COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE ANALYSIS OF THE VESSEL WALL TRANSITION

NUMBER S-202-P A 279
SHEET 11 OF 24
DATE MAY 26, 1966 BY CORRELL
CHECK DATE MAY 26, 1966 BY ALEXANDER

5- DETAILED ANALYSIS:

a STRESSES:

THE FOLLOWING EXPRESSIONS WILL BE USED TO CALCULATE STRESSES AT THE FOUR LOCATIONS AS SHOWN ON SHEET 4

LOCATION 1:

$$\sigma_t = \frac{6M_1}{t_1^2} + \frac{b_1^2 P}{2R_1 t_1} + \frac{E\alpha(T_m - T)}{1-\nu} = 0.05192\,M_1 + 3.72970\,P + 0.30714\,(T_m - T)$$

$$\sigma_\theta = \frac{\nu 6M_1}{t_1^2} + \frac{E\Delta_{r1}}{R_1} + \frac{b_1 P}{t_1} + \frac{E\alpha(T_m - T)}{1-\nu} = 0.01558\,M_1 + 0.01099\,E\Delta_{r1} + 7.94772\,P + 0.30714(T_m - T)$$

LOCATION 2:

$$\sigma_t = \frac{-6M_1}{t_1^2} + \frac{b_1^2 P}{2R_1 t_1} + \frac{E\alpha(T_m - T)}{1-\nu} = -0.05192\,M_1 + 3.72970\,P + 0.30714\,(T_m - T)$$

$$\sigma_\theta = \frac{-\nu 6M_1}{t_1^2} + \frac{E\Delta_{r1}}{R_1} + \frac{b_1 P}{t_1} + \frac{E\alpha(T_m - T)}{1-\nu} = -0.01558\,M_1 + 0.01099\,E\Delta_{r1} + 7.94772\,P + 0.30714(T_m - T)$$

LOCATION 3:

$$\sigma_t = \frac{6M_2}{t_3^2} + \frac{b_3^2 P}{2R_3 t_3} + \frac{E\alpha(T_m - T)}{1-\nu} = 0.08066\,M_2 + 4.76490\,P + 0.30714\,(T_m - T)$$

$$\sigma_\theta = \frac{\nu 6M_2}{t_3^2} + \frac{E\Delta_{r2}}{R_3} + \frac{b_3 P}{t_3} + \frac{E\alpha(T_m - T)}{1-\nu} = 0.02420\,M_2 + 0.01099\,E\Delta_{r2} + 10.02899\,P + 0.30714(T_m - T)$$

LOCATION 4:

$$\sigma_t = -\frac{6M_2}{t_3^2} + \frac{b_3^2 P}{2R_3 t_3} + \frac{E\alpha(T_m - T)}{1-\nu} = -0.08066\,M_2 + 4.76490\,P + 0.30714\,(T_m - T)$$

$$\sigma_\theta = -\frac{\nu 6M_2}{t_3^2} + \frac{E\Delta_{r2}}{R_3} + \frac{b_3 P}{t_3} + \frac{E\alpha(T_m - T)}{1-\nu} = -0.02420\,M_2 + 0.01099\,E\Delta_{r2} + 10.02899\,P + 0.30714(T_m - T)$$

NOTE: $T_m - T$ = THERMAL STRESS WILL BE CONSERVATIVELY TREATED AS A SKIN TYPE STRESS.

$E\alpha = 0.215$ FOR SA-302B MATERIAL AT 550°F

5. Detailed Analysis:

e. Stresses:

Point Location	M	± 6M/t²	pR/2t	σr	± γEM/t	EΔ	EΔ/R	pR/t	σθ	σr	Stress Intensity σr-σθ	σr-σr	σθ-σr
1	13.068	0.68	9.32	10.00	0.20	163.46	1.80	19.87	21.87	-2.5	-11.87	12.50	24.37
2	13.068	-0.68	9.32	9.64	-0.20	163.46	1.80	19.87	21.67	0	-12.03	9.64	21.67
3	-0.326	-0.03	11.91	11.88	-0.01	-186.97	-2.05	25.07	23.01	-2.5	-11.13	14.38	25.51
4	-0.326	0.03	11.91	11.94	0.01	-186.97	-2.05	25.07	23.03	0	-11.09	11.94	23.03

The Values Of H & M Are Taken From Sheet 10.
The Movement Equations Are Given On Sheets 7 & 9.

Criterion 5.e.1 - Primary General Membrane:

$S.I._{max} = \sigma_\theta - \sigma_r = \frac{pR}{t} - \left(\frac{-p}{2}\right) = 25.07 + 1.25 = \underline{26.3\ ksi} < 26.7\ ksi$ @ Location 3 & 4

Criterion 5.e.2 - Local Membrane Stress:

$S.I. \cdot \sigma_\theta = \frac{E\Delta}{R} = -2.05 < 40\ ksi$ @ Location 3 & 4

Or Combined With 1. Above;

$S.I._{max} = \underline{24.3\ ksi} < 40\ ksi$ @ Location 3 & 4

Criterion 5.e.4 - Range Of Stress Intensity:

$(S.I.)_{max} = (\sigma_\theta - \sigma_r) + \left[\frac{pR}{t} + \frac{E\Delta}{R} + \frac{\gamma EM}{t^2}\right] + P = \underline{28.0\ ksi} < 80\ KSI$ @ Location 3

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

CHARGE NO. ______

DESCRIPTION: Structural And Fatigue Analysis Of The Vessel Wall Transition

NUMBER: S-203-P | A-[illegible]
SHEET: 13 OF 26
DATE: May 26, 1966 BY: [illegible]
CHECK DATE: May 26, 1966 BY: Alexander

5- Detailed Analysis:

c. Stresses:

The Following Tables Give The Combined Pressure And Thermal Stresses (Neglecting Stress Concentration Factors).

Location - 1

Transient		Internal Pressure ksia	(T_m-T) °F	Thermal Stress $\sigma_z=\sigma_\theta$	Pressure Stress σ_z	σ_θ	σ_r	Total Stress σ_z	σ_θ	σ_r	Stress Intensity $\sigma_z-\sigma_\theta$	$\sigma_z-\sigma_r$	$\sigma_\theta-\sigma_r$
Steady State		2.250	0	0	9.00	19.68	-2.25	9.00	19.68	-2.25	-10.68	11.25	21.93
a	6.47 hrs	2.250	-65	-19.96	9.00	19.68	-2.25	-10.96	-0.28	-2.25	-10.68	-8.71	1.97
b	6.47 hrs	0.315	65	19.96	1.26	2.76	[illegible]	21.22	22.72	-0.32	-1.50	21.54	23.04
c	20 min	2.250	-7.8	-2.40	9.00	19.68	-2.25	6.60	17.28	-2.25	-10.68	8.85	19.53
d	20 min	2.250	7.8	2.40	9.00	19.68	-2.25	11.40	22.08	-2.25	-10.68	13.65	24.33
e	100 sec	2.140	11.2	3.44	8.56	18.72	-2.14	12.00	22.16	-2.14	-10.16	14.14	24.30
	225 sec	2.275	1.7	0.52	9.10	19.90	-2.28	9.62	20.42	-2.28	-10.80	11.90	22.70
f	40 sec	2.320	-9.3	-2.86	9.28	20.29	-2.32	6.42	17.43	-2.32	-11.01	8.74	19.75
	110 sec	2.260	-13.3	-4.08	9.04	19.77	-2.26	4.96	15.69	-2.26	-10.73	7.22	17.95
	260 sec	2.140	-1.3	-0.40	8.56	18.72	-2.14	8.16	18.32	-2.14	-10.16	10.30	20.46
g	2 min	2.370	-12.0	-3.69	9.48	20.73	-2.37	5.79	17.04	-2.37	-11.25	8.16	19.41
	3.2 min	2.350	-15.0	-4.61	9.40	20.53	-2.35	4.79	15.92	-2.35	-11.13	7.14	18.27
	10.4 min	2.150	0	0	8.60	18.81	-2.15	8.60	18.81	-2.15	-10.21	10.75	20.96
h	10 sec	2.220	-9.5	-2.92	8.88	19.42	-2.22	5.96	16.50	-2.22	-10.54	8.18	18.72
	65 sec	1.910	8.5	2.61	7.64	16.71	-1.91	10.25	19.32	-1.91	-9.07	12.16	21.23
i	220 min	3.125	0	0	12.50	27.34	-3.13	12.50	27.34	-3.13	-14.84	15.63	30.43
j	Heatup 3.5 hrs	1.250	-64	-19.66	5.00	10.94	-1.25	-14.66	-8.72	-1.25	-5.94	13.41	-7.47
	5.5	2.500	0	0	10.00	21.87	-2.50	10.00	21.87	-2.50	-11.87	12.50	24.37
	Cooldown 3.5 hrs	0.315	64	19.66	1.26	2.76	-0.32	20.92	22.42	-0.32	-1.50	21.24	22.74
k	~	2.350	6.0	1.84	9.40	20.53	-2.35	11.24	22.37	-2.35	-11.13	13.59	24.72
	~	2.150	-6.0	-1.84	8.60	18.81	-2.15	6.76	16.97	-2.15	-10.21	8.91	19.12
l	12 sec	2.250	33.3	10.23	9.00	19.68	-2.25	19.23	29.91	-2.25	-10.68	21.48	32.16
m	10 sec	2.760	-30.2	-9.28	11.04	24.14	-2.76	1.76	14.86	-2.76	-13.10	4.52	17.62
	28 sec	2.120	-41.2	-12.65	8.48	18.55	-2.12	-4.17	5.90	-2.12	-10.07	-2.05	8.02
	160 sec	1.440	4.8	1.47	5.76	12.60	-1.44	7.23	14.07	-1.44	-6.84	8.67	15.51
n	33 sec	0.300	117	35.94	1.20	2.62	-0.30	37.14	38.56	-0.30	-1.42	37.44	38.86
	56 sec	0.700	197	60.51	2.80	6.12	-0.70	63.31	66.63	-0.70	-3.32	64.01	67.33

$SI_{max} = (\sigma_\theta - \sigma_r) = 37.9$ ksi $< 3S_m = 80.1$ ksi (Criterion 5-C-4

