QUARTERLY PROGRESS REPORT VI

August 1964

THE STUDY OF TRANSIENT HEAT TRANSFER PROBLEMS

Prepared for:

George C. Marshall Space Flight Center

NASA, Huntsville, Alabama

BER

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Quarterly Progress Report VI

for

The Study of Transient Heat Transfer Problems

Contract NAS 8-5217

Period: 1 June 1964 to 31 August 1964

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[redacted]

August 31, 1964

THE STUDY OF TRANSIENT HEAT TRANSFER PROBLEMS

I. SUMMARY OF PREVIOUS WORK

In the previous reporting period (12 March 1964 to 31 May 1964) the following facets of the research effort were accomplished:

1. Experimental Facilities

A controlled area for high temperature facilities was constructed by the College of Engineering in the Aerospace Engineering Laboratory wing for contract NAS 8-5217.

Fabrication of the 2 1/2-inch diameter test facility including the calorimeter and flow thru test section was completed.

The infra red heater assembly was designed and fabricated for use in the 2 1/2-inch diameter test facility.

2. Equipment

The acquisition of nine additional sub-miniature galvanometers brought the total of compatible reporting instruments to fifteen.

The switching unit and calibration circuits were designed to utilize the fifteen galvanometers in either the room temperature test facility or the high temperature test facility.

The design of the high temperature test facility was fifty per cent completed and drawings of the stainless steel test assembly were submitted to fabricators for bidding.

The free stream air heater assembly and power supply were being developed and evaluated in a prototype test facility fabricated during an earlier reporting period.

3. Calibration

Existing test facilities were calibrated and modified to adapt the 2 1/2-inch diameter test sections. Included in the calibration were velocity profiles, instrument response and calibration of new switching units.

Velocity profile measurements and flow through test section velocity calibrations were reexamined for the 4-inch test facility as a final check prior to dismantling.

4. Experimental Effort

Additional experimental data were collected for one geometric configuration examined under the previous contract, NAS 8-1519; particularly the geometric parameter angle $\gamma = 90^{\circ}$ (Configuration 1). Heat transfer data were collected using both the negative step temperature and the positive step temperature to provide uniform data sets for all geometric configurations examined under both contracts.

Experimental investigation was initiated to evaluate and develop design criteria for the high temperature test facility. The design of the calorimeter, the calibrating devices, the air heater design, the power supply and associated instrumentation were in progress.

The experimental data collected for the 4-inch diameter test facility were completed and prepared in card form for computer reduction.

II. TECHNICAL EFFORT (Report Period: 1 June 1964 to 31 August 1964)

A. Facilities and Equipment

The design, fabrication and calibration of an intermediate range (Room temperature to 600°F) high temperature hot gas facility has been completed. The test loop is diagramed in Figure 1 and is shown in the photograph of Figure 2.

The upper temperature limit of the free stream air passing over the heater elements, without recirculation, is approximately 600°F for the system shown. The recirculation loop will be added later in the test program for studies at gas temperatures above 600°F. The recirculation jet pump is described on Figure 1 with dotted lines.

The recirculation jet pump can be easily adapted to the existing test facility with a minimum of modification to permit heat transfer measurements at free stream temperatures in excess of 1000°F. The modifications involve the fabrication of an inconel heater housing, a stainless steel calorimeter block and titanium calorimeter. The other components of the test facility need no further additions or modifications to extend the system capability.

The complete test facility has been fabricated at the University of Alabama. The bids returned by potential subcontractors to fabricate the complete test facility were far above the monies available to complete the test objectives. The limited funds available made it necessary to develop this test facility in two units, an intermediate temperature range unit and a future high temperature range unit.

The calorimeter block and calorimeter assembly are pictured in Figures 4 and 5. The costs of machining and particularly the lead time required for fabricating this assembly precluded the use of stainless steel

or other high temperature materials. A 7075 Aluminum alloy was used instead and is more than adequate for the intermediate temperature range.

The heater assembly pictured in Figure 6 and Figure 7 is contained in the upper portion of the test loop and at the present time dissipates in excess of 25 KW in power for heating the air from 70°F to 600°F in a heater section ten feet long, without recirculation. A DC voltage is impressed upon the heater elements with three DC power supplies connected in series located outside the test area. The power supplies are pictured in Figure 9. The DC power supply was necessary in order to minimize the response of the measuring galvanometers to the collapsing magnetic field that would have been present in powering the heaters with an AC voltage. The DC power supply can provide a maximum DC voltage of 90 volts at 300 amperes. The power supply was acquired from the Surplus Property Depot at an estimated cost of $50.

The measuring instrumentation, reference junction, power supply, switching unit and thermocouple connecters are shown in Figure 7.

B. Calibration

The hot gas test facility has been operated and calibrated. Velocity profiles in the calorimeter test section have been obtained by the use of a hot gas pitot tube available from theDepartment of Aerospace Engineering. A built-in elbow meter in the test loop pictured in Figure 1 has been calibrated to provide a constant monitor of the free stream velocity conditions.

The heat transfer from the calorimeter test section by conduction through the thermocouple leads and through the insulation has been measured and calibrated with respect to free stream velocity and pressure. This was necessary in order to fully evaluate the transient conditions that will

be observed in experimental evaluation of heat transfer coefficient.

The 2 1/2-inch calorimeter test assembly has been calibrated for all test geometries to be examined. Velocity profiles, velocity calibration and heat transfer by conduction through thermocouples and insulation has been measured.

