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LOFT CALIBRATION TUBE THERMAL EXPANSION ANALYSIS

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DEPARTMENT OF ENERGY

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IDAHO NATIONAL ENGINEERING LABORATORY
LOFT TECHNICAL REPORT
LOFT PROGRAM

TITLE LOFT Calibration Tube Thermal Expansion Analysis		REPORT NO. LTR 1111-57
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AUTHOR G. A. Tatar <i>George A. Tatar</i>		GWA NO. 56131-500-694
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SUMMARY

This analysis is in response to a request to determine the maximum relative linear displacement of the lower end of the calibration tube towards the bottom of the guide tube that can occur during any operating mode of the LOFT reactor. The path of the calibration tube through the reactor corner fuel assembly as is shown in Figure 7^[4]. It was found that the worst case occurs during nuclear test L2-4 with a maximum displacement of 0.78 inches at 40 seconds. This is a conservative value and no factors should be applied for analysis uncertainties.

CALIBRATION TUBE THERMAL EXPANSION

I. INTRODUCTION

In the LOFT reactor vessel there are several components which must be sized to allow for thermal expansion. This analysis concerns the relative displacement of the lower end of the 304 Stainless Steel calibration tube towards the bottom of the guide tube in the corner fuel assembly (Figure 1). The calibration tube is welded to the pressure plate while the core (guide tube) is supported by the core barrel.

II. DISCUSSION

A relative displacement of the calibration tube towards the bottom of the guide tube occurs when the thermal expansion of the calibration tube is greater than that of the core barrel. The worst case occurs during L2-4, the 80°F ECC injection cools the core barrel while the calibration tube remains hot.

III. ANALYSIS

This analysis combines the results of a past analysis with RELAP4/MOD6 predictions. The core barrel expansion was previously calculated in Reference 1. The fluid temperatures and convection coefficients used in Reference 1 were compared with RELAP predictions and were found to be conservative (Figure 2). RELAP data were also used for the temperatures of the calibration tube in the core and above core regions. The calibration tube temperature is assumed to be a constant 610°F in the region above the core. This is a conservative value since RELAP results indicate the surface temperatures in the upper plenum and upper core support drop slightly (Figures 3 and 4). In the core region the calibration tube temperature is conservatively assumed to be equal to the fuel clad temperature. The clad temperatures are from RELAP predictions for L2-4 for the hottest fuel rod in the corner fuel assemblies (Figures 5 and 6).

The core barrel expansion is calculated from its support lip at Station 300.00 down to Station 113.25 which is the elevation of the lower tie box. This expansion is added to the expansion of the reactor vessel and instrument head up to the elevation of the pressure plate. The calibration tube expansion is calculated from the pressure plate to Station 113.25.

Calculations were carried out through 40 seconds (Appendix). At 38 seconds reflood occurs causing the core to cool rapidly relative to the core barrel^[2]. Therefore, after 40 seconds, the distance between the bottom of the guide tube and end of the calibration tube will increase.

A number of conservatisms were used in this report:

- 1) The core barrel analysis is based on a more rapid cool down than RELAP predictions indicate will occur.
- 2) It was assumed that in the above core region the calibration tube did not cool.
- 3) It was assumed that the calibration tube temperature was equal to the hottest fuel rod clad temperature in the corner fuel assembly

This analysis was not refined because of cost and time considerations and also the conservative approach gave acceptable results.

IV. CONCLUSIONS

The relative displacement of the guide tube towards the bottom of the guide tube will be a maximum of 0.78 inch. This is a conservative value, therefore, no factors should be added for analysis uncertainties.

Figure 1. LOFT Reactor Vessel Cross Section

RELAP4/MOD8 L2-4

Figure 2. Downcomer Fluid Temperature.

RELAP4/MOD8 L2-4

Figure 3. Upper Plenum Surface Temperature.

1 SR29

RELAP4/MOD8 L2-4

Figure 4. Surface Temperature Upper Core Area.

RELAP4/MOD 6 PREDICTION FOR L2-4

Figure 5. LOFT Corner Fuel Assembly Hottest Fuel Rod Clad Temperatures at Different Axial Locations.

RELAP4/MOD 6 PREDICTION FOR L2-4

Figure 6. LOFT Corner Fuel Assembly Hottest Fuel Rod Clad Temperatures at Different Axial Locations.