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION: STRUCTURAL AND FATIGUE ANALYSIS OF THE VESSEL WALL TRANSITION

NUMBER: S-202-P | A
SHEET 14 OF 24
DATE: MAY 26, 1966 BY
CHECK DATE: MAY 26, 1966 BY

5. DETAILED ANALYSIS:

C. STRESSES:

LOCATION -2

Transient		Internal Pressure KSIA	$(T_m - T)$ °F	Thermal Stress $\sigma_z - \sigma_\theta$	Pressure Stress σ_z	σ_θ	σ_r	Total Stress σ_z	σ_θ	σ_r	Stress Intensity $\sigma_z - \sigma_\theta$	$\sigma_\theta - \sigma_r$	$\sigma_\theta - \sigma_r$
Steady State		2.250	0	0	7.78	19.32	0	7.78	19.32	0	-11.54	7.78	19.32
a	4.47 hrs	2.250	33	10.14	7.78	19.32		17.92	29.46		-11.54	17.92	29.46
b	4.47 hrs	0.315	-33	-10.14	1.09	2.70		-9.05	-7.44		-1.61	-9.05	-7.44
c	20 min	2.250	0	0	7.78	19.32		7.78	19.32		-11.54	7.78	19.32
d	20 min	2.250			7.78	19.32		7.78	19.32		-11.54	7.78	19.32
e	100 sec	2.140			7.40	18.37		7.40	18.37		-10.97	7.40	18.37
	225 sec	2.275			7.87	19.53		7.87	19.53		-11.66	7.87	19.53
g	40 sec	2.320			8.02	19.92		8.02	19.92		-11.90	8.02	19.92
f	100 sec	2.260			7.82	19.40		7.82	19.40		-11.58	7.82	19.40
	240 sec	2.140			7.40	18.37		7.40	18.37		-10.97	7.40	18.37
	2 min	2.370			8.20	20.35		8.20	20.35		-12.15	8.20	20.35
9	3.2 min	2.350			8.13	20.17		8.13	20.17		-12.04	8.13	20.17
	10.4 min	2.150			7.44	18.46		7.44	18.46		-11.02	7.44	18.46
h	10 sec	2.220			7.68	19.06		7.68	19.06		-11.38	7.68	19.06
	65 sec	1.910			6.61	16.40		6.61	16.40		-9.79	6.61	16.40
i	220 min	3.125	↓	↓	10.81	26.83		10.81	26.83		-16.02	10.81	26.83
	HEAT UP 3.5 hrs	1.250	33	10.14	4.32	10.73		14.46	20.87		-6.41	14.46	20.87
j	5.5	2.590	0	0	8.65	21.46		8.65	21.46		-12.81	8.65	21.46
	COOL DOWN 3.5 hrs	0.315	-33	-10.14	1.09	2.70		-9.05	-7.44		-1.61	-9.05	-7.44
k	~	2.350	0	0	8.13	20.17		8.13	20.17		-12.04	8.13	20.17
	~	2.150			7.44	18.46		7.44	18.46		-11.02	7.44	18.46
l	12 sec	2.250			7.78	19.32		7.78	19.32		-11.54	7.78	19.32
	10 sec	2.760			9.54	23.69		9.54	23.69		-14.15	9.54	23.69
m	20 sec	2.120			7.33	18.20		7.33	18.20		-10.87	7.33	18.20
	160 sec	1.440			4.98	12.36		4.98	12.36		-7.38	4.98	12.36
n	33 sec	0.300	↓	↓	1.04	2.58	↓	1.04	2.58		-1.54	1.04	2.58
	54 sec	0.700			2.42	6.01		2.42	6.01		-3.59	2.42	6.01

$S.I_{max} = (\sigma_\theta - \sigma_r) = 36.9$ ksi $< 3S_m = 80.1$ ksi (CRITERION 5C-4)

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

NUMBER S-202-P | A-289
SHEET 15 OF 24
DATE MAY 26, 1966 BY CRICCHIO
CHECK DATE MAY 26, 1966 BY ALEXANDER

DESCRIPTION STRUCTURAL AND FATIGUE ANALYSIS OF TUBE VESSEL WALL TRANSITION

5- DETAILED ANALYSIS:

C. STRESSES:

LOCATION - 3

TRANSIENT		INTERNAL PRESSURE KSIA	$(T_o - T)$ °F	THERMAL STRESS $\sigma_z - \sigma_\theta$	PRESSURE STRESS σ_x	σ_θ	σ_r	TOTAL STRESS σ_x	σ_θ	σ_r	STRESS INTENSITY $\sigma_x - \sigma_\theta$	$\sigma_x - \sigma_r$	$\sigma_\theta - \sigma_r$
STEADY STATE		2.250	0	0	10.70	20.71	-2.25	10.70	20.71	-2.25	-10.01	12.95	22.96
a	4.47 hrs	2.250	-43	-13.21	10.70	20.71	-2.25	-2.51	7.50	-2.25	-10.01	-0.26	9.75
b	4.47 hrs	0.315	43	13.21	1.50	2.90	-0.32	14.71	16.11	-0.32	-1.40	15.03	16.43
c	20 min	2.250	-7.8	-2.40	10.70	20.71	-2.25	8.30	18.31	-2.25	-10.01	10.55	20.56
d	20 min	2.250	7.8	2.40	10.70	20.71	-2.25	13.10	23.11	-2.25	-10.01	15.35	25.36
e	100 sec	2.140	11.2	3.44	10.17	19.70	-2.14	13.61	23.14	-2.14	-9.53	15.75	25.28
	225 sec	2.275	1.7	0.52	10.82	20.94	-2.28	11.34	21.46	-2.28	-10.12	13.62	23.72
f	40 sec	2.320	-9.3	-2.86	11.03	21.35	-2.32	8.17	18.49	-2.32	-10.32	10.49	20.81
	100 sec	2.260	-13.3	-4.09	10.75	20.80	-2.26	6.67	16.72	-2.26	-10.05	8.93	18.98
	260 sec	2.140	-1.3	-0.40	10.17	19.70	-2.14	9.77	19.30	-2.14	-9.53	11.91	21.44
g	2 min	2.370	-12.0	-3.69	11.27	21.81	-2.37	7.58	18.12	-2.37	-10.54	9.95	20.49
	3.2 min	2.350	-15.0	-4.61	11.17	21.63	-2.35	6.56	17.02	-2.35	-10.46	8.91	19.37
	10.4 min	2.150	0	0	10.22	19.79	-2.15	10.22	19.79	-2.15	-9.57	12.37	21.94
h	10 sec	2.220	-9.5	-2.92	10.55	20.43	-2.22	7.63	17.51	-2.22	-9.88	9.85	19.73
	65 sec	1.910	8.5	2.61	9.08	17.58	-1.91	11.69	20.19	-1.91	-8.50	13.60	22.10
i	220 min	3.125	0	0	14.86	28.76	-3.13	14.86	28.76	-3.13	-13.90	17.99	31.89
j	Heat up 3.5 hrs	1.250	-43	-13.21	5.94	11.50	-1.25	-7.27	-1.71	-1.25	-5.56	-6.02	-0.46
	S.S	2.500	0	0	11.89	23.01	-2.50	11.89	23.01	-2.50	-11.12	14.39	25.51
	Cool down 3.5 hrs	0.315	43	13.21	1.50	2.90	-0.32	14.71	16.11	-0.32	-1.40	15.03	16.43
k	~	2.350	6.0	1.84	11.17	21.63	-2.35	13.01	23.47	-2.35	-10.46	15.36	25.82
	~	2.150	-6.0	-1.84	10.22	19.79	-2.15	8.38	17.95	-2.15	-9.57	10.53	20.10
l	12 sec	2.250	33.3	10.23	10.70	20.71	-2.25	20.93	30.94	-2.25	-10.01	23.18	33.19
m	10 sec	2.760	-30.2	-9.28	13.12	25.40	-2.76	3.84	16.12	-2.76	-12.28	6.60	18.88
	20 sec	2.120	-41.2	-12.65	10.08	19.51	-2.12	-2.57	6.86	-2.12	-9.43	-0.45	8.98
	160 sec	1.460	4.8	1.47	6.95	13.25	-1.46	8.32	14.72	-1.46	-6.40	9.76	16.16
n	33 sec	0.300	117	35.94	1.43	2.76	-0.30	37.37	38.70	-0.30	-1.33	37.67	39.00
	54 sec	0.700	197	60.51	3.33	6.44	-0.70	63.84	66.95	-0.70	-3.11	64.54	67.65

$S.I._{max} = (\sigma_\theta - \sigma_r) = 22.4$ ksi $< 3S_m = 80.1$ ksi. CRITERION 5-C-4

5. DETAILED ANALYSIS:

c: STRESSES:

LOCATION - 4

Transient		Internal Pressure ksia	$(T_m - T)$ °F	Thermal Stress $\sigma_z - \sigma_\theta$	Pressure Stress σ_r	σ_θ	σ_z	Total Stress σ_r	σ_θ	σ_z	Stress Intensity $\sigma_r - \sigma_\theta$	$\sigma_\theta - \sigma_z$	$\sigma_z - \sigma_r$
Steady State		2.250	0	0	10.74	20.72	0	10.74	20.72	0	-9.98	10.74	20.72
a	4.67 hrs	2.250	22	6.76	10.74	20.72		17.50	27.48	"	-9.98	17.50	27.48
b	4.47 hrs	0.315	-22	-6.76	1.50	2.90		-5.26	-3.86		-1.40	-5.26	-3.86
c	20 min	2.250	0	0	10.74	20.72		10.74	20.72		-9.98	10.74	20.72
d	20 min	2.250	↓	↓	10.74	20.72		10.74	20.72		-9.98	10.74	20.72
e	100 sec	2.140			10.22	19.71		10.22	19.71		-9.49	10.22	19.71
	225 sec	2.275			10.88	20.95		10.88	20.95		-10.07	10.88	20.95
f	40 sec	2.320			11.08	21.37		11.08	21.37		-10.29	11.08	21.37
	100 sec	2.260			10.79	20.82		10.79	20.82		-10.03	10.79	20.82
	260 sec	2.140			10.22	19.71		10.22	19.71		-9.49	10.22	19.71
g	2 min	2.370			11.32	21.83		11.32	21.83		-10.51	11.32	21.83
	3.2 min	2.350			11.22	21.64		11.22	21.64		-10.42	11.22	21.64
	10.4 min	2.150			10.27	19.80		10.27	19.80		-9.53	10.27	19.80
h	10 sec	2.220			10.60	20.45		10.60	20.45		-9.85	10.60	20.45
	65 sec	1.910			9.12	17.59		9.12	17.59		-8.47	9.12	17.59
i	22 hours	3.125	↓	↓	14.92	28.78		14.92	28.78		-13.86	14.92	28.78
j	Heatup 3.5 hrs	1.250	22	6.76	5.97	11.51		12.73	18.27		-5.54	12.73	18.27
	S.S	2.500	0	0	11.94	23.02		11.94	23.02		-11.08	11.94	23.02
	Cooldown 3.5 hrs	0.315	-22	-6.76	1.50	2.90		-5.26	-3.86		-1.40	-5.26	-3.86
k	~	2.350	0	0	11.22	21.64		11.22	21.64		-10.42	11.22	21.64
	~	2.150	↓	↓	10.27	19.80		10.27	19.80		-9.53	10.27	19.80
l	12 sec	2.250			10.74	20.72		10.74	20.72		-9.98	10.74	20.72
m	10 sec	2.760			13.18	26.42		13.18	26.42		-12.24	13.18	25.42
	20 sec	2.120			10.12	19.53		10.12	19.53		-9.41	10.12	19.53
	160 sec	1.440			6.88	13.26		6.88	13.26		-6.38	6.88	13.26
n	33 sec	0.300	↓	↓	1.43	2.76	↓	1.43	2.76	↓	-1.33	1.43	2.76
	54 sec	0.700			3.34	6.45		3.34	6.45		-3.11	3.34	6.45

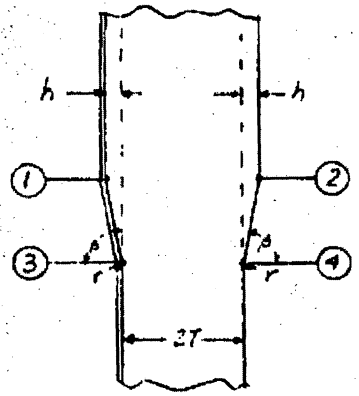
$S.I._{max} = \sigma_\theta - \sigma_r = 32.6$ ksi $< 3S_m = 60.1$ ksi Criterion 5-c-4

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION Structural And Fatigue Analysis Of The Vessel Wall Transition

NUMBER S-302-P | A 283
SHEET 17 OF 24
DATE MAY 26, 1966 BY Lovell
CHECK DATE MAY 26, 1966 BY Dillmore

5. Detailed Analysis:
+ Fatigue Evaluation:

In Order To Perform The Fatigue Evaluation, Peak Stresses Must Be Known At The Four Locations As Shown Below. The Stress Expressions Given On Sheet 10 Will Be Modified To Account For Stress Concentrations. With The Peak Stresses, A Fatigue Evaluation Will Be Made By The Cumulative Method Where Superposition Of All Cycles Is Taken Into Consideration.



