LA-SUB--95-71-Pt.3

SOLAR DYNAMIC HEAT PIPE DEVELOPMENT AND ENDURANCE TEST

CONTRACT NO. 9 - X6H - 8102L - 1
MONTHLY TECHNICAL PROGRESS REPORT NO. 3

28 JULY TO 27 AUGUST 1987

PREPARED FOR
LOS ALAMOS NATIONAL LABORATORY
LOS ALAMOS, NEW MEXICO 87545

PREPARED BY: Sept 03, 87
(M.B. PAREKH)

APPROVED BY: 9-8-87
(G. HEIDENREICH) PROGRAM MANAGER

(G.HILL) SPACE STATION SECTION MANAGER

(R. RUDEY) ENGINEERING MANAGER

- Mike Merrigan 9/11/87

DISCLAIMER

I. Introduction

The Space Station requires a high level of reliable electric power. The baseline approach is to utilize a hybrid system in which power is provided by photovoltaic arrays and by solar dynamic power conversion modules. The organic Rankine cycle (ORC) engine is one approach to solar dynamic conversion. The ORC provides the attributes of high efficiency at low temperature and compact simple designs utilizing conventional techniques and materials. The heat receiver is one area which must be addressed in applying the proven ORC to long life applications such as the Space Station. Heat pipes with integral thermal energy storage (TES) canisters and a toluene heater tube are the prime components of the heat receiver from the Phase B preliminary design. This contract is a task order type addressing the design, fabrication and testing of a full scale heat pipe. The contract was initiated on April 16, 1987. Sundstrand has specific responsibilities in each task. Los Alamos National Laboratory (LANL) in turn has the prime contract responsibility to NASA-LeRC.

Task No. 1 - Transient Tests with the Phase B Heat Pipe

The objective of these tests is the determination of the operating characteristics and power input limits of the heat pipe under conditions corresponding to reacquisition of the sun during emergence from eclipse or conditions corresponding to initial startup of the solar dynamic power system. The heat pipe designed and fabricated under NASA contract NAS3-24666 will be used for these tests. The tests will be conducted by LANL in a vacuum test facility. After completion of these tests, the heat pipe is to be disassembled, inspected and analyzed. Sundstrand's responsibilities for Task 1 are:

1. Review LANL test plans.
2. Witness (at our option) and analyze all tests.
3. Witness disassembly of the heat pipe.
4. Upon receipt of the canisters from the disassembled heat pipe, perform chemical and metallurgical analysis on the canisters and LiOH salt.

Task 2 - New Heat Pipe Design Fabrication and Testing

The objective of this task is to design, fabricate and performance test a new heat pipe with thermal energy storage and a simulated toluene heater. Structural analysis and a random vibration test of the complete assembly are to be performed. Performance characterization by test is to be conducted before and after the dynamic testing. Sundstrand's responsibilities for Task 2 are:

1. Design and fabricate flight weight thermal energy storage canisters with a thermocouple well to allow for monitoring the phase change material temperature during testing.
2. Review LANL's heat pipe analyses and test plans.
3. Develop specifications of input heat flux and design vibration spectrum.
4. Design, fabricate, analyze and checkout vibration test fixture.
5. Perform a random vibration test in each of three mutually orthogonal axes.
6. Witness and analyze heat pipe performance tests conducted by LANL.

Task 3 - Endurance Testing

The objectives of this task is to perform a six-month continuous thermal cycling test of the new heat pipe with TES charge and discharge cycles corresponding to a typical space station orbital cycle. Post test physical, chemical and metallurgical analysis of the heat pipe assembly is to be performed. Sundstrand's responsibilities for Task 3 are:

1. Review LANL instrumentation, test plans and test data.
2. Perform post-test chemical and metallurgical analyses on the canisters and LiOH.

Task 4 - Toluene Heater Tube

The objectives of this task, to be performed solely by Sundstrand are:

1. Design and fabricate a supercritical reverse flow heater for use with toluene.
2. Modify an existing toluene flow facility to accommodate testing and characterization of the toluene heater.
3. Perform a series of tests to determine the heat transfer and flow characteristics of the toluene heater.

Task 5 - Reporting

Sundstrand's responsibilities are:

1. Prior to the initiation of any testing, submit a test plan for the approval of the LANL Project Manager.
2. Support LANL at oral briefings at LeRC or a location to be specified by the LANL Project Manager.
3. Provide (8) copies of a written final report giving each task objective, approach, design, fabrication and testing details to LANL at the completion of the total program.

II. Technical Progress Summary

Overview

This report covers the period from 28 July to 27 August, 1987. The primary activities were the fabrication of three 74.4 inch long LiOH canisters and a 72-inch long toluene heater tube. The LiOH canisters were received by Los Alamos National Lab on August 20, 1987. Additional activities related to the heat pipe vibration fixture are also in progress. Figure 1 shows the Sundstrand program schedule and milestones.

Task 1 - Transient Tests on the Existing Phase B Heat Pipe

Transient tests on the Phase B heat pipe were completed and the test results review was reported in the monthly technical progress report no. 1.

A test plan for an additional test was prepared by LANL to measure the hydrogen permeation through the Phase B heat pipe wall. A copy of the test plan was received and is being reviewed by Sundstrand. The technical comments on the test plan will be transmitted to LANL in the first week of September 1987.

Task 2 - New Heat Pipe Design, Fabrication and Testing

Thermal Energy Storage Canisters:

Six (6) Ni-201 cases filled with Ni-201 fins and LiOH, vacuum baked and sealed in moisture proof bags, were shipped to the vendor for the final electron beam (EB) welding operations. A secondary seal was EB welded to each case as shown in Figure 2. After successful completion of the secondary seal EB weld operation, the necessary weld preparation and cleaning operations were performed on the mating cases. Three sets of mating cases were EB welded which resulted into three (3) full size (74.4 inch long) LiOH TES canisters (See Figures 2 and 3). The final radiographic examination of these weld joints were performed by an independent inspection laboratory. The weld joints met the NAS 1514 Class I (highest class) requirements. All three canisters were received by LANL on August 20, 1987. Figure 4 provides the weight summary of three LiOH canisters. A detailed fabrication procedure report of this process will be prepared during the next reporting period.

Heat Pipe Vibration

A schematic describing the vibration fixture is shown in Figure 5. The vibration fixture design activities were just begun. The detailed vibration fixture design will be reported next month.

Task 4 - Toluene Heater Tube (THT)

Thermal Analysis

A thermal standoff provides varying thermal resistance between the outer tube heat input and the working fluid flowing through the center tube. Two different geometries were analyzed, a disc fin design (Figure 12) and a longitudinal fin design (Figure 11).

Disc Fin Model

The conditions of (1) end of insolation, (2) end of eclipse, (3) TES sizing, and (4) maximum insolation were run using the disc fin model. An improvement in convergence was achieved by solving all fluid nodes and center body temperatures in a subroutine separate from SINDA. Results are presented in Figures 6 through 9.

The THT design being fabricated is slightly different from the preliminary design for the THT described above. Minor modifications of the computer input data (fin thickness, spacing, number of fins, etc.) enabled the fabrication design geometry to be considered. The results of the analysis are presented in Figure 10. A reduction in the fin gap from .275 to .195 decreases the temperature differential between fins to approximately 20°F.

Longitudinal Fin Model

The thermal analysis of the longitudinal fin concept resulted in a geometry shown in Figure 11. The plan is to fabricate this design. No further thermal model analysis is planned until the disc fin heater tube is performance tested and the test results are compared with the disc fin math model.

Fabrication:

Disc Fin Design

The necessary raw materials for the fabrication of the 72-inch prototype was procured. The thermal standoff assemblies are shown in Figures 12 and 13. The heater tube consists of seven thermal standoff assemblies having different thermal resistances. The fin thickness, spacing and number of fins for each thermal standoff assembly is described in Figure 14. These thermal standoff assemblies are in the brazing process for joining the fins and 1.000 dia. tube. The parts will be radiographically examined after completion of the brazing operation. The principal manufacturing operations prior to completion of the 72-inch prototype heater tube include gun drilling, welding, radiographic/ultrasonic, proof pressure and helium leak check. The schedule delivery date for the disc fin heater tube is October 15, 1987.

Longitudinal Fin Design

The .375, .500 and 1.000 dia. SS 316L tubes were procured for the longitudinal fin heater tube. The strip materials for the fins are ordered and scheduled to be received the first week of September 1987.

The cross sectional examination of the braze samples received from the brazing vendor was completed and the results were presented in reference 1. The vendor was requested to provide process improvement corrective actions. The fabrication of the 72-inch long longitudinal fin heater tube will proceed as soon as the vendor quotes are received and reviewed.

Toluene Heater Tube Test Facility

Sundstrand received an authorization on July 29, 1987 from LANL to utilize the existing toluene stability test facility. The removal of salt bath from the existing test facility is in progress. The horizontal fluidized bed required as a heat source for the toluene heater tube test was ordered on July 31, 1987. The scheduled delivery date for the fluidized bed is September 30, 1987.

Program

The actual cumulative expenditures through August 15, 1987 are $225,615.00.

Work Planned for the Next Reporting Period

Task 2

- Complete heat pipe vibration fixture design

Task 4

- Fabricate full size longitudinal fin and disk fin heater tubes.

- Add bypass system on the therminol heat exchanger of the test facility

- Receive fluidized bed

<u>Reference</u>:

1. 9-X6H-8102L-1 - Solar Dynamic Heat Pipe Development and Endurance Test Monthly Technical Progress Report No. 2, dated July 27, 1987.

