DESIGN STRESS REPORT

Customer: Bechtel Power Corp., Agents, Gaithersburg, Maryland	Customer P.O. No. PEHA-470
	Customer Item No. 002
Owner: Georgia Power Company	Walworth Order No. LN29977
Project: E.I. Hatch Nuclear Units 1 & 2, Baxley, Georgia	Walworth Item No. 003
Customer Spec. No. GPC P.O. PEHA 470	Rev. 0 Date 1/26/83

Valve Size	ANSI Rating	Figure Number	Valve Type	Assembly Dwg. No. & Rev.	Valve Mark No.
16"	300 lb.	5281WE	Globe	A-8868-M-9B	2E11-F016A,B

Given Data:

Valve Material: SA-216 WCB	Max. Horizontal Acceleration: 3.00
ASME Section III Nuclear Class: 2	Max. Horizontal Acceleration: 3.00
Design Pressure: 450 PSIG	Max. Vertical Acceleration: 3.00
Design Temperature: 225 ^{o}F	Valve Orientation: Pipe Line: Horizontal
Max. Diff. Pressure: 450 PSI	Stem: Horizontal
	Allowable Natural Frequency: 33.0 Hz

Type of Operation: Limitorque SB-3-150

OBJECTIVES AND CONCLUSION: See Page 5.

Prepared by Donald J. Karter Date 12/9/83
Verified by Peter A. Adams Date 12/9/83
Approved by Bruce A. Kasten Date 12/9/83
Certified by John L. Bawley Date 12/9/83
PE Lic. GE15569 State: New Jersey

REVISION PAGE

Rev. No.	Date	Revisions	Prepared By	Verified By	Approved By
0	12/9/83	Initial Report	D.J.K.	P.A.A.	B.a.X.

ALOYCO
CORROSION RESISTANT VALVES

Report No. ADSR-31
Rev. 0

CERTIFICATION PAGE

A. VERIFICATION REVIEW STATEMENT

I have reviewed the Design Calculations and verify that the calculation method used is within the Owner's Certified Design Specification by the following method

- [x] Traditional Hand Calculation Method
- [x] Program Tape Method
- [ ] Other

I, the undersigned verify that this Design Calculation is accurate.

By Peter A. Adams Date 12/9/83

B. DESIGN REPORT REVIEW

I, the undersigned, being a registered Professional Engineer and competent in the applicable field of design and related nuclear power plant requirement, have reviewed this Design Report, and certify that it is based on the Design and Operating conditions stated in the Owner's Certified Design Specification on Page 1 and that the valve design is adequate for the intended service.

Certified by John L. Hawley P.E.
John L. Hawley

Registration No. GE15569 State N.J.

Date 12/9/83

Form NE-33, Rev. B

The Walworth Company ▫ Aloyco Division ▫ 1400 W. Elizabeth Avenue ▫ Linden, New Jersey 07036 ▫ Phone (201) 862-4600

TABLE OF CONTENTS

OBJECTIVES:

To verify that the maximum stress applied at the most highly stressed cross section on valve assembly components such as the body/bonnet flanges, body-to-bonnet bolting, bonnet neck, bonnet-to-yoke bolting, upper and lower yoke arms, and motor-to-yoke bolting due to the specified combined seismic and operational loads do not exceed the allowable stress permitted for the material.

To verify by analysis that the lowest natural frequency of the rigid part of the valve structure is determined to be greater than the allowable natural frequency.

CONCLUSION:

A review of the summary page (6) of this report quickly identifies the areas of the subject valve(s) which are overstressed by replacing the motor operator.

Whereas the lower yoke arm, the Body-Bonnet studs and Motor-Yoke bolting all appear to be stressed over allowables, the Body neck-flange is overstressed far beyond minimum yield strength and very near to the minimum ultimate Tensile Strength. The load conditions that exist on the valve(s) are not acceptable and Georgia Power must remedy the situation by limiting those loads.

SUMMARY OF HIGHEST CALCULATED STRESSES

Stress - PSI

Area Evaluated	Calculated	Allowable	See Page
Body Flange	65,327	26,250	12
Bonnet Neck Root	19,145	26,250	17
Bonnet Neck at Section A-A	9,330	26,250	30
Yoke Structure at Section D-D	9,669	26,250	33
Lower Yoke Arm at Section C-C	27,604	26,250	34
Upper Yoke Arm at Section D-D	11,373	26,250	35
Bonnet/Yoke Bolting at Section N/A	—	—	—
Motor/Yoke Bolting at Section E-E	25,174	25,000	40

NATURAL FREQUENCY DETERMINATION

	Calculated	Nat. Frequency Allowable	See Page
Beam Orientation	17.2	33.0	44
Frame Orientation	36.6	33.0	48

Body/Bonnet Studs: Minimum required Stress area: 26.31 In^2
Actually available stress area: 25.41 In^2

FLANGE ANALYSIS

THE BOLTING AND FLANGE OF THE BOD: TO BONNET JOINT SHALL BE DESIGNED AS FOLLOWS AND SHALL BE IN ACCORDANCE WITH NB-3546.1. AND ARTICLE XI-3000 OF ASME B&PV CODE SECTION III.

FREE BODY DIAGRAM SHOWING THREE DIMENSIONAL SEISMIC, DEAD WEIGHT AND OPERATIONAL LOADS

STEM HORIZONTAL

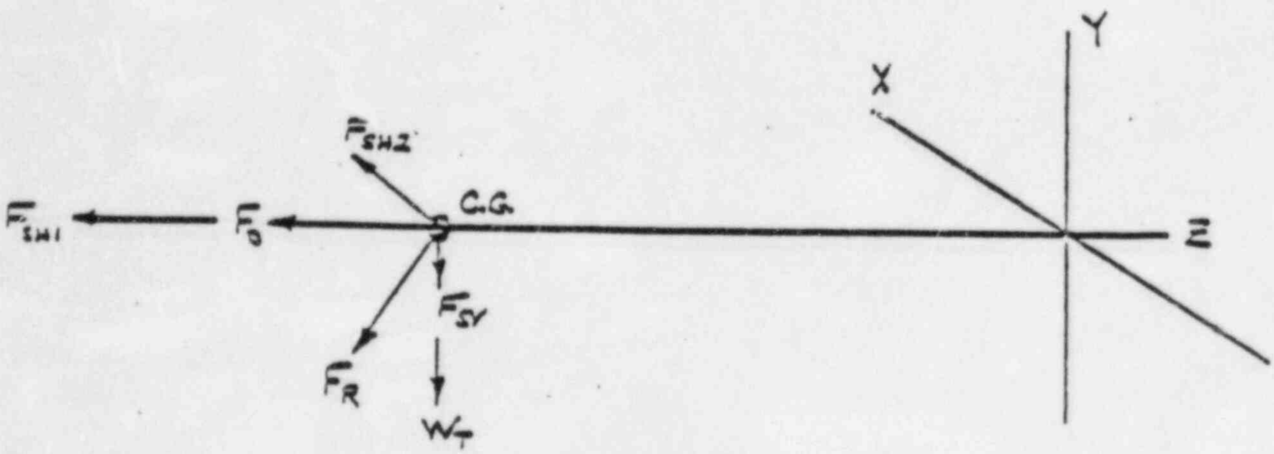


FIGURE A

Flange Analysis

Weight of valve parts above body flange = W_t 2,593.25 lb

Center of gravity above body flange = C. G. 41.01 in

Horizontal seismic acceleration = G_H 3.00

Vertical seismic acceleration = G_V 3.00

Seismic Force = W_tG
Refer to Figure A

Horizontal = F_{SH1} = 7,779.75 lb

= F_{SH2} = 7,779.75

Vertical = F_{SV} = 7,779.75 lb

$F_R = \sqrt{F_{SH2}^2 + (F_{SV} + W_t)^2}$ = 12,966.25

Seismic Moment = M = F_R(C.G.) = 531,745.81 in-lb

F_d = STEM THRUST (OPERATIONAL LOAD)

ORIGIN	~~GATE~~	GLOBE	LOAD = lb.
PRESSURE	~~$.25\pi D^2 \Delta P \tan\alpha$~~	$.25\pi D^2 \Delta P$	80,521.3
SEATING FORCE	~~$.75\pi D \Delta P \sin\emptyset$~~	$.75\pi D\Delta P(\sin\emptyset + \mu\cos\emptyset)$	7,233.8
STEM LOAD	~~$.25\pi d^2 \Delta P$~~		

Seating Angle $\emptyset$ = 15°

Seat Diameter D = 15.094

Stem Diameter d = 3.50

Pressure Diff. ΔP = 450

Friction + Seat Angle α = ———

Tan α = ——— μ = 0.2

F_d = Total Thrust = 87,755.1 lb

STEM THRUST

GLOBE VALVES

Definitions Q_d = Total axial force to close the valve

F_p = Axial force to resist line pressure

= Effective area x fluid pressure

F_s = Axial force at the seat face

= Area of seat edge x *clamping pressure

$$F_p = \frac{\pi}{4} D^2 P$$

$$F_s = (.063)\pi D(\text{Sin}\varnothing + \text{Cos}\varnothing) * 6P(2)$$

$$= .75\pi D(\text{Sin}\varnothing + \mu \text{Cos}\varnothing)P$$

$$Q_d = F_p + F_s$$

$$= \frac{\pi}{4} D^2 P + .75\pi D(\text{Sin}\varnothing + \mu\text{Cos}\varnothing)P$$

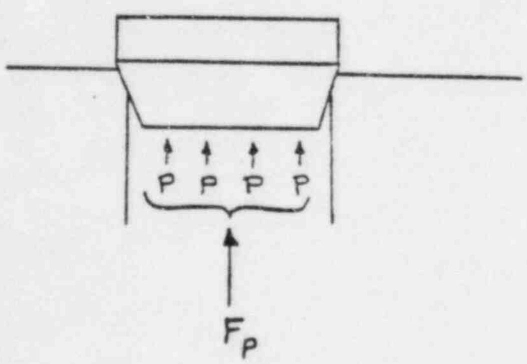
Terms

D = Seat Dia.

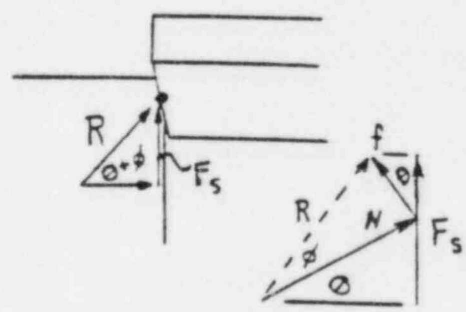
P = Pressure

$\varnothing$ = Seat Angle

μ = Coefficient of Friction



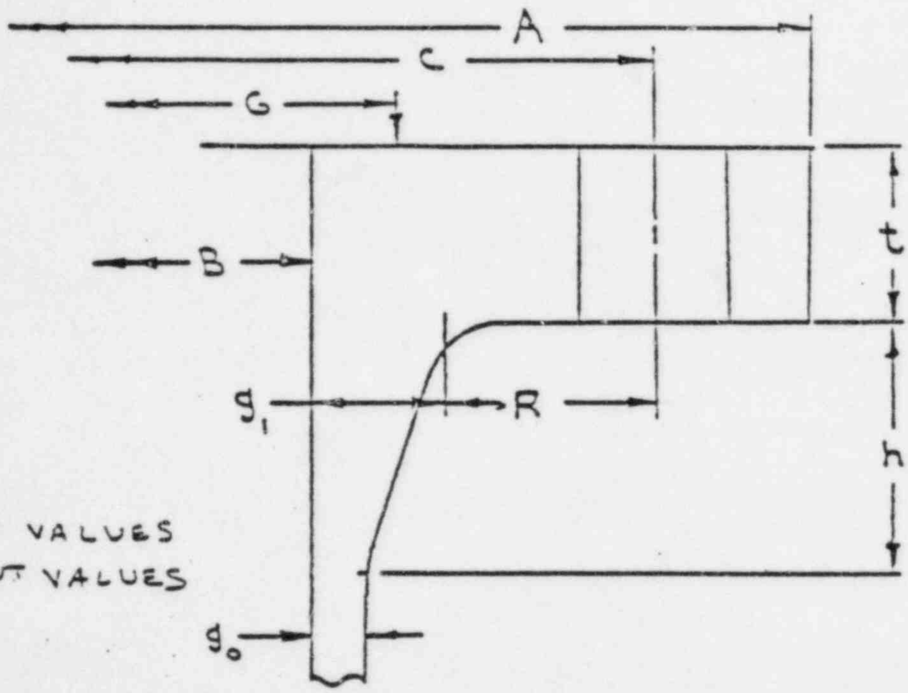
Pressure Force



Seating Force

*The force F_s is similar to the compression load from Article 3-3 Sec. VIII of the ASME Code, therefore the clamping pressure is a multiple of the line pressure. The value 6 is from Table 3-320-1 of Sec. VIII under gasket factor for solid flat metal, 4-6% chrome.

