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

CHARGE NO. ______

DESCRIPTION: Structural and Fatigue Evaluation of Outlet Nozzle - Vessel Support

NUMBER: S-212-P | A 246
SHEET: 74 OF 90
DATE: 6-22-68 BY Cockrell
CHECK DATE: 6-22-68 BY Henker

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

Location 9A

	Transient	Pressure Stress σ_x	Pressure Stress σ_θ	Pressure Stress σ_r	Thermal Stress σ_x	Thermal Stress σ_θ	Thermal Induced Pipe Reaction Stress σ_x	Thermal Induced Pipe Reaction Stress σ_θ	Thermal Induced Pipe Reaction Stress $\tau_{x\theta}$	Seismic Pipe Reaction Stress σ_x	Seismic Pipe Reaction Stress σ_θ	Seismic Pipe Reaction Stress $\tau_{x\theta}$	Static Weight Stress σ_x	Static Weight Stress σ_θ	Static Weight Stress $\tau_{x\theta}$
a. Heatup	4.00 HRS	-3.18	49.29	-1.88	-13.44	-15.77	-4.64	-1.48	-0.05	-2.56	-1.32	-0.43	1.62	0.55	0
	4.25	-3.51	54.42	-2.08	-13.59	-15.91	-4.93	-1.57	↓	↓	↓	↓	↓	↓	↓
	4.35	-3.64	56.46	-2.16	-13.63	-15.96	-5.04	-1.61	↓	↓	↓	↓	↓	↓	↓
	4.47	-3.90	58.92	-2.25	-14.19	-16.37	-5.18	-1.65	↓	↓	↓	↓	↓	↓	↓
	5.00	-3.90	58.92	-2.25	-6.50	-7.84	-5.18	-1.65	↓	↓	↓	↓	↓	↓	↓
	4.00	-3.18	49.29	-1.88	-13.44	-15.44	-4.64	-1.48	↓	2.56	1.32	0.43	↓	↓	↓
	4.25	-3.51	54.42	-2.08	-13.58	-15.91	-4.93	-1.57	↓	↓	↓	↓	↓	↓	↓
	4.36	-3.64	56.46	-2.16	-13.62	-15.96	-5.04	-1.61	↓	↓	↓	↓	↓	↓	↓
	4.47	-3.90	58.92	-2.25	-14.14	-16.36	-5.18	-1.65	↓	↓	↓	↓	↓	↓	↓
	5.00	-3.90	58.92	-2.25	-6.50	-7.84	-5.18	-1.65	↓	↓	↓	↓	↓	↓	↓
No Load Steady State		-3.80	58.92	-2.25	0.17	-0.08	-5.18	-1.65	↓	0	0	0	↓	↓	↓
b. Cooldown	4.00 HRS	-0.53	8.25	-0.31	12.24	14.29	-0.54	-0.17	-0.01	-2.56	-1.32	-0.43	↓	↓	↓
	4.25	↓	↓	↓	12.10	14.15	-0.26	-0.08	0	↓	↓	↓	↓	↓	↓
	4.35	↓	↓	↓	12.04	14.09	-0.14	-0.04	↓	↓	↓	↓	↓	↓	↓
	4.47	↓	↓	↓	12.39	14.34	0	0	↓	↓	↓	↓	↓	↓	↓
	5.00	↓	↓	↓	5.57	6.64	0	0	↓	↓	↓	↓	↓	↓	↓
	4.00	↓	↓	↓	12.24	14.29	-0.54	-0.17	-0.01	2.56	1.32	0.43	↓	↓	↓
	4.25	↓	↓	↓	12.10	14.15	-0.26	-0.08	0	↓	↓	↓	↓	↓	↓
	4.35	↓	↓	↓	12.04	14.09	-0.14	-0.04	↓	↓	↓	↓	↓	↓	↓
	4.47	↓	↓	↓	12.39	14.34	0	0	↓	↓	↓	↓	↓	↓	↓
	5.00	↓	↓	↓	5.57	6.64	0	0	↓	↓	↓	↓	↓	↓	↓

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

LOCATION 9A

Transient		Pressure Stress σ_x	Pressure Stress σ_θ	Pressure Stress σ_r	Thermal Stress σ_x	Thermal Stress σ_θ	Thermal Induced Pipe Reaction Stress σ_x	Thermal Induced Pipe Reaction Stress σ_θ	Thermal Induced Pipe Reaction Stress $\tau_{x\theta}$	Seismic Pipe Reaction Stress σ_x	Seismic Pipe Reaction Stress σ_θ	Seismic Pipe Reaction Stress $\tau_{x\theta}$	Static Weight Stress σ_x	Static Weight Stress σ_θ	Static Weight Stress $\tau_{x\theta}$
c. Plant Loading	10 min	-2.90	58.92	-2.25	-1.78	-0.49	-5.18	-1.65	-0.05	0	0	0	1.62	0.55	0
	15	↓	↓	↓	-2.94	-0.66	↓	↓	↓	↓	↓	↓	↓	↓	↓
	20				-4.25	-0.77									
	25				-4.41	-0.36									
	30				-4.06	0.21									
Full Load Steady State					-4.88	4.51									
d. Plant Unloading	10 min				1.57	6.19									
	15				2.68	6.24									
	20				3.59	6.16									
	25				4.03	5.86									
	30				3.52	5.08									
e	100 sec	-3.62	56.04	-2.14	-3.22	1.26									
	225	-3.84	59.58	-2.27	-6.15	-1.68									
f	40 sec	-3.92	60.76	-2.32	-9.54	-5.07									
	100	-3.82	59.18	-2.26	-10.78	-6.30									
	260	-3.62	56.04	-2.14	-7.08	-2.60									
g	3.5 min	-3.97	61.54	-2.35	-5.13	-0.67									
	11	-3.63	56.30	-2.15	-0.21	4.26									
	15.5	-3.80	58.92	-2.25	0.09	4.57									

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

Location 9A

Transient		Pressure Stress			Thermal Stress		Thermal Induced Pipe Reaction Stress			Seismic Pipe Reaction Stress			Static Weight Stress		
		σ_x	σ_θ	σ_r	σ_x	σ_θ	σ_x	σ_θ	$\tau_{x\theta}$	σ_x	σ_θ	$\tau_{x\theta}$	σ_x	σ_θ	$\tau_{x\theta}$
h	10 sec	-3.75	58.14	-2.22	-3.59	0.87	-5.18	-1.65	-0.05	0	0	0	1.62	0.55	0
	90	-3.28	50.80	-1.94	1.94	6.41	-5.18	-1.65	-0.05	↓	↓	↓	↓	↓	↓
i	220 min	-5.28	81.84	-3.12	0	0	0	0	0	↓	↓	↓	↓	↓	↓
j	H.U. 2.0 HRS	-2.11	32.73	-1.25	-13.32	-15.46	-3.48	-1.11	-0.03	↓	↓	↓	↓	↓	↓
	S.S.	-4.22	65.47	-2.50	0.11	-0.06	-3.48	-1.11	-0.03	↓	↓	↓	↓	↓	↓
	C.D. 3.0 HRS	-0.53	8.25	-0.31	13.51	14.27	0	0	0	↓	↓	↓	↓	↓	↓
k	~	-3.97	61.54	-2.35	-4.82	-0.36	-5.18	-1.65	-0.05	↓	↓	↓	↓	↓	↓
	~	-3.63	56.30	-2.15	-8.51	-4.05	↓	↓	↓	↓	↓	↓	↓	↓	↓
l	12 sec	-3.80	58.92	-2.25	9.32	13.78	↓	↓	↓	↓	↓	↓	↓	↓	↓
	18.5	-3.80	58.92	-2.25	-0.15	4.26	↓	↓	↓	↓	↓	↓	↓	↓	↓
m	12 sec	-4.65	72.02	-2.75	-10.05	-5.59	↓	↓	↓	↓	↓	↓	↓	↓	↓
	26	-3.38	54.38	-2.00	-13.13	-8.67	↓	↓	↓	↓	↓	↓	↓	↓	↓
	144	-2.49	38.63	-1.47	1.02	5.49	↓	↓	↓	↓	↓	↓	↓	↓	↓
n	33 sec	-0.51	7.86	-0.30	29.03	33.53	↓	↓	↓	↓	↓	↓	↓	↓	↓
	54	-1.18	18.33	-0.70	53.46	57.95	↓	↓	↓	↓	↓	↓	↓	↓	↓

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

NUMBER 5-218-P | A249
SHEET 77 OF 80
CHARGE NO. ______
DATE 4-27-69 BY Cockrell
DESCRIPTION Structural And Fatigue Evaluation Of Outlet Nozzle - Vessel Support
CHECK DATE 4-22-69 BY Helper

5. Detailed Analysis:

e. Stresses:

2. Peak Stresses:

LOCATION 9A

Transient		Earthquake Loading Thermal Shoulder Stress σ_x	σ_ϕ	$\tau_{x\theta}$	Expansion And Contraction Stress σ_r	σ_θ	Total Stresses σ_x	σ_θ	σ_r	$\tau_{x\theta}$	Principal Stress σ_1	σ_2	σ_3	Stress Intensity $\sigma_1-\sigma_2$	$\sigma_1-\sigma_3$	$\sigma_2-\sigma_3$
a. Heatup	4.00 HRS	-0.38	-0.13	-0.20	-0.28	0.53	-22.86	31.67	-1.88	-0.68	31.68	-22.87	-1.88	54.55	33.56	-20.99
	4.25						-23.63	36.57	-2.08	-0.68	36.58	-23.64	-2.08	60.21	38.65	-21.56
	4.35						-23.92	38.52	-2.16	-0.68	38.53	-23.92	-2.16	62.45	40.69	-21.77
	4.47						-24.73	40.54	-2.25	-0.69	40.54	-24.73	-2.25	65.28	42.79	-22.48
	5.00						-17.08	49.06	-2.25	-0.69	49.07	-17.09	-2.25	66.16	51.32	-14.84
	4.00	0.38	0.13	0.20			-16.97	34.56	-1.88	0.59	34.57	-16.98	-1.88	51.55	36.45	-15.10
	4.25						-17.74	39.46	-2.08	0.59	39.47	-17.74	-2.08	57.22	41.55	-15.67
	4.35						-18.03	41.42	-2.16	0.58	41.42	-18.03	-2.16	59.46	43.58	-15.88
	4.47						-18.84	43.43	-2.25	0.58	43.44	-18.84	-2.25	62.28	45.69	-16.59
	5.00						-11.20	51.95	-2.25	0.58	51.96	-11.20	-2.25	63.16	54.21	-8.95
No Load Steady State		0	0	0	0	0	-7.20	57.73	-2.25	-0.05	57.74	-7.20	-2.25	64.93	59.99	-4.95
b. Cooldown	4.00 Hrs	-0.38	-0.13	-0.20	0.28	-0.53	10.11	20.94	-0.31	-0.64	20.98	10.08	-0.31	10.90	21.29	10.39
	4.25						10.27	20.89		-0.64	20.93	10.23		10.70	21.24	10.55
	4.35						10.32	20.87		-0.64	20.91	10.28		10.63	21.22	10.59
	4.47						10.81	21.16		-0.63	21.20	10.77		10.43	21.52	11.09
	5.00						3.99	13.46		-0.63	13.50	3.95		9.56	13.82	4.26
	4.00	0.38	0.13	0.20			16.00	23.83		0.63	23.88	15.95		7.93	24.19	16.26
	4.25						16.15	23.79		0.63	23.84	16.10		7.74	24.15	16.41
	4.35						16.20	23.76		0.63	23.81	16.15		7.66	24.13	16.46
	4.47						16.69	24.05		0.63	24.11	16.64		7.47	24.42	16.95
	5.00						9.81	16.35		0.63	16.41	9.81		6.60	16.73	10.12

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

CHARGE NO. ______

DESCRIPTION: Structural And Fatigue Evaluation Of Outlet Nozzle – Vessel Supports

NUMBER: 5-212-P | A 250
SHEET: 78 OF 80
DATE: 4-22-68 BY: Cockerell
CHECK DATE: 4-22-68 BY: Hemker

5-Detailed Analysis:

e. Stresses:

2-Peak Stresses:

LOCATION 9A

Transient		Earthquake Loading Thermal Supports Stresses σ_x	σ_θ	$\tau_{x\theta}$	Expansion And Contraction Stress σ_x	σ_θ	Total Stress σ_x	σ_θ	σ_r	$\tau_{x\theta}$	Principal Stress σ_1	σ_2	σ_3	Stress Intensity $\sigma_1-\sigma_2$	$\sigma_1-\sigma_3$	$\sigma_2-\sigma_3$
Plant Loading c	10 min	0	0	0	0	0	-9.15	57.33	-2.25	-0.05	57.53	-9.15	-2.25	66.47	59.58	-6.90
	15						-10.31	57.16			57.16	-10.31		67.47	59.41	-8.06
	20						-11.61	57.05			57.05	-11.61		68.66	59.30	-9.36
	25						-11.78	57.45			57.45	-11.78		69.23	59.70	-9.53
	30						-11.43	58.03			58.03	-11.43		69.46	60.28	-9.18
Full Load Steady State							-9.25	62.33			62.33	-9.25		71.58	64.58	-7.00
Plant Unloading d	10 min						-5.80	64.01			64.01	-5.80		69.80	66.26	-3.55
	15						-4.69	64.06			64.06	-4.69		68.75	66.31	-2.44
	20						-3.78	63.98			63.98	-3.78		67.75	66.23	-1.53
	25						-3.33	63.68			63.68	-3.33		67.01	65.93	-1.08
	30						-3.84	62.90			62.90	-3.84		66.74	65.15	-1.59
e	100 sec						-10.40	56.19	-2.14		56.19	-10.40	-2.14	66.59	58.33	-8.26
	285						-13.56	56.80	-2.27		56.80	-13.56	-2.27	70.35	59.07	-11.28
f	40 sec						-17.03	54.58	-2.32		54.58	-17.03	-2.32	71.61	56.90	-14.71
	100						-18.16	51.78	-2.26		51.78	-18.16	-2.26	69.94	54.04	-15.90
	260						-14.26	52.34	-2.14		52.84	-14.26	-2.14	66.59	54.48	-12.12
g	35 min						-12.66	59.77	-2.35		59.77	-12.66	-2.35	72.43	62.12	-10.31
	11						-7.40	59.46	-2.15		59.46	-7.40	-2.15	66.86	61.61	-5.25
	15.5						-7.27	62.38	-2.25		62.38	-7.27	-2.25	69.65	64.63	-5.02

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

CHARGE NO. ______

DESCRIPTION: Structural And Fatigue Evaluation Of Outlet Nozzle - Vessel Supports

NUMBER 5-212-P | A251
SHEET 79 OF 80
DATE 4-21-63 BY Cockrell
CHECK DATE 4-22-63 BY Heiker

5. Detailed Analysis:

e. Stresses:

2. Peak Stresses

LOCATION 9A

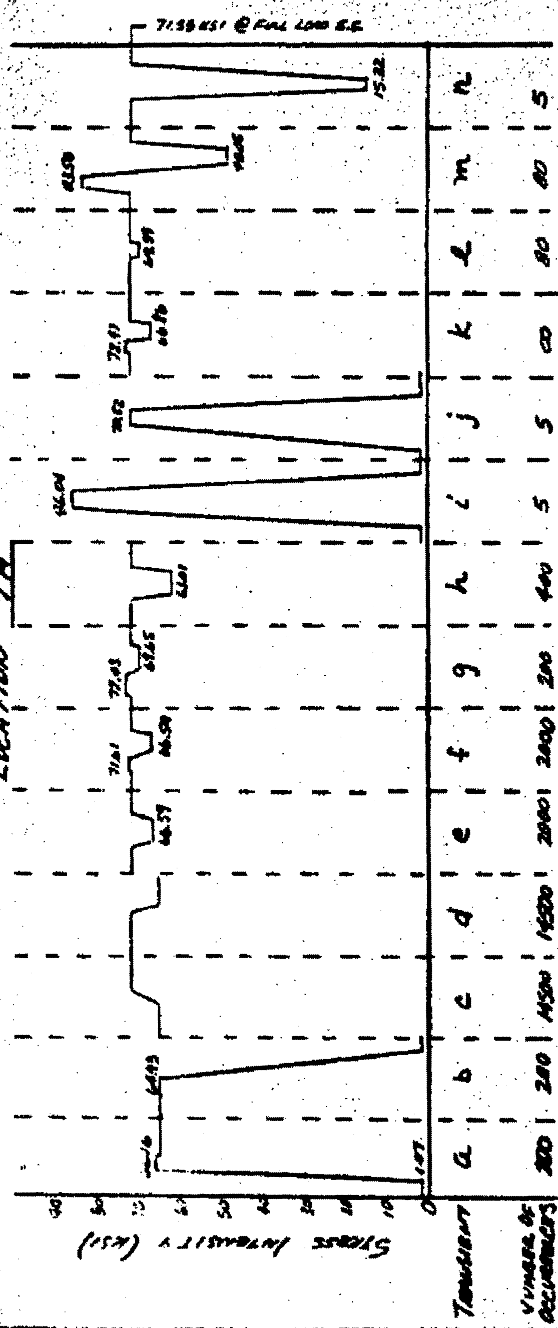
	Trans. Ev.	Earthquake Loading Thermal Stress σ_x	σ_θ	$\tau_{x\theta}$	Expansion And Deflection Stress σ_x	σ_θ	Total Stress σ_x	σ_θ	σ_r	$\tau_{x\theta}$	Principal Stress σ_1	σ_2	σ_3	Stress Intensity $\sigma_1-\sigma_2$	$\sigma_1-\sigma_3$	$\sigma_2-\sigma_3$
h	10 sec	0	0	0	0	0	-10.91	57.90	-2.22	-0.05	57.90	-10.91	-2.22	68.81	60.12	-9.69
	90						-4.90	56.11	-1.94	-0.05	56.11	-4.90	-1.94	61.01	59.05	-2.96
i	220 min						-3.66	82.38	-3.12	0	82.38	-3.66	-3.12	86.04	85.51	-0.54
j	4.0 3.0 hrs						-17.29	16.72	-1.25	-0.03	16.72	-17.29	-1.25	34.01	17.97	-16.04
	S.S.						-5.97	64.85	-2.50	-0.03	64.85	-5.97	-2.25	70.82	67.35	-3.47
	C.D 36 hrs						14.60	23.06	-0.31	0	23.06	14.60	-0.31	8.46	23.38	14.91
k	~						-12.36	60.08	-2.35	-0.05	60.08	-12.36	-2.35	72.43	62.43	-10.01
	~						-15.71	51.15	-2.15		51.15	-15.71	-2.15	66.86	53.30	-13.56
l	12 sec						1.96	71.60	-2.25		71.60	1.96	-2.25	69.64	73.85	4.21
	195						-7.51	62.08	-2.25		62.08	-7.51	-2.25	69.59	64.33	-5.26
m	12 sec						-18.26	65.32	-2.75		65.32	-18.26	-2.75	83.58	68.07	-15.51
	26						-20.07	42.60	-2.00		42.60	-20.07	-2.00	62.67	44.60	-18.07
	144						-5.04	43.01	-1.47		43.01	-5.04	-1.47	48.05	44.49	-3.56
n	33 sec						24.96	40.28	-0.30		40.28	24.96	-0.30	15.32	40.58	25.26
	54						48.71	75.18	-0.70		75.18	48.71	-0.70	26.47	75.88	49.41

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

NUMBER 5-218-P | A 252
SHEET 80 OF 80
CHARGE NO.
DATE 4-22-68 BY COCKRELL
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE – VESSEL SUBSET
CHECK DATE 4-22-68 BY HOWKER

5. DETAILED ANALYSIS:

f. FATIGUE EVALUATION:



S_{MAX}	S_{MIN}	S_{ALT}	No. of Occurrences	N^*	U
86.04	1.07	42.49	5	7000	.0007
93.58	1.07	41.26	80	7700	.0104
72.43	1.07	35.68	120	11500	.0104
70.82	1.07	34.88	5	13000	.0004
72.43	15.32	28.56	5	26000	.0002
72.43	48.05	12.19	80	∞	0

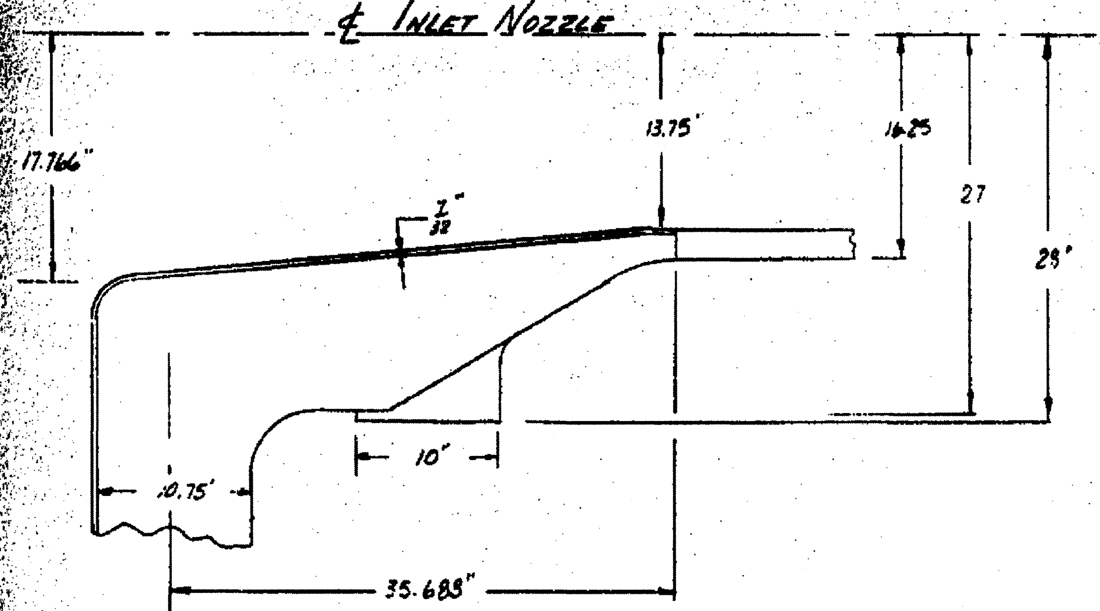
* FROM FIG. N-415(A) REFERENCE 1

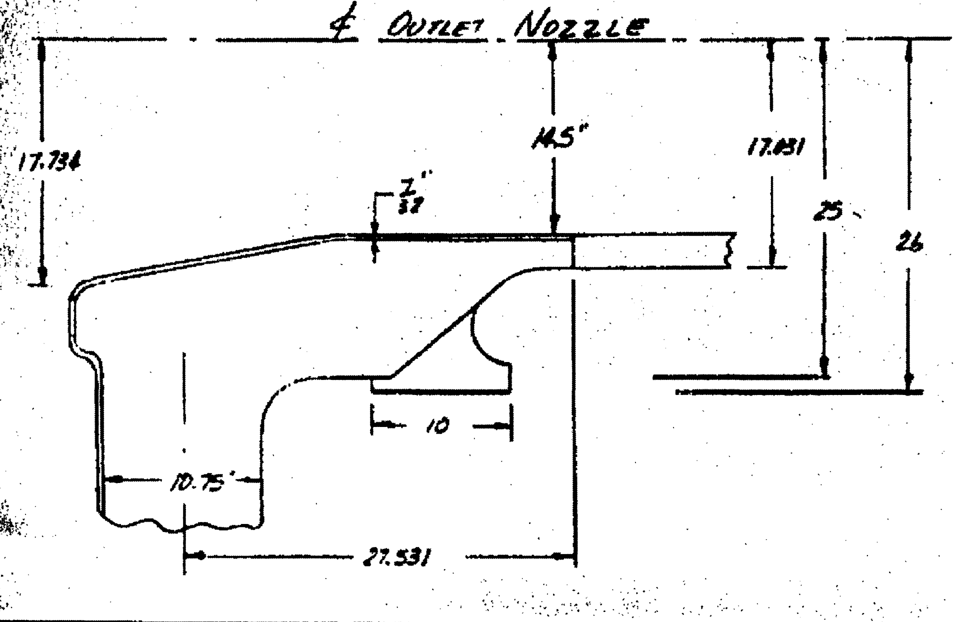
$U_{OVERALL} = 0.022$

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION Structural Analysis Of Inlet & Outlet Nozzles Vessel Supports Under Pipe Break Loads

NUMBER 5-2M-P | A 253
SHEET 5 OF 10
DATE 1-11-67 BY Cockrell
CHECK DATE 1-11-67 BY Couple

5. Detailed Analysis:
a. System Geometry:





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

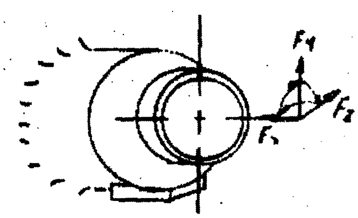
NUMBER S-2M-P | A234
SHEET 6 OF 10
DATE 4-11-69 BY Cochrell
CHARGE NO. ____
DESCRIPTION Structural Analysis Of Inlet And Outlet Nozzles - Vessel Supports Under Pipe Break Loads
CHECK DATE ____ BY ____

5- DETAILED ANALYSIS:

5.6- LOADS ON NOZZLES:

IN THIS SECTION, ANALYSIS WILL BE PERFORMED FOR THE FOLLOWING SEVEN INDEPENDANT REACTOR COOLANT PIPE BREAK ACCIDENT CONDITIONS

	CASE	F_x	F_y	F_z	M_x	M_y	M_z
OUTLET	1	1485	—	—	—	—	—
OUTLET	2	955	-1140	—	—	—	80300
OUTLET	3	260	390	-800	—	-97100	-37500
INLET	1	1337	—	—	—	—	—
INLET	2	220	--	1473	—	61750	—
INLET	3	—	—	—	-89000	—	—
INLET	4	—	1437	—	—	—	-63700



THE PIPE BREAK LOADS WILL BE COMBINED WITH THE NORMAL OPERATING DEADWEIGHT, INTERNAL PRESSURE, AND THERMAL PIPE REACTIONS. THE THERMAL PIPE REACTIONS ON THE NOZZLE WITH THE PIPE BREAK ARE INSTANTANEOUS RELIEVED AND WILL NOT BE CONSIDERED IN THE EVALUATION OF THAT NOZZLE DURING THE PIPE BREAK ACCIDENT.

