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MECHANICAL ANALYSIS OF LOFT REACTOR INTERNALS DUE TO LOSS OF COOLANT ACCIDENTS

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MECHANICAL ANALYSIS OF LOFT REACTOR INTERNALS

DUE TO LOSS OF COOLANT ACCIDENTS

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Mechanical Analysis of LOFT Reactor Internals Due to Loss of Coolant Accidents	1115-34 Supp. 1 RE-A-77-189, Supp. 1
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ABSTRACT

A linear elastic analysis of the LOFT reactor internals was conducted to demonstrate the structural integrity of the reactor system during two Loss-of-Coolant Accidents (LOCA). Time dependent pressure transients were used to predict the behavior of the internals for the following LOCA's:

14" 15 msec Reactor Vessel Nozzle Hot Leg Break

14" 15 msec Reactor Vessel Nozzle Cold Leg Break.

For the most severe design LOCA (Cold Leg LOCA), the LOFT reactor internals can safely withstand stresses due to a combination of pressure transient loading and seismic loading.

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MECHANICAL ANALYSIS OF LOFT REACTOR INTERNALS DUE TO LOSS OF COOLANT ACCIDENTS

I. INTRODUCTION

The structural analysis of the LOFT reactor internals for Loss-of-Coolant Accident (LOCA) conditions is documented in this report. The analysis accounts for the lateral time history interactions of the vessel, vessel fillers, core barrel, flow skirt, core fillers, corner modules, center module, control modules, control guide assembly, and control rods. The model is shown in Figure 1, and is the same model as that used in Reference 2 for analyzing the internals for Loss-of-Coolant Experiment (LOCE) conditions.