By Inspection, We See That The Stress Concentration Factors At Locations 1 & 2 Equal 1. At Locations 3 & 4, Stress Concentration Factor For Bending And Tension Will Be Determined By The Method Presented In Reference 3.

$T = 4.3125"$
$h = 1.063"$ $\quad \frac{r}{T} = 0.464$ $\quad \frac{\beta}{90} = 0.999$
$\beta = 80°$
$r = 2"$ $\quad \frac{r}{h} = 1.931$

From Figure A.7-1 Of Ref. 3

$K_T = 1.85$
$K_B = 1.53$

From Figure A.7-2 Of Ref. 3

$\left[\frac{K'-1}{K_3-1}\right] = 0.4$

$K'_T = 1 + 0.4(K_T - 1) = \underline{1.34}$

$K'_B = 1 + 0.4(K_B - 1) = \underline{1.21}$

Location 3

$\sigma_x = \frac{b_1 M_1}{I_1} K'_B + \frac{b_2 P}{A_2 t_1} K'_T + \frac{E\alpha(T_m - T)}{1-\nu} K'_T = \underline{6.37232P + 0.41157(T_m - T)}$

$\sigma_\theta = \frac{\nu b_1 M_1}{I_1} K'_B + \frac{E\Delta_{11}}{R_3} + \frac{b_2 P}{t_3} + \frac{E\alpha(T_m - T)}{1-\nu} = \underline{9.20326P + 0.30714(T_m - T)}$

Location 4

$\sigma_x = -\frac{b_1 M_1}{I_1} K'_B + \frac{b_2 P}{2 R_3 t_1} K'_T + \frac{E\alpha(T_m - T)}{1-\nu} K'_T = \underline{6.39762P + 0.41157(T_m - T)}$

$\sigma_\theta = \frac{\nu b_1 M_1}{I_1} K'_B + \frac{E\Delta_{11}}{R_3} + \frac{b_2 P}{t_3} + \frac{E\alpha(T_m - T)}{1-\nu} = \underline{9.21096P + 0.30714(T_m - T)}$

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

CHARGE NO.

DESCRIPTION Structural And Fatigue Analysis Of The Vessel Wall Transitions

NUMBER S-202-P | A 288
SHEET 18 OF 24
DATE May 26, 1966 BY [illegible]
CHECK DATE May 26, 1966 BY [illegible]

5- Detailed Analysis:

f. Fatigue Evaluation:

Peak Stress At Location -3

Transient		Internal Pressure psia	$T_m - T$ °F	Thermal Stress σ_z	Thermal Stress σ_θ	Pressure Stress σ_z	Pressure Stress σ_θ	Pressure Stress σ_r	Peak Stress: σ_z	Peak Stress: σ_θ	Peak Stress: σ_r
Steady State		2.250	0	0	0	14.34	20.71	-2.25	14.34	20.71	-2.25
a	4.47 hrs	2.250	-43	-17.70	-13.21	14.34	20.71	-2.25	-3.36	7.50	-2.25
b	4.47 hrs	0.315	43	17.70	13.21	2.01	2.90	-0.32	19.71	16.11	-0.32
c	20 min	2.250	-7.8	-3.21	-2.40	14.34	20.71	-2.25	11.13	18.31	-2.25
d	20 min	2.250	7.8	3.21	2.40	14.34	20.71	-2.25	17.55	23.11	-2.25
e	100 sec	2.140	11.2	4.61	3.44	13.64	19.69	-2.14	19.25	23.13	-2.14
	225 sec	2.275	1.7	0.70	0.52	14.50	20.94	-2.28	15.20	21.46	-2.28
f	40 sec	2.320	-9.3	-3.83	-2.86	14.78	21.35	-2.32	10.95	18.49	-2.32
	100 sec	2.260	-13.3	-5.47	-4.08	14.40	20.80	-2.26	8.93	16.72	-2.26
	269 sec	2.140	-1.3	-0.54	-0.40	13.64	19.69	-2.14	13.10	19.29	-2.14
g	2 min	2.370	-12.0	-4.94	-3.69	15.10	21.81	-2.37	10.16	18.12	-2.37
	3.2 min	2.350	-15.0	-6.17	-4.61	14.97	21.63	-2.35	8.80	17.02	-2.35
	18.4 min	2.150	0	0	0	13.70	19.79	-2.15	13.70	19.79	-2.15
h	10 sec	2.220	-9.5	-3.91	-2.92	14.15	20.43	-2.22	10.24	17.51	-2.22
	65 sec	1.910	8.3	3.50	2.61	12.17	17.58	-1.91	15.67	20.19	-1.91
i	220 min	3.125	0	0	0	19.91	28.76	-3.13	19.91	28.76	-3.13
j	Heatup 5.5 hrs	1.250	-43	-17.70	-13.21	7.96	11.50	-1.25	-9.74	-1.71	-1.25
	S.S.	2.500	0	0	0	15.93	23.01	-2.50	15.93	23.01	-2.50
	Cooldown 3.5 hrs	0.315	43	17.70	13.21	2.01	2.90	-0.32	19.71	16.11	-0.32
k	~	2.350	6.0	2.47	1.84	14.97	21.63	-2.35	17.44	23.47	-2.35
	~	2.150	-6.0	-2.47	-1.84	13.70	19.79	-2.15	11.23	17.95	-2.15
l	12 sec	2.250	33.3	13.71	10.23	14.34	20.71	-2.25	28.05	30.94	-2.25
m	10 sec	2.760	-30.2	-12.43	-9.28	17.59	25.40	-2.76	5.16	16.12	-2.76
	28 sec	2.120	-41.2	-16.96	-12.65	13.51	19.51	-2.12	-3.45	6.86	-2.12
	160 sec	1.440	4.8	1.98	1.47	9.18	13.25	-1.44	11.16	16.72	-1.44
n	35 sec	3.300	117	48.15	35.94	1.91	2.76	-0.30	50.06	38.70	-0.30
	54 sec	0.700	19.7	8.108	60.51	4.46	6.44	-0.70	85.54	66.95	-0.70

5- DETAILED ANALYSIS:

1. FATIGUE EVALUATION:

PEAK STRESS AT LOCATION -4

TRANSIENT		INTERNAL PRESSURE PSIG	Tm-T °F	THERMAL STRESS σ_r	THERMAL STRESS σ_θ	PRESSURE STRESS σ_r	PRESSURE STRESS σ_θ	PRESSURE STRESS σ_z	PEAK STRESS σ_1	PEAK STRESS σ_θ	PEAK STRESS σ_r
STEADY STATE		2.350	0	0	0	14.39	20.72	0	14.39	20.72	0
a	4.47 hrs	2.250	22	9.05	6.76	14.39	20.72		23.44	27.48	
b	4.47 hrs	0.315	-22	-9.05	-6.76	2.01	2.90		-7.04	-3.86	
c	20 min	2.250	0	0	0	14.39	20.72		14.39	20.72	
d	20 min	2.250				14.39	20.72		14.39	20.72	
e	100 sec	2.160				13.69	19.71		13.69	19.71	
	225 sec	2.275				14.55	20.95		14.55	20.95	
f	40 sec	2.320				14.84	21.37		14.84	21.37	
	100 sec	2.260				14.46	20.82		14.46	20.82	
	240 sec	2.160				13.69	19.71		13.69	19.71	
g	2 min	2.370				15.16	21.83		15.16	21.83	
	3.2 min	2.350				15.03	21.65		15.03	21.65	
	10.8 min	2.150				13.75	19.80		13.75	19.80	
h	10 sec	2.220				14.20	20.45		14.20	20.45	
	65 sec	1.910				12.22	17.59		12.22	17.59	
i	220 min	3.125	↓	↓	↓	14.99	28.78		19.99	28.78	
j	HEATUP 3.5 hrs	1.250	22	9.05	6.76	8.00	11.51		17.05	18.27	
	S.S	2.500	0	0	0	15.99	23.02		15.99	23.02	
	COOLDOWN 25 hrs	0.315	-22	-9.05	-6.76	2.01	2.90		-7.04	-3.86	
k	~	2.350	0	0	0	15.03	21.65		15.03	21.65	
	~	2.150				13.75	19.80		13.75	19.80	
l	12 sec	2.250				14.39	20.72		14.39	20.72	
m	10 sec	2.760				17.66	25.42		17.66	25.42	
	28 sec	2.120				13.56	19.53		13.56	19.53	
	160 sec	1.440				9.21	13.26		9.21	13.26	
n	33 sec	1.300				1.92	2.76		1.92	2.76	
	54 sec	0.700	↓	↓	↓	4.48	6.45	↓	4.48	6.45	↓

5 Detailed Analysis:

f. Fatigue Evaluation:

Peak Stress Intensities

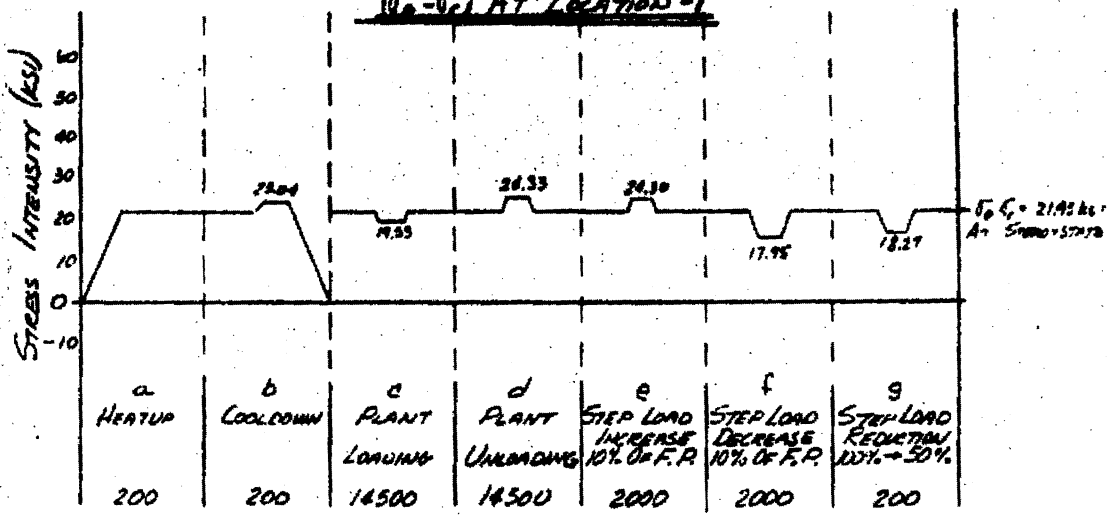
Transient		Location -1			Location -2			Location -3			Location -4		
		$\sigma_x-\sigma_\theta$	$\sigma_x-\sigma_r$	$\sigma_\theta-\sigma_r$	$\sigma_x-\sigma_\theta$	$\sigma_x-\sigma_r$	$\sigma_\theta-\sigma_r$	$\sigma_x-\sigma_\theta$	$\sigma_x-\sigma_r$	$\sigma_\theta-\sigma_r$	$\sigma_x-\sigma_\theta$	$\sigma_x-\sigma_r$	$\sigma_\theta-\sigma_r$
Steady State		-10.68	11.25	21.93	-11.54	7.78	19.32	-6.37	16.59	22.96	-6.33	14.39	20.72
a	4.47 hrs	-10.63	-9.71	1.97	-11.54	17.92	29.46	-10.86	-1.11	9.75	-4.04	23.44	27.48
b	4.47 hrs	-1.50	21.54	23.04	-1.61	-9.05	-7.44	3.60	20.03	16.43	-3.18	-7.04	-3.86
c	20 min	-10.68	8.35	19.53	-11.54	7.78	19.32	-7.18	13.38	20.56	-6.33	14.39	20.72
d	20 min	-10.68	13.65	24.33	-11.54	7.78	19.32	-5.56	19.80	25.36	-6.33	14.39	20.72
e	100 sec	-10.16	14.14	24.30	-10.97	7.40	18.37	-4.88	20.39	25.27	-6.02	13.69	19.71
	225 sec	-10.80	11.90	22.70	-11.66	7.87	19.53	-6.26	17.68	23.94	-6.40	14.55	20.95
f	40 sec	-11.01	8.74	19.75	-11.90	8.02	19.92	-7.54	13.27	20.81	-6.53	14.84	21.37
	100 sec	-10.73	7.22	17.95	-11.58	7.82	19.40	-7.79	11.19	18.98	-6.36	14.46	20.82
	260 sec	-10.16	10.30	20.46	-10.97	7.40	18.37	-6.19	15.24	21.43	-6.02	13.69	19.71
g	2 min	-11.25	9.16	19.41	-12.15	8.20	20.35	-7.96	12.53	20.49	-6.67	15.16	21.83
	3.2 min	-11.13	7.14	18.27	-12.04	8.13	20.17	-8.22	11.15	19.37	-6.62	15.03	21.65
	10.4 min	-10.21	10.75	20.96	-11.02	7.44	18.46	-6.09	15.85	21.94	-6.05	13.75	19.80
h	10 sec	-10.54	8.18	18.72	-11.38	7.68	19.06	-7.27	12.46	19.73	-6.25	14.20	20.45
	65 sec	-9.07	12.16	21.23	-9.79	6.61	16.40	-4.52	17.58	22.10	-5.37	12.22	17.59
i	220 min	-14.84	15.63	30.43	-16.02	10.81	26.83	-8.85	23.04	31.89	-9.79	19.99	29.78
j	Heat up 3.5 hrs	-5.96	13.41	-7.47	-6.41	14.46	20.87	-8.63	-8.49	-0.46	-1.22	17.05	18.27
	5.5	-11.87	12.50	24.37	-12.81	8.65	21.46	-7.08	18.43	25.51	-7.03	15.99	23.02
	Cooldown 3.5 hrs	-1.50	21.24	22.74	-1.61	-9.05	-7.44	3.60	20.03	16.43	-3.18	-7.04	-3.86
k	~	-11.13	13.59	24.72	-12.04	8.13	20.17	-6.03	19.79	25.82	-6.62	15.03	21.65
	~	-10.21	8.91	19.12	-11.02	7.44	18.46	-6.72	13.38	20.10	-6.05	13.75	19.80
l	12 sec	-10.68	21.48	32.16	-11.54	7.78	19.32	-2.89	30.30	33.19	-6.33	14.39	20.72
m	10 sec	-13.10	4.52	17.62	-14.15	9.54	23.69	-10.96	7.92	18.88	-7.76	17.66	25.42
	26 sec	-10.07	-2.05	8.02	-10.87	7.33	18.20	-10.31	-1.33	8.98	-5.97	13.56	19.53
	160 sec	-6.84	8.67	15.51	-7.38	4.98	12.36	-3.56	12.60	16.16	-4.05	9.21	13.26
n	33 sec	-1.42	37.44	38.86	-1.54	1.04	2.58	11.36	50.36	39.00	-0.84	1.92	2.76
	54 sec	-3.32	64.01	67.33	-3.59	2.42	6.01	18.59	86.24	67.65	-1.97	4.48	6.45

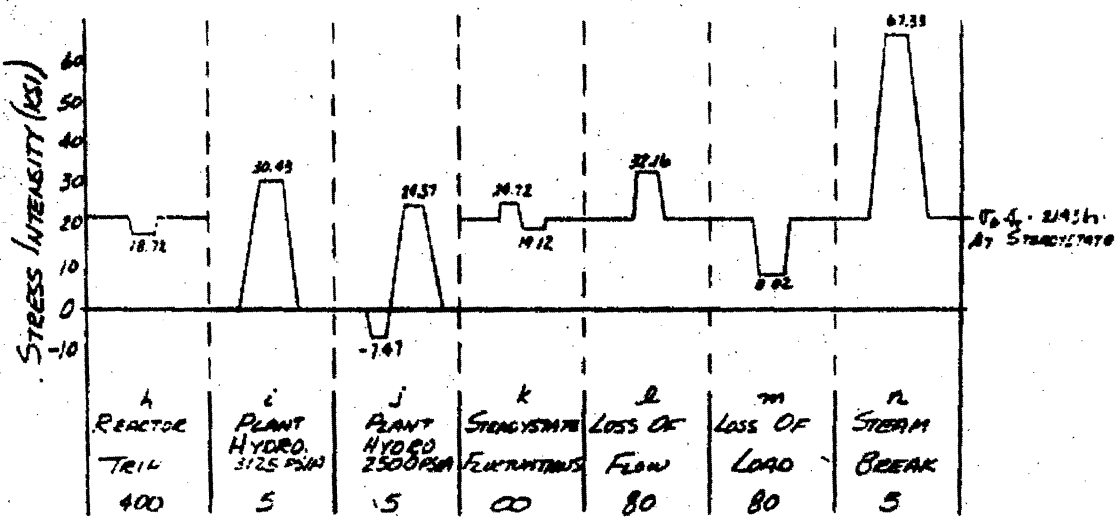
COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
NUMBER S-202-P
SHEET 21 OF 24
DATE MAY 26, 1966 BY CARRELL
DESCRIPTION STRUCTURAL AND FATIGUE ANALYSIS OF THE VESSEL WALL TRANSITION
CHECK DATE MAY 26, 1966 BY ALEXANDER

5. DETAILED ANALYSIS:

f. FATIGUE EVALUATION:

$(\sigma_0 - \sigma_i)$ AT LOCATION -1





S_{MAX}	S_{MIN}	NUMBER OF OCCURRENCES	S_{ALT}	N^*	U
67.33	-7.47	5	37.4	12000	0.00050
32.16	0	80	16.1	250,000	0.00080
30.43	0	5	15.2	340000	0.00001
24.22	0	115	12.1	∞	0

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

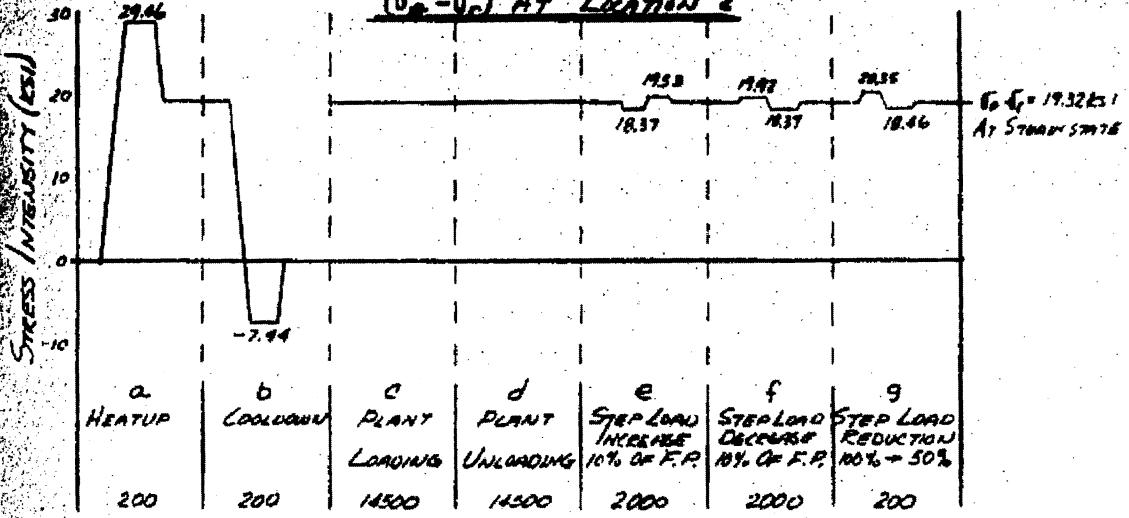
$U_{OVERALL} = 0.00106$

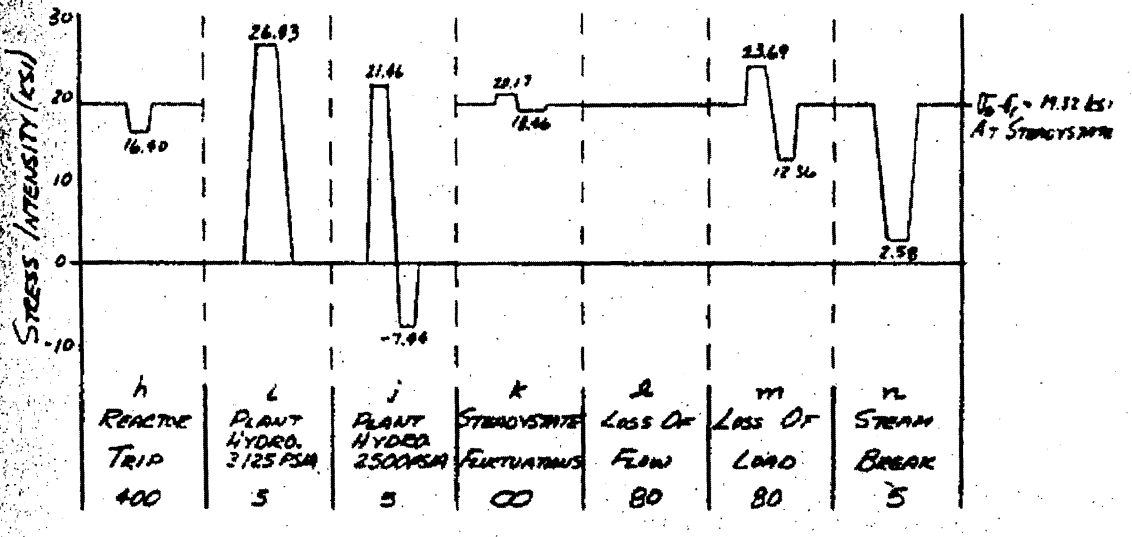
COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE ANALYSIS OF THE VESSEL WALL TRANSITION