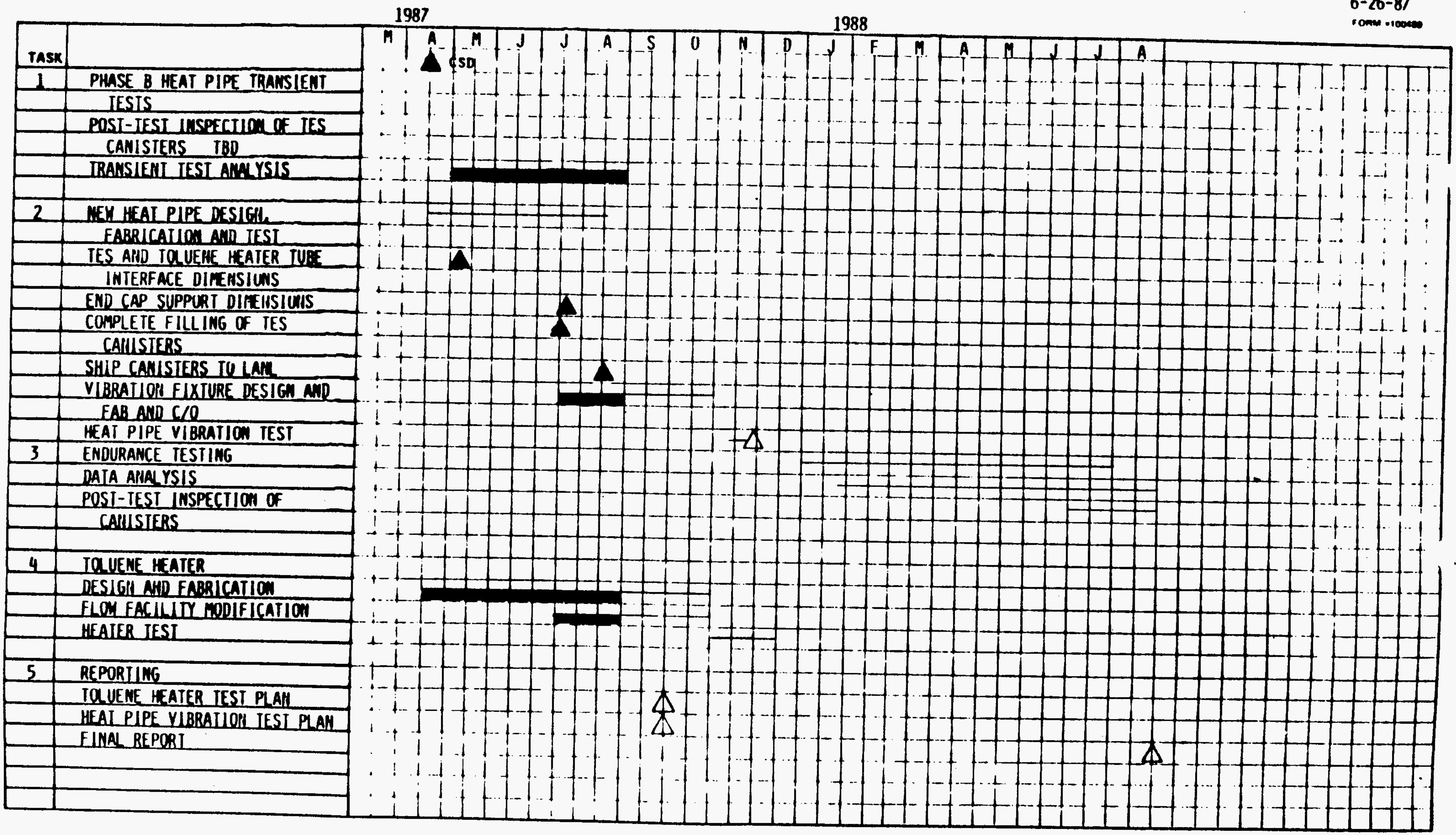
Sundstrand

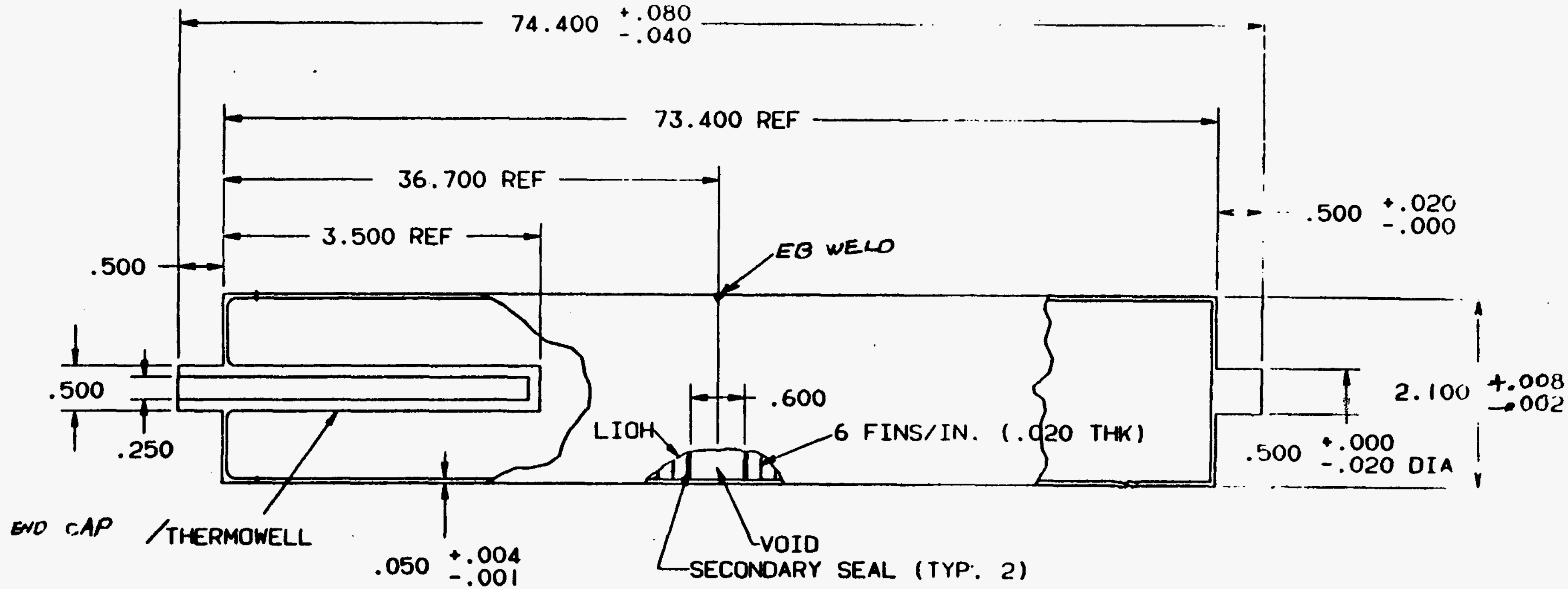
FIGURE 1

SUNDSTRAND PROGRAM SCHEDULE AND MILESTONES, LANL HEAT PIPE CONTRACT 9-X6H-8102L-1

6-26-87

FORM #100480





P/N: EP 2809-664
NAME: TES CANISTER
MATERIAL: NI-201
DATE: 6/30/87
PERRY DETERS

FIGURE 2 - THERMAL ENERGY STORAGE CANISTER INTERFACE DRAWING

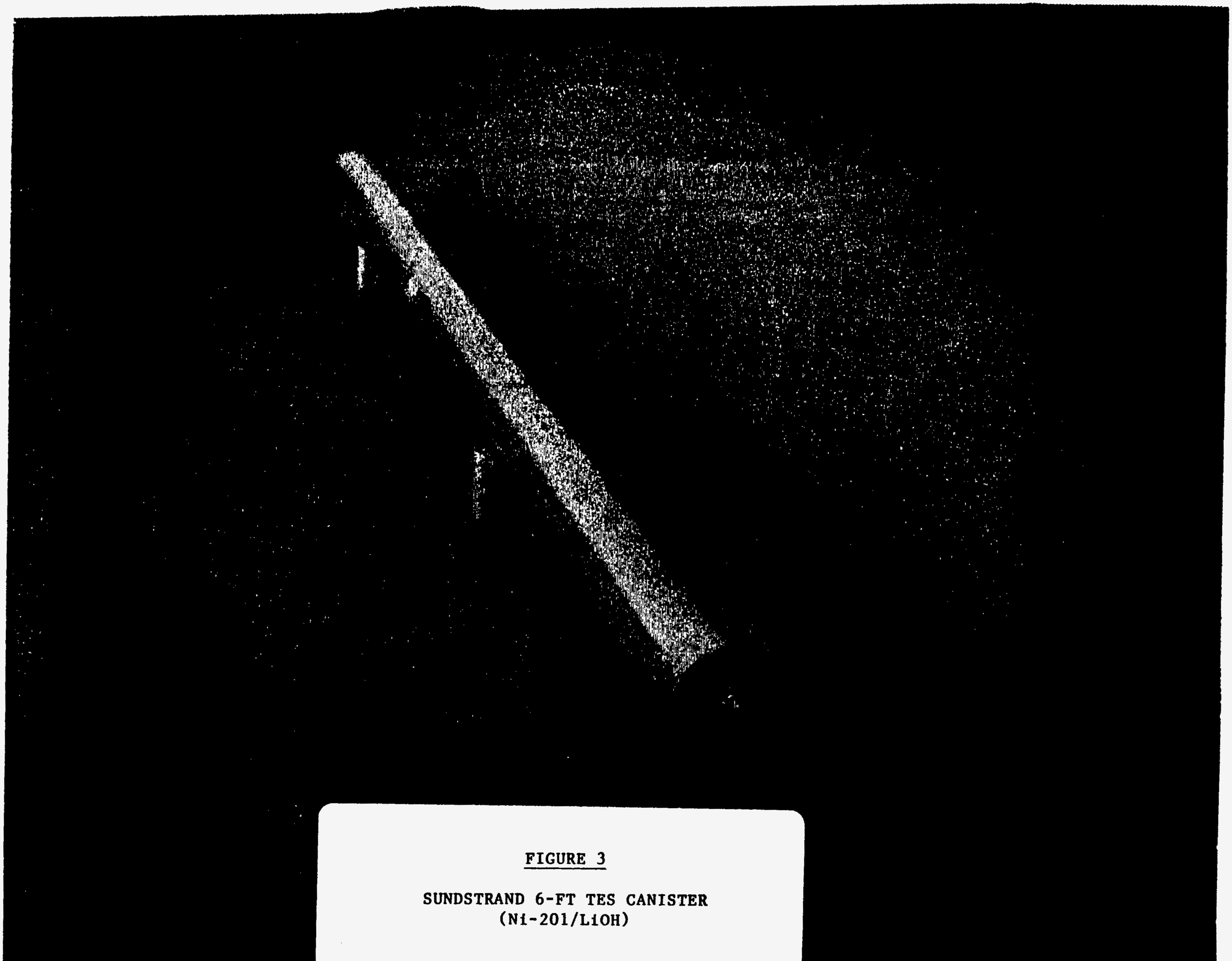


FIGURE 3

SUNDSTRAND 6-FT TES CANISTER
(Ni-201/LiOH)

