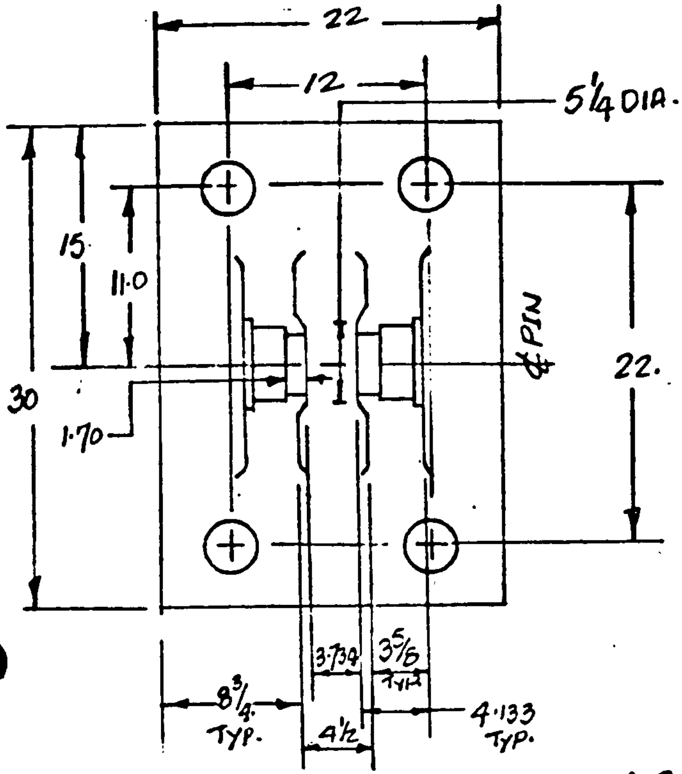
SEISMIC MARGIN EVALUATION

FOR TYPICAL RCS COMPONENTS

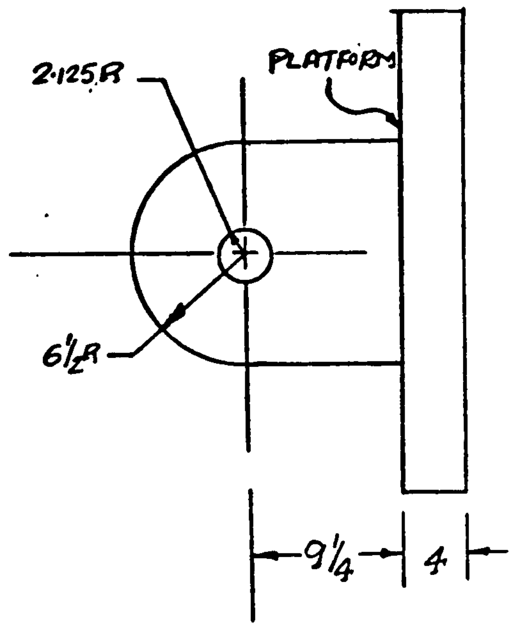
SCE - UNIT #2 AND #3 :-

SEISMIC MARGIN EVAULATION - PUMP SUPORTS :-

VERTICAL COLUMN CLEVIS :-



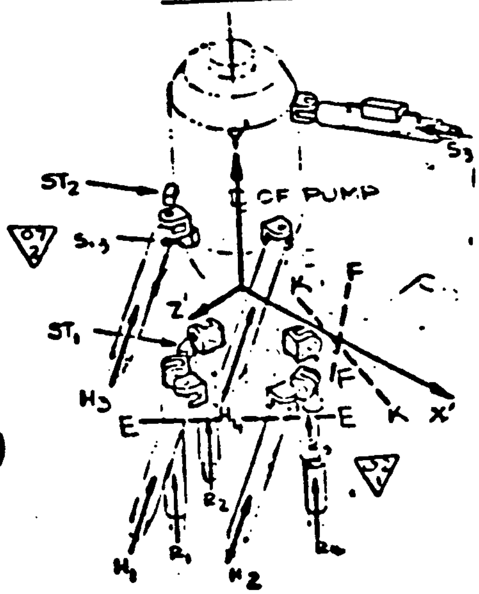
MATERIAL - SA481 GR < CAGNM / CENPS.



-: GEOMETRY OF CLEVIS :-

LOADS :- (REF: R.C.S.S. DESIGN LOADS - CE DWG: E-1370-320-001 REV 3 SHEET 2)
THE DESIGN LOADS TABULATED BELOW ARE THE MAXIMUM AXIAL FORCES ON THE COLUMNS.

PUMP Nº 1A



COLUMN	FORCES IN KIPS			
	*NORMAL & UPSET CONDITION		FAULTED CONDITION	
	TENSION	COMPRESSION	TENSION	COMPRESSION
R_i	356	412	1431	1363

* NORMAL OPERATING LOAD = -146 KIPS.

SCE - UNIT #2 AND #3 :
SEISMIC MARGIN EVALUATION - PUMP SUPPORTS:

VERTICAL COLUMN CLEVIS - DETAILED ANALYSIS:

CLEVIS MATERIAL : SA 487 GR CENPS OR CA6NM

NORMAL OPERATING TEMPERATURE : 130°F
(REF: (R.C.P. SUPPORT COLS. SPEC. FOR SANONFORE UNIT #2 AND #3 - SPEC. NO. 1270-PE-513 REV. 1)

MATERIAL PROPERTIES :
(REF: ASME SECT. III, 1974 ED, INCLUDING WINTER 1974 ADDENDA

S_m = 36.7 KSI

S_y = 80.0 KSI

S_u = 110.0 KSI

STRESS ALLOWABLES FOR FAULTED CONDITION :
(REF: ASME SECT. III, SECT. F1323.1 OF SUBSECT. NA) (1974 ED.)

PRIMARY MEMBRANE STRESS INTENSITY = $0.7 S_u$ = 77.0 KSI

PRIMARY MEMBRANE PLUS PRIMARY BENDING STRESS INTENSITY = $1.5 (0.7 S_u)$ = 115.5 KSI

PURE SHEAR STRESS = $0.6 (0.7 S_u)$ = 46.2 KSI.

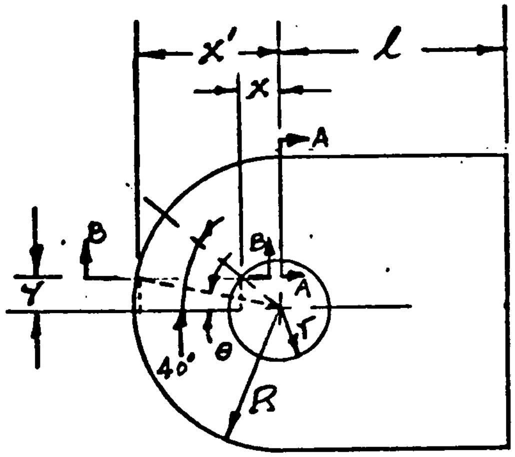
POWER SYSTEMS
COMBUSTION ENGINEERING INC

Calculation Number	Rev.

SCE - UNIT #2 AND #3:
SEISMIC MARGIN EVALUATION - PUMP SUPPORTS:

VERTICAL COLUMN CLEVIS - DETAILED ANALYSIS - CONT'D:

r = 2.125"
R = 6.5"
THICKNESS = 3.625"
ℓ = 9.25"
LOAD = 1431 K (TENSION)
(REF: PG. 1)



TENSION - NET SECTION A-A

AVERAGE SHEAR - SECTION B-B.

$$AREA = (6.5'' - 2.125'')(3.625'') = 15.86\ IN^2.$$

$$LOAD\ (N.O.P + SSE + LOCA) = \frac{1431}{2} K = 715.5\ K/SIDE$$

$$\sigma_A = P/A = \frac{715.5}{2(15.86)} = 22.6\ KSI < 77.0\ KSI$$
O.K.

LENGTH B-B = x' - x

$$\cos 40° = \frac{x}{r} = \frac{x}{2.125};\quad x = 1.63''$$

$$\sin 40° = \frac{y}{r} = \frac{y}{2.125};\quad y = 1.37''$$

$$\sin\theta = \frac{1.37}{6.5};\quad \theta = 12.17°$$

$$\cos 12.17° = \frac{x'}{R} = \frac{x'}{6.5};\quad x' = 6.35''$$

$$LENGTH\ B\text{-}B = 6.35'' - 1.63'' = 4.72''$$

$$AREA = 4.72(3.625) = 17.1\ IN^2$$

$$\tau_B = P/A = \frac{715.5}{2(17.1)} = 20.9\ KSI < 46\ KSI$$
OK.

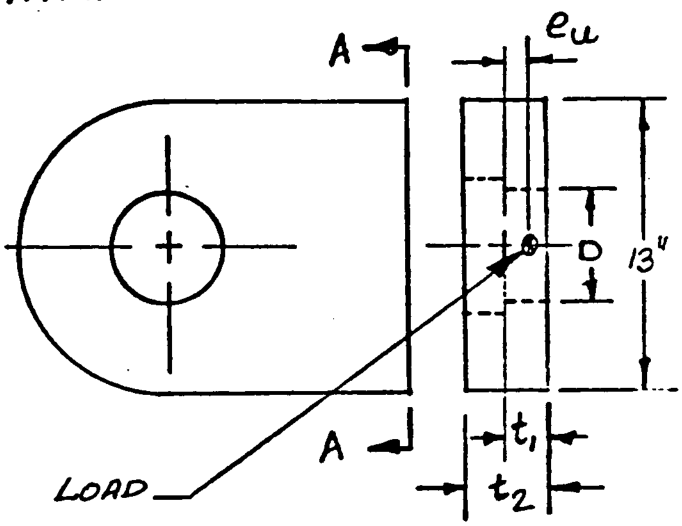
Enclosure (1) to S-PSE-400

SCE-UNIT #2 AND #3:

SEISMIC MARGIN EVALUATION – PUMP SUPPORTS:

VERTICAL COLUMN CLEVIS – DETAILED ANALYSIS – CONT'D:

σ_U = UNSYMMETRICAL STRESS @ SECT. A-A



AREA @ A-A = $3.625(13) = 47.125\ IN^2$

I_{A-A} = M.O.I @ A-A

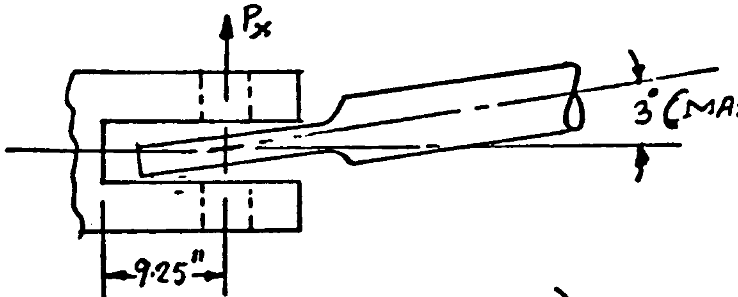
$$= \frac{13(3.625)^2}{12} = 51.6\ IN^4$$

$$\sigma_u = P/A + \frac{P e_u\, t_2/2}{I_{AA}}$$

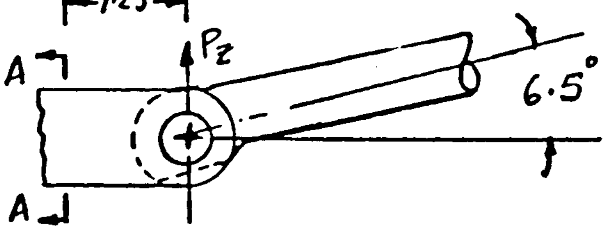
$$e_u = \frac{3.625}{2} - \frac{1.7}{2} = 0.9625''$$

$$\sigma_u = \frac{1431}{2(47.125)} + \frac{1431(3.625/2)(.963)}{2(51.6)} = 39.4\ KSI$$

COLUMN MISALIGNMENT STRESS CALCULATION:



3° (MAX. DESIGN CAPABILITY)



6.5° (REF: SCE #2 RC PUMP TOLERANCE STUDY CAL. NO. S-PEC-159

SCE – UNIT #2 AND #3:–

SEISMIC MARGIN EVALUATION – PUMP SUPPORTS:–

VERTICAL COLUMN CLEVIS – DETAILED ANALYSIS – CONT'D:–

P_x = LOAD IN X-DIRECTION = 1431 (sin 3°) = 75 KIPS.

P_z = LOAD IN Z-DIRECTION = 1431 (sin 6.5°) = 162 KIPS.

$M_z = 162\,(9.25) = 1498.5$ K-IN.

$M_x = 75\,(9.25) = 693.8$ K-IN.

$I_x = 13\,(3.625)^3/12 = 51.6$ IN⁴.

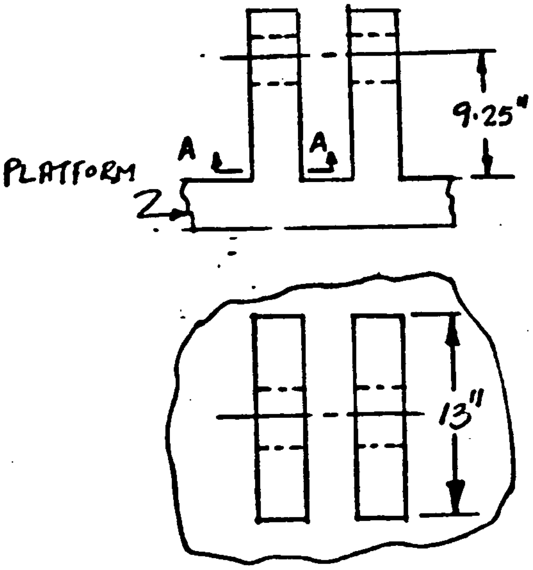
$I_z = 3.625\,(13)^3/12 = 663.7$ IN⁴.

