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

CHARGE NO. ___
DESCRIPTION: STRUCTURAL ANALYSIS OF CORE SUPPORT PADS
NUMBER: S-201-P
SHEET 46 OF 51 BY ALEXANDER
DATE 1-22-67
CHECK DATE 1-27-67 BY [illegible]

5. DETAILED ANALYSIS
5.1 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	22.2	20.1	-2.4	8.6	18.5	16.4	6.2	2.1	12.3	10.2
REDUCTION	2 MIN.	2.37	-12.0	-3.7	22.2	20.1	-2.4	3.1	18.5	16.4	0.7	2.1	17.8	15.7
FROM 100%	32 MIN.	2.35	-15.0	-4.6	22.0	20.0	-2.4	8.6	17.4	15.4	6.2	2.0	11.2	9.2
TO 50%	32 MIN.	2.35	-15.0	-4.6	22.0	20.0	-2.4	3.1	17.4	15.4	0.7	2.0	16.7	14.7
FULL	144 MIN.	2.15	0	0	20.1	18.3	-2.2	8.6	20.1	18.3	6.4	1.8	13.7	11.9
POWER	144 MIN.	2.15	0	0	20.1	18.3	-2.2	3.1	20.1	18.3	0.9	1.8	19.2	17.4
REACTOR	10 SEC.	2.22	-9.5	-2.9	20.8	18.8	-2.2	8.6	17.9	15.9	6.4	2.0	11.5	9.5
TRIP FROM	10 SEC.	2.22	-9.5	-2.9	20.8	18.8	-2.2	3.1	17.9	15.9	0.9	2.0	17.0	15.0
FULL	65 SEC.	1.91	8.5	2.6	17.9	16.2	-1.9	8.6	20.5	18.8	6.7	1.7	13.8	12.1
POWER	65 SEC.	1.91	8.5	2.6	17.9	16.2	-1.9	3.1	20.5	18.8	1.2	1.7	19.3	17.6
PLANT HYDRO	220 MIN.	3.13	0	0	29.3	26.6	-3.1	8.6	29.3	26.6	5.5	2.7	23.8	21.1
AT 3125 PSIA	220 MIN.	3.13	0	0	29.3	26.6	-3.1	3.1	29.3	26.6	0	2.7	29.3	26.6
PLANT	~	2.50	-43	-13.1	23.4	21.2	-2.5	8.6	10.3	8.1	6.1	2.2	4.2	2.0
HYDRO		2.50	-43	-13.1	23.4	21.2	-2.5	3.1	10.3	8.1	0.6	2.2	9.7	7.5
AT	~	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
2500 PSIA		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
STEADY STATE	~	2.35	6.0	1.8	22.0	20.0	-2.4	8.6	23.8	21.8	6.2	2.0	17.6	15.6
FLUCTUATIONS		2.35	6.0	1.8	22.0	20.0	-2.4	3.1	23.8	21.8	0.7	2.0	23.1	21.1
OF PRESS.	~	2.15	-6.0	-1.8	20.1	18.3	-2.2	8.6	18.3	16.5	6.4	1.8	11.9	10.1
AND TEMP.		2.15	-6.0	-1.8	20.1	18.3	-2.2	3.1	18.3	16.5	0.9	1.8	17.4	15.6
	10 SEC.	2.76	-30.2	-9.2	25.8	23.4	-2.8	8.6	16.6	14.2	5.8	2.4	10.8	8.4
LOSS	10 SEC.	2.76	-30.2	-9.2	25.8	23.4	-2.8	3.1	16.6	14.2	0.3	2.4	16.3	13.9
OF	28 SEC.	2.12	-41.2	-12.6	19.8	18.0	-2.1	8.6	7.2	5.4	6.5	1.8	0.7	-1.1
LOAD	28 SEC.	2.12	-41.2	-12.6	19.8	18.0	-2.1	3.1	7.2	5.4	1.0	1.8	6.2	4.4
	100 SEC.	1.44	4.8	1.5	13.6	12.2	-1.4	8.6	15.0	13.7	7.2	1.3	7.8	6.5
	100 SEC.	1.44	4.8	1.5	13.6	12.2	-1.4	3.1	15.0	13.7	1.7	1.3	13.3	12.0

S.I. max. range $= \sigma_z - \sigma_r = 29.3$ KSI $< 3S_m = 80$ KSI. Criterion 5-C-2

COMBUSTION ENGINEERING, INC. NUMBER S-204-P 14.3.6
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN. SHEET 17 OF 31
CHARGE NO. DATE 1-27-67 BY ALEXANDER
DESCRIPTION STRUCTURAL ANALYSIS OF CHECK DATE 1-27-67 BY CRAIG
CORE SUPPORT BARS

5. DETAILED ANALYSIS
4) STRESSES - UNCONTROLLED

SUMMARY OF STRESSES AND STRESS INTENSITIES AT LOCATION C

TRANSIENT	TIME	PRESS.	$(T_m - T)$	THERM. STRESS $\sigma_x = \sigma_r$	PRESS. STRESS $\sigma_x = \sigma_\theta = \sigma_r$	LOAD STRESS σ_r	TOTAL STRESSES σ_x	σ_θ	σ_r	STRESS INTENSITIES $\sigma_x - \sigma_\theta$	$\sigma_x - \sigma_r$	$\sigma_\theta - \sigma_r$
STEADY STATE	~	2.25	0	0	-2.3	-5.3	-2.3	-2.3	-7.6	0	5.3	5.3
HEAT-UP	4.47 HRS.	2.25	-43	-15.6	-2.3	-14.9	-17.9	-2.3	-32.8	-15.6	14.9	30.5
		2.25	-43	-15.6	-2.3	-5.3	-17.9	-2.3	-23.2	-15.6	5.3	20.9
COOL-DOWN	4.47 HRS.	0.32	43	15.6	-0.3	-14.9	15.3	-0.3	0.4	15.6	14.9	-0.7
		0.32	43	15.6	-0.3	-5.3	15.3	-0.3	10.0	15.6	5.3	-10.3
PLANT LOADING	20 MIN.	2.26	-7.8	-2.8	-2.3	-14.9	-5.1	-2.3	-20.0	-2.8	14.9	17.7
		2.25	-7.8	-2.8	-2.3	-5.3	-5.1	-2.3	-10.4	-2.8	5.3	8.1
PLANT UNLOADING	20 MIN.	2.25	7.8	2.8	-2.3	-14.9	0.5	-2.3	-14.4	2.8	14.9	12.1
		2.25	7.8	2.8	-2.3	-5.3	0.5	-2.3	-4.8	2.8	5.3	2.5
STEP LOAD INCREASE	100 SEC.	2.14	11.2	4.1	-2.1	-14.9	2.0	-2.1	-12.9	4.1	14.9	10.8
	100 SEC.	2.14	11.2	4.1	-2.1	-5.3	2.0	-2.1	-3.3	4.1	5.3	1.2
10% OF FULL POWER	225 SEC.	2.28	1.7	0.6	-2.3	-14.9	-1.7	-2.3	-16.6	0.6	14.9	14.3
	225 SEC.	2.28	1.7	0.6	-2.3	-5.3	-1.7	-2.3	-7.0	0.6	5.3	4.7
STEP LOAD DECREASE	40 SEC.	2.32	-9.3	-3.4	-2.3	-14.9	-5.7	-2.3	-20.6	-3.4	14.9	18.3
	40 SEC.	2.32	-9.3	-3.4	-2.3	-5.3	-5.7	-2.3	-11.0	-3.4	5.3	8.7
10% OF FULL POWER	100 SEC.	2.26	-13.3	-4.8	-2.3	-14.9	-7.1	-2.3	-22.0	-4.8	14.9	19.7
	100 SEC.	2.26	-13.3	-4.8	-2.3	-5.3	-7.1	-2.3	-12.4	-4.8	5.3	10.1
	260 SEC.	2.14	-1.3	-0.5	-2.1	-14.9	-2.6	-2.1	-17.5	-0.5	14.9	15.4
	260 SEC.	2.14	-1.3	-0.5	-2.1	-5.3	-2.6	-2.1	-7.9	-0.5	5.3	5.8
LOSS OF FLOW	12 SEC.	2.25	33.3	12.1	-2.3	-14.9	9.8	-2.3	-5.1	12.1	14.9	2.8
		2.25	33.3	12.1	-2.3	-5.3	9.8	-2.3	4.5	12.1	5.3	-6.8
STEAM BREAK	54 SEC.	0.70	197	71.5	-0.7	-14.9	70.8	-0.7	55.9	71.5	14.9	-56.6
		0.70	197	71.5	-0.7	-5.3	70.8	-0.7	65.5	71.5	5.3	-66.2

5. DETAILED ANALYSIS

A) STRESSES - 1. UNCONCENTRATED

TRANSIENT	TIME	PRESS.	$(T_m - T)$	THERM. STRESS $\sigma_z - \sigma_r$	PRESS. STRESS $\sigma_z = \sigma_\theta = \sigma_r$	LOAD STRESS σ_r	TOTAL STRESSES σ_z	TOTAL STRESSES σ_θ	TOTAL STRESSES σ_r	STRESS INTENSITIES $\sigma_z - \sigma_\theta$	STRESS INTENSITIES $\sigma_z - \sigma_r$	STRESS INTENSITIES $\sigma_\theta - \sigma_r$
STEP LOAD	2 MIN.	2.37	-12.0	-4.4	-2.4	-14.9	-6.8	-2.4	-21.7	-4.4	14.9	19.3
REDUCTION	2 MIN.	2.37	-12.0	-4.4	-2.4	-5.3	-6.8	-2.4	-12.1	-4.4	5.3	9.7
FROM 100%	32 MIN.	2.35	-15.0	-5.4	-2.4	-14.9	-7.8	-2.4	-22.7	-5.4	14.9	20.3
TO 50%	32 MIN.	2.35	-15.0	-5.4	-2.4	-5.3	-7.8	-2.4	-13.1	-5.4	5.3	10.7
FULL	104 MIN.	2.15	0	0	-2.2	-14.9	-2.2	-2.2	-17.1	0	14.9	14.9
POWER	104 MIN.	2.15	0	0	-2.2	-5.3	-2.2	-2.2	-7.5	0	5.3	5.3
REACTOR	10 SEC.	2.22	-9.5	-3.4	-2.2	-14.9	-5.6	-2.2	-20.5	-3.4	14.9	18.3
TRIP	10 SEC.	2.22	-9.5	-3.4	-2.2	-5.3	-5.6	-2.2	-10.9	-3.4	5.3	8.7
FROM FULL	65 SEC.	1.91	8.5	3.1	-1.9	-14.9	1.2	-1.9	-13.7	3.1	14.9	11.8
POWER	65 SEC.	1.91	8.5	3.1	-1.9	-5.3	1.2	-1.9	-4.1	3.1	5.3	2.2
PLANT HYDRO	220 MIN.	3.13	0	0	-3.1	-14.9	-3.1	-3.1	-18.0	0	14.9	14.9
AT 3125 PSIA	220 MIN.	3.13	0	0	-3.1	-5.3	-3.1	-3.1	-8.4	0	5.3	5.3
PLANT	~	2.50	-43	-15.6	-2.5	-14.9	-18.1	-2.6	-33.0	-15.6	14.9	30.5
HYDRO		2.50	-43	-15.6	-2.6	-5.3	-18.1	-2.5	-23.4	-15.6	5.3	20.9
AT	~	0.32	43	15.6	-0.3	-14.9	15.3	-0.3	0.4	15.6	14.9	-0.7
2500 PSIA		0.32	43	15.6	-0.3	-5.5	15.3	-0.3	10.0	15.6	5.3	-10.3
STEADY STATE		2.35	6.0	2.2	-2.4	-14.9	-0.2	-2.4	-15.1	2.2	14.9	12.7
FLUCTUATIONS	~	2.35	6.0	2.2	-2.4	-5.3	-0.2	-2.4	-5.5	2.2	5.3	3.1
OF PRESS.	~	2.15	-6.0	-2.2	-2.2	-14.9	-4.4	-2.2	-19.3	-2.2	14.9	17.1
AND TEMP.		2.16	-6.0	-2.2	-2.2	-5.3	-4.4	-2.2	-9.7	-2.2	5.3	7.5
LOSS	10 SEC.	2.76	-30.2	-11.0	-2.8	-14.9	-13.8	-2.8	-28.7	-11.0	14.9	25.9
OF	10 SEC.	2.76	-30.2	-11.0	-2.8	-5.3	-13.8	-2.8	-19.1	-11.0	5.3	16.3
LOAD	28 SEC.	2.12	-41.2	-14.9	-2.1	-14.9	-17.0	-2.1	-31.9	-14.9	14.9	29.8
	28 SEC.	2.12	-41.2	-14.9	-2.1	-5.3	-17.0	-2.1	-22.3	-14.9	5.3	20.2
	160 SEC.	1.44	4.8	1.7	-1.4	-14.9	0.3	-1.4	-14.6	1.7	14.9	13.2
	160 SEC.	1.44	4.8	1.7	-1.4	-5.3	0.3	-1.4	-5.0	1.7	5.3	3.6

S.I. MAX. RANGE $= \sigma_\theta - \sigma_r = 40.8$ KSI $< 3S_m = 69.9$ KSI   CRITERION 5-L.2

COMBUSTION ENGINEERING, INC. JOB NUMBER 5-2042 | 1107
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN. SHEET 12 OF 31
CHARGE NO. _____ DATE 1-27-42 BY ALEXANDER
TION STRUCTURAL ANALYSIS OF CHECK DATE 1-27-42 BY Cowie
CASE SUPPORT ANS

5 DETAILED ANALYSIS
4) STRESSES - KILOGRAMS/SQ.CM.

SUMMARY OF STRESSES AND STRESS INTENSITIES AT LOCATION D

TRANSIENT	TIME	PRESS	(T_m-T)	THERM. STRESS	PRESS. STRESS	LOAD STRESS	TOTAL STRESSES			STRESS INTENSITIES		
				$\sigma_x=\sigma_r$	$\sigma_x+\sigma_\theta+\sigma_r$	σ_r	σ_x	σ_θ	σ_r	$\sigma_x-\sigma_\theta$	$\sigma_x-\sigma_r$	$\sigma_\theta-\sigma_r$
STEADY STATE	~	2.25	0	0	-2.3	5.3	-2.3	-2.3	3.0	0	-5.3	-5.3
HEAT-UP	4 HRS.	2.25	-43	-15.6	-2.3	14.7	-17.9	-2.3	-3.0	-15.6	-14.9	0.7
		2.25	-43	-15.6	-2.3	5.3	-17.9	-2.3	-12.6	-15.6	-5.3	10.3
COOL-DOWN	4 HRS.	0.32	43	15.6	-0.3	14.9	15.3	-0.3	30.2	15.6	-14.9	-30.5
		0.32	43	15.6	-0.3	5.3	15.3	-0.3	20.6	15.6	-5.3	-20.9
PLANT LOADING	20 MIN.	2.25	-7.8	-2.8	-2.3	14.9	-5.1	-2.3	9.8	-2.8	-14.9	-12.1
		2.25	-7.8	-2.8	-2.3	5.3	-5.1	-2.3	0.2	-2.8	-5.3	-2.5
PLANT UNLOADING	20 MIN.	2.25	7.8	2.8	-2.3	14.9	0.5	-2.3	15.4	2.8	-14.9	-17.7
		2.25	7.8	2.8	-2.3	5.3	0.5	-2.3	5.8	2.8	-5.3	-8.1
STEP LOAD	100 SEC.	2.14	11.2	4.1	-2.1	14.9	2.0	-2.1	16.9	4.1	-14.9	-19.0
INCREASE	100 SEC.	2.14	11.2	4.1	-2.1	5.3	2.0	-2.1	7.3	4.1	-5.3	-9.4
10% OF	925 SEC.	2.28	1.7	0.6	-2.3	14.9	-1.7	-2.3	13.2	0.6	-14.9	-15.5
FULL POWER	925 SEC.	2.28	1.7	0.6	-2.3	5.3	-1.7	-2.3	3.6	0.6	-5.3	-5.9
STEP	40 SEC.	2.32	-9.3	-3.4	-2.3	14.9	-5.7	-2.3	9.2	-3.4	-14.9	-11.5
LOAD	40 SEC.	2.32	-9.3	-3.4	-2.3	5.3	-5.7	-2.3	-0.4	-3.4	-5.3	-1.9
DECREASE	100 SEC.	2.26	-13.3	-4.8	-2.3	14.9	-7.1	-2.3	7.8	-4.8	-14.9	-10.1
10% OF	100 SEC.	2.26	-13.3	-4.8	-2.3	5.3	-7.1	-2.3	-1.8	-4.8	-5.3	-0.5
FULL	260 SEC.	2.14	-1.3	-0.5	-2.1	14.9	-2.6	-2.1	12.3	-0.5	-14.9	-14.4
POWER	260 SEC.	2.14	-1.3	-0.5	-2.1	5.3	-2.6	-2.1	2.7	-0.5	-5.3	-4.8
LOSS OF	12 SEC.	2.25	33.3	12.1	-2.3	14.9	9.8	-2.3	24.7	12.1	-14.9	-27.0
FLOW		2.25	33.3	12.1	-2.3	5.3	9.8	-2.3	15.1	12.1	-5.3	-17.4
STEAM	54 SEC.	0.70	197	71.5	-0.7	14.9	70.8	-0.7	85.7	71.5	-14.9	-86.4
BREAK		0.70	197	71.5	-0.7	5.3	70.8	-0.7	76.1	71.5	-5.3	-76.8

COMBUSTION ENGINEERING, INC. NUMBER S-302-0 REV A 3/80
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN. SHEET 32 OF 31
CHARGE NO. DATE 1-27-12 BY AMMINGER
DESCRIPTION STRUCTURAL ANALYSIS OF CHECK DATE 1-27-12 BY CALVERT
CORE SUPPORT BARS