FIGURE 4

TES CANISTER WEIGHT SUMMARY

S/N	NO. OF FINS	LiOH WEIGHT (GMS)	TOTAL WEIGHT (GMS)
001	425	4610 (10.15 LBS)	11,656 (25.67 LBS)
002	428	4630 (10.20 LBS)	11,333 (24.96 LBS)
003	425	4626 (10.19 LBS)	11,387 (25.08 LBS)

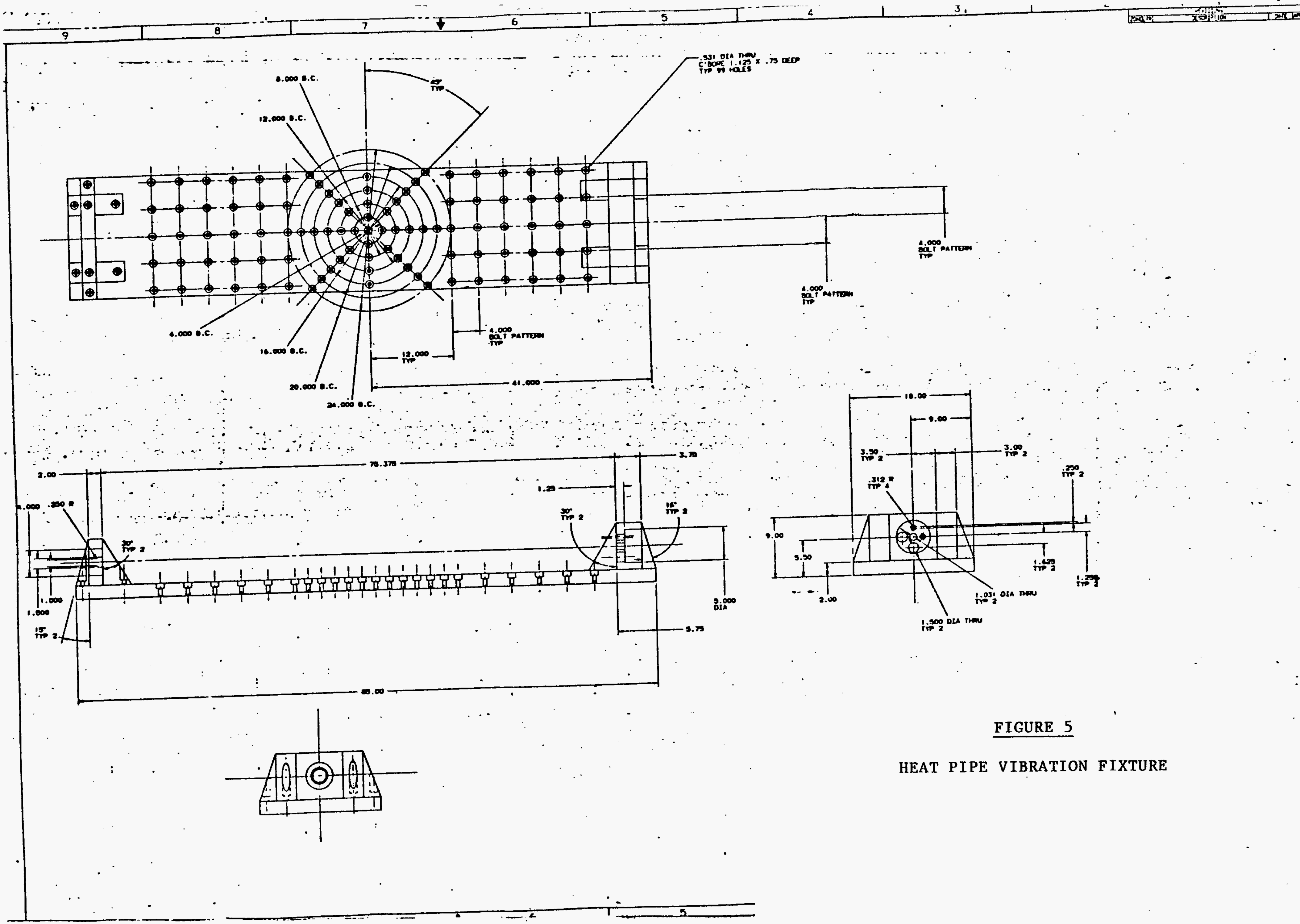
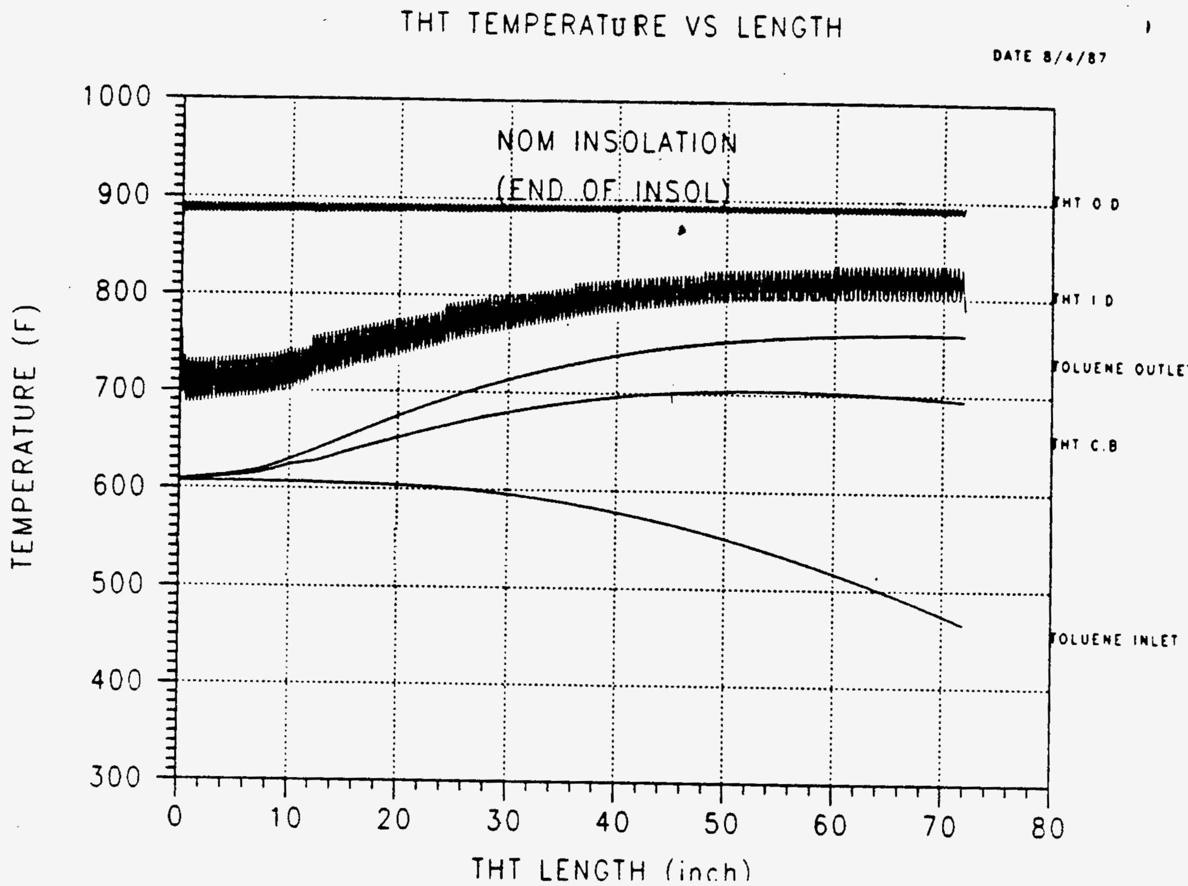
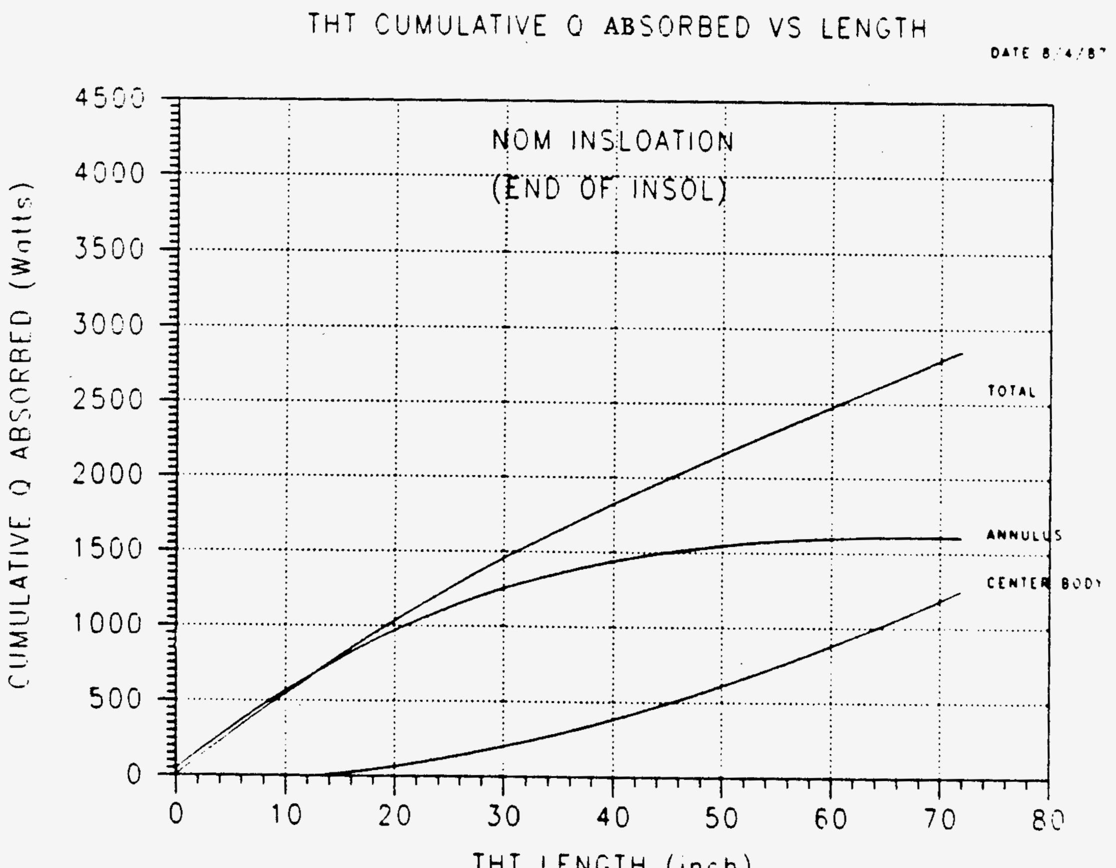


