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ULTRA HIGH TEMPERATURE
INSTRUMENTATION AMPLIFIER
COMPONENTS FINAL REPORT

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MRI-2942-F2

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September 1977

Prepared for:

Energy Research and Development Administration
Division of Geothermal Energy

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ULTRA HIGH TEMPERATURE
INSTRUMENTATION AMPLIFIER

Components Final Report
September 1976 - March 1977

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Sept. 1977

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Mechanics Research, Inc.
Santa Monica, California (USA)

Prepared for

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
Division of Geothermal Energy

ULTRA HIGH TEMPERATURE
INSTRUMENTATION AMPLIFIER

COMPONENTS FINAL REPORT, SEPTEMBER 1976 - SEPTEMBER 1977

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TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
1.0 Introduction.	1
1.1 Objectives of Component Testing	1
1.2 Scope of Component Testing.	1
1.3 Brief History of Component Testing.	1
1.4 Information Presented in this Report	3
2.0 Summary of Component Tests.	4
2.1 Ceramic Vacuum Tubes.	4
2.2 Resistors	4
2.3 Capacitors.	5
2.4 Insulated Wire.	5
2.5 Circuit Boards.	6
2.6 Terminals/Connectors.	6
2.7 Other Components Tested	7
3.0 Ceramic Vacuum Tubes	8
3.1 Tubes Chosen for Evaluation	8
3.2 Tube Characteristics	10
3.3 Test Results.	11
3.4 Conclusions	14
4.0 Resistors	16
4.1 Items Tested.	16
4.2 Tests Performed	16
4.3 Test Results.	17
4.4 Conclusions	22
5.0 Capacitors	25
5.1 Items Tested.	25
5.2 Tests Performed	25
5.3 Test Results.	25
5.4 Conclusions	27
6.0 Wire.	28
6.1 Items Tested	28
6.2 Tests Performed	28
6.3 Test Results.	28
6.4 Conclusions	28

TABLE OF CONTENTS, Continued

<u>Section</u>	<u>Page</u>
7.0 Circuit Boards.	29
7.1 Items Tested	29
7.2 Tests Performed	29
7.3 Test Results	29
7.4 Conclusions	
8.0 Terminals/Connectors.	30
8.1 Items Tested.	30
8.2 Tests Performed	30
8.3 Test Results.	31
8.4 Conclusions	31
9.0 Other Components.	32
9.1 Items Tested.	32
9.2 Test Performed and Results Obtained.	32
9.3 Conclusions	33
10.0 References	34
APPENDIX A -- CERAMIC VACUUM TUBE TEST DATA	A1 - A38
APPENDIX B -- RESISTOR TEST DATA.	B1 - B4
APPENDIX C -- CAPACITOR TEST DATA	C1
APPENDIX D -- COMPONENT TEST RECORD - CHRONOLOGICAL ORDER	D1 - D3

1.0 Introduction

1.1 Objectives of Component Testing

The primary objective of contract E (04-3) - 1330, Ultra High Temperature Electronic Amplifier was to develop a downhole instrumentation amplifier to support geothermal well logging without thermal protection at temperatures up to 500°C. The primary objective of the components tests was to obtain all the components required for the amplifier with the capability of operating satisfactorily over the temperature range of 25-500°C for long periods of time. Additional objectives were to obtain small size components in order to reduce the overall package size and obtain components at reasonable costs.

1.2 Scope of Component Testing

The components tested over the 25-500°C temperature range include ceramic vacuum tubes, resistors, capacitors, insulated hook-up wire, circuit boards, terminals, connectors, feedthroughs, thermal switch, magnet wire, and high temperature coatings and cements.

1.3 Brief History of Component Testing

The above components were tested on a daily basis from 2/9/76 to 7/13/77. The tests consisted of measuring the resistance, capacitance and other parameters of interest for each component at room temperature each morning, exposing them to a temperature of 500° (930F) all day in the oven, measuring the parameters at 500°C at the end of the day and shutting down the oven at night. Values of ΔR_T and ΔC_T , etc. were calculated where ΔR_T = percent change in resistance over the temperature range from 25 to 500°C and ΔC_T = percent change in capacitance over this temperature range. The target values in these tests were $\Delta R_T < 1\%$ and $\Delta C_T < 10\%$.

The following items were selected for use in the prototype amplifier as a result of these tests:

1. GE ceramic vacuum tubes, Type 7462, .33 dia. x .5" long.
2. Dale Electronics Evanohm wire wound resistors, Type RS-5, .31 dia. x 1" long. with high temperature ceramic coating and nickle wire leads. $\Delta R_T < 1\%$ after baking at 650°C for 1 day. These were used for the 11 resistors in the amplifier where the power $> .16\text{W}$.
3. Caddock Electronics flat, thick film resistors, Type TK 133, .2 X .25 X .1", uncoated, with 2 x 10 mil gold leads. $\Delta R_T < 1\%$ if power does not exceed .16W. These were used for the 15 low power resistors required for the amplifier.
4. Gulton Industries hookup wire consisting of 22 gage solid nickle wire with Duroflex I insulation, rated for continuous operation at 1000°F .
5. Mykroy Ceramics Corp. circuit boards made of 1/8" thick Mykroy 1100 glass bonded mica, rated for continuous operation at 1100°F . These were cut by means of a band saw from standard 1/8" x 6" dia. discs and drilled by means of a carbide drill.
6. Interconnection terminals for the circuit boards fabricated from 3/16" dia. x 5 mil thick nickle foil spot welded to 1/8" dia. x 1/8" long. stainless steel rods in the holes in the circuit boards (item 5).
7. A 3" dia. x 7 3/4" long 4130 steel housing rated at 7500 psi at 500°C .
8. H and W Products (Houston) electrical feedthrough for the housing, Type A 1107, manufactured by Alberox Corp. in New Bedford, Mass. They are 1/4" dia x 1 3/4" long. and are made of alumina and Kovar alloy. They are rated for 30K psi and 500°C and have > 200 Megohms resistance between the center pin and outer shell at 500°C .

9. A Conax MK-062-A all metal swage fitting and .062" dia. stainless steel pinch-off tube to permit the housing to be purged and filled with N_2 in the event that an inert atmosphere was required for the El Menco capacitors, which, it turned out were not required for the amplifier.

1.4 Information Presented in this Report.

In the following section 2.0 a summary of all components tested is presented. In section 3.0 to 9.0 details of the tests are presented for all components. Tube test data are presented in Appendix A. Values of ΔR_T and ΔC_T versus time are presented in Appendix B and C respectively, for the resistors and capacitors tested. A chronological list of components tested is given in Appendix D, showing the test number, start date and completion date for the tests.

