



ALOYCO
CORROSION RESISTANT VALVES
Report No. ADSR-31 Rev. 0
Page 1 of 50

DESIGN STRESS REPORT

Customer Bechtel Power Corp., Agents Customer P.O. No. PEHA-470
Gaithersburg, Maryland Customer Item No. 002
Owner Georgia Power Company Walworth Order No. LN29977
Project E.I. Hatch Nuclear Units 1 & 2 Walworth Item No. 003
Baxley, Georgia
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. |
|------------|----------------|---------------|--------------|--------------------------|---------------------|
| <u>16"</u> | <u>300 lb.</u> | <u>5281WE</u> | <u>Globe</u> | <u>A-8868-M-9B</u> | <u>2E11-F016A,B</u> |

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 °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.

BEST SOURCE DOCUMENT AVAILABLE, MAY NOT BE OF MICROFILM-ABLE QUALITY.

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

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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

- ☒ Traditional Hand Calculation Method
☒ 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

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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

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

NATURAL FREQUENCY DETERMINATION

| | <u>Calculated</u> | <u>Nat. Frequency Allowable</u> | <u>See Page</u> |
|-------------------|-------------------|---------------------------------|-----------------|
| Beam Orientation | <u>17.2</u> | <u>33.0</u> | <u>44</u> |
| Frame Orientation | <u>36.6</u> | <u>33.0</u> | <u>48</u> |

Body/Bonnet Studs: Minimum required Stress area: 26.31 In²
 Actually available stress area: 25.41 In²

FLANGE ANALYSIS

THE BOLTING AND FLANGE OF THE BOLL 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

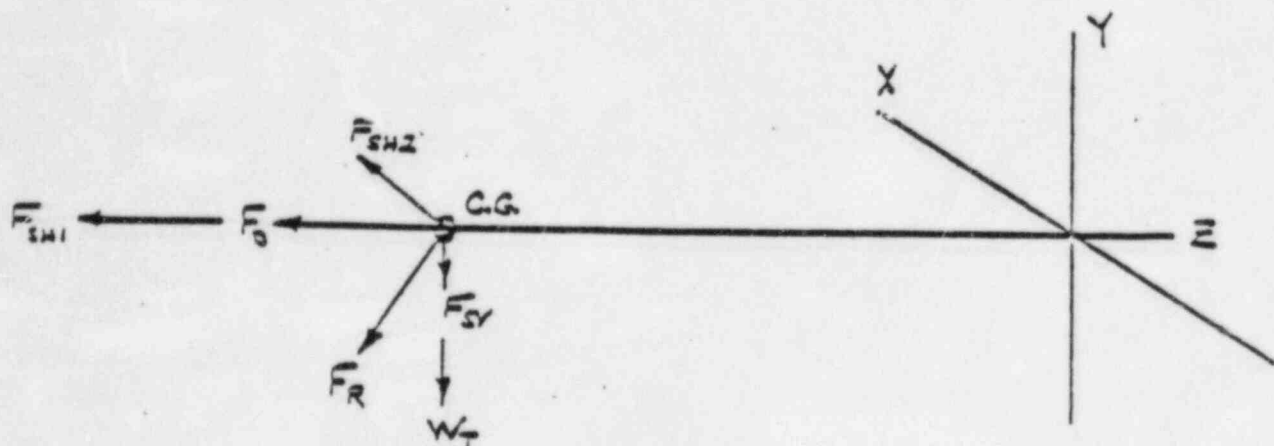


FIGURE A

Flange Analysis

Weight of valve parts above body flange = W_f 2593.25 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 = $W_f G$
Refer to Figure A

Horizontal = F_{SH1} = 7,779.75 lb

= F_{SH2} = 7,779.75

Vertical = F_{SV} = 7,779.75 lb

$F_R = \sqrt{F_{SH2}^2 + (F_{SV} + W_f)^2}$ = 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 | $.25\pi D^2 \Delta P \tan \alpha$ | $.25\pi D^2 \Delta P$ | <u>80,521.3</u> |
| SEATING FORCE | $.75\pi D \Delta P \sin \theta$ | $.75\pi D \Delta P (\sin \theta +$ | |
| STEM LOAD | $.25\pi d^2 \Delta P$ | $\mu \cos \theta)$ | <u>7,233.8</u> |

Seating Angle θ = 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 = 87,755.1 lb Thrust

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

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

$$F_s = (.063)\pi D (\sin\theta + \mu \cos\theta) * 6P(2)$$

$$= .75\pi D (\sin\theta + \mu \cos\theta) P$$

$$Q_d = F_p + F_s$$

$$= \frac{\pi}{4} D^2 P + .75\pi D (\sin\theta + \mu \cos\theta) P$$

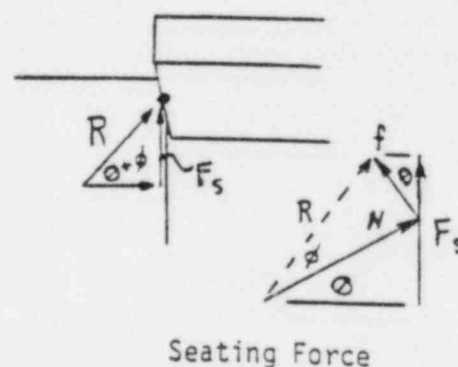
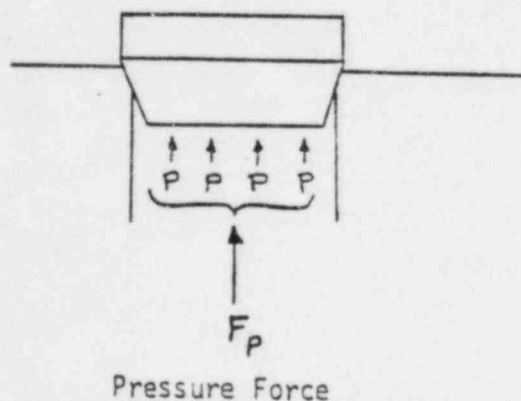
Terms

D = Seat Dia.

P = Pressure

θ = Seat Angle

μ = Coefficient of Friction



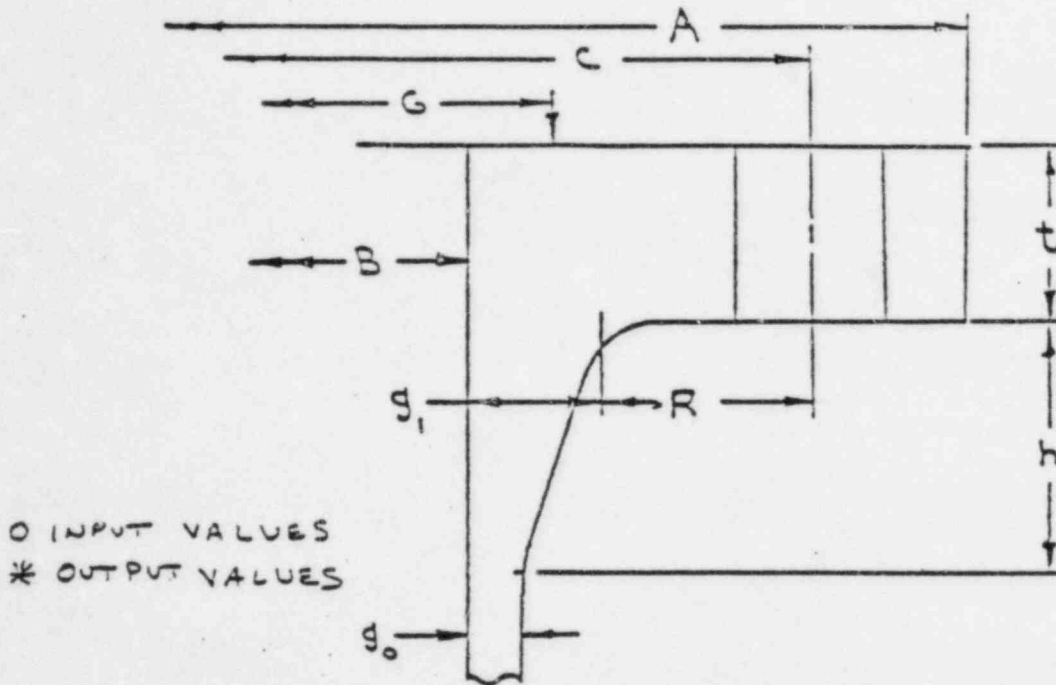
*The force F_s is similar to the compression load from Article 3-3 Sec. VIII of the ASME Code, therefore the clamping pressure is a multiple of the line pressure. The value 6 is from Table 3-320-1 of Sec. VIII under gasket factor for solid flat metal, 4-6% chrome.