C. Experimental Data Collection

Experimental heat transfer data have been collected with the 2 1/2-inch calorimeter for geometric Configuration 1 (parameter angle $\gamma = 90^{\circ}$). These data have been collected for a positive step temperature only. (calorimeter heating).

Geometric Configurations 2 and 3 ($\gamma = 45^{\circ}$, $\gamma = 135^{\circ}$) have been fabricated and test data is in the process of being collected at the present time.

High temperature test data have been collected with the hot gas facility for the following test conditions:

Geometric Parameter:	$\gamma = 90^{\circ}$ (Configuration 1)
Free stream velocity:	150 fps, 300 fps
Free stream temperature:	200, 300, 400 $^{\circ}$F
Pressure:	16.00 psia

Data is presently being collected at a free stream temperature of 500°F at 150 fps and P = 16.00 psia. Experimental data up to a free stream temperature of 600°F will be collected for the $\gamma = 90^{\circ}$ geometric configuration.

A calorimeter block assembly has been fabricated in geometric Configurations 2 and 3 ($\gamma = 45^{\circ}$, $\gamma = 135^{\circ}$) for the hot gas facility and data collection is expected during the next quarterly reporting period.

D. Heat Transfer Data Analysis

The reduction of heat transfer data collected to this date is in progress and includes:

1. Configuration 1, $\gamma = 90^{\circ}$ velocities 100 through 300 feet per second, 2 1/2-inch calorimeter assembly.

2. Configuration 1, $\gamma = 90^{\circ}$, free stream temperature 200°F, 700°F, a free stream velocity of 150 feet per second.

These data are being prepared for computer reduction. The hot gas heat transfer data will require a change in the computer program for data reduction in order to account for the heat transfer by conduction through the thermocouple leads and insulation.

E. Flow Visualization Studies

A transparent calorimeter testsection has been substituted in the 2 1/2-inch calorimeter test facility for Configuration 1, $\gamma = 90^{\circ}$. Flow visualization studies reveal the development of a vortex along the length of the calorimeter section very similar in nature to the flow patterns developed in the 4-inch calorimeter test sections.

Flow visualization studies will be extended to the other geometric arrangements in the 2 1/2-inch test facility in the 1 1/4-inch hot gas facility.

F. Conferences

The pace at which the development of the test facilities were fabricated, assembled and calibrated required the constant attention of all project personnel during the past quarterly period. Consequently, no conference with the contract representative has taken place during this reporting period.

The status of the experimental program at the present time will require an early conference during the next reporting period to review the scope of the experimental program to be completed.

III. TECHNICAL HOURS EXPENDED (1 June 1964 to 31 August 1964)

Associate Project Director	423 hours
Graduate Research Associate	405 hours
Undergraduate Research Assistants	580 hours
TOTAL HOURS TECHNICAL EFFORT	1,408 hours

To date, 1,879 hours of technical effort have been expended in completing the contract objectives. This represents an excess of 100% of the total number of technical hours obligated under the terms of the proposal issued for the contract extension.