NUMBER S-202-P | A 290
SHEET 22 OF 24
DATE MAY 26, 1966 BY CORRIE
CHECK DATE MAY 26, 1966 BY ALEXANDER

5. DETAILED ANALYSIS:
F. FATIGUE EVALUATION:

$(\sigma_a - \sigma_c)$ AT LOCATION 2





S_{MAX}	S_{MIN}	NUMBER OF CYCLES	S_{ALT}	N^*	U
29.46	-7.44	200	18.5	185,000	0.00148
26.83	-7.44	5	17.1	190,000	0.00003
23.69	2.58	5	10.6	∞	0

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

$U_{TOTAL} = 0.00151$

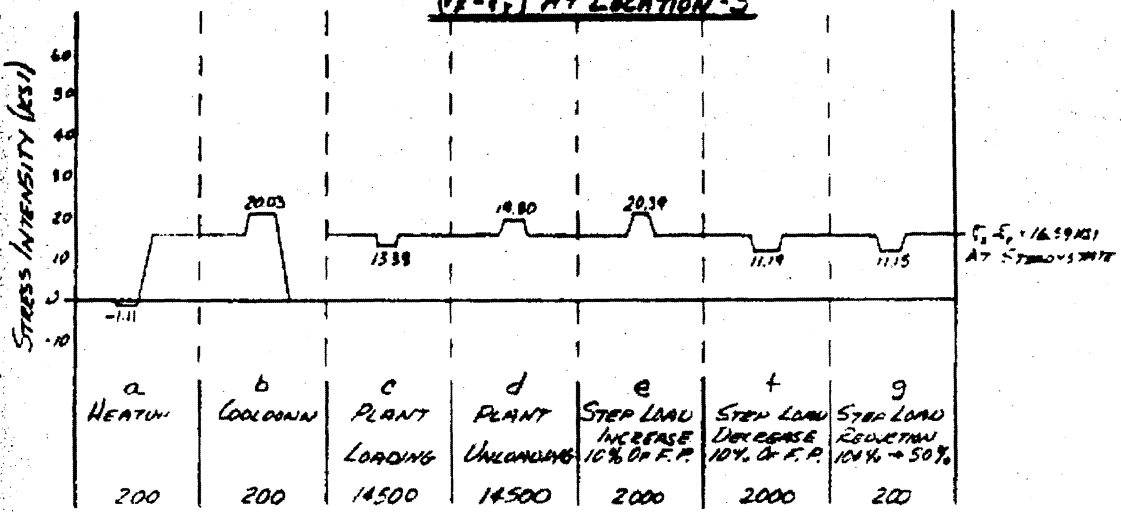
COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO. _____
DESCRIPTION STRUCTURAL AND FATIGUE ANALYSIS OF THE VESSEL WALL TRANSITION

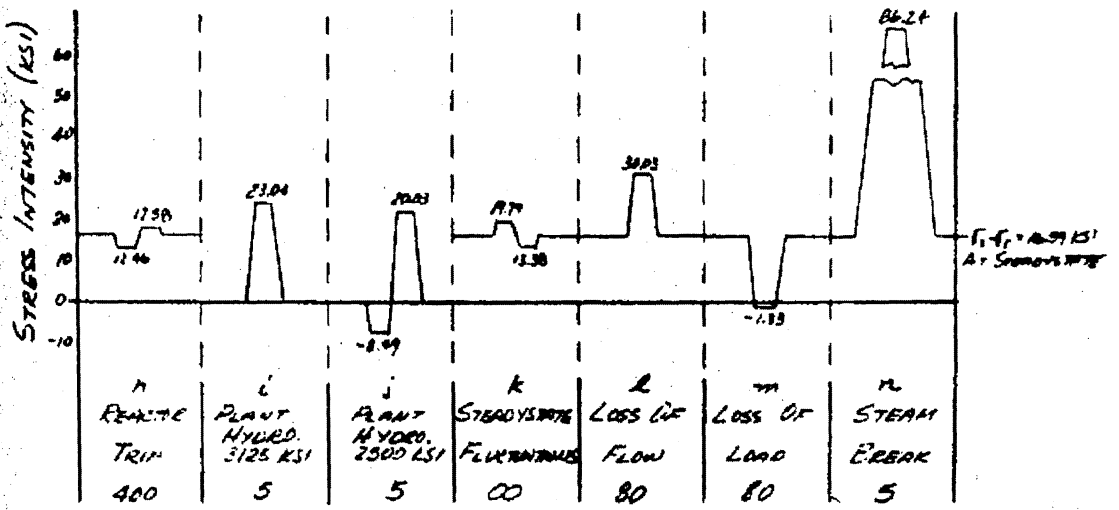
NUMBER S-202-P | A291
SHEET 23 OF 24
DATE Mar 26 1966 BY CORRELL
CHECK DATE 4/11/26/1966 BY ALEXANDER

5. DETAILED ANALYSIS:

F. FATIGUE EVALUATION:

$(\sigma_1 - \sigma_3)$ AT LOCATION - 3





$S_{max.}$	S_{min}	Number Of Occurrences	S_{alt}	N^*	U
26.24	-8.99	5	17.4	5000	0.00100
30.03	-1.33	80	15.7	29000	0.00027
23.04	-1.11	5	12.1	∞	0

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

$U_{overall}$ = 0.00127

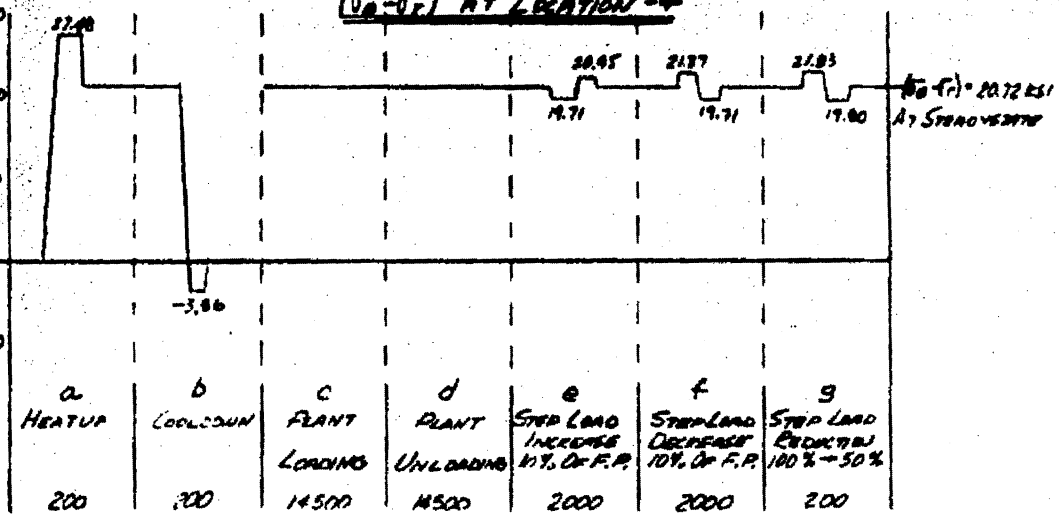
COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE ANALYSIS OF THE VESSEL WALL TRANSITION

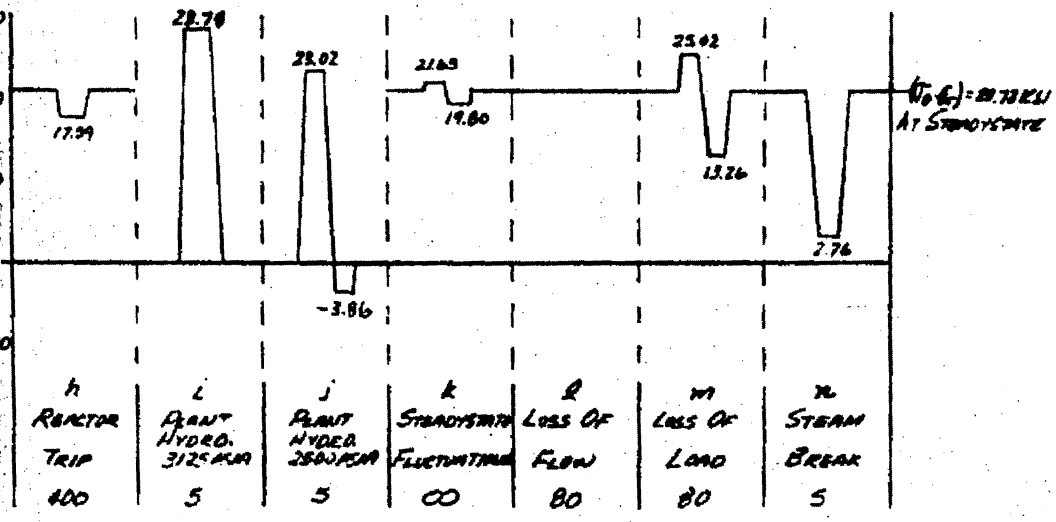
NUMBER S-202-P | A 242
SHEET 24 OF 24
DATE May 24, 1966 BY [illegible]
CHECK DATE May 24, 1966 BY ALEX SALMER

5. DETAILED ANALYSIS:

F. FATIGUE EVALUATION:

$(\sigma_0 - \sigma_r)$ AT LOCATION -4





S_{MAX}	S_{MIN}	NUMBER OF OCCURRENCES	S_{ALT}	N^*	U
28.78	-3.86	5	16.3	230000	0.00002
27.48	-3.86	200	15.7	290000	0.00069
25.42	2.76	5	11.3	∞	0

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

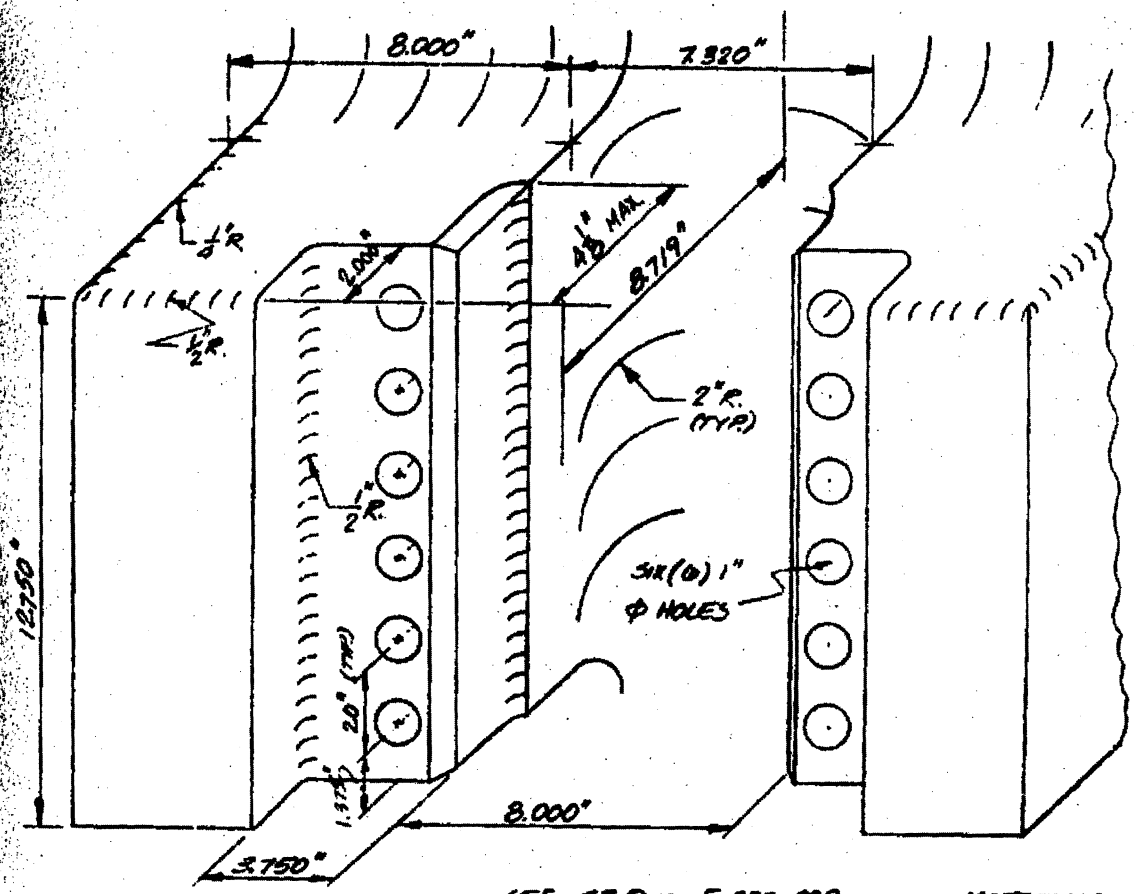
$U_{OVERALL}$ = 0.00071

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL ANALYSIS OF CORE SUPPORT PADS