3) STRESSES - FUNCTIONAL WORKING

TRANSIENT	TIME	ΔPRESS.	$(T_M - T)$	THERM. STRESS $\sigma_1 = \sigma_r$	PRESS. STRESS $\sigma_2 = \sigma_\theta - \sigma_r$	LOAD STRESS σ_r	TOTAL STRESSES σ_1	σ_θ	σ_r	STRESS INTENSITIES $\sigma_\theta - \sigma_r$	$\sigma_1 - \sigma_r$	$\sigma_\theta - \sigma_r$
STEP LOAD	2 MIN.	2.37	-12.0	-4.4	-2.4	14.9	-6.8	-2.4	8.1	-4.4	-14.9	-10.5
REDUCTION	2 MIN.	2.37	-12.0	-4.4	-2.4	5.3	-6.8	-2.4	-1.5	-4.4	-5.3	-0.9
FROM 100%	32 MIN.	2.35	-15.0	-5.4	-2.4	14.9	-7.8	-2.4	7.1	-5.4	-14.9	-9.5
TO 50%	32 MIN.	2.35	-15.0	-5.4	-2.4	5.3	-7.8	-2.4	-2.5	-5.4	-5.3	0.1
FULL	104 MIN.	2.15	0	0	-2.2	14.9	-2.2	-2.2	12.7	0	-14.9	-14.9
POWER	104 MIN.	2.15	0	0	-2.2	5.3	-2.2	-2.2	3.1	0	-5.3	-5.3
REACTOR	10 SEC.	2.22	-9.5	-3.4	-2.2	14.9	-5.6	-2.2	7.3	-3.4	-14.9	-11.5
TRIP	10 SEC.	2.22	-9.6	-3.4	-2.2	5.3	-5.6	-2.2	-0.3	-3.4	-5.3	-1.9
FROM FULL	65 SEC.	1.91	8.5	3.1	-1.9	14.9	1.2	-1.9	16.1	3.1	-14.9	-18.0
POWER	65 SEC.	1.91	8.5	3.1	-1.9	5.3	1.2	-1.9	6.6	3.1	-5.3	-8.4
PLANT HYDRO	220 MIN.	3.13	0	0	-3.1	14.9	-3.1	-3.1	11.8	0	-14.9	-14.9
AT 2125 PSIA	220 MIN.	3.13	0	0	-3.1	5.3	-3.1	-3.1	2.2	0	-5.3	-5.3
PLANT	~	2.50	-4.3	-15.6	-2.5	14.9	-18.1	-2.5	-3.2	-15.6	-14.9	0.7
HYDRO	~	2.50	-4.3	-15.6	-2.5	5.3	-18.1	-2.5	-12.8	-15.6	-5.3	-15.3
AT	~	0.32	4.3	15.6	-0.3	14.9	15.3	-0.3	30.2	15.6	-14.9	-30.5
2500 PSIA		0.32	4.3	15.6	-0.3	5.3	15.3	-0.3	20.6	15.6	-5.3	-20.9
STEADY STATE		2.35	6.0	2.2	-2.4	14.9	-0.2	-2.4	14.7	2.2	-14.9	-17.1
FLUCTUATING	~	2.35	6.0	2.2	-2.4	5.3	-0.2	-2.4	5.1	2.2	-5.3	-7.5
OF PRESS.	~	2.15	-6.0	-2.2	-2.2	14.9	-4.4	-2.2	10.5	-2.2	-14.9	-12.7
AND TEMP.		2.15	-6.0	-2.2	-2.2	5.3	-4.4	-2.2	0.9	-2.2	-5.3	-3.1
	10 SEC.	2.76	-30.2	-11.0	-2.8	14.9	-13.8	-2.8	1.1	-11.0	-14.9	-3.9
LOSS	10 SEC.	2.76	-30.2	-11.0	-2.8	5.3	-13.8	-2.8	-8.5	-11.0	-5.3	5.7
OF	28 SEC.	2.12	-41.2	-14.9	-2.1	14.9	-17.0	-2.1	-2.1	-14.9	-14.9	0
LOAD	28 SEC.	2.12	-41.2	-14.9	-2.1	5.3	-17.0	-2.1	-11.7	-14.9	-5.3	9.6
	160 SEC.	1.44	4.8	1.7	-1.4	14.9	0.3	-1.4	15.2	1.7	-14.9	-16.6
	160 SEC.	1.44	4.8	1.7	-1.4	5.3	0.3	-1.4	5.6	1.7	-5.3	-7.0

S_I MAX. RANGE = $\sigma_\theta - \sigma_r$ = 10.1 KSI < $3S_m$ = 69 KSI

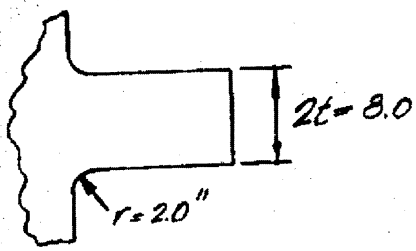
CENTERLINE 5-C-2

5. DETAILED ANALYSIS

f.) STRESSES

2. CONCENTRATED

IN ORDER TO REPERFORM THE FATIGUE EVALUATION, PEAK STRESSES MUST BE KNOWN AT POINTS "A", "B", "C" AND "D" (SEE PAGE 11). THE STRESS EXPRESSIONS GIVEN ON SHEETS 12 & 13 WILL BE MODIFIED TO ACCOUNT FOR STRESS CONCENTRATIONS. STRESS CONCENTRATION FACTORS FOR BENDING AND TENSION WILL BE DETERMINED BY THE METHOD PRESENTED IN REF. 3.



$$\frac{r}{t} = \frac{2}{4} = 0.50$$

FROM FIG. A.7-1 OF REF. 3

K_T = STRESS CONC. FACTOR FOR TENSILE STRESSES = 1.80
K_B = " " " " BENDING " = 1.50

APPLYING THE APPROPRIATE S.C.F. TO THE STRESS EXPRESSIONS PREVIOUSLY DERIVED YIELDS:

FOR THERMAL STRESSES -
POINTS 'A' AND 'B'

$$\sigma_t = \sigma_\theta = K_T \frac{E\alpha}{1-\nu}(T_M - T) = 0.55028\,(T_M - T)$$

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

NUMBER S-201-P A 310
SHEET 22 OF 31
DATE 1-27-67 BY ALEXANDER
CHECK DATE 1-27-67 BY CAUDLE

5. DETAILED ANALYSIS

f.) STRESSES

2. CONCENTRATED

POINTS "C" AND "D"

$$\sigma_x - \sigma_r = K_T \frac{E\alpha}{1-\nu}(T_M - T) = 0.65313\,(T_m - T)$$

FOR PRESSURE STRESSES -

POINT "A"

$\sigma_x = K_T\ 5.285\ P = 9.513\ P$
$\sigma_\theta = K_T\ 8.671\ P = 15.608\ P$
$\sigma_r = -K_T P = -1.80\ P$

POINT "B"

$\sigma_x = K_T\ 9.358\ P = 16.844\ P$
$\sigma_\theta = K_T\ 8.490\ P = 15.282\ P$
$\sigma_r = -K_T P = -1.80\ P$

POINTS "C" AND "D"

$\sigma_x = \sigma_\theta = \sigma_r = -K_T P = -1.80\ P$

FOR STRESSES DUE TO APPLIED LOADS -

POINT "A"

$$\sigma_r = -K_B \frac{Mc}{I_{YY}} = K_B \begin{pmatrix} -8.6\ KSI \\ -3.1\ KSI \end{pmatrix} = \begin{matrix} -12.9\ KSI \\ -4.7\ KSI \end{matrix}$$

POINT "B"

$$\sigma_r = K_B \begin{pmatrix} 8.6\ KSI \\ 3.1\ KSI \end{pmatrix} = \begin{matrix} 12.9\ KSI \\ 4.7\ KSI \end{matrix}$$

POINT "C"

$$\sigma_r = -K_B \frac{Mc}{I_{YY}} = K_B \begin{pmatrix} -14.9 \\ -5.3 \end{pmatrix} = \begin{matrix} -22.4\ KSI \\ -8.0\ KSI \end{matrix}$$

POINT "D" $\sigma_r = K_B \begin{pmatrix} 14.9 \\ 5.3 \end{pmatrix} = \begin{matrix} 22.4\ KSI \\ 8.0\ KSI \end{matrix}$

NOTE: DUE TO THE SYMMETRY OF POINTS C AND D ONLY POINT C WILL BE GIVEN IN THE FOLLOWING TABLES AND FATIGUE CURVES.

COMBUSTION ENGINEERING, INC. NUMBER 5-201-P-1.311
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN. SHEET 23 OF 31
CHARGE NO. DATE 1-27-67 BY ALEXANDER
SECTION STRUCTURAL ANALYSIS OF CHECK DATE 1-27-67 BY GRUBE
CORE SUPPORT PADS
5. DETAILED ANALYSIS
5.1 STRESSES - 2. CONCENTRATED

SUMMARY OF STRESSES AND STRESS INTENSITIES AT LOCATION A

TRANSIENT	TIME	PRESS (KSI)	$(T_m - T)$	FROM $\sigma_z - \sigma_\theta$	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	21.4	35.1	-4.1	-4.7	21.4	35.1	-8.8	-13.7	30.2	43.7
HEAT-UP	4.47 HRS.	2.25	-43	-23.7	21.4	35.1	-4.1	-12.9	-2.3	11.4	-17.0	-13.7	14.7	28.4
		2.25	-43	-23.7	21.4	35.1	-4.1	-4.7	-2.3	11.4	-8.8	-13.7	6.5	20.2
COOLDOWN	4.47 HRS.	0.32	43	23.7	3.0	5.0	-0.6	-12.9	24.7	28.7	-13.5	-2.0	40.2	42.2
		0.32	43	23.7	3.0	5.0	-0.6	-4.7	24.7	28.7	-5.3	-2.0	32.0	34.0
PLANT LOADING	20 MIN	2.25	-7.8	-4.3	21.4	35.1	-4.1	-12.9	17.1	30.8	-17.0	-13.7	34.1	47.8
		2.25	-7.8	-4.3	21.4	35.1	-4.1	-4.7	17.1	30.8	-8.8	-13.7	25.9	39.6
PLANT UNLOADING	20 MIN	2.25	7.8	4.3	21.4	35.1	-4.1	-12.9	25.7	39.4	-17.0	-13.7	42.7	56.4
		2.25	7.8	4.3	21.4	35.1	-4.1	-4.7	25.7	39.4	-8.8	-13.7	34.5	48.2
STEP LOAD	110 SEC.	2.14	11.2	6.2	20.4	33.4	-3.9	-12.9	26.6	39.6	-16.8	-13.0	43.4	56.4
INCREASE	110 SEC.	2.14	11.2	6.2	20.4	33.4	-3.9	-4.7	26.6	39.6	-8.6	-13.0	35.2	48.2
10% OF	225 SEC.	2.28	1.7	0.9	21.7	35.6	-4.1	-12.9	22.6	36.5	-17.0	-12.9	39.6	53.5
FULL POWER	225 SEC.	2.28	1.7	0.9	21.7	35.6	-4.1	-4.7	22.6	36.5	-8.8	-12.9	31.4	45.3
STEP	40 SEC.	2.32	-9.3	-5.1	22.1	36.2	-4.2	-12.9	17.0	31.1	-17.1	-14.1	34.1	48.2
LOAD	40 SEC.	2.32	-9.3	-5.1	22.1	36.2	-4.2	-4.7	17.0	31.1	-8.9	-14.1	25.9	40.0
DECREASE	100 SEC.	2.26	-13.3	-7.3	21.5	35.3	-4.1	-12.9	14.2	28.0	-17.0	-13.8	31.2	45.0
10% OF	110 SEC.	2.26	-13.3	-7.3	21.5	35.3	-4.1	-4.7	14.2	28.0	-8.8	-13.8	23.0	36.8
FULL	260 SEC.	2.14	-1.3	-0.7	20.4	33.4	-3.9	-12.9	19.7	32.7	-16.8	-13.0	36.5	49.5
POWER	260 SEC.	2.14	-1.3	-0.7	20.4	33.4	-3.9	-4.7	19.7	32.7	-8.6	-13.0	28.3	41.3
LOSS OF	12 SEC.	2.25	33.3	18.3	21.4	35.1	-4.1	-12.9	39.7	53.4	-17.0	-12.7	56.7	70.4
FLOW		2.26	33.3	18.3	21.4	35.1	-4.1	-4.7	39.7	53.4	-8.8	-13.7	48.5	62.2
STEAM	54 SEC.	0.70	197	108.4	6.7	10.9	-1.3	-12.9	115.1	119.3	-14.2	-4.2	129.3	133.5
BREAK		0.70	197	108.4	6.7	10.9	-1.3	-4.7	115.1	119.3	-6.0	-4.2	121.1	125.3

SECTION: STRUCTURAL ANALYSIS OF CORE SUPPORT BARREL

5. DETAILED ANALYSIS

e) STRESSES - 2 DIMENSIONAL

TRANSIENT	TIME	PRESS. (KSI)	$(T_m - T)$	THERM. STRESS	PRESSURE STRESSES			LOAD STRESS	TOTAL STRESSES			STRESS INTENSITIES		
				$\sigma_z = \sigma_\theta$	σ_z	σ_θ	σ_r	σ_r	σ_z	σ_θ	σ_r	$\sigma_z - \sigma_\theta$	$\sigma_z - \sigma_r$	$\sigma_\theta - \sigma_r$
STEP LOAD	2 MIN.	2.37	-12.0	-6.6	22.5	37.0	-4.3	-12.9	15.9	30.4	-17.2	-14.5	33.1	47.6
REDUCTION	2 MIN.	2.37	-12.0	-6.6	22.5	37.0	-4.3	-4.7	15.9	30.4	-9.0	-14.5	24.9	39.4
FROM 100%	32 MIN.	2.35	-15.0	-8.3	22.4	36.7	-4.2	-12.9	14.1	28.4	-17.1	-14.3	31.2	45.5
TO 50%	32 MIN.	2.35	-15.0	-8.3	22.4	36.7	-4.2	-4.7	14.1	28.4	-8.9	-14.3	23.0	37.3
FULL	104 MIN.	2.15	0	0	20.5	33.6	-3.9	-12.9	20.5	33.6	-16.8	-13.1	37.3	50.4
POWER	104 MIN.	2.15	0	0	20.5	33.6	-3.9	-4.7	20.5	33.6	-8.6	-13.1	29.1	42.2
REACTOR	10 SEC.	2.22	-9.5	-5.2	21.1	34.6	-4.0	-12.9	15.9	29.4	-16.9	-13.5	32.8	46.3
TRIP FROM	10 SEC.	2.22	-9.5	-5.2	21.1	34.6	-4.0	-4.7	15.9	29.4	-8.7	-13.5	24.6	38.1
FULL	65 SEC.	1.91	8.5	4.7	18.2	29.8	-3.4	-12.9	22.9	34.5	-16.3	-11.6	39.2	50.8
POWER	65 SEC.	1.91	8.5	4.7	18.2	29.8	-3.4	-4.7	22.9	34.5	-8.1	-11.6	31.0	42.6
PLANT HYDRO	220 MIN.	3.13	0	0	29.8	48.9	-5.6	-12.9	29.8	48.9	-18.5	-19.1?	48.3	67.4
AT 3125 PSIA	220 MIN.	3.13	0	0	29.8	48.9	-5.6	-4.7	29.8	48.9	-10.3	-19.1	40.1	59.2
PLANT	~	2.50	-43	-23.7	23.8	39.0	-4.6	-12.9	0.1	15.3	-17.4	-15.2	17.5	32.7
HYDRO		2.50	-43	-23.7	23.8	39.0	-4.6	-4.7	0.1	15.3	-9.2	-15.2	9.3	24.5
AT	~	0.32	43	23.7	3.0	5.0	-0.6	-12.9	26.7	28.7	-13.5	-2.0	40.2	42.2
2500 PSIA		0.32	43	23.7	3.0	5.0	-0.6	-4.7	26.7	28.7	-5.3	-2.0	32.0	34.0
STEADY STATE	~	2.35	6.0	3.3	22.4	36.7	-4.2	-12.9	25.7	40.0	-17.1	-14.3	42.8	57.1
FLUCTUATIONS		2.35	6.0	3.3	22.4	36.7	-4.2	-4.7	25.7	40.0	-8.9	-14.3	34.6	48.9
OF PRESS.	~	2.15	-6.0	-3.3	20.5	33.6	-3.9	-12.9	17.2	30.3	-16.8	-13.1	34.0	47.1
AND TEMP.		2.15	-6.0	-3.3	20.5	33.6	-3.9	-4.7	17.2	30.3	-8.6	-13.1	25.8	38.9
LOSS	10 SEC.	2.76	-30.2	-16.6	26.3	43.1	-5.0	-12.9	9.7	26.5	-17.9	-16.8	27.6	44.4
OF	10 SEC.	2.76	-30.2	-16.6	26.3	43.1	-5.0	-4.7	9.7	26.5	-9.7	-16.8	19.4	36.2
LOAD	28 SEC.	2.12	-41.2	-22.7	20.2	33.1	-3.8	-12.9	-2.5	10.4	-16.7	-12.9	14.2	27.1
	28 SEC.	2.12	-41.2	-22.7	20.2	33.1	-3.8	-4.7	-2.5	10.4	-8.5	-12.9	6.0	18.9
	140 SEC.	1.44	4.8	2.6	13.7	22.6	-2.6	-12.9	16.3	25.1	-15.5	-8.8	31.8	40.6
	140 SEC.	1.44	4.8	2.6	13.7	22.6	-2.6	-4.7	16.3	25.1	-7.3	-8.8	23.6	32.4

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

CHARGE NO. _____ SHEET 22 OF 24

DESCRIPTION STRUCTURAL ANALYSIS OF CHECK DATE 1-27-67 BY CAUSE

CORE SUPPORT PADS

NUMBER 5-20-[illegible]

BY M ALEXANDER

DATE 1-27-67

S. GETTLER ANALYSIS

1) STRESS - 2 GAUGE NITRONIC

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	~	2.25	0	0	37.9	34.4	-4.1	4.7	37.9	34.4	0.6	3.5	37.3	33.9
HEAT-UP	4.47 HRS.	2.25	-43	-23.7	37.9	34.4	-4.1	12.9	14.2	10.7	8.8	3.5	5.4	1.9
		2.25	-43	-23.7	37.9	34.4	-4.1	4.7	14.2	10.7	0.6	3.5	13.6	10.1
COOLDOWN	4.47 HRS.	0.32	43	23.7	5.4	4.9	-0.6	12.9	29.1	28.6	12.3	0.5	16.8	16.3
		0.32	43	23.7	5.4	4.9	-0.6	4.7	29.1	28.6	4.1	0.5	25.0	24.5
PLANT LOADING	20 MIN	2.25	-7.8	-4.3	37.9	34.4	-4.1	12.9	33.6	30.1	8.8	3.5	24.8	21.3
		2.25	-7.8	-4.3	37.9	34.4	-4.1	4.7	33.6	30.1	0.6	3.5	33.0	29.5
PLANT UNLOADING	20 MIN	2.25	7.8	4.3	37.9	34.4	-4.1	12.9	42.2	38.7	8.8	3.5	33.4	29.9
		2.25	7.8	4.3	37.9	34.4	-4.1	4.7	42.2	38.7	0.6	3.5	41.6	38.1
STEP LOAD	100 SEC.	2.14	11.2	6.2	36.0	32.7	-3.9	12.9	42.2	38.9	9.0	3.3	33.2	29.9
INCREASE	100 SEC.	2.14	11.2	6.2	36.0	32.7	-3.9	4.7	42.0	38.9	0.8	3.3	41.4	38.1
10% OF	110 SEC	2.28	1.7	0.9	38.4	34.8	-4.1	12.9	39.3	35.7	8.8	3.6	30.5	26.9
FULL POWER	110 SEC	2.28	1.7	0.9	38.4	34.8	-4.1	4.7	39.3	35.7	0.6	3.6	38.7	35.1
STEP	40 SEC.	2.32	-9.3	-5.1	39.1	35.5	-4.2	12.9	34.0	30.4	8.7	3.6	25.3	21.7
LOAD	40 SEC.	2.32	-9.3	-5.1	39.1	35.6	-4.2	4.7	34.0	30.4	0.5	3.6	33.5	29.9
DECREASE	100 SEC.	2.26	-13.3	-7.3	38.1	34.5	-4.1	12.9	30.8	27.2	8.8	3.6	22.0	18.4
10% OF	110 SEC.	2.26	-13.3	-7.3	38.1	34.5	-4.1	4.7	30.8	27.2	0.6	3.6	30.2	26.6
FULL	240 SEC	2.14	-1.3	-0.7	36.0	32.7	-3.9	12.9	35.3	32.0	9.0	3.3	26.3	23.0
POWER	240 SEC.	2.14	-1.3	-0.7	36.0	32.7	-3.9	4.7	35.3	32.0	0.8	3.3	34.5	31.2
LOSS OF	12 SEC.	2.25	33.3	18.3	37.9	34.4	-4.1	12.9	56.2	52.7	8.8	3.5	47.4	43.9
FLOW		2.26	33.3	18.3	37.9	34.4	-4.1	4.7	56.2	52.7	0.6	3.5	55.6	52.1
STEAM	54 SEC.	0.70	197	108.4	11.8	10.7	-1.3	12.9	120.2	119.1	11.6	1.1	108.6	107.5
BREAK		0.70	197	108.4	11.8	10.7	-1.3	4.7	120.2	119.1	3.4	1.1	116.8	115.7

