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REACTOR COOLANT PUMPS GENERATOR
AND FLYWHEEL SEISMIC ANALYSIS

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APPLIED MECHANICS BRANCH

REACTOR COOLANT PUMPS GENERATOR
AND FLYWHEEL SEISMIC ANALYSIS

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P&CSB Mgr.		PSB Mgr.		RSB Mgr.	
SA&TSS Supvr.		ABSTRACT			

The LOFT Primary System Motor Generator Set was analyzed for sliding and overturning during a seismic event. The assembly is located in TAN 650, Room B239, and is satisfactory against seismic loading.

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1.0 INTRODUCTION

An assembly consisting of a generator, a flywheel, fluid coupling, and motor are attached to a base consisting of two 16 x 88 wide flanges in the TAN LOFT support building. The base is then attached to the concrete floor. Seismic analysis verifies that the vital equipment, the generator, flywheel, and fluid coupling assembly will not slide or overturn from the base. The analysis also shows that the base will not slide or overturn with relationship to the floor.

2.0 CONDITIONS OF ANALYSIS

Seismic accelerations for LOFT analyses are developed in Reference (1). These result in loads of less than 1G for 4% damping (see page 1 of Appendix A). The machinery is considered to be able to withstand a 1G load (shipping and installation requirements). Only the rigid body modes of sliding and rotation are examined. Activating forces are calculated according to RDT-F9-2T in Appendix A.

2.1 Sliding Displacement

The assembly is assumed to undergo maximum horizontal acceleration concurrently with maximum vertical acceleration in opposition to gravity. The coefficient of friction of the generator, the flywheel, and the fluid coupling assembly to the base is assumed to be zero. The coefficient of friction is assumed to be zero between the base and the floor, also.

2.2 Overturning

The loading condition is the same as for the sliding mode. Calculations for sliding and overturning appear in Appendix A.

3.0 RESULTS

Stress results for sliding shear stress and axial overturning stress are combined using stress intensity calculated from Mohr's circle. The resulting stress for the welds is compared to AISC allowable stress level of

Section 1.5.3. The material for the bolts was conservatively assumed to be a steel with yield stress of 30 ksi. The allowable stress in the bolts is developed in AISC Section 1.5.2.

Comparison is made in Table I:

<u>TABLE I</u>				
<u>Figure</u>	<u>Shear Stress (psi)</u>	<u>Axial Stress (psi)</u>	<u>Intensity (psi)</u>	<u>Allowable (psi)</u>
1	290	433	725	14,400
2	352	365	793	14,400
3	1181	2046	3,125	18,000
4	6100	6700	13,900	18,000

4.0 CONCLUSION

The assembly consisting of the generator, flywheel, motor, fluid coupling, and base are satisfactory under seismic loading.

5.0 REFERENCES

1. V. W. Gorman and R. C. Guenzler, "LOFT SSE Definition and Seismic Analysis Methods", LOFT Technical Report LTR 10-19, October 8, 1974.
2. American Institute of Steel Construction, "Steel Construction Manual", Seventh Edition, 1971.

FIGURE 1 : GENERATOR TO BASE

FIGURE 2: FLYWHEEL/PEDESTAL TO BASE

Figure 3: Fluid Coupling Assembly to Base.

FIGURE 4: BASE TO FLOOR

APPENDIX A
CALCULATIONS

CALCULATION WORK SHEET

SUBJECT SEISMIC ANALYSIS GENERATOR & FLYWHEEL PAGE A-1 OF PAGES
DATE
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APPENDIX A

PEAK RESPONSE SPECTRUM ACCELERATION FOR THE LOFT SITE
IS 19.5 FT/SEC^2

MAXIMUM VERTICAL GROUND ACCELERATION IS $2/3$ 'S HORIZONTAL
ACCELERATION ACTING UP OR DOWN

RDT-F9-2T

LEVELS OF LOFT FACILITIES BELOW GROUND ARE CONSIDERED
TO RESPOND AS GROUND MOTION, THEREFORE:

$$A = 1.5 \times A_s$$

WHERE

A = RESULTING ACCELERATION

A_s = PEAK GROUND ACCELERATION FROM RESPONSE SPECTRUM

$$A_H = 1.5 \times 19.5 \text{ FT/SEC}^2$$

$$= 29.25 \text{ FT/SEC}^2$$

$$= 0.91 \text{ G}$$

$$A_V = 2/3 A_H$$

$$= 0.61 \text{ G}$$

CALCULATION WORK SHEET

PAGE A-2 OF PAGES

SUBJECT

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SEISMIC ANALYSIS

I. GENERATOR TO BASE
WEIGHT = 9000 #

A. SLIDING

$$F_H = 0.91 \times W$$

WHERE W IS THE WEIGHT

$$F_H = 0.91 \times 9000$$

$$= 8190^\#$$

FRICTION BETWEEN GENERATOR AND BASE ASSUMED TO BE ZERO.

GENERATOR HELD IN PLACE BY 32-2" WELDS. WELDS ARE

5/8" ASSUMED TO BE FILLET.

SHEAR AREA OF WELDS:

$$A = 0.707 \times \frac{5}{8} \times 2 \times 32$$

$$= 28.28 \text{ in}^2$$

SHEAR STRESS

$$\sigma = P/A$$

8190[#]
/28.28

$$= 290 \text{ PSI}$$

CALCULATION WORK SHEET

PAGE A-3 OF PAGES

SUBJECT _____ **DATE** _____

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B. OVERTURN MOMENT

OVERTURN MOMENT IS

$$M_T = A_H \times W \times H$$

A_H — HORIZONTAL ACCELERATION
 W — WEIGHT
 H — HEIGHT TO CENTER OF GRAVITY

MINIMUM RESTORING MOMENT

$$M_R = (1 - A_v) W \left(\text{WIDTH} / 2 \right)$$

MINIMUM WIDTH OR DEPTH
 WEIGHT
 MAXIMUM VERTICAL ACCELERATION

$$M_T = (0.91 \times 9000) \times 139.7$$

$$= 325,000 \text{ \#-IN}$$

$$M_R = (1 - 0.61) \times 9000 \times 23.25$$

$$= 82000 \text{ \#-IN}$$

UNBALANCED FORCE DEVELOPED BY STRESS IN ANCHORS ONE HALF OF WELDS AVAILABLE TO PREVENT OVERTURNING

$$\sigma = \frac{(M_T - M_R) Z}{\text{WIDTH } A}$$

$$\sigma = \frac{(390,000 - 82000)2}{28.28 \times 39.7}$$

$$= 433 \text{ PSI}$$

CALCULATION WORK SHEET

PAGE A-4 OF PAGES

SUBJECT _____ **DATE** _____

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STRESS INTENSITY

$$2 \left(\left(\frac{433}{2} \right)^2 + 290^2 \right)^{1/2} = 725 \text{ PSI}$$

II FLYWHEEL AND PEDESTALS TO BASE

ASSUME FLYWHEEL & PEDESTAL ACT AS ONE

$$W_T = W_{\text{FLYWHEEL}} + W_{\text{PEDESTAL}}$$

$$= 9500 + 1500 = 11000^{\#}$$

A. SLIDING

$$F_H = 0.91 \times 11000 = 10,010 \text{ ft}$$

FRICTION ASSUMED TO BE ZERO.

CONNECTIONS OF PEDESTAL TO BASE CONSIST OF
8- $\frac{7}{8}$ " BOLTS, 16-1" WELDS AND 20-2" WELDS. ASSUME
WELDS $\frac{5}{8}$ " FILLET

$$A_{BOLTS} = 8 \times 0.4617 = 3.69 \text{ IN}^2$$

TENSILE STRESS AREA

$$A_{WELDS} = .707 \times 5/8 [(16 \times 1) + (20 \times 2)] = 24.75 \text{ IN}^2$$

