

Contract No. NAS 8-11,349

23 September 1964

EXPERIMENTAL INVESTIGATION OF INTERNAL RESISTANCE  
SHOCK TUBE DRIVER GAS HEATING SYSTEMS

Monthly Technical Progress Report

September 1964

Prepared For  
George C. Marshall Space Flight Center  
Huntsville, Alabama

By  
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Project Memo No. 7208-117/64-4

FACILITY FORM 602	N66 23799	
	(ACCESSION NUMBER)	(THRU)
	21	1
	(PAGES)	(CODE)
		11
	(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)

GPO PRICE \$ \_\_\_\_\_

CFSTI PRICE(S) \$ \_\_\_\_\_

Hard copy (HC) \$ 1.00

Microfiche (MF) .50

Advanced Concepts Department  
Advanced Studies Division  
LOCKHEED-GEORGIA COMPANY  
Marietta, Georgia

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## FOREWORD

Contract NAS 8-11,349 between the NASA George C. Marshall Space Flight Center and the Lockheed-Georgia Company, effective 28 May 1964, provides for an experimental investigation of internal resistance shock tube driver gas heating systems. The selection of a heating system based on internal resistance techniques for this experimental investigation was a result of a recent analytical study of shock tube driver gas heating techniques conducted by the Lockheed-Georgia Company under Contract NAS 8-11,078. The contract is monitored by the Aero-Astroynamics Laboratory with J. W. Davis as Project Manager.

The work at the Lockheed-Georgia Company under this contract is the responsibility of the Advanced Concepts Department, R. H. Lange, Manager. R. F. Sturgeon is the Project Leader.

The monthly technical progress report for September 1964, the fourth of nine monthly reports, is submitted herein in partial fulfillment of the terms of the subject contract.



R. H. Lange, Manager  
Advanced Concepts Department  
Advanced Studies Division

## WORK ACCOMPLISHED

Efforts have been continued toward the goal of completing the testing of thermal insulation materials during September. However, delays have been encountered in the delivery of the insulation samples, resulting in an interruption of the testing program. While it is still possible that these tests will be conducted during the latter part of September, it appears that some of the insulation tests will continue into October. As indicated by Figure 1, all components required for the tests of thermal insulating materials are complete and have been installed and tested.

Progress in all other areas of activity has been consistent with the program schedule. Functions receiving attention during this reporting period include:

- o Design
- o Procurement
- o Fabrication
- o Testing

### Design

Final design of the axial heating element and the tentative design of the circumferential heating element were completed during the period covered by this progress report. It is anticipated that this configuration of the

Component or Subsystem	Design		Materials		Fabrication		Installation	Insulation Tests		Element Tests																												
	Start	Complete	Ordered	Received	Start	Complete		0.25" Wall Thickness	0.5" Wall Thickness	Unheated			Heated																									
										1	2	3	4	5	6																							
Power Supply	18 Jun	1 Jul	8 Jul																																			
Driver End Cap Assembly	6 Jun	1 Jul	23 Jun	29 Jun	8 Jul	15 Aug	8 Sept*																															
Instrumentation	15 Jul	20 Aug*	20 Aug*																																			
Insulation Mountings	1 Jul	15 Jul	23 Jun	10 Jul	22 Jul	3 Aug																																
Fused Silica Insulation	1 Jul	15 Jul	1 Jul																																			
AlSiMag 665 Insulation	1 Jul	15 Jul	1 Jul																																			
Element A	6 Jul	17 Aug*	10 Jul																																			
Element B	22 Jul	21 Aug*	28 Jul																																			
Element A Modifications			10 Jul																																			
Element B Modifications			28 Jul																																			

\* Additions

Figure 1 Program Status: 15 September 1964



circumferential element will be employed if the use of a thermal insulation proves to be feasible.

An investigation of the instrumentation necessary for a determination of heating system performance has been conducted and an appropriate design is complete.

With the completion of these tasks, the design of all heating system components is finished. It is possible, however, that additional design efforts will be required if modification of components is necessary.

#### Axial Heating Element

The configuration of the axial heating element is illustrated in Figure 2.

Values of pertinent element parameters are as follows:

Effective Surface Area	10.75 ft <sup>2</sup>
Cross-sectional Area	0.57 in <sup>2</sup>
Weight	85 lb
Resistivity	135 microhm-cm
Emissivity	0.85

This design permits operation of the heating system at power levels up to 400 KW while maintaining an element temperature below 1700°F.