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

CHANGE NO. _____ SHEET 26 OF 31

DESCRIPTION STRUCTURAL ANALYSIS OF CORE SUPPORT BAR BY ALEXANDER

DATE 1-27-67 CHECK DATE 1-27-67 BY CAMPLE

5. DETAILED ANALYSIS

5.1 STRESSES - 2 DIMENSIONAL

TRANSIENT	TIME	PRESS. (KSI)	$(T_m - T)$	THERM. STRESS $\sigma_t = \sigma_\theta$	PRESSURE STRESSES σ_r	σ_θ	σ_z	LOAD STRESS σ_z	TOTAL STRESSES σ_1	σ_θ	σ_r	STRESS INTENSITIES $\sigma_1 - \sigma_\theta$	$\sigma_1 - \sigma_r$	$\sigma_\theta - \sigma_r$
STEP LOAD	2 MIN.	2.37	-12.0	-6.6	39.9	36.2	-4.3	12.9	33.3	29.6	8.6	3.7	24.7	21.0
REDUCTION	2 MIN.	2.37	-12.0	-6.6	39.9	36.2	-4.3	4.7	33.3	29.6	0.4	3.7	32.9	29.2
FROM 100%	32 MIN.	2.35	-15.0	-8.3	39.6	35.9	-4.2	12.9	31.3	27.6	8.7	3.7	22.6	18.9
TO 50%	32 MIN.	2.35	-15.0	-8.3	39.6	35.9	-4.2	4.7	31.3	27.6	0.5	3.7	30.8	27.1
FULL	104 MIN.	2.15	0	0	36.2	32.9	-3.9	12.9	36.2	32.9	9.0	3.3	27.2	23.9
POWER	104 MIN.	2.15	0	0	36.2	32.9	-3.9	4.7	36.2	32.9	0.8	3.3	35.4	32.1
REACTOR	10 SEC.	2.22	9.5	-5.2	37.4	33.9	-4.0	12.9	32.2	28.7	8.9	3.5	23.3	19.8
TRIP FROM	10 SEC.	2.22	9.5	-5.2	37.4	33.9	-4.0	4.7	32.2	28.7	0.7	3.5	31.5	28.0
FULL	65 SEC.	1.91	8.5	4.7	32.2	29.2	-3.4	12.9	36.9	33.9	9.5	3.0	27.4	24.4
POWER	65 SEC.	1.91	8.5	4.7	32.2	29.2	-3.4	4.7	36.9	33.9	1.3	3.0	35.6	32.6
PLANT HYDRO	220 MIN.	3.13	0	0	52.7	47.8	-5.6	12.9	52.7	47.8	7.3	4.9	45.4	40.5
AT 2126 PSIA	220 MIN.	3.13	0	0	52.7	47.8	-5.6	4.7	52.7	47.8	-0.9	4.9	53.6	48.7
PLANT	~	2.50	-43	-23.7	42.1	38.2	-4.5	12.9	18.4	14.5	8.4	3.9	10.0	6.1
HYDRO		2.50	-43	-23.7	42.1	38.2	-4.5	4.7	18.4	14.5	0.2	3.9	18.2	14.3
AT	~	0.32	43	23.7	5.4	4.9	-0.6	12.9	29.1	28.6	12.3	0.5	16.8	16.3
2500 PSIA		0.32	43	23.7	5.4	4.9	-0.6	4.7	29.1	28.6	4.1	0.5	25.0	24.5
STEADY STATE	~	2.35	6.0	3.3	39.6	35.9	-4.2	12.9	42.9	39.2	8.7	3.7	34.2	30.6
FLUCTUATIONS		2.35	6.0	3.3	39.6	35.9	-4.2	4.7	42.9	39.2	0.5	3.7	42.4	38.7
OF PRESS.	~	2.15	-6.0	-3.3	36.2	32.9	-3.9	12.9	32.9	29.6	9.0	3.3	23.9	20.6
AND TEMP.		2.15	-6.0	-3.3	36.2	32.9	-3.9	4.7	32.9	29.6	0.8	3.3	32.1	28.8
	10 SEC.	2.76	-30.2	-16.6	46.5	42.2	-5.0	12.9	29.9	25.6	7.9	4.3	22.0	17.7
LOSS	10 SEC.	2.76	-30.2	-16.6	46.5	42.2	-5.0	4.7	29.9	25.6	-0.3	4.3	30.2	25.9
OF	28 SEC.	2.12	-41.2	-22.7	35.7	32.4	-3.8	12.9	13.0	9.7	9.1	3.3	3.9	0.6
LOAD	28 SEC.	2.12	-41.2	-22.7	35.7	32.4	-3.8	4.7	13.0	9.7	0.9	3.3	12.1	8.8
	100 SEC.	1.44	4.8	2.6	24.3	22.0	-2.6	12.9	26.9	24.6	10.3	2.3	16.6	14.3
	100 SEC.	1.44	4.8	2.6	24.3	22.0	-2.6	4.7	26.9	24.6	2.1	2.3	24.8	22.5

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

CHARGE NO. ______
DESCRIPTION STRUCTURAL ANALYSIS OF CORE SUPPORT PADS

DATE 1-27-67 BY [illegible]
CHECK DATE 1-27-67 BY [illegible]

A 37

5 DETAILED ANALYSIS
5.2 STRESSES - 2 [illegible]

SUMMARY OF STRESSES AND STRESS INTENSITIES AT LOCATION C*

TRANSIENT	TIME	PRESS.	$(T_m - T)$	THERM. STRESS $\sigma_z = \sigma_r$	PRESS. STRESS $\sigma_z = \sigma_\theta = \sigma_r$	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	~	2.25	0	0	-4.1	-8.0	-4.1	-4.1	-12.1	0	8.0	8.0
HEAT-UP	4.47 HRS.	2.25	-43	-28.1	-4.1	-22.4	-32.2	-4.1	-54.6	-28.1	22.4	50.5
		2.25	-43	-28.1	-4.1	-8.0	-32.2	-4.1	-40.2	-28.1	8.0	36.1
COOL-DOWN	4.47 HRS.	0.32	43	28.1	-0.6	-22.4	27.5	-0.6	5.1	28.1	22.4	-5.7
		0.32	43	28.1	-0.6	-8.0	27.5	-0.6	19.5	28.1	8.0	-20.1
PLANT LOADING	20 MIN.	2.25	-7.8	-5.1	-4.1	-22.4	-9.2	-4.1	-31.6	-5.1	22.4	27.5
		2.25	-7.8	-5.1	-4.1	-8.0	-9.2	-4.1	-17.2	-5.1	8.0	13.1
PLANT UNLOADING	20 MIN.	2.25	7.8	5.1	-4.1	-22.4	1.0	-4.1	-21.4	5.1	22.4	17.3
		2.25	7.8	5.1	-4.1	-8.0	1.0	-4.1	-7.0	5.1	8.0	2.9
STEP LOAD	100 SEC.	2.14	11.2	7.3	-3.9	-22.4	3.4	-3.9	-19.0	7.3	22.4	15.1
INCREASE	100 SEC.	2.14	11.2	7.3	-3.9	-8.0	3.4	-3.9	-4.6	7.3	8.0	0.7
10% OF	225 SEC.	2.28	1.7	1.1	-4.1	-22.4	-3.0	-4.1	-25.4	1.1	22.4	21.3
FULL POWER	225 SEC.	2.28	1.7	1.1	-4.1	-8.0	-3.0	-4.1	-11.0	1.1	8.0	6.9
STEP	40 SEC.	2.32	-9.3	-6.1	-4.2	-22.4	-10.3	-4.2	-32.7	-6.1	22.4	28.5
LOAD	40 SEC.	2.32	-9.3	-6.1	-4.2	-8.0	-10.3	-4.2	-18.3	-6.1	8.0	14.1
DECREASE	100 SEC.	2.26	-13.3	-8.7	-4.1	-22.4	-12.8	-4.1	-35.2	-8.7	22.4	31.1
10% OF	100 SEC.	2.26	-13.3	-8.7	-4.1	-8.0	-12.8	-4.1	-20.8	-8.7	8.0	16.7
FULL	260 SEC.	2.14	-1.3	-0.8	-3.9	-22.4	-4.7	-3.9	-27.1	-0.8	22.4	23.2
POWER	260 SEC.	2.14	-1.3	-0.8	-3.9	-8.0	-4.7	-3.9	-12.7	-0.8	8.0	8.8
LOSS OF FLOW	12 SEC.	2.25	33.3	21.7	-4.1	-22.4	17.6	-4.1	-4.8	21.7	22.4	0.7
		2.25	33.3	21.7	-4.1	-8.0	17.6	-4.1	9.6	21.7	8.0	-13.7
STEAM BREAK	54 SEC.	0.70	197	128.7	-1.3	-22.4	127.4	-1.3	105.0	128.7	22.4	-106.3
		0.70	197	128.7	-1.3	-8.0	127.4	-1.3	119.4	128.7	8.0	-120.7

* DUE TO THE SYMMETRY BETWEEN POINTS C AND D, POINT D WILL NOT BE SHOWN HERE.

COMBUSTION ENGINEERING, INC. NUMBER 5-204-C | A.S.M.E.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN. SHEET 28 OF 41
CHARGE NO. DATE 1-22-67 BY ANDERSON
DESCRIPTION STRUCTURAL ANALYSIS OF CHECK DATE 1-22-67 BY CAUSE
CORE SUPPORT PADS

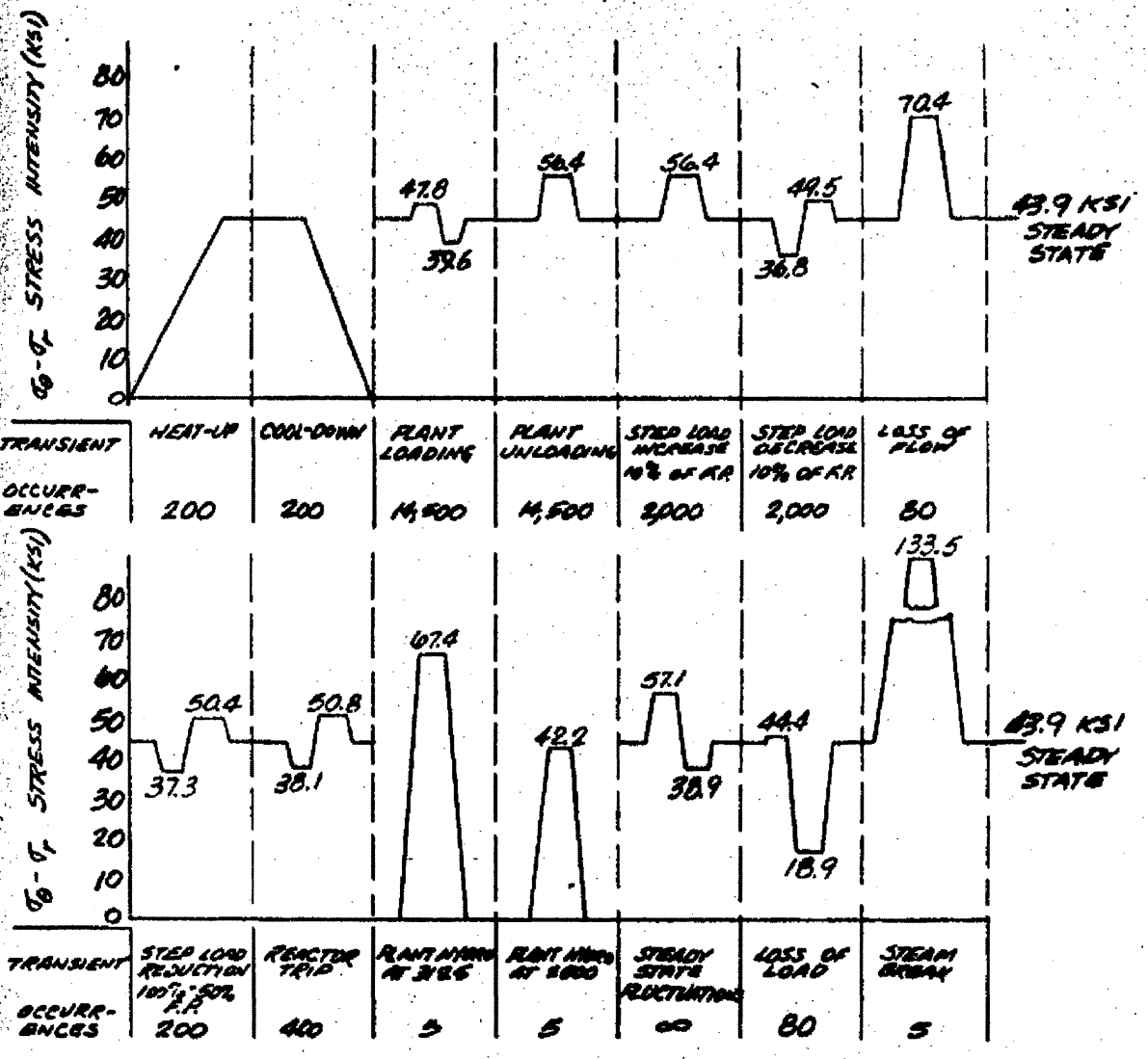
5) DETAILED ANALYSIS
a) STRESSES - 2. CONTINUED

TRANSIENT	TIME	PRESS.	$(T_M - T)$	THERM. STRESS	PRESS STRESS	LOAD STRESS	TOTAL STRESSES			STRESS INTENSITIES		
				$\sigma_z - \sigma_r$	$\sigma_\theta - \sigma_r - \sigma_r$	σ_r	σ_z	σ_θ	σ_r	$\sigma_\theta - \sigma_r$	$\sigma_z - \sigma_r$	$\sigma_\theta - \sigma_r$
STEP LOAD	2 MIN.	2.37	-12.0	-7.8	-4.3	-22.4	-12.1	-4.3	-34.5	-7.8	22.4	30.2
REDUCTION	2 MIN.	2.37	-12.0	-7.8	-4.3	-8.0	-12.1	-4.3	-20.1	-7.8	8.0	15.8
FROM 100%	3.2 MIN.	2.35	-15.0	-9.8	-4.2	-22.4	-14.0	-4.2	-36.4	-9.8	22.4	32.2
TO 50%	3.2 MIN.	2.35	-15.0	-9.8	-4.2	-8.0	-14.0	-4.2	-22.0	-9.8	8.0	17.8
FULL	10.4 MIN.	2.15	0	0	-3.9	-22.4	-3.9	-3.9	-26.3	0	22.4	22.4
POWER	10.4 MIN.	2.15	0	0	-3.9	-8.0	-3.9	-3.9	-11.9	0	8.0	8.0
REACTOR	10 SEC.	2.22	-9.5	-6.2	-4.0	-22.4	-10.2	-4.0	-32.6	-6.2	22.4	28.6
TRIP	10 SEC.	2.22	-9.5	-6.2	-4.0	-8.0	-10.2	-4.0	-18.2	-6.2	8.0	14.2
FROM FULL	65 SEC.	1.91	8.5	5.6	-3.4	-22.4	2.2	-3.4	-20.2	5.6	22.4	16.8
POWER	65 SEC.	1.91	8.5	5.6	-3.4	-8.0	2.2	-3.4	-5.8	5.6	8.0	2.4
PLANT HYDRO	220 MIN.	3.13	0	0	-5.6	-22.4	-5.6	-5.6	-28.0	0	22.4	22.4
AT 3125 PSIA	220 MIN.	3.13	0	0	-5.6	-8.0	-5.6	-5.6	-13.6	0	8.0	8.0
PLANT		2.50	-4.3	-28.1	-4.5	-22.4	-32.6	-4.5	-55.0	-28.1	22.4	50.5
HYDRO	~	2.50	-4.3	-28.1	-4.5	-8.0	-32.6	-4.5	-40.6	-28.1	8.0	36.1
AT	~	0.32	4.3	28.1	-0.6	-22.4	27.5	-0.6	5.1	28.1	22.4	-5.7
2500 PSIA		0.32	4.3	28.1	-0.6	-8.0	27.5	-0.6	19.5	28.1	8.0	-20.1
STEADY STATE		2.35	6.0	3.9	-4.2	-22.4	-0.3	-4.2	-22.7	3.9	22.4	18.5
FLUCTUATIONS	~	2.35	6.0	3.9	-4.2	-8.0	-0.3	-4.2	-8.3	3.9	8.0	4.1
OF PRESS.	~	2.15	-6.0	-3.9	-3.9	-22.4	-7.8	-3.9	-30.2	-3.9	22.4	26.3
AND TEMP.		2.16	-6.0	-3.9	-3.9	-8.0	-7.8	-3.9	-15.8	-3.9	8.0	11.9
	10 SEC.	2.76	-30.2	-19.7	-5.0	-22.4	-24.7	-5.0	-47.1	-19.7	22.4	42.1
LOSS	10 SEC.	2.76	-30.2	-19.7	-5.0	-8.0	-24.7	-5.0	-32.7	-19.7	8.0	27.7
OF	28 SEC.	2.12	-41.2	-26.9	-3.8	-22.4	-30.7	-3.8	-53.1	-26.9	22.4	49.3
LOAD	28 SEC.	2.12	-41.2	-26.9	-3.8	-8.0	-30.7	-3.8	-38.7	-26.9	8.0	34.9
	160 SEC.	1.44	4.8	3.1	-2.6	-22.4	0.5	-2.6	-21.9	3.1	22.4	19.3
	160 SEC.	1.44	4.8	3.1	-2.6	-8.0	0.5	-2.6	-7.5	3.1	8.0	4.9

5 DETAILED ANALYSIS

9) FATIGUE EVALUATION

$S_0 - S_i$ AT LOCATION A



$S_{max.}$	$S_{min.}$	NUMBER OF OCCURRENCES	S_a	N^*	U
133.5	0	5	66.8	1800	0.00277
70.4	0	80	35.2	12,000	0.00666
67.4	0	5	33.7	15,000	0.00033
57.1	0	115	28.6	25,000	0.00460
42.2	0	5	21.1	80,000	0.00006
57.1	18.9	80	19.1	110,000	0.00072
57.1	36.9	2000	10.2	∞	0

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

$U_{max.} = 0.01514$

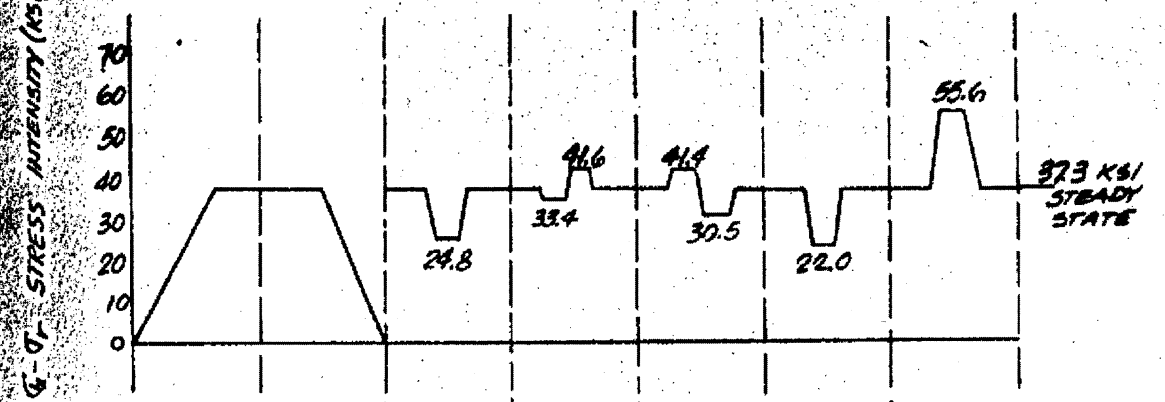
COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.