THE EFFECT OF THESE LOADS WILL BE EVALUATED FOR THE REINFORCED PORTION OF THE NOZZLE, THE NOZZLE TO SHELL JUNCTURE, AND THE VESSEL SUPPORTS.

FOR THE PIPE BREAK ACCIDENT CONDITIONS, THE RESULTING STRESSES WILL BE LIMITED TO 1.2 TIMES THE CODE ALLOWABLE STRESSES. EACH OF THE ABOVE CASES HAVE BEEN INVESTIGATED TO DETERMINE WHICH GAVE THE HIGHEST STRESSES AT THE LOCATIONS OF INTEREST.

5- DETAILED ANALYSIS:

b- LOADS ON NOZZLES:

INLET NOZZLE

REINFORCED PORTION OF NOZZLE

THE LOCATIONS OF INTEREST ARE 7 & 8 (SEE SHEET 40 OF S-211-P). THE CASES WHICH GAVE THE HIGHEST STRESSES WERE CASE 4 FOR POINTS A & B AND CASE 2 FOR POINTS C & D. NOTE THAT THE HIGHEST STRESSES OCCURRED ON INLET NOZZLES 2 & 4 BECAUSE THE SUPPORT LOADS HELP TO RELIEVE THE STRESSES.

FOR CASE 4		FOR CASE 2	
$\bar{F}_x$ = 0	$\bar{M}_x$ = 0	$\bar{F}_x$ = 0	$\bar{M}_x$ 0
$\bar{F}_y$ = 1437	$\bar{M}_y$ = 0	$\bar{F}_y$ = 0	$\bar{M}_y$ = 106401
$\bar{F}_z$ = 0	$\bar{M}_z$ = -107260	$\bar{F}_z$ = 1473	$\bar{M}_z$ 0

VESSEL WALL AT THE NOZZLE TO VESSEL SHELL JUNCTURE

THE LOCATIONS OF INTEREST ARE 9 & 10 (SEE SHEET 43 OF S-211-P). THE CASES WHICH GAVE THE HIGHEST STRESSES WERE CASE 4 FOR POINTS A & B AND CASE 2 FOR POINTS C & D. THE HIGHEST STRESSES OCCURRED ON INLET NOZZLES 2 & 4

FOR CASE 4		FOR CASE 2	
$\bar{F}_x$ = 0	$\bar{M}_x$ = 0	$\bar{F}_x$ = 0	$\bar{M}_x$ = 0
$\bar{F}_y$ = 1437	$\bar{M}_y$ = 0	$\bar{F}_y$ = 0	$\bar{M}_y$ = 113034
$\bar{F}_z$ = 0	$\bar{M}_z$ = -114984	$\bar{F}_z$ = 1473	$\bar{M}_z$ = 0

SUPPORT PADS:

THE LOCATIONS OF INTEREST ARE THE SIDE AND BOTTOM OF THE PADS. CASES 2 AND 4 GAVE THE HIGHEST FORCES

H_{MAX} = -1304[K] FOR CASE 2

V_{MAX} = 1642[K] FOR CASE 4

NOTE THAT THE VESSEL TENDS TO LIFT OF THE SUPPORTS FOR CASE No 4 - INLET NOZ.

5- DETAILED ANALYSIS:
6. LOADS ON NOZZLES:

OUTLET NOZZLE:

REINFORCED PORTION OF NOZZLE:

THE LOCATIONS OF INTEREST ARE 7 & 8 (SEE SHEET 46 OF S-212-P). THE CASE WHICH GAVE THE HIGHEST STRESSES WAS CASE 3. THE HIGHEST STRESSES WILL OCCUR ON OUTLET NOZZLES 1 AND 3 BECAUSE THE SUPPORT LOAD STRESSES HELP TO RELIEVE THE STRESSES.

FOR CASE 3

$\bar{F}_x = 0$ $\bar{M}_x =$ $\sqrt{\bar{M}_y^2 + \bar{M}_z^2} = 114441$ IN-KIP

$\bar{F}_y = 390$ $\bar{M}_y = -104825$

$\bar{F}_z = -800$ $\bar{M}_z = -45919$ $F_y \sin\theta + F_z \cos\theta = -27^k$ FOR $\theta = \tan^{-1} \frac{M_y}{M_z}$

VESSEL WALL AT THE NOZZLE TO VESSEL SHELL JUNCTURE:

THE LOCATIONS OF INTEREST ARE 9 & 10 (SEE SHEET 49 OF S-212-P). THE CASES WHICH GAVE THE HIGHEST STRESSES WERE CASE 2 FOR POINTS A & B AND CASE 3 FOR POINTS C & D. THE HIGHEST STRESSES OCCURRED ON OUTLET NOZZLES NO. 1 AND 3.

CASE 2		CASE 3	
$\bar{F}_x = 0$	$\bar{M}_x = 0$	$\bar{F}_x = 0$	$\bar{M}_x = 0$
$\bar{F}_y = -1140$	$\bar{M}_y = 0$	$\bar{F}_y = 390$	$\bar{M}_y = -109125$
$\bar{F}_z = 0$	$\bar{M}_z = 111685$	$\bar{F}_z = -800$	$\bar{M}_z = -47962$

SUPPORT PADS:

THE LOCATIONS OF INTEREST ARE THE SIDE AND BOTTOM OF THE PADS. CASE 2 FOR THE OUTLET NOZZLE GAVE THE HIGHEST VERTICAL FORCE AND CASE 2 FOR THE INLET NOZZLE GAVE THE HIGHEST HORIZONTAL FORCE.

$H_{MAX} = 1021^k$ FOR CASE 2 (INLET NOZ)

$V_{MAX} = 1637^k$ FOR CASE 2 (OUTLET NOZ)

NOTE THAT THE VESSEL TENDS TO LIFT OFF THE SUPPORTS FOR CASE 4 - INLET NOZ.

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

NUMBER S-214-C | A 251
SHEET 9 OF 10
CHARGE NO.
DATE 4-11-69 BY [illegible]
CHECK DATE BY

DESCRIPTION STRUCTURAL ANALYSIS OF INLET AND OUTLET NOZZLES - VESSEL SUPPORTS UNDER PIPE BREAK LOADS

5. DETAILED ANALYSIS:

c. STRESSES:

INLET NOZZLE:

REINFORCED PORTION OF NOZZLE:

LOCATION	PRESSURE STRESS			PIPE BREAK LOAD STRESS		PRINCIPAL STRESS			STRESS INTENSITY		
	σ_x	σ_θ	σ_r	σ_x	$\tau_{x\theta}$	σ_1	σ_2	σ_3	$\sigma_1-\sigma_2$	$\sigma_1-\sigma_3$	$\sigma_2-\sigma_3$
7 A	1.40	3.68	-2.25	-5.36	0	-3.96	3.68	-2.25	-7.64	-1.71	5.93
B	↓	↓	↓	5.36	0	6.76	↓	↓	3.08	9.01	↓
C	↓	↓	↓	5.32	0	6.72	↓	↓	3.04	8.97	↓
D	↓	↓	↓	-5.32	0	-3.92	↓	↓	-7.60	-1.67	↓
8 A	↓	↓	0	-8.58	0	-7.18	↓	0	-10.86	-4.93	3.68
B	↓	↓	↓	8.58	0	9.93	↓	↓	6.30	12.23	↓
C	↓	↓	↓	8.51	0	9.91	↓	↓	6.23	12.16	↓
D	↓	↓	↓	-8.51	0	-7.11	↓	↓	-10.79	-4.86	↓

$S_{max} = \sigma_1 - \sigma_3 = \underline{12.23\ KSI} < 1.2\ S_m = 32\ KSI$ @ LOCATION 8B

VESSEL WALL AT THE NOZZLE TO VESSEL SHELL JUNCTURE:

LOCATION	PRESSURE STRESS			PIPE BREAK LOAD STRESS			PRINCIPAL STRESS			STRESS INTENSITY		
	σ_x	σ_ϕ	σ_r	σ_x	σ_ϕ	$\tau_{x\phi}$	σ_1	σ_2	σ_3	$\sigma_1-\sigma_2$	$\sigma_1-\sigma_3$	$\sigma_2-\sigma_3$
9 A	6.44	27.92	-2.25	15.87	5.63	0	22.31	33.55	-2.25	-11.24	24.56	35.80
B	6.44	27.92	↓	-15.87	-5.63	0	-9.43	22.29	↓	-31.72	-7.18	24.54
C	18.42	6.36	↓	-11.08	-22.38	0	7.43	-16.02	↓	23.45	9.68	-13.77
D	18.42	6.36	↓	11.08	22.38	0	29.50	28.74	↓	0.76	31.75	30.99
10 A	6.44	27.92	0	-18.63	-15.52	0	-21.48	12.40	0	-33.88	-21.48	12.40
B	6.44	27.92	↓	18.63	15.52	0	34.36	43.44	↓	9.08	34.36	43.44
C	18.42	6.36	↓	16.05	25.09	0	34.47	31.45	↓	3.02	34.47	31.45
D	18.42	6.36	↓	-16.05	-25.09	0	2.37	-18.73	↓	16.36	2.37	-18.73

$S_{max} = \sigma_2 - \sigma_3 = \underline{43.44\ KSI} < 1.8\ S_m = 48.1\ KSI$ @ LOCATION 10B

SUPPORT PAD:

$\sigma_{B_{MAX}} = \frac{H_{MAX}}{A_{S \cdot OB}} = \underline{52.2\ KSI}$

$\tau_{F\ BOTTOM} = \frac{V_{MAX}}{A_{BOTTOM}} = \underline{7.5\ KSI}$

$< 1.2 S_y = 56.6\ KSI$ @ 200°F

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ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

NUMBER S-2M-P | A 259
SHEET 10 OF 10
CHARGE NO. ______
DATE 4-11-69 BY Cockrell
CHECK DATE ______ BY ______

DESCRIPTION Structural Analysis Of Inlet And Outlet Nozzles – Vessel Supports Under Pipe Break Loads

5. Detailed Analysis:

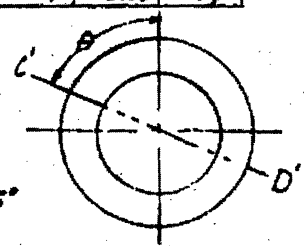
c. Stresses:

Outlet Nozzle:

Reinforced Portion Of Nozzle:

Location	Pressure Stress σ_x	σ_θ	σ_r	Pipe Break Load Stress σ_x	$\tau_{x\theta}$	Principal Stress σ_1	σ_2	σ_3	Stress Intensity $\sigma_1-\sigma_2$	$\sigma_1-\sigma_3$	$\sigma_2-\sigma_3$
7 C'	1.36	3.59	-2.25	-6.87	.04	-5.51	3.59	-2.25	-9.10	-3.26	5.84
D'	↓	↓	-2.25	6.87	↓	8.32	↓	-2.25	4.73	10.57	5.84
8 C'	↓	↓	0	-11.44	↓	-10.08	↓	0	-13.67	-10.08	3.59
D'	↓	↓	0	11.44	↓	12.80	↓	0	9.21	12.80	3.59

$S_{max} = \sigma_1 - \sigma_2 = \underline{13.67\ KSI} < 1.2 S_m = 32\ KSI$ @ Location 8C'



$\theta = 66.35°$

Vessel Wall At The Nozzle To Vessel Shell Juncture:

Location	Pressure Stress σ_x	σ_θ	σ_r	Pipe Break Load Stress σ_x	σ_θ	$\tau_{x\theta}$	Principal Stress σ_1	σ_2	σ_3	Stress Intensity $\sigma_1-\sigma_2$	$\sigma_1-\sigma_3$	$\sigma_2-\sigma_3$
9 A	6.23	27.97	-2.25	-17.53	-5.92	0	-11.30	22.05	-2.25	-33.35	-9.05	24.30
B	6.23	27.97	↓	17.53	5.92	0	23.76	33.89	↓	-10.13	26.01	36.14
C	18.48	6.16	↓	11.79	23.79	.42	30.56	29.66	↓	0.90	32.81	31.91
D	18.48	6.16	↓	-11.79	-23.79	-.42	6.70	17.64	↓	-10.94	8.95	19.89
10 A	6.23	27.97	0	20.44	16.42	0	26.67	44.39	0	-17.72	26.67	44.39
B	6.23	27.97	↓	-20.44	-16.42	0	-14.21	11.55	↓	-25.76	-14.21	11.55
C	18.48	6.16	↓	-16.59	-26.41	.42	1.90	-20.26	↓	22.16	1.90	-20.26
D	18.48	6.16	↓	16.59	26.41	-.42	35.14	32.50	↓	2.64	35.14	32.50