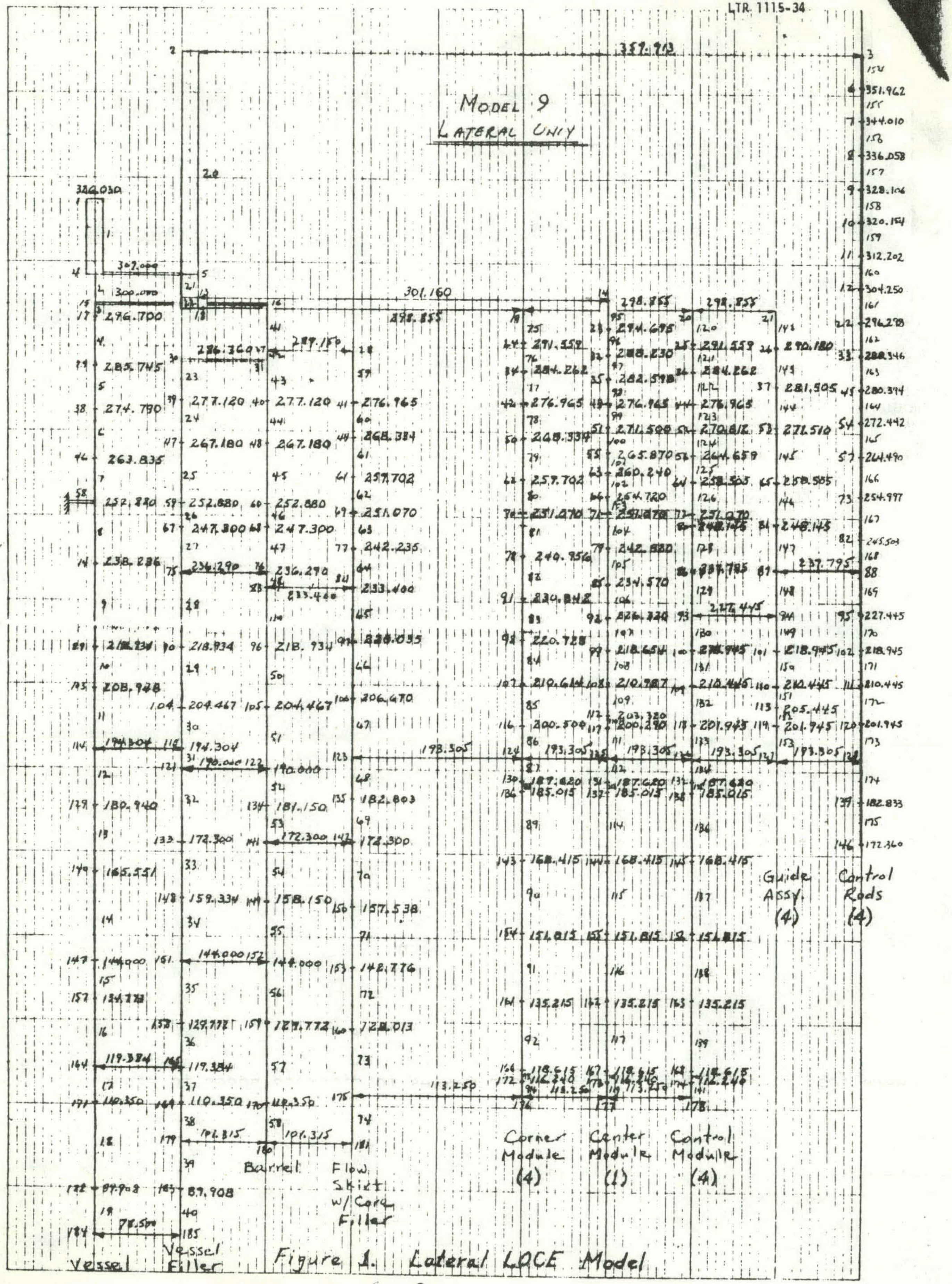

Figure 1. Lateral LOCE Model

II. DISCUSSION OF THE MODEL

The various internal components were all modeled as linear, elastic beams compatible with the SAP IV structural analysis computer program. Appendix A of the original report (LTR 1115-34) contains a listing of the CDC version used for this analysis. The four corner fuel modules were represented by a single beam having four times the mass and four times the stiffness of a single module but with the same mass/stiffness distribution. This yields forces in the model which are four times the forces in a single corner module but displacements in the model which are correct without modification. This same procedure was used in modeling the four control modules, guide assemblies, and control rods. Model 9 (Figure 1) is the designation used for the model employed in this analysis.

All lateral stiffness values were based on the centroidal moment of inertia. In the fuel region of the modules, guide tubes and fuel rods were accounted for in the stiffness. In a dynamic analysis by MPR of the fuel modules, Reference 4, a procedure is outlined for using a reduced fuel stiffness to account for the deflected shape of the fuel region. While this approach to the analysis is currently being reviewed, the effect of fuel module stiffness on the structural integrity of the core support components is not considered to be significant.

Lumped masses were applied to discrete node points to obtain an accurate representation of the actual mass distribution in each of the beams.

Hydrodynamic effects from the interaction of the water with the internals were accounted for by applying lumped masses to discrete nodes to represent the distribution of the water's mass. At bearing pad locations between the vessel and vessel fillers, vessel fillers and barrel, support was assumed to exist based on hydrodynamic mass considerations. Details of these calculations are available if desired.

III. FORCING FUNCTIONS

Pressure transients predicted by WHAM analyses of two LOCA conditions were used as the basis for calculating lateral time-varying loads imposed on the vessel, vessel fillers, and barrel. The analysis was conducted for 0.100 sec with 1000 time increments over the interval. The WHMPLT computer program was used to convert the pressure transients to equivalent time-varying forces on the internals. A listing of WHMPLT is contained in Appendix A of the original report. To reduce the computer time required for a solution, each force transient was reduced from 1000 time increments to an equivalent transient consisting of 200 time increments using the WHATAB computer program. A listing of WHATAB is contained in Appendix C of the original report. These forcing functions were then input to SAP IV to analyze the response of the internals to the following LOCA conditions:

(a) 14" 15 msec Hot Leg LOCA

(b) 14" 15 msec Cold Leg LOCA.

The use of these LOCA conditions, as the basis for the analysis, is justified in Reference 5 where the LOCA is defined as a double-ended offset shear occurring in 15 msec. The 15 msec is a total break time consisting of a 5 msec pipe break time plus 10 msec allowance for the offset to occur.

IV. DISCUSSION OF RESULTS

Bending stresses for the internal components due to a LOCA Cold Leg Break are shown in Figures 2 to 10. The maximum stress in each component is:

Vessel:	1,087 psi
Vessel Fillers:	339 psi
Barrel:	549 psi
Flow Skirt w/Core Filler:	444 psi
Corner Module:	24,742 psi
Center Module:	10,508 psi
Control Module:	9,483 psi
Guide Assembly:	1,522 psi
Control Rod Assembly:	4,766 psi

The maximum stress occurs in the guide tube assemblies of the corner module just below the Upper End Box. This is, according to Reference 1, the same location where the maximum seismic stress occurs. Seismic stress corresponds to a Safe Shutdown Earthquake. The maximum LOCA and seismic stresses are 24,742 psi and 17,148 psi, respectively, having a sum of 41,890 psi. The allowable bending stress for this 304 L SS Cold worked region of the module, according to Reference 3, is 50,000 psi at 600 °F. The analysis was performed for 650 °F, which is quite close.