2.0 - Summary of Component Tests

Table 2.0 Summary of Test Results

Note: ΔR_T = % Change in resistance from 25 to 500°C (target < 1%)
 ΔC_T = % Change in capacitance from 25 to 500°C (target < 10%)
DF = % Dissipation factor at 500°C (target < 10%)

Component	Test Results
2.1 - Ceramic Vacuum Tubes	
1. G.E. Ceramic vacuum tubes, types 7462, 7625 and Y2191 (.33 dia. x .5" long.); 7296 and 7588 (.5" diam. x .8" long.)	<u>Type 7462 was selected for use in the amplifier.</u>
2.2 - Resistors	
2. Dale Evanohm wirewound resistors, type RS-5 (.312" dia. x 1" long.) and RS-10 (.375" dia. x 1.8" long.) with high temp. ceramic coating.	Type RS-5 selected for use in amplifier where power > .16 W. ΔR_T < 1% after 8 hrs. bake at 650°C. High values of R have very short life.
3. Dale Cupron wirewound resistors, type RS-5 with ceramic coating	ΔR_T < 1% after temperature cycling for 1 week but low resistivity results in larger size for high R.
4. Dale Kanthal A-1 wirewound resistors, type H125 with ceramic coating.	ΔR_T < 1% after 1 day bake at 500°C. Same resistivity as Evanohm but min. order = \$500 for each wire size required.
5. Caddock flat thick film resistors, type TK 133 with ceramic coating, .29 x .29 x .1"	ΔR_T < 1% after 2 days but coating cracked and resistor failed after a few more days due to use of soldered connections.
6. Caddock cylindrical thick film resistors, type MS220 (.140 dia. x .4" long.) and MS245 (.25 dia. x .5" long.), uncoated.	High ΔR_T of 4 to 5 % for one and 7 to 27% for another tested versus a target of < 1%.

Table 2.0 Summary of Test Results (continued)

Note: ΔR_T = % Change in resistance from 25 to 500°C (target < 1%)
 ΔC_T = % Change in capacitors from 25 to 500°C (target < 1%)
DF = % Dissipation factor at 500°C (target < 10%)

Component	Test Results
7. Caddock flat thick film uncoated type TK 133 (.2 x .25 x .1") resistors with 2 x 10 mil gold leads.	$\Delta R < 1\%$ if power is limited to .16W <u>This type was selected for use in the amplifier for the 20 resistors with P < .17W.</u>
8. Omitronics wirewound coated resistor, 1/8 dia. x 3/8 long.; same as for 500°F amplifier.	ΔR_T increased from 1.1% to 2.6% during 30 days of testing.
2.3 - Capacitors	
9. Sandia flat thick film capacitors, 1 x 1 x .1", C = 1000 Pf.	$\Delta C_T = 51$ to 72% and DF = 31 to 40% versus target values of < 10%
10. El Menco flat mica/silver capacitors, type MCM10, (.125 x .5 x .2"), 60 Pf.	Met objectives of ΔC_T and DF < 10% for first 9 days but then failed due to oxidation.
11. El Menco flat mica/silver capacitors, type EMJ-112 (.4" x .9" x .1")	Met objectives of ΔC_T and DF < 10% over 22 days of testing.
12. Semetex Bn/Au thin film capacitor (.3 x .3 x .1").	Excessive $\Delta C_T = 4.5$ to 61%, DF = 1.2 to 1.6% for 5 days.
13. Simmonds Precision cylindrical mica/aluminum, hemetically sealed, .5 dia. x 2.75" long., .03 Mfd (30000 Pf).	$\Delta C_T = 28$ to 51% and DF = 16 to 30%. Hemetic seal failed on 2 capacitors tested after 10 and 15 days respectively.
2.4 - Insulated Wire	
14. Gulton Industries Duroflex I insulated 22 gage solid nickle wire rated at 1000°F.	<u>Used in Prototype Amplifier.</u> Performed very satisfactorily in all component and amplifier breadboard tests.
15. Continental Wire Corp., Anaconda MG-300-20, 20 gage solid nickle wire insulated with mica tape and glass braid and rated for use at 500°C (930°F).	Performed very satisfactorily in tests. It is much lower cost than the Gulton wire (\$185 vs \$500 for 1000 ft.) but was discovered after the Gulton wire was ordered.
16. Hitemp Wires Inc. TMI wire rated at 850°F.	Tested at 930°F and insulation crumbled away after a few weeks of testing.

Table 2.0 Summary of Test Results (continued)

Component	Test Results
17. Cerro Wire Co. Rockbestos Mica-temp RSS5-304 insulated wire rated at 1200° F.	Tested at 930° F and insulation crumbled away after a few weeks of testing.
2.5 - Circuit Boards	
18. Fiberglass breadboards - 1/8" thick. Manufacturer unknown - Used from stock in MRI laboratory.	Performed very satisfactorily for this purpose during months of testing after volatiles were driven off during first day in oven at 500° C.
19. Mykroy Ceramics Corp. Mykroy 1100 machinable molded mica rated for continuous use at 1100° F.	1/8" thick x 6" dia. discs used for circuit boards in prototype amplifier. 1/4" thick discs performed very satisfactorily in use as insulators in oven during > 8 mos of component tests.
2.6 - Terminals/Connectors	
20. Co-Operative Industries 7 pin electrical connectors with glass insulators, rated at 1000° F.	The resistance between pins at 500° C decreased from 70 megohms to less than .1 Megohm during several days of testing. A resistance of > 20 Megohms is required for the amplifier.
21. H & W Products electrical feedthrough type Al107 manufactured by Alberox Corp.; alumina/Kovar alloy, 1/4" dia. x 1.75" long., rated at 30 K psi and 500° C.	The resistance between the central pin and the outer shell was > 200 Megohms over several days of testing. <u>Used in prototype amplifier.</u>
22. Interconnection terminals for the prototype amplifier circuit boards consisting of 3/16" dia. x 5 mil thick nickle foil spotwelded to 1/8" dia. x 1/8" long. stainless steel rods.	<u>Used in prototype amplifier.</u> Performed satisfactorily.

Table 2.0 continued

Component	Test Results
2.7 - Other Components Tested	
Control Products Corp. Thermal switch, type X-2, with bimetallic element probe rated at 1750°F and electrical contacts head rated at 800°F.	Tested by inserting probe in insulated housing containing electrical heater, with head exposed to 850°F in oven. Switch opened at housing inside temp. of 970°F and closed at 930°F.

3.0 - Ceramic Vacuum Tubes

Ceramic vacuum tubes were developed in Germany in 1934 and were actively promoted in the United States following World War II by the Armed Services. The high temperature capabilities of ceramic tubes have always been recognized and many of the early development types were tested in 500°C ambient temperatures. An evaluation of the suitability of commercial ceramic vacuum tubes for application to geothermal well logging is presented in Reference 1. The objective of component testing of ceramic tubes was not so much to determine if they will work in high ambient temperatures, but to obtain temperature related performance data that can be utilized in circuit design.

3.1 - Tubes Chosen for Evaluation

Two samples each of four commercial tube types, including EIA numbers 7296, 7588, 7625, and 7462, were selected for temperature testing. These tubes were chosen to permit trade-offs of temperature performance primarily in terms of amplification, transconductance, and plate power. Other important characteristics not necessarily related to temperature are filament power requirements, physical size, and cost. Table 3.1 summarizes the significant nominal characteristics of the selected commercial tube types.