FIGURE 5

HEAT PIPE VIBRATION FIXTURE

FIGURE 6 - DISC FIN MODEL, END OF INSOLATION





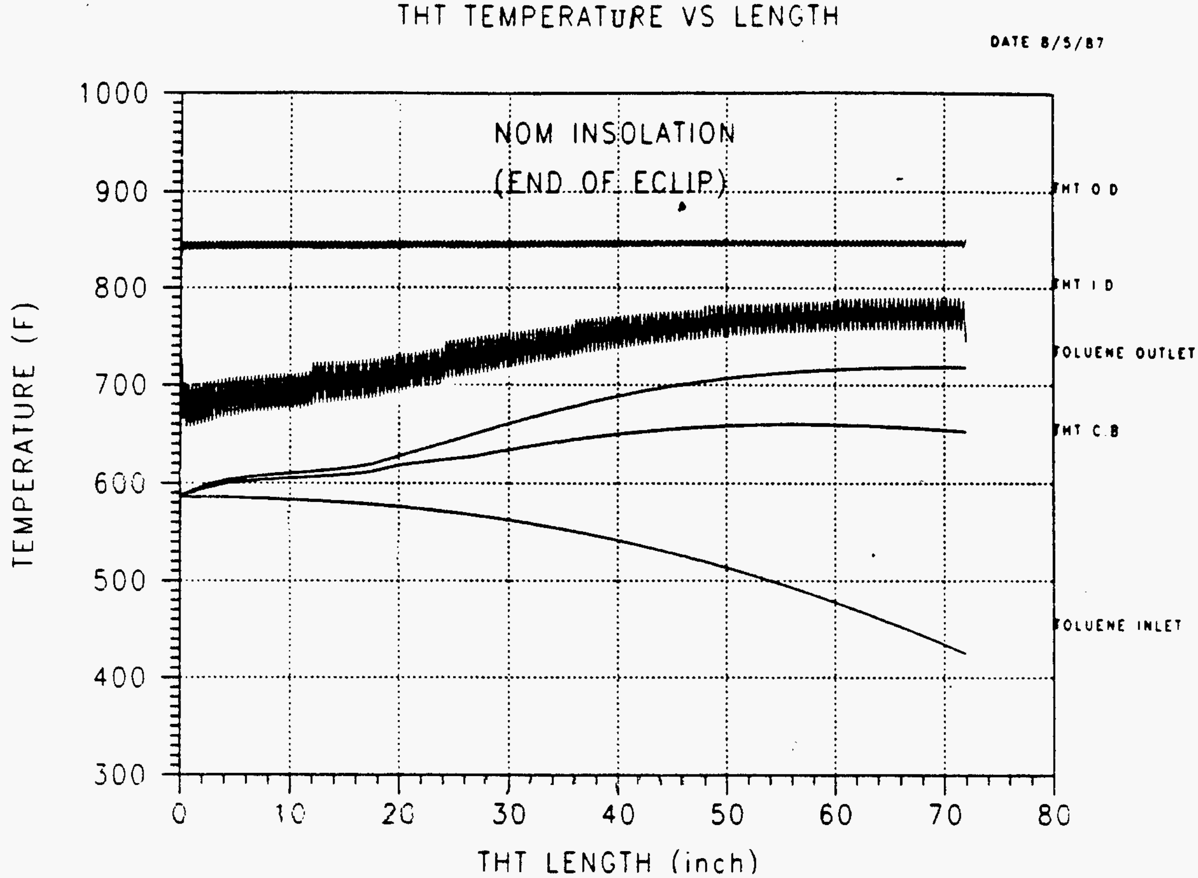
THT MATERIAL IS SS316L
THT OD = 1.00" THK = .035"
THT ID = .500" THK = .035"
CB OD = .375" THK = .035"

