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MASTER

FAULTED STRESS ANALYSIS
OF THE
LOFT LOWER CORE SUPPORT PLATE

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DEPARTMENT OF ENERGY

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FAULTED STRESS ANALYSIS OF THE LOFT LOWER CORE SUPPORT PLATE

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FAULTED STRESS ANALYSIS OF THE LOFT LOWER CORE SUPPORT PLATE

I. ANALYSIS

The faulted analysis of the Lower Core Support Plate (LCSP), contained in this report, used the computer model generated in LTR 1115-23, Ref. 3 (see Figure 3). The seismic loads and the LOCA loads were applied to this computer model. The most critically stressed area is around the inner spacing shaft openings denoted by a 1 on Figure 4. Stresses through the critical section of the LCSP are plotted on Figures 5 through 10, as well as the linearized stresses through the critical section.

The maximum stress intensity at the highest stressed section is 12,144 psi which is a membrane plus bending stress ($P_L + P_B$). The allowable for this type of stress for faulted conditions is 50,400 psi at 600°F. The LOCE analysis contained in LTR 1115-23, showed a maximum stress intensity of 12,000 psi. The reason that the LOCE stress is equal to the LOCA plus SSE is that the LOCE stress includes peak stresses. The stresses for LOCE were low so the analyst did not linearize the stresses to separate the peak portion out.

II. REFERENCES

1. R. K. Blandford, "Dynamic Analysis of LOFT Reactor Flow Skirt/Core Filler Assembly for LOCA + SSE", LOFT Technical Report LTR 1115-39, to be issued.
2. T. R. Thompson, "Seismic Analysis of LOFT Reactor Internals", LOFT Technical Report LTR 1115-31, July 8, 1976.
3. S. Timurtas, "Stress Analysis of LOFT Lower Core Support Plate", LOFT Technical Report LTR 1115-23, February 19, 1974.
4. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, "Nuclear Power Plant Components", 1977.
5. V. T. Berta, "LOFT LOCA-WHAM6 Model and Code Application", LOFT Technical Report LTR 114-100 (to be issued).

Spring Designations

- - Linear
- - Variable Load
- - Compression Only
- - Tension Only

Mass

Component

1	Fixed-Upper Support Structure
2-4	Flow Skirt Core Filler
5	Lower Core Support Structure
6-8	Core Barrel
9-12	Center Fuel Module
13-16	4 Control Fuel Modules
17-20	4 Corner Fuel Modules

Model of LOFT Reactor Core and Support Structure

FIGURE 1

Figure 2 Vertical Seismic Model

3-D. VIEW OF THE LOWER
CORE SUPPORT PLATE COMPUTER MODEL

FIGURE 3

* Dimensions after final machining on assembly.

The numbers 1 and 2 on spacing shaft holes refer to the forces P_1 and P_2 , respectively, transmitted to the lower core support plate

FIGURE 4 LOWER CORE SUPPORT PLATE

I ES

3430.00

1520.00

-1070.00

-3600.00

-16300.00

AVG STRESS=

130.6

EAR INNE

STRESS=

8996.56

LINEAR OUTER

SURF STRESS=

-8785.30

PEAK STRESS IN=

8103.44

PEAK STRESS OUT=

ELEMENTS 69 - 72

STRESS THRU THE THICKNESS

σ_x

FIGURE 5

INF ES

5220.00

13400.00

4910.00

-4090.00

-13200.00

-4620.00

OUT STRESS=

279.98

INNER

STRESS=

10638.63

LINEAR OUTER

SURE STRESS=

-13073.67

PEAK STRESS IN=

10638.63

PEAK STRESS OUT=

ELEMENTS 69-72

STRESS THRU THE THICKNESS

σ_y

FIGURE 6

BOTTOM OF LCSP

TOP OF LCSP

2721

1150

25

INP

1150.00

2070.00

652.00

-2000.00

-2000.00

OUT STRESS =
245.2

EAR INNER

STRESS =

2720.75

LINEAR OUTER

SURF STRESS =

-2200.00

PEAK STRESS IN =

1150.75

PEAK STRESS OUT =

24

-771

-771

ELEMENTS 69-72

STRESS THRU THE THICKNESS

σ_z

FIGURE 7

INF

8004.00

-10025.00

-10000.00

-10000.00

-10004.00

-10000.00

STRESS =

-1007.70

LINEAR INNER

SURF STRESS =

-1006.50

LINEAR OUTER

SURF STRESS =

1438.94

PEAK STRESS IN =

1755.50

PEAK STRESS OUT =

ELEMENTS 69-72

STRESS THRU THE THICKNESS

σ_{zx}

FIGURE 8

ELEMENTS 69-72

STRESS THRU THE THICKNESS.

