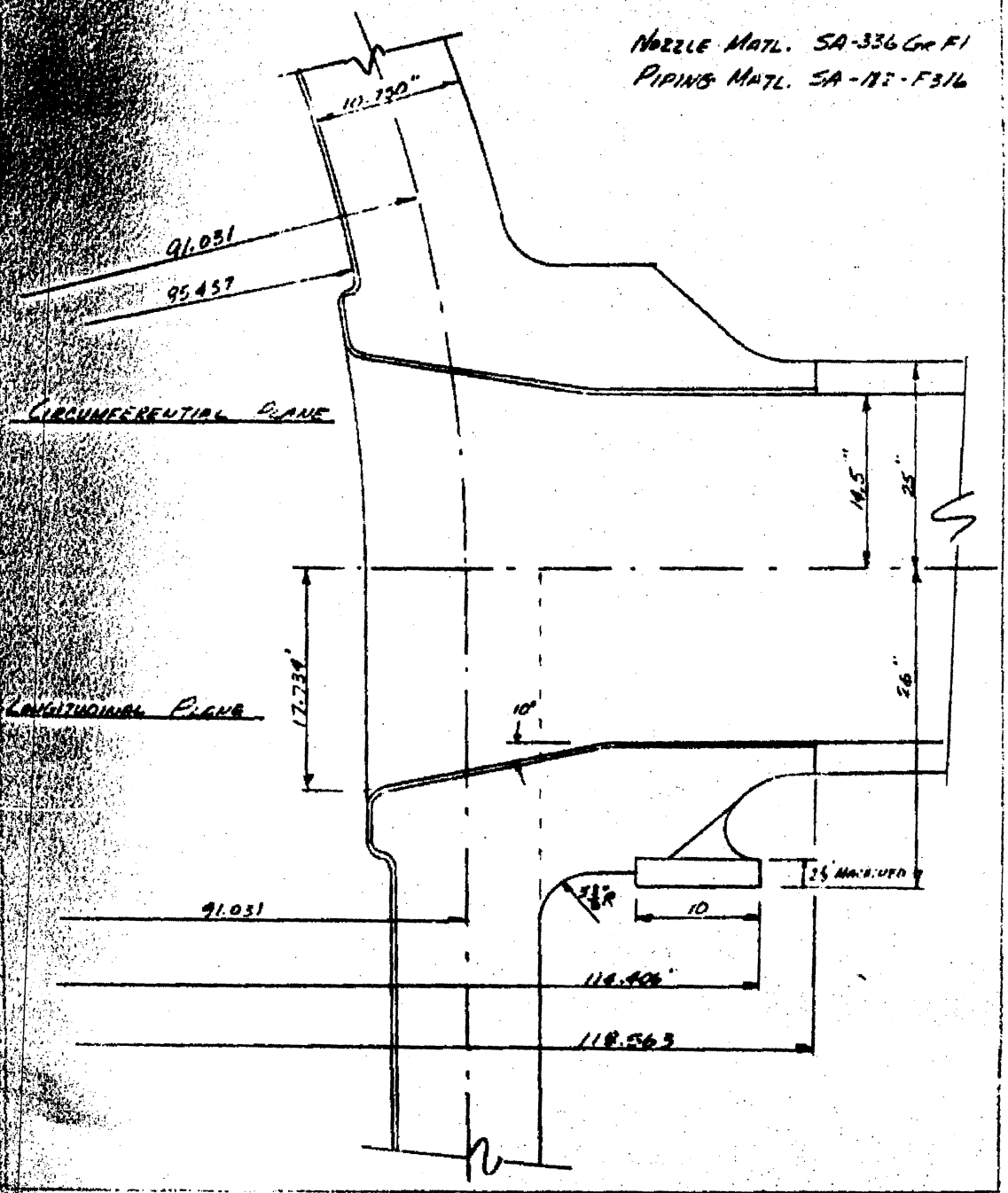
COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION: STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUMMETS

NUMBER S-218-P | A 178
SHEET 6 OF 80
DATE 4-22-68 BY CARRELL
CHECK DATE 4-22-68 BY HELLER

5. DETAILED ANALYSIS:

5.1 SYSTEM GEOMETRY:



COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION: STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE – VESSEL SUPPORTS

NUMBER S-712-P | A179
SHEET 7 OF 82
DATE 4-27-69 BY JCARELL
CHECK DATE 5-22-69 BY KEILER

5- DETAILED ANALYSIS:

b- SYSTEM ALLOWABLES:

1- THE STRESS INTENSITY IN THE REINFORCEMENT PORTION OF THE NOZZLE RESULTING FROM DESIGN PRESSURE AND FROM EXTERNAL LOAD OR MOMENT SHALL NOT EXCEED S_m AT DESIGN TEMP.

2- THE STRESS INTENSITY DERIVED FROM THE AVERAGE PRIMARY PLUS THE LOCAL PRIMARY STRESS SHALL NOT EXCEED $1.5S_m$ AT DESIGN TEMP.

3- THE STRESS INTENSITY AROUND THE NOZZLE TO SHELL JUNCTURE RESULTING FROM INTERNAL PRESSURE, PIPE LOADS, WEIGHT OF VESSEL AND REACTIONS FROM EXTERNAL LOADS SHALL NOT EXCEED $1.5S_m$ AT DESIGN TEMP.

4- THE STRESS INTENSITY IN THE NOZZLE OUTSIDE OF THE REINFORCEMENT PORTION OF THE NOZZLE AND THE SAFE END RESULTING FROM DESIGN PRESSURE AND FROM DESIGN SEISMIC LOAD OR MOMENT SHALL NOT EXCEED $1.5S_m$ AT DESIGN TEMP.

5- THE RANGE OF PRIMARY PLUS SECONDARY STRESS INTENSITY RESULTING FROM MECHANICAL OR THERMAL LOADS SHALL NOT EXCEED $3S_m$ AT OPERATING PRESSURE AND TEMP.

6- SHOW THAT EACH POINT MEETS THE REQUIREMENTS FOR PEAK STRESS INTENSITY GIVEN IN N-414.5 OF THE ASME CODE. THE PROCEDURE WILL BE AS OUTLINED IN N-415.2 OF SECT. III.

NOTE THAT FOR THE CONSIDERATION OF "NO LOSS OF FUNCTION" SEISMIC NOZZLE LOADS, THE ABOVE ALLOWABLES (WHERE APPLICABLE) WILL BE INCREASED BY A FACTOR OF 1.2.

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION 3e OUTLET NOZZLE - VESSEL SUPPORTS

NUMBER S-212-P | A180
SHEET 8 OF 80
DATE 4-27-69 BY SCOFIELD
CHECK DATE 4-21-69 BY MILLER

5-DETAILED ANALYSIS:

C. SYSTEM LOADINGS:

1. INTERNAL PRESSURE:

THE OUTLET NOZZLE AND THE VESSEL WALL IN THE VICINITY OF THE NOZZLE WILL BE INVESTIGATED FOR THE DESIGN PRESSURE WHERE APPLICABLE AND THE OPERATING PRESSURES DURING THE TRANSIENTS LISTED IN 5.C.2. THE STRESSES RESULTING FROM INTERNAL PRESSURE ARE DETERMINED FROM AN INTERACTION ANALYSIS AND ARE PRESENTED IN 5.C. THE PEAK STRESSES DUE TO INTERNAL PRESSURE AT THE JUNCTURE OF THE NOZZLE TO VESSEL SHELL WILL BE TAKEN AS GIVEN IN I-610 OF THE ASME CODE SECT. III.

2. THERMAL TRANSIENTS:

THE OUTLET NOZZLE AND THE VESSEL WALL WILL BE ANALYZED FOR THE FOLLOWING TRANSIENT CONDITIONS.

TRANSIENT	NUMBER OF OCCURRENCES
a. PLANT HEATUP AT 100°F PER HOUR	200
b. PLANT COOLDOWN AT 100°F PER HOUR	200
c. PLANT LOADING AT 5% OF FULL POWER PER MIN.	14500
d. PLANT UNLOADING AT 5% OF FULL POWER PER MIN.	14500
e. STEP LOAD INCREASE OF 10% OF FULL POWER BUT NOT TO EXCEED FULL POWER	2000
f. STEP LOAD DECREASE OF 10% OF FULL POWER FROM 100% POWER	2000
g. STEP LOAD REDUCTION FROM 100% TO 50% FULL POWER	200
h. REACTOR TRIP FROM FULL POWER	400
i. PLANT HYDROSTATIC TEST OF 3125 PSIA AT ROOM TEMP.	5
j. PLANT HYDROSTATIC TEST OF 2500 PSIA UP TO 400°F.	5
k. STEADY STATE FLUCTUATIONS OF ±6°F AND ± 100 PSI PER MIN.	00
l. LOSS OF FLOW, ONE PUMP	80
m. LOSS OF LOAD	80
n. STEAM SPRAY	5

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

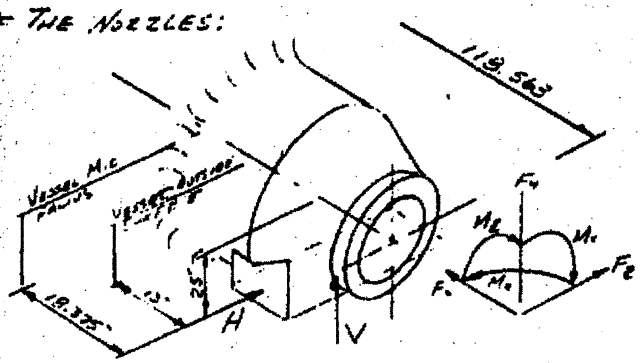
NUMBER S-212-P | A181
SHEET 9 OF 90
DATE 6-22-69 BY COCKRELL
CHECK DATE 3-27-69 BY HEDLUND

5. DETAILED ANALYSIS:

C. SYSTEM LOADING:

3. THERMAL INDUCED PIPE REACTIONS:

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



F_y = 26.2 KIPS
F_x = -230 KIPS
F_z = -10 KIPS
M_y = -2010 IN-KIPS
M_x = -1830 IN-KIPS
M_z = 2706 IN-KIPS

4. SEISMIC PIPE REACTIONS:

THE FOLLOWING PIPE REACTIONS DUE TO SEISMIC CONDITIONS WILL BE COMBINED WITH THE THERMAL PIPE REACTIONS IN THE WORST POSSIBLE COMBINATION WHEN ANALYZING THE NOZZLE AND SUPPORTS. TO DETERMINE THE MAXIMUM EFFECT OF THE SEISMIC PIPE REACTIONS ON THE NOZZLE TO VESSEL JUNCTURE AND THE SUPPORT PAD, IT IS NECESSARY TO DETERMINE THE WORSE COMBINATION OF FORCES. THIS HAS BEEN DONE AND THE FORCES RESULTING ARE LABELED H AND V. NOTE THAT THE EFFECT OF TWO OF THE INLET AND OUTLET NOZZLE SEISMIC REACTIONS MUST BE TAKEN BY THE INLET AND OUTLET NOZZLES WHICH SUPPORT THE VESSEL. THE FOLLOWING ARE THE PIPE REACTIONS

DESIGN SEISMIC LOADING	NO LOSS OF FUNCTION SEISMIC LOADING
$F_x = \pm$ 122 KIPS	$F_x = \pm 122$ KIPS
$F_y = \pm$ 90 KIPS	$F_y = \pm 162$ KIPS
$F_z = \pm$ 71 KIPS	$F_z = \pm 124$ KIPS
$M_x = \pm$ 572 IN-KIPS	$M_x = \pm 2830$ IN-KIPS
$M_y = \pm$ 12089 IN-KIPS	$M_y = \pm 19569$ IN-KIPS
$M_z = \pm$ 7292 IN-KIPS	$M_z = \pm 13200$ IN-KIPS

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

CHARGE NO.