$S_{max} = \sigma_2 - \sigma_3 = \underline{44.39\ KSI} < 1.8 S_m = 48.1\ KSI$ @ Location 10 A

Support Pads:

$\sigma_{Bshear} = \dfrac{H_{MAX}}{A_{SHEAR}} = 40.8\ KSI$

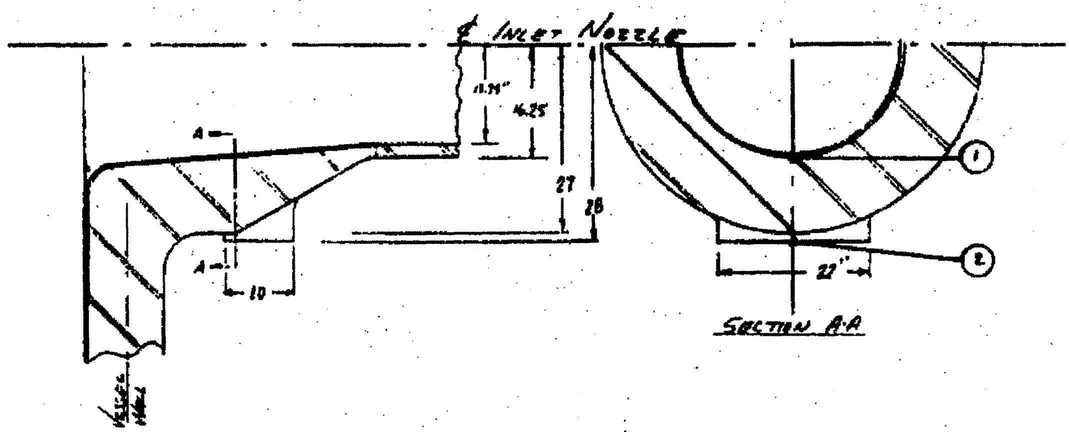
$\sigma_{Bearing} = \dfrac{V_{MAX}}{A_{SIDE}} = 7.4\ KSI$

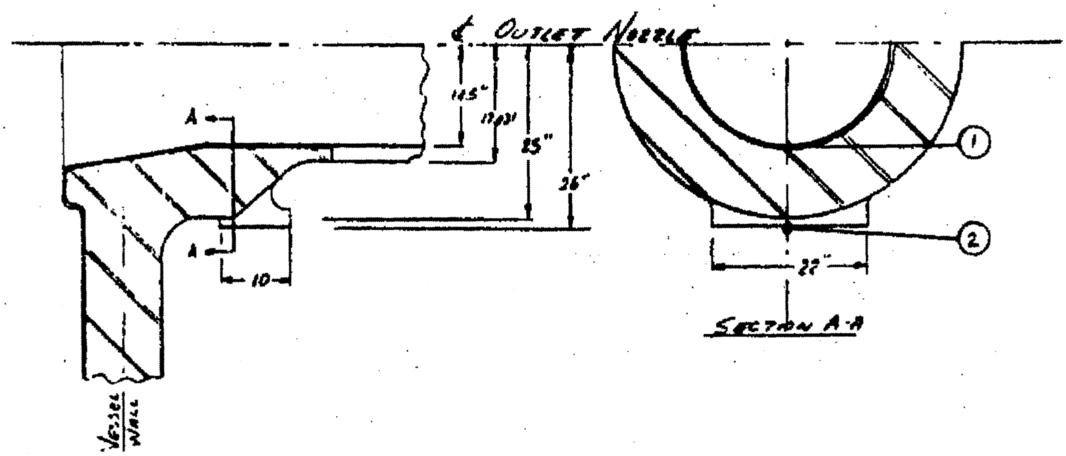
$\Big\} < 1.2 S_y = 56.6\ KSI$ @ 200°F

5. Detailed Analysis:

a. System Geometry:

A Cross Section Of The Inlet And Outlet Nozzles Is Shown Below.





b. System Allowables:

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

5- Detailed Analysis:

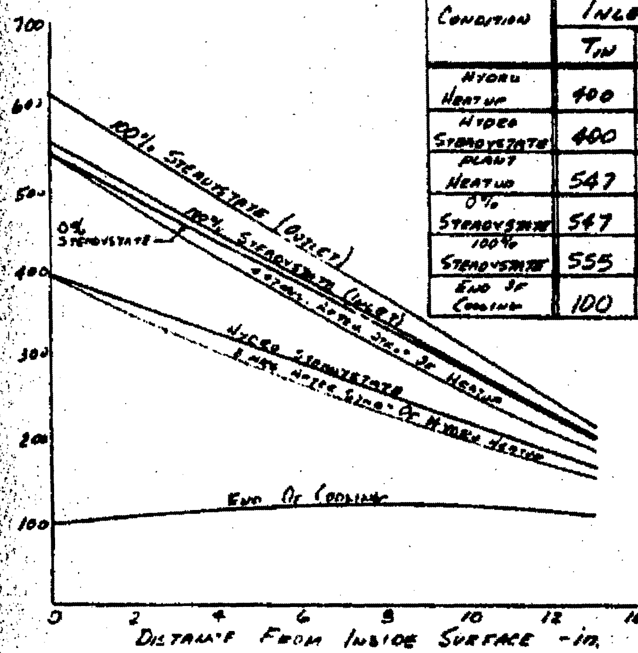
-C- System Loads:

The Vessel Support Pad At Section A-A As Shown On Sheet-4 Will Be Investigated For The Following Loads:

1- The Pressure And Thermal Transients As Given In Reference-[illegible]:

The Vessel Is Supported By Four Nozzles (Two Inlet And Two Outlet). The Temperature Gradient Thru The Nozzle Wall And Support Pad For The Heatup And Cooldown Transients And Steadystate Conditions Will Be As Follows

Condition	Inlet Nozzle			Outlet Nozzle		
	T_{in}	T_{out}	T_m	T_{in}	T_{out}	T_m
Hydro Heatup	400	150	263	400	150	263
Hydro Steadystate	400	170	285	400	170	285
Plant Heatup	547	186	354	547	186	354
0% Steadystate	547	203	375	547	203	375
100% Steadystate	555	203	379	613	217	415
End Of Cooling	100	115	120	100	115	120



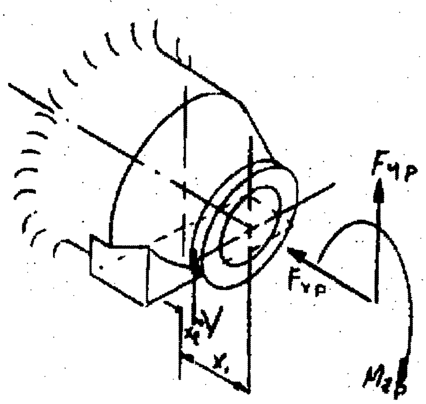
For All Transients Other Than The Heatup And Cooldown Transient, The Inside Surface Of The Nozzle (Point-1 As Shown On Sheet-4) Will Be At A Temperature Equal To The Reactor Coolant Temperature, While The Outside Surface (Point-2) And The Mean Temperature Of The Crossection Will Be At A Temperature Corresponding To Steadystate Conditions.

5. Detailed Analysis:

c. System Loads

2. External Loads

The External Loads Consist Of Thermal And Seismic Pipe Reactions, Static Weight And Earthquake Loading. The Following Figure Shows The Pipe Reactions And Loading Through The Supports Which Produce Stresses At The Points In Consideration.



Force	Inlet Nozzle				Outlet Nozzle			
	Thermal Induced Pipe Reactions	Seismic Pipe Reactions	Static Weight	Earthquake Loading Through Supports	Thermal Induced Pipe Reactions	Seismic Pipe Reactions	Static Weight	Earthquake Loading Through Supports
$\bar{F}_x$	14.8	± 57.9	0	0	26.2	± 122	0	0
$\bar{F}_y$	-92.0	∓ 67.0	0	0	-230.0	∓ 90	0	0
$\bar{M}_z$	9291	± 11250	-1515	± 341	29909	± 9337	-1796	± 424
V	0	0	561.1	∓ 126.4	0	0	561.1	∓ 132.5

The Above Loads Are The Resolved Loads To The Cross Section In Consideration As Follows

$$\bar{F}_x = F_{xp}$$
$$\bar{F}_y = F_{yp}$$
$$\bar{M}_z = M_{zp} - X_1 F_{yp} - X_2 V$$

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

CHARGE NO. ______

DESCRIPTION: *Fatigue Evaluation Of Vessel Support Pads*

NUMBER: S-215-P | A-292
SHEET 7 OF 16
DATE 2-3-67 BY Carnegie
CHECK DATE 2-3-67 BY Alexander

5. Detailed Analysis:

d. Stresses:

The following expressions will be used to calculate stresses at the two points 1 and 2 as indicated on Sheet-4.

Inlet Nozzle:

Pressure Stresses:

$$\sigma_x = \pm \frac{6M}{t^2} + \frac{bP}{2Rt} = \underline{3.26717P} \quad \text{Point-1}$$

$$\underline{-2.14795P} \quad \text{Point-2}$$

$$\sigma_\theta = \pm \frac{\nu 6M}{t^2} + \frac{E\Delta}{R} + \frac{bP}{t}$$

$$= \underline{3.39848P} \quad \text{Point 1}$$

$$= \underline{1.77444P} \quad \text{Point 2}$$

Thermal Stresses:

$$\sigma_x = \pm \frac{6M}{t^2} + \frac{E\alpha(T_m - T)}{(1-\nu)}$$

$$= \underline{\pm 0.05254M + 1.42857E\alpha(T_m - T)}$$

$$\sigma_\theta = \pm \frac{\nu 6M}{t^2} + \frac{E\Delta_{fixed}}{R} + \frac{E\alpha(T_m - T)}{(1-\nu)}$$

$$= \underline{\pm 0.01576M + 0.04617E\Delta_{fixed} + 1.42857E\alpha(T_m - T)}$$

Outlet Nozzle:

Pressure Stresses:

$$\sigma_x = \pm \frac{M}{t^2} + \frac{bP}{2Rt} = \underline{2.91772P} \quad \text{Point-1}$$

$$\underline{-1.83498P} \quad \text{Point-2}$$

$$\sigma_\theta = \pm \frac{\nu 6M}{t^2} + \frac{E\Delta}{R} + \frac{bP}{t}$$

$$= \underline{3.20524P} \quad \text{Point 1}$$

$$\underline{1.77942P} \quad \text{Point 2}$$

Thermal Stresses:

$$\sigma_x = \pm \frac{6M}{t^2} + \frac{E\alpha(T_m - T)}{(1-\nu)}$$

$$= \underline{\pm 0.05450M + 1.42857E\alpha(T_m - T)}$$

$$\sigma_\theta = \pm \frac{\nu 6M}{t^2} + \frac{E\Delta_{fixed}}{R} + \frac{E\alpha(T_m - T)}{(1-\nu)}$$

$$= \underline{\pm 0.01185M + 0.05005E\Delta_{fixed} + 1.42857E\alpha(T_m - T)}$$

Where:

$M = M_1 + M_T$

M_1 is the redundant moment determined in the thermal interaction

M_T is the thermal moment at the crossection due to the radial gradient

Inlet Nozzle:

Support Load Stresses:

$$\sigma_x = -\frac{F_{yp}}{A} + \frac{M_z C}{I}$$

$$= \underline{-0.00069F_{yp} - 0.00005\bar{M}_z} \quad \text{Point 1}$$

$$= \underline{-0.00069F_{yp} - 0.00007\bar{M}_z} \quad \text{Point 2}$$

Where:

$$\bar{M}_z = M_{zp} - x_1(F_{yp}) - x_2 V$$

$$\sigma_r = -\frac{V}{A_{pad}} = \underline{-0.00455V} \quad (\text{Point 2})$$

Outlet Nozzle:

Support Load Stresses:

$$\sigma_x = -\frac{F_{yp}}{A} + \frac{M_z C}{I}$$

$$= \underline{-0.00078F_{yp} - 0.00005\bar{M}_z} \quad \text{Point 1}$$

$$= \underline{-0.00078F_{yp} - 0.00009\bar{M}_z} \quad \text{Point 2}$$

Where:

$$M_z = M_{zp} - x_1(F_{yp}) - x_2 V$$

$$\sigma_r = -\frac{V}{A} = \underline{-0.00455V} \quad (\text{Point 2})$$

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

CHARGE NO.