NUMBER 5-211-2 Add 316
SHEET 30 OF 31
DATE 1-27-67 BY ALEXANDER
CHECK DATE 1-27-67 BY CAUDLE

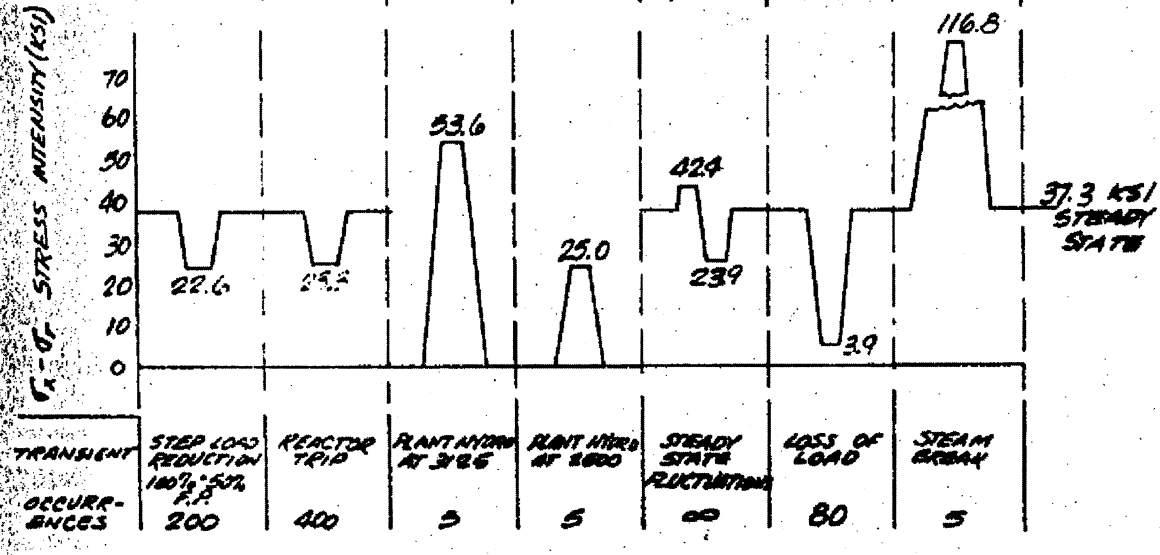
DESCRIPTION STRUCTURAL ANALYSIS OF CORE SUPPORT PADS

5 DETAILED ANALYSIS

9) FATIGUE EVALUATION $\sigma_1 - \sigma_3$ AT LOCATION B



TRANSIENT	HEAT-UP	COOL-DOWN	PLANT LOADING	PLANT UNLOADING	STEP LOAD INCREASE 10% OF RR	STEP LOAD DECREASE 10% OF RR	LOSS OF FLOW
OCCURRENCES	200	200	14,500	14,500	2,000	2,000	80



TRANSIENT	STEP LOAD REDUCTION 100% - 50% F.P.	REACTOR TRIP	PLANT HYDRO AT 3125	PLANT HYDRO AT 2800	STEADY STATE FLUCTUATIONS	LOSS OF LOAD	STEAM BREAK
OCCURRENCES	200	400	5	5	∞	80	5

$S_{max.}$	$S_{min.}$	NUMBER OF OCCURRENCES	S_a	N*	U
116.8	0	5	58.4	2700	0.00185
55.6	0	80	27.8	27,000	0.00296
53.6	0	5	26.8	31,000	0.00016
42.4	0	115	21.2	80,000	0.00143
42.4	3.9	80	19.3	110,000	0.00072
25.0	0	5	12.5	∞	0

$U_{TOTAL} = 0.00712$

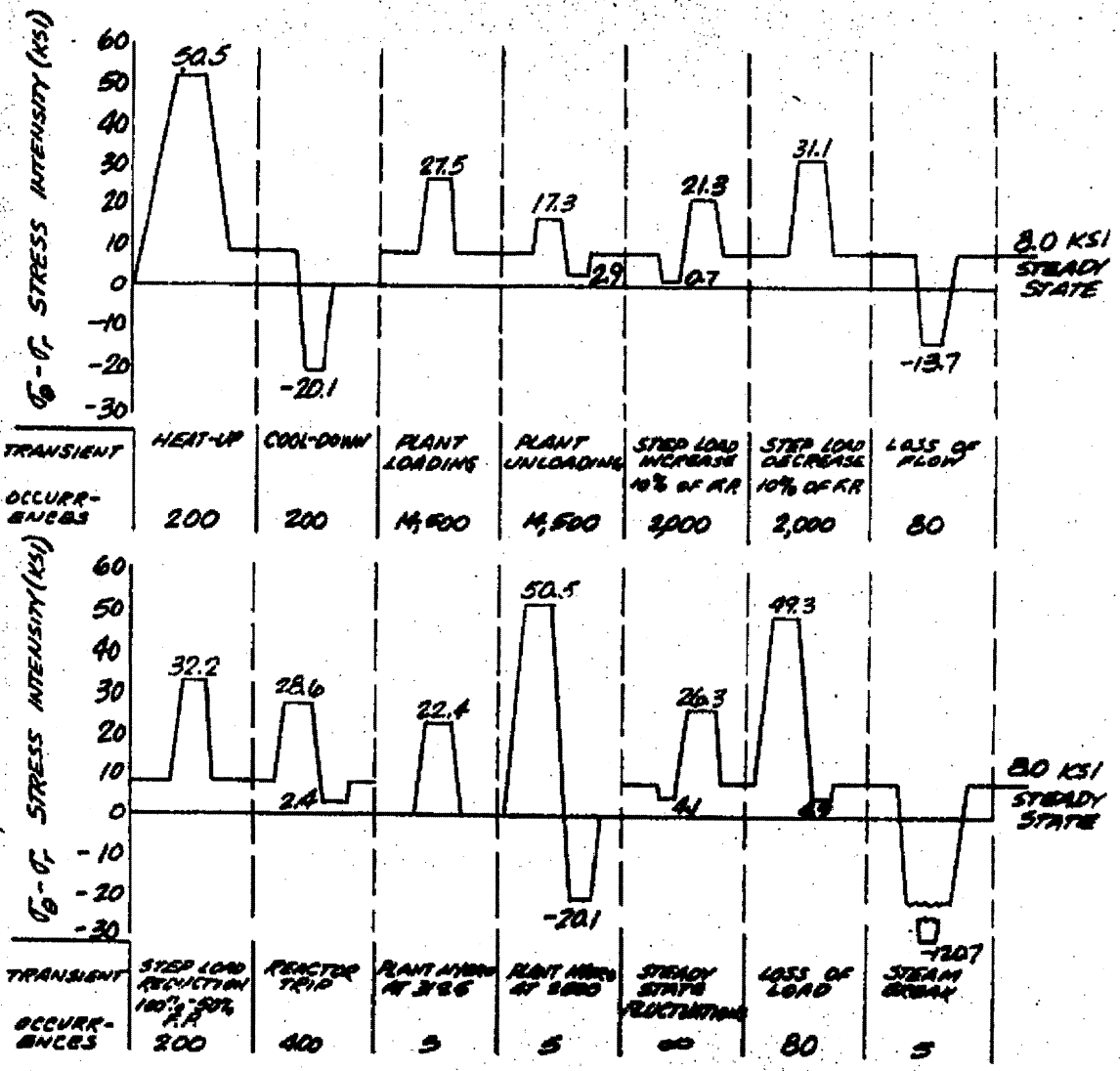
* FROM FIG. N-415 (A) REF. 1

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

NUMBER 5-1101-P A317
SHEET 31 OF 31
CHARGE NO.
DATE 1-27-67 BY ALEXANDER
CRIPTION STRUCTURAL ANALYSIS OF CORE SUPPORT PADS
CHECK DATE 1-27-67 BY CAUDLE

5. DETAILED ANALYSIS

9) FATIGUE EVALUATION $S_\theta - S_r$ AT LOCATION C



$S_{max.}$	$S_{min.}$	NUMBER OF OCCURRENCES	S_A	N^*	U
50.5	-120.7	5	85.6	2500	0.00217
50.5	-20.1	195	35.3	130,000	0.00150
50.5	-20.1	5	35.3	130,000	0.00003
49.3	-13.7	80	31.5	250,000	0.00032
32.2	0.7	200	15.8	∞	0

$U_{TOTAL} = 0.00402$

* FROM FIG. N-415 (B) REF. 1

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

CHARGE NO. _____

DESCRIPTION Structural Analysis Of Vessel And Bottom Head Juncture

W.S. NUMBER S-700-A A-320

SHEET 9 OF 15

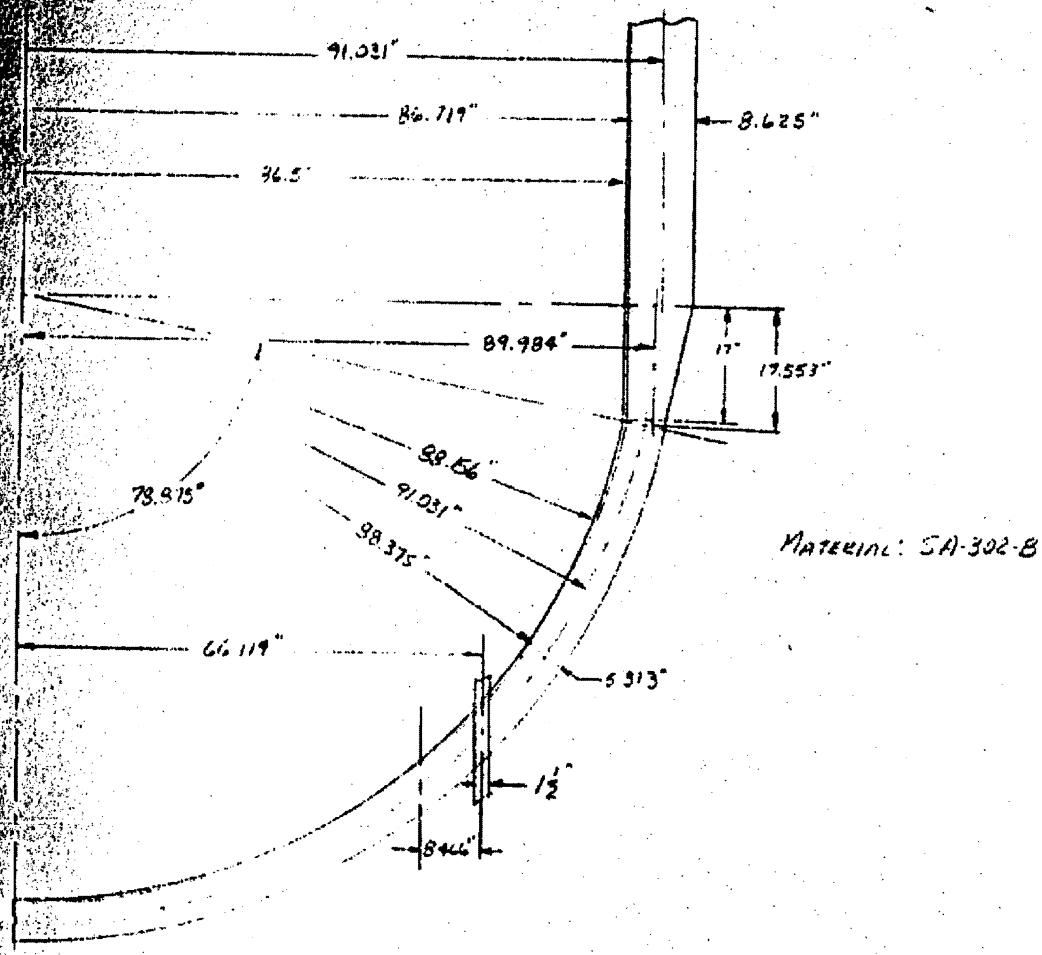
DATE 11-27-65 BY Cockrell

CHECK DATE 12-29-65 BY Ferguson

5. Detailed Analysis:

a. System Geometry:

A Cross Section Of The Vessel Wall And Bottom Head Is Shown Below



Material: SA-302-B

DESCRIPTION STRUCTURAL ANALYSIS OF VESSEL AND BOTTOM HEAD JUNCTURE

5- DETAILED ANALYSIS:

b- SYSTEM LOADS:

THE VESSEL SHELL AND BOTTOM HEAD SHOWN ON THE PREVIOUS SHEET ARE INVESTIGATED FOR INTERNAL PRESSURE OF 2.5 ksi (DESIGN PRESSURE) AT DESIGN TEMPERATURE OF 650°F

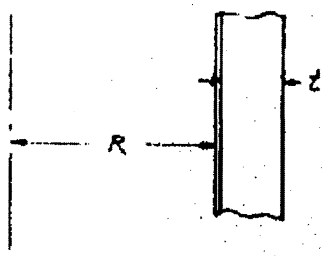
c- SYSTEM ALLOWABLES:

THE FOLLOWING ALLOWABLE STRESSES ARE BASED ON THE A.S.M.E. SECTION III NUCLEAR CODE, REFERENCE 1 AND ARE RELEVANT FOR THIS ANALYSIS.

1. THE AVERAGE PRIMARY STRESS INTENSITY ACROSS A SOLID SECTION SHALL NOT EXCEED S_m AT 650°F.
2. THE LOCAL PRIMARY STRESS COMBINED WITH 1. ABOVE SHALL NOT EXCEED 1.5 S_m AT 650°F
3. THE RANGE OF PRIMARY PLUS SECONDARY STRESS RESULTING FROM MECHANICAL OR THERMAL LOADS SHALL NOT EXCEED $3S_m$ AT ACTUAL METAL TEMPERATURE.

d. DESIGN SIZING:

CONSIDER THE SIZING OF THE VESSEL WALL:



MATERIAL SA-302-B
DESIGN PRESS = 2.5 ksi
DESIGN TEMP = 650°F
S_m = 26.7 ksi @ 650°F

FROM N-431 OF SECTION III NUCLEAR CODE

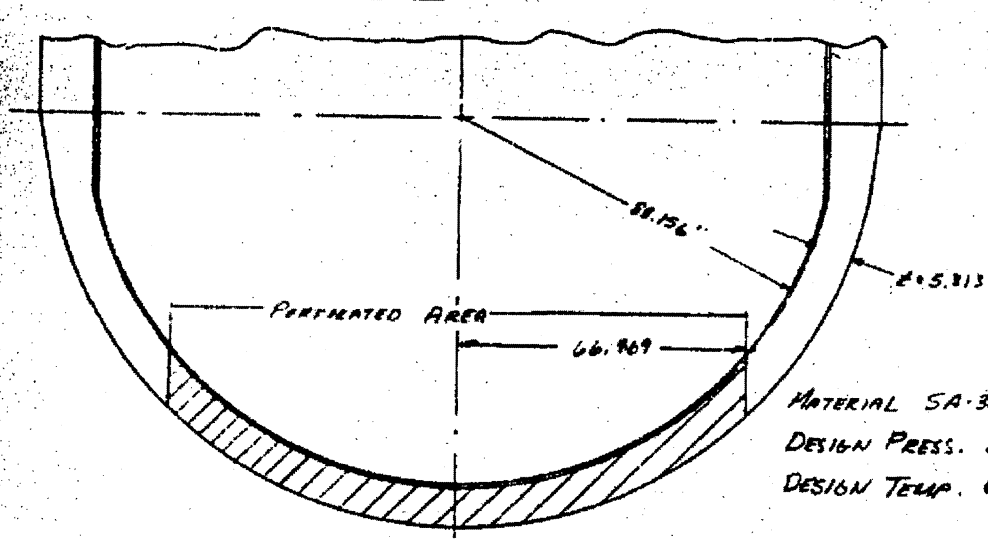
$$t = \frac{PR}{S_m - 0.5P} = \frac{2.5(86.5)}{26.7 - 1.25} = 8.497"$$

∴ THE 8.625" THICKNESS IS ADEQUATE

5- DETAILED ANALYSIS:

d- DESIGN SIZING:

CONSIDER THE BOTTOM HEAD:



MATERIAL SA-302-B
DESIGN PRESS. 2.5 KSI
DESIGN TEMP. 650°F

CONSIDER THE REQUIRED THICKNESS IN THE UN-PERFORATED AREA:

REFERENCE PARAGRAPH N-431, SECTION III NUCLEAR CODE, WHERE

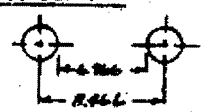
$$t_{REQ'D} = \frac{PR}{S_m - F} = \frac{2.5(58.156)}{2(26.7) + 2.5}$$

$$= 4.330" \text{ (USE } 5\tfrac{5}{16}\text{" MIN TO ALLOW FOR PERFORATIONS)}$$

$t_{REQ'D}$ = SHELL THICKNESS (EXCLUDING CLAD)
P = DESIGN PRESSURE
R = INSIDE RADIUS OF HEAD
S_m = ALLOWABLE STRESS AT 650°F

CONSIDER THE REQUIRED THICKNESS IN THE PERFORATED AREA:

THE REQUIRED THICKNESS MAY BE CONSERVATIVELY ESTIMATED BY ASSUMING THE LIGAMENT EFFICIENCY TO BE (L.E. = $\frac{6.966}{8.466}$ = 0.823). THIS INSURES SATISFACTION OF THE PRIMARY STRESS, S_m, REQUIREMENT IN THE PERFORATED REGION



L.E. = 0.823

$$t_{REQ'D(MINIMUM)} = \frac{t}{L.E.} = \frac{4.330}{0.823} = 5.261" < 5.313"$$

$$\sigma_{PRIMARY(CALCULATED)} = \frac{PR}{2t(L.E.)} = \frac{P}{2} = 26.5 \text{ KSI} < S_m = 26.7 \text{ KSI}$$

∴ CRITERION S.C.1 IS SATISFIED

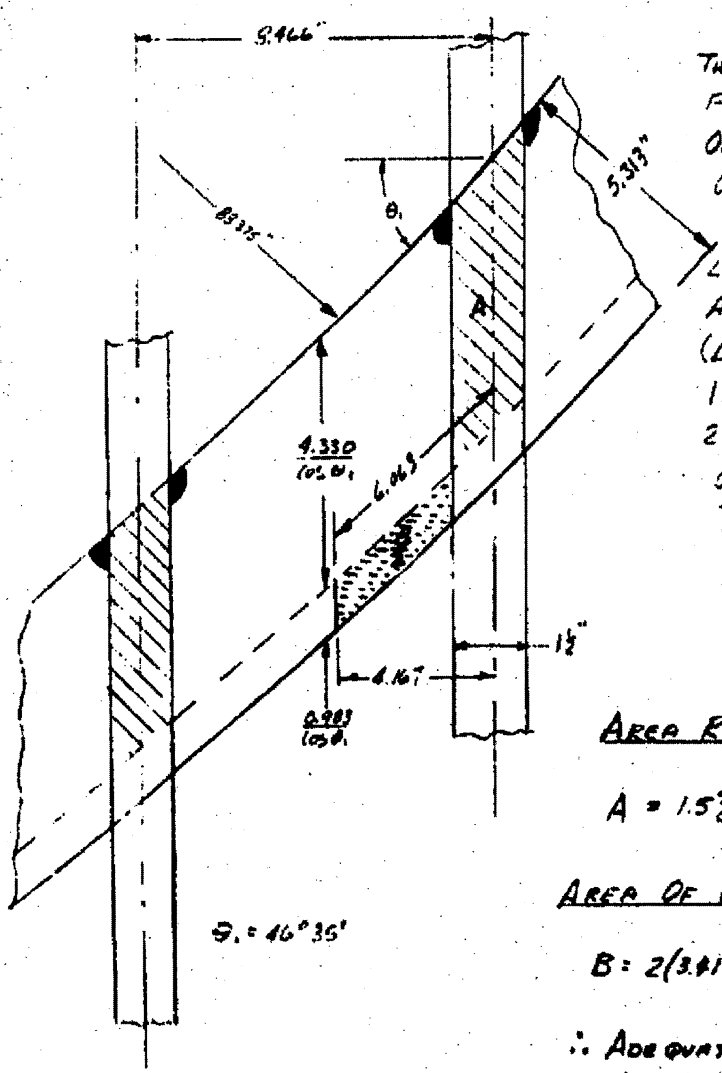
COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, Tenn.
CHARGE NO.
DESCRIPTION STRUCTURAL ANALYSIS OF VESSEL AND BOTTOM HEAD JUNCTURE

SHEET 7 OF 11
DATE 10-27-65 BY CORRELL
CHECK DATE 10-29-65 BY FERGUSON

5. DETAILED ANALYSIS:

d. DESIGN SIZING:

ANOTHER APPROACH WHICH MAY BE USED TO INSURE ADEQUATE HEAD THICKNESS IS TO ASSURE THE BOTTOM HEAD PENETRATIONS AS CONNECTIONS WHICH REQUIRE REINFORCEMENT. THE CONTROLLING LOCATION IS AT THE EXTREME POSITION AS SHOWN BELOW.