FLANGE ANALYSIS

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Calculation No. ADSR-31

Body Flange



0 INPUT VALUES
* OUTPUT VALUES

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

- | | | |
|-----------------------------------|---|------------------------------------|
| ① A = <u>30.75</u> in | ⑥ t = <u>2.875</u> in | ⑪ y = <u>18,000</u> |
| ② B = <u>18.75</u> in | ⑦ h = <u>0.0</u> in | ⑫ m = <u>5.5</u> |
| ③ C = <u>27.75</u> in | ⑧ P = <u>450</u> PSI | * 1 G = <u>20.6708</u> in |
| ④ g ₁ = <u>1.25</u> in | * 2 b = <u>0.4146</u> in | * 3 R = <u>3.25</u> in |
| ⑤ g ₀ = <u>1.25</u> in | ⑨ A _b = <u>25.41</u> in ² | (22) <u>1 3/8" Dia. Studs</u> |
| | 10 (F _D + F _{SH}) = <u>95,535.1</u> LB | ⑬ GASKET OD = <u>21.500</u> in |
| | | ⑭ GASKET ID = <u>18.750</u> in |
| | | 15 Seis. Mo. = <u>531,745.8</u> in |

Allowable Stresses:

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

Bolting
⑬ S_a_{b1} @ 100°F = 25,000 psi
S_a_{b2} @ 225°F = 25,000 psi

A-193 B-7

Flange Design Pressure

$$P_{FD} = P + \frac{16M}{\pi G^3} + \frac{4FS_1}{\pi G^2} + \frac{4FD}{\pi G^2} =$$

1,041.3 psi

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FLANGE ANALYSIS

Body

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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 the vertical direction.

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

Bolt Loading:

Operating $W_{m1} = P_{FD} (.785G^2 + 2\pi bGm) = \underline{657,647.3} \text{ lb}$

Gasket Seating $W_{m2} = \pi bGy = \underline{484,603.1} \text{ lb}$

Bolt Area:

Required $A_m = \text{Larger of } \frac{W_{m2}}{S_{ab1}} \text{ or } \frac{W_{m1}}{S_{ab2}} = \underline{26.31} \text{ in}^2$

Actual $A_b = \underline{25.41} \text{ in}^2$

Flange Design Bolt Load

Operating $W_{m1} = \underline{657,647.3} \text{ lb}$

Gasket Seating $\frac{(A_m + A_b)}{2} S_{ab1} = W = \underline{646,448.1} \text{ lb}$

Flange Moment Operating Conditions

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

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

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

$M_o = M_D + M_G + M_T = \underline{2,454,598.0} \text{ in-lb}$

FLANGE ANALYSIS

Body

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Calculation No. ADSR-31

Flange Moment Gasket Seating

$$M_0 = W(C-G).5 =$$

$$\underline{2,288,155.0} \text{ in-lb}$$

Shape constants

$$K=A/B = \underline{1.64}; \quad g_1/g_0 = \underline{1.00}; \quad h_0 = \sqrt{Bg_0} = \underline{4.8412}$$

$$h = \underline{0.0}; \quad h/h_0 = \underline{0.0}; \quad P = \underline{450} \text{ psi}$$

$$T = \underline{1.6505} \quad Z = \underline{2.1837} \quad Y = \underline{4.0994} \quad U = \underline{4.5049}$$

$$F = \underline{0.908920} \quad V = \underline{0.550103} \quad f = \underline{1.000} \quad e=F/h_0 = \underline{0.18775}$$

$$d = (U/V)h_0g_0^2 = \underline{61.94612} \quad L = \frac{te+1}{T} + \frac{t^3}{d} = \underline{1.31653}$$

Flange Stresses:

Longitudinal Hub Stress:

Operating

Gasket Seating

$$S_H = (fM_0/Lg_1^2B) + (P B/4g_0) =$$

$$\underline{65,327.2} \text{ psi}$$

$$\underline{61,011.9} \text{ psi}$$

Radial Flange Stress:

$$S_R = (1.33te+1)M_0/Lt^2B =$$

$$\underline{20,666.6} \text{ psi}$$

$$\underline{19,265.2} \text{ psi}$$

Tangential Flange Stress:

$$S_T = (YM_0/t^2B) - ZS_R =$$

$$\underline{19,797.1} \text{ psi}$$

$$\underline{18,454.7} \text{ psi}$$

Allowable Stresses:

$$\text{Operating } 1.5S_{af_2} = \underline{26,250} \text{ psi}$$

$$\text{Gasket Seating } 1.5S_{af_1} = \underline{26,250} \text{ psi}$$

$$S_R \leq 1.5S_{af}$$

$$S_T \leq 1.5S_{af}$$

Bonnet Neck Root

SYMBOLS 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 BONNET

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

ϕ = 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

q_v = VERTICAL SEISMIC ACCELERATION

q_{H1}, q_{H2} = THE TWO HORIZONTAL SEISMIC ACCELERATION.

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

$M \equiv$ MOMENTS

$\sigma \equiv$ STRESSES

SUBSCRIPTS

$R, T, L \equiv$ RADIAL, TANGENTIAL, LONGITUDINAL

$O \equiv$ OPERATIONAL LOADING

$G \equiv$ GASKET SEATING REACTION

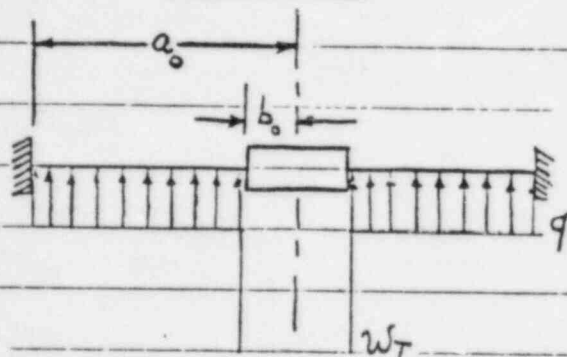
$S \equiv$ SEISMIC

ν = POISSON'S RATIO

REFERENCE :

ROARK'S "FORMULAS FOR STRESS AND STRAIN" 5TH EDITION

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



$$G = 20.671 \text{ INCHES}$$

$$a_0 = \frac{G}{2} = 10.336 \text{ INCHES}$$

$$b_0 = 6.0 \text{ INCHES}$$

$$F_d = T = 87,755 \text{ LBS}$$

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

WEIGHT OF VALVE STRUCTURE ABOVE BONNET NECK: 2091.9 LBS

$$q = P = 450 \text{ PSI}$$

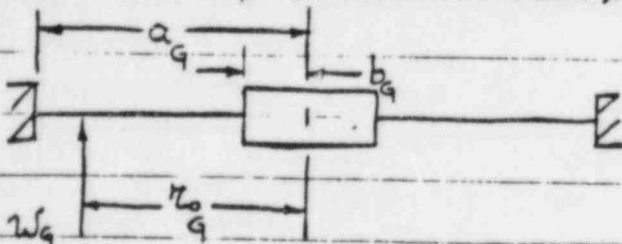
C.G. OF VALVE STRUCTURE ABOVE BONNET NECK: 46.5 INCHES

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

$$W_T = (T + g_{H_2} \times \text{WEIGHT}) / 2\pi b_0 = 2494.2 \text{ LB/IN (PER INCH OF CIRCUMFERENCE)}$$

GASKET SEATING CONDITIONS: CASE 1f PAGE 336

$$C = 27.75 \text{ INCHES}$$



$$a_g = \frac{C}{2} = 13.875 \text{ INCHES}$$

$$b_g = 6.0 \text{ INCHES}$$

$$r_{ag} = G/2 = 10.336 \text{ INCHES}$$

$$m = 5.5 \text{ (UNITLESS FACTOR)}$$

$$\phi = 0.415 \text{ INCHES}$$

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

$$Y = 18,000 \text{ PSI}$$

W_m = LARGER OF THE TWO W_{m1} AND W_{m2}

$$W_{m1} = q \left[\frac{\pi}{4} G^2 + 2\pi \phi G m \right] + T = 372,175 \text{ LBS.}$$

$$W_{m2} = \pi \phi G Y = 485,101 \text{ LBS.}$$

OPERATING STRESSES AT INNER RADIUS "b" :

$$t_b = 2.375 \text{ INCHES}$$

$$M_{R_{b_0}} = M_{R_{b_{01}}} + M_{R_{b_{02}}} = -w_T a_0 \frac{L_6}{C_5} - q a_0^2 \frac{L_{14}}{C_5} = -6,182.7 \frac{\text{IN} \cdot \text{LBS}}{\text{IN}}$$

$$\text{since } \theta = 0$$

$$M_{T_{b_0}} = \nabla M_{R_{b_0}} = -1,854.8 \frac{\text{IN} \cdot \text{LBS}}{\text{IN}}$$

$$\sigma_{R_{b_0}} = \frac{6}{t_b^2} M_{R_{b_0}} = -6,576.6 \text{ PSI}$$

$$\sigma_{T_{b_0}} = \frac{6}{t_b^2} M_{T_{b_0}} = -1,973.0 \text{ PSI}$$

$$\sigma_{L_{b_0}} = 0$$

OPERATING STRESSES AT OUTER RADIUS "a" :

$$t_a = 2.375 \text{ INCHES}$$

$$M_{R_{a_0}} = w_T a_0 \left(L_9 - \frac{C_8 L_6}{C_5} \right) + q a_0^2 \left(L_{17} - \frac{C_8 L_{14}}{C_5} \right) = 4,880.8 \frac{\text{IN} \cdot \text{LBS}}{\text{IN}}$$

$$\sigma_{R_{a_0}} = \frac{6}{t_a^2} M_{R_{a_0}} = 5,191.8 \text{ PSI}$$

$$\sigma_{T_{a_0}} = \nabla M_{R_{a_0}} \frac{6}{t_a^2} = 1,557.5 \text{ PSI}$$

$$\sigma_{L_{a_0}} = \frac{1}{t_a} \left[\frac{w_T b_0}{a_0} + \frac{q}{2a_0} (a_0^2 - b_0^2) \right] = 1,258.9 \text{ PSI}$$