Respectfully submitted,

Raymond M. Hollub

Raymond M. Hollub
Associate Project Director

for

Dr. J. D. Matheny
Project Director

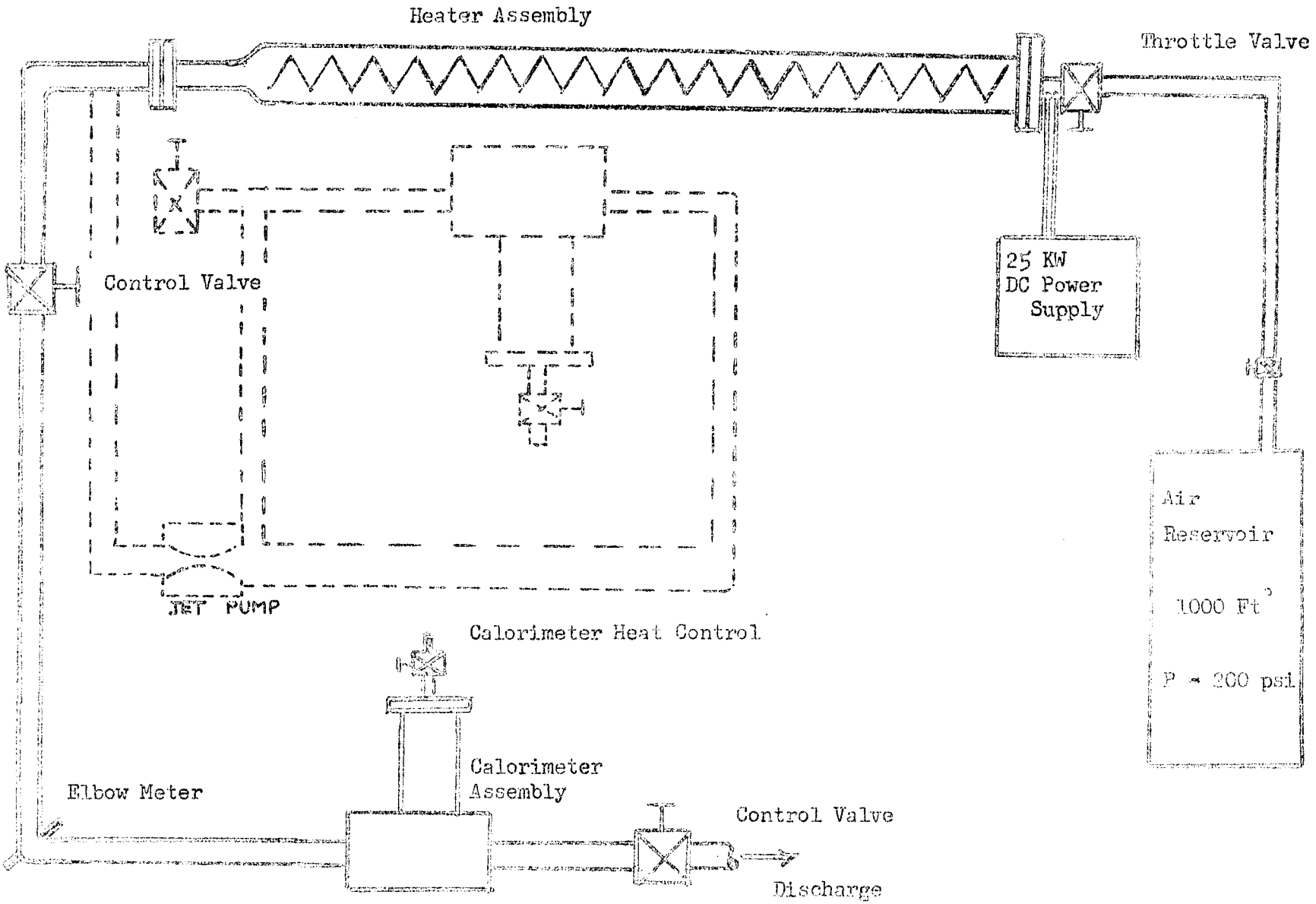

FIGURE 1.--HOT GAS FACILITY TEST LOOP - NAS 8-5217

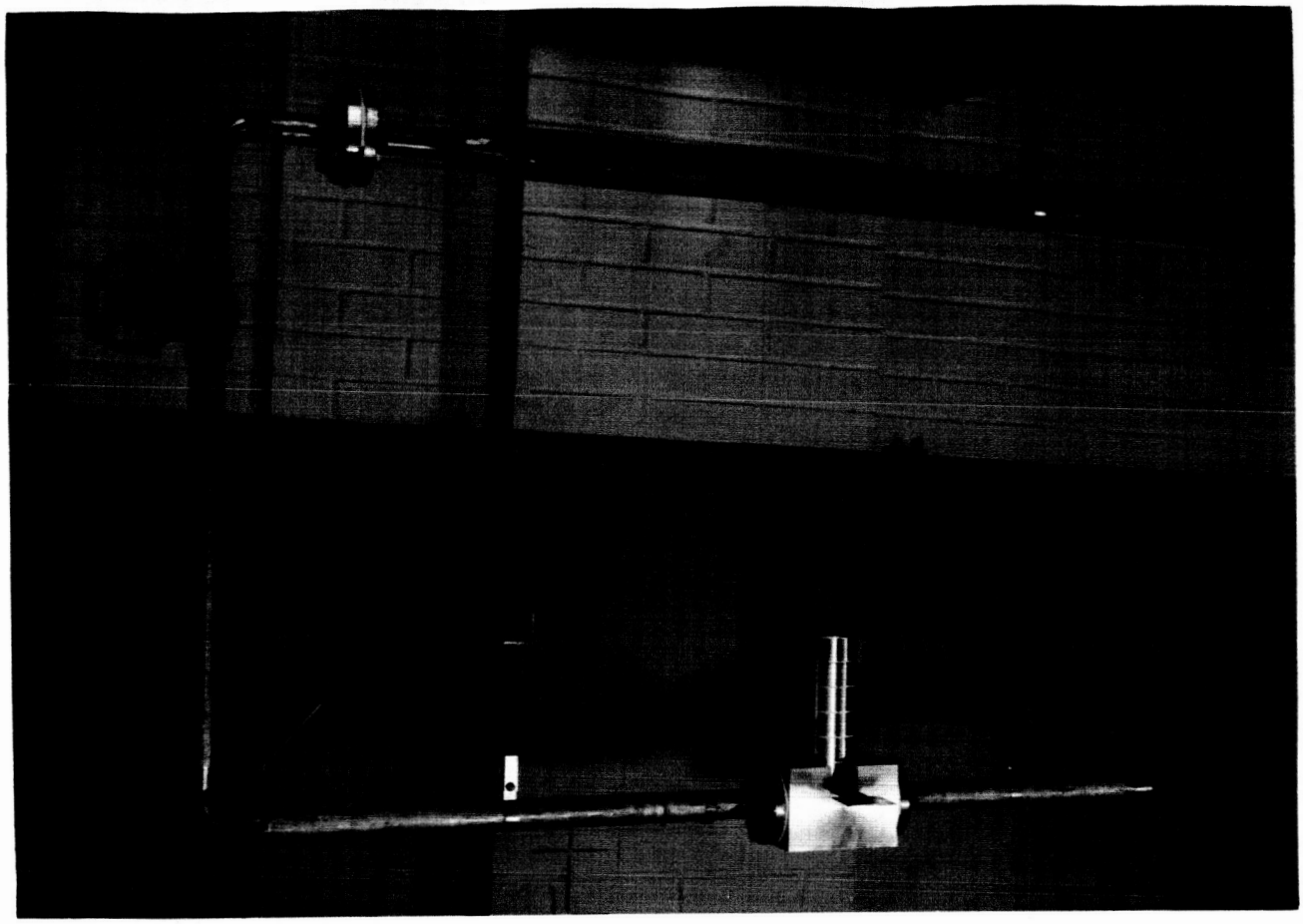

FIGURE 2.--HOT TEST FACILITY, (600°F MAXIMUM FREE STREAM TEMP)

