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APPARATUS FOR MEASURING TEMPERATURE DROP ACROSS AN INTERFACE

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ABSTRACT

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The apparatus and techniques used to determine the temperature drop across a bolted interface are described in this report. The parameters studied during this experiment were specimen heat input, interface surface treatment, bolt torque, and vacuum. Determinations were made on aluminum alloys 2024-T4, 6061-T6, and Almag "35" with various finish treatments.

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MATERIALS DIVISION
PROPULSION AND VEHICLE ENGINEERING LABORATORY
RESEARCH AND DEVELOPMENT OPERATIONS

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APPARATUS FOR MEASURING TEMPERATURE DROP ACROSS AN INTERFACE

SUMMARY

The apparatus and techniques used to determine the temperature drop across a bolted interface are described in this report. The parameters studied during this experiment were specimen heat input, interface surface treatment, bolt torque, and vacuum. Determinations were made on aluminum alloys 2024-T4, 6061-T6 and Almag "35" with various finish treatments.

INTRODUCTION

The purpose of this project was to establish optimum conditions in vacuum for dissipating ten watts of thermal energy across an interface between an electronic component package and a temperature-controlled plate that would simulate conditions expected in the Saturn S-IC instrument compartment. This interface is composed of a one-inch diameter boss on each component. These bosses are bolted together and serve as both heat conduction paths and equipment mounts. The material, specimen heat input, surface finish, bolt torque, and vacuum were the experimental parameters controlled to maintain the necessary environmental conditions set by design.

Considerable work has been done on thermal contact measurements of many types of metallic joints. However, each particular application presents its own problems, and data from similar applications are generally not valid. Therefore, it is necessary that experimental measurements be made to determine the magnitude of the parameters involved for the stated condition.

DESIGN AND CONSTRUCTION OF APPARATUS

General Description

The apparatus used in these investigations is shown in FIG 1. It consists of a two-piece specimen, vacuum system, temperature control equipment, regulated power supply, and measuring instrumentation. The two-piece specimen is assembled by bolting the top and bottom portions together through the center and is then mounted by placing the bottom portion in a copper heat sink. The top of the specimen is recessed to hold the specimen heater. Thermocouples are mounted in the specimen for determining the temperature drop. This assembly is mounted in a vacuum chamber, and a thermal gradient is established by heating the specimen at the top and cooling it at the bottom. Once thermal equilibrium has been obtained, the temperature drop across the interface is measured for a given set of conditions.

Apparatus

The vacuum system is composed of a four-inch, 720 liter/second, water-cooled, oil-diffusion pump and a 6.2 liter/second mechanical fore pump. This system is capable of maintaining a pressure of 10^{-4} to 10^{-7} torr. A variable leak rate valve is used to control the pressure which is measured with a hot cathode ionization gauge.

The sample chamber consists of a 14" x 18" bell jar mounted on a stainless steel plate (FIG 2). A copper heat sink with a cooling coil is mounted on this plate. The heat sink temperature is controlled by a constant pressure apparatus and a refrigeration unit. Tap water from the constant pressure tank is circulated through the refrigeration unit and heat sink coil. The flow is controlled by a needle valve and is monitored on a flow meter.

Power is supplied to the specimen heater from a fully regulated power supply. The heater is a 10 ohm resistance coil helically wound on a lava form.

There are three special limit iron-constantan thermocouples mounted in each half of the specimen. Two of the thermocouples on each half are mounted 180° apart and 1/8 inch from the interface.

The other thermocouple is located one inch above one of these thermocouples. All thermocouples are mounted in wells 0.052 inch diameter by .0625 inch deep. To insure good thermal contact, these wells are filled with silicone vacuum grease, and the thermocouple junctions are inserted and anchored in position. The thermocouple and power leads are fed through the vacuum chamber using a Conax fitting mounted in the stainless steel plate.

All thermocouple reference junctions were potted in an epoxy resin and then positioned in the center of a glass dewar equipped with a siphon overflow tube for maintaining a constant water level. The dewar was then packed with crushed ice, filled with water, and repacked with crushed ice. The above precautions were taken to minimize fluctuations in reference junction temperature.

The thermocouples were mounted in the apparatus and checked against each other at a pressure of 10^{-4} torr with no current applied to the sample heater. Any thermocouple which deviated significantly from the others was replaced.