GASKET SEATING LOAD STRESSES AT INNER RADIUS "b" $t_b = 2.375$ INCHES

$$M_{R_{bg}} = -W_g a_g \frac{L_g}{C_5} = -5328.9 \frac{\text{IN} \cdot \text{LBS}}{\text{IN}}$$

$$M_{T_{bg}} = \nabla M_{R_{bg}} = -1598.7 \frac{\text{IN} \cdot \text{LBS}}{\text{IN}}$$

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

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

$$\sigma_{L_{bg}} = 0 \text{ PSI}$$

GASKET SEATING LOAD STRESSES AT THE OUTER RADIUS "a" $t_a = 2.125$ INCHES

$$M_{R_{ag}} = W_g a_g \left(L_g - \frac{C_8 L_g}{C_5} \right) = 14,408.7 \frac{\text{IN} \cdot \text{LBS}}{\text{IN}}$$

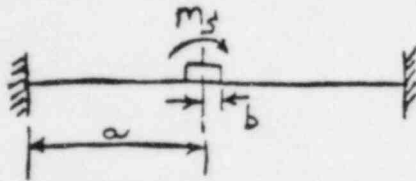
$$M_{T_{ag}} = \nabla M_{R_{ag}} = 4,322.6 \frac{\text{IN} \cdot \text{LBS}}{\text{IN}}$$

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

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

$$\sigma_{L_{ag}} = \frac{1}{t_a} \left[\frac{W_g b_g}{a_g} \right] = 1,520.1 \text{ PSI}$$

SEISMIC LOAD STRESSES: CASE 21 PAGE 368



$$t_a = 2.375 \text{ INCHES}$$

$$t_b = 2.375 \text{ INCHES}$$

$$a = 10.336 \text{ INCHES}$$

$$b = 6.0 \text{ INCHES}$$

$$b/a = 0.58$$

WEIGHT OF VALVE STRUCTURE ABOVE BONNET NECK: $W = 2091.9 \text{ LBS}$

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

$$g_v = 3.0; g_h = 3.0; g = \sqrt{3+3} = 4.24$$

$$M_s = (4.24)(46.5)(2091.9) = 412,439 \text{ IN} \cdot \text{LBS}$$

$$g \times \text{C.G.} \times W$$

AT INNER RADIUS "b" $\sigma_{R_{b_s}} = \frac{\beta M_s}{a t_b^2} = 5,857.5 \text{ PSI}$

$$\beta = 0.828 \text{ INTERPOLATED FROM CASE 21'S TABLE}$$

AT OUTER RADIUS "a" $\sigma_{R_{a_s}} = \frac{\beta \pi_0 M_s}{a^2 t_a^2} = 3,400.2 \text{ PSI}$

$$\pi_0 = b$$

SUMMARY OF STRESSES: BONNET NECK

OPERATIONAL & SEISMIC

$$\sigma_{R_b} = \sigma_{R_{b_o}} + \sigma_{R_{b_s}} = |5191.8| + |5857.5| = |11,049.3| \text{ PSI}$$

$$\sigma_{T_b} = -1973.0 \text{ PSI}$$

$$\sigma_{L_b} = 0 \text{ PSI}$$

$$\sigma_{R_a} = \sigma_{R_{a_o}} + \sigma_{R_{a_s}} = |5191.8| + |3400.2| = |8592.0| \text{ PSI}$$

$$\sigma_{T_a} = 1557.5 \text{ PSI}$$

$$\sigma_{L_a} = 1258.9 \text{ PSI}$$

GASKET SEATING

$$\sigma_{R_b} = -5668.4 \text{ PSI}$$

$$\sigma_{T_b} = -1700.6 \text{ PSI}$$

$$\sigma_{L_b} = 0 \text{ PSI}$$

$$\sigma_{R_a} = 19,145.1 \text{ PSI}$$

$$\sigma_{T_a} = 5,743.5 \text{ PSI}$$

$$\sigma_{L_a} = 1,520.1 \text{ PSI}$$

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 $r_o = \frac{G}{2}$

$$L_6 = \frac{r_o}{4a} \left[\left(\frac{r_o}{a} \right)^2 - 1 + 2 \ln \frac{a}{r_o} \right];$$

$$L_6 = 0.0616$$

$$0.0209$$

$$L_9 = \frac{r_o}{a} \left\{ \frac{1+\nu}{2} \ln \frac{a}{r_o} + \frac{1-\nu}{4} \left[1 - \left(\frac{r_o}{a} \right)^2 \right] \right\};$$

$$L_9 = 0.2478$$

$$0.1758$$

$$L_{14} = \frac{1}{16} \left[1 - \left(\frac{r_o}{a} \right)^4 - 4 \left(\frac{r_o}{a} \right)^2 \ln \frac{a}{r_o} \right];$$

$$L_{14} = 0.0096$$

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

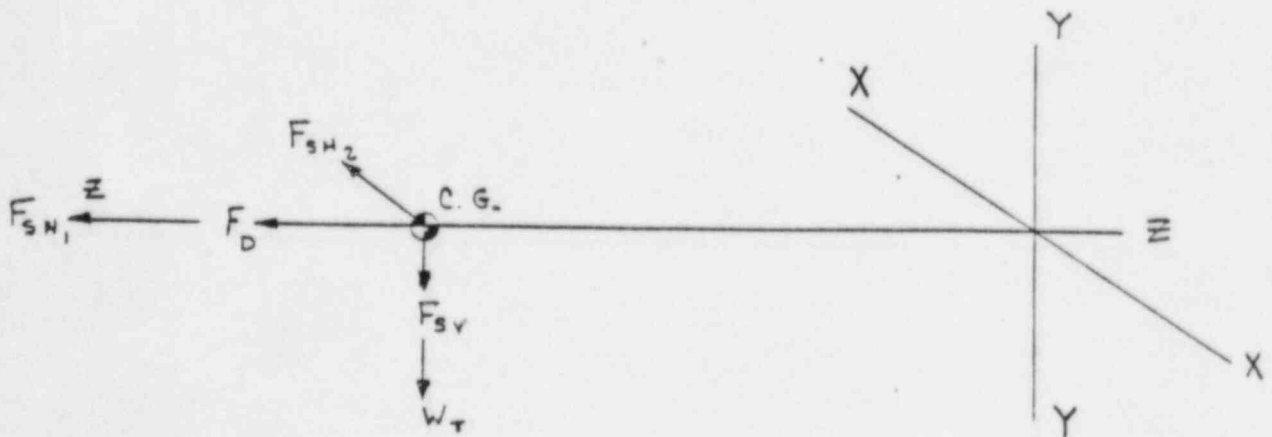
| | |
|----------------|--|
| P | = Design Pressure |
| A | = Cross-Sectional Area of Section (other than Bolting) |
| A_T | = Cross-Sectional Area per Bolt |
| C | = Distance from Neutral Axis to Outer Fiber |
| D | = Seat Bore Diameter |
| d | = Stem Diameter |
| F_D | = Direct or Operational Force |
| 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 |
| θ | = Seating Angle |
| σ_{FD} | = Stress from Direct Force |
| σ_{MD} | = Stress from Direct Moment |
| σ_{SV} | = Stress from Vertical Seismic Force |
| σ_{SH1} | = Stress from Horizontal Seismic Force |
| σ_{SH2} | = 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_r) 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



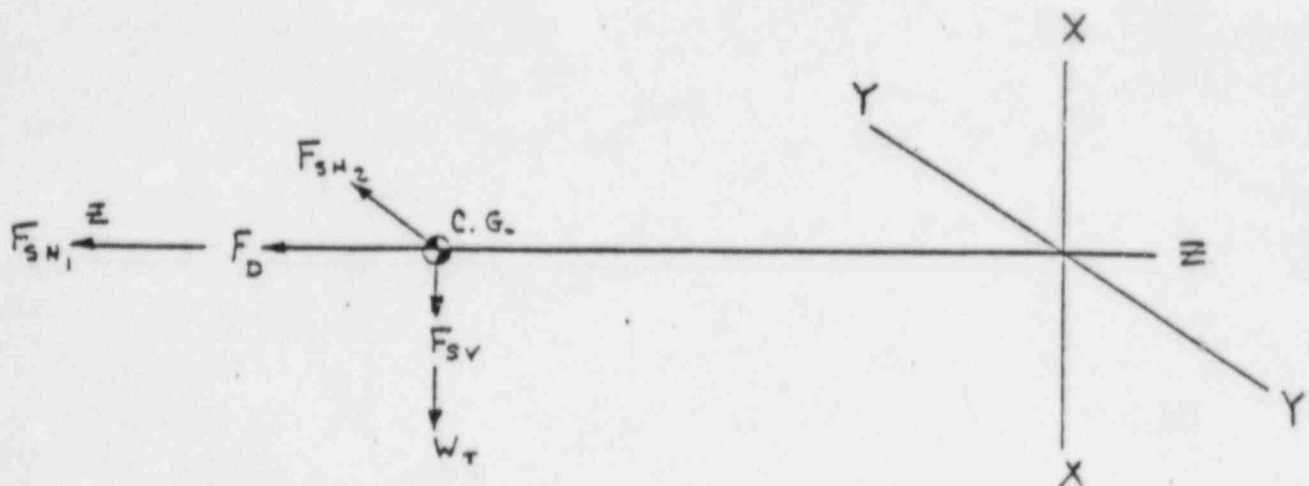
It has been determined that the above orientation results in the greatest stress.

