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SEISMIC ANALYSIS OF THE LOFT DIESEL
GENERATOR "A" COOLING SYSTEM

D. P. Finicle

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APPLIED MECHANICS BRANCH

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ABSTRACT

The Diesel Generator "A" Cooling System has been analyzed for a Safe Shutdown Earthquake (SSE). A static equivalent seismic analysis was performed in accordance with RDT F9-2T, Ref. 1. The cooling system was found to be structurally adequate.

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SEISMIC ANALYSIS OF THE LOFT DIESEL
GENERATOR "A" COOLING SYSTEM

I. SUMMARY

A static equivalent seismic analysis of the Diesel Generator "A" Cooling System has been completed. The static equivalent loads were applied to the radiator, over-pressure tank, piping, and the pipe supports. The cooling system was found to be structurally adequate for the applied SSE loading.

II. INTRODUCTION

The diesel generator "A" is located in the Hanger at the LOFT Facility. The cooling system is a closed loop system, and the coolant is cooled by use of a radiator. Very little information was provided on the LOFT diesel generator "A" cooling system. Most of the values used in the analysis were obtained from field measurements or by assumption. All assumed values were selected to produce conservative results.

III. DESCRIPTION OF SYSTEM

The diesel generator "A" is located in the Hanger at the LOFT Facility. Its purpose is to provide electrical power during a power outage. The diesel generator "A" consists of a diesel engine connected to an electrical generator. The coolant for the diesel engine is provided by a closed loop system which contains a radiator. The radiator and the engine are connected by a set of pipes. A sketch of this system is shown in Figures 1 and 2.

Ⓝ - Numbers used to Identify Lines

FIGURE 1

~ DIESEL GENERATOR "A" COOLING SYSTEM ~
ELEVATION

~OVER PRESSURE TANK DETAILS~

FIGURE 2

IV. LOADING

The only load combination considered in this analysis is the sum of dead weight and seismic loads. The dead weight loads were calculated based on the weight of the components being considered. The static equivalent seismic loads were determined in accordance with RDT F9-2T, Ref. 1. The static equivalent seismic forces were calculated using the following relationship:

$$F = 1.5 \frac{W_e}{g} A$$

where F = static equivalent force

W_e = weight of component

A = peak acceleration from the response spectrum curve.

The response spectrum curve, obtained from LTR 10-19, Ref. 2, is shown on page 2 of Appendix A. Damping values are given on page 3 of Appendix A, which are from Ref. 1.

V. ANALYSIS

A simplified static equivalent seismic analysis was done. The radiator and its supports were analyzed like a cantilever beam. The piping lines were analyzed as simply supported beams in order to obtain the maximum possible bending moments. The attachments to the pumps were not analyzed since they were not included in the scope of this job.

VI. RESULTS

The entire diesel generator "A" cooling system was found to be structurally adequate to withstand an SSE event.

VII. CONCLUSIONS

The static equivalent seismic analysis of the deisel generator "A" cooling system has been completed. Conservative analytical techniques and loading were used in the analysis. No problem areas were found with the cooling system.

VIII. REFERENCES

1. RDT Standard F9-2T, "Seismic Requirements for Nuclear Design of Nuclear Power Plants and Test Facilities" (January 1974).
2. V. W. Gorman and R. C. Guenzler, "LOFT SSE Definition and Seismic Analysis Methods", LOFT Technical Report LTR 10-19 (October 8, 1974).

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SUBJECT DIESEL GENERATOR "A" COOLING SYSTEM DATE
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SEISMIC ANALYSIS OF THE DIESEL GENERATOR "A" COOLING SYS.

A static equivalent seismic analysis of the LOFT Diesel Generator Cooling System will be performed. Static Equivalent Loads will be determined based on the following two formula's from RDT F9-2T, ref 1:

$$F_{EQ} = 1.5 \frac{W_e A_s}{g} \quad \text{where spectra is available for the support point}$$

or.

$$F_{EQ} = 8.0 \frac{W_e}{g} A_s \quad \text{where response spectra is not available for the support point}$$

The Acceleration values obtained from the response spectrum are from LTR 10-19, ref. 2. This is shown on pg 2.