THE GENERAL REQUIREMENTS FOR COMPENSATION ARE OUTLINED IN PAR. N-451 - 456 OF SECTION III.

LIMIT OF REINFORCEMENT ALONG VESSEL WALL: (LARGER OF)
1. DIA. OF OPENING = 1.5"
2. FINISHED RADIUS OF OPENING PLUS VESSEL WALL THICKNESS = 0.75 + 5.313 = 6.063"

AREA REMOVED:

$$A = 1.5\frac{4.330}{\cos\theta_1} = 9.450 \text{ in}^2$$

AREA OF COMPENSATION:

$$B = 2(3.917)\frac{0.983}{\cos\theta_1} = 9.774 \text{ in}^2$$

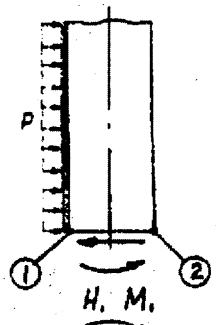
∴ ADEQUATE COMPENSATION IS PROVIDED

5. Detailed Analysis:

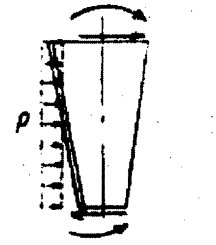
e. Development Of Continuity Equations:

1. Analytical Model:

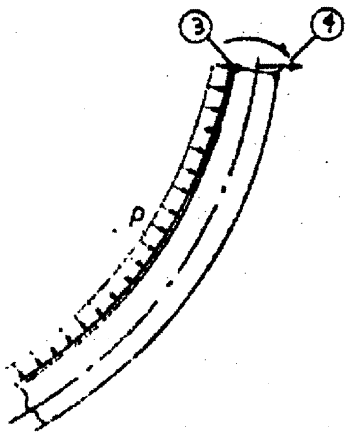
The Actual Structure Is Divided Into The Analytical Model As Shown Below To Facilitate The Analysis. The Assumed Direction Of The Redundant Forces Is Illustrated.



Body-1
Long Cylinder



Body-2
Short Tapered Cylinder



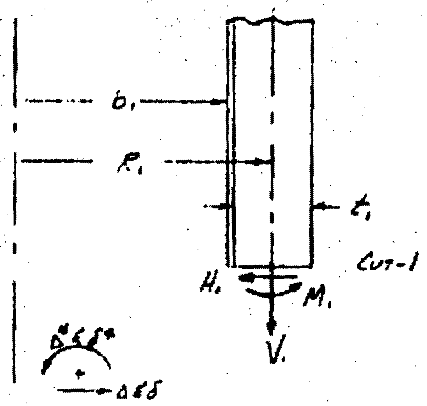
Body-3
Long Sphere

5. Detailed Analysis:

e. Development Of Continuity Equations:

2. Movements Due To Redundant And Applied Forces:

Body-1:



$R_1 = 91.031''$

$b_1 = 86.500''$

$t_1 = 8.625''$

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

$\beta^2 = 0.00210$

$D = \frac{E t_1^3}{12(1-\nu^2)} = 58.7563E$

$V_1 = \frac{P b_1^2}{2R_1} = 41.09726P$

Displacements Due To Redundant Forces:

$$E\Delta_{11} = -\frac{E}{2\beta^3 D}\left[\frac{1}{\beta}H_1 - M_1\right]$$

$$= \underline{-88.14883H_1 + 4.04373M_1}$$

$$E\Delta_{11}^* = -\frac{E}{2\beta^2 D}\left[H_1 - 2\beta M_1\right]$$

$$= \underline{-4.04373H_1 + 0.37100M_1}$$

Displacements Due To Applied Forces:

$$E\delta_{11} = \frac{b_1^2}{t_1}\left(\frac{R_1}{b_1} - \frac{\nu}{2}\right)P$$

$$= \underline{132.82249P}$$

$$E\delta_{11}^* = 0$$

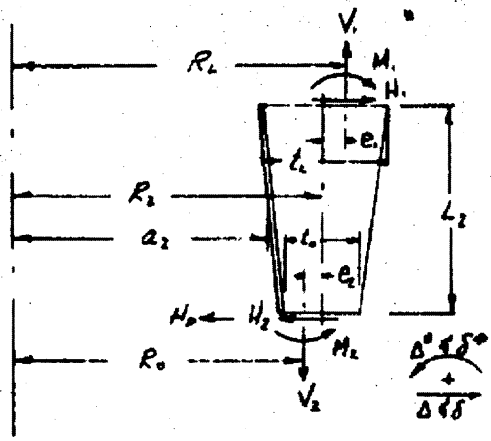
From Theory Of Plates And Shells By Timoshenko, Ref. 7

5. DETAILED ANALYSIS:

e. DEVELOPMENT OF CONTINUITY EQUATIONS:

2. MOVEMENTS DUE TO REDUNDANT AND APPLIED FORCES:

BODY - 2:



$R_2 = 89.984"$ $\quad V_1 = 41.09726P$

$a_2 = 36.500"$ $\quad V_2 = 41.89383P$

$t_0 = 5.313"$ $\quad H_p = V_2' \cos\theta$

$t_L = 8.625"$ $\quad = 3.23624P$

$L_2 = 17.553"$

$R_0 = 89.321"$ $\quad \lambda = \frac{1}{L}(t_L - t_0) = 0.19868$

$R_L = 91.031"$

$e_1 = 1.047"$ $\quad \beta^4 = \frac{12(1-\nu^2)}{\lambda^2 R_2^2} = 0.03788$

$e_2 = 0.663"$

THE INFLUENCE COEFFICIENTS FOR A SHORT TAPERED CYLINDER ARE CALCULATED BY THE METHOD OUTLINED ON PAGES 488 TO 492 OF REFERENCE 7 AND ARE PRINTED OUT ON C.E. COMPUTER PROGRAM IN THE FOLLOWING FORM.

DISPLACEMENTS DUE TO REDUNDANT FORCES:

$$E\Delta_{21} = -\phi_{23} H_1 \frac{R_2}{R_2} + \phi_{24} M_1 \frac{R_2}{R_2} - \phi_{21} H_2 \frac{R_0}{R_2} + \phi_{22} M_2 \frac{R_0}{R_L}$$

$$= 240.74307 H_1 + 21.75745 M_1 + 132.07532 H_2 - 20.68908 M_2$$

$$E\Delta^*_{21} = \phi_{43} H_1 \frac{R_2}{R_2} - \phi_{44} M_1 \frac{R_2}{R_2} + \phi_{41} H_2 \frac{R_0}{R_2} - \phi_{42} M_2 \frac{R_0}{R_L}$$

$$= -21.79896 H_1 - 2.79456 M_1 - 24.31443 H_2 + 2.52823 M_2$$

$$E\Delta_{22} = -\phi_{13} H_1 \frac{R_2}{R_2} + \phi_{14} M_1 \frac{R_2}{R_2} - \phi_{11} H_2 \frac{R_0}{R_2} + \phi_{12} M_2 \frac{R_0}{R_L}$$

$$= -134.67524 H_1 - 24.74586 M_1 - 300.85321 H_2 + 25.38360 M_2$$

$$E\Delta^*_{22} = \phi_{23} H_1 \frac{R_2}{R_2} - \phi_{24} M_1 \frac{R_2}{R_2} + \phi_{21} H_2 \frac{R_0}{R_2} - \phi_{22} M_2 \frac{R_0}{R_L}$$

$$= -21.14812 H_1 - 2.57940 M_1 - 25.44608 H_2 + 2.94507 M_2$$

5. Detailed Analysis:

c- Development Of Continuity Equations:

2. Movements Due To Redundant And Applied Forces:

Body -2

Displacements Due To Applied Forces:

$$E\delta_{21} = a_2'\left(\frac{R_1}{a_2} - \frac{\nu'}{2}\right)\left[(\phi_{32}+\phi_{34})\frac{-\lambda'}{6(1-\nu')} + \frac{1}{t_2}\right]P - \phi_{34}\,V.e.\,\frac{R_1}{R_2} + \phi_{32}\,V_2 e_2\,\frac{R_0}{R_2} - \phi_{31}\,H_p\,\frac{R_0}{R_2}$$

$$= 320.56163P$$

$$E\delta_{21}^{M} = -a_2'\left(\frac{R_1}{a_1} - \frac{\nu'}{2}\right)\left[(\phi_{42}+\phi_{44})\frac{-\lambda^2}{6(1-\nu')} - \frac{\lambda}{t_2^2}\right]P + \phi_{44}\,V.e.\,\frac{R_1}{R_2} - \phi_{42}\,V_2 e_2\,\frac{R_0}{R_2} + \phi_{41}\,H_p\,\frac{R_0}{R_2}$$

$$= 16.37180P$$

$$E\delta_{22} = a_2'\left(\frac{R_1}{a_2} - \frac{\nu'}{2}\right)\left[(\phi_{12}+\phi_{14})\frac{-\lambda^2}{6(1-\nu')} + \frac{2}{t_2}\right]P - \phi_{14}\,V.e.\,\frac{R_1}{R_2} + \phi_{12}\,V_2 e_2\,\frac{R_0}{R_2} - \phi_{11}\,H_p\,\frac{R_0}{R_2}$$

$$= 497.32142P$$

$$E\delta_{22}^{M} = -a_2'\left(\frac{R_1}{a_1} - \frac{\nu'}{2}\right)\left[(\phi_{22}+\phi_{24})\frac{-\lambda^2}{6(1-\nu')} - \frac{\lambda}{t_2^2}\right]P + \phi_{24}\,V.e.\,\frac{R_1}{R_2} - \phi_{32}\,V_2 e_2\,\frac{R_0}{R_2} + \phi_{21}\,H_p\,\frac{R_0}{R_2}$$

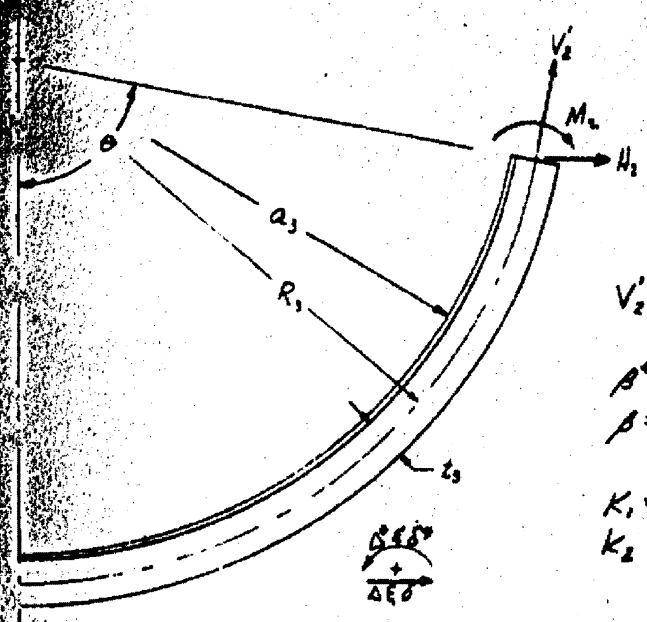
$$= 9.56919P$$

5. DETAILED ANALYSIS:

c. DEVELOPMENT OF CONTINUITY EQUATIONS:

2. MOVEMENTS DUE TO REDUNDANT AND APPLIED FORCES:

BODY-3:



$R_3 = 91.031"$
$a_3 = 88.156"$
$t_3 = 5.313$
$\theta = 78.875°$

$V_2' = \frac{a_3^2}{2R_3} P = 42.68590\,P$

$\beta^4 = 3(1-\nu^2)\left(\frac{R}{t}\right)^2$
$\beta = 5.32066$

$K_1 = 1 - \frac{(1-2\nu)}{2\beta} \cot\theta = 0.99261$
$K_2 = 1 - \frac{(1+2\nu)}{2\beta} \cot\theta = 0.97044$

DISPLACEMENTS DUE TO REDUNDANT FORCES:

$$E\Delta_{32} = \frac{2\beta^2 \sin\theta}{t_3}\left[\frac{R_3 \sin\theta}{2\beta}\left(\frac{1}{K_1} + K_2\right)H_2 + \frac{1}{K_1} M_2\right]$$

$$= 173.59327\,H_2 + 10.53420\,M_2$$

$$E\Delta_{32}^* = -\frac{2\beta^2 \sin\theta}{t_3}\left[\frac{1}{K_1} H_2 + \frac{2\beta}{K_2 \sin\theta}\left(\frac{1}{K_1}\right) M_2\right]$$

$$= -10.53420\,H_2 - 1.25498\,M_2$$

FROM THEORY OF PLATES AND SHELLS BY TIMOSHENKO, REF. 7

DISPLACEMENTS DUE TO APPLIED FORCES

$$E\delta_{32} = \frac{(1-\nu)a_3^2 P}{2t_3} \sin\theta = 502.33559\,P$$

$$E\delta_{32}^* = 0$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION Structural Analysis Of Vessel And Bottom Head Junction

NUMBER C-274-1 1 of 5B-1
SHEET 13 OF 15
DATE 10-27-65 BY Cockrell
CHECK DATE 10-29-65 BY Ferguson

5. Detailed Analysis:

e. Development Of Continuity Equations:

3. Continuity Matrix And Loading Vectors:

Only A Pressure Solution Is Required For This Analysis. The Redundant Loads Are Determined By Requiring Radial And Rotational Continuity. The Column Vectors Are Written In Terms Of P. The Matrix Will Be Arranged As Follows

$$E\Delta_{11} - E\Delta_{21} = E\delta_{11} - E\delta_{11}$$
$$E\Delta''_{11} - E\Delta''_{21} = E\delta''_{21} - E\delta''_{11}$$
$$E\Delta_{22} - E\Delta_{32} = E\delta_{31} - E\delta_{32}$$
$$E\Delta''_{22} - E\Delta''_{32} = E\delta''_{31} - E\delta''_{32}$$

The Continuity Requirements Are Expressed Below In Matrix Form.

$$\begin{bmatrix} -328.89140 & -17.71972 & -132.07532 & 20.68908 \\ 17.75523 & 3.16556 & 24.31443 & -2.52873 \\ -134.67524 & -24.74568 & -471.44948 & 14.84960 \\ -21.14812 & -2.57940 & -14.91138 & 4.20005 \end{bmatrix} \begin{bmatrix} H_1 \\ M_1 \\ H_2 \\ M_2 \end{bmatrix} = \begin{bmatrix} -462.26086 \\ 16.37180 \\ 5.01416 \\ -9.56819 \end{bmatrix} P$$

Inverting The Above Matrix And Multiplying Times The Column Vectors Yields The Following Redundants Resulting From Pressure. Design Pressure Is 2.5 ksi.

4 Redundant Load Values:

$H_1 = 1.85888\,P$
$M_1 = 6.44620\,P$
$H_2 = -0.59500\,P$
$M_2 = 8.92779\,P$

DESCRIPTION: STRUCTURAL ANALYSIS OF VESSEL AND BOTTOM HEAD JUNCTURE

5. DETAILED ANALYSIS:

5.1 STRESS CALCULATIONS:

THE STRESS EXPRESSIONS TO BE USED FOR THE LOCATIONS AS SHOWN OF SHEET 8 ARE GIVEN BELOW.

POINT-1

$$\sigma_x = \frac{6M_1}{t_1^2} + \frac{b^2P}{2R_1t_1} = \underline{0.08065\,M_1 + 4.76490P}$$

$$\sigma_\theta = \frac{\nu 6M_1}{t_1^2} + \frac{E\Delta_{11}}{R_1} + \frac{bP}{t_1} = \underline{0.02420\,M_1 + 0.01099\,E\Delta_{11} + 10.02898P}$$

POINT-2

$$\sigma_x = -\frac{6M_1}{t_1^2} + \frac{b^2P}{2R_1t_1} = \underline{-0.08065\,M_1 + 4.76490P}$$

$$\sigma_\theta = -\frac{\nu 6M_1}{t_1^2} + \frac{E\Delta_{11}}{R_1} + \frac{bP}{t_1} = \underline{-0.02420M_1 + 0.01099\,E\Delta_{11} + 10.02898P}$$

POINT-3

$$\sigma_x = \frac{6M_2}{t_3^2} + \frac{H_2\cos\theta}{t_3} + \frac{Pa_i^2}{2R_3t_3} = \underline{0.21255\,M_2 + 0.03631\,H_2 + 8.03423P}$$

$$\sigma_\theta = \frac{\nu 6M_2}{t_3^2} + \frac{\nu H_2\cos\theta}{t_3} + \frac{E\Delta_{22}}{R_3\sin\theta} + \frac{tE\Delta^*_{21}\cos\theta}{2R_3\sin\theta} + \frac{Pa_i^2}{2R_3t_3}$$

$$= \underline{0.06377M_2 + 0.01089H_2 + 0.01120E\Delta_{22} + 0.00574\,E\Delta^*_{21} + 8.03423P}$$

POINT-4

$$\sigma_x = -\frac{6M_2}{t_3^2} + \frac{H_2\cos\theta}{t_3} + \frac{Pa_i^2}{2R_3t_3} = \underline{-0.21255\,M_2 + 0.03631H_2 + 8.03423P}$$

$$\sigma_\theta = -\frac{\nu 6M_2}{t_3^2} + \frac{\nu H_2\cos\theta}{t_3} + \frac{E\Delta_{22}}{R_3\sin\theta} - \frac{tE\Delta^*_{21}\cos\theta}{2R_3\sin\theta} + \frac{Pa_i^2}{2R_3t_3}$$

$$= \underline{-0.06377\,M_2 + 0.01089\,H_2 + 0.01120E\Delta_{22} - 0.00574\,E\Delta^*_{21} + 8.03423P}$$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO. _____
DESCRIPTION STRUCTURAL ANALYSIS OF VESSEL AND BOTTOM HEAD JUNCTURE

NUMBER S-200-P | A 381
SHEET 15 OF 15
DATE 10-27-65 BY CARRELL
CHECK DATE 10-29-65 BY FERGUSON

5- DETAILED ANALYSIS:

f. STRESSES:

POINT	$\pm\frac{6M}{t^3}$	$\frac{\cos\theta H}{t}$	$\frac{PR}{2t}$	σ_x	$\pm\frac{rH\sin\theta}{t^2}$	$\frac{rH\sin\theta}{t}$	$E\Delta$	$\frac{E\Delta}{R}$	$E\Delta^2$	$\pm\frac{E\Delta^2}{2R}$	$\frac{PR}{2t}/\frac{PR}{t}$	σ_θ	σ_r	STRESS INTENSITY $\sigma_x-\sigma_\theta$	$\sigma_x-\sigma_r$	$\sigma_\theta-\sigma_r$
1	1.30	—	11.91	13.21	0.39	—	-344.98	-3.79	—	—	25.07	21.67	-2.5	-8.5	15.7	24.2
2	-1.30	—	11.91	10.61	-0.39	—	-344.98	-3.79	—	—	25.07	20.89	0	-10.3	10.6	20.9
3	4.74	-0.05	20.09	24.78	1.42	-0.02	-23.109	-0.26	-12.341	-0.07	20.09	21.16	-2.5	3.6	27.3	23.7
4	-4.74	-0.05	20.09	15.30	-1.42	-0.02	-23.109	-0.26	-12.341	0.07	20.09	18.46	0	-3.2	15.3	18.5

THE VALUES OF THE H's & M's ARE TAKEN FROM SHEET 13.
THE MOVEMENT EQUATIONS ARE GIVEN ON SHEETS 9 & 12.