γ_{yz}

FIGURE 9

BOTTOM OF LCSP

TOP OF LCSP

LINE	ES
1	0.00
2	432.00
3	-432.00
4	-1260.00
5	-3450.00

AVG STRESS = 0.01

LINEAR INNER
SURF STRESS = 2350.95

LINEAR OUTER
SURF STRESS = -2350.94

PEAK STRESS IN = 1187.05

PEAK STRESS OUT =

ELEMENTS 69-72

STRESS THRU THE THICKNESS

 σ_{xy} FIGURE 10

APPENDIX A
LOWER CORE SUPPORT PLATE
FAULTED STRESS ANALYSIS

CALCULATION WORK SHEET

Page A-1 of Pages

Subject LOWER CORE SUPPORT PLATE FAULTED ANALYSIS Date

Prepared By DOUG FINICLE Checked Work Request

A dynamic LOCA analysis of the LOFT Reactor internals has been completed by R. K. Blandford and is documented in LTR1115-39, ref. 1. LOCA Loads from that analysis will be used to analyze the Lower Core Support Plate. The computer model used in ref. 1, is shown on figure 1.

Looking at fig 1 it can be seen that Mass 5 is the lower core support plate. Mass 5 is connected by 5 springs, 4 of which are compression only and one of which is tension only. The loads of interest will be those in springs 4-5, 12-5, 16-5, 20-5 and 6-5.

There are two LOCA runs that were made; 1) Hot Leg Break and 2) Cold Leg Break.

LOCA - HOT LEG BREAK SPRING FORCES

SPRING	TIME	MAX	TIME	MIN.
4-5	.323 - 01	-.348 + 06	.976 - 01	0.
12-5	.599 - 01	-.212 + 05	.100 + 00	0.
16-5	.612 - 01	-.835 + 05	.100 + 00	0.
20-5	.574 - 01	-.366 + 05	.100 + 00	0.
6-5	.319 - 01	-.373 + 06	.100 + 00	0.

✓ All of the above forces are downward on the L.C.S.P. except 6-5 which is upward. 6-5 is a reaction load.

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Prepared By D P FINICLE Checked _____ Work Request _____

SPRING	TIME	MAX.	TIME	MIN.
4-5	.1256-01	-1629+06	.1000+00	0.
12-5	.1620-01	-1464+05	.1000+00	0.
16-5	.7357-01	-7062+05	.100+00	0.
20-5	.7139-01	-2929+05	.100+00	0.
6-5	.1222-01	-2257+06	.100+00	0.

↑ All of the above forces are downward on the L.C.S.P except 4-5 which is upward.

SPRING 6-5 represents the core barrel support which provides support to the lower core support plate. Therefore the down loads that are applied by the fuel modules 9-20 and the flow skirt, are reacted by an up load at the core barrel. Since these loads are an action-reaction type, the maximum ^{TOTAL} load on the L.C.S.P will be maximum when the reaction is maximum.

By scanning the loading, it can be seen that the maximum load loads occur for a HOT LEG LOCE. It can also be seen that the most significant loading is on spring 4-5.

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CALCULATION WORK SHEET

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Seismic loading on the lower core support plate will be obtained from LTR 1115-31, ref. 2. A sketch of the computer model is shown in figure 2. The following loads are from computer output obtained from T. R. Thompson.

Y-Quake Z-Response

Beam No.	COMPONENT LOCATION	AXIAL FORCE
73	FLOW SKIRT & CORE FILLER	1807 lbs.
94	CORNER MODULES (4)	699 "
119	CENTER MODULES (1)	572 "
141	CONTROL MODULE (4)	1881 "

X-QUAKE Z-RESPONSE

Beam No	COMPONENT LOCATION	AXIAL FORCE
73	FLOW SKIRT & CORE FILLER	2139 lbs.
94	CORNER MODULES (4)	828 "
119	CENTER MODULE (1)	678 "
141	CONTROL MODULES (4)	2228 "

The above forces are obtained from a response-spectrum seismic analysis. The forces have no signs or times associated with them and are maximum absolute values. These forces will be combined with the LOCA loads listed on pgs 1 & 2.

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The Hot Leg LOCA loads listed on pg 1 are the largest LOCA loads and the X-quake is the largest seismic loads. These loads are combined below. NOTE, see figure 1 where a correlation between mass & component is given, for the LOCA loads.