$$A_{\text{TOTAL}} = 3.69 + 24.75 = 28.44 \text{ in}^2$$

SHEAR STRESS

$$\sigma = \frac{10000}{28.44} = 352 \text{ PSI}$$

CALCULATION WORK SHEET

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BOVERTURN MOMENT

$$M_T = A \times W \times H$$

$$= 0.91 \times 11000 \times 34 = 340,000 \text{ #-IN}$$

$$M_R = (1 - A_v) W (\text{WIDTH}/2)$$

$$= (1 - 0.61) 11000 (46.5/2) = 99,700 \text{ #-IN}$$

$$\sigma = \frac{(M_T - M_R) Z}{\text{WIDTH } A}$$

$$\sigma = \frac{(340000 - 99700) Z}{46.5 \times 28.44}$$

$$= 365 \text{ PSI}$$

STRESS INTENSITY

$$SI = 2 \left(\left(\frac{365}{2} \right)^2 + 352^2 \right)^{1/2}$$

$$= 793 \text{ PSI}$$

III. BASE TO FLOOR

10-1/8" BOLTS CONNECTING BASE TO FLOOR, TENSILE STRESS AREA .76 IN²

DUE TO UNEVEN LOADING CAUSED BY THE CONCENTRIC LOADS OF THE GENERATOR AND FLYWHEEL/PEDESTAL THE FORCES WERE CHANGED TO AN EQUIVALENT FORCE AND A MOMENT ACTING AT THE CENTER OF GRAVITY OF THE BOLTS.

CALCULATION WORK SHEET

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$$\text{CENTER OF GRAVITY OF BOLTS} = \frac{76(29.5 + 96.13 + 124.13 + 175.63 + 242.13)}{5 \times 76}$$

$$C.G. = 133.50 \text{ IN}$$

$$\sum M_{CG} = 0 \quad ; \quad M = 104(9000) + 23.4(11000) + 1.5(10000) - 42.13(7500) - 109(7500) = 75000 \text{ #-IN}$$

THE EQUIVALENT SYSTEM CONSISTS OF A FORCE OF $45,000^{\#}$ AND A COUNTER-CLOCKWISE MOMENT OF $75000^{\#-IN}$

$$\sigma = \frac{A_H M_C}{I} + \frac{A_H P}{A}$$

WHERE

$$M = 75000 \text{ #-IN}$$

A_H - HORIZONTAL ACCELERATION

C = DISTANCE TO FURTHEREST BOLT

$$I = \Sigma Ad^2$$

P = 45,000

$$I = 2(.76)(104^2 + 37.38^2 + 9.38^2 + 42.13^2 + 108.63^2)$$

$$= 390000 \text{ in}^4$$

ALLOWABLE = 4.4/KSI

H.K. 1510-20 (48)

Fluid Coupling Assembly (Sliding & overturning)

Dynamic loading (Seismic)

Horizontal acceleration is 0.91G.

Therefore,

$$F_{HD} = 4400 \times 0.91 = 4004 \text{ lb.}$$

$$F_{HC} = 220 \times 0.91 = 200 \text{ lb.}$$

$$\therefore \text{Total shear force taken by the 4, } 1\frac{1}{4}'' \text{ bolts} = 4004 + 200 \\ = 4204 \text{ lb.}$$

$$\therefore \text{Shear force in each bolt} = \frac{4204}{4} = 1051 \text{ lb.}$$

$$\text{The small c.s. for a } 1\frac{1}{4}'' \text{ dia. bolt} = 0.890 \text{ sq. in.}$$

The shear stress in the bolt for side restraint, S_s ,

$$S_s = \frac{1051}{0.890} = 1181 \text{ lb./in}^2$$

Overturning moment.

$$= 4004 \times 32 + 220 \times 9.25$$

$$= 130163 \text{ in. lb.}$$

Let the force in each bolt be P.

Therefore

$$2P \times 35.75 \text{ (in)} = 71.50P$$

$$71.50P = 130163$$

$$P = \frac{130163}{71.50} = 1821 \text{ lb.}$$

$$\therefore \text{Bending or tipping stress} = \frac{1821}{0.890} = 2046 \text{ lb./in}^2$$

$$\therefore \text{Intensity} = 2 \left[\left(\frac{2046}{2} \right)^2 + (1181)^2 \right]^{\frac{1}{2}} = 3125 \text{ lb./in}^2$$

The allowable stress in a bolt of this nature is 18,000 lb./in².

The individual stresses of sliding (shear) and tipping (bending) are so small that there does not appear to be any need for looking for their combination.

In conclusion, it can be said that the mounting is within allowable limit for seismic condition.