σ_1 = BENDING STRESS DUE TO P_x @ A-A

σ_2 = BENDING STRESS DUE TO P_z @ A-A

$$\sigma_1 = \frac{M_x C}{I_x} = \frac{693.8\,(1.81)}{51.6} = 24.4 \text{ KSI.}$$

$$\sigma_2 = \frac{M_z C}{I_z} = \frac{1498.5\,(6.5)}{2\,(663.7)} = 7.4 \text{ KSI}$$



COMBINING ALL THE STRESSES @ SECT-A:

$\sigma_U = 39.4$ KSI { 15.2 KSI AXIAL; 24.2 KSI BENDING

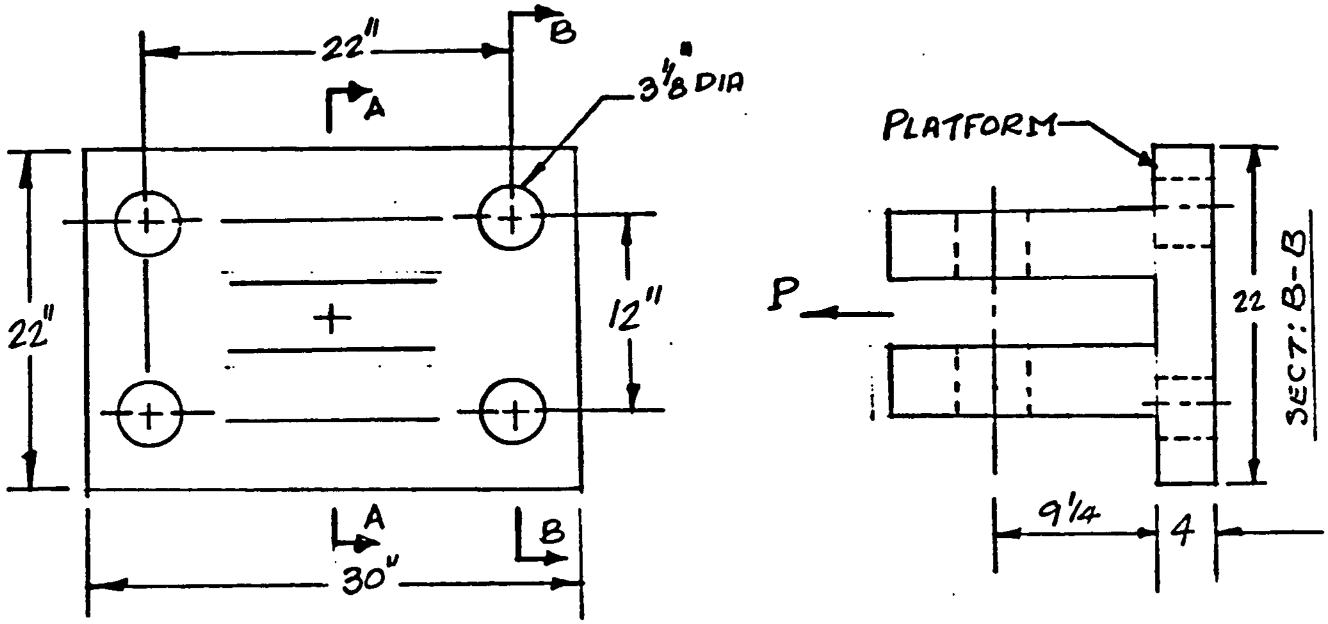
$\sigma_{A-A} = 39.4 + 24.4 + 7.4$

$= 71.2 \text{ KSI} < 115.5 \text{ KSI}$ (OK)

SCE - UNIT # 2 AND # 3:
SEISMIC MARGIN EVALUATION - PUMP SUPPORTS:

VERTICAL COLUMN CLEVIS - DETAILED ANALYSIS - CONT'D:

PLATFORM ANALYSIS:



ASSUME FIXED-FIXED ABOUT ℄ OF BOLTS.
THIS FIXED BOUNDARY CONDITION FOR A BEAM IS A CONSERVATIVE APPROACH BECAUSE IT DOES NOT CONSIDER THE STIFFNESS OF THE LUGS AND CLOSELY REPRESENTS THE ACTUAL RESTRAINED CONDITIONS.

$$I_{BB} = \frac{bh^3}{12} = \frac{[22-2(3.125)]4^3}{12} = 84 \text{ IN}^4$$

$$M = PL/8 = \frac{1431(22)}{8} = 3935.3 \text{ K-IN.}$$

$\sigma_{AA} < \sigma_{BB}$ SINCE $I_{AA} > I_{BB}$

σ_{B-B} = BENDING STRESS AT FAULTED CONDITION

$$\sigma_{B-B} = \frac{3935.3(2)}{84} = 93.7 \text{ KSI} < 115.5 \text{ KSI}$$

SCE - UNIT #2 AND #3:

SEISMIC MARGIN EVAULUATION — PUMP SUPPORTS:

VERTICAL COLUMN CLEVIS - FAULTED LOAD CAPACITY EVAULATION:

FROM THE RESULTS OF VERTICAL COL. CLEVIS ANALYSIS IT IS SEEN THAT THE CLEVIS DESIGN IS CONTROLLED BY THE BENDING STRESS OF CLEVIS PLATFORM @ SECT. B-B DUE TO THE TENSILE LOAD P (1431 K) (REF. PG. 6). HENCE PLATFORM BENDING STRESS EQUATION IS USED TO FIND THE FAULTED CAPACITY OF VERTICAL COLUMN CLEVIS, AS FOLLOWS.

$$\text{FAULTED CAPACITY} = F_{CAP.} = \frac{115.5(8)(84)}{44}$$

$$\boxed{F_{CAP.} = 1765.\ \text{KIPS}}$$

THE N.O.P. LOAD = 146 KIPS (REF. PG. 1)

$$\therefore \text{ALLOWABLE SSE LOAD} = F_{CAP} - N.O.P$$

$$= 1765 - 146$$

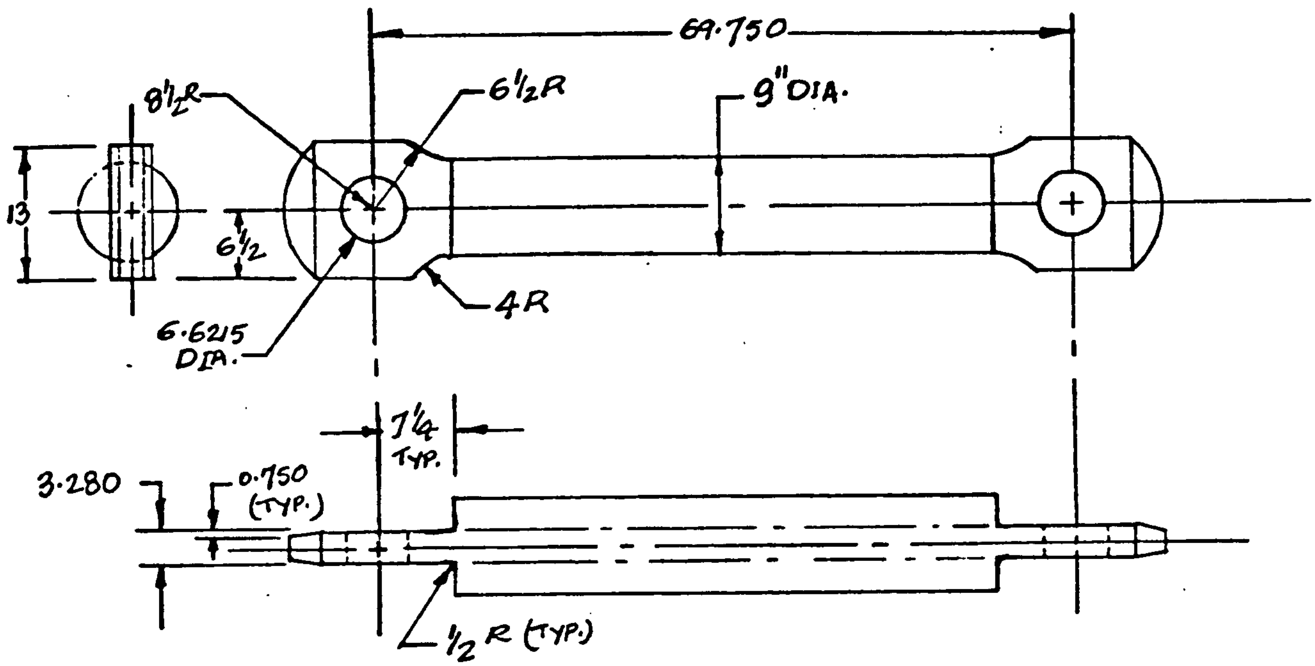
$$\boxed{\text{ALLOWABLE SSE LOAD} = 1619\ \text{KIPS}}$$

SCE - UNIT # 2 AND # 3:

SEISMIC MARGIN EVALUATION - PUMP SUPPORTS:

VERTICAL COLUMN:

(REF: CE DRAWING. D-1370-320-056 REV.5)



GEOMETRY OF VERTICAL COLUMN:

LOADS: (REF: FIG. 1, VERTICAL COL. CLEVIS CAL.)

COLUMN	FORCES IN KIPS			
	*NORMAL AND UPSET CONDITION		FAULTED CONDITION	
	TENSION	COMPRESSION	TENSION	COMPRESSION
R_i	356	412	1431	1363

* NORMAL OPERATING LOAD = -146 KIPS.

SCE - UNIT # 2 AND # 3 :-

SEISMIC MARGIN EVAULATION - PUMP SUPPORTS :-

VERTICAL COLUMN - DETAILED ANALYSIS :-

COLUMN MATERIAL : SA 540 CL 4 GR B 23 OR B 24 -

NORMAL OPERATING TEMPERATURE : 130°F.
(REF: R.C.P. SUPPORT COLS FOR SAN ONFORE UNITS 2 AND 3 SPEC. NO. 1370-PE-513 REV. 01)

MATERIAL PROPERTIES :-
(REF: ASME SECT. III, 1974 ED, INCLUDING WINTER 1974 ADDENDA)

$S_m = 39.0$ KSI

$S_y = 120.0$ KSI

$S_u = 135.0$ KSI

STRESS ALLOWABLES FOR FAULTED CONDITION :-
(REF: ASME SECT. III, 1974, SECT. F.1323.1 OF SUBSECT. NA)

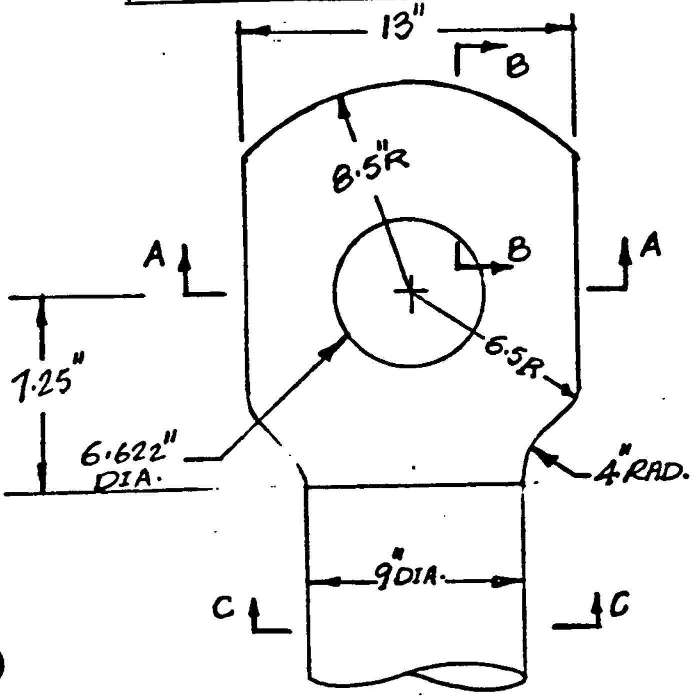
PRIMARY MEMBRANE STRESS INTENSITY $= 0.7 S_u = 94.5$ KSI

PRIMARY MEMBRANE PLUS PRIMARY BENDING STRESS INTENSITY $= 1.5(0.7 S_u) = 141.8$ KSI

PURE SHEAR STRESS $= 0.6(.7 S_u) = 56.7$ KSI

SCE - UNIT #2 AND #3 :-
SEISMIC MARGIN EVALUATION - PUMP SUPPORTS :-

VERTICAL COLUMN - DETAILED ANALYSIS :-



TENSILE STRESS @ SECT. A-A :-

$$\sigma_{A-A} = \frac{P}{A} = \frac{1431}{(13-6.622)3.25}$$

$\sigma_{A-A} = 68.4$ KSI < 94.5 KSI $\therefore$ OK

SHEAR STRESS @ SECT. B-B :-

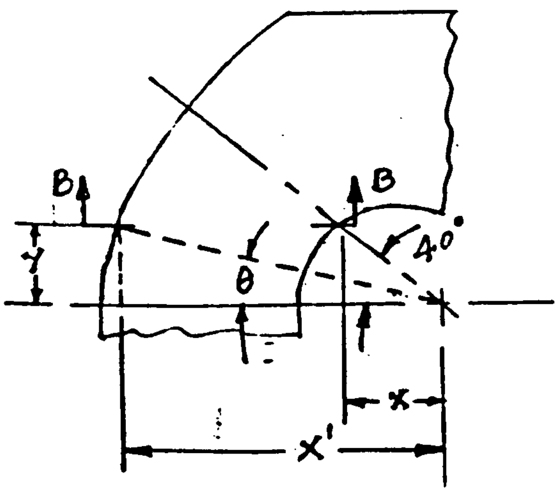
$\cos 40° = x/r = x/3.311$; $x = 2.537"$

$\sin 40° = y/r = y/3.311$; $y = 2.13"$

$\sin\theta = \frac{2.13}{8.5} = 0.25"$; $\theta = 14.5°$

$\cos 14.5° = \frac{x'}{R} = x'/8.5$; $x' = 8.23"$

LENGTH B-B $= x' - x = 8.23 - 2.13$
$= 6.1"$.



$$\tau_{B-B} = \frac{P}{A} = \frac{1431}{(6.1)(3.25)2 - 2(3/4)3}$$

$\tau_{B-B} = 40.3$ KSI < 56.7 KSI
$\therefore$ OK.