NUMBER 5-215-P | A 253
SHEET 8 OF 16
DATE 2-3-67 BY [illegible]
DESCRIPTION *Fatigue Evaluation of Vessel Support Pads* CHECK DATE 2-3-67 BY [illegible]

5. Detailed Analysis:

d. Stresses:

Transient		Internal Pressure ksi	Inlet Nozzle M	Inlet Nozzle EΔ	Inlet Nozzle T_{in}	Inlet Nozzle T_{out}	Inlet Nozzle T_m	Inlet Nozzle $E\alpha_i$	Outlet Nozzle M	Outlet Nozzle EΔ	Outlet Nozzle T_{in}	Outlet Nozzle T_{out}	Outlet Nozzle T_m	Outlet Nozzle $E\alpha_i$
a	4.47 hrs	2.250	51.584	43.232	547	196	354	0.201	31.778	35.395	547	196	354	0.201
b	4.47 hrs	0.315	-43.494	-43.279	100	115	120	0.180	-11.134	-20.673	100	115	120	0.180
c	20 min	2.250	6.065	-1.302	554.8	203	375	0.202	32.714	7.763	603	203	375	0.202
Full Load Steady State		2.250	↓	↓	555	203	379	↓	8.541	-11.015	613	217	415	0.205
d	20 min	2.250			547	203	379		-4.250	-19.516	556	217	415	0.205
No Load Steady State		2.250			547	203	375		17.157	7.489	547	203	375	0.202
e	100 sec	2.140			543.6	203	379		8.541	-11.015	572.8	217	415	0.205
f	100 sec	2.260			568.1	↓	↓		↓	↓	597.3	↓	↓	↓
g	3.2 sec / 1.5 sec	2.350			570						628			
h	10 sec / [illegible]	2.230 1.910 / 1.910	↓	↓	564 546	↓	↓	↓	↓	↓	592 547	↓	↓	↓
i	220 min	3.125	0	0	100	100	100	~	0	0	100	100	100	~
j	Heatup 2.5 hrs S.S. Cooldown 3.6 hrs	1.250 2.500 0.315	51.584 6.065 -43.494	43.232 -1.302 -43.279	400 400 100	150 170 115	263 255 120	0.193 0.197 0.180	31.778 17.57 -11.134	35.395 7.489 -20.673	400 400 100	150 170 115	263 285 120	0.193 0.197 0.180
k	~ ~	2.350 2.150	6.065 ↓	-1.302 ↓	548.8 560.8	203 ↓	379 ↓	0.202	8.541 ↓	-11.015 ↓	607 619	217 ↓	415 ↓	0.205 ↓
l	12 sec	2.250			521.9						513			
m	[illegible]	[illegible]			595 596 559.6	↓	↓		↓	↓	553 635 550	↓	↓	↓
n	56 sec	0.700	↓	↓	350	203	375	↓	17.157	7.489	430	203	375	0.202

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

CHARGE NO. ________

DESCRIPTION Fatigue Evaluation Of Vessel Support Pads

NUMBER 5-315-P | A-2
SHEET 9 OF 16
DATE 2-3-67 BY Caddell
CHECK DATE 2-3-67 BY Alexander

5. Detailed Analysis:

d. Stresses

Inlet Nozzle   Point-1

Transient		Pressure Stress σ_x	Pressure Stress σ_θ	Pressure Stress σ_r	Thermal Stress σ_x	Thermal Stress σ_θ	Pipe Load Stress σ_x	Pipe Load Stress σ_r	Total Stress σ_x	Total Stress σ_θ	Total Stress σ_r	Stress Intensity $\sigma_x-\sigma_\theta$	Stress Intensity $\sigma_x-\sigma_r$	Stress Intensity $\sigma_\theta-\sigma_r$
a	4.47 hrs	7.35	7.65	-2.25	-52.71	-52.61	-1.02	0	-46.38	-44.96	-2.25	-1.42	-44.13	-42.71
b	4.47 hrs	1.03	1.07	-0.32	2.85	2.45	0.70	↓	4.58	3.52	-0.32	1.06	4.90	3.84
c	20 min	7.35	7.65	-2.25	-51.56	-51.84	-0.40	↓	-44.61	-44.19	-2.25	-0.42	-42.36	-41.94
Full Load Steady State		7.35	7.65	-2.25	-50.47	-50.75	↓	↓	-43.52	-43.10	-2.25	-0.42	-41.27	-40.85
d	20 min	7.35	7.65	-2.25	-48.16	-48.44	↓	↓	-41.21	-40.79	-2.25	-0.42	-38.96	-38.54
No Load Steady State		7.35	7.65	-2.25	-49.31	-49.59	↓	↓	-42.36	-41.94	-2.25	-0.42	-40.11	-39.69
e	100 sec	6.99	7.27	-2.14	-47.18	-47.46	↓	↓	-40.59	-40.19	-2.14	-0.40	-38.45	-38.05
f	100 sec	7.38	7.68	-2.26	-54.25	-54.53	↓	↓	-47.27	-46.85	-2.26	-0.42	-45.01	-44.59
g	3.2 min	7.68	7.99	-2.35	-54.80	-55.08	↓	↓	-47.52	-47.09	-2.35	-0.43	-45.17	-44.74
h	10 sec	7.35	7.65	-2.22	-53.07	-53.35	↓	↓	-46.22	-45.80	-2.22	-0.42	-44.00	-43.58
	65 sec	6.24	6.49	-1.91	-47.87	-48.15	↓	↓	-42.03	-41.66	-1.91	-0.37	-40.12	-39.75
i	220 min	10.21	10.62	-3.13	0	0	0.08	↓	10.29	10.62	-3.13	-0.33	13.42	13.75
j	Heatup 3.5 hrs	4.08	4.25	-1.25	-35.06	-34.96	-0.40	↓	-31.38	-30.71	-1.25	-0.67	-30.13	-29.46
	S.S.	8.17	8.50	-2.50	-32.04	-32.32	-0.40	↓	-24.27	-23.82	-2.50	-0.45	-21.77	-21.32
	Cooldown 3.5 hrs	1.03	1.07	-0.32	2.85	2.45	0.08	↓	3.96	3.52	-0.32	0.44	4.28	3.84
k	~	7.68	7.99	-2.35	-48.68	-48.96	-0.40	↓	-41.40	-40.97	-2.35	-0.43	-39.05	-38.62
	~	7.02	7.31	-2.15	-52.14	-52.42	↓	↓	-45.52	-45.11	-2.15	-0.41	-43.37	-42.96
l	12 sec	7.35	7.65	-2.25	-40.89	-41.17	↓	↓	-33.94	-33.52	-2.25	-0.42	-31.69	-31.27
m	10 sec	9.02	9.38	-2.76	-59.13	-59.41	↓	↓	-50.51	-50.03	-2.76	-0.48	-47.75	-47.27
	28 sec	6.93	7.21	-2.12	-62.30	-62.58	↓	↓	-56.05	-55.37	-2.12	-0.68	-53.93	-53.25
	160 sec	4.70	4.89	-1.44	-51.80	-52.08	↓	↓	-47.50	-47.19	-1.44	-0.31	-46.06	-45.75
n	34 sec	2.29	2.38	-0.70	7.53	7.25	↓	↓	9.42	9.63	-0.70	-0.21	10.12	10.33

5. Detailed Analysis:

d. Stresses:

INLET NOZZLE POINT - 2

Transient	Pressure Stress			Thermal Stress		Pipe Load Stress		Total Stress			Stress Intensity		
	σ_x	σ_θ	σ_r	σ_x	σ_θ	σ_x	σ_r	σ_x	σ_θ	σ_r	$\sigma_x - \sigma_\theta$	$\sigma_x - \sigma_r$	$\sigma_\theta - \sigma_r$
Dead Weight Only	0	0	0	0	0	0	-2.55	0	0	-2.55	0	2.55	2.55
a 4.47 hrs	-4.83	3.99	↓	45.53	49.43	-1.40	-2.70	39.30	53.42	-2.70	-14.12	42.00	56.12
b 4.47 hrs	-0.68	0.56	↓	3.58	-0.02	0.96	-3.35	3.86	0.54	-3.35	3.32	7.71	4.39
c 20 min	-4.83	3.99	↓	49.31	49.47	-0.55	-2.97	43.93	53.46	-2.97	-9.53	46.90	56.43
Full Load Steady State	-4.83	3.99	↓	50.47	50.63	↓	↓	45.09	54.62	↓	-9.53	48.06	57.59
d 20 min	-4.83	3.99	↓	50.47	50.63	↓	↓	45.09	54.62	↓	-9.53	48.06	57.59
No Load Steady State	-4.83	3.99	↓	49.31	49.47	↓	↓	43.93	53.46	↓	-9.53	46.90	56.43
e 100 sec	-4.60	3.80	↓	50.47	50.63	↓	↓	45.32	54.43	↓	-9.11	48.29	57.40
f 100 sec	-4.85	4.01	↓	↓	↓	↓	↓	45.07	54.64	↓	-9.57	48.04	57.61
g 2.2 min	-5.03	4.17	↓	↓	↓	↓	↓	44.87	54.80	↓	-9.93	47.84	57.77
h 10 sec	-4.77	3.94	↓	↓	↓	↓	↓	45.15	54.57	↓	-9.42	48.12	57.54
h 65 sec	-4.10	3.39	↓	↓	↓	↓	↓	45.92	54.02	↓	-8.20	48.79	56.99
i 220 min	-6.71	5.59	↓	0	0	0.11	-2.55	-6.60	5.59	-2.55	-12.19	-4.05	8.14
j Heat up 3.5 hrs	-2.68	2.22	↓	28.45	32.35	-0.55	-2.97	25.22	34.57	-2.97	-9.35	28.19	37.54
j S.S.	-5.37	4.44	↓	32.04	32.20	-0.55	-2.97	26.12	36.64	-2.97	-10.52	29.09	39.61
j Cooldown 2.5 hrs	-0.68	0.56	↓	3.58	-0.02	0.11	-2.55	3.01	0.54	-2.55	2.47	5.56	3.09
k ~	-5.03	4.17	↓	50.47	50.63	-0.55	-2.97	44.87	54.80	-2.97	-9.93	47.84	57.77
k ~	-4.62	3.82	↓	↓	↓	↓	↓	45.30	54.45	↓	-9.15	48.27	57.42
l 12 sec	-4.83	3.99	↓	↓	↓	↓	↓	45.09	54.62	↓	-9.53	48.06	57.59
m 10 sec	-5.93	4.90	↓	↓	↓	↓	↓	43.99	55.53	↓	-11.54	46.96	58.50
m 20 sec	-4.55	3.76	↓	↓	↓	↓	↓	45.37	54.39	↓	-9.02	48.34	57.36
m 160 sec	-3.09	2.56	↓	↓	↓	↓	↓	46.83	53.19	↓	-6.36	49.30	56.16
n 54 sec	-1.50	1.24	↓	49.31	49.47	↓	↓	47.26	50.71	↓	-3.45	50.23	53.68

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

NUMBER _E-215-P_ | A296
SHEET _11_ OF _16_
CHARGE NO. ____________
DATE _2-3-67_ BY _Cockrell_
DESCRIPTION _Fatigue Evaluation Of Vessel Support Pads_ CHECK DATE _2-3-67_ BY _Alexander_