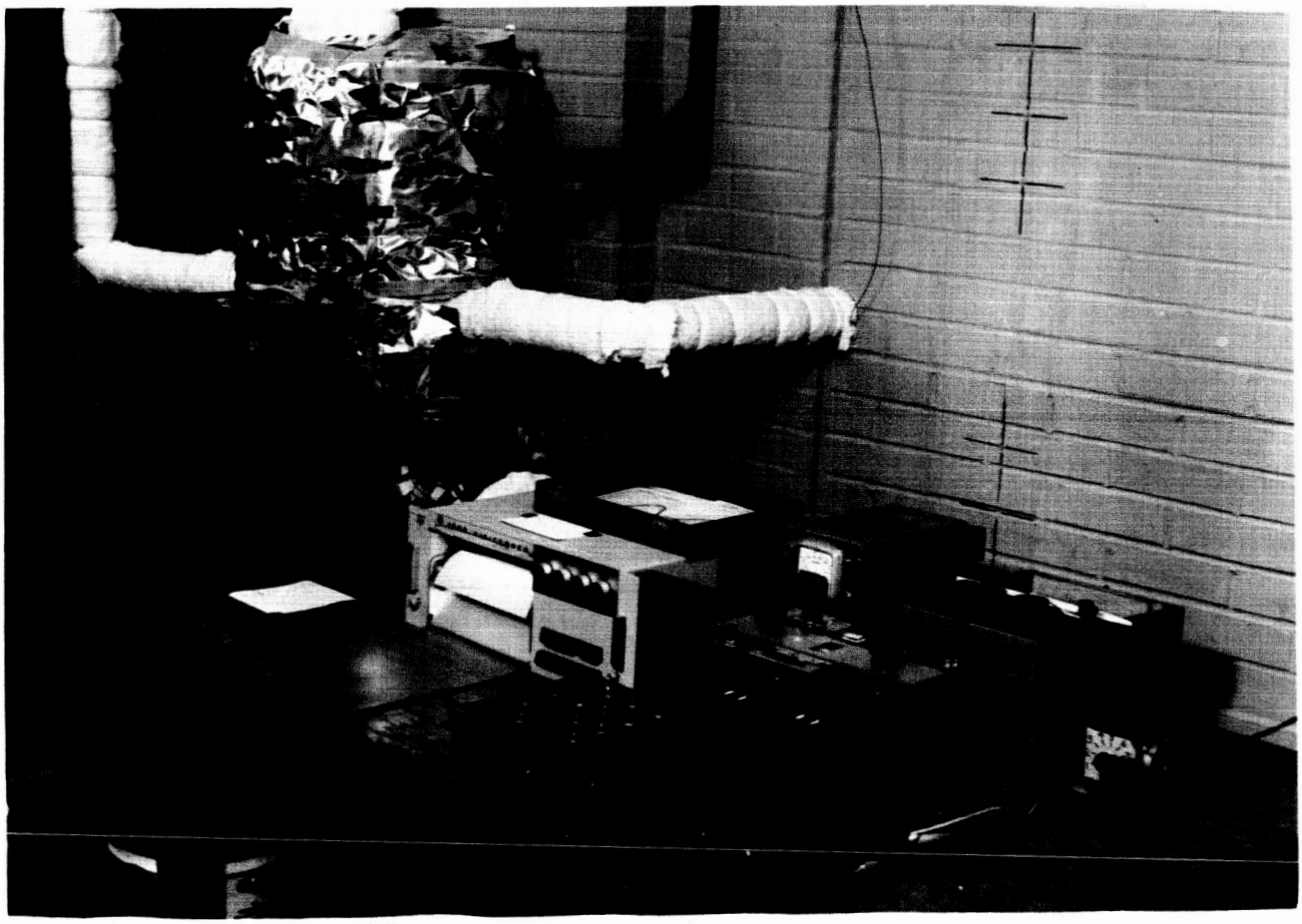

FIGURE 3.--HOT TEST FACILITY, (INSULATED)