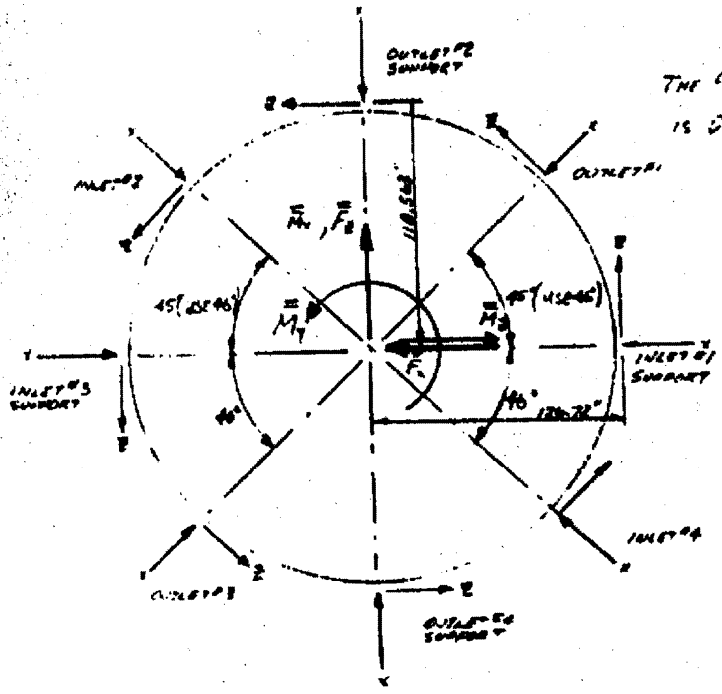
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORT

NUMBER 5-211-P | A182
SHEET 10 OF 90
DATE 4-22-64 BY CALDWELL
CHECK DATE 4-22-64 BY HELLYER

3. DETAILED ANALYSIS:
3C. SYSTEM LOADING:
3C4. SEISMIC PIPE REACTIONS:

AS CAN BE SEEN FROM THE TABLE ON SHEET 9, THERE ARE MANY COMBINATIONS OF FORCES. SINCE THE SEISMIC FORCES CAN ALTERNATE, IT WILL BE NECESSARY TO DETERMINE THE COMBINATION OF FORCES WHICH PRODUCE THE MAXIMUM AND MINIMUM STRESSES AT CUT-4. THIS WILL OCCUR WHEN THE VALUES FOR F_x, F_y, F_z, M_x, M_y, AND M_z AS GIVEN ON SHEETS 47 - 52 ARE SOLVED TO GIVE MAXIMUM AND MINIMUM VALUES. THE METHOD USED TO DETERMINE THIS IS AS FOLLOWS:

(1) THE LOADS ON THE INDIVIDUAL NOZZLES ARE TRANSFERRED TO THE C.G. OF THE REACTOR VESSEL,
(2) THE FORCES H AND V ARE DETERMINED IN RELATION TO THE LOADS AT THE ℄ OF THE VESSEL, AND
(3) TAKING THE COMBINATION OF SEISMIC LOADS GIVEN ON SHEET 9 TO GIVE THE MAXIMUM AND MINIMUM VALUES OF H & V.



THE POSITIVE Y DIRECTION IS OUT OF THE PAPER

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

NUMBER S-212-P 1 A/B3
SHEET 11 OF 80
DATE 4-17-68 BY Cockrell
CHECK DATE 4-22-68 BY Heilker

5. Detailed Analysis:
C. System Loading:
4. Seismic Pipe Reactions:

(1) Forces At ℄ Of Vessel:

See Sheet 11 Of S-211-P

(2) Forces On Supports:

$$H = \pm \frac{\bar{F}_x}{2} - \frac{\bar{M}_y}{4(104.400)}$$

$$V = -\frac{\bar{F}_y}{4} \pm \frac{\bar{M}_x}{2(104.400)}$$

Note Here That The Top Sign Is For Outlet Nozzle #2 And The Bottom Sign Is For Outlet Nozzle #4. However, With Substitution Of Formulas For $\bar{F}_x, \bar{F}_y$ & $\bar{M}_y$, And $\bar{M}_x$ And Solving, We Yield The Same Results.

(3) Values Of Forces On Supports:

With The Above Expressions For H & V And The Expressions For $\bar{F}_x$, $\bar{F}_y$, $\bar{M}_x$, And $\bar{M}_y$ Given On Sheet 11 Of S-211-P, We Get The Following:

$$H = -0.5(F_{x_{IN\#1}} - F_{x_{IN\#3}}) + 0.34733(F_{x_{IN\#2}} - F_{x_{IN\#4}}) - 0.25956(F_{z_{IN\#1}} + F_{z_{IN\#3}}) - 0.64923 F_{z_{IN\#2}}$$
$$+ 0.07011 F_{z_{IN\#4}} - 0.34733(F_{x_{OUT\#1}} - F_{x_{OUT\#3}}) - 0.63059 F_{z_{OUT\#1}} - 0.77092 F_{z_{OUT\#2}}$$
$$+ 0.08975 F_{z_{OUT\#3}} + 0.22849 F_{z_{OUT\#4}} - 0.002295(M_{y_{IN\#1}} + M_{y_{IN\#2}} + M_{y_{IN\#3}} + M_{y_{IN\#4}})$$
$$- 0.002295(M_{y_{OUT\#1}} + M_{y_{OUT\#2}} + M_{y_{OUT\#3}} + M_{y_{OUT\#4}})$$

$$V = -0.25(F_{y_{IN\#1}} + F_{y_{IN\#3}}) - 0.66659 F_{y_{IN\#2}} + 0.16659 F_{y_{IN\#4}} - 0.63977 F_{y_{OUT\#1}} - 0.79184 F_{y_{OUT\#2}} + 0.13977 F_{y_{OUT\#3}}$$
$$+ 0.24144 F_{y_{OUT\#4}} + 0.00037(M_{x_{IN\#1}} - M_{x_{IN\#3}}) - 0.00817(M_{y_{IN\#2}} - M_{y_{IN\#4}}) + 3.00329(M_{z_{IN\#2}} - M_{z_{IN\#4}})$$
$$+ 0.00317(M_{x_{OUT\#1}} - M_{x_{OUT\#3}}) + 3.00329(M_{z_{OUT\#1}} - M_{z_{OUT\#3}}) + 0.000457(M_{z_{OUT\#2}} - M_{z_{OUT\#4}})$$

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

NUMBER S-212-P | A184
SHEET 12 OF 80
DATE 4-22-69 BY LOCKREY
CHECK DATE 4-22-69 BY WALKER

5.0 DETAILED ANALYSIS:

5.1 SYSTEM LOADING:

5.1.4 SEISMIC PIPE REACTIONS:

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

FOR DESIGN SEISMIC:

NOZZLE	PIPE REACTION					
	F_x	F_y	F_z	M_x	M_y	M_z
INLET #1	57.9	67	132.9	-982	12972	
2	-57.9	67	132.9	982	12972	-9910
3	-57.9	67	1329	982	12972	
4	57.9	-67	-132.9	-982	12972	9910
OUTLET #1	122	90	-71	-1572	11248	-7292
2	-122	-90	-71	-1572	-11248	7282
3	-122	-90	71	1572	11248	7282
4		-90	71		11248	7282

H = -538.5 KIPS
V = -252.8 KIPS

REVERSING SIGNS GIVES,

H = 538.5 KIPS
V = 252.8 KIPS

FOR NO LOSS OF FUNCTION SEISMIC:

NOZZLE	PIPE REACTION					
	F_x	F_y	F_z	M_x	M_y	M_z
INLET #1	91.9	81.9	262	-2900	23655	
2	-91.9	91.9	262	2900	23655	-10005
3	-81.9	819	262	2900	23655	
4	91.9	-919	-262	-2800	23655	10005
OUTLET #1	122	162	-124	-2930	19569	-13200
2	-122	-162	-124	-2930	-19569	13200
3	-122	-162	124	2930	19569	13200
4		-162	124		19569	13200

H = -892.2 K
V = -407.2 K

REVERSING SIGNS GIVES,

H = 892.2 K
V = 407.2 K

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

NUMBER S-212-D | A185
SHEET 13 OF 80
DATE 6-22-68 BY CALDWELL
CHECK DATE 6-22-68 BY HELLER

5- DETAILED ANALYSIS:

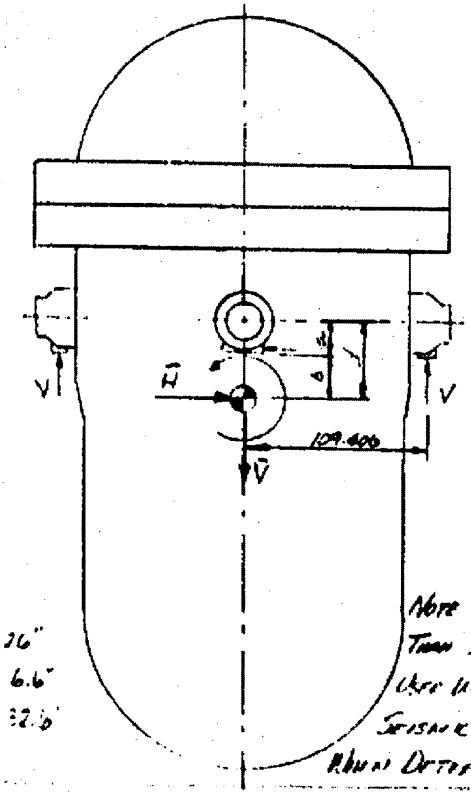
c. SYSTEM LOADING:

5- STATIC LOADING THROUGH SUPPORTS:

THE STATIC LOAD PER SUPPORT WAS FOUND TO BE 561.1 KIPS, SEE SHEET 14 OF S-212-P.

6- EARTHQUAKE LOADING THROUGH SUPPORTS:

DURING AN EARTHQUAKE, THE SUPPORTS MUST RESIST THE VERTICAL AND HORIZONTAL FORCES APPLIED THROUGH THE C.G. OF THE VESSEL DUE TO THE EARTHQUAKE SHOCK FORCES. SINCE THE BOTTOM OF THE VESSEL SUPPORTS IS AT A DIFFERENT ELEVATION THAN THE C.G. OF THE VESSEL, AN OVERTURNING MOMENT DUE TO THE HORIZONTAL SHOCK FORCE RESULTS AND MUST BE RESISTED BY THE SUPPORTS. THE FOLLOWING FIGURE ILLUSTRATES THE METHOD FOR DETERMINING THE FORCES IN THE PADS.



