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CONTRACT REQUIREMENTS	CONTRACT ITEM	MODEL	CONTRACT NO.	DATE
			NAS 8-27793	

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REPORT

CR-123552

NO. HPM-2 DATE: 11-24-71

THERMAL TEST PLAN FOR LARGE

VARIABLE CONDUCTANCE HEAT PIPE

CODE 26512

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DATE	REV. BY	REVISIONS & ADDED PAGES	REMARKS

(NASA-CR-123652) THERMAL TEST PLAN FOR LARGE VARIABLE CONDUCTANCE HEAT PIPE F. Edelstein (Grumman Aerospace Corp.) 24 Nov. 1971 15 p CSCL 20M

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GRUMMAN AEROSPACE CORPORATION

ENG. 344

1.0 Introduction

In compliance with Task C of contract number NAS 8-27793, this test plan documents the procedure to be followed in determining the thermal performance of Huntsville's variable conductance heat pipe. The nominal one inch diameter aluminum pipe is a cold reservoir type whose overall length is nine feet. It has a capacity of 2 to 4 Kw's equivalent to 8 to 16 Kw-Ft and an overall temperature control range of 50 to 95°F. Initial tests will be conducted with the pipe charged with ammonia to determine its capacity limits. Following introduction of the non-condensible gas (nitrogen), the variable conductance features of the pipe will be exercised.

2.0 Test Objectives

There are three primary test objectives:

2.1 Demonstrate achievement of the basic design requirements outlined below:

2.1.1 Maximum thermal transport capacity shall be equal to 2 to 4 kilowatts equivalent to approximately 8 to 16 kilowatt-feet.

2.1.2 Provide a fully operative to fully shut off condenser length at evaporator outside wall temperatures of approximately 95 to 50°F and a reservoir temperature range of 40°F to -40°F.

2.2 Evaluate operational characteristics, such as pipe start-up and transient response to changes in load and environment.

2.3 Conduct tests to allow comparison between results and analytical predictions.

A fourth objective, beyond the scope of the present contract, will be considered pending completion of the primary objectives, and evaluation of possible schedule and manpower impacts.

2.4 Evaluate pipe performance under asymmetrical heat input and output conditions that simulate spacecraft use.

3.0 Test Article

The item to be tested is the 1st deliverable heat pipe specified in the contract, a sketch of which is shown in Figure 1. It has an aluminum outer envelope consisting of a nominal 46 inch evaporator, 46 inch condenser and a 147 cubic inch reservoir. The wick consists of fine radial grooves machined into the aluminum wall and a nine foot long stainless steel artery fabricated from mesh screen. Ammonia is used as the working fluid and nitrogen as the non-condensible gas. Further details of the test article can be found in Drawings AD 508-1000 and AD 508-1001.

4.0 Test Setup

The pipe will be setup as shown in the test schematic in Figure 2. A nichrome strip heater is installed uniformly around the evaporator along a length of $45\frac{1}{2}$ inches. The heater is symmetrically divided between each half of the evaporator (heater #1 and heater #2). In addition, leads to the first 6 inch heater length are provided. See Figure 3 for heater schematic. Power will be supplied through a 230 volt, 30 ampere AC power supply controlled through a variac. Volt and ampere meters will be used to monitor the power. An automatic power shutdown circuit will be installed which monitors evaporator temperature and interrupts power in the event of evaporator dryout.

Temperature control of the reservoir is provided by placing the reservoir in a CO_2 chamber capable of temperature control between $-100^{\circ}F$ and $425^{\circ}F$. Condenser cooling is provided through a water spray bath. Thermocouple instrumentation is shown in Figure 4. Attachment of thermocouples to the pipe is achieved by mechanically holding the bead against the pipe wall using a nylon tie strap. T/C leads are run along the pipe to minimize conduction losses. Temperature readout will be accomplished through two 24 point Bristol recorders.

