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INTERNAL TECHNICAL REPORT

Title: LOFT LTSF THERMOCOUPLE THERMAL ANALYSIS
TO DETERMINE TRANSIENT TEMPERATURE RESPONSE

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LOFT TECHNICAL REPORT

Title		LTR No.
LOFT LTSF THERMOCOUPLE THERMAL ANALYSIS TO		LO-87-80-136
DETERMINE TRANSIENT TEMPERATURE RESPONSE		RE-A-80-055
Author	S. K. Howell <i>S. K. Howell</i>	Released By LOFT CDCS
Performing Organization	Thermal Analysis Branch	Date June 23, 1980
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SUMMARY

A two-dimensional finite element model of the LOFT LTSF thermocouple assembly was developed to study the thermal response of the thermocouples to the expected temperature transient in the L3-4, 5 and 6 experiments. Subjecting the thermocouple model to a 10°F fluid temperature step change resulted in a .10 second delay before 95% of the step change was observed in the thermocouple temperature response.

DISPOSITION OF RECOMMENDATIONS

No disposition required.

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LOFT LTSF THERMOCOUPLE THERMAL ANALYSIS
TO DETERMINE TRANSIENT TEMPERATURE RESPONSE

INTRODUCTION

A thermal analysis was performed on the Loft Test Support Facility (LTSF) small-break thermocouple assembly to evaluate the thermal response of the thermocouples during the upcoming L3-4, 5 and 6 small-break experiments.

The thermocouple assembly (see Figure 1) consists of 3 Type K thermocouples placed radially through an 8 inch diameter section on the pressurizer relief line in the LTSF. In support of the upcoming L3-4, 5 and 6 experiments the LTSF will be used to define thermal conditions expected during these tests. The temperature transients these thermocouples are required to follow are very rapid step changes. Therefore, it is necessary that these thermocouples have a short response time in order to follow the temperature transient in this line.

A two-dimensional finite element model of the thermocouple assembly was constructed using COUPLE⁽²⁾, a finite element heat conduction code. The model was subjected to a step change in fluid temperature expected to be "seen" by the actual thermocouple and its thermal response observed. Details pertinent to this analysis are contained in appropriate sections of this report.

Area Modeled
(cross-hatched)

Figure 1. Cross Sectional View of
LOFT LTSE Thermocouple
Assembly

ANALYSIS

1.0 Model Development

Figure 1 shows a cross-sectional view of the actual thermocouple assembly. The assembly is located on the pressurizer relief piping near the top of the pressurizer. The thermocouples are chromel-alumel enclosed in a 304 stainless steel sheath. These are fitted into an 8 inch diameter cylindrical block in the 1-1/2 inch pressurizer relief piping. The thermocouple protrudes .25 inch into the pipe. This assembly consists of 3 such thermocouples placed radially around the pipe. During the L3-4,5 and 6 experiments the LOFT primary side will be depressurized through the PORV. This thermocouple assembly is required to follow a rapid temperature transient. During the experiment saturated steam flow will be followed by a slug of subcooled water.⁽¹⁾ Therefore, it is necessary to know the response time of the TC's to this fluid temperature step change.

The axisymmetric finite element representation of one of the thermocouples is shown in Figures 2 - 4. Only a quarter section of the assembly was modeled. The actual thermocouple was modeled with a fine detail and the body of the assembly modeled with a much coarser mesh. Only the temperature gradient in the thermocouple itself is of importance in this analysis, the body is modeled for its contribution as a heat sink. The body of the assembly is 316 stainless steel. The thermocouple is in a 304 stainless steel sheath, so 304 stainless steel material properties were used to represent this part of the model. Temperature dependent thermal properties were used in this model and are listed in Tables I and II.⁽³⁾

2.0 Transient Modeled

The actual L3-4 transient is expected to include a saturated or superheated steam regime, followed by a subcooled water regime, followed by a two-phase regime.⁽¹⁾ The temperatures during the steam and two-phase regions are expected to follow a slow ramp corresponding to a decrease in saturation pressure, but the transition from steam to water is expected to include an approximate 10°F step change in fluid temperature. It is this fluid temperature step change which this analysis addresses. Therefore, the

thermocouple was subjected to a fluid step change from 556°F to 546°F, which is the expected fluid temperature change when the slug of subcooled water passes the thermocouple. A convective film coefficient of 10,000 Btu/hr-ft²-°F was used for the inside pipe wall and thermocouple, which assumes nucleate boiling heat transfer predominates. All other surface boundaries were assumed adiabatic. The assembly was assumed to initially be at 556°F. Table II lists the thermal boundary conditions assumed. A one millisecond time step was used for the duration of the transient.

