta_{32}^* = Pa_3^2\left(\frac{R_3}{a_3} - \frac{\nu}{2}\right)\left[(\phi_{22}+\phi_{24})\frac{-\lambda^2}{6(1-\nu^2)} - \frac{\lambda}{t_o^2}\right] + \phi_{22} V_2 e_1 \frac{R_2}{R_3} - \phi_{24} V_3 e_2 \frac{R_4}{R_3} = -\underline{40.8173P}$$

$$E\delta_{32} = Pa_3^2\left(\frac{R_3}{a_3} - \frac{\nu}{2}\right)\left[(\phi_{32}+\phi_{34})\frac{-\lambda^2}{6(1-\nu^2)} + \frac{1}{t_i}\right] + \phi_{32} V_2 e_1 \frac{R_2}{R_3} - \phi_{34} V_3 e_2 \frac{R_4}{R_3} = \underline{-19.7843P}$$

$$E\delta_{32}^* = Pa_3^2\left(\frac{R_3}{a_3} - \frac{\nu}{2}\right)\left[(\phi_{42}+\phi_{44})\frac{-\lambda^2}{6(1-\nu^2)} - \frac{\lambda}{t_i^2}\right] + \phi_{42} V_2 e_1 \frac{R_2}{R_3} - \phi_{44} V_3 e_2 \frac{R_4}{R_3} = -\underline{8.8063P}$$

DISPLACEMENTS DUE TO THERMAL EFFECTS:

FOR RANGE OF STRESS	FOR PEAK STRESS
$E\delta_{32T} = R_2 E\alpha_m(T_{32}-100)$	$R_2 E\alpha_m(T_{32}-100) + \phi_{12} M_{2T} \frac{R_2}{R_3} + \phi_{14} M_{3T} \frac{R_4}{R_3}$
$= \underline{15.110\, E\alpha(T_{32}-100)}$	$= \underline{15.110\, E\alpha(T_{32}-100) + 3.3409 M_{2T} - 1.2909 M_{3T}}$
$E\delta_{32T}^* = R_3 E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{32}$	$R_3 E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{32} + \phi_{22} M_{2T} \frac{R_2}{R_3} + \phi_{21} M_{3T} \frac{R_4}{R_3}$
$= \underline{18.383\, E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{32}}$	$= \underline{18.383\, E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{32} - 1.4814 M_{2T} + 0.0605 M_{3T}}$
$E\alpha_{33T} = R_4 E\alpha_m(T_{33}-100)$	$R_4 E\alpha_m(T_{33}-100) + \phi_{32} M_{2T} \frac{R_2}{R_3} + \phi_{34} M_{3T} \frac{R_4}{R_3}$
$= \underline{21.657\, E\alpha_m(T_{33}-100)}$	$= \underline{21.657\, E\alpha_m(T_{33}-100) - 0.4916 M_{2T} + 1.4232 M_{3T}}$
$E\alpha_{33T}^* = R_3 E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{33}$	$= R_3 E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{33} + \phi_{42} M_{2T} \frac{R_2}{R_3} + \phi_{44} M_{3T} \frac{R_4}{R_3}$
$= \underline{18.383\, E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{33}}$	$= \underline{18.383\, E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{33} - 0.0425 M_{2T} + 0.2817 M_{3T}}$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT. CHATTANOOGA. TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

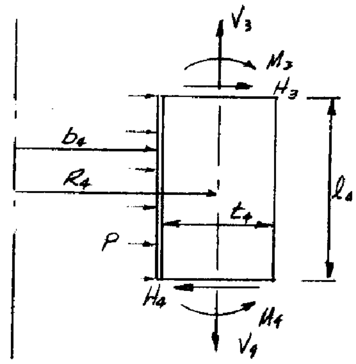
NUMBER 5-211-P | A 131
SHEET 23 **OF** 69
DATE 4-22-68 **BY** COCKRELL
CHECK DATE 4-22-68 **BY** HEILKER

5- DETAILED ANALYSIS:

d- PRESSURE AND THERMAL INTERACTION:

2- DEFLECTIONS:

BODY-4:



$R_4 = 21.657''$
$b_4 = 16.094''$
$t_4 = 10.686''$
$\ell_4 = 15.688''$

$\beta^4 = \frac{3(1-\nu^2)}{R_4^2 t_4^2}$
$\beta = 0.09450$
$D = \frac{Et^3}{12(1-\nu^2)} = 111.74365E$

FOR $\beta\ell = 1.32557$

$B_{11} = 1.5523$ $G_{11} = -0.7220$
$B_{12} = 1.8882$ $G_{12} = -1.6017$
$B_{22} = 3.5493$ $G_{22} = -2.2458$

DISPLACEMENTS DUE TO REDUNDANT FORCES:

$$E\Delta_{43} = \frac{E}{2\beta^2 D}\left[\frac{1}{\beta}B_{11}H_3 + B_{12}M_3 - \frac{1}{\beta}G_{11}H_4 + G_{12}M_4\right]$$

$$= \underline{11.5139\,H_3 + 1.1834\,M_3 + 5.3553\,H_4 - 1.0038\,M_4}$$

$$E\Delta^*_{43} = \frac{E}{2\beta^2 D}\left[-B_{12}H_3 - \beta B_{22}M_3 + G_{12}H_4 - \beta G_{22}M_4\right]$$

$$= -\underline{1.1834\,H_3 - 0.1880\,M_3 - 1.0038\,H_4 + 0.1189\,M_4}$$

$$E\Delta_{44} = \frac{E}{2\beta^2 D}\left[\frac{1}{\beta}G_{11}H_3 + G_{12}M_3 - \frac{1}{\beta}B_{11}H_4 + B_{12}M_4\right]$$

$$= -\underline{5.3553\,H_3 - 1.0038\,M_3 - 11.5139\,H_4 + 1.1834\,M_4}$$

$$E\Delta^*_{44} = \frac{E}{2\beta^2 D}\left[G_{12}H_3 + \beta G_{22}M_3 - B_{12}H_4 + \beta B_{22}M_4\right]$$

$$= -\underline{1.0038\,H_3 - 0.1189\,M_3 - 1.1834\,H_4 + 0.1880\,M_4}$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT. CHATTANOOGA. TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

NUMBER 5-211-P | A 132
SHEET 24 OF 69
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

d- PRESSURE AND THERMAL INTERACTION:

2- DEFLECTIONS:

DISPLACEMENTS DUE TO APPLIED FORCES:

$$E\delta_{43} = E\delta_{44} = \frac{b_4^2}{t_4}\left(\frac{R_4}{b_4} - \frac{\nu}{2}\right)P = \underline{28.9814P}$$

$$E\delta_{43}^{*} = E\delta_{44}^{*} = 0$$

DISPLACEMENTS DUE TO THERMAL EFFECTS:

FOR RANGE OF STRESS	FOR PEAK STRESS
$E\delta_{43T} = R_4 E\alpha_m(T_{43}-100)$	$= R_4 E\alpha_m(T_{43}-100) + \frac{E}{2\beta^2 D}\left[B_{12} M_{3T} + G_{12} M_{4T}\right]$
$= \underline{21.657E\alpha_m(T_{43}-100}$	$= \underline{21.657E\alpha_m(T_{43}-100) + 1.1834 M_{3T} - 1.0038 M_{4T}}$
$E\delta_{43T}^{*} = R_4 E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{43}$	$= \underline{R_4 E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{43} + \frac{E}{2\beta^2 D}\left[-\beta B_{22} M_{3T} - \beta G_{22} M_{4T}\right]}$
$= 21.657 E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{43}$	$= \underline{21.657 E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{43} - 0.1880 M_{3T} + 0.1189 M_{4T}}$
$E\delta_{44T} = R_4 E\alpha_m(T_{44}-100)$	$= \underline{R_4 E\alpha_m(T_{44}-100) + \frac{E}{2\beta^2 D}\left[G_{12} M_{3T} + B_{12} M_{4T}\right]}$
$= 21.657 E\alpha_m(T_{44}-100)$	$= \underline{21.657E\alpha_m(T_{44}-100) - 1.0038 M_{3T} + 1.1834 M_{4T}}$
$E\delta_{44T}^{*} = R_4 E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{44}$	$= R_4 E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{44} + \frac{E}{2\beta^2 D}\left[\beta G_{22} M_{3T} + \beta B_{22} M_{4T}\right]$
$= 21.657 E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{44}$	$= \underline{21.657 E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{44} - 0.1189 M_{3T} + 0.1880 M_{4T}}$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

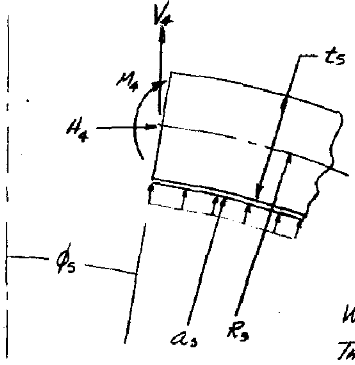
NUMBER 5-211-P | A133
SHEET 25 OF 69
CHARGE NO. ______
DATE 4-22-68 BY COCKRELL
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS
CHECK DATE 4-22-68 BY HEILFER

5. DETAILED ANALYSIS:

d. PRESSURE AND THERMAL INTERACTION:

2. DEFLECTIONS:

BODY-5:



$R_5 = 136.546''$
$a_5 = 130.952''$
$t_5 = 10.75''$
$\phi_5 = 9°7.54'$

For $\phi\sqrt{\frac{R}{t}} = 32.53119$
$P_{11} = 0.6718$
$P_{12} = 0.6084$
$P_{22} = 3.1457$

NOTE THAT THE VESSEL SHELL IS IDEALIZED AS A SPHERICAL SEGMENT OF THE SAME THICKNESS AS THE VESSEL AND WITH A MID-RADIUS 1.5 TIMES THAT OF THE VESSEL. THIS YIELDS A MODEL WITH MEMBRANE STRESS EQUAL TO THE AVERAGE OF THAT IN THE LONG. & CIRC DIRECTIONS OF THE VESSEL

DISPLACEMENTS DUE TO REDUNDANT FORCES:

$$E\Delta_{54} = \frac{180}{\pi t_5^2 \phi_5}\left[t_5^2 P_{11} H_4 + t_5 P_{12} M_4\right] = \underline{4.2123 H_4 + 0.3553 M_4}$$

$$E\Delta_{54}^* = -\frac{180}{\pi t_5^2 \phi_5}\left[t_5 P_{12} H_4 + P_{22} M_4\right] = \underline{-0.3553 H_4 - 0.1708 M_4}$$

DISPLACEMENTS DUE TO APPLIED FORCES:

$$E\delta_{54} = \frac{a_5^2}{2}\left[\frac{180 \cos\phi}{\pi R_5 \phi} P_{11} + \frac{\sin\phi}{t_5}(1-\nu)\right] = \underline{349.9944 P}$$

$$E\delta_{54}^* = -\frac{90 a_5^2 \cos\phi}{\pi R_5 t_5 \phi} P_{12} P = \underline{-22.0252 P}$$

DISPLACEMENTS DUE TO THERMAL EFFECTS:

FOR RANGE OF STRESS	FOR PEAK STRESS
$E\Delta_{54} = R_5 \sin\phi E\alpha_m (T_{54}-100)$	$= R_5 \sin\phi E\alpha_m (T_{54}-100) + \frac{180}{\pi t_5^2 \phi_5} P_{12} M_{5T}$
$= \underline{21.657 E\alpha (T_{54}-100)}$	$= \underline{21.657 E\alpha_m (T_{54}-100) + 0.3553 M_{5T}}$
$E\Delta_{54}^* = R_5 \sin\phi E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{54}$	$= R_5 \sin\phi E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{54} - \frac{180}{\pi t_5^2 \phi_5} P_{22} M_{5T}$
$= \underline{21.657 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{54}}$	$= \underline{21.657 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{54} - 0.1708 M_{5T}}$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER 5-211-P 1A134
SHEET 26 OF 69
CHARGE NO.
DATE 4-22-68 BY COCKRELL
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

d- PRESSURE AND THERMAL INTERACTION:

2- DEFLECTIONS:

THE FOLLOWING TABLES GIVE THE MEAN TEMPERATURE, SLOPE OF THE AXIAL GRADIENT, AND THE THERMAL MOMENT DUE TO THE RADIAL GRADIENT AT EACH CUT. THES VALUES ARE USED TO CALCULATE THE DEFLECTIONS AND ROTATIONS OF EACH CUT DUE TO THERMAL EFFECTS.

TRANSIENT		T_{11} & T_{21}	T_{22} & T_{32}	T_{33} & T_{43}	T_{44}	T_{54}	$\left(\frac{\Delta T}{\Delta X}\right)_{11}$	$\left(\frac{\Delta T}{\Delta X}\right)_{21}$ & $\left(\frac{\Delta T}{\Delta Y}\right)_{22}$	$\left(\frac{\Delta T}{\Delta X}\right)_{32}$ & $\left(\frac{\Delta T}{\Delta X}\right)_{33}$
a - HEATUP	4.00 HRS	492	490	423	426	435	1.000	-0.684	-3.923
	4.25	517	515	448	451	460	↓	↓	↓
	4.35	527	525	458	461	470	↓	↓	↓
	4.47	539	537	470	473	482	↓	↓	↓
	5.00	547	546	508	510	515	0	-0.342	-2.225
STEADYSTATE		547	547	547	547	547	0	0	0
b- COOLDOWN	4.00 HRS	155	157	224	221	212	-1.000	0.684	3.923
	4.25	130	132	199	196	187	↓	↓	↓
	4.35	120	122	189	186	177	↓	↓	↓
	4.47	108	110	177	174	165	↓	↓	↓
	5.00	100	101	139	137	132		0.342	2.225
c		547	547	547	547	547	0	0	0
d → f		554.8	554.8	554.8	554.8	554.8	↓	↓	↓
g		555	555	555	555	555	↓	↓	↓
h		554.5	554.5	554.5	554.5	554.5	↓	↓	↓
i		100	100	100	100	100	↓	↓	↓
j	H.U. 3.00 HRS	392	390	323	326	335	1.000	-0.684	-3.923
	S.S.	400	400	400	400	400	0	0	0
	C.D 3.00 HRS	108	110	177	174	165	-1.000	0.684	3.923
k → m		554.8	554.8	554.8	554.8	554.8	0	0	0
n		547	547	547	547	547	0	0	0

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

NUMBER 5-211-P | A 135
SHEET 27 OF 69
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEIKER

5- DETAILED ANALYSIS:

d- PRESSURE AND THERMAL INTERACTION:

2. DEFLECTIONS:

TRANSIENT		$\left(\frac{\Delta T}{\Delta X}\right)_{43} \& \left(\frac{\Delta T}{\Delta X}\right)_{44}$	$\left(\frac{\Delta T}{\Delta X}\right)_{54}$	M_{1T} IN-KIP/IN	M_{2T} IN-KIP/IN	M_{3T} IN-KIP/IN	M_{4T} IN-KIP/IN	M_{5T} IN-KIP/IN
a - HEATUP	4.00HRS	0.333	0.666	1.432	1.884	296.455	308.138	336.543
	4.25	↓	0.500	1.439	1.893	297.894	311.129	338.168
	4.35	↓	0.500	1.446	1.903	299.333	312.625	339.794
	4.47	↓	0.250	1.453	1.910	300.772	314.121	341.420
	5.00	0.222	0	0	0.398	171.974	169.914	184.075
STEADYSTATE		0	0	0	0	0	0	0
b - COOLDOWN	4.00HRS	-0.333	-0.666	-1.432	-1.884	-296.455	-308.138	-336.543
	4.25	↓	-0.500	-1.439	-1.893	-297.894	-311.129	-338.168
	4.35	↓	-0.500	-1.446	-1.902	-299.333	-312.625	-339.794
	4.47	↓	-0.250	-1.453	-1.910	-300.772	-314.121	-341.420
	5.00	-0.222	0	0	-0.398	-171.974	-169.914	-184.075
c		0	↓	↓	0	0	0	0
d → f		↓	↓	↓	↓	↓	↓	↓
g		↓	↓	↓	↓	↓	↓	↓
h		↓	↓	↓	↓	↓	↓	↓
i		↓	↓	↓	↓	↓	↓	↓
j	H.U. 3.00HRS	0.333	0.666	1.453	1.910	300.772	314.121	341.420
	S.S.	0	0	0	0	0	0	0
	C.D 3.00HRS	-0.333	-0.666	-1.453	-1.910	-300.772	-314.121	-341420
k → m		0	0	0	0	0	0	0
n		0	0	0	0	0	0	0

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT. CHATTANOOGA. TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORT

NUMBER S-21-P | A136
SHEET 28 OF 69
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

d- PRESSURE AND THERMAL INTERACTION:

2. DEFLECTIONS:

WITH THE EXPRESSIONS FOR THE DISPLACEMENTS AS PRESENTED ON SHEETS 18 → 25 AND THE VALUES GIVEN IN THE TABLES ON SHEETS 26 & 27, THE FOLLOWING VALUES OF DISPLACEMENT WERE OBTAINED FOR RANGE OF STRESS

TRANSIENT		$E\delta_{11T}$	$E\delta^{*}_{11T}$	$E\delta_{21T}$	$E\delta^{*}_{21T}$	$E\delta_{22T}$	$E\delta^{*}_{22T}$	$E\delta_{32T}$	$E\delta_{32T}$
a- HEATUP	4.00 HRS	1475.4	3.736	1102.6	-1.924	1096.9	-1.924	1096.9	-13.424
	4.25	1568.9	3.735	1172.8	-1.924	1167.2	-1.924	1167.2	-13.424
	4.35	1606.1	3.734	1200.7	-1.923	1195.1	-1.923	1195.1	-13.421
	4.47	1650.7	3.733	1233.9	-1.923	1228.4	-1.923	1228.4	-13.416
	5.00	1680.2	0	1256.0	-0.961	1253.3	-0.961	1253.3	-7.607
STEADY STATE		1680.2	0	1256.0	0	1256.0	0	1256.0	0
b- COOLDOWN	4.00 HRS	203.0	-3.663	149.4	1.858	154.9	1.958	154.9	12.967
	4.25	110.4	-3.655	81.2	1.851	86.6	1.951	86.6	12.919
	4.35	73.6	-3.651	54.0	1.847	59.4	1.848	59.4	12.895
	4.47	29.4	-3.647	21.5	1.842	26.9	1.843	26.9	12.861
	5.00	0	0	0	0.919	2.7	0.919	2.7	7.278
c		1680.2	0	1256.0	0	1256.0	0	1256.0	0
d → f		1709.0	↓	1277.5	↓	1277.5	↓	1277.5	↓
g		1709.7		1278.1		1278.1		1278.1	
h		1707.9		1276.7		1276.7		1276.7	
i		0		0		0		0	
j	3 HRS	1127.3	3.730	838.9	-1.913	838.9	-1.913	838.9	-13.346
	S.S.	1127.3	0	838.9	0	838.9	0	838.9	0
	3 HRS	44.1	-3.648	32.4	1.844	32.4	1.844	32.4	12.867
k → m		1709.0	0	1277.5	0	1277.5	0	1277.5	0
n		1680.2	0	1256.0	0	1256.0	0	1256.0	0

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT. CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

NUMBER 5-211-P | A 137
SHEET 29 OF 69
DATE 4-22-69 BY COCKRELL
CHECK DATE 4-22-69 BY HEILKER

5- DETAILED ANALYSIS:

d- PRESSURE AND THERMAL INTERACTION:

2- DEFLECTIONS:

FOR RANGE OF STRESS

TRANSIENT		$E\delta_{33T}$	$E\delta^*_{33T}$	$E\delta_{43T}$	$E\delta^*_{43T}$	$E\delta_{44T}$	$E\delta^*_{44T}$	$E\delta_{54T}$	$E\delta^*_{54T}$
a HEATUP	4.00HRS	1291.5	-13.376	1297.5	1.338	1309.9	1.338	1347.0	2.678
	4.25	1400.6	-13.402	1400.6	1.340	1412.9	1.340	1449.9	2.014
	4.35	1441.7	-13.410	1441.7	1.341	1454.0	1.341	1490.8	2.015
	4.47	1490.8	-13.417	1490.8	1.342	1503.0	1.342	1539.7	1.008
	5.00	1644.8	-7.614	1644.8	0.895	1652.9	0.895	1672.9	0
STEADYSTATE		1800.3	0	1800.3	0	1800.3	0	1800.3	0
b. COOLDOWN	4.00HRS	486.4	13.062	486.4	-1.306	474.5	-1.306	438.8	-2.609
	4.25	387.3	13.029	387.3	-1.303	375.5	-1.302	340.0	-1.954
	4.35	347.9	13.015	347.9	-1.302	336.0	-1.301	300.6	-1.952
	4.47	300.6	12.998	300.6	-1.300	288.8	-1.299	253.4	-0.975
	5.00	151.5	7.336	151.5	-0.862	143.7	-0.862	124.1	0
c		1800.3	0	1800.3	0	1800.3	0	1800.3	0
d → f		1831.1	↓	1831.1	↓	1831.1	↓	1831.1	↓
g		1831.8		1331.8		1831.8		1831.8	
h		1829.9		1829.9		1829.9		1829.9	
i		0		0		0		0	
j	3.0 HRS	1202.3	-13.346	1202.3	1.335	1202.3	1.335	1202.3	1.002
	S.S.	1202.3	0	1202.3	0	1202.3	0	1202.3	0
	3.0 HRS	46.4	12.867	46.4	-1.287	46.4	-1.287	46.4	-0.097
k → m		1831.1	0	1831.1	0	1831.1	0	1831.1	0
n		1800.3	0	1800.3	0	1800.3	0	1800.3	0

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER 5-211-P | A 138
SHEET 30 OF 69
CHARGE NO.
DATE 4-22-68 BY COCKRELL
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS
CHECK DATE 4-23-68 BY HEILKER

5- DETAILED ANALYSIS:

d- PRESSURE AND THERMAL INTERACTION:

2- DEFLECTIONS:

FOR PEAK STRESS

TRANSIENT		$E\delta_{11T}$	$E\delta_{11T}^*$	$E\delta_{21T}$	$E\delta_{21T}^*$	$E\delta_{22T}$	$E\delta_{22T}^*$	$E\delta_{32T}$	$E\delta_{32T}^*$
a - HEATUP	4.00 HRS	1486.8	8.539	1071.8	17.734	1129.8	22.190	720.5	1.721
	4.25	1580.4	8.561	1141.9	17.821	1200.2	22.297	789.0	1.795
	4.35	1617.7	8.584	1169.6	17.955	1228.4	22.454	815.0	1.870
	4.47	1662.3	8.606	1202.9	17.946	1261.7	22.464	846.5	1.951
	5.00	1680.2	0.0	1228.2	18.043	1281.4	18.578	1032.6	2.208
STEADYSTATE		1680.2	0.0	1256.0	0.0	1256.0	0.0	1256.0	0.0
b - COOLDOWN	4.00 HRS	191.5	-8.466	180.1	-17.800	122.0	-22.255	531.3	-2.177
	4.25	98.9	-8.481	112.0	-17.893	53.6	-22.370	464.8	-2.299
	4.35	62.0	-8.501	85.0	-17.983	26.3	-22.481	439.5	-2.397
	4.47	17.8	-8.520	52.6	-18.026	-6.3	-22.544	408.8	-2.506
	5.00	0.0	0.0	27.9	-18.085	-25.5	-18.619	223.4	-2.537
c		1680.2	↓	1256.0	0.0	1256.0	0.0	1256.0	0.0
d → f		1709.0		1277.5	↓	1277.5	↓	1277.5	↓
g		1709.7		1278.1		1278.1		1278.1	
h		1707.9		1276.7		1276.7		1276.7	
i		0.0		0.0		0.0		0.0	
j	H.U. 3.0 HRS	1138.9	8.604	807.8	17.956	872.1	22.475	457.0	2.021
	S.S.	1127.3	0.0	838.9	0.0	838.9	0.0	838.9	0.0
	C.D. 3.0 HRS	32.5	-8.522	63.4	-18.025	-0.9	-22.543	414.2	-2.500
k → m		1709.0	0.0	1277.5	0.0	1277.5	0.0	1277.5	0.0
n		1680.2	0.0	1256.0	0.0	1256.0	0.0	1256.0	0.0

NUMBER S-211-P | A 139
SHEET 31 OF 69
CHARGE NO.
DATE 4-22-69 BY COCKRELL
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS
CHECK DATE 4-22-69 BY HEILKER

5. DETAILED ANALYSIS:

d. PRESSURE AND THERMAL INTERACTION:

2. DEFLECTIONS:

FOR PEAK STRESS

TRANSIENT		$E\delta_{33T}$	$E\delta^*_{33T}$	$E\delta_{43T}$	$E\delta^*_{43T}$	$E\delta_{44T}$	$E\delta^*_{44T}$	$E\delta_{54T}$	$E\delta_{54T}$
a - HEATUP	4.00 HRS	1718.5	70.055	1339.0	-17.758	1377.0	24.019	1466.6	-54.804
	4.25	1823.6	70.434	1440.8	-17.671	1482.1	24.413	1570.0	-55.745
	4.35	1866.7	70.832	1482.1	-17.763	1523.5	24.524	1611.5	-56.022
	4.47	1917.9	71.229	1531.4	-17.854	1572.9	24.635	1661.0	-57.307
	5.00	1889.4	40.814	1677.8	-11.233	1681.3	12.391	1738.3	-31.440
STEADY STATE		1800.3	0.0	1800.3	0.0	1800.3	0.0	1800.3	0.0
b - COOLDOWN	4.00 HRS	65.4	-70.369	444.9	17.790	407.4	-23.987	319.2	54.872
	4.25	-35.7	-70.808	347.1	17.708	306.3	-24.375	219.8	55.805
	4.35	-77.2	-71.226	307.4	17.802	266.5	-24.484	179.8	56.085
	4.47	-126.6	-71.648	259.9	17.896	218.9	-24.592	132.1	57.340
	5.00	-93.1	-41.092	118.5	11.266	115.2	-12.358	58.7	31.440
c		1800.3	0.0	1800.3	0.0	1800.3	0.0	1800.3	0.0
d → f		1831.1	↓	1831.1	↓	1831.1	↓	1831.1	↓
g		1831.8		1831.8		1831.8		1831.8	
h		1829.9		1829.9		1829.9		1829.9	
i		0.0		0.0		0.0		0.0	
j	H.U. 3 HRS	1629.5	71.300	1243.0	-17.862	1272.2	24.629	1323.7	-57.313
	S.S.	1202.3	0.0	1202.3	0.0	1202.3	0.0	1202.3	0.0
	C.D 3.0 HRS	-380.8	-71.779	5.8	17.909	-23.4	-24.580	-74.9	58.218
k → m		1831.1	0.0	1831.1	0.0	1831.1	0.0	1831.1	0.0
n		1800.3	0.0	1800.3	0.0	1800.3	0.0	1800.3	0.0

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

NUMBER S-211-P | A 140
SHEET 32 **OF** 69
DATE 4-22-68 **BY** COCKRELL
CHECK DATE 4-22-68 **BY** HEIKER

5. DETAILED ANALYSIS:

d. PRESSURE AND THERMAL INTERACTION:

3. CONTINUITY MATRIX AND LOADING VECTORS:

WRITING THE COMPATIBILITY EQUATIONS IN MATRIX FORM,

$$\begin{bmatrix} -175.2520 & -62.7120 & -68.3242 & 70.0465 & 0 & & 0 & 0 \\ 62.7120 & 52.4457 & 70.0465 & -47.7482 & 0 & & 0 & 0 \\ -68.3242 & -70.0465 & -158.1166 & 67.3601 & -6.5006 & 1.2909 & 0 & 0 \\ -70.0465 & -47.7482 & -67.3668 & 50.5732 & 0.7004 & -0.0605 & 0 & 0 \\ 0 & 0 & -4.5332 & -0.4916 & -23.5999 & 0.2398 & -5.3553 & 1.0038 \\ 0 & 0 & -0.9061 & -0.0425 & -0.2428 & 0.4696 & 1.0038 & -0.1189 \\ 0 & 0 & 0 & 0 & -5.3553 & -1.0038 & -15.7262 & 0.8281 \\ 0 & 0 & 0 & 0 & -1.0038 & -0.1189 & -0.8281 & 0.3588 \end{bmatrix} \begin{bmatrix} H_1 \\ M_1 \\ H_2 \\ M_2 \\ H_3 \\ M_3 \\ H_4 \\ M_4 \end{bmatrix}$$

	FOR RANGE OF STRESS							
	HEATUP					STEADYSTATE	COOLDOWN	
PRESSURE	T=4.00HRS	T=4.25	T=4.35	T=4.47	T=5.00		T=4.00HRS	T=4.25
12.9919P	-372.8	-396.1	-405.5	-416.7	-424.2	-424.2	-53.6	-29.3
3.3091P	-5.660	-5.659	-5.657	-5.655	-0.961	0	5.521	5.505
97.5249P	0	0	0	0	0	0	0	0
-40.8173P	-11.500	-11.500	-11.498	-11.494	-6.646	0	11.109	11.067
48.7657P	0	0	0	0	0	0	0	0
8.8063P	14.714	14.742	14.751	14.759	8.509	0	-14.368	-14.332
321.0130P	37.2	36.9	36.8	36.7	20.1	0	-35.7	-35.5
-22.0252P	1.340	0.673	0.673	-0.334	-0.895	0	-1.303	-0.651

FOR RANGE OF STRESS								
COOLDOWN								
T=4.35	T=4.47	T=500	c	d → f	g	h	i	$j_{H.U}$ T=3.00HRS
-19.5	-7.8	0	-424.2	-431.5	-431.6	-431.2	0	-288.4
5.499	5.489	0.919	0	0	0	0	0	-5.643
0	0	0	0	0	0	0	0	0
11.047	11.018	6.358	0	0	0	0	0	-11.433
0	0	0	0	0	0	0	0	0
-14.317	-14.298	-8.198	0	0	0	0	0	14.680
-35.5	-35.4	-19.5	0	0	0	0	0	0
-0.651	0.325	0.862	0	0	0	0	0	-0.333

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER 5-211-P | A141
SHEET 33 OF 69
CHARGE NO.
DATE 4-22-68 BY Cockrell
DESCRIPTION Structural And Fatigue Evaluation Of Inlet Nozzle - Vessel Supports
CHECK DATE 4-22-68 BY Heilker

5- DETAILED ANALYSIS:

d- PRESSURE AND THERMAL INTERACTION:

3. CONTINUITY MATRIX AND LOADING VECTORS:

FOR RANGE OF STRESS				FOR PEAK STRESS				
j		k → m	n	HEATUP				
S.S	C.O 3.00 HRS			T=4.00 HRS	T=4.25	T=4.35	T=4.47	T=5.00
-288.4	-11.8	-431.5	-424.2	-415.0	-438.5	-448.1	-459.4	-452.1
0	5.493	0	0	9.195	9.259	9.371	9.340	13.043
0	0	0	0	-409.3	-411.3	-413.3	-415.1	-248.8
0	11.023	0	0	20.469	-20.503	-20.585	-20.513	-16.369
0	0	0	0	-379.5	-382.8	-384.7	-386.5	-211.6
0	-14.154	0	0	-87.813	-88.105	-88.594	-89.084	-52.047
0	0	0	0	89.7	87.9	89.1	89.2	57.0
0	1.190	0	0	-78.823	-80.159	-80.546	-81.942	-43.831

FOR PEAK STRESS								
	COOLDOWN							
STEADY STATE	T=4.00 HRS	T=4.25	T=4.35	T=4.47	T=5.00	c	d → f	g
-424.2	-11.4	13.1	23.0	34.8	27.9	-424.2	-431.5	-431.6
0	-9.334	-9.412	-9.482	-9.506	-18.085	0	0	0
0	409.3	411.3	413.2	415.1	248.8	0	0	0
0	20.078	20.070	20.084	20.038	16.082	0	0	0
0	379.5	382.8	384.7	386.5	211.6	0	0	0
0	88.159	88.516	89.028	89.544	52.358	0	0	0
0	-88.2	-86.5	-86.7	-86.9	-56.5	0	0	0
0	78.860	80.180	80.569	81.932	43.798	0	0	0

FOR PEAK STRESS						
h	i	j			k → m	n
		H.U. T=3.00 HRS	S.S	C.D T=3.00 HRS		
-431.1	0	-331.1	-288.4	30.9	-431.5	-424.2
0	0	9.353	0	-9.503	0	0
0	0	-415.1	0	415.1	0	0
0	0	-20.453	0	20.043	0	0
0	0	-386.5	0	386.5	0	0
0	0	-89.162	0	89.688	0	0
0	0	51.5	0	-51.5	0	0
0	0	-81.940	0	82.798	0	0

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

NUMBER 5-211-P | A142
SHEET 34 **OF** 69
DATE 4-22-68 **BY** COCKRELL
CHECK DATE 4-22-68 **BY** HEILKER

5- DETAILED ANALYSIS:

d- PRESSURE AND THERMAL INTERACTION:

4. REDUNDANT FORCES:

THE ABOVE MATRIX WITH THE GIVEN LOADING VECTORS FOR PRESSURE AND THE TRANSIEN CONDITIONS FOR BOTH RANGE OF STRESS AND PEAK STRESS GIVE THE FOLLOWING VALUES FOR THE REDUNDANT FORCES.

