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DYNAMIC ANALYSIS OF LOFT
REACTOR FLOW SKIRT/CORE FILLER
ASSEMBLY FOR LOCA + SSE

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DEPARTMENT OF ENERGY

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RESEARCH, ENGINEERING AND CONSTRUCTION REPORT ENGINEERING ANALYSIS DIVISION

APPLIED MECHANICS BRANCH

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IDAHO NATIONAL ENGINEERING LABORATORY
LOFT TECHNICAL REPORT
LOFT PROGRAM

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<i>OKM</i> P&CSB Mgr.	RSB Mgr. <i>[Signature]</i> PSB Mgr.	

ABSTRACT

A detailed dynamic analysis of the LOFT reactor core support structures was performed to determine the ability of the flow skirt/core filler and hold down springs to withstand Loss-of-Coolant Accident (LOCA) plus Safe Shutdown Earthquake (SSE) loadings. A double-ended offset shear occurring in 15 msec (5 msec break time + 10 msec for offset to occur) in the intact loop at the reactor vessel nozzle provided the basis for LOCA loads.

The flow skirt/core filler and lower core support structure separate from the core barrel approximately .068 inch as a result of the hot leg LOCA. This small displacement and the resulting impact loads produce stresses in the springs, core barrel, flow skirt/core filler, and shear pins within allowables as specified in Section III of the ASME Code for faulted conditions.

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DYNAMIC ANALYSIS OF LOFT
REACTOR FLOW SKIRT/CORE FILLER
ASSEMBLY FOR LOCA + SSE

I. INTRODUCTION

The arrangement of the LOFT reactor internals is shown in Figure 1. The flow skirt/core filler assembly is made up of three subassemblies stacked vertically to line the entire length of the core support barrel. Each subassembly consists of a cylindrical shell flow skirt section to which core filler segments are permanently attached (Figure 2). The flow skirt/core filler assembly rests on the lower core support structure, which in turn rests on the lower interior flange of the core barrel. Seven spring preload cells, extending down below the upper core support structure bear on the top of the upper flow skirt maintaining the position of the flow skirt/core filler and lower support structure assemblies.

The flow skirt/core filler assembly serves to: (a) channel coolant flow through the fuel assemblies and minimize bypass flow, (b) provide thermal shielding for the core support barrel, and (c) displace excess coolant from the core and outlet plenum regions.

II. METHOD OF ANALYSIS

1. GENERAL APPROACH

The ability of the flow skirt/core filler assembly to withstand LOCA + SSE loadings is verified by a detailed dynamic analysis of the core support structures. Using the faulted load conditions, the analysis performed herein reiterates that done by B. F. Saffell, Jr. in Reference 1.

The WHAM computer code^[2] is used to determine the pressure transients which occur during a LOCA blowdown. Results of this analysis are used as input to the SHOCK computer code^[3] to define the axial response of each subassembly. Accelerations, displacements and forces are computed for both hot and cold leg LOCA's. These results are used to perform a linear elastic stress analysis of each component per Section III of the ASME Code^[4].

2. LOADS

Two computer codes were used in this analysis to obtain loads on the reactor components for use in the ASME Code^[4] analysis. The WHAM^[2] code is used to determine pressure transients which occur during a LOCA and act on each component as a function of time. These transients represent the forcing functions which accelerate each component during a LOCA. The SHOCK^[3] code is used to determine the structural dynamic response of the reactor internals to the forcing functions. Forcing functions for the flow skirt/core filler assemblies are illustrated in Figure 3.

Safe Shutdown Earthquake loads were obtained from work done by T. R. Thompson in Reference 5. A summary of SSE loads on the reactor components taken from Reference 5 is given in Table I. The stresses shown account for bending and axial superposition.

A detailed description of the WHAM^[2] model of the LOFT primary coolant system is contained in LTR 20-4^[6]. This is the same hydraulic model used for the LOCE analysis of the flow skirt/core filler assembly described in LTR 1115-25^[1]. The WHAM portion of the LOCA analysis was performed by V. T. Berta using an input wave form describing the manner in which the pressure at the LOCA rupture points decreases from the initial system pressure to saturation pressure. The LOCA was 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. Saturation pressure is reached in 1 msec. (See Reference 8.) A summary of LOCA conditions is given in Table II.

The SHOCK structural model, shown in Figure 4, utilizes the force transients from the WHAM output to determine displacements, accelerations, and forces on each component. Structural modeling is accomplished by representing the fuel modules and internal components with a finite number of lumped masses coupled by springs which correspond to the component axial stiffnesses. The model includes the core barrel, lower core support structure, the flow skirt/core filler assembly, and the nuclear core. The upper core barrel flange, which is supported by the reactor vessel, is assumed rigid with respect to vertical motion. This model was developed by B. F. Saffell, Jr. for analysis of the flow skirt/core filler and fuel modules for LOCE conditions (References 1 and 7). LTR 1111-31^[7] should be consulted for a detailed description of the model, its development and its verification. Results of the hot leg LOCA SHOCK analysis for the flow skirt/core filler assemblies, core barrel, and lower core support structure are contained in Appendix B. Cold leg LOCA SHOCK results are available but are not presented because of bulk. The hot leg LOCA resulted in the worse stress conditions for all of the analysis performed herein. A summary of component maximum forces and accelerations is contained in Table III.

