LA-SUB--95-71-Pt.4

SOLAR DYNAMIC HEAT PIPE DEVELOPMENT AND ENDURANCE TEST

CONTRACT NO. 9 - X6H - 8102L - 1
MONTHLY TECHNICAL PROGRESS REPORT NO. 4

28 AUGUST TO 29 SEPTEMBER

PREPARED FOR
LOS ALAMOS NATIONAL LABORATORY
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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.

<u>Task 3</u> - 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.

<u>Task 5</u> - 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 August 28 to September 29, 1987. The primary activities were the fabrication of a 72-inch long toluene heater tube and the design of a vibration fixture for the heat pipe. Additional activity included the witnessing of H_2 permeation tests on the Phase B heat pipe at Los Alamos National Laboratory. 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 review of the test results was reported in Reference 1.

Additional tests were performed on the Phase B heat pipe to measure the hydrogen permeation rate through the heat pipe wall. (Reaction between the thermal energy storage (TES) material (LiOH) and the TES canister and fins can cause the liberation of hydrogen). The hydrogen permeation tests were partially witnessed by Sundstrand. The preliminary test data are being reviewed and the results are expected to be published in the near future by LANL.

Task 2 - New Heat Pipe Design, Fabrication and Testing

Thermal Energy Storage Canisters:

As reported in Reference 2, LiOH TES canisters were received by LANL on August 20, 1987. Based upon the measured minimum void volume of these canisters, the maximum operating temperature limitation of 530°C was established for the LiOH canisters and conveyed to LANL. Operation of the TES canisters above this limit could result in a zero void volume and subject the canisters to high internal stresses.

The manufacturing and assembly processes used for the LiOH canisters are being documented in the engineering report for the future use.

Heat Pipe Vibration

A finite element model analysis was utilized in the design of vibration fixture for the heat pipe. The model consisted of 548 nodes. A Swanson Analysis System (ANSYS) computer code was used in analyzing the dynamic characteristics of the fixture. The analytical results showed that the resonant frequency of the fixture was greater than 500 Hz in all three axis. Figure 2 shows a finite element model of the vibration fixture and its overall dimensions. An estimated weight of the aluminum vibration fixture is 760 lbs.

As shown on Figure 2, the fixture will be dynamically checked in the middle of November. A dummy heat pipe will be used in place of the test article to checkout the vibration fixture. The dummy heat pipe will be manufactured from the solid stainless steel 2-3/8" dia. bar stock having equivalent mass to that of the test article. The dummy heat pipe ends will also be similar to that of the test article. Figure 3 shows a sketch of the dummy heat pipe.

Task 4 - Toluene Heater Tube (THT)

Fabrication

Disc Fin Design

The heater tube consists of seven thermal standoff (as described in Figure 4) assemblies having different thermal resistances. The joints between the fins and 1.000 dia. tubes were brazed using Nicrobraz filler materials. The braze joints were radiographically inspected for their integrity. The inspection results showed that the majority (>90%) of fins were brazed to the 1.000 dia. tube. A .375 in. dia. hole was gun drilled in each of these assemblies prior to finish boring to .430 in. dia. The thermal standoff assemblies are presently being machined for the weld joint preparation.

Two center body units (.375 inch dia. stainless tube with a spiral wound wire) were received from the vendor. The thermal standoff assemblies will be assembled with the center body prior to welding them together (See Figure 4). The end caps and flange were also completed and ready for the welding operation. The disc heater tube delivery date is October 15, 1987.

Longitudinal Fin Design

The fin strip material and tube sections were cut to the required size. Contour grinding of the strip material to meet the required fin configuration is being investigated.

Toluene Heater Tube Test Facility

The removal of salt bath from the existing test facility was completed. The minor plumbing modification is in progress. The vendor reported that the scheduled delivery date for the fluidized bed was expected to be the week of October 5, 1987.

Task 5 - Test Plans

The heat pipe vibration and the heater tube test plans are planned to be delivered to LANL for their review and comments by October 9th.

Work planned for the next reporting period:

Task 2

- Fabricate the vibration fixture.