— FOR RANGE OF STRESS —

TRANSIENT		H_1 KIP/IN	M_1 IN-KIP/IN	H_2 KIP/IN	M_2 IN-KIP/IN	H_3 KIP/IN	M_3 IN-KIP/IN	H_4 KIP/IN	M_4 IN-KIP/IN
PRESSURE ONLY		-1.4880P	-4.0236P	-1.4597P	-8.5635P	0.9949P	51.5296P	-29.8560P	-110.4336P
a- HEATUP	4.00 HRS	5.4218	-1.9397	2.8411	9.2769	1.6582	53.9849	-5.6804	13.1555
	4.25	5.7652	-1.8840	2.9719	9.9809	1.5267	53.8035	-5.7380	10.7364
	4.35	5.9028	-1.8632	3.0245	10.2617	1.5114	53.9330	-5.7330	10.7487
	4.47	6.0690	-1.8299	3.0865	10.6073	1.3483	53.2669	-5.8186	7.0657
	5.00	6.2067	-0.3086	2.7739	11.9022	0.3808	32.3727	-3.3944	1.4660
STEADY STATE		6.2340	0.9222	2.3724	12.6809	-0.6379	5.6658	-0.1588	-0.2734
b- COOLDOWN	4.00 HRS	0.8400	2.7851	-0.4398	3.4015	-2.2358	-47.0402	5.3413	-13.1506
	4.25	0.4919	2.7183	-0.5732	2.6625	-2.0994	-46.7069	5.3900	-10.7289
	4.35	0.3387	2.6930	-0.6270	2.3680	-2.0822	-46.7841	5.3859	-10.7136
	4.47	0.1653	2.6543	-0.6907	2.0043	-1.9219	-46.0909	5.4718	-7.1183
	5.00	0.0249	1.1797	-0.3880	0.7399	-0.9844	-25.7664	3.1338	-1.6585
c		6.2340	0.9222	2.3724	12.6809	-0.6379	5.6658	-0.1588	-0.2734
d → f		6.3407	0.9380	2.4131	12.8981	-0.6488	5.7628	-0.1616	-0.2781
g		6.3435	0.9384	2.4141	12.9037	-0.6491	5.7653	-0.1616	-0.2782
h		6.3366	0.9374	2.4115	12.8898	-0.6484	5.7591	-0.1614	-0.2779
i		0	0	0	0	0	0	0	0
j	HU 3.0 HRS	4.1645	-2.0371	2.2937	6.7150	0.9230	45.0705	-2.6381	10.5043
	S.S	4.2388	0.6271	1.6131	8.6224	-0.4337	3.8525	-0.1080	-0.1859
	CD 3.00 HRS	0.2437	2.5950	-0.5902	2.1894	-1.2013	-38.8840	2.5159	-7.1246
k → m		6.3407	0.9380	2.4131	12.8981	-0.6488	5.7628	-0.1616	-0.2781
n		6.2340	0.9222	2.3724	12.6809	-0.6379	5.6658	-0.1588	-0.2734

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

NUMBER 5-211-P A 143
SHEET 35 OF 69
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:
d- PRESSURE AND THERMAL INTERACTION:
4- REDUNDANT FORCES:

- FOR PEAK STRESS -

TRANSIENT		H_1 KIP/IN	M_1 IN-KIP/IN	H_2 KIP/IN	M_2 IN-KIP/IN	H_3 KIP/IN	M_3 IN-KIP/IN	H_4 KIP/IN	M_4 IN-KIP/IN
a - HEATUP	4.00 HRS	5.4314	-3.3474	2.8545	7.4518	1.1275	-244.7520	-6.9856	-313.7740
	4.25	5.7743	-3.2997	2.9846	8.1440	1.0213	-246.2679	-6.9801	-318.2831
	4.35	5.9120	-3.2858	3.0372	8.4150	1.0037	-247.5879	-6.9811	-319.8529
	4.47	6.0782	-3.2595	3.0993	8.7540	0.8381	-249.7035	-7.0727	-325.1178
	5.00	6.2115	-0.2963	2.7805	11.5336	0.1159	-140.7465	-4.0447	-177.8202
STEADYSTATE		6.2340	0.9222	2.3724	12.6809	-0.6379	5.6658	-0.1588	-0.2734
b - COOLDOWN	4.00 HRS	0.8304	4.1928	-0.4532	5.2265	-1.7052	251.6967	6.6465	313.7789
	4.25	0.4728	4.1341	-0.5859	4.4994	-1.5941	253.3645	6.6322	318.2906
	4.35	0.3295	4.1157	-0.6397	4.2136	-1.5744	254.7368	6.6341	319.8880
	4.47	0.1561	4.0838	-0.7035	3.8577	-1.4117	256.8794	6.7259	325.0652
	5.00	0.0201	1.1673	-0.3946	1.1085	-0.7195	147.3528	3.7840	177.6277
c		6.2340	0.9222	2.3724	12.6809	-0.6379	5.6658	-0.1588	-0.2734
d → f		6.3407	0.9380	2.4131	12.6981	-0.6488	5.7628	-0.1616	-0.2781
g		6.3435	0.9384	2.4141	12.9037	-0.6491	5.7653	-0.1616	-0.2782
h		6.3366	0.9374	2.4115	12.8898	-0.6484	5.7591	-0.1614	-0.2779
i		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
j	H.U. 3.0 HRS	4.1737	-3.4666	2.3064	4.8617	0.4128	-257.8999	-3.8922	-321.6793
	S.S.	4.2388	0.6271	1.6131	8.6224	-0.4337	3.8525	-0.1080	-0.1859
	C.O 3.0 HRS	0.2344	4.0246	-0.6030	4.0428	-0.6911	264.0863	3.7700	325.0589
k → m		6.3407	0.9380	2.4131	12.8981	-0.6488	5.7628	-0.1616	-0.2781
n		6.2340	0.9222	2.3724	12.6809	-0.6379	5.6658	-0.1588	-0.2734

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION Structural And Fatigue Evaluation Of Inlet Nozzle - Vessel Supports

NUMBER S-211-P | A144
SHEET 36 OF 69
DATE 4-22-68 BY Cockrell
CHECK DATE 4-22-68 BY Heilker

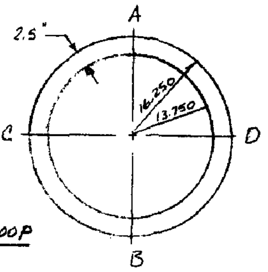
5- DETAILED ANALYSIS:

e- STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

FOR THIS SECTION OF THE ANALYSIS, STRESSES WILL BE CALCULATED AT THE TEN LOCATIONS AS SHOWN ON SHEET 17.

LOCATION 1 & 2:



PRESSURE STRESS:

$$\sigma_x = \pm \frac{6M_1}{t_1^2}\frac{R_1}{R_1} + \frac{b_1^2 P}{2R_1 t_1} = \underline{\pm 0.9670 M_1 + 2.5208P}$$

$$\sigma_\theta = \pm \frac{\nu 6M_1}{t_1^2}\frac{R_1}{R_1} + \frac{EW_{11}}{R_1} + \frac{b_1 P}{t_1} = \underline{\pm 0.2901 M_1 + 0.06667 EW_{11} + 5.5000P}$$

$$\sigma_r = -P$$

$$I = \frac{\pi}{4}(r_o^4 - r_i^4) = 26691 \text{ IN}^4$$

$$A = \pi(r_o^2 - r_i^2) = 235.6 \text{ IN}^2$$

THERMAL STRESS:

$$\sigma_x = \pm \frac{6M_1}{t_1^2}\frac{R_1}{R_1} = \underline{\pm 0.9670 M_1}$$

$$\sigma_\theta = \pm \frac{\nu 6M_1}{t_1^2}\frac{R_1}{R_1} + \frac{EW_{11}}{R_1} = \pm \underline{0.2901 M_1 + 0.06667 EW_{11}}$$

THERMAL INDUCED PIPE REACTIONS:

	LOCATION -1		LOCATION - 2	
$\sigma_x = -\frac{F_x}{A} \pm \frac{Mc}{I}$	$= -0.00424F_x + 0.00052M_z$	POINT A	$= -0.00424F_x + 0.00061M_z$	POINT A
	$= -0.00424F_x - 0.00052M_z$	B	$= -0.00424F_x - 0.00061M_z$	B
	$= -0.00424F_x + 0.00052M_y$	C	$= -0.00424F_x + 0.00061M_y$	C
	$= -0.00424F_x - 0.00052M_y$	D	$= -0.00424F_x - 0.00061M_y$	D
$\tau_{x\theta} = \frac{FQ}{Ib'} \pm \frac{Mc}{2I}$	$= 0.00845F_z + 0.00026M_x$	POINT A	$= 0.00845F_z + 0.00031M_x$	POINT A
	$= 0.00845F_z - 0.00026M_x$	B	$= 0.00345F_z - 0.00031M_x$	B
	$= 0.00845F_y + 0.00026M_x$	C	$= 0.00345F_y + 0.00031M_x$	C
$b' = 2t_1$	$= 0.00845F_y - 0.00026M_x$	D	$= 0.00845F_y - 0.00031M_x$	D

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER S-211-P | A145
SHEET 37 OF 69
CHARGE NO.
DATE 4-22-68 BY COCKRELL
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS
CHECK DATE 4-22-68 BY HEILKER

5. DETAILED ANALYSIS:

e- STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

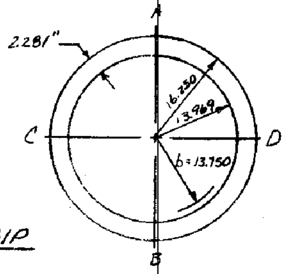
SEISMIC PIPE REACTIONS:

THE FORMULAS FOR CALCULATING THE STRESSES DUE TO THE SEISMIC PIPE REACTIONS ARE THE SAME AS FOR THE THERMALLY INDUCED PIPE REACTIONS.

NOTE:

THERE WILL BE NO STRESS PRODUCED AT LOCATIONS 1→6 DUE TO THE STATIC LOADING THROUGH SUPPORTS, EARTHQUAKE LOADING THROUGH SUPPORTS, OR DUE TO THERMAL EXPANSION OR CONTRACTION.

LOCATION 3 & 4:



PRESSURE STRESS:

$$\sigma_x = \pm \frac{6M_1}{t_2^2} + \frac{b^2P}{2R_2t_2} = \pm \underline{1.1532\,M_1 + 2.7428P}$$

$$\sigma_\theta = \pm \frac{\nu 6M_1}{t_2^2} + \frac{EW_{21}}{R_2} + \frac{bP}{t_2} = \underline{\pm 0.3460M_1 + 0.0662\,EW_{21} + 6.0281P}$$

$$\sigma_r = -P$$

$$I = \frac{\pi}{4}(r_o^4 - r_i^4) = 24861\ \text{IN}^4$$

$$A = \pi(r_o^2 - r_i^2) = 216.6\ \text{IN}^2$$

THERMAL STRESS

$$\sigma_x = \pm \frac{6M_1}{t_2^2} = \pm \underline{1.1532\,M_1}$$

$$\sigma_\theta = \pm \frac{\nu 6M_1}{t_2^2} + \frac{EW_{21}}{R_2} = \underline{\pm 0.3460\,M_1 + 0.0662\,EW_{21}}$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

NUMBER 5-211-P | A146
SHEET 38 OF 69
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

e- STRESSES:

1- COMBINED STRESSES – UNCONCENTRATED:

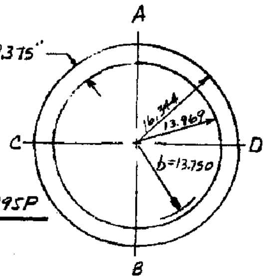
THERMAL INDUCED PIPE REACTIONS:

	LOCATION-3		LOCATION-4	
$\sigma_x = -\frac{F_x}{A} \pm \frac{M_c}{I}$	$= -0.00462 F_x + 0.00056 M_z$	POINT A	$= -0.00462 F_x + 0.00065 M_z$	POINT A
	$= -0.00462 F_x - 0.00056 M_z$	B	$= -0.00462 F_x - 0.00065 M_z$	B
	$= -0.00462 F_x + 0.00056 M_y$	C	$= -0.00462 F_x + 0.00065 M_y$	C
	$= -0.00462 F_x - 0.00056 M_y$	D	$= -0.00462 F_x - 0.00065 M_y$	D
$\tau_{x\theta} = \frac{FQ}{Ib'} \pm \frac{Mc}{2I}$	$= 0.00926 F_z + 0.00028 M_x$	POINT A	$= 0.00926 F_z + 0.00033 M_x$	POINT A
	$= 0.00926 F_z - 0.00028 M_x$	B	$= 0.00926 F_z - 0.00033 M_x$	B
	$= 0.00926 F_y + 0.00028 M_x$	C	$= 0.00926 F_y + 0.00033 M_x$	C
$b' = 2t_2$	$= 0.00926 F_y - 0.00028 M_x$	D	$= 0.00926 F_y - 0.00033 M_x$	D

SEISMIC PIPE REACTIONS:

THE FORMULAS FOR CALCULATING THE STRESSES ARE THE SAME AS FOR THE THERMAL INDUCED PIPE REACTIONS.

LOCATION 5-6:



PRESSURE STRESS:

$$\sigma_x = \pm \frac{6M_z}{t_{2A}^2} + \frac{b^2 P}{2R_2 t_{2A}} = \underline{\pm 1.0637 M_2 + 2.6342P}$$

$$\sigma_\theta = \pm \frac{\nu 6 M_z}{t_{2A}^2} + \frac{EW_{2z}}{R_2} + \frac{bP}{t_{2A}} = \underline{\pm 0.3191 M_z + 0.0662 EW_{2z} + 5.7895P}$$

$$\sigma_r = -P$$

$$I = \frac{\pi}{4}(r_o^4 - r_i^4) = 26138 \text{ IN}^4$$

$$A = \pi(r_o^2 - r_i^2) = 226.2 \text{ IN}^2$$

THERMAL STRESS:

$$\sigma_x = \pm \frac{6M_z}{t_{2A}^2} = \pm \underline{1.0637 M_2}$$

$$\sigma_\theta = \pm \frac{\nu 6 M_z}{t_{2A}^2} + \frac{EW_{2z}}{R_z} = \underline{\pm 0.3191 M_z + 0.0662 EW_{2z}}$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

NUMBER 5-211-P | A147
SHEET 39 **OF** 69
DATE 4-22-68 **BY** COCKRELL
CHECK DATE 4-27-68 **BY** HEKKER

5- DETAILED ANALYSIS:

e- STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

THERMAL INDUCED PIPE REACTIONS:

SINCE THE PIPE REACTIONS ARE APPLIED AT THE SMALL END OF THE NOZZLE, THE PIPE REACTIONS MUST BE RESOLVED TO THE CROSS SECTION OF INTEREST. THIS IS DONE AS FOLLOWS.

$\bar{F}_x = F_x = 14.8$ $\qquad \bar{M}_x = M_x = -3783$

$\bar{F}_y = F_y = -92$ $\qquad \bar{M}_y = M_y + 2.923 F_z = 4579.4$

$\bar{F}_z = F_z = 27.5$ $\qquad \bar{M}_z = M_z - 2.923 F_y = 7710.0$

	LOCATION - 5		LOCATION - 6	
$\sigma_x = -\frac{\bar{F}_x}{A} \pm \frac{\bar{M}c}{I}$	$= -0.00442\bar{F}_x + 0.00053\bar{M}_z$	POINT A	$= -0.00442\bar{F}_x + 0.00062\bar{M}_z$	POINT A
	$= -0.00442\bar{F}_x - 0.00053\bar{M}_z$	B	$= -0.00442\bar{F}_x - 0.00062\bar{M}_z$	B
	$= -0.00442\bar{F}_x + 0.00053\bar{M}_y$	C	$= -0.00442\bar{F}_x + 0.00062\bar{M}_y$	C
	$= -0.00442\bar{F}_x - 0.00053\bar{M}_y$	D	$= -0.00442\bar{F}_x - 0.00062\bar{M}_y$	D
$\tau_{x\theta} = \frac{FQ}{Ib'} \pm \frac{Mc}{2I}$	$= 0.00881\bar{F}_z + 0.00026\bar{M}_x$	POINT A	$= 0.00881\bar{F}_z + 0.00031\bar{M}_x$	POINT A
	$= 0.00881\bar{F}_z - 0.00026\bar{M}_x$	B	$= 0.00881\bar{F}_z - 0.00031\bar{M}_x$	B
$b' = 2t_{2A}$	$= 0.00881\bar{F}_y + 0.00026\bar{M}_x$	C	$= 0.00881\bar{F}_y + 0.00031\bar{M}_x$	C
	$= 0.00881\bar{F}_y - 0.00026\bar{M}_x$	D	$= 0.00881\bar{F}_y - 0.00031\bar{M}_x$	D

SEISMIC PIPE REACTIONS:

THE FORMULAS FOR CALCULATING THE STRESSES DUE TO THE SEISMIC PIPE REACTIONS ARE THE SAME AS FOR THE THERMAL INDUCED PIPE REACTIONS.

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

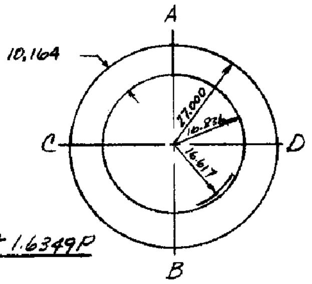
NUMBER 5-211-P | A 148
SHEET 40 OF 69
DATE 4-22-63 BY COCKRELL
CHECK DATE 4-22-63 BY HEILKER

5- DETAILED ANALYSIS:

e- STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

LOCATION 7 & 8:



PRESSURE STRESS:

$$\sigma_x = \pm \frac{6M_4}{t_{4A}^2}\frac{R_4}{R_{4A}} + \frac{b^2P}{2R_{4A}t_{4A}} = \underline{\pm 0.0574\,M_4 + 0.6197\,P}$$

$$\sigma_\theta = \pm \frac{\nu 6M_4}{t_{4A}^2}\frac{R_4}{R_{4A}} + \frac{EW_{44}}{R_{4A}} + \frac{bP}{t_{4A}} = \underline{\pm 0.0172\,M_4 + 0.0456\,EW_{44} + 1.6349\,P}$$

$$\sigma_r = -P$$

$I = \frac{\pi}{4}(r_o^4 - r_i^4) = 354290\,\text{IN}^4$

$A = \pi(r_o^2 - r_i^2) = 1400\,\text{IN}^2$

THERMAL STRESS:

$$\sigma_x = \pm \frac{6M_4}{t_{4A}^2}\frac{R_4}{R_{4A}} = \underline{\pm 0.0574\,M_4}$$

$$\sigma_\theta = \pm \frac{\nu 6M_4}{t_{4A}^2}\frac{R_4}{R_{4A}} + \frac{EW_{44}}{R_{4A}} = \underline{\pm 0.0172\,M_4 + 0.0456\,EW_{44}}$$

THERMAL INDUCED PIPE REACTIONS:

SINCE THE PIPE REACTIONS ARE APPLIED AT THE SMALL END OF THE NOZZLE, THE PIPE REACTIONS MUST BE RESOLVED TO THE CROSS SECTION OF INTEREST. THIS IS DONE AS FOLLOWS.

$\bar{F}_x = F_x = 14.8$
$\bar{F}_y = F_y = -92$
$\bar{F}_z = F_z = 27.5$

$\bar{M}_x = M_x = -3783$
$\bar{M}_y = M_y + 30.313\,F_z = 5332.6$
$\bar{M}_z = M_z - 30.313\,F_y = 10229.8$

	LOCATION - 7		LOCATION - 8	
$\sigma_x = -\frac{\bar{F}_x}{A} \pm \frac{\bar{M}c}{I}$	$= -0.00071\,\bar{F}_x + 0.00005\,\bar{M}_z$	POINT A	$= -0.00071\,\bar{F}_x + 0.00008\,\bar{M}_z$	POINT A
	$= -0.00071\,\bar{F}_x - 0.00005\,\bar{M}_z$	B	$= -0.00071\,\bar{F}_x - 0.00008\,\bar{M}_z$	B
	$= -0.00071\,\bar{F}_x + 0.00005\,\bar{M}_y$	C	$= -0.00071\,\bar{F}_x + 0.00008\,\bar{M}_y$	C
	$= -0.00071\,\bar{F}_x - 0.00005\,\bar{M}_y$	D	$= -0.00071\,\bar{F}_x - 0.00008\,\bar{M}_y$	D

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION Structural And Fatigue Evaluation Of Inlet Nozzle - Vessel Supports

NUMBER 5-211-P | A 149
SHEET 41 OF 69
DATE 4-22-68 BY Cockrell
CHECK DATE 4-22-68 BY Heilker

5. Detailed Analysis:

e- Stresses:

1- Combined Stresses - Unconcentrated:

	Location - 7		Location - 8	
$\tau_{x\theta} = \frac{FQ}{Ib'} \pm \frac{\bar{M}c}{2I}$	$= 0.00138\,\bar{F}_z + 0.000024\bar{M}_x$	Point A	$= 0.00138\,\bar{F}_z + 0.000038\bar{M}_x$	Point A
	$= 0.00138\,\bar{F}_z - 0.000024\bar{M}_x$	B	$= 0.00138\,\bar{F}_z - 0.000038\bar{M}_x$	B
$b' = 2t_{4A}$	$= 0.00138\bar{F}_y + 0.000024\bar{M}_x$	C	$= 0.00138\,\bar{F}_y + 0.000038\bar{M}_x$	C
	$= 0.00138\bar{F}_y - 0.000024\bar{M}_x$	D	$= 0.00138\,\bar{F}_y - 0.000038\bar{M}_x$	D

Seismic Pipe Reactions:

In Setting Up Equations To Account For The Seismic Pipe Reactions, The Forces Exerted On The Nozzle Which Are Applied Thru The Support Pad Must Be Resolved To The Cross Section Of Interest. These Forces Are Labeled H And V As Shown On Sheet 9. The Values For The Design Earthquake And The No Loss Of Function Condition Which Will Be Considered Are Presented In The Table On Sheet 9. The Equations For Stress Will Be The Same For The Seismic Conditions As For The Thermal Induced Pipe Reactions Except The Values For F_x, $\bar{F}_y$, $\bar{F}_z$, $\bar{M}_x$, $\bar{M}_y$, And $\bar{M}_z$ Will Be As Follows.

$\bar{F}_x = F_x = -57.9$ $\bar{M}_x = M_x - 27H = -1492.7$
$\bar{F}_y = F_y + V = -340.2$ $\bar{M}_y = M_y + 30.313F_z + 13.0H = 23715.1$
$\bar{F}_z = F_z + H = 649.4$ $\bar{M}_z = M_z - 30.313F_y - 13.0V = 15492.6$

Static Loading Through Supports:

The Equations For Stress Are The Same As For The Thermally Induced Pipe Reactions With The Following Values For $\bar{F}_y$ & $\bar{M}_z$.

$\bar{F}_y = V = 561.1$ See Sheet 14 For Values Of V With Or Without
$\bar{M}_z = -13.0V = 7294.3$ The Dynamic Load Of Tripped Control Rods.

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE – VESSEL SUPPORTS

NUMBER 5-211-P | A 150
SHEET 42 OF 69
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

e - STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

EARTHQUAKE LOADING THRU SUPPORTS:

THE EQUATIONS FOR STRESS DUE TO THE EARTHQUAKE LOADING THROUGH THE SUPPORTS WILL BE THE SAME AS FOR THE THERMAL INDUCED PIPE REACTIONS WITH THE FOLLOWING VALUES FOR $\bar{F}_y$, $\bar{F}_z$, $\bar{M}_x$, $\bar{M}_y$, AND $\bar{M}_z$

$\bar{F}_y = V = -126.4$

$\bar{F}_z = H = 336.7$

$\bar{M}_x = -27H = -9090.9$

$\bar{M}_y = 13H = 4377.1$

$\bar{M}_z = -13V = 1643.2$

THERMAL EXPANSION AND CONTRACTION:

THE EQUATIONS FOR STRESS DUE TO EXPANSION AND CONTRACTION ARE AS FOLLOWS WITH THE VALUES FOR $\bar{F}_x$ AND $\bar{M}_z$ EQUAL TO.

$\bar{F}_x = F = 168.3$

$\bar{M}_z = 28F = 4712.4$

SEE SHEET 16 FOR VALUES OF F.

	LOCATION - 7		LOCATION - 8	
$\sigma_x = -\frac{\bar{F}_x}{A} \pm \frac{\bar{M}c}{I}$	$= -0.00071\,\bar{F}_x + 0.00005\,\bar{M}_z$	POINT A	$= -0.00071\,\bar{F}_x + 0.00008\,\bar{M}_z$	POINT A
	$= -0.00071\,\bar{F}_x - 0.00005\,\bar{M}_z$	B	$= -0.00071\,\bar{F}_x - 0.00008\,\bar{M}_z$	B
	$= -0.00071\,\bar{F}_x$	C	$= -0.00071\,\bar{F}_x$	C
	$= -0.00071\,\bar{F}_x$	D	$= -0.00071\,\bar{F}_x$	D

	LOCATION-7	LOCATION-8	
σ_x	$= 0.00069F$	$= 0.00153F$	POINT A
	$= -0.00211F$	$= -0.00295F$	B
	$= -0.00071F$	$= -0.00071F$	C
	$= -0.00071F$	$= -0.00071F$	D

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER 5-211-P | A151
SHEET 43 OF 69
CHARGE NO.
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

5- DETAILED ANALYSIS:

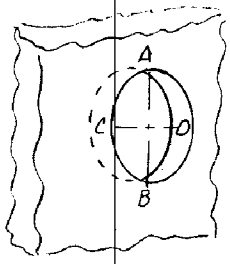
e- STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

LOCATION 9 & 10:

PRESSURE STRESS:

NOTE HERE THAT IT WILL BE NECESSARY TO CALCULATE STRESSES IN BOTH THE LONGITUDINAL AND CIRCUMFERENTIAL DIRECTIONS FOR PRESSURE



POINTS A & B (LONGITUDINAL PLANE):

$$\sigma_x = \pm\frac{6M_4}{t_5^2} - \frac{H_4}{t_5} + \frac{V_4 \sin\phi}{t_5} = \underline{\pm 0.05192 M_4 - 0.09302 H_4 + 0.0882 P}$$

$$\sigma_\theta = \pm\frac{\nu 6 M_4}{t_5^2} + \frac{E W_{54}}{R_5 \sin\phi} + \frac{b_V P}{t_5} = \underline{\pm 0.01558 M_4 + 0.0462\ E W_{54} + 7.9477 P}$$

$$\sigma_r = -P$$

POINTS C & D (CIRCUMFERENTIAL PLANE):

$$\sigma_x = \pm\frac{\nu 6 M_4}{t_5^2} + \frac{E W_{54}}{R_5 \sin\phi} + \frac{b_V^2 P}{2 R_V t_4} = \underline{\pm 0.01558 M_4 + 0.0462\ E W_{54} + 3.7297 P}$$

$$\sigma_\theta = \pm\frac{6M_4}{t_5^2} - \frac{H_4 \cos\phi}{t_5} + \frac{V_4 \sin\phi}{t_5} = \underline{\pm 0.05192 M_4 - 0.0918 H_4 + 0.0882 P}$$

$$\sigma_r = -P$$

THERMAL STRESS:

POINTS A & B (LONGITUDINAL PLANE):

$$\sigma_x = \pm\frac{6M_4}{t_5^2} - \frac{H_4}{t_5} = \underline{\pm 0.05192 M_4 - 0.0930 H_4}$$

$$\sigma_\theta = \pm\frac{\nu 6 M_4}{t_5^2} + \frac{E W_{54}}{R_5 \sin\phi} = \underline{\pm 0.01558 M_4 + 0.0462 E W_{54}}$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO. 6866
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORT

NUMBER 5-211-P | A 152
SHEET 44 OF 69
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

e- STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

POINTS C&D (CIRCUMFERENTIAL PLANE):

$$\sigma_x = \pm \frac{\nu 6 M_4}{t_5^2} + \frac{EW_{54}}{R_5 \sin\phi} = \underline{\pm 0.01558 M_4 + 0.0462 EW_{54}}$$

$$\sigma_\theta = \pm \frac{6 M_4}{t_5^2} - \frac{H_4 \cos\phi}{t_5} = \underline{\pm 0.05192 M_4 - 0.0918 H_4}$$

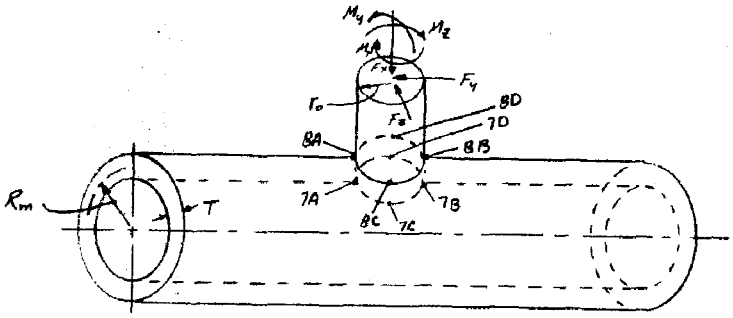
THERMAL INDUCED PIPE REACTIONS:

THE STRESSES IN THE VESSEL WALL DUE TO THE THERMALLY INDUCED PIPE REACTIONS WILL BE CALCULATED BY THE METHOD OUTLINED IN REF 21 FOR A CYLINDRICAL ATTACHMENT TO A CYLINDRICAL SHELL. SINCE THE PIPE REACTIONS ARE APPLIED AT THE SMALL END OF THE NOZZLE, THEY MUST BE RESOLVED TO THE MID-RADIUS OF THE VESSEL WALL. THIS IS DONE BY THE FOLLOWING RELATIONSHIP OF FORCES.

$\bar{F}_x = F_x = 14.8$ $\qquad \bar{M}_x = M_x = -3783$

$\bar{F}_y = F_y = -92$ $\qquad \bar{M}_y = M_y + 35.688\ F_z = 5480.4$

$\bar{F}_z = F_z = 27.5$ $\qquad \bar{M}_z = M_z - 35.688\ F_y = 10724.3$



$R_m = 91.032''$
$T = 10.75''$
$r_o = 27''$

WITH THE GEOMETRIC PARAMETERS OF $\gamma = \frac{R_m}{T} = 8.5$ AND $\beta = 0.875 \frac{r_o}{R_m} = 0.260$ AND THE CURVES IN REF 21 WE GET THE FOLLOWING EXPRESSIONS FOR STRESS.

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION Structural and Fatigue Evaluation of Inlet Nozzle - Vessel Supports

NUMBER 5-211-P | A153
SHEET 45 OF 69
DATE 4-22-68 BY Cockrell
CHECK DATE 4-22-68 BY Helker

5. DETAILED ANALYSIS:

e. STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

$$\sigma_x = -\left(\frac{N_x}{\bar F_x/R_m}\right)\frac{\bar F_x}{R_m T} \pm \left(\frac{M_x}{\bar F_x}\right)\frac{6\bar F_x}{T^2} \pm \left(\frac{N_x}{\bar M_y/R_m^2\beta}\right)\frac{\bar M_y}{R_m^2\beta T} \pm \left(\frac{M_x}{\bar M_y/R_m\beta}\right)\frac{6\bar M_y}{R_m\beta T^2} \pm \left(\frac{N_x}{\bar M_z/R_m^2\beta}\right)\frac{\bar M_z}{R_m^2\beta T} \pm \left(\frac{M_x}{\bar M_z/R_m\beta}\right)\frac{6\bar M_z}{R_m\beta T^2}$$

$$= -(1.45)\frac{\bar F_x}{978.58} \pm (0.072)\frac{6\bar F_x}{115.56} \pm (0.50)\frac{\bar M_y}{23162} \pm (0.055)\frac{6\bar M_y}{2735.2} \pm (0.28)\frac{\bar M_z}{23162} \pm (0.067)\frac{6\bar M_z}{2735.2}$$

LOCATION- 9		LOCATION-10	
$-0.00148\bar F_x + 0.00374\bar F_x + 0.000012\bar M_z - 0.00015\bar M_z$	POINT A	$-0.00148\bar F_x - 0.00374\bar F_x + 0.000012\bar M_z + 0.00015\bar M_z$	POINT A
$-0.00148\bar F_x + 0.00574\bar F_y - 0.000012\bar M_z + 0.00015\bar M_z$	B	$-0.00148\bar F_x - 0.00374\bar F_x - 0.000012\bar M_z - 0.00015\bar M_z$	B
$-0.00148\bar F_x + 0.00374\bar F_y + 0.000022\bar M_y - 0.00012\bar M_y$	C	$-0.00148\bar F_x - 0.00374\bar F_x + 0.000022\bar M_y + 0.00012\bar M_y$	C
$-0.00148\bar F_x + 0.00374\bar F_x - 0.000022\bar M_y + 0.00012\bar M_y$	D	$-0.00148\bar F_x - 0.00374\bar F_x - 0.000022\bar M_y - 0.00012\bar M_y$	D

$$\sigma_\theta = -\left(\frac{N_\theta}{\bar F_x/R_m}\right)\frac{\bar F_x}{R_m T} \pm \left(\frac{M_\theta}{\bar F_x}\right)\frac{6\bar F_x}{T^2} \pm \left(\frac{N_\theta}{\bar M_y/R_m^2\beta}\right)\frac{\bar M_y}{R_m^2\beta T} \pm \left(\frac{M_\theta}{\bar M_y/R_m\beta}\right)\frac{6\bar M_y}{R_m\beta T^2} \pm \left(\frac{N_\theta}{\bar M_z/R_m^2\beta}\right)\frac{\bar M_z}{R_m^2\beta T} \pm \left(\frac{M_\theta}{\bar M_z/R_m\beta}\right)\frac{6\bar M_z}{R_m\beta T^2}$$

$$= -(1.25)\frac{\bar F_x}{978.58} \pm (0.094)\frac{6\bar F_x}{115.56} \pm (0.27)\frac{\bar M_y}{23162} \pm (0.097)\frac{6\bar M_y}{2735.2} \pm (1.00)\frac{\bar M_z}{23162} \pm (0.042)\frac{6\bar M_z}{2735.2}$$

LOCATION- 9		LOCATION-10	
$-0.00128\bar F_x + 0.00488\bar F_x + 0.000043\bar M_z - 0.000092\bar M_z$	POINT A	$-0.00128\bar F_x - 0.00488\bar F_x + 0.000043\bar M_z + 0.000092\bar M_z$	POINT A
$-0.00128\bar F_x + 0.00488\bar F_x - 0.000043\bar M_z + 0.000092\bar M_z$	B	$-0.00128\bar F_x - 0.00488\bar F_x - 0.000043\bar M_z - 0.000092\bar M_z$	B
$-0.00128\bar F_x + 0.00488\bar F_x + 0.000012\bar M_y - 0.00021\bar M_y$	C	$-0.00128\bar F_x - 0.00488\bar F_x + 0.000012\bar M_y + 0.00021\bar M_y$	C
$-0.00128\bar F_x + 0.00488\bar F_x - 0.000012\bar M_y + 0.00021\bar M_y$	D	$-0.00128\bar F_x - 0.00488\bar F_x - 0.000012\bar M_y - 0.00021\bar M_y$	D

LOCATION 9 & 10

$$\tau_{x\theta} = \pm\frac{\bar F_y}{\pi r_o T} \pm \frac{\bar F_z}{\pi r_o T} + \frac{\bar M_x}{2\pi r_o T} = 0.00110\bar F_z + 0.00002\bar M_x \quad \text{POINT } A$$

$$= -0.00110\bar F_z + 0.00002\bar M_x \quad B$$

$$= 0.00110\bar F_y + 0.00002\bar M_x \quad C$$

$$= -0.00110\bar F_y + 0.00002\bar M_x \quad D$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION Structural And Fatigue Evaluation Of Inlet Nozzle - Vessel Support

NUMBER 5-211-P | A 154
SHEET 46 **OF** 69
DATE 4-22-63 **BY** Cockrell
CHECK DATE 4-22-63 **BY** Heilker

5. DETAILED ANALYSIS:

C- STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

SEISMIC PIPE REACTIONS.

THE EQUATIONS FOR STRESS FOR THE SEISMIC PIPE REACTIONS WILL BE THE SAME AS FOR THE THERMALLY INDUCED PIPE REACTIONS. THE VALUES FOR $\bar{F}_x$, $\bar{F}_y$, $\bar{F}_z$, $\bar{M}_x$, $\bar{M}_y$, AND $\bar{M}_z$ WILL BE AS FOLLOWS. SEE SHEET 13 FOR VALUES OF H AND V.

$$\bar{F}_x = F_x = -57.9 \qquad \bar{M}_x = M_x - 27H = -14927.5$$
$$\bar{F}_y = F_y + V = -340.2 \qquad \bar{M}_y = M_y + 35.688 F_z + 18.375\,H = 27205.6$$
$$\bar{F}_z = F_z + H = 649.4 \qquad \bar{M}_z = M_z - 35.688 F_y - 18.375\,V = 17321.1$$

STATIC LOADING THROUGH SUPPORTS:

THE EQUATIONS FOR STRESS ARE THE SAME AS FOR THE THERMALLY INDUCED PIPE REACTIONS WITH THE FOLLOWING VALUES FOR $\bar{F}_y$ AND $\bar{M}_z$

$$\bar{F}_y = V = 561.1$$
$$\bar{M}_z = -18.375V = -10310.2$$

SEE SHEET 14 FOR VALUES OF V WITH OR WITHOUT THE DYNAMIC LOAD OF TRIPPED CONTROL RODS.