FIN THK = .060" TO .120"
FIN GAP = .275"
K = 0.89+11.0

198 FINS
.000" THK Cu LAYER
6 SEGMENTS

T_{in} = 464.2 F
T_{out} = 897.0 F
P_{in} = 614 psia
MDOT = 39.25 LBM/HR

FIGURE 7 - DISC FIN MODEL, END OF ECLIPSE



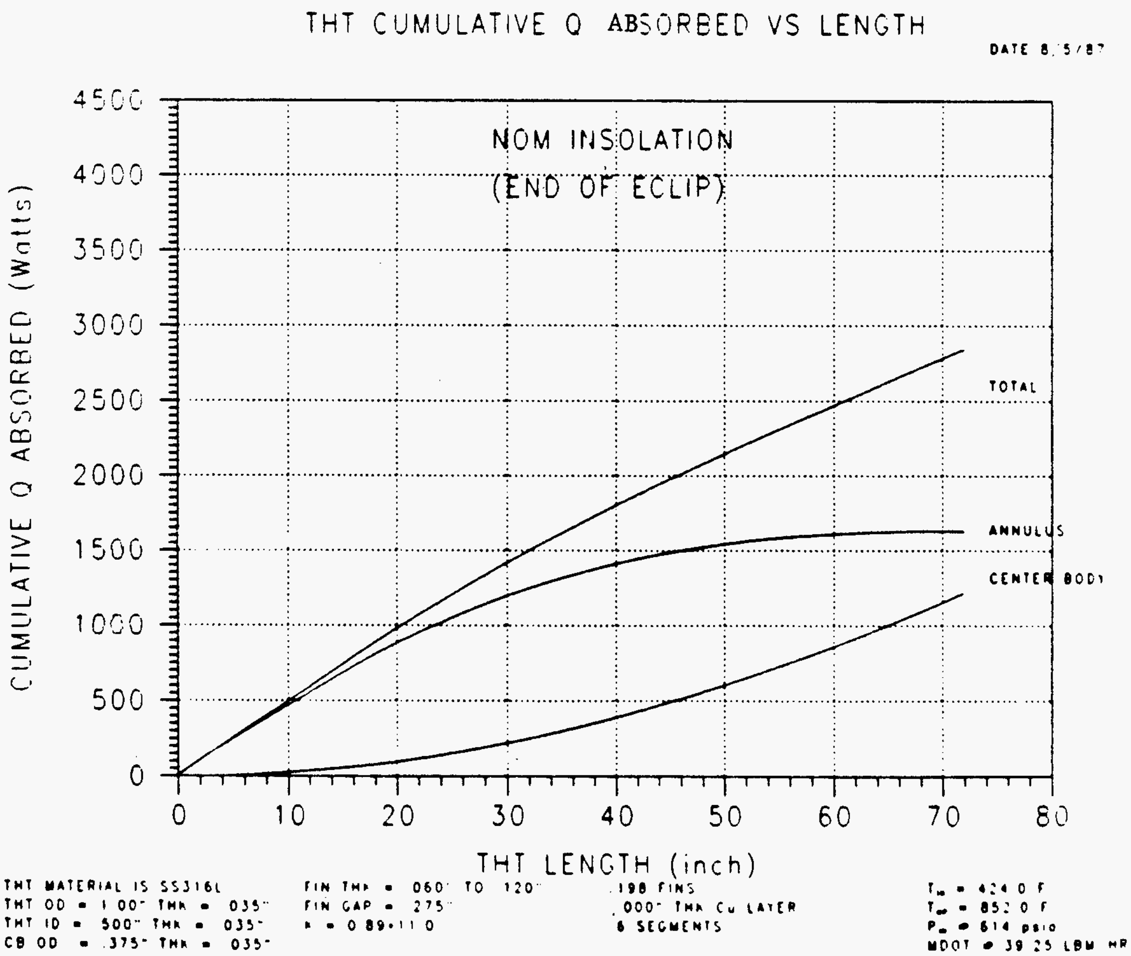
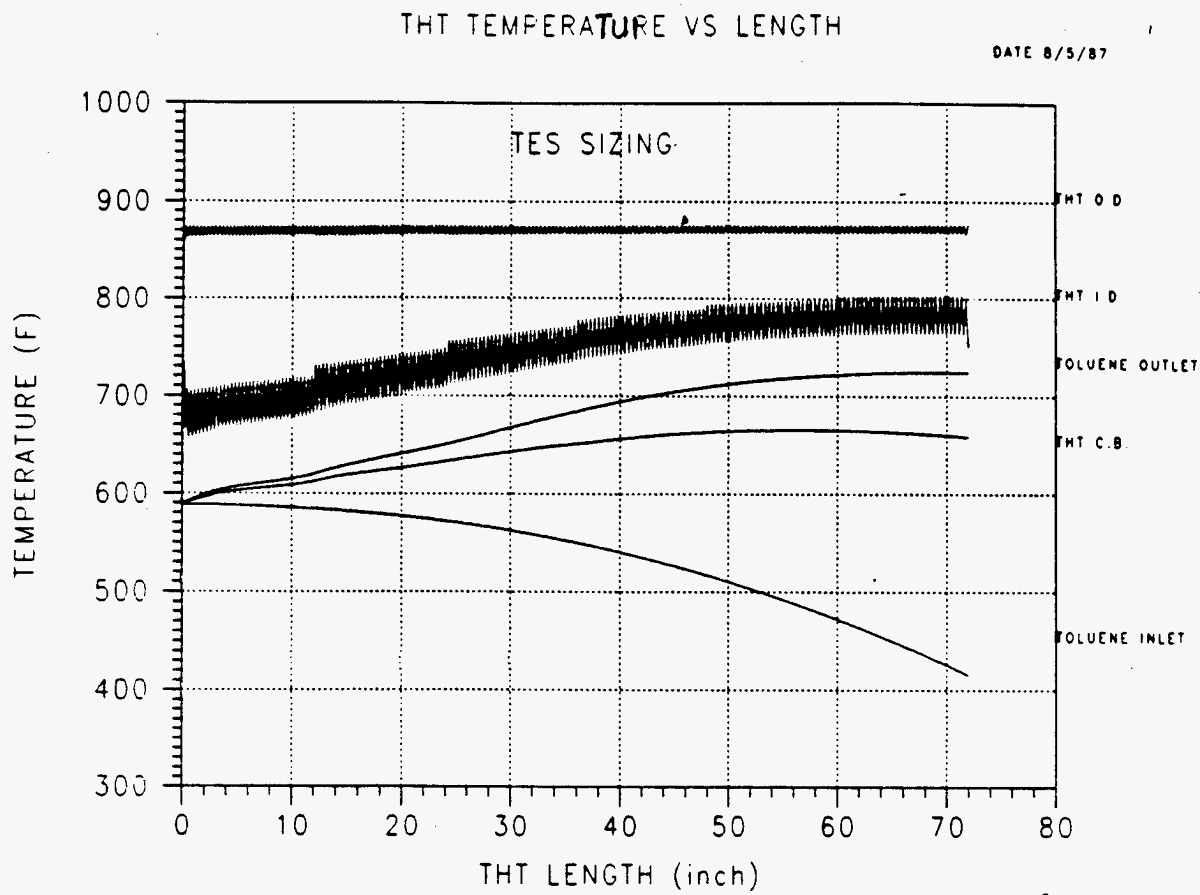
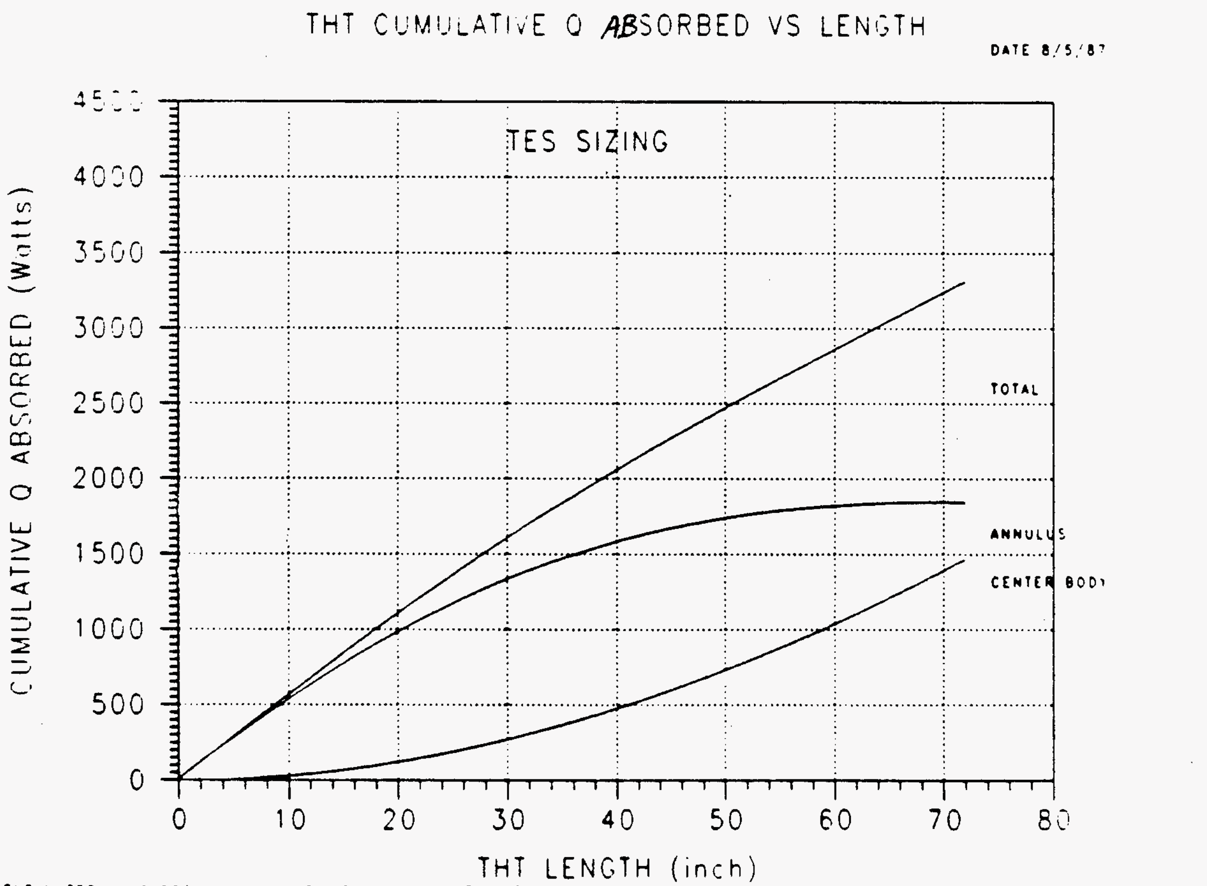


FIGURE 8 - DISC FIN MODEL, TES SIZING





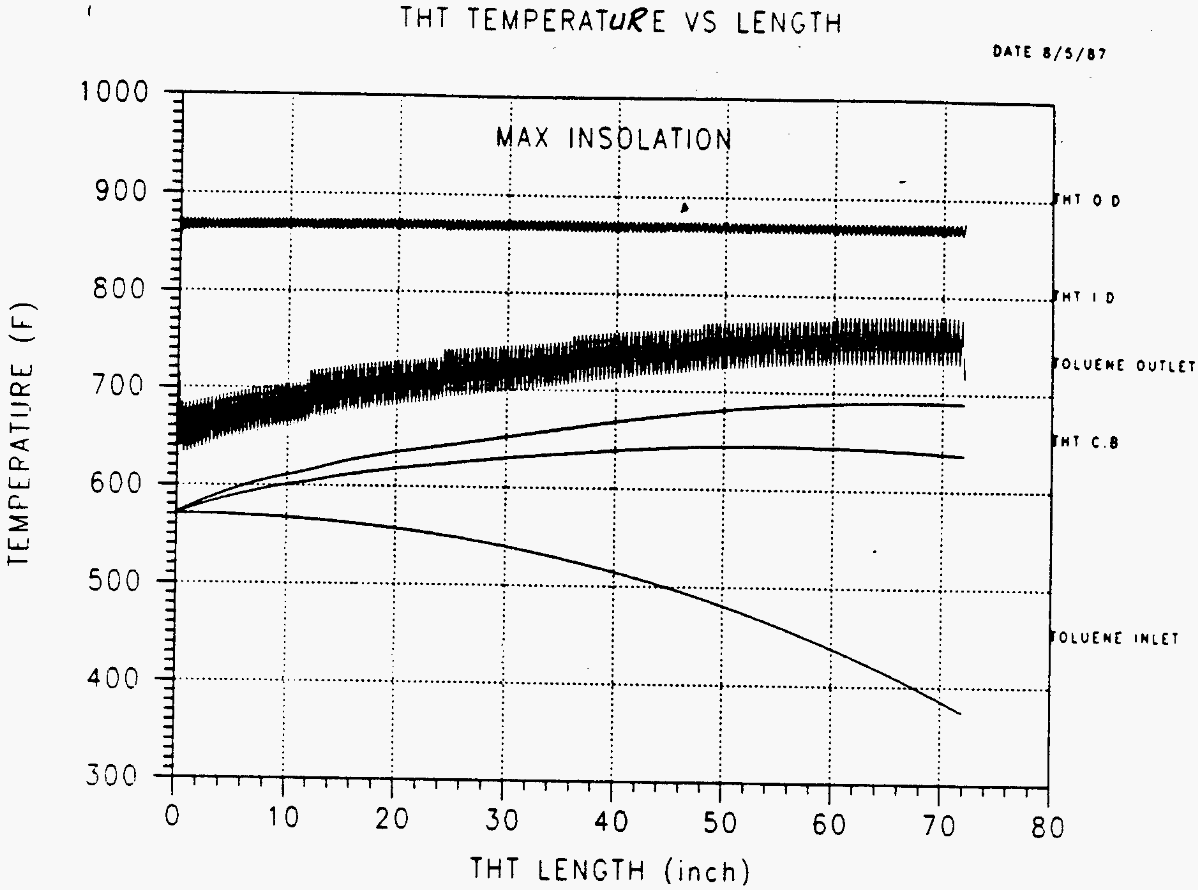
THT MATERIAL IS SS316L
THT OD = 1 00" THK = .035"
THT ID = .500" THK = .035"
CB OD = .375" THK = .035"