α = Coefficient of Thermal Expansion $\times 10^6$

CALIBRATION TUBE WELDED TO THE PRESSURE PLATE

K-SEAL SURFACE

38"

PRESSURE TUBE REGION
INC. 372 MP

$\alpha = 7.91 \mu\text{in}/\text{in}/^\circ\text{F}$

UPPER STRUCTURE REGION

110"

CALIBRATION TUBE
304 SST

CAL TUBE IS EXPOSED IN THIS REGION

FUEL ASSY REGION

72"

CAL TUBE IS INSIDE GUIDE TUBE IN THIS REGION

Figure 7: LOFT Calibration Tube

$\Delta T =$

V. REFERENCES

1. R. A. Lindly, LOFT Fuel Assembly and Upper Support Structure Thermal Expansion Analysis, Aerojet Nuclear Co., LTR 1111-7 (March 12, 1973).
2. Personal Conversation with J. R. White (September 28, 1978) These RELAP results to be published in Report EPC2-2.
3. Nuclear System Materials Handbook, Vol. 1, Part 1, Hanford Engineering Development Laboratory, Richland, Washington (September 30, 1976).
4. J. O. Carlson ltr to J. L. Liebenthal, "Fuel Module Assembly Calibration Tube Linear Displacement Analysis," JOC-15-78 (September 5, 1978).

APPENDIX

EXPANSION CALCULATIONS

Thermal Expansion Calculations

Expansion: $\Delta L = \text{Temp.} \times \text{Co. of Linear Exp.}^{[3]} \text{ (See Next Page)}$

Net Relative Displacement = $\Delta L (\text{calib. tube}) - \Delta L (\text{core barrel})$

time - seconds
length - IN.
expansion Coef. $10^{-6}/^{\circ}\text{F}$

Expansion Table (up to 300.00)

Time	Core Barrel		Upper Area		Core Area		ΔL	$\Delta L \text{ Net}$
	Tavg	ΔL	Tavg	ΔL	Tavg	Expansion Coef.		
	$L = 186.4 \text{ in.}$		$L = 112.7 \text{ in.}$				$L = 78.6 \text{ in.}$	
0	573	.876	610	.582	630	.6350	.416	.460
4	565	.864			917	10.061	.659	.389
8	554	.845			911	9.980	.654	.371
12	533	.796			1011	11.329	.742	.548
16	513	.759			918	10.075	.660	.483
20	501	.736			986	10.992	.720	.566
28	476	.689			1034	11.640	.762	.655
32	463	.664			1052	11.882	.778	.696
36	452	.645			1059	11.977	.785	.712
40	443	.626			1062	12.017	.788	.714
Sec.	$^{\circ}\text{F}$	IN.	$^{\circ}\text{F}$	IN.	$^{\circ}\text{F}$	$10^{-6}/^{\circ}\text{F}$	IN.	IN.

The max displacement is $.744 \pm .030$
= .78

Upper Area Calc.

$$T = 610^{\circ}\text{F}; L^* = 112.7 \text{ in. Coef} = 6.2(10^{-6}) \text{ in./}^{\circ}\text{F}$$

$$\Delta L = 112.7 \text{ in.} \cdot 6.2/10^{-6} \text{ in./}^{\circ}\text{F} = .582 \text{ in.}$$

This length includes 2-18" R bends in the calibration tube.

Differential Expansion of Calib. Tube and Mount above Ref. 300.0

As indicated by J.O. Carlson the point where the calibration tube is effectively mounted to the Reactor Vessel is at the K-seal. However from the K-seal to the pressure plate both paths are of Inconel 600 and therefore cancel. The section from the top of the Instrument head to ref 300.0 has different materials for each path. The calibration tube is 304 SS. while the Instrument head and reactor vessel are Carbon Steel.

The differential expansion in this region is:

$$\Delta L = 540^{\circ}F \times (\alpha_{CS} - \alpha_{SS}) \times 25.7 \text{ in}$$

$$\alpha_{SS} = 9.45 (10^{-6}) / ^{\circ}F$$

$$\alpha_{CS} = 7.28 (10^{-6}) / ^{\circ}F$$

$$\Delta L = 540^{\circ} \times 2.17 (10^{-6}) \times 25.7 = \underline{\underline{.030 \text{ in}}}$$

NUCLEAR SYSTEMS MATERIALS HANDBOOK VOL 1-DESIGN DATA

PART I - STRUCTURAL MATERIALS	GROUP 1 - HIGH ALLOY STEELS	SECTION 2 - 304 SS ANNEALED
REVISION 0, 8-1-77	PREVIOUS REVISION	THERMAL EXPANSION, LINEAR

APPLICABLE PRODUCT FORMS:

NOTES: The curve also applies to 304L, 304H, and 304N stainless steels.

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