EARTHQUAKE LOADING THROUGH SUPPORTS:

THE EQUATIONS FOR STRESS ARE THE SAME AS FOR THE THERMALLY INDUCED PIPE REACTIONS WITH THE FOLLOWING VALUES FOR $\bar{F}_y$, $\bar{F}_z$, $\bar{M}_x$, $\bar{M}_y$, AND $\bar{M}_z$.

$$\bar{F}_y = V = -126.4 \qquad \bar{M}_x = -27H = -9090.9$$
$$\bar{F}_z = H = 336.7 \qquad \bar{M}_y = 18.375H = 6186.9$$
$$\bar{M}_z = -18.375V = 2322.6$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

NUMBER 5-211-P | A155
SHEET 41 OF 69
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HELLKER

5- DETAILED ANALYSIS:

e- STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

THERMAL EXPANSION AND CONTRACTION:

THE EQUATIONS FOR STRESS ARE THE SAME AS FOR THE THERMALLY INDUCED PIPE REACTIONS WITH THE FOLLOWING VALUES FOR $\bar{F}_x$ & $\bar{M}_z$

$\bar{F}_X = F = \pm 168.3$ KIPS
$\bar{M}_z = 28F = \pm 4712.4$ IN-KIPS

CONSIDER CRITERION 5.b.1:

THE CROSS SECTION OF INTEREST IS THE SECTION SHOWN ON SHEET 40 FOR LOCATIONS 7 & 8. SINCE THERE IS BENDING IN TWO DIRECTIONS, THE FOLLOWING RELATIONSHIPS WILL BE USED TO DETERMINE THE MAXIMUM EFFECT OF BENDING BY THE THERMAL AND DESIGN SEISMIC PIPE LOADS, WEIGHT, ETC.

$$\sigma_X = -\frac{\bar{F}_x}{A} \pm \frac{c}{I}\sqrt{\bar{M}_y^2 + \bar{M}_z^2} = -0.00071\bar{F}_x \pm 0.00005\sqrt{\bar{M}_y^2 + \bar{M}_z^2} \quad \text{INSIDE}$$
$$= -0.00071\bar{F}_x \pm 0.00008\sqrt{\bar{M}_y + \bar{M}_z^2} \quad \text{OUTSIDE}$$

$$\tau_{X\theta} = \frac{Q}{Ib'}\left[\bar{F}_y\sin\theta + \bar{F}_z\cos\theta\right] \pm \frac{\bar{M}_x c}{2I} = 0.00138\left[\bar{F}_y\sin\theta + \bar{F}_z\cos\theta\right] \pm 0.000024\bar{M}_x \quad \text{INSIDE}$$
$$= 0.06138\left[\bar{F}_y\sin\theta + \bar{F}_z\cos\theta\right] \pm 0.000038\bar{M}_x \quad \text{OUTSIDE}$$

$$\theta = \tan^{-1}\frac{\bar{M}_y}{\bar{M}_z}$$

LOCATION	PRESSURE STRESS			DUE TO EXT. LOADS, WEIGHT, ETC.		PRINCIPAL STRESS			STRESS INTENSITY		
	σ_X	σ_θ	σ_r	σ_X	$\tau_{X\theta}$	σ_1	σ_2	σ_3	$\sigma_1-\sigma_2$	$\sigma_1-\sigma_3$	$\sigma_2-\sigma_3$
7	1.55	4.09	-2.5	1.99	0.17	4.14	3.49	-2.5	0.65	6.64	5.99
	↓	↓	-2.5	-2.17	1.50	4.53	-1.06	-2.5	5.59	7.03	1.44
8	↓	↓	0	3.24	-0.21	4.85	4.03	0	0.82	4.85	4.03
	↓	↓	0	-3.42	1.90	4.64	-2.42	0	7.06	4.64	-2.42

$SI_{MAX} = \sigma_1 - \sigma_2 = \underline{7.06\ KSI} < S_m = 26.7\ KSI$ LOCATION 8

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER S-211-P | A156
SHEET 49 OF 69
CHARGE NO.
DATE 4-22-68 BY COCKRELL
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

e- STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

CONSIDER CRITERION 5.b.2:

CUT	BODY	$\frac{b^2P}{2Rt}$	$\frac{bP}{t}$	$\frac{EW}{R}$	σ_x	σ_θ	σ_r	STRESS INTENSITY		
								$\sigma_x-\sigma_\theta$	$\sigma_x-\sigma_r$	$\sigma_\theta-\sigma_r$
1	1	6.30	13.75	3.16	6.30	16.91	-1.25	-10.61	7.55	18.16
1	2	6.86	15.07	1.90	6.86	16.97	↓	-10.11	8.11	18.22
2	2	6.59	14.47	-3.59	6.59	10.88	↓	-4.29	7.84	12.13
4	4	1.55	4.09	17.79	1.55	21.88	↓	-20.33	2.80	23.13
4	5 LONG AXIS	7.16	19.87	11.15	7.16	31.02	↓	-23.86	8.41	32.27
4	5 CIRC AXIS	9.32	7.07	11.15	20.47	7.07	↓	13.40	21.72	8.32

$S.I._{MAX} = \sigma_\theta - \sigma_r = \underline{32.27} \text{ KSI} < 1.5 S_m = 40 \text{ KSI}$

CUT 4 BODY 5
LONGITUDINAL AXIS
SEE SHEET
POINTS 9 & 10

CONSIDER CRITERION 5.b.3:

LOCATION	PRESSURE STRESS			STRESS DUE TO PIPE LOADS, WEIGHT, ETC			PRINCIPAL STRESS			STRESS INTENSITY		
	σ_x	σ_θ	σ_r	σ_x	σ_θ	$\tau_{x\theta}$	σ_1	σ_2	σ_3	$\sigma_1-\sigma_2$	$\sigma_1-\sigma_3$	$\sigma_2-\sigma_3$
9 A	7.16	31.02	-2.5	4.53	1.30	1.20	32.34	11.67	-2.5	20.67	34.84	14.17
B	7.16	31.02	↓	4.01	2.11	1.56	33.24	11.06	↓	22.18	35.74	8.56
C	20.47	7.07	↓	3.85	7.42	1.61	24.58	14.22	↓	10.36	27.08	16.72
D	20.47	7.07	↓	4.29	8.64	-1.25	24.79	15.55	↓	9.24	27.29	18.05
10 A	7.16	31.02	0	3.36	2.57	1.20	33.60	10.51	0	23.09	33.60	10.51
B	7.16	31.02	↓	6.73	6.24	1.56	37.37	13.79	↓	23.58	37.37	13.79
C	20.47	7.07	↓	6.62	9.93	1.61	27.12	16.97	↓	10.15	27.12	16.97
D	20.47	7.07	↓	5.86	8.74	-1.25	26.48	15.66	↓	10.82	26.48	15.66

$S.I._{MAX} = \sigma_1 - \sigma_3 = \underline{37.4} \text{ KSI} < 1.5 S_m = 40 \text{ KSI}$ LOCATION 10B

RIV000052C
Submitted: December 22, 2011

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO. ________
DESCRIPTION Structural And Fatigue Evaluation Of Inlet Nozzle - Vessel Supports

NUMBER S-211-P | A157
SHEET 49 OF 69
DATE 4-22-69 BY Cockrell
CHECK DATE 4-22-69 BY Heilker

5- DETAILED ANALYSIS:

e- STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

CONSIDER CRITERION 5.b.4:

SAFE END

$$\sigma_x = -\frac{\bar{F}_x}{A} \pm \frac{c}{I}\sqrt{\bar{M}_y^2 + \bar{M}_z^2} = -0.00424\,\bar{F}_x \pm 0.00052\sqrt{\bar{M}_y^2+\bar{M}_z^2} \quad \text{POINT 1}$$
$$= -0.00424\,\bar{F}_x \pm 0.00061\sqrt{\bar{M}_y^2+\bar{M}_z^2} \quad \text{POINT 2}$$

$$\tau_{x\theta} = \frac{Q}{Ib'}\left[\bar{F}_y \sin\theta + \bar{F}_z \cos\theta\right] \pm \frac{\bar{M}_x c}{2I} = 0.00845\left[\bar{F}_y \sin\theta + \bar{F}_z\cos\theta\right] \pm 0.00026\,\bar{M}_x \quad \text{POINT 1}$$
$$= 0.00845\left[\bar{F}_y \sin\theta + \bar{F}_z\cos\theta\right] \pm 0.00031\,\bar{M}_x \quad \text{POINT 2}$$

$$\theta = \tan^{-1}\frac{\bar{M}_y}{\bar{M}_z}$$

LOCATION	PRESSURE STRESS			STRESS DUE TO SEISMIC LOADS		PRINCIPAL STRESS			STRESS INTENSITY		
	σ_x	σ_θ	σ_r	σ_x	$\tau_{x\theta}$	σ_1	σ_2	σ_3	$\sigma_1-\sigma_2$	$\sigma_1-\sigma_3$	$\sigma_2-\sigma_3$
1	6.30	16.91	-2.5	8.74	1.39	17.50	14.25	-2.5	3.25	20.00	16.75
	↓	↓	-2.5	-8.24	0.87	16.95	-1.98	-2.5	18.93	19.45	0.52
2	↓	↓	0	10.21	1.43	19.16	16.28	0	2.88	19.16	16.28
	↓	↓	0	-9.71	0.83	16.94	-3.44	0	20.38	16.94	-3.44

$SI_{max} = \sigma_1 - \sigma_2 = \underline{20.38\text{ KSI}} < 1.5\,S_m = 25.05\text{ KSI}$ LOCATION -

SMALL END OF NOZZLE

$$\sigma_\theta = -\frac{\bar{F}_x}{A} \pm \frac{c}{I}\sqrt{\bar{M}_y^2 + \bar{M}_z^2} = -0.00462\,\bar{F}_x \pm 0.00056\sqrt{\bar{M}_y^2+\bar{M}_z^2} \quad \text{POINT 3}$$
$$= -0.00462\,\bar{F}_x \pm 0.00065\sqrt{\bar{M}_y^2+\bar{M}_z^2} \quad \text{POINT 4}$$

$$\tau_{x\theta} = \frac{Q}{Ib'}\left[\bar{F}_y \sin\theta + \bar{F}_z\cos\theta\right] \pm \frac{\bar{M}_x c}{2I} = 0.00926\left[\bar{F}_y \sin\theta + \bar{F}_z\cos\theta\right] \pm 0.00029\,\bar{M}_x \quad \text{POINT 3}$$
$$= \left[\bar{F}_y \sin\theta + \bar{F}_z\cos\theta\right] \pm 0.00033\,\bar{M}_x \quad \text{POINT 4}$$

$$\theta = \tan^{-1}\frac{\bar{M}_y}{\bar{M}_z}$$

LOCATION	PRESSURE STRESS			STRESS DUE TO SEISMIC LOADS		PRINCIPAL STRESS			STRESS INTENSITY		
	σ_x	σ_θ	σ_r	σ_x	$\tau_{x\theta}$	σ_1	σ_2	σ_3	$\sigma_1-\sigma_2$	$\sigma_1-\sigma_3$	$\sigma_2-\sigma_3$
3	6.86	16.97	-2.5	9.41	1.51	18.17	15.07	-2.5	3.10	20.67	17.57
	↓	↓	-2.5	-8.87	0.97	17.02	-2.06	-2.5	19.08	19.52	0.44
4	↓	↓	0	10.88	1.56	18.96	15.75	0	3.21	18.96	15.75
	↓	↓	0	-10.34	0.92	17.01	-3.52	0	20.53	17.01	-3.52

$S.I._{max} = \sigma_1 - \sigma_3 = \underline{20.67\text{ KSI}} < 1.5\,S_m = 40.05\text{ KSI}$ LOCATION 3

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORT

NUMBER 5-211-P | A158
SHEET 50 OF 69
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

e- STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

CONSIDER CRITERION 5.b.5:

NOTE HERE THAT THE RANGE OF STRESS INTENSITY WAS CALCULATED AT THE TEN LOCATIONS AS SHOWN ON SHEET 17 FOR THE FOUR ORIENTATIONS A, B, C AND D. THE FOLLOWING TABLE GIVES THE RANGE OF STRESS INTENSITY FOR EACH LOCATION AND ORIENTATION. STRESSES AND STRESS INTENSITIES PRODUCING THESE RANGE OF STRESS INTENSITIES WILL NOT BE PRESENTED FOR ALL LOCATIONS AND ORIENTATIONS. ONLY STRESSES AND STRESS INTENSITIES AT THE LOCATION AND ORIENTATION WHICH PRODUCED THE HIGHEST RANGE OF STRESS WILL BE PRESENTED. THIS WAS LOCATION-10B.

LOCATION AND ORIENTATION	S.I. RANGE
1A	24.31
B	26.83
C	27.26
D	28.17
2A	33.31
B	33.46
C	33.48
D	33.27
3A	31.14
B	39.14
C	34.36
D	38.80
4A	37.68
B	35.45
C	36.78
D	35.35

LOCATION AND ORIENTATION	S.I. RANGE
5A	28.12
B	25.30
C	26.89
D	26.43
6A	36.70
B	37.07
C	36.70
D	36.70
7A	18.29
B	18.28
C	18.44
D	18.44
8A	33.28
B	33.28
C	33.33
D	33.33

LOCATION AND ORIENTATION	S.I. RANGE
9A	41.44
B	43.28
C	29.32
D	29.32
10A	42.75
B	45.54 ←
C	32.20
D	31.05

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER S-211-P | A159
SHEET 51 OF 69
CHARGE NO.
DATE 4-22-68 BY COCKRELL
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS
CHECK DATE 4-22-68 BY HEILKER

5. DETAILED ANALYSIS:

e- STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

LOCATION 10B

TRANSIENT		PRESSURE STRESS			THERMAL STRESS		THERMAL INDUCED PIPE REACTION STRESS			SEISMIC PIPE REACTION STRESS			STATIC WEIGHT STRESS		
		σ_x	σ_θ	σ_r	σ_x	σ_θ	σ_x	σ_θ	$\tau_{x\theta}$	σ_x	σ_θ	$\tau_{x\theta}$	σ_x	σ_θ	$\tau_{x\theta}$
a - HEATUP	4.00 HRS	10.16	16.70	0	-0.15	-1.09	-1.62	-1.38	-0.09	-2.50	-1.98	-1.01	1.67	1.39	0
	4.25	17.87	29.35	↓	-0.02	-1.11	-1.73	-1.46	-0.10	↓	↓	↓	↓	↓	↓
	4.35	18.54	30.46	↓	-0.02	-1.11	-1.77	-1.50	-0.10	↓	↓	↓	↓	↓	↓
	4.47	19.35	31.78	↓	0.17	-1.13	-1.81	-1.54	-0.11	↓	↓	↓	↓	↓	↓
	5.00	19.35	31.78	↓	0.24	-0.66	-1.81	-1.54	-0.11	↓	↓	↓	↓	↓	↓
	4.00	10.16	16.70	↓	-0.15	-1.09	-1.62	-1.38	-0.09	2.50	1.98	1.01	↓	↓	↓
	4.25	17.87	29.35	↓	-0.02	-1.11	-1.73	-1.46	-0.10	↓	↓	↓	↓	↓	↓
	4.35	18.54	30.48	↓	-0.02	-1.11	-1.77	-1.50	-0.10	↓	↓	↓	↓	↓	↓
	4.47	19.35	31.78	↓	0.17	-1.13	-1.81	-1.54	-0.11	↓	↓	↓	↓	↓	↓
	5.00	19.35	31.78	↓	0.24	-0.66	-1.81	-1.54	-0.11	↓	↓	↓	↓	↓	↓
STEADY-STATE		↓	↓	↓	0.03	0.03	-1.81	-1.54	-0.11	-2.50	-1.98	-1.01	↓	↓	↓
		↓	↓	↓	0.03	0.03	-1.81	-1.54	-0.11	2.50	1.98	1.01	↓	↓	↓
		↓	↓	↓	0.03	0.03	-1.81	-1.54	-0.11	0	0	0	↓	↓	↓
b - COOLDOWN	4.00 HRS	2.71	4.45	↓	0.19	1.03	-0.19	-0.16	-0.01	-2.50	-1.98	-1.01	↓	↓	↓
	4.25	↓	↓	↓	0.06	1.04	-0.09	-0.08	-0.01	↓	↓	↓	↓	↓	↓
	4.35	↓	↓	↓	0.06	1.04	-0.05	-0.04	0	↓	↓	↓	↓	↓	↓
	4.47	↓	↓	↓	-0.14	1.06	0	0	0	↓	↓	↓	↓	↓	↓
	5.00	↓	↓	↓	-0.21	0.61	0	0	0	↓	↓	↓	↓	↓	↓
	4.00	↓	↓	↓	0.19	1.03	-0.19	-0.16	-0.01	2.50	1.98	1.01	↓	↓	↓
	4.25	↓	↓	↓	0.06	1.04	-0.09	-0.08	-0.01	↓	↓	↓	↓	↓	↓
	4.35	↓	↓	↓	0.06	1.04	-0.05	-0.04	0	↓	↓	↓	↓	↓	↓
	4.47	↓	↓	↓	-0.14	1.06	0	0	0	↓	↓	↓	↓	↓	↓
	5.00	↓	↓	↓	-0.21	0.61	0	0	0	↓	↓	↓	↓	↓	↓

CHARGE NO.
DESCRIPTION Structural And Fatigue Evaluation Of Inlet Nozzle - Vessel Supports

NUMBER 5-211-P A160
SHEET 52 OF 69
DATE 4-22-68 BY Cockrell
CHECK DATE 4-22-68 BY Heilker

5. Detailed Analysis:
e. Stresses:
1. Combined Stresses - Unconcentrated:

LOCATION 10B

Transient		Pressure Stress			Thermal Stress		Thermal Induced Pipe Reaction Stress			Seismic Pipe Reaction Stress			Static Weight Stress		
		σ_x	σ_θ	σ_r	σ_x	σ_θ	σ_x	σ_θ	$\tau_{x\theta}$	σ_x	σ_θ	$\tau_{x\theta}$	σ_x	σ_θ	$\tau_{x\theta}$
c	20 min	19.35	31.78	0	0.03	-0.03	-1.81	-1.54	-0.11	0	0	0	1.67	1.39	0
d	20 min	19.35	31.78	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
e	160 sec	18.40	30.23	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
	225 sec	19.56	32.14	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
f	40 sec	19.95	32.77	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
	100 sec	19.43	31.93	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
	260 sec	18.40	30.23	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
g	2 min	20.38	33.48	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
	3.2 min	20.21	33.20	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
	10.4 min	18.49	30.37	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
h	10 sec	19.09	31.36	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
	65 sec	16.42	26.98	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
i	220 min	26.87	44.14	↓	0	0	0	0	0	↓	↓	↓	↓	↓	↓
j	H.D 2.0 HRS	10.75	17.66	↓	-0.30	-0.50	-1.22	-1.04	-0.08	↓	↓	↓	↓	↓	↓
	S.S.	21.50	35.32	↓	0.02	-0.02	-1.22	-1.04	-0.08	↓	↓	↓	↓	↓	↓
	C.D. 3.0 HRS	2.71	4.45	↓	0.14	0.48	0	0	0	↓	↓	↓	↓	↓	↓
k	~	20.21	33.20	↓	0.03	-0.03	-1.81	-1.54	-0.11	↓	↓	↓	↓	↓	↓
	~	18.49	30.37	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
l	12 sec	19.35	31.78	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
m	10 sec	23.73	38.99	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
	28 sec	18.23	29.95	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
	160 sec	12.39	20.34	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
n	33 sec	2.58	4.24	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
	54 sec	6.02	9.89	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION Structural And Fatigue Evaluation Of Inlet Nozzle - Vessel Supports

NUMBER 5-211-P | A161
SHEET 53 OF 69
DATE 4-22-69 BY Cockrell
CHECK DATE 4-22-69 BY Meilker

5. Detailed Analysis:
e. Stresses:
1- Combined Stresses - Unconcentrated:

Location 10B

Transient		Earthquake Loading Through Supports Stress			Expansion And Contraction Stress		Total Stress				Principal Stress			Stress Intensity		
		σ_x	σ_θ	$\tau_{x\theta}$	σ_x	σ_θ	σ_x	σ_θ	σ_r	$\tau_{x\theta}$	σ_1	σ_2	σ_3	$\sigma_1-\sigma_2$	$\sigma_1-\sigma_3$	$\sigma_2-\sigma_3$
a - Heatup	4.00 HRS	-0.38	-0.31	-0.55	-1.64	-1.67	5.53	11.65	0	-1.66	12.07	5.11	0	6.96	12.07	5.11
	4.25						13.27	24.21		-1.67	24.46	13.02		11.44	24.46	13.02
	4.35						13.90	25.28		-1.67	25.52	13.66		11.86	25.52	13.66
	4.47						14.86	26.54		-1.67	26.78	14.62		12.16	26.78	14.62
	5.00						14.92	27.01		-1.67	27.24	14.69		12.54	27.24	14.69
	4.00	0.38	0.31	0.55			11.29	16.24		1.47	16.64	10.89		5.75	16.64	10.89
	4.25						19.03	28.80		1.46	29.01	18.81		10.20	29.01	18.81
	4.35						19.67	29.89		1.46	30.10	19.47		10.63	30.10	19.47
	4.47						20.62	31.13		1.46	31.33	20.42		10.91	31.33	20.42
	5.00						20.68	31.60		1.46	31.79	20.49		11.30	31.79	20.49
Steady-State		-0.38	-0.31	-0.55	0	0	16.35	29.31		-1.67	29.52	16.14		13.38	29.52	16.14
		0.38	0.31	0.55			22.11	33.90		1.46	34.08	21.93		12.14	34.08	21.93
		0	0	0			19.23	31.61		-0.11	31.61	19.23		12.38	31.61	19.23
b - Cooldown	4.00 HRS	-0.38	-0.31	-0.55	1.64	1.67	3.14	6.09		-1.58	6.77	2.45		4.32	6.77	2.45
	4.25						3.11	6.18		-1.57	6.84	2.45		4.40	6.84	2.45
	4.35						3.15	6.22		-1.57	6.97	2.49		4.39	6.97	2.49
	4.47						3.00	6.28		-1.57	6.90	2.37		4.53	6.90	2.37
	5.00						2.93	5.83		-1.57	6.51	2.25		4.26	6.51	2.25
	4.00	0.38	0.31	0.55			8.39	10.67		1.55	11.58	7.99		3.58	11.58	7.99
	4.25						8.97	10.77		1.56	11.65	7.99		3.66	11.65	7.99
	4.35						8.91	10.81		1.56	11.68	8.03		3.66	11.68	8.03
	4.47						8.76	10.37		1.57	11.70	7.93		3.77	11.70	7.93
	5.00						8.69	10.42		1.57	11.34	7.77		3.57	11.34	7.77

COMBUSTION ENGINEERING, INC.

ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION Structural And Fatigue Evaluation Of Inlet Nozzle - Vessel Supports

NUMBER 5-211-P | A 162

SHEET 54 OF 69

DATE 4-22-68 BY Cockrell

CHECK DATE 4-22-68 BY Heilker

5. Detailed Analysis:

e. Stresses:

1. Combined Stresses - Unconcentrated:

LOCATION 10 B

Transient		Earthquake Loading Through Supports Stress			Expansion And Contraction Stress		Total Stress				Principal Stress			Stress Intensity		
		σ_x	σ_θ	$\tau_{x\theta}$	σ_x	σ_θ	σ_x	σ_θ	σ_r	$\tau_{x\theta}$	σ_1	σ_2	σ_3	$\sigma_1-\sigma_2$	$\sigma_1-\sigma_3$	$\sigma_2-\sigma_3$
c	20 min	0	0	0	0	0	19.23	31.61	0	-0.11	31.61	19.23	0	12.38	31.61	19.23
d	20 min						19.23	31.61			31.61	19.23		12.37	31.61	19.23
e	100 sec						18.29	30.05			30.05	18.29		11.77	30.05	18.29
	225 sec						19.45	31.96			31.96	19.45		12.51	31.96	19.45
f	40 sec						19.84	32.59			32.60	19.83		12.76	32.60	19.83
	100 sec						19.32	31.75			31.75	19.32		12.43	31.75	19.32
	260 sec						19.29	30.05			30.05	18.29		11.77	30.05	18.29
g	2 min						20.27	33.30			33.30	20.26		13.04	33.30	20.26
	3.2 min						20.09	33.02			33.02	20.09		12.93	33.02	20.09
	10.4 min						18.37	30.19			30.19	18.37		11.82	30.19	18.37
h	10 sec						18.98	31.18			31.18	18.97		12.21	31.18	18.97
	65 sec						16.31	26.80		↓	26.80	16.31		10.50	26.80	16.31
i	220 min						28.54	45.54		0	45.54	28.54		16.99	45.54	28.54
j	H.U. 3.0 HRS						10.90	17.51		-0.08	17.51	10.90		6.61	17.51	10.90
	S.S.						21.97	35.65		-0.08	35.65	21.96		13.68	35.65	21.96
	C.D 3.0 HRS						4.51	6.33		0	6.33	4.51		1.81	6.33	4.57
k	~						20.09	33.02		-0.11	33.02	20.09		12.93	33.02	20.09
	~						18.37	30.19			30.19	18.37		11.82	30.19	18.37
l	12 sec						19.23	31.61			31.61	19.23		12.37	31.61	19.23
m	10 sec						23.62	38.81			38.81	23.62		15.19	38.81	23.62
	28 sec						19.12	29.77			29.77	18.11		11.66	29.77	18.11
	160 sec						12.27	20.16			20.16	12.27		7.90	20.16	12.27
n	33 sec						2.46	4.06			4.07	2.46		1.61	4.07	2.46
	54 sec	↓	↓	↓	↓	↓	5.90	9.71	↓	↓	9.71	5.90	↓	3.81	9.71	5.90

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

NUMBER 5-211-P | A163
SHEET 55 OF 69
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5. DETAILED ANALYSIS:

e- STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

CONSIDER STRESSES DURING NO LOSS OF FUNCTION SEISMIC LOADING:

IN THIS SECTION THE ALLOWABLE STRESSES LISTED ON SHEET 7 FOR CRITERION 5.b.1, 5.b.3, AND 5.b.4 WILL BE INCREASED BY A FACTOR OF 1.2, SEE REF 10.

CONSIDER CRITERION 5.b.1:

LOCATION	PRESSURE STRESS			STRESS DUE TO EXTERNAL LOADS		PRINCIPAL STRESS			STRESS INTENSITY		
	σ_x	σ_θ	σ_r	σ_x	$\tau_{x\theta}$	σ_1	σ_2	σ_3	$\sigma_1-\sigma_2$	$\sigma_1-\sigma_3$	$\sigma_2-\sigma_3$
7	1.55	4.09	-2.5	3.08	-0.36	4.81	3.91	-2.5	0.90	7.31	6.41
	↓	↓	-2.5	-3.22	1.78	4.60	-2.18	-2.5	6.78	7.10	0.32
8	↓	↓	0	4.97	-0.99	6.87	3.34	0	3.13	6.97	3.34
	↓	↓	0	-5.11	2.41	4.79	-4.26	0	9.05	4.79	-4.26

$S.I._{MAX} = \sigma_1 - \sigma_2 = \underline{9.05\ KSI} < 1.2 S_m = 32.04\ KSI$ LOCATION 8

CONSIDER CRITERION 5.b.3:

LOCATION	PRESSURE STRESS			STRESSES DUE TO EXTERNAL LOADS			PRINCIPAL STRESS			STRESS INTENSITY		
	σ_x	σ_θ	σ_r	σ_x	σ_θ	$\tau_{x\theta}$	σ_1	σ_2	σ_3	$\sigma_1-\sigma_2$	$\sigma_1-\sigma_3$	$\sigma_2-\sigma_3$
9 A	7.16	31.02	-2.5	5.24	1.63	1.02	32.67	12.26	-2.5	20.41	35.17	14.76
B	7.16	31.02	↓	5.49	2.70	2.66	34.06	12.32	↓	21.74	36.56	14.82
C	20.47	7.07	↓	5.70	11.48	2.32	26.82	17.90	↓	8.92	29.32	20.40
D	20.47	7.07	↓	7.04	13.84	-0.52	27.55	20.87	↓	6.68	30.05	23.37
10 A	7.16	31.02	0	5.06	4.27	0.98	35.34	12.18	0	23.16	35.34	12.18
B	7.16	31.02	↓	7.52	6.98	2.61	38.29	14.39	↓	23.90	38.29	14.39
C	20.47	7.07	↓	8.49	13.56	2.31	29.56	20.04	↓	9.52	29.56	20.04
D	20.47	7.07	↓	9.56	14.51	-0.51	30.06	21.56	↓	8.50	30.06	21.56

$SI_{MAX} = \sigma_1 - \sigma_3 = \underline{38.3\ KSI} < 1.2(1.5 S_m) = 48.1\ KSI$ LOCATION 10B

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER 5-211-P | A164
SHEET 56 OF 69
CHARGE NO.
DATE 4-22-68 BY COCKRELL
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORT
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

e- STRESSES

1- COMBINED STRESSES - UNCONCENTRATED:

CONSIDER CRITERION 5.b.4:

SAFE END

LOCATION	PRESSURE STRESS			STRESS DUE TO SEISMIC LOADS		PRINCIPAL STRESSES			STRESS INTENSITY		
	σ_x	σ_θ	σ_r	σ_x	$\tau_{x\theta}$	σ_1	σ_2	σ_3	$\sigma_1-\sigma_2$	$\sigma_1-\sigma_3$	$\sigma_2-\sigma_3$
1	6.30	16.91	-2.5	13.71	2.46	21.37	15.55	-2.5	5.82	23.87	18.05
	↓	↓	-2.5	-13.01	1.00	16.95	-6.75	-2.5	23.70	19.45	-4.25
2	↓	↓	0	16.02	2.60	23.37	15.86	0	7.50	23.37	15.86
	↓	↓	0	-15.32	0.86	16.94	-9.05	0	25.99	16.94	-9.05

$S.I._{MAX} = \sigma_1 - \sigma_2 = \underline{25.99\ KSI} < 1.2(1.5S_m) = 30.06\ KSI$ LOCATION 2

SMALL END OF NOZZLE

LOCATION	PRESSURE STRESS			STRESS DUE TO SEISMIC LOADS		PRINCIPAL STRESS			STRESS INTENSITY		
	σ_x	σ_θ	σ_r	σ_x	$\tau_{x\theta}$	σ_1	σ_2	σ_3	$\sigma_1-\sigma_2$	$\sigma_1-\sigma_3$	$\sigma_2-\sigma_3$
3	6.86	16.97	-2.5	14.76	2.67	22.84	15.75	-2.5	7.09	25.34	18.25
	↓	↓	-2.5	-14.00	1.11	17.02	-7.19	-2.5	24.21	19.52	-4.69
4	↓	↓	0	17.07	2.81	24.92	15.98	0	8.94	24.92	15.98
	↓	↓	0	-16.31	0.97	17.01	-9.49	0	26.50	17.01	-9.49

$S.I._{MAX} = \sigma_1 - \sigma_3 = \underline{25.07\ KSI} < 1.2(1.5S_m) = 48.06\ KSI$ LOCATION 3

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT. CHATTANOOGA, TENN.

CHARGE NO.
DESCRIPTION Structural And Fatigue Evaluation Of Inlet Nozzle – Vessel Support

NUMBER S-211-P | A 165
SHEET 57 OF 69
DATE 4-22-68 BY Cockrell
CHECK DATE 4-22-68 BY Heilker

5- Detailed Analysis:

e- Stresses:

1- Combined Stresses – Unconcentrated:

Consider The Combined Forces On The Pad:

The Maximum And Minimum Vertical Force On The Inlet Nozzle Pads Was Found To Be,

$\bar{V}_{MAX}$ = 1172.1 kips
$\bar{V}_{MIN}$ = 42.1 kips

Note Here That These Forces Were Determined Using The Design Seismic Pipe Loads, Thermal Induced Pipe Loads And The Seismic Shock Factors Given In Ref 9 & 10

Note That Since The Minimum Value Of $\bar{V}$ Is Positive, The Vessel Will Not Lift Off The Support Structure Under The Design Conditions.

The Maximum Horizontal Force On The Inlet Nozzle Pads Was Found To Be,

$\bar{H}_{MAX}$ = 925.5 kips   See Note Above For $\bar{V}_{MAX}$ & $\bar{V}_{MIN}$.

The Above Maximum Forces Produce Bearing Stresses On The Pad Equal To,

$$\left.\begin{array}{l} \sigma_{BRG.} = \frac{\bar{V}_{MAX}}{A} = \frac{1172.1}{10\times 22} = 5.3\ KSI \\ \sigma_{BRG.} = \frac{\bar{H}_{MAX}}{A} = \frac{925.5}{2.5\times 10} = 37.0\ KSI \end{array}\right\} < S_y = 44.5\ KSI\ @\ 400^\circ F$$

Note That The Bearing Stress On The Bottom Of The Pad Is 3.0 KSI When Considering Dead Weight And Thermal Pipe Reactions Only. This Compares With A Desired Bearing Stress Of 5.0 KSI. This Stress Becomes 4.0 KSI When Considering Three Support Only.

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE – VESSEL SUPPORTS

NUMBER 5-211-P | A166
SHEET 58 OF 69
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

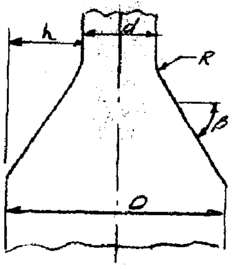
5. DETAILED ANALYSIS:

e. STRESSES:

2. PEAK STRESSES:

THE FOLLOWING VALUES OF STRESS CONCENTRATION FACTORS WILL BE USED TO CALCULATE PEAK STRESSES AT LOCATIONS 6, 8 AND 10. THE STRES CONCENTRATION FACTORS AT ALL OTHER LOCATIONS WILL BE ONE; HENCE, THE EXPRESSIONS FOR PEAK STRESS WILL BE THE SAME AS THOSE GIVEN ON SHEETS 36 → 47 WITH THE FOLLOWING EXCEPTIONS (1) THE TERM $\frac{E\alpha}{(1-\nu)}(T_m-T)$ IS ADDED TO REFLECT THE STRESS DUE TO THE RADIAL GRADIENT (2) THE $\frac{6M}{t^2}$ AND $\frac{\nu 6M}{t^2}$ TERMS FOR STRESSES DUE TO THERMAL EFFECTS WILL INCLUDE THE THERMAL MOMENT DUE TO THE RADIAL GRADIENT, AND (3) FOR LOCATION-10, THE PRESSURE STRESS WILL BE CALCULATED USING THE STRESS INDICES GIVEN IN I-612 OF SECTION III.

LOCATION 6:



$D = 26.062''$ $h = 10.75$ $\beta = 58°$ $\Delta = \frac{D}{d} = 5.713$

$d = 4.562$ $R = 3.219$ $\frac{\beta}{90} = 0.644$ $\frac{h}{R} = 3.34$

FROM EQUATIONS 6.20 AND 6.24 OF REF. 13:

$K_{TO} = 1.42$

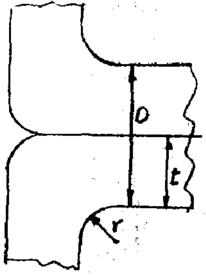
$K_{BO} = 1.22$

FROM EQUATION 6.22 OF REF. 13:

$K_T = \underline{1.27}$ ←

$K_B = \underline{1.14}$

LOCATION 8 & 10



$t = 10.686''$ $r = 5.375$

$D = 21.372''$ $\frac{r}{t} = 0.503$

FOR $\frac{r}{t} = 0.503$

$\left.\begin{array}{l} K_T = \underline{1.80} \\ K_B = \underline{1.50} \end{array}\right]$ FROM FIG. A.7-1 REF 6 ←

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

NUMBER 5-211-P | A167
SHEET 59 OF 69
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:
e. STRESSES:
2. PEAK STRESS:

THE FOLLOWING EXPRESSIONS FOR STRESS WILL BE USED TO CALCULATE PEAK STRESSES AT LOCATIONS 6, 8 AND 10.