COUPLE MOD 3 (JUNE-13,78) UPDATE 1 (JUN-13,78) ECL HGK

UNITS- INCHES, SECONDS, DEG. F., LB.,BTU

UNITS- INCHES, SECONDS, DEG. F., LB.,BTU

TABLE I

Material Properties for 304 and 316 Stainless Steel

Temp. (°F)	304 SST			316 SST		
	$K, \frac{\text{Btu}}{\text{hr-ft-}^\circ\text{F}}$	$C_p, \frac{\text{Btu}}{\text{lbm}}$	$\rho, \frac{\text{lbm}}{\text{ft}^3}$	$K, \frac{\text{Btu}}{\text{hr-ft-}^\circ\text{F}}$	$C_p, \frac{\text{Btu}}{\text{lbm}}$	$\rho, \frac{\text{lbm}}{\text{ft}^3}$
100	8.742	.1156	↑	7.889	.1128	↑
200	9.295	.1202		8.432	.1176	
400	10.35	.1274	494.90	9.490	.1252	491.96
600	11.33	.1326	↓	10.51	.1307	↓
800	12.27	.1364		11.49	.1347	

TABLE II

Thermal Boundary Conditions

Time (sec.)	T (°F)	$h, \text{Btu}/(\text{hr-ft}^2\text{-}^\circ\text{F})$
0.0	556°	10,000
1.E-6	546°	10,000
∞	546°	10,000

RESULTS and CONCLUSIONS

Figure 5 shows the temperature of Node 5 in the model which corresponds to the chromel-alumel junction in the thermocouple. As this figure indicates, approximately a .10 second delay is required before 95% of the temperature step change is observed. The thermocouple lag of less than .10 seconds should give acceptable results for the transients expected to be "seen" by this TC. The error introduced by the TC delay is believed to be negligible for all expected driving conditions in this assembly.

REFERENCES

1. Personal communication with Don Jarrell, April 24, 1980, EG&G.
2. E. C. Lemmon, COUPLE/MOD³, A Two-Dimensional Finite Element Steady State and Transient Thermal Conduction Code with Inverse and Contiguuim Element Capabilities for Use on a CDC CYBER 76/CYBER 173 Computer, Report RE-A-78-191, EG&G Idaho, Inc., August 1978.
3. Nuclear Systems Materials Handbook Vol. 1, Part 1, Section 4, Hanford Engineering Development Laboratory, Richland, Washington (September 30, 1976 revision).

APPENDIX

COUPLE INPUT DATA LISTING

1234567890123456789012345678901234567890123456789012345678901234567890

TITLE
LOFT THERMOCOUPLE RESPONSE FOR SMALL BRACK TESTS
UNITS- INCHES, SECONDS, DEG. F., LB., BTU

AUTOMESH

10	22	2	C	4	1	.031	.419
1	1	.031	.419	4	4	.031	.469
4	1	.031	.419	4	4	.031	.469
1	1	.031	.419	1	4	0.0	.469
4	4	.031	.469	6	4	.0475	.489
6	4	.0475	.469	6	10	.093	.669
6	10	.093	.669	10	10	.3345	.3345
1	4	0.0	.469	1	10	0.0	.669
1	10	0.0	.669	1	16	0.0	4.0
10	10	.3345	.3345	10	16	2.0	2.0
10	16	2.0	2.0	4	16	.375	4.0
1	16	0.0	4.0	4	16	.375	4.0
1	16	0.0	4.0	6	10	.093	.669
1	16	0.0	4.0	1	22	0.0	7.2
1	22	0.0	7.2	4	22	.172	7.2
4	16	.375	4.0	4	22	.375	7.2

1 1 4 1 4 22

MATERIAL

2	1	.2664	304 STAINLESS STEEL	2
2.315	1-5	.2847	316 STAINLESS STEEL	4
2.315	1-5			

STEP

0.0 .100 .001 1 556.0 1

FUNCTIONS

4	5	2	304 SST THERMAL CONDUCTIVITY	10.35
100.0	8.742	200.0	9.295	400.0
600.0	11.33	600.0	12.27	
2	5	2	304 SST HEAT CAPACITY	.1274
100.0	.1156	200.0	.1202	400.0
600.0	.1326	600.0	.1364	
3	5	2	316 SST THERMAL CONDUCTIVITY	9.490
100.0	7.689	200.0	6.432	400.0
600.0	10.51	600.0	11.49	
4	5	2	316 SST HEAT CAPACITY	.1252
100.0	.1123	200.0	.1176	400.0
600.0	.1307	600.0	.1347	

0 1 2 3 4 5 6 7 8
123456789012345678901234567890123456789012345678901234567890

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