NUMBER S-201-P | A-293
SHEET 5 OF 21
DATE 1-27-67 BY
CHECK DATE 1-27-67 BY CAMPLE

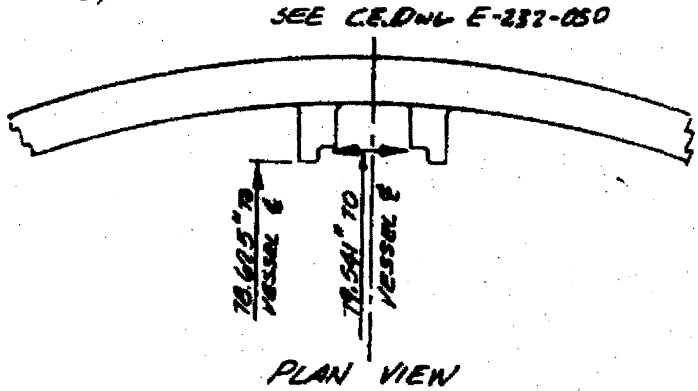
5. DETAILED ANALYSIS

a.) SYSTEM GEOMETRY



SEE C.E. DWG E-232-050

MATERIAL: INCONEL



PLAN VIEW

5. DETAILED ANALYSIS

A) SYSTEM LOADS

THE SYSTEM SHOWN ON SHEET 5 WILL BE ANALYZED FOR THE FOLLOWING LOADINGS:

1. A MOMENTARY VERTICAL LOAD OF 250 KIPS DURING INSERTION OF THE CORE.
2. A NON-CYCLIC STEADY LOADING OF 125 KIPS IN THE CIRCUMFERENTIAL DIRECTION.
3. A VERTICAL THERMAL GROWTH FRICTION LOAD OF 125 KIPS BETWEEN THE KEY ON THE CORE BARREL AND THE PAD AT ONE VERTICAL INTERFACE ONLY.
4. A CYCLIC LOADING OF PLUS/MINUS 100 KIPS ACTING IN THE CIRCUMFERENTIAL DIRECTION FOR AN INFINITE NUMBER OF CYCLES.
5. AN ADDITIONAL CYCLIC LOAD OF 125 KIPS IN THE CIRCUMFERENTIAL DIRECTION DUE TO EARTHQUAKE CONSIDERATIONS.
6. THE OPERATING TRANSIENTS DESCRIBED IN E-SPEC. #676208.

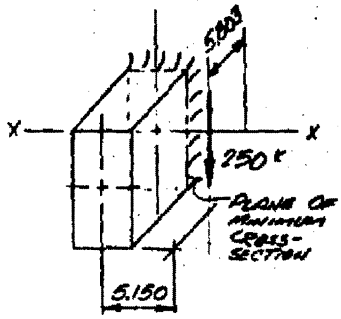
C) SYSTEM ALLOWABLES

1. SHOW THAT THE STRESS INTENSITY DERIVED FROM PRIMARY MEMBRANE (GENERAL OR LOCAL) PLUS PRIMARY BENDING STRESSES PRODUCED BY DESIGN PRESSURE AND OTHER MECHANICAL LOADS IS LESS THAN 1.5 S_m.
2. SHOW THAT THE RANGE OF STRESS INTENSITY AT EACH POINT DUE TO THE COMBINATION OF MECHANICAL LOADING PLUS THERMAL EFFECTS (NEGLECTING STRESS CONCENTRATIONS) IS LESS THAN $3S_m$.
3. SHOW THAT EACH POINT MEETS THE REQUIREMENTS FOR PEAK STRESS INTENSITIES GIVEN IN N-415 OF THE A.S.M.E. CODE. THE PROCEDURE WILL BE THAT DESCRIBED IN N-415.2 AND N-416.2 OF SECTION III.

5 DETAILED ANALYSIS

d) STRESS DURING INSERTION OF CORE

CONSIDER LOADING 1 SHOWN ON SHEET 6. DURING INSTALLATION OF THE CORE, IF ALIGNMENT FAILS TO BE SMOOTH, A VERTICAL LOAD OF 250 KIPS OF MOMENTARY DURATION WILL BE TRANSMITTED TO ONE LUG AS SHOWN BELOW. STRESSES WERE CONSIDERED AT THE JUNCTURE OF THE LUG TO THE VESSEL WALL AND AT THE PLANE OF MINIMUM CROSS-SECTION. IT WAS DETERMINED THAT THE CONTROLLING LOCATION WAS THE PLANE OF MINIMUM CROSS-SECTION.



FOR THE MINIMUM CROSS-SECTION:

$I_{x-x} = \frac{6h^3}{12} = \frac{8(12.75)^3}{12} = 1381.781 \text{ in.}^4$

AND, FROM PG. 289, REF. 8 -

$\frac{b}{c} = \frac{12.75}{8.0} = 1.59$; $\alpha = 0.234$

	SHORT SIDE	LONG SIDE
BENDING STRESS $\sigma = \frac{Mc}{I_{x-x}}$	$\frac{5803(250)6.375}{1381.781} = 6.7$ KSI	0
TORSION $T_f = \frac{T}{\alpha b c^2}$	$\frac{250(5.15)}{.234(8)12.75^2} = 4.2$ KSI	$\frac{250(5.15)}{.234(12.75)8^2} = 6.7$ KSI
DIRECT SHEAR $T_s = 1.5\frac{V}{A}$	0	$1.5\frac{250}{102.0} = 3.7$ KSI

CONSIDER MID-POINT OF SHORT SIDE

$\sigma_1 = \frac{\sigma}{2} + \sqrt{\left(\frac{\sigma}{2}\right)^2 + T^2} = 8.7$ KSI

$\sigma_2 = \frac{\sigma}{2} - \sqrt{\left(\frac{\sigma}{2}\right)^2 + T^2} = -2.0$ KSI

$\sigma_1 - \sigma_2 = 8.7 - (-2.0) = 10.7$ KSI $< 1.1 S_m = 38.0$ KSI

CONSIDER MID-POINT OF LONG SIDE

$\sigma = 0$

$T = 6.7 + 3.7 = 10.4$ KSI $< 0.8 S_m = 18.6$ KSI

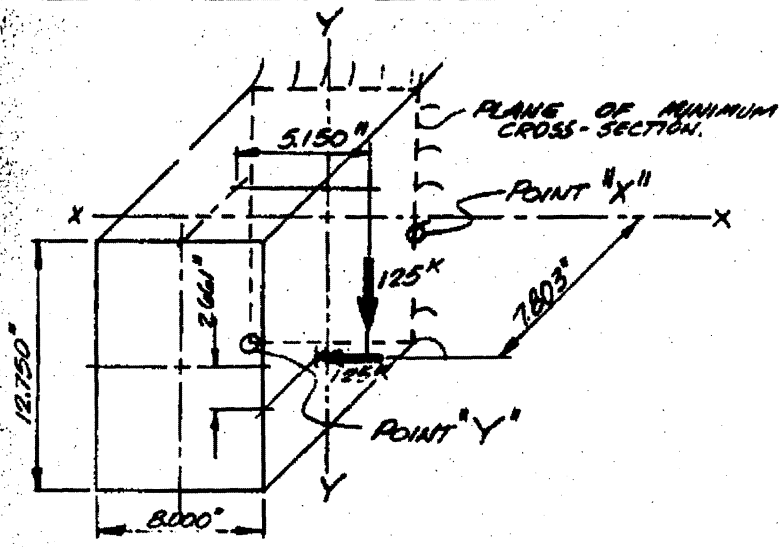
COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL ANALYSIS OF CORE SUPPORT PADS

NUMBER S-201-P | A2%
SHEET 8 OF 31
DATE 1-27-67 BY ALEXANDER
CHECK DATE 1-27-67 BY CAUPLE

5. DETAILED ANALYSIS

e) STRESS DUE TO STEADY SIDE LOAD OF 125 KIPS, STEADY VERTICAL LOAD (THERMAL GROWTH) OF 185 KIPS AND DESIGN PRESSURE

AT THE MINIMUM CROSS-SECTION-



CONSIDERATION OF POINTS ALONG THE PERIPHERY OF THE PLANE OF MINIMUM CROSS-SECTION SHOWED THAT POINT "X" AS SHOWN ABOVE WAS THE CONTROLLING LOCATION FOR THIS PLANE. THE FOLLOWING IS A TABULATION OF THE STRESSES AT POINT "X".

$T = 125(5.150) + 185(2.661) = 976.375$ IN-KIPS

$\frac{b}{c} = \frac{12.750}{8.0} = 1.59$, $\alpha = 0.234$ (PAGE 289, ROARK)

$I_{YY} = \frac{bh^3}{12} = 544$ IN^4

$\text{BENDING STRESS} = \frac{Mc}{I_{YY}} = + \frac{185(5.803)\,4.0}{544} = +5.3$ KSI

$\text{TORSIONAL SHEAR} = \frac{T}{\alpha bc^2} = \frac{976.375}{.234(12.75)\,8.0^2} = 5.1$ KSI

$\text{DIRECT SHEAR} = 1.5\frac{V}{A} = 1.5\frac{125}{102} = 1.8$ KSI

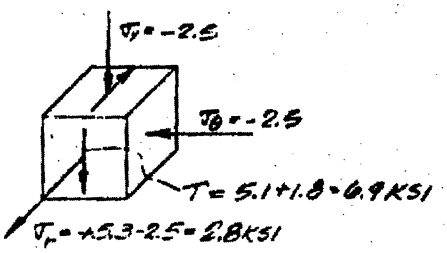
5. DETAILED ANALYSIS

c.) STRESS DUE TO STEADY SIDE LOAD OF 125 KIPS, STEADY VERTICAL LOAD (THERMAL GROWTH) OF 125 KIPS AND DESIGN PRESSURE

THE DESIGN PRESSURE IS 2.5 KSI WHICH GIVES -

$\sigma_z = \sigma_\theta = \sigma_r = -2.5$ KSI

CONSIDER A STRESS BLOCK AT POINT "X" -



$$\sigma_1 = \frac{\sigma_r + \sigma_z}{2} + \sqrt{\left(\frac{\sigma_r - \sigma_z}{2}\right)^2 + T^2} = 7.5 \text{ KSI}$$

$$\sigma_2 = \frac{\sigma_r + \sigma_z}{2} - \sqrt{\left(\frac{\sigma_r - \sigma_z}{2}\right)^2 + T^2} = -7.2 \text{ KSI}$$

$\sigma_3 = -2.5$ KSI

$S.I._{MAX} = (\sigma_1 - \sigma_2) = 7.5 - (-7.2) = 14.7 \text{ KSI} < 1.5 S_m = 35.0$

CRITERION 5.C.1

AT THE VESSEL WALL -

CONSIDERATION OF POINTS AT THE JUNCTURE OF THE PAD TO THE VESSEL WALL SHOWS THAT THE CONTROLLING LOCATION IS POINT "Y" (SEE SHEET 8).