CRITERION 5-C-1 PRIMARY GENERAL MEMBRANE:

$S.I._{max} = \sigma_\theta - \sigma_r = \frac{PR}{t} + \frac{P}{2} =$ 23.9 KSI $< S_m =$ 26.7 KSI — FOR LOCATIONS 1 & 2

CRITERION 5-C-2 LOCAL MEMBRANE STRESS:

FOR CUT 1:

$\sigma_\theta = \frac{E\Delta}{R} =$ -3.8 KSI

OR COMBINED WITH GENERAL MEMBRANE,

$S.I._{max} = \frac{PR}{t} + \frac{E\Delta}{R} + \frac{P}{2} =$ 20.1 KSI $< 1.5S_m =$ 40 KSI — FOR LOCATIONS 1 & 2

FOR CUT 2:

$\sigma_\theta = \frac{rH\cos\theta}{t} + \frac{E\Delta}{R} =$ -0.3 KSI

OR COMBINED WITH GENERAL MEMBRANE

$S.I._{max} = \frac{PR}{t} + \frac{rH\cos\theta}{t} + \frac{E\Delta}{R} + \frac{P}{2} =$ 21.1 KSI $< 1.5S_m =$ 40 KSI — FOR LOCATIONS 3 & 4

CRITERION 5-C-3 RANGE OF STRESS INTENSITY:

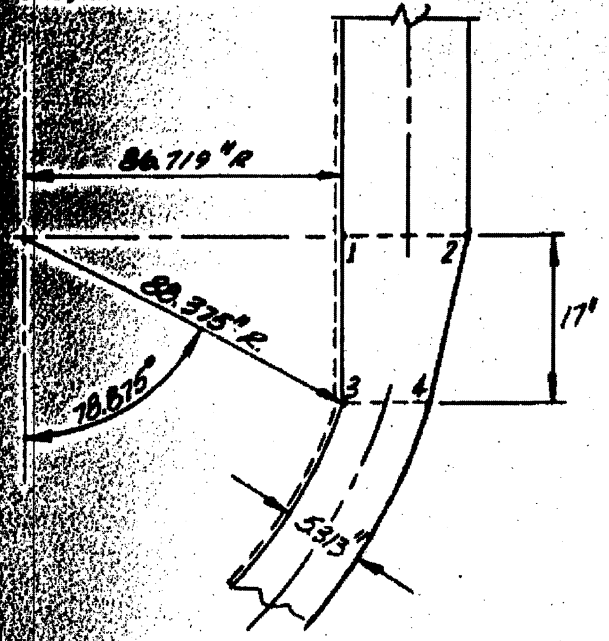
$S.I._{max} = \sigma_1 - \sigma_r = \left[\frac{6M}{t^3} + \frac{\cos\theta H}{t} + \frac{PR}{2t}\right] + P =$ 24.6 KSI $< 3S_m =$ 80 KSI — FOR LOCATION 3

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

NUMBER S-705-P | A532
SHEET 4 OF No
CHARGE NO.
DATE 9-8-66 BY ALEXANDER
DESCRIPTION FATIGUE EVALUATION OF BOTTOM HEAD-TO-VESSEL JUNCTURE
CHECK DATE 9-8-66 BY CALDER

5. DETAILED ANALYSIS

a) SYSTEM GEOMETRY



b) SYSTEM LOADS

THE BOTTOM HEAD TO SHELL JUNCTURE WILL BE ANALYZED UNDER THE TRANSIENT CONDITIONS AS GIVEN IN REFERENCE 9.

c) SYSTEM ALLOWABLES

1. THE RANGE OF PRIMARY PLUS SECONDARY STRESS RESULTING FROM MECHANICAL OR THERMAL LOADS SHALL NOT EXCEED $3S_m$ AT ACTUAL METAL TEMPERATURE AND OPERATING PRESSURE.

2. SHOW THAT EACH POINT MEETS THE REQUIREMENTS FOR PEAK STRESS INTENSITIES GIVEN IN N-414.6 OF THE A.S.M.E. CODE, SECTION III. THE PROCEDURE WILL BE AS OUTLINED IN N-415.2 OF SECTION III.

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

NUMBER 5-203-P
SHEET 2 OF No
DATE 9-8-66 BY ALEXANDER
CHECK DATE 9-8-66 BY CAUDLE

RIPTION FATIGUE EVALUATION OF BOTTOM HEAD-TO-VESSEL JUNCTURE

5 DETAILED ANALYSIS

d.) UNCONCENTRATED STRESSES

AN INTERACTION ANALYSIS WAS MADE FOR THE BOTTOM HEAD TO SHELL AND REPORTED IN ANALYSIS No. 5-200-P. THE FOLLOWING EXPRESSIONS FOR STRESS DUE TO PRESSURE WERE TAKEN FROM THAT ANALYSIS. TO THESE EXPRESSIONS HAS BEEN ADDED A TERM FOR THE THERMAL STRESSES WHICH WILL BE CONSERVATIVELY TREATED AS SKIN STRESSES.

LOCATION 1

$$\sigma_x = \frac{6M_1}{t_1^2} + \frac{b_1^2 P}{2R_1 t_1} + \frac{E\alpha(T_m - T)}{(1-\nu)} = 0.08065\,M_1 + 4.76490\,P + 0.30571\,(T_m - T)$$

$$\sigma_\theta = \frac{\nu 6M_1}{t_1^2} + \frac{E\Delta_H}{R_1} + \frac{b_1 P}{t_1} + \frac{E\alpha(T_m - T)}{(1-\nu)} = 0.02420\,M_1 + 0.01099\,E\Delta_H + 10.02898\,P + 0.30571\,(T_m - T)$$

LOCATION 2

$$\sigma_x = -\frac{6M_1}{t_1^2} + \frac{b_1^2 P}{2R_1 t_1} + \frac{E\alpha(T_m - T)}{(1-\nu)} = -0.08065\,M_1 + 4.76490\,P + 0.30571\,(T_m - T)$$

$$\sigma_\theta = -\frac{\nu 6M_1}{t_1^2} + \frac{E\Delta_H}{R_1} + \frac{b_1 P}{t_1} + \frac{E\alpha(T_m - T)}{(1-\nu)} = -0.02420\,M_1 + 0.01099\,E\Delta_H + 10.02898\,P + 0.30571\,(T_m - T)$$

LOCATION 3

$$\sigma_x = \frac{6M_2}{t_3^2} + \frac{H_2 \cos\theta}{t_3} + \frac{Pa_3^2}{2R_3 t_3} + \frac{E\alpha(T_m - T)}{(1-\nu)} = 0.21255\,M_2 + 0.03631\,H_2 + 8.03423\,P + 0.30571\,(T_m - T)$$

$$\sigma_\theta = \frac{\nu 6M_2}{t_3^2} + \frac{\nu H_2 \cos\theta}{t_3} + \frac{E\Delta_{T2}}{R_3 \sin\theta} + \frac{t_2 E\Delta_{T2}^{*} \cos\theta}{2R_3 \sin\theta} + \frac{Pa_3^2}{2R_3 t_3} + \frac{E\alpha(T_m - T)}{(1-\nu)}$$

$$= 0.06377\,M_2 + 0.01089\,H_2 + 0.01180\,E\Delta_{T2} + 0.00574\,E\Delta_{T2}^{*} + 8.03423\,P + 0.30571\,(T_m - T)$$

LOCATION 4

$$\sigma_x = -\frac{6M_2}{t_3^2} + \frac{H_2 \cos\theta}{t_3} + \frac{Pa_3^2}{2R_3 t_3} + \frac{E\alpha(T_m - T)}{(1-\nu)} = -0.21255\,M_2 + 0.03631\,H_2 + 8.03423\,P + 0.30571\,(T_m - T)$$

$$\sigma_\theta = -\frac{\nu 6M_2}{t_3^2} + \frac{\nu H_2 \cos\theta}{t_3} + \frac{E\Delta_{T2}}{R_3 \sin\theta} - \frac{t_2 E\Delta_{T2}^{*} \cos\theta}{2R_3 \sin\theta} + \frac{Pa_3^2}{2R_3 t_3} + \frac{E\alpha(T_m - T)}{(1-\nu)}$$

$$= -0.06377\,M_2 + 0.01089\,H_2 + 0.01180\,E\Delta_{T2} - 0.00574\,E\Delta_{T2}^{*} + 8.03423\,P + 0.30571\,(T_m - T)$$

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

NUMBER 5-203-P | A 300
SHEET 6 OF 16
DATE 9-8-66 BY ALEXANDER
CHECK DATE 9-8-66 BY CAUBLE
CHARGE NO.
DESCRIPTION FATIGUE EVALUATION OF BOTTOM HEAD-TO-SHELL JUNCTURE

3. DETAILED ANALYSIS

d) UNCONCENTRATED STRESSES

SUMMARY OF STRESSES AND STRESS INTENSITIES AT LOCATION 1 *

TRANSIENT	TIME FROM START OF TRANS.	PRESS. (KSI)	$(T_m - T)$ °F	THERMAL STRESS $\sigma_x = \sigma_\theta$	PRESSURE STRESS σ_x	PRESSURE STRESS σ_θ	PRESSURE STRESS σ_r	TOTAL STRESSES σ_x	TOTAL STRESSES σ_θ	TOTAL STRESSES σ_r	STRESS INTENSITY $\sigma_x - \sigma_\theta$	STRESS INTENSITY $\sigma_x - \sigma_r$	STRESS INTENSITY $\sigma_\theta - \sigma_r$
STEADY STATE	~	2.25	0	0	11.9	19.5	-2.3	11.9	19.5	-2.3	-7.6	14.2	21.8
HEAT-UP	4.47 hrs.	2.25	-43	-13.1	11.9	19.5	-2.3	-1.2	6.4	-2.3	-7.6	1.1	8.7
COOL-DOWN	4.47 hrs.	0.32	43	13.1	1.7	2.8	-0.3	14.8	15.9	-0.3	-1.1	15.1	16.2
PLANT LOADING	20 min.	2.25	-7.8	-2.4	11.9	19.5	-2.3	9.5	17.1	-2.3	-7.6	11.8	19.4
PLANT UNLOADING	20 min.	2.25	7.8	2.4	11.9	19.5	-2.3	14.3	21.9	-2.3	-7.6	16.6	24.2
STEP LOAD INCREASE 10% OF FULL POWER	100 sec.	2.14	11.2	3.4	11.3	18.6	-2.1	14.7	22.0	-2.1	-7.3	16.8	24.1
	225 sec.	2.28	1.7	0.5	12.0	19.8	-2.3	12.5	20.3	-2.3	-7.8	14.8	22.6
STEP LOAD DECREASE 10% OF FULL POWER	40 sec.	2.32	-9.3	-2.8	12.3	20.1	-2.3	9.5	17.3	-2.3	-7.8	11.8	19.6
	100 sec.	2.26	-13.3	-4.1	11.9	19.6	-2.3	7.8	15.5	-2.3	-7.7	10.1	17.8
	160 sec.	2.14	-1.3	-0.4	11.3	18.6	-2.1	10.9	18.2	-2.1	-7.3	13.0	20.3
LOSS OF FLOW	12 sec.	2.25	33.3	10.2	11.9	19.5	-2.3	22.1	29.7	-2.3	-7.6	24.4	32.0
STEP LOAD REDUCTION FROM 100% TO 50% FULL POWER	2 min.	2.37	-12.0	-3.7	12.5	20.5	-2.4	8.8	16.8	-2.4	-8.0	11.2	19.2
	32 min.	2.35	-15.0	-4.6	12.4	20.4	-2.4	7.8	15.8	-2.4	-8.0	10.2	18.2
	104 min.	2.15	0	0	11.4	18.6	-2.2	11.4	18.6	-2.2	-7.2	13.6	20.8
REACTOR TRIP FROM FULL POWER	10 sec.	2.22	-9.5	-2.9	11.7	19.2	-2.2	8.8	16.3	-2.2	-7.5	11.0	18.6
	65 sec.	1.91	8.5	2.6	10.1	16.6	-1.9	12.7	19.2	-1.9	-6.5	14.6	21.1
PLANT HYDRO AT 3125 PSIA	120 min.	3.13	0	0	16.5	27.1	-3.1	16.5	27.1	-3.1	-10.6	19.6	30.2
PLANT HYDRO AT 2500 PSIA	HEAT. S.S. COOL.	1.25 2.50 0.32	-43 0 43	-13.1 0 13.1	6.6 13.2 1.7	10.8 21.7 2.8	-1.3 -2.5 -0.3	-6.5 13.2 14.8	-2.3 21.7 15.9	-1.3 -2.5 -0.3	-4.2 -8.5 -1.1	-5.2 15.7 15.1	-1.0 24.2 16.2
STEADY STATE FLUCTUATIONS	~	2.35	6.0	1.8	12.4	20.4	-2.4	14.2	22.2	-2.4	-8.0	16.6	24.6
		2.15	-6.0	-1.8	11.4	18.6	-2.2	9.6	16.8	-2.2	-7.2	11.8	19.0
LOSS OF LOAD	10 sec.	2.76	-30.2	-9.2	14.6	23.9	-2.8	5.4	14.7	-2.8	-9.3	8.2	17.5
	28 sec.	2.12	-41.2	-12.6	11.2	18.4	-2.1	-1.4	5.8	-2.1	-7.2	0.7	7.9
	160 sec.	1.44	4.8	1.5	7.6	12.5	-1.4	9.1	14.0	-1.4	-4.9	10.5	15.4
STEAM BREAK	54 sec.	0.70	197.0	60.2	3.7	6.1	-0.7	63.9	66.3	-0.7	-2.4	64.6	67.0

* THIS TABLE AND THE FOLLOWING ONES GIVE THE STRESSES AND STRESS INTENSITIES (UNCONCENTRATED) AT THE FOUR LOCATIONS AS SHOWN ON SHEET-4 USING THE EXPRESSIONS AS GIVEN ON SHEET-5.

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

NUMBER S-203-P | A 335
SHEET 7 OF 16
CHARGE NO.
DATE 9-8-66 BY ALEXANDER
DESCRIPTION FATIGUE EVALUATION OF BOTTOM HEAD-TO-SHELL JUNCTURE
CHECK DATE 9-8-66 BY CAUDLE

5. DETAILED ANALYSIS
d) UNCONCENTRATED STRESSES
SUMMARY OF STRESSES AND STRESS INTENSITIES AT LOCATION 2

TRANSIENT	TIME FROM START OF TRANS	PRESS. (KSI)	$(T_m - T)$ °F	THERMAL STRESS $\sigma_t = \sigma_\theta$	PRESSURE STRESS σ_x	σ_θ	σ_r	TOTAL STRESSES σ_x	σ_θ	σ_r	STRESS INTENSITY $\sigma_x - \sigma_\theta$	$\sigma_x - \sigma_r$	$\sigma_\theta - \sigma_r$
STEADY STATE	~	2.25	0	0	9.6	18.8	0	9.6	18.8	0	-9.2	9.6	18.8
HEAT-UP	4.47 hrs.	2.25	22	6.7	9.6	18.8		16.3	25.5		-9.2	16.3	25.5
COOL-DOWN	4.47 hrs.	0.32	-22	-6.7	1.4	2.7		-5.3	-4.0		-1.3	-5.3	-4.0
PLANT LOADING	20 min.	2.25	0	0	9.6	18.8		9.6	18.8		-9.2	9.6	18.8
PLANT UNLOADING	20 min.	2.25			9.6	18.8		9.6	18.8		-9.2	9.6	18.8
STEP LOAD INCREASE	100 sec.	2.14			9.1	17.9		9.1	17.9		-8.8	9.1	17.9
10% OF FULL POWER	225 sec.	2.28			9.7	19.1		9.7	19.1		-9.4	9.7	19.1
STEP LOAD DECREASE	40 sec.	2.32			9.8	19.4		9.8	19.4		-9.6	9.8	19.4
10% OF	100 sec.	2.26			9.6	18.9		9.6	18.9		-9.3	9.6	18.9
FULL POWER	160 sec.	2.14			9.1	17.9		9.1	17.9		-8.8	9.1	17.9
LOSS OF FLOW	12 sec.	2.25			9.6	18.8		9.6	18.8		-9.2	9.6	18.8
STEP LOAD REDUCTION	2 min.	2.37			10.1	19.8		10.1	19.8		-9.7	10.1	19.8
FROM 100% TO 50%	3.2 min.	2.35			10.0	19.6		10.0	19.6		-9.6	10.0	19.6
FULL POWER	10.4 min.	2.15			9.1	18.0		9.1	18.0		-8.9	9.1	18.0
REACTOR TRIP FROM	10 sec.	2.22			9.4	18.6		9.4	18.6		-9.2	9.4	18.6
FULL POWER	65 sec.	1.91			8.1	16.0		8.1	16.0		-7.9	8.1	16.0
PLANT HYDRO AT 3125 PSIA	220 min.	3.13			13.3	26.2		13.3	26.2		-12.9	13.3	26.2
PLANT HYDRO AT 2500 PSIA	HEAT.	1.25	22	6.7	5.3	10.4		12.0	17.1		-5.1	12.0	17.1
	S.S.	2.50	0	0	10.6	20.9		10.6	20.9		-10.3	10.6	20.9
	COOL.	0.32	-22	-6.7	1.4	2.7		-5.3	-4.0		-1.3	-5.3	-4.0
STEADY STATE FLUCTUATIONS	~	2.35	0	0	10.0	19.6		10.0	19.6		-9.6	10.0	19.6
		2.15			9.1	18.0		9.1	18.0		-8.9	9.1	18.0
LOSS	10 sec.	2.76			11.7	23.1		11.7	23.1		-11.4	11.7	23.1
OF	28 sec.	2.12			9.0	17.7		9.0	17.7		-8.7	9.0	17.7
LOAD	160 sec.	1.44			6.1	12.0		6.1	12.0		-5.9	6.1	12.0
STEAM BREAK	54 sec.	0.10			3.0	5.9		3.0	5.9		-2.9	3.0	5.9