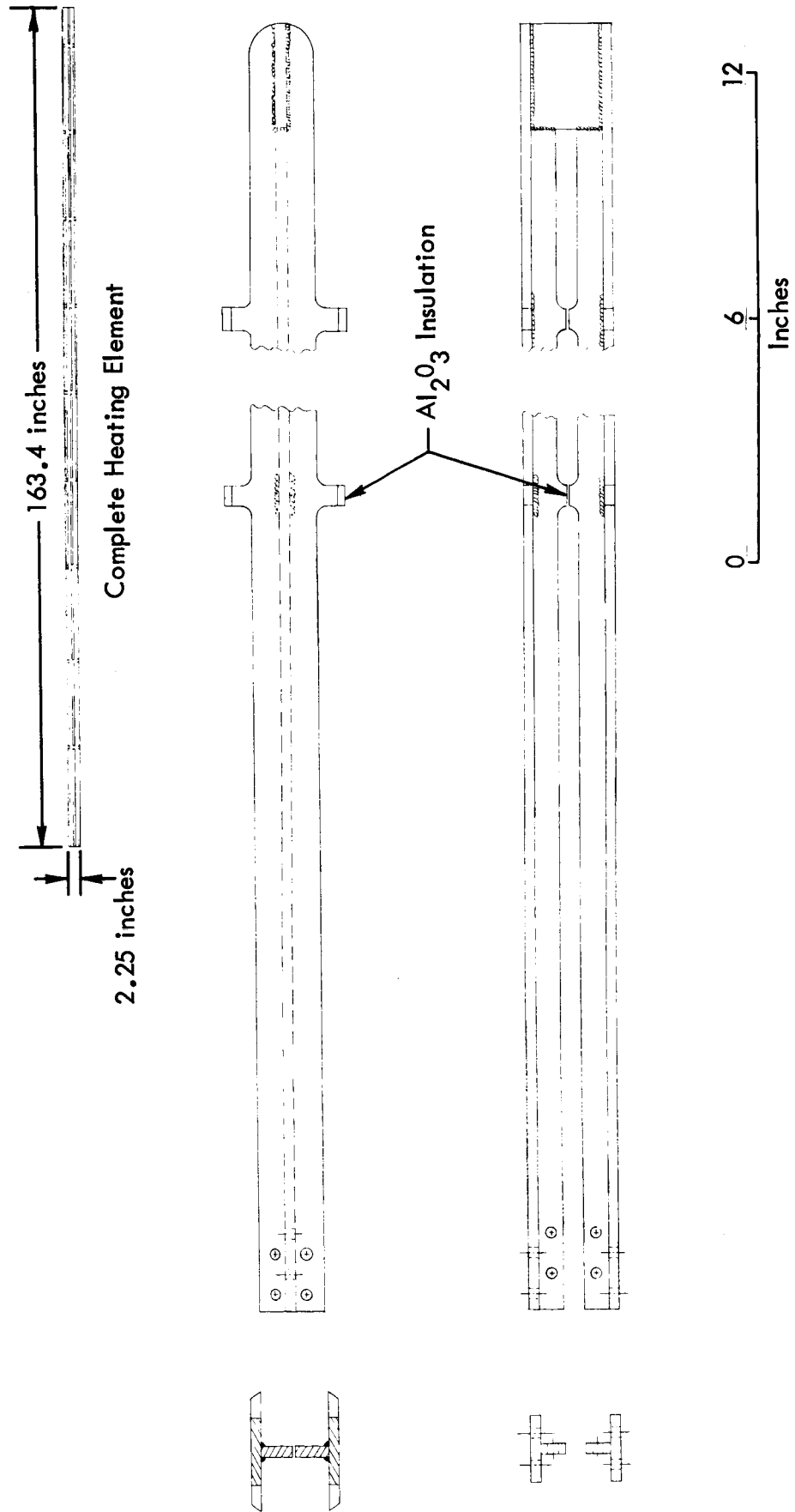


Figure 2 Axial Heating Element

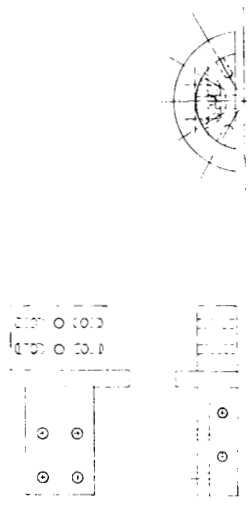
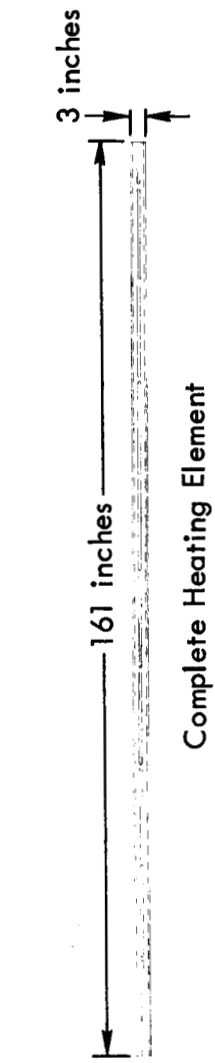
The element will be made of Hastelloy B nickel-base superalloy, machined and welded into the indicated configuration. The two terminals of the heating element fit directly into machined grooves in the BeCu electrodes. Each is secured by six BeCu bolts. The element sections are electrically insulated from each other and the shock tube walls by a sprayed coating of  $Al_2O_3$  ground to the required tolerances.

### Circumferential Heating Element

In Figure 3 is presented a diagram of the circumferential heating element. Values of parameters describing this configuration are:

	Thermal Insulation Thickness	
	<u>0.25 inch</u>	<u>0.5 inch</u>
Effective Surface Area	8.45 ft <sup>2</sup>	6.70 ft <sup>2</sup>