Task 4

- Complete fabrication of disc fin heater tube
- Fabricate longitudinal fin thermal standoff samples
- Receive fluidized bed and complete modification of the test facility

References

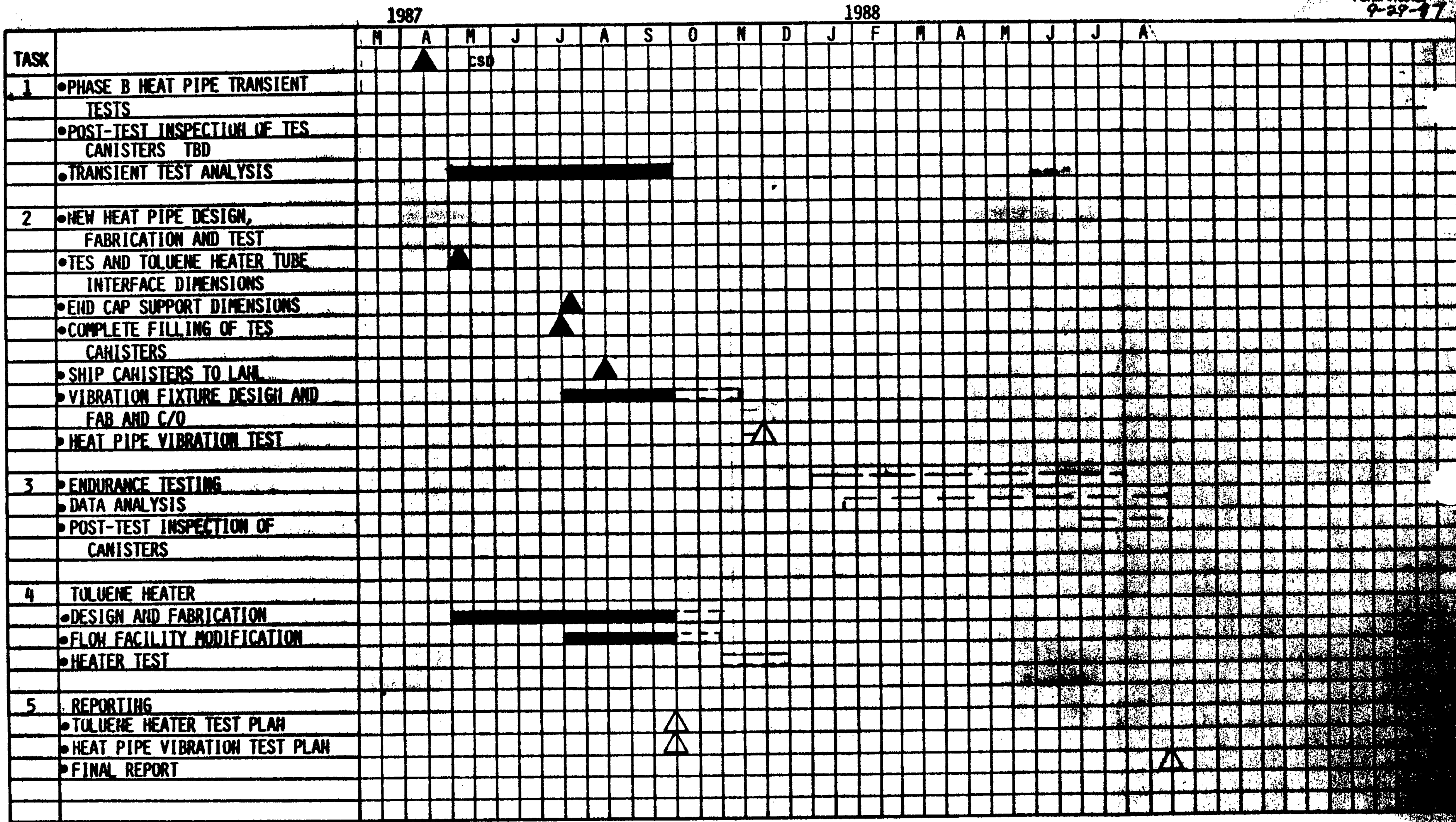
1. 9-X6H-8102L-1 Solar Dynamic heat Pipe Development and Endurance Test Monthly Technical Progress Report No. 1, dated June 26, 1987.

2. 9-X6H-8102L-1 Solar Dynamic Heat Pipe Development and Endurance Test Monthly Technical Progress Report No. 3, dated August 27, 1987.