Body Flange



O INPUT VALUES
* OUTPUT VALUES

Reference Drawing Number A-8868-1-3 Material SA-216 WCB

① A = 30.75 in	⑥ t = 2.875 in	⑪ y = 18,000
② B = 18.75 in	⑦ h = 0.0 in	⑫ m = 5.5
③ C = 27.75 in	⑧ P = 450 PSI	*1 G = 20.6708 in
④ g_1 = 1.25 in	*2 b = 0.4146 in	*3 R = 3.25 in
⑤ g_0 = 1.25 in	⑨ A_b = 25.41 in^2	(22) 1 3/8" Dia. Studs
	10 $(F_D + F_{SH_1})$ = 95,535.1 LB	⑬ GASKET OD = 21.500 IN
		⑭ GASKET ID = 18.750 IN
		15 Seis. Mo. = 531,745.8 IN

Allowable Stresses:

Flange
Sa_{f1} @ 100°F = 17,500 psi
Sa_{f2} @ 225°F = 17,500 psi

Bolting
⑯ Sa_{b1} @ 100°F = 25,000 psi
Sa_{b2} @ 225°F = 25,000 psi
A-193 B-7

Flange Design Pressure

$$P_{FD} = P + \frac{16M}{\pi G^3} + \frac{4F_{SH_1}}{\pi G^2} + \frac{4F_D}{\pi G^2} = 1,041.3 \text{ psi}$$

FLANGE ANALYSIS

Body

Calculation No. ADSR-31

M = Longitudinal bending moment caused by seismic force acting at center of mass of upper valve assembly.

F_{SV} = Longitudinal force acting on bonnet caused by the seismic accelerations in t vertical direction.

F_d = Longitudinal force acting on bonnet from reaction to closing force.

Bolt Loading:

Operating	$Wm_1 = P_{FD}\,(.785G^2 + 2\pi bGm)$	657,647.3	lb
Gasket Seating	$Wm_2 = \pi bGy =$	484,603.1	lb

Bolt Area:

Required	$A_m =$ Larger of $\frac{Wm_2}{Sa_{b_1}}$ or $\frac{W_{m_1}}{Sa_{b_2}}$ =	26.31	in^2
Actual	A_b =	25.41	in^2

Flange Design Bolt Load

Operating	$Wm_1 =$	657,647.3	lb
Gasket Seating	$\frac{(A_m+A_b)}{2} S_{a_{b_1}} = W$	646,448.1	lb

Flange Moment Operating Conditions

$M_D = (\pi B^2 P_{FD}/4)(R+.5g_1) =$ 1,114,139.0 in-lb

$M_G = (2\pi bGmP_{FD})(\frac{C-G}{2}) =$ 1,091,525.0 in-lb

$M_T = \frac{\pi}{4}(G^2-B^2)P_{FD}\left[\frac{R+g_1 + .5(C-G)}{2}\right]$ 248,934.3 in-lb

$M_o = M_D + M_G + M_T =$ 2,454,598.0 in-lb

FLANGE ANALYSIS
Body

Calculation No. ADSR-31

Flange Moment Gasket Seating

$M_o = W(C-G).5 =$ 2,288,155.0 in-lb

Shape constants

$K = A/B =$ 1.64 ; $g_1/g_o =$ 1.00 ; $h_o = \sqrt{Bg_o} =$ 4.8412

$h =$ 0.0 ; $h/h_o =$ 0.0 ; $P =$ 450 psi

$T =$ 1.6505 $Z =$ 2.1837 $Y =$ 4.0994 $U =$ 4.5049

$F =$ 0.908920 $V =$ 0.550103 $f =$ 1.000 $e = F/h_o =$ 0.18775

$d = (U/V)h_o g_o^2 =$ 61.94612 $L = \frac{te+1}{T} + \frac{t^3}{d} =$ 1.31653

Flange Stresses:

	Operating	Gasket Seating
Longitudinal Hub Stress:		
$S_H = (fM_o/Lg_1^2B) + (PB/4g_0) =$	65,327.2 psi	61,011.9 psi
Radial Flange Stress:		
$S_R = (1.33te+1)M_o/Lt^2B =$	20,666.6 psi	19,265.2 psi
Tangential Flange Stress:		
$S_T = (YM_o/t^2B) - ZS_R =$	19,797.1 psi	18,454.7 psi

Allowable Stresses:

Operating $1.5Sa_{f_2} =$ 26,250 psi

Gasket Seating $1.5Sa_{f_1} =$ 26,250 psi

$S_R \leq 1.5Sa_f$

$S_T \leq 1.5Sa_f$

Bonnet Neck Root

SYMBOL'S LEGEND

a_o = OUTSIDE RADIUS OF PLATE WHEN MODELED FOR INTERNAL PRESSURE AND OPERATOR'S THRUST.

a_G = OUTSIDE RADIUS OF PLATE WHEN MODELED FOR GASKET SEATING LOADS.

b_o, b_G = INSIDE RADIUS OF PLATE.

C = BOLT CIRCLE DIAMETER

G = EFFECTIVE DIAMETER OF GASKET

q = INTERNAL PRESSURE

r_o = GENERIC RADIUS OF ANULAR LOAD. SUBSCRIPT IDENTIFIES SPECIFIC LOC

t = MINIMUM THICKNESS OF PLATE

T = OPERATOR'S THRUST AS SET ON THE TORQUE SWITCHES

W_T = OPERATOR'S THRUST & SEISMIC LOAD EXPRESSED AS ANULARLY AROUND BONNE

W_G = GASKET'S PRELOAD EXPRESSED AS AN ANULAR LOAD AT THE GASKET'S EFFECTIVE I

b = GASKET'S EFFECTIVE WIDTH.

m = GASKET'S FACTOR AS SPECIFIED BY ASME B&PV Code Section VIII

y = GASKET'S SEATING STRESS AS SPECIFIED BY B&PV Code Section VIII

g_V = VERTICAL SEISMIC ACCELERATION

g_{H_1}, g_{H_2} = THE TWO HORIZONTAL SEISMIC ACCELERATION.

θ = ANGLE OF INCIDENCE OF THE PLATE FROM THE HORIZONTAL PLANE

M ≡ MOMENTS

σ ≡ STRESSES

SUBSCRIPTS

R, T, L ≡ RADIAL, TANGENTIAL, LONGITUDINAL

O ≡ OPERATIONAL LOADING

G ≡ GASKET SEATING REACTION

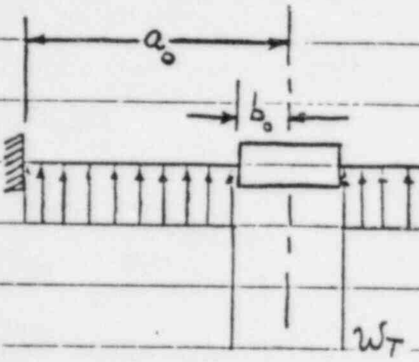
S ≡ SEISMIC

ν = POISSON'S RATIO

REFERENCE :

ROARK'S "FORMULAS FOR STRESS AND STRAIN" 5^{th} EDITION

OPERATING CONDITIONS : CASES 1f PAGE 336 AND 2f PAGE 340 SUPERIMP



$G = 20.671$ INCHES

$a_o = \frac{G}{2} = 10.336$ INC

$b_o = 6.0$ INCHE

$Fd = T = 87{,}755$ LBS

$g_V = g_{H_1} = g_{H_2} = 3.0$

$q = P = 450$ psi

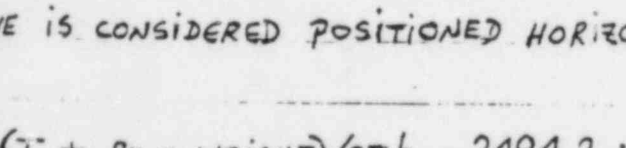
WEIGHT OF VALVE STRUCTURE ABOVE BONNET NECK: 20919 LBS

C.G OF VALVE STRUCTURE ABOVE BONNET NECK: 46.5 INCHES

IF VALVE IS CONSIDERED POSITIONED HORIZONTALLY, THE UNIT BENDING MOMENT AT "b" IS

$W_T = (T + g_{H_2} \times \text{WEIGHT})/2\pi b_o = 2{,}494.2$ LB/IN (PER INCH OF CIRCUMFERENCE)

GASKET SEATING CONDITIONS : CASE 1f PAGE 336



$C = 27.75$ INCHES

$a_G = \frac{C}{2} = 13.875$ INCHE

$b_G = 6.0$ INCHES

$r_{o_G} = G/2 = 10.336$ IN

$m = 5.5$ (UNITLESS FACT

$b = 0.415$ INCHES

GASKET PRELOAD: $W_G = W_m/\pi G = 7{,}470.0$ LBS/IN

$Y = 18{,}000$ psi

W_m = LARGER OF THE TWO W_{m_1} AND W_{m_2}

$W_{m_1} = q\left[\frac{\pi}{4} G^2 + 2\pi b G m\right] + T = 372{,}175$ LBS.

$W_{m_2} = \pi b G Y = 485{,}101$ LBS.

OPERATING STRESSES AT INNER RADIUS "b":

$t_b = 2.375$ INCHES

$M_{R_{b_o}} = M_{R_{b_{o_1}}} + M_{R_{b_{o_2}}} = -w_T a_o \frac{L_6}{C_5} - q a_o^2 \frac{L_{14}}{C_5} = -6,182.7 \frac{\text{IN.·LBS}}{\text{IN}}$

SINCE $\theta = 0$

$M_{T_{b_o}} - \nu M_{R_{b_o}} = -1,854.8 \frac{\text{IN·LBS}}{\text{IN}}$

$\sigma_{R_{b_o}} = \frac{6}{t_b^2} M_{R_{b_o}} = -6,576.6$ PSI

$\sigma_{T_{b_o}} = \frac{6}{t_b^2} M_{t_{b_o}} = -1,973.0$ PSI

$\sigma_{L_{b_o}} = 0$

OPERATING STRESSES AT OUTER RADIUS "a":

$t_a = 2.375$ INCHES

$M_{R_{a_o}} = w_T a_o \left(L_9 - \frac{C_8 L_6}{C_5}\right) + q a_o^2 \left(L_{17} - \frac{C_8 L_{14}}{C_5}\right) = 4,880.8 \frac{\text{IN. LBS}}{\text{IN}}$

$\sigma_{R_{a_o}} = \frac{6}{t_a^2} M_{R_{a_o}} = 5,191.8$ PSI

$\sigma_{T_{a_o}} = \nu M_{R_{a_o}} \frac{6}{t_a^2} = 1,557.5$ PSI

$\sigma_{L_{a_o}} = \frac{1}{t_a}\left[\frac{w_t b_o}{a_o} + \frac{q}{2a_o}\left(a_o^2 - b_o^2\right)\right] = 1,258.9$ PSI

GASKET SEATING LOAD STRESSES AT INNER RADIUS "b"

$t_b \cdot 2.375$ INCHES

$M_{R_{b_G}} = -W_G a_G \frac{L_6}{C_5} = -5,328.9 \quad \frac{IN \cdot LBS}{IN}$

$M_{T_{b_G}} = \nu M_{R_{b_G}} = -1,598.7 \quad \frac{IN \cdot LBS}{IN}$

$\sigma_{R_{b_G}} = \frac{6}{t_b^2} M_{R_{b_G}} = -5,668.4$ PSI

$\sigma_{T_{b_G}} = \frac{6}{t_b^2} M_{t_{b_G}} = -1,700.6$ PSI

$\sigma_{L_{b_G}} = 0$ PSI

GASKET SEATING LOAD STRESSES AT THE OUTER RADIUS "a"