ORIENTATION #2

SUMMARY OF RESULTANT STRESS

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

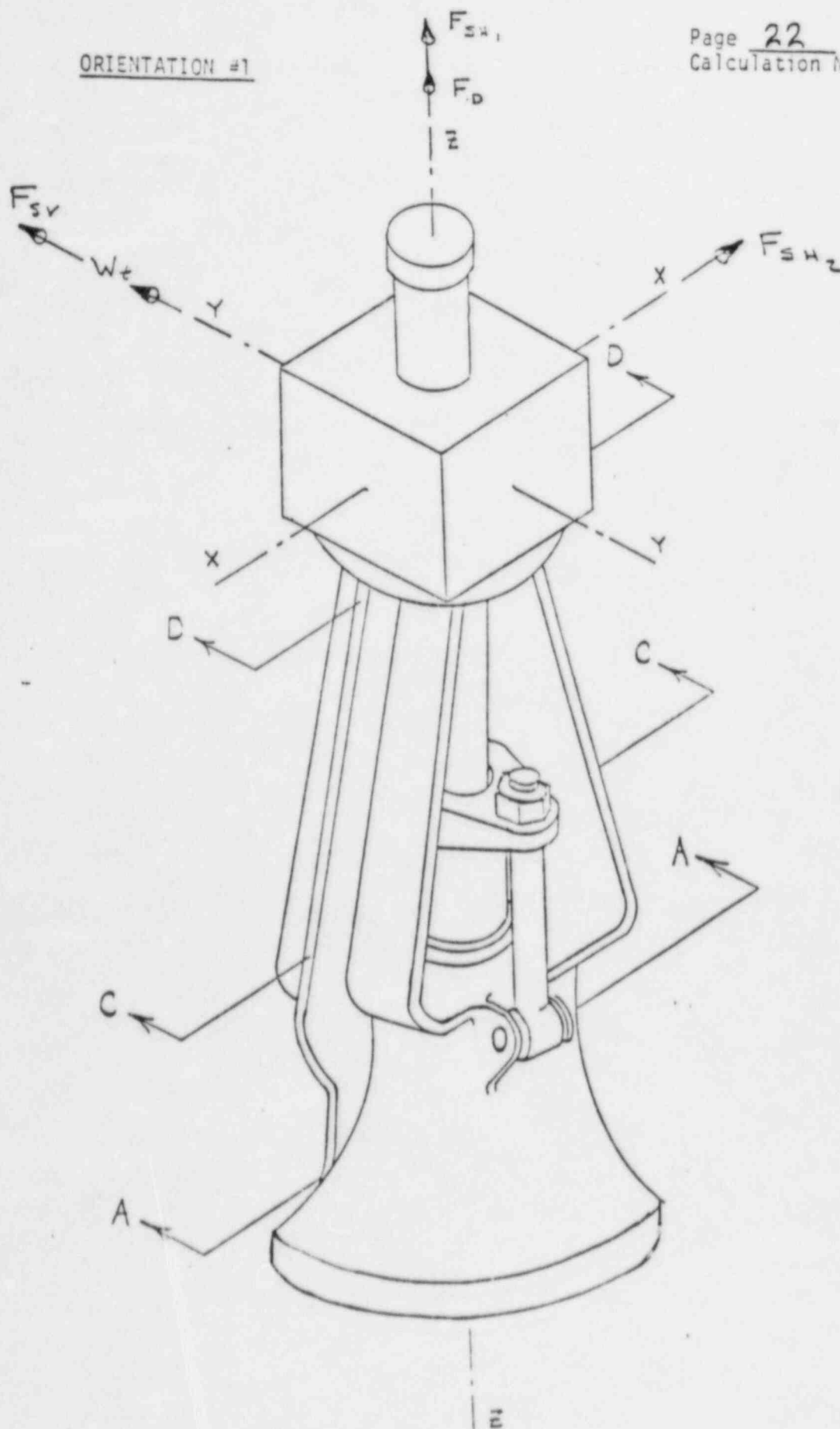
FREE BODY DIAGRAM SHOWING THREE DIMENSIONAL SEISMIC,
 DEAD WEIGHT AND OPERATIONAL LOADS



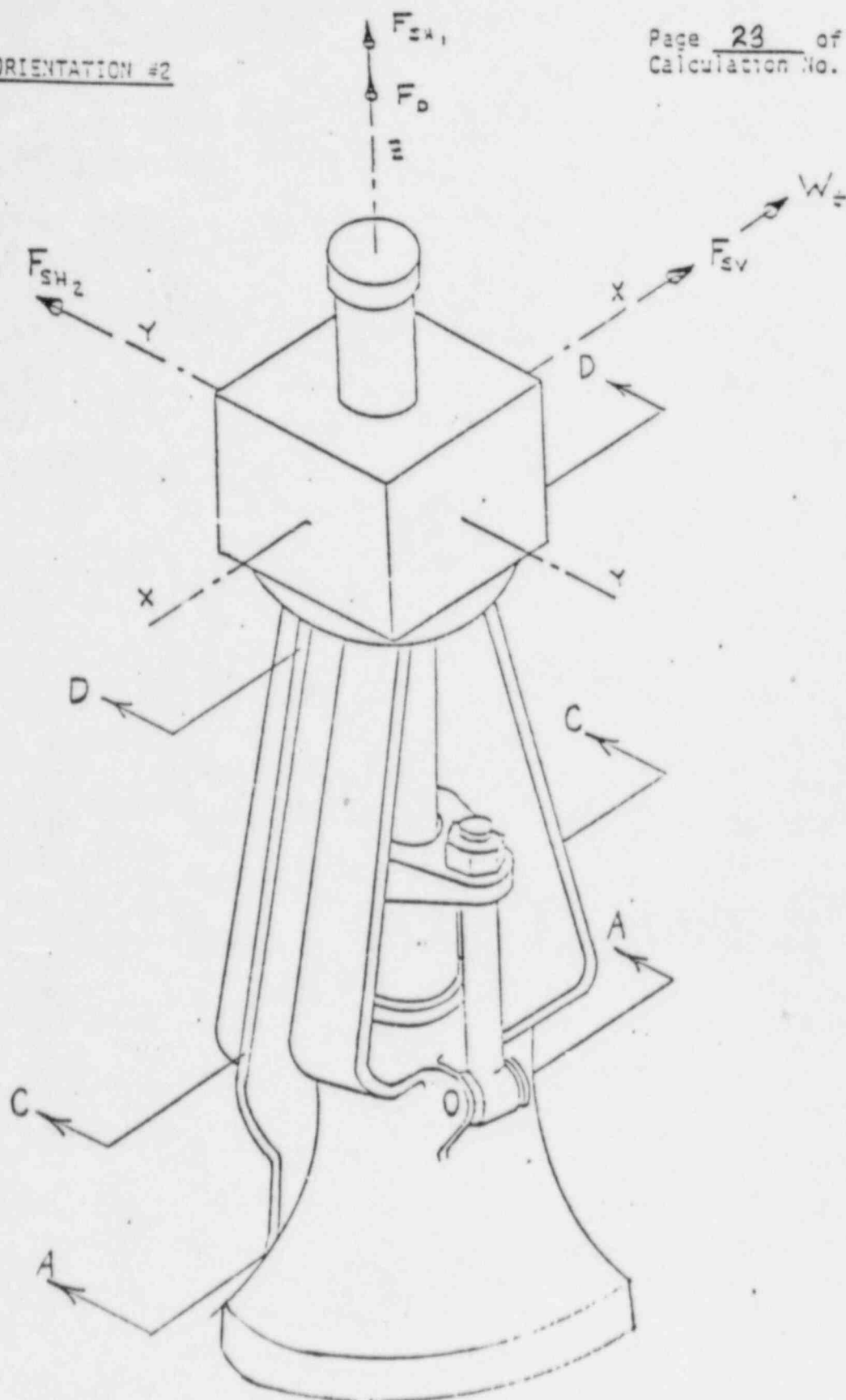
It has been determined that the above orientation
 results in the greatest stress.