SCE - UNIT #2 AND #3:-
SEISMIC EVALUATION - PUMP SUPPORTS:-

VERTICAL COLUMN - DETAILED ANALYSIS - CONT'D:-

BUCKLING ANALYSIS OF VERTICAL COLUMN UNDER AXIAL LOAD: (REF: ASME SECT. III 1974 ED, APP. XVII)

AXIAL LOAD = 1363 KIPS.

ALLOWABLE AXIAL STRESS: $F_a = \dfrac{\left[1-\left(\frac{Kl}{r}\right)^2 / 2C_c^2\right] S_y}{5/3 + 3/8 \frac{Kl/r}{C_c} - \frac{(Kl/r)^3}{C_c^3}}$

$l = 69.75"$; $I_{xx} = I_{zz} = \pi 9^4/64 = 322.06\ IN^4$.

$A = \pi 9^2/4 = 63.62\ IN^2$, $r = 2.25"$; $\frac{Kl}{r} = \frac{69.75}{2.25} = 31.0$

$C_c = \sqrt{\frac{2\pi^2 E}{S_y}} = \sqrt{\frac{2\pi^2 \times 30\times 10^3}{100}} = 76.95 < \frac{Kl}{r}$

FOR FAULTED LOAD CASE F_a SHALL BE EQUAL TO OR LESS THAN 2/3 BUCKLING STRESS (REF: ASME SECT. III, APP. F-...

BUCKLING STRESS $= \left[1-\left(\frac{Kl}{r}\right)/2C_c^2\right] S_y$

$= \left[1-\left(\frac{31}{76.95}\right)^2/2\right] 100 = 91.89\ KSI$

$\therefore F_a = 2/3\ (91.89) = 61.56\ KSI$

AXIAL STRESS $f_a = \frac{1363}{63.62} = 21.42\ KSI < 61.56\ KSI$ (OK)

SCE - UNIT # 2 AND # 3 :-

SEISMIC MARGIN EVAULATION - PUMP SUPPORTS:-

VERTICAL COLUMN - FAULTED LOAD CAPACITY EVAULATION:-

FROM THE RESULTS OF VERTICAL COL. ANALYSIS IT IS SEEN THAT THE COLUMN DESIGN IS CONTROLLED BY THE TENSILE STRESS @ SECT: A-A AND SHEAR STRESS @ SECT. B-B DUE TO TENSILE LOAD P (1431K) (REF: PG. 10).
HENCE THE FAULTED LOAD CAPACITY OF VERTICAL COLUMN IS DETERMINED USING EITHER EQ. FOR TENSILE STRESS @ SECT. A-A OR SHEAR STRESS @ SECT. B-B, WHICHEVER GIVES THE LEAST FAULTED LOAD CAPACITY OF COLUMN.

FAULTED LOAD CAPACITY USING SHEAR STRESS EQUATION:-

FAULTED CAPACITY = $F_{CAP.} = 56.7\,[(6.1)3.28(2) - 2(.75)(3)]$ (REF: PG. 10)

$F_{CAP.} = 2014.$ KIPS.

FAULTED LOAD CAPACITY USING TENSILE STRESS EQUATION:-

FAULTED CAPACITY = $F_{CAP.} = 94.5\,[(13 - 6.622)3.28]$

= 1977. KIPS.

∴ FAULTED LOAD CAPACITY = 1977. KIPS

ALLOWABLE SSE LOAD } = $F_{CAP.}$ − N.O.P.

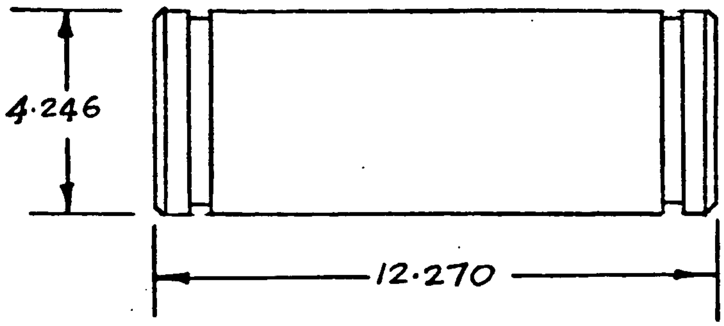
= 1977 − 146 = 1831K

ALLOWABLE SSE LOAD = 1831. KIPS.

SCE - UNIT #2 AND #3:-
SEISMIC MARGIN EVAULATION - PUMP SUPPORTS:-

VERTICAL COLUMN PIN:-

(REF: DWG: D-1370-320-053)



GEOMETRY OF PIN

LOADS:- (REF: PG. 1)

COLUMN	FORCES IN KIPS			
	*NORMAL AND UPSET CONDITION		FAULTED CONDITION	
	TENSION	COMPRESSION	TENSION	COMPRESSION
R_i	356	412	1431	1363

* NORMAL OPERATING LOAD = -146 KIPS

SCE - UNIT #2 AND #3:-
SEISMIC MARGIN EVAULATION - PUMP SUPPORTS:-

VERTICAL COLUMN PIN - DETAILED ANALYSIS:-

PIN MATERIAL:- SA540 CL1.

NORMAL OPERATING TEMPERATURE: 130°F.
(REF: R.C.P. SUPPORT COLS. SAN ONFORE UNITS 2 AND 3, SPEC. #1370-PE-513 REV.01)
MATERIAL PROPERTIES:
(REF: ASME SECT. III 1974, EDITION INCLUDING WINTER 1974 ADDENDA

$S_m = 39.0$ KSI

$S_y = 120.0$ KSI

$S_u = 135.0$ KSI

STRESS ALLOWABLES FOR FAULTED CONDITION:-
(REF: ASME SECT III 1974, SECT. F.1323.1, OF SUBSECT. NA)

PRIMARY MEMBRANE STRESS INTENSITY $= 0.7 S_u = 115.5$ KSI.

PRIMARY MEMBRANE PLUS PRIMARY BENDING STRESS INTENSITY $= 1.5(.7S_u) = 173.3$ KSI

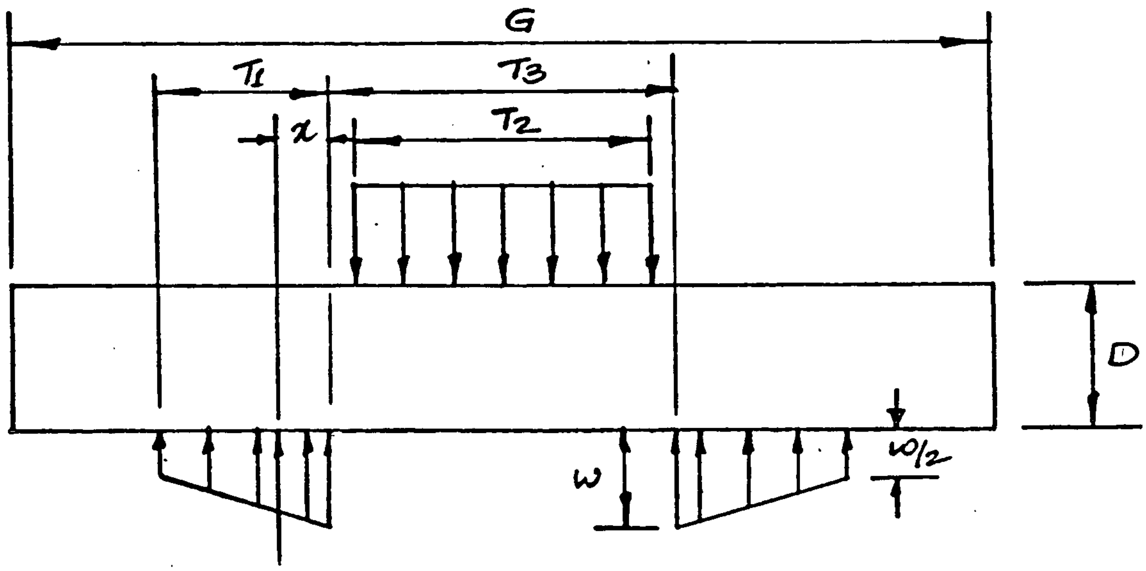
PURE SHEAR STRESS $= (0.7 S_u) 0.6 = 0.42 S_u = 69.3$ KSI

SCE - UNIT #2 AND #3:-
SEISMIC MARGIN EVALUATION - PUMP SUPPORTS:-

VERTICAL COLUMN PIN - DETAILED ANALYSIS - CONT'D:-

PIN STRESSES:-

THE PIN STRESSES ARE CALCULATED FROM PIN GEOMETRY AND LINE LOADING DISTRIBUTION SHOWN BELOW.

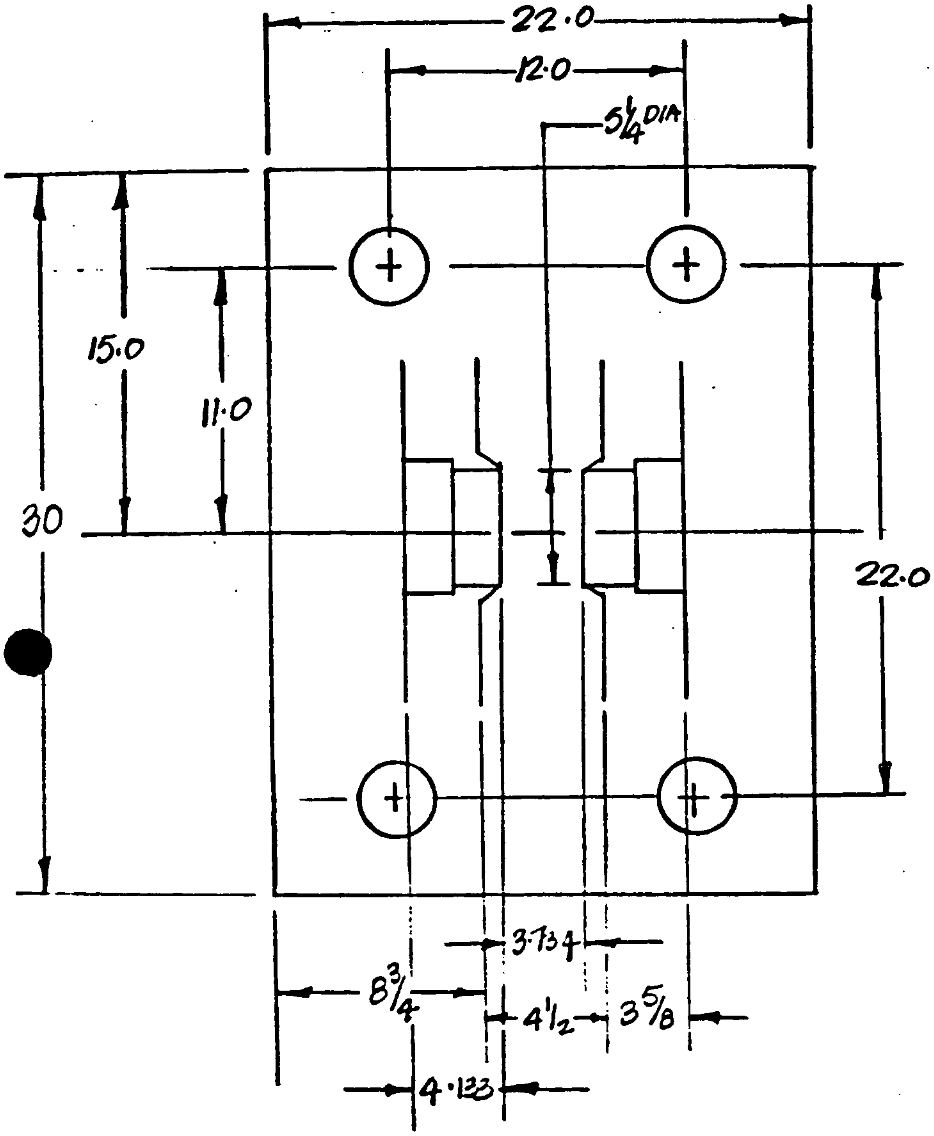


THIS BEARING STRESS DISTRIBUTION ON CLEVIS LUG/PIN CONTACT AREA IS BASED ON FINITE ELEMENT ANALYSIS PERFORMED ON CLEVIS LUG/PIN INTERFACE.

SCE-UNIT #2 AND #3:

SEISMIC MARGIN EVAULATION- PUMP SUPPORTS:

VERTICAL COLUMN PIN- DETAILED ANALYSIS-CONT'D:



THE FOLLOWING ARE THE VALUES FOR VERTICAL COL. PIN.