$t_a = 2.125$ INCHES

$M_{R_{a_G}} = W_G \, a_G \left(L_9 - \frac{C_8 L_6}{C_5} \right) = 14,408.7 \quad \frac{IN \cdot LBS}{IN}$

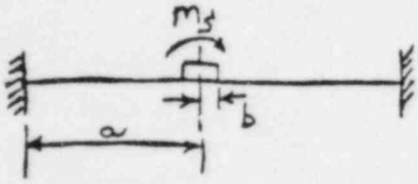
$M_{T_{a_G}} = \nu M_{R_{a_G}} = 4,322.6 \quad \frac{IN \cdot LBS}{IN}$

$\sigma_{R_{a_G}} = \frac{6}{t_a^2} M_{R_{a_G}} = 19,145.1$ PSI

$\sigma_{T_{a_G}} = \frac{6}{t_a^2} M_{t_{a_G}} = 5,743.5$ PSI

$\sigma_{L_{a_G}} = \frac{1}{t_a} \left[\frac{W_G \, b_G}{a_G} \right] = 1,520.1$ PSI

SEISMIC LOAD STRESSES: CASE 21 PAGE 368



$t_a = 2.375$ INCHES
$t_b = 2.375$ INCHES
$a = 10.336$ INCHES
$b = 6.0$ INCHES
$b/a = 0.58$

WEIGHT OF VALVE STRUCTURE ABOVE BONNET NECK : $W = 2091.9$ LBS

C.G. " " " " " " : 46.5 INCHES

$g_V = 3.0;\ g_H = 3.0;\ g = \sqrt{3+3} = 4.24$

$M_S = (4.24)(46.5)(2091.9) = 412{,}439$ IN·LBS
$g \times C.G. \times W$

AT INNER RADIUS "b" $\sigma_{R_{b_S}} = \dfrac{\beta M_S}{a t_b^2} = 5{,}857.5$ PSI

$\beta = 0.828$ INTERPOLATED FROM CASE21'S TABLE

AT OUTER RADIUS "a" $\sigma_{R_{a_S}} = \dfrac{\beta r_o M_S}{a^2 t_a^2} = 3{,}400.2$ PSI

$r_o = b$

SUMMARY OF STRESSES :
BONNET NECK

OPERATIONAL & SEISMIC	GASKET SEATING
$\sigma_{R_b} = \sigma_{R_{b_o}} + \sigma_{R_{b_S}} = \lvert 6576.5\rvert + \lvert 5857.5\rvert = \lvert 12{,}434.1\rvert$ PSI	$\sigma_{R_b} = -5668.4$ PSI
$\sigma_{T_b} = -1973.0$ PSI	$\sigma_{T_b} = -1700.6$ PSI
$\sigma_{L_b} = 0$ PSI	$\sigma_{L_b} = 0$ PSI
$\sigma_{R_a} = \sigma_{R_{a_o}} + \sigma_{R_{a_S}} = \lvert 5191.8\rvert + \lvert 3400.2\rvert = \lvert 8592.0\rvert$ PSI	$\sigma_{R_a} = 19{,}145.1$ PSI
$\sigma_{T_a} = 1557.5$ PSI	$\sigma_{T_a} = 5{,}743.5$ PSI
$\sigma_{L_a} = 1258.9$ PSI	$\sigma_{L_a} = 1{,}520.1$ PSI

Plate Constants:

		operating	gasket seating
$C_5 = \frac{1}{2}\left[1-\left(\frac{b}{a}\right)^2\right]$;	$C_5 =$	0.3315	0.4065
$C_8 = \frac{1}{2}\left[1+\nu+(1-\nu)\left(\frac{b}{a}\right)^2\right]$;	$C_8 =$	0.7679	0.7154

Load Constants: for operating conditions $r_o = b$ for both pressure and operators thrust loading, for gasket seating $r_o = \frac{G}{2}$

$L_6 = \frac{r_o}{4a}\left[\left(\frac{r_o}{a}\right)^2 - 1 + 2\ln\frac{a}{r_o}\right]$;	$L_6 =$	0.0616	0.0209
$L_9 = \frac{r_o}{a}\left\{\frac{1+\nu}{2}\ln\frac{a}{r_o} + \frac{1-\nu}{4}\left[1-\left(\frac{r_o}{a}\right)\right]\right\}$;	$L_9 =$	0.2478	0.1758
$L_{14} = \frac{1}{16}\left[1-\left(\frac{r_o}{a}\right)^4 - 4\left(\frac{r_o}{a}\right)^2\ln\frac{a}{r_o}\right]$;	$L_{14} =$	0.0096	N/A
$L_{17} = \frac{1}{4}\left\{1-\frac{1-\nu}{4}\left[1-\left(\frac{r_o}{a}\right)^4\right] - \left(\frac{r_o}{a}\right)^2\left[1+(1+\nu)\ln\frac{a}{r_o}\right]\right\}$;	$L_{17} =$	0.0674	N/A

YOKE SEISMIC STRESS SYMBOLS

P = Design Pressure

A = Cross-Sectional Area of Section (other than Bolting)

A_T = Cross-Sectional Area per Bolt

C = Distance from Neutral Axis to Outer Fiber

D = Seat Bore Diameter

d = Stem Diameter

F_D = Direct or Operational Force

F_{SV} = Vertical Seismic Force

F_{SH} = Horizontal Seismic Force

G_H = Horizontal Seismic Acceleration

G_V = Vertical Seismic Acceleration

I = Moment of Inertia

b = Tipping Moment Arm for Bolting

M_{SV} = Vertical Seismic Moment

M_{SH} = Horizontal Seismic Moment

ΔP = Maximum Pressure Differential

W_T = Total Weight of Components Above Section

$\bar{Y}$ = Center of Gravity of Combined Components

Z = Section Modulus

μ = Coefficient of Friction

α = Seating Angle + Friction Angle

ϕ = Seating Angle

σ_{FD} = Stress from Direct Force

σ_{MD} = Stress from Direct Moment

σ_{SV} = Stress from Vertical Seismic Force

σ_{SH_1} = Stress from Horizontal Seismic Force

σ_{SH_2} = Stress from Structure Analysis

σ_T = Total Resultant Stress

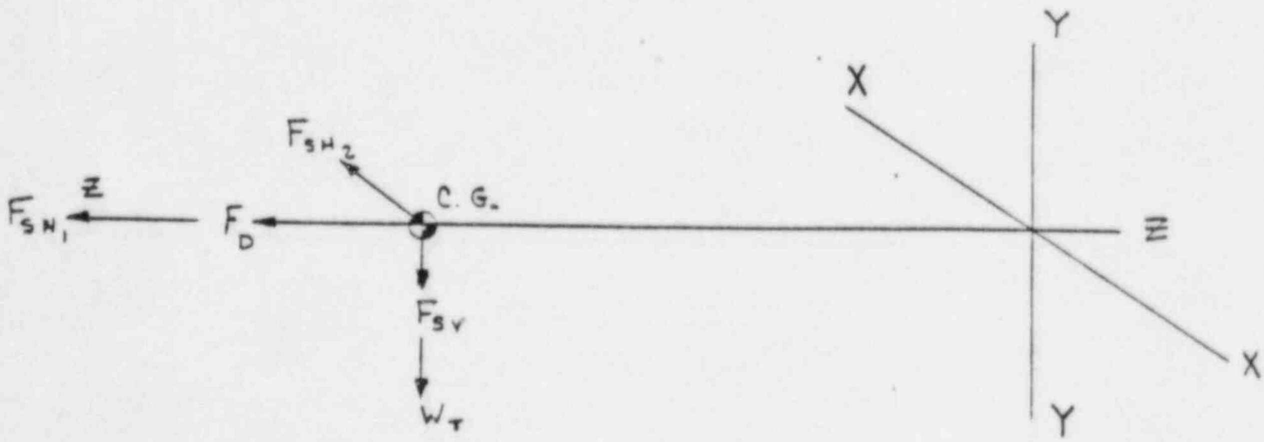
S_a = Allowable Stress, ASME Section III, Table I-7

ORIENTATION #1

SUMMARY OF RESULTANT STRESS

SECTION	TOTAL RESULTANT STRESS (σ_T) psi
A-A bonnet neck	9,330
C-C yoke leg bottom	27,604
motor / Yoke bolting	25,174

FREE BODY DIAGRAM SHOWING THREE DIMENSIONAL SEISMIC, DEAD WEIGHT AND OPERATIONAL LOADS



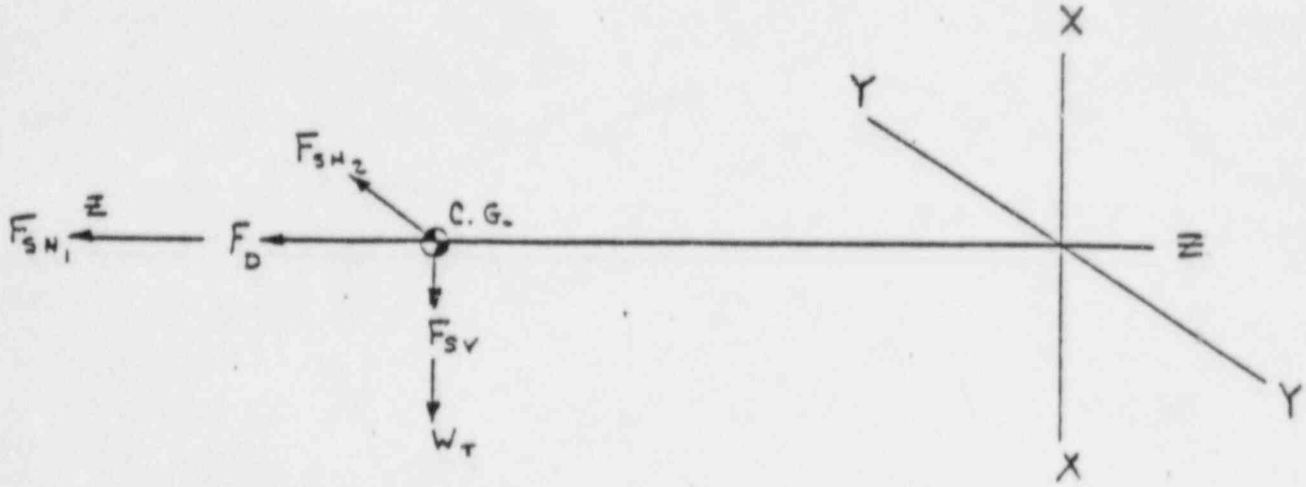
It has been determined that the above orientation results in the greatest stress.