In addition to the four commercial tube types, samples of a special design were ordered for evaluation. The objective of the special design was to provide a tube with both a high amplification factor and moderately high transconductance. This approach, if successful, will permit a single tube type to perform both voltage amplification and line driving functions. The design goals for the tube include:

Size:	0.33 Inch Diameter
Filament Current:	215 ma @ 6.3V
Amplification Factor:	$300 \pm 75 @ I_p = 5\text{ma}$
Transconductance:	$21,000 \pm 1000 \text{ mho} @ I_p = 10 \text{ ma}$

A total of five tubes were received from the General Electric Tube Department for evaluation. All five were within tolerance for amplification. Only one, however, was within tolerance for transconductance,

Type	Description	Heater Current Amps (6.3V)	Max. Plate Volts (Watts)	AVERAGE CHARACTERISTICS				
				Plate Volts	Plate Current	Mu	Gm M-mho	r _p ohm
7462	Miniature Triode Intended for low-noise VHF amplifier service.	.24	250 (1.1)	150	7.2	94	10,500	9,000
7625	Miniature Triode Intended for low-level audio frequency ampli- fier service.	.215	275 (0.85)	150	0.95	80	1,400	57,000
7296	Triode Intended for VHF oscil- lator or amplifier service.	.4	330 (5.5)	200	17.0	90	16,500	5,450
7588	Triode Intended for VHF ampli- fier service.	.4	300 (5.5)	200	24.0	175	45,000	3,900

Table 3.1 Ceramic Vacuum Tube Characteristics

3.2

Tube Characteristics

Ideally, the temperature performance variations, as well as power requirements and size, should be as small as possible for geothermal applications since a well log must operate over a wide range of temperatures. Performance parameters commonly used to describe electron tube operation include:

- Plate current (i_p) - current reaching the plate with constant voltages applied to the grid and plate.
- Amplification factor (μ) - variation of plate voltage with grid voltage (constant current).
- Transconductance (g_m) - variation of plate current with grid voltage (constant plate voltage).
- Dynamic plate resistance (r_p) - variation of plate voltage with plate current (constant grid voltage).

In normal operation the current is drawn from a heated cathode to the positively charged plate. In general, the hotter the cathode, the greater the current for a given grid bias and voltage difference between the plate and cathode. The normally desired operating condition for a tube is to have slightly more electrons emitted from the cathode than can be attracted to the anode so that a cloud of negatively charged electrons forms in front of the cathode and the grid has maximum effect on control of the current flow. When this condition prevails small changes in cathode temperature serve to change the electron cloud density which in effect appears as a change in cathode voltage, with respect to the grid and plate. In this case, the grid to cathode bias is more significant, and changes in cathode temperature can be cancelled by small changes in grid voltage. At high plate voltages the anode can attract all electrons emitted from the cathode, and the plate current is dependent primarily on the cathode temperature and plate voltage. This condition is referred to as temperature limited.

Results of supplemental testing of ceramic vacuum tubes are presented in Appendix A. Table A1 gives data for 13 tubes of which eight were commercial (two tubes each of four types), and five were special design. Tests were conducted at room temperature and 500°C with heater voltages of 6.3 volts (room temperature only), 5.3 volts and 4.3 volts; plate voltages of 100 and 200 volts; and grid bias of 0 volts. Current measurements were also made at other grid biases for the commercial tubes. A brief summary of the data is also given in Table 3.3.1 for convenience and to show the degree of consistency (or lack of) for characteristic change with temperature. A plot of the variation in amplification factor and transconductance for all of the tubes tested in going from room temperature and a heater voltage of 6.3 volts to 500°C and 5.3 volts is also shown on Figure 2.1.1.

As indicated on Figure 3.3 all of the tubes exhibit significant change in going from one condition to another. The two 7462 types track each other better than the rest. This characteristic can be used to advantage in differential amplifier stages.

A convenient means of correlating temperature effects is to plot plate current and transconductance versus a voltage parameter defined as $E_g + E_b/\mu$ where E_g is grid bias (normally negative), and E_b is plate to cathode potential. In theory, the plots should be straight lines on log-log paper for high plate currents indicating that current and transconductance vary as a power of the voltage parameter. Plots are presented in Appendix A for the commercial tubes at both room temperature and 500°C. From these plots it can be seen that the data does, in fact, plot as straight lines. Therefore, plate current can be expressed analytically as:

$$i_b = C(E_g + E_b/\mu)^N$$

CHARACTERISTIC CHANGE-ROOM TEMPERATURE TO 500°C
(HEATER VOLTAGE = 5.3 VOLTS)

Tube	Plate Current ($E_b=100V$)	Amplification ($E_b=100V$)	Transconductance ($E_b=200V$)
7462-1A	+ 27%	- 2%	+ 12%
7462-2A	+ 47%	- 1%	+ 77%
7625-1A	+ 52%	- 28%	- 18%
7625-2A	+ 50%	- 17%	+ 3%
7296-2A	- 16%	+ 7%	+ 6%
7588-1A	+ 24%	- 33%	- 1%
7588-2A	- 12%	- 24%	- 35%
Y2191-1B	+241%	- 41%	+ 18%
Y2191-2B	+ 14%	- 3%	+ 10%
Y2191-3B	+166%	+ 7%	+ 55%
Y2191-4B	+163%	- 2%	+ 33%
Y2191-5B	+936%	- 11%	+ 76%

Table 3.3.1 Vacuum Tube Test Data Summary
Effect of Increasing Temperature

Figure 3.3 Variation of Amplification Factor and Transconductance with Temperature

For most triodes, N should lie between 1.5 and 2.0 or greater (Reference 2). The constant C is a function of tube geometry and can, therefore, be expected to change with temperature due to thermal expansions. A summary of the current correlations derived from the test data in Appendix A is given in Table 3.3.2. It can be seen from this table that the exponent for the ceramic tubes are somewhat less than expected except for tube 7296-1A. Also, the exponent and, therefore, the slope of current characteristic increases in most cases with temperature.

A similar relationship for transconductance can be derived from the definition:

$$g_m = \left(\frac{\partial i_b}{\partial E_b} \right)_{E_g} = C \cdot N (E_g + E_b / \mu)^{N-1}$$

The test data corresponding to this correlation is shown plotted in Appendix A.

Amplification factor is a function of tube geometry and is directly proportional to the grid to plate spacing. Transconductance, on the other hand, increases as the grid to cathode distance decreases up to some maximum, whereupon, it decreases as grid to cathode spacing is further decreased. Transconductance is also proportional to a power of the plate current where amplification factor is not.

3.4 Conclusions

The net effect of the above observations is that there is no clear cut generalization that can be made as to the effect of high ambient temperature on tube performance. In general, the net plate current should increase with temperature with a given heater current since the cathode will be hotter. Conversely, the effect of high ambient temperature can be cancelled by lowering heater voltage. Test Results indicate that this is normally true. It had been expected that amplification factor would increase since thermal expansion should cause the grid to anode distance to increase. Test results showed, however, that for a fixed heater current the amplification factor in most cases either stayed relatively constant or decreased. Transconductance seemed more likely to increase with temperature as expected.

Tube	Room Temperature $E_f = 6.3 \text{ V}$	Room Temperature $E_f = 5.3 \text{ V}$	500°C $E_f = 5.3 \text{ V}$
7462-1A	$i = .0074(X)^{1.28}$	$i = .0050(X)^{1.34}$	$i = .0055(X)^{1.42}$
7462-2A	$i = .0096(X)^{1.15}$	$i = .0053(X)^{1.17}$	$i = .0072(X)^{1.19}$
7625-1A	$i = .0017(X)^{1.05}$	$i = .0013(X)^{1.26}$	$i = .0015(X)^{1.0}$
7625-1A	$i = .00125(X)^{1.17}$	$i = .0011(X)^{1.26}$	$i = .0014(X)^{1.03}$
7296-1A	$i = 0.22(X)^{1.77}$	$i = .10(X)^{2.25 *}$	$i = .09(X)^{2.4 *}$
7296-2A	$i = 0.25(X)^{1.13}$	$i = .0195(X)^{1.26}$	$i = .017(X)^{1.49}$
7588-1A	$i = .060(X)^{1.20}$	$i = .037(X)^{1.29}$	$i = .046(X)^{1.45}$
7588-2A	$i = .039(X)^{0.89}$	$i = .031(X)^{1.21}$	$i = .022(X)^{1.26}$