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

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

DIRECTION	EARTHQUAKE FACTORS	
	DESIGN	NO LOSS OF FUNCTION
HORIZONTAL	0.3g	0.6g
VERTICAL	0.2g	0.4g

FORCE	DESIGN	NO LOSS OF FUNCTION
H	± 336.7	± 672.4
V	± 132.5	± 265.1

NOTE THAT THE ABOVE SEISMIC SHOCK FACTORS ARE LARGER THAN THOSE LISTED IN REF 20. THE ABOVE FACTORS WILL BE USED WHEN CALCULATING STRESSES; HOWEVER, THE SPECIFIED SEISMIC SHOCK FACTORS GIVEN IN REF 10. WILL BE USED WHEN DETERMINING THE MAX. FORCES ON THE PAD, SEE SHEET 66.

5. DETAILED ANALYSIS:

c. SYSTEM LOADING:

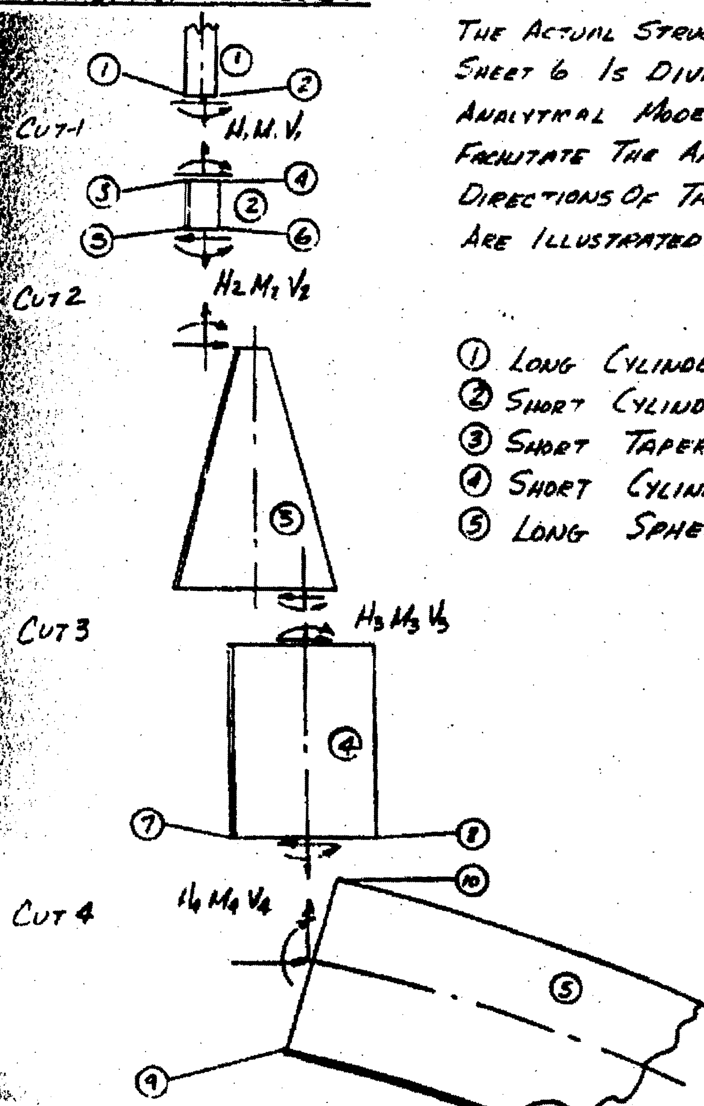
7. DUE TO THERMAL EXPANSION & CONTRACTION

THE FRICTIONAL FORCE DUE TO EXPANSION AND CONTRACTION WAS FOUND TO BE 162.3 KIPS, SEE SHEET 16 OF S-211-P.

d. PRESSURE AND THERMAL INTERACTION:

1. ANALYTICAL MODEL:

THE ACTUAL STRUCTURE AS SHOWN ON SHEET 6 IS DIVIDED INTO THE ANALYTICAL MODEL AS SHOWN TO FACILITATE THE ANALYSIS. THE ASSUMED DIRECTIONS OF THE REDUNDANT FORCES ARE ILLUSTRATED.



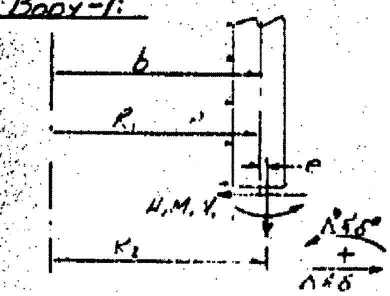
① LONG CYLINDER
② SHORT CYLINDER
③ SHORT TAPERED CYLINDER
④ SHORT CYLINDER
⑤ LONG SPHERE

5. DETAILED ANALYSIS:

d. PRESSURE & THERMAL INTERACTION:

1- DEFLECTIONS:

BODY-1:



$R_1 = 15.766''$

$b_1 = 14.5'$

$t_1 = 2.531'$

$R_2 = 15.975''$

$e = 0.109''$

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

$\beta = 0.20349$

$D = \frac{Et_1^3}{12(1-\nu^2)} = 1.49475E$

$\frac{E_{508}}{E_{316}} = 1$

DISPLACEMENTS DUE TO REDUNDANT FORCES:

$$E\Delta_{11} = -\frac{E}{2\beta^3 D}\left[\frac{1}{\beta}H_1 - M_1\right]\frac{R_2}{R_1}\frac{E_{508}}{E_{316}} = \underline{-40.2444\,H_1 + 8.1892\,M_1}$$

$$E\Delta_{11}^{*} = -\frac{E}{2\beta^2 D}\left[H_1 - 2\beta M_1\right]\frac{R_2}{R_1}\frac{E_{508}}{E_{316}} = \underline{-8.1892\,H_1 + 3.3329\,M_1}$$

DISPLACEMENTS DUE TO APPLIED FORCES:

$$E\delta_{11} = \frac{R_1^2}{t_1}\left(\frac{R_2}{R_1} - \frac{\nu}{2}\right)P\,\frac{E_{508}}{E_{316}} - \frac{E}{2\beta^2 D}(V_1 e)\frac{R_2}{R_1}\frac{E_{508}}{E_{316}} = \underline{71.9513P}$$

$$E\delta_{11}^{*} = -\frac{E}{\beta D}(V_1 e)\frac{R_2}{R_1}\frac{E_{508}}{E_{316}} = \underline{-2.4056P}$$

DISPLACEMENTS DUE TO THERMAL EFFECTS:

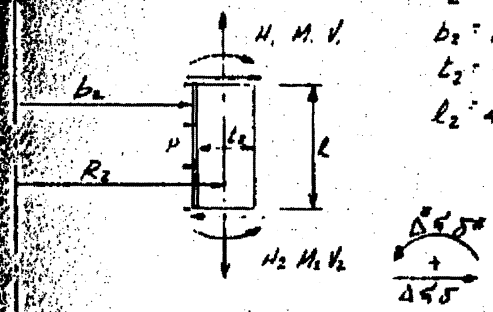
FOR RANGE OF STRESS	FOR PEAK STRESS
$E\delta_{11T} = R_2 E\alpha_m (T_{11} - 100)\frac{E_{508}}{E_{316}}$	$= R_2 E\alpha_m (T_{11} - 100)\frac{E_{508}}{E_{316}} + \frac{E}{2\beta^2 D}\frac{R_2}{R_1}\frac{E_{508}}{E_{316}} M_{1T}$
$= \underline{15.975\,E\alpha_m (T_{11} - 100)}$	$= \underline{15.975\,E\alpha_m (T_{11} - 100) + 8.1892\,M_{1T}}$
$E\delta_{11}^{*} = R_1 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{11}\frac{E_{508}}{E_{316}}$	$= R_1 E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{11}\frac{E_{508}}{E_{316}} + \frac{E}{\beta D}\frac{R_2}{R_1}\frac{E_{508}}{E_{316}} M_{1T}$
$=$ [illegible] $E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{11}$	$= \underline{15.766\,E\alpha_m \left(\frac{\Delta T}{\Delta X}\right)_{11} + 3.3329\,M_{1T}}$

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

NUMBER S-212-P | A188
SHEET 16 OF 30
DATE 4-22-69 BY Cockrell
CHECK DATE 4-23-69 BY Hellyer

5. Detailed Analysis:
a. Pressure And Thermal Interaction:
b. Deflections:

Body-2:



$R_2 = 15.375"$
$b_2 = 14.500"$
$t_2 = 2.312"$
$l_2 = 4.0625"$

$\beta^4 = \frac{3(1-\nu^2)}{R^2 t^2}$
$\beta = 0.21217$
$D = \frac{Et^3}{12(1-\nu^2)} = 1.13172E$

For $\Delta C = 0.462$

$B_{11} = 7.3326$ $G_{11} = -1.1511$
$B_{12} = 4.1158$ $G_{12} = -3.3924$
$B_{22} = 10.0093$ $G_{22} = -9.1500$

Displacements Due To Redundant Forces:

$$E\Delta_{21} = \frac{E}{2\beta^3 D}\left[\frac{1}{\beta} B_{11} H_1 + B_{12} M_1 - \frac{1}{\beta} G_{11} H_2 + G_{12} M_2\right]$$

$$= 107.8952 H_1 + 40.3930 M_1 + 53.2445 H_2 - 39.1819 M_2$$

$$E\Delta_{21}^* = \frac{E}{2\beta^3 D}\left[-B_{12} H_1 - \beta B_{22} M_1 + G_{12} H_2 - \beta G_{22} H_2\right]$$

$$= -40.3930 H_1 - 20.4425 M_1 - 39.1819 H_2 + 19.0519 M_2$$

$$E\Delta_{22} = \frac{E}{2\beta^3 D}\left[\frac{1}{\beta} G_{11} H_1 + G_{12} M_1 - \frac{1}{\beta} B_{11} H_2 + B_{12} M_1\right]$$

$$= -53.2445 H_1 - 39.1819 M_1 - 107.8952 H_2 + 40.3930 M_2$$

$$E\Delta_{22}^* = \frac{E}{2\beta^3 D}\left[G_{12} H_1 + \beta G_{22} M_1 - B_{12} H_2 + \beta B_{22} M_1\right]$$

$$= -39.1319 H_1 - 19.0519 M_1 - 40.3930 H_2 + 20.4425 M_2$$

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

NUMBER S-212-C | A189
SHEET 17 OF 80
DATE 4-27-60 BY CAGARELL
CHECK DATE 4-27-60 BY HEILER

5- DETAILED ANALYSIS:

d. PRESSURE AND THERMAL INTERACTION:

2. DEFLECTIONS:

DISPLACEMENTS DUE TO APPLIED FORCES

$$E\delta_{21} = E\delta_{22} = \frac{b_2^2}{t_2}\left(\frac{R_2}{b_2} - \frac{\nu}{2}\right)P = 35.9213P$$

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

DISPLACEMENTS DUE TO THERMAL EFFECTS:

FOR RANGE OF STRESS	FOR PEAK STRESS
$E\delta_{21T} = K_2 Ed_m (T_{21} - 100)$	$= K_2 Ed_m (T_{21} - 100) + \frac{E}{2\beta^3 D}\left[B_{12} M_{1T} + G_{12} M_{2T}\right]$
$= 15.875\, Ed_m (T_{21} - 100)$	$= 15.875\, Ed_m (T_{21} - 100) + 40.3930 M_{1T} - 39.1819 M_{2T}$
$E\delta_{21T}^* = K_2 Ed_m \left(\frac{\Delta T}{\Delta x}\right)_{21}$	$= K_2 Ed_m \left(\frac{\Delta T}{\Delta x}\right)_{21} + \frac{E}{2\beta^3 D}\left[-\beta B_{22} M_{1T} - \beta G_{22} M_{2T}\right]$
$= 15.875\, Ed_m \left(\frac{\Delta T}{\Delta x}\right)_{21}$	$= 15.875\, Ed_m \left(\frac{\Delta T}{\Delta x}\right)_{21} - 20.9423 M_{1T} + 19.0519 M_{2T}$
$E\delta_{22T} = K_2 Ed_m (T_{22} - 100)$	$= K_2 Ed_m (T_{21} - 100) + \frac{E}{2\beta^3 D}\left[G_{12} M_{1T} + B_{12} M_{2T}\right]$
$= 15.875\, Ed_m (T_{22} - 100)$	$= 15.875\, Ed_m (T_{22} - 100) - 39.1819 M_{1T} + 40.3930 M_{2T}$
$E\delta_{22T}^* = K_2 Ed_m \left(\frac{\Delta T}{\Delta x}\right)_{22}$	$= K_2 Ed_m \left(\frac{\Delta T}{\Delta x}\right)_{22} + \frac{E}{2\beta^3 D}\left[\beta G_{22} M_{1T} + \beta B_{22} M_{2T}\right]$
$= 15.875\, Ed_m \left(\frac{\Delta T}{\Delta x}\right)_{22}$	$= 15.875\, Ed_m \left(\frac{\Delta T}{\Delta x}\right) - 19.0519 M_{1T} + 20.9423 M_{2T}$

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

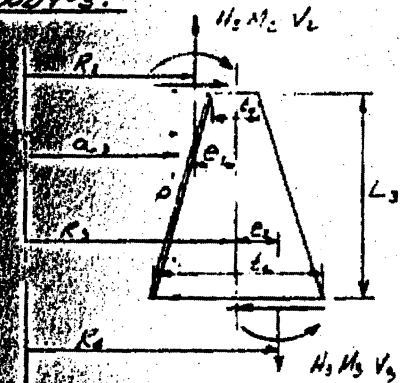
NUMBER S-218-P | A190
SHEET 18 OF 80
DATE 4-22-69 BY CACKETT
CHECK DATE 4-17-69 BY HEILER

5. DETAILED ANALYSIS:

2. PRESSURE AND THERMAL INTERATION:

2. DEFLECTIONS:

BODY 3:



$R_2 = 15.975$
$R_3 = 17.928$
$R_4 = 19.980$
$a_3 = 14.500$

$t_0 = 2.312$
$t_L = 10.281$
$L_3 = 8.219$
$e_1 = 2.053$
$e_2 = 2.052$

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

$\beta = 45° = 0.46458$

$\Delta\alpha\beta$

THE INFLUENCE COEFFICIENTS FOR A SHORT TAPERED CYLINDER ARE CALCULATED BY THE METHOD OUTLINED ON PAGES 488-492 OF REF. 7 AND ARE PRINTED OUT ON C.E.'s COMPUTER PROGRAM AS FOLLOWS.

DISPLACEMENTS DUE TO REDUNDANT FORCES:

$$E\Delta_{22} = \phi_{11} H_2 \frac{R_2}{R_3} + \phi_{12} M_2 \frac{R_2}{R_3} + \phi_{13} H_3 \frac{R_4}{R_3} + \phi_{14} M_3 \frac{R_4}{R_3}$$

$$= 34.1884 H_2 + 6.1893 M_2 + 15.7490 H_3 - 6.9346 M_3$$

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

$$= -6.1847 H_2 - 1.9617 M_2 - 4.4781 H_3 + 1.3550 M_3$$

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

$$= -15.5178 H_2 - 3.5624 M_2 - 21.9623 H_3 + 4.6783 M_3$$

$$E\Delta_{23}^{*} = \phi_{01} H_2 \frac{R_2}{R_3} + \phi_{02} M_2 \frac{R_2}{R_3} + \phi_{03} H_3 \frac{R_4}{R_3} + \phi_{04} M_3 \frac{R_4}{R_3}$$

$$= -5.5112 H_2 - 1.0776 M_2 - 4.6773 H_3 + 1.4794 M_3$$

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

NUMBER 5-212-P | A191
SHEET 19 OF 80
DATE 4-22-68 BY CERRELL
CHECK DATE 4-22-68 BY HILLYER

5. DETAILED ANALYSIS:

d. PRESSURE AND THERMAL INTERACTION:

2. DEFLECTIONS:

DISPLACEMENTS DUE TO APPLIED FORCES:

$$E\delta_{11}^{P} = Pa_3^2\left(\frac{R_1}{a_3} - \frac{\nu'}{2}\right)\left[(\phi_{12}+\phi_{14})\frac{-\lambda^2}{4(1-\nu')} + \frac{1}{L_0}\right] + \phi_{12}V_2 e_1\frac{R_1}{R_3} - \phi_{14}V_3 e_2\frac{R_1}{R_3} = \underline{227.6294P}$$

$$E\delta_{12}^{P} = Pa_3^2\left(\frac{R_1}{a_3} - \frac{\nu'}{2}\right)\left[(\phi_{22}+\phi_{24})\frac{-\lambda^2}{4(1-\nu')} - \frac{\lambda}{L_0'}\right] + \phi_{22}V_2 e_1\frac{R_2}{R_3} - \phi_{24}V_3 e_2\frac{R_1}{R_3} = \underline{-46.4974P}$$

$$E\delta_{31} = Pa_3^2\left(\frac{R_1}{a_3} - \frac{\nu'}{2}\right)\left[(\phi_{32}+\phi_{34})\frac{-\lambda^2}{4(1-\nu')} + \frac{1}{L_1}\right] + \phi_{32}V_2 e_1\frac{R_1}{R_3} - \phi_{34}V_3 e_2\frac{R_1}{R_3} = \underline{-93.5960P}$$

$$E\delta_{33}^{P} = Pa_3^2\left(\frac{R_3}{a_3} - \frac{\nu'}{2}\right)\left[(\phi_{42}+\phi_{44})\frac{-\lambda^2}{4(1-\nu')} - \frac{\lambda}{L_1'}\right] + \phi_{42}V_2 e_1\frac{R_3}{R_3} - \phi_{44}V_3 e_2\frac{R_3}{R_3} = \underline{-37.0640P}$$

DISPLACEMENTS DUE TO THERMAL EFFECTS:

FOR RANGE OF STRESS	FOR PEAK STRESS
$E\delta_{32T} = R_2 Ed_m(T_{32}-100)$	$= R_2 Ed_m(T_{32}-100) + \phi_{12}M_{2T}\frac{R_1}{R_3} + \phi_{14}M_{3T}\frac{R_1}{R_3}$
$= \underline{15.875\,Ed_m(T_{32}-100)}$	$= \underline{15.875\,Ed_m(T_{32}-100) + 6.1993M_{2T} - 6.9346M_{3T}}$
$E\delta_{32T}^{*} = R_3 Ed_m\left(\frac{\Delta T}{\Delta X}\right)_{32}$	$= R_3 Ed_m\left(\frac{\Delta T}{\Delta X}\right)_{32} + \phi_{22}M_{2T}\frac{R_2}{R_3} + \phi_{24}M_{3T}\frac{R_1}{R_3}$
$= \underline{17.928\,Ed_m\left(\frac{\Delta T}{\Delta X}\right)_{32}}$	$= \underline{17.928\,Ed_m\left(\frac{\Delta T}{\Delta X}\right)_{32} - 1.8617M_{2T} + 1.3550M_{3T}}$
$E\delta_{33T} = R_4 Ed_m(T_{33}-100)$	$= R_4 Ed_m(T_{33}-100) + \phi_{32}M_{2T}\frac{R_2}{R_3} + \phi_{34}M_{3T}\frac{R_1}{R_3}$
$= \underline{19.990\,Ed_m(T_{33}-100)}$	$= \underline{19.990\,Ed_m(T_{33}-100) - 3.5624M_{2T} + 4.6783M_{3T}}$
$E\delta_{33T}^{*} = R_3 Ed_m\left(\frac{\Delta T}{\Delta X}\right)_{33}$	$= R_3 Ed_m\left(\frac{\Delta T}{\Delta X}\right)_{33} + \phi_{42}M_{2T}\frac{R_2}{R_3} + \phi_{44}M_{3T}\frac{R_1}{R_3}$
$= \underline{17.928\,Ed_m\left(\frac{\Delta T}{\Delta X}\right)_{33}}$	$= \underline{17.928\,Ed_m\left(\frac{\Delta T}{\Delta X}\right)_{33} - 1.0776M_{2T} + 1.4794M_{3T}}$

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

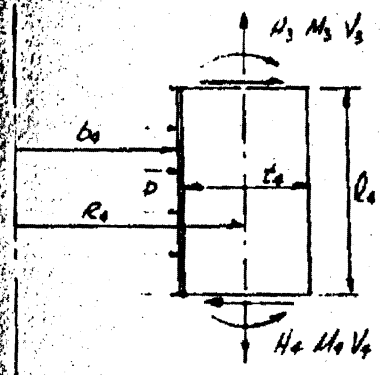
NUMBER 5-212-P | A192
SHEET 20 OF 80
DATE 4-22-69 BY J. ROSSELLI
CHECK DATE 4-22-69 BY J. FILKER

E- DETAILED ANALYSIS:

1. PRESSURE AND THERMAL INTERACTION:

2. DEFLECTIONS:

Body-4:



$R_4 = 19.980"$
$b_4 = 14.739"$
$t_4 = 10.042"$
$\ell_4 = 15.25"$

$\beta = \frac{3(1-\nu^2)}{R_4^2 t_4^2}$
$\beta = 0.09075$
$D = \frac{E t_4^3}{12(1-\nu^2)} = 92.7338\,E$

For $R\beta = 1.384$

$B_{11} = 1.4944$	$G_{11} = -0.6859$
$B_{12} = 1.7630$	$G_{12} = -1.4519$
$B_{22} = 3.2777$	$G_{22} = -1.9212$

Displacements Due To Redundant Forces:

$$E\Delta_{43} = \frac{E}{2\beta^3 D}\left[\frac{1}{\beta} B_{11} H_3 + B_{12} M_3 - \frac{1}{\beta} G_{11} H_4 + G_{12} M_4\right]$$

$$= 10.7821\,H_3 + 1.1543\,M_3 + 4.9488\,H_4 - 0.9506\,M_4$$

$$E\Delta^*_{43} = \frac{E}{2\beta^3 D}\left[-B_{12} H_3 - \beta B_{22} M_3 + G_{12} H_4 - \beta G_{22} M_4\right]$$

$$= -1.1543\,H_3 - 0.1948\,M_3 - 0.9506\,H_4 + 0.1142\,M_4$$

$$E\Delta_{44} = \frac{E}{2\beta^3 D}\left[\frac{1}{\beta} G_{11} H_3 + G_{12} M_3 - \frac{1}{\beta} B_{11} H_4 + B_{12} M_4\right]$$

$$= -4.9488\,H_3 - 0.9506\,M_3 - 10.7821\,H_4 + 1.1543\,M_4$$

$$E\Delta^*_{44} = \frac{E}{2\beta^3 D}\left[G_{12} H_3 + \beta G_{22} M_3 - B_{12} H_4 + \beta B_{22} M_4\right]$$

$$= -0.9506\,H_3 - 0.1142\,M_3 - 1.1543\,H_4 + 0.1948\,M_4$$

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

NUMBER S-212-P | A193
SHEET 21 OF 80
DATE 4-22-69 BY Cockrell
CHECK DATE 4-22-69 BY Hellard