ORIENTATION #1

Page 22 of 50
Calculation No. ADS2-31



SECTION LOCATIONS



五

SECTION LOCATIONS

CROSS SECTIONAL PROPERTIES

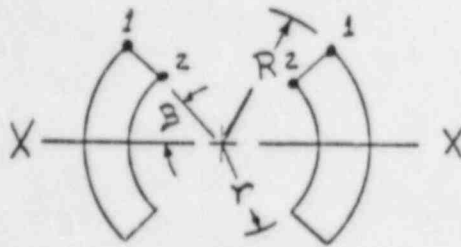


FIG. A

β In Radians

Except in Trig. Functions

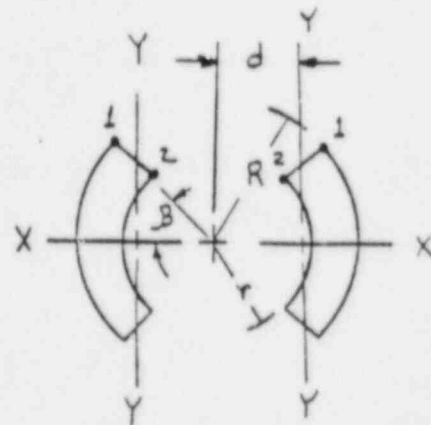


FIG. B

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.] | $r \sin \beta$ |
| \bar{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.] | $r \cos \beta - d$ |
| \bar{z} [In. 3] | I/C |
| A [In. 2] | $\beta (R^2 - r^2)$ |

(One Segment)

CROSS SECTIONAL PROPERTIES

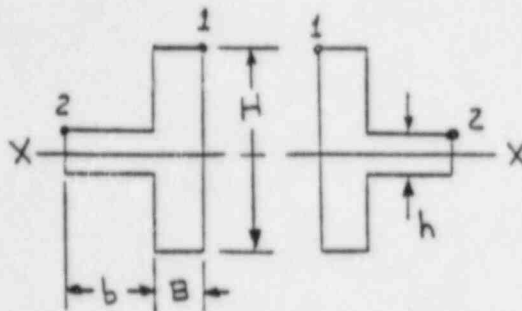


FIG. C

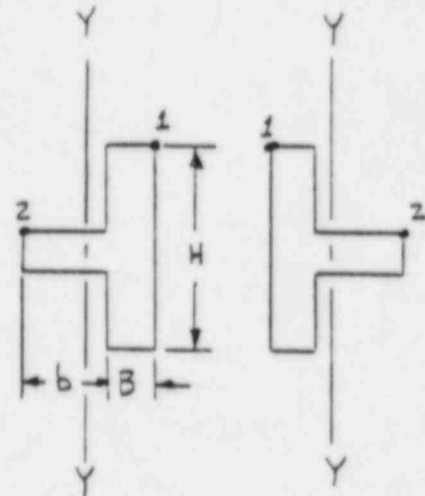


FIG. D

| 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] | $\frac{1}{3} [(B+b-C_1)^3 h + (C_1)^3 (H) - (C_1-B)^3 (H-h)]$ |
| Point 2 I_{y-y} [In. ⁴] | $\frac{1}{3} [(C_2)^3 h + (B+b-C_2)^3 (H) - (b-C_2)^3 (H-h)]$ |
| 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

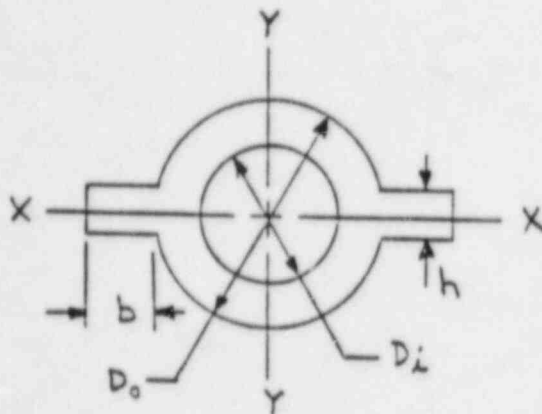


FIG. E

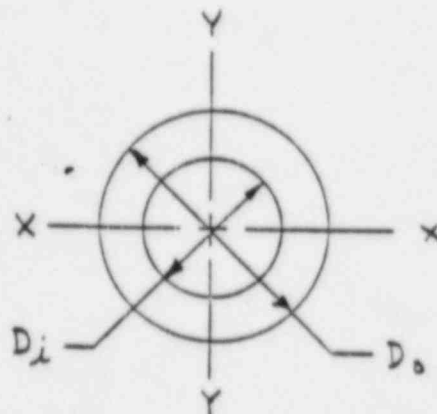


FIG. F

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

POINTS OF HIGHEST STRESS

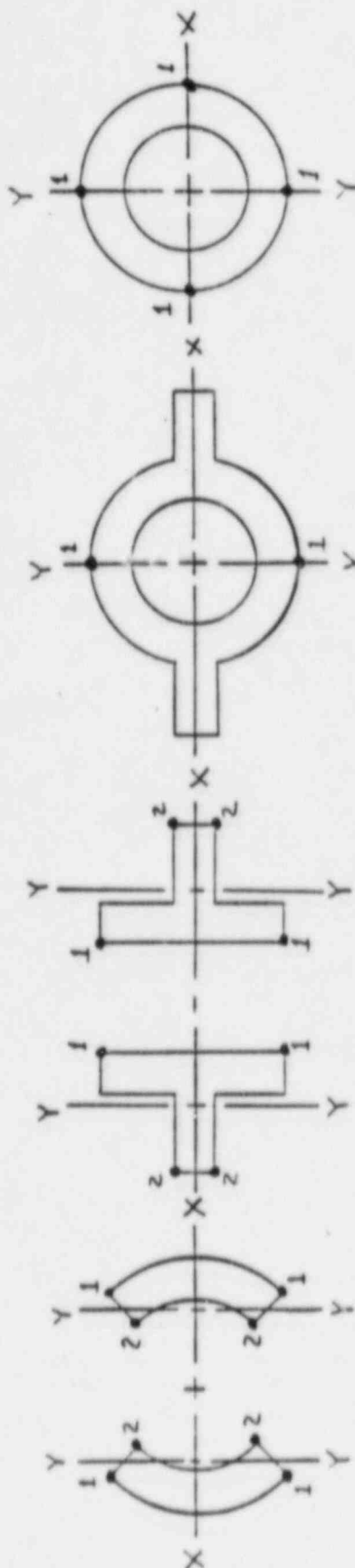


FIG. A & B

FIG. C & D

FIG. E

FIG. F

POINT 1 OF FIG. C HAS THE HIGHEST STRESS

PROPERTIES TABLE

@ Pt. #1

| SEC. <u>A-A</u> | SEC. <u>C-C</u> | SEC. <u>C-C</u> | SEC. <u>E-E</u> | SEC. _____ |
|---|--|---|--|-------------------------------------|
| Description: Bonnet neck FIG. <u>F</u> | Description: Yoke leg bottom FIG. <u>C</u> | Description: Yoke leg structure FIG. <u>D</u> | Description: Yoke plate structure FIG. <u>F</u> | 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. <u>D-D</u> | SEC. <u>D-D</u> | SEC. <u>E-E</u> | SEC. _____ | SEC. _____ |
|--|---|--|-------------------------------------|-------------------------------------|
| Description: yoke leg top FIG. <u>C</u> | Description: yoke leg structure FIG. <u>D</u> | Description: yoke plate structure FIG. <u>F</u> | 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 neckDead Weight and Vertical Seismic Load:

Direct Moment: $W_e \bar{Y} = M_{FD} = \underline{97,190.1}$ in-lb.

Direct Stress: $M_{FD}/Z = \sigma_{MD} = \underline{2,216.2}$ PSI

Vertical Seismic Load: $G_v = \underline{3.00}$

Vertical Seismic Force: $W_e G_v = F_{SV} = \underline{6,275.7}$ lb.

Vertical Seismic Moment: $F_{SV} \bar{Y} = M_{SV} = \underline{291,570.2}$ in-lb.

Vertical Seismic Stress: $M_{SV}/Z = \sigma_{SV} = \underline{6,648.7}$ PSI

Operational and Horizontal Seismic Load (F_{SH_1})

Direct Force: $F_D = \underline{87,755.3}$ lb.

Direct Stress: $F_D/A = \sigma_{FD} = \underline{2,715.8}$ PSI

Horizontal Seismic Load: $G_H = \underline{3.00}$

Horizontal Seismic Force: $W_e G_H = F_{SH_1} = \underline{6,275.7}$ lb.

Horizontal Seismic Stress: $F_{SH_1}/A = \sigma_{SH_1} = \underline{194.2}$ PSI

Horizontal Seismic Load (F_{SH_2})From Structure Analysis Pg.