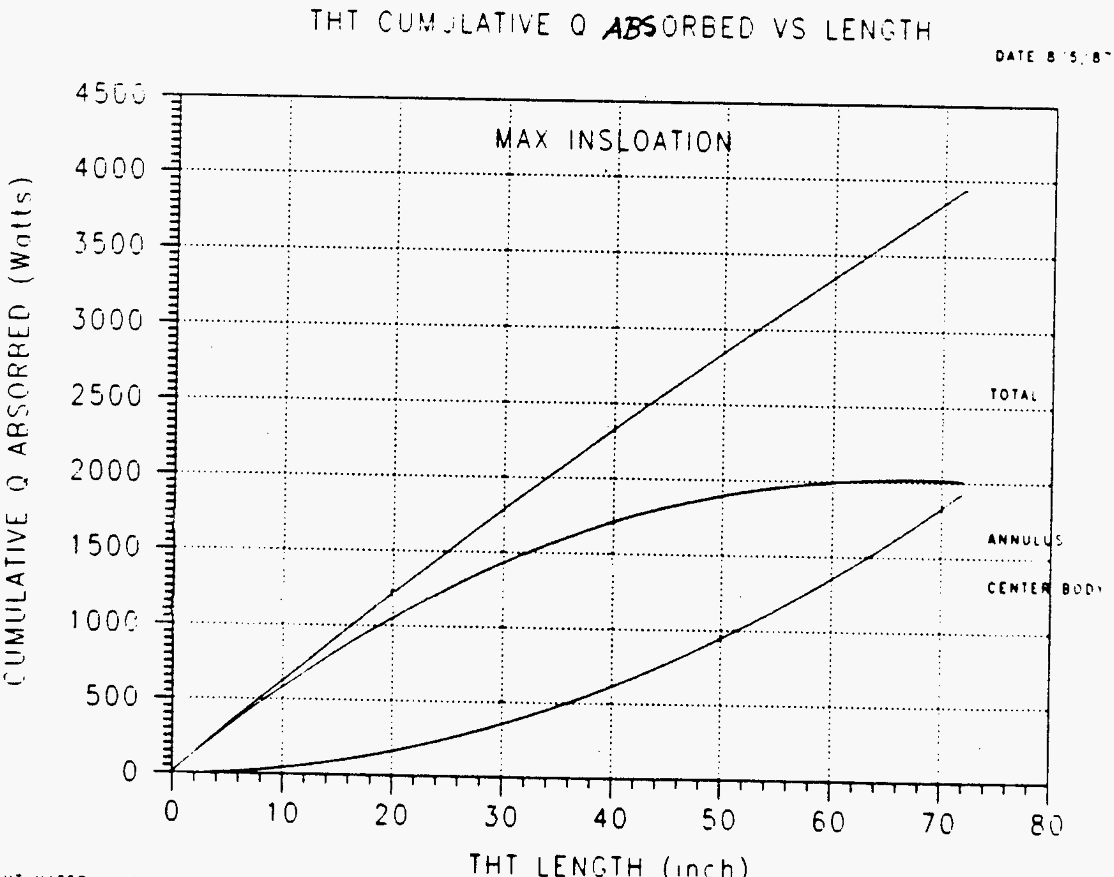
FIN THK = .060" TO .120"
FIN GAP = .275"
k = 0 89+11 0

198 FINS
.000" THK Cu LAYER
6 SEGMENTS

T = 414 8 F
T = 878 0 F
P = 664 psia
MDOT = 44 63 LBM HR

FIGURE 9 - DISC FIN MODEL, MAXIMUM INSOLATION





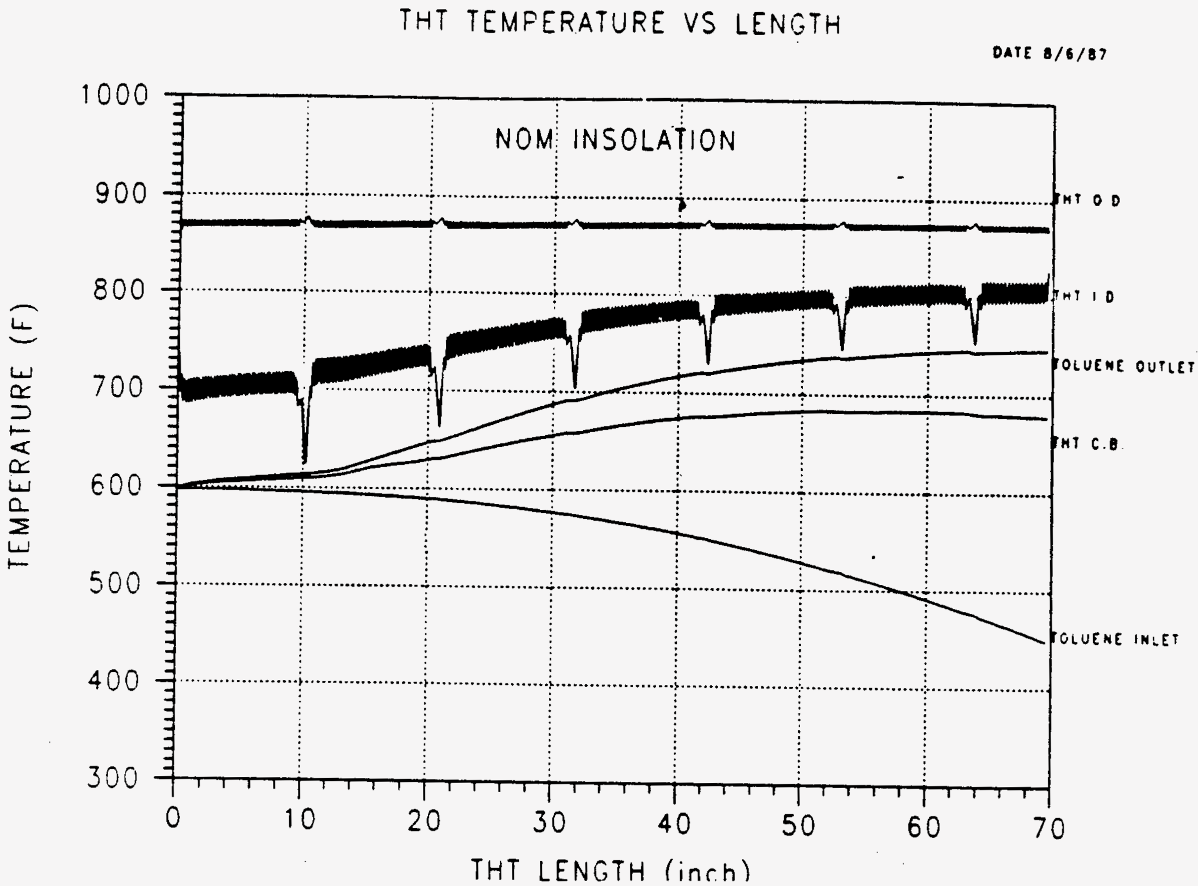
THT MATERIAL IS SS316L
THT OD = 1.00" THK = .035"
THT ID = .500" THK = .035"
CB OD = .375" THK = .035"

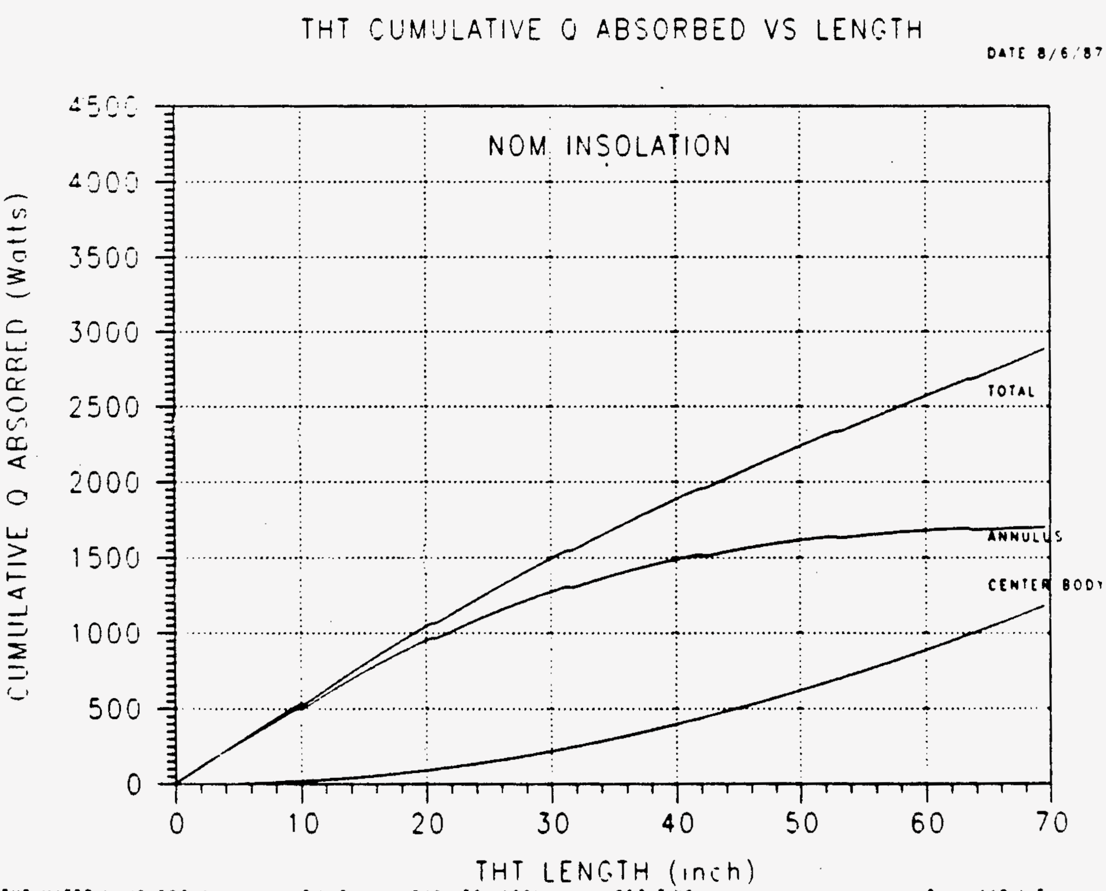
FIN THK = .060 TO .120"
FIN GAP = .275"
k = 0.89+11.0

198 FINS
.000" THK Cu LAYER
6 SEGMENTS

T_{in} = 372.9 F
T_{out} = 878.0 F
P_{in} = 731 psia
MDOT = 54.36 LBM/HR

FIGURE 10 - DISC FIN MODEL, FABRICATION GEOMETRY





THT MATERIAL IS SS316L
THT OD = 1.00" THK = .035"
THT ID = .500" THK = .035"
CB OD = .375" THK = .035"