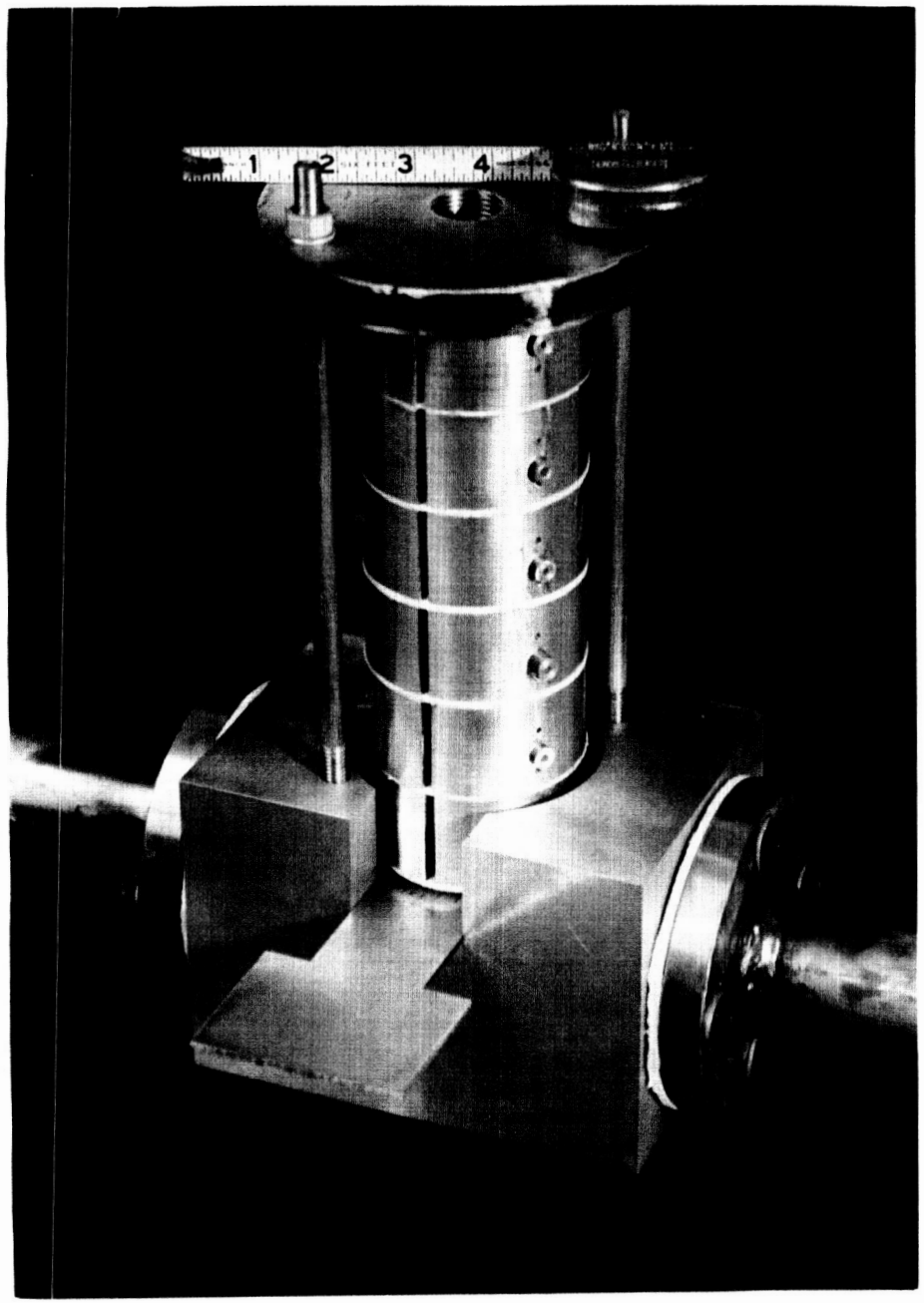

FIGURE 4.--HOT TEST CALORIMETER

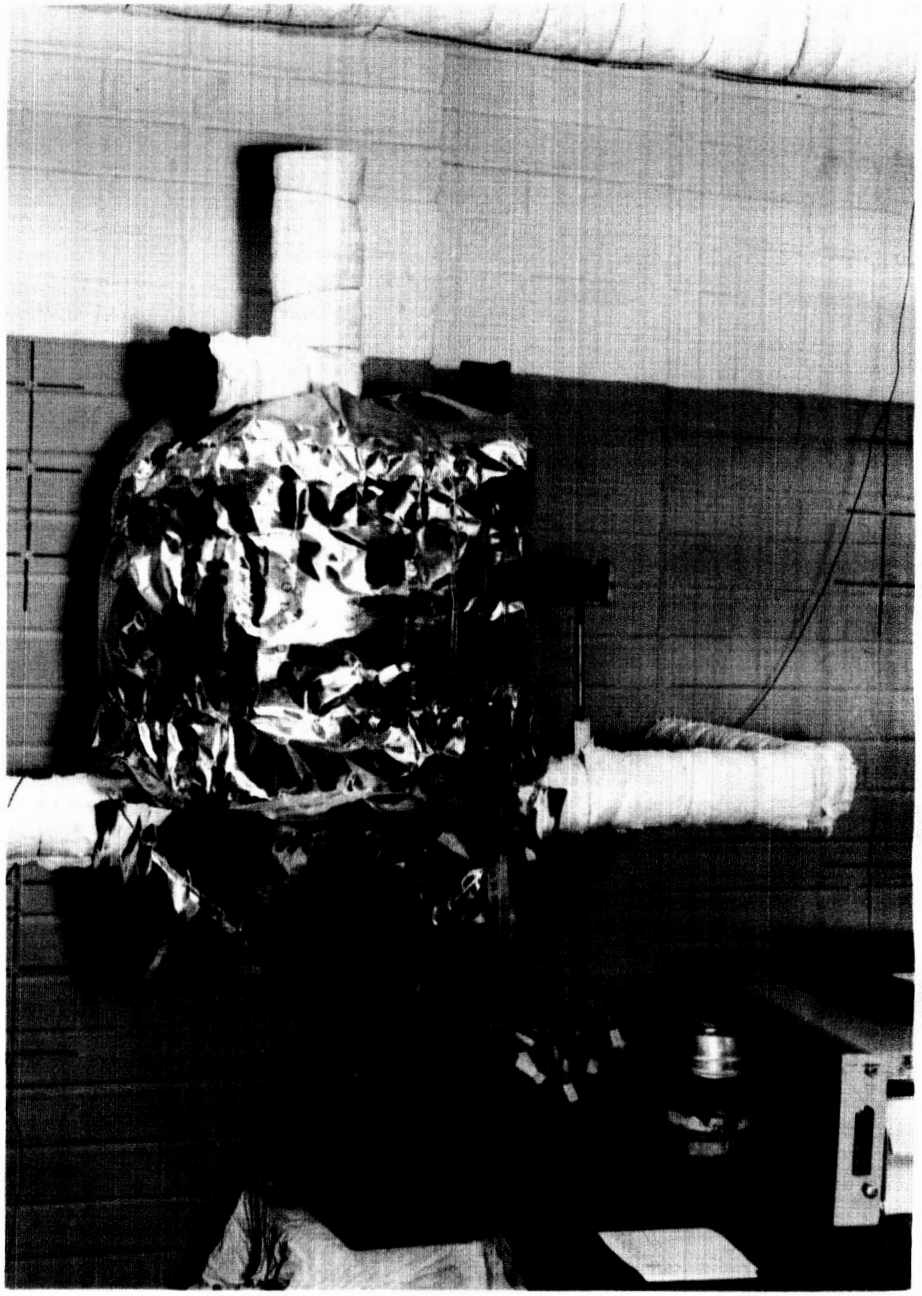

FIGURE 5.--HOT TEST CALORIMETER (INSULATED)