$I_{Y-Y'} = \frac{bh^3}{12}$ WHERE ; $b = 12.750 + 2(.78)2 = 15.75$

$h = 8.000 + 2(.75)2 = 11.0$

$= \frac{15.75(11)^3}{12} = 1746.938 \text{ IN.}^4$

$I_{XX'} = \frac{11.0(15.75)^3}{12} = 3581.402 \text{ IN.}^4$

$T = 976375$ IN-KIPS

BENDING STRESS: $= -\frac{Mc}{I_{X-X'}} - \frac{Mc}{I_{YY'}} = -\frac{125(7.803)7.875}{3581.402} - \frac{125(7.803)5.5}{1746.938} = -5.2$ KSI

TORSION AND DIRECT SHEAR = 0

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
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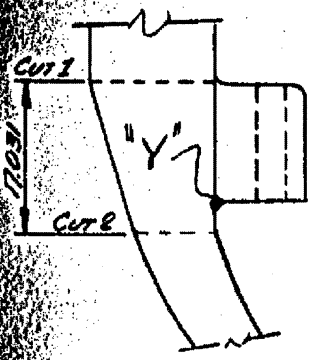
NUMBER S-201-P | A
SHEET 10 OF 31
DATE 1-27-67 BY ALEXANDER
CHECK DATE 1-27-67 BY CALDER

6. DETAILED ANALYSIS

c) STRESS DUE TO STEADY SIDE LOAD OF 125 KIPS, STEADY VERTICAL LOAD (THERMAL GROWTH) OF 125 KIPS AND DESIGN PRESSURE

EXPRESSIONS FOR THE STRESSES AT THE INSIDE SURFACE OF THE VESSEL WERE PREVIOUSLY DERIVED AT CUTS 1 AND 2 (SEE BELOW) IN C.E. CALCULATION S-200-P. PRESSURE STRESSES AT POINT "Y" WILL BE DETERMINED BY PERFORMING A LINEAR INTERPOLATION BETWEEN CUTS 1 AND 2.



CUT	σ_x	σ_θ	σ_r	
1	5.285P	8.671P	-P	} FROM SHEET -14 OF S-200-P
2	9.910P	8.465P	-P	

INTERPOLATION YIELDS THE FOLLOWING STRESSES FOR POINT "Y":

$\sigma_x = 9.358P$ FOR $P = 2.5$; $\sigma_x = 23.4$ KSI
$\sigma_\theta = 8.490P$ $\sigma_\theta = 21.2$ KSI
$\sigma_r = -P$ $\sigma_r = -2.5$ KSI

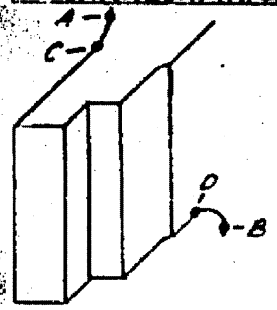
COMBINING PRESSURE AND BENDING STRESSES -

$\sigma_x = 23.4$ KSI
$\sigma_\theta = 21.2$ KSI
$\sigma_r = -5.2 - 2.6$ KSI $= -7.7$ KSI

$S.I._{MAX} = (\sigma_x - \sigma_r) = 31.1$ KSI $< 1.5 S_m = 350$ KSI
CRITERION 5.C.1

f) STRESSES

1. UNCONCENTRATED



THE LOCATIONS SHOWN AT LEFT WILL BE INVESTIGATED FOR THE FOLLOWING LOADS:

1.) A STEADY SIDE LOAD OF 125 K
2.) A CYCLIC LOADING OF ±10K IN THE CIRCUMFERENTIAL DIRECTION.
3.) A CYCLIC LOADING OF ±125K IN THE CIRCUMFERENTIAL DIRECTION DUE TO EARTHQUAKE CONSIDERATIONS
4.) THE EFFECTS OF THE OPERATING TRANSIENTS DESCRIBED IN E-SERIES REF. 19

5. DETAILED ANALYSIS

f.) STRESSES

1. UNCONCENTRATED

THERMAL STRESSES - *

POINTS "A" & "B" -

$$\sigma_x = \sigma_\theta = \frac{E\alpha (T_m - T')}{1-\nu}$$

WHERE; $E\alpha$ = YOUNG'S MODULUS x COEFFICIENT OF THERMAL EXPANSION. TAKEN AS 0.214 FOR POINTS "A" & "B" AND 0.254 FOR POINTS "C" & "D."

T_m = MEAN TEMPERATURE AT STEADY STATE.

T = INSTANTANEOUS REACTOR INLET COOLANT TEMPERATURE DURING TRANSIENT.

ν = POISSON'S RATIO, TAKEN AS 0.3.

POINTS "C" & "D" -

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

PRESSURE STRESSES -

POINT "A" -

$\sigma_x = 5.285\ P$ FROM PG. 10

$\sigma_\theta = 2.671\ P$

$\sigma_r = -P$

POINT "B" -

$\sigma_x = 9.258\ P$ FROM PG. 10

$\sigma_\theta = 2.490\ P$

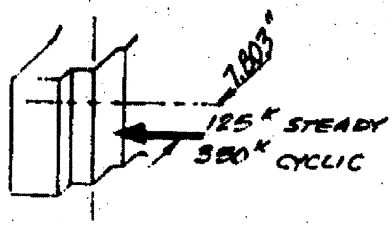
$\sigma_r = -P$

POINTS "C" & "D"

$\sigma_x = \sigma_\theta = \sigma_r = -P$

STRESSES DUE TO APPLIED LOADS -

COMBINING THE CYCLIC AND STEADY LOADS AS GIVEN ON PAGE 10 YIELDS THE FOLLOWING APPLIED LOADING:



* NOTE - ALL THERMAL STRESSES CONSERVATIVELY TREATED AS "SKIN" TYPE STRESSES.

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL ANALYSIS OF CORE SUPPORT PADS

NUMBER S-201-P | A300
SHEET 12 OF 31
DATE 1-27-67 BY ALEXANDER
CHECK DATE 1-27-67 BY CAUDLE

5. DETAILED ANALYSIS

f) STRESSES

1. UNCONCENTRATED

STRESSES DUE TO APPLIED LOADS -

POINT "A" - (VESSEL WALL)

$$\sigma_r = -\frac{Mc}{I_{y-y'}} = \frac{-\left(\frac{350}{125}\right)7.803(5.5)}{1746.938} = \begin{matrix} -8.6\ KSI \\ -9.1\ KSI \end{matrix}$$

POINT "B" - (VESSEL WALL)

$$\sigma_r = \begin{matrix} +8.6\ KSI \\ +3.1\ KSI \end{matrix}$$

POINT "C" -

$$\sigma_r = -\frac{Mc}{I_{y-y}} = \frac{-\left(\frac{350}{125}\right)5.803(4)}{544} = \begin{matrix} -14.9\ KSI \\ -5.3\ KSI \end{matrix}$$

POINT "D" -

$$\sigma_r = \begin{matrix} +14.9\ KSI \\ +5.3\ KSI \end{matrix}$$

SHEAR STRESSES NEGLECTED.

NOTE: THE FOLLOWING TABLES SUMMARIZE THE STRESSES AND STRESS INTENSITIES FOR THE FOUR LOCATIONS AS SHOWN ON SHEET 10. COMPARISON WITH $3S_m$ ALLOWABLES (CRITERION 5-C-2) IS GIVEN AT THE END OF EACH TABLE. FOR THE $3S_m$ CONSIDERATION, THE FOLLOWING TRANSIENTS ARE NOT CONSIDERED:

1 - "LOSS OF FLOW"
2 - "STEAM BREAK"
3 - "LOSS OF LOAD"

COMBUSTION ENGINEERING, INC. NUMBER 5-80-CLASS
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN. SHEET 12 OF 21
CHARGE NO. _____ DATE 4-27-67 BY ANDERSON
DESCRIPTION STRUCTURAL ANALYSIS OF CHECK DATE 4-27-67 BY CRANE
CORE SUPPORT PADS

3. DETAILED ANALYSIS
3.1 STRESSES - LOCATION A

SUMMARY OF STRESSES AND STRESS INTENSITIES AT LOCATION A

TRANSIENT	TIME	PRESS (KSI)	$(T_m - T)$	THERM. STRESS $\sigma_T = \sigma_\theta$	PRESSURE STRESSES σ_z	σ_θ	σ_r	LOAD STRESS σ_{r_L}	TOTAL STRESSES σ_z	σ_θ	σ_r	STRESS INTENSITIES $\sigma_z - \sigma_\theta$	$\sigma_z - \sigma_r$	$\sigma_\theta - \sigma_r$
STEADY STATE	—	2.26	0	0	11.9	19.5	-2.3	-3.1	11.9	19.5	-5.4	-7.6	17.3	24.9
HEAT-UP	4.47 HRS.	2.25	-43	-13.1	11.9	19.5	-2.3	-3.6	-1.2	6.4	-10.9	-7.6	9.7	17.3
		2.25	-43	-13.1	11.9	19.5	-2.3	-3.1	-1.2	6.4	-5.4	-7.6	4.2	11.8
COOLDOWN	4.47 HRS.	0.32	43	13.1	1.7	2.8	-0.3	-8.6	14.8	15.9	-8.9	-1.1	23.7	24.8
		0.32	43	13.1	1.7	2.8	-0.3	-3.1	14.8	15.9	-3.4	-1.1	18.2	19.3
PLANT LOADING	20 MIN	2.25	-7.8	-2.4	11.9	19.5	-2.3	-8.6	9.5	17.1	-10.9	-7.6	20.4	28.0
		2.25	-7.8	-2.4	11.9	19.5	-2.3	-3.1	9.5	17.1	-5.4	-7.6	14.9	22.5
PLANT UNLOADING	20 MIN	2.25	7.8	2.4	11.9	19.5	-2.3	-8.6	14.3	21.9	-10.9	-7.6	25.2	32.8
		2.25	7.8	2.4	11.9	19.5	-2.3	-3.1	14.3	21.9	-5.4	-7.6	19.7	27.3
STEP LOAD INCREASE	100 SEC.	2.14	11.2	3.4	11.3	18.6	-2.1	-8.6	14.7	22.0	-10.7	-7.3	25.4	32.7
	100 SEC.	2.14	11.2	3.4	11.3	18.6	-2.1	-5.1	14.7	22.0	-5.2	-7.3	19.9	27.2
10% OF FULL POWER	220 SEC.	2.28	1.7	0.5	12.0	19.8	-2.3	-8.6	12.6	20.3	-10.9	-7.8	23.4	31.2
	220 SEC.	2.28	1.7	0.5	12.0	19.8	-2.3	-3.1	12.6	20.3	-5.4	-7.8	17.9	25.7
STEP LOAD DECREASE	40 SEC.	2.32	-9.3	-2.8	12.3	20.1	-2.3	-8.6	9.5	17.3	-10.9	-7.8	20.4	28.2
	40 SEC.	2.32	-9.3	-2.8	12.3	20.1	-2.3	-3.1	9.5	17.3	-5.4	-7.8	14.9	22.7
10% OF FULL POWER	100 SEC.	2.26	-13.3	-4.1	11.9	19.6	-2.3	-8.6	7.8	15.5	-10.9	-7.7	18.7	26.4
	100 SEC.	2.26	-13.3	-4.1	11.9	19.6	-2.3	-3.1	7.8	15.5	-5.4	-7.7	13.2	20.9
	260 SEC.	2.14	-1.3	-0.4	11.3	18.6	-2.1	-8.6	10.9	18.2	-10.7	-7.3	21.6	28.9
	260 SEC.	2.14	-1.3	-0.4	11.3	18.6	-2.1	-3.1	10.9	18.2	-5.2	-7.3	16.1	23.4
LOSS OF FLOW	12 SEC.	2.25	33.3	10.2	11.9	19.5	-2.3	-8.6	22.1	29.7	-10.9	-7.6	33.0	40.6
		2.25	33.3	10.2	11.9	19.5	-2.3	-3.1	22.1	29.7	-5.4	-7.6	27.5	35.1
STEAM BREAK	54 SEC.	0.70	197	60.2	3.7	6.1	-0.7	-8.6	63.9	66.3	-9.3	-2.4	73.2	75.6
		0.70	197	60.2	3.7	6.1	-0.7	-3.1	63.9	66.3	-3.8	-2.4	67.7	70.1