ORIENTATION #2

SUMMARY OF RESULTANT STRESS

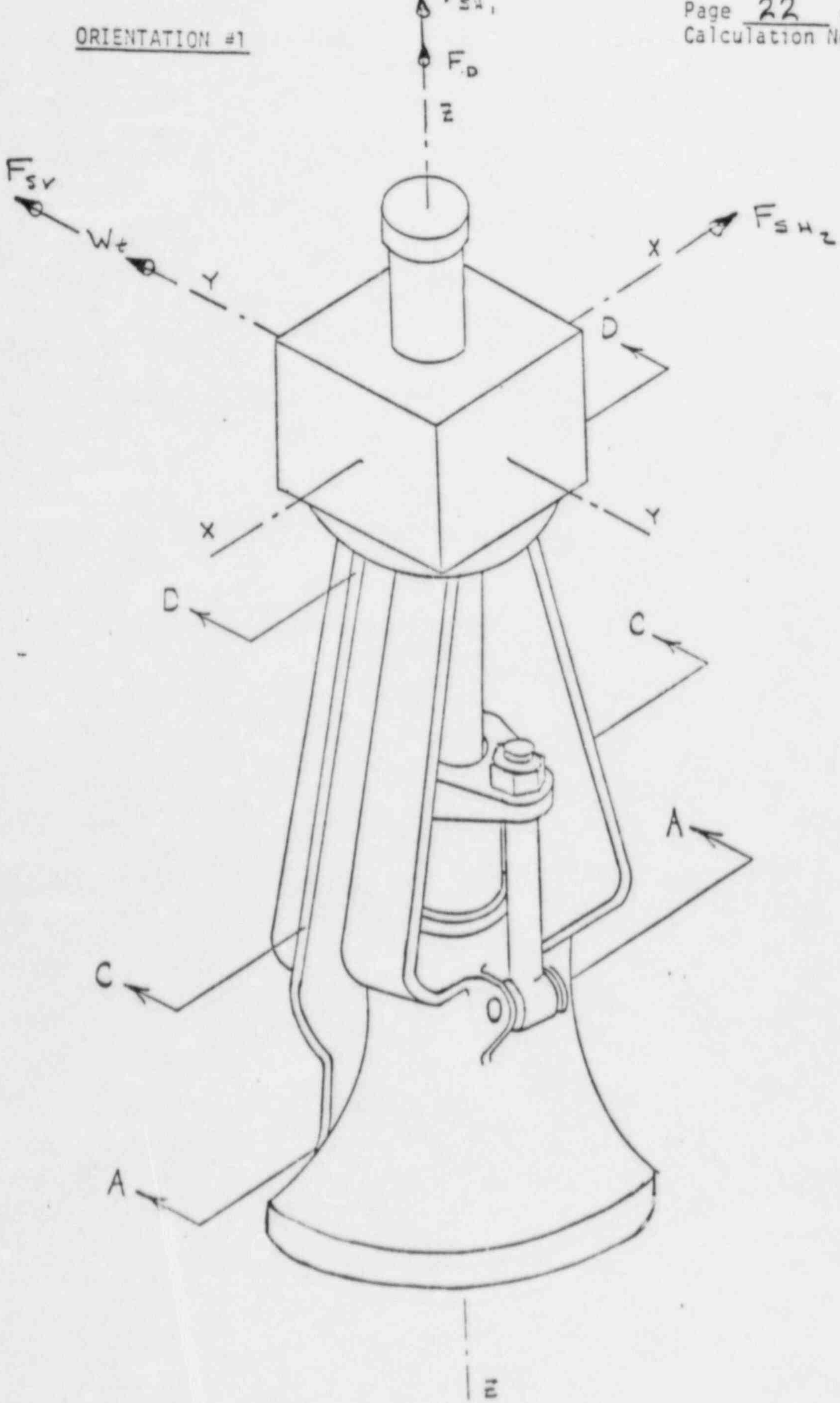
SECTION	TOTAL RESULTANT STRESS (σ_T) psi
D-D yoke leg top	11,373

FREE BODY DIAGRAM SHOWING THREE DIMENSIONAL SEISMIC, DEAD WEIGHT AND OPERATIONAL LOADS



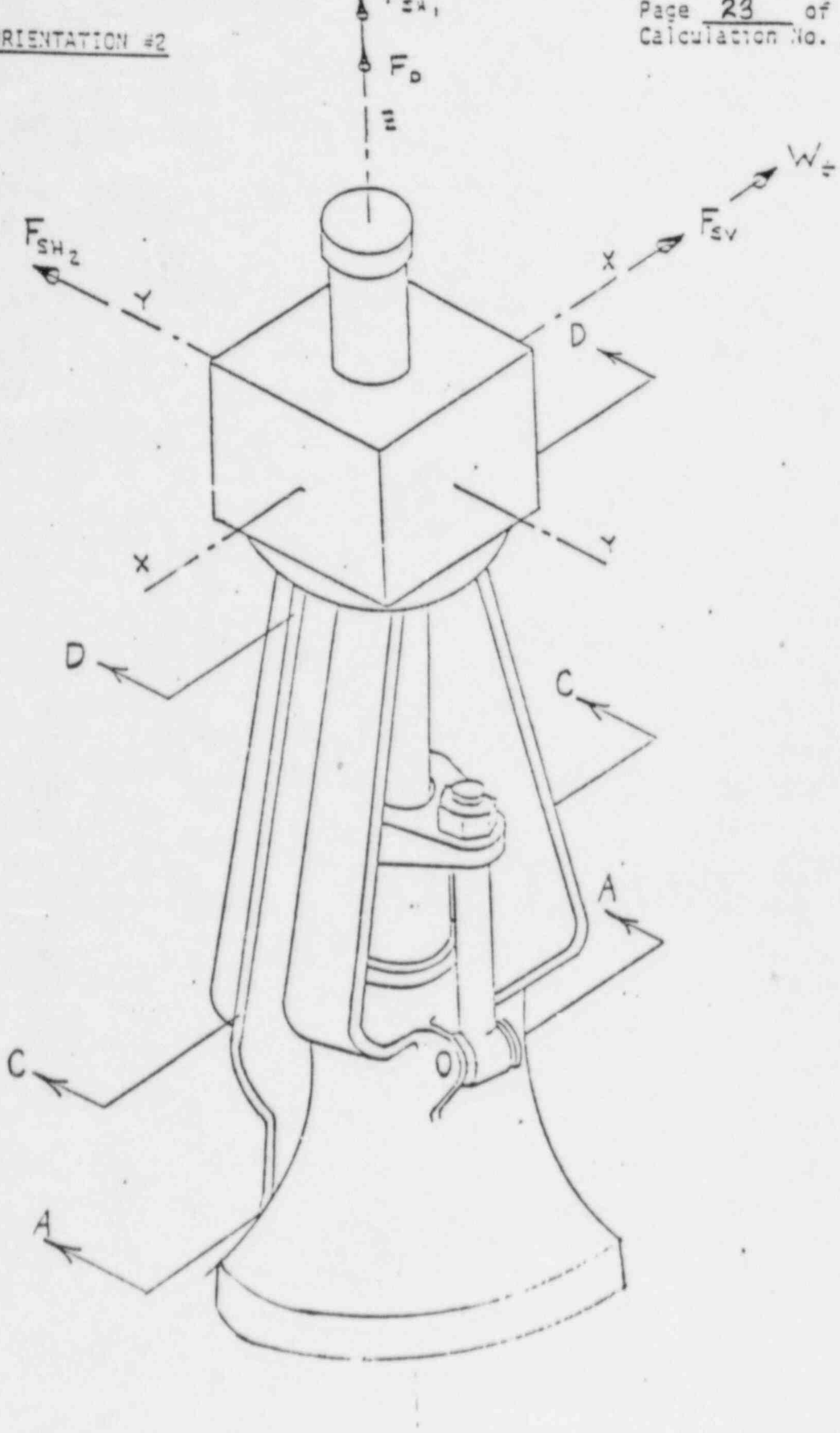
It has been determined that the above orientation results in the greatest stress.

ORIENTATION #1



SECTION LOCATIONS

ORIENTATION #2



SECTION LOCATIONS

CROSS SECTIONAL PROPERTIES

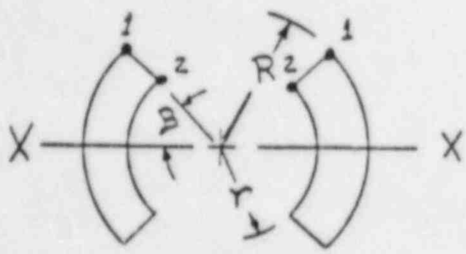


FIG. A

β In Radians

Except in Trig. Functions

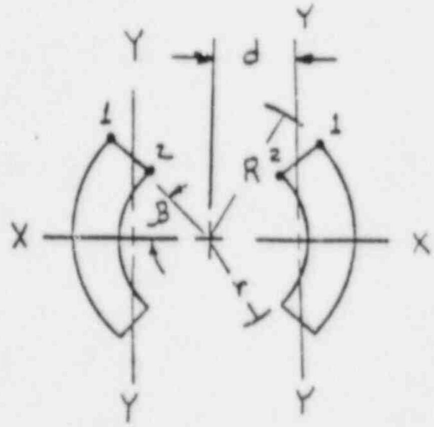


FIG. B

where d =

$$\frac{0.66666\ (R^3 - r^3)\sin\beta}{(R^2 - r^2)\ \beta}$$

β in Radians Except in Trig. Functions

VAR.	FIG. A (REF. 6)
I_{x-x} [In.^{4}]	$\left[\frac{R^4-r^4}{2}\right]\left[\beta-\sin\beta\cos\beta\right]$
Point 1 C_1 [In.]	$R\sin\beta$
Point 2 C_2 [In.]	$r\sin\beta$
Z [In.^{3}]	I/C
A [In.^{2}]	$2\beta(R^2-r^2)$

(Two Segments)

VAR.	FIG. B (REF. 4)
I_{y-y} [In.^{4}]	$\left[\frac{R^4-r^4}{4}\right]\left[\beta+\sin\beta\cos\beta\right]-Ad^2$
Point 1 C_1 [In.]	$R\cos\beta-d$
Point 2 C_2 [In.]	$r\cos\beta-d$
Z [In.^{3}]	I/C
A [In.^{2}]	$\beta(R^2-r^2)$

(One Segment)

CROSS SECTIONAL PROPERTIES

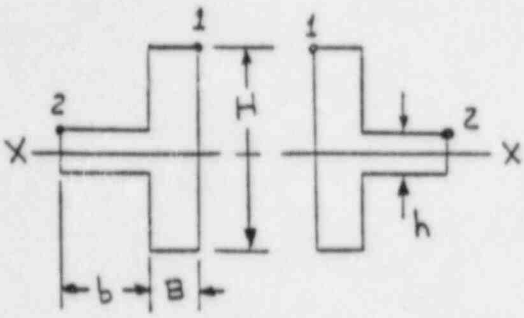


FIG. C

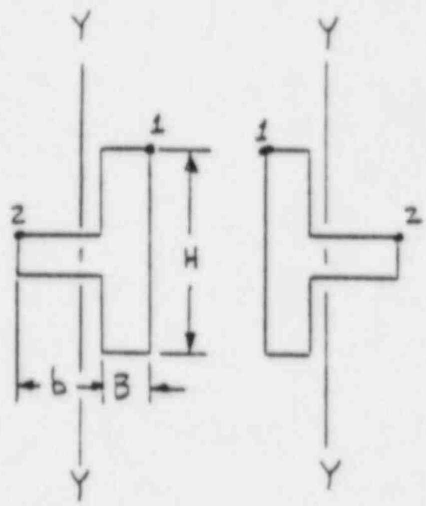


FIG. D

VAR.	FIG. C (REF. 8)
I_{x-x} [In.^{4}]	$BH^3/6+bh^3/6$
Point 1 C_1 [In.]	$H/2$
Point 2 C_2 [In.]	$h/2$
Z [In.^{3}]	I/c
A [In.^{2}]	$2BH+2bh$

(Two Segments)

VAR.	FIG. D (REF. 9)
Point 1 I_{y-y} [In.^{4}]	$\frac{1}{3}\left[(B+b-C_1)^3h+(C_1)^3(H)-(C_1-B)^3(H-h)\right]$
Point 2 I_{y-y} [In.^{4}]	$\frac{1}{3}\left[(C_2)^3h+(B+b-C_2)^3(H)-(b-C_2)^3(H-h)\right]$
Point 1 C_1 [In.]	$\frac{B^2(H-h)+h(B+b)^2}{2A}$
Point 2 C_2 [In.]	$(B+b)-\left[\frac{B^2(H-h)+h(B+b)^2}{2A}\right]$
Z [In.^{3}]	I/c
A [In.^{2}]	$BH+bh$

(One Segment)

CROSS SECTIONAL PROPERTIES

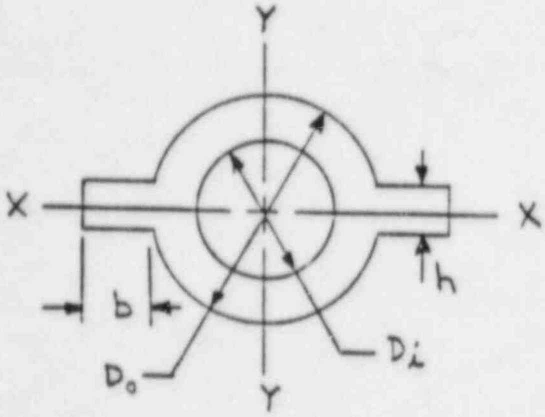


FIG. E

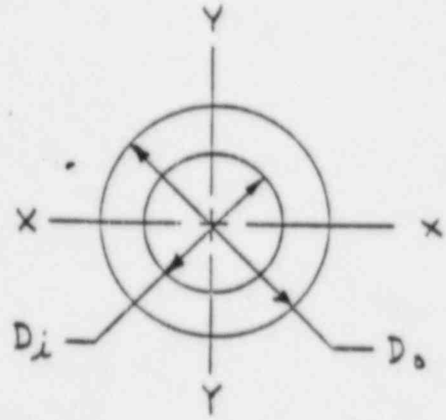


FIG. F

VAR.	FIG. E (REF. 8)	FIG. F (REF. 8)
I_{x-x} [In.^{4}]	$\frac{\pi}{64}(D_0^4-D_i^4)+bh^3/6$	$\frac{\pi}{64}(D_0^4-D_i^4) = I_{x-x}$ or I_{y-y}
C [In.]	$D_0/2$	$D_0/2$
Z [In.^{3}]	I/C	I/C
A [In.^{2}]	$(\pi/4)(D_0^2-D_i^2)+2bh$	$(\pi/4)(D_0^2-D_i^2)$
I_{y-y} [In.^{4}]	$(\pi/64)(D_0^4-D_i^4)+\left[\frac{hb^3}{6}+(2bh)\left(\frac{D_0}{2}+\frac{b}{2}\right)^2\right]$	