3. ASME CODE ANALYSIS

Using the loads predicted by the SHOCK^[3] computer code for LOCA conditions and those reported in Reference 5 for SSE; a linear elastic analysis was performed on the LOFT core barrel, lower core barrel flange, flow skirt/core filler, shear pins and hold down springs. Since SSE + LOCA is considered a faulted condition, allowable stresses were determined per Appendix F of Section III of the ASME Code^[4]. The details of this analysis are contained in Appendix A.

III. RESULTS AND CONCLUSIONS

The occurrence of a LOCA causes separation of the flow skirt/core filler assembly from the lower core support structure which in turn lifts from the lower core barrel interior flange (Table III). The predicted separations do not include the effects of friction between the components or the influence of the water environment. The deflections and loads resulting from an SSE were found to add to the LOCA condition but were negligibly small in comparison.

The separation and resulting impact loads for the LOCA + SSE case do not create stresses in either the flow skirt/core filler assembly, the core barrel, or the hold down springs greater than allowables for the faulted condition. The flow skirt and Inconel 718 pins which couple the core fillers to the flow skirt were found to be structurally adequate for the faulted loading. A summary of component stresses is presented in Table V. The details of the component stress analysis can be found in Appendix A.

IV. REFERENCES

1. B. F. Saffell, Jr., Dynamic Analysis of LOFT Reactor Flow Skirt-Core Filler Assembly for Nonnuclear and Nuclear Loss-Of-Coolant Experiments, Aerojet Nuclear Engineering Report AM-33, LTR 1115-25, March 29, 1974.
2. S. Fabric, Computer Program WHAM for Calculation of Pressure Velocity and Force Transients in Liquid Filled Piping Systems, Kaiser Engineers Report No. 67-49R, November 1967.
3. V. K. Gabrielson and R. T. Reese, SHOCK Code User's Manual, A Computer Code to Solve Dynamic Response of Lumped-Mass Systems, Sandia Laboratories, Report No. SCL-DR-69-98, November 1969.
4. ASME Boiler and Pressure Vessel Code, "Nuclear Power Plant Components," Section III, 1974.
5. T. R. Thompson, Seismic Analysis of LOFT Reactor Internals, Aerojet Nuclear Company Report RE-E-76-004, LTR 1115-31, October 5, 1976.
6. V. T. Berta, WHAM Code Applications to the LOFT Primary Coolant System, LTR 20-4, October 2, 1973.
7. B. F. Saffell, Jr., Dynamic Analysis of the LOFT Reactor Fuel Modules For Subcooled Blowdown Loads, EG&G Idaho, Inc., Report No. RE-E-76-011, LTR 1111-31, December 21, 1976.
8. V. T. Berta, LOFT LOCA-WHAM6 Model and Code Application, LOFT Technical Report LTR 114-100, to be published.

Figure 1 Internals Arrangement

WELDING SHALL BE DONE IN ACCORDANCE WITH ROT 10-17.
TYPE 1 INCLUDE B LARGENT.

1 REMOVED

2 REMOVED

4 CEARLESS SHALL BE IN ACCORDANCE WITH ROT 16-17.

ALL BOLTS TO BE TORQUED TO 90-95 FT. LB.

5 REMOVED

6 REMOVED

7 REMOVED

8 DIMENSIONS IN INCHES WITH THE PART UNRESTRAINED AT 20°F (70°C).
DIMENSIONAL SYMBOLS ARE IN ACCORDANCE WITH ANSI Y14.6.

NOTES: (CONTINUED)

10. REMOVED

11. UNLESS OTHERWISE NOTED SURFACE FINISH TO BE 125/10 ALL OVER AS DETERMINED IN ACCORDANCE WITH AMS 2641.

12. REMOVED

13. 0°, 90°, 180° AND 270° CENTERLINES SHALL BE INDICATED ON OUTSIDE CYLINDRICAL SURFACE WITH SCRIBED MARKS AND STAMPED NUMBERS INDICATING 0°, 90°, 180° AND 270° PER ROT 17-37 FOR ORIENTATION AT MEET ASSEMBLY.