The appropriate damping values are obtained from RDT F9-2T, ref. 1. These values are shown on page 3.

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~ RESPONSE SPECTRUM CURVES ~

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Table 1. Damping Coefficients

Structural System	Percent of Critical Damping	
	OBE and 0.5 SSE (At or close to one-half yield)	SSE (At or just below yield)
Reinforced concrete containment structures and concrete foundations	4.0	7.0
Prestressed concrete structures	2.0	5.0
Conventionally reinforced concrete structures above ground; i.e., shear walls and rigid frames	4.0	7.0
Steel structures		
Welded steel structures	2.0	4.0
Bolted or riveted steel structures	4.0	7.0
Piping systems (welded)		
Small diameter	1.0	2.0
Large diameter (>12 in. nominal dia.)	2.0	3.0
Foundation materials for structures		
On rock c >6000 fps ^a	2.0	5.0
On firm soil c ≥2000 fps ^a	5.0	7.0
On soft soil c <2000 fps ^a	7.0	10.0

^a Where c = shear wave velocity in the material.

The diesel generator A cooling system is a closed loop cooling system. This VITAL POWER Generator is located in the AIRPLANE HANGER.

As far as could be determined, the cooling system is not shown on the drawings that were provided. Sketches were made during a recent trip to the site and these sketches will be used to analyze the cooling system.

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The details on the Radiator were obtained from Young Radiator in Racine Wisc. A Mr. MARC EAMAN was contacted and he gave the weight of the radiator (dry) as 2000 lb and the C.G. as being 54.5" from the top and 29.5" from the left side. The capacity of the radiator was given as 40 gal.

ANALYZE THE RADIATOR SUPPORTS

The radiator is shown in fig 1. It is encased in an 8" channel section. The radiator is 6' wide.

Assume that the c.g. of the cooling fluid is up 42"

3 - $\frac{1}{2}$ " - BOLTS ON EACH FRAME

from pg 3, the appropriate damping value is 7% for an SSE. From pg 2, the peak acceleration is 15 ft/sec².

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$$F_{EQ \text{ HOR}} = \frac{1.5 W_e}{g} A_s = \frac{1.5 W}{32.2} \times 15 = .70 W = \text{HORIZONTAL}$$

$$F_{EQ \text{ VERT}} = \frac{2}{3} (.70 W) = .47 W$$

$$W_{RAD} = 2000 \text{ lb}$$

$$F_{EQ \text{ HOR}} = .7(2000) = 1400 \text{ lb}$$

$$F_{EQ \text{ VERT}} = 933 \text{ lb}$$

$$W_{FLUID} = 8.34 \frac{\text{lb}}{\text{gal}} \times 40 = 334 \text{ lb}$$

$$F_{EQ \text{ HOR}} = .7(334) = 234 \text{ lb}$$

$$F_{EQ \text{ VERT}} = 156 \text{ lb}$$

$$M @ \text{BASE OF RADIATOR} = 30(1400) + 42(234) = 51828 \text{ " \#}$$

$$M / \text{BOLT PATTERN} = 25914 \text{ " \#}$$

$$\text{Assume } d = 2"$$

EQUATE MOMENTS OF THE AREAS

$$2(3.025) = .1419 [2 + 10 + 22]$$

$$6.05 = 4.54 \text{ in}^3$$

$$\text{try } d = 1.75"$$

$$\frac{1.75^2}{2} (3.025) = .1419 [2.25 + 10.25 + 22.25]$$

$$4.63 \text{ in}^3 = 4.93 \text{ in}^3$$

← CLOSE ENOUGH

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$$I_{\text{BOLT PATTERN}} = \frac{3.025 (1.75)^3}{3} + .1419 (2.25^2 + 10.25^2 + 22.25^2)$$