$T_1 = 1.7''$, $T_2 = 3.716''$

$T_3 = 3.734''$, $G = 12.270''$

$D = 4.246''$, $A = \frac{\pi D^2}{4} = 14.1$

$x = 4/9(1.7) = 0.756''$

SECTION MODULUS

$S = \pi D^3/32 = 7.515\ IN^3$

MAX. FORCE ON PIN CONNECTION = 1431 KIPS

MAX. BENDING STRESS IN PIN IN INCH-KIPS:

$$= \left[\frac{1431}{2}\left[0.756 + \frac{3.734}{2}\right] - \left(\frac{1431}{3.716}\right)\frac{(3.716)^2}{8}\right] \div 7.515$$

$$= 161.18\ KSI < 173.3\ KSI$$

MAX. AVG. SHEAR STRESS IN KSI $= \frac{1431}{2(14.17)} = 50.5\ KSI < 69.3\ KSI$

MAX. MEMBRANE STRESS INTENSITY IN KSI = 2(50.5)
= 101.0 KSI < 115.5 KSI

SCE - UNIT #2 AND #3:-
SEISMIC MARGIN EVAULATION - PUMP SUPPORTS:-

VERTICAL COLUMN PIN - FAULTED LOAD CAPACITY EVAULATION:-

FROM THE RESULTS OF VERTICAL COLUMN PIN ANALYSIS IT IS SEEN THAT THE COLUMN PIN DESIGN IS CONTROLLED BY THE BENDING STRESS IN PIN DUE TO TENSILE LOAD P(1431K) (REF: PG:16).
HENCE THE FAULTED LOAD CAPACITY OF VERTICAL COLUMN PIN IS DETERMINED BY USING MAXIMUM BENDING STRESS EQUATION TO EVAULATE THE FAULTED LOAD CAPACITY.

FAULTED LOAD CAPACITY :- (REF: PG. 16)
($F_{CAP.}$)

$$173.3 = \frac{\frac{F_{CAP.}}{2}\left[0.756 + \frac{3.734}{2}\right] - \frac{F_{CAP.}}{3.716}\left[\frac{(3.716)^2}{8}\right]}{7.515}$$

$$F_{CAP}[1.3115 - 0.4645] = 173.3(7.515)$$

$$F_{CAP.} = \frac{173.3(7.515)}{0.847} = 1537 \text{ KIPS}$$

FAULTED LOAD CAPACITY = 1537. KIPS

: ALLOWABLE SSE LOAD } = $F_{CAP.}$ - N.O.P

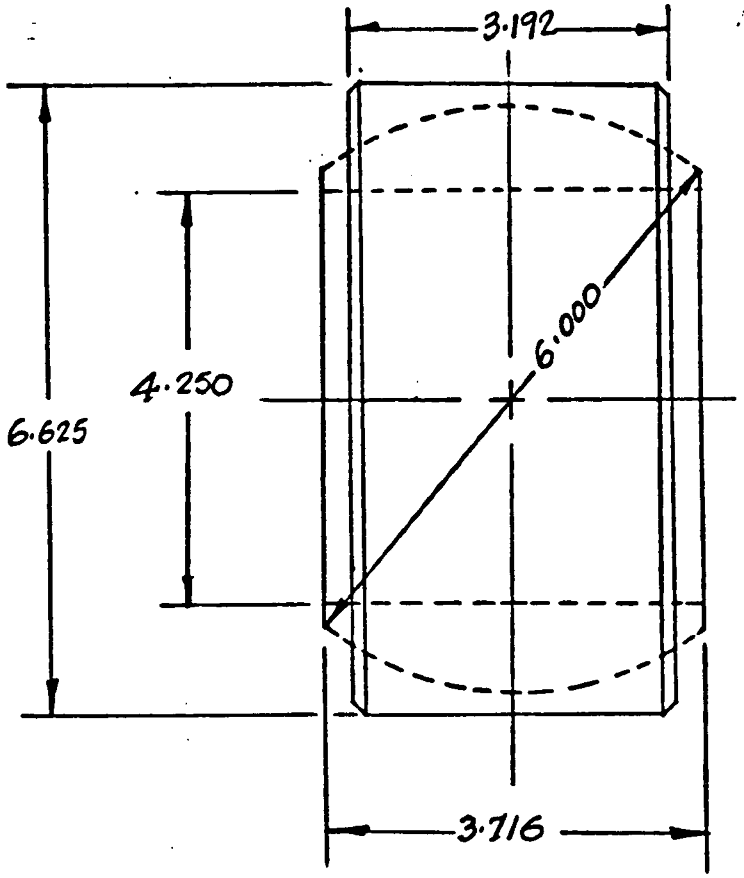
= 1537 - 146 = 1391 K

ALLOWABLE SSE LOAD = 1391. KIPS

SCE - UNIT #2 AND #3 :-
SEISMIC MARGIN EVALUATION - PUMP SUPPORTS :-

VERTICAL COLUMN BEARING :-

REF: 1) CE DRAWING 71278-229-001 REV.2



GEOMETRY - SPHERICAL BEARING

LOADS :- (REF: PG.1)

	FORCES IN KIPS			
COLUMN	*NORMAL AND UPSET CONDITION		FAULTED CONDITION	
	TENSION	COMPRESSION	TENSION	COMPRESSION
R_i	356	412	1431	1363

* NORMAL OPERATING LOAD = -146. KIPS.

SCE - UNIT #2 AND #3 :-
SEISMIC MARGIN EVAULATION - PUMP SUPPORTS :-

VERTICAL COLOMN BEARING - FAULTED LOAD CAPACITY EVAULATION :-

THE BEARING IS ASSUMED CONSERVATIVELY TO BE STRESSED TO THE MAXIMUM ALLOWABLE DUE TO TENSILE LOAD P (1431K).

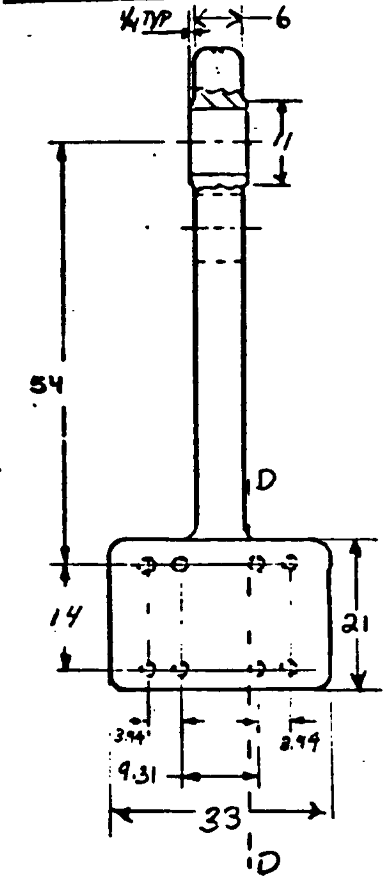
HENCE THE FAULTED LOAD CAPACITY OF BEARING IS EQUAL TO LOAD P.

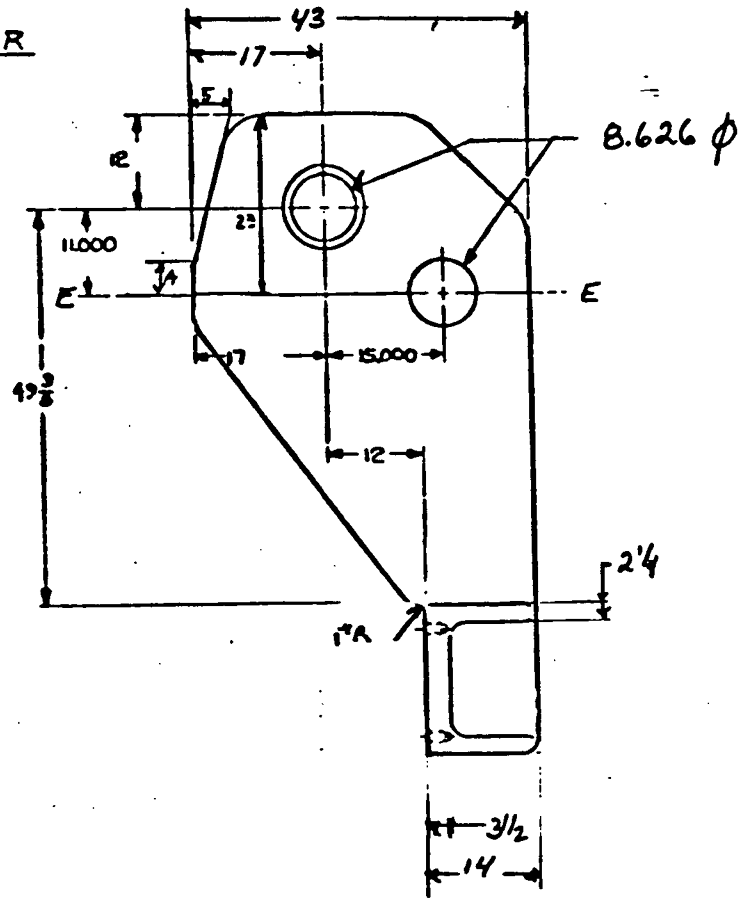
∴ FAULTED LOAD CAPACITY = 1431 KIPS. ($F_{CAP.}$)

ALLOWABLE SSE LOAD } = $F_{CAP.}$ − N.O.P.
= 1431 − 146 = 1285. K

ALLOWABLE SSE CAPACITY = 1285 KIPS.

STEAM GENERATOR LEVER

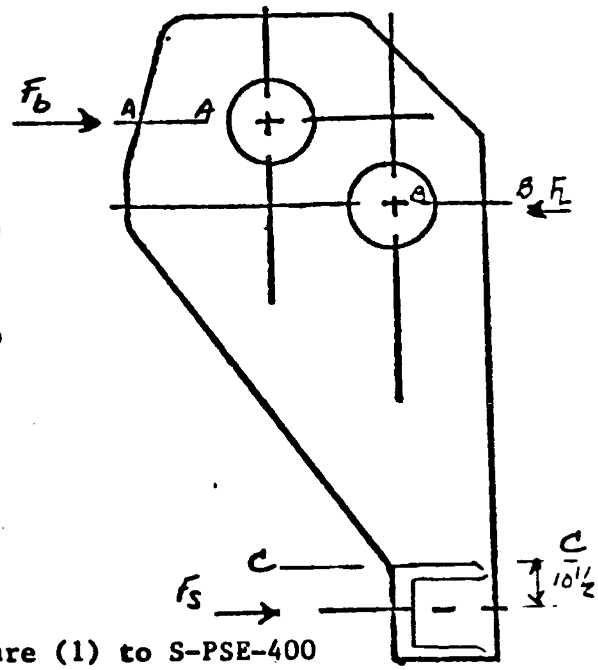




MATERIAL: ASTM - A - 148 - 71 GR 90-60

	100°F	300°F
F_y	60 ksi	55.9 ksi
S_u	90 ksi	90 ksi

DESIGN TEMP = 300°F



LOADS - UPPER ST. GEN. SUPPORT
SPECIFICATION NO. 1370-PE-507 REV 01
CE DWG E-1370-320-001 REV 08
NORMAL OPERATION LOADS ARE ZERO

	F_L	F_B	F_S
DBE	689[k]	564[k]	125[k]
FAULTED	2334[k]	1913	421[k]

Enclosure (1) to S-PSE-400

STEAM GENERATOR LEVER

ALLOWABLE STRESSES - ASME BOILER AND PRESSURE VESSEL CODE SECTION III 1977 ED.

SHEAR $F_v = 0.4F_y(1.5)$

$= 33.54$ KSI

TENSION $F_t = .6(F_y)(1.88) = 63$ KSI

BENDING - STRONG $F_{bs} = .6(F_y)(1.88) = 63$

BENDING WEAK $F_{bw} = .75(F_y)(1.88) = 78.8$

NORMAL ALLOWABLE INCREASE FOR FAULTED CONDITIONS:

$F_R = 1.2(S_y/F_t) \le .7(S_u/F_t)$

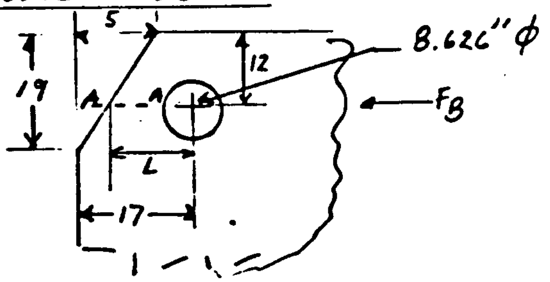
$= 1.2\left(\frac{55.9}{.6(55.9)}\right) \le .7\frac{(90)}{(55.9)(.6)}$