14. STAIN PEAR AND 40000 WITH ACCEPTANCE CRITERIA PER ROT 13-67.
NO WELD SHALL PROTRUDE BEYOND FLOW SHIRT OUTER CONTOUR.

15. ADJUST LENGTH OF PLATE GUIDES (ITEMS 14 & 15) TO OBTAIN SPECIFIED CLEARANCE AT FINAL ASSEMBLY.

16. MACHINE ASSEMBLY AS SHOWN TO PROVIDE DIMENSION 36000.

NO.	REV.	DESCRIPTION	DATE	BY	CHKD.
10	A	REMOVED DIMS 100	3/1/74	1A	10
11	B	REMOVED PARTS 1ST	4/1/74	1B	11
12	C	REMOVED BOTTOM VIEW	4/1/74	1C	12
13	D	REMOVED PER SCRA #L-584	4/1/74	1D	13
14	B	GENERAL DRAWING REVISION	4/1/74	1B	14
15	C	GENERAL DRAWING REVISION	4/1/74	1C	15
16	D	GENERAL DWG REVISION	4/1/74	1D	16
17	E	GENERAL DWG REVISION	4/1/74	1E	17

NO.	DESCRIPTION	QTY	UNIT	REMARKS
10	205123-11 BEARING PLATE	1	EA	10
11	204061-5 SPACER	1	EA	11
12	WELD FILLER METAL ER 308	1	LOT	12
13	205126-2 PLATE GUIDE FLOW SHIRT	1	EA	13
14	205126-1 PLATE GUIDE FLOW SHIRT	1	EA	14
15	205122-6 FILLER BOLT-FLOW SHIRT	1	EA	15
16	205122-5 FILLER BOLT-FLOW SHIRT	1	EA	16
17	205122-4 FILLER BOLT-FLOW SHIRT	1	EA	17
18	205122-3 FILLER BOLT-FLOW SHIRT	1	EA	18
19	205122-2 FILLER BOLT-FLOW SHIRT	1	EA	19
20	WELD FILLER METAL ERN-C-3	1	LOT	20
21	204061-4 PN- FILLER FLOW SHIRT	1	EA	21
22	204061-3 PN- FILLER FLOW SHIRT	1	EA	22
23	204071-1 FLOW SHIRT INTERMEDIATE	1	EA	23
24	204071-1 CORE FILLER TYPE 4	1	EA	24
25	204071-1 CORE FILLER TYPE 3C	1	EA	25
26	205127-1 CORE FILLER TYPE 2C	1	EA	26
27	204071-1 CORE FILLER TYPE 1	1	EA	27

NO.	DESCRIPTION	QTY	UNIT	REMARKS
10	204081-1 LOFT	1	EA	10
11	204081-1 LOFT	1	EA	11
12	204081-1 LOFT	1	EA	12
13	204081-1 LOFT	1	EA	13
14	204081-1 LOFT	1	EA	14
15	204081-1 LOFT	1	EA	15
16	204081-1 LOFT	1	EA	16
17	204081-1 LOFT	1	EA	17
18	204081-1 LOFT	1	EA	18
19	204081-1 LOFT	1	EA	19
20	204081-1 LOFT	1	EA	20

FIGURE 2
FLOW SHIRT/CORE FILLER
SUB ASSEMBLY

b

FIGURE 3

FORCE ON LOWER FS-CF ASBLY--HOT LEG LOCA CASE 1

FIGURE 3 CONT'D

FORCE ON INNER FS-CF ASBLY--H3T LEG LOCA-CASE 1

//

FIGURE 3 CONT'D

FORCE ON UPPER FS-CF ASBLY--HOT LEG LOCA-CASE 1

Spring Designations

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

Mass

Component

1	Fixed-Upper Support Structure
2-4	Flow Skirt Subassemblies
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

Figure 4. Structural Model

TABLE I
SSE LOADS & STRESSES

MAXIMUM SEISMIC STRESSES

Vessel:	169 psi
Vessel Fillers:	101 psi
Barrel:	110 psi
Flow Skirt w/Core Fillers:	280 psi
Corner Module:	17,148 psi
Center Module:	5,370 psi
Control Module:	5,955 psi
Guide Assy:	1,365 psi
Control Rod Assy:	5,590 psi

MAXIMUM VERTICAL SEISMIC FORCE

Flow Skirt:	5522#
Corner Module:	207#/module
Center Module:	678#
Control Module:	557#/module

TABLE II
LOCA CONDITIONS

CONDITION	TEMPERATURE	SATURATION PRESSURE
HOT LEG LOCA	610°F	950 PSIG
COLD LEG LOCA	544°F	950 PSIG

TABLE III
MAXIMUM FORCES AND ACCELERATIONS

MASS	MAXIMUM ACCELERATION (g's)	
	HOT LEG LOCA	COLD LEG LOCA
1	0	0
2	76.4	18.0
3	68.7	11.9
4	73.5	12.9
5	184.2	43.7
6	81.9	28.9
7	66.9	18.3
8	31.9	11.4

MASS COUPLING	MAXIMUM FORCE IN COUPLING (lbs)	
	HOT LEG LOCA	COLD LEG LOCA
1-2	28490	26990
2-3	186000	65520
3-4	259400	108860
4-5	348000	162900
5-6	372900	225700
6-7	402500	236000
7-8	390600	247000
8-1	471700	253600