5. DETAILED ANALYSIS:

d. STRESSES

OUTLET NOZZLE POINT-1

Transient		Pressure Stress σ_z	Pressure Stress σ_θ	Pressure Stress σ_r	Thermal Stress σ_z	Thermal Stress σ_θ	Pipe Load Stress σ_z	Pipe Load Stress σ_r	Total Stress σ_z	Total Stress σ_θ	Total Stress σ_r	Stress Intensity $\sigma_z-\sigma_\theta$	Stress Intensity $\sigma_z-\sigma_r$	Stress Intensity $\sigma_\theta-\sigma_r$
a	4.67 hrs	6.59	7.21	-2.25	-53.53	-53.08	-1.96	0	-48.90	-45.97	-2.25	-3.03	-46.65	-43.62
b	4.67 hrs	0.92	1.01	-0.32	4.48	3.91	0.63		5.03	4.92	-0.32	1.11	6.35	5.24
c	20 min	6.59	7.21	-2.25	-63.78	-64.77	-1.42		-58.61	-57.56	-2.25	-1.05	-56.36	-55.31
Full Load Steady State		6.59	7.21	-2.25	-57.49	-58.39			-52.31	-51.18	-2.25	-1.13	-50.06	-48.93
d	20 min	6.59	7.21	-2.25	-41.54	-42.30			-36.37	-35.09	-2.25	-1.28	-34.12	-32.84
No Load Steady State		6.59	7.21	-2.25	-48.61	-48.95			-43.44	-41.74	-2.25	-1.70	-41.19	-39.49
e	100 sec	6.27	6.86	-2.14	-45.70	-46.61			-40.85	-39.75	-2.14	-1.10	-38.71	-37.61
f	100 sec	6.62	7.24	-2.26	-52.88	-53.79			-47.68	-46.55	-2.26	-1.13	-45.42	-44.29
g	3.5 min	6.88	7.53	-2.35	-61.87	-62.78			-56.41	-55.25	-2.35	-1.16	-54.06	-52.90
h	10 sec	6.50	7.12	-2.22	-51.33	-52.24			-46.25	-45.12	-2.22	-1.13	-44.03	-42.90
	90 sec	5.66	6.22	-1.94	-38.15	-39.06			-33.91	-32.84	-1.94	-1.07	-31.97	-30.90
i	220 min	9.15	10.02	-3.13	0	0	0.09		9.24	10.02	-3.13	-0.78	12.37	13.15
j	Heatup 25 min	3.66	4.01	-1.25	-35.88	-35.43	-1.42		-33.64	-31.42	-1.25	-2.22	-32.39	-30.17
	S.S.	7.32	8.01	-2.50	-31.34	-31.68	-1.42		-25.44	-23.67	-2.50	-1.77	-22.94	-21.17
	Cooldown 25 min	0.92	1.01	-0.32	4.48	3.91	0.09		5.49	4.92	-0.32	0.57	5.81	5.24
k	~	6.88	7.53	-2.35	-55.72	-56.63	-1.42		-50.26	-49.10	-2.35	-1.25	-47.91	-46.75
	~	6.29	6.89	-2.15	-59.23	-60.14			-54.36	-53.25	-2.15	-1.11	-52.21	-51.10
l	12 sec	6.59	7.21	-2.25	-57.48	-58.39			-52.31	-51.18	-2.25	-1.13	-50.06	-48.93
m	12 sec	8.05	8.85	-2.76	-69.19	-70.10			-62.56	-61.25	-2.76	-1.31	-59.80	-58.49
	26 sec	5.84	6.41	-2.00	-63.92	-64.83			-59.50	-58.42	-2.00	-1.08	-57.50	-56.42
	144 sec	4.30	4.73	-1.48	-39.03	-39.94			-36.15	-35.21	-1.48	-0.94	-34.67	-33.73
n	56 sec	2.03	2.24	-0.70	-14.91	-15.25			-14.28	-13.01	-0.70	-1.27	-13.58	-12.31

5. Detailed Analysis:

d. Stresses:

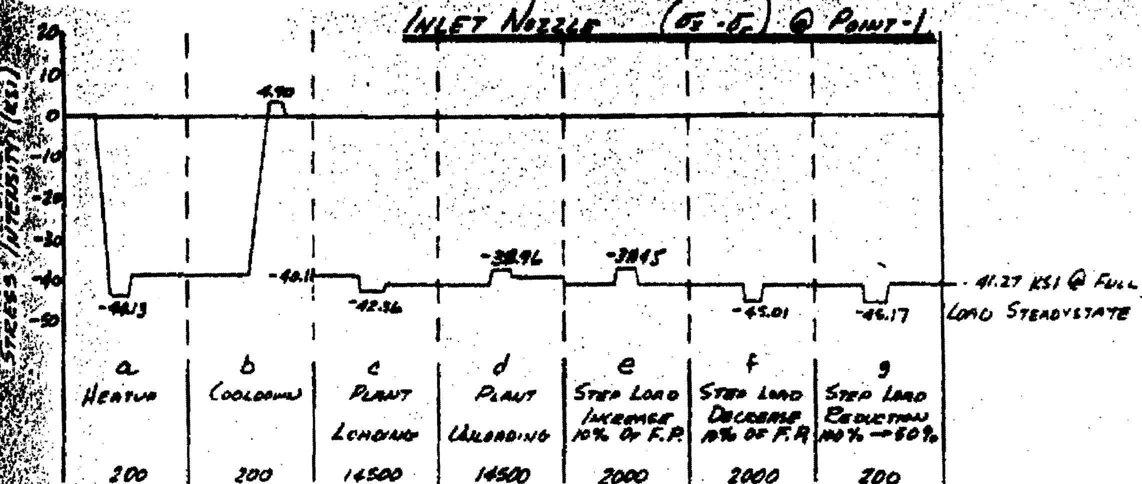
Outlet Nozzle Point - 2

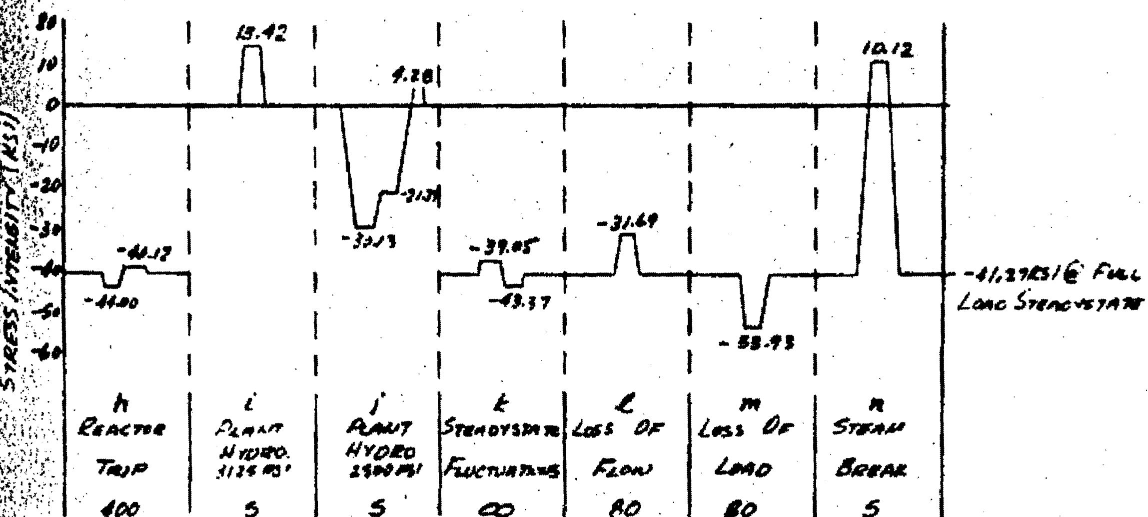
Transient		Pressure Stress σ_x	Pressure Stress σ_θ	Pressure Stress σ_r	Thermal Stress σ_x	Thermal Stress σ_θ	Pipe Load Stress σ_x	Pipe Load Stress σ_r	Total Stress σ_x	Total Stress σ_θ	Total Stress σ_r	Stress Intensity $\sigma_x-\sigma_\theta$	Stress Intensity $\sigma_x-\sigma_r$	Stress Intensity $\sigma_\theta-\sigma_r$
Lead Weight Only		0	0	0	0	0	0	-2.55	0	0	-2.55	0	2.55	2.55
a	4.47 hrs	-4.13	4.00		46.36	49.44	-3.44	-3.41	39.79	53.44	-3.41	-14.65	42.20	56.85
b	6.47 hrs	-0.58	0.56		1.95	0.46	1.05	-4.61	2.42	1.02	-4.61	1.30	7.03	5.73
c	20 min	-4.13	4.00		47.62	49.43	-2.55	-3.60	40.94	53.43	-3.60	-12.49	44.54	57.03
Full Load Steady State		-4.13	4.00		57.48	57.29			50.90	61.21		-10.41	54.40	64.81
d	20 min	-4.13	4.00		58.24	57.14			51.56	61.14		-9.58	55.16	64.74
No Load Steady State		-4.13	4.00		48.61	49.69			41.93	53.69		-11.76	45.43	57.19
e	100 sec	-3.93	3.81		57.48	57.29			51.00	61.10		-10.10	54.60	64.70
f	100 sec	-4.15	4.02						50.78	61.31		-10.53	54.38	64.91
g	3.5 min	-4.31	4.18						50.62	61.47		-10.85	54.22	65.07
h	105 sec	-4.07	3.95						50.86	61.24		-10.38	54.46	64.84
	105 sec	-3.56	3.45						51.37	60.74		-9.37	54.97	64.34
i	220 min	-5.73	5.56		0	0	0.16	-2.55	-5.57	5.56	-2.55	-11.13	-3.02	8.11
j	Heatup 3.5 hrs	-2.29	2.22		29.27	32.36	-2.55	-3.60	24.43	34.58	-3.60	-10.15	28.03	38.18
	SS	-4.57	4.45		31.34	32.42	-2.55	-3.60	24.20	36.87	-3.60	-12.67	27.80	40.47
	Cooldown 3.5 hrs	-0.58	0.56		1.95	0.46	0.16	-2.55	1.53	1.02	-2.55	0.51	4.08	3.57
k	~	-4.31	4.18		57.48	57.29	-2.55	-3.60	50.62	61.47	-3.60	-10.85	54.22	65.07
	~	-3.95	3.83						50.98	61.12		-10.14	54.58	64.72
l	12 sec	-4.13	4.00						50.80	61.29		-10.49	54.40	64.89
m	12 sec	-5.06	4.91						49.87	62.20		-12.33	53.47	65.80
	26 sec	-3.67	3.56						51.26	60.85		-9.59	54.86	64.45
	144 sec	-2.71	2.62						52.72	64.91		-7.69	55.82	63.51
n	54 sec	-1.28	1.25		48.61	49.69			44.78	50.94		-6.16	48.38	54.54

Maximum Bearing Stress On Pad = σ_r = -4.61 KSI ←

5- Detailed Analysis:

C- Fatigue Evaluation:





S_{max}	S_{min}	Number Of Occurrences	S_{alt}	N*	U
13.42	-53.93	5	33.68	15,000	0.00033
10.12	-53.93	5	32.03	18,000	0.00027
4.90	-53.93	70	29.42	23000	0.00304
4.90	-45.17	130	25.04	42000	0.00310
4.28	-45.17	5	24.73	43000	0.00012
-31.69	-45.17	65	6.74	∞	0

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

$U_{cumul.}$ = 0.00686

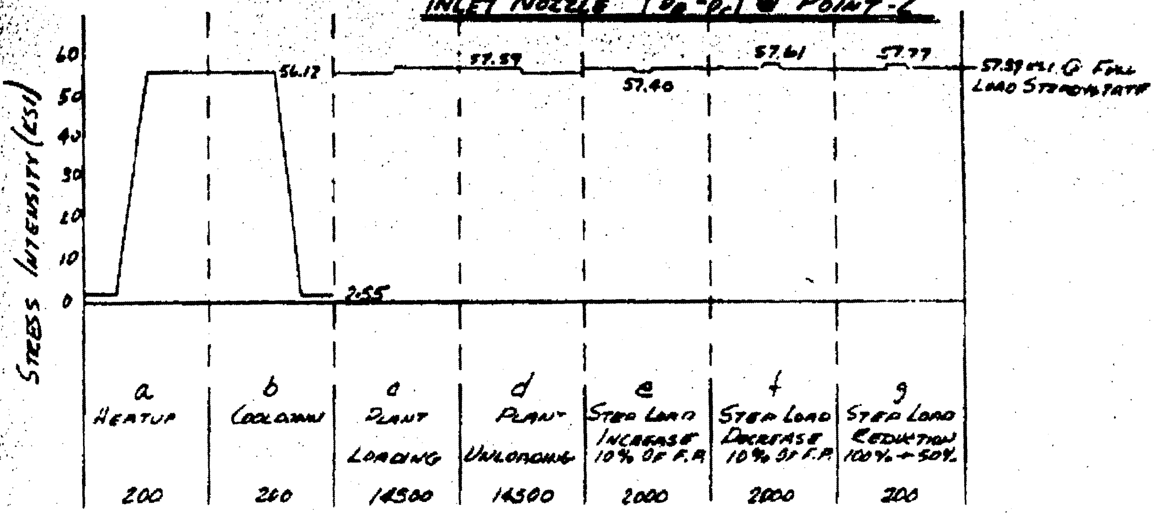
COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO. ______

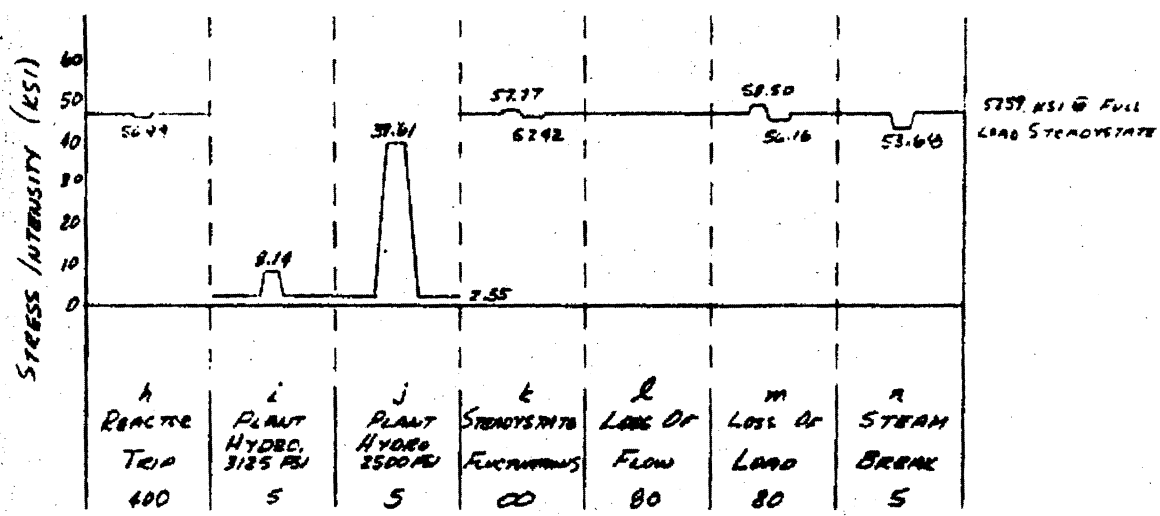
NUMBER S-215-P | R 2A
SHEET 14 OF 16
DATE 2-3-67 BY COCKRELL
DESCRIPTION Fatigue Evaluation of Vessel Support Pads CHECK DATE 2-3-67 BY ALEXANDER