* $E_f = 4.3 \text{ V}$

Table 3.3.2 Current Correlations Derived From Test for Commercial Tube Types
($X = E_g + E_b/\mu$)

4.0 - Resistors

4.1 - Items Tested

The following 3 kinds of resistors were tested:

1. Dale Electronics wire wound with a high temperature ceramic coating.
Three different kinds of wire were tested: Evanohm, Cupron and Kanthal Al. Two different sizes of resistors were tested: Type RS-5 (.312 dia. x 1" long.) and Type RS-10 (.375 dia. x 1.8" long.).
2. Caddock Electronics thick film. Two different kinds were tested as follows:
 - A. Flat type TK 133 with a ceramic coating measuring .3 x .3 x .1: and uncoated measuring .25 x .2 x .1"
 - B. Cylindrical uncoated thick film type MS220 (.140 dia. x .4" long.) and MS 245 (.25 dia. x .5: long.)
3. Omitronics wire wound with a ceramic coating. These were the same as the resistors used in the 500^oF amplifier and were .125 dia. x 3/8" long.

4.2 - Tests performed

All resistors were tested by measuring the resistance at room temperature each morning, heating to 500^oC and holding at that temperature in the oven all day, measuring the resistance at 500^oC at the end of the day and then shutting down the oven overnight. Resistance measurements were made by means of a General Radio Impedance Bridge, Mod. 1656. The resistors were connected to stainless steel screw/nut/washer terminals mounted in fiberglass breadboards. The fiberglass is not rated for 500^oC (930F) but it performs satisfactorily

after the volatiles are driven off during the first day in the oven. The test breadboards were laid on 6" dia. x 1/4" thick Mykroy molded mica disks rated at 1100°F to insulate them from the metal floor of the oven. Gulton Industries "Duroflex I" 1000°F insulated 22 gage nickle wire leads were brought outside the oven through penetrations in the sides and top.

Values of ΔR_T were calculated for all tests where ΔR_T = % change in resistance from room temperature to 500°C for each day's test. The target value in the tests was < 1%.

4.3 - Test Results

1. Dale Electronics wire wound resistors:

Values of ΔR_T are summarized in Appendix B for the total of 3 months of temperature cycling tests from 25 to 500°C for the three kinds of resistance wire tested. It can be seen that the Evanohm which started out with a ΔR_T of 1.1 to 1.6% have been improving with time, decreasing to less than 1% after a total of 18 days (1 month of calendar time) of temperature cycling. They continued to improve, varying between 0 and .5% after another 7 days of cycling.

2. The Cupron wire resistor ΔR_T values decreased from 1.7 to < 1% after only 6 days of cycling except for a few cases later which occurred for all 4 Cupron resistors under test and which were believed to be due to a bad connection for the common ground wire. They continued to improve, reaching values below .6% after a total of 2 calendar months of cycling.

3. The Kanthal A-1 wire resistors ΔR_T was much less than 1% after the first day over the total of nearly 2 months of testing. It was decided to use the Kanthal resistors in the amplifier but unfortunately Dale Electronics stocks only the Evanohm and Cupron wire and there would be a minimum charge of \$300 for each wire size required and an excessively long delay in delivery. The resistivity of the Cupron is lower than for the Evanohm which results in larger resistors for the high R values. This narrowed the choice of wire-wound resistors for use in the amplifier to the Evanohm.

Efforts were made to find ways to stabilize the Evanohm quickly instead of by the slow process of temperature cycling over 1-2 months. The first stabilization procedure tried was baking at 100°F for 8 hours. After seven subsequent days at 500°C the change in resistance from room temperature to 500°C had decreased from about 5% to about 2%. Power was applied to one of the Evanohm resistors while at 500°C. Ten watts were successfully dissipated in the resistor. After one day of 10 watts application at 500°C, the change in resistance from room temperature to 500°C was reduced to less than 1% as shown in Appendix B, test #86. This showed that high power dissipation was possible and that it also appears to stabilize the ΔR_T . In a subsequent test the surface temperature of an Evanohm resistor was measured by means of a thermocouple while subjected to 10W power in an ambient of 500°C (930°F). It was found that the surface temperature was 1200°F. Additional Evanohm resistors were subjected to a 1200°F bake cycle for one day and it was found that this reduced the ΔR_T to <1% without the necessity of applying 10W power. A total of 350 Dale Evanohm resistors was ordered on 4/29, consisting of an average of 15 of each of 23 resistance values from 1Ω to 250K ohms. They were received on 5/25 and one of each resistance value was baked 7 hours and the ΔR_T was measured over the next 16 days. The results are summarized in Table 4.3 below in the order of decreasing resistance values.

It can be seen that the ΔR_T values were less than 1% in most cases with maximum values not much greater than 1% or they were decreasing with time to less than 1% except for the values below 40 ohms. It was found that the latter were Cupron resistors as it is standard procedure to use Cupron for the low values due to its lower resistivity.

The remaining resistors above 40 ohms were baked at 650°C for 7 hours for use in the amplifier breadboard tests. During all these tests the resistor leads were corroding badly and the connections were failing. It was found that all 350 resistors had "Copperweld" leads instead of the nickel leads on the resistors obtained previously. Copperweld is tinned, copper sheathed steel which corrodes badly at high temperature. Also, many of the resistors began to fail open in the breadboard circuits at room temperature as shown in table 4.3.1. Most of the failures occurred in the high resistance values.

Table 4.3.1 - Failures of baked Evanohm resistors with copperweld leads in breadboard circuits at 25C

Resistance Value						
	250K	200K	100K	70K	40K	10K
Number failed	23	14	2	3	6	2
Number received	30	15	15	11	12	13
% failed	77	93	13	27	50	15

The failed resistors were returned to Dale Electronics for examination in their failure analysis laboratory. There the ceramic coating was dissolved away and the wire was examined under a 950 to 1900 power microscope. Each resistor had one or more broken turns of wire which are believed to be due to brittle fracture and stress corrosion of the very small wire diameter. The cause was believed to be the 1200°F bake temperature and differences in thermal expansion of the wire, alumina tube and ceramic coating. The wire diameter is only .00050" for the 250K RS-10 resistors and is .00055 for the 200K RS-10 and the 70K RS-5 resistors.

In the meantime a new set of 160 Dale Evanohm resistors with nickel leads was ordered on 6/16/77 and received on 6/30. These consisted of 10-30 each of 13 resistance values from 100Ω to 250K ohms. On 7/1, 3 to 10 each of the 1K to 250K were baked at 1200F for 8 hours for use in the amplifier. Two to three each of these were monitored thereafter for ΔR_T for the next 2 days. One of each of these R values was not baked and was monitored for comparison. The results are summarized in Table 4.3.2.