E. DETAILED ANALYSIS

1) STRESSES - 1. UNCONCENTRATED

TRANSIENT	TIME	PRESS. (KSI)	$(T_m - T)$	THERMAL STRESS $\sigma_z = \sigma_\theta$	PRESSURE STRESSES σ_z	σ_θ	σ_r	LOAD STRESS σ_r	TOTAL STRESSES σ_z	σ_θ	σ_r	STRESS INTENSITIES $\sigma_z - \sigma_\theta$	$\sigma_z - \sigma_r$	$\sigma_\theta - \sigma_r$
STEP LOAD	2 MIN.	2.37	-12.0	-3.7	12.5	20.6	-2.4	-8.6	8.8	16.9	-11.0	-8.1	19.8	27.9
REDUCTION	2 MIN.	2.37	-12.0	-3.7	12.5	20.6	-2.4	-3.1	8.8	16.9	-5.5	-8.1	14.3	22.4
FROM 100%	32 MIN	2.35	-15.0	-4.6	12.4	20.4	-2.4	-8.6	7.8	15.8	-11.0	-8.0	18.8	26.8
TO 50%	32 MIN	2.35	-15.0	-4.6	12.4	20.4	-2.4	-3.1	7.8	16.8	-5.5	-8.0	13.3	21.3
FULL	104 MIN	2.15	0	0	11.4	18.6	-2.2	-8.6	11.4	18.6	-10.8	-7.2	22.2	29.4
POWER	104 MIN	2.15	0	0	11.4	18.6	-2.2	-3.1	11.4	18.6	-5.3	-7.2	16.7	23.9
REACTOR	10 SEC.	2.22	-9.5	-2.9	11.7	19.2	-2.2	-8.6	8.8	16.3	-10.8	-7.5	19.6	27.1
TRIP FROM	10 SEC.	2.22	-9.5	-2.9	11.7	19.2	-2.2	-3.1	8.8	16.3	-5.3	-7.5	14.1	21.6
FULL	65 SEC.	1.91	8.5	2.6	10.1	16.6	-1.9	-8.6	12.7	19.2	-10.5	-6.5	23.2	29.7
POWER	65 SEC.	1.91	8.5	2.6	10.1	16.6	-1.9	-3.1	12.7	19.2	-5.0	-6.5	17.7	24.2
PLANT HYDRO	220 MIN	3.13	0	0	16.5	27.1	-3.1	-8.6	16.6	27.1	-11.7	-10.6	28.2	38.8
AT 3125 PSIA	220 MIN	3.13	0	0	16.5	27.1	-3.1	-3.1	16.6	27.1	-6.2	-10.6	22.7	33.3
PLANT	~	2.50	-43	-13.1	13.2	21.7	-2.5	-8.6	0.1	8.6	-11.1	-8.5	11.2	19.7
HYDRO		2.50	-43	-13.1	13.2	21.7	-2.5	-3.1	0.1	8.6	-5.6	-8.5	5.7	14.2
AT	~	0.32	43	13.1	1.7	2.8	-0.3	-8.6	14.8	15.9	-8.9	-1.1	23.7	24.8
2500 PSIA		0.32	43	13.1	1.7	2.8	-0.3	-3.1	14.8	15.9	-3.4	-1.1	18.2	19.3
STEADY STATE	~	2.35	6.0	1.8	12.4	20.4	-2.4	-8.6	14.2	22.2	-11.0	-8.0	25.2	33.2
FLUCTUATIONS		2.35	6.0	1.8	12.4	20.4	-2.4	-3.1	14.2	22.2	-5.5	-8.0	19.7	27.7
OF PRESS.	~	2.15	-6.0	-1.8	11.4	18.6	-2.2	-8.6	9.6	16.8	-10.8	-7.2	20.4	27.6
AND TEMP.		2.15	-6.0	-1.8	11.4	18.6	-2.2	-3.1	9.6	16.8	-5.3	-7.2	14.9	22.1
	10 SEC.	2.76	-30.2	-9.2	14.6	23.9	-2.8	-8.6	5.4	14.7	-11.4	-9.3	16.8	26.1
LOSS	10 SEC.	2.76	-30.2	-9.2	14.6	23.9	-2.8	-3.1	5.4	14.7	-5.9	-9.3	11.3	20.6
OF	28 SEC.	2.12	-41.2	-12.6	11.2	18.4	-2.1	-8.6	-1.4	5.8	-10.7	-7.2	9.3	16.5
LOAD	28 SEC.	2.12	-41.2	-12.6	11.2	18.4	-2.1	-3.1	-1.4	5.8	-5.2	-7.2	3.8	11.0
	100 SEC.	1.44	4.8	1.5	7.6	12.5	-1.4	-8.6	9.1	14.0	-10.0	-4.9	19.1	24.0
	100 SEC.	1.44	4.8	1.5	7.6	12.6	-1.4	-3.1	9.1	14.0	-4.5	-4.9	13.6	18.5

S_I max range $= \sigma_\theta - \sigma_r = 38.8$ KSI $< 3S_m = 80$ KSI (Criterion 5-2-2)

COMBUSTION ENGINEERING, INC. NUMBER 5-201-P | A-88
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN. SHEET 15 OF 51
CHARGE NO. DATE 1-27-42 BY ALEXANDER
DESCRIPTION STRUCTURAL ANALYSIS OF CHECK DATE 1-27-42 BY CAMUS
CORE SUPPORT PADS

2. DETAILED ANALYSIS
3. STRESSES - A UNIQUE APPROACH

SUMMARY OF STRESSES AND STRESS INTENSITIES AT LOCATION B

TRANSIENT	TIME	PRESS (KSI)	$(T_m - T)$	THERM STRESS $\sigma_z + \sigma_\theta$	PRESSURE STRESSES σ_z	σ_θ	σ_r	LOAD STRESS σ_r	TOTAL STRESSES σ_z	σ_θ	σ_r	STRESS INTENSITIES $\sigma_z - \sigma_\theta$	$\sigma_z - \sigma_r$	$\sigma_\theta - \sigma_r$
STEADY STATE	~	2.26	0	0	21.1	19.1	-2.3	3.1	21.1	19.1	0.8	2.0	20.3	18.3
HEAT-UP	4.47 HRS.	2.25	-43	-13.1	21.1	19.1	-2.3	8.6	8.0	6.0	6.3	2.0	1.7	-0.3
		2.25	-43	-13.1	21.1	19.1	-2.3	3.1	8.0	6.0	0.8	2.0	7.2	5.2
COOLDOWN	4.47 HRS.	0.32	43	13.1	3.0	2.7	-0.3	8.6	16.1	15.8	8.3	0.3	7.8	7.5
		0.32	43	13.1	3.0	2.7	-0.3	3.1	16.1	15.8	2.8	0.3	13.3	13.0
PLANT LOADING	20 MIN.	2.25	-7.8	-2.4	21.1	19.1	-2.3	8.6	18.7	16.7	6.3	2.0	12.4	10.4
		2.25	-7.8	-2.4	21.1	19.1	-2.3	3.1	18.7	16.7	0.8	2.0	17.9	15.9
PLANT UNLOADING	20 MIN.	2.25	7.8	2.4	21.1	19.1	-2.3	8.6	23.5	21.5	6.3	2.0	17.2	15.2
		2.25	7.8	2.4	21.1	19.1	-2.3	3.1	23.5	21.5	0.8	2.0	22.7	20.7
STEP LOAD	100 SEC.	2.14	11.2	3.4	20.0	18.2	-2.1	8.6	23.4	21.6	6.5	1.8	16.9	15.1
INCREASE	100 SEC.	2.14	11.2	3.4	20.0	18.2	-2.1	3.1	23.4	21.6	1.0	1.8	22.4	20.6
10% OF	870 SEC.	2.28	1.7	0.5	21.3	19.4	-2.3	8.6	21.8	19.9	6.3	1.9	15.5	13.6
FULL POWER	7755EC.	2.28	1.7	0.5	21.3	19.4	-2.3	3.1	21.8	19.9	0.8	1.9	21.0	19.1
STEP	40 SEC.	2.32	-9.3	-2.8	21.7	19.7	-2.3	8.6	18.9	16.9	6.3	2.0	12.6	10.6
LOAD	40 SEC.	2.32	-9.3	-2.8	21.7	19.7	-2.3	3.1	18.9	16.9	0.8	2.0	18.1	16.1
DECREASE	100 SEC.	2.26	-13.3	-4.1	21.1	19.2	-2.3	8.6	17.0	15.1	6.3	1.9	10.7	8.8
10% OF	110 SEC.	2.26	-13.3	-4.1	21.1	19.2	-2.3	3.1	17.0	15.1	0.8	1.9	16.2	14.3
FULL	260 SEC.	2.14	-1.3	-0.4	20.0	18.2	-2.1	8.6	19.6	17.8	6.5	1.8	13.1	11.3
POWER	260 SEC.	2.14	-1.3	-0.4	20.0	18.2	-2.1	3.1	19.6	17.8	1.0	1.8	18.6	16.8
LOSS OF	12 SEC.	2.25	33.3	10.2	21.1	19.1	-2.3	8.6	31.3	29.3	6.3	2.0	25.0	23.0
FLOW		2.25	33.3	10.2	21.1	19.1	-2.3	3.1	31.3	29.3	0.8	2.0	30.5	28.5
STEAM	54 SEC.	0.70	197	60.2	6.6	5.9	-0.7	8.6	66.8	66.1	7.9	0.7	58.9	58.2
BREAK		0.70	197	60.2	6.6	5.9	-0.7	3.1	66.8	66.1	2.4	0.7	64.4	63.7