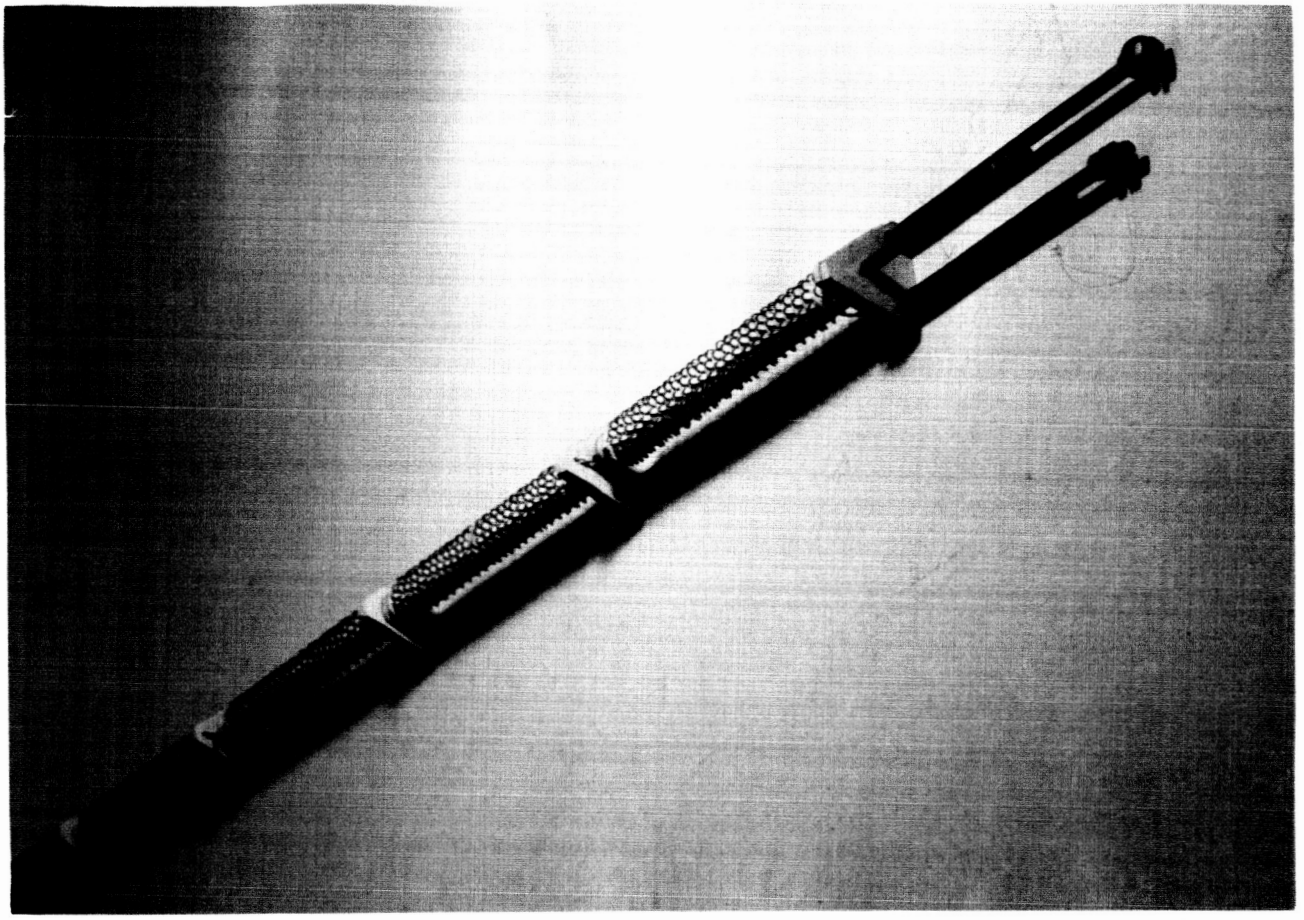

FIGURE 6.-- HOT GAS HEATER ASSEMBLY

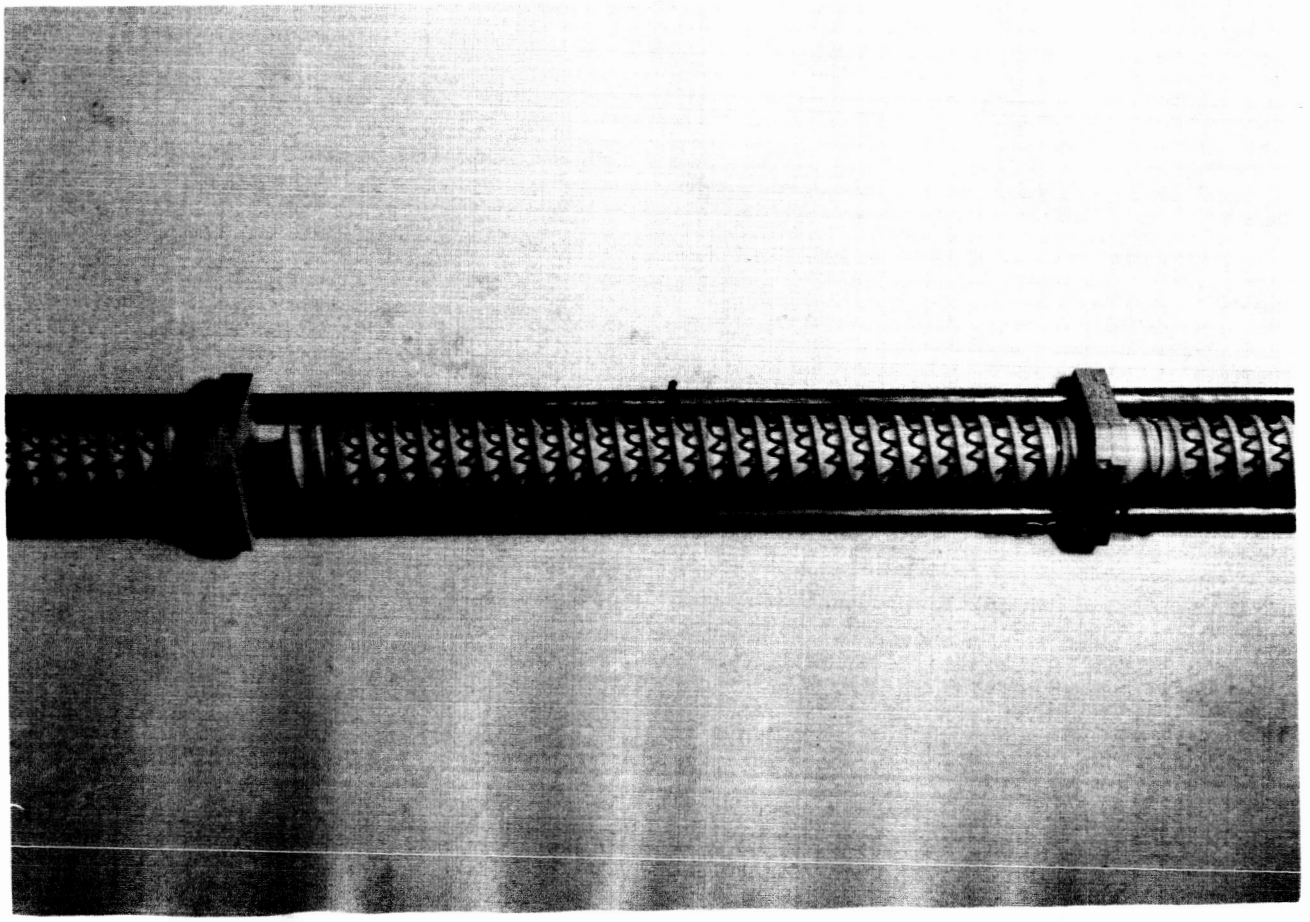