POINTS OF HIGHEST STRESS

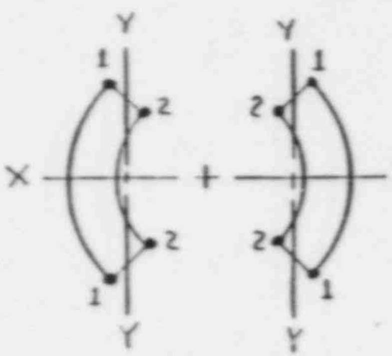


FIG. A & B

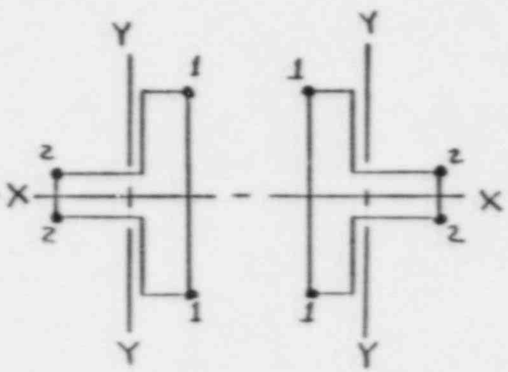


FIG. C & D

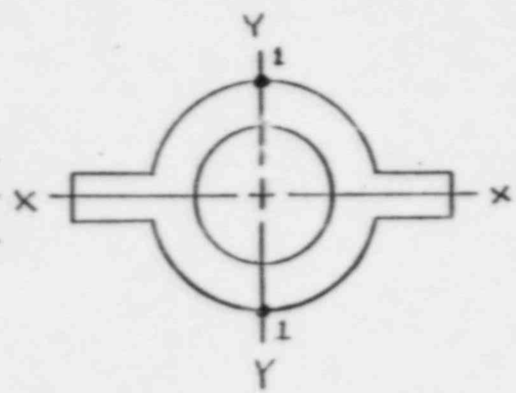


FIG. E

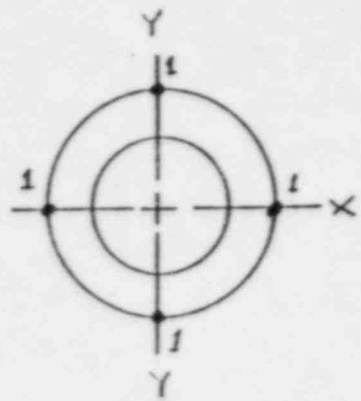


FIG. F

POINT 1 OF FIG. C HAS THE HIGHEST STRESS

PROPERTIES TABLE

@ Pt. #1

	SEC. A-A	SEC. C-C	SEC. C-C	SEC. E-E	SEC.
	Description: Bonnet neck FIG. F	Description: yoke leg bottom FIG. C	Description: yoke leg structure FIG. D	Description: Yoke plate structure FIG. F	Description: FIG.
	D_o = 8.00 D_I = 4.781	B = 0.750 H = 6.500 b = 2.625 h = 0.750	B = 0.750 H = 6.500 b = 2.625 h = 0.750 m = 6.25 ℓ = 10.50 s = 29.358 h_1 = 29.281	D_o = 16.0000 D_I = 3.7500	
I_{x-x}	175.4139	34.5126	———	———	
I_{y-y}	———	———	5.3525	3207.2803	
C	4.0000	3.2500	0.8604	8.000	
Z	43.8535	10.6193	6.2207	400.9099	
A	32.3128	13.6875	6.8438	190.0171	
Wt.	2091.91	1903.62	1903.62	1560.00	
$\bar{Y}$	46.46	36.77	36.77	9.30	

PROPERTIES TABLE

@ Pt. #2

	SEC. D-D	SEC. D-D	SEC. E-E	SEC.	SEC.
	Description: yoke leg top FIG. C	Description: yoke leg structure FIG. D	Description: yoke plate structure FIG. F	Description: FIG.	Description: FIG.
	B = 0.75 H = 6.5 b = 3.875 h = 0.75	B = 0.75 H = 6.5 b = 3.875 h = 0.75 m = 6.25 ℓ = 10.5 s = 29.358 h_1 = 29.281	D_o = 16.0 D_I = 3.75		
I_{x-x}	34.6005	———	———		
I_{y-y}	———	13.602	3207.2803		
C	0.375	3.3863	8.000		
Z	92.2679	4.0168	400.9099		
A	15.5625	7.7813	190.0171		
Wt.	1673.99	1673.99	1560.00		
$\bar{Y}$	10.43	10.43	9.30		

RESULTANT SEISMIC STRESS FOR SECTION A-A
bonnet neck

Dead Weight and Vertical Seismic Load:

Direct Moment: $W_t\bar{Y} = M_{FD} =$ 97,190.1 in-lb.
Direct Stress: $M_{FD}/Z = \sigma_{MD} =$ 2,216.2 PSI

Vertical Seismic Load: $G_V =$ 3.00
Vertical Seismic Force: $W_tG_V = F_{SV} =$ 6,275.7 lb.
Vertical Seismic Moment: $F_{SV}\bar{Y} = M_{SV} =$ 291,570.2 in-lb.
Vertical Seismic Stress: $M_{SV}/Z = \sigma_{SV} =$ 6,648.7 PSI

Operational and Horizontal Seismic Load (F_{SH_1})

Direct Force: $F_D =$ 87,755.3 lb.
Direct Stress: $F_D/A = \sigma_{FD} =$ 2,715.8 PSI

Horizontal Seismic Load: $G_H =$ 3.00
Horizontal Seismic Force: $W_tG_H = F_{SH_1} =$ 6,275.7 lb
Horizontal Seismic Stress: $F_{SH_1}/A = \sigma_{SH_1} =$ 194.2 PSI

Horizontal Seismic Load (F_{SH_2})

From Structure Analysis Pg. — $\sigma_{SH_2} =$ N/A PSI

Total Stress

$$\sqrt{(\sigma_{MD} + \sigma_{SV})^2 + (\sigma_{FD} + \sigma_{SH_1})^2 + (\sigma_{SH_2})^2} = \sigma_T = 9330.4 \text{ PSI}$$

Allowable Stress: $^*S_A = 1.5\, S_a =$ 26,250 PSI

$^*S_a =$ 17,500 For SA-216 Gr WCB at 225 °F

STRUCTURE ANALYSIS

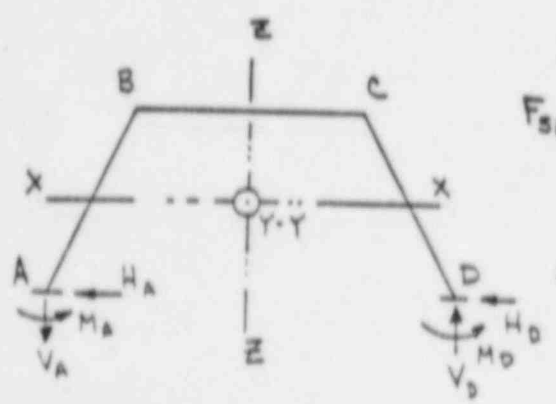
ASSUMPTIONS:-

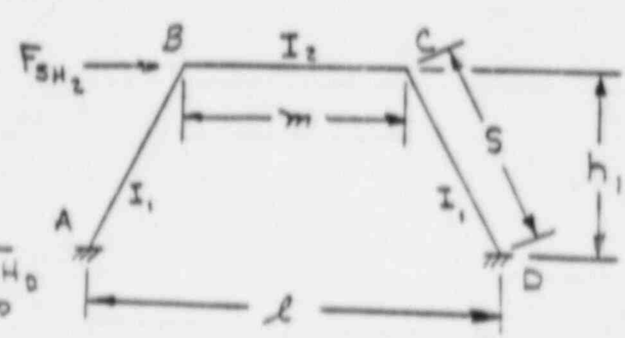
1. Structure consist of rigid supports with no rotation or displacements.

2. The influence of different moment of inertia is taken care of by using the stiffness coefficient K. It is assumed that the moment of inertia of any member remains constant.

SYMBOLS:-

A, B, C, D	= Special Points of the Frame.
I_1, I_2	= Moment of Inertia.
K	= Reciprocal of Stiffness Coefficients.
M_A, M_B, M_C, M_D	= Bending Moments.
H_A, H_D	= Horizontal Reactions.
V_A, V_D	= Vertical Reactions.
λ	= Dimensionless Length = m/ℓ
N_2	= Denominator in the Formulus for Determining Statically Indeterminate Quantities.
K_2	= Constant from "Rigid Frame Formulas" A. Kleinlogel, Pg. 272.





ORIENTATION #1
(1) Pt. #1

STRUCTURE ANALYSIS:-

$(I_2/I_1)\ (S/m) = K = \underline{2814.6401}$

$(m/\ell) = \lambda = \underline{0.5952}$

$K(1+\lambda)+\lambda(1+K) = K_2 = \underline{6165.9922}$

$2(1+\lambda+\lambda^2)K+\lambda^2 = N_2 = \underline{10974.8906}$

$W_tG_h = F_{SH_2} = \underline{5710.86}$

$Z = \underline{6.2207}$

SECTION C-C :-

BENDING MOMENT:-

$$\frac{-F_{SH_2}h_1\lambda K_2}{2N_2} = M_a = -M_d = \underline{27960.85} \text{ in-lb.}$$

STRESS:-

$$M/Z = \sigma_{SH_2} = \underline{4494.83} \text{ PSI}$$

SECTION N/A :-

BENDING MOMENT:-

$$\frac{F_{SH_2}h_1\lambda K(2+\lambda)}{2N_2} = M_b = -M_c = \underline{\quad\text{—}\quad} \text{ in-lb.}$$

STRESS:-

$$M/Z = \sigma_{SH_2} = \underline{\quad\text{—}\quad} \text{ PSI}$$

ORIENTATION #2
@ Pt. #2

STRUCTURE ANALYSIS:-

(I_2/I_1) (S/m) = K = 1107.5911

(m/ℓ) = λ = 0.5952

$K(1+\lambda)+\lambda(1+K)$ = K_2 = 2426.7463

$2(1+\lambda+\lambda^2)K+\lambda^2$ = N_2 = 4318.9492

W_T = 1673.99

$W_tG_v = F_{SV}$ = 5021.97

Z = 4.0168

SECTION N/A :-

BENDING MOMENT:-

$$\frac{(W_T+F_{SV})\ h_1\lambda K_2}{2N_2} = M_a = -M_d = \text{———} \text{ in-lb.}$$

STRESS:-

$M/Z = \sigma_{SV} =$ ——— PSI

SECTION D-D :-

BENDING MOMENT:-

$$\frac{(W_T+F_{SV})\ h_1\lambda K(2+\lambda)}{2N_2} = M_b = -M_c = 38836.26 \text{ in-lb.}$$

STRESS:-

$M/Z = \sigma_{SV}$ = 9668.50 PSI

ORIENTATION #1
@ Pt. #1

RESULTANT SEISMIC STRESS FOR SECTION C-C
yoke leg bottom

Dead Weight and Vertical Seismic Load:

Direct Moment: $W_t \bar{Y} = M_{FD} =$ 69996.1 in-lb.
Direct Stress: $M_{FD}/Z = \sigma_{MD} =$ 6591.4 PSI

Vertical Seismic Load: $G_V =$ 3.00
Vertical Seismic Force: $W_t G_V = F_{SV} =$ 5710.9 lb.
Vertical Seismic Moment: $F_{SV}\bar{Y} = M_{SV} =$ 209988.2 in-lb.
Vertical Seismic Stress: $M_{SV}/Z = \sigma_{SV} =$ 19774.3 PSI