5. Detailed Analysis:

e- Fatigue Evaluation:

Inlet Nozzle $(\sigma_2-\sigma_3)$ @ Point-2





S_{max}	S_{min}	Number of Occurrences	S_{alt}	N^*	U
58.50	2.55	80	27.98	27000	0.00296
57.77	2.55	120	27.61	29000	0.00413
39.61	2.55	5	18.53	130000	0.00003
57.77	53.68	5	2.05	∞	0

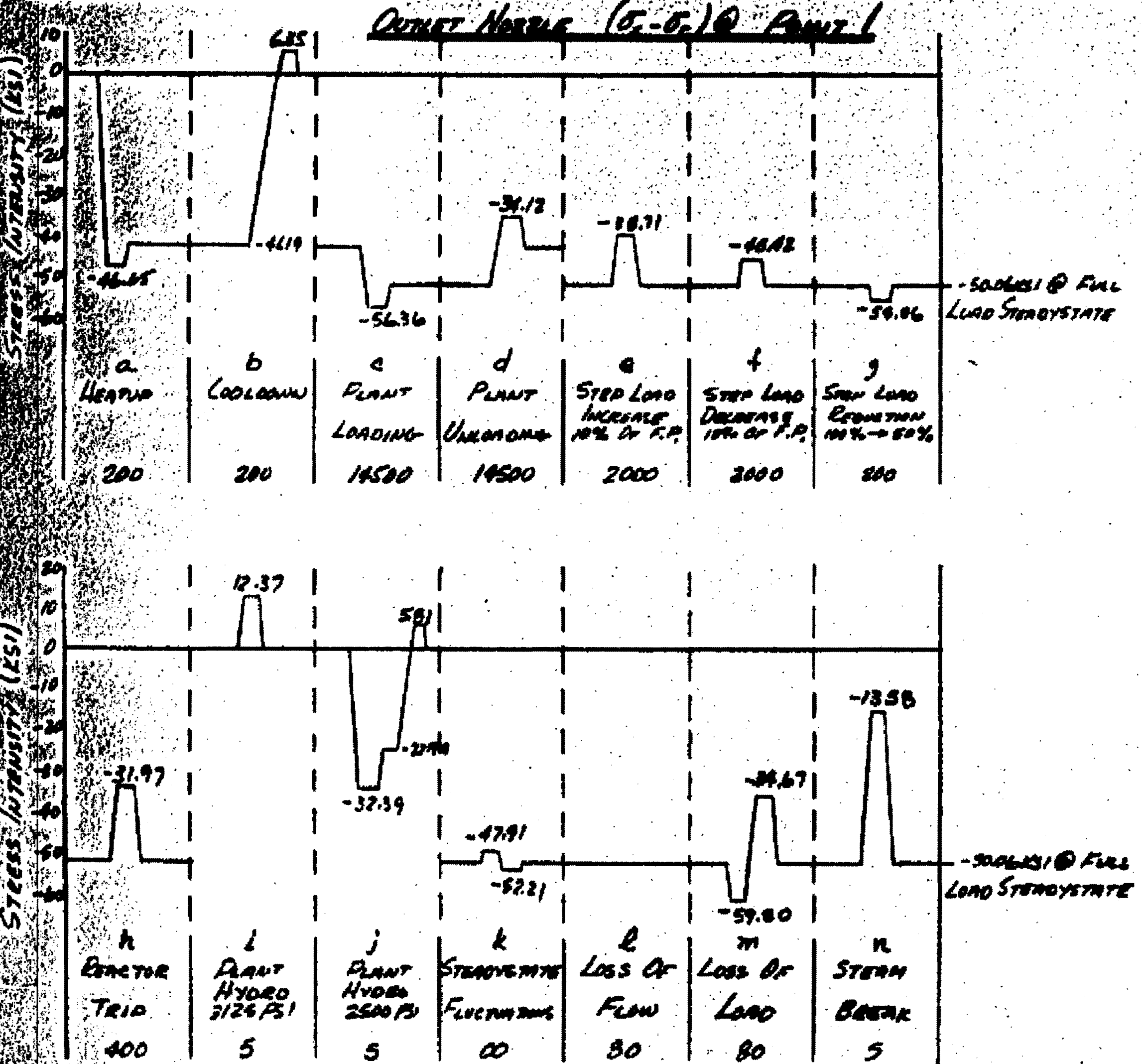
* From Fig. N-415(A) Reference 1

$U_{overall} = 0.00712$

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

CHARGE NO. ______ NUMBER S-215-P | A 278
SHEET 15 OF 16
DATE 2-8-67 BY Cockrell
DESCRIPTION Fatigue Evaluation Of Vessel Support Pads CHECK DATE 2-8-67 BY Alexander

5-Detailed Analysis:
e- Fatigue Evaluation:



S_{max}	S_{min}	Number Of Occurrences	S_{alt}	N^*	U
12.37	-59.80	5	36.09	11,000	0.00045
6.35	-59.80	75	32.58	15,000	0.00500
6.35	-56.36	120	31.36	18,000	0.00667
-13.58	-56.36	5	21.39	76,000	0.00006
5.81	-32.39	5	18.75	101,000	0.00005
-31.97	-56.36	400	12.20	∞	0

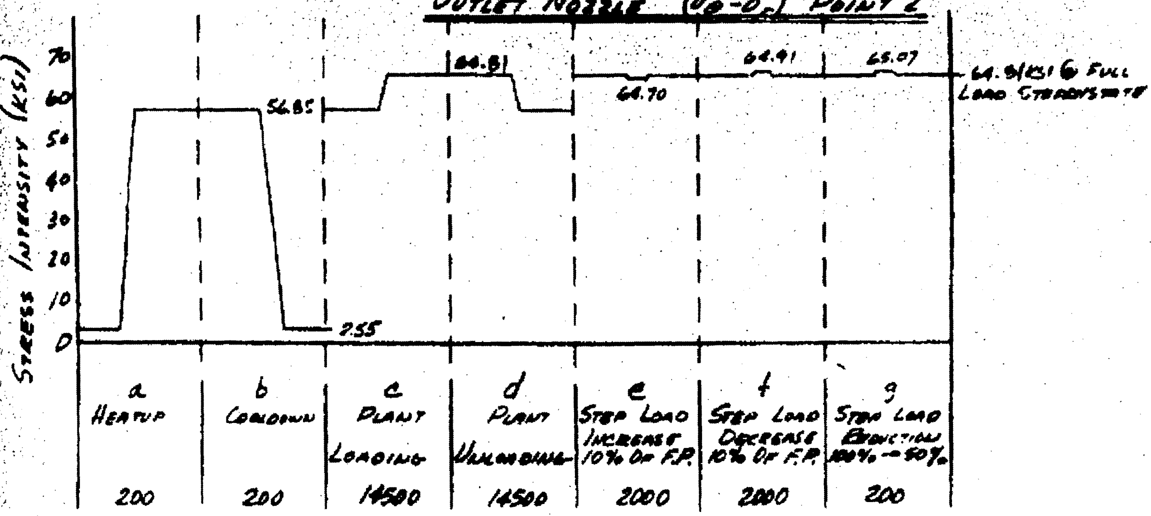
* From Fig. N-415(A) Reference 1

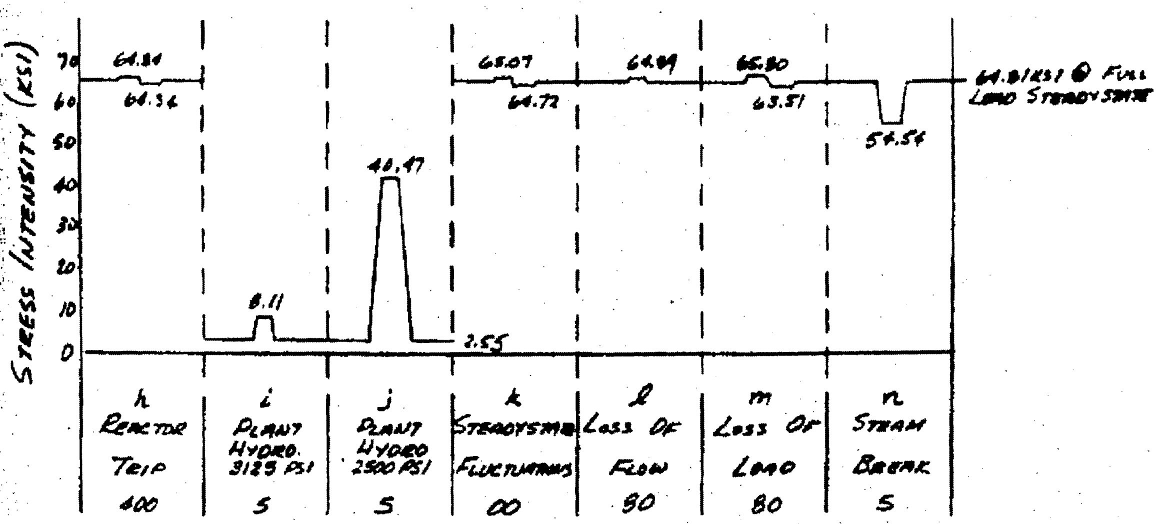
$U_{overall} = 0.01223$

5- Detailed Analysis:

e. Fatigue Evaluation:

Outlet Nozzle (σ_θ-σ_r) Point 2





S_{max}	S_{min}	Number Of Occurrences	S_{alt}	N^*	U
65.80	2.55	80	31.63	17,000	0.00470
65.07	2.55	120	31.26	18,000	0.00666
40.47	2.55	5	18.96	120,000	0.00004
65.07	54.54	5	5.27	∞	0

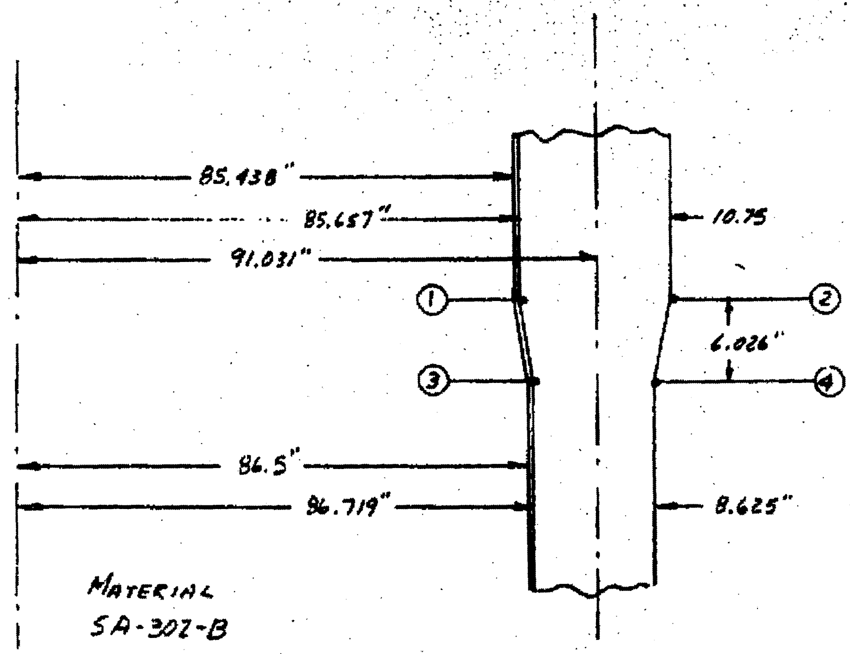
* From Fig. N-415(A) Reference 1

$U_{overall}$ = 0.01140

5. Detailed Analysis:

a. System Geometry:

A Cross Section Of The Vessel Wall Transition Is Shown Below.



b. System Loads:

The Vessel Shell Juncture (Transition) As Shown Above Will Be Investigated For Design Conditions (Internal Press Of 2.5 ksi). The Effects Of The Following Transient Conditions Will Be Investigated.