COMBINED LOCA + SSE Loading (HOT LEG LOCA + X-QUAKE)

COMPONENT	FORCE
FLOW SKIRT & CORE FILLER	350,133 lbs.
CORNER MODULES (4)	37,428 "
CENTER MODULES (1)	21,878 "
CONTROL MODULES (4)	85,728 "

TOTAL FORCE = 495173 lbs.

The dimensions of the LCSP are shown on figure 4. This sketch was taken from LTR 1115-23, ref 3, as well as the SAP computer model. The methods used for determining the loading at each node, used in ref. 3, will be used in this analysis also.

The following assumptions are made to determine the distribution of the mechanical forces listed in the chart above.

- 1) The dynamic force on the flow skirt is transmitted to the LCSP by the cylindrical lower core support structure skirt.

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- 2) The dynamic force on the fuel assembly at the center and that on the corner fuel element is transmitted to the LCSP by the spacing shafts only.
- 3) The dynamic ^{force} of the four square control modules are transmitted to the LCSP by the spacing shafts as well as by the lower core support structure skirt.

The dynamic force of 350,139 lbs. on the flow skirt plus the dead weight of the lower core support structure skirt of 240 lb, gives a total force of 350,379 lbs. It is assumed that this is uniformly distributed on the circular ring shaped area bounded by the diameters 29.872 & 28.25 inches as shown in figure 5.

The dynamic force of 21878 lbs on the center module is transmitted to the four spacing shafts ^① each carrying a force of (See fig 4)

$$P_i = \frac{21878}{4} = \underline{\underline{5470 \text{ lb}}}$$

The dynamic force of $85728/4 = 21432 \text{ lbs}$ on the $1/4$ of it

square control modules is assumed to be carried by spacing shafts 1, 2, 2 and the lower core support structure skirt, See fig 4. It is further assumed that $1/4$ of the the force is carried by the skirt and $3/4$ by the spacing shafts 1, 2, 2.

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Solving for these forces

$$P_A = \frac{1}{4} (21432) = \underline{5358\#}$$

$$P_1' + 2P_2' = \frac{3}{4}(21432) = 16074$$

Summing Moments about pt C, see fig 4, gives

$$4.233 P_1' + 2(.60) P_2' - 5.598 P_A = 0$$

Solving

$$4.233 P_1' + 1.208 P_2' = 29994 \quad \text{①}$$

$$P_1' + 2 P_2' = 16074 \quad (2)$$

$$4.233 P_1' + 8.47 P_2' = 68041 \quad 4.233 \times (2) = (3)$$

$$7.26 P_2' = 38047 \quad \textcircled{3} - \textcircled{1} = \textcircled{4}$$

$$\therefore P_2' = 5240 \text{ #}$$

$P' = 5592 \#$

$$\sum F = 0 = 5240(2) + 5592 + 5358 - 21432 = 0 \text{ kgs.}$$

The dynamic force of 37428 lbs on the ⁴ triangular corner modules is carried equally by the two spacing shafts 2,2, per module.

Therefore the load/shaft = $\frac{37428}{2 \times 4} = 4679 \text{ lbs.} = P_2''$

The dead weight of the various components is included in the seismic loads that were combined with the LOCA loads. Therefore deadweight is not included here.

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$$P_2 = P_2' + P_2'' = 5240 + 4679 = 9919 \text{ lb.}$$

The distributed force acting on the LCSP are obtained as follows: The uniformly distributed force p acting on the circular shaped area bounded by the diameters 29.872 and 28.250 inches is

$$p = \frac{\overset{\text{from pg 5}}{350,379}}{\frac{\pi}{4} (29.872^2 - 28.25^2)} = \underline{\underline{473.2 \text{ #/in}^2}} \quad 2361$$

The uniformly distributed force P acting only on the shaded area of figure 4, is given approximately by

$$P_A = \frac{18}{360} \frac{\pi}{4} \left[29.872^2 - 28.25^2 \right] = 1447.16 \text{ lb/in}^2$$