5.0 Test Procedure

The procedure for four test sequences will be described below:

- Burnout vs. tilt for single fluid HP
- Performance map of VCHP
- Operational characteristics of VCHP
- Asymmetrical heat input and output

5.1 Burnout vs. Tilt for Single Fluid

5.1.1 The pipe will be charged only with ammonia and configured as shown in Figure 2 except that the reservoir will be insulated. Heaters #1 and #2 will be wired in parallel to provide uniform load over the entire evaporator area.

5.1.2 "Level" the pipe use leveling shims. Beginning of evaporator should be approximately 1/16 inch above end of condenser to allow for any excess fluid accumulation in the reservoir.

5.1.3 Turn on condenser cooling and allow pipe temperatures to stabilize.

5.1.4 Apply load in steps of 100 to 500 watts allowing the pipe to stabilize between steps. Continue to load pipe until pipe dryout or power supply limit is reached.

5.1.5 Repeat the above procedures at tilts of 0.5, 1.0, and 1.5 inches measured from beginning of evaporator to end of condenser ($\sim$ 8 feet).

5.2 Performance Map of VCHP

5.2.1 Pipe will be charged with ammonia and nitrogen and configured as shown in Figure 2. Heaters #1 and #2 will be wired in parallel to provide uniform load over the entire evaporator area.

5.2.2 Tests will be run with evaporator end approximately 1/16 inch above condenser end.

5.2.3 Adjust reservoir temperature to approximately 40°F. Turn on cooling water and allow pipe temperatures to stabilize.

5.2.4 Apply a step power load of between 100 and 500 watts. Continue to increase load in gradual steps, recording data at approximately five stable temperature points. Increase power until condenser is fully operative.

5.2.5 Reduce power in gradual steps, recording data at stable temperature points. At low power levels use small step changes to determine the minimum load necessary to just shut off the condenser.

5.2.6 Repeat above procedures at two additional reservoir temperatures of approximately 0°F and -40°F. At low reservoir temperatures the interface between the active and inactive portions of the condenser may be difficult to detect because the cooling water temperature ($\sim$55°F) and evaporator temperature ($\sim$60°F) are nearly the same. In this event it may be necessary to use a lower cooling water temperature (ice water) or raise the evaporator temperature via an increase in reservoir temperature.

5.2.7 During above runs, the reservoir should be maintained at a near constant temperature by adjusting the chamber CO_2 temperature control.

5.3 Operational Characteristics of VCHP

5.3.1 Pipe will be configured as in paragraphs 5.2.1 and 5.2.2. The reservoir temperature will be adjusted and maintained at approximately 40°F, and the cooling water turned on.

5.3.2 A number of runs will be made to determine the transient and operational characteristics of the pipe. The aim of each run or test series is outlined below.

a) Start-up Loads - apply various start-up loads to the pipe to evaluate the maximum load that can be accommodated and the resulting transient response of the pipe.

b) Step Increase - with the pipe operating at some steady partial load condition, evaluate the maximum step increase that can be accommodated.

c) Step Decrease - with the pipe operating at some steady partial load condition, evaluate the maximum step decrease that can be accommodated without depriming the tunnel.

d) Reservoir Temperature Change - with pipe operating at some steady partial load condition, change reservoir temperature as rapidly as is possible and evaluate response of pipe.

5.4 Asymmetrical Heat Input and Output

5.4.1 Pipe will be configured as in paragraphs 5.2.1 and 5.2.2 except as follows:

a) only one heater (#1 or #2) will be energized

b) only one side of the condenser cooling spray will be activated.

5.4.2 Pipe performance will be evaluated as described in paragraph 5.2 except that only one constant reservoir temperature run will be made.

6.0 Data Acquisition

Data from the power meters and temperature recorders will be transcribed to data sheets shown in Figure 5.

The data recorded on the first sheet facilitates rapid evaluation of overall pipe performance. This includes 24 thermocouples and power readings. The second data sheet tabulates the remaining pipe temperatures.