$= 2 \le 1.88$

LIMIT $F_R = 1.5$ FOR $F_r \le .42 S_u$

DETAILED ANALYSIS BASED ON FAULTED LOADS

SHEAR AT SECTION A-A

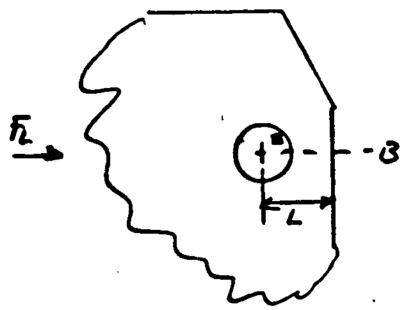


$L = 17 - 5(7/19) = 15.16$ IN

$A = 2\left[15.16 - \frac{8.626}{2}\right]6 = 130.2 \text{ IN}^2$

$f_v = \frac{1913}{130.2} = 14.7 \text{ KSI} \le 33.54$

SHEAR AT SECTION B-B



$L = 43 - 17 - 15 = 11$ IN

$A = 2\left[11 - \frac{8.626}{2}\right]6 = 80.24 \text{ IN}^2$

$f_v = \frac{2334}{80.24} = 29.1 \text{ KSI} \le 33.54$

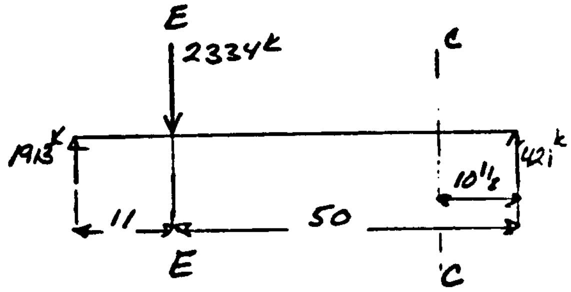
STEAM GENERATOR LEVER

DETAIL ANALYSIS

SHEAR BETWEEN BEARING AND BUSHING HOLE

$$A = 15(6) = 90 \text{ IN}^2$$

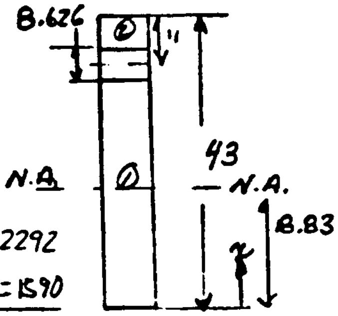
$$f_v = \frac{1913}{90} = 21.3 \text{ KSI} \leq 33.54$$



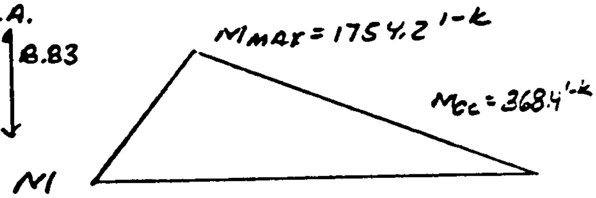
BENDING OF LEVER

STRESS AT SECTION E-E

PROPERTIES:



SECTION	A	x A
1	27.69(6) = 166.1	166.1(13.8) = 2292
2	(6.69)(6) = 40.1	40.1(39.66) = 1590
Σ	206.2	3882



$$N.A.\ \bar{x} = 3882/206.2 = 18.83$$

$$I = 1/12(6)(27.69)^3 + [166.1](4.99)^2 + 1/12(6)(6.69)^3 + 40.1(20.8)^2 = 32{,}292 \text{ IN}^4$$

$$S_{MIN} = 32{,}292/24.17 = 1336 \text{ IN}^3$$

$$f_{b_{MAX}} = \frac{1754.2(12)}{1336} = 15.76 \text{ KSI} \leq 63$$

STRESS AT SECTION C-C

$$I = 1/12(6)(14)^3 = 1372 \text{ IN}^4 \ ; \ S = 1372/7 = 196 \text{ IN}^3$$

$$f_b = \frac{368.4(12)}{196} = 22.6 \text{ KSI} \leq 63$$

STEAM GENERATOR LEVER

STRESS AT SECTION D-D

$P = 421/2 = 210.5^k \qquad M = 3.625(210.5) = 763.1 \text{ IN-K}$

$A = 21(3\tfrac{1}{2}) = 73.5 \text{ IN}^2$

$I = 1/12(21)(3\tfrac{1}{2})^3 = 75 \text{ IN}^4 \qquad S = 75/1.75 = 42.9 \text{ IN}^3$

$f_v = \frac{210.5}{73.5} = 2.86 \text{ KSI} \leq 33.54$

$f_b = \frac{763.1}{42.9} = 17.8 \text{ KSI} \leq 78.8 \text{ KSI}$

FAULTED CAPACITY

THE MOST CRITICAL SECTION IS SHEAR AT SECTION A-A

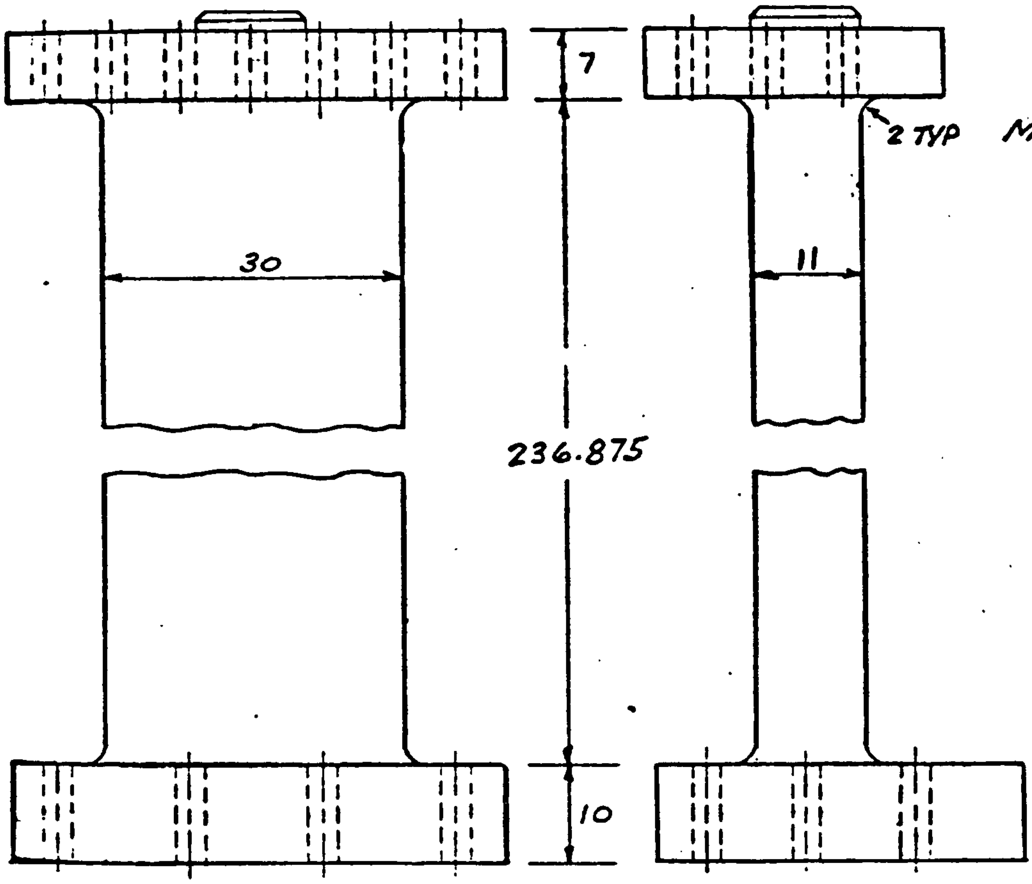
$F_L = 2334\left(\frac{33.54}{29.1}\right) = 2690^k$ FAULTED CAPACITY

SEISMIC MARGIN

$\frac{F_L - N.O.P}{DBE} = \frac{2690}{689} = 3.90$

CE POWER SYSTEMS
COMBUSTION ENGINEERING, INC

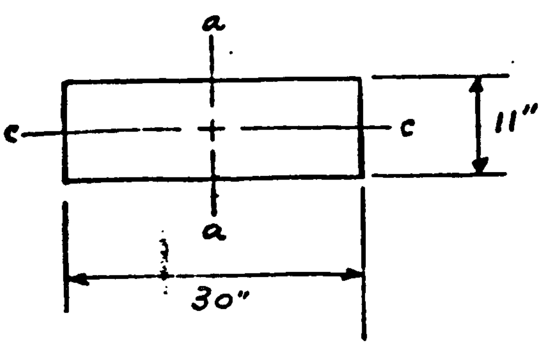
REACTOR VESSEL COLUMN



MATERIAL: SA533-GRB-CL1

	100°F	600°F
Fy, ksi	50	42
Su, ksi	80	80
E, ksi	29800	27,400

COLUMN X-SECTION PROPERTIES



$A = 330\ IN^2$

$I_a = 24750\ IN^4, \quad S_A = 1650\ IN^3$

$I_c = 3327.5\ IN^4 \quad S_c = 605\ IN^3$

$r_a = 8.660\ IN$

$r_c = 3.175\ IN$

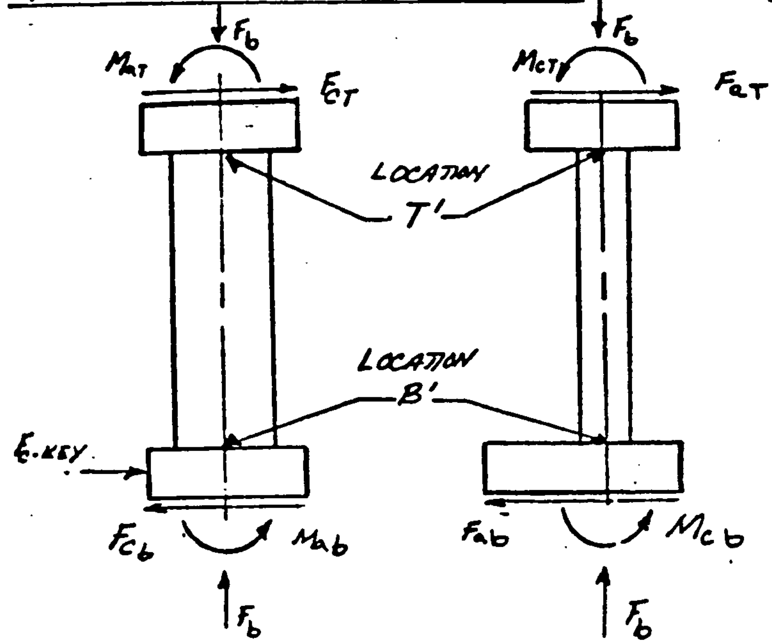
$\ell = 236.875\ IN$

$\left(\frac{\ell}{r}\right)_{MAX} = 236.875/3.175 = 74.6063$

$\left(\frac{\ell}{r}\right)_{MIN} = 236.875/8.66 = 27.4$

Enclosure (1) to S-PSE-400

REACTOR VESSEL COLUMN



LOADS - R.V. ASS'Y SPECIFICATION
SPECIFICATION NO. 01370-PE-110

	LOCATION	F_a	F_b	F_c	M_a	M_c
NORMAL OPERATION	T	38	1068+	2	22	394
	T'	38	1068	2	22	372
	B'	38	1068	2	22	377
	KEY			2		
	B	38	1068	4	22	409
DBE SEISMIC	T**	7	628	8	733	213
	T'*	7	628	8	738	217
	B'*	7	628	8	537	71
	KEY			401		
	B	7	628	409	363	65

LOADS ARE IN KIPS
MOMENTS IN FT-K

* LOADS AT THESE LOCATIONS ARE CONSERVATIVELY OBTAINED ASSUMING SINGLE CURVATURE

** SEISMIC LOADS AT TOP OF COLUMN ARE OBTAINED BY TRANSPOSITION OF LOADS AT THE BOTTOM OF THE COLUMN, CONSIDERING WORST CASE SIGNS NOTING THAT F_{cKEY} AND F_{cB} ARE OF OPPOSITE SIGN.

\+ INCLUDES 22½ K CEDM SCRAM LOAD

ALLOWABLE STRESSES

- FROM AISC WITH 1⅓ INCREASE FOR FAULTED CONDITIONS

$F_{bc} = 0.75 F_y (1\tfrac{1}{3})$ - BENDING ABOUT C-AXIS

$F_{bc} = 0.75(42)(1\tfrac{1}{3}) = 42$ ksi

$F_{ba} = 0.6 F_y (1\tfrac{1}{3})$ - BENDING ABOUT a-AXIS

$F_{ba} = 0.6(42)(1\tfrac{1}{3}) = 33.6$ ksi

F_a = ALLOWABLE COMPRESSIVE STRESS

$$F_a = \frac{\left[1 - \frac{(kl/r)^2}{2C_c^2}\right] F_y (1\tfrac{1}{3})}{5/3 + \frac{3(kl/r)}{8C_c} - \frac{(kl/r)^3}{8C_c^3}}$$

$= 28$ ksi

$k = 0.65$ FOR RESTRAINED COMP. MEMBERS PER AISC

$(kl/r)_{max} = 0.65(74.6) = 48.5$

$$C_c = \sqrt{\frac{2\pi^2 E}{F_y}} = 113.48$$

EULER BUCKLING STRESS

$$F'_{ea} = \frac{12}{23} \frac{\pi^2 E}{(kl/r_a)^2} (1\tfrac{1}{3})$$

$= 595$ ksi

$(kl/r_a) = 0.65(27.4) = 17.81$

$E = 27,400$ ksi

REACTOR VESSEL COLUMN

ALLOWABLE STRESSES

EULER BUCKLING STRESS

$$F'_{ec} = \frac{12}{23}\frac{\pi^2 E}{\left(\frac{kl}{r_c}\right)^2} \qquad \left(\frac{kl}{r_c}\right) = \left(kl/r\right)_{MAX} = 48.5$$

$$= 79.8 \text{ ksi}$$

COMPRESSION - BENDING INTERACTION

$$(1) \quad \frac{f_a}{F_a} + \frac{C_{ma} f_{ba}}{\left(1 - \frac{f_a}{F'_{ea}}\right) F_{ba}} + \frac{C_{mc} f_{bc}}{\left(1 - \frac{f_a}{F'_{ea}}\right) F_{ba}} \leq 1.0 \qquad \text{AISC EQ. 16-1a}$$

- CONSERVATIVELY ASSUME $C_{ma} = C_{mc} = 1.0$ WHICH IS THE HIGHEST POSSIBLE VALUE CONSIDERING RESTRAINED, JOINT TRANSLATION PREVENTED, SINGLE CURVATURE BENDING.