Both the LOCA and seismic stresses are considerably lower than this throughout the remainder of the reactor internals, and do not approach the allowable stress for 304 L stainless steel under faulted conditions (32,880 psi).

The maximum overturning moment transmitted to the vessel lugs is:

12,980 in-kips (Cold Leg LOCA)

4,472 in-kips (Hot Leg LOCA).

The design limit, according to Reference 2, is 20,000 in.-kips.

A comparison between stresses in the three most highly stressed areas of the model for the two LOCA's is given in Figure 11.

Natural frequencies for the LOFT reactor internals are presented in Table I.

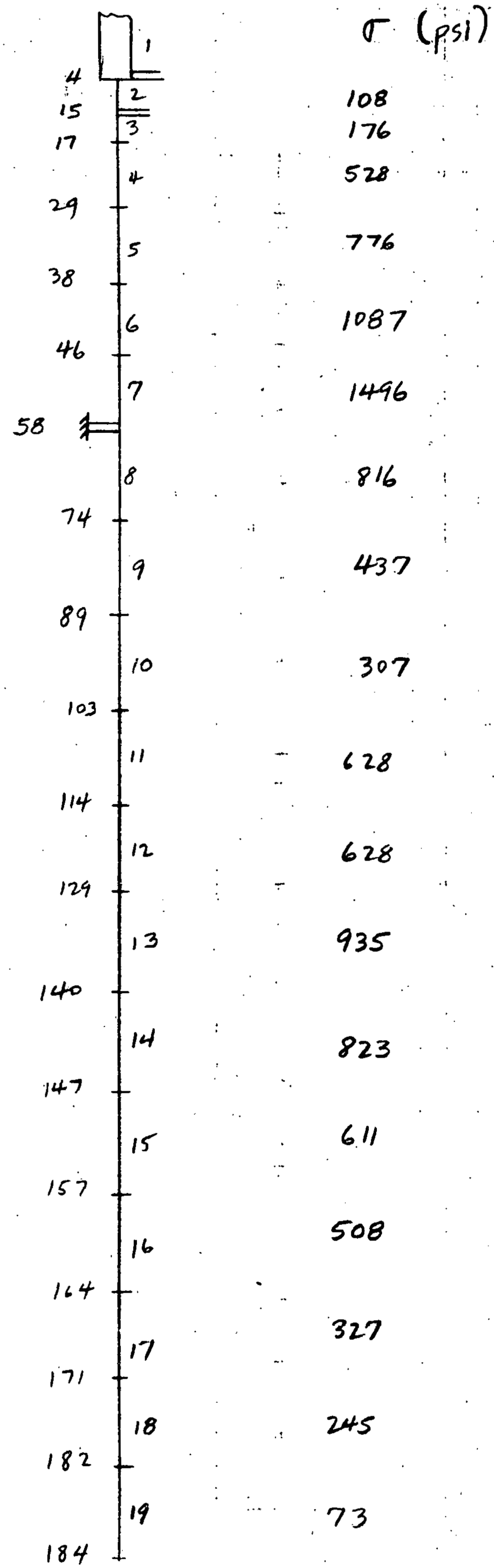

FIG. 2 Bending Stress - Vessel