Operational and Horizontal Seismic Load (F_{SH_1})

Direct Force: $F_D =$ 87755.3 lb.
Direct Stress: $F_D/A = \sigma_{FD} =$ 6411.3 PSI

Horizontal Seismic Load: $G_H =$ 3.00
Horizontal Seismic Force: $W_t G_H = F_{SH_1} =$ 5710.9 lb
Horizontal Seismic Stress: $F_{SH_1}/A = \sigma_{SH_1} =$ 417.2 PSI

Horizontal Seismic Load (F_{SH_2})

From Structure Analysis Pg. 32 $\sigma_{SH_2} =$ 4494.8 PSI

Total Stress

$$\sqrt{(\sigma_{MD} + \sigma_{SV})^2 + (\sigma_{FD} + \sigma_{SH_1})^2 + (\sigma_{SH_2})^2} = \sigma_T = 27604.0 \text{ PSI}$$

Allowable Stress: $^*S_A = 1.5\ S_a =$ 26250 PSI

$^*S_a =$ 17,500 For SA-216 Gr WCB at 100 °F

ORIENTATION #2
@ Pt. #2

RESULTANT SEISMIC STRESS FOR SECTION D-D
yoke leg top

Horizontal Seismic Load (σ_{SH_2})

Horizontal Seismic Load: G_H = 3.00
Horizontal Seismic Force: $W_tG_H = F_{SH_2}$ = 5022.0 lb.
Horizontal Seismic Moment: $F_{SH_2}\bar{y} = M_{SH_2}$ = 52,379.1 in-lb.
Horizontal Seismic Stress: $M_{SH_2}/Z = \sigma_{SH_2}$ = 567.7 PSI

Operational and Horizontal Seismic Load (F_{SH_1})

Direct Force: F_D = 87,755.3 lb.
Direct Stress: $F_D/A = \sigma_{FD}$ = 5,638.9 PSI

Horizontal Seismic Load: G_H = 3.00
Horizontal Seismic Force: $W_tG_H = F_{SH_1}$ = 5022.0 lb
Horizontal Seismic Stress: $F_{SH_1}/A = \sigma_{SH_1}$ = 322.7 PSI

Dead Weight and Vertical Seismic Load:

From Structure Analysis Pg. 33 σ_{SV} = 9668.5 PSI

Total Stress

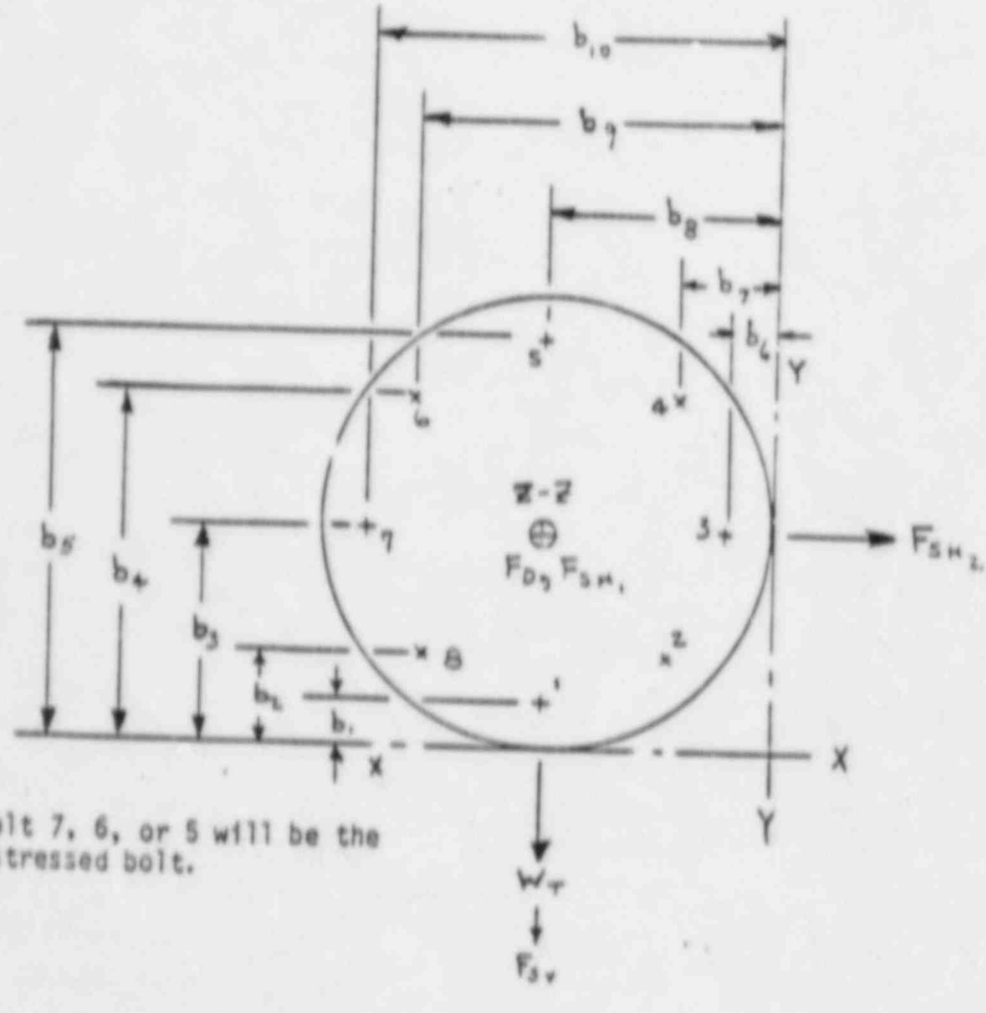
$$\sqrt{(\sigma_{SH_2})^2 + (\sigma_{FD} + \sigma_{SH_1})^2 + (\sigma_{SV})^2} = \sigma_T = 11,372.9 \text{ PSI}$$

Allowable Stress: *S_A = 1.5 S_a = 26,250 PSI

*S_a = 17,500 For SA-216 Gr WCB at 100 °F

Motor Unit-To-Yoke Bolting Stresses

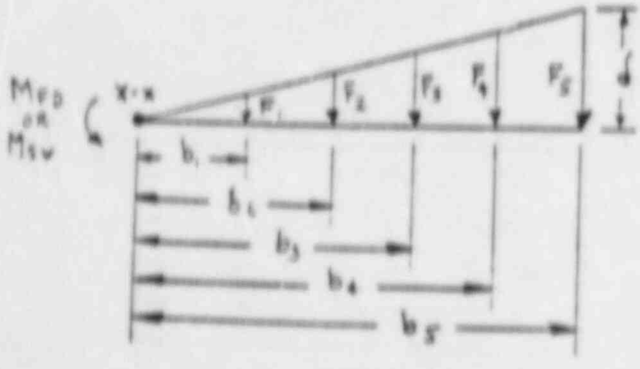
**8 Bolt Unit



** Either Bolt 7, 6, or 5 will be the highest stressed bolt.

① Dead Weight and Vertical Seismic Load:

* Assume Loading Attempts Rotation about x-x Axis.



F_5 acts on Bolt 5

F_4 acts on Bolts 4 & 6

F_3 acts on Bolts 3 & 7

F_2 acts on Bolts 2 & 8

F_1 acts on Bolt 1

MOTOR UNIT-TO-YOKE BOLTING

(1) $\Sigma M_{x-x} \Rightarrow M_{FD}$ or $M_{SV} = F_5b_5+F_4b_4+F_3b_3+F_2b_2+F_1b_1$

(2) $\frac{\delta_1}{b_1} = \frac{\delta_2}{b_2} = \frac{\delta_3}{b_3} = \frac{\delta_4}{b_4} = \frac{\delta_5}{b_5}$

where

$\delta = \frac{FL}{AE}$ = bolt deflection

The length (L), Area (A) and modulus of elasticity (E) are the same for all 8 bolts; thus:

(3) $\frac{F_1}{b_1} = \frac{F_2}{b_2} = \frac{F_3}{b_3} = \frac{F_4}{b_4} = \frac{F_5}{b_5}$

Putting eq. (1) in terms of F_5

(4) M_{FD} or $M_{SV} = F_5 \left(\frac{b_5^2}{b_5} + \frac{b_4^2}{b_5} + \frac{b_3^2}{b_5} + \frac{b_2^2}{b_5} + \frac{b_1^2}{b_5}\right)$ (for Bolt 5)

Putting eq. (1) in terms of F_4

(5) M_{FD} or $M_{SV} = F_4 \left(\frac{b_5^2}{b_4} + \frac{b_4^2}{b_4} + \frac{b_3^2}{b_4} + \frac{b_2^2}{b_4} + \frac{b_1^2}{b_4}\right)$ (for Bolts 4 & 6)

Putting eq. (1) in terms of F_3

(6) M_{FD} or $M_{SV} = F_3 \left(\frac{b_5^2}{b_3} + \frac{b_4^2}{b_3} + \frac{b_3^2}{b_3} + \frac{b_2^2}{b_3} + \frac{b_1^2}{b_3}\right)$ (for Bolts 3 & 7)

Direct Moment: $W_T\bar{Y} = M_{FD}$ = 14,508 in-lb

Direct Stress:

(4) $\frac{M_{FD}}{A_T} \left(\frac{b_5}{(b_5^2+b_1^2)+2(b_2^2+b_3^2+b_4^2)}\right)$ = (Bolt 5) σ_{MD} = 665.30 PSI

(5) $\frac{M_{FD}}{A_T} \left(\frac{b_4}{(b_5^2+b_1^2)+2(b_2^2+b_3^2+b_4^2)}\right)$ = (Bolts 4 & 6) σ_{MD} = 574.38 PSI

(6) $\frac{M_{FD}}{A_T} \left(\frac{b_3}{(b_5^2+b_1^2)+2(b_2^2+b_3^2+b_4^2)}\right)$ = (Bolts 3 & 7) σ_{MD} = 354.83 PSI

(Use Highest Stress)

Vertical Seismic Force: $W_T G_V = F_{SV}$ 4,680 lb

Vertical Seismic Moment: $F_{SV}\bar{Y} = M_{SV} =$ 43,524 in-lb

Vertical Seismic Stress:

(4) $\frac{M_{SV}}{A_T}\left(\frac{b_5}{(b_5^2+b_1^2)+2(b_2^2+b_3^2+b_4^2)}\right) =$ (Bolt 5) $\sigma_{SV} =$ 1,995.90 PSI

(5) $\frac{M_{SV}}{A_T}\left(\frac{b_4}{(b_5^2+b_1^2)+2(b_2^2+b_3^2+b_4^2)}\right) =$ (Bolts 4 & 6) $\sigma_{SV} =$ 1,723.13 PSI

(6) $\frac{M_{SV}}{A_T}\left(\frac{b_3}{(b_5^2+b_1^2)+2(b_2^2+b_3^2+b_4^2)}\right) =$ (Bolts 3 & 7) $\sigma_{SV} =$ 1,064.48 PSI

(Use Highest Stress)

② Operational and Horizontal Seismic Load (F_{SH_1}):

Direct Force: $F_D =$ 87,755.3 lb

Direct Stress:

$\frac{F_D}{8A_T} = \sigma_{FD} =$ 23,743.32 PSI

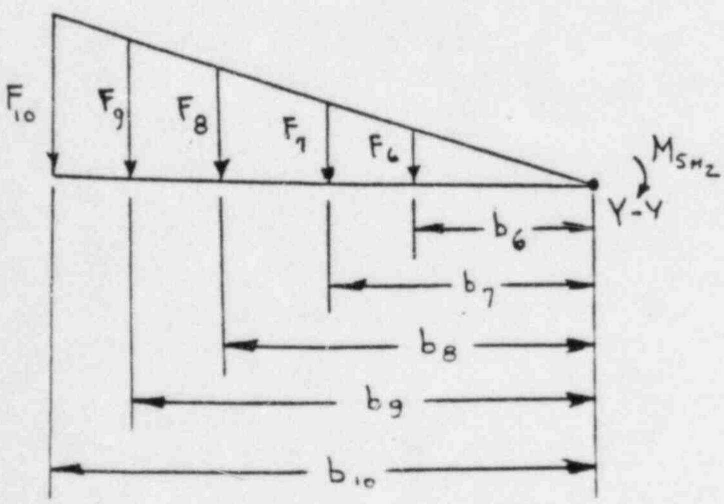
Horizontal Seismic Force: $W_T G_H = F_{SH_1} =$ 4,680 lb

Horizontal Seismic Stress:

$\frac{F_{SH_1}}{8A_T} = \sigma_{SH_1} =$ 1,266.23 PSI

③ Horizontal Seismic Load (F_{SH_2}):

* Assume load attempts rotation about y-y axis.