$$5.4 + 85.9 = 91.30 \text{ in}^4$$

Stress in the Bolts

$$\sigma_{\text{TENSILE}} = \frac{Mc}{I} = \frac{25914(22.5)}{91.3} = 6386 \text{ psi}$$

$$\tau = \frac{(1400 + 234)}{3 (.1419)} = 3840 \text{ psi}$$

The BOLT STRESSES ARE RELATIVELY LOW, ANY BOLT MATERIAL WOULD BE OK.

CHECK "G" LOADING IN THE OTHER DIRECTION

$$M = 51828$$

The Moment is resisted by a couple acting at 72"

$$\text{FORCE/BOLT PATTERN} = \frac{51828^{\text{lb}}}{72} = 719.16/\text{BOLT PAT.}$$

$$\text{FORCE/BOLT} = 719/3 = 239 \text{ lb/BOLT}$$

$$\sigma_T = 239 / 1.419 = 169.0 \text{ psi}$$

Stresses how.

∴ Support for The RADIATOR is Adequate

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ANALYZE THE OVERPRESSURE TANK SUPPORTS
(See figs 1 & 2)

The over pressure tank is shown sitting on top of the radiator in fig. 1. The details for the supports are shown on fig. 2.

Per. Gary Hegerhorst of LOFT, This tank will never be over $\frac{1}{4}$ Full. This would put the fluid level at $18\frac{1}{4} = 4.5$ " deep.

Wt of tank.

Assume $\frac{3}{8}$ " Thick Wall.

$$\text{VOL. STEEL} = \pi (2 (\frac{3}{8})) 18 + \frac{\pi}{4} (12)^2 \frac{3}{8} =$$

$$= 254 + 42 = 297 \text{ in}^3$$

$$\text{WT. TANK} = .284 \text{ lb/in} (297) \approx 85 \text{ lb.}$$

$$\text{WT. WATER} = \frac{\pi}{4} (12)^2 4.5 (62.4) = 18.4 \text{ lb.}$$

$$M_{\text{OF BOLTS}} = 8 [125 + 27] + 9 (59.5) + 2.25 (12.9)$$

$$M_{\text{OF BOLTS}} = 1780 \text{ "#}$$

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$$M/BOLT \text{ PATTERN} = 1780/2 = 890 \text{ " \#}$$

THIS MOMENT IS RESISTED
BY A COUPLE

$$FORCE = M/3 = \frac{890}{3} = 296 \text{ lb.}$$

$$FORCE/BOLT_{MAX} = \left[\frac{296}{2} \right] \frac{4}{3} = 197 \text{ lb.}$$

BOLT STRESSES

$$\text{TENSILE AREA} = .0524 \text{ in}^2$$

5/16" BOLTS.

$$\sigma_{TENSILE} = \frac{197}{.0524} = 3759 \text{ psi}$$

Check Bending in the $\angle$ Sections. Bolt Stresses are low

$$1\frac{1}{4} \times 1\frac{1}{4} \times \frac{1}{8} \angle$$

$$A = .297 \text{ in}^2$$

$$S_{xx} = .049 \text{ in}^3$$

$$\sigma_{BENDING} = \frac{890}{.049} = 18163 \text{ psi}$$

Assuming A-36 Steel

$$f_y = 36000 \text{ psi} >> 18163$$

$\angle$ Sections are OK

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The welds are OK By Inspection

4. THE OVERPRESSURE - TANK SUPPORTS ARE ADEQUATE

ANALYZE THE PIPING & SUPPORTS (See figure 1)

From pg. 3, the appropriate damping value for piping is 2% of Critical Damping.