LOCATION 6:

PRESSURE STRESS:

$$\sigma_x = -\frac{6M_2}{t_{2A}^2}K_B + \frac{b^2P}{2R_2t_{2A}}K_T = \underline{-1.2126M_2 + 3.3454P}$$

$$\sigma_\theta = -\frac{\nu 6M_2}{t_{2A}^2}K_B + \frac{EW_{22}}{R_2} + \frac{bP}{t_{2A}} = \underline{-0.3638M_2 + 0.0662EW_{22} + 5.7895P}$$

$$\sigma_r = 0$$

THERMAL STRESS:

$$\sigma_x = -\frac{6(M_2+M_{2T})}{t_{2A}^2}K_B + \frac{E\alpha_i}{(1-\nu)}(T_m-T)K_T = \underline{-1.2126M_2 + 1.8143E\alpha_i(T_m-T)}$$

$$\sigma_\theta = -\frac{-\nu(M_2+M_{2T})}{t_{2A}^2}K_B + \frac{EW_{22}}{R_2} + \frac{E\alpha_i}{(1-\nu)}(T_m-T) = \underline{-0.3638(M_2+M_{2T}) + 0.0662EW_{22}}$$
$$\underline{+1.4286E\alpha_i(T_m-T)}$$

THERMAL INDUCED PIPE REACTIONS:

$$\sigma_x = -\frac{\bar{F}_x}{A}K_1 + \frac{\bar{M}c}{I}K_B = -0.00561\bar{F}_x + 0.00071\bar{M}_z \quad \text{POINT A}$$
$$-0.00561\bar{F}_x - 0.00071\bar{M}_z \quad B$$
$$-0.00561\bar{F}_x + 0.00071\bar{M}_y \quad C$$
$$-0.00561\bar{F}_x - 0.00071\bar{M}_y \quad D$$

$$\tau_{x\theta} = \frac{FQ}{Ib}K_B \pm \frac{Mc}{2I}K_B = 0.01004\bar{F}_z + 0.00035\bar{M}_x \quad \text{POINT A}$$
$$0.01004\bar{F}_z - 0.00035\bar{M}_x \quad B$$
$$0.01004\bar{F}_y + 0.00035\bar{M}_x \quad C$$
$$0.01004\bar{F}_y - 0.00035\bar{M}_x \quad D$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORT

NUMBER 5-211-P | A168
SHEET 60 OF 69
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

e- STRESSES:

2. PEAK STRESSES:

SEISMIC PIPE REACTIONS:

THE FORMULAS FOR CALCULATING THE STRESSES DUE TO THE SEISMIC PIPE REACTIONS ARE THE SAME AS FOR THE THERMAL INDUCED PIPE REACTIONS.

LOCATION B:

PRESSURE STRESS

$$\sigma_x = -\frac{6M_4}{t_{4A}^2}\frac{R_4}{R_{4A}}K_B + \frac{b^2P}{2R_{4A}t_{4A}}K_T = \underline{-0.0861\,M_4 + 1.1155P}$$

$$\sigma_\theta = -\frac{\nu 6M_4}{t_{4A}^2}\frac{R_4}{R_{4A}}K_B + \frac{EW_{44}}{R_{4A}} + \frac{bP}{t_{4A}} = -\underline{0.0258M_4 + 0.0456EW_{44} + 1.6349P}$$

$$\sigma_r = 0$$

THERMAL STRESS

$$\sigma_x = -\frac{6(M_4+M_{4T})}{t_{4A}^2}\frac{R_4}{R_{4A}}K_B + \frac{E\alpha_i}{(1-\nu)}(T_m-T)K_T = \underline{-0.0861(M_4+M_{4T}) + 2.5714E\alpha(T_m-T)}$$

$$\sigma_\theta = -\frac{\nu 6(M_4+M_{4T})}{t_{4A}^2}\frac{R_4}{R_{4A}}K_B + \frac{EW_{44}}{R_{4A}} + \frac{E\alpha_i}{(1-\nu)}(T_m-T) = -\underline{0.0258(M_4+M_{4T}) + 0.0456\,EW_{44}}$$
$$+\underline{1.4286\,E\alpha_i\,(T_m-T)}$$

THERMAL INDUCED PIPE REACTIONS:

$$\sigma_x = -\frac{\bar{F}_x}{A}K_T \pm \frac{Mc}{I}K_B = -0.00128\,\bar{F}_x + 0.00012\,\bar{M}_z$$
$$= -0.00128\,\bar{F}_x - 0.00012\,\bar{M}_z$$
$$= -0.00128\bar{F}_x + 0.00012\,\bar{M}_y$$
$$= -0.00128\bar{F}_x - 0.00012\,\bar{M}_y$$

$$\tau_{x\theta} = \frac{\bar{F}Q}{Ib}K_B \pm \frac{\bar{M}c}{2I}K_B = 0.00207\,\bar{F}_z + 0.000057\,\bar{M}_x$$
$$= 0.00207\,\bar{F}_z - 0.000057\,\bar{M}_x$$
$$= 0.00207\,\bar{F}_y + 0.000057\,\bar{M}_x$$
$$= 0.00207\bar{F}_y - 0.000057\,\bar{M}_x$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.

NUMBER 5-211-P | A169
SHEET 61 OF 69
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-69 BY HEILKER

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

5- DETAILED ANALYSIS:

e. STRESSES:

2. PEAK STRESSES:

THE EQUATIONS FOR STRESS DUE TO SEISMIC PIPE REACTIONS, STATIC LOADING THROUGH SUPPORTS, EARTHQUAKE LOADING THROUGH SUPPORTS, AND THERMAL EXPANSION & CONTRACTION ARE THE SAME AS FOR THE THERMAL INDUCED PIPE REACTIONS. THE VALUES OF F_x, F_y, F_z, $\bar{M}_x$, $\bar{M}_y$, AND $\bar{M}_z$ ARE THE SAME AS THOSE LISTED ON SHEETS 40 → 42.

LOCATION 10:

PRESSURE STRESS:

	POINTS A&B LONGITUDINAL PLANE	POINTS C&D CIRCUMFERENTIAL PLANE
$\sigma_x = i_x\left(\frac{bP}{t} + \frac{P}{2}\right) =$	$8.4477P$	$= 17.7402P$
$\sigma_\theta = i_\theta\left(\frac{bP}{t} + \frac{P}{2}\right) =$	$10.1373P$	$= 21.9641P$
$\sigma_r = 0$		

THERMAL STRESS:

POINTS A&B (LONGITUDINAL PLANE):

$$\sigma_x = -\frac{6}{t_s^2}(M_4 + M_{5T})K_B - \frac{H_4}{t_s}K_T + \frac{E\alpha_i}{(1-\nu)}(T_m - T)K_T = \underline{-0.0779(M_4 + M_{5T}) - 0.1674\,H_4}$$
$$\underline{+ 2.5714\,E\alpha_i\,(T_m - T)}$$

$$\sigma_\theta = -\frac{\nu 6}{t_s^2}(M_4 + M_{5T})K_B + \frac{EW_{54}}{R_5 \sin\phi} + \frac{E\alpha_i}{(1-\nu)}(T_m - T) = \underline{-0.0234(M_4 + M_{5T}) + 0.0462\,EW_{54}}$$
$$\underline{+ 1.4286(T_m - T)}$$

POINTS C&D (CIRCUMFERENTIAL PLANE):

$$\sigma_x = -\frac{\nu 6}{t_s^2}(M_4 + M_{5T})K_B + \frac{EW_{54}}{R_5 \sin\phi} + \frac{E\alpha_i}{(1-\nu)}(T_m - T) = \underline{-0.0234(M_4 + M_{5T}) + 0.0462\,EW_{54}}$$
$$\underline{+ 1.4286(T_m - T)}$$

$$\sigma_\theta = -\frac{6}{t_s^2}(M_4 + M_{5T})K_B - \frac{H_4 \cos\phi}{t_s}K_T + \frac{E\alpha_i}{(1-\nu)}(T_m - T)K_T = -\underline{0.0779(M_4 + M_{5T}) - 0.1652\,H_4}$$
$$\underline{+ 2.5714\,E\alpha_i\,(T_m - T)}$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER 5-211-P | A170
SHEET 62 OF 69
CHARGE NO.
DATE 4-22-69 BY COCKRELL
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS
CHECK DATE 4-22-69 BY HEILKER

5- DETAILED ANALYSIS:

e. STRESSES:

2 PEAK STRESSES:

THERMAL INDUCED PIPE REACTIONS:

$$\sigma_X = -\left(\frac{N_x}{\bar{F}_x/R_m}\right)\frac{\bar{F}_x}{R_m T}K_T \pm \left(\frac{M_x}{\bar{F}_x}\right)\frac{6\bar{F}_x}{T^2}K_B \pm \left(\frac{N_x}{\bar{M}/R^2_m\beta}\right)\frac{\bar{M}}{R^2_m\beta T}K_T \pm \left(\frac{M_x}{\bar{M}/R_m\beta}\right)\frac{6\bar{M}}{R_m\beta T^2}K_B$$

$= -0.00827\bar{F}_x + 0.00025\bar{M}_z$ POINT A

$= -0.00827\bar{F}_x - 0.00025\bar{M}_z$ B

$= -0.00827\bar{F}_x + 0.00022\bar{M}_y$ C

$= -0.00827\bar{F}_x - 0.00022\bar{M}_y$ D

$$\sigma_\theta = -\left(\frac{N_\theta}{\bar{F}_x/R_m}\right)\frac{F_x}{R_m T}K_T \pm \left(\frac{M_\theta}{\bar{F}_x}\right)\frac{6\bar{F}_x}{T^2}K_B \pm \left(\frac{N_\theta}{\bar{M}/R^2_m\beta}\right)\frac{\bar{M}}{R^2_m\beta T}K_T \pm \left(\frac{M_x}{\bar{M}/R_m\beta}\right)\frac{6\bar{M}}{R_m\beta T^2}K_B$$

$= -0.00962\bar{F}_x + 0.00022\bar{M}_z$ POINT A

$-0.00962\bar{F}_x - 0.00022\bar{M}_z$ B

$-0.00962\bar{F}_x + 0.00034\bar{M}_y$ C

$-0.00962\bar{F}_x - 0.00034\bar{M}_y$ D

$\tau_{x\phi} = \pm\frac{\bar{F}}{\pi r_0 T}K_B + \frac{\bar{M}_x}{2\pi R_0 T}K_B = 0.00165\bar{F}_z + 0.00003\bar{M}_x$ POINT A

$= -0.00165\bar{F}_z + 0.00003\bar{M}_x$ B

$= 0.00165\bar{F}_y + 0.00003\bar{M}_x$ C

$= -0.00165\bar{F}_y + 0.00003\bar{M}_x$ D

THE EQUATIONS FOR STRESS DUE TO SEISMIC PIPE REACTIONS, STATIC LOADING THROUGH SUPPORTS, EARTHQUAKE LOADING THROUGH SUPPORTS, AND THERMAL EXPANSION AND CONTRACTION ARE THE SAME AS FOR THE THERMAL INDUCED PIPE REACTIONS. THE VALUES OF $\bar{F}_x$, $\bar{F}_y$, $\bar{F}_z$, $\bar{M}_x$, $\bar{M}_y$, AND $\bar{M}_z$ ARE THE SAME AS THOSE GIVEN ON SHEETS 44 THRU 47.

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION Structural And Fatigue Evaluation Of Inlet Nozzle - Vessel Supports

NUMBER 5-211-P | AMI
SHEET 63 OF 69
DATE 4-22-68 BY Cockrell
CHECK DATE 4-22-68 BY Heilker

5- Detailed Analysis:

e- Stresses:

2- Peak Stresses

The Following Values Of ($T_{MEAN} - T_{SURFACE}$) For The Inside And Outside Surfaces Are To Be Used To Calculate Peak Stresses For The Fatigue Evaluation.

Transient		Cut-1 Body-1		Cut-1 Body-2		Cut-2 Body-2		Cut-4 Body-4 & Body-5	
		ΔT_{inside}	$\Delta T_{outside}$	ΔT_{inside}	$\Delta T_{outside}$	ΔT_{inside}	ΔT_{inside}	ΔT_{inside}	$\Delta T_{outside}$
a - Heatup	4.00 Hrs	-8	3	-4	3	-6	4	-55	30
	4.25	↓	↓	↓	↓	↓	↓	↓	↓
	4.35	↓	↓	↓	↓	↓	↓	↓	↓
	4.47	↓	↓	↓	↓	↓	↓	↓	↓
	5.00	0	0	0	0	-1	1	-28	17
Cooldown	4.00 Hrs	8	-3	4	-3	6	-4	55	-30
	4.25	↓	↓	↓	↓	↓	↓	↓	↓
	4.35	↓	↓	↓	↓	↓	↓	↓	↓
	4.47	↓	↓	↓	↓	↓	↓	↓	↓
	5.00	0	0	0	0	1	1	28	-17

Transient		For All Bodies	
		ΔT_{inside}	$\Delta T_{outside}$
Steadystate		0	0
c	20 min	-7.8	↓
d	20 min	7.8	↓
e	100 sec	11.2	↓
	225 sec	1.7	↓
f	40 sec	-9.3	↓
	100 sec	-13.3	↓
	260 sec	-1.3	↓
g	2 min	12	↓
	3.2 min	15	↓
	10.4 min	0	↓
h	10 sec	-9.5	↓
	65 sec	8.5	↓
i	220 min	0	↓
j	H.U. 3 Hrs	-8	3
	S.S	0	0
	C.D 3 Hrs	8	-3
k	~	6	0
	~	-6	↓
l	12 sec	33.3	↓
m	10 sec	-30.2	↓
	28 sec	-41.2	↓
	160 sec	-4.8	↓
n	33 sec	117	↓
	54 sec	197	↓

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER S-211-P | A172
SHEET 64 OF 69
CHARGE NO.
DATE 4-22-68 BY COCKRELL
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

e - STRESSES

2- PEAK STRESSES

NOTE HERE THAT PEAK STRESSES WERE CALCULATED AT THE TEN LOCATIONS AS SHOWN ON SHEET 17 FOR THE FOUR ORIENTATIONS A, B, C AND D. THE FOLLOWING TABLE GIVES THE OVERALL USAGE FACTORS FOR EACH LOCATION AND EACH ORIENTATION. STRESSES AND STRESS INTENSITIES PRODUCING THESE USAGE FACTORS WILL NOT BE PRESENTED FOR ALL LOCATIONS AND ORIENTATIONS. ONLY STRESSES AND STRESS INTENSITIES AT THE LOCATION AND ORIENTATION WHICH PRODUCED THE HIGHEST OVERALL USAGE FACTOR WILL BE PRESENTED. THIS WAS LOCATION 10C.

LOCATION AND ORIENTATION	$U_{OVERALL}$
1 A	0.00015
B	0.00013
C	0.00014
D	0.00014
2 A	0
B	0
C	0
D	0
3 A	0.0011
B	0.0015
C	0.0011
D	0.0013
4 A	0.0018
B	0.00053
C	0.0016
D	0.00096

LOCATION AND ORIENTATION	$U_{OVERALL}$
5 A	0.00092
B	0.00083
C	0.00089
D	0.00088
6 A	0.0098
B	0.0038
C	0.0098
D	0.0058
7 8	0.0034
B	0.0038
C	0.0037
D	0.0039
8 A	0.0060
B	0.0046
C	0.0059
D	0.0054

LOCATION AND ORIENTATION	$U_{OVERALL}$
9 A	0.018
B	0.015
C	0.0032
D	0.0030
10 A	0.0061
B	0.0024
C	0.042
D	0.037

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

NUMBER S-211-P | AM3
SHEET 65 OF 69
DATE 4-22-69 BY COCKRELL
CHECK DATE 4-22-69 BY HEILKER

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

5. DETAILED ANALYSIS:

e- STRESSES:

2 -PEAK STRESSES:

LOCATION 10C

TRANSIENT		PRESSURE STRESS			THERMAL STRESS		THERMAL INDUCED PIPE REACTION STRESS			SEISMIC PIPE REACTION STRESS			STATIC WEIGHT STRESS		
		σ_x	σ_θ	σ_r	σ_x	σ_θ	σ_x	σ_θ	$\tau_{x\theta}$	σ_x	σ_θ	$\tau_{x\theta}$	σ_x	σ_θ	$\tau_{x\theta}$
a - HEATUP	4.00 HRS	33.39	41.34	0	7.35	15.34	0.95	1.54	-0.24	6.54	9.81	-1.01	0	0	0.93
	4.25	36.86	45.64	→	7.44	15.69	1.01	1.64	-0.25	→	→	→	→	→	→
	4.35	38.25	47.35	→	7.47	15.74	1.03	1.67	-0.26	→	→	→	→	→	→
	4.47	39.92	49.42	→	7.51	16.10	1.06	1.72	-0.27	→	→	→	→	→	→
	5.00	39.92	49.42	→	4.32	9.44	1.06	1.72	-0.27	→	→	→	→	→	→
	4.00	33.39	41.34	→	7.35	15.34	0.95	1.54	-0.24	-6.54	-9.81	1.01	→	→	→
	4.25	36.86	45.64	→	7.44	15.69	1.01	1.64	-0.25	→	→	→	→	→	→
	4.35	38.28	47.40	→	7.47	15.74	1.03	1.67	-0.26	→	→	→	→	→	→
	4.47	39.92	49.42	→	7.51	16.10	1.06	1.72	-0.27	→	→	→	→	→	→
	5.00	→	→	→	4.32	9.44	→	→	→	→	→	→	→	→	→
STEADY-STATE		→	→	→	-0.03	0.05	→	→	→	6.54	9.81	-1.01	→	→	→
		→	→	→	-0.03	0.05	→	→	→	-6.54	-9.81	1.01	→	→	→
		→	→	→	-0.03	0.05	→	→	→	0	0	0	→	→	→
b - COOLDOWN	4.00 HRS	5.59	6.92	→	-6.65	-13.91	0.11	0.18	-0.03	6.54	9.81	-1.01	→	→	→
	4.25	→	→	→	-6.59	-13.98	0.05	0.08	-0.01	→	→	→	→	→	→
	4.35	→	→	→	-6.56	-13.92	0.03	0.05	-0.01	→	→	→	→	→	→
	4.47	→	→	→	-6.53	-14.14	0	0	0	→	→	→	→	→	→
	5.00	→	→	→	-3.66	-8.11	0	0	0	→	→	→	→	→	→
	4.00	→	→	→	-6.65	-13.91	0.11	0.18	-0.03	-6.54	-9.81	1.01	→	→	→
	4.25	→	→	→	-6.59	-13.98	0.05	0.08	-0.01	→	→	→	→	→	→
	4.35	→	→	→	-6.56	-13.92	0.03	0.05	-0.01	→	→	→	→	→	→
	4.47	→	→	→	-6.53	-14.14	0	0	0	→	→	→	→	→	→
	5.00	→	→	→	-3.66	-8.11	0	0	0	→	→	→	→	→	→

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

NUMBER 5-211-P | A174
SHEET 66 OF 69
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5. DETAILED ANALYSIS:
e. STRESSES:
2. PEAK STRESSES:

LOCATION 10C

TRANSIENT		PRESSURE STRESS			THERMAL STRESS		THERMAL INDUCED PIPE REACTION STRESS			SEISMIC PIPE REACTION STRESS			STATIC WEIGHT STRESS		
		σ_x	σ_θ	σ_r	σ_x	σ_θ	σ_x	σ_θ	$\tau_{x\theta}$	σ_x	σ_θ	$\tau_{x\theta}$	σ_x	σ_θ	$\tau_{x\theta}$
c	20 min	39.92	49.42	0	-0.03	0.05	1.06	1.72	-0.27	0	0	0	0	0	0.93
d	20 min	39.92	49.42	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
e	100 sec	37.96	47.00	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
	225 sec	40.36	49.97	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
f	40 sec	41.16	50.96	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
	100 sec	40.09	49.64	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
	260 sec	37.96	47.80	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
g	2 min	42.04	52.05	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
	3.2 min	41.69	51.62	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
	10.4 min	38.14	47.22	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
h	10 sec	39.38	48.76	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
	65 sec	33.88	41.95	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
i	220 min	55.44	68.64	↓	0	0	0	0	0	↓	↓	↓	↓	↓	↓
j	H.U 3.0 HRS	22.18	27.46	↓	-0.02	0.68	0.71	1.15	-0.18	↓	↓	↓	↓	↓	↓
	S.S.	44.35	54.91	↓	-0.02	0.03	0.71	1.15	-0.18	↓	↓	↓	↓	↓	↓
	C.O. 3.0 HRS	5.59	6.92	↓	0.07	-0.74	0	0	0	↓	↓	↓	↓	↓	↓
k	~	41.69	51.62	↓	-0.03	0.05	1.06	1.72	-0.27	↓	↓	↓	↓	↓	↓
	~	39.14	47.22	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
l	12 sec	39.92	49.42	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
m	10 sec	48.96	60.62	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
	28 sec	37.61	46.56	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
	160 sec	25.55	31.63	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
n	33 sec	5.32	6.59	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
	54 sec	12.42	15.37	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓

RIV000052C
Submitted: December 22, 2011

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT. CHATTANOOGA. TENN.

CHARGE NO.

DESCRIPTION Structural And Fatigue Evaluation Of Inlet Nozzle - Vessel Supports

NUMBER 5-211-P | A175
SHEET 67 OF 69
DATE 4-22-69 BY Cockrell
CHECK DATE 4-22-69 BY Heilker

5. Detailed Analysis:
e. Stresses:
2. Peak Stresses:

Location 10C

Transient		Earthquake Loading Through Supports Stress			Expansion And Contraction Stress		Total Stress				Principal Stress			Stress Intensity		
		σ_x	σ_θ	$\tau_{x\theta}$	σ_x	σ_θ	σ_x	σ_θ	σ_r	$\tau_{x\theta}$	σ_1	σ_2	σ_3	$\sigma_1-\sigma_2$	$\sigma_1-\sigma_3$	$\sigma_2-\sigma_3$
a- Heatup	4.00 HES	1.36	2.10	-0.48	-1.39	-1.62	47.97	68.73	0	-0.80	68.77	47.94	0	20.83	68.77	47.94
	4.25						51.60	73.49		-0.82	73.52	51.57		21.95	73.52	51.57
	4.35						53.04	75.29		-0.82	75.32	53.00		22.32	7532	53.00
	4.47						54.77	77.76		-0.83	77.79	54.74		23.05	77.79	54.74
	5.00	↓	↓	↓			51.58	71.11		-0.83	71.14	51.54		19.60	71.14	51.54
	4.00	-1.36	-2.10	0.48			32.16	44.91		2.18	45.28	31.79		13.49	45.28	31.79
	4.25						35.79	49.67		2.16	50.01	35.46		14.55	50.01	35.46
	4.35						37.26	51.51		2.16	51.84	36.94		14.90	51.84	36.94
	4.47						38.96	53.94		2.15	54.24	38.66		15.59	54.24	38.66
	5.00	↓	↓	↓	↓	↓	35.77	47.29		2.15	47.68	35.38		12.31	47.68	35.38
Steady-State		1.36	2.10	-0.48	0	0	48.85	63.10		-0.83	63.15	48.80		14.34	63.15	48.80
		-1.36	-2.10	0.48			3305	39.28		2.15	39.95	32.38		7.57	39.95	3238
		0	0	0	↓	↓	40.95	51.19		0.66	51.23	40.91		10.32	51.23	4091
b- Cooldown	4.00 HES	1.36	2.10	-0.48	1.39	1.62	8.57	6.49		-0.59	6.55	8.52		-1.97	6.55	8.52
	4.25						8.57	6.32		-0.58	6.39	8.49		-2.10	6.39	8.49
	4.35						8.58	6.34		-0.57	6.42	8.50		-2.08	6.42	8.50
	4.47						8.58	6.07		-0.56	6.17	8.48		-2.32	6.17	8.48
	5.00	↓	↓	↓			11.45	12.10		-0.56	11.17	12.38		-1.20	11.17	12.38
	4.00	-1.36	-2.10	0.48			-7.24	-17.33		1.97	-17.48	-7.09		-10.39	-17.48	-7.09
	4.25						-7.24	-17.50		1.99	-17.65	-7.09		-10.56	-17.65	-7.09
	4.35						-7.23	-17.48		1.99	-17.63	-7.08		-10.56	-17.63	-7.08
	4.47						-7.22	-17.75		2.00	-17.89	-7.08		-10.81	-17.89	-7.08
	5.00	↓	↓	↓	↓	↓	-4.36	-11.72	↓	2.00	-12.01	-4.06	↓	-7.95	-12.01	-4.06

COMBUSTION ENGINEERING, INC.

ENGINEERING DEPARTMENT. CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

NUMBER 5-211-P | A176

SHEET 68 **OF** 69

DATE 4-22-69 **BY** COCKRELL

CHECK DATE 4-22-69 **BY** HEIKKER

5. DETAILED ANALYSIS:

e. STRESSES:

2. PEAK STRESSES:

LOCATION 10C

TRANSIENT		EARTHQUAKE LOADING THROUGH SUPPORTS STRESS			EXPANSION AND CONTRACTION STRESS		TOTAL STRESS				PRINCIPAL STRESS			STRESS INTENSITY		
		σ_x	σ_θ	$\tau_{x\theta}$	σ_x	σ_θ	σ_x	σ_θ	σ_r	$\tau_{x\theta}$	σ_1	σ_2	σ_3	$\sigma_1-\sigma_2$	$\sigma_1-\sigma_3$	$\sigma_2-\sigma_3$
c	20 min	0	0	0	0	0	40.95	51.19	0	0.66	51.23	40.91	0	10.32	51.23	40.91
d	20 min						40.95	51.19			51.23	40.91		10.32	51.23	40.91
e	100 sec						39.00	48.77			48.82	38.95		9.86	48.82	38.95
	225 sec						41.39	51.74			51.78	41.35		10.43	51.78	41.35
f	40 sec						42.19	52.73			52.77	42.15		10.62	52.77	42.15
	100 sec						41.13	51.41			51.45	41.08		10.37	51.45	41.08
	260 sec						39.00	48.77			48.82	38.95		9.86	48.82	38.95
g	2 min						43.08	53.82			53.86	43.04		10.83	53.86	43.04
	3.2 min						42.72	53.38			53.43	42.68		10.74	53.43	42.68
	10.4 min						39.18	48.99			49.04	39.13		9.91	49.04	39.13
h	10 sec						40.42	50.53			50.57	40.37		10.20	50.57	40.37
	65 sec						34.92	43.72			43.77	34.87		8.90	43.77	34.87
i	220 min						55.44	68.64		0.93	68.70	55.37		13.33	68.70	55.37
j	H.U. 3.0 HRS						22.86	29.28		0.74	29.37	22.78		6.59	29.37	22.78
	S.S.						45.04	56.09		0.74	56.14	44.99		11.15	56.14	44.99
	C.D 3.0 HRS						5.66	6.17		0.93	6.88	4.96		1.92	6.88	4.96
k	~						42.72	53.38		0.66	53.43	42.68		10.74	53.43	42.68
	~						39.18	48.99			49.04	39.13		9.91	49.04	39.13
l	12 sec						40.95	51.19			51.23	40.91		10.32	51.23	40.91
m	10 sec						50.00	62.39			62.43	49.96		12.46	62.43	49.96
	28 sec						38.64	48.33			48.38	38.60		9.78	48.38	38.60
	160 sec						26.58	33.40			33.46	26.52		6.94	33.46	26.52
n	33 sec						6.36	8.36			8.56	6.16		2.40	8.56	6.16
	54 sec						13.45	17.14			17.26	13.34		3.92	17.26	13.34

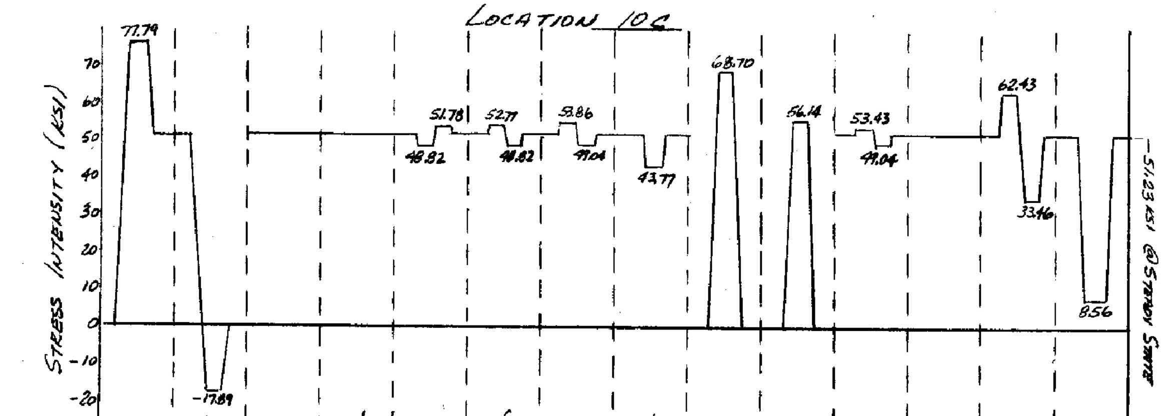
COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF INLET NOZZLE - VESSEL SUPPORTS

NUMBER S-211-P | A177
SHEET 69 OF 69
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5. DETAILED ANALYSIS:

f. FATIGUE EVALUATION:



TRANSIENT	a	b	c	d	e	f	g	h	i	j	k	l	m	n
NUMBER OF OCCURRENCES	200	200	14500	14500	2000	2000	200	400	5	5	∞	80	80	5

S_{MAX}	S_{MIN}	S_{ALT}	NUMBER OF OCCURRENCES	N^*	U
77.79	-17.89	47.84	200	4900	0.0408
68.70	0	34.35	5	14000	0.0004
62.43	8.56	26.94	5	34000	0.0002
62.43	33.46	14.49	75	460000	0.0002
56.14	0	28.07	5	28000	0.0002
53.86	43.77	5.05	200	∞	0

* FROM FIG N-415(A)
REFERENCE 1

$U_{OVERALL} = \underline{\underline{0.042}}$ ←

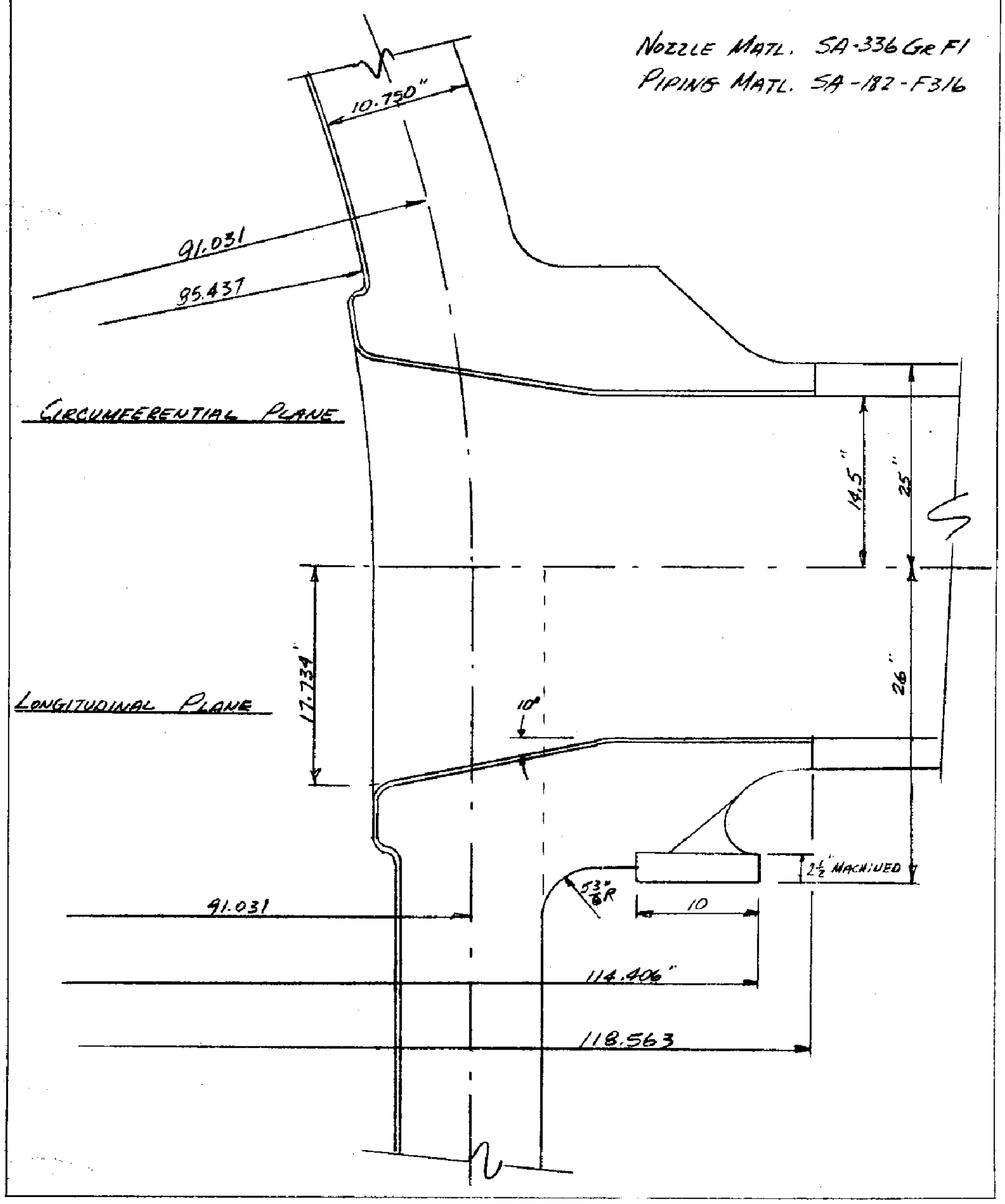
COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.
DESCRIPTION Structural and Fatigue Evaluation of Outlet Nozzle - Vessel Supports

NUMBER 5-212-P | A 178
SHEET 6 OF 80
DATE 4-22-68 BY Cockrell
CHECK DATE 4-22-68 BY Heilker

5. Detailed Analysis:

a. System Geometry:



COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION Structural And Fatigue Evaluation Of Outlet Nozzle – Vessel Supports

NUMBER S-212-P | A179
SHEET 7 OF 80
DATE 4-22-68 BY Cockrell
CHECK DATE 4-22-68 BY Heilker

5- Detailed Analysis:

b- System Allowables:

1- The Stress Intensity In The Reinforcement Portion Of The Nozzle Resulting From Design Pressure And From External Load Or Moment Shall Not Exceed S_m At Design Temp.

2- The Stress Intensity Derived From The Average Primary Plus The Local Primary Stress Shall Not Exceed $1.5 S_m$ At Design Temp.

3- The Stress Intensity Around The Nozzle To Shell Juncture Resulting From Internal Pressure, Pipe Loads, Weight Of Vessel And Reactions From External Loads Shall Not Exceed $1.5 S_m$ At Design Temp.

4- The Stress Intensity In The Nozzle Outside Of The Reinforcement Portion Of The Nozzle And The Safe End Resulting From Design Pressure And From Design Seismic Load Or Moment Shall Not Exceed $1.5 S_m$ At Design Temp.

5- The Range Of Primary Plus Secondary Stress Intensity Resulting From Mechanical Or Thermal Loads Shall Not Exceed $3 S_m$ At Operating Pressure And Temp.

6- Show That Each Point Meets The Requirements For Peak Stress Intensity Given In N-414.5 Of The ASME Code. The Procedure Will Be As Outlined In N-415.2 Of Sect. III.

Note That For The Consideration Of "No Loss Of Function" Seismic Nozzle Loads, The Above Allowables (Where Applicable) Will Be Increased By A Factor Of 1.2.

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION Structural And Fatigue Evaluation Of Outlet Nozzle - Vessel Supports

NUMBER S-212-P | A180
SHEET 8 OF 80
DATE 4-22-68 BY Cockrell
CHECK DATE 4-22-68 BY Heilker

5- Detailed Analysis:

c. System Loading:

1. Internal Pressure:

The Outlet Nozzle And The Vessel Wall In The Vicinity Of The Nozzle Will Be Investigated For The Design Pressure Where Applicable And The Operating Pressures During The Transients Listed In 5.c.2. The Stresses Resulting From Internal Pressure Are Determined From An Interaction Analysis And Are Presented In 5.e. The Peak Stresses Due To Internal Pressure At The Juncture Of The Nozzle To Vessel Shell Will Be Taken As Given In I-610 Of The ASME Code Sect. III.

2. Thermal Transients:

The Outlet Nozzle And The Vessel Wall Will Be Analyzed For The Following Transient Conditions.