5. Detailed Analysis

d. Pressure And Thermal Interaction:

2. Deflections:

Displacements Due To Applied Forces:

$$E\delta_{43}^{P} - E\delta_{44}^{P} = \frac{b_4^2}{t_4}\left(\frac{R_4}{b_4} - \frac{1}{2}\right)P = 26.0803P$$

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

Displacements Due To Thermal Effects:

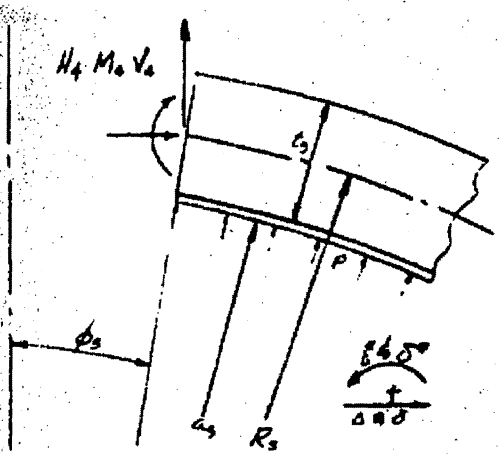
For Range Of Stress	For Peak Stress
$E\delta_{43T} = R_4 E\alpha_m (T_{43} - 100)$	$= R_4 E\alpha_m (T_{43} - 100) + \frac{E}{2\beta^3 D}\left[B_{12} M_{3T} + G_{12} M_{4T}\right]$
$= 19.980 E\alpha_m (T_{43} - 100)$	$= 19.980 E\alpha_m (T_{43} - 100) + 1.1543 M_{3T} - 0.9506 M_{4T}$
$E\delta_{43T}^{\Delta T} = R_4 E\alpha_m \left(\frac{\Delta T}{\Delta x}\right)_{43}$	$= R_4 E\alpha_m \left(\frac{\Delta T}{\Delta x}\right)_{43} + \frac{E}{2\beta^3 D}\left[-\beta B_{22} M_{3T} - \beta G_{22} M_{4T}\right]$
$= 19.980 E\alpha_m \left(\frac{\Delta T}{\Delta x}\right)_{43}$	$= 19.980 E\alpha_m \left(\frac{\Delta T}{\Delta x}\right)_{43} - 0.1949 M_{3T} + 0.1142 M_{4T}$
$E\delta_{44T} = R_4 E\alpha_m (T_{44} - 100)$	$= R_4 E\alpha_m (T_{44} - 100) + \frac{E}{2\beta^3 D}\left[G_{12} M_{3T} + B_{12} M_{4T}\right]$
$= 19.980 E\alpha_m (T_{44} - 100)$	$= 19.980 E\alpha_m (T_{44} - 100) - 0.9506 M_{3T} + 1.1543 M_{4T}$
$E\delta_{44T}^{\Delta T} = R_4 E\alpha_m \left(\frac{\Delta T}{\Delta x}\right)_{44}$	$= R_4 E\alpha_m \left(\frac{\Delta T}{\Delta x}\right)_{44} + \frac{E}{2\beta^3 D}\left[\beta G_{22} M_{3T} + \beta B_{22} M_{4T}\right]$
$= 19.980 E\alpha_m \left(\frac{\Delta T}{\Delta x}\right)_{44}$	$= 19.980 E\alpha_m \left(\frac{\Delta T}{\Delta x}\right)_{44} - 0.1142 M_{3T} + 0.1948 M_{4T}$

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

NUMBER S-212-P | A199
SHEET 22 OF 80
DATE 4-22-69 BY JCKERR
CHECK DATE 4-22-69 BY HELLYER

5. DETAILED ANALYSIS:
d. PRESSURE AND THERMAL INTERACTION:
2. DEFLECTIONS:

BODY-5:



$R_3 = 136.546"$
$a_3 = 130.952"$
$t_3 = 10.750"$
$\phi_3 = 9.4138°$

For $\phi\sqrt{\frac{R}{t}} = 29.932$
$P_{11} = 0.5387$
$P_{12} = 0.4851$
$P_{22} = 2.7734$

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

DISPLACEMENTS DUE TO REDUNDANT FORCES:

$$E\Delta_{34} = \frac{180}{\pi t_3^2 \phi_3}\left[t_3^2 P_{11} H_4 + t_3 P_{12} M_4\right] = 3.6684 H_4 + 0.3073 M_4$$

$$E\Delta^{\circ}_{34} = -\frac{180}{\pi t_3^2 \phi_3}\left[t_3 P_{12} H_4 + P_{22} M_4\right] = -0.3073 H_4 - 0.1634 M_4$$

DISPLACEMENTS DUE TO APPLIED FORCES:

$$E\delta^{P}_{34} = \frac{a_3^2}{2}\left[\frac{180\cos\phi}{\pi R_3 \phi} P_{11} + \frac{\sin\phi}{t_3}(1-\nu)\right]P = 309.5691P$$

$$E\delta^{P}_{34} = -\frac{90 a_3^2 \cos\phi}{\pi R_3 t_3 \phi} P_{12} P = -19.0884P$$

DISPLACEMENTS DUE TO THERMAL EFFECTS:

FOR RANGE OF STRESS	FOR PEAK STRESS
$E\Delta_{34} = R_3 \sin\phi\, E\alpha_m (T_{34} - T_{04})$	$= R_3 \sin\phi\, E\alpha_m (T_{34} - T_{04}) + \frac{180}{\pi t_3^2 \phi_3} P_{12} M_{4T}$
$= 19.980 E\alpha_m (T_{34} - T_{04})$	$= 19.980 E\alpha_m (T_{34} - T_{04}) + 0.3073 M_{4T}$
$E\Delta^{\circ}_{34} = R_3 \sin\phi\, E\alpha_m \left(\frac{\Delta T}{\Delta x}\right)_{34}$	$= R_3 \sin\phi\, E\alpha_m \left(\frac{\Delta T}{\Delta x}\right)_{34} - \frac{180}{\pi t_3^2 \phi_3} P_{22} M_{4T}$
$= 19.980 E\alpha_m \left(\frac{\Delta T}{\Delta x}\right)_{34}$	$= 19.980 E\alpha_m \left(\frac{\Delta T}{\Delta x}\right)_{34} - 0.1634 M_{4T}$

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

NUMBER S-212-D | 1195
SHEET 23 OF 80
DATE 4-22-69 BY Crockett
CHECK DATE 4-22-69 BY Hewitt

5- Detailed Analysis:
4. Pressure And Thermal Interaction:
2. Deflections:

The Following Tables Give The Mean Temperature, Slope Of The Axial Gradient, And The Thermal Moment Due To The Radial Gradient For Each Cut. These Values Are Used To Calculate The Deflections Of Each Cut Due To The Thermal Effects As Presented On Sheets 15-22.

Transient		T_{11} & T_{21}	T_{12} & T_{22}	T_{13} & T_{23}	T_{14}	T_{15}	$\left(\frac{\Delta T}{\Delta x}\right)_{11}$	$\left(\frac{\Delta T}{\Delta x}\right)_{12}$ & $\left(\frac{\Delta T}{\Delta x}\right)_{22}$	$\left(\frac{\Delta T}{\Delta x}\right)_{23}$ & $\left(\frac{\Delta T}{\Delta x}\right)_{33}$
Heatup	4.00 hrs	492	498	440	433	435	1.000	-0.985	-4.668
	4.25	517	513	465	458	460			
	4.35	527	523	475	468	470			
	4.47	539	535	487	480	481			
	5.00	547	544	521	516	516	0	-0.738	-2.237
No Load Steady-State		547	547	547	547	547	0	0	0
Cooldown	4.00 hrs	155	159	207	214	212	-1.000	0.985	4.668
	4.25	130	134	182	189	187			
	4.35	120	124	172	179	177			
	4.47	108	112	160	167	166			
	5.00	103	103	126	131	131	0	0.738	2.237
Plant Loading	10 min	568	568	553	552	548	0.666	0	-1.459
	5	593	592	558	556	549	1.333	-0.246	-2.334
	20	599	597	565	562	550	1.444	-0.492	-3.112
	24	608	605	571	567	552	1.000	-0.738	-3.307
	30	610	608	576	571	555	0.666	-0.492	-3.112
Full Load Steady-State		613	613	607	598	574	0	0	-0.584
Plant Unloading	10 min	592	592	602	593	573	-1.000	0	0.373
	5	577	577	596	589	572	-1.333	0	1.943
	20	561	562	590	583	570	-1.666	0.246	2.723
	24	552	554	584	578	568	-1.333	0.492	2.918
	30	549	552	578	574	566	-0.666	0.738	2.529

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

NUMBER S-2127P | A196
SHEET 24 OF 80
DATE 4-22-64 BY CORLETT
CHECK DATE 4-27-64 BY HUNTER

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORT

5. DETAILED ANALYSIS:

d. PRESSURE AND THERMAL INTERACTION:

2. DEFLECTIONS:

TRANSIENT		T_{11} & T_{21}	T_{12} & T_{22}	T_{32} & T_{42}	T_{04}	T_{34}	$\left(\frac{\Delta T}{\Delta x}\right)_{11}$	$\left(\frac{\Delta T}{\Delta x}\right)_{21}$ & $\left(\frac{\Delta T}{\Delta x}\right)_{22}$	$\left(\frac{\Delta T}{\Delta x}\right)_{12}$ & $\left(\frac{\Delta T}{\Delta x}\right)_{33}$
e		594	594	594	594	594	0	0	-0.594
g	3.5 MIN	620	620	609	575	575			
	11 MIN	604	604	606	575	575			
	15.5 MIN	591	591	602	574	574			
h	10 SEC	612	612	607	574	574			
	90 SEC	593	593	603	573	573			
i		100	100	100	100	100	0	0	0
j	0.0 30 MPS	392	388	340	333	334	1.0	-0.985	-4.668
	S.S.	400	900	400	400	400	0	0	0
	C.O 3.0 MPS	108	112	160	167	166	-1.0	0.985	4.668
k		613	613	613	574	574	0	0	-0.584
l	17 SEC	613	613	607	573	573			
	3.5 MIN	609	609	606	573	573			
m	12 SEC	616	616	603	574	574			
	26 MIN	619	619	609	575	575			
	144 SEC	595	595	603	575	575			
n		547	547	547	547	547			

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

NUMBER 5-212-P | A197
SHEET 25 OF 80
DATE 4-22-68 BY COGSWELL
CHECK DATE 4-22-68 BY HEILKER

5. DETAILED ANALYSIS:

d. PRESSURE & THERMAL INTERACTION:

2. DEFLECTIONS:

TRANSIENT		$\left(\frac{\Delta T}{\Delta x}\right)_{03}$ & $\left(\frac{\Delta T}{\Delta x}\right)_{04}$	$\left(\frac{\Delta T}{\Delta x}\right)_{Ca}$	M_{1T}	M_{2T}	M_{3T}	M_{4T}	M_{5T}
HEATUP	4.00 HRS	-0.933	0.250	1.432	2.296	201.261	259.971	320.808
	4.25	-0.933	-0.250	1.439	2.307	202.228	262.483	322.358
	4.35	-0.933	-0.250	1.446	2.318	203.196	263.739	323.908
	4.47	-0.933	0	1.453	2.328	204.164	264.995	325.458
	5.00	-0.667	0	0	0.677	98.858	136.549	174.296
NO LOAD STEADY STATE		0	0	0	0	0	0	0
COOLDOWN	4.00 HRS	0.933	-0.250	-1.432	-2.296	-201.261	-259.971	-320.808
	4.25	0.933	-0.250	-1.439	-2.307	-202.228	-262.483	-322.358
	4.35	0.933	-0.250	-1.446	-2.318	-203.196	-263.739	-323.908
	4.47	0.933	0	-1.453	-2.328	-204.164	-264.995	-325.458
	5.00	0.667	0	0	-0.677	-98.858	-136.549	-174.296
PLANT LOADING	10 MIN	-0.133	0	2.219	2.199	67.384	78.067	11.629
	15	-0.267	-0.100	2.511	2.571	107.043	123.200	16.178
	20	-0.400	-0.400	2.825	2.946	142.450	169.119	22.245
	25	-0.533	-0.700	1.070	1.655	145.947	180.557	18.706
	30	-0.667	-1.050	0.646	1.090	134.611	178.923	15.167
FULL LOAD STEADY STATE		-1.200	-4.500	0	0	23.488	95.758	-108.694
PLANT UNLOADING	10 MIN	-1.200	-2.750	-2.300	-2.129	-42.350	7.834	-120.431
	15	-0.933	-2.750	-2.531	-2.601	-82.208	-40.630	-125.024
	20	-0.933	-2.500	-2.619	-2.739	-118.670	-82.080	-130.637
	25	-0.800	-2.000	-1.020	-1.460	-120.442	-100.958	-128.000
	30	-0.533	-1.750	-0.420	-1.040	-111.940	-94.772	-121.397

COMBUSTION ENGINEERING, INC.
ENGINEERING DEPARTMENT, CHATTANOOGA, TENN.
CHARGE NO.
DESCRIPTION: STRUCTURAL AND FATIGUE EVALUATION DE OUTLET NOZZLE - VESSEL SUPPORT

NUMBER S-212-P | A198
SHEET 26 OF 90
DATE 4-22-69 BY CAMPBELL
CHECK DATE 4-22-69 BY WALKER

5.- DETAILED ANALYSIS:
5.1.- PRESSURE AND THERMAL INTERACTION:
5.2.- DEFLECTIONS:

TRANSIENT CONDITION		$\left(\frac{\Delta T}{\Delta T_{W3}}\right)\varepsilon\left(\frac{\Delta T'}{\Delta T'}\right)_{III}$	$\left(\frac{\Delta T}{\Delta T'}\right)_{S4}$	M_{1T}	M_{2T}	M_{3T}	M_{4T}	M_{5T}
e' → f'		-1.200	-4.500	0	0	23.488	95.758	-108.694
g	3.5 min							
h	11 min							
i	15.5 min							
j	10 sec							
k	90 sec							
l		0	0	0	0	0	0	0
m	N.O. 2 CHRS	-0.933	0	1.453	2.329	204.164	264.995	325.458
	SS	0	0	0	0	0	0	0
	CO 3.0 HRS	0.933	0	-1.453	-2.329	-204.164	-264.995	-325.458
n		-1.200	-4.500	0	0	23.488	95.758	-108.694
o	12 SEC							
	18.5 SEC							
p	12 SEC							
	26 SEC							
	140 SEC							
q								

WITH THE EXPRESSIONS FOR DISPLACEMENTS AS PRESENTED ON SHEETS 15 THRU 22 AND THE VALUES GIVEN ON SHEETS 23 - 25, THE FOLLOWING VALUES FOR DISPLACEMENTS WERE OBTAINED.

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

NUMBER S-212-P | A199
SHEET 27 OF 90
DATE 4-22-69 BY BICKETT
CHECK DATE 4-22-69 BY HENLEY

DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS

5. DETAILED ANALYSIS:

d. PRESSURE & THERMAL INTERACTION:

2. DEFLECTIONS:

FOR RANGE OF STRESS

TRANSIENT		$E\delta_{11T}$	$E\delta^{*}_{11T}$	$E\delta_{21T}$	$E\delta^{*}_{21T}$	$E\delta_{22T}$	$E\delta^{*}_{22T}$	$E\delta_{12T}$	$E\delta^{*}_{32T}$
HEATUP	4.00 HRS	1550.1	3.927	1158.2	-2.911	1146.5	-2.911	1146.5	-15.577
	4.25	1649.4	3.926	1232.7	-2.911	1220.4	-2.911	1220.4	-15.578
	4.35	1697.5	3.925	1261.5	-2.910	1249.8	-2.910	1249.8	-15.575
	4.47	1734.2	3.923	1296.4	-2.909	1284.8	-2.909	1284.8	-15.570
	5.00	1765.3	0.0	1319.6	-2.179	1310.9	-2.179	1310.9	-7.459
16 IDAO STEADY STATE		1765.3	0.0	1319.6	0.0	1319.6	0.0	1319.6	0.0
COOLDOWN	4.00 HRS	213.2	-3.950	157.0	2.811	168.5	2.912	168.5	15.052
	4.25	116.0	-3.841	95.3	2.800	96.7	2.802	96.7	14.997
	4.35	77.3	-3.838	56.7	2.795	68.2	2797	68.2	14.970
	4.47	30.9	-3.838	22.6	2.787	34.0	2.790	34.0	14.932
	5.00	0.0	0.0	0.0	0.0	8.5	0.0	9.5	7.140
PLANT LOADING	10 MIN	1846.4	2.610	1380.3	0.0	1380.3	0.0	1380.3	-4.860
	15	1903.9	5.219	1423.5	-0.725	1420.6	-0.725	1420.6	-7.769
	20	1964.8	5.647	1469.6	-1.449	1463.8	-1449	14638	-10.351
	25	1998.9	3.908	1495.6	-2.173	1486.9	-2.173	1486.9	-10.996
	30	2006.4	2.602	1501.4	-1.448	1495.6	-1.449	1495.6	-10.347
FULL LOAD STEADY STATE		2017.7	0.0	1510.1	0.0	1510.1	0.0	1510.1	-1.941
PLANT UNLOADING	10 MIN	1938.2	-3.912	1449.4	0.0	1449.4	0.0	1449.4	3.237
	15	1880.9	-5.220	1406.2	0.725	1406.2	0.725	1406.2	6.152
	20	1819.4	-0.530	1360.1	1.452	1363.0	1.451	1363.0	9.072
	25	1794.7	-5.227	1334.1	2.178	1339.9	2.178	1339.9	9.726
	30	1773.0	-2.612	1325.4	0.0	1334.1	0.0	1334.1	9.426

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

NUMBER S-212-P | A200
SHEET 29 OF 80
DATE 4-22-68 BY SICKBELL
CHECK DATE 4-22-68 BY HEILER

2.0 DETAILED ANALYSIS:
2.1 PRESSURE & THERMAL INTERACTION:
2.1.1 DEFLECTIONS:

FOR RANGE OF STRESS

LOCATION		$E\delta_{11T}$	$E\delta^{*}_{11T}$	$E\delta_{21T}$	$E\delta^{*}_{21T}$	$E\delta_{22T}$	$E\delta^{*}_{22T}$	$E\delta_{32T}$	$E\delta^{*}_{32T}$
$T_m \rightarrow f_n$		1907.7	0	1426.3	0	1426.3	0	1426.3	-1.944
a	3.5 min	2044.1		1530.6		1530.6		1530.6	-1.941
b	11 min	1983.8		1484.0		1484.0		1484.0	-1.942
c	15.5 min	1934.4		1446.5		1446.5		1446.5	-1.943
d	10 sec	2014.0		1507.2		1507.2		1507.2	-1.942
e	90 sec	1942.0		1452.3		1452.3		1452.3	-1.943
f		0		0		0		0	0
g	N.D.	1152.4	3.919	857.1	-2.891	944.9	-2.890	944.9	-15.466
h	3.0 hrs	1184.4	0	881.3	0	881.3	0	881.3	0
i	5.5	30.9	-3.833	22.6	2.787	34.0	2.790	34.0	14.996
j	2.0	2017.7	0	1510.1	0	1510.1	0	1510.1	-1.941
k	2.0 hrs	2017.7		1510.1		1510.1		1510.1	-1.941
l	12 sec	2002.7		1498.5		1498.5		1498.5	-1.942
m	18.5 sec	2029.0		1518.9		1518.9		1518.9	-1.941
n	12 sec	2036.5		1524.7		1524.7		1524.7	-1.941
o	26 sec	1949.6		1458.0		1458.0		1458.0	-1.943
p	144 sec	1765.3		1319.6		1319.6		1319.6	-1.947

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

NUMBER 5-212-P | A201
SHEET 29 OF 80
CHARGE NO. _____
DATE 4-22-68 BY COCKRELL
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS
CHECK DATE 4-22-68 BY HEICKER

5- DETAILED ANALYSIS:

d. PRESSURE & THERMAL INTERACTION:

2- DEFLECTIONS:

FOR RANGE OF STRESS

TRANSIENT		$E\delta_{33}$	$E\delta^{*}_{33}$	$E\delta_{43}$	$E\delta^{*}_{43}$	$E\delta_{44}$	$E\delta^{*}_{44}$	$E\delta_{34}$	$E\delta^{*}_{34}$
NORMAL	4.30 HRS	1241.7	-15.544	1261.7	-3.462	1235.1	-3.461	1242.7	3.927
	4.25	1256.5	-15.567	1356.5	-3.467	1330.0	-3.466	1337.6	0.929
	4.35	1394.2	-15.572	1394.2	-3.469	1367.8	-3.468	1375.4	0.929
	4.47	1439.2	-15.577	1439.2	-3.470	1413.0	-3.469	1416.7	0
	5.00	1565.5	-7.464	1565.5	-2.480	1547.1	-2.481	1547.1	0
NO LOAD STEADY STATE		1660.9	0	1660.9	0	1660.9	0	1660.9	0
COOLDOWN	4.00 HRS	386.5	15.131	386.5	3.371	412.1	3.373	404.8	-0.904
	4.25	295.5	15.092	295.5	3.362	320.9	3.364	313.6	-0.901
	4.35	259.1	15.076	259.1	3.358	284.6	3.361	277.3	-0.900
	4.47	215.6	15.054	215.6	3.353	241.0	3.356	237.4	0
	5.00	93.0	7.177	93.0	2.385	110.9	2.387	110.9	0
PLANT LOADING	10 MIN	1692.7	-4.843	1682.7	-0.494	1679.1	-0.494	1664.5	0
	15	1700.9	-7.778	1700.9	-0.992	1693.6	-0.992	1668.2	-0.372
	20	1726.3	-10.367	1726.3	-1.495	1715.4	-1.495	1671.8	-1.486
	25	1748.1	-11.013	1748.1	-1.978	1733.6	-1.979	1679.1	-2.600
	30	1766.2	-10.361	1766.2	-2.475	1748.1	-2.476	1690.0	-3.900
FULL LOAD STEADY STATE		1878.7	-1.942	1878.7	-4.447	1845.9	-4.448	1758.9	-16.699
PLANT UNLOADING	10 MIN	1860.5	3.236	1860.5	-4.447	1827.8	-4.449	1755.3	-10.205
	15	1838.7	6.147	1838.7	-3.459	1813.3	-3.460	1751.7	-10.206
	20	1816.9	9.060	1816.9	-3.460	1791.5	-3.461	1744.4	-9.279
	25	1795.2	9.711	1795.2	-2.967	1773.4	-2.968	1737.2	-7.424
	30	1773.4	8.416	1773.4	-1.977	1758.9	-1.978	1729.9	-6.497