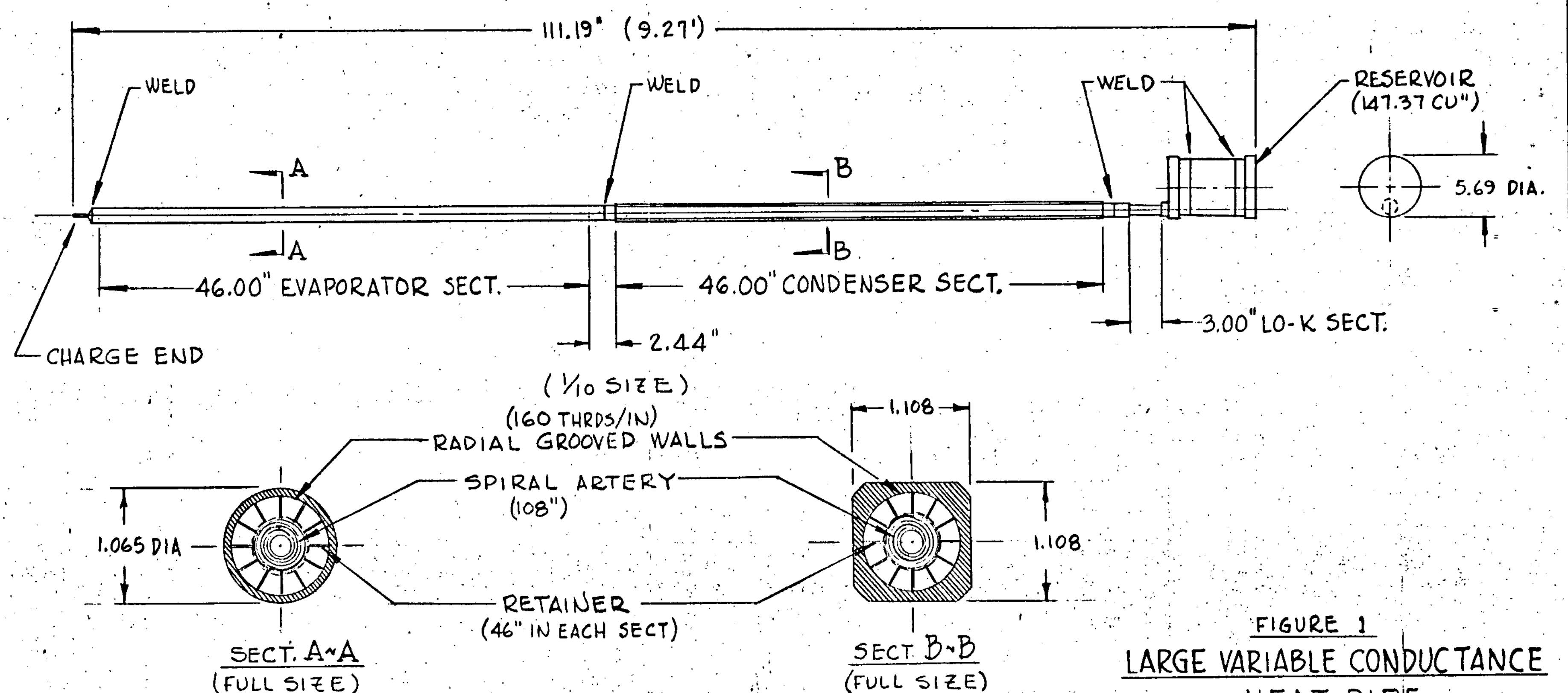

FIGURE 1
LARGE VARIABLE CONDUCTANCE HEAT PIPE

CONTRACT # NAS 8-27793