SINCE $C_{ma} = C_{mc} = 1.0$ EQ 1.6 - 1b IS SATISFIED BY INSPECTION.

FAULTED CAPACITY

THE FAULTED CAPACITY IS DESCRIBED BY EQ 1 AND HAS AN INFINITE NUMBER OF SOLUTIONS. THE FAULTED CAPACITY IS DEFINED AS NORMAL OPERATION PLUS A LINEAR MULTIPLE OF THE FSAR SEISMIC RESPONSE. (FAULTED CAPACITY = N. OP. + X (DBE)) THE MOST CRITICAL LOCATION IS THE BOTTOM OF THE TOP FLANGE (T') SINCE MAXIMUM NORMAL OPERATION PLUS DBE LOADS EXIST HERE.

BY TRIAL AND ERROR ASSUME A DBE MULTIPLICATION FACTOR OF $X = 1.9$

$$f_b = 1068 + 1.9(628) = 2262^k$$

$$M_A = 22 + 1.9(738) = 1424^{'-k}$$

$$M_C = 372 + 1.9(217) = 784^{'-k}$$

REACTOR VESSEL COLUMN

FAULTED CAPACITY

- CONSERVATIVELY, AN OFFSET MOMENT EQUAL TO 1/4 INCH (.021') TIMES THE AXIAL LOAD (F_b) IS ADDED TO M_A AND M_C WHEN CALCULATING BENDING STRESSES.

$$f_{ba} = \frac{M_a}{S_a} = \frac{[1424 + .021(2262)]12}{1650} = 10.7 \text{ KSI}$$

$$f_{bc} = \frac{M_c}{S_c} = \frac{[784 + .021(2262)]12}{605} = 16.49 \text{ KSI}$$

$$f_a = \frac{F_b}{A} = \frac{2262}{330} = 6.86 \text{ KSI}$$

SUBSTITUTING IN EQ.1

$$\frac{6.86}{28} + \frac{(1)(10.7)}{(1 - \frac{6.86}{595})33.6} + \frac{(1)(16.49)}{(1 - \frac{6.86}{770})42} = 0.245 + 0.322 + 0.43$$

$$= 0.997 \leq 1.0$$

WHICH DEFINES THE FAULTED CAPACITY BY THE PREVIOUSLY DEVELOPED CRITERIA AS: (AT LOCATION T')

$F_b = 2262^k$

$M_a = 1424^{1-k}$

$M_c = 784^{1-k}$

SEISMIC MARGIN

$F_b = (2262 - 1068)/628 = 1.9$

$M_A = (1424 - 22)/738 = 1.9$

$M_C = (784 - 372)/217 = 1.9$

THE MARGIN IN THE TABLE IS REPRESENTATIVE OF THE SAFETY FACTOR AVAILABLE ABOVE THE EXISTING DESIGN BASIS EARTHQUAKE.

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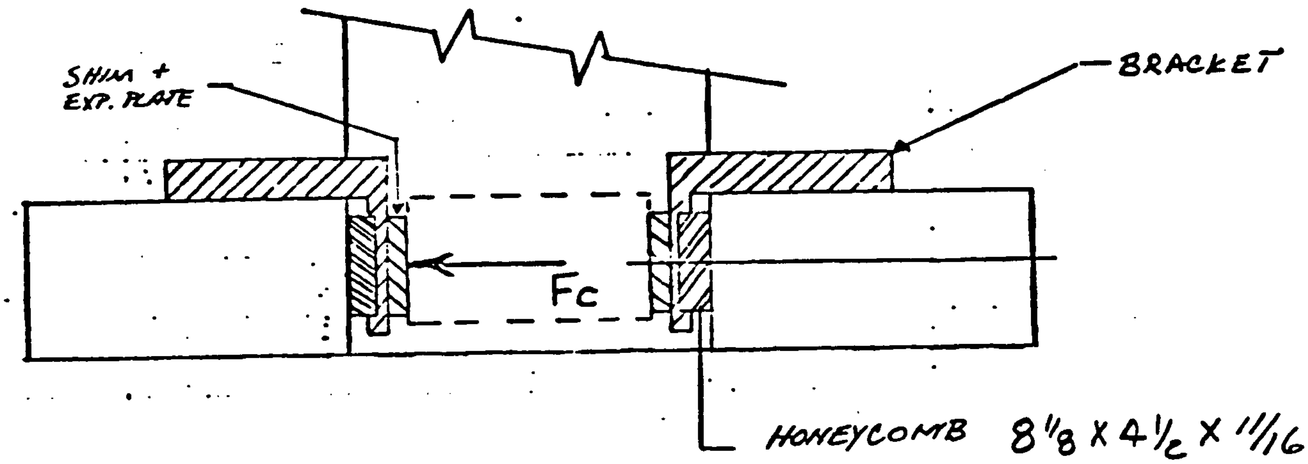
REACTOR VESSEL LOWER SUPPORT
HONEYCOMB ASSEMBLY



MATERIAL:
SA240 TYPE 321
FOIL SIZE = .010"
CELL SIZE = 1/8"
1" THK PRECRUSHED TO 11/16

LOADS

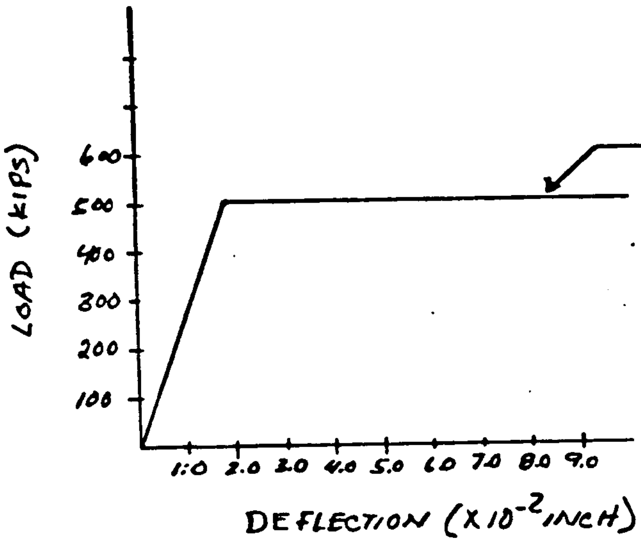
	F_c
NORMAL OPERATION	~0
DBE	≐ 400^k

LOAD DEFLECTION CHARACTERISTICS - DESIGN CURVE

- THE FOLLOWING PROPERTIES ARE FROM THE PROJECT SPECIFICATION FOR REACTOR VESSEL COLUMN EXPANSION PLATE ASSEMBLIES FOR SOUTHERN CALIFORNIA EDISON SAN ONOFRE 2 AND 3. SPECIFICATION NO. 1370-PE-514 R02

REACTOR VESSEL LOWER SUPPORT
HONEYCOMB ASSEMBLY

LOAD DEFLECTION CHARACTERISTICS -(CON'T)



FAULTED CAPACITY -ASME SECTION III APPENDIX F 1370(a).

$$F_{CMAX} = 0.8L = 0.8(500) = 400^{k}$$

SEISMIC MARGIN

$$= 400/400 = 1.0$$

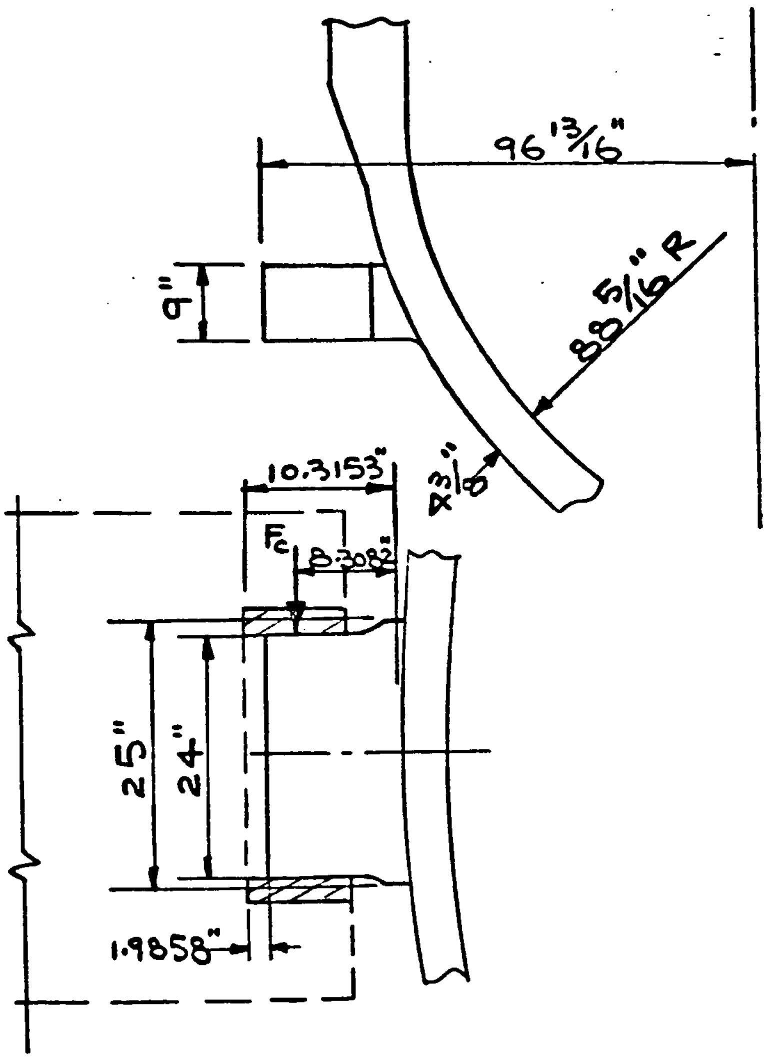
NO MARGIN EXISTS BASED ON CODE ANALYSIS. 25% MARGIN EXISTS BASED ON THE MATERIAL SPECIFICATION.

ELASTIC DESIGN LIMIT = 500^{k}

$$\text{SEISMIC MARGIN} = \frac{500}{400} = 1.25$$

SCE Units #2 and #3:
Seismic Margin Evaluation - Reactor Vessel Bottom Head Support Lug:

A. Geometry:



Material: Lug and Bottom Head - SA-533 Gr. B class 1

$S_m = 26.7$ KSI
$S_Y = 41.4$ KSI
$S_U = 80$ KSI
} @ 650°F design temperature

S_m value for the faulted condition (See par. F-1323.1 (a) and (b) of Ref. 3):

$_F S_m = 1.2 S_y = 49.68$ KSI — For the Lug
$= 0.7 S_u = 56$ KSI — For the bottom Head

B. Stress calculation:

(1) Support Lug: From p. A-417 through A-422 of Ref. 1 and par. F-1323.1 (a) of Ref. 3

Average Shear stress

$$\tau = \frac{F_c}{9 \times 24} = .00463 F_c \le .6 ({}_F S_m) = .6 \times 49.68 = 29.8^{KSI}$$

$$\text{or } F_c = \frac{29.8}{.00463} = 6436.2^K$$

Bending stress

$$\sigma_B = \frac{F_c \times 8.3082}{\frac{1}{12} \times 9 \times 25^3} \left(\frac{25}{2}\right) = .00886 F_c \le 1.5 ({}_F S_m) = 74.5^{KSI}$$

$$\text{or } F_c = \frac{74.5}{.00886} = 8408.5^K$$

Max. stress intensity

$$S.I. = (\sigma_B^2 + 4\tau^2)^{1/2} \le 1.5 ({}_F S_m) = 74.5^{KSI}$$

$$\text{or } [(.00886 F_c)^2 + 4(.00463 F_c)^2]^{1/2} = 74.5$$

$$\text{or } F_c = 5813^K$$

Bearing stress

$$\sigma_{Bearing} = \frac{F_c}{9 \times 4.01425} = 0.0277 F_c \le \left(\frac{S_y}{S_m}\right) S_y = \frac{41.4^2}{26.7} = 64.1^{KSI}$$

$$\text{or } F_c = \frac{64.1}{.0277} = 2314^K$$

Enclosure (1) to S-PSE-400

(2) Reactor Vassel Bottom Head: From P. A-430 through A-432 of Ref. 1, we have the local membrane stress due to Fc for the head

$$\sigma_\theta = .0001892\, M_c = .0001892(8.9991\, F_c) = .001703\, F_c$$

$$\sigma_x = .0001809\, M_c = .00163\, F_c$$

Shear stress

$$\tau = \frac{F_c}{9 \times 25} + .001688\, \overset{3.3563 F_c}{M_T} = .01011\, F_c$$

The pressure stress

$$\sigma_p = \frac{pR}{2t} = \frac{\overset{\text{(operating press.)}}{2.25 \times 88.3125}}{2 \times 4.375} = 22.71^{ksi}$$

Therefore the limiting stress is

$$S.I. = [(\sigma_p + \sigma_\theta)^2 + 4\tau^2]^{1/2} + p$$

$$= [(22.71 + .001703 F_c)^2 + 4(.01011 F_c)^2]^{1/2} + 2.25$$

$$\leq 1.5({}_F S_m) = 1.5 \times 56 = 84^{ksi}$$

or $F_c = 3750^K$

(3) SSE capacity load: The SSE capacity load is the smallest Fc value calculated in Section (1) and (2) above or

$${}_{\substack{SSE\\cap.}}F_c = 2314^K$$

The bearing stress of the support lug governs.