Transient	Number Of Occurrences
a_ Plant Heatup At 100°F Per Hour	200
b_ Plant Cooldown At 100°F Per Hour	200
c_ Plant Loading At 5% Of Full Power Per Min.	14,500
d_ Plant Unloading At 5% Of Full Power Per Min.	14,500
e_ Step Load Increase Of 10% Of Full Power But Not To Exceed Full Power	2,000

5- Detailed Analysis:

C- System Loads:

Transient	Number Of Occurrences
f- Step Load Decrease Of 10% Of Full Power From 100% Power	2000
g- Step Load Reduction From 100% To 50% Full Power	200
h- Reactor Trip From Full Power	400
i- Plant Hydrostatic Test Of 3125 PSIA At Room Temp.	5
j- Plant Hydrostatic Test Of 2500 PSIA At 100°F Per Hour To 400°F	5
k- Steady State Fluctuations Of ± 6°F And ± 100 psi Per Min.	∞
l- Loss Of Flow, One Pump	80
m- Loss Of Load	80
n- Steam Break	5

C. System Allowables:

The Following Allowable Stresses Are Based On The A.S.M.E Nuclear Code Section III, Reference 1 And Are Relevant For This Analysis.

1- The Average Primary Stress Intensity Across A Solid Section Shall Not Exceed S_m At Design Temp. (650°F) And Design Pressure (2.5 ksi).
2- The Local Primary Stress Alone Or Combined With 1- Above Shall Not Exceed $1.5 S_m$ At Design Temp. (650°F) And Design Pressure (2.5 ksi).
3- The Primary Bending Stress Alone Or Combined With 1. And 2. Above Shall Not Exceed $1.5 S_m$ At Design Temp (650°F) And Design Pressure (2.5 ksi).
4- 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.
5- Show That Each Point Meets The Requirements For Peak Stress Intensity Given In N-414.5 Of The A.S.M.E Code Section III. The Procedure Will Be As Outlined In N-415.2 Of Section III.

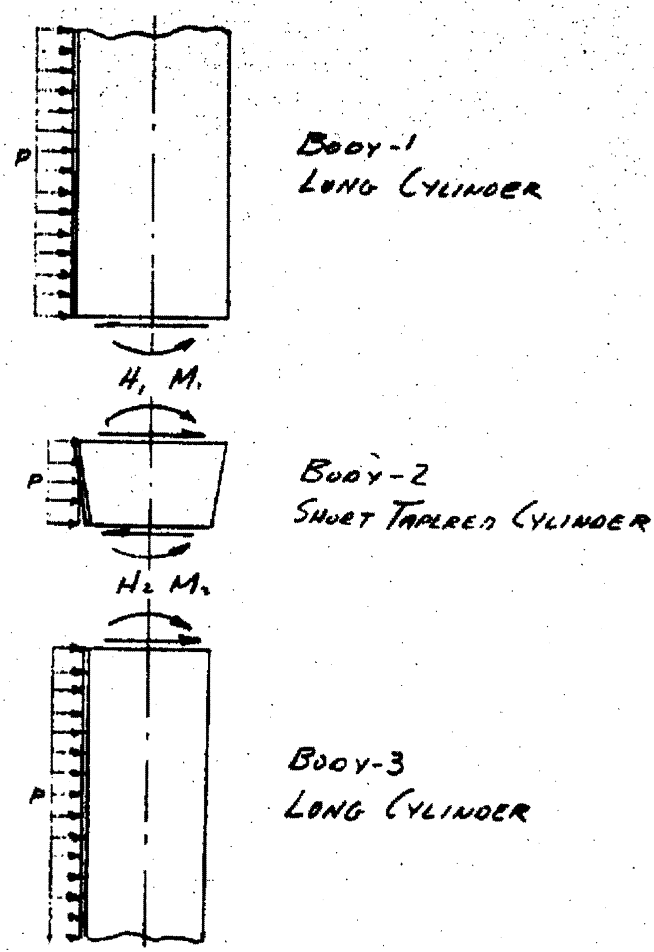
COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.

CHARGE NO.________

DESCRIPTION: STRUCTURAL AND FATIGUE ANALYSIS OF THE VESSEL WALL TRANSITION

NUMBER 5-202-P | A 294
SHEET 6 OF 24
DATE MAY 26, 1966 BY [illegible]
CHECK DATE MAY 26, 1966 BY ALEXANDER

5. DETAILED ANALYSIS:
d. DEVELOPMENT OF CONTINUITY EQUATIONS:
1. ANALYTICAL MODEL:



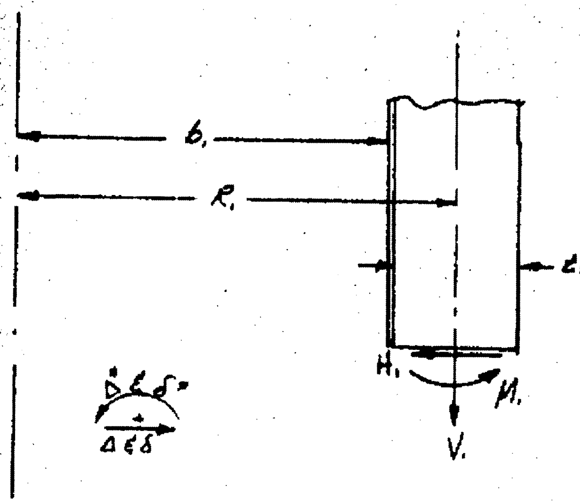
THE ACTUAL STRUCTURE IS DIVIDED INTO THE ANALYTICAL MODEL AS SHOWN ABOVE TO FACILITATE THE ANALYSIS. THE ASSUMED DIRECTIONS OF THE REDUNDANT FORCES ARE ILLUSTRATED.

5. Detailed Analysis:

d. Development Of Continuity Equations:

2. Movements Due To Redundant And Applied Forces:

Body-1:



$R_1 = 91.031''$

$b_1 = 85.438''$

$t_1 = 10.75''$

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

$\beta = 0.04109$

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

Displacements Due To Redundant Forces:

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

$$= -63.34937H_1 + 2.60306M_1$$

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

$$= -2.60306H_1 + 0.21392M_1$$

Displacements Due To Applied Forces:

$$E\delta_{11} = \frac{b_1^2}{t_1}\left(\frac{R_1}{b_1} - \frac{\nu}{2}\right)p = 621.63338p$$

$$E\delta^*_{11} = 0$$

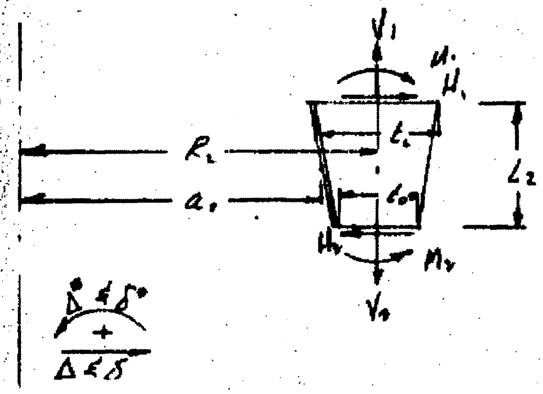
From Ref. 7

5. DETAILED ANALYSIS:

4. DEVELOPMENT OF CONTINUITY EQUATIONS:

2. MOVEMENTS DUE TO REDUNDANT AND APPLIED FORCES:

BODY - 2:



$R_2 = 91.031''$
$a_2 = 85.969''$
$t_0 = 8.625''$
$t_2 = 10.75''$
$L_2 = 6.026''$

$$\lambda = \frac{1}{L_2}(t_2 - t_0) = 0.35264$$

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

DISPLACEMENTS DUE TO REDUNDANT FORCES:

$$E\Delta_{21} = -\phi_{33} H_1 + \phi_{34} M_1 - \phi_{31} H_2 + \phi_{32} M_2$$

$$= 546.07025 H_1 + 139.51823 M_1 + 288.79601 H_2 - 139.54705 M_2$$

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

$$= -139.06016 H_1 - 48.24337 M_1 - 149.53615 H_2 + 48.23308 M_2$$

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

$$= -288.92626 H_1 - 150.09585 M_1 - 609.44910 H_2 + 150.20263 M_2$$

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

$$= -139.21081 H_1 - 48.37539 M_1 - 149.77380 H_2 + 48.3[illegible] M_2$$

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

CHARGE NO.

DESCRIPTION Structural And Fatigue Analysis Of The Vessel Wall Transition

NUMBER S-202-P | A2??
SHEET 9 OF 24
DATE May 26, 1966 BY Colwell
CHECK DATE May 26, 1966 BY Alexander

5. Detailed Analysis:

d. Development Of Continuity Equations:

2. Movements Due To Redundant And Applied Forces:

Body 2 (cont'd):

Displacements Due To Applied Forces:

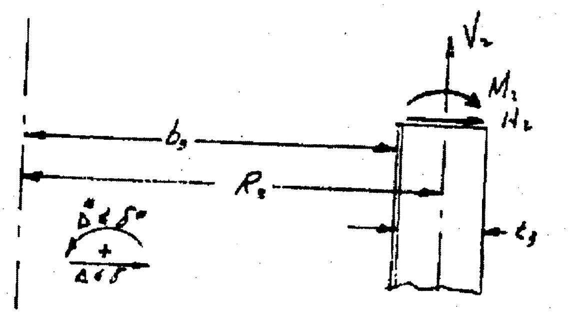
$$E\delta_{21} = a_2^2\left(\frac{R_2}{a_2} - \frac{\nu}{2}\right)\left[(\phi_{32}+\phi_{20})\frac{-\lambda^2}{6(1-\nu^2)} + \frac{1}{t_2}\right]P = 629.27110P$$

$$E\delta_{21}^{\phi} = -a_2^2\left(\frac{R_2}{a_2} - \frac{\nu}{2}\right)\left[(\phi_{12}+\phi_{20})\frac{-\lambda^2}{6(1-\nu^2)} - \frac{\lambda}{t_2^2}\right]P = 22.03255P$$

$$E\delta_{22} = a_2^2\left(\frac{R_2}{a_2} - \frac{\nu}{2}\right)\left[(\phi_{12}+\phi_{20})\frac{-\lambda^2}{6(1-\nu^2)} + \frac{1}{t_0}\right]P = 762.47399P$$

$$E\delta_{22}^{\phi} = -a_2^2\left(\frac{R_2}{a_2} - \frac{\nu}{2}\right)\left[(\phi_{22}+\phi_{20})\frac{-\lambda^2}{6(1-\nu^2)} - \frac{\lambda}{t_0^2}\right]P = 22.09972P$$

Body - 3:



$R_3 = 91.031''$

$b_3 = 86.5''$

$t_3 = 8.625''$

$$\beta^4 = \frac{3(1-\nu^2)}{R_3^2 t_3^2} \qquad D = \frac{Et^3}{12(1-\nu^2)}$$

$\beta = 0.04587$ $\qquad D = 58.7563E$

Displacements Due To Redundant Forces:

$$E\Delta_{32} = \frac{E}{2\beta^3 D}\left[\frac{1}{\beta}H_2 + M_2\right] = 88.14883H_2 + 4.04373M_2$$

$$E\Delta_{32}^{\phi} = -\frac{E}{2\beta^2 D}\left[H_2 + 2\beta M_2\right] = -4.04373H_2 - 0.37100M_2$$

Displacements Due To Applied Forces:

$$E\delta_{32} = \frac{b_3^2}{t_3}\left(\frac{R_3}{b_3} - \frac{\nu}{2}\right)P = 782.82249P$$

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

} From Ref. 7:

DESCRIPTION Structural And Fatigue Analysis Of The Vessel Wall Transition

5. Detailed Analysis:

1. Development Of Continuity Equations:

3. Continuity Matrix And Loading Vectors:

From Continuity At Each Cut, We Write The Continuity Matrix In The Following Form,

$$E\Delta_{11} - E\Delta_{21} = E\delta_{21} - E\delta_{11}$$
$$E\Delta_{11}^{\phi} - E\Delta_{21}^{\phi} = E\delta_{21}^{\phi} - E\delta_{11}^{\phi}$$
$$E\Delta_{22} - E\Delta_{32} = E\delta_{32} - E\delta_{22}$$
$$E\Delta_{22}^{\phi} - E\Delta_{32}^{\phi} = E\delta_{32}^{\phi} - E\delta_{22}^{\phi}$$

In Matrix Form We Have,

$$\begin{bmatrix} -609.41962 & -136.91517 & -288.79601 & 139.54705 \\ 136.45710 & 49.45729 & 149.53615 & -48.23308 \\ -288.92626 & -150.09585 & -697.59753 & 146.15890 \\ -139.21089 & -48.27539 & -145.73007 & 48.70999 \end{bmatrix} \begin{bmatrix} H_1 \\ M_1 \\ H_2 \\ M_2 \end{bmatrix} = \begin{bmatrix} 7.63772 \\ 22.03255 \\ 20.34850 \\ -22.09972 \end{bmatrix} P$$

4. Redundant Load Values:

Solving The Above Matrix, We Get The Following Values For The Redundant Forces,

$H_1 = -0.81732P$
$M_1 = 5.22711P$
$H_2 = -0.84249P$
$M_2 = -0.12963P$