$\sigma_{SH_2} = \underline{N/A}$ PSI

Total Stress

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

Allowable Stress:

$\sigma_A = 1.5 S_A = \underline{26,250}$ PSI

$\sigma_A = \underline{17,500}$ For SA-216 Gr WCB at 225 °F

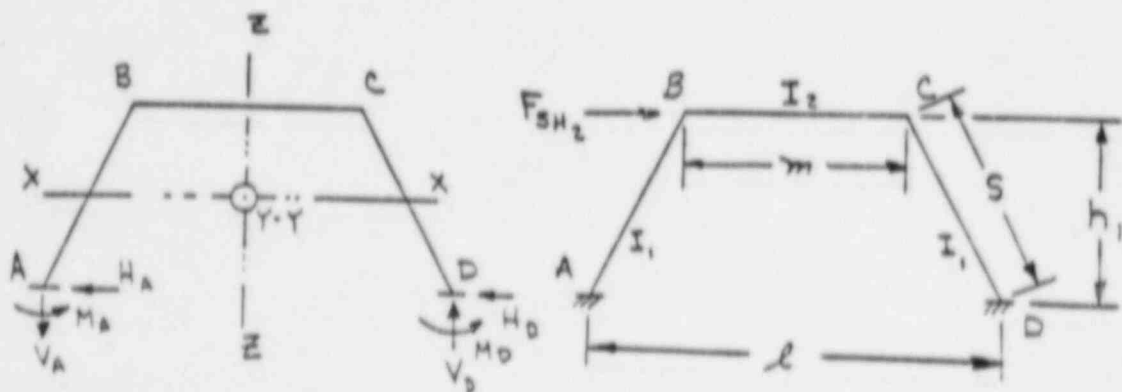
STRUCTURE ANALYSIS

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

(3) Pt. #1

STRUCTURE ANALYSIS:-

$$\begin{aligned} (I_2/I_1) (S/m) &= K = \underline{2814.6401} \\ (m/\ell) &= \lambda = \underline{0.5952} \\ K(1+\lambda)+\lambda(1+K) &= K_2 = \underline{6165.9922} \\ 2(1+\lambda+\lambda^2)K+\lambda^2 &= N_2 = \underline{10974.8906} \\ W_{tGh} = F_{SH_2} &= \underline{5710.86} \\ Z &= \underline{6.2207} \end{aligned}$$

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:-

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

STRESS:-

$$M/Z = \sigma_{SH_2} = \underline{\hspace{2cm}} \text{ PSI}$$

ORIENTATION #2

⊙ Pt. #2

STRUCTURE ANALYSIS:-

$$\begin{aligned} (I_2/I_1) (S/m) &= K = \underline{1107.5911} \\ (m/L) &= \lambda = \underline{0.5952} \\ K(1+\lambda) + \lambda(1+K) &= K_2 = \underline{2426.7463} \\ 2(1+\lambda + \lambda^2)K + \lambda^2 &= N_2 = \underline{4318.9492} \\ W_T &= \underline{1673.99} \\ W_T G_V = F_{SV} &= \underline{5021.97} \\ Z &= \underline{4.0168} \end{aligned}$$

SECTION N/A :-

BENDING MOMENT:-

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

STRESS:-

$$M/Z = \sigma_{SV} = \underline{\hspace{2cm}} \text{ PSI}$$

SECTION D-D :-

BENDING MOMENT:-

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

STRESS:-

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

@ Pt. #1

RESULTANT SEISMIC STRESS FOR SECTION C-C
yoke leg bottomDead Weight and Vertical Seismic Load:Direct Moment: $W_t \bar{Y} = M_{FD} = \underline{69996.1}$ in-lb.

Direct Stress:

$$M_{FD}/Z = \sigma_{MD} = \underline{6591.4} \text{ PSI}$$

Vertical Seismic Load: $G_v = \underline{3.00}$ Vertical Seismic Force: $W_t G_v = F_{SV} = \underline{5710.9}$ lb.Vertical Seismic Moment: $F_{SV} \bar{Y} = M_{SV} = \underline{209988.2}$ in-lb.

Vertical Seismic Stress:

$$M_{SV}/Z = \sigma_{SV} = \underline{19774.3} \text{ PSI}$$

Operational and Horizontal Seismic Load (F_{SH_1})

Direct Force:

$$F_D = \underline{87755.3} \text{ lb.}$$

Direct Stress:

$$F_D/A = \sigma_{FD} = \underline{6411.3} \text{ PSI}$$

Horizontal Seismic Load: $G_H = \underline{3.00}$ Horizontal Seismic Force: $W_t G_H = F_{SH_1} = \underline{5710.9}$ lb

Horizontal Seismic Stress:

$$F_{SH_1}/A = \sigma_{SH_1} = \underline{417.2} \text{ PSI}$$

Horizontal Seismic Load (F_{SH_2})From Structure Analysis Pg. 32

$$\sigma_{SH_2} = \underline{4494.8} \text{ PSI}$$

Total Stress

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

Allowable Stress:

$$*S_A = 1.5 S_a = \underline{26250} \text{ PSI}$$

$$*S_a = \underline{17,500} \text{ For SA-216 Gr WCB at } \underline{100} \text{ } ^\circ\text{F}$$

ORIENTATION #2

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Calculation No. ADSQ-31

⊙ Pt. #2

RESULTANT SEISMIC STRESS FOR SECTION D-D
yoke leg top

Horizontal Seismic Load (σ_{SH2})

Horizontal Seismic Load: $G_H = \underline{3.00}$
Horizontal Seismic Force: $W_t G_H = F_{SH2} = \underline{5022.0}$ lb.
Horizontal Seismic Moment: $F_{SH2} \bar{Y} = M_{SH2} = \underline{52,379.1}$ in-lb.
Horizontal Seismic Stress: $M_{SH2}/Z = \sigma_{SH2} = \underline{567.7}$ PSI

Operational and Horizontal Seismic Load (F_{SH1})

Direct Force: $F_D = \underline{87,755.3}$ lb.
Direct Stress: $F_D/A = \sigma_{FD} = \underline{5,638.9}$ PSI
Horizontal Seismic Load: $G_H = \underline{3.00}$
Horizontal Seismic Force: $W_t G_H = F_{SH1} = \underline{5022.0}$ lb.
Horizontal Seismic Stress: $F_{SH1}/A = \sigma_{SH1} = \underline{322.7}$ PSI

Dead Weight and Vertical Seismic Load:

From Structure Analysis Pg. 33 $\sigma_{SV} = \underline{9668.5}$ PSI

Total Stress

$$\sqrt{(\sigma_{SH2})^2 + (\sigma_{FD} + \sigma_{SH1})^2 + (\sigma_{SV})^2} = \sigma_T = \underline{11,372.9} \text{ PSI}$$

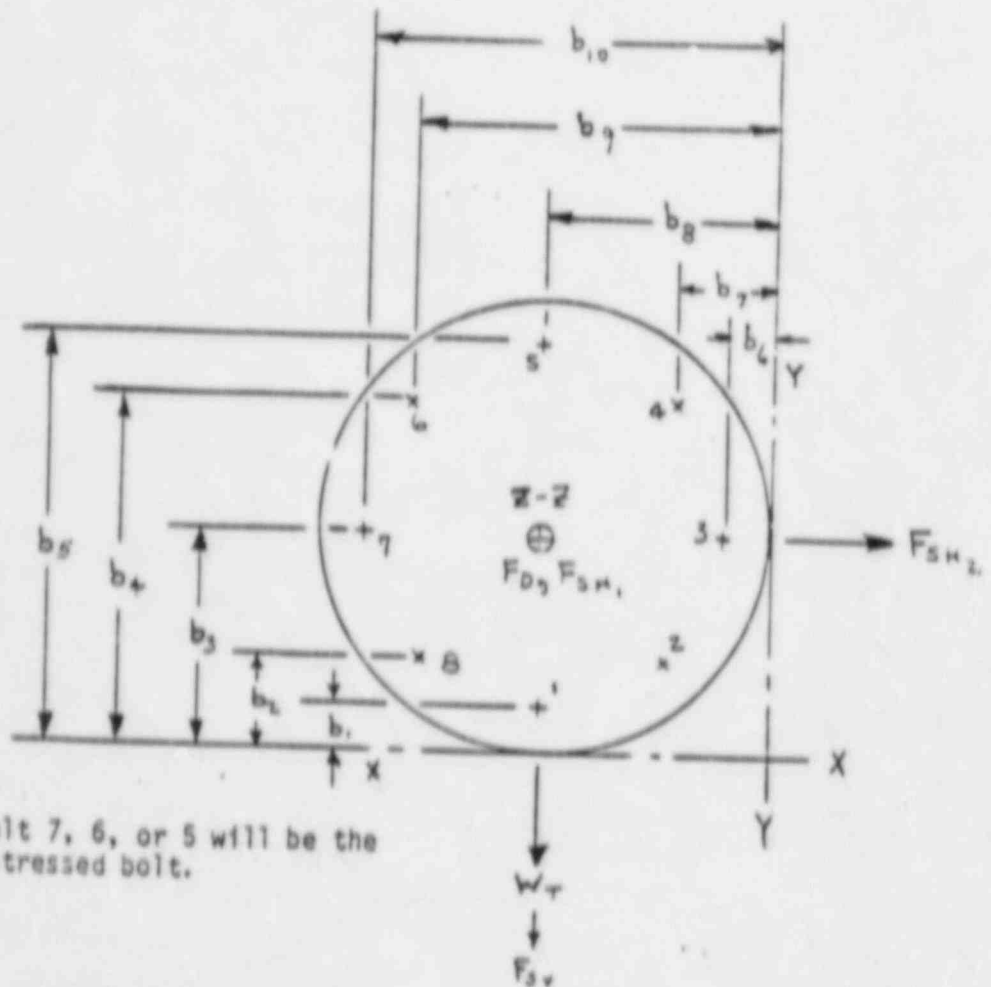
Allowable Stress:

$*S_A = 1.5 S_a = \underline{26,250}$ PSI

$*S_a = \underline{17,500}$ 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

$$(1) \sum M_{x-x} \Rightarrow \frac{M_{FD}}{M_{SV}} = F_5 b_5 + F_4 b_4 + F_3 b_3 + F_2 b_2 + F_1 b_1$$