Sundstrand

FIGURE 1

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



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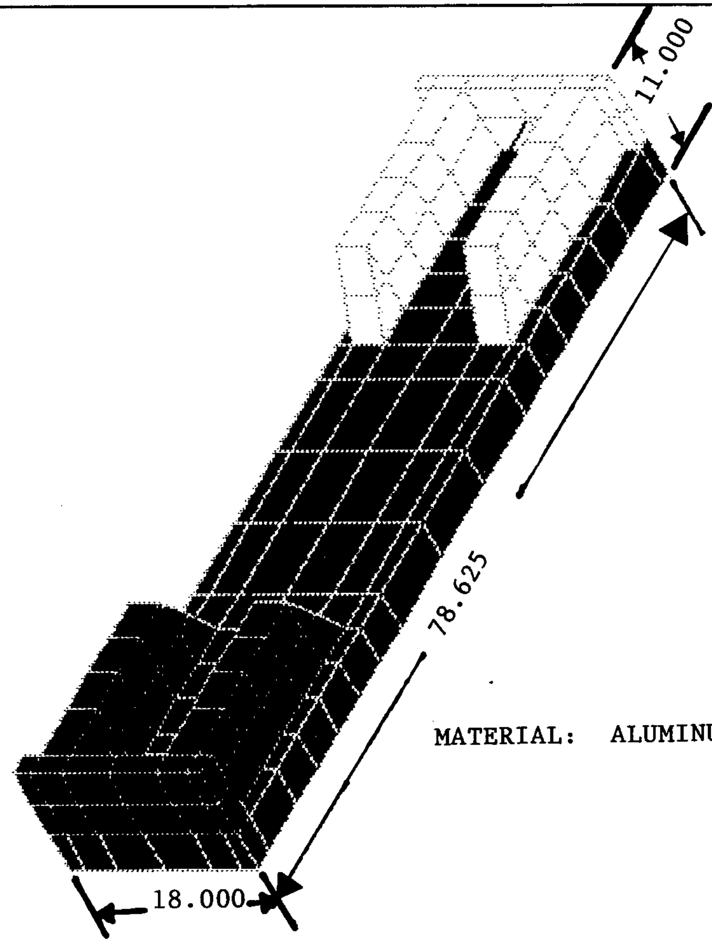

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SEP 25 1987
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YV=1
ZV=1
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* YF=9
* ZF=2
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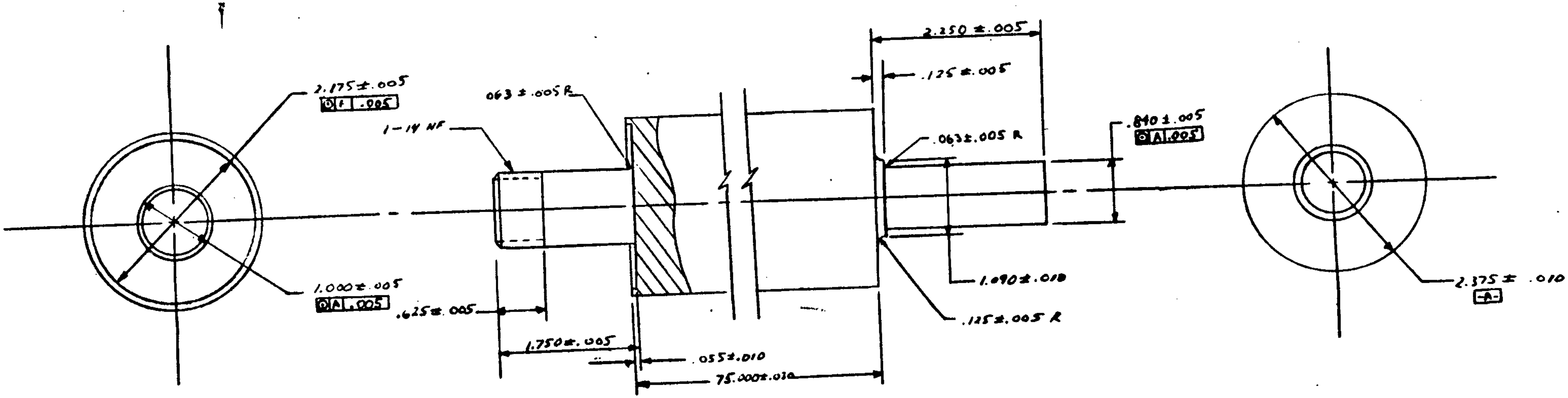
HIDDEN

FIGURE 2

SPACE STATION HEAT PIPE VIBRATION FIXTURE



MATERIAL: S.S.