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

NUMBER 5-212-P | A202
SHEET 30 OF 90
DATE 4-22-68 BY Cockrell
CHECK DATE 4-22-68 BY Heller

5. Detailed Analysis:
4. Pressure & Thermal Interaction:
2. Deflections:

For Range Of Stress

Equivalent		$E\delta_{33T}$	$E\delta^{*}_{33T}$	$E\delta_{03T}$	$E\delta^{*}_{03T}$	$E\delta_{00T}$	$E\delta^{*}_{00T}$	$E\delta_{SAT}$	$E\delta^{*}_{SAT}$
a-e → f		1795.2	-1.944	1795.2	-4.451	1795.2	-4.451	1795.2	-16.691
1	3.5 min	1896.0	-1.942	1886.0	-4.446	1762.6	-4.453	1762.6	-16.698
2	11 min	1875.1	↓	1875.1	-4.447	1762.6	↓	1762.6	-16.698
3	155 min	1860.5	↓	1860.5	↓	1758.9	↓	1758.9	-16.699
4	10 sec	1878.7	↓	1878.7	↓	1758.9	↓	1758.9	-16.699
5	90 sec	1864.1	↓	1864.1	↓	1755.3	↓	1755.3	-16.700
12		0	0	0	0	0	0	0	0
13	N.U. 2.0 Mts.	980.9	-15.372	992.9	-3.424	854.3	-3.421	958.1	0
14	S.S.	1109.2	0	1109.2	0	1109.2	0	1109.2	0
15	C.O. 3.0 Mts.	215.6	15.119	215.6	3.353	241.0	3.356	237.4	0
11		1900.6	-1.941	1900.6	-4.446	1758.9	-4.453	1758.9	-16.699
10	12 sec	1878.7	-1.942	1878.7	-4.447	1755.3	↓	1755.3	-16.700
9	195 sec	1875.1	↓	1875.1	↓	1755.3	↓	1755.3	-16.700
7	12 sec	1882.4	↓	1882.4	↓	1758.9	↓	1758.9	-16.699
6	26 sec	1882.4	↓	1882.4	↓	1762.6	↓	1762.6	-16.698
8	144 sec	1864.1	↓	1864.1	↓	1762.6	↓	1762.6	-16.698
N		1660.9	-1.947	1660.9	-4.459	1660.9	-4.459	1660.9	-16.720

5- DETAILED ANALYSIS:

d. PRESSURE AND THERMAL INTERACTION:

2. DEFLECTIONS:

FOR PEAK STRESS

TRANSIENT		E^{*}	$E\delta^{*}_{11}$	$S\delta_{21}$	$E\delta^{*}_{21}$	$E\delta_{227}$	$E\delta^{*}_{127}$	$E\delta_{327}$	$E\delta^{*}_{327}$
HEATUP	4.00 HRS	1561.0	9.700	1126.3	10.986	1193.1	17.661	-235.0	252.957
	4.25	1660.1	9.722	1199.9	11.050	1257.2	17.767	-167.7	251.146
	4.35	1699.3	9.744	1229.0	11.114	1296.7	17.853	-145.0	255.483
	4.47	1745.1	9.766	1263.9	11.160	1321.9	17.929	-116.6	256.738
	5.00	1765.3	0.0	1293.1	10.719	1338.3	11.931	679.6	125.233
NO LOAD STEADY STATE		1765.3	0.0	1319.6	0.0	1319.6	0.0	1319.6	0.0
COOLDOWN	4.00 HRS	201.5	-9.623	189.1	-11.086	131.8	-17.759	1549.3	-253.382
	4.25	104.3	-9.637	117.6	-11.160	59.9	-17.965	1494.9	-254.727
	4.35	65.4	-9.657	99.2	-11.229	31.2	-17.966	1462.9	-256.045
	4.47	19.0	-9.676	55.2	-11.292	-5.1	-18.048	1435.4	-257.376
	5.00	0.0	0.0	26.5	-12.898	-18.9	-14.110	619.8	-126.552
FULL LOAD	10 MIN	1964.6	10.005	1383.9	-4.354	1392.2	3.556	956.6	82.352
	15	1924.5	13.597	1424.2	-4.078	1426.0	5.021	694.2	132.488
	20	1987.9	15.062	1469.3	-4.202	1472.1	6.131	494.2	177.184
	25	2007.6	7.474	1474.0	7.057	1511.9	11.936	385.1	183.681
	30	2011.3	4.788	1495.2	5.646	1513.9	3.772	568.9	170.322
FULL LOAD STEADY STATE		2017.7	0.0	1510.1	0.0	1510.1	0.0	1347.3	29.885
FULL LOADING	10 MIN	1919.4	-11.578	1439.9	7.376	1453.5	-0.554	1774.9	-50.184
	15	1860.2	-13.656	1405.9	3.923	1400.3	-5.265	1960.2	-100.397
	20	1798.0	-15.259	1361.6	3.854	1355.0	-5.739	2169.0	-146.626
	25	1776.3	-9.626	1350.1	-4.379	1320.9	-8.819	2166.1	-150.755
	30	1769.6	-4.012	1349.2	-11.060	1308.6	-13.674	2103.9	-141.316

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

NUMBER S-212-P | A204
SHEET 32 OF 80
DATE 4-22-69 BY Caldwell
CHECK DATE 4-22-69 BY Heller

5.0 Detailed Analysis:
4.1 Pressure And Thermal Interaction:
4.2 Deflections:

For Peak Stress

Transient		$E\delta_{1T}$	$F\delta_{1T}$	$E\delta_{2T}$	$E\delta'_{2T}$	$E\delta_{22T}$	$E\delta'_{22T}$	$E\delta_{32T}$	$E\delta'_{32T}$
1		1907.7	0.0	1426.3	0.0	1426.3	0.0	1263.5	29.883
2	3.5 min	2044.1		1530.6		1530.6		1367.7	29.985
	11 min	1983.8		1494.0		1494.0		1321.1	29.984
	15.5 min	1934.4		1446.5		1446.5		1283.6	29.983
3	10 sec	2014.0		1507.2		1507.2		1344.4	29.985
	90 sec	1942.0		1452.3		1452.3		1299.4	29.983
4		0.0		0.0		0.0		0.0	0.0
5	N.D. 3.0 hrs	1164.1	8.662	823.3	11.803	893.2	18.520	-556.4	256.842
	55 C.D. 3.0 hrs	1194.4	0.0	991.3	0	991.3	0.0	991.3	0.0
		19.2	-8.576	564	-17.482	-4.3	-24.200	1435.4	-287.304
6		2017.7	0.0	1510.1	0.0	1510.1	0.0	1347.3	29.995
7	12 sec	2017.7		1510.1		1510.1		1347.3	
	195 sec	2002.7		1498.5		1498.5		1335.6	
8	12 sec	2029.7		1519.9		1519.9		1356.0	
	26 sec	2036.5		1524.7		1524.7		1361.8	
	144 sec	1949.6		1458.0		1458.0		1295.2	29.894
n		1765.3		1319.6		1319.6		1156.7	29.879

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

NUMBER S-212-P | A205
SHEET 33 OF 91
DATE 4-27-79 BY DEKRELL
CHARGE NO.
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORTS
CHECK DATE 4-27-79 BY HEILFER

5. DETAILED ANALYSIS:
d. PRESSURE AND THERMAL INTERACTIONS:
2. DEFLECTIONS:

FOR PENN STRESS

TRANSIENT		$E\delta_{SAT}$	$E\delta^{*}_{SST}$	$E\delta_{SST}$	$E\delta^{*}_{SST}$	$E\delta_{SAT}$	$E\delta^{*}_{SAT}$	$E\delta_{SAT}$	$E\delta^{*}_{SAT}$
100% HEATUP	4.00 HRS	2196.1	239.727	1246.9	-12.979	1343.9	24.235	1741.3	-51.493
	4.25	2294.4	241.124	1249.4	-12.886	1440.8	24.608	1836.7	-51.744
	4.35	2336.5	242.541	1278.0	-12.933	1479.1	24.740	1874.0	-51.997
	4.67	2390.1	243.955	1423.0	-12.978	1524.8	24.873	1916.7	-53.180
	5.00	2025.6	138.057	1549.9	-6.144	1610.7	12.830	1601.7	-29.480
110% LOAD STEADY STATE		1660.9	0.0	1669.9	0.0	1660.9	0.0	1660.9	0.0
100% LOAD COOLDOWN	4.00 HRS	-542.3	-238.140	401.4	12.887	303.4	-24.295	306.2	51.516
	4.25	-642.4	-241.598	311.5	12.780	210.2	-24.673	214.6	51.772
	4.35	-683.2	-243.035	275.3	12.822	173.3	-24.811	177.8	53.026
	4.67	-781.2	-244.478	231.9	12.862	129.2	-24.949	137.4	53.180
	5.00	-967.1	-138.246	108.7	6.048	47.3	-12.923	57.4	29.480
75% LOAD	10 MIN	1799.1	92.455	1686.3	-4.705	1705.1	7.018	1668.1	-1.900
	15	2141.5	147.811	1707.3	-7.774	1734.1	10.783	1673.1	-3.015
	20	2380.2	197.199	1730.0	-9.921	1775.2	15.191	1678.6	-5.121
	25	2425.0	203.117	1744.9	-9.789	1803.2	16.527	1684.8	-5.657
	30	2392.1	187.608	1750.5	-8.150	1827.8	17.201	1694.7	-6.378
FULL LOAD STEADY STATE		1819.6	30.826	1824.3	0.771	1922.6	9.575	1725.5	1.062
PLANT VARIATIONS	4.00 HRS	1670.0	-57.123	1804.2	4.697	1877.1	1.913	1718.3	9.473
	4.25	1463.4	-112.669	1782.4	7.916	1844.5	-1.916	1713.3	10.223
	4.35	1371.5	-165.549	1758.0	10.284	1809.6	-5.898	1704.3	12.067
	4.67	1236.9	-166.897	1752.1	8.965	1771.4	-5.880	1697.9	13.491
	5.00	1253.4	-156.067	1734.3	9.005	1756.0	-7.656	1692.6	13.540