Table 4.3.2 - Dale Evanohm resistors with nickel leads - R_T for 1200F bake versus no bake

Test no.	Norm. R, K	Baked at 1200F	<u>% ΔR_T as of:</u>		
			<u>7/6</u>	<u>7/7</u>	<u>7/8</u>
1	1	↓	1.4	1.0	1.0
2	1		1.4	1.0	.74
3	10		2.2	1.8	1.8
4	10		2.2	1.8	1.8
5	40		1.4	.95	.92
6	40		1.3	.90	.91
7	70		1.2	.80	.77
8	70		1.0	.56	.52
9	100		.68	.58	.29
10	--				
11	100		.58	.19	0
12	200		.67	.14	.19
13	200		.68	.29	.29
14	250		1.0	.58	.42
15	--	No 1200F			
16	--	<u>bake</u>			
17	1	↓	6.2	1.6	1.1
18	10		4.2	1.5	1.1
19	40		4.1	.74	.23
20	70		4.1	1.8	2.5
21	100		3.7	1.9	2.6
22	250		4.2	1.9	2.7

As of 8/16, 9 of the nickel lead resistors had failed in use in a circuit and 10 had failed on the shelf as shown in the table 4.3.3 Five of the 19 were not baked at 1200F (denoted*),

Table 4.3.3 - Failures of baked and unbaked Evanohm Resistors with nickel leads

<u>Resistor</u>	<u>Failed in Circuit</u>	<u>Failed on Shelf</u>	<u>Total Failed</u>	<u>Total Rec'd</u>	<u>Percent Failed</u>
10K	2*	1	3	10	30
40K	5*	1	6	20	30
70K	1*	3	4	10	40
100K	0	3*	3	10	30
200K	0	1	1	10	10
250K	<u>1*</u>	<u>1</u>	<u>2</u>	<u>30</u>	<u>.7</u>
Total	9	10	19	90	

* 1 each of these was not baked at 1200F; maximum temperature = 930F.

All resistors above 70K ohms in the prototype amplifier are low power (<.2W) so the Caddock thick film type can be used for them. The 70K wirewound resistors were replaced with 40K and 20K wirewound resistors in series.

2. Test results for Caddock thick film resistors.

The ΔR_T values for both of the coated thick film type versus time are shown in Appendix B, tests no. 68A and 75. The ΔR_T decreased from 2.6% and 3.7% respectively to less than 1% during the first few days but the coating cracked badly and both failed completely a few days later. The manufacturer was called and he found that the wrong type had been sent to us. They had leads soldered by low temperature solder prior to coating. He was amazed that they lasted so long at 500C.

Two uncoated, 1/8" dia. X 1/2" long cylindrical type resistors (test nos. 77 & 81 in Appendix B) were then tested. One of these survived for 52 days. However, its ΔR_T varied from 3.4 to 6% during this time. The other survived for 42 days, but its ΔR_T increased from 2% to as high as 32% during this time. Ten additional Caddock thick film

resistors, including three matched pairs selected for good ratio tracking were received for test. One pair of unmatched and one pair of matched were tested on April 7 and the room temperature values increased by over 40% when measured the following day. A second unmatched pair was then tested and the room temperature values changed by only 6.5%. This variation is believed to result from the lapping procedure used to adjust the resistance value.

A total of 150 Caddock flat, uncoated, thick film, type TK133, resistors were ordered on 5/9/77 for use in the amplifier since they use a different kind of thick film than the cylindrical type and had such a low ΔR_T initially in the coated TK133 tests. They were received on 5/8 without leads so they were sent out for welding of 2 X 10 mil gold leads on 5/25 and returned on 5/30.

In the meantime they were tested for ΔR_T by using mechanical screw type connections on the fiberglass breadboard. The results are shown in Appendix B, tests #95 and 96. The latter was excellent, being less than 1%, 90% of the time while #95 varied from .5 to as much as 2.2%

Tests were also made to determine the effect of power on these resistors and it was found that ΔR_T was unaffected below .16W but degraded excessively above this value. This led to the hybrid amplifier design using the wirewound resistors for cases where the power was greater than .16W and the thick film type for the low power cases.

4.4 - Conclusions

The Dale Evanohm wirewound resistors, type RS-5 (.31 dia. X 1" long) have $\Delta R_T < 1\%$ after a 1200°F bake for 1 day and can tolerate 10W or more power without damage. However, a large percentage of them fail open later in use and on the shelf and in several cases even when they are not baked at 1200°F. This was surprising because no failures occurred in months of testing of low R values previously. The uncoated Caddock TK133 thick film resistors exhibit $\Delta R_T < 1\%$ but are limited to .16W power at 500°C. Some of these were sent to

Dave Palmer at Sandia Laboratories for testing and they obtained $\Delta R_T < .3\%$ over the temperature range from 25 to 300°C. Larger ones are now available from Caddock using the same thick film as the TK133 but measuring 1.5X.5X.1" so they should theoretically be able to dissipate over 10 times as much power. It is hoped that some of these can be obtained for tests in the near future.

Table 4.3 Summary of Dale Resistor Tests

Tested 16 days from 6/2-6/23 after baking 7 hours at 650°C

Item No.	Test #	R, Ω	Range % ΔR After 1st Day	Comments
1E	3	250K	--	(Failed Internally)
2E	4	200K	1.22 to .87	~ OK
3E	5	100K	.97 to .097	
4E	6	70K	.93 to .65	OK*
5E	14	40K	1.06 to .94	OK
6E	7	20K	1.11 to .87	~ OK*
7E	9	10K	.96 to .57	OK
8E	11	7K	1.31 to 1.03	~ OK
9E	15	4K	1.67 to 1.05	~ OK
10E	1	2K	2.55 to .05	OK, improving with time
11E	2	1K	.57 to .10	OK
12E	8	700	.58 to .01	OK*
13E	23	400	.98 to .05	OK*
14E	22	200	.33 to .05	OK*
15C	13	100	1.35 to .19	~ OK
16C	10	70	2.65 to .46	~ OK, improving with time
17C	12	40	3.27 to 1.42	~ OK, improving with time
18C	21	20	6.7 to 3.14	ΔR increasing with time
19C	20	10	5.9 to 4.5	ΔR too high
20C	19	7	19.55 to 6.4	ΔR too high
21C	17	4	13.2 to 9.21	ΔR too high
22C	18	2	124.22 to 5.1	ΔR too high
23C	16	1	58.52 to 2.82	ΔR too high

E denotes Evanohm, C denotes Cupron

* Bad connection for 5 days, then repaired.

5.0 - Capacitors

5.1 - Items Tested

The following major types of capacitors were tested:

1. Sandia Laboratories flat thick film capacitors, 1" x 1" x .1"; C = 1000 Pf developed under their ERDA contract for capacitors and other components suitable for use at 300°C.
- 2A. Electro Motive Corp. (Florence, S.C.) El Menco Type MCM 10 flat mica/silver capacitors (.125 x .5" x .2"), rated at 400°C for 1 minute; 60Pf (up to 500 Pf available).
- 2B. Electro Motive Corp. El Menco Type EMJ-112 flat mica/silver capacitors (.4" x .9" x .1") rated at 400°C continuously; 100 Pf (up to 500 Pf available).
3. Simmonds Precision, Inc. (Norwich, N.Y.) cylindrical mica/aluminum, hermetically sealed, .5" dia. x 2.75" long, .03 Mfd. (30,000 Pf).

5.2 - Tests Performed

The primary objective of the capacitor tests was to obtain capacitors capable of operating at 300V at 500°C with a change in capacitance of <10% over the temperature range of 25 to 500°C (denoted ΔC_T) and a dissipation factor of <10% at 500°C (denoted DF). Additional objectives were to obtain capacitors in the range from 10 Pf to 10 Mfd with a small change in capacitance over long periods of time, small size, long life and low cost.