TABLE 4
MAXIMUM COMPONENT SEPARATIONS

MASS COUPLING	DEFLECTION (IN)	
	HOT LEG LOCA	COLD LEG LOCA
δ_{1-2}	.080	.018
δ_{2-3}	.0057	.0017
δ_{3-4}	.0175	.0032
δ_{4-5}	.0325	.0042
δ_{5-6}	.0680	.0086

- δ_{1-2} - MAXIMUM COMPRESSION OF FLOW SKIRT HOLD DOWN SPRING
 δ_{2-3} - MAXIMUM SEPARATION BETWEEN UPPER AND INTERMEDIATE FLOW SKIRT ASSEMBLIES
 δ_{3-4} - MAXIMUM SEPARATION BETWEEN INTERMEDIATE AND LOWER FLOW SKIRT ASSEMBLIES
 δ_{4-5} - MAXIMUM SEPARATION BETWEEN FLOW SKIRT AND LOWER CORE SUPPORT STRUCTURE
 δ_{5-6} - MAXIMUM SEPARATION BETWEEN CORE BARREL AND LOWER CORE SUPPORT STRUCTURE

TABLE 5
SUMMARY OF COMPONENT STRESSES

COMPONENT	MAXIMUM STRESS (PSI)	ALLOWABLE STRESS (PSI)
CORE BARREL	33 59	$1.5S_m = 20850$
CORE BARREL INTERIOR FLANGE	32 07	$1.5S_m = 20850$
FLOW SKIRT HOLD DOWN SPRINGS	60 863	$1.8S_y = 108880$
FLOW SKIRT - CORE FILLER SHEAR PINS (BEARING)	23 437	$1.8S_y = 27720$

APPENDIX A

ASME CODE ANALYSIS

CORE BARRELLOCA LOADS

FIXED UPPER SUPPORT STRUCTURE

CORE
BARREL
MASSES

MASS COUPLING	HOT LEG LOCA		COLD LEG LOCA	
	MAXIMUM FORCE (lb)	MINIMUM FORCE (lb)	MAXIMUM FORCE (lb)	MINIMUM FORCE (lb)
1-8	471700	-136100	253600	-42000
8-7	390600	-110600	247000	-37020
7-6	402500	-86610	236000	-25960
6-5	0	-372900	0	-225700

MAX & MIN SPRING FORCES*
SHOCK RESULTS

TENSION ONLY CONNECTION

LOWER CORE SUPPORT STRUCTURE

MAXIMUM CORE BARREL TENSION ~ 471700 lb
 MAXIMUM CORE BARREL COMPRESSION ~ 136100 lb
 MAXIMUM CORE BARREL INTERIOR
 FLANGE LOAD (TENSION IN BARREL ~ 372900 lb

* SIGNS ON FORCES DO NOT IMPLY TENSION OR COMPRESSION DIRECTLY. THE ORDER OF THE MASS COUPLING DEFINITION IN THE PROGRAM DETERMINES THE SIGN. TENSION & COMPRESSION ARE BEST DETERMINED BY OBSERVING THE RELATIVE LINEAR DISPLACEMENTS BETWEEN MASSES.

CORE BARRELSSE LOADS

SEISMIC LOADS FOR THE SAFE SHUTDOWN EARTHQUAKE (SSE) ARE OBTAINED FROM LTR 1115-31. MAXIMUM LOADS REPORTED ARE CONSERVATIVELY USED (IE: LOADS VARY ALONG THE LENGTH OF THE BARREL BUT THE MAXIMUM IS COMBINED WITH LOCA LOADS REGARDLESS OF LOCATION)

THE SEISMIC LOADS REPORTED IN LTR 1115-31 ACCOUNT FOR BOTH VERTICAL AND LATERAL MOTION. BENDING LOADS WERE COMBINED WITH AXIAL LOADS TO GIVE THE RESULTANT AXIAL STRESSES REPORTED FOR THE FLOWSKIRT/CORE FILLER & CORE BARREL.

CORE BARREL TENSION

MAXIMUM LOCA TENSION LOAD = 471700 LB
MAXIMUM SSE STRESS = 180 PSI

CORE BARREL CROSS-SECTIONAL AREA

$$A_B = \pi \left\{ (D_o/2)^2 - (D_i/2)^2 \right\}$$

$$D_o = 33 \text{ in}$$

$$D_i = 30 \text{ in}$$

$$A = (3.14)(16.5^2 - 15^2) = 148.4 \text{ in}^2 \quad (\text{MINIMUM DIMENSION})$$

$$\sigma_T = \frac{471700}{148.4} + 180 = 3359 \text{ psi}$$

CORE BARREL MATL ~ 304L SST

$$\text{DESIGN } T = 610^\circ\text{F}$$

$$\text{@ } 610^\circ\text{F} \quad \left\{ \begin{array}{l} S_m = 13900 \text{ PSI} \quad (\text{APPENDIX I, SECTION III ASME CODE}) \\ S_y = 15400 \text{ PSI} \\ S_u = 57000 \text{ PSI} \quad (\text{TABLE I-3.2, 1977 CODE}) \end{array} \right.$$