F_{10} acts on Bolt 7

F_9 acts on Bolts 6 & 8

F_8 acts on Bolts 1 & 5

F_7 acts on Bolts 2 & 4

F_6 acts on Bolt 3

MOTOR UNIT-TO-YOKE BOLTING

(7) $\Sigma M_{y-y} \Rightarrow M_{SH_2} = F_{10}b_{10}+F_9b_9+F_8b_8+F_7b_7+F_6b_6$

(8) $$\frac{\delta_{10}}{b_{10}} = \frac{\delta_9}{b_9} = \frac{\delta_8}{b_8} = \frac{\delta_7}{b_7} = \frac{\delta_6}{b_6}$$

where $\delta = \frac{FL}{AE}$

(9) $$\frac{F_{10}}{b_{10}} = \frac{F_9}{b_9} = \frac{F_8}{b_8} = \frac{F_7}{b_7} = \frac{F_6}{b_6}$$

putting eq. (7) in terms of F_{10}

(10) $$M_{SH_2} = F_{10}\left(\frac{b_{10}^2}{b_{10}} + \frac{b_9^2}{b_{10}} + \frac{b_8^2}{b_{10}} + \frac{b_7^2}{b_{10}} + \frac{b_6^2}{b_{10}}\right)$$ (for Bolt 7)

putting eq. (7) in terms of F_9

(11) $$M_{SH_2} = F_9\left(\frac{b_{10}^2}{b_9} + \frac{b_9^2}{b_9} + \frac{b_8^2}{b_9} + \frac{b_7^2}{b_9} + \frac{b_6^2}{b_9}\right)$$ (for Bolts 6 & 8)

putting eq. (7) in terms of F_8

(12) $$M_{SH_2} = F_8\left(\frac{b_{10}^2}{b_8} + \frac{b_9^2}{b_8} + \frac{b_8^2}{b_8} + \frac{b_7^2}{b_8} + \frac{b_6^2}{b_8}\right)$$ (for Bolts 1 & 5)

Horizontal Seismic Force $W_TG_H = F_{SH_2}$ = 4,680 lb

Horizontal Seismic Moment: $F_{SH_2}\bar{Y} = M_{SH_2}$ = 43,524 in-lb

Horizontal Seismic Stress:

(10) $$\frac{M_{SH_2}}{A_T}\left(\frac{b_{10}}{(b_{10}^2+b_6^2)+2(b_9^2+b_8^2+b_7^2)}\right) =$$ (Bolt 7) σ_{SH_2} 1,995.90 PSI

(11) $$\frac{M_{SH_2}}{A_T}\left(\frac{b_9}{(b_{10}^2+b_6^2)+2(b_9^2+b_8^2+b_7^2)}\right) =$$ (Bolts 6&8) σ_{SH_2} 1,723.13 PSI

(12) $$\frac{M_{SH_2}}{A_T}\left(\frac{b_8}{(b_{10}^2+b_6^2)+2(b_9^2+b_8^2+b_7^2)}\right) =$$ (Bolts 1&5) σ_{SH_2} 1,064.48 PSI

(Use Highest Stress)

MOTOR UNIT-TO-YOKE BOLTING

(4) Maximum Total Stress:

$$\sqrt{(\sigma_{MD}+\sigma_{SV})^2+(\sigma_{FD}+\sigma_{SH})^2+(\sigma_{SH_2})^2}=\sigma_T = \underline{25,173.9} \text{ PSI}$$

Bolt 6 is Highest Stressed

(5) Allowable Stress:

for A-193 B-7 S_a = 25,000 PSI

W_T =	1560.0	lb	$b_1 = b_6$ =	1.00	in.
$\bar{Y}$ =	9.3	in.	$b_2 = b_7$ =	3.05	in.
A_T =	0.462	In.^{2}	$b_3 = b_8$ =	8.00	in.
F_D =	87,755.3	lb	$b_4 = b_9$ =	12.95	in.
G_V =	3.00		$b_5 = b_{10}$ =	15.00	in.
G_H =	3.00				

FREQUENCY ANALYSIS

Beam Orientation - 4 Part

ASSUMPTIONS:-

1. The yoke or the yoke section of the bonnet will be the piece subjected to the frequency analysis; therefore, the valve bonnet or the lower bonnet in the bonnet-yoke combination will be considered to be a rigid foundation.

2. The structure will be considered a simple single degree of freedom system.

3. The moment of inertia will not be constant throughout the yoke leg. The yoke leg will be divided into 4 equal sections each with its characteristic moment of inertia (explained below).

4. The effect of damping on the response of the structure will be considered to be negligible and therefore the structure will be considered to have no damping.

5. $I_{55} \gg I_{44}$ or I_{33} or I_{22} or I_{11}

6. Mass of the frame or beam is neglected.

7. Deformation due to tension and compression are neglected.

SYMBOLS:-

E = Modulus of elasticity (PSI)

g = Acceleration due to gravity (In/Sec)

I_{44} = The moment of inertia at the yoke top and assumed constant one-fourth of the way down the yoke leg.

I_{33} = The moment of inertia down one-fourth from the top of the yoke leg and assumed constant to the mid point of the yoke leg.

I_{22} = The moment of inertia at the yoke leg mid point and assumed constant one-fourth of the way down from the mid point.

I_{11} = The moment of inertia down three-fourths from the yoke leg top and assumed constant down to the yoke leg bottom.

I_{55} = Moment of inertia of yoke plate. (In.^{4})

W_{op} = Weight of motor operator, gear unit, or handwheel (LB.)

K_t = Spring constant (lb/in.)

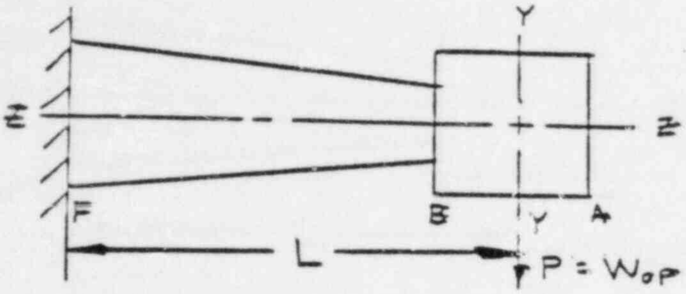
$4a$ = Height of structure from yoke bottom to yoke plate (in.)

$L=4a+c$ = Length from yoke bottom to the center of gravity of the operator (in.)

f_n = Natural frequency of operator and yoke system (CPS)

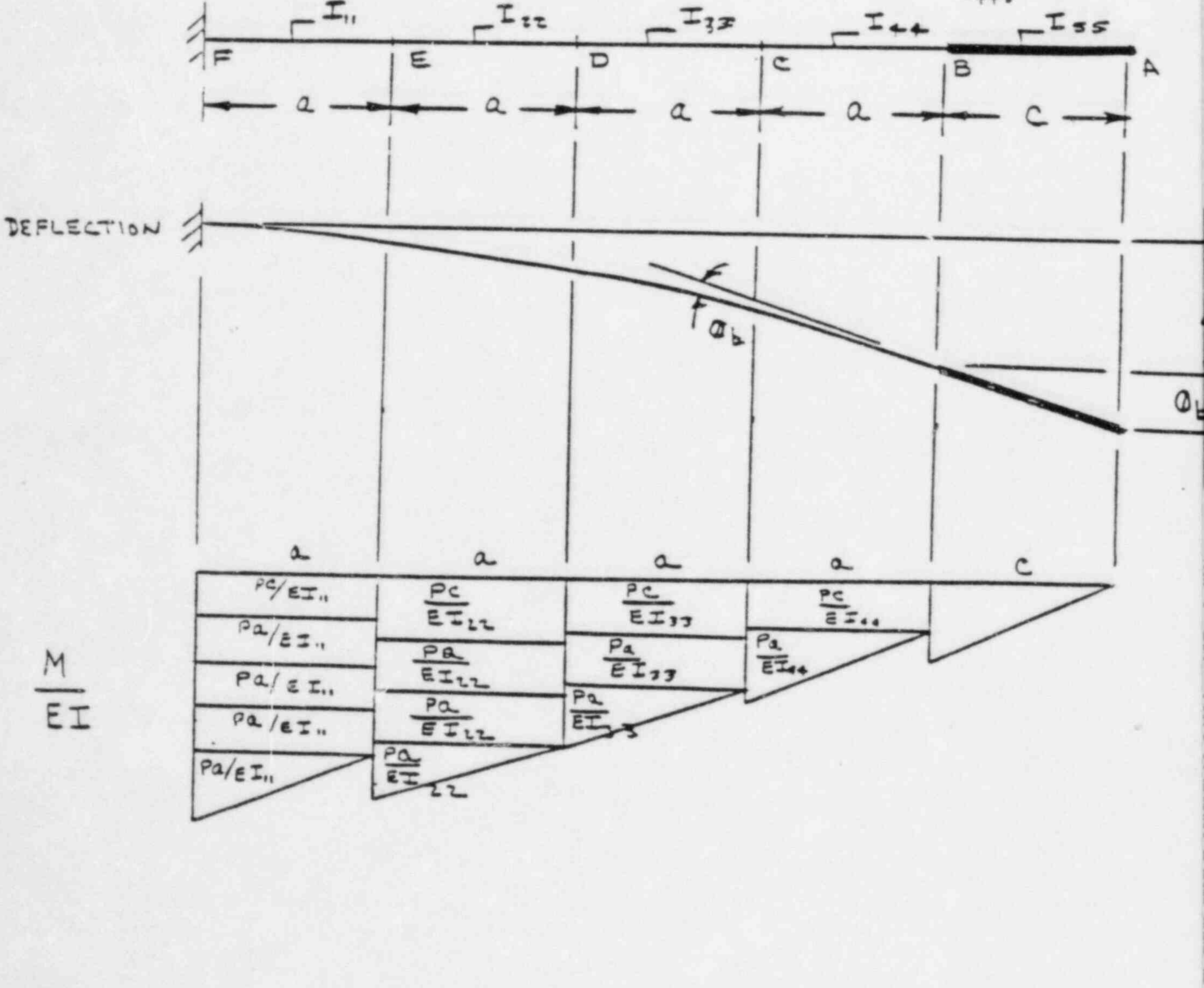
f_s = Minimum acceptable natural frequency specified by customer (CPS)

BEAM ORIENTATION - 4 PART



VALVE YOKE LEG BROKEN INTO 4 EQUAL PARTS.

ASSUME I_{55} IS RIGID $I_{55} >> I_{11}$ + I_{44}.



BEAM ORIENTATION - 4 PART

$$\delta_T = \delta_A + \emptyset_b c$$

$$\delta_A = \Sigma \bar{x}(\text{AREA})\Big|_B^F = \left(\frac{a}{2}\right)\left(\frac{Pca}{EI_{44}}\right) + \left(\frac{2a}{3}\right)\left(\frac{Pa^2}{2EI_{44}}\right) + \left(\frac{3a}{2}\right)\left(\frac{Pca}{EI_{33}} + \frac{Pa^2}{EI_{33}}\right)$$

$$+ \left(\frac{5a}{3}\right)\left(\frac{Pa^2}{2EI_{33}}\right) + \left(\frac{5a}{2}\right)\left(\frac{Pca}{EI_{22}} + \frac{2Pa}{EI_{22}}\right) + \left(\frac{8a}{3}\right)\left(\frac{Pa^2}{2EI_{22}}\right)$$

$$+ \left(\frac{7a}{2}\right)\left(\frac{Pca}{EI_{11}} + \frac{3Pa^2}{EI_{11}}\right) + \left(\frac{11a}{3}\right)\left(\frac{Pa^2}{2EI_{11}}\right)$$

$$\delta_A = \frac{Pa}{6E}\left[\frac{3ac+2a^2}{I_{44}} + \frac{9ac+14a^2}{I_{33}} + \frac{15ac+38a^2}{I_{22}} + \frac{21ac+74a^2}{I_{11}}\right]$$

$$\emptyset_b = \Sigma(\text{AREA})\Big|_B^F = \frac{2Pca+Pa^2}{2EI_{44}} + \frac{2Pca+3Pa^2}{2EI_{33}} + \frac{2Pca+5Pa^2}{2EI_{22}}$$

$$+ \frac{2Pca+7Pa^2}{2EI_{11}}$$

$$\emptyset_b c = \frac{Pa}{6E}\left[\frac{6c^2+3ac}{I_{44}} + \frac{6c^2+9ac}{I_{33}} + \frac{6c^2+15ac}{I_{22}} + \frac{6c^2+21ac}{I_{11}}\right]$$

CALCULATION NO. ADSR-31

BEAM ORIENTATION - 4 PART

$$\delta_T = \frac{Pa}{6E}\left[\frac{2a^2+6ac+6c^2}{I_{44}} + \frac{14a^2+18ac+6c^2}{I_{33}} + \frac{38a^2+30ac+6c^2}{I_{22}} + \frac{74a^2+42ac+6}{I_{11}}\right.$$

$\delta_T =$ 0.033153 IN.