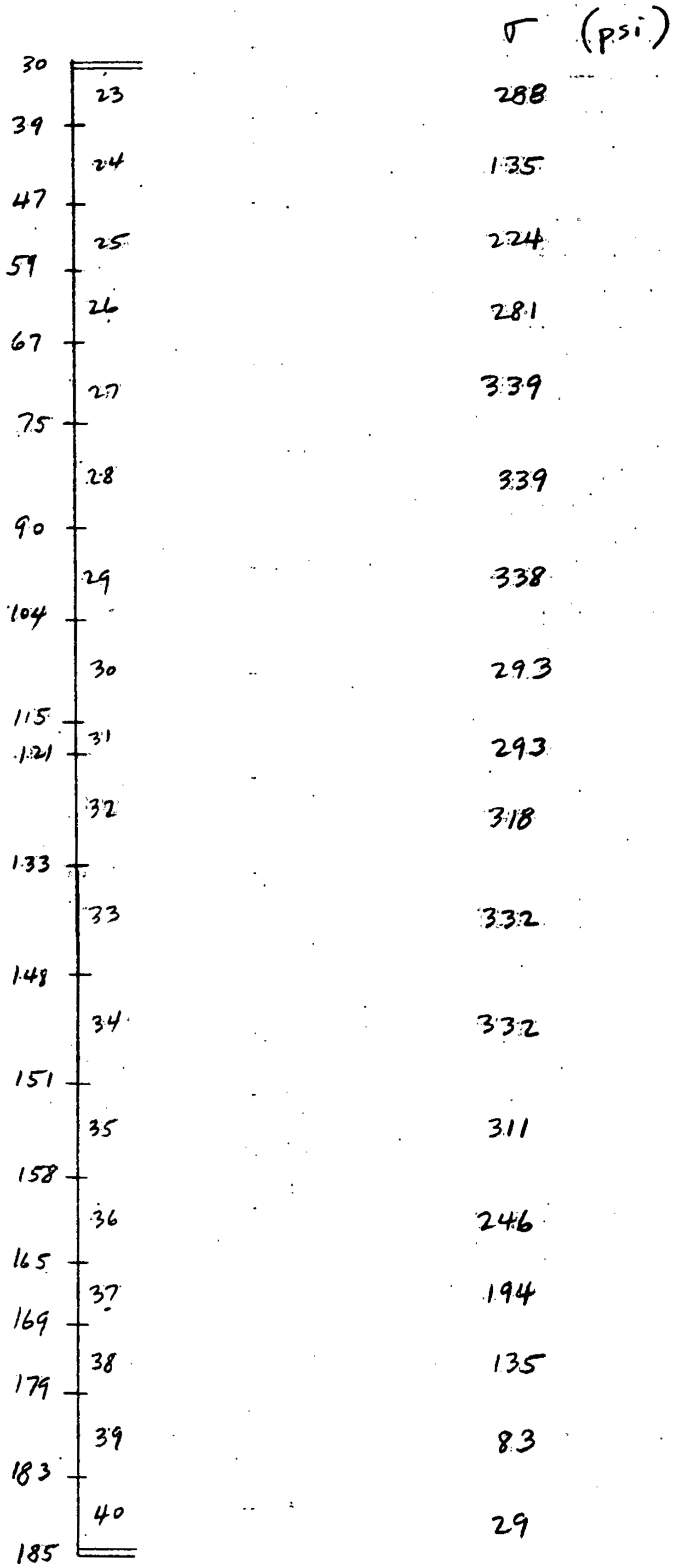

FIG. 3 Bending Stress - Vessel Filler

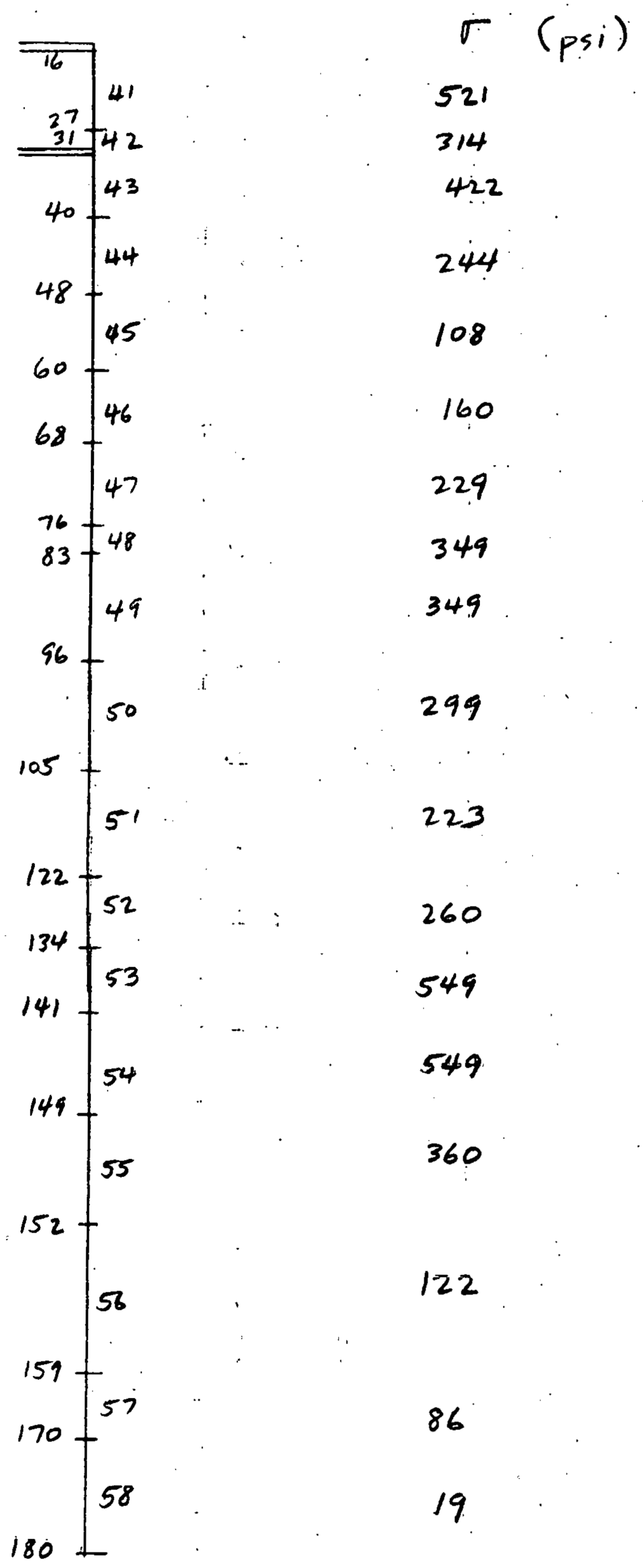

FIG. 4 Bending Stress - Barrel

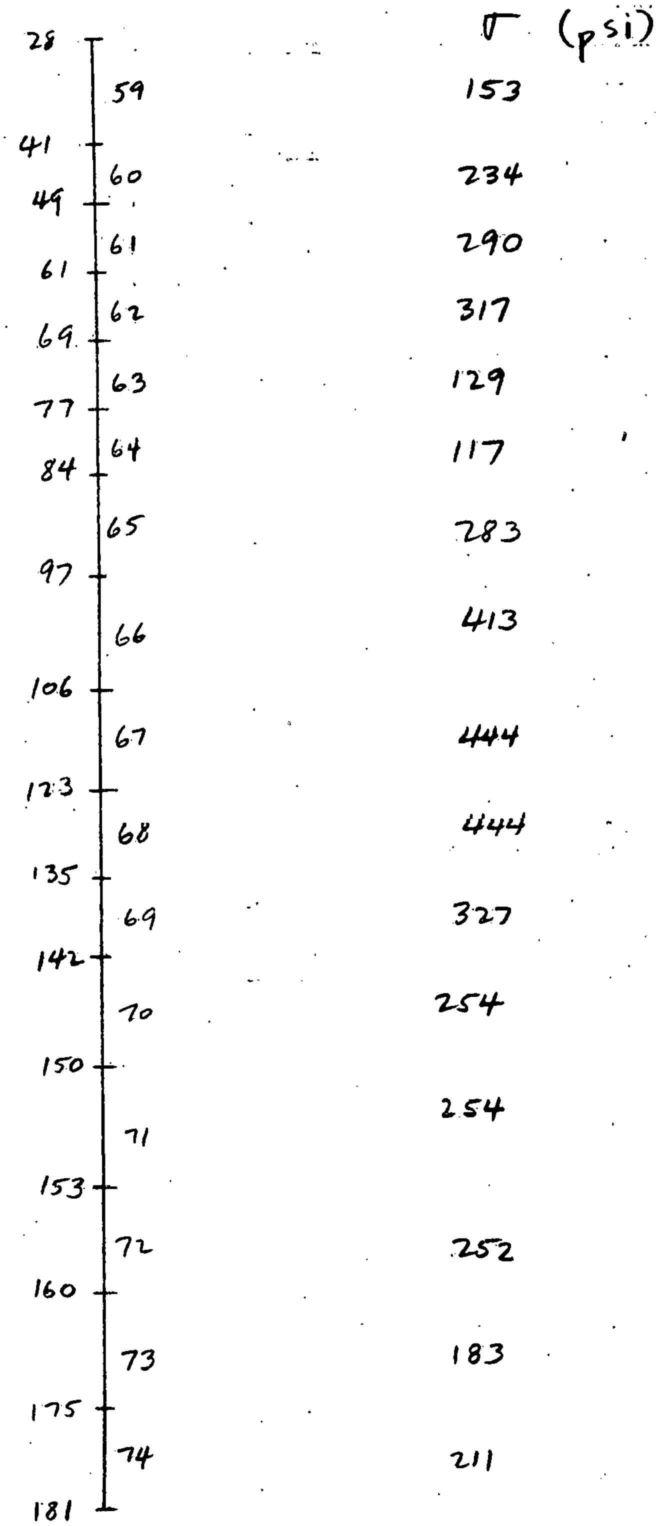

FIG. 5 Bending Stress - Flow Skirt w/ Core Filler

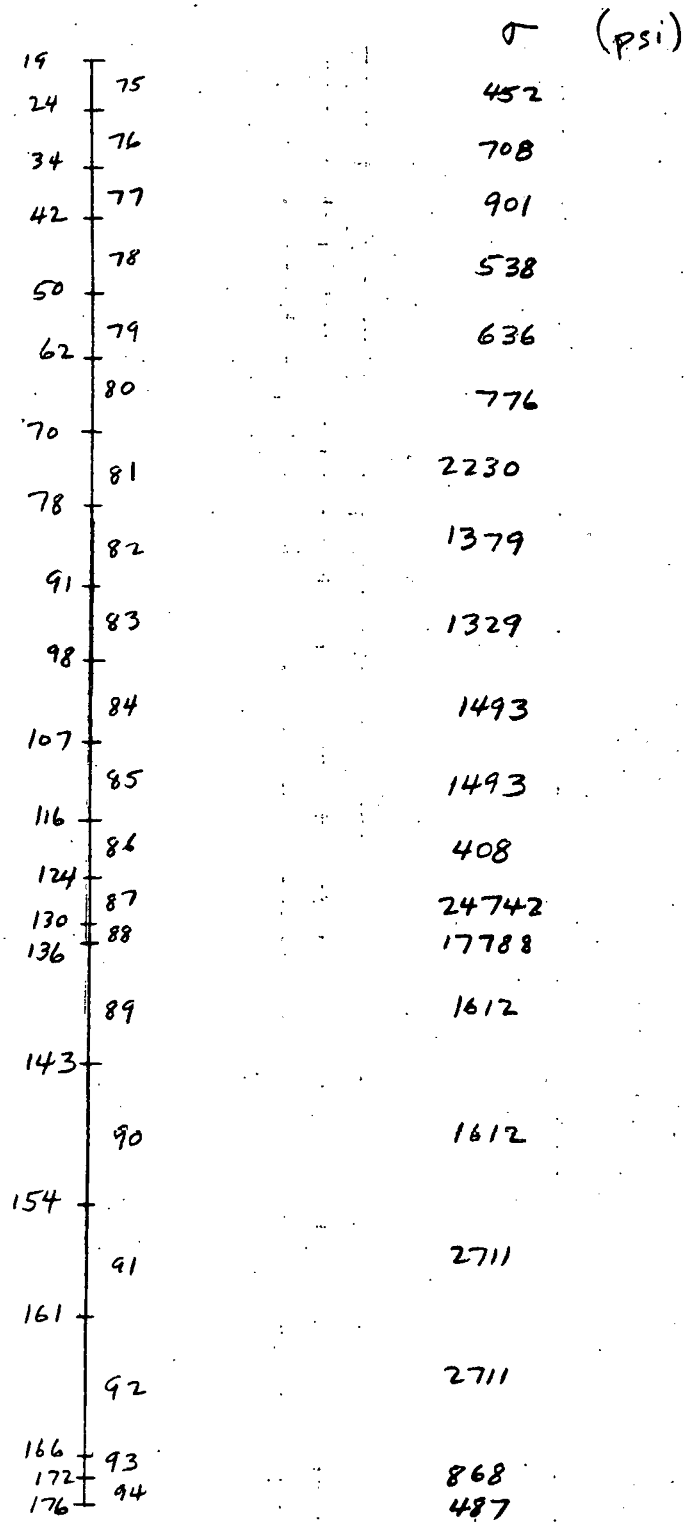

FIG. 6 Bending Stress – Corner Module

Station	Element	σ (psi)
14		
	95	196
23		
	96	378
32		
	97	357
35		
	98	407
43		
	99	414
51		
	100	1419
55		
	101	1351
63		
	102	889
66		
	103	1470
71		
	104	1344
79		
	105	1142
85		
	106	1156
92		
	107	1905
99		
	108	1725
108		
	109	1329
112		
	110	758
117		
	111	428
125		
	112	7984
131		
	113	10508
137		
	114	730
144		
	115	1257
155		
	116	2013
162		
	117	2013
167		
	118	620
173		
	119	347
177		