CORE BARRELCORE BARREL TENSION

ALLOWABLE STRESSES FOR THE FAULTED CONDITION ARE GIVEN IN APPENDIX F OF SECTION III OF THE ASME CODE FOR COMPONENT SUPPORTS AS:

$$\left. \begin{array}{l} 1.5 S_m \\ 1.2 S_y \end{array} \right\} \begin{array}{l} \text{WHICHEVER IS GREATER} \\ \text{BUT NOT } > 0.7 S_u \end{array}$$

$$1.5 S_m = 1.5 (13900) = \underline{20850} \text{ PSI}$$

$$1.2 S_y = 1.2 (15400) = 18480 \text{ PSI}$$

$$0.7 S_u = 0.7 (57000) = 39900 \text{ PSI}$$

$$\therefore \text{ALLOWABLE TENSILE STRESS } F_t = 1.5 S_m$$

$$F_t = 20850 \text{ PSI} > 3359 \text{ PSI} \quad \underline{\text{OK}}$$

CORE BARREL COMPRESSION

$$\text{MAXIMUM LOCA COMPRESSION LOAD} = 136100 \text{ lb}$$

$$\text{MAXIMUM SSE STRESS} = 180 \text{ PSI}$$

$$\sigma_c = \frac{136100}{148.4} + 180 = 1097 \text{ PSI}$$

$$\text{ALLOWABLE COMPRESSIVE STRESS} = 20850 \text{ PSI}$$

$$20850 \text{ PSI} > 1097 \text{ PSI} \quad \underline{\text{OK}}$$

CHECK BUCKLING OF CORE BARREL

$$\text{MAXIMUM COMPRESSIVE LOAD}$$

$$P_c = (1097 \text{ PSI})(148.4 \text{ in}^2) = 162795 \text{ lb}$$

IN GENERAL THE CRITICAL BUCKLING LOAD FOR A COLUMN IS GIVEN BY:

$$P_{cr} = \frac{\pi^2 E A}{\left(\frac{KL}{r}\right)^2}$$

CORE BARRELBUCKLING CHECK

WHERE

E = MODULUS OF ELASTICITY

A = CROSS-SECTIONAL AREA

K = EQUIVALENT LENGTH FACTOR (DEPENDS ON FIXITY OF ENDS)

L = Laterally Unbraced Column Length

r = RADIUS OF GYRATION

THE CORE BARREL END FIXITY IS ASSUMED FIXED-FREE WITH $K = 1.2$

$$E = 25.4 \times 10^6 \text{ PSI} \quad (610^\circ\text{F})$$

$$A = 148.4 \text{ IN}^2$$

$$L = 203.5 \text{ IN}$$

$$I = \frac{\pi}{64} (33^4 - 30^4) = 1.845 \times 10^4 \text{ IN}^4$$

$$r = \sqrt{I/A} = \sqrt{1.845 \times 10^4 / 148.4} = 124.3 \text{ IN}$$

$$P_{cr} = \frac{(25.4 \times 10^6)(148.4) \pi^2}{\left(\frac{(1.2)(203.5)}{124.3} \right)^2}$$

$$P_{cr} = 963.9 \times 10^7 \text{ lb} \gg P_c = 162795 \text{ lb} \quad \underline{\text{OK}}$$

CORE BARREL INTERIOR FLANGE

$$\text{SHEAR FORCE } F_s = 372400 \text{ lb (LOCA)}$$

$$F_s = 5522 \text{ lb (SSE)*}$$

$$\text{SHEAR AREA } A_s = \pi D_i t_f$$

$$A_s = \pi (30)(2.5) = 236 \text{ IN}^2$$

$$\tau_s = 378422 / 236 = 1603 \text{ PSI}$$

$$\text{STRESS INTENSITY} = 2(1603) = 3207 \text{ PSI}$$

FOR THE FAULTED CONDITION THE ALLOWABLE STRESS INTENSITY IS $1.5 S_m = 20950 \text{ PSI}$ (REF F1322.2)

$$20950 > 3207$$

OK

* SEE LTR 1115-31 Pg 4

FLOW SKIRT / CORE FILLERSHEAR PINS

THE FLOW SKIRT / CORE FILLERS EXPERIENCE SUBSTANTIAL ACCELERATIONS DURING THE OCCURRENCE OF A LOCA. IN MOST INSTANCES PEAK ACCELERATIONS RESULT FROM IMPACT OF THE FLOW SKIRT WITH THE LOWER CORE SUPPORT PLATE. THE SUDDEN DECELERATION CAUSES A SHEAR LOAD ON THE INCONEL 718 PINS WHICH ATTACH THE CORE FILLERS TO THE FLOW SKIRT.