FIGURE 7.--ELEMENT ARRANGEMENT, HEATER ASSEMBLY

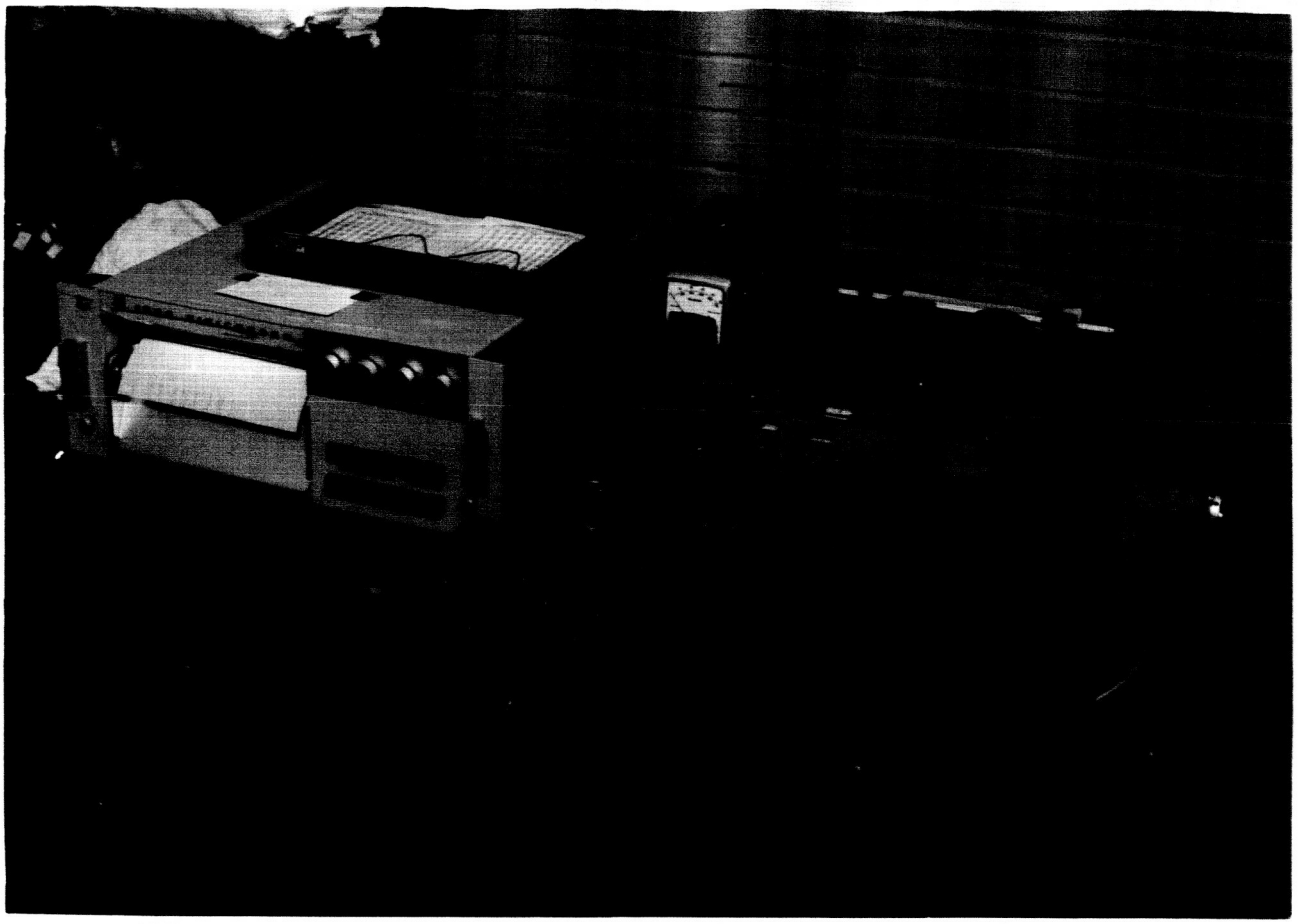