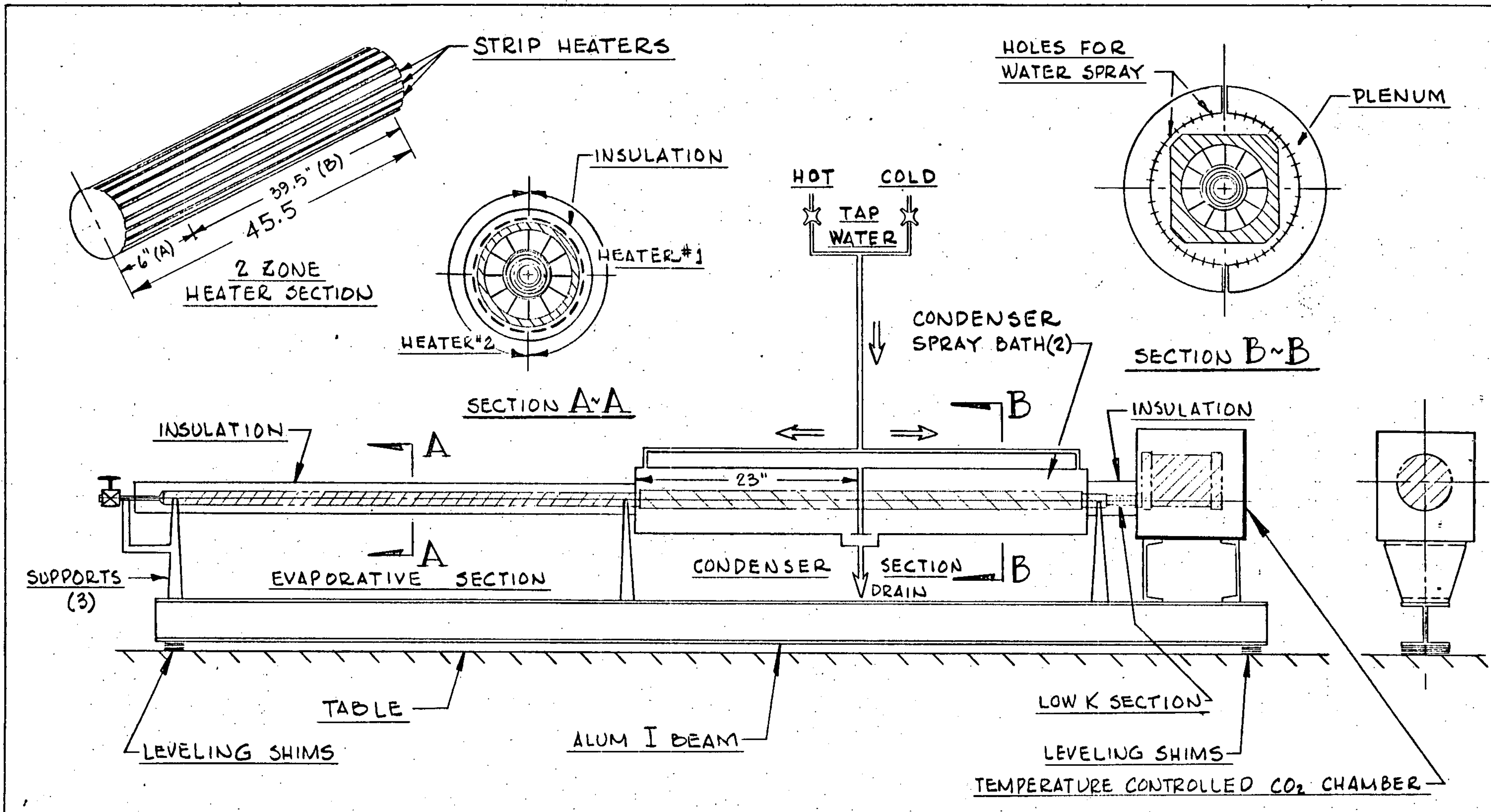

FIGURE 2

TEST SCHEMATIC FOR LARGE VARIABLE CONDUCTANCE HEAT PIPE