The next lowest F_c is 3750^K governed by the bottom head.

(4) SSE allowable load and seismic margin:
From Refs. 1 and 2, for the normal operation case

$${}_{N.op.}F_c = 2^K$$

$$\therefore {}_{\substack{SSE\\Allow.}}F_c = {}_{\substack{SSE\\cap.}}F_c - {}_{N.op.}F_c$$

$$= 2314 - 2 \quad = 2312^K$$

From Ref. 4

$${}_{DBE}F_c = 400^K$$

$$\therefore \text{Seismic Margin } \% = \frac{{}_{\substack{SSE\\All.}}F_c - {}_{DBE}F_c}{{}_{\substack{SSE\\All.}}F_c} 100\%$$

$$= \frac{2312 - 400}{2312} 100\%$$

$$= 82.6\%$$

C. References:

1. Analytical Report For Southern California San Onofre Unit 3 Reactor Vessel, Report Number CENC-1292, August 1977

2. Project Specification For A Reactor Vessel Assembly For San Onofre Units No.2 & No.3, Specification No. 01370-PE-110 Revision 4

3. ASME Boiler and Pressure Vessel Code Section III, 1974

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4. FSAR Table 3.7-23

Enclosure (1) to S-PSE-400

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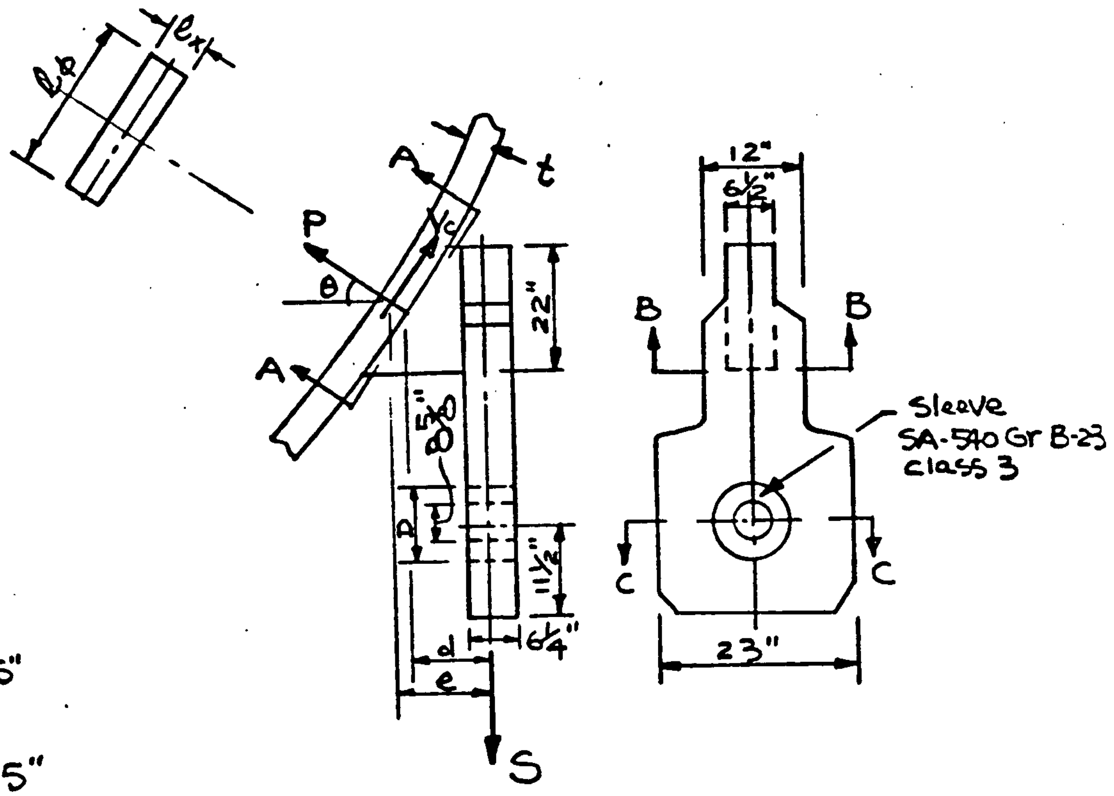
SCE Units #2 and #3:
Seismic Margin Evaluation - Steam Generator Snubber Lug:

A. Geometry:



$\ell_x = 6.5"$

$\ell_\phi = 22.945"$

$\theta = 16.5°$

$t = 5.5625"$

$d = 5.1236"$

$e = d + \frac{1}{2} t \cos\theta = 7.79"$

$D = 9.75"$

$V_c = S\cos\theta = .9588S$

$P = S\sin\theta = .284S$

$A_{A\text{-}A} = \ell_x \times \ell_\phi = 149.14 \text{ in}^2$

$Z_{A\text{-}A} = \frac{1}{6}\ell_x \ell_\phi^2 = 570.35 \text{ in}^3$

Material: Vessel shell - SA-533 A class 1 } $S_m = 26.7^{ksi}$, $S_y = 42.5^{ksi}$
Lug - SA-533 B class 1 } $S_u = 80^{ksi}$, all @ 560°F design temperature
Sleeve - SA-540 Gr. B-23 class 3 - $S_m = 36.58^{ksi}$, $S_y = 109^{ksi}$ } @ 560°F

C-E 0090257-B (Rev. 9/76)

Enclosure (1) to S-PSE-400

B. Stress calculation:

(1) Lug: By Par. F-1323.1 (a) of Ref. 3 and P.A-659 of Ref. 1, stress limits used in the calculation are:

Primary membrance stress $\sigma_t \leq 1.2S_y = 51^{KSI}$

Average shear stress $\tau \leq .6(1.2S_y) = 30.6^{KSI}$

Bearing stress $\sigma_{Bearing} \leq (\frac{S_y}{S_m}) S_y = 67.6^{KSI}$

Primary membrane plus primary bending stress

$$(\sigma_t + \sigma_B) \leq 1.5(1.2S_y) = 76.5^{KSI}$$

Max. stress intensity

$$S.I. = [(\sigma_t + \sigma_B)^2 + 4\tau^2]^{1/2} \leq 1.5(1.2S_y) = 76.5^{KSI}$$

Bearing stress for the sleave

$$_{sleave}\sigma_{Bearing} \leq S_y = 109^{KSI}$$

The three critical stress regions, Sections A-A, B-B and C-C are analyzed.

a) Section A-A:

1) Primary membrance stress

$$\sigma_t = \frac{P}{A_{A\text{-}A}} = \frac{.2845}{149.14} = .0019\,S \leq 51^{KSI}$$

$$\text{or } S = \frac{51}{.0019} = 26842^{K}$$

2. Primary membrane plus primary bending:

$$\sigma_B = \frac{Sd}{Z_{AA}} = \frac{5.12365}{570.35} = .008985$$

$$\therefore (\sigma_t + \sigma_B) = .0019S + .008985 \leq 76.5^{KSI}$$

$$\text{or} \quad S = \frac{76.5}{.01088} = 7031^{K}$$

3. Average shear stress:

$$\tau = \frac{Vc}{A_{A\text{-}A}} = \frac{.95885}{149.14} = .006435 \leq 30.6^{KSI}$$

$$\text{or} \quad S = \frac{30.6}{.00643} = 4758.9^{K}$$

4. Max. stress intensity:

$$S.I. = [(\sigma_t + \sigma_B)^2 + 4\tau^2]^{1/2}$$

$$= [(.0019S + .008985)^2 + 4(.00643S)^2]^{1/2}$$

$$= .01684S \leq 76.5^{KSI}$$

$$\text{or} \quad S = \frac{76.5}{.01684} = 4542.7^{K}$$

b) Section B-B:

: Primary membrane stress

$$\sigma_t = \frac{S}{A_{B\text{-}B}} = \frac{S}{12 \times 6.25} = .013335 \leq 51^{KSI}$$

$$\text{or} \quad S = 3825^{K}$$

c) Section C-C :

1. Primary membrane stress :

$$\sigma_t = \frac{S}{A_{C\text{-}C}} = \frac{S}{(23-9.75)6.25} = .0121\,S \le 51^{KSI}$$

or $S = 4214.8^K$

2. Tearout shear stress :

$$\tau = \frac{S}{A_{Tearout}} = \frac{S}{(11.5-\frac{9.75}{2}\cos 45°)\,2\times 6.25}$$

$$= .00993\,S \le 30.6^{KSI}$$

or $S = 3081.5^K$

3. Bearing stress :

$$_{Lug}\sigma_{Bearing} = \frac{S}{9.75\times 6.25} = .01641\,S \le 67.6^{KSI}$$

or $S = 4119.4^K$

$$_{Sleeve}\sigma_{Bearing} = \frac{S}{8.625\times 6.25} = .01855\,S \le 109^{KSI}$$

or $S = 5876^K$

From the above calculations, one can see that the tearout shear stress at Section C-C governs. The max. allowable load for S is

$S = 3081.5^K$

(2) Steam Generator upper Shell: The allowable load S can be calculated from the stress intensity equation. From p. A-674 of Ref. 1, we have

$$S.I. = [({}_p\sigma_\phi + \sigma_{N\phi})^2 + 4(\tau_{x\phi})^2]^{1/2} + p$$

$$= [(20.5 + .00695\,P)^2 + 4(\frac{V_c}{255.05})^2]^{1/2} + 0.9$$

$$= [(20.5 + .001974S)^2 + 4(.003765)^2]^{1/2} + 0.9$$

$$\leq 1.5(0.75u) = 84^{KSI}$$, See par. F-1323.1 (b) of Ref. 3

$$\therefore \quad S = 9700\ K$$

(3) SSE capacity load: The SSE capacity load is the smallest S load calculated in Sections (1) and (2) above, or

$$_{\substack{SSE\\cap.}}S = 3081.5^{K}$$

The tearout shear stress of the lug governs.

(4) SSE allowable load and seismic margin:

For the normal operation case, see Refs 1 and 2, ${}_{N.op.}S = 0$. Therefore

$$_{\substack{SSE\\Allowable}}S = {}_{\substack{SSE\\cap.}}S - {}_{N.op.}S$$

$$= 3081.5 - 0$$

$$= 3081.5^{K}$$

From Ref 4, DBE load

$$_{DBE}S = \frac{_{DBE}F_x}{2} = \frac{1378}{2} = 689^K$$

$$\therefore \text{Seismic Margin } G = \frac{^{SSE}_{All.}S - {}_{DBE}S}{^{SSE}_{All.}S} = \frac{3081.5 - 689}{3081.5}$$

$$= .776 = 77.6\%$$

C. References :

1. Analytical Report For Southern California Edison San Onofre Unit No. 2 Steam Generator, Report Number CENC-1272, September 1976

2. Project specification For Steam Generator Assemblies for San Onofre Unit No. 2, Specification No. 01370-PE-120 Revision 5

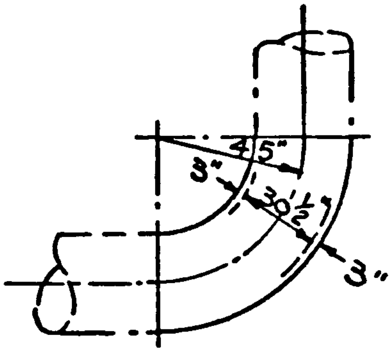
3. ASME Boiler and Pressure Vessel Code Section III, 1974

4. FSAR Table 3.7-23

SCE Units # 2 and # 3:

Seismic Margin Evaluation — primary piping Cold Leg Discharge Elbow:

A. Geometry:



$R_o = 18.25''$

$R_i = 15.25''$

$t = 3''$, $t_{clad} = .25''$

$I = \frac{\pi}{4}(R_o^4 - R_i^4) = 44646.2 \text{ in}^4$

Material: SA-516 Gr. 70

$S_m = 18.4^{ksi}$ @ 650°F design temp.

B. Stress Calculation:

The primary stress of the elbow is analyzed by EQ. (9) of Ref. 3. From p. A-35 of Ref. 1, we have

$$S_{EQ.9} = B_1 \frac{PD_o}{2t} + B_2 \frac{D_o M_i}{2I} = (15.21 + .01168 M_i)^{ksi}$$

where $B_1 = 1.0$

$B_2 = 2.382$

$D_o = 36.5''$

$t = 3''$

$I = 44646.2 \text{ in}^4$

$P = 2.5^{ksi}$, Design pressure

(1) SSE Capacity:

By Par. F-1360 (b) of Ref. 3 and the above equation $S_{EQ.9}$, the SSE capacity of the elbow can be calculated as follows:

$$S_{EQ.9} = 15.21 + .01168 M_i \leq 3 S_m = 55.2^{ksi}$$

$\therefore \ {}_{\substack{SSE\\cap.}}M_i = 3423.8^{\text{FT-K}}$

(2) SSE allowable load and Seismic margin:

From p. A-34 of Ref. 1 and Ref. 2

$_{N.op.}M_i = 1390.6^{\text{FT-K}}$

From Ref. 3

$_{DBE}M_i = 1607^{\text{in-K}} = 134^{\text{FT-K}}$

$\therefore \ {}_{\substack{SSE\\Allow.}}M_i = {}_{\substack{SSE\\cap.}}M_i - {}_{N.op.}M_i$

$= 3423.8 - 1390.6 = 2033.2^{\text{FT-K}}$

and Seismic Margin

$$G = \frac{{}_{\substack{SSE\\All.}}M_i - {}_{DBE}M_i}{{}_{\substack{SSE\\All.}}M_i} = \frac{2033.2 - 134}{2033.2} = .934 \text{ or } 93.4\%$$

The primary bending stress governs.