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

NUMBER S-212-P | A 206
SHEET 34 OF 84
DATE 4-22-69 BY CARPENTER
CHECK DATE 4-22-69 BY HENLEE

5. DETAILED ANALYSIS:
d. PRESSURE AND THERMAL INTERACTION:
2. DEFLECTIONS:

FOR PEAK STRESS

TRANSIENT		$E\delta_{137}$	$E\delta^{*}_{137}$	$E\delta_{437}$	$E\delta^{*}_{437}$	$E\delta_{447}$	$E\delta^{*}_{447}$	$E\delta_{547}$	$E\delta^{*}_{547}$
e → f		1905.1	32.805	1740.8	0.767	1871.8	9.572	1761.8	1.070
g	3.5 min	1995.9	32.806	1831.6	0.772	1839.2	9.571	1729.2	1.063
	11 min	1984.9	↓	1820.7	0.771	1839.2	9.571	1729.2	1.063
	155 min	1970.4		1806.1	↓	1835.6	9.571	1725.5	1.062
h	10 sec	1988.6		1824.3		1835.6	9.570	1725.5	1.062
	90 sec	1974.0	↓	1809.7	↓	1832.0	9.570	1721.9	1.061
i		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
j	N.D. 30 HRS	1027.7	244.159	964.6	-12.933	966.1	24.884	953.1	-53.180
	S.S. CD 30 HRS	1109.2	0.0	1109.2	0.0	1109.2	0.0	1109.2	0.0
		-731.2	-314.650	231.9	12.862	129.2	-24.949	137.4	53.180
k		2010.5	32.806	1846.2	0.772	1835.6	9.570	1725.5	1.062
l	12 sec	1988.6	↓	1824.3	0.771	1832.0	↓	1721.9	1.061
	18.5 sec	1984.9		1813.4	0.771	1832.0		1721.9	1.061
m	12 sec	1992.2		1828.0	0.772	1835.6	↓	1725.5	1.062
	26 sec	1992.2		1828.0	0.772	1839.2	9.571	1729.2	1.063
	144 sec	1974.0	↓	1809.7	0.771	1839.2	9.571	1729.2	1.063
n		1770.7	32.805	1606.5	0.759	1737.5	9.565	1627.2	1.041

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

NUMBER 5-518-D | A207
SHEET 35 OF 84
DATE 5-2-79 BY STEELE
CHECK DATE 5-21-79 BY HEALEY

5. DETAILED ANALYSIS:

J. PRESSURE AND THERMAL INTERACTION:

3. CONTINUITY MATRIX AND LOADING VECTORS

WRITING THE COMPATIBILITY EQUATIONS IN MATRIX FORM

$$\begin{bmatrix} -149.1916 & -32.2032 & -53.2445 & 39.1819 & 0 & 0 & 0 & 0 \\ 32.2032 & 24.1750 & 39.1819 & -19.0519 & 0 & 0 & 0 & 0 \\ -53.2445 & -39.1819 & -142.0836 & 34.2037 & -15.7490 & 6.9346 & 0 & 0 \\ -39.1819 & -19.0519 & -34.2083 & 22.7039 & 4.4781 & -1.3550 & 0 & 0 \\ 0 & 0 & -12.5173 & -3.5624 & -32.7443 & 5.5240 & -4.4438 & 2.9506 \\ 0 & 0 & -5.5112 & -1.0776 & -3.5230 & 1.6742 & 2.9506 & -0.1142 \\ 0 & 0 & 0 & 0 & -4.9488 & -0.9506 & -14.4505 & 6.2470 \\ 0 & 0 & 0 & 0 & -0.9506 & -0.1142 & -6.2470 & 3.2582 \end{bmatrix} \begin{bmatrix} H_1 \\ M_1 \\ H_2 \\ M_2 \\ H_3 \\ M_3 \\ H_4 \\ M_4 \end{bmatrix} =$$

RANGE OF STRESS

	HEATUP					NO LOAD STEADY STATE	COOLDOWN	
PRESSURE	T=4.03 MIN	T=4.25	T=435	T=447	T=500		T=4.00 MIN	T=4.25
13.30005	-391.7	-416.2	-426.0	-427.8	-445.7	-445.7	-56.3	-30.8
3.40559	-6.838	-6.956	-6.835	-6.832	-2.179	0	3.631	2.682
141.49742	0	0	0	0	0	0	0	0
-46.49742	-12.667	-12.667	-12.665	-12.661	-5.290	0	12.240	12.195
109.67643	0	0	0	0	0	0	0	0
37.06395	12.092	12.099	12.104	12.107	4.984	0	-11.761	-11.730
243.44144	7.6	7.6	7.5	3.8	0	0	-7.3	-7.3
-49.08540	4.396	4.395	4.397	3.469	2.481	0	-4.277	-4.266

RANGE OF STRESS

COOLDOWN			PLANT LOADING					FULL LOAD STEADY STATE
T=435	T=447	T=500	T=10 MIN	T=15	T=20	T=25	T=30	
-20.5	-8.2	0	-466.1	-480.4	-495.2	-503.2	-505.0	-507.6
6.633	6.621	0	-2.610	-5.943	-7.096	-6.081	-4.051	0
0	0	0	0	0	0	0	0	0
1.173	2.142	7.140	-4.860	-7.044	-9.902	-9.923	-9.898	-1.941
0	0	0	0	0	0	0	0	0
-1.717	-1.701	4.792	4.369	6.786	8.982	9.035	7.886	-2.505
-3.8	-3.16	0	-14.6	-29.3	-42.6	-54.5	-59.1	-9.70
-4.261	-3.356	-2.317	0.494	0.620	-0.001	-0.822	-1.424	-12.257

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

NUMBER 5-212-P | A 208
SHEET 36 OF 80
DATE 4-22-68 BY LOCKRELL
CHECK DATE 4-22-68 BY HEILPER

5. DETAILED ANALYSIS:
d. PRESSURE AND THERMAL INTERACTION:
3. CONTINUITY MATRIX AND LOADING VECTORS:

RANGE OF STRESS

PLANT UNLOADING					e	f	g		
T=10min	T=15	T=20	T=25	T=30			T=3.5min	T=11	T=15.5
-488.8	-474.7	-459.3	-459.6	-447.6	-491.4	-513.5	-449.7	-497.9	
2.912	5.945	7.982	7.405	2.612	0	0	0	0	
0	0	0	0	0	0	0	0	0	
5.237	5.427	7.621	7.548	3.426	-1.944	-1.941	-1.942	-1.943	
0	0	0	0	0	0	0	0	0	
-7.693	-9.606	-13.519	-12.679	-10.393	-2.507	-2.505	-2.505	2505	
-72.5	-61.6	-47.1	-36.2	-29.0	0	0	0	0	
-5.756	-6.746	-5.819	-4.456	-4.519	-12.240	-12.245	-12.245	-12.246	

RANGE OF STRESS

h		i	j			k	l		
T=15sec	T=90		T=2.115	S.S.	T=2.085		T=12sec	T=18.5	
-506.7	-499.8	0	-295.3	-309.0	-9.2	-507.6	-507.6	-504.1	
0	0	0	-6.811	0	6.620	0	0	0	
0	0	0	0	0	0	0	0	0	
-1.942	-1.943	0	-12576	0	12.206	-1.941	-1.941	-1.942	
0	0	0	0	0	0	0	0	0	
-2.505	-2.505	0	11.948	0	-11.765	-2.504	-2505	-2.505	
0	0	0	0	0	0	0	0	0	
-12.246	-12.246	0	3.421	0	-3.356	-12.246	-12.246	-12.246	

RANGE OF STRESS				PEAK STRESS INTENSITY				
m			n					
T=12sec	T=26	T=144		T=0.05	T=4.25	T=6.85	T=9.47	T=26.00
-510.1	-511.8	-491.6	-445.7	-435.6	-460.2	-470.3	-472.2	-472.2
0	0	0	0	2.287	2.328	2.370	2.394	10.719
0	0	0	0	-1418.1	-1424.9	-1431.7	-1438.5	-708.7
-1.941	-1.941	-1.949	-1.947	236.196	236.309	237.559	238.909	118.302
0	0	0	0	-949.2	-953.9	-958.5	-963.1	-475.8
-2.505	-2.505	-2.505	-2512	-292.707	-294.009	-295.474	-296.933	-144.201
0	0	0	0	-2.6	-4.1	-4.2	-8.0	-10.1
-12.246	-12.245	-12.245	-12.261	-75.728	-76.353	-76.738	-77.053	-41.310

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

NUMBER S-21C-P | A209
SHEET 37 OF 90
CHARGE NO.
DATE 4-22-68 BY COLWELL
DESCRIPTION STRUCTURAL AND FATIGUE EVALUATION OF OUTLET NOZZLE - VESSEL SUPPORT
CHECK DATE 4-22-68 BY WELKER

5. DETAILED ANALYSIS:

d. PRESSURE AND THERMAL INTERACTION:

3. CONTINUITY MATRIX AND LOADING VECTORS:

PEAK STRESS

NO LOAD STEADY STATE	COOLDOWN T=4.00 HRS	T=4.25	T=4.35	T=4.47	T=5.00	PLANT LOADING T=10 HRS	T=15	T=20
-445.7	-12.4	12.3	23.7	36.2	26.5	-493.8	-500.4	-517.7
0.0	-2.495	-2.529	-2.573	-2.606	-12.791	-14.359	-17.665	-19.263
	1419.1	1424.9	1431.7	1438.5	708.7	-455.6	-731.9	-977.9
	-235.627	-236.862	-238.079	-239.329	-111.442	78.796	127.467	171.053
	949.2	953.9	959.5	962.1	475.3	-308.8	-495.2	-652.3
	293.07	294.378	295.856	297.340	144.393	-97.160	-155.585	-207.120
	2.9	4.4	4.5	9.2	10.1	-37.1	-61.0	-96.6
	75.812	76.445	76.837	78.129	41.403	-8.918	-12.798	-20.312

PEAK STRESS

PLANT LOADING F=25	F=30	FULL LOAD STEADY STATE	PLANT UNLOADING T=0 HRS	T=15	T=20	T=25	T=30	e → f
-533.6	-526.6	-507.6	-479.5	-454.3	-436.4	-426.2	-470.4	-481.4
-0.417	0.857	0.0	18.954	17.579	19.113	4.248	-7.049	0.0
-1026.8	-945.1	-162.9	276.4	559.9	814.0	945.2	795.4	-162.9
171.745	161.250	29.885	-49.630	-95.132	-140.888	-141.936	-127.642	29.883
-680.1	-641.5	-164.3	134.2	319.1	486.5	515.2	480.9	-164.3
-212.907	-195.758	-32.035	61.820	120.584	173.833	175.863	165.073	-32.037
-118.4	-133.1	-197.1	-158.8	-131.3	-105.3	-73.5	-65.3	-110.1
-22.184	-23.979	-9.513	7.560	12.209	17.965	22.372	20.996	-9.503

PEAK STRESS

g T=35 MIN	T=11	T=15	h T=0 SEC	T=90	i	j T=0 HRS	S.S.	T=20 HRS
-513.5	-499.7	-487.9	-506.7	-499.8	0.0	-349.7	-303.0	37.1
0.0	0.0	0.0	0.0	0.0		3.141	0.0	-8.906
-162.9	-162.9	-162.9	-162.9	-162.9		-1439.7		1439.7
29.885	29.884	29.883	29.885	29.883		238.322		-263.109
-164.3	-164.3	-164.3	-164.3	-164.3		-963.1		963.1
-32.035	-32.035	-32.035	-32.035	-32.035		-297.092		327.512
-110.1	-110.1	-110.1	-110.1	-110.1		-8.0		8.2
-9.508	-9.508	-9.509	-9.509	-9.509		-78.064		78.129