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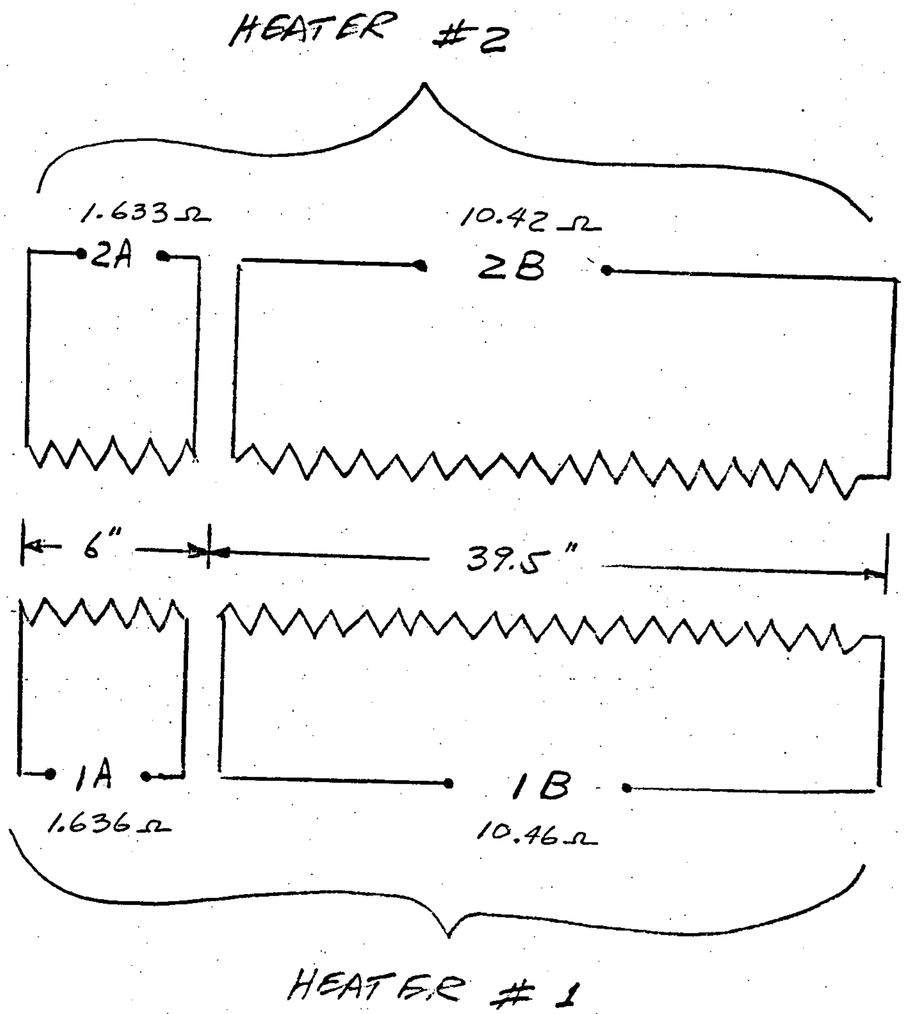
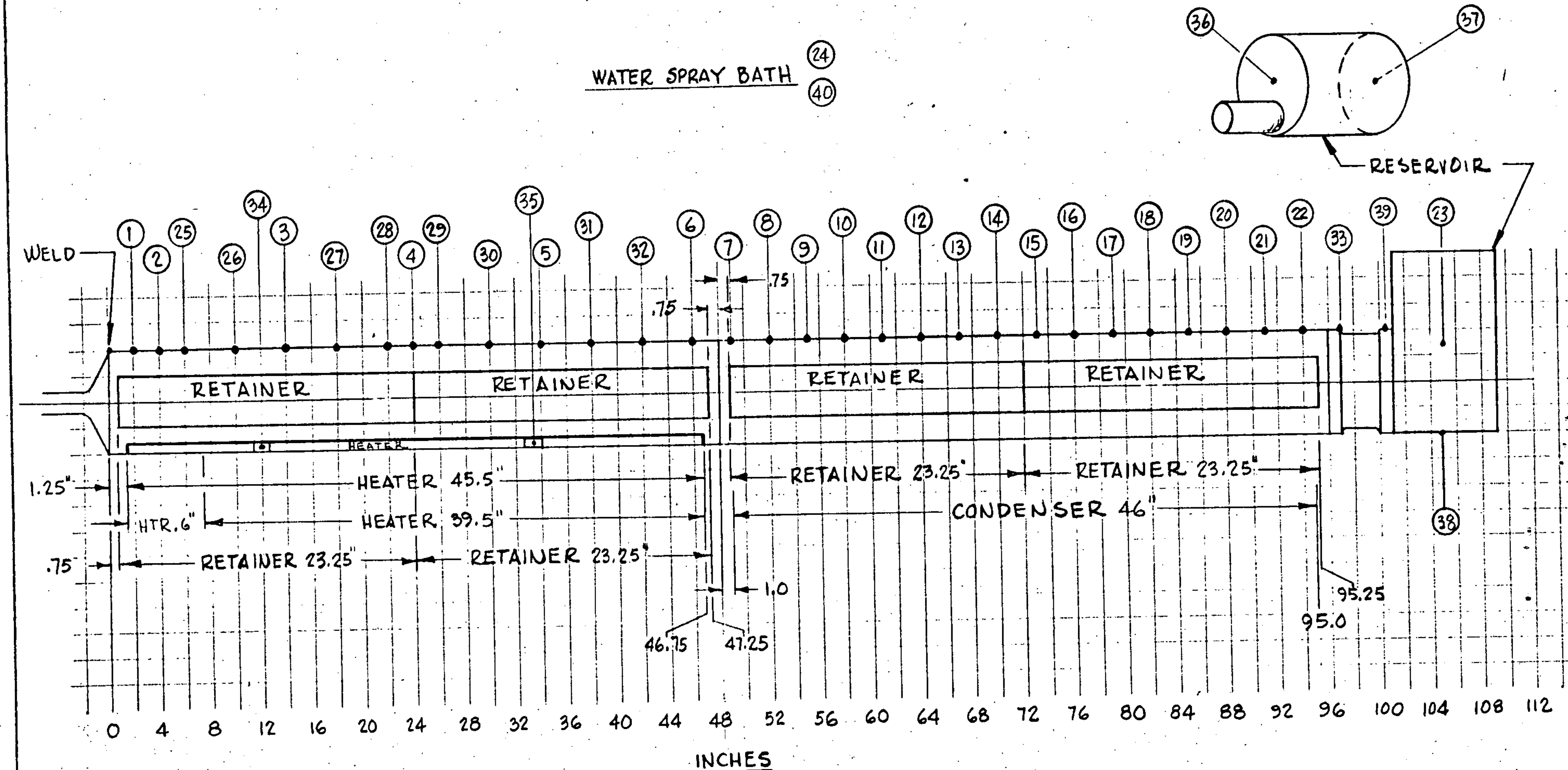