ANALYSIS OF THE INCONEL PINS WAS DONE IN LTR 1115-25 (B.F. SAFFELL, Jr, 3/29/74) FOR LOCE LOADINGS BY COMPUTING A MAXIMUM ALLOWABLE g -LOAD. THE ANALYSIS HERE WILL BE CONDUCTED BY COMPARING THE g -LOADS RESULTING FROM LOCA TO THE MAXIMUM ALLOWABLE DETERMINED IN LTR 1115-25 TAKING INTO ACCOUNT THE DIFFERENT ALLOWABLE STRESSES ASSOCIATED WITH A LOCA. BOTH THE SHEAR ALLOWABLE STRESS OF THE PINS AND THE BEARING STRESS ON THE FLOW SKIRT ARE CONSIDERED.

EACH CORE FILLER SEGMENT IS COUPLED TO THE FLOW SKIRT WITH TWO PINS.* THE SHEAR FORCE TRANSMITTED THRU THE TWO PINS FROM A CORE FILLER ASSEMBLY IS:

$$F_s = M_a a$$

M_a = MASS OF CORE FILLER ASSEMBLY
 a = ACCELERATION OF ASSEMBLY

* REF DWGS

- 1) "FLOW SKIRT ASSEMBLY - UPPER SECTION" ANC 204079
- 2) "FLOW SKIRT ASSEMBLY - LOWER SECTION" ANC 204080
- 3) "FLOW SKIRT ASSEMBLY - INTERMEDIATE SECTION" ANC 204081

FLOW SKIRT, CORE FILLERSHEAR PINS

IF THE ACCELERATION IS IN g 'S THE EQUATION BECOMES:

$$F_s = W_{CF} g$$

W_{CF} = WEIGHT of CORE FILLER

MAXIMUM ALLOWABLE g LOAD of PIN

PIN MATERIAL ~ INCONEL 718

$$\begin{array}{lcl} @ 610^\circ F & \begin{array}{l} S_u = 163800 \text{ PSI} \\ S_y = 136100 \text{ PSI} \\ S_m = 54600 \text{ PSI} \end{array} & \left. \begin{array}{l} \text{REF LTR 1115-25} \\ \text{B C3 AND} \\ \text{ASME CODE} \\ \text{SECTION III} \end{array} \right\} \end{array}$$

AS REPORTED IN LTR 1115-25 THE MAXIMUM ALLOWABLE ACCELERATION IS 74.2 g 'S FOR THE LOCE LOAD CONDITION BASED ON AN ALLOWABLE (ASME CODE) STRESS OF
 $\tau_{max} = S_{all} = 0.6 S_m$ FOR PURE SHEAR

$$g_{all} = \frac{S_{all} (A_{pins})}{W_{CF}}$$

FOR THE FAULTED CONDITION (LOCA+SSE) THE ALLOWABLE SHEAR STRESS IS: (REF APPENDIX F-1380)

$$P_m = 2 \tau_{max} = 2 S_m$$

$$\tau_{max} = S_m$$

$$g_{all \text{ FAULTED}} = g_{all \text{ LOCE}} \left(\frac{S_m}{0.6 S_m} \right)$$

$$g_{all \text{ FAULTED}} = 1.67 (74.2) = 123.9 g's$$

FLOW SKIRT / CORE FILLERSHEAR PINSMAXIMUM ALLOWABLE g LOAD OF FLOW SKIRT

FLOW SKIRT MATERIAL 304L SST

$$610^{\circ}\text{F} \quad \left\{ \begin{array}{l} S_u = 57000 \text{ PSI} \\ S_y = 15400 \text{ PSI} \\ S_m = 13900 \text{ PSI} \end{array} \right\} \begin{array}{l} \text{ASME CODE} \\ \text{SECTION II} \end{array}$$

AS REPORTED IN LTR-1115-25 THE MAXIMUM ALLOWABLE ACCELERATION IS 73.2 g 's FOR LOCA LOADS BASED ON AN ALLOWABLE STRESS OF $S_{all} = 1.5 S_y$

FOR THE FAULTED CONDITION THE ALLOWABLE BEARING STRESS IS TAKEN AS: (REF APPENDIX F-1370)

$$S_{all}^{FB} = \left(\frac{1.2 S_y}{F_t} \right) (.90 S_y)$$

WHERE F_t = ALLOWABLE TENSILE STRESS FOR NORMAL CONDITIONS = $.60 S_y$

$$S_{all}^{FB} = (2.0)(.90) S_y = 1.80 S_y = 1.2 (1.5 S_y)$$

THE MAXIMUM ALLOWABLE g LOAD FOR LOCA+SSE BECOMES

$$g_{all}^F = (1.2)(73.2) = 87.8 g's$$

FOR LOCA MAXIMUM FLOW SKIRT / CORE FILLER ACCELERATIONS ARE

MASS #	HOT LEG LOCA g 's	COLD LEG LOCA g 's
2	76.42	18.03
3	68.68	11.98
4	73.53	12.90

MAXIMUM ACCELERATIONS
SHOCK RESULTS

FLOW SKIRT / CORE FILLERSHEAR PINS

ACCELERATIONS ARE NOT DIRECTLY OBTAINABLE FROM THE SEISMIC ANALYSIS REPORTED IN LTR 1115-31. PEAK ACCELERATIONS IN THE FLOW SKIRT / CORE FILLER RESULTING FROM SSE LOADING ARE ESTIMATED AS FOLLOWS:

THE MAXIMUM FORCE IN THE FLOW SKIRT-CORE FILLER STRUCTURE RESULTING FROM SSE LOADING AS REPORTED IN LTR 1115-31 IS

$$F = 5522 \#$$

ASSUMING THIS ENTIRE FORCE TO BE THE RESULT OF SEISMIC ACCELERATIONS AND RIGID BODY MOTION:

$$F = W_{CF-FS} g$$

THE WEIGHT OF THE FLOW SKIRT-CORE FILLER ASSEMBLY IS 9550 lb *

$$\therefore g = 5522 / 9550 = .58 g's$$

THE MAXIMUM ACCELERATION EXPECTED IN THE FLOW SKIRT / CORE FILLER AS A RESULT OF LOCA + SSE LOADS IS

$$g_{max} = 73.5 + .58 = 74.08 g's$$

$$87.8 g > 74.08 g \quad \underline{OK}$$

* THIS WEIGHT WAS OBTAINED FROM WORK DONE BY B.F. SAFFEL JR IN SUPPORT OF LTR 1111-31, "DYNAMIC ANALYSIS OF THE LOFT REACTOR FUEL MODULES FOR SUBCOOLED BLOWDOWN LOADS, DISC 21, 1976"

FLOW SKIRT / CORE FILLERSHEAR PINS

USING THE MAXIMUM PREDICTED q LOAD DUE TO LOCA + SSE LOADINGS, THE RESULTING PIN SHEAR STRESS WILL BE CALCULATED:

$$S_{\max}^S = \frac{W_{CF} q_{\max}}{2 (A_{PIN})}$$

$$A_{PIN} = .442 \text{ in}^2$$

$$S_{\max} = \frac{(390.4)(74.08)}{2 (.442)} = 32716 \text{ PSI}$$

$$S_{ALL} = S_m = 54600 \text{ PSI}$$

THE MAXIMUM BEARING STRESS IS

$$S_{\max}^B = \frac{W_{CF} q_{\max}}{2 (A_b)}$$

$$A_b = .617 \text{ in}^2 \text{ (REF LTR 1115-25)}$$

$$S_{\max}^B = \frac{(390.4)(74.08)}{2 (.617)} = 23437 \text{ PSI}$$

$$S_{ALL}^B = 1.8 S_y = 1.8 (15400) = 27720 \text{ PSI}$$

$$27720 \text{ PSI} > 23437 \text{ PSI} \quad \underline{\text{OK}}$$

NOTE: THE ABOVE SHEAR PIN ANALYSIS WAS DONE USING A CORE FILLER WEIGHT FOR THE THREE-PLATE INTERMEDIATE AND LOWER ASSEMBLIES. THE PIN LOAD FOR BOTH THE SINGLE PLATE AND CORE FILLER ASSEMBLIES IS LESS DUE TO THE REDUCED MASS OF THESE PARTS. REFERENCE TO LTR 1115-25 FOR WEIGHT & MASS CALCULATIONS IS MADE.

FLOW SKIRT HOLD DOWN SPRINGS

THE HOLD DOWN SPRING STRESS IS
GIVEN BY

$$\tau = \frac{8K\delta Dk}{\pi d^3}$$

WHERE

K = SPRING RATE 16/LB
 δ = SPRING DISPLACEMENT (IN)
 (δ PRELOAD + δ SSE + δ LOCA)
 D = COIL DIAMETER (IN)
 k = WAHL CORRECTION FACTOR
 d = WIRE DIAMETER (IN)

SPRING DATA IS OBTAINED FROM BF SAFFEL, JR.
 LTR TO KLDREXLEK, SAFF-7-73, 3-16-73 LOFT
 FLOW SKIRT CORE FILLER ASSEMBLY

DEFLECTIONS DUE TO LOCA LOADS ARE
 OBTAINED FROM THE SHOCK ANALYSIS
 δ = .080 IN (HOT LEG LOCA)
 δ = .018 IN (COLD LEG LOCA)

SPRING PRELOAD DEFLECTIONS ARE OBTAINED
 FROM THE LTR 1115-25
 δ = 1.25 IN (SPRING 1)
 δ = 1.37 IN (SPRING 2)

DEFLECTIONS RESULTING FROM SSE LOADINGS
 ARE IGNORED. FORCES IN THE HOLD
 DOWN SPRINGS RESULTING FROM THE SSE
 (AS REPORTED IN WORK DONE IN SUPPORT
 OF LTR 1115-31) ARE ON THE ORDER OF 10 LB.
 RESULTING STRESSES ARE CONSIDERED
 INSIGNIFICANT.