FIN THK = .040" TO .100"
FIN GAP = .195"
k = 0.89+11.0

253 FINS
.000" THK Cu LAYER
7 SEGMENTS

T = 448.1 F
T = 878.0 F
P = 614 psia
MDOT = 39.25 LBM/HR

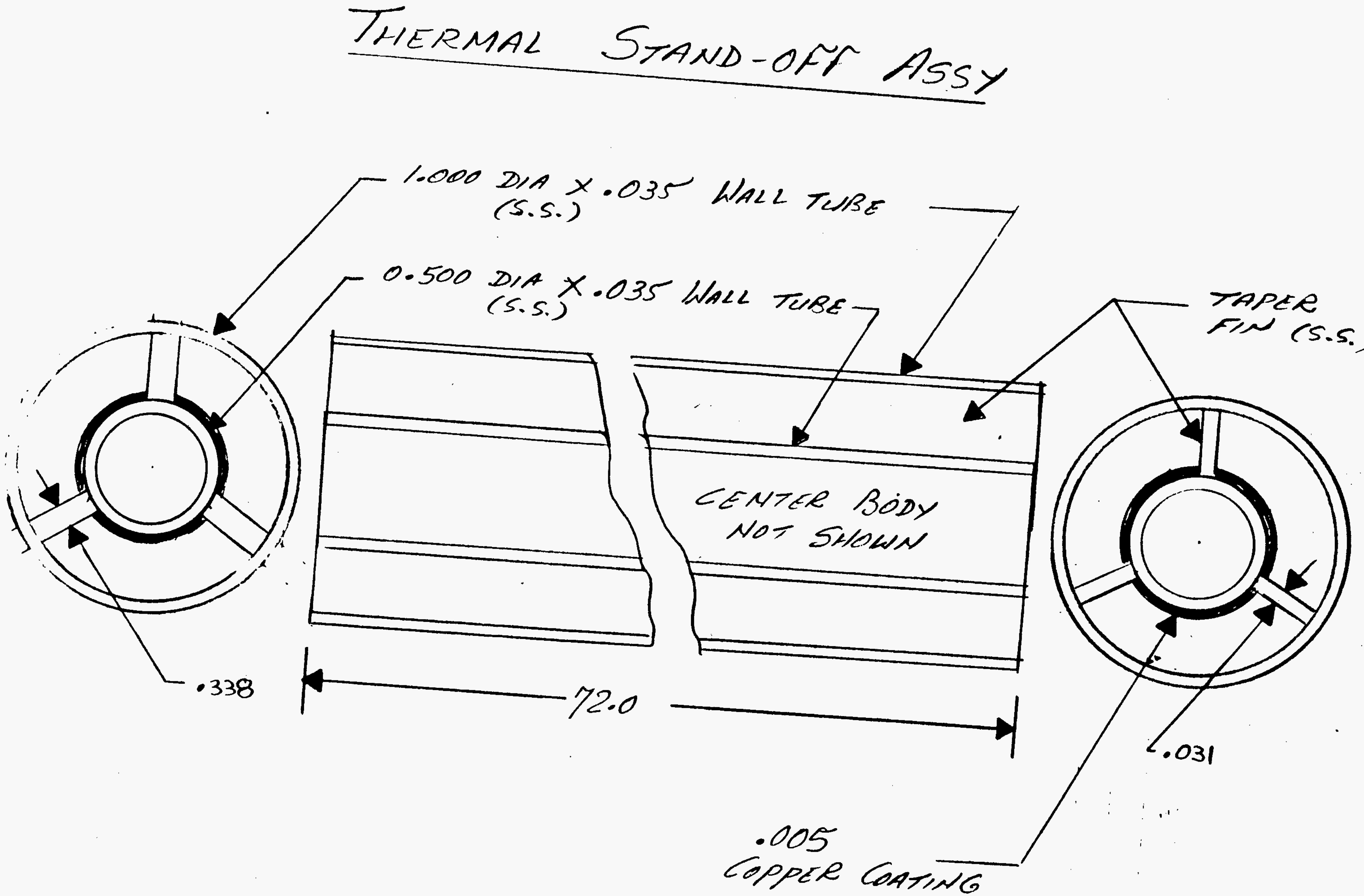


FIGURE 11. LONGITUDINAL FIN DESIGN

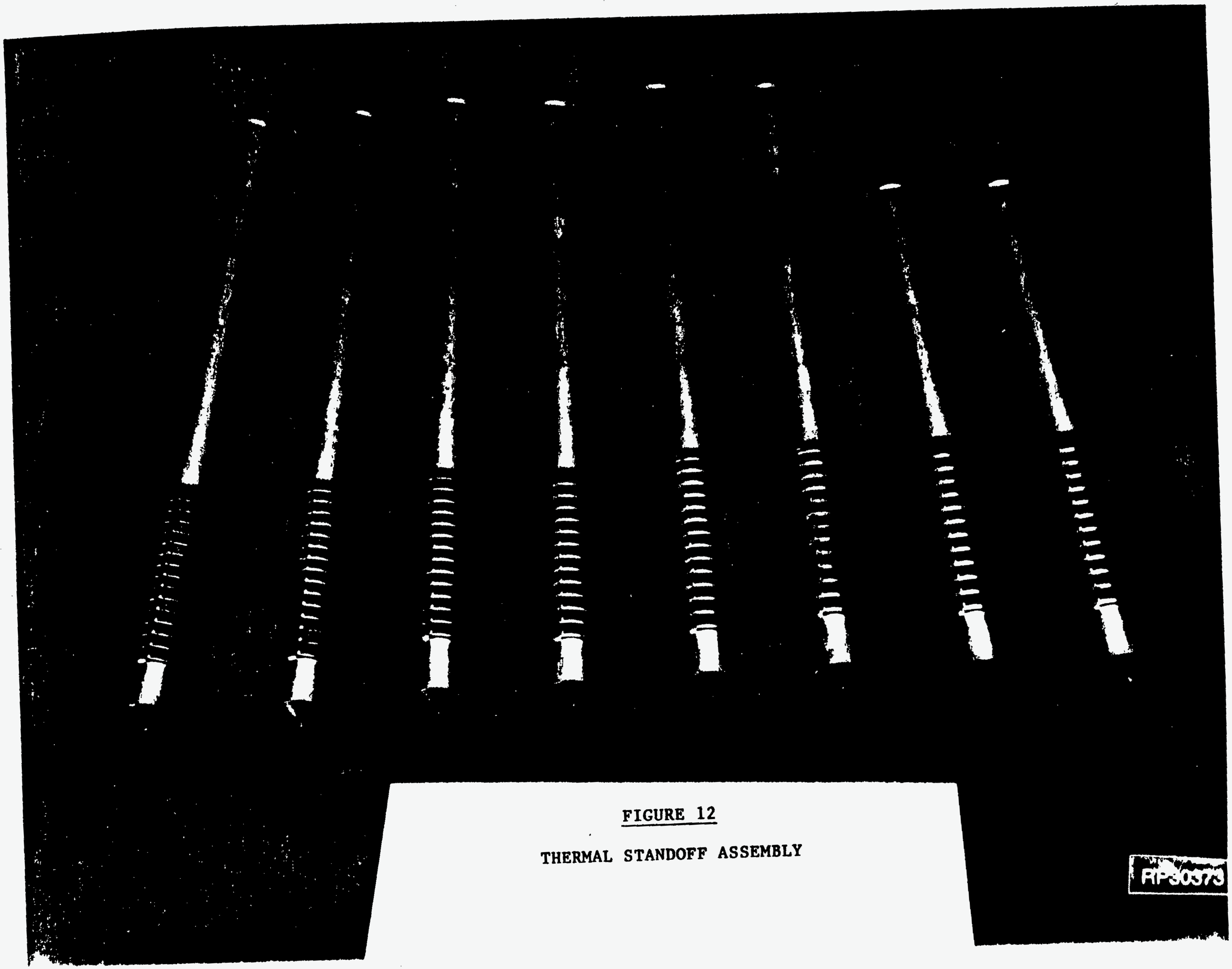


FIGURE 12

THERMAL STANDOFF ASSEMBLY

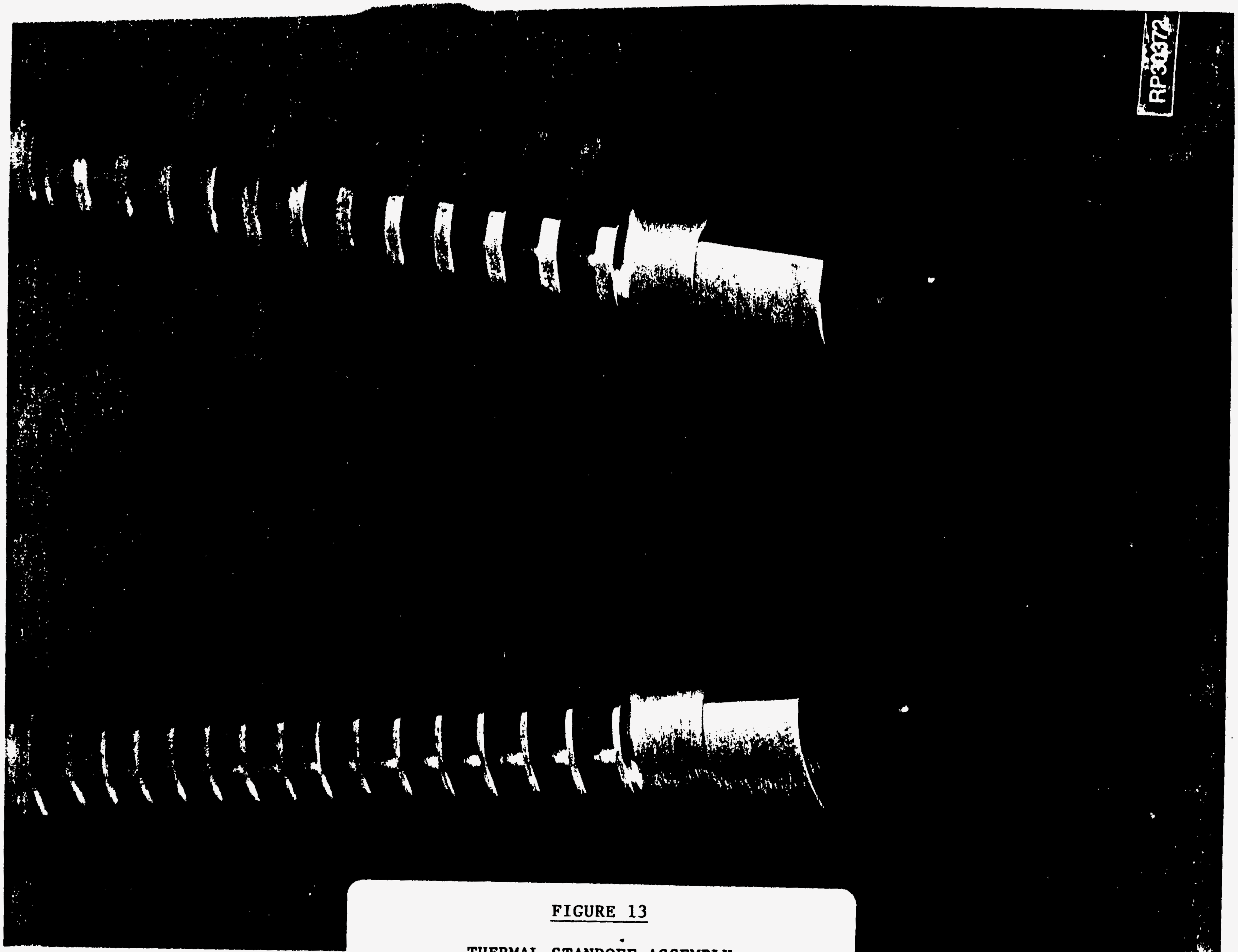


FIGURE 13

THERMAL STANDOFF ASSEMBLY
(THIN AND THICK DISC FINS)

FIGURE 14

THERMAL STANDOFF ASSEMBLY
(DISC FIN HEATER TUBE)

DASH NO.	FIN SPACING (INCHES)	FIN THICKNESS (INCHES)	NO. OF FINS
R1	.195	.040	42
R2	.195	.050	41
R3	.195	.060	40
R4	.195	.070	38
R5	.195	.080	37
R6	.195	.090	35
R7	.195	.100	22

SUNDSTRAND ADVANCED TECHNOLOGY OPERATIONS

MONTHLY FINANCIAL MANAGEMENT REPORT

PROGRAM: SPACE STATION HEAT PIPE DEVELOPMENT

LOS ALAMOS NATIONAL LABORATORY

CONTRACT: 9-X6H-8102L-1

REPORT SUBMITTAL: September 8, 1987

ACTUALS THROUGH: August

PREPARED BY Lynda Vickery

APPROVED BY

DISK:CMA4
CMA-00159

MONTHLY CONTRACTOR FINANCIAL MANAGEMENT REPORT

REPORT FOR MONTH ENDING AUGUST 28, 1987

TO	FROM	CONTRACT VALUE	
UNIVERSITY OF CALIFORNIA LOS ALAMOS NATIONAL LABORATORY P.O. BOX 990 LOS ALAMOS, N.M. 87544-0990	SUNDSTRAND CORPORATION AVIATION DIVISION 4747 HARRISON AVENUE ROCKFORD, ILLINOIS 61125	COSTS: $0	FEE: $0

DESCRIPTION OF CONTRACT				
	TYPE: COST PLUS FIXED FEE	CONTRACT NO. & DEFINITIZED AMENDMENT NO. 9-X6H-8102L-1 LETTER DATED: 6/12/87	FUND LIMITATION $400,000	
	SCOPE OF WORK: SPACE STATION HEAT PIPE DEVELOPMENT	AUTHORIZED CONTRACT REP. DATE	INVOICE AMTS BILLED $225,615	TOTAL PYMTS REC'D $0

REPORTING CATEGORY	COST INCURRED				ESTIMATED COST TO COMPLETE									ESTIMATED FINAL COST			
SUMMARY BY TASK	DURING MONTH OF AUGUST		CUM TO DATE 8/28/87		MONTH: SEPT 1987	MONTH:	MONTH:	QUARTER: IV 1987	QUARTER: I 1988	QUARTER: II 1988	BALANCE OF FY 1988	VARIANCE TO PLAN	ESTIMATE TO COMPLETE	CONTRACTOR ESTIMATE	CONTRACT VALUE (PROPOSAL)		
	ACTUALS	PLANNED	ACTUALS	PLANNED													
TASK I	0.001	0.000	0.004	0.007	0.001			0.035	0.000	0.000	0.000	0.003	0.039	0.043	0.043		
TASK II	0.037	0.051	0.120	0.154	0.029			0.099	0.000	0.000	0.000	0.034	0.162	0.282	0.282		
TASK III	0.000	0.013	0.000	0.000	0.000			0.004	0.003	0.006	0.043	0.000	0.056	0.056	0.056		
TASK IV	0.027	0.042	0.100	0.119	0.051			0.193	0.000	0.000	0.004	0.019	0.267	0.367	0.367		
TASK V	0.001	0.004	0.002	0.013	0.002			0.007	0.006	0.006	0.014	0.011	0.046	0.048	0.048		
TOTAL COST & FEE	0.066	0.110	0.226	0.293	0.083	0.000	0.000	0.338	0.009	0.012	0.061	0.067	0.570	0.796	0.796	0.000	0.0

MONTHLY CONTRACTOR FINANCIAL MANAGEMENT REPORT

REPORT FOR MONTH END AUGUST 28, 1987

TO: UNIVERSITY OF CALIFORNIA
LOS ALAMOS NATIONAL LABORATORY