The measuring apparatus consists of a Leeds and Northrup K-3 potentiometer, electronic galvanometer, standard cell, zener regulated d. c. voltage source, and a voltage divider network suspended in a constant temperature bath. FIG 3 shows an electrical schematic of the apparatus. The voltage divider network is composed of three NBS calibrated resistors in series: 10K, 10K, and 1K ohms. The voltage drop across the 1K ohm resistor is measured and multiplied by a factor of 21 to obtain the voltage applied to the specimen heater. Since the 1 ohm resistor is in series with the heater, the voltage drop across this resistor will give the current in the heater circuit. From this information the power input to the specimen heater can be calculated.

Specimen Assembly

The two-piece specimen consists of a top half, one-inch diameter by three and one-half inches long, and a bottom half, one-inch diameter by two and seven-eighth inches long. FIG 4 shows an exploded view of the specimen. The top of the upper half is drilled to accommodate the specimen heater; the bottom of the lower half is drilled to accept the nut on the torquing bolt and is tapered on the outside to mate with the copper heat sink. Both pieces of the specimen are drilled through longitudinally for a specially designed torquing bolt which aligns the assembly. To improve thermal contact, the tapered portion on the bottom of the specimen is coated with a thin film of silicone grease prior to mounting it in the heat sink.

The interface surfaces are machined and lapped to produce a 25-35 microinch finish. These surface finish measurements are made on a Taylor-Hobson Talysurf, Model 100 instrument.

RESULTS

The results of tests made to date are presented in Tables I, II, III, IV, V & VI. The temperature drop across an interface would be expected to increase with increased heat input, increased surface roughness (not a variable in these tests), decreased torque, and higher vacuum. The data show that in all tests the temperature drop increases with an increase in heat input, and as torque is increased the temperature drop decreases. Among the variables investigated, varying the pressure had the least effect on the temperature drop. A minimum Δt was established with bare 6061-T6 interfaces, and Δts were maximum for anodized 6061-T6 interfaces. Both 2024-T4 and 6061-T6 aluminum without surface treatment yielded Δt values which lie between those for base 6061-T6 and anodized 6061-T6 aluminum. Tables I and II show that 6061-T6 has a greater conductance than 2024-T4 under similar conditions. Tests conducted on hybrid specimens of 6061-T6 aluminum and Almag "35" showed a decrease in Δt with an increase in torque. The hybrid specimen employing the alodined 6061-T6 surface yielded Δts approximately one-half that of the specimen with the anodized 6061-T6 surface.