Transient	Number Of Occurrences
a. Plant Heatup At 100°F Per Hour	200
b. Plant Cooldown At 100°F Per Hour	200
c. Plant Loading At 5% Of Full Power Per Min.	14500
d. Plant Unloading At 5% Of Full Power Per Min.	14500
e. Step Load Increase Of 10% Of Full Power But Not To Exceed Full Power	2000
f. Step Load Decrease Of 10% Of Full Power From 100% Power	2000
g. Step Load Reduction From 100% To 50% Full Power	200
h. Reactor Trip From Full Power	400
i. Plant Hydrostatic Test Of 3125 PSIA At Room Temp.	5
j. Plant Hydrostatic Test Of 2500 PSIA Up To 400°F.	5
k. Steadystate Fluctuations Of ±6°F And ± 100PSI Per Min.	∞
l. Loss Of Flow, One Pump	80
m. Loss Of Load	80
n. Steam Break	5

RIV000052C
Submitted: December 22, 2011

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

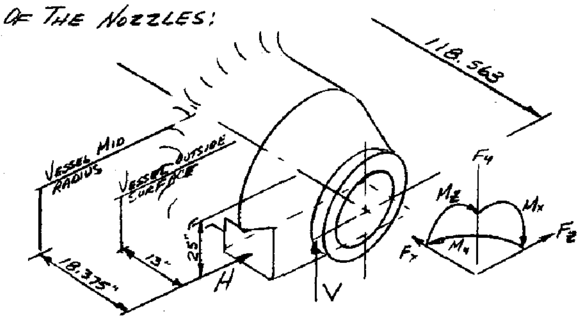
NUMBER S-212-P | A181
SHEET 9 OF 80
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

C.- SYSTEM LOADING:

3.- THERMAL INDUCED PIPE REACTIONS:

THE FOLLOWING FIGURE SHOWS THE OUTLET NOZZLE WITH THE POSITIVE DIRECTIONS. THE PIPE REACTIONS ARE APPLIED AT THE SMALL END OF THE NOZZLES:



F_x = 26.2 KIPS
F_y = -230 KIPS
F_z = -10 KIPS
M_x = -2010 IN-KIPS
M_y = -1830 IN-KIPS
M_z = 27084 IN-KIPS

4- SEISMIC PIPE REACTIONS:

THE FOLLOWING PIPE REACTIONS DUE TO SEISMIC CONDITIONS WILL BE COMBINED WITH THE THERMAL PIPE REACTIONS IN THE WORST POSSIBLE COMBINATION WHEN ANALYZING THE NOZZLE AND SUPPORTS. TO DETERMINE THE MAXIMUM EFFECT OF THE SEISMIC PIPE REACTIONS ON THE NOZZLE TO VESSEL JUNCTURE AND THE SUPPORT PAD, IT IS NECESSARY TO DETERMINE THE WORSE COMBINATION OF FORCES. THIS HAS BEEN DONE AND THE FORCES RESULTING ARE LABELED H AND V. NOTE THAT THE EFFECT OF TWO OF THE INLET AND OUTLET NOZZLE SEISMIC REACTIONS MUST BE TAKEN BY THE INLET AND OUTLET NOZZLES WHICH SUPPORT THE VESSEL. THE FOLLOWING ARE THE PIPE REACTIONS

DESIGN SEISMIC LOADING	NO LOSS OF FUNCTION SEISMIC LOADING
$F_x = \pm$ 122 KIPS	$F_x = \pm$ 122 KIPS
$F_y = \pm$ 90 KIPS	$F_y = \pm$ 162 KIPS
$F_z = \pm$ 71 KIPS	$F_z = \pm$ 124 KIPS
$M_x = \pm$ 1572 IN-KIPS	$M_x = \pm$ 2830 IN-KIPS
$M_y = \pm$ 11248 IN-KIPS	$M_y = \pm$ 19569 IN-KIPS
$M_z = \pm$ 7282 IN-KIPS	$M_z = \pm$ 13200 IN-KIPS

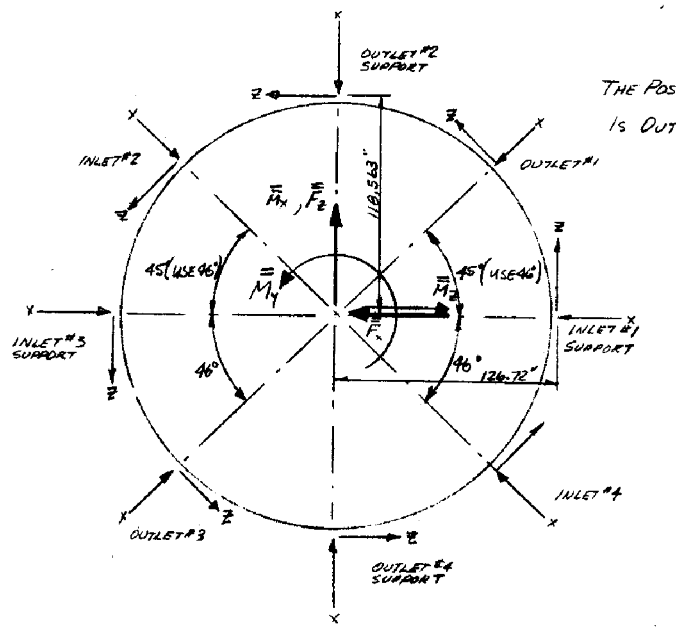
COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORT

NUMBER S-211-P | A182
SHEET 10 OF 80
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:
C- SYSTEM LOADING:
4- SEISMIC PIPE REACTIONS:

AS CAN BE SEEN FROM THE TABLE ON SHEET 9, THERE ARE MANY COMBINATIONS OF FORCES. SINCE THE SEISMIC FORCES CAN ALTERNATE, IT WILL BE NECESSARY TO DETERMINE THE COMBINATION OF FORCES WHICH PRODUCE THE MAXIMUM AND MINIMUM STRESSES AT CUT-4. THIS WILL OCCUR WHEN THE VALUES FOR $\bar{F}_x$, $\bar{F}_y$, $\bar{F}_z$, $\bar{M}_x$, $\bar{M}_y$, AND $\bar{M}_z$ AS GIVEN ON SHEETS 47-52 ARE SOLVED TO GIVE MAXIMUM AND MINIMUM VALUES. THE METHOD USED TO DETERMINE THIS IS AS FOLLOWS:

(1) THE LOADS ON THE INDIVIDUAL NOZZLES ARE TRANSFERRED TO THE C.G. OF THE REACTOR VESSEL,
(2) THE FORCES H AND V ARE DETERMINED IN RELATION TO THE LOADS AT THE ℄ OF THE VESSEL, AND
(3) TAKING THE COMBINATION OF SEISMIC LOADS GIVEN ON SHEET 9 TO GIVE THE MAXIMUM AND MINIMUM VALUES OF H & V.



THE POSITIVE Y DIRECTION IS OUT OF THE PAPER

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER S-212-P | A183
SHEET 11 OF 80
CHARGE NO.
DATE 4-22-68 BY COCKRELL
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLES - VESSEL SUPPORTS
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:
C- SYSTEM LOADING:
4. SEISMIC PIPE REACTIONS:

(1) FORCES AT ℄ OF VESSEL:

SEE SHEET 11 OF S-211-P

(2) FORCES ON SUPPORTS:

$$H = \mp \frac{\bar{\bar{F}}_x}{2} - \frac{\bar{\bar{M}}_y}{4(109.406)}$$

$$V = -\frac{\bar{\bar{F}}_y}{4} \pm \frac{\bar{\bar{M}}_x}{2(109.406)}$$

NOTE HERE THAT THE TOP SIGN IS FOR OUTLET NOZZLE #2 AND THE BOTTOM SIGN IS FOR OUTLET NOZZLE #4. HOWEVER, WITH SUBSITUTION OF FORMULAS FOR $\bar{\bar{F}}_x$, $\bar{\bar{F}}_y$ & $\bar{\bar{M}}_y$, AND $\bar{\bar{M}}_x$ AND SOLVING WILL YIELD THE SAME RESULTS.

(3) VALUES OF FORCES ON SUPPORTS:

WITH THE ABOVE EXPRESSIONS FOR H & V AND THE EXPRESSIONS FOR $\bar{\bar{F}}_x$, $\bar{\bar{F}}_y$, $\bar{\bar{M}}_x$, AND $\bar{\bar{M}}_y$ GIVEN ON SHEET-11 OF S-211-P, WE GET THE FOLLOWING.

$$\begin{aligned}H = &-0.5(F_{x_{IN\#1}} - F_{x_{IN\#3}}) + 0.34733(F_{x_{IN\#2}} - F_{x_{IN\#4}}) - 0.28956(F_{z_{IN\#1}} + F_{z_{IN\#3}}) - 0.64923\,F_{z_{IN\#2}} \\ &+ 0.07011\,F_{z_{IN\#4}} - 0.34733(F_{x_{OUT\#1}} - F_{x_{OUT\#3}}) - 0.63059\,F_{z_{OUT\#1}} - 0.77092\,F_{z_{OUT\#2}} \\ &+ 0.08875\,F_{z_{OUT\#3}} + 0.22849\,F_{z_{OUT\#4}} - 0.002285(M_{y_{IN\#1}} + M_{y_{IN\#2}} + M_{y_{IN\#3}} + M_{y_{IN\#4}}) \\ &- 0.002285(M_{y_{OUT\#1}} + M_{y_{OUT\#2}} + M_{y_{OUT\#3}} + M_{y_{OUT\#4}})\end{aligned}$$

$$\begin{aligned}V = &-0.25(F_{y_{IN\#1}} + F_{y_{IN\#3}}) - 0.66659\,F_{y_{IN\#2}} + 0.16659\,F_{y_{IN\#4}} - 0.63977\,F_{y_{OUT\#1}} - 0.79184\,F_{y_{OUT\#2}} + 0.13977\,F_{y_{OUT\#3}} \\ &+ 0.29184\,F_{y_{OUT\#4}} + 0.00457(M_{x_{IN\#1}} - M_{x_{IN\#3}}) - 0.00317(M_{x_{IN\#2}} - M_{x_{IN\#4}}) + 0.00329(M_{z_{IN\#2}} - M_{z_{IN\#4}}) \\ &+ 0.00317(M_{x_{OUT\#1}} - M_{x_{OUT\#3}}) + 0.00329(M_{z_{OUT\#1}} - M_{z_{OUT\#3}}) + 0.000457(M_{z_{OUT\#2}} - M_{z_{OUT\#4}})\end{aligned}$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER S-212-P | A184
SHEET 12 OF 80
CHARGE NO.
DATE 4-22-68 BY COCKRELL
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLES - VESSEL SUPPORTS
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

C. SYSTEM LOADING:

4- SEISMIC PIPE REACTIONS:

WITH THE ABOVE EQUATIONS AND THE FOLLOWING VALUES FOR THE SEISMIC PIPE REACTIONS, THE VALUES FOR H & V ARE DETERMINED THAT WILL GIVE THE MAXIMUM AND MINIMUM STRESSES AT CUT-4.

FOR DESIGN SEISMIC:

NOZZLE	PIPE REACTION					
	F_x	F_y	F_z	M_x	M_y	M_z
INLET #1	57.9	67	132.9	-982	12972	
2	-57.9	67	132.9	982	12972	-9910
3	-57.9	67	132.9	982	12972	
4	57.9	-67	-132.9	-982	12972	9910
OUTLET #1	122	90	-71	-1572	11248	-7282
2	-122	-90	-71	-1572	-11248	7282
3	-122	-90	71	1572	11248	7282
4		-90	71		11248	7282

H = -538.5 KIPS
V = -252.8 KIPS

REVERSING SIGNS GIVES,
H = 538.5 KIPS
V = 252.8 KIPS

FOR NO LOSS OF FUNCTION SEISMIC:

NOZZLE	PIPE REACTION					
	F_x	F_y	F_z	M_x	M_y	M_z
INLET #1	91.9	81.9	262	-2800	23655	
2	-81.9	81.9	262	2800	23655	-10005
3	-81.9	81.9	262	2800	23655	
4	81.9	-81.9	-262	-2800	23655	10005
OUTLET #1	122	162	-124	-2830	19569	-13200
2	-122	-162	-124	-2830	-19569	13200
3	-122	-162	124	2830	19569	13200
4		-162	124		19569	13200

$H = -892.2^K$
$V = -407.2^K$

REVERSING SIGNS GIVES,
$H = 892.2^K$
$V = 407.2^K$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLES - VESSEL SUPPORTS

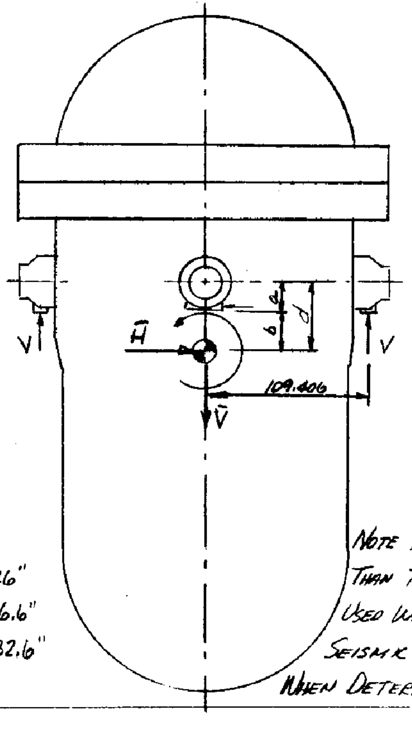
NUMBER 5-212-P | A185
SHEET 13 OF 80
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:
c- SYSTEM LOADING:
5- STATIC LOADING THROUGH SUPPORTS:

THE STATIC LOAD PER SUPPORT WAS FOUND TO BE 561.1 KIPS, SEE SHEET 14 OF S-211-P.

6- EARTHQUAKE LOADING THROUGH SUPPORTS:

DURING AN EARTHQUAKE, THE SUPPORTS MUST RESIST THE VERTICAL AND HORIZONTAL FORCES APPLIED THROUGH THE C.G. OF THE VESSEL DUE TO THE EARTHQUAKE SHOCK FORCES. SINCE THE BOTTOM OF THE VESSEL SUPPORTS IS AT A DIFFERENT ELEVATION THAN THE C.G. OF THE VESSEL, AN OVERTURNING MOMENT DUE TO THE HORIZONTAL SHOCK FORCE RESULTS AND MUST BE RESISTED BY THE SUPPORTS. THE FOLLOWING FIGURE ILLUSTRATES THE METHOD FOR DETERMINING THE FORCES ON THE PADS.



$$V = \pm \frac{\bar{V}}{4} \pm \frac{\bar{M}}{2(109.406)}$$

$$H = \pm \frac{\bar{H}}{2}$$

DIRECTION	EARTHQUAKE FACTORS	
	DESIGN	NO LOSS OF FUNCTION
HORIZONTAL	0.3g	0.6g
VERTICAL	0.2g	0.4g

FORCE	DESIGN	NO LOSS OF FUNCTION
H	±336.7	±673.4
V	±132.5	±265.1

a = 26"
b = 6.6"
d = 32.6"

NOTE THAT THE ABOVE SEISMIC SHOCK FACTORS ARE LARGER THAN THOSE LISTED IN REF 10. THE ABOVE FACTORS WILL BE USED WHEN CALCULATING STRESSES; HOWEVER, THE SPECIFIED SEISMIC SHOCK FACTORS GIVEN IN REF 10, WILL BE USED WHEN DETERMINING THE MAX. FORCES ON THE PAD, SEE SHEET 65.

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER S-212-P | A186
SHEET 14 OF 80
CHARGE NO.
DATE 4-22-68 BY COCKRELL
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS
CHECK DATE 4-22-68 BY HEILKER

5. DETAILED ANALYSIS:

c. SYSTEM LOADING:

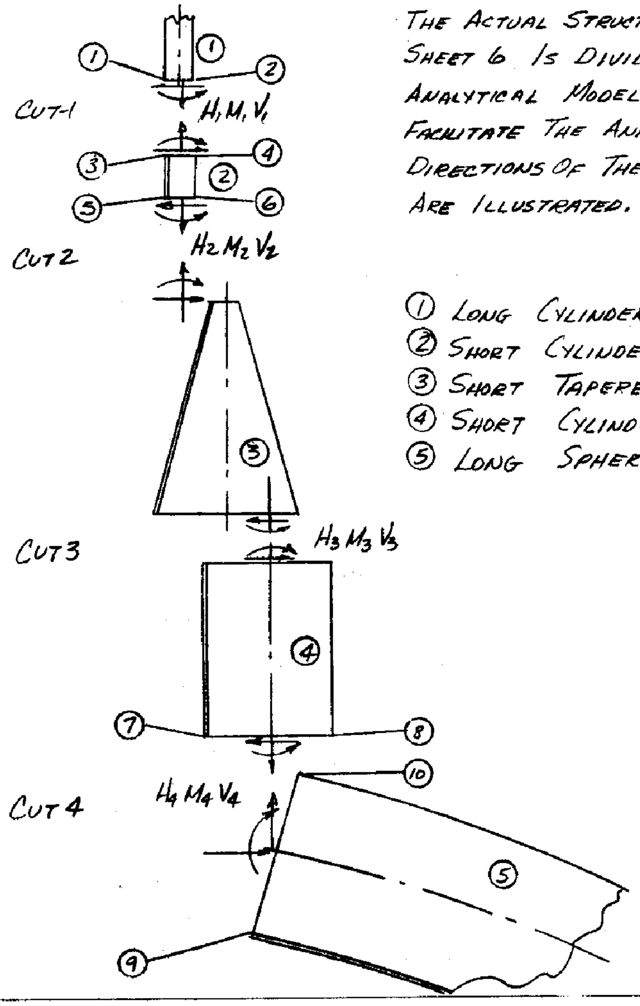
7. DUE TO THERMAL EXPANSION & CONTRACTION

THE FRICTIONAL FORCE DUE TO EXPANSION AND CONTRACTION WAS FOUND TO BE 168.3 KIPS, SEE SHEET 16 OF S-211-P.

d. PRESSURE AND THERMAL INTERACTION:

1. ANALYTICAL MODEL:

THE ACTUAL STRUCTURE AS SHOWN ON SHEET 6 IS DIVIDED INTO THE ANALYTICAL MODEL AS SHOWN TO FACILITATE THE ANALYSIS. THE ASSUMED DIRECTIONS OF THE REDUNDANT FORCES ARE ILLUSTRATED.



① LONG CYLINDER
② SHORT CYLINDER
③ SHORT TAPERED CYLINDER
④ SHORT CYLINDER
⑤ LONG SPHERE

RIV000052C
Submitted: December 22, 2011

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.

NUMBER S-212-P | A187
SHEET 15 **OF** 80
DATE 4-22-68 **BY** COCKRELL
CHECK DATE 4-22-68 **BY** HEILKER

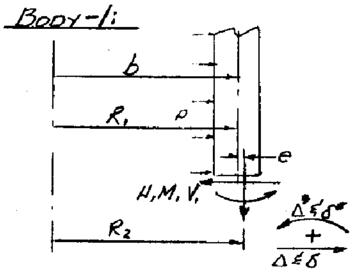
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

5. DETAILED ANALYSIS:

d- PRESSURE & THERMAL INTERACTION:

1- DEFLECTIONS:

BODY-1:



$R_1 = 15.766''$
$b_1 = 14.5''$
$t_1 = 2.531''$
$R_2 = 15.875''$
$e = 0.109''$

$\beta^4 = \frac{3(1-\nu^2)}{R_1^2 t_1^2}$
$\beta = 0.20349$
$D = \frac{Et_1^3}{12(1-\nu)} = 1.48475E$
$\frac{E_{302B}}{E_{316SS}} = 1$

DISPLACEMENTS DUE TO REDUNDANT FORCES:

$$E\Delta_{11} = -\frac{E}{2\beta^2 D}\left[\frac{1}{\beta}H_1 - M_1\right]\frac{R_2}{R_1}\frac{E_{302B}}{E_{316}} = \underline{-40.2444 H_1 + 8.1892 M_1}$$

$$E\Delta_{11}^* = -\frac{E}{2\beta^2 D}\left[H_1 - 2\beta M_1\right]\frac{R_2}{R_1}\frac{E_{302B}}{E_{316}} = \underline{-8.1892 H_1 + 3.3328 M_1}$$

DISPLACEMENTS DUE TO APPLIED FORCES:

$$E\delta_{11} = \frac{b_1^2}{t_1}\left(\frac{R_1}{b_1} - \frac{\nu}{2}\right)P\frac{E_{302B}}{E_{316}} - \frac{E}{2\beta^2 D}(V_1 e)\frac{R_2}{R_1}\frac{E_{302B}}{E_{316}} = \underline{71.9513P}$$

$$E\delta_{11}^* = -\frac{E}{\beta D}(V_1 e)\frac{R_2}{R_1}\frac{E_{302B}}{E_{316}} = \underline{-2.4056P}$$

DISPLACEMENTS DUE TO THERMAL EFFECTS:

FOR RANGE OF STRESS	FOR PEAK STRESS
$E\delta_{11T} = R_2 E\alpha_m (T_{11} - 100)\frac{E_{302B}}{E_{316}}$	$= R_2 E\alpha_m (T_{11} - 100)\frac{E_{302B}}{E_{316}} + \frac{E}{2\beta^2 D}\frac{R_2}{R_1}\frac{E_{302B}}{E_{316}} M_{1T}$
$= \underline{15.875 E\alpha_m (T_{11} - 100)}$	$= \underline{15.875 E\alpha_m (T_{11} - 100) + 8.1892 M_{1T}}$
$E\delta_{11T}^* = R_1 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{11} \frac{E_{302B}}{E_{316}}$	$= R_1 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{11} \frac{E_{302B}}{E_{316}} + \frac{E}{\beta D}\frac{R_2}{R_1}\frac{E_{302B}}{E_{316}} M_{1T}$
$= 15.766 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{11}$	$= \underline{15.766 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{11} + 3.3328 M_{1T}}$

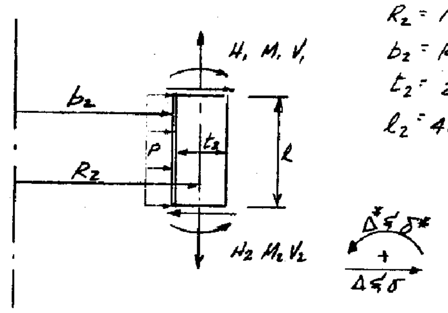
NUMBER 5-212-P | A188
SHEET 16 OF 80
CHARGE NO.
DATE 4-22-68 BY Cockrell
DESCRIPTION Structural And Fatigue Evaluation Of Outlet Nozzle - Vessel Supports
CHECK DATE 4-22-68 BY Heilker

5- Detailed Analysis:

d. Pressure And Thermal Interaction:

2- Deflections:

Body-2:



$R_2 = 15.875''$

$b_2 = 14.500''$

$t_2 = 2.312''$

$l_2 = 4.0625''$

$\beta^4 = \frac{3(1-\nu^2)}{R_2^2 t_2^2}$

$\beta = 0.21217$

$D = \frac{Et^3}{12(1-\nu^2)} = 1.13172E$

For $\beta l = 0.862$

$B_{11} = 2.3326$	$G_{11} = -1.1511$
$B_{12} = 4.1158$	$G_{12} = -3.9924$
$B_{22} = 10.0093$	$G_{22} = -9.1500$

Displacements Due To Redundant Forces:

$$E\Delta_{21} = \frac{E}{2\beta^2 D}\left[\frac{1}{\beta} B_{11} H_1 + B_{12} M_1 - \frac{1}{\beta} G_{11} H_2 + G_{12} M_2\right]$$

$$= \underline{107.8952 H_1 + 40.3930 M_1 + 53.2445 H_2 - 39.1819 M_2}$$

$$E\Delta_{21}^* = \frac{E}{2\beta^2 D}\left[-B_{12} H_1 - \beta B_{22} M_1 + G_{12} H_2 - \beta G_{22} M_2\right]$$

$$= \underline{-40.3930 H_1 - 20.8423 M_1 - 39.1819 H_2 + 19.0519 M_2}$$

$$E\Delta_{22} = \frac{E}{2\beta^2 D}\left[\frac{1}{\beta} G_{11} H_1 + G_{12} M_1 - \frac{1}{\beta} B_{11} H_2 + B_{12} M_1\right]$$

$$= \underline{-53.2445 H_1 - 39.1819 M_1 - 107.8952 H_2 + 40.3930 M_2}$$

$$E\Delta_{22}^* = \frac{E}{2\beta^2 D}\left[G_{12} H_1 + \beta G_{22} M_1 - B_{12} H_2 + \beta B_{22} M_1\right]$$

$$= \underline{-39.1819 H_1 - 19.0519 M_1 - 40.3930 H_2 + 20.8423 M_2}$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

NUMBER 5-212-D A189
SHEET 17 OF 80
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

d- PRESSURE AND THERMAL INTERACTION:

2- DEFLECTIONS:

DISPLACEMENTS DUE TO APPLIED FORCES

$$E\delta_{21} = E\delta_{22} = \frac{b_2^2}{t_2}\left(\frac{R_2}{b_2} - \frac{\nu}{2}\right)P = \underline{85.9213P}$$

$$E\delta_{21}^* = E\delta_{22}^* = 0$$

DISPLACEMENTS DUE TO THERMAL EFFECTS:

FOR RANGE OF STRESS	FOR PEAK STRESS
$E\delta_{21T} = R_2 E\alpha_m (T_{21} - 100)$	$= R_2 E\alpha_m (T_{21} - 100) + \frac{E}{2\beta^2 D}\left[B_{12} M_{1T} + G_{12} M_{2T}\right]$
$= \underline{15.875 E\alpha_m (T_{21} - 100)}$	$= \underline{15.875 E\alpha_m (T_{21} - 100) + 40.3930 M_{1T} - 39.1819 M_{2T}}$
$E\delta_{21T}^* = R_2 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{21}$	$= R_2 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{21} + \frac{E}{2\beta^2 D}\left[-\beta B_{22} M_{1T} - \beta G_{22} M_{2T}\right]$
$= \underline{15.875 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{21}}$	$= \underline{15.875 E\alpha \left(\frac{\Delta T}{\Delta X}\right)_{21} - 20.8423 M_{1T} + 19.0519 M_{2T}}$
$E\delta_{22T} = R_2 E\alpha_m (T_{22} - 100)$	$= R_2 E\alpha_m (T_{22} - 100) + \frac{E}{2\beta^2 D}\left[G_{12} M_{1T} + B_{12} M_{2T}\right]$
$= \underline{15.875 E\alpha_m (T_{22} - 100)}$	$= \underline{15.875 E\alpha_m (T_{22} - 100) - 39.1819 M_{1T} + 40.3930 M_{2T}}$
$E\delta_{22T} = R_2 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{22}$	$= R_2 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{22} + \frac{E}{2\beta^2 D}\left[\beta G_{22} M_{1T} + \beta B_{22} M_{2T}\right]$
$= \underline{15.875 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{22}}$	$= \underline{15.875 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right) - 19.0519 M_{1T} + 20.8423 M_{2T}}$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

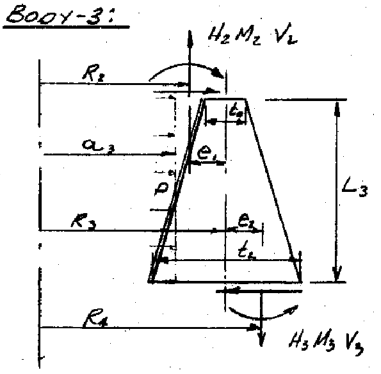
NUMBER S-212-P | A190
SHEET 18 **OF** 80
DATE 4-22-68 **BY** COCKRELL
CHECK DATE 4-22-68 **BY** HEILKER

5- DETAILED ANALYSIS:

d- PRESSURE AND THERMAL INTERACTION:

2. DEFLECTIONS:

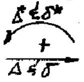
BODY-3:



$R_2 = 15.875$
$R_3 = 17.928$
$R_4 = 19.980$
$a_3 = 14.500$

$t_0 = 2.312$
$t_L = 10.281$
$L_3 = 8.219$
$e_1 = 2.053$
$e_2 = 2.052$

$$\lambda = \frac{1}{L_3}(t_L - t_0)$$
$$= 0.96958$$



THE INFLUENCE COEFFICIENTS FOR A SHORT TAPERED CYLINDER ARE CALCULATED BY THE METHOD OUTLINED ON PAGES 488→492 OF REF. 12 AND ARE PRINTED OUT ON C.E.'S COMPUTER PROGRAM AS FOLLOWS.

DISPLACEMENTS DUE TO REDUNDANT FORCES:

$$E\Delta_{22} = \phi_{11} H_2 \frac{R_2}{R_3} + \phi_{12} M_2 \frac{R_2}{R_3} + \phi_{13} H_3 \frac{R_4}{R_3} + \phi_{14} M_3 \frac{R_4}{R_3}$$

$$= \underline{34.1884 H_2 + 6.1893 M_2 + 15.7480 H_3 - 6.9346 M_3}$$

$$E\Delta^*_{32} = \phi_{21} H_2 \frac{R_2}{R_3} + \phi_{22} M_2 \frac{R_2}{R_3} + \phi_{23} H_3 \frac{R_4}{R_3} + \phi_{24} M_3 \frac{R_4}{R_3}$$

$$= \underline{-6.1847 H_2 - 1.8617 M_2 - 4.4781 H_3 + 1.3550 M_3}$$

$$E\Delta_{33} = \phi_{31} H_2 \frac{R_2}{R_3} + \phi_{32} M_2 \frac{R_2}{R_3} + \phi_{33} H_3 \frac{R_4}{R_3} + \phi_{34} M_3 \frac{R_4}{R_3}$$

$$= \underline{-12.5173 H_2 - 3.5624 M_2 - 21.9623 H_3 + 4.6783 M_3}$$

$$E\Delta^*_{23} = \phi_{41} H_2 \frac{R_2}{R_3} + \phi_{42} M_2 \frac{R_2}{R_3} + \phi_{43} H_3 \frac{R_4}{R_3} + \phi_{44} M_3 \frac{R_4}{R_3}$$

$$= -5.5112 H_2 - 1.0776 M_2 - 4.6773 H_3 + 1.4794 M_3$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

NUMBER S-212-P A191
SHEET 19 OF 80
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HELLKER

5- DETAILED ANALYSIS:

d- PRESSURE AND THERMAL INTERACTION:

2- DEFLECTIONS:

DISPLACEMENTS DUE TO APPLIED FORCES:

$$E\delta_{32} = Pa_3^2\left(\frac{R_3}{a_3} - \frac{\nu}{2}\right)\left[(\phi_{12}+\phi_{14})\frac{-\lambda^2}{6(1-\nu^2)} + \frac{1}{t_0}\right] + \phi_{12} V_2 e_1 \frac{R_2}{R_3} - \phi_{14} V_3 e_2 \frac{R_4}{R_3} = \underline{227.6294P}$$

$$E\delta_{32}^{*} = Pa_3^2\left(\frac{R_3}{a_3} - \frac{\nu}{2}\right)\left[(\phi_{22}+\phi_{24})\frac{-\lambda^2}{6(1-\nu^2)} - \frac{\lambda}{t_0^2}\right] + \phi_{22} V_2 e_1 \frac{R_2}{R_3} - \phi_{24} V_3 e_2 \frac{R_4}{R_3} = -\underline{46.4974P}$$

$$E\delta_{33} = Pa_3^2\left(\frac{R_3}{a_3} - \frac{\nu}{2}\right)\left[(\phi_{32}+\phi_{34})\frac{-\lambda^2}{6(1-\nu^2)} + \frac{1}{t_L}\right] + \phi_{32} V_2 e_1 \frac{R_2}{R_3} - \phi_{34} V_3 e_2 \frac{R_4}{R_3} = -\underline{83.5960P}$$

$$E\delta_{33}^{*} = Pa_3^2\left(\frac{R_3}{a_3} - \frac{\nu}{2}\right)\left[(\phi_{42}+\phi_{44})\frac{-\lambda^2}{6(1-\nu^2)} - \frac{\lambda}{t_L^2}\right] + \phi_{42} V_2 e_1 \frac{R_2}{R_3} - \phi_{44} V_3 e_2 \frac{R_4}{R_3} = -\underline{37.0640P}$$

DISPLACEMENTS DUE TO THERMAL EFFECTS:

FOR RANGE OF STRESS	FOR PEAK STRESS
$E\delta_{32T} = R_2 E\alpha_m(T_{32}-100)$	$= R_2 E\alpha_m(T_{32}-100) + \phi_{12} M_{2T}\frac{R_2}{R_3} + \phi_{14} M_{3T}\frac{R_4}{R_3}$
$= \underline{15.875\,E\alpha_m(T_{32}-100)}$	$= \underline{15.875\,E\alpha_m(T_{32}-100) + 6.1893\,M_{2T} - 6.9346\,M_{3T}}$
$E\delta_{32T}^{*} = R_3 E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{32}$	$= R_3 E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{32} + \phi_{22} M_{2T}\frac{R_2}{R_3} + \phi_{24} M_{3T}\frac{R_4}{R_3}$
$= \underline{17.928\,E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{32}}$	$= \underline{17.928\,E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{32} - 1.8617\,M_{2T} + 1.3550\,M_{3T}}$
$E\delta_{33T} = R_4 E\alpha_m(T_{33}-100)$	$= R_4 E\alpha_m(T_{33}-100) + \phi_{32} M_{2T}\frac{R_2}{R_3} + \phi_{34} M_{3T}\frac{R_4}{R_3}$
$= \underline{19.980\,E\alpha_m(T_{33}-100)}$	$= \underline{19.980\,E\alpha_m(T_{33}-100) - 3.5624\,M_{2T} + 4.6783\,M_{3T}}$
$E\delta_{33T}^{*} = R_3 E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{33}$	$= R_3 E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{33} + \phi_{42} M_{2T}\frac{R_2}{R_3} + \phi_{44} M_{3T}\frac{R_4}{R_3}$
$= \underline{17.928\,E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{33}}$	$= \underline{17.928\,E\alpha_m\left(\frac{\Delta T}{\Delta X}\right)_{33} - 1.0776\,M_{2T} + 1.4794\,M_{3T}}$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION Structural And Fatigue Evaluation Of Outlet Nozzle – Vessel Supports

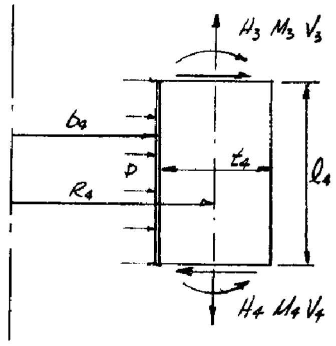
NUMBER 5-212-P | A192
SHEET 20 **OF** 80
DATE 4-22-68 **BY** Cockrell
CHECK DATE 4-22-68 **BY** Heilker

5- Detailed Analysis:

d. Pressure And Thermal Interaction:

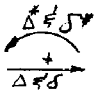
2. Deflections:

Body-4:



$R_4 = 19.980''$
$b_4 = 14.739''$
$t_4 = 10.042''$
$l_4 = 15.25''$

$\beta^4 = \frac{3(1-\nu^2)}{R_4^2 t_4^2}$
$\beta = 0.09075$
$D = \frac{Et^3}{12(1-\nu^2)} = 92.7338E$



For $\beta l = 1.384$

$B_{11} = 1.4944$ $G_{11} = -0.6859$
$B_{12} = 1.7630$ $G_{12} = -1.4519$
$B_{22} = 3.2777$ $G_{22} = -1.9212$

Displacements Due To Redundant Forces:

$$E\Delta_{43} = \frac{E}{2\beta^2 D}\left[\frac{1}{\beta}B_{11}H_3 + B_{12}M_3 - \frac{1}{\beta}G_{11}H_4 + G_{12}M_4\right]$$

$$= \underline{10.7821\,H_3 + 1.1543\,M_3 + 4.9488\,H_4 - 0.9506\,M_4}$$

$$E\Delta^*_{43} = \frac{E}{2\beta^2 D}\left[-B_{12}H_3 - \beta B_{22}M_3 + G_{12}H_4 - \beta G_{22}M_4\right]$$

$$= -\underline{1.1543\,H_3 - 0.1948\,M_3 - 0.9506\,H_4 + 0.1142\,M_4}$$

$$E\Delta_{44} = \frac{E}{2\beta^2 D}\left[\frac{1}{\beta}G_{11}H_3 + G_{12}M_3 - \frac{1}{\beta}B_{11}H_4 + B_{12}M_4\right]$$

$$= \underline{-4.9488\,H_3 - 0.9506\,M_3 - 10.7821\,H_4 + 1.1543\,M_4}$$

$$E\Delta^*_{44} = \frac{E}{2\beta^2 D}\left[G_{12}H_3 + \beta G_{22}M_3 - B_{12}H_4 + \beta B_{22}M_4\right]$$

$$= \underline{-0.9506\,H_3 - 0.1142\,M_3 - 1.1543\,H_4 + 0.1948\,M_4}$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

NUMBER S-212-P A193
SHEET 21 OF 80
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILVER

5- DETAILED ANALYSIS

d. PRESSURE AND THERMAL INTERACTION:

2. DEFLECTIONS:

DISPLACEMENTS DUE TO APPLIED FORCES:

$$E\delta_{43} = E\delta_{44} = \frac{b_4^2}{t_4}\left(\frac{R_4}{b_4} - \frac{\nu}{2}\right)P = \underline{26.0803P}$$

$$E\delta_{43}^{*} = E\delta_{44}^{*} = 0$$

DISPLACEMENTS DUE TO THERMAL EFFECTS:

FOR RANGE OF STRESS	FOR PEAK STRESS
$E\delta_{43T} = R_4 E\alpha_m (T_{43}-100)$	$= R_4 E\alpha_m (T_{43}-100) + \frac{E}{2\beta^2 D}\left[B_{12} M_{3T} + G_{12} M_{4T}\right]$
$= \underline{19.980 E\alpha_m (T_{43}-100)}$	$= \underline{19.980 E\alpha_m (T_{43}-100) + 1.1543 M_{3T} - 0.9506 M_{4T}}$
$E\delta_{43T}^{*} = R_4 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{43}$	$= R_4 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{43} + \frac{E}{2\beta^2 D}\left[-\beta B_{22} M_{3T} - \beta G_{22} M_{4T}\right]$
$= \underline{19.980 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{43}}$	$= \underline{19.980 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{43} - 0.1948 M_{3T} + 0.1142 M_{4T}}$
$E\delta_{44T} = R_4 E\alpha_m (T_{44}-100)$	$= R_4 E\alpha_m (T_{44}-100) + \frac{E}{2\beta^2 D}\left[G_{12} M_{3T} + B_{12} M_{4T}\right]$
$= \underline{19.980 E\alpha_m (T_{44}-100)}$	$= \underline{19.980 E\alpha_m (T_{44}-100) - 0.9506 M_{3T} + 1.1543 M_{4T}}$
$E\delta_{44T}^{*} = R_4 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{44}$	$= R_4 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{44} + \frac{E}{2\beta^2 D}\left[\beta G_{22} M_{3T} + \beta B_{22} M_{4T}\right]$
$= \underline{19.980 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{44}}$	$= \underline{19.980 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{44} - 0.1142 M_{3T} + 0.1948 M_{4T}}$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

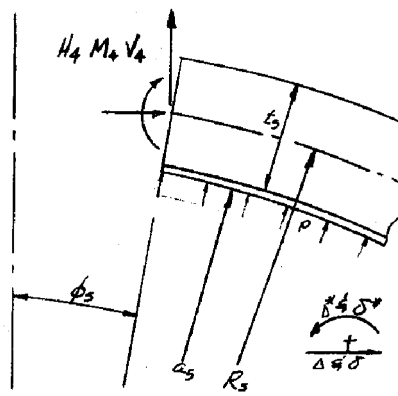
NUMBER S-212-P | A194
SHEET 22 OF 80
DATE 4-22-63 BY COCKRELL
CHECK DATE 4-22-63 BY HEILKER

5- DETAILED ANALYSIS:

d- PRESSURE AND THERMAL INTERACTION:

2. DEFLECTIONS:

BODY-5:



$R_5 = 136.546''$
$a_5 = 130.952''$
$t_5 = 10.750''$
$\phi_5 = 8.4138°$

For $\phi\sqrt{\frac{R}{t}} = 29.987$
$P_{11} = 0.5387$
$P_{12} = 0.4851$
$P_{22} = 2.7734$

NOTE THAT THE VESSEL SHELL IS IDEALIZED AS A SPHERICAL SEGMENT OF THE SAME THICKNESS AS THE VESSEL AND WITH A MID-RADIUS 1.5 TIMES THAT OF THE VESSEL. THIS YIELDS A MODEL WITH MEMBRANE STRESS EQUAL TO THE AVERAGE OF THAT IN THE LONGITUDINAL AND CIRCUMFERENTIAL DIRECTIONS OF THE VESSEL.