$f_n = \frac{1}{2\pi}\sqrt{g K_T / W_{op}} = \frac{1}{2\pi}\sqrt{g/\delta_T} =$ 17.173 CPS

where $K_T = \frac{W_{op}}{\delta_T}$

$f_s =$ 33.0 CPS

W_{op} = 1560.0 LB

E = 28.675×10^6 PSI

g = 386 IN/SEC^2

a = 7.3202 IN.

c = 10.80 IN.

I_{11} = 34.5126 IN.^{4}

I_{22} = 34.5346 IN.^{4}

I_{33} = 34.5565 IN.^{4}

I_{44} = 34.5785 IN.^{4}

FREQUENCY ANALYSIS

Frame Orientation - 4 Part

ASSUMPTIONS:-

1. The yoke or the yoke section of the bonnet will be the piece subjected to the frequency analysis; therefore, the valve bonnet or the lower bonnet in the bonnet-yoke combination will be considered to be a rigid foundation.

2. The structure will be considered a simple single degree of freedom system.

3. The moment of inertia will not be constant throughout the yoke leg. The yoke leg will be divided into 4 equal sections each with its characteristic moment of inertia (explained below).

4. The effect of damping on the response of the structure will be considered to be negligible and therefore the structure will be considered to have no damping.

5. Mass of the frame or beam is neglected.

6. Deformation due to tension and compression are neglected.

SYMBOLS:-

E = Modulus of elasticity (PSI)

g = Acceleration due to gravity (In/Sec)

I_{44} = The moment of inertia at the yoke top and assumed constant one-fourth of the way down the yoke leg.

I_{33} = The moment of inertia down one-fourth from the top of the yoke leg and assumed constant to the mid point of the yoke leg.

I_{22} = The moment of inertia at the yoke leg mid point and assumed constant one-fourth of the way down from the mid point.

I_{11} = The moment of inertia down three-fourths from the yoke leg top and assumed constant down to the yoke leg bottom.

W_{op} = Weight of motor operator, gear unit, or handwheel (LB.)

K_t = Spring constant (lb/in.)

$4c$ = Height of structure from yoke bottom to yoke plate (in.)

f_n = Natural frequency of operator and yoke system (CPS)

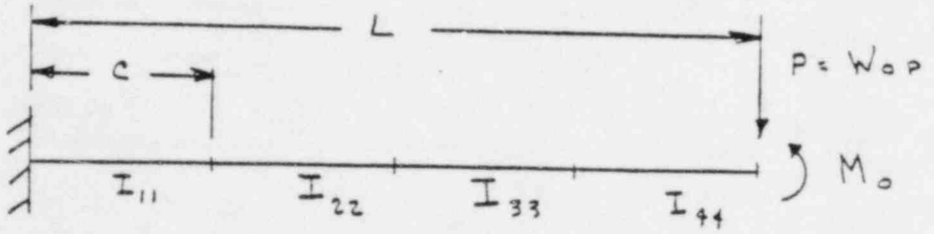
f_s = Minimum acceptable natural frequency specified by customer (CPS)

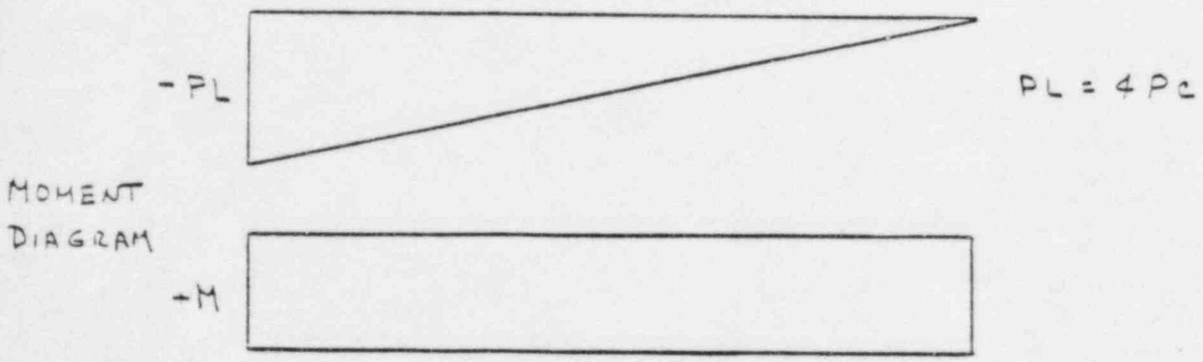
FREQUENCY ANALYSIS

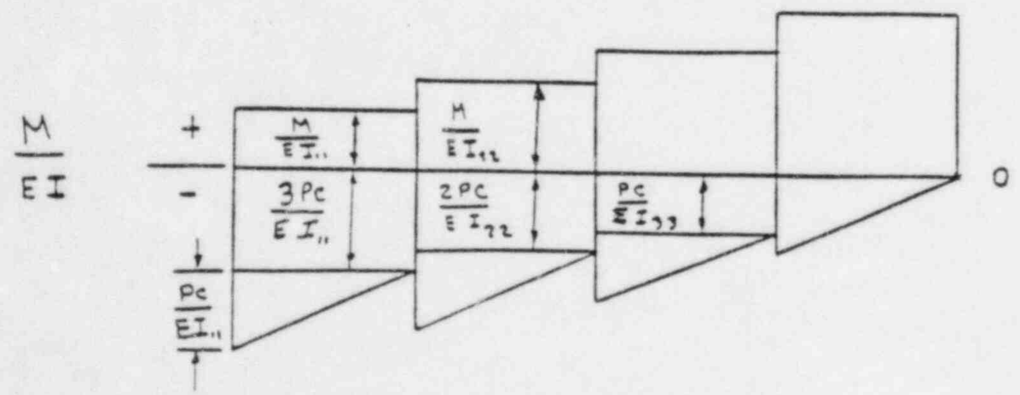
FRAME ORIENTATION - 4 PART

AREA MOMENT METHOD.

THE VALVE STRUCTURE IS BROKEN INTO FOUR EQUAL PARTS







FRAME ORIENTATION - 4 PART

$\Sigma A = \emptyset$ at Pt. O $\Sigma A = 0 = \emptyset$

$$\text{at Pt. O } \Sigma A = 0 = \frac{1}{E}\left[M_o c\left(\frac{1}{I_{11}} + \frac{1}{I_{22}} + \frac{1}{I_{33}} + \frac{1}{I_{44}}\right) - \frac{Pc^2}{2 I_{44}} - \left(\frac{Pc^2 + \frac{1}{2}Pc^2}{I_{33}}\right) - \left(\frac{2Pc^2 + \frac{1}{2}Pc^2}{I_{22}}\right) - \left(\frac{3Pc^2 + \frac{1}{2}Pc^2}{I_{11}}\right)\right]$$

SOLVE FOR M_o

$$1)\ M_o = \frac{Pc}{2}\left[\frac{1}{I_{44}} + \frac{3}{I_{33}} + \frac{5}{I_{22}} + \frac{7}{I_{11}}\right]\left[\frac{1}{\frac{1}{I_{44}} + \frac{1}{I_{33}} + \frac{1}{I_{22}} + \frac{1}{I_{11}}}\right]$$

$$2)\ \Delta\delta\Big|_0^L = \Sigma(\text{AREA})(\bar{x})$$

$$2)\ E\delta = \frac{M_o c^2}{2}\left[\frac{1}{I_{44}} + \frac{3}{I_{33}} + \frac{5}{I_{22}} + \frac{7}{I_{11}}\right] - \frac{Pc^2}{2 I_{44}} \cdot \frac{2c}{3} - \left[\frac{Pc^2}{2I_{33}} \cdot \frac{5c}{3} + \frac{Pc^2}{I_{33}} \cdot \frac{3c}{2}\right] - \left[\frac{Pc^2}{2I_{22}} \cdot \frac{8c}{3} + \frac{2Pc^2}{I_{22}} \cdot \frac{5c}{2}\right] - \left[\frac{Pc^2}{2I_{11}} \cdot \frac{11c}{3} + \frac{3Pc^2}{I_{11}} \cdot \frac{7c}{2}\right]$$

$$2)\ E\delta = \frac{M_o c}{2}\left[\frac{1}{I_{44}} + \frac{3}{I_{33}} + \frac{5}{I_{22}} + \frac{7}{I_{11}}\right] - \frac{Pc^3}{3}\left[\frac{1}{I_{44}} + \frac{7}{I_{33}} + \frac{19}{I_{22}} + \frac{37}{I_{11}}\right]$$

δ IS THE DEFLECTION FOR ONE FRAME LEG ONLY, THEREFORE:

$$\delta_{max} = \frac{1}{2}\delta$$

FRAME ORIENTATION – 4 PART

$$\frac{1}{2}\delta = \delta_{MAX} = \left\{\frac{W_{OP}C^3}{2E}\right\}\left\{\left[\frac{\left(\frac{1}{I_{44}}+\frac{3}{I_{33}}+\frac{5}{I_{22}}+\frac{7}{I_{11}}\right)^2}{4\left(\frac{1}{I_{44}}+\frac{1}{I_{33}}+\frac{1}{I_{22}}+\frac{1}{I_{11}}\right)}\right] - \left[\left(\frac{1}{3}\right)\left(\frac{1}{I_{44}}+\frac{7}{I_{33}}+\frac{19}{I_{22}}+\frac{37}{I_{11}}\right)\right]\right.$$

δ_{MAX} = -0.007296 IN.

$W_{OP}/\delta_{MAX} = K_t$ = -213815.79 LB/IN

$\frac{1}{2\pi}\sqrt{g\,K_t/W_{OP}} = f_n$ = 36.608 CPS

f_s = 33.0 CPS

W_{OP} = 1560.0 LB

g = 386 IN/SEC^2

E = 28.675×10^6 PSI

C = 10.80 IN.

I_{11} = 5.3525 IN.^{4}

I_{22} = 6.9709 IN.^{4}

I_{33} = 8.8740 IN.^{4}

I_{44} = 11.0789 IN.^{4}

BIBLIOGRAPHY

1. ASME Boiler and Pressure Vessel Code, Section III, Nuclear Power Plant Components, the American Society of Mechanical Engineers, New York, 1980 Winter 1982 Addenda.

2. ASME Boiler and Pressure Vessel Code, Section VIII Pressure Vessels, the American Society of Mechanical Engineer, New York, 1980, Winter '82 Addenda.

3. J. E. Shigley, Mechanical Engineering Design, Second Edition, McGraw-Hill Book Company, New York 1972.

4. R. J. Roark, Formulas for Stress and Strain, Fourth Edition, McGraw-Hill Book Company, New York 1965.

5. Handbook H28 (1969) Screw-Thread Standards for Federal Services, U.S. Department of Commerce, 1970.

6. O. W. Eshbach, Handbook of Engineering Fundamentals, Second Edition, John Wiley & Sons, Inc., New York, 1952.

7. Taylor Forge, Modern Flange Design, Fifth Edition Bulletin 502, Taylor Forge & Pipe Works, Illinois, 1964.

8. E. Oberg and F. D. Jones, Machinery's Handbook, 18th Edition, Industrial Press, Inc., 1969.