COMBUSTION ENGINEERING, INC. NUMBER 5-903-2 | A 316
ENGINEERING [illegible] CHATTANOOGA, TENN. SHEET 8 OF 46
CHARGE NO. _____ DATE 9-2-66 BY A. EVANDER
DESCRIPTION Fatigue Evaluation of Bottom Head - To - Shell Junctures CHECK DATE 9-2-66 BY CAMPBELL

A. Detailed Analysis
d) Unbalance Nitrator Stresses
Summary of Stresses and Stress Intensities at Location 3

TRANSIENT	TIME FROM START OF TRANS.	ASSES. (KSI)	$(T_M - T)$ °F	THERMAL STRESS $\sigma_r - \sigma_\theta$	PRESSURE STRESS σ_x	σ_θ	σ_r	TOTAL STRESSES σ_x	σ_θ	σ_r	STRESS INTENSITY $\sigma_\theta - \sigma_r$	$\sigma_x - \sigma_r$	$\sigma_\theta - \sigma_r$
STEADY STATE	~	2.25	0	0	22.3	19.0	-2.3	22.3	19.0	-2.3	3.3	24.6	21.3
HEAT-UP	4.47 hrs.	2.25	-18	-5.5	22.3	19.0	-2.3	16.8	13.5	-2.3	3.3	19.1	15.8
COOL-DOWN	4.47 hrs.	0.32	18	5.5	3.2	2.7	-0.3	8.7	8.2	-0.3	0.5	9.0	8.5
PLANT LOADING	20 min.	2.25	-7.8	-2.4	22.3	19.0	-2.3	19.9	16.6	-2.3	3.3	22.2	18.9
PLANT UNLOADING	20 min.	2.25	7.8	2.4	22.3	19.0	-2.3	24.7	21.4	-2.3	3.3	27.0	23.7
STEP LOAD INCREASE 10 % OF FULL POWER	100 sec.	2.14	11.2	3.4	21.2	18.1	-2.1	24.6	21.5	-2.1	3.1	26.7	23.6
	225 sec.	2.28	1.7	0.5	22.6	19.3	-2.3	23.1	19.8	-2.3	3.3	25.4	22.1
STEP LOAD DECREASE 10% OF FULL POWER	40 sec.	2.32	-9.3	-2.8	23.0	19.6	-2.3	20.2	16.8	-2.3	3.4	22.5	19.1
	100 sec.	2.26	-13.3	-4.1	22.4	19.1	-2.3	18.3	15.0	-2.3	3.3	20.6	17.3
	240 sec.	2.14	-1.3	-0.4	21.2	18.1	-2.1	20.8	17.7	-2.1	3.1	22.9	19.8
LOSS OF FLOW	12 sec.	2.25	33.3	10.2	22.3	19.0	-2.3	32.5	29.2	-2.3	3.3	34.8	31.5
STEP LOAD REDUCTION FROM 100% TO 50% FULL POWER	2 min.	2.37	-12.0	-3.7	23.5	20.1	-2.4	19.8	16.4	-2.4	3.4	22.2	18.8
	3.2 min.	2.35	-15.0	-4.6	23.3	19.9	-2.4	18.7	15.3	-2.4	3.4	21.1	17.7
	10 min.	2.15	0	0	21.3	18.2	-2.2	21.3	18.2	-2.2	3.1	23.5	20.4
REACTOR TRIP FROM FULL POWER	10 sec.	2.22	-9.5	-2.9	22.0	18.8	-2.2	19.1	15.9	-2.2	3.2	21.3	18.1
	65 sec.	1.91	8.5	2.6	18.9	16.2	-1.9	21.5	18.8	-1.9	2.7	23.4	20.7
PLANT HYDRO AT 3125 PSIA	220 min.	3.13	0	0	31.0	26.5	-3.1	31.0	26.5	-3.1	4.5	34.1	29.6
PLANT HYDRO AT 2500 PSIA	HEAT.	1.25	-18	-5.5	12.4	10.6	-1.3	6.9	5.1	-1.3	1.8	8.2	6.4
	S.S.	2.50	0	0	24.8	21.2	-2.5	24.8	21.2	-2.5	3.6	27.3	23.7
	COOL.	0.32	18	5.5	3.2	2.7	-0.3	8.7	8.2	-0.3	0.5	9.0	8.5
STEADY STATE FLUCTUATIONS	~	2.35	6.0	1.8	23.3	19.9	-2.4	25.1	21.7	-2.4	3.4	27.5	24.1
		2.15	-6.0	-1.8	21.3	18.2	-2.2	19.5	16.4	-2.2	3.1	21.7	18.6
LOSS OF LOAD	10 sec.	2.76	-30.2	-9.2	27.4	23.4	-2.8	18.2	14.2	-2.8	4.0	21.0	17.0
	28 sec.	2.12	-41.2	-12.6	21.0	17.9	-2.1	8.4	5.3	-2.1	3.1	10.5	7.4
	160 Sec.	1.44	4.8	1.5	14.3	12.2	-1.4	15.8	13.7	-1.4	2.1	17.2	15.1
STEAM FLOW	54 Sec	0.70	197.0	60.2	6.9	5.9	-0.7	67.1	66.1	-0.7	1.0	67.8	66.8

5. DETAILED ANALYSIS

d.) UNCONCENTRATED STRESSES

SUMMARY OF STRESSES AND STRESS INTENSITIES AT LOCATION 4.

TRANSIENT	TIME FROM START OF TRANS	PRESS. (KSI)	$(T_M - T)$ °F	THERMAL STRESS $\sigma_x = \sigma_\theta$	PRESSURE STRESS σ_x	σ_θ	σ_r	TOTAL STRESSES σ_x	σ_θ	σ_r	STRESS INTENSITY $\sigma_x - \sigma_\theta$	$\sigma_x - \sigma_r$	$\sigma_\theta - \sigma_r$
STEADY STATE	~	2.25	0	0	13.8	16.6	0	13.8	16.6	0	-2.8	13.8	16.6
HEAT-UP	4.47 hrs.	2.25	8	2.4	13.8	16.6		16.2	19.0		-2.8	16.2	19.0
COOL-DOWN	1.41 hrs.	0.32	-8	-2.4	2.0	2.4		-0.4	0		-0.4	-0.4	0
PLANT LOADING	20 min.	2.25	0	0	13.8	16.6		13.8	16.6		-2.8	13.8	16.6
PLANT UNLOADING	20 min.	2.26			13.8	16.6		13.8	16.6		-2.8	13.8	16.6
STEP LOAD INCREASE 10% OF FULL POWER	100 sec.	2.14			13.1	15.8		13.1	15.8		-2.7	13.1	15.8
	225 sec.	2.28			13.9	16.8		13.9	16.8		-2.9	13.9	16.8
STEP LOAD DECREASE 10% OF FULL POWER	40 sec.	2.32			14.2	17.1		14.2	17.1		-2.9	14.2	17.1
	100 sec.	2.26			13.8	16.7		13.8	16.7		-2.9	13.8	16.7
	160 sec.	2.14			13.1	15.8		13.1	15.8		-2.7	13.1	15.8
LOSS OF FLOW	12 sec.	2.25			13.8	16.6		13.8	16.6		-2.8	13.8	16.6
STEP LOAD REDUCTION FROM 100% TO 20% FULL POWER	2 min.	2.37			14.5	17.5		14.5	17.5		-3.0	14.5	17.5
	3.2 min.	2.35			14.4	17.4		14.4	17.4		-3.0	14.4	17.4
	10.4 min.	2.15			13.1	15.9		13.1	15.9		-2.8	13.1	15.9
REACTOR TRIP FROM FULL POWER	10 sec.	2.22			13.6	16.4		13.6	16.4		-2.8	13.6	16.4
	65 sec.	1.91			11.7	14.1		11.7	14.1		-2.4	11.7	14.1
PLANT HYDRO AT 3125 PSIA	200 min.	3.13			19.1	23.1		19.1	23.1		-4.0	19.1	23.1
PLANT HYDRO AT 2150 PSIA	HEAT.	1.25	8	2.4	7.6	9.2		10.0	11.6		-1.6	10.0	11.6
	S.S.	2.50	0	0	15.3	18.5		15.3	18.5		-3.2	15.3	18.5
	COOL.	0.32	-8	-2.4	2.0	2.4		-0.4	0		-0.4	-0.4	0
STEADY STATE FLUCTUATIONS	~	2.35	0	0	14.4	17.4		14.4	17.4		-3.0	14.4	17.4
		2.15			13.1	15.9		13.1	15.9		-2.8	13.1	15.9
LOSS OF LOAD	10 sec.	2.76			16.9	20.4		16.9	20.4		-3.5	16.9	20.4
	28 sec.	2.12			13.0	15.7		13.0	15.7		-2.7	13.0	15.7
	160 sec.	1.44			8.8	10.6		8.8	10.6		-1.8	8.8	10.6
STEAM BYPASS	54 sec.	0.70			4.3	5.2		4.3	5.2		-0.9	4.3	5.2

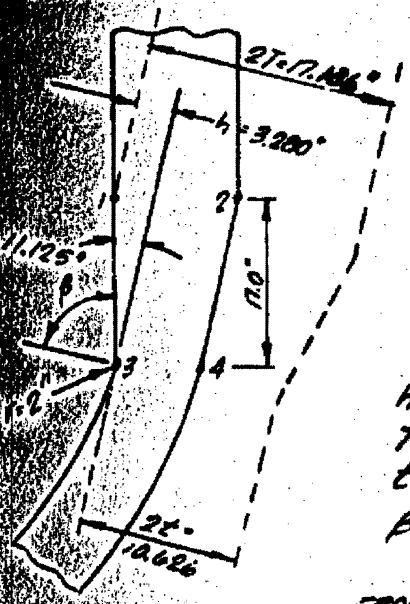
FROM THE ABOVE TABLES, WE SEE THAT THE MAXIMUM RANGE OF STRESS INTENSITY OCCURS AT LOCATION 3 AND IS $S.I._{max\ range} = 34.1$ KSI $< 3S_m = 80.1$ KSI   CRITERION 5-C-1

DESCRIPTION: FATIGUE EVALUATION OF BOTTOM HEAD-TO-VESSEL JUNCTURE

5. CONTINUED ANALYSIS

(e) PEAK STRESSES

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 5 WILL BE MODIFIED TO ACCOUNT FOR STRESS CONCENTRATIONS. WITH THE PEAK STRESSES, A FATIGUE EVALUATION WILL BE MADE BY THE CUMULATIVE METHOD WHEREIN SUPERPOSITION OF ALL CYCLES IS TAKEN INTO CONSIDERATION.



BY INSPECTION, WE SEE THAT THE STRESS CONCENTRATION FACTOR AT LOCATIONS 1, 2 AND 4 EQUALS 1.0. AT LOCATION 3, STRESS CONCENTRATION FACTORS FOR BENDING AND TENSION WILL BE DETERMINED BY THE METHOD PRESENTED IN REFERENCE 3.

$h = 17.0 \sin 11.125° = 3.280"$

$T = 8.593"$ $\quad \frac{r}{t} = 0.376$

$t = 5.313"$ $\quad \frac{r}{h} = 0.610$

$\beta = 78.875°$ $\quad \frac{R}{R_0} = 0.876$

FROM FIGURE A.7-1 OF REF 3:

$K_T = 2.0$, $K_B = 1.65$

FROM FIGURE A.7-2 OF REF 3:

$\left[\frac{K'-1}{K_0-1}\right] = 0.31$ $\qquad K'_T = 1 + 0.31(K_T - 1) = 1 + 0.31(2-1) = 1.31$

$K'_B = 1 + 0.31(K_B - 1) = 1 + 0.31(1.65-1) = 1.20$

STRESS EXPRESSIONS FOR LOCATION 3

$$\sigma_x = \frac{6M_s}{t_3^2} K'_B + \frac{H_s \cos\theta}{t_3} K'_T + \frac{P R_3^2}{2R_3 t_3} K'_T + \frac{E\alpha(T_m - T)}{(1-\nu)} K'_T = 12.77366\,P + 0.40048(T_m - T)$$

$$\sigma_\theta = \frac{2\nu 6M_s}{t_3^2} K'_B + \frac{\nu H_s \cos\theta}{t_3} + \frac{PR_3}{R_3 \sin\theta} + \frac{t_3 P R_3^2 \cos\theta}{2R_3 \sin\theta} + \frac{P R_3^2}{2R_3 t_3} + \frac{E\alpha(T_m - T)}{(1-\nu)} = 8.57104\,P + 0.30811(T_m - T)$$

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

CHARGE NO.________

DESCRIPTION FATIGUE EVALUATION OF BOTTOM HEAD - TO - VESSEL JUNCTURE

NUMBER S-203-P | A 3??
SHEET 11 OF 16
DATE 9-8-66 BY ALEXANDER
CHECK DATE 9-8-66 BY CAUDLE

5. DETAILED ANALYSIS

e) PEAK STRESSES

WITH THE EXPRESSIONS FOR STRESSES AS GIVEN ON SHEET 10 WE GET THE FOLLOWING VALUES FOR PEAK STRESSES.

TRANSIENT	TIME	PRESS. (KSI)	$T_m - T$ (°F)	THERMAL STRESSES		PRESS. STRESSES			PEAK STRESSES		
				σ_x	σ_θ	σ_x	σ_θ	σ_r	σ_x	σ_θ	σ_r
STEADY STATE	—	2.25	0	0	0	28.7	19.3	-2.3	28.7	19.3	-2.3
HEAT-UP	4.47 HRS.	2.25	-18	-7.2	-5.5	28.7	19.3	-2.3	21.5	13.8	-2.3
COOL-DOWN	4.47 HRS.	0.32	18	7.2	5.5	4.1	2.7	-0.3	11.3	8.2	-0.3
PLANT LOADING	20 MIN	2.25	-7.8	-3.1	-2.4	28.7	19.3	-2.3	25.6	16.9	-2.3
PLANT UNLOADING	20 MIN.	2.25	7.8	3.1	2.4	28.7	19.3	-2.3	31.8	21.7	-2.3
STEP LOAD INCREASE 10% OF FULL POWER	100 SEC.	2.14	11.2	4.5	3.4	27.3	18.4	-2.1	31.8	21.8	-2.1
	225 SEC.	2.28	1.7	0.7	0.5	29.1	19.6	-2.3	29.8	20.1	-2.3
STEP LOAD DECREASE 10% OF FULL POWER	20 SEC.	2.32	-9.3	-3.7	-2.8	29.6	19.9	-2.3	25.9	17.1	-2.3
	100 SEC.	2.26	-13.3	-5.3	-4.1	28.9	19.4	-2.3	23.6	15.3	-2.3
	260 SEC.	2.14	-1.3	-0.5	-0.4	27.3	18.4	-2.1	26.8	18.0	-2.1
LOSS OF FLOW	12 SEC	2.25	33.3	13.3	10.2	28.7	19.3	-2.3	42.0	29.5	-2.3
STEP LOAD REDUCTION FROM 100% TO 50% FULL POWER	2 MIN.	2.37	-12.0	-4.8	-3.7	30.3	20.3	-2.4	25.5	16.6	-2.4
	3.2 MIN.	2.35	-15.0	-6.0	-4.6	30.0	20.2	-2.4	24.0	15.6	-2.4
	10.4 MIN.	2.15	0	0	0	27.5	18.4	-2.2	27.5	18.4	-2.2
REACTOR TRIP FROM FULL POWER	10 SEC.	2.22	-9.5	-3.8	-2.9	28.4	19.0	-2.2	24.6	16.1	-2.2
	65 SEC.	1.91	8.5	3.4	2.6	24.4	16.4	-1.9	27.8	19.0	-1.9
PLANT HYDRO AT 3125 PSIA	820 MIN.	3.13	0	0	0	40.0	26.8	-3.1	40.0	26.8	-3.1
PLANT HYDRO AT 2500 PSIA	HEAT.	1.25	-18	-7.2	-5.5	16.0	10.7	-1.3	8.8	5.2	-1.3
	S.S.	2.50	0	0	0	32.0	21.4	-2.5	32.0	21.4	-2.5
	COOL.	0.32	18	7.2	5.5	4.1	2.7	-0.3	11.3	8.2	-0.3
STEADY STATE FLUCTUATIONS	—	2.35	6.0	2.4	1.8	30.0	20.2	-2.4	32.4	22.0	-2.4
	—	2.15	-6.0	-2.4	-1.8	27.5	18.4	-2.2	25.1	16.6	-2.2
LOSS OF LOAD	10 SEC.	2.76	-30.2	-12.1	-9.2	35.3	23.7	-2.8	23.2	14.5	-2.8
	28 SEC.	2.12	-41.2	-16.5	-12.6	27.1	18.2	-2.1	10.6	5.6	-2.1
	140 SEC.	1.44	4.8	1.9	1.5	18.4	12.4	-1.4	20.3	13.9	-1.4
STEAM BREAK	54 SEC.	0.70	197.0	78.9	60.2	8.9	6.0	-0.7	87.8	66.2	-0.7

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.________
DESCRIPTION FATIGUE EVALUATION OF BOTTOM HEAD-TO-VESSEL JUNCTURE

[illegible]
SHEET 12 OF 16
DATE 9-8-66 BY ALEXANDER
CHECK DATE 9-8-66 BY CAUDLE

5. DETAILED ANALYSIS
e) PEAK STRESSES

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	-7.6	14.2	21.8	-9.2	9.6	18.8	9.4	31.0	21.6	-2.8	13.8	16.6
HEAT-UP	-7.6	1.1	8.7	-9.2	16.3	25.5	7.7	23.8	16.1	-2.8	16.2	19.0
COOL-DOWN	-1.1	15.1	16.2	-1.3	-5.3	-4.0	3.1	11.6	8.5	-0.4	-0.4	0
PLANT LOADING	-7.6	11.8	19.4	-9.2	9.6	18.8	8.7	27.9	19.2	-2.8	13.8	16.6
PLANT UNLOADING	-7.6	16.6	24.2	-9.2	9.6	18.8	10.1	34.1	24.0	-2.8	13.8	16.6
STEP LOAD INCREASE 10% OF FULL POWER	-7.3	16.8	24.1	-8.8	9.1	17.9	10.0	33.9	23.9	-2.7	13.1	15.8
	-7.8	14.8	22.6	-9.4	9.7	19.1	9.7	32.1	22.4	-2.9	13.9	16.8
STEP LOAD DECREASE 10% OF FULL POWER	-7.8	11.8	19.6	-9.6	9.8	19.4	8.8	28.2	19.4	-2.9	14.2	17.1
	-7.7	10.1	17.8	-9.3	9.6	18.9	8.3	25.9	17.6	-2.9	13.8	16.7
	-7.3	13.0	20.3	-8.8	9.1	17.9	8.8	28.9	20.1	-2.7	13.1	15.8
LOSS OF FLOW	-7.6	24.4	32.0	-9.2	9.6	18.8	12.5	44.3	31.8	-2.8	13.8	16.6
STEP LOAD REDUCTION FROM 100% TO 50% FULL POWER	-8.0	11.2	19.2	-9.7	10.1	19.8	8.9	27.9	19.0	-3.0	14.5	17.5
	-8.0	10.2	18.2	-9.6	10.0	19.6	8.4	26.4	18.0	-3.0	14.4	17.4
	-7.2	13.6	20.8	-8.9	9.1	18.0	9.1	29.7	20.6	-2.8	13.1	15.9
REACTOR TRIP FROM FULL POWER	-7.5	11.0	18.5	-9.2	9.4	18.6	8.5	26.8	18.3	-2.8	13.6	16.4
	-6.5	14.6	21.1	-7.9	8.1	16.0	8.8	29.7	20.9	-2.4	11.7	14.1
PLANT HYDRO AT SIZE	-10.6	19.6	30.2	-12.9	13.3	26.2	13.2	43.1	29.9	-4.0	19.1	23.1
PLANT HYDRO AT 2500 PSIA	-4.2	-5.2	-1.0	-5.1	12.0	17.1	3.6	10.1	6.5	-1.6	10.0	11.6
	-8.5	15.7	24.2	-10.3	10.6	20.9	10.6	34.5	23.9	-3.2	15.3	18.5
	-1.1	15.1	16.2	-1.3	-5.3	-4.0	3.1	11.6	8.5	-0.4	-0.4	0
STEADY STATE FLUCTUATIONS	-8.0	16.6	24.6	-9.6	10.0	19.6	10.4	34.8	24.4	-3.0	14.4	17.4
	-7.2	11.8	19.0	-8.9	9.1	18.0	8.5	27.3	18.8	-2.8	13.1	15.9
LOSS OF LOAD	-9.3	8.2	17.5	-11.4	11.7	23.1	8.7	26.0	17.3	-3.5	16.9	20.4
	-7.2	0.7	7.9	-8.7	9.0	17.7	5.0	12.7	7.7	-2.7	13.0	15.7
	-4.9	10.5	15.4	-5.9	6.1	12.0	6.4	21.7	15.3	-1.8	8.8	10.6
STEAM BREAK	-2.4	64.6	67.0	-2.9	3.0	5.9	21.6	88.5	66.9	-0.9	4.3	5.2