C. References:

1. Analytical Report for Southern California Edison San Onofre Unit No. 2 Piping, Report Number CENC-1365, March, 1979

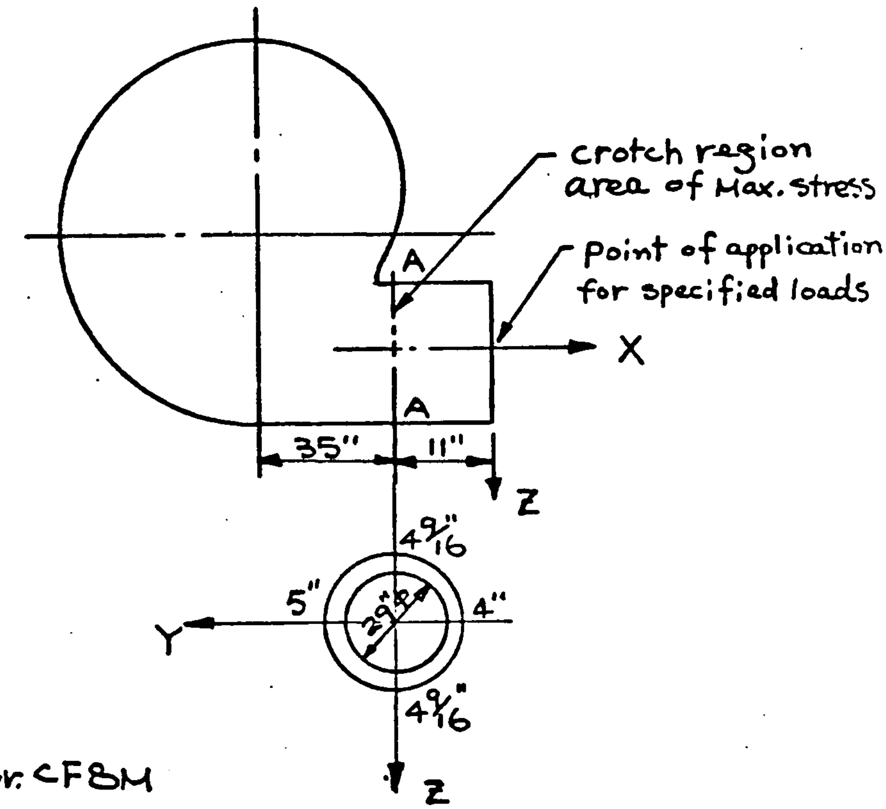
2. Project Specification For Reactor Coolant Pip and Fittings For San Onofre Unit No. 2, Specification No. 01370-PE-140 Revision 6

3. ASME Boiler and Pressure Vessel Code Section III, 1974

4. FSAR Table 3.7-23

SCE Units # 2 and # 3:
Seismic Margin Evaluation - R.C. Pump Discharge Nozzle:

A. Geometry: pump 1B is used for this analysis



Material: SA-351 Gr. CF8M

$S_m = 16.6^{KSI}$
$S_Y = 18.5^{KSI}$ } @ 650°F design temperature
$S_U = 67^{KSI}$

By par. F-1323.1 (b) of Ref. 3, the S_m value for the faulted condition is chosen as the smaller of $2.4 S_m$ or $0.7 S_u$

$$\therefore {}_{Faulted}S_m = 2.4\, S_m = 2.4 \times 16.6 = 39.84^{KSI}$$

Conservatively the Max. stress region Section A-A is considered as a 29" I.D. × 37" O.D. ring, and

$$A_{A\text{-}A} = \frac{\pi}{4}(d_o^2 - d_i^2) = \frac{\pi}{4}(37^2 - 29^2) = 414.7 \text{ in}^2$$

$$I_{A\text{-}A} = \frac{\pi}{64}(d_o^4 - d_i^4) = \frac{\pi}{64}(37^4 - 29^4) = 57279 \text{ in}^4$$

$$J_{A\text{-}A} = 2 I_{A\text{-}A} = 114558 \text{ in}^4$$

B. stress calculation:

(1) Stress Limits: From Par. F-1323.1 (b) of Ref. 3, the following stress limits are used in the analysis:

(a) For the max. primary membrane stress

$$_mS_t = \frac{F_x}{A_{A\text{-}A}} + \frac{pr_i}{2t} \leq {}_{\text{Faulted}}S_m$$

or $$_mS_t = \frac{F_x}{414.7} + \frac{2.25 \times 14.5}{2 \times 4} = .002411 F_x + 4.08^{\text{KSI}} \leq 39.84^{\text{KSI}}$$

(b) For the Max. primary membrane plus primary bending stress:

$$S_t = \frac{F_x}{A_{A\text{-}A}} + \frac{\bar{M}c}{I_{A\text{-}A}} + \frac{pr_i}{2t} \leq 1.5({}_{\text{Faulted}}S_m)$$

or $$S_t = \frac{F}{A_{A\text{-}A}} + \frac{\bar{M} \times 18.5}{57279} + \frac{2.25 \times 14.5}{2 \times 4}$$

$$= .002411 F_x + .000323 \bar{M} + 4.08 \leq 59.76^{\text{KSI}}$$

(c) For the Max. average shear stress:

$$S_s = \frac{\bar{F}}{A_{A\text{-}A}} + \frac{M_x c}{J_{A\text{-}A}} \leq .6({}_{\text{Faulted}}S_m)$$

or $$S_s = .002411 \bar{F} + .0001615 M_x \leq 23.9^{\text{KSI}}$$

(d) For the Max. stress intensity:

$$S.I. = (S_t^2 + 4S_s^2)^{1/2} + p \leq 1.5({}_{\text{Faulted}}S_m) = 59.76^{\text{KSI}}$$

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where $\bar{F} = (F_Y^2 + F_Z^2)^{1/2}$

$\bar{M} = [(M_Y - 11F_Z)^2 + (M_Z + 11F_Y)^2]^{1/2}$

$P = 2.25^{KSI}$, system operating pressure

$r_i = \frac{29}{2} = 14.5''$

$c = \frac{37}{2} = 18.5''$

$t = 4''$

(2) Load stresses for the normal operating condition: From Table 10 of Ref 2, we have

$F_X = 106^K$

$\bar{F} = (F_Y^2 + F_Z^2)^{1/2} = (119^2 + 16^2)^{1/2} = 120.1^K$

$M_X = 41^{FT-K} = 492^{in-K}$

$\bar{M} = [(M_Y - 11F_Z)^2 + (M_Z + 11F_Y)^2]^{1/2}$

$= [(141 \times 12 + 11 \times 16)^2 + (1057 \times 12 + 11 \times 119)^2]^{1/2}$

$= 14117$ in-K

Substituting the forces and moments into the above Par. B. (1) equations, we have

${}_m S_t = .002411 F_X = .002411 \times 106 = .26^{KSI}$

$S_t = .000323\bar{M} + {}_m S_t = .000323 \times 14117 + .26 = 4.82^{KSI}$

$S_s = .002411\bar{F} + .0001615 M_X = .002411 \times 120.1 + .0001615 \times 492$

$= .37^{KSI}$

$S.I. = [S_t^2 + 4S_s^2]^{1/2} = [4.82^2 + 4 \times .37^2]^{1/2} = 4.88^{KSI}$

(3) Load stresses for the DBE condition: From Table 3.7-23 of Ref. 4, the DBE load stresses of the nozzle can be calculated as follows:

(a) Combined North-South and Vertical DBE case:

$F_x = F_a = 790^K$

$\bar{F} = (F_b^2 + F_c^2)^{1/2} = (61^2 + 145^2)^{1/2} = 157.31^K$

$M_x = M_a = 1119^{in\text{-}K}$

$\bar{M} = [(M_b + 11F_c)^2 + (M_c + 11F_b)^2]^{1/2}$

$= [(11531 + 11 \times 145)^2 + (5499 + 11 \times 61)^2]^{1/2} = 14503.82^{in\text{-}K}$

$\therefore {}_mS_t = .002411 F_x = .002411 \times 790 = 1.9^{KSI}$

$S_t = .000323\bar{M} + {}_mS_t = .000323 \times 14503.82 + 1.9$
$= 6.59^{KSI}$

$S_s = .002411\bar{F} + .0001615 M_x$
$= .002411 \times 157.31 + .0001615 \times 1119 = .56^{KSI}$

$S.I. = (S_t^2 + 4S_s^2)^{1/2}$

$= (6.59^2 + 4 \times .56^2)^{1/2} = 6.68^{KSI}$

(b) Combined East-West and Vertical DBE case:

$F_x = F_a = 222^K$

$\bar{F} = (F_b^2 + F_c^2)^{1/2} = (36^2 + 56^2)^{1/2} = 66.6^K$

$M_x = M_a = 1181^{in\text{-}K}$

$\bar{M} = [(M_b + 11F_c)^2 + (M_c + 11F_b)^2]^{1/2}$

$= [(2864 + 11 \times 56)^2 + (3793 + 11 \times 36)^2]^{1/2} = 5446^{in\text{-}K}$

To compare case (a) with case (b), one can see case (a) governs.

C. SSE Capacity Loads: The SSE capacity loads are conservatively calculated by ratioing up the DBE loads by a factor K, where

$$K = \frac{\text{(ASME Code Allowable stress)} - \text{(pressure stress)}}{\text{(DBE Load stress)}}$$

Therefore from par. B. (1) and (3) above, we have:

(1) For the primary membrane stress:

$$K_m = \frac{39.84 - 4.08}{1.9} = 18.8$$

(2) For the primary membrane plus primary bending stress:

$$K_t = \frac{59.76 - 4.08}{6.59} = 8.4$$

(3) For the shear stress:

$$K_s = \frac{23.9 - 0}{.56} = 42.6$$

(4) For the Max. stress intensity:

$$K_{s.I.} \doteq \frac{59.76 - 4.08}{6.68} = 8.3$$

Using the smallest value of the above K's

$\therefore K = K_{s.1.} = 8.3$

and $_{\substack{SSE \\ cap.}}(Load) = K \times {}_{DBE}(Load)$

$$\therefore \left.\begin{aligned} {}_{\substack{SSE\\cap.}}F_a &= 790 \\ {}_{\substack{SSE\\cap.}}F_b &= 61 \\ {}_{\substack{SSE\\cap.}}F_c &= 145 \\ {}_{\substack{SSE\\cap.}}M_a &= 1119 \\ {}_{\substack{SSE\\cap.}}M_b &= 11531 \\ {}_{\substack{SSE\\cap.}}M_c &= 5499 \end{aligned}\right\} \times 8.3 = \left\{\begin{aligned} &6557^{K} \\ &506^{K} \\ &1203^{K} \\ &9287^{in\text{-}K} \\ &95707^{in\text{-}K} \\ &45641^{in\text{-}K} \end{aligned}\right.$$

D. SSE allowable loads and seismic margin:

(1) SSE allowable loads: The following equation is used in the analysis

$$_{\substack{SSE\\Allowable}}(Load) = {}_{\substack{SSE\\cap.}}(Load) - {}_{N.op.}(Load)$$

From Table 10 of Ref. 2 and Par. C. above, we have

$$_{\substack{SSE\\all.}}F_a = 6557 - 106 = 6451^{K}$$

$$_{\substack{SSE\\All.}}F_b = 506 - 119 = 387^{K}$$

$$_{\substack{SSE\\All.}}F_c = 1203 - 16 = 1187^{K}$$

$_{\substack{SSE\\All.}}Ma = 9287 - 41 \times 12 = 8795 \text{ in-K} = 733 \text{ FT-K}$

$_{\substack{SSE\\All.}}Mb = 95707 - 141 \times 12 = 94015 \text{ in-K} = 7834.6 \text{ FT-K}$

$_{\substack{SSE\\All.}}Mc = 45641 - 1057 \times 12 = 32957 \text{ in-K} = 2746.4 \text{ FT-K}$

(2) Seismic Margin: the seismic margin is conservatively calculated by

$$\text{Seismic Margin} \quad G = \frac{_{\substack{SSE\\All.}}(\text{Load}) - _{DBE}(\text{Load})}{_{\substack{SSE\\All.}}(\text{Load})}$$

From Table 3.7-23 of Ref. 4 and Pars. B.(3) & D above, we have

$$G_{Fa} = \frac{6451-790}{6451} = .877 \text{ or } 87.7\%$$

$$G_{Fb} = \frac{387-61}{387} = .842 \text{ or } 84.2\%$$

$$G_{Fc} = \frac{1187-145}{1187} = .877 \text{ or } 87.7\%$$

$$G_{Ma} = \frac{8795-1119}{8795} = .872 \text{ or } 87.2\%$$

$$G_{Mb} = \frac{94015-11531}{94015} = .877 \text{ or } 87.7\%$$

$$G_{Mc} = \frac{32957-5499}{32957} = .833 \text{ or } 83.3\%$$

The seismic margin is conservatively chosen the smallest value of the abve G's, or

$$G = G_{Mc} = 83.3\%$$

E. References:

1. Pump Case Analysis For Southern California Edison San Onofre Station, Units 2 And 3, Byron Jackson Report TCF-1025-STR, Vol. 2.

2. Project Specification For Reactor Coolant Pumps For Southern California Edison San Onofre Station, Units 2 And 3, Specification No. 1370-PE-480 Revision 05

3. ASME Boiler AND Pressure Vessel Code Section III, 1977 AND Addenda Through The Winter of 1978.

4. FSAR Table 3.7-23