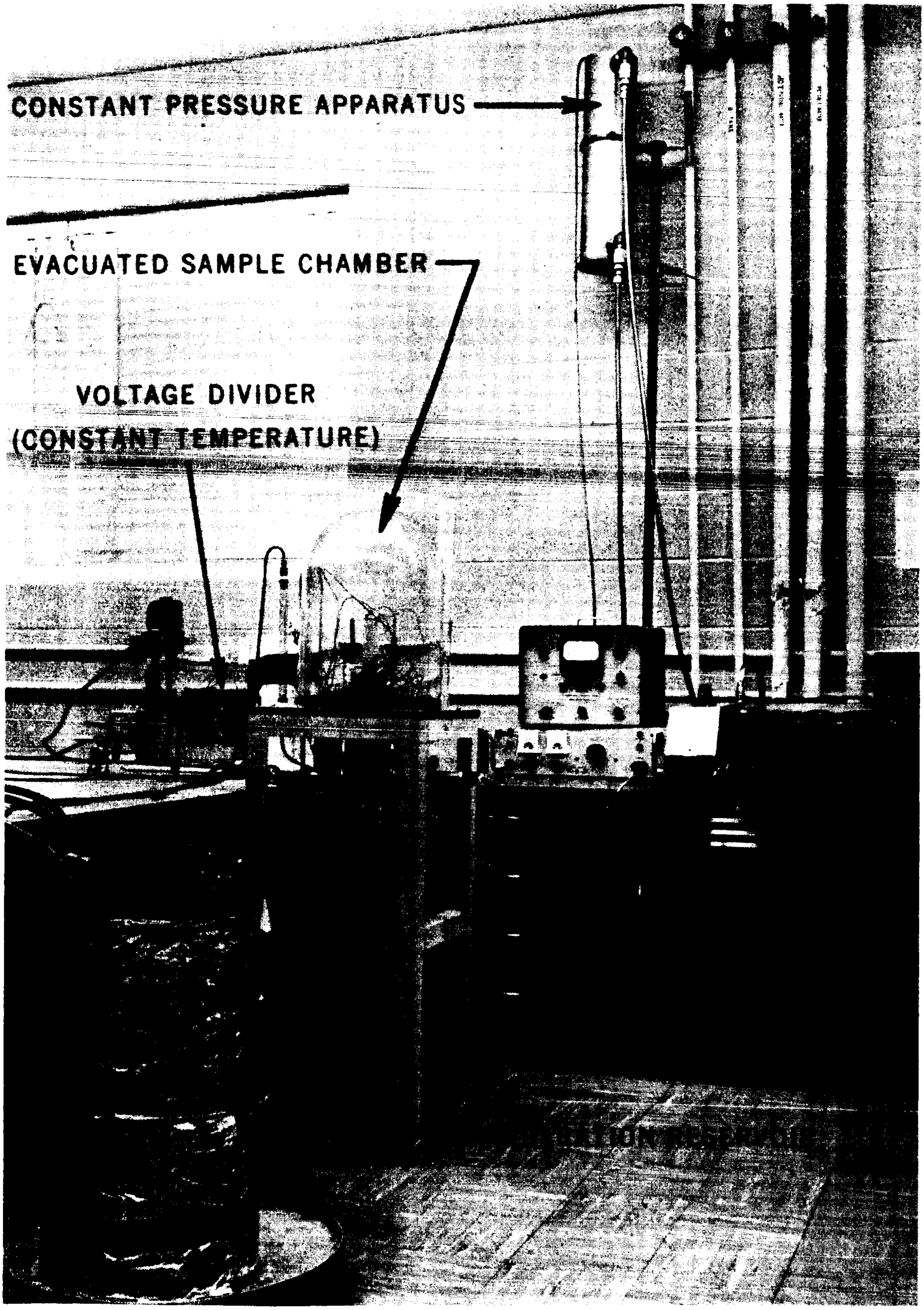


FIGURE 1 APPARATUS FOR MEASURING TEMPERATURE DROP ACROSS