HEATER #1 = $R_{1A} + R_{1B}$ = 12.096 ohms
HEATER #2 = $R_{2A} + R_{2B}$ = 12.053 ohms

FIGURE 3 HEATER SCHEMATIC



NOTES:
1. PIPE T/C POSITIONS @ 3 O'CLOCK POSITION LOOKING TOWARD RESERVOIR.
2. SYMBOLS:
- • PIPE T/C
- ⊡ HEATER T/C
- ⊙ WATER BATH

FIGURE 4
THERMOCOUPLE LOCATIONS
LARGE VARIABLE CONDUCTANCE
HEAT PIPE

CONTRACT # NAS 8-27793

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NASA/MSFC Large Variable Conductance Heat Pipe

Test Condition: ______ Date ______ Sheet ______ A

Time														
Voltage														
Current														
Power, Watts														
Tilt, Inches														
Location	T/C No.													
	1													
	2													
	3													
Evaporator	4													
	5													
	6													
Transport	7													
	8													
	9													
	10													
	11													
	12													
	13													
	14													
Condenser	15													
	16													
	17													
	18													
	19													
	20													
	21													
	22													
Reservoir	23													
Water Spray	24													

FIG 5

Location	T/C No.													
	25													
	26													
	27													
Evaporator	28													
	29													
	30													
	31													
	32													
Low K (C)	33													
Low K (R)	39													
Heater	34													
Heater	35													
	36													
Reservoir	37													
	38													
Water Spray	40													

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