FLOW SKIRT HOLD DOWN SPRINGS

SPRING #1

$$K^* = 2390 \text{ lb/in}$$

$$D = 3.5 \text{ in}$$

$$k = 1.4$$

$$d = .975 \text{ in}$$

$$\delta = .080 + 1.25 = 1.33 \text{ in}$$

$$\tau_1 = \frac{8(2390)(3.5)(1.4)(1.33)}{\pi(.975)^3}$$

$$\tau_1 = 59205 \text{ PSI}$$

SPRING #2

$$K^* = 725 \text{ lb/in}$$

$$D = 2.03 \text{ in}$$

$$k = 1.4$$

$$d = .5 \text{ in}$$

$$\delta = 1.080 + 1.37 = 1.45 \text{ in}$$

$$\tau_2 = \frac{8(725)(2.03)(1.4)(1.45)}{\pi(.5)^3}$$

$$\tau_2 = 60863 \text{ PSI}$$

SPRING MATERIAL IS INCONEL 718

$$610^\circ\text{F} \begin{cases} S_y = 136100 \text{ PSI} \\ S_m = 54600 \text{ PSI} \\ S_u = 163800 \text{ PSI} \end{cases}$$

THE ALLOWABLE SHEAR STRESS FOR THE
FAULTED CASE IS TAKEN AS

$$S_{ALL} = 1.2(S_y / F_t)(.4 S_y) \quad (REF. F-1370)$$

$$F_t = .6 S_y$$

$$S_{ALL} = (.80)(136100) = 108880 \text{ PSI}$$

$$108880 > 60863$$

OK

* K IS TAKEN AT 100°F. THIS IS CONSERVATIVE BECAUSE
A REDUCED K WOULD BE EXPECTED AT 610°F

APPENDIX B

SHOCK COMPUTER CODE RESULTS

HOT LEG LOCA

LTR1115 39

ACCELERATION (G's)

HOT LEG LOCA
LINEAR ACCELERATION OF MASS 8

ACCELERATION (G'S)

LTR1115 39

HOT LEG LOCH
LINEAR ACCELERATION OF MASS 7

LTR1115 39

ACCELERATION (G's)

HOT LEG LOCA
LINEAR ACCELERATION of MASS 6

LTR1115 39

ACCELERATION

HOT LEG LOCA
LINEAR ACCELERATION OF MASS 5

LTR1115 39

ACCELERATION

HOT LEG LOCH
LINEAR ACCELERATION of MASS 4

LTR1115 39

ACCELERATION (G's)

HOT LEG LOCA

LINEAR ACCELERATION OF MASS 3

ACCELERATION (G's)

HOT LEG L200A
LINEAR ACCELERATION of MASS 2
B-7

LTR1115 39

LOAD (lbs)

-100000

-200000

-300000

TIME (SEC)

HOT LEG LOCA
LOAD AT MASS 5 from 6

B-8

LTR1115 39

LOAD (lbs)

-100000

-200000

HOT LEG LOCA
LOAD AT MASS 4 from 5

B-9

LTR1115 39

LOAD (lbs)

-100000

-200000

TIME (SEC)

HOT LEG LOCA
LOAD AT MASS 3 from 4

B-10

LTR1115 38

LOAD (lbs)

-50000.0

-100000.0

2 FROM

3

.02

.04

.06

.08

0

TIME (SEC)

HOT LEG LOCH
LOAD AT MASS 2 FROM 3

B-11

LTR1115 39

LOAD (lbs)

-27000

-28000

1 FROM

2

HOT LEG LOCA
LOAD AT MASS 1 FROM 2

B-12

LTR1115 39

LOAD (lbs)

200000

TIME (SEC)

HOT LEG LOCA
LOAD AT MASS 1 FROM 8

B-13

LTR1115 39

LOAD (lbs)

200000

TIME (SEC)

HOT LEG LOCA
LOAD AT MASS 8 from 7
8-14

LTR1115 39

7 FROM

8

LOAD (lbs)

200000

HOT LEG LOCA
LOAD AT MASS 7 from 6
0-15

LTR1115 139

DISPLACEMENT (IN)

HOT LEG LOCA
LINEAR DISPLACEMENT OF MASS 8
B-16

LTR1115 39

DISPLACEMENT (IN)

.0000

.02

.04

.06

.08

.10

TIME (SEC)

HOT LEG LOCA
LINEAR DISPLACEMENT OF MASS 7

B-17

LTR1115 39

DISPLACEMENT (IN)

HOT LEG LOCA
LINEAR DISPLACEMENT OF MASS 6

LIR1115 39

DISPLACEMENT (IN)

TIME (SEC)

NOT FOR DISPLACEMENT 0 MISS 5

LTR1115 39

HOT LEG LOCA
LINEAR DISPLACEMENT of MASS 4

LTR1115 39

DISPLACEMENT (IN)

HOT LEG LOCA
LINEAR DISPLACEMENT OF MASS 3

LTR1115 39

DISPLACEMENT (IN)

0.000

TIME (SEC)

HOT LEG LOCA
LINEAR DISPLACEMENT OF MASS 2

B-22

APPENDIX C
SHOCK COMPUTER CODE LISTING