FIG. 7 Bending Stress – Center Module

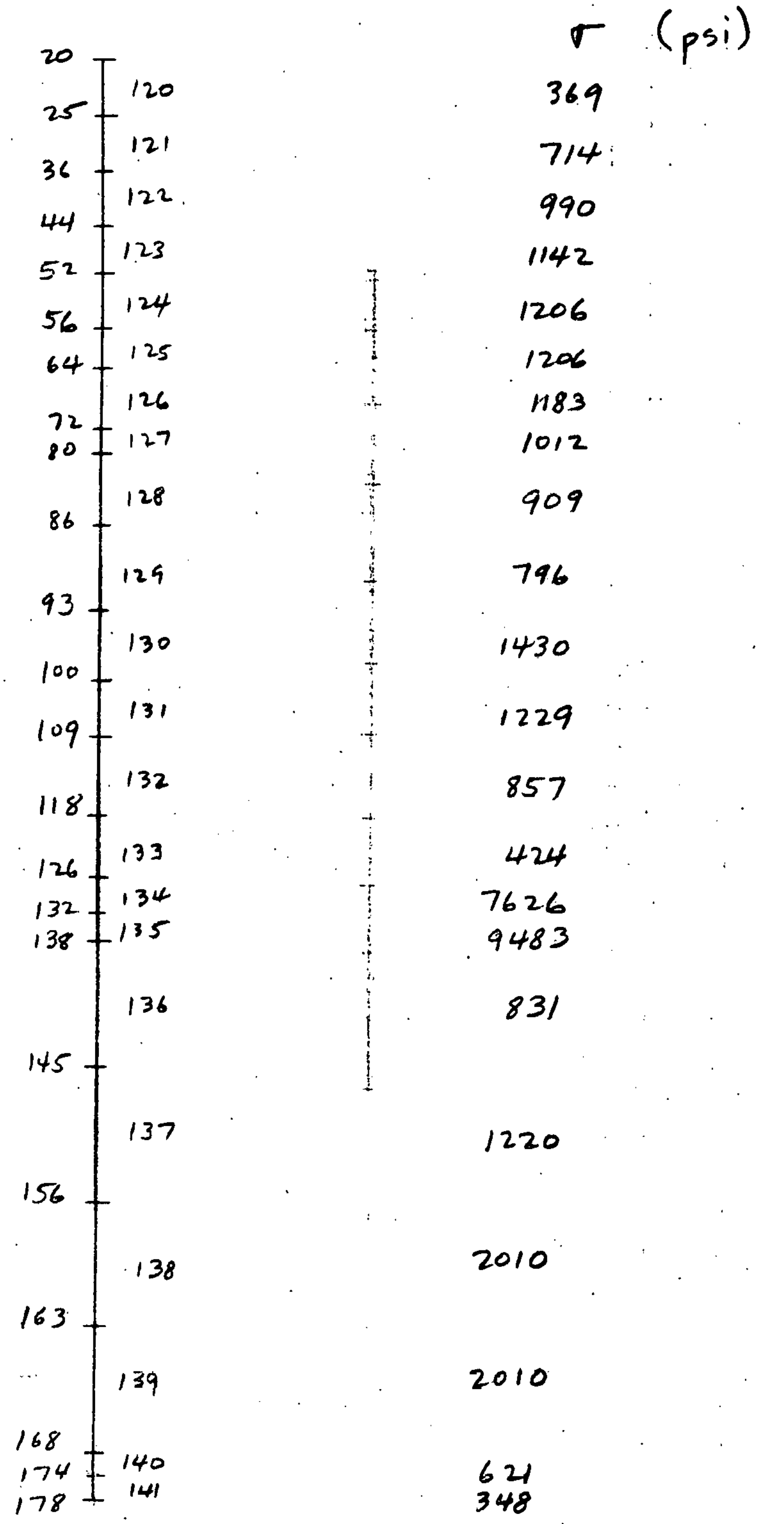

FIG. 8 Bending Stress - Control Module

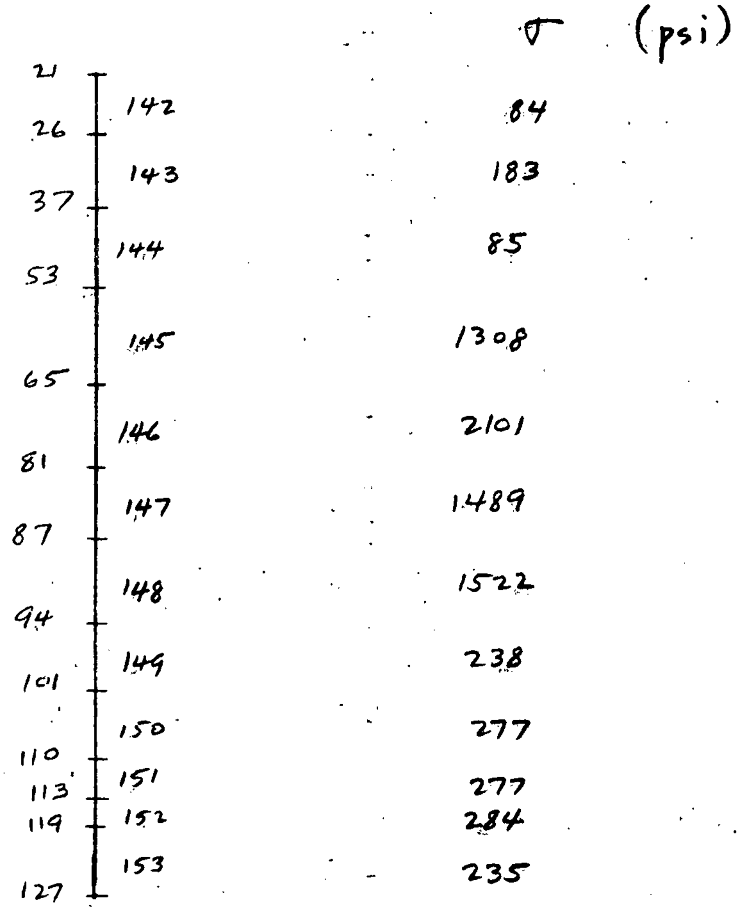

FIG. 9 Bending Stress – Guide Assembly

Station (from)	Station (to)	Element	σ (psi)
3	6	154	2880
6	7	155	3838
7	8	156	3838
8	9	157	2608
9	10	158	3013
10	11	159	3853
11	12	160	1243
12	22	161	1638
22	33	162	1958
33	45	163	1958
45	54	164	1797
54	57	165	1910
57	73	166	3721
73	82	167	4766
82	88	168	125
88	95	169	223
95	102	170	318
102	111	171	318
111	120	172	255
120	128	173	366
128	139	174	366
139	146	175	127

FIG. 10 Bending Stress – Control Rod Assembly

MAXIMUM STRESS COMPARISON

	ELEMENT NO.	COLD LEG LOCA (psi)	HOT LEG LOCA (psi)
Corner	87	24742	3493
Module	88	17788	3131
Center	112	7984	1434
Module	113	10508	1953
Control	134	7626	1205
Module	135	9483	1719

FIG. 11

TABLE 1

NATURAL FREQUENCY SUMMARY (LATERAL MODEL 9)

	Freq. (Hz)	Period (Sec)
1	12.61	.0793
2	20.52	.0487
3	40.50	.0247
4	42.07	.0238
5	46.35	.0216
6	46.83	.0214
7	46.98	.0213
8	53.49	.0187
9	54.96	.0182
10	76.01	.0132

V. CONCLUSION

The worst-case LOCA design conditions is that of a 14" 15 msec cold leg break. Under this LOCA condition and a Safe Shutdown Earthquake, the LOFT reactor internals have sufficient strength to withstand imposed loading.

VI. REFERENCES

1. T. R. Thompson, Seismic Analysis of LOFT Reactor Internals, LTR 1115-31, July 8, 1976.

2. T. R. Thompson, Mechanical Analysis of LOFT Reactor Internals Due to Loss-of-Coolant Experiments, LTR 1115-34, April 28, 1977.

3. LOFT Fuel Assembly Structural Design and Analysis, Design Report, JN-72-10, May 8, 1972.

4. Report of LOFT Fuel Module Dynamic Analysis, Vol. I and Vol. II, MPR-509, (March 1976).

5. V. T. Berta, "LOFT LOCA-WHAM6 Model and Code Application", LTR 114-100 (to be published).