From pg. 2, the peak acceleration is 25.5 ft/sec^2

This will give static equivalent seismic loading.

$$F_{EQ, \text{HOR.}} = 1.5 \frac{A_s' W}{g} = \frac{1.5 (25.5)}{32.2} W = \underline{1.19 W}$$

$$F_{EQ, VERT} = \frac{2}{3} (1.19 W) = \underline{.79 W}$$

ANALYZE THE 1" LINE ① see fig 1

the longest span on this line is about 75 inches
Assume Sch. 40 Pipe.

$$S_{\text{pipe}} = 0.1328$$

$$W_{\text{pipe}} = 1.678 \text{ lb/ft}$$

$$W_{\text{WATER}} = .375 \text{ lb/ft.}$$

$$\Sigma W = 2.053 \text{ lb/ft} = .171 \text{ lb/inch}$$

Assuming a Simply Supported Span 75' Long.

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$$M_{\max} = \frac{wL^2}{8} = \frac{2.5(0.175)^2}{8} = 258 \text{ N}\cdot\text{m}$$

$$\tau_{\text{BENDING}} = \frac{M}{S} = \frac{258}{1.328} = 1950 \text{ psi}$$

CHECK STRESSES IN THE 4" LINE (2) See fig. 1

The length of this line is $\approx 124''$

Assuming Schedule 40 pipe $S = 3.214$

$$W_{\text{pipe}} = 10.79 \text{ lb/ft}$$

$$W_{\text{WATER}} = 5.50 \text{ lb/ft}$$

$$\Sigma W = 16.29 \text{ lb/ft} = 1.36 \text{ lb/in}$$

$$M_{\max} = \frac{Wl^2}{8} = \frac{2.15 (1.39) 124^2}{8} = 5610 \text{ " \#}$$

$$\tau_{\text{bending}} = \frac{M}{S} = \frac{5610}{3.214} = 1750 \text{ psi}$$

CHECK STRESSES IN THE $\frac{1}{2}$ " LINE (3)

The unsupported length of this line $\approx 50"$

Assume Sch. 40 Pipe:

$$W_p = .850 \text{ lb/ft} \quad S = .04069 \text{ in}^3$$

$$W_w = 0.132 \text{ lb/ft}$$

$$\Sigma W_f = .98 \text{ lb/ft} = .0817 \text{ lb/in}$$

$$M_{\text{max}} = \frac{Wl^2}{8} = \frac{2.15 (.082) 50^2}{8} = 55 \text{ " - \#}$$

$$\sigma_{\text{bending}} = \frac{M}{S} = \frac{55}{.04069} = 1348 \text{ psi}$$

APPENDIX A
SEISMIC ANALYSIS OF THE DIESEL
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CHECK STRESSES IN THE 2 1/2" LINE (4) See Fig. 1

This line is 135" long

Assume Sch 40 Pipe $S = 1.064$

$$W_p = 5.79 \text{ \#/ft}$$

$$W_w = 2.07 \text{ \#/ft}$$

$$\Sigma W = 7.86 \text{ \#/ft} = .6550 \text{ lb/in}$$

$$M_{max} = \frac{wl^2}{8} = \frac{.6550 (135)^2}{8} (2.15) = 3208 \text{ \#}$$

$$\sigma_{bending} = \frac{3208}{1.064} = \underline{\underline{3016 \text{ psi}}}$$

As can be seen, the stresses in the pipes are all very low. $\therefore$ The Piping is structurally Adequate

Check the supports

The only supports that exist are the clip supports on the 1" line (1). The weakest of these supports would be the ones with only one bolt. The bolts are 3/8" Dia.

The Tensile Stress Area is .0775 in²

The maximum load/clip and load/bolt $\approx \frac{wl}{2}$. From pg

$$\frac{2.15 (.0775) 75}{2} = 14 \text{ lb. } \underline{\underline{OK BY INSPECTION}}$$

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Since no information is available on the pumps that are on the Diesel Generator, and these pumps are not included in the scope of this job, they will not be analyzed here.

The piping supports are structurally adequate.

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