The test procedure consisted of measuring the capacitance and dissipation factor at room temperature every morning, operating at 500°C all day, measuring the capacitance and dissipation factor again at about 5:00 p.m., and then shutting down the oven all night and weekends. Capacitance and DF measurements were made by means of a General Radio Impedance Bridge, Model 1656. The capacitors were mounted on the same fiberglass breadboards used for the resistor tests.

5.3 - Test Results

The values of ΔR_T and DF are summarized in Appendix C and the test results are discussed in detail below:

1. Sandia Thick Film. ΔC_T varied from 51 to 72%, and DF varied from 31 to 40% for the two capacitors tested over a total of 56 test days. They failed to meet the test objectives, although they had previously met Sandia's objectives for ΔC_T and DF over their temperature range of interest from 25 to 300°C.

2. El Menco Mica. As shown in Appendix C, the first type MCM10 tested (Test No. 65) met the objectives of ΔC_T and $DF < 10\%$ for the first nine days of test, but then degraded severely after that. The other two were not as good but came fairly close to meeting the objectives. All failed due to severe oxidation of the metal parts. Four were tested later with various high temperature Aremco coatings, but all of these failed due to the large decrease in resistance of the coatings at 500°C . An inert atmosphere test rig was built to determine the temperature stability of uncoated versions of these capacitors with the oxidation problem eliminated but problems with leakage of the test rig prevented these tests from being made. The leak problems were finally corrected but priority tests on the amplifier breadboards prevented these tests from being made.

In the meantime, some type EMJ El Menco capacitors were obtained for test, rated at 400°C continuously. As shown in Appendix C (test #97), they met the test objectives of less than 10% for ΔC_T and DF over a period of 22 days of tests, except for a few cases where ΔC_T was 26 to 57% which are believed to be due to corroded connections.

3. Simmonds Precision Mica. These were wound using unimpregnated mica paper and aluminum foil inserted in a hermetically sealed ceramic tube. As shown in Appendix C, two were tested (#80A and 80B) starting on 2/25. The first one started out with $\Delta C_T = 28\%$, and $DF = 16\%$, but steadily degraded to 51% and 28% over 15 days. It was then tested for leaks by immersing in hot water, and bubbles were observed at the interface between the nickel end caps and the ceramic tube. The second one held fairly constant with $\Delta C_T = 34$ to 36% until it suddenly increased to 51% on the 10th day, at which time it was leak tested and found to be leaking at the end of the evacuation tube. Two others, including one with a high temperature impregnant, were scheduled to be tested in the inert gas test fixture but could not be due to the test fixture leakage problems.
4. Other Capacitors Tested. As shown in Appendix C, starting on 1/21 a Semetex Boron Nitride/gold capacitor was tested, but its performance was very erratic, and the lead wire failed after three days. NASA Lewis sent 51 Westinghouse 2500 Pfd PBN/PT capacitors and associated parts to MRI for use in the amplifier development program. They were previously tested by Westinghouse at 600°C and showed exceptionally good temperature stability ($\Delta C_T = 1.7\%$ from 25 to 600°C and $DF = 1.7\%$ at 600°C).

5.4 - Conclusions

The El Menco type EMJ capacitors would have been satisfactory for use in the amplifier if they had been needed, but in the final design no capacitors were required. The Simmonds Precision mica capacitors performed quite well and would be expected to perform much better in an inert atmosphere or in the event that the manufacturer could solve the hermetic seal failure problem. They are the best capacitors found in the high capacity range.

6.0 - Wire Tested

6.1 - Items Tested

The following types of high temperature insulated wires were tested:

1. Gulton Industries (Newport Beach, Ca.) Duroflex I silicone dioxide fiber insulated 22 gage solid nickle wire rated at 1000°F continuous,
2. Continental Wire and Cable Co. (York, Pa.) Anaconda MG-300-20 wire insulated with mica tape and glass braid and rated for use at 500°C continuous.
3. Hitemp Wires, Inc. (Hauppauge, N.Y.), TMI 5107 Inorganic Tape/glass braid insulated wire rated at 850°F.
4. Cerro Wire Co. (Sherman Oaks, Ca.) Rockbestos Micatemp RSS5-304 insulated wire rated at 1200°F.

6.2 - Tests Performed

The Gulton Industries wire was tested by subjecting it to daily cycles of 25 to 500°C for about 7 hours/day while using it for component tests over the period from 1/18/76 to 7/13/77. The Continental/Anaconda wire was tested by subjecting it to the same daily temperature cycles for over 2 months starting on 3/8/77. The other wires were tested in a similar manner.

6.3 - Test Results

Both the Gulton Industries and the Continental/Anaconda wire performed very well. The insulation on the other two types of wires crumbled away after a few weeks of testing.

6.4 - Conclusions

The Gulton Industries wire was used in the prototype amplifier. The Anaconda wire is equally good and is much lower in cost than the Gulton wire (\$185 vs \$500 per 1000 ft.) but was discovered after the Gulton wire was ordered.

7.0 - Circuit Boards

7.1 - Items Tested

The following two types of circuit boards were tested:

1. 1/8" thick fiberglass breadboards. The manufacturer is not known, They were found in stock in the MRI laboratory storeroom.
2. Mykroy Ceramics Corp. (Ledgwood, N.J.), Mykroy 1100 machinable, molded mica, rated for continuous use at 1100°F. It is available in the form of 1/8 and 1/4 x 6" diameter discs. It can be cut by means of a high speed handsaw and can be drilled quite easily with a carbide tipped drill.

7.2 - Tests performed

The fiberglass breadboard and the 6" dia. x 1/4" thick Mykroy discs were subjected to over 8 months of daily cycling from 25 to 500°C during component tests in the oven. The Mykroy discs were used as insulators for the component test breadboards and were later used for the amplifier breadboard tests. 1/8" thick x 6" discs were used to fabricate the circuit boards used in the prototype amplifier tests.

7.3 - Test results

The fiberglass performed very satisfactorily in the breadboard tests once the volatiles were driven off. However the material was not strong enough for use in the prototype amplifier. The Mykroy performed very satisfactorily in the amplifier breadboard and prototype tests.

7.4 - Conclusions

The Mykroy 1100 molded mica is a good material for 500°C prototype circuit boards because of its high volume resistivity (10^7 ohm cm at 500°C) and ease of drilling and cutting compared to alumina.

8.0 - Terminals and Connectors

8.1 - Items Tested.

The following were tested:

1. Co-Operative Industries (Chester, N.J.), Type C102, 7 pin electrical connectors with glass insulated pins, rated at 1000°F.
2. H & W Products (Houston) electrical feedthrough Type A1107 manufactured by Alborox Corp., New Bedford, Mass. They are 1/4" dia. x 1.76" long. and consist of alumina (Al_2O_3) insulation and Kovar nickle iron alloy which are brazed together at the factory at 960°C. These feedthroughs are rated at 30K psi and 500°C.
3. Interconnection terminals for the prototype amplifier Mykroy circuit boards, fabricated from 3/16" dia. x 5 mil thick nickle foil spotwelded to 1/8" dia. x 1/8" long stainless steel rods in the holes in the circuit boards. They permit interconnections to be made between the 2 x 10 mil gold leads on the Caddock thick film resistors and the tube lugs and heavy 40 mil nickle leads on the Dale wirewound resistors.

8.2 - Tests performed

The resistance between the pins of the 7 pin connector and between the pin and shell of the feedthrough was measured at 500°C. A value of > 20 Megohms is required for the amplifier.

The resistance between the pin and shell of the feedthrough was measured during several days of tests at 500°C

The interconnection terminals were subjected to several weeks of temperature cycling of the prototype amplifier.