FIGURE: 3 DUMMY HEAT PIPE

1. TOLUENE OUTLET/INLET ARE FORMED BY SWAGELOK FITTINGS (NOT SHOWN)

2. THERMAL STANDOFF ASSEMBLY CONSISTS OF OUTER TUBE, MIDDLE TUBE AND FINS

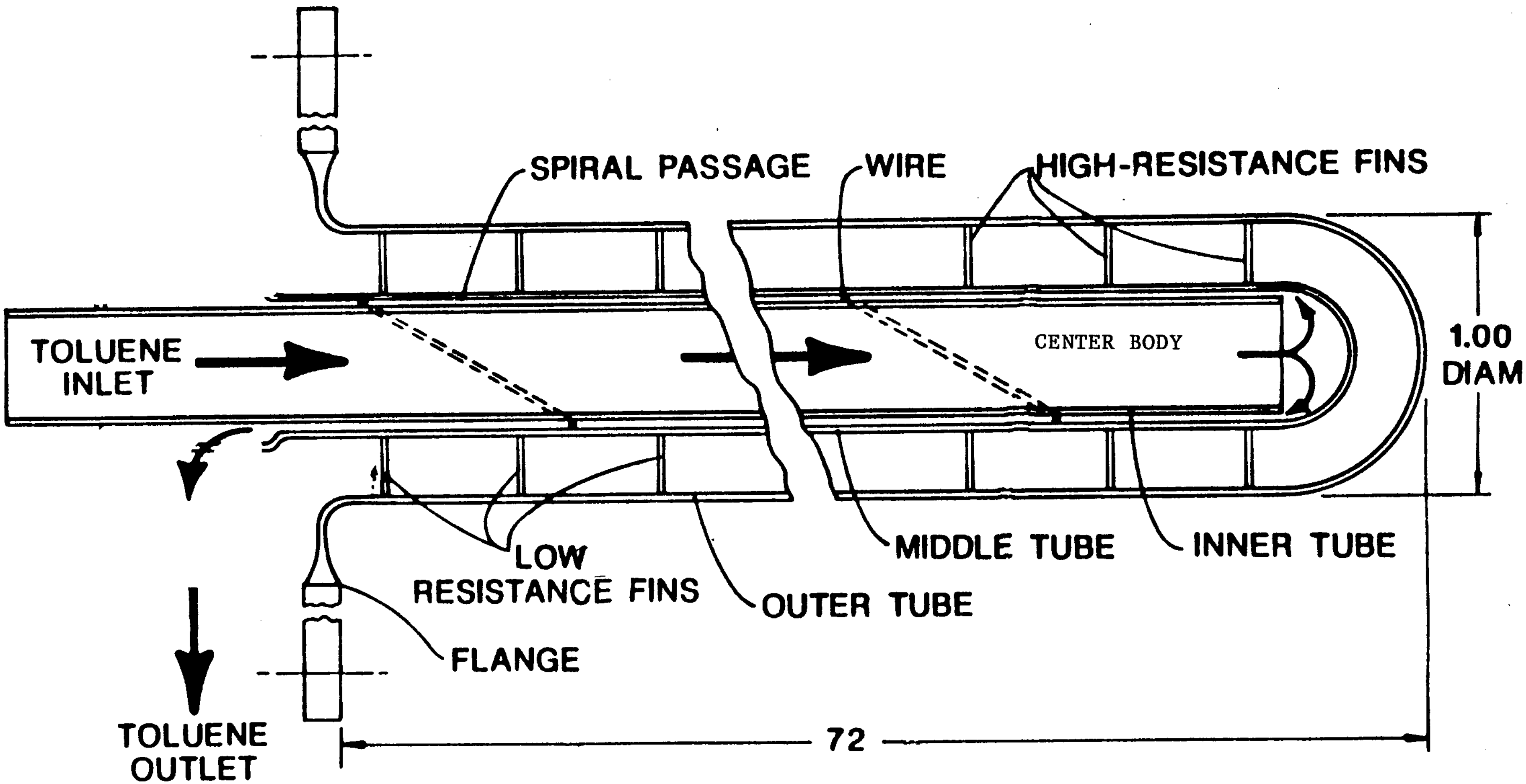


FIGURE 4: TOLUENE HEATER TUBE

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