Cross-sectional Area	0.50 in <sup>2</sup>	0.37 in <sup>2</sup>
Weight	53 lb	40 lb
Resistivity	135 microhm-cm	135 microhm-cm
Emissivity	0.85	0.85

The insulation thickness which will be utilized depends upon the outcome of the thermal insulation decompression tests. The element design corresponding to either insulation thickness permits operation over a wide range of power levels without exceeding element temperature limits.



Mounting Adaptor

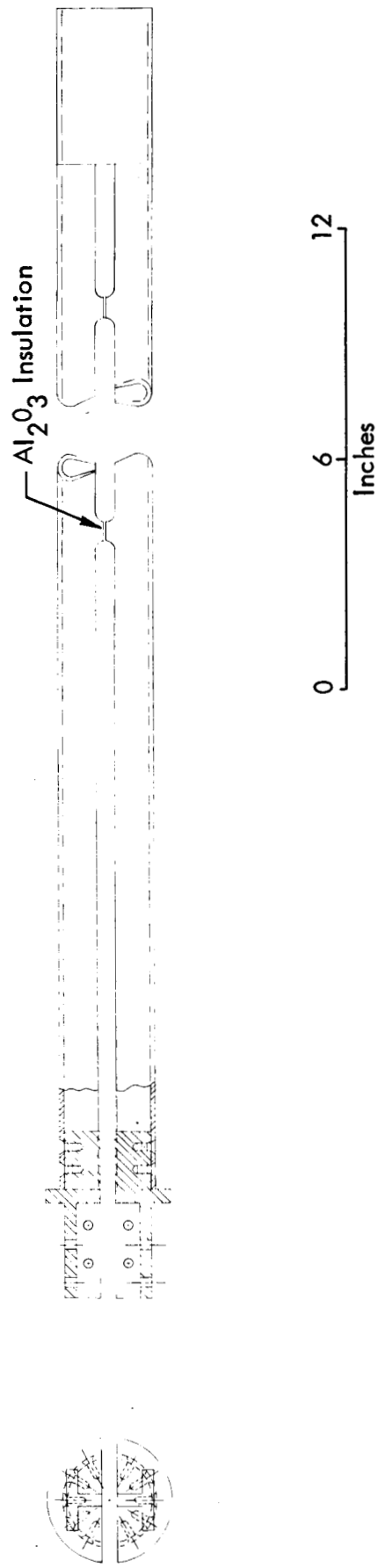


Figure 3 Circumferential Heating Element Assembly

The element will be made of Hastelloy B tubing with machined slots and sprayed  $\text{Al}_2\text{O}_3$  electrical insulation separating the two conducting halves. The thermal insulation provides the necessary electrical insulation from the shock tube walls. BeCu adaptors secure the heating element to the electrodes in a manner similar to that used for the axial element configuration.