AN INTERFACE

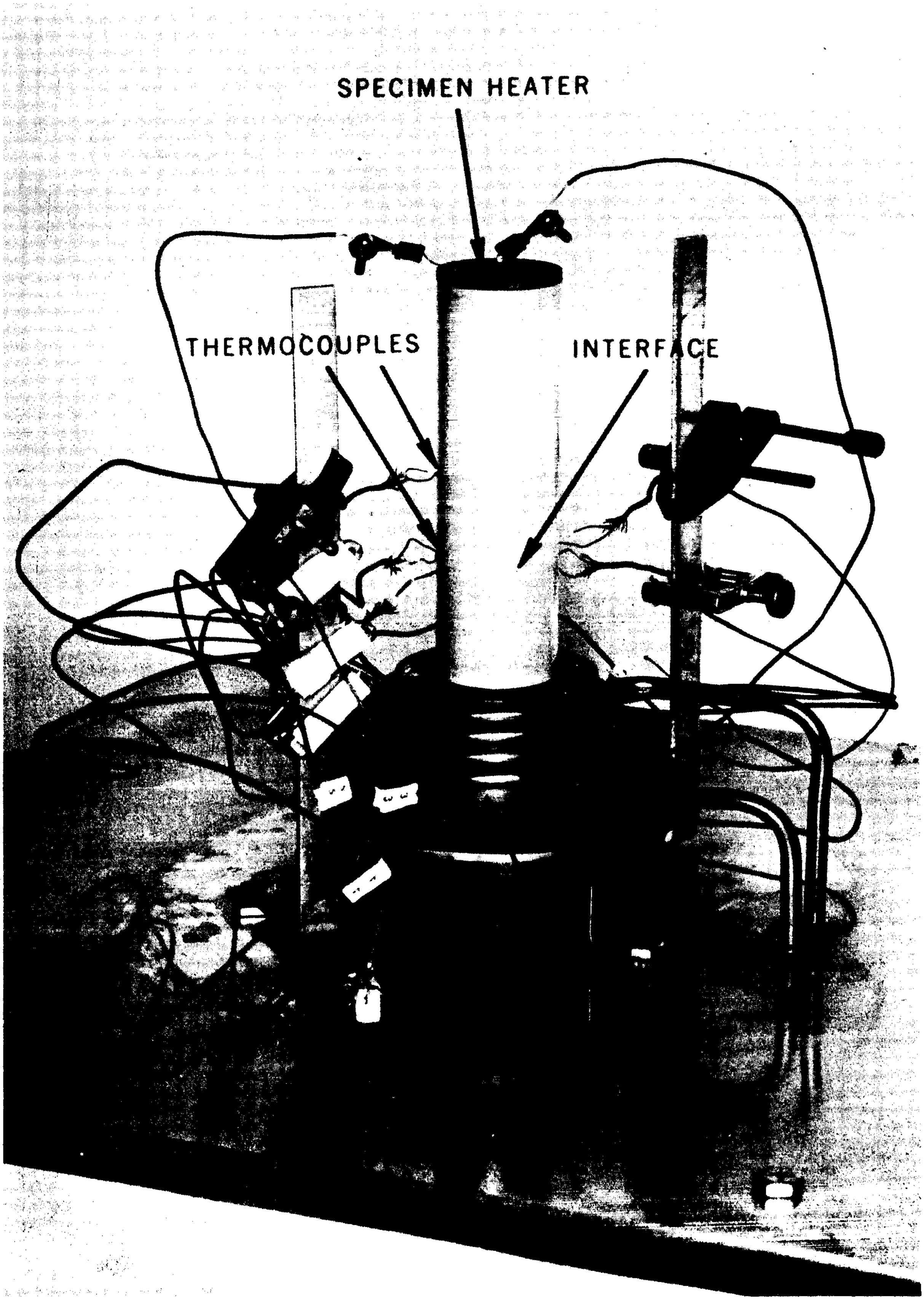
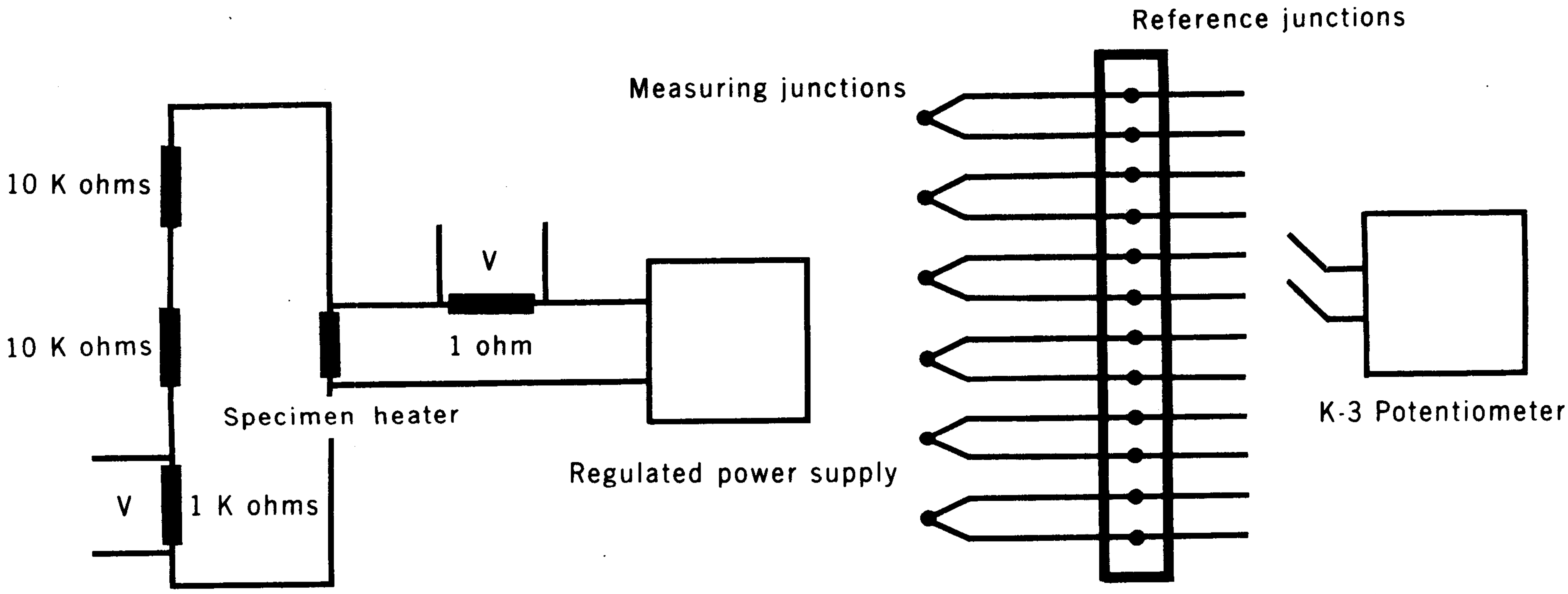