DISPLACEMENTS DUE TO REDUNDANT FORCES:

$$E\Delta_{54} = \frac{180}{\pi t_5^3 \phi_5}\left[t_5^2 P_{11} H_4 + t_5 P_{12} M_4\right] = \underline{3.6684 H_4 + 0.3073 M_4}$$

$$E\Delta^*_{54} = -\frac{180}{\pi t_5^3 \phi_5}\left[t_5 P_{12} H_4 + P_{22} M_4\right] = \underline{-0.3073 H_4 - 0.1634 M_4}$$

DISPLACEMENTS DUE TO APPLIED FORCES:

$$E\delta^*_{54} = \frac{a_5^2}{2}\left[\frac{180\cos\phi}{\pi R_5 \phi} P_{11} + \frac{\sin\phi}{t_5}(1-\nu)\right]P = \underline{309.5291 P}$$

$$E\delta^*_{54} = -\frac{90 a_5^2 \cos\phi}{\pi R_5 t_5 \phi} P_{12} P = \underline{-19.0884 P}$$

DISPLACEMENTS DUE TO THERMAL EFFECTS:

FOR RANGE OF STRESS	FOR PEAK STRESS
$E\Delta_{54} = R_5 \sin\phi E\alpha_m (T_{54} - 100)$	$= R_5 \sin\phi E\alpha_m (T_{54} - 100) + \frac{180}{\pi t_5^2 \phi_5} P_{12} M_{ST}$
$= \underline{19.980 E\alpha_m (T_{54} - 100)}$	$= \underline{19.980 E\alpha_m (T_{54} - 100) + 0.3073 M_{ST}}$
$E\Delta^*_{54} = R_5 \sin\phi E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{54}$	$= R_5 \sin\phi E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{54} - \frac{180}{\pi t_5^3 \phi_5} P_{22} M_{ST}$
$= \underline{19.980 E\alpha \left(\frac{\Delta T}{\Delta X}\right)_{54}}$	$= \underline{19.980 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{54} - 0.1634 M_{ST}}$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER S-212-P | A195
SHEET 23 OF 80
CHARGE NO.
DATE 4-22-68 BY COCKRELL
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

d- PRESSURE AND THERMAL INTERACTION:

2- DEFLECTIONS:

THE FOLLOWING TABLES GIVE THE MEAN TEMPERATURE, SLOPE OF THE AXIAL GRADIENT, AND THE THERMAL MOMENT DUE TO THE RADIAL GRADIENT FOR EACH CUT. THESE VALUES ARE USED TO CALCULATE THE DEFLECTIONS OF EACH CUT DUE TO THE THERMAL EFFECTS AS PRESENTED ON SHEETS 15 - 22.

TRANSIENT		T_{11} & T_{21}	T_{22} & T_{32}	T_{33} & T_{43}	T_{44}	T_{54}	$\left(\frac{\Delta T}{\Delta X}\right)_{11}$	$\left(\frac{\Delta T}{\Delta X}\right)_{21}$ & $\left(\frac{\Delta T}{\Delta X}\right)_{22}$	$\left(\frac{\Delta T}{\Delta X}\right)_{32}$ & $\left(\frac{\Delta T}{\Delta X}\right)_{33}$
HEATUP	4.00 hrs	492	488	440	433	435	1.000	-0.985	-4.668
	4.25	517	513	465	458	460	↓	↓	↓
	4.35	527	523	475	468	470			
	4.47	539	535	487	480	481			
	5.00	547	544	521	516	516	0	-0.738	-2.237
NO LOAD STEADY STATE		547	547	547	547	547	0	0	0
COOLDOWN	4.00 hrs	155	159	207	214	212	-1.000	0.985	4.668
	4.25	130	134	182	189	187	↓	↓	↓
	4.35	120	124	172	179	177			
	4.47	108	112	160	167	166			
	5.00	100	103	126	131	131	0	0.738	2.237
PLANT LOADING	10 min	568	568	553	552	548	0.666	0	-1.459
	15	583	582	558	556	549	1.333	-0.246	-2.334
	20	599	597	565	562	550	1.444	-0.492	-3.112
	25	608	605	571	567	552	1.000	-0.738	-3.307
	30	610	608	576	571	555	0.666	-0.442	-3.112
FULL LOAD STEADY STATE		613	613	607	598	574	0	0	-0.584
PLANT UNLOADING	10 min	592	592	602	593	573	-1.000	0	0.973
	15	577	577	596	589	572	-1.333	0	1.848
	20	561	562	590	583	570	-1.666	0.246	2.723
	25	552	554	584	578	568	-1.333	0.492	2.918
	30	549	552	578	574	566	-0.666	0.738	2.529

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORT

NUMBER 5-212-P | A196
SHEET 24 OF 80
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILER

5- DETAILED ANALYSIS:

d- PRESSURE AND THERMAL INTERACTION:

2- DEFLECTIONS:

TRANSIENT		T_{11} & T_{21}	T_{22} & T_{32}	T_{33} & T_{43}	T_{44}	T_{54}	$\left(\frac{\Delta T}{\Delta x}\right)_{11}$	$\left(\frac{\Delta T}{\Delta X}\right)_{21}$ & $\left(\frac{\Delta T}{\Delta X}\right)_{22}$	$\left(\frac{\Delta T}{\Delta X}\right)_{32}$ & $\left(\frac{\Delta T}{\Delta X}\right)_{33}$
e → f		584	584	584	584	584	0	0	-0.584
g	3.5 MIN	620	620	609	575	575	↓	↓	↓
	11 min	604	604	606	575	575	↓	↓	↓
	15.5 min	591	591	602	574	574	↓	↓	↓
h	10 sec	612	612	607	574	574	↓	↓	↓
	90 sec	593	593	603	573	573	↓	↓	↓
i		100	100	100	100	100	0	0	0
j	H.O 3.0 HRS	392	388	340	333	334	1.0	-0.985	-4.668
	S.S.	400	400	400	400	400	0	0	0
	C.D 3.0 HRS	108	112	160	167	166	-1.0	0.985	4.668
k		613	613	613	574	574	0	0	-0.584
l	12 sec	613	613	607	573	573	↓	↓	↓
	18.5 sec	609	609	606	573	573	↓	↓	↓
m	12 sec	616	616	608	574	574	↓	↓	↓
	26 sec	618	618	608	575	575	↓	↓	↓
	144 sec	595	595	603	575	575	↓	↓	↓
n		547	547	547	547	547	↓	↓	↓

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

NUMBER 5-212-P | A197
SHEET 25 OF 80
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

d- PRESSURE & THERMAL INTERACTION:

2- DEFLECTIONS:

TRANSIENT		$\left(\frac{\Delta T}{\Delta X}\right)_{43}$ & $\left(\frac{\Delta T}{\Delta X}\right)_{44}$	$\left(\frac{\Delta T}{\Delta X}\right)_{54}$	M_{1T}	M_{2T}	M_{3T}	M_{4T}	M_{5T}
HEATUP	4.00 HRS	-0.933	0.250	1.432	2.296	201.261	259.971	320.808
	4.25	-0.933	-0.250	1.439	2.307	202.228	262.483	322.358
	4.35	-0.933	-0.250	1.446	2.318	203.196	263.739	323.908
	4.47	-0.933	0	1.453	2.328	204.164	264.995	325.458
	5.00	-0.667	0	0	0.677	98.858	136.549	174.296
NO LOAD STEADYSTATE		0	0	0	0	0	0	0
COOLDOWN	4.00 HRS	0.933	-0.250	-1.432	-2.296	-201.261	-259.971	-320.808
	4.25	0.933	-0.250	-1.439	-2.307	-202.228	-262.483	-322.358
	4.35	0.933	-0.250	-1.446	-2.318	-203.196	-263.739	-323.908
	4.47	0.933	0	-1.453	-2.328	-204.164	-264.995	-325.458
	5.00	0.667	0	0	-0.677	-98.858	-136.549	-174.296
PLANT LOADING	10 MIN	-0.133	0	2.219	2.199	67.384	78.067	11.628
	15	-0.267	-0.100	2.511	2.571	107.043	123.200	16.178
	20	-0.400	-0.400	2.825	2.946	142.450	169.119	22.245
	25	-0.533	-0.700	1.070	1.655	145.947	180.557	18.706
	30	-0.667	-1.050	0.646	1.090	134.611	178.923	15.167
FULL LOAD STEADYSTATE		-1.200	-4.500	0	0	23.488	85.758	-108.694
PLANT UNLOADING	10 MIN	-1.200	-2.750	-2.300	-2.129	-42.350	7.834	-120.431
	15	-0.933	-2.750	-2.531	-2.601	-82.208	-40.630	-125.024
	20	-0.933	-2.500	-2.619	-2.739	-118.670	-82.080	-130.637
	25	-0.800	-2.000	-1.020	-1.460	-120.442	-100.958	-128.000
	30	-0.533	-1.750	-0.420	-1.040	-111.940	-94.772	-121.397

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORT

NUMBER 5-212-P | A198
SHEET 26 OF 80
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

d- PRESSURE AND THERMAL INTERACTION:

2- DEFLECTIONS:

TRANSIENT		$\left(\frac{\Delta T}{\Delta X}\right)_{43}$ & $\left(\frac{\Delta T}{\Delta Y}\right)_{44}$	$\left(\frac{\Delta T}{\Delta X}\right)_{54}$	M_{1T}	M_{2T}	M_{3T}	M_{4T}	M_{5T}
e → f		-1.200	-4.500	0	0	23.488	85.758	-108.694
g	3.5 min 11 min 15.5 min	│	│	│	│	│	│	│
h	10 sec 90 sec	↓	↓	↓	↓	↓	↓	↓
i		0	0	0	0	0	0	0
j	H.U. 3.0 HRS	-0.933	0	1.453	2.328	204.164	264.995	325.458
	S.S	0	0	0	0	0	0	0
	C.D. 3.0 HRS	0.933	0	-1.453	-2.328	-204.164	-264.995	-325.458
k		-1.200	-4.500	0	0	23.488	85.758	-108.694
l	12 sec 18.5 sec	│	│	│	│	│	│	│
m	12 sec 26 sec 144 sec	│	│	│	│	│	│	│
n.		↓	↓	↓	↓	↓	↓	↓

WITH THE EXPRESSIONS FOR DISPLACEMENTS AS PRESENTED ON SHEETS 15 THRU 22 AND THE VALUES GIVEN ON SHEETS 23 - 25, THE FOLLOWING VALUES FOR DISPLACEMENT WERE OBTAINED,

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER S-212-P | A199
SHEET 27 OF 80
CHARGE NO.
DATE 4-22-69 BY COCKRELL
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS
CHECK DATE 4-22-69 BY HEILKER

5. DETAILED ANALYSIS:

d. PRESSURE & THERMAL INTERACTION:

2. DEFLECTIONS:

FOR RANGE OF STRESS

TRANSIENT		$E\delta_{11T}$	$E\delta^*_{11T}$	$E\delta_{21T}$	$E\delta^*_{21T}$	$E\delta_{22T}$	$E\delta^*_{22T}$	$E\delta_{32T}$	$E\delta^*_{32T}$
HEATUP	4.00 HRS	1550.1	3.927	1158.4	-2.911	1146.5	-2.911	1146.5	-15.577
	4.25	1648.4	3.926	1232.2	-2.911	1220.4	-2.911	1220.4	-15.578
	4.35	1687.5	3.925	1261.5	-2.910	1249.8	-2.910	1249.8	-15.575
	4.47	1734.2	3.923	1296.4	-2.909	1284.8	-2.909	1284.8	-15.570
	5.00	1765.3	0.0	1319.6	-2.179	1310.9	-2.179	1310.9	-7.459
NO LOAD STEADYSTATE		1765.3	0.0	1319.6	0.0	1319.6	0.0	1319.6	0.0
COOL DOWN	4.00 HRS	213.2	-3.850	157.0	2.811	168.5	2.812	168.5	15.052
	4.25	116.0	-3.841	85.3	2.800	96.7	2.802	96.7	14.997
	4.35	77.3	-3.838	56.7	2.795	68.2	2.797	68.2	14.970
	4.47	30.9	-3.838	22.6	2.787	34.0	2.790	34.0	14.932
	5.00	0.0	0.0	0.0	0.0	8.5	0.0	8.5	7.140
PLANT LOADING	10 MIN	1846.4	2.610	1380.3	0.0	1380.3	0.0	1380.3	-4.860
	15	1903.9	5.218	1423.5	-0.725	1420.6	-0.725	1420.6	-7.769
	20	1964.8	5.647	1469.6	-1.449	1463.8	-1449	1463.8	-10.351
	25	1998.9	3.908	1495.6	-2.173	1486.9	-2.173	1486.9	-10.996
	30	2006.4	2.602	1501.4	-1.448	1495.6	-1.449	1495.6	-10.347
FULL LOAD STEADYSTATE		2017.7	0.0	1510.1	0.0	1510.1	0.0	1510.1	-1.941
PLANT UNLOADING	10 MIN	1938.2	-3.912	1449.4	0.0	1449.4	0.0	1449.4	3.237
	15	1880.9	-5.220	1406.2	0.725	1406.2	0.725	1406.2	6.152
	20	1819.4	-6.530	1360.1	1.452	1363.0	1.451	1363.0	9.072
	25	1784.7	-5.227	1334.1	2.178	1339.9	2.178	1339.9	9.726
	30	1773.0	-2.612	1325.4	0.0	1334.1	0.0	1334.1	8.426

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER S-212-P | A200
SHEET 28 OF 80
CHARGE NO.
DATE 4-22-68 BY COCKRELL
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

d- PRESSURE & THERMAL INTERACTION:

2- DEFLECTIONS:

FOR RANGE OF STRESS

TRANSIENT		$E\delta_{11T}$	$E\delta^*_{11T}$	$E\delta_{21T}$	$E\delta^*_{21T}$	$E\delta_{22T}$	$E\delta^*_{22T}$	$E\delta_{32T}$	$E\delta^*_{32T}$
e → f		1907.7	0	1426.3	0	1426.3	0	1426.3	-1.944
g	3.5 min	2044.1	↓	1530.6	↓	1530.6	↓	1530.6	-1.941
	11 min	1983.8		1484.0		1484.0		1484.0	-1.942
	15.5 min	1934.4		1446.5		1446.5		1446.5	-1.943
h	10 sec	2014.0		1507.2		1507.2		1507.2	-1.942
	90 sec	1942.0		1452.3		1452.3		1452.3	-1.943
i		0		0		0		0	0
j	H.U. 3.0 HRS	1152.4	3.919	857.1	-2.891	844.9	-2.890	844.9	-15.466
	S.S	1184.4	0	881.3	0	881.3	0	891.3	0
	C.O 3.0 HRS	30.9	-3.833	22.6	2.787	34.0	2.790	34.0	14.996
k		2017.7	0	1510.1	0	1510.1	0	1510.1	-1.941
l	12 sec	2017.7	↓	1510.1	↓	1510.1	↓	1510.1	-1.941
	18.5 sec	2002.7		1498.5		1498.5		1498.5	-1.942
m	12 sec	2029.0		1518.9		1518.9		1518.9	-1.941
	26 sec	2036.5		1524.7		1524.7		1524.7	-1.941
	144 sec	1949.6		1458.0		1458.0		1459.0	-1.943
n		1765.3		1319.6		1319.6		1319.6	-1.947

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT. CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

NUMBER S 212-P A 201
SHEET 29 **OF** 80
DATE 4-22-68 **BY** COCKRELL
CHECK DATE 4-27-68 **BY** HEILKER

5- DETAILED ANALYSIS:

d- PRESSURE & THERMAL INTERACTION:

2- DEFLECTIONS:

FOR RANGE OF STRESS

TRANSIENT		$E\delta_{33T}$	$E\delta^*_{33T}$	$E\delta_{43T}$	$E\delta^*_{43T}$	$E\delta_{44T}$	$E\delta^*_{44T}$	$E\delta_{54T}$	$E\delta^*_{54T}$
HEATUP	4.00 HRS	1261.7	-15.544	1261.7	-3.462	1235.1	-3.461	1242.7	0.927
	4.25	1356.5	-15.567	1356.5	-3.467	1330.0	-3.466	1337.6	0.929
	4.35	1394.2	-15.572	1394.2	-3.469	1367.8	-3.468	1375.4	0.929
	4.47	1439.2	-15.577	1439.2	-3.470	1413.0	-3.469	1416.7	0
	5.00	1565.5	-7.464	1565.5	-2.480	1547.1	-2.481	1547.1	0
NO LOAD STEADYSTATE		1660.9	0	1660.9	0	1660.9	0	1660.9	0
COOL DOWN	4.00 HRS	386.5	15.131	386.5	3.371	412.1	3.373	404.8	-0.904
	4.25	295.5	15.092	295.5	3.362	320.9	3.364	313.6	-0.901
	4.35	259.1	15.076	259.1	3.358	284.6	3.361	277.3	-0.900
	4.47	215.6	15.054	215.6	3.353	241.0	3.356	237.4	0
	5.00	93.0	7.177	93.0	2.385	110.9	2.387	110.9	0
PLANT LOADING	10 MIN	1682.7	-4.863	1682.7	-0.494	1679.1	-0.494	1664.5	0
	15	1700.9	-7.778	1700.9	-0.992	1693.6	-0.992	1668.2	-0.372
	20	1726.3	-10.367	1726.3	-1.485	1715.4	-1.485	1671.8	-1.486
	25	1748.1	-11.013	1748.1	-1.978	1733.6	-1.979	1679.1	-2.600
	30	1766.2	-10.361	1766.2	-2.475	1748.1	-2.476	1690.0	-3.900
FULL LOAD STEADYSTATE		1878.7	-1.942	1878.7	-4.447	1845.9	-4.448	1758.9	-16.699
PLANT UNLOADING	10 MIN	1860.5	3.236	1860.5	-4.447	1827.8	-4.449	1755.3	-10.205
	15	1838.7	6.147	1838.7	-3.459	1813.3	-3.460	1751.7	-10.206
	20	1816.9	9.060	1816.9	-3.460	1791.5	-3.461	1744.4	-9.279
	25	1795.2	9.711	1795.2	-2.967	1773.4	-2.968	1737.2	-7.424
	30	1773.4	8.416	1773.4	-1.977	1758.9	-1.978	1729.9	-6.497

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER S-212-P | A 202
SHEET 30 OF 80
CHARGE NO.
DATE 4-22-68 BY COCKRELL
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

d- PRESSURE & THERMAL INTERACTION:

2- DEFLECTIONS:

FOR RANGE OF STRESS

TRANSIENT		$E\delta_{33T}$	$E\delta^*_{33T}$	$E\delta_{43T}$	$E\delta^*_{43T}$	$E\delta_{44T}$	$E\delta^*_{44T}$	$E\delta_{54T}$	$E\delta^*_{54T}$
e → f		1795.2	-1.944	1795.2	-4.451	1795.2	-4.451	1795.2	-16.691
g	3.5 min	1886.0	-1.942	1886.0	-4.446	1762.6	-4.453	1762.6	-16.698
	11 min	1875.1	↓	1875.1	-4.447	1762.6	↓	1762.6	-16.698
	15.5 min	1860.5	↓	1860.5	↓	1758.9	↓	1758.9	-16.699
h	10 sec	1878.7	↓	1878.7	↓	1758.9	↓	1758.9	-16.699
	90 sec	1864.1	↓	1864.1	↓	1755.3	↓	1755.3	-16.700
i		0	0	0	0	0	0	0	0
j	H.U 3.0 HRS	880.8	-15.372	880.8	-3.424	854.3	-3.421	858.1	0
	S.S.	1109.2	0	1109.2	0	1109.2	0	1109.2	0
	C.D 3.0 HRS	215.6	15.118	215.6	3.353	241.0	3.356	237.4	0
k		1900.6	-1.941	1900.6	-4.446	1758.9	-4.453	1758.4	-16.699
l	12 sec	1878.7	-1.942	1878.7	-4.447	1755.3	↓	1755.3	-16.700
	185 sec	1875.1	↓	1875.1	↓	1755.3	↓	1755.3	-16.700
m	12 sec	1882.4	↓	1882.4	↓	1758.9	↓	1758.9	-16.699
	26 sec	1882.4	↓	1882.4	↓	1762.6	↓	1762.6	-16.698
	144 sec	1864.1	↓	1864.1	↓	1762.6	↓	1762.6	-16.698
n		1660.9	-1.947	1660.9	-4.459	1660.9	-4.459	1660.9	-16.720

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.________

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

NUMBER S-212-P A 203
SHEET 31 OF 80
DATE 4-22-69 BY COCKRELL
CHECK DATE 4-22-69 BY HEILKER

5- DETAILED ANALYSIS:

d- PRESSURE AND THERMAL INTERACTION:

2. DEFLECTIONS:

FOR PEAK STRESS

TRANSIENT		$E\delta_{11T}$	$E\delta^{*}_{11T}$	$E\delta_{21}$	$E\delta^{*}_{21T}$	$E\delta_{22T}$	$E\delta^{*}_{22T}$	$E\delta_{32T}$	$E\delta^{*}_{32T}$
HEATUP	4.00HRS	1561.0	8.700	1126.3	10.986	1183.1	17.661	-235.0	252.957
	4.25	1660.1	8.722	1199.9	11.050	1257.2	17.757	-167.7	254.146
	4.35	1699.3	8.744	1229.0	11.114	1286.7	17.853	-145.0	255.443
	4.47	1746.1	8.766	1263.9	11.160	1321.9	17.929	-116.6	256.738
	5.00	1765.3	0.0	1293.1	10.719	1338.3	11.931	629.6	125.233
NO LOAD STEADYSTATE		1765.3	0.0	1319.6	0.0	1319.6	0.0	1319.6	0.0
COOLDOWN	4.00HRS	201.5	-8.623	189.1	-11.086	131.8	-17.759	1549.3	-253.382
	4.25	104.3	-8.637	117.6	-11.160	59.9	-17.865	1494.8	-254.727
	4.35	65.4	-8.657	89.2	-11.229	31.2	-17.966	1462.9	-256.045
	4.47	19.0	-8.676	55.2	-11.282	-3.1	-18.048	1435.4	-257.376
	5.00	0.0	0.0	26.5	-12.898	-18.9	-14.110	689.3	-125.552
PLANT LOADING	10 MIN	1864.6	10.005	1383.8	-4.354	1382.2	3.556	926.6	82.352
	15	1924.5	13.587	1424.2	-4.078	1426.0	5.021	694.2	132.488
	20	1987.9	15.062	1468.3	-4.202	1472.1	6.131	494.2	177.184
	25	2007.6	7.474	1474.0	7.057	1511.9	11.936	485.1	183.681
	30	2011.8	4.788	1485.2	5.646	1513.9	8.772	568.9	170.022
FULL LOAD STEADYSTATE		2017.7	0.0	1510.1	0.0	1510.1	0.0	1347.3	29.885
PLANT UNLOADING	10 MIN	1919.4	-11.578	1439.9	7.376	1453.5	-0.554	1729.9	-50.184
	15	1860.2	-13.656	1405.9	3.923	1400.3	-5.265	1960.2	-100.397
	20	1798.0	-15.259	1361.6	3.854	1355.0	-5.739	2169.0	-146.626
	25	1776.3	-8.626	1350.1	-4.378	1320.9	-8.919	2166.1	-150.755
	30	1769.6	-4.012	1349.2	-11.060	1308.6	-13.674	2103.9	-141.316

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.

NUMBER S-212-P | A204
SHEET 32 OF 80
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

5- DETAILED ANALYSIS:
d- PRESSURE AND THERMAL INTERACTION:
2- DEFLECTIONS:

FOR PEAK STRESS

TRANSIENT		$E\delta_{11T}$	$E\delta^*_{11T}$	$E\delta_{21T}$	$E\delta^*_{21T}$	$E\delta_{22T}$	$E\delta^*_{22T}$	$E\delta_{32T}$	$E\delta^*_{32T}$
e → f		1907.7	0.0	1426.3	0.0	1426.3	0.0	1263.5	29.883
g	3.5 min	2044.1	↓	1530.6	↓	1530.6	↓	1367.7	29.985
	11 min	1983.8	↓	1484.0	↓	1484.0	↓	1321.1	29.984
	15.5 min	1934.4	↓	1446.5	↓	1446.5	↓	1283.6	29.983
h	10 sec	2014.0	↓	1507.2	↓	1507.2	↓	1344.4	29.985
	90 sec	1942.0	↓	1452.3	↓	1452.3	↓	1289.4	29.983
i		0.0	↓	0.0	↓	0.0	↓	0.0	0.0
j	H.U. 3.0 HRS	1164.1	8.662	823.3	11.803	883.2	18.520	-556.4	256.842
	S.S	1194.4	0.0	891.3	0	891.3	0.0	891.3	0.0
	C.D 3.0 HRS	19.2	-8.576	56.4	-17.482	-4.3	-24.200	1435.4	-287.304
k		2017.7	0.0	1510.1	0.0	1510.1	0.0	1347.3	29.895
l	12 sec	2017.7	↓	1510.1	↓	1510.1	↓	1347.3	
	18.5 sec	2002.7	↓	1498.5	↓	1498.5	↓	1335.6	
m	12 sec	2029.7	↓	1518.9	↓	1518.9	↓	1356.0	
	26 sec	2036.5	↓	1524.7	↓	1524.7	↓	1361.8	
	144 sec	1949.6	↓	1458.0	↓	1458.0	↓	1295.2	29.894
n		1765.3	↓	1319.6	↓	1319.6	↓	1156.7	29.879

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.

NUMBER S-212-P A205
SHEET 33 **OF** 80
DATE 4-22-69 **BY** COCKRELL
CHECK DATE 4-22-69 **BY** HEILKER

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

5-DETAILED ANALYSIS:

d. PRESSURE AND THERMAL INTERACTION:

2 DEFLECTIONS:

FOR PEAK STRESS

TRANSIENT		$E\delta_{33T}$	$E\delta^*_{33T}$	$E\delta_{43T}$	$E\delta^*_{43T}$	$E\delta_{44T}$	$E\delta^*_{44T}$	$E\delta_{54T}$	$E\delta^*_{54T}$
HEATUP	4.00 HRS	2195.1	279.727	1246.9	-12.979	1343.9	24.235	1341.3	-51.493
	4.25	2294.4	281.124	1340.4	-12.886	1440.8	24.608	1436.7	-51.744
	4.35	2336.5	282.541	1378.0	-12.933	1479.1	24.740	1474.9	-51.997
	4.47	2386.1	283.955	1423.0	-12.978	1524.8	24.873	1516.7	-53.180
	5.00	2025.6	138.057	1549.9	-6.144	1610.7	12.830	1600.7	-29.480
NO LOAD STEADY STATE		1660.9	0.0	1660.9	0.0	1660.9	0.0	1660.9	0.0
COOLDOWN	4.00 HRS	-546.8	-290.140	401.4	12.887	303.4	-24.295	306.2	51.516
	4.25	-642.4	-291.598	311.5	12.780	210.2	-24.673	214.6	51.772
	4.35	-683.2	-293.035	275.3	12.822	173.3	-24.811	177.8	52.026
	4.47	-731.2	-294.478	231.9	12.862	129.2	-24.949	137.4	53.180
	5.00	-367.1	-138.344	108.7	6.048	47.3	-12.923	57.4	29.480
PLANT LOADING	10 MIN	1990.1	92.455	1686.3	-4.705	1705.1	7.018	1668.1	-1.900
	15	2192.5	147.811	1707.3	-7.774	1734.1	10.783	1673.1	-3.015
	20	2392.2	197.199	1730.0	-9.921	1775.2	15.191	1678.6	-5.121
	25	2425.0	203.117	1744.9	-9.789	1803.2	16.527	1684.8	-5.657
	30	2392.1	187.608	1750.5	-8.150	1827.8	17.201	1694.7	-6.378
FULL LOAD STEADY STATE		1988.6	32.806	1824.3	0.771	1922.6	9.575	1725.5	1.062
PLANT UNLOADING	4.00 HRS	1670.0	-57.123	1804.2	4.697	1877.1	1.913	1718.3	9.473
	4.25	1463.4	-112.669	1782.4	7.916	1844.5	-1.986	1713.3	10.223
	4.35	1271.5	-163.549	1758.0	10.284	1809.6	-5.898	1704.3	12.067
	4.47	1236.9	-166.897	1752.1	8.965	1771.4	-3.880	1697.9	13.491
	5.00	1253.4	-156.067	1734.3	9.005	1756.0	-7.656	1692.6	13.340

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION Structural And Fatigue Evaluation Of Outlet Nozzle - Vessel Supports

NUMBER S-212-P | A 206
SHEET 34 OF 80
DATE 4-22-68 BY Cockrell
CHECK DATE 4-22-68 BY Heilker

5- Detailed Analysis:

d- Pressure And Thermal Interaction:

2- Deflections:

For Peak Stress

Transient		$E\delta_{33T}$	$E\delta^*_{33T}$	$E\delta_{43T}$	$E\delta^*_{43T}$	$E\delta_{44T}$	$E\delta^*_{44T}$	$E\delta_{54T}$	$E\delta^*_{54T}$
e → f		1905.1	32.805	1740.8	0.767	1871.8	9.572	1761.8	1.070
g	3.5 min	1995.9	32.806	1831.6	0.772	1839.2	9.571	1729.2	1.063
	11 min	1984.9	↓	1820.7	0.771	1839.2	9.571	1729.2	1.063
	15.5 min	1970.4		1806.1	↓	1835.6	9.571	1725.5	1.062
h	10 sec	1988.6		1824.3		1835.6	9.570	1725.5	1.062
	90 sec	1974.0		1809.7		1832.0	9.570	1721.9	1.061
i		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
j	N.U. 3.0 HRS	1827.7	284.159	864.6	-12.933	966.1	24.884	958.1	-53.180
	S.S.	1109.2	0.0	1109.2	0.0	1109.2	0.0	1109.2	0.0
	CD 3.0 HRS	-731.2	-314.650	231.9	12.862	129.2	-24.949	137.4	53.180
k		2010.5	32.806	1846.2	0.772	1835.6	9.570	1725.5	1.062
l	12 sec	1988.6	↓	1824.3	0.771	1832.0	↓	1721.9	1.061
	18.5 sec	1984.9		1813.4	0.771	1832.0		1721.9	1.061
m	12 sec	1992.2		1828.0	0.772	1835.6		1725.5	1.062
	26 sec	1992.2		1828.0	0.772	1839.2	9.571	1729.2	1.063
	144 sec	1974.0		1809.7	0.771	1839.2	9.571	1729.2	1.063
n		1710.7	32.805	1606.5	0.759	1737.5	9.565	1627.2	1.041

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

NUMBER 5-212-P A207
SHEET 35 **OF** 86
DATE 4-22-68 **BY** COCKRELL
CHECK DATE 4-22-68 **BY** HENKER

5- DETAILED ANALYSIS:

d. PRESSURE AND THERMAL INTERACTION:

3- CONTINUITY MATRIX AND LOADING VECTORS

WRITING THE COMPATIBILITY EQUATIONS IN MATRIX FORM

$$\begin{bmatrix} -148.1396 & -32.2032 & -53.2445 & 39.1819 & 0 & 0 & 0 & 0 \\ 32.2038 & 24.1750 & 39.1819 & -19.0519 & 0 & 0 & 0 & 0 \\ -53.2445 & -39.1819 & -142.0836 & 34.2037 & -15.7480 & 6.9346 & 0 & 0 \\ -39.1819 & -19.0519 & -34.2083 & 22.7039 & 4.4781 & -1.3550 & 0 & 0 \\ 0 & 0 & -12.5173 & -3.5624 & -32.7443 & 3.5240 & -4.9488 & 0.9506 \\ 0 & 0 & -5.5112 & -1.0776 & -3.5230 & 1.6742 & 0.9506 & -0.1142 \\ 0 & 0 & 0 & 0 & -4.9488 & -0.9506 & -14.4505 & 0.8470 \\ 0 & 0 & 0 & 0 & -0.9506 & -0.1142 & -0.8470 & 0.3582 \end{bmatrix} \begin{bmatrix} H_1 \\ M_1 \\ H_2 \\ M_2 \\ H_3 \\ M_3 \\ H_4 \\ M_4 \end{bmatrix} =$$

	RANGE OF STRESS							
	HEATUP					NO LOAD STEADYSTATE	COOLDOWN	
PRESSURE	T=4.00 HRS	T=4.25	T=4.35	T=4.47	T=5.00		T=4.00 HRS	T=4.25
13.96994	-391.7	-416.2	-426.0	-437.8	-445.7	-445.7	-56.3	-30.8
2.40559	-6.838	-6.836	-6.835	-6.832	-2.179	0	6.661	6.642
141.49742	0	0	0	0	0	0	0	0
-46.49742	-12.667	-12.667	-12.665	-12.661	-5.280	0	12.240	12.195
109.67643	0	0	0	0	0	0	0	0
37.06395	12.092	12.099	12.104	12.107	4.984	0	-11.761	-11.730
283.44869	7.6	7.6	7.5	3.8	0	0	-7.3	-7.3
-19.08840	4.388	4.395	4.397	3.469	2.481	0	-4.277	-4.266

RANGE OF STRESS								
COOL DOWN			PLANT LOADING					FULL LOAD STEADYSTATE
T=4.35	T=4.47	T=5.00	T=10 MIN	T=15	T=20	T=25	T=30	
-20.5	-8.2	0	-466.1	-480.4	-495.2	-503.2	-505.0	-507.6
6.633	6.621	0	-2.610	-5.943	-7.096	-6.081	-4.051	0
0	0	0	0	0	0	0	0	0
12.173	12.142	7.140	-4.860	-7.044	-8.902	-8.923	-8.898	-1.941
0	0	0	0	0	0	0	0	0
-11.717	-11.701	-4.792	4.369	6.786	8.882	9.035	7.886	-2.505
-7.3	-3.6	0	-14.6	-25.9	-43.6	-54.5	-58.1	-87.0
-4.261	-3.356	-2.387	0.494	0.620	-0.001	-0.622	-1.424	-12.251

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION Structural And Fatigue Evaluation of Outlet Nozzle - Vessel Supports

NUMBER S-212-P | A 208
SHEET 36 **OF** 80
DATE 4-22-68 **BY** Cockrell
CHECK DATE 4-22-68 **BY** Heilker

5- DETAILED ANALYSIS:

d- PRESSURE AND THERMAL INTERACTION:

3- CONTINUITY MATRIX AND LOADING VECTORS:

RANGE OF STRESS								
PLANT UNLOADING					e → f	g		
T=10min	T=15	T=20	T=25	T=30		T=3.5min	T=11	T=15.5
-488.8	-474.7	-459.3	-450.6	-447.6	-481.4	-513.5	-499.7	-497.9
3.912	5.945	7.982	7.405	2.612	0	0	0	0
0	0	0	0	0	0	0	0	0
3.237	5.427	7.621	7.548	8.426	-1.944	-1.941	-1.942	-1.943
0	0	0	0	0	0	0	0	0
-7.683	-9.606	-12.519	-12.679	-10.393	-2.507	-2.505	-2.505	2.505
-72.5	-61.6	-47.1	-36.2	-29.0	0	0	0	0
-5.756	-6.746	-5.818	-4.456	-4.519	-12.240	-12.245	-12.245	-12.246

RANGE OF STRESS								
h		i	j			k	l	
T=10sec	T=90		T=3 HRS	S.S.	T=3.0HRS		T=12SEC	T=18.5
-506.7	-489.8	0	-295.3	-303.0	-8.2	-507.6	-507.6	-504.1
0	0	0	-6.811	0	6.620	0	0	0
0	0	0	0	0	0	0	0	0
-1.942	-1.943	0	-12.576	0	12.206	-1.941	-1.941	-1.942
0	0	0	0	0	0	0	0	0
-2.505	-2.505	0	11.948	0	-11.765	-2.504	-2.505	-2.505
0	0	0	0	0	0	0	0	0
-12.246	-12.246	0	3.421	0	-3.356	-12.246	-12.246	-12.246

RANGE OF STRESS				PEAK STRESS				
m			n	HEATUP				
T=12sec	T=26	T=144		T=4.00HRS	T=4.25	T=4.35	T=4.47	T=5.00
-510.1	-511.8	-491.6	-445.7	-435.6	-460.2	-470.3	-482.2	-472.2
0	0	0	0	2.287	2.328	2.370	2.394	10.719
0	0	0	0	-1418.1	-1424.9	-1431.7	-1438.5	-708.7
-1.941	-1.941	-1.943	-1.947	235.196	236.389	237.589	238.809	113.302
0	0	0	0	-948.2	-953.9	-958.5	-963.1	-475.8
-2.505	-2.505	-2.505	-2.512	-292.707	-294.009	-295.474	-296.933	-144.201
0	0	0	0	-2.6	-4.1	-4.2	-8.0	-10.1
-12.246	-12.245	-12.245	-12.261	-75.728	-76.353	-76.738	-78.053	-41.310

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.________
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORT

NUMBER 5 212-P | A209
SHEET 37 OF 80
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

d- PRESSURE AND THERMAL INTERACTION:

3- CONTINUITY MATRIX AND LOADING VECTORS:

PEAK STRESS								
NO LOAD STEADYSTATE	COOLDOWN					PLANT LOADING		
	T=4.00HRS	T=4.25	T=4.35	T=4.47	T=5.00	T=10min	T=15	T=20
-445.7	-12.4	13.3	23.7	36.2	26.5	-480.8	-500.3	-519.7
0.0	-2.463	-2.523	-2.573	-2.606	-12.898	-14.359	-17.665	-19.263
↓	1418.1	1424.9	1431.7	1438.5	708.7	-455.6	-731.9	-977.9
	-235.623	-236.862	-238.079	-239.328	-111.442	78.796	127.467	171.053
	948.2	953.9	958.5	963.1	475.8	-303.8	-485.2	-652.3
	293.027	294.378	295.856	297.340	144.393	-97.160	-155.585	-207.120
	2.9	4.4	4.5	8.2	10.1	-37.1	-61.0	-96.6
	75.802	76.445	76.837	78.129	41.403	-8.918	-13.798	-20.312

PEAK STRESS								
PLANT LOADING →		FULL LOAD STEADYSTATE	PLANT UNLOADING					e → f
T=25	T=30		T=10min	T=15	T=20	T=25	T=30	
-533.6	-526.6	-507.6	-479.5	-454.3	-436.4	-426.2	-420.4	-481.4
-0.417	0.857	0.0	18.954	17.579	19.113	4.248	-7.049	0.0
-1026.8	-945.1	-162.9	276.4	559.9	814.0	845.2	795.4	-162.9
171.745	161.250	29.885	-49.630	-95.132	-140.888	-141.936	-127.642	29.883
-680.1	-641.5	-164.3	134.2	319.1	486.5	515.2	480.9	-164.3
-212.907	-195.758	-32.035	61.820	120.584	173.833	175.863	165.073	-32.037
-118.4	-133.1	-197.1	-158.8	-131.3	-105.3	-73.5	-63.3	-110.1
-22.184	-23.579	-8.513	7.560	12.209	17.965	22.372	20.996	-8.503

PEAK STRESS								
g			h		i	j		
T=35min	T=11	T=15.5	T=10sec	T=90		T=3.0HRS	S.S.	T=3.0HRS
-513.5	-499.7	-497.9	-506.7	-499.8	0.0	-340.7	-303.0	37.1
0.0	0.0	0.0	0.0	0.0	↓	3.141	0.0	-8.906
-162.9	-162.9	-162.9	-162.9	-162.9		-1439.7	↓	1439.7
29.885	29.884	29.883	29.885	29.883		238.322		-263.109
-164.3	-164.3	-164.3	-164.5	-164.3		-963.1		963.1
-32.035	-32.035	-32.035	-32.035	-32.035		-297.092		327.512
-110.1	-110.1	-110.1	-110.1	-110.1		-8.0		8.2
-8.508	-8.508	-8.509	-8.509	-8.509		-78.064		78.129

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

NUMBER 5-212-P | A210
SHEET 38 **OF** 80
DATE 4-22-68 **BY** Cockrell
CHECK DATE 4-22-68 **BY** Heilker

5- DETAILED ANALYSIS:

d- PRESSURE AND THERMAL INTERACTION:

3- CONTINUITY MATRIX AND LOADING VECTORS:

PEAK STRESS

k	l		m			n
	T=12sec	T=18.5	T=12sec	T=26	T=144	
-507.6	-507.6	-504.1	-510.1	-511.8	-491.6	-445.7
0	0	0	0	0	0	0
-162.9	-162.9	-162.9	-162.9	-169.2	-162.9	-162.9
29.885	29.885	29.885	29.885	29.885	29.884	29.879
-164.3	-164.3	-164.3	-164.3	-164.3	-164.3	-164.3
-32.035	-32.035	-32.035	-32.035	-32.035	-32.042	-32.042
-110.1	-110.1	-110.1	-110.1	-110.1	-110.1	-110.1
-8.509	-8.509	-8.509	-8.509	-8.508	-8.508	-8.524

4. REDUNDANT FORCES

THE ABOVE MATRIX WITH THE GIVEN LOADING VECTORS FOR PRESSURE AND THE TRANSIENT CONDITIONS FOR BOTH RANGE OF STRESS AND PEAK STRESS GIVE THE FOLLOWING VALUES FOR THE REDUNDANT FORCES

FOR RANGE OF STRESS

TRANSIENT		H_1	M_1	H_2	M_2	H_3	M_3	H_4	M_4
PRESSURE ONLY		-0.08706P	-1.45312P	1.36218P	06.8414P	1.69431P	39.9392P	-28.9497P	-104.5276P
a- HEATUP	4.00 HRS	5.6039	-2.0100	3.2354	13.9348	1.7995	33.3171	-1.9903	22.9379
	4.25	5.9455	-1.9919	3.3521	14.7748	1.7711	34.2241	-2.0287	23.0809
	4.35	6.0826	-1.9843	3.3986	15.1119	1.7591	34.5837	-2.0432	23.1348
	4.47	6.2343	-1.9571	3.4044	15.4146	1.5562	34.0666	-1.8431	20.3141
	5.00	6.2633	-0.5405	2.6465	15.4582	0.4170	23.9627	-0.9296	13.4707
NO LOAD STEADYSTATE		6.2065	0.3245	2.0862	15.1932	-0.5580	16.0273	-0.7554	1.8407
b- COOLDOWN	4.00 HRS	0.6360	2.2667	-1.1040	1.3310	-2.2977	-16.7133	1.1875	-20.5559
	4.25	0.2805	2.2406	-1.2203	0.4591	-2.2596	-17.5945	1.2262	-20.6104
	4.35	0.1382	2.2296	-1.2669	0.1092	-2.2442	-17.9330	1.2417	-20.6310
	4.47	-0.0209	2.2186	-1.2747	-0.2146	-2.0435	-17.4380	1.0506	-17.8663
	5.00	0.0143	0.7376	-0.4299	0.0759	-0.9460	-7.0540	0.1375	-11.0977

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

NUMBER 5-212-P | A-211
SHEET 39 OF 80
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEIKER

5. DETAILED ANALYSIS

d- PRESSURE AND THERMAL INTERACTION:

4- REDUNDANT FORCES:

FOR RANGE OF STRESS

TRANSIENT		H_1	M_1	H_2	M_2	H_3	M_3	H_4	M_4
c- PLANT LOADING	10 min	6.4929	-0.5009	2.5287	15.6769	-0.1994	21.0567	0.1563	7.9302
	15	6.7022	-1.1715	2.8107	15.9349	-0.0687	23.6785	0.8849	11.1877
	20	6.8971	-1.4753	2.9610	16.2481	-0.2166	24.6551	2.2040	12.4923
	25	6.9927	-1.2919	2.9131	16.4907	-0.4869	23.6338	3.0728	11.7705
	30	6.9521	-0.9933	2.6891	16.2339	-0.8029	20.9701	3.4227	8.6691
FULL LOAD STEADYSTATE		6.6404	0.4482	1.0413	13.9346	-4.0488	-3.0711	5.7086	-32.4274
d- PLANT UNLOADING	10 min	6.3890	1.3950	0.6621	13.7260	-3.5952	-5.3616	5.8021	-13.6008
	15	6.2001	1.8924	0.4456	13.4856	-3.7752	-7.6626	4.9047	-19.6976
	20	5.9656	2.3548	0.1637	12.9895	-3.7545	-10.1310	4.0471	-19.8667
	25	5.8635	2.2243	0.2191	12.7955	-3.3887	-9.7301	3.2773	-16.4659
	30	5.9676	1.6185	0.6659	13.3731	-2.9803	-4.1214	2.3434	-16.2973
e → f		6.4606	0.3163	1.5463	14.5021	-2.4906	5.8903	-2.1070	-43.8878
g	3.5 min	6.9080	0.3400	1.6969	15.5981	-2.5313	7.0469	-2.1625	-43.7734
	11	6.7163	0.3300	1.6324	15.1287	-2.5140	6.5514	-2.1391	-43.8303
	15.5	6.5517	0.3213	1.5770	14.7255	-2.4994	6.1253	-2.1191	-43.8816
h	10 sec	6.8139	0.3351	1.6653	15.3677	-2.5229	6.8033	-2.1511	-43.8036
	90	6.5775	0.3226	1.5857	14.7885	-2.5018	6.1916	-2.1224	-43.8761
i		0	0	0	0	0	0	0	0
j	H.U. 3.0 HRS	4.2455	-2.0491	2.7181	10.5235	1.7090	29.6858	-1.5933	19.4611
	S.S	4.2201	0.2206	1.4185	10.3306	-0.3794	10.8978	-0.5136	1.2516
	C.D 3.0 HRS	-0.0217	2.2049	-1.2809	-0.2207	-2.0517	-17.5242	1.0571	-17.9001
k		6.8259	0.3357	1.6693	15.3971	-2.5239	6.8348	-2.1526	-43.7998
l	12 sec	6.8259	0.3357	1.6693	15.3969	-2.5241	6.8338	-2.1526	-43.8022
	18.5 sec	6.7777	0.3332	1.6531	15.2789	-2.5197	6.7092	-2.1468	-43.8166
m	12 sec	6.8614	0.3376	1.6812	15.4841	-2.5272	6.9261	-2.1569	-43.7894
	26	6.8849	0.3388	1.6891	15.5414	-2.5292	6.9869	-2.1597	-43.7803
	144	6.6031	0.3240	1.5943	14.8513	-2.5039	6.2584	-2.1253	-43.8641
n		5.9628	0.2903	1.3779	13.2811	-2.4492	4.5857	-2.0488	-44.1163

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

NUMBER 5-212-P | A 212
SHEET 40 OF 80
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

d. PRESSURE AND THERMAL INTERACTION:

4- REDUNDANT FORCES:

FOR PEAK STRESS

TRANSIENT		H_1	M_1	H_2	M_2	H_3	M_3	H_4	M_4
HEATUP	4.00 HRS	5.5928	-3.3263	3.1279	11.5458	0.8151	-171.355	-4.9870	-275.663
	4.25	5.9345	-3.3170	3.2464	12.3765	0.8022	-171.361	-4.9780	-277.423
	4.35	6.0716	-3.3159	3.2924	12.7021	0.7855	-171.988	-5.0070	-278.811
	4.47	6.2232	-3.2951	3.2976	12.9943	0.5778	-173.487	-4.8213	-283.074
	5.00	6.2564	-0.4691	2.5802	14.7238	-0.1910	-77.001	-2.7858	-146.967
NO LOAD STEADYSTATE		6.2065	0.3245	2.0862	15.1932	-0.5580	16.027	-0.7554	1.841
COOLDOWN	4.00 HRS	0.6469	3.5835	-0.9975	3.7184	-1.3182	187.938	4.1793	277.910
	4.25	0.2913	3.5662	-1.1155	2.9560	-1.2956	187.980	4.1706	279.758
	4.35	0.1490	3.5617	-1.1615	2.5175	-1.2755	188.615	4.2007	281.180
	4.47	-0.0101	3.5371	-1.1689	2.2041	-1.0701	190.095	4.0240	285.387
	5.00	0.0211	0.6662	-0.3636	0.8104	-0.3381	93.910	1.9938	149.340
PLANT LOADING	10 MIN	6.5060	-2.8445	2.6479	13.5372	0.8731	-42.592	3.4223	-28.062
	15	6.7234	-3.8831	3.0027	13.5399	1.6589	-77.347	6.1459	-44.237
	20	6.9261	-4.5757	3.2245	13.5437	2.1543	-109.537	9.4241	-63.615
	25	7.0247	-2.6654	3.2034	15.1018	2.1257	-113.213	11.0291	-66.292
	30	6.9847	-1.9584	2.9846	15.4146	1.8565	-104.378	11.5217	-66.922
FULL LOAD STEADYSTATE		6.6783	0.0829	1.3890	14.2503	-0.9113	-15.640	15.2675	4.933
PLANT UNLOADING	10 MIN	6.4139	3.4538	0.8911	16.0618	-1.5261	44.186	12.1073	59.769
	15	6.2162	4.2645	0.5958	16.2213	-2.4143	79.277	9.0533	74.354
	20	5.9747	4.8921	0.2496	15.8043	-2.9721	111.255	6.4340	92.940
	25	5.8683	3.1930	0.2665	14.2961	-2.9535	113.219	4.6068	101.597
	30	5.9723	1.9880	0.7126	14.4531	-2.5517	109.303	3.6523	95.316

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.__________
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE – VESSEL SUPPORT

NUMBER 5-212-P | A 213
SHEET 41 OF 80
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

d- PRESSURE AND THERMAL INTERACTION:

4- REDUNDANT FORCES:

FOR PEAK STRESS

TRANSIENT		H_1	M_1	H_2	M_2	H_3	M_3	H_4	M_4
e → f		6.4986	-0.0489	1.8940	14.8178	0.6469	-6.6734	7.4518	-6.5275
g	3.5 min	6.9460	-0.0252	2.0446	15.9139	0.6062	-5.5218	7.3964	-6.4131
	11	6.7543	-0.0353	1.9801	15.4444	0.6255	-6.0173	7.4198	-6.4700
	15.5	6.5897	-0.0440	1.9247	15.0412	0.6381	-6.4434	7.4398	-6.5213
h	10 sec	6.8519	-0.0302	2.0130	15.6834	0.6146	-5.7654	7.4078	-6.4433
	90	6.6154	-0.0426	1.9334	15.1042	0.6358	-6.3771	7.4365	-6.5158
i		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
j	H.U. 3.0 HRS	4.2346	-3.3576	2.6122	8.1047	0.7356	-178.8470	-4.5667	-283.7917
	S.S	4.2201	0.2206	1.4185	10.3306	-0.3794	10.8978	-0.5136	1.2516
	C.D. 3.0 HRS	0.5206	0.3475	2.0263	5.9557	2.7407	231.9337	0.9093	301.4685
k		6.8638	-0.0295	2.0170	15.7128	0.6136	-5.7339	7.4063	-6.4395
l	12 sec	6.8638	-0.0295	2.0170	15.7127	0.6135	-5.7348	7.4062	-6.4419
	18.5 sec	6.8042	-0.0817	1.9981	15.5069	0.9902	-5.0031	7.2845	-5.4967
m	12 sec	6.8994	-0.0277	2.0289	15.7998	0.6103	-5.6426	7.4020	-6.4291
	26	6.9228	-0.0264	20368	15.8571	0.6083	-5.5817	7.3992	-6.4200
	144	6.6410	-0.0443	1.9420	15.1670	0.6336	-6.3103	7.4336	-6.5038
n		6.0008	-0.0750	1.7256	13.5968	0.6883	-7.9830	7.5101	-6.7560

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

NUMBER S-212-P | A214
SHEET 42 OF 80
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

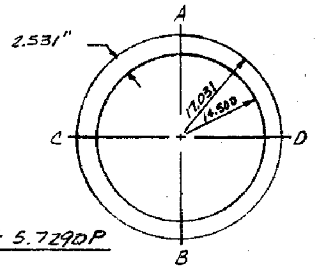
5. DETAILED ANALYSIS:

e. STRESSES:

1. COMBINED STRESSES - UNCONCENTRATED:

FOR THIS SECTION OF THE ANALYSIS, STRESSES WILL BE CALCULATED AT THE TEN LOCATIONS AS SHOWN ON SHEET 14.

LOCATION 1 & 2:



PRESSURE STRESS:

$$\sigma_x = \pm \frac{6M_1}{t_1^2}\frac{R_2}{R_1} + \frac{b^2P}{2R_1t_1} = \underline{\pm 0.94311 M_1 + 2.6345 P}$$

$$\sigma_\theta = \pm \frac{\nu 6M_1}{t_1^2}\frac{R_2}{R_1} + \frac{EW_{11}}{R_1} + \frac{bP}{t_1} = \underline{\pm 0.2829 M_1 + 0.0634 EW_{11} + 5.7290 P}$$

$$\sigma_r = - P$$

$$I = \frac{\pi}{4}(r_o^4 - r_i^4) = 31358 \text{ IN}^4$$

$$A = \pi(r_o^2 - r_i^2) = 251 \text{ IN}^2$$

THERMAL STRESS:

$$\sigma_x = \pm \frac{6M_1}{t_1^2}\frac{R_2}{R_1} = \underline{\pm 0.9431 M_1}$$

$$\sigma_\theta = \pm \frac{\nu 6M_1}{t_1^2}\frac{R_2}{R_1} + \frac{EW_{11}}{R_1} = \underline{\pm 0.2829 M_1 + 0.0634 EW_{11}}$$

THERMAL INDUCED PIPE REACTIONS:

	LOCATION-1		LOCATION-2	
$\sigma_x = -\frac{F_x}{A} \pm \frac{Mc}{I}$	$= -0.00398 F_x + 0.00046 M_z$	POINT A	$= -0.00398 F_x + 0.00054 M_z$	POINT A
	$= -0.00398 F_x - 0.00046 M_z$	B	$= -0.00398 F_x - 0.00054 M_z$	B
	$= -0.00398 F_x + 0.00046 M_y$	C	$= -0.00398 F_x + 0.00054 M_y$	C
	$= -0.00398 F_x - 0.00046 M_y$	D	$= -0.00398 F_x - 0.00054 M_y$	D
$\tau_{x\theta} = \frac{FQ}{Ib'} \pm \frac{Mc}{2I}$	$= 0.00794 F_z + 0.00023 M_x$	POINT A	$= 0.00794 F_z + 0.00027 M_x$	POINT A
	$= 0.00794 F_z - 0.00023 M_x$	B	$= 0.00794 F_z - 0.00027 M_x$	B
$b' = 2t_1$	$= 0.00794 F_y + 0.00023 M_x$	C	$= 0.00794 F_y + 0.00027 M_x$	C
	$= 0.00794 F_y - 0.00023 M_x$	D	$= 0.00794 F_y - 0.00027 M_x$	D

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO. ____

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

NUMBER 5-212-P | A215
SHEET 43 OF 80
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

e. STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

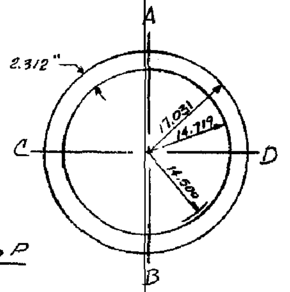
SEISMIC PIPE REACTIONS:

THE FORMULAS FOR CALCULATING THE STRESSES DUE TO THE SEISMIC PIPE REACTIONS ARE THE SAME AS FOR THE THERMALLY INDUCED PIPE REACTIONS.

NOTE:

THERE WILL BE NO STRESS PRODUCED AT LOCATIONS 1 → 6 DUE TO THE STATIC LOADING THROUGH SUPPORTS, EARTHQUAKE LOADING THROUGH SUPPORTS, OR DUE TO THERMAL EXPANSION OR CONTRACTION.

LOCATION 3&4 :



PRESSURE STRESS:

$$\sigma_x = \pm \frac{6M_1}{t_2^2} + \frac{b^2 P}{2R_2 t_2} = \underline{\pm 1.1225\, M_1 + 2.8642\, P}$$

$$\sigma_\theta = \pm \frac{\nu 6 M_1}{t_2^2} + \frac{EW_{21}}{R_2} + \frac{bP}{t_2} = \underline{\pm 0.3367\, M_1 + 0.0630\, EW_{21} + 6.2716\, P}$$

$$\sigma_r = -P$$

$$I = \frac{\pi}{4}(r_o^4 - r_i^4) = 29213\ IN^4$$

$$A = \pi(r_o^2 - r_i^2) = 231\ IN^2$$

THERMAL STRESS:

$$\sigma_x = \pm \frac{6M_1}{t_2^2} = \underline{\pm 1.1225\, M_1}$$

$$\sigma_\theta = \pm \frac{\nu 6 M_1}{t_2^2} + \frac{EW_{21}}{R_1} = \underline{\pm 0.3367\, M_1 + 0.0630\, EW_{21}}$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO. ________

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

NUMBER S 312-P | A 216
SHEET 44 OF 80
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

e. STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

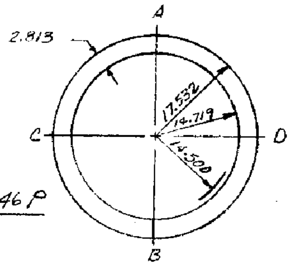
THERMAL INDUCED PIPE REACTIONS:

	LOCATION-3		LOCATION-4	
$\sigma_x = -\frac{F_x}{A} \pm \frac{Mc}{I}$	$= -0.00434 F_x + 0.00050 M_z$	POINT A	$= -0.00434 F_x + 0.00058 M_z$	POINT A
	$= -0.00434 F_x - 0.00050 M_z$	B	$= -0.00454 F_x - 0.00058 M_z$	B
	$= -0.00434 F_x + 0.00050 M_y$	C	$= -0.00434 F_x + 0.00058 M_y$	C
	$= -0.00434 F_x - 0.00050 M_y$	D	$= -0.00434 F_x - 0.00058 M_y$	D
$\tau_{x\theta} = \frac{FQ}{Ib'} \pm \frac{Mc}{2I}$	$= 0.00864 F_z + 0.00025 M_x$	POINT A	$= 0.00864 F_z + 0.00029 M_x$	POINT A
	$= 0.00864 F_z - 0.00025 M_x$	B	$= 0.00864 F_z - 0.00029 M_x$	B
	$= 0.00864 F_y + 0.00025 M_x$	C	$= 0.00864 F_y + 0.00029 M_x$	C
	$= 0.00864 F_y - 0.00025 M_x$	D	$= 0.00864 F_y - 0.00029 M_x$	D

SEISMIC PIPE REACTIONS:

THE FORMULAS FOR CALCULATING THE STRESSES ARE THE SAME AS FOR THE THERMAL INDUCED PIPE REACTIONS.

LOCATION 5-6:



PRESSURE STRESS:

$$\sigma_x = \pm \frac{6M_z}{t_{2A}^2} + \frac{b^2 P}{2R_z t_{2A}} = \underline{\pm 0.7582 M_z + 2.3541 P}$$

$$\sigma_\theta = \pm \frac{\nu 6 M_z}{t_{2A}^2} + \frac{EW_{22}}{R_z} + \frac{bP}{t_{2A}} = \underline{\pm 0.2275 M_z + 0.0630 EW_{22} + 5.1546 P}$$

$$\sigma_r = -P$$

$$I = \frac{\pi}{4}(r_o^4 - r_i^4) = 37338 \text{ IN}^4$$

$$A = \pi(r_o^2 - r_i^2) = 285 \text{ IN}^2$$

THERMAL STRESS:

$$\sigma_x = \pm \frac{6M_z}{t_{2A}^2} = \underline{\pm 0.7582 M_z}$$

$$\sigma_\theta = \pm \frac{\nu 6 M_z}{t_{2A}^2} + \frac{EW_{22}}{R_z} = \underline{\pm 0.2275 M_z + 0.0630 EW_{22}}$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.________
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

NUMBER S-212-P A 217
SHEET 45 **OF** 80
DATE 4-22-68 **BY** COCKRELL
CHECK DATE 4-22-68 **BY** HEILKER

5-DETAILED ANALYSIS:

e- STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

THERMAL INDUCED PIPE REACTIONS:

SINCE THE PIPE REACTIONS ARE APPLIED AT THE SMALL END OF THE NOZZLE, THE PIPE REACTIONS MUST BE RESOLVED TO THE CROSS SECTION OF INTEREST. THIS IS DONE AS FOLLOWS.

$\bar{F}_x = F_x = 26.2 \qquad \bar{M}_x = M_x = -2010$

$\bar{F}_y = F_y = -230 \qquad \bar{M}_y = M_y + 4.0625 F_z = -1870.6$

$\bar{F}_z = F_z = -10 \qquad \bar{M}_z = M_z - 4.0625 F_y = 28018.4$

	LOCATION-5		LOCATION-6	
$\sigma_x = -\frac{\bar{F}_x}{A} \pm \frac{\bar{M}c}{I}$	$= -0.00351\bar{F}_x + 0.00039\bar{M}_z$	POINT A	$= -0.00351\bar{F}_x + 0.00047\bar{M}_z$	POINT A
	$= -0.00351\bar{F}_x - 0.00039\bar{M}_z$	B	$= -0.00351\bar{F}_x - 0.00047\bar{M}_z$	
	$= -0.00351\bar{F}_x + 0.00039\bar{M}_y$	C	$= -0.00351\bar{F}_x + 0.00047\bar{M}_y$	
	$= -0.00351\bar{F}_x - 0.00039\bar{M}_y$	D	$= -0.00351\bar{F}_x - 0.00047\bar{M}_y$	
$\tau_{x\theta} = \frac{FQ}{Ib'} \pm \frac{Mc}{2I}$	$= 0.00698\bar{F}_z + 0.00020\bar{M}_x$	POINT A	$= 0.00698\bar{F}_z + 0.00024\bar{M}_x$	POINT A
	$= 0.00698\bar{F}_z - 0.00020\bar{M}_x$	B	$= 0.00698\bar{F}_z - 0.00024\bar{M}_x$	B
$b' = 2t_{ea}$	$= 0.00698\bar{F}_y + 0.00020\bar{M}_x$	C	$= 0.00698\bar{F}_y + 0.00024\bar{M}_x$	C
	$= 0.00698\bar{F}_y - 0.00020\bar{M}_x$	D	$= 0.00698\bar{F}_y - 0.00024\bar{M}_x$	D

SEISMIC PIPE REACTIONS:

THE FORMULAS FOR CALCULATING THE STRESSES DUE TO THE SEISMIC PIPE REACTIONS ARE THE SAME AS FOR THE THERMAL INDUCED PIPE REACTIONS.

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

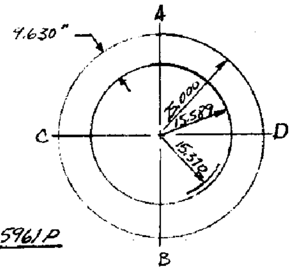
NUMBER 5-312-P | A 21B
SHEET 46 **OF** 80
DATE 4-22-68 **BY** COCKRELL
CHECK DATE 4-22-68 **BY** HEILKER

5- DETAILED ANALYSIS:

e- STRESSES.

1- COMBINED STRESSES - UNCONCENTRATED:

LOCATION 7 & 8:



$I = \frac{\pi}{4}(r_o^4 - r_i^4) = 260413 \text{ IN}^4$
$A = \pi(r_o^2 - r_i^2) = 1200 \text{ IN}^2$

PRESSURE STRESS:

$$\sigma_x = \pm \frac{6M_4}{t_{4A}^2}\frac{R_4}{R_{4A}} + \frac{b^2 P}{2R_{4A}t_{4A}} = \underline{\pm 0.0637 M_4 + 0.6044P}$$

$$\sigma_\theta = \pm \frac{\nu 6 M_4}{t_{4A}^2}\frac{R_4}{R_{4A}} + \frac{EW_{44}}{R_{4A}} + \frac{bP}{t_{4A}} = \underline{\pm 0.0191 M_4 + 0.0493 EW_{44} + 1.5961P}$$

$$\sigma_r = -P$$

THERMAL STRESS:

$$\sigma_x = \pm \frac{6M_4}{t_{4A}^2}\frac{R_4}{R_{4A}} = \underline{\pm 0.0637 M_4}$$

$$\sigma_\theta = \pm \frac{6M_4}{t_{4A}^2}\frac{R_4}{R_{4A}} + \frac{EW_{44}}{R_{4A}} = \underline{\pm 0.0191 M_4 + 0.0493 EW_{44}}$$

THERMAL INDUCED PIPE REACTIONS:

SINCE THE PIPE REACTIONS ARE APPLIED AT THE SMALL END OF THE NOZZLE, THE PIPE REACTIONS MUST BE RESOLVED TO THE CROSS SECTION OF INTEREST. THIS IS DONE AS FOLLOWS.

$\bar F_x = F_x = 26.2 \quad \bar M_x = M_x = -2010$
$\bar F_y = F_y = -230 \quad \bar M_y = M_y + 22.156 F_z = -2051.6$
$\bar F_z = F_z = -10 \quad \bar M_z = M_z - 22.156 F_y = 321799$

$\sigma_x = -\frac{\bar F_x}{A} \pm \frac{\bar M c}{I}$

LOCATION-7		LOCATION-8	
$= -0.00082\bar F_x + 0.00006 \bar M_z$	POINT A	$= -0.00082 \bar F_x + 0.00010 \bar M_z$	POINT A
$= -0.00082\bar F_x - 0.00006 \bar M_z$	B	$= -0.00082 \bar F_x - 0.00010 \bar M_z$	B
$= -0.00082\bar F_x + 0.00006 \bar M_y$	C	$= -0.00082 \bar F_x + 0.00010 \bar M_y$	C
$= -0.00082\bar F_x - 0.00006 \bar M_y$	D	$= -0.00082 \bar F_x - 0.00010 \bar M_y$	D

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.