FIGURE 8.--INSTRUMENTATION AND SWITCHING ASSEMBLY

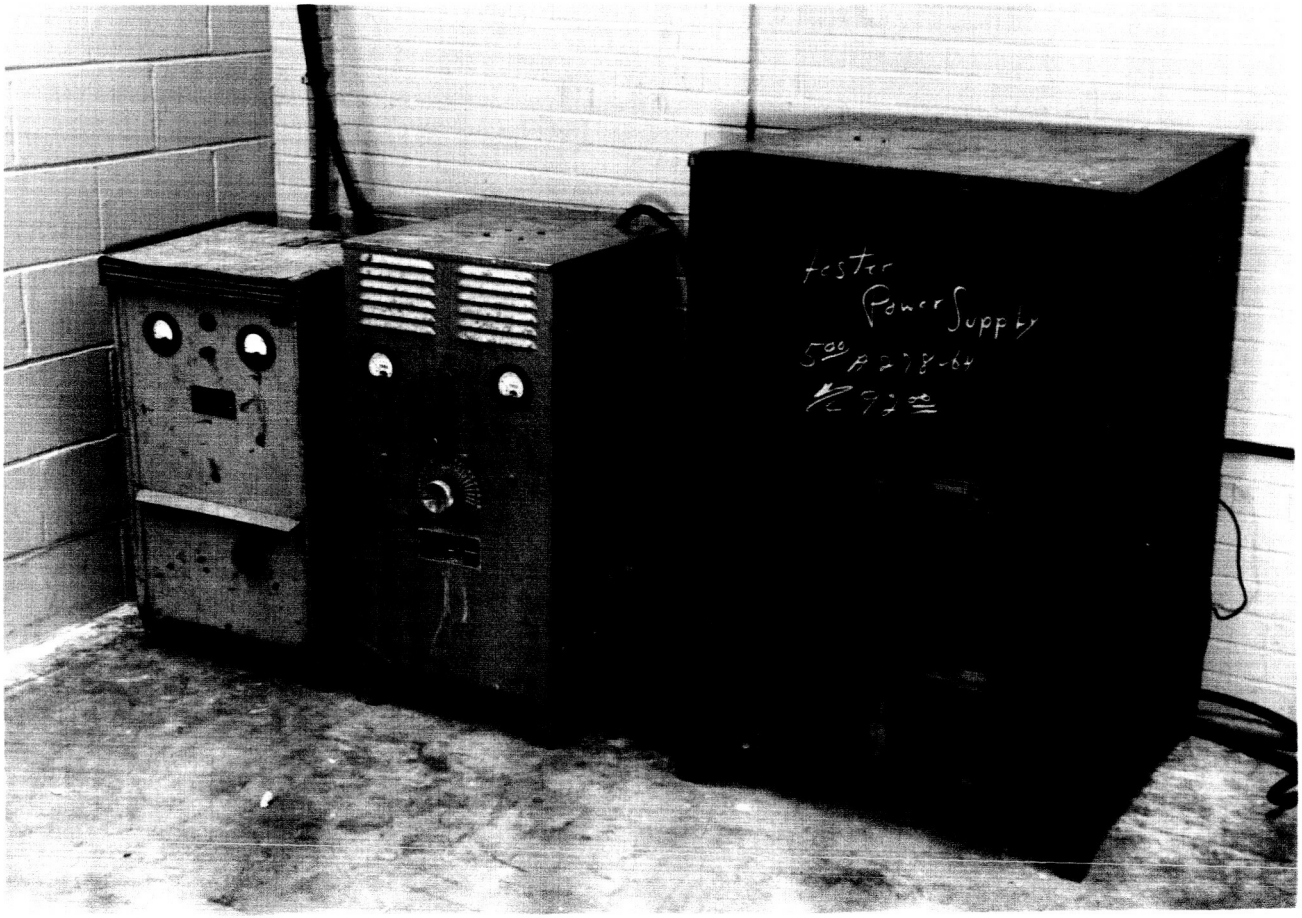

FIGURE 9.-- DC POWER SUPPLY ASSEMBLY