P.O. BOX 990
LOS ALAMOS, N.M. 87544-0990

FROM: SUNDSTRAND CORPORATION
AVIATION DIVISION
4747 HARRISON AVENUE
ROCKFORD, ILLINOIS 61125

CONTRACT VALUE
COSTS: $0 | FEE: $0

DESCRIPTION OF CONTRACT
TYPE: COST PLUS FIXED FEE
SCOPE OF WORK: SPACE STATION HEAT PIPE DEVELOPMENT

CONTRACT NO. & DEFINITIZED AMENDMENT NO.
9-X6H-8102L-1 LETTER DATED: 6/12/87

AUTHORIZED CONTRACT REP. [illegible] DATE 9-8-87

FUND LIMITATION $400,000

INVOICE AMTS BILLED $225,615

TOTAL PYMTS REC'D $0

REPORTING CATEGORY	COST INCURRED				ESTIMATED COST TO COMPLETE									ESTIMATED FINAL COST			
SUMMARY BY	DURING MONTH OF AUGUST		CUM TO DATE 8/28/87		MONTH: SEPT 1987	MONTH:	MONTH:	QUARTER: IV 1987	QUARTER: I 1988	QUARTER: II 1988	BALANCE OF FY 1988	VARIANCE TO PLAN	ESTIMATE TO COMPLETE	CONTRACTOR ESTIMATE	CONTRACT VALUE (PROPOSAL)		
COST CATAGORIES:	ACTUALS	PLANNED	ACTUALS	PLANNED													
ENGINEERING	0.029	0.040	0.137	0.153	0.030			0.105	0.004	0.006	0.034	0.016	0.195	0.332	0.332		
ADMINISTRATIVE	0.000	0.001	0.000	0.003	0.001			0.003	0.003	0.004	0.004	0.003	0.018	0.018	0.018		
FACTORY LABOR	0.003	0.000	0.005	0.000	0.000			0.000	0.000	0.000	0.000	(0.005)	(0.005)	0.000	0.000		
TEST FACTORY LABOR	0.000	0.008	0.000	0.008	0.009			0.049	0.000	0.000	0.000	0.008	0.066	0.066	0.066		
MATERIAL	0.022	0.015	0.036	0.027	0.009			0.039	0.000	0.000	0.000	(0.009)	0.039	0.075	0.075		
OTHER DIRECT COST	0.000	0.005	0.000	0.020	0.010			0.066	0.000	0.000	0.004	0.020	0.100	0.100	0.100		
ENGINEERING SUPPORT	0.000	0.001	0.000	0.002	0.001			0.003	0.000	0.000	0.000	0.002	0.006	0.006	0.006		
OEM SUPPORT	0.001	0.002	0.004	0.004	0.001			0.005	0.000	0.000	0.000	0.000	0.006	0.010	0.010		
TOTAL	0.055	0.072	0.182	0.217	0.061	0.000	0.000	0.270	0.007	0.010	0.042	0.035	0.425	0.607	0.607	0.000	0.000
G & A	0.010	0.012	0.040	0.044	0.010			0.044	0.002	0.002	0.007	0.002	0.067	0.107	0.107		
TOTAL COST	0.065	0.084	0.222	0.261	0.071	0.000	0.000	0.314	0.009	0.012	0.049	0.037	0.492	0.714	0.714	0.000	0.000
CAS 414	0.001	0.001	0.004	0.003	0.001			0.004	0.000	0.000	0.001	0.001	0.007	0.011	0.011		
FIXED FEE	0.000	0.025	0.000	0.029	0.011			0.020	0.000	0.000	0.011	0.029	0.071	0.071	0.071		
TOTAL COST & FEE	0.066	0.110	0.226	0.293	0.083	0.000	0.000	0.338	0.009	0.012	0.061	0.067	0.570	0.796	0.796	0.000	0.000
CUM COST & FEE					0.309	0.309	0.309	0.647	0.656	0.668	0.729	0.796	0.796				
PTL & UNLIQ COMM					0.093	0.135	0.178	0.050	0.050	0.055	0.067						
TOTAL FUNDING REQ				0.000	0.402	0.444	0.487	0.697	0.706	0.723	0.796	0.796	0.796	0.000	0.000	0.000	0.000

Report Number (14) LA-SUB--95-71-Pt.3

Publ. Date (11) 19870903

Sponsor Code (18) DOD, XF

UC Category (19) UC-000, DOE/ER