NUMBER 5-212-P A219
SHEET 47 **OF** 80
DATE 4-22-68 **BY** COCKRELL
CHECK DATE 4-22-68 **BY** HEILKER

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

5- DETAILED ANALYSIS:

e- STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

	LOCATION -7		LOCATION -8	
$\tau_{x\theta} = \frac{\bar{F}Q}{Ib'} \pm \frac{\bar{M}c}{2I}$	$= 0.00156\,\bar{F}_z + 0.00003\,\bar{M}_x$	POINT A	$= 0.00156\,\bar{F}_z + 0.000048\,\bar{M}_x$	POINT A
	$= 0.00156\,\bar{F}_z - 0.00003\,\bar{M}_x$	B	$= 0.00156\,\bar{F}_z - 0.000048\,\bar{M}_x$	B
	$= 0.00156\,\bar{F}_y + 0.00003\,\bar{M}_x$	C	$= 0.00156\,\bar{F}_y + 0.000048\,\bar{M}_x$	C
	$= 0.00156\,\bar{F}_y - 0.00003\,\bar{M}_x$	D	$= 0.00156\,\bar{F}_y - 0.000048\,\bar{M}_x$	D

SEISMIC PIPE REACTIONS:

IN SETTING UP EQUATIONS TO ACCOUNT FOR SEISMIC PIPE REACTIONS, THE FORCES EXERTED ON THE NOZZLE WHICH ARE APPLIED THRU THE SUPPORT PAD MUST BE RESOLVED TO THE CROSS SECTION OF INTEREST. THESE FORCES ARE LABELED H AND V AS SHOWN ON SHEET 9. THE VALUES FOR THE DESIGN EARTHQUAKE AND THE NO LOSS OF FUNCTION CONDITION WHICH WILL BE CONSIDERED ARE PRESENTED IN THE TABLE ON SHEET 12. THE EQUATIONS FOR STRESS WILL BE THE SAME FOR THE SEISMIC CONDITIONS AS FOR THE THERMAL INDUCED PIPE REACTIONS EXCEPT THE VALUES FOR $\bar{F}_x$, $\bar{F}_y$, $\bar{F}_z$, $\bar{M}_x$, $\bar{M}_y$, AND $\bar{M}_z$ WILL BE AS FOLLOWS.

$\bar{F}_x = F_x = -122$ $\bar{M}_x = M_x - 25H = 11890.5$
$\bar{F}_y = F_y + V = -342.8$ $\bar{M}_y = M_y + 22.156\,F_z + 13.0H = -19851.6$
$\bar{F}_z = F_z + H = -609.5$ $\bar{M}_z = M_z - 22.156\,F_y - 13.0V = 12562.4$

STATIC LOADING THROUGH SUPPORTS:

THE EQUATIONS FOR STRESS ARE THE SAME AS FOR THE THERMALLY INDUCED PIPE REACTIONS WITH THE FOLLOWING VALUES FOR $\bar{F}_y$ AND $\bar{M}_z$.

$\bar{F}_y = V = 561.1$ SEE SHEET 13 FOR VALUES OF V WITH OR WITHOUT
$\bar{M}_z = -13V =$ THE DYNAMIC LOAD OF TRIPPED CONTROL RODS.
$= -7294.3$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER S-212-P | A220
SHEET 48 OF 80
CHARGE NO.
DATE 4-22-68 BY COCKRELL
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS
CHECK DATE 4-22-68 BY HELLKER

5- DETAILED ANALYSIS:

e- STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

EARTHQUAKE LOADING THRU SUPPORTS:

THE EQUATIONS FOR STRESS DUE TO THE EARTHQUAKE LOADING THROUGH THE SUPPORTS WILL BE THE SAME AS FOR THE THERMAL INDUCED PIPE REACTIONS WITH THE FOLLOWING VALUES FOR $\bar{F}_y$, $\bar{F}_z$, $\bar{M}_x$, $\bar{M}_y$ AND $\bar{M}_z$.

$$\left.\begin{array}{ll} \bar{F}_y = V = -132.5 & \bar{M}_x = -25H = 8412.5 \\ \bar{F}_z = H = -336.5 & \bar{M}_y = 13H = -4374.5 \\ & \bar{M}_z = -13V = 1722.5 \end{array}\right\}$$

SEE SHEET 13 FOR VALUES OF H AND V.

THERMAL EXPANSION AND CONTRACTION:

THE EQUATIONS FOR STRESS DUE TO EXPANSION AND CONTRACTION ARE AS FOLLOWS WITH THE VALUES FOR F_x AND $\bar{M}_z$ EQUAL TO.

$$\left.\begin{array}{l} \bar{F}_x = F = 168.3 \\ \bar{M}_z = 26F \\ \quad = 4375.8 \end{array}\right\}$$

SEE SHEET 14 FOR VALUES OF F.

	LOCATION-7		LOCATION-8	
$\sigma_x = -\frac{\bar{F}_x}{A} \pm \frac{\bar{M}c}{I}$	$= -0.00082\bar{F}_x + 0.00006\bar{M}_z$	POINT A	$= -0.00082\bar{F}_x + 0.00010\bar{M}_z$	POINT A
	$= -0.00082\bar{F}_x - 0.00006\bar{M}_z$	B	$= -0.00082\bar{F}_x - 0.00010\bar{M}_z$	B
	$= -0.00082\bar{F}_x$	C	$= -0.00082\bar{F}_x$	C
	$= -0.00082\bar{F}_x$	D	$= -0.00082\bar{F}_x$	D

	LOCATION-7	LOCATION 8	
σ_x	$= 0.00074F$	$0.00178F$	POINT A
	$= -0.00238F$	$-0.00342F$	B
	$= -0.00082F$	$-0.00082F$	C
	$= -0.00082F$	$-0.00082F$	D

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

NUMBER 5-212-P | A 221
SHEET 49 OF 80
DATE 4-22-69 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

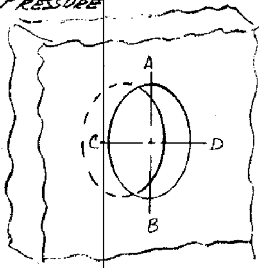
e- STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

LOCATION 9 & 10:

PRESSURE STRESS:

NOTE HERE THAT IT WILL BE NECESSARY TO CALCULATE STRESSES IN BOTH THE LONGITUDINAL AND CIRCUMFERENTIAL DIRECTIONS FOR PRESSURE



POINTS A & B (LONGITUDINAL PLANE):

$$\sigma_x = \pm \frac{6M_4}{t_5^2} - \frac{H_4}{t_5} + \frac{V_4 \sin\phi}{t_5} = \underline{\pm 0.05192 M_4 - 0.09302 H_4 + 0.0740P}$$

$$\sigma_\theta = \pm \frac{\nu 6M_4}{t_5^2} + \frac{EW_{S4}}{R_5 \sin\phi} + \frac{b\nu P}{t_5} = \underline{\pm 0.01558 M_4 + 0.0501 E W_{S4} + 7.9477P}$$

$$\sigma_r = -P$$

POINTS C & D (CIRCUMFERENTIAL PLANE):

$$\sigma_x = \pm \frac{\nu 6M_4}{t_5^2} + \frac{EW_{S4}}{R_5 \sin\phi} + \frac{b_\nu^2 P}{2R_\nu t_4} = \pm \underline{0.01558 M_4 + 0.0501 EW_{S4} + 3.7297P}$$

$$\sigma_\theta = \pm \frac{6M_4}{t^2_5} - \frac{H_4 \cos\phi}{t_5} + \frac{V_4 \sin\phi}{t_5} = \pm \underline{0.05192 M_4 - 0.09202 H_4 + 0.0740P}$$

$$\sigma_r = -P$$

THERMAL STRESS

POINTS A & B (LONGITUDINAL PLANE):

$$\sigma_x = \pm \frac{6M_4}{t_5^2} - \frac{H_4}{t_5} = \underline{\pm 0.05192 M_4 - 0.09302 H_4}$$

$$\sigma_\theta = \pm \frac{\nu 6M_4}{t_5^2} + \frac{EW_{S4}}{R_5 \sin\phi} = \underline{\pm 0.01558 M_4 + 0.0501 EW_{S4}}$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION Structural And Fatigue Evaluation Of Outlet Nozzle - Vessel Supports

NUMBER 5-212-P A222
SHEET 50 OF 80
DATE 4-22-69 BY Cockrell
CHECK DATE 4-22-69 BY Henker

5- Detailed Analysis:

e- Stresses:

1- Combined Stresses- Unconcentrated:

Points C & D (Circumferential Plane):

$$\sigma_x = \pm \frac{\nu 6 M_\phi}{t_s^2} + \frac{EW_{5A}}{R_5 \sin\phi} = \underline{\pm 0.01558 M_\phi + 0.0501\, EW_{5A}}$$

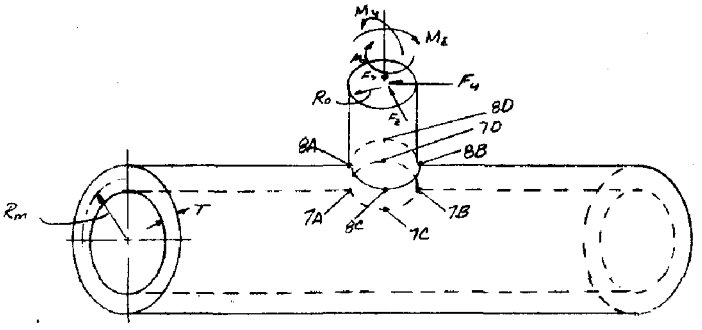
$$\sigma_\theta = \pm \frac{6M_\phi}{t_5^2} - \frac{H_4 \cos\phi}{t_5} = \underline{\pm 0.05192 M_\phi - 0.09202\, H_\phi}$$

Thermal Induced Pipe Reactions:

The Stresses In The Vessel Wall Due To The Thermally Induced Pipe Reactions Will Be Calculated By The Method Outlined In Ref. 21 For A Cylindrical Attachment To A Cylindrical Shell. Since The Pipe Reactions Are Applied At The Small End Of The Nozzle, They Must Be Resolved To The Mid-Radius Of The Vessel. This Is Done By The Following Relationship Of Forces.

$\bar{F}_x = F_x = 26.2$
$\bar{F}_y = F_y = -230$
$\bar{F}_z = F_z = -10$

$\bar{M}_x = M_x = -2010$
$\bar{M}_y = M_y + 27.531\, F_z = -2105.3$
$\bar{M}_z = M_z - 27.531\, F_y = 33416.1$



$R_m = 91.032''$
$T = 10.75''$
$r_o = 25$

With The Geometric Parameters Of $\gamma = \frac{R_m}{T} = 8.5$ And $\beta = 0.875 \frac{r_o}{R_m} = 0.24$ And The Curves In Ref. 2 We Get The Following Expressions For Stress.

NUMBER 5212-P | A223
SHEET 51 OF 80
CHARGE NO. ______
DATE 4-22-68 BY COCKRELL
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

e- STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

$$\sigma_x = -\left(\frac{N_x}{\bar{F}_x/R_m}\right)\frac{\bar{F}_x}{R_m T} \pm \left(\frac{M_x}{\bar{F}_x}\right)\frac{6\bar{F}_x}{T^2} \pm \left(\frac{N_x}{\bar{M}_y/R_m^2\beta}\right)\frac{\bar{M}_y}{R_m^2\beta T} \pm \left(\frac{M_x}{\bar{M}_y/R_m\beta}\right)\frac{6\bar{M}_y}{R_m\beta T^2} \pm \left(\frac{N_x}{\bar{M}_z/R_m^2\beta}\right)\frac{\bar{M}_z}{R_m^2\beta T} \pm \left(\frac{M_x}{\bar{M}_z/R_m\beta}\right)\frac{6\bar{M}_z}{R_m\beta T^2}$$

$$= -(1.42)\frac{\bar{F}_x}{978.58} \pm (0.075)\frac{6\bar{F}_x}{115.56} \pm (0.48)\frac{\bar{M}_y}{21380} \pm (0.056)\frac{6\bar{M}_y}{2524.8} \pm (0.28)\frac{\bar{M}_z}{21380} \pm (0.070)\frac{6\bar{M}_z}{2524.8}$$

LOCATION - 9		LOCATION -10	
$-0.00145\bar{F}_y + 0.00389\bar{F}_x + 0.000013\bar{M}_z - 0.00017\bar{M}_z$	POINT A	$-0.00145\bar{F}_x - 0.00389\bar{F}_x + 0.000013\bar{M}_z + 0.00017\bar{M}_z$	POINT A
$-0.00145\bar{F}_x + 0.00389\bar{F}_x - 0.000013\bar{M}_z + 0.00017\bar{M}_z$	B	$-0.00145\bar{F}_x - 0.00389\bar{F}_x - 0.000013\bar{M}_z - 0.00017\bar{M}_z$	B
$-0.00145\bar{F}_x + 0.00389\bar{F}_x + 0.000022\bar{M}_y - 0.00013\bar{M}_y$	C	$-0.00145\bar{F}_x - 0.00389\bar{F}_y + 0.000022\bar{M}_y + 0.00013\bar{M}_y$	C
$-0.00145\bar{F}_x + 0.00389\bar{F}_x - 0.000022\bar{M}_y + 0.00013\bar{M}_y$	D	$-0.00145\bar{F}_x - 0.00389\bar{F}_x - 0.000022\bar{M}_y - 0.00013\bar{M}_y$	D

$$\sigma_\theta = -\left(\frac{N_\theta}{\bar{F}_x/R_m}\right)\frac{\bar{F}_x}{R_m T} \pm \left(\frac{M_\theta}{\bar{F}_x}\right)\frac{6\bar{F}_x}{T^2} \pm \left(\frac{N_\theta}{\bar{M}_y/R_m^2\beta}\right)\frac{\bar{M}_y}{R_m^2\beta T} \pm \left(\frac{M_\theta}{\bar{M}_y/R_m\beta}\right)\frac{6\bar{M}_y}{R_m\beta T^2} \pm \left(\frac{N_\theta}{\bar{M}_z/R_m^2\beta}\right)\frac{\bar{M}_z}{R_m^2\beta T} \pm \left(\frac{M_\theta}{\bar{M}_z/R_m\beta}\right)\frac{6\bar{M}_z}{R_m\beta T^2}$$

$$= -(1.15)\frac{\bar{F}_x}{978.58} \pm (0.11)\frac{6\bar{F}_x}{115.56} \pm (0.26)\frac{\bar{M}_y}{21380} \pm (0.097)\frac{6\bar{M}_y}{2524.8} \pm (1.00)\frac{\bar{M}_z}{21380} \pm (0.044)\frac{6\bar{M}_z}{2524.8}$$

LOCATION - 9		LOCATION -10	
$-0.00118\bar{F}_x + 0.00571\bar{F}_x + 0.000047\bar{M}_z - 0.00010\bar{M}_z$	POINT A	$-0.00118\bar{F}_x - 0.00571\bar{F}_x + 0.000047\bar{M}_z + 0.00010\bar{M}_z$	POINT A
$-0.00118\bar{F}_x + 0.00571\bar{F}_x - 0.000047\bar{M}_z + 0.00010\bar{M}_z$	B	$-0.00118\bar{F}_x - 0.00571\bar{F}_x - 0.000047\bar{M}_z - 0.00010\bar{M}_z$	B
$-0.00118\bar{F}_x + 0.00571\bar{F}_x + 0.000012\bar{M}_y - 0.00023\bar{M}_y$	C	$-0.00118\bar{F}_x - 0.00571\bar{F}_x + 0.000012\bar{M}_y + 0.00023\bar{M}_y$	C
$-0.00118\bar{F}_x + 0.00571\bar{F}_x - 0.000012\bar{M}_y + 0.00023\bar{M}_y$	D	$-0.00118\bar{F}_x - 0.00571\bar{F}_x - 0.000012\bar{M}_y - 0.00023\bar{M}_y$	D

LOCATION 9 & 10

$$\tau_{x\theta} = \pm\frac{\bar{F}_y}{\pi r_o T} \pm \frac{\bar{F}_z}{\pi r_o T} + \frac{\bar{M}_x}{2\pi r_o T} = 0.00110\bar{F}_z + 0.00002\bar{M}_x \quad \text{POINT A}$$

$$= -0.00110\bar{F}_z + 0.00002\bar{M}_x \quad \text{B}$$

$$= 0.00110\bar{F}_y + 0.00002\bar{M}_x \quad \text{C}$$

$$= -0.00110\bar{F}_y + 0.00002\bar{M}_x \quad \text{D}$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT. CHATTANOOGA. TENN.

CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE – VESSEL SUPPORTS

NUMBER 5-212-P | A224
SHEET 52 OF 80
DATE 4-22-69 BY COCKRELL
CHECK DATE 4-22-69 BY HEILKER

5- DETAILED ANALYSIS:

C. STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

SEISMIC PIPE REACTIONS:

THE EQUATIONS FOR STRESS FOR THE SEISMIC PIPE REACTIONS WILL BE THE SAME AS FOR THE THERMALLY INDUCED PIPE REACTIONS. THE VALUES FOR $\bar{F}_x$, $\bar{F}_y$, $\bar{F}_z$, $\bar{M}_x$, $\bar{M}_y$, AND $\bar{M}_z$ WILL BE AS FOLLOWS. SEE SHEET 12 FOR VALUES OF H AND V.

$\bar{F}_x = F_x = -122$ $\quad \bar{M}_x = M_x - 25H = 11890.5$

$\bar{F}_y = F_y + V = -342.8$ $\quad \bar{M}_y = M_y + 27.531 F_z + 18.375 H = -23127.6$

$\bar{F}_z = F_z + H = -609.5$ $\quad \bar{M}_z = M_z - 27.531 F_y - 18.375 V = 14405.0$

STATIC LOAD THROUGH SUPPORTS:

THE EQUATIONS FOR STRESS ARE THE SAME AS FOR THE THERMALLY INDUCED PIPE REACTIONS WITH THE FOLLOWING VALUES FOR $\bar{F}_y$ AND $\bar{M}_z$.

$\bar{F}_y = V$ SEE SHEET 13 FOR VALUES OF V WITH OR WITHOUT
$\bar{M}_z = -18.375 V$ THE DYNAMIC LOAD OF TRIPPED CONTROL RODS.

EARTHQUAKE LOADING THROUGH SUPPORTS:

THE EQUATIONS FOR STRESS ARE THE SAME AS FOR THE THERMALLY INDUCED PIPE REACTIONS WITH THE FOLLOWING VALUES FOR $\bar{F}_y$, $\bar{F}_z$, $\bar{M}_x$, $\bar{M}_y$, AND $\bar{M}_z$

$\bar{F}_y = V = -132.5$ $\quad \bar{M}_x = -25H = 8412.5$

$\bar{F}_z = H = -336.5$ $\quad \bar{M}_y = 18.375 H = -6183.2$

$\bar{M}_z = -18.375 V = 2434.7$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORT

NUMBER S-212-P | A225
SHEET 53 OF 80
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

e- STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

THERMAL EXPANSION AND CONTRACTION:

THE EQUATIONS FOR STRESS ARE THE SAME AS FOR THE THERMALLY INDUCED PIPE REACTIONS WITH THE FOLLOWING VALUES FOR $\bar{F}_x$ & $\bar{M}_z$.

$\bar{F}_x = F = \pm 168.3$ KIPS

$\bar{M}_z = 26F = \pm 4375.8$ IN-KIPS

CONSIDER CRITERION 5.b.1:

THE CROSS SECTION OF INTEREST IS THE SECTION SHOWN ON SHEET 46 FOR LOCATIONS 7 & 8. SINCE THERE IS BENDING IN TWO DIRECTIONS, THE FOLLOWING RELATIONSHIPS WILL BE USED TO DETERMINE THE MAXIMUM EFFECT OF BENDING BY THE THERMAL AND DESIGN SEISMIC PIPE LOADS, WEIGHT, ETC.

$$\sigma_x = -\frac{\bar{F}_x}{A} \pm \frac{c}{I}\sqrt{\bar{M}_y^2+\bar{M}_z^2} = -0.00082\,\bar{F}_x \pm 0.00006\sqrt{\bar{M}_y^2+\bar{M}_z^2} \quad \text{INSIDE}$$
$$= -0.00082\,\bar{F}_x \pm 0.00010\sqrt{\bar{M}_y^2+\bar{M}_z^2} \quad \text{OUTSIDE}$$

$$\tau_{x\theta} = \frac{Q}{Ib'}\left[\bar{F}_y \sin\theta + \bar{F}_z \cos\theta\right] \pm \frac{\bar{M}_x c}{I} = 0.00156\left[\bar{F}_y \sin\theta + \bar{F}_z \cos\theta\right] \pm 0.00003\bar{M}_x \quad \text{INSIDE}$$
$$= 0.00156\left[\bar{F}_y \sin\theta + \bar{F}_z \cos\theta\right] \pm 0.0000[illegible]\,\bar{M}_x \quad \text{OUTSIDE}$$

$$\theta = \tan^{-1}\frac{\bar{M}_y}{\bar{M}_z}$$

LOCATION	PRESSURE STRESS			DUE TO EXTERNAL LOADS, WEIGHT, ETC		PRINCIPAL STRESS			STRESS INTENSITY		
	σ_x	σ_θ	σ_r	σ_x	$\tau_{x\theta}$	σ_1	σ_2	σ_3	$\sigma_1-\sigma_2$	$\sigma_1-\sigma_3$	$\sigma_2-\sigma_3$
7	1.51	3.99	-2.5	2.99	-0.61	4.91	3.58	-2.5	1.33	7.41	6.08
			-2.5	-3.11	-1.71	4.47	-2.08	-2.5	6.55	6.97	0.42
8	↓	↓	0	5.03	-0.28	6.57	3.96	0	2.61	6.57	3.96
			0	-5.15	-2.04	4.50	-4.15	0	8.65	4.50	-4.15

$S.I_{MAX} = \sigma_1 - \sigma_2 =$ <u>8.65 KSI</u> $< S_m = 26.7$ KSI   LOCATION 8

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORT

NUMBER S-212-P | A226
SHEET 54 **OF** 80
DATE 4-22-68 **BY** COCKRELL
CHECK DATE 4-22-68 **BY** HEILKER

5- DETAILED ANALYSIS:

e- STRESSES:

1- COMBINED STRESSES - UNCONCENTRATED:

CONSIDER CRITERION 5.b.2:

CUT	BODY	$\frac{b^2P}{2Rt}$	$\frac{bP}{t}$	$\frac{EW}{R}$	σ_x	σ_θ	σ_r	STRESS INTENSITY		
								$\sigma_x-\sigma_\theta$	$\sigma_x-\sigma_r$	$\sigma_\theta-\sigma_r$
1	1	6.59	14.32	-2.52	6.59	11.80	-1.25	-5.21	7.84	13.05
1	2	7.16	15.68	-3.52	7.16	12.16	↓	-5.00	8.41	13.41
2	2	5.89	12.89	-9.10	5.89	3.79	↓	2.10	7.14	5.04
4	4	1.51	3.99	17.89	1.51	21.88	↓	-20.37	2.76	23.13
4	5 LONG. AXIS	6.92	19.87	11.21	6.92	31.08	↓	-24.16	8.17	32.33
4	5 CIRC. AXIS	9.32	6.84	11.21	20.53	6.84	↓	13.69	21.78	8.09

$SI_{MAX} = \sigma_\theta - \sigma_r = 32.33\ KSI < 1.5 S_m = 40.0 KSI$

CUT 4 BODY 5
LONGITUDINAL AXIS
SEE SHEET 14
POINTS 9 & 10

CONSIDER CRITERION 5.b.3:

LOCATION	PRESSURE STRESS			STRESS DUE TO PIPE LOADS, WEIGHT, ETC			PRIMARY STRESS			STRESS INTENSITY		
	σ_x	σ_θ	σ_r	σ_x	σ_θ	$\tau_{x\theta}$	σ_1	σ_2	σ_3	$\sigma_1-\sigma_2$	$\sigma_1-\sigma_3$	$\sigma_2-\sigma_3$
9A	6.92	31.08	-2.5	4.84	1.46	0.63	32.55	11.74	-2.5	20.81	35.05	14.24
B	6.92	31.08	↓	7.14	2.68	1.42	33.86	13.96	↓	19.90	36.36	16.46
C	20.53	6.84	↓	3.57	7.18	0.21	24.10	14.02	↓	10.08	26.60	16.52
D	20.53	6.84	↓	3.88	7.71	-1.55	24.65	14.31	↓	10.34	27.15	16.81
10A	6.92	31.08	0	7.72	7.02	-0.68	38.11	14.62	0	23.49	38.11	14.62
B	6.92	31.08	↓	6.02	4.31	-1.45	35.48	12.85	↓	22.63	35.48	12.85
C	20.53	6.84	↓	4.71	7.41	0.73	26.29	15.21	↓	11.08	26.29	15.21
D	20.53	6.94	↓	6.19	9.42	0.53	26.75	16.23	↓	10.52	26.75	16.23

$S.I_{MAX} = \sigma_1 - \sigma_3 = \underline{38.11\ KSI} < 1.5 S_m = 40.05\ KSI$ LOCATION 10A

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

NUMBER S-212-P | A-227
SHEET 55 OF 80
DATE 4-22-68 BY COCKRELL
CHECK DATE 4-22-68 BY HEILKER

5- DETAILED ANALYSIS:

e- STRESSES:

1- COMBINED STRESS- UNCONCENTRATED:

CONSIDER CRITERION 5.6.4:

SAFE END

$$\sigma_x = -\frac{\bar{F}_x}{A} \pm \frac{c}{I}\sqrt{\bar{M}_y^2 + \bar{M}_z^2} = -0.00398\,\bar{F}_x \pm 0.00046\sqrt{\bar{M}_y + \bar{M}_z} \qquad \text{POINT 1}$$

$$= -0.00398\,\bar{F}_x \pm 0.00054\sqrt{\bar{M}_y + \bar{M}_z} \qquad \text{POINT 2}$$

$$\tau_{x\theta} = \frac{Q}{Ib}\left[\bar{F}_y \sin\theta + \bar{F}_z \cos\theta\right] \pm \frac{\bar{M}_x c}{2I} = 0.00794\left[\bar{F}_y \sin\theta + \bar{F}_z \cos\theta\right] \pm 0.00023\,\bar{M}_x \qquad \text{POINT 1}$$

$$\theta = \tan^{-1}\frac{\bar{M}_y}{\bar{M}_z} \qquad = 0.00794\left[\bar{F}_y \sin\theta + \bar{F}_z \cos\theta\right] \pm 0.00027\,\bar{M}_x \qquad \text{POINT 2}$$

LOCATION	PRESSURE STRESS			STRESS DUE TO SEISMIC LOADS		PRINCIPAL STRESS			STRESS INTENSITY		
	σ_x	σ_θ	σ_r	σ_x	$\tau_{x\theta}$	σ_1	σ_2	σ_3	$\sigma_1-\sigma_2$	$\sigma_1-\sigma_3$	$\sigma_2-\sigma_3$
1	6.59	11.80	-2.5	6.67	1.27	13.99	11.07	-2.5	2.92	16.49	13.57
	↓	↓	-2.5	-5.69	0.55	11.83	0.87	-2.5	10.96	14.33	3.37
2	↓	↓	0	6.76	1.33	14.11	11.04	0	2.07	14.11	11.04
	↓	↓	0	-5.78	0.49	11.82	0.79	0	11.03	11.82	0.79

$S.I._{max} = \sigma_1 - \sigma_3 = \underline{16.49\,KSI} < 1.5\,S_m = 25.05\,KSI$ LOCATION -1

SMALL END OF NOZZLE

$$\sigma_x = -\frac{\bar{F}_x}{A} \pm \frac{C}{I}\sqrt{\bar{M}_y^2 + \bar{M}_z^2} = -0.00434\,\bar{F}_x \pm 0.00050\sqrt{\bar{M}_y^2 + \bar{M}_z^2} \qquad \text{POINT 3}$$

$$= -0.00434\,\bar{F}_x \pm 0.00058\sqrt{\bar{M}_y^2 + \bar{M}_z^2} \qquad \text{POINT 4}$$

$$\tau_{x\theta} = \frac{Q}{Ib'}\left[\bar{F}_y \sin\theta + \bar{F}_z \cos\theta\right] \pm \frac{\bar{M}_x c}{2I} = 0.00864\left[\bar{F}_y \sin\theta + \bar{F}_z \cos\theta\right] \pm 0.00025\,\bar{M}_x \qquad \text{POINT 3}$$

$$\theta = \tan^{-1}\frac{\bar{M}_y}{\bar{M}_z} \qquad = 0.00864\left[\bar{F}_y \sin\theta + \bar{F}_z \cos\theta\right] \pm 0.00029\,\bar{M}_x \qquad \text{POINT 4}$$

LOCATION	PRESSURE STRESS			STRESS DUE TO SEISMIC LOADS		PRINCIPAL STRESS			STRESS INTENSITY		
	σ_x	σ_θ	σ_r	σ_x	$\tau_{x\theta}$	σ_1	σ_2	σ_3	$\sigma_1-\sigma_2$	$\sigma_1-\sigma_3$	$\sigma_2-\sigma_3$
3	7.16	12.16	-2.5	7.24	1.38	15.06	11.50	-2.5	3.56	17.56	14.00
	↓	↓	-2.5	-6.18	0.60	12.19	0.95	-2.5	11.24	14.69	3.45
4	↓	↓	0	8.32	1.45	16.02	11.62	0	4.40	16.02	11.62
	↓	↓	0	-7.26	0.53	12.18	-0.12	0	12.30	12.18	-0.12

$S.I._{max} = \sigma_1 - \sigma_3 = \underline{17.56\,KSI} < 1.5\,S_m = 40.05\,KSI$ LOCATION 3

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.

NUMBER S-212-P | A228
SHEET 56 **OF** 80
DATE 4-22-69 **BY** COCKRELL
CHECK DATE 4-22-69 **BY** HEILKER

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE- VESSEL SUPPORTS

5- DETAILED ANALYSIS:

e- STRESSES

1- COMBINED STRESSES - UNCONCENTRATED:

CONSIDER CRITERION 5.b.5:

NOTE HERE THAT THE RANGE OF STRESS INTENSITY WAS CALCULATED AT THE TEN LOCATIONS AS SHOWN ON SHEET 14 FOR THE FOUR ORIENTATIONS A, B, C AND D. THE FOLLOWING TABLE GIVES THE RANGE OF STRESS INTENSITY FOR EACH LOCATION AND ORIENTATION. STRESSES AND STRESS INTENSITIES PRODUCING THESE RANGE OF STRESS INTENSITIES WILL NOT BE PRESENTED FOR ALL LOCATIONS AND ORIENTATIONS. ONLY STRESSES AND STRESS INTENSITIES AT THE LOCATION AND ORIENTATION WHICH PRODUCE THE HIGHEST RANGE OF STRESS WILL BE PRESENTED. THIS WAS LOCATION 10B.

LOCATION AND ORIENTATION	S.I. RANGE
1A	26.72
B	28.13
C	20.84
D	20.59
2A	34.76
B	29.27
C	26.53
D	26.23
3A	29.84
B	36.95
C	30.06
D	29.91
4A	33.31
B	34.64
C	29.87
D	29.64

LOCATION AND ORIENTATION	S.I. RANGE
5A	34.75
B	15.10
C	23.77
D	26.15
6A	11.85
B	28.27
C	18.47
D	16.96
7A	40.36
B	39.48
C	39.96
D	39.96
8A	33.48
B	33.48
C	33.55
D	33.55

LOCATION AND ORIENTATION	S.I. RANGE
9A	41.00
B	43.15
C	29.10
D	29.01
10A	42.42
B	45.46 ←
C	30.83
D	31.39

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION Structural And Fatigue Evaluation Of Outlet Nozzle - Vessel Support

NUMBER 5-212-P A229
SHEET 57 OF 80
DATE 4-22-69 BY Cockrell
CHECK DATE 4-22-69 BY Heilker

5- Detailed Analysis:
e- Stresses:
1- Combined Stresses - Unconcentrated:

Location 10B

Transient		Pressure Stress			Thermal Stress		Thermal Induced Pipe Reaction Stress			Seismic Pipe Reaction Stress			Static Weight Stress		
		σ_x	σ_θ	σ_r	σ_x	σ_θ	σ_x	σ_θ	$\tau_{x\theta}$	σ_x	σ_θ	$\tau_{x\theta}$	σ_x	σ_θ	$\tau_{x\theta}$
a- Heatup	4.00 HRS	15.42	26.46	0	-1.01	-0.37	-5.60	-4.56	-0.03	-1.97	-1.28	0.91	1.89	1.52	0
	4.25	17.03	29.22	↓	-1.01	-0.38	-5.95	-4.84	↓	↓	↓	↓	↓	↓	↓
	4.35	17.68	30.34	↓	-1.01	-0.38	-6.09	-4.96	↓	↓	↓	↓	↓	↓	↓
	4.47	18.44	31.64	↓	-0.89	-0.34	-6.26	-5.09	↓	↓	↓	↓	↓	↓	↓
	5.00	18.44	31.64	↓	-0.61	-0.17	-6.26	-5.09	↓	↓	↓	↓	↓	↓	↓
	4.00	15.42	26.46	↓	-1.01	-0.37	-5.60	-4.56	↓	1.97	1.28	-0.91	↓	↓	↓
	4.25	17.03	29.22	↓	-1.01	-0.39	-5.95	-4.84	↓	↓	↓	↓	↓	↓	↓
	4.35	17.67	30.31	↓	-1.01	-0.38	-6.09	-4.96	↓	↓	↓	↓	↓	↓	↓
	4.47	18.44	31.64	↓	-0.83	-0.34	-6.26	-5.09	↓	↓	↓	↓	↓	↓	↓
	5.00	18.44	31.64	↓	-0.61	-0.17	-6.26	-5.09	↓	↓	↓	↓	↓	↓	↓
No Load Steadystate		18.44	31.64	↓	-0.03	-0.14	-6.26	-5.09	↓	0	0	0	↓	↓	↓
b- Cooldown	4.00 HRS	2.58	4.43	↓	0.96	0.22	-0.66	-0.54	0	-1.97	-1.28	0.91	↓	↓	↓
	4.25	↓	↓	↓	0.96	0.23	-0.31	-0.25	↓	↓	↓	↓	↓	↓	↓
	4.35	↓	↓	↓	0.96	0.23	-0.17	-0.14	↓	↓	↓	↓	↓	↓	↓
	4.47	↓	↓	↓	0.83	0.20	0	0	↓	↓	↓	↓	↓	↓	↓
	5.00	↓	↓	↓	0.53	0.03	0	0	↓	↓	↓	↓	↓	↓	↓
	4.00	↓	↓	↓	0.96	0.22	-0.66	-0.54	↓	1.97	1.28	-0.91	↓	↓	↓
	4.25	↓	↓	↓	0.96	0.23	-0.31	-0.25	↓	↓	↓	↓	↓	↓	↓
	4.35	↓	↓	↓	0.96	0.23	-0.17	-0.14	↓	↓	↓	↓	↓	↓	↓
	4.47	↓	↓	↓	0.83	0.20	0	0	↓	↓	↓	↓	↓	↓	↓
	5.00	↓	↓	↓	0.56	0.03	0	0	↓	↓	↓	↓	↓	↓	↓

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.

DESCRIPTION Structural And Fatigue Evaluation Of Outlet Nozzle – Vessel Supports

NUMBER 5-212-P | A230
SHEET 58 OF 80
DATE 4-22-63 BY Cockerell
CHECK DATE 4-22-63 BY Heilker

5- Detailed Analysis:

e- Stresses:

1- Combined Stresses - Unconcentrated:

LOCATION 10B

Transient		Pressure Stress			Thermal Stress		Thermal Induced Pipe Reaction Stress			Seismic Pipe Reaction Stress			Static Weight Stress		
		σ_x	σ_θ	σ_r	σ_x	σ_θ	σ_x	σ_θ	$\tau_{x\theta}$	σ_x	σ_θ	$\tau_{x\theta}$	σ_x	σ_θ	$\tau_{x\theta}$
c. Plant Loading	10 min	18.44	31.64	0	-0.43	0.03	-6.26	-5.09	-0.03	0	0	0	1.39	1.52	0
	15				-0.66	0.16									
	20				-0.95	0.40									
	25				-0.90	0.56									
	30				-0.77	0.63									
Full Load Steady State					1.15	1.06									
d. Plant Unloading	10 min				0.17	1.07									
	15				0.57	0.91									
	20				0.66	0.75									
	25				0.55	0.61									
	30				0.63	0.43									
e	100 sec	17.54	30.09		2.47	-0.38									
	225	18.64	31.99												
f	40 sec	19.01	32.62												
	100	18.52	31.78												
	260	17.54	30.09												
g	3.5 min	19.26	33.04			-0.39									
	11	17.62	30.23			-0.39									
	15.5	18.44	31.64		2.48	-0.39									