8.3 - Test Results

The resistance between the pins of the 7 pin connector decreased from 70 M Ω to .1 M Ω over several days of tests. The resistance of the feedthrough was < 200 M Ω during the tests. The interconnection terminals performed satisfactorily during the prototype amplifier tests.

8.4 - Conclusions

The 7 pin connectors could not be used for the amplifier. Both the feedthroughs and interconnection terminals were used in the prototype amplifier.

9.0 Other Components Tested

9.1 Items Tested

The following items were tested:

1. Control Products, Inc. (Hanover, New Jersey) thermal switch, type X-2, consisting of a 1/4" diameter x 5" long probe containing a bimetallic element operating an electrical switch in the head of the unit. The probe is rated for 1750°F continuous while the head is rated for 800°F maximum. The thermal switch is designed to maintain the temperature inside an enclosure close to the setpoint temperature by controlling the on/off time for the power applied to an electrical heater in the enclosure. It therefore has the possibility of being used to maintain the operating temperature of the amplifier close to 1000°F in spite of changes in ambient temperature from room temperature to 500°C (930°F). The switch was ordered with a setpoint of 1000°F for test at MRI.
2. It was planned to test a high temperature inductor using a Vanadium Permandur core wound with high temperature magnet wire but the latter could not be obtained in time. Vanadium Permandur is a 2% V, 49%Co, 49% Fe alloy which decreases in permeability by only 11% from 25 to 500°C based on tests at Westinghouse in 1970. Two 1" ID by 1.5" OD x .5" high cores were obtained from Arnold Engineering, Morengo, Illinois, wound from .5" wide by 5 mil thick Vanadium Permandur strip.

9.2 Tests Performed and Results Obtained.

The probe of the thermal switch was placed inside a steel housing insulated with Johns Manville, high temperature fiberglass bath insulation and containing a large Dale Evanohm wirewound resistor as a heater. The power required for the resistor exceeded the 45 W power rating of the switch so the resistor power was controlled by a Variac and the position of the

switch contacts was monitored by an ohmeter and the inside and outside temperatures were monitored by thermocouples. The outside temperature was maintained at 850°F while the inside temperature was raised to 970°F at which point the switch contacts opened. The resistor power was turned off and the switch contacts closed when the inside temperature decreased to 930°F.

The test was repeated using an oven temperature of 930°F (500°C). The switch contacts again opened at 970°F but did not close again until the oven temperature was reduced to 890°F. Further tests were not made due to priority use of the oven for the amplifier tests.

9.3 Conclusions

Further tests should be made to determine repeatability over a long period and how the setpoint should be adjusted to obtain the opening and closing points required.

10.0 - REFERENCES

1. R. D. Kelly, "Ceramic Vacuum Tubes for Geothermal Well Logging," MRI-2942-TR1, 12 January 1977, Mechanics Research, Inc., 2500 Colorado Avenue, Santa Monica, California.

APPENDIX A
CERAMIC VACUUM TUBE TEST DATA

TABLE A1
CERAMIC VACUUM TUBE TEST DATA

TUBE		TEST CONDITIONS			MEASUREMENTS - ROOM TEMP			MEASUREMENTS - 500°C		
Type	Sample Number	Heater Voltage	Plate Voltage	Grid Voltage	Pl. Current i_p (ma)	Amplification μ	Transcond. g_m (M-mho)	Pl. Current i_p (ma)	Amplification μ	Transcond. g_m (M-mho)
7462	1A	6.3	100	0	8.44	108	9,500	-	-	-
				-.25	6.15					
			200	0	16.9	107	11,900	-	-	-
		5.3	100	0	12.3					
				-.25	3.9	111	7,120	4.95	109	7,760
			200	0	2.3			3.1		
		4.3	100	0	11.4	108	9,050	13.3	107	10,100
				-.25	9.2			10.7		
			200	0	1.35	109	3,600	2.5	109	5,840
		2A	100	0	0.63			1.25		
				-.25	5.3	113	4,200	9.15	108	8,100
			200	0	4.1			7.16		
		6.3	100	0	9.15	98	11,100	-	-	-
				-.25	6.67					
			200	0	22.3	96	12,700	-	-	-
		5.3	100	0	19.0					
				-.25	5.04	100	7,000	7.41	99	6,460
			200	0	3.47			4.04		
		4.3	100	0	12.3	98	5,940	17.2	97	10,510
				-.25	10.5			13.4		
			200	0	0.96	102	561	3.5	100	6,090
				0	0.58			2.1		
				-.25	1.4	101	344	12.0	99	7,020
				-.25	1.0			9.1		

TABLE A1 (Continued)
CERAMIC VACUUM TUBE TEST DATA

TUBE		TEST CONDITIONS			MEASUREMENTS - ROOM TEMP			MEASUREMENTS - 500°C		
Type	Sample Number	Heater Voltage	Plate Voltage	Grid Voltage	Pl. Current i_p (ma)	Amplification μ	Transcond. g_m (M-mho)	Pl. Current i_p (ma)	Amplification μ	Transcond. g_m (M-mho)
7625	1A	6.3	100	0	2.74	57	1,490	-	-	-
				-.2	2.39					
			200	0	5.57	62	1,860	-	-	-
		5.3	100	0	5.14					
				-.2	1.98	69	1,410	3.0	50	1,304
			200	0	1.78					
		4.3	100	0	4.3	76	1,830	6.1	50	1,507
				-.2	3.9					
			200	0	.71	76	259	2.1	56	1,090
		2A	100	0	.64					
				-.2	.94	72	144	4.3	61	1,490
			200	0	2.35	56	1,370	-	-	-
	2A	6.3	100	0	2.05					
				-.2	5.03	62	1,860	-	-	-
			200	0	4.62					
		5.3	100	0	1.63	72	1,320	2.45	60	1,280
				-.2	1.35					
			200	0	3.55	78	1,470	5.02	58	1,510
		4.3	100	0	3.25					
				-.2	.32	95	109	1.98	59	1,130
			200	0	.27					
				0	.45	107	99	4.31	65	1,540
				-.2	.42					

TABLE A1 (Continued)
CERAMIC VACUUM TUBE TEST DATA

TUBE		TEST CONDITIONS			MEASUREMENTS - ROOM TEMP			MEASUREMENTS - 500°C		
Type	Sample Number	Heater Voltage	Plate Voltage	Grid Voltage	Pl. Current i_p (ma)	Amplification μ	Transcond. g_m (M-mho)	Pl. Current i_p (ma)	Amplification μ	Transcond. g_m (M-mho)
7296	1A	6.3	100	0	26.1	91.5	31,350	-	-	-
				-.25	19.7					
			200	0	58.3	115.	47,520	-	-	-
		5.3	100	0	49.7					
				-.25	10.4	-	-	12.5	105	19,090
			200	0	7.1					
		4.3	100	0	21.6	-	-	36.3	120	39,180
				-.25	18.2					
			200	0	3.2	134.	11,000	8.3	103	14,170
		2A	100	0	2.2					
				-.25	5.2	173.	12,000	29.4	120	24,850
			200	0	-					
	2A	6.3	100	0	23.7	97.	30,000	-	-	-
				-.25	17.8					
			200	0	42.3	120.	37,300	-	-	-
		5.3	100	0	34.6					
				-.25	15.3	115.	21,000	12.9	123	18,840
			200	0	10.5					
		4.3	100	0	33.1	134.	25,500	31.8	130	26,920
				-.25	26.9					
			200	0	8.4	135.	11,800	10.2	126	17,170
				0	-					
				-.25	14.2	151.	5,290	27.6	129	23,760
				0	-					