### Instrumentation

Instrumentation employed in the testing program will include that required for controlling, measuring, and recording the performance and operating characteristics of both the shock tube and the driver gas heating system.

Routine operation of a shock tube requires that driver tube pressure, driven tube pressure, and shock Mach number be measured. The normal shock tube instrumentation provided for measuring these quantities will be utilized throughout the testing program. Measurement of the driver tube pressure is accomplished through the use of a Foxboro 10-inch recorder which produces a continuous time recording. The driven tube pressure is recorded by an oscilloscope trace photograph of the output from a Kistler pressure transducer. The shock Mach number is determined by measuring the time in microseconds required for the shock wave to traverse the distance between two ion gages or pressure transducers

located in the driven tube. A Beckman time interval counter is connected to these transducers to provide a direct read-out of the elapsed time.

Control of the driver gas heating system and the accumulation of data necessary to define heat transfer processes and to gain a general understanding of system performance requires that the following quantities be measured and recorded as a function of time:

- o Power input
- o Element temperature
- o Driver wall temperature
- o Driver gas temperature

A schematic diagram of the instrumentation designed to permit a determination of these quantities is presented in Figure 4.

Electrical power input to the heating element is determined by measuring and recording the input current and voltage. Direct reading indicators permit continuous monitoring of the power input.

The temperature of the heating element is measured at three places with chromel-alumel thermocouples. These thermocouples are shielded and ungrounded, allowing the shield to be spot welded directly to the element. The thermocouple wires are insulated by ceramic beads and tubes to

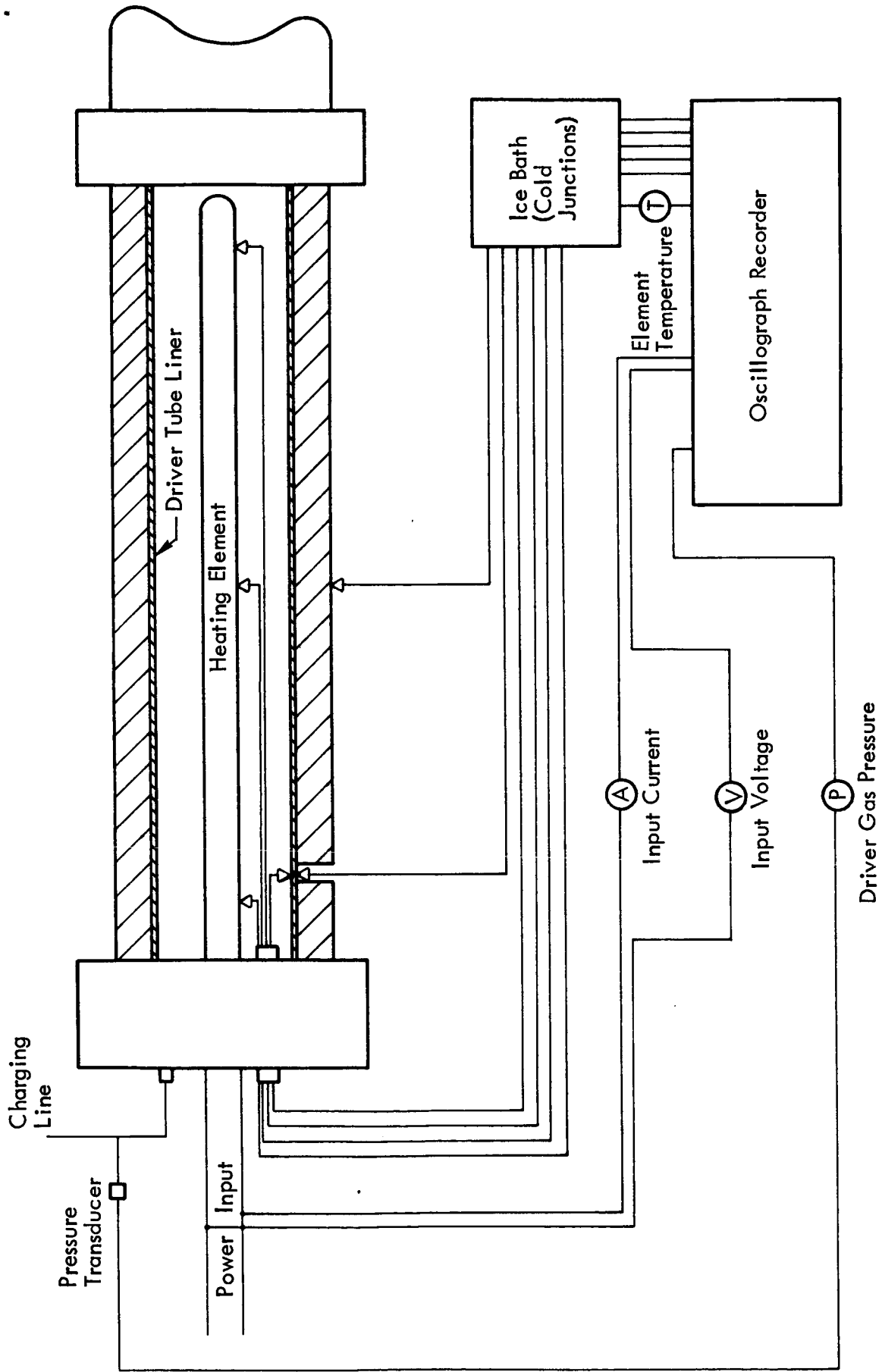


Figure 4 Heating System Instrumentation

protect the leads and minimize wire heating. The leads are passed through a pressure sealing gland in the end cap of the driver tube. Grounded thermocouples are employed to measure the temperature of the shock tube driver on the inside of the liner, at the interface between the liner and the main tube, and on the outside surface of the tube. The cold junctions of the thermocouples are formed by the transition to copper wire and are maintained at 32°F by an ice bath.

The driver gas temperature is not measured directly but is calculated from a knowledge of the driver gas pressure. This pressure measurement is accomplished through the use of a Sensonic piezo-electric pressure transducer and is independent of the normal shock tube instrumentation.

All of the quantities describing the operation of the heating system are recorded on an oscillograph as a function of time for the complete heating cycle. The oscillograph galvanometers have a natural frequency of approximately 200 cycles-per-second, which provides a satisfactory response for the anticipated rates of variation. The oscillograph permits continuous monitoring of the measured quantities.

#### Procurement

The anticipated delivery dates for both types of thermal insulating materials and the Hastelloy B to be used in the fabrication of heating



elements have been revised by the manufacturers.

The samples of thermal insulation were originally scheduled for delivery during August. Latest estimates indicate that delivery will be delayed about one month. The fused silica insulation is now scheduled for delivery on 22 September and the AlSiMag 665 insulation is expected on 29 September. These delays result from manufacturing problems encountered in satisfying specified tolerances.

The Hastelloy B nickel-base superalloy was originally scheduled for delivery on 20 August to permit the fabrication of the axial heating element before the anticipated initiation of heated tests on 1 October. Difficulties in the manufacture of the material caused the postponement of the delivery date to 18 September. Assuming that the material is received according to current expectations, fabrication will be completed in time to permit tests of the axial element configuration during October.

At this time, all other materials and components are expected to be delivered on schedule.

#### Fabrication

Photographs of completed components to be used in the decompression tests of thermal insulating materials and in the operational heating system are

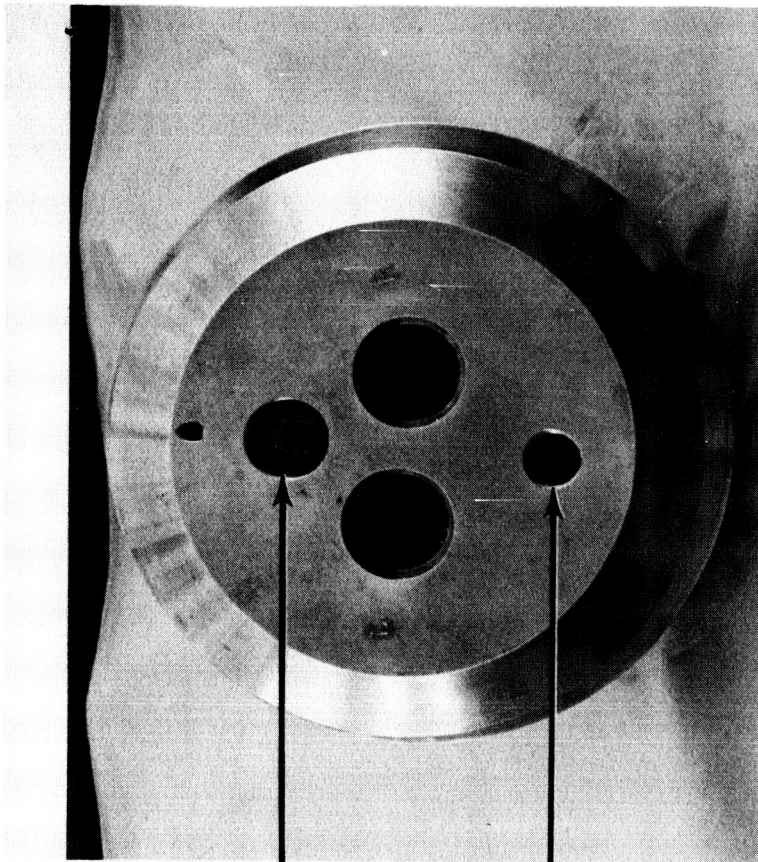
presented in the accompanying illustrations. Figure 5 shows the component parts of the modified end cap assembly. Two views of the complete assembly, ready for installation on the shock tube, are available in Figure 6. In Figure 7 are photographs of the insulation mounting attachments with partial views of the insulation mountings.

Fabrication of the heating elements will proceed when the required materials are received.

#### Testing

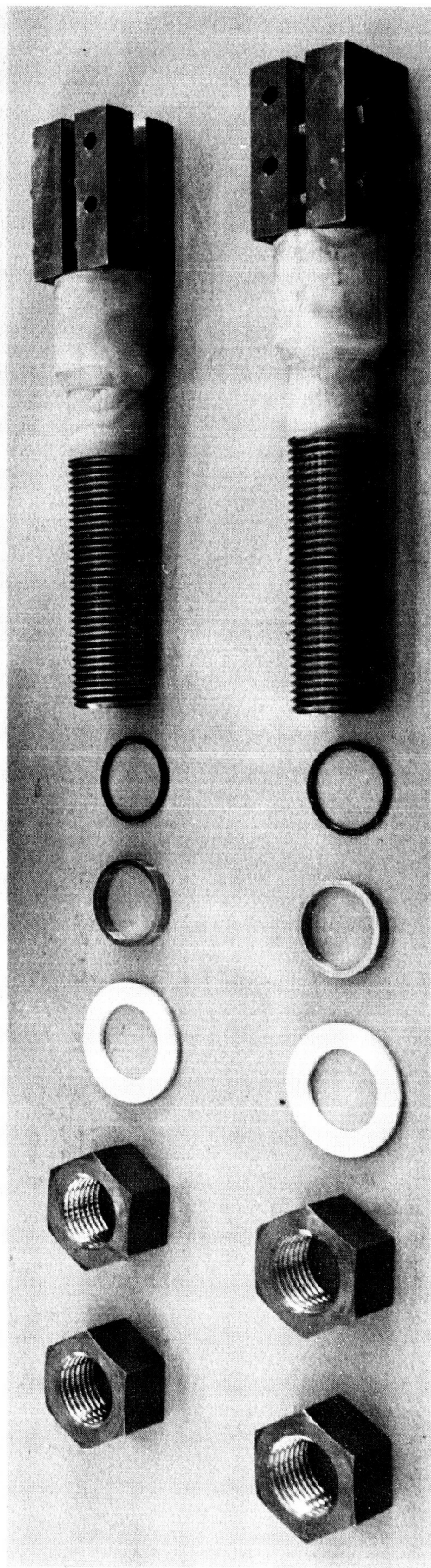
Initiation of the decompression tests of thermal insulation samples, originally scheduled for 1 September, has been delayed as a result of the revised delivery dates of the insulation materials. All components required for these tests are complete and testing will commence upon receipt of the insulation samples.

The modified driver section end cap assembly has been installed on the shock tube and pressurized to 18,000 psi with helium to check the pressure seals around the electrodes. Since this is 20 percent greater than the pressure to be used in the testing program, no sealing problems are anticipated.



Charging Port

Instrumentation Port



Retaining Nuts

Insulated Washer

"O" Ring

"O" Ring Retainer

$Al_2O_3$  Insulation

Figure 5 Driver Section End Cap Components

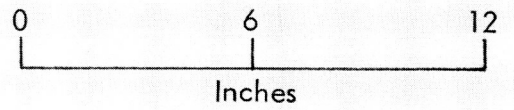
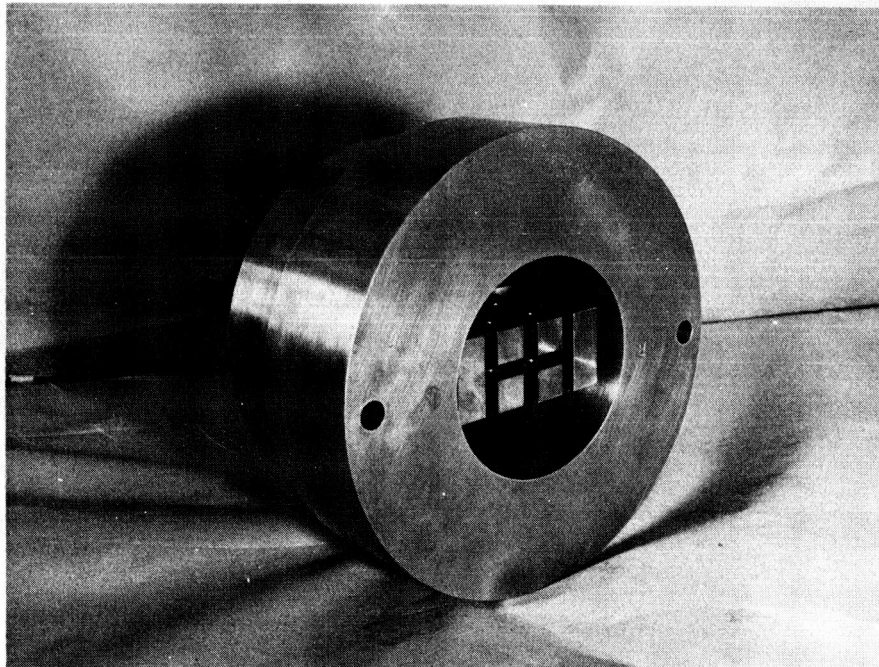
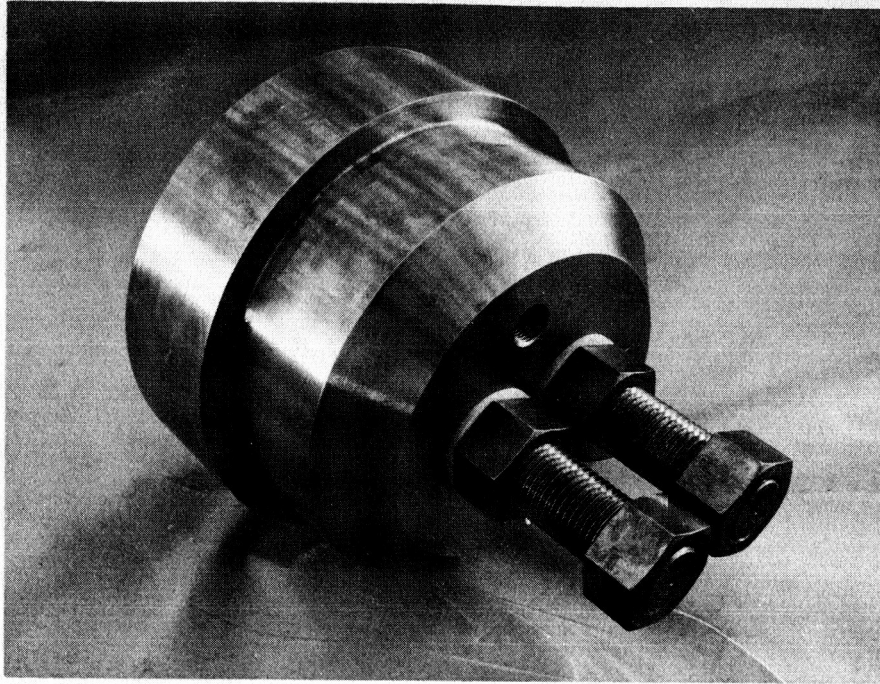


Figure 6 Driver Section End Cap Assembly



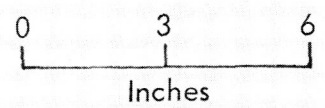
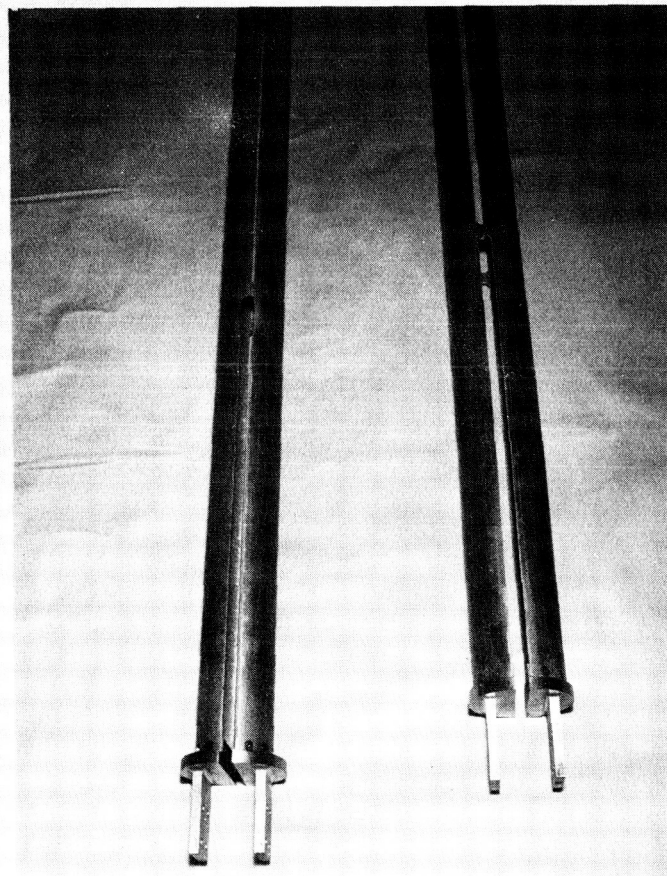
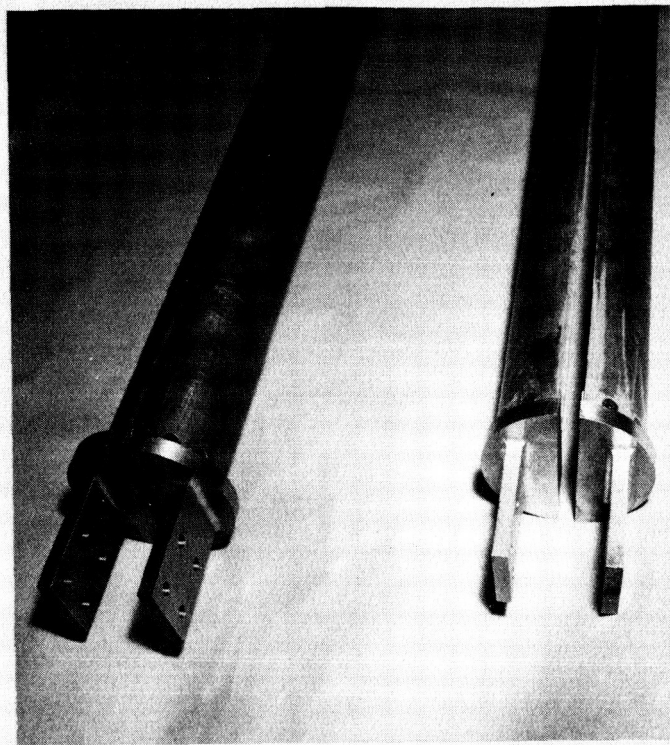


Figure 7 Thermal Insulation Mounting Assemblies

## WORK PLANNED

Preparations are complete for the decompression tests of thermal insulation samples. These tests will be conducted as soon as the samples are available.

Fabrication and installation of heating system components will continue. Current scheduling will allow the completion of the axial heating element during the early part of October. Delivery and installation of power supply and instrumentation components should also occur during this period, thus permitting initial testing of the heating system during the latter half of the month.

## ADMINISTRATIVE REPORT

There were no trips or visits conducted in support of the contract during this reporting period.

Engineering personnel actively engaged in the study during this reporting period include:

R. F. Sturgeon, Advanced Concepts Department

D. E. Alford, Advanced Concepts Department

T. E. Harper, Experimental Fluid Dynamics Department

R. W. Arnold, Materials Research Laboratory

E. G. Nicholson, Instrumentation & Test Services Laboratory

R. D. Neal, Research Division

D. R. Peters, Research Division

R. C. Carman, Plant Engineering Division