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

where

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

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

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

Putting eq. (1) in terms of F_4

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

Putting eq. (1) in terms of F_3

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

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

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) | $\sigma_{MD} = \underline{665.30} \text{ PSI}$ |
| (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) | $\sigma_{MD} = \underline{574.38} \text{ PSI}$ |
| (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) | $\sigma_{MD} = \underline{354.83} \text{ PSI}$ |
| (Use Highest Stress) | | |

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

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

Vertical Seismic Stress:

| | |
|--|--|
| $(4) \frac{M_{SV}}{A_T} \left(\frac{b_5}{(b_5^2 + b_1^2) + 2(b_2^2 + b_3^2 + b_4^2)} \right) =$ | $(Bolt\ 5) \quad \sigma_{SV} = \underline{1,995.90} \text{ PSI}$ |
| $(5) \frac{M_{SV}}{A_T} \left(\frac{b_4}{(b_5^2 + b_1^2) + 2(b_2^2 + b_3^2 + b_4^2)} \right) =$ | $(Bolts\ 4\ \&\ 6) \quad \sigma_{SV} = \underline{1,723.13} \text{ PSI}$ |
| $(6) \frac{M_{SV}}{A_T} \left(\frac{b_3}{(b_5^2 + b_1^2) + 2(b_2^2 + b_3^2 + b_4^2)} \right) =$ | $(Bolts\ 3\ \&\ 7) \quad \sigma_{SV} = \underline{1,064.48} \text{ PSI}$ |

(Use Highest Stress)

② Operational and Horizontal Seismic Load (F_{SH1}):

Direct Force: $F_D = \underline{87,755.3}$ lb

Direct Stress:

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

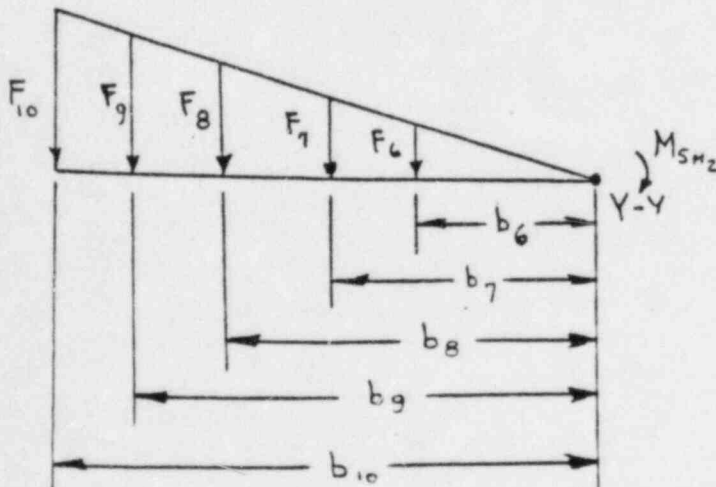
Horizontal Seismic Force: $W_T G_H = F_{SH1} = \underline{4,680}$ lb

Horizontal Seismic Stress:

$$\frac{F_{SH1}}{8A_T} = \sigma_{SH1} = \underline{1,266.23} \text{ PSI}$$

③ Horizontal Seismic Load (F_{SH2}):

* 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

$$(7) \quad \Sigma M_{y-y} \Rightarrow M_{SH2} = F_{10}b_{10} + F_9b_9 + F_8b_8 + F_7b_7 + F_6b_6$$

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

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

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

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

$$(10) \quad M_{SH2} = F_{10} \left(\frac{b_{10}^2}{b_{10}} + \frac{b_9^2}{b_{10}} + \frac{b_8^2}{b_{10}} + \frac{b_7^2}{b_{10}} + \frac{b_6^2}{b_{10}} \right) \quad (\text{for Bolt 7})$$

putting eq. (7) in terms of F_9

$$(11) \quad M_{SH2} = F_9 \left(\frac{b_{10}^2}{b_9} + \frac{b_9^2}{b_9} + \frac{b_8^2}{b_9} + \frac{b_7^2}{b_9} + \frac{b_6^2}{b_9} \right) \quad (\text{for Bolts 6 \& 8})$$

putting eq. (7) in terms of F_8

$$(12) \quad M_{SH2} = F_8 \left(\frac{b_{10}^2}{b_8} + \frac{b_9^2}{b_8} + \frac{b_8^2}{b_8} + \frac{b_7^2}{b_8} + \frac{b_6^2}{b_8} \right) \quad (\text{for Bolts 1 \& 5})$$

Horizontal Seismic Force $W_{TGH} = F_{SH2} = \underline{4,680} \text{ lb}$

Horizontal Seismic Moment: $F_{SH2} \bar{Y} = M_{SH2} = \underline{43,524} \text{ in-lb}$

Horizontal Seismic Stress:

$$(10) \quad \frac{M_{SH2}}{A_T} \left(\frac{b_{10}}{(b_{10}^2 + b_6^2) + 2(b_9^2 + b_8^2 + b_7^2)} \right) = (\text{Bolt 7}) \quad \sigma_{SH2} \underline{1,995.90} \text{ PSI}$$

$$(11) \quad \frac{M_{SH2}}{A_T} \left(\frac{b_9}{(b_{10}^2 + b_6^2) + 2(b_9^2 + b_8^2 + b_7^2)} \right) = (\text{Bolts 6 \& 8}) \quad \sigma_{SH2} \underline{1,723.13} \text{ PSI}$$

$$(12) \quad \frac{M_{SH2}}{A_T} \left(\frac{b_8}{(b_{10}^2 + b_6^2) + 2(b_9^2 + b_8^2 + b_7^2)} \right) = (\text{Bolts 1 \& 5}) \quad \sigma_{SH2} \underline{1,064.48} \text{ PSI}$$

(Use Highest Stress)

MOTOR UNIT-TO-YOKE BOLTING

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Calculation No. ADSR-31

- ④ Maximum Total Stress:

$$\sqrt{(\sigma_{MD} + \sigma_{SV})^2 + (\sigma_{FD} + \sigma_{SH1})^2 + (\sigma_{SH2})^2} = \sigma_T = \underline{25,173.9} \text{ PSI}$$

Bolt 6 is Highest Stressed

- ⑤ Allowable Stress:

for

A-193 B-7

$$S_a = \underline{25,000} \text{ PSI}$$

$$W_T = \underline{1560.0} \text{ lb}$$

$$\bar{Y} = \underline{9.3} \text{ in.}$$

$$A_T = \underline{0.462} \text{ In.}^2$$

$$F_D = \underline{87,755.3} \text{ lb}$$

$$G_V = \underline{3.00}$$

$$G_H = \underline{3.00}$$

$$b_1 = b_6 = \underline{1.00} \text{ in.}$$

$$b_2 = b_7 = \underline{3.05} \text{ in.}$$

$$b_3 = b_8 = \underline{8.00} \text{ in.}$$

$$b_4 = b_9 = \underline{12.95} \text{ in.}$$

$$b_5 = b_{10} = \underline{15.00} \text{ in.}$$

FREQUENCY ANALYSIS

Beam Orientation - 4 Part

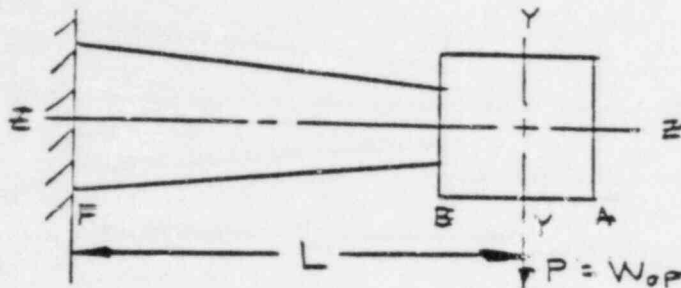
ASSUMPTIONS:-

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:-

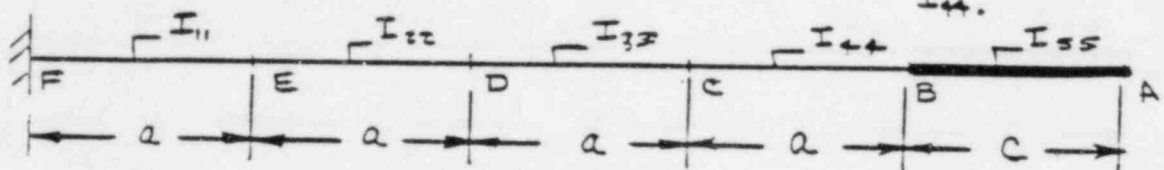
- E = Modulus of elasticity (PSI)
- g = Acceleration due to gravity (In/Sec)
- I_{44} = The moment of inertia at the yoke top and assumed constant one-fourth of the way down the yoke leg.
- I_{33} = The moment of inertia down one-fourth from the top of the yoke leg and assumed constant to the mid point 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