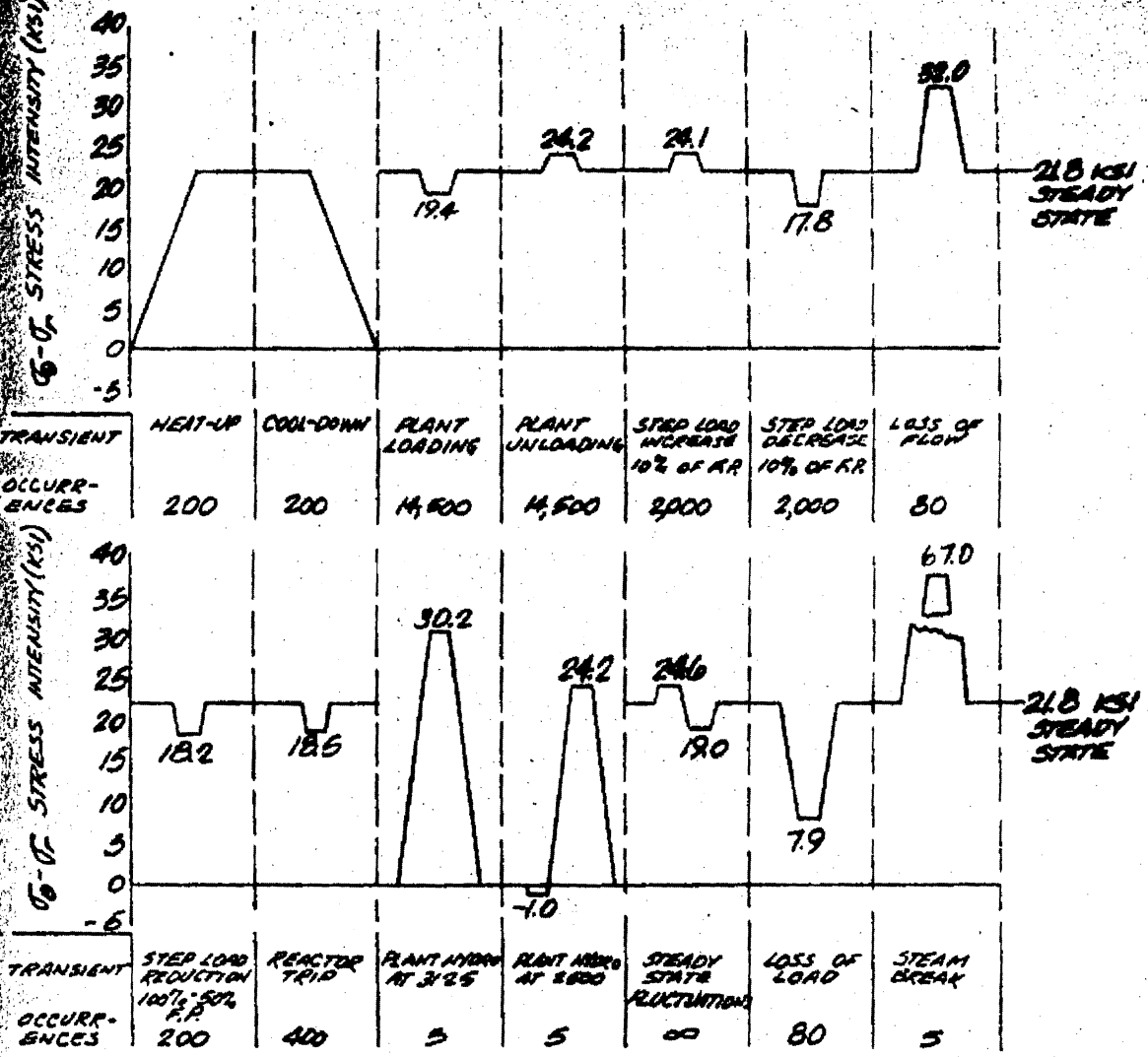
COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER S-203-P | A 001
SHEET 13 OF 16
CHARGE NO.
DATE 9-8-66 BY ALEXANDER
DESCRIPTION FATIGUE EVALUATION OF BOTTOM HEAD-TO-SHELL JUNCTURE
CHECK DATE 9-8-66 BY CRANE

5 DETAILED ANALYSIS

f) FATIGUE EVALUATION

$\sigma_0 - \sigma_r$ AT LOCATION 1



$S_{max.}$	$S_{min.}$	NUMBER OF OCCURRENCES	S_a	N^*	U
67.0	-1.0	5	34.0	14,000	0.00035
32.0	0	80	16.0	250,000	0.00032
30.2	0	5	15.1	350,000	0.00001
24.6	0	115	12.3	∞	0

$U_{total} = 0.0007$

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

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

CHARGE NO. _____

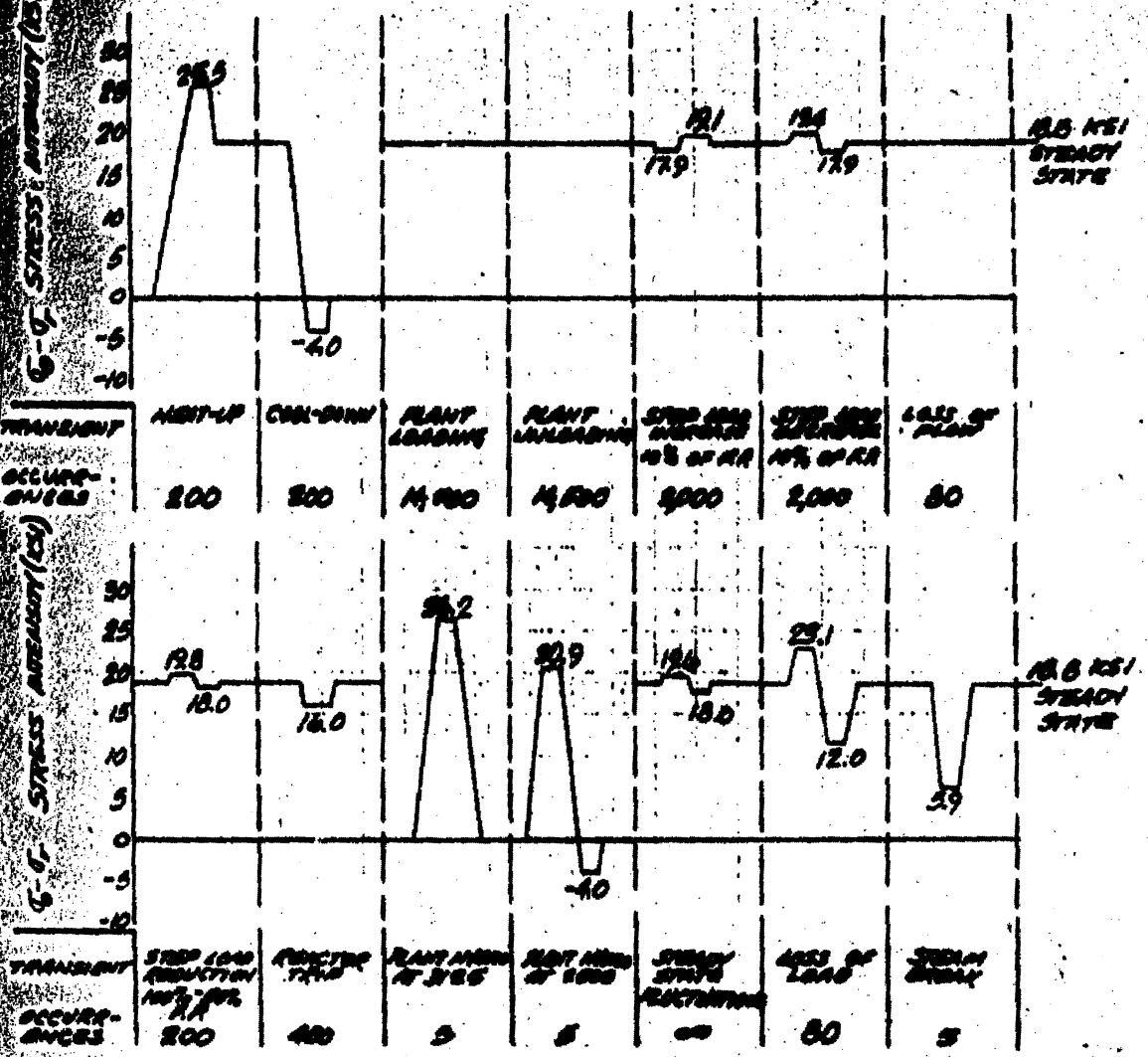
NUMBER S-203-P | A RIV.
SHEET 14 OF 114
DATE 9-8-66 BY ALEXANDER
CHECK DATE 9-8-66 BY CAUDLE

DESCRIPTION: FATIGUE ANALYSIS OF METAL MIXED-TO-METAL JUNCTURE

5 DETAILED ANALYSIS

5.1 FATIGUE EVALUATION

$S_0 - S_T$ AT LOCATION 2



S_{max}	S_{min}	NUMBER OF OCCURRENCES	S_a	N^*	U
26.2	-4.0	5	15.1	3500,000	0.000001
25.5	-4.0	200	14.8	400,000	0.00050
23.1	5.9	5	8.6	∞	0

* FROM FIG. N-415 (A)
USAGE FACTOR = 0.00051
USAGE = 1.0005

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

CHARGE NO.

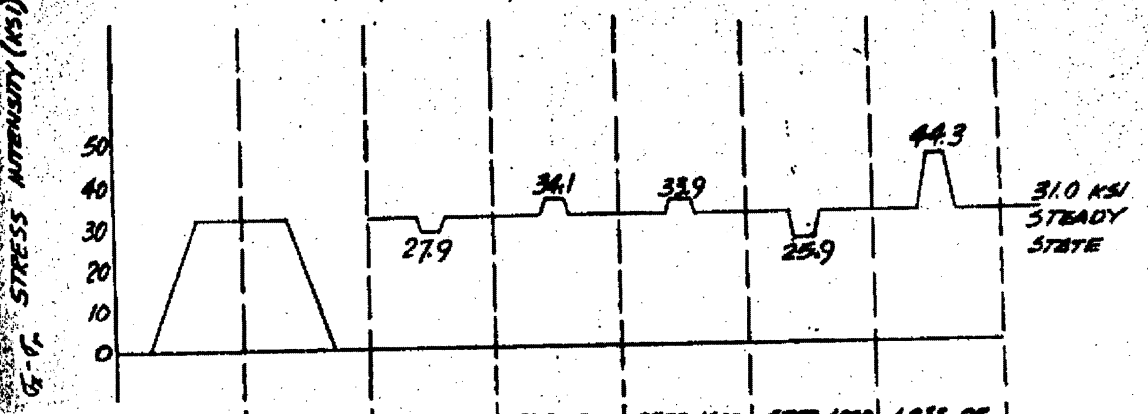
DESCRIPTION FATIGUE ANALYSIS OF NOZZLE HEAD-TO-VESSEL JUNCTURE

NUMBER S-203-P | A-200
SHEET 12 OF 160
DATE 9-8-66 BY ALEXANDER
CHECK DATE 9-8-66 BY CALDER

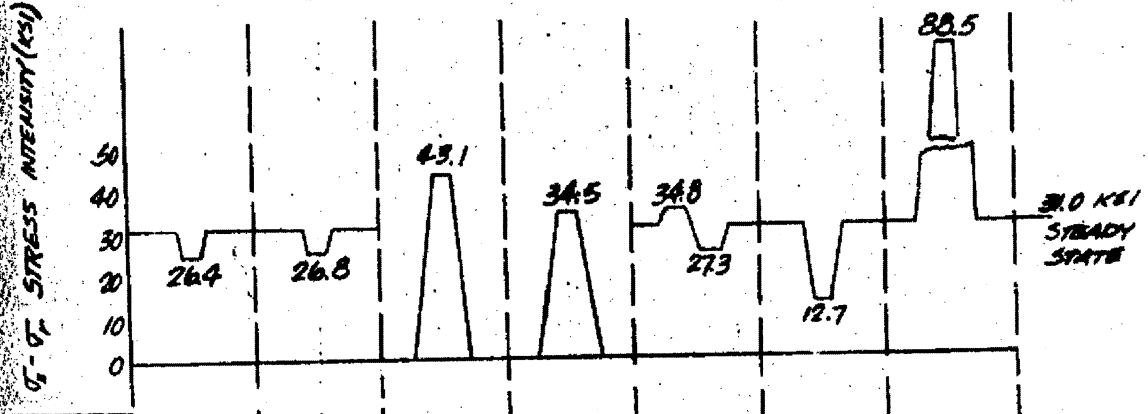
5 DETAILED ANALYSIS

f) FATIGUE EVALUATION

$\sigma_x - \sigma_r$ AT LOCATION 3



TRANSIENT	HEAT-UP	COOL-DOWN	PLANT LOADING	PLANT UNLOADING	STEP LOAD INCREASE 10% OF RA	STEP LOAD DECREASE 10% OF RA	LOSS OF PLANT
OCCURRENCES	200	200	14,600	14,600	2,000	2,000	80



TRANSIENT	STEP LOAD REDUCTION 100%-50% F.P.	REACTOR TRIP	PLANT HEATUP AT 325	PLANT HEATUP AT 2250	STEADY STATE FLUCTUATIONS	LOSS OF LOAD	STEAM BREAK
OCCURRENCES	200	400	3	5	∞	80	5

$S_{max.}$	$S_{min.}$	NUMBER OF CONSECUTIVE	S_{alt}	N^*	U
88.5	0	5	44.3	6000	0.00084
44.3	0	80	22.2	60,000	0.00133
43.1	0	5	21.6	70,000	0.00007
34.8	0	115	17.4	170,000	0.00067
34.5	0	5	17.3	180,000	0.00002
34.8	12.7	80	11.1	∞	0

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

Usage = 0.003

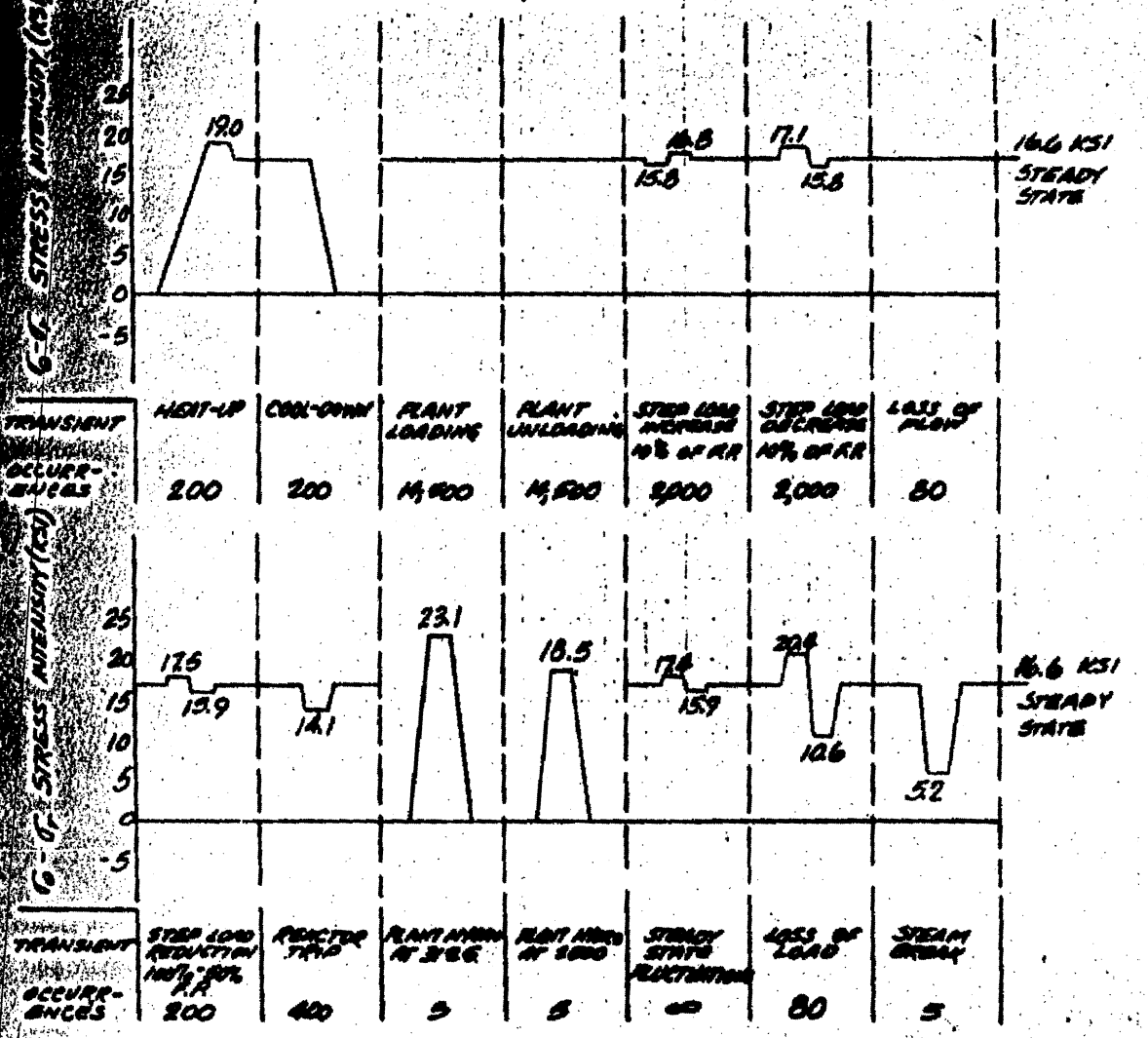
COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO. _____
DESCRIPTION: FATIGUE ANALYSIS OF NOZZLE-TO-VESSEL JUNCTIONS

NAME: Submitted to Docket
SHEET 16 OF 16
DATE: 9-8-66 BY: ALEXANDER
CHECK DATE: 9-8-66 BY: CRUSE

DETAILED ANALYSIS

A) FATIGUE EVALUATION

$\sigma_1 - \sigma_3$ AT LOCATION 4



$S_{max.}$	$S_{min.}$	NUMBER OF CYCLES	S_a	N^*	U
23.1	0	.5	11.6	∞	0

TOTAL $U = 0$

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