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Per NB-3225, Level D Service Limits, ref 4, the rules of Appendix F are to be used. From appendix F of ref 3, F-1380 applies to core support structures. F-1380 refers you to F-1320. F-1320 refs you to NB 3221 except that the S_m values are increased as shown below

$$S_m = \begin{cases} 2.4 S_u \\ \text{or} \\ 0.7 S_u \end{cases} \text{ lesser of for mat from tbl. I-1.2}$$

for 304L SS, from Hbl. I-1.2

$$S_m = 14.0 \text{ ksi} \quad @ 600^\circ\text{F.}$$

$$S_u = 57.0 \text{ ksi @ } 600^\circ\text{F}$$

$$2.4 S_m = 2.4(14) = \underline{33.6 \text{ ksi}} \leftarrow \text{governs}$$

$$0.7 S_u = 0.7 (57) = 39.9 \text{ ksi}$$

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From scanning the computer output, contained in attachment 1, it appears that the maximum stress occurs at element # 33. This element is located next to the hole for the inner spacing shaft, designated by 1 in fig. 4. Looking at Fig 4, it can be seen that this region is the most likely to have the highest stressed elements since it is the furthest from the supported edge and there are large concentrated forces applied at this point.

Thru the thickness, elements number 69, 70, 71, 72 are the elements that make up a section thru the KCSP.

The stresses on these elements must be linearized and then principle stresses calculated.

ELEMENT	LOCATION	σ_x	σ_y	σ_z	τ_{xy}	τ_{yz}	τ_{zx}
69	BOTTOM	17100	5220	1150	3500	-404	659
69	CENTER	3430	13400	1150	1350	-454	-625
70	CENTER	1520	4910	2070	432	816	-1990
71	CENTER	-1070	-4090	652	-480	61	-597
72	CENTER	-3600	-13200	-2890	-1260	-646	-504
72	TOP	-16300	-4620	-2890	-3450	-219	-789

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FROM FIG. 5 thru. FIG 11

	σ_x	σ_y	σ_z	τ_{xy}	τ_{yz}	τ_{zx}
Ave. Stress	130	280	245	8.	-39	-768
LINER STRESS INNER	8997	13634	2720	2353	152	-1097
LINER STRESS OUTER	-8735	-13073	-2230	-2337	-232	-439
PEAK STRESS IN	8103	-8414	-1570	1147	-556	1755
PEAK STRESS OUT	-7565	8453	-659	-1113	12	1228

These stresses were determined by use of a program on the 9815-A, written by R.G. Pahl.

CALCULATING PRINCIPLE STRESSES USING THE 9815

Membrane $\left\{ \begin{array}{l} \sigma_1 = 958 \text{ psi} \\ \sigma_2 = -582 \text{ " } \\ \sigma_3 = 278 \text{ " } \end{array} \right.$

$$P_m = 1540 \text{ psi}$$

Bending INNER (BOTTOM) $\begin{cases} T_1 = 14649 \text{ psi} \\ T_2 = 2506 \text{ " } \\ T_3 = 8223 \text{ " } \end{cases}$

$$P_L + P_B = 12144 \text{ psi}$$

DENDING
OUTER
(TOP) $\left\{ \begin{array}{l} \sigma_1 = -1996 \text{ psi} \\ \sigma_2 = -14120 \text{ " } \\ \sigma_3 = -7920 \text{ " } \end{array} \right.$

$$P_c + U_B = 12124 \text{ psi}$$

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five m NB 3221, ref. 4

$$P_m \subset S_m$$

$$P_L + P_B < 1.55 \text{ m.}$$

Using the Sun values determined on pg 8

$$\sigma_{w1} = 33.6 \text{ ksi} = 33600 \text{ psi}$$

$$P_m = 1540 < S_m = 33600 \text{ psi} \quad \text{OK}$$

$$P_t + P_g = 12144 < 1.55 S_m = 1.5(53600) = 50400 \text{ psi} \quad \text{OK}$$

Secondary & Peak Stresses do not need to be considered for faulted loading

• The LCSP is Structurally Adequate for the LOCA+SSE Faulted Loading

APPENDIX B

SAP 4 COMPUTER CODE LISTING

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LOFT TECHNICAL REPORT
LOFT PROGRAM

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RSB Mgr.	P&CSB Mgr.	

ABSTRACT

The LOFT Reactor Lower Core Support Plate has been analyzed using LOCA plus SSE loading. The LOCA loading was obtained from LTR 1115-39, Ref. 1, which used LOCA pressures from Ref. 5. SSE loading on the Lower Core Support Plate was obtained from LTR 1115-31, Ref. 2. The combination of LOCA plus SSE is considered a faulted loading condition. The analysis showed the lower Core Support Plate to be structurally adequate and that it meets all of the ASME Section III requirements for faulted conditions. A listing of the computer code used in this analysis is contained in Appendix B.

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