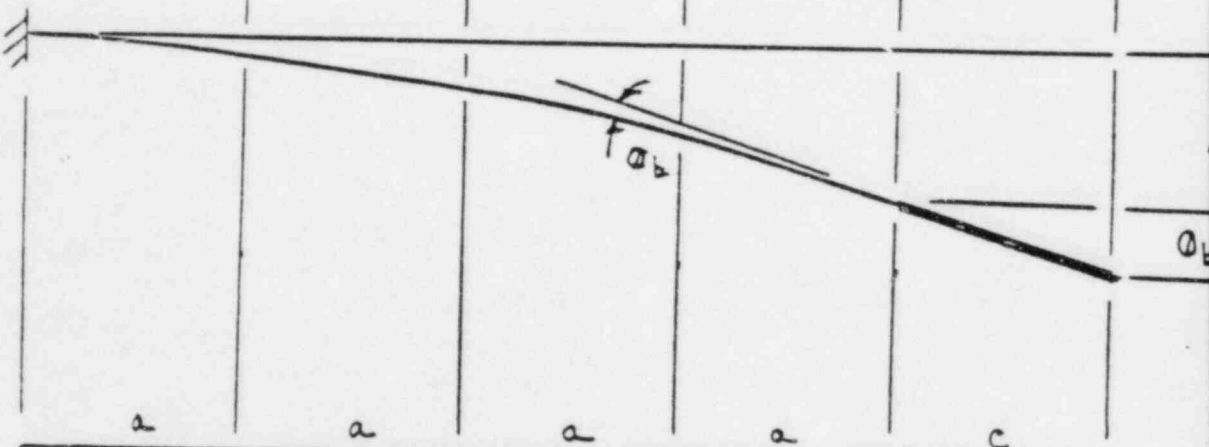


VALVE YOKE LEG
BROKEN INTO 4
EQUAL PARTS.

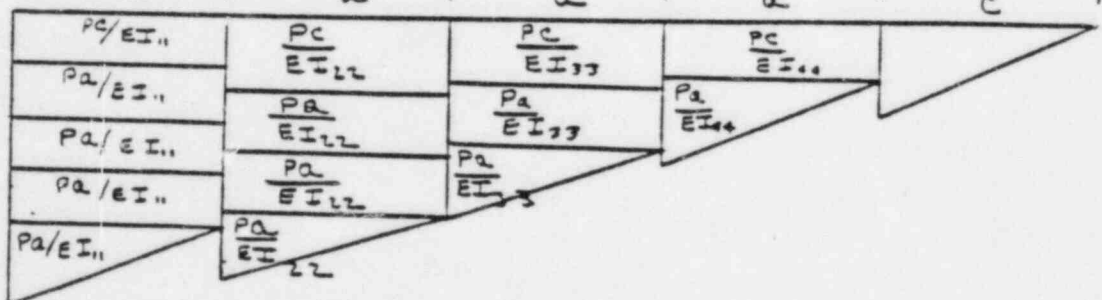
ASSUME I_{55} IS
RIGID $I_{55} > 7I_{11} +$
 I_{44} .



DEFLECTION



$\frac{M}{EI}$



BEAM ORIENTATION - 4 PART

$$\delta_T = \delta_A + \phi_b C$$

$$\begin{aligned} \delta_A = \sum X(AREA) \Big|_B^F &= \left(\frac{2}{2}\right) \left(\frac{Pca}{EI_{44}}\right) + \left(\frac{2a}{3}\right) \left(\frac{Pa^2}{2EI_{44}}\right) + \left(\frac{3a}{2}\right) \left(\frac{Pca}{EI_{33}} - \frac{Pa^2}{EI_{33}}\right) \\ &+ \left(\frac{5a}{3}\right) \left(\frac{Pa^2}{2EI_{33}}\right) + \left(\frac{5a}{2}\right) \left(\frac{Pca}{EI_{22}} + \frac{2Pa^2}{EI_{22}}\right) + \left(\frac{8a}{3}\right) \left(\frac{Pa^2}{2EI_{22}}\right) \\ &+ \left(\frac{7a}{2}\right) \left(\frac{Pca}{EI_{11}} + \frac{3Pa^2}{EI_{11}}\right) + \left(\frac{11a}{3}\right) \left(\frac{Pa^2}{2EI_{11}}\right) \end{aligned}$$

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

$$\begin{aligned} \phi_b = \sum (AREA) \Big|_B^F &= \frac{2Pca + Pa^2}{2EI_{44}} + \frac{2Pca + 3Pa^2}{2EI_{33}} + \frac{2Pca + 5Pa^2}{2EI_{22}} \\ &+ \frac{2Pca + 7Pa^2}{2EI_{11}} \end{aligned}$$

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

BEAM ORIENTATION - 4 PART

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

$$\Delta_T = \underline{0.033153} \text{ IN.}$$

$$f_n = \frac{1}{2\pi} \sqrt{g K_T / W_{OP}} = \frac{1}{2\pi} \sqrt{g / \Delta_T} = \underline{17.173} \text{ CPS}$$

$$\text{where } K_T = \frac{W_{OP}}{\Delta_T}$$

$$f_3 = \underline{33.0} \text{ CPS}$$

$$W_{OP} = \underline{1560.0} \text{ LB}$$

$$E = \underline{28.675 \times 10^6} \text{ PSI}$$

$$g = \underline{386} \text{ IN/SEC}^2$$

$$a = \underline{7.3202} \text{ IN.}$$

$$c = \underline{10.80} \text{ IN.}$$

$$I_{11} = \underline{34.5126} \text{ IN.}^4$$

$$I_{22} = \underline{34.5346} \text{ IN.}^4$$

$$I_{33} = \underline{34.5565} \text{ IN.}^4$$

$$I_{44} = \underline{34.5785} \text{ IN.}^4$$

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:-

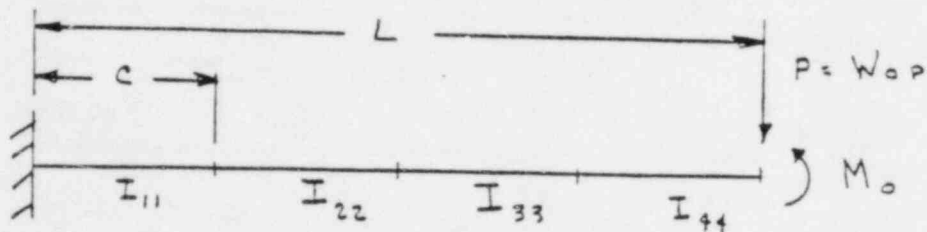
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- g = Acceleration due to gravity (In/Sec)
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- I_{33} = The moment of inertia down one-fourth from the top of the yoke leg and assumed constant to the mid point of the yoke leg.
- I_{22} = The moment 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

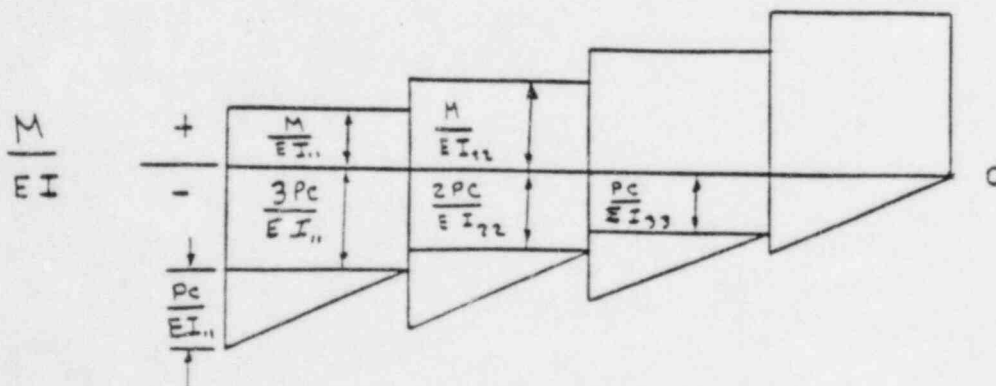
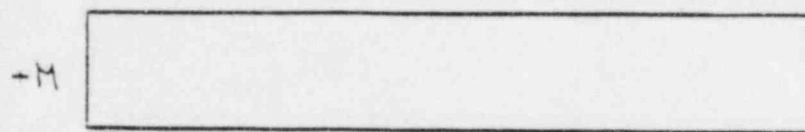
AREA MOMENT METHOD.

THE VALVE STRUCTURE IS BROKEN INTO
FOUR EQUAL PARTS



$$PL = 4Pc$$

MOMENT
DIAGRAM



FRAME ORIENTATION - 4 PART

$$\Sigma A = 0 \quad \text{at Pt. O} \quad \Sigma A = 0 = 0$$

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

SOLVE FOR M_o

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

$$2) \Delta \delta /_o^L = \Sigma (\text{AREA})(\bar{x})$$

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

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

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

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

FRAME ORIENTATION - 4 PART

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

$$\delta_{MAX} = \underline{-0.007296 \text{ IN.}}$$

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

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

$$f_3 = \underline{33.0 \text{ CPS}}$$

$$W_{OP} = \underline{1560.0 \text{ LB}}$$

$$g = \underline{386 \text{ IN/SEC}^2}$$

$$E = \underline{28.675 \times 10^6 \text{ PSI}}$$

$$C = \underline{10.80 \text{ IN.}}$$

$$I_{11} = \underline{5.3525 \text{ IN.}^4}$$

$$I_{22} = \underline{6.9709 \text{ IN.}^4}$$

$$I_{33} = \underline{8.8740 \text{ IN.}^4}$$

$$I_{44} = \underline{11.0789 \text{ IN.}^4}$$

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