TABLE A1 (Continued)
CERAMIC VACUUM TUBE TEST DATA

TUBE		TEST CONDITIONS			MEASUREMENTS - ROOM TEMP			MEASUREMENTS - 500°C		
Type	Sample Number	Heater Voltage	Plate Voltage	Grid Voltage	Pl. Current i_p (ma)	Amplification μ	Transcond. g_m (M-mho)	Pl. Current i_p (ma)	Amplification μ	Transcond. g_m (M-mho)
7588	1A	6.3	100	0	22.2	209	52,000	-	-	-
				-.25	10.6	187				
			200	0	56.6	215	68,000			
				-.25	38.7	215				
		5.3	100	0	12.1	228	30,000	15.0	153	37,000
				-.25	3.8					
			200	0	32.6	223	47,000	48.4	177	46,500
				-.25	18.1					
		4.3	100	0	3.2	206		12.9	163	11,850
				-.25	0.95					
			200	0	11.4	222		26.0	141	3,980
				-.25	7.0					
	2A	6.3	100	0	24.0	164	42,300	-	-	-
				-.25	7.36					
			200	0	42.6	182	53,100	-	-	-
				-.25	26.8					
		5.3	100	0	15.0	181	33,100	13.24	138	17,500
				-.25	4.02					
			200	0	33.2	187	38,300	26.9	177	25,000
				-.25	16.4					
		4.3	100	0	7.6	192	23,900	8.5	171	14,000
				-.25	1.42					
			200	0	21.0	192	28,500	14.7	140	6,000
				-.25	6.04					

TABLE A1 (Continued)
CERAMIC VACUUM TUBE TEST DATA

TUBE		TEST CONDITIONS			MEASUREMENTS - ROOM TEMP			MEASUREMENTS - 500°C		
Type	Sample Number	Heater Voltage	Plate Voltage	Grid Voltage	Pl. Current i_p (ma)	Amplification μ	Transcond. g_m (M-mho)	Pl. Current i_p (ma)	Amplification μ	Transcond. g_m (M-mho)
Y2191	1B	6.3	100	0	4.1	303	7,360	-	-	-
			200		9.0	317	19,020	-	-	-
		5.3	100		1.47	319	2,950	5.02	187	8,420
			200		4.4	357	9,980	10.43	210	11,820
		4.3	100		0.28	305	570	2.59	252	7,210
			200		1.22	330	3,490	5.66	277	8,850
	2B	6.3	100	0	6.07	300	12,850	-	-	-
			200		10.7	359	16,160	-	-	-
		5.3	100		2.88	335	9,294	3.28	326	10,470
			200		5.86	394	11,258	6.88	343	12,340
		4.3	100		.66	359	3,590	1.57	330	6,410
			200		1.90	396	5,120	4.24	352	10,120
	3B	6.3	100	0	5.3	263	12,930	-	-	-
			200		10.9	289	17,030	-	-	-
		5.3	100		1.82	261	7,930	4.84	278	12,630
			200		5.10	303	9,920	9.59	301	15,400
		4.3	100		0.35	265	2,130	2.16	309	9,270
			200		1.12	324	1,220	5.54	324	11,580
	4B	6.3	100	0	5.71	304	10,710	-	-	-
			200		13.42	362	25,050	-	-	-
		5.3	100		1.41	330	6,290	3.71	325	13,260
			200		4.38	378	13,460	9.16	340	17,880

TABLE A1 (Continued)
CERAMIC VACUUM TUBE TEST DATA

TUBE		TEST CONDITIONS			MEASUREMENTS - ROOM TEMP			MEASUREMENTS - 500°C		
Type	Sample Number	Heater Voltage	Plate Voltage	Grid Voltage	Pl. Current i_p (ma)	Amplification μ	Transcond. g_m (M-mho)	Pl. Current i_p (ma)	Amplification μ	Transcond. g_m (M-mho)
Y2191	4B	4.3	100	0	0.16	305	1,260	1.66	245	6,430
			200		0.88	353	3,490	5.42	314	9,600
	5B	6.3	100		2.10	234	7,930	-	-	-
			200		8.58	287	20,300	-	-	-
		5.3	100		0.5	234	3,050	5.18	209	16,590
			200		3.36	279	10,830	12.05	233	19,080
		4.3	100		0.1	216	570	2.71	186	11,260
			200		0.89	270	3,580	8.17	221	15,410

14
41
A6

Figure A1, Measured Plate Current, Tube 7462-1A, Room Temperature

Figure A2, Measured Plate Current, Tube 7462-1A, 500°C.

NO. 3-6122 DIETZGEN GRAPH PAPER
LOGARITHMIC
2 CYCLES X 2 CYCLES
EUGENE DIETZGEN CO.
MADE IN U. S. A.

Figure A3, Measured Transconductance, Tube 7462-1A, Room Temperature

EUGENE DIETZGEN CO.
MADE IN U. S. A.

NO. 34-22 DIETZGEN GRAPH PAPER
LOGARITHMIC
2 CYCLES X 2 CYCLES

Figure A4, Measured Transconductance, Tube 7 62-2A, 500°C.

A10

EUGENE DIETZGEN CO.
MADE IN U. S. A.

NO. 341022 DIETZGEN GRAPH PAPER
LOGARITHMIC
2 CYCLES X 2 CYCLES

Figure A5, Measured Plate Current, Tube 7467-2A, Room Temperature

Figure A6, Measured Plate Current, Tube 7462-2A, 500°C.

Figure A7, Measured Transconductance, Tube 7462-2A, Room Temperature.

Figure A8, Measured Transconductance, Tube 7462-2A, 500°C.

NO. 34 22 DIETZGEN GRAPH PAPER
LOGARITHMIC
2 CYCLES X 2 CYCLES
EUGENE DIETZGEN CO.
MADE IN U. S. A.

Figure A9, Measured Plate Current, Tube 7625-1A, Room Temperature

Figure A10, Measured Plate Current, Tube 7625-1A, 500°C.

EUGENE DIETZGEN CO.
MADE IN U. S. A.

NO. 341-L-1
DIETZGEN GRAPH PAPER
LOGARITHMIC
2 CYCLES X 2 CYCLES

Figure A11, Measured Transconductance, Tube 7625-1A, Room Temperature.

Figure A12, Measured Transconductance, Tube 7625-1A, 500°C.

NO. 346 L22 DIETZGEN GRAPH PAPER
LOGARITHMIC
2 CYCLES X 2 CYCLES
EUGENE DIETZGEN CO.
MADE IN U. S. A.

Figure A13, Measured Plate Current, Tube 7625-2A, Room Temperature

Figure A14, Measured Plate Current, Tube 7625-2A, 500°C

NO. 34-22 DIETZGEN GRAPH PAPER
LOGARITHMIC
2 CYCLES X 2 CYCLES
JUGENE DIETZGEN CO.
MADE IN U. S. A.

NO. 3 L22 DIETZGEN GRAPH PAPER
LOGARITHMIC
2 CYCLES X 2 CYCLES
EUGENE DIETZGEN CO.
MADE IN U. S. A.

Figure A16, Measured Transconductance, Tube 7625-2A, 500°C.

EUGENE DIETZGEN CO.
MADE IN U. S. A