FIGURE 2 SAMPLE CHAMBER



POWER MEASURING CIRCUIT

TEMPERATURE MEASURING CIRCUIT

FIGURE 3 ELECTRICAL SCHEMATIC

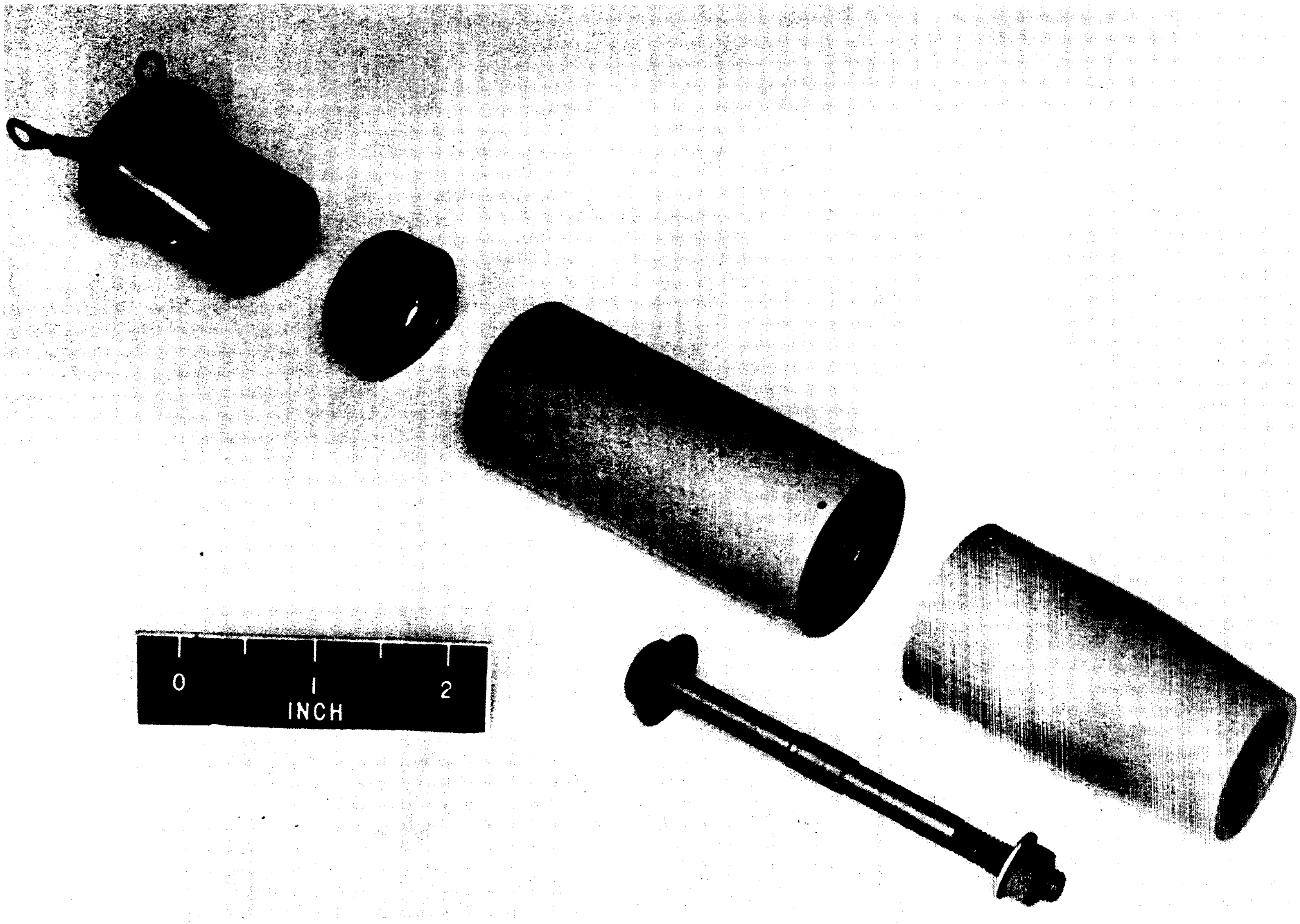


FIGURE 4 EXPLODED VIEW OF SPECIMEN AND HEATER

Table I

2024-T4 Aluminum Without Surface Treatment

Torque (in-lbs)	Pressure (torr)	Power Input (watts)	Av Δt(°F)
20	10^{-7}	10	11.05
40	10^{-7}	10	6.96
40	10^{-7}	20	15.4
60	10^{-7}	10	4.9
60	10^{-7}	20	10.86
80	10^{-7}	10	3.9
80	10^{-7}	20	8.16
90	10^{-7}	10	3.4
90	10^{-7}	20	8.6
110	10^{-7}	10	3.1
110	10^{-7}	20	7.83
130	10^{-7}	10	2.53
130	10^{-7}	20	6.93
170	10^{-7}	10	2.7

Table II

6061-T6 Aluminum Without Surface Treatment

Torque (in-lbs)	Pressure (torr)	Power Input (watts)	Av Δt (°F)
50	10^{-7}	10	0.9
50	10^{-7}	20	3.26
50	10^{-7}	40	4.61
100	10^{-7}	10	0.45
100	10^{-7}	20	0.6
100	10^{-4}	20	0.9
100	10^{-4}	40	4.2
150	10^{-7}	10	0.5
150	10^{-7}	20	0.9
150	10^{-7}	40	1.46
150	10^{-4}	10	0.63
150	10^{-4}	20	1.06
150	10^{-4}	40	1.7

Table III

Anodized 6061-T6 Aluminum

Torque (in-lbs)	Pressure (torr)	Power Input (watts)	Av Δt (°F)
50	10^{-6}	10.03	8.73
50	10^{-4}	10.04	8.42
50	10^{-6}	19.87	14.05
50	10^{-4}	19.89	14.32
50	10^{-6}	39.86	25.87
50	10^{-4}	39.90	26.04
100	10^{-6}	10.03	4.75
100	10^{-4}	9.94	4.69
100	10^{-6}	19.93	9.41
100	10^{-4}	19.93	9.36
100	10^{-6}	40.85	17.52
100	10^{-4}	40.84	17.35
150	10^{-6}	10.10	3.38
150	10^{-4}	10.10	3.45
150	10^{-6}	19.87	6.99
150	10^{-4}	19.90	6.84

Table IV

Anodized 6061-T6 Aluminum with Bare Interface

Torque (in-lbs)	Pressure (torr)	Power Input (watts)	Av Δt (°F)
50	10^{-7}	10.02	0.65
50	10^{-4}	10.05	0.73
50	10^{-4}	19.86	1.39
50	10^{-6}	19.87	1.40
50	10^{-7}	20.08	1.31
50	10^{-7}	39.99	2.48
50	10^{-4}	39.98	2.60
100	10^{-7}	9.98	0.48
100	10^{-4}	9.99	0.55
100	10^{-7}	20.05	0.92
100	10^{-4}	20.04	1.16
100	10^{-7}	40.23	2.34
100	10^{-4}	40.23	2.32
150	10^{-6}	9.91	0.63
150	10^{-4}	10.00	0.66
150	10^{-6}	20.00	1.25
150	10^{-4}	20.01	1.15
150	10^{-6}	40.15	2.56
150	10^{-4}	40.23	2.59

Table V

6061-T6 Aluminum With Alodined Surface Mated to Almag 35

Torque (in-lbs)	Pressure (torr)	Power Input (watts)	Av Δt (°F)
50	10^{-6}	40.18	6.85
100	10^{-6}	40.19	4.83

Table VI

6061-T6 Aluminum With Anodized Surface Mated to Almag 35

Torque (in-lbs)	Pressure (torr)	Power Input (watts)	Av Δt (°F)
50	10^{-6}	40.21	12.75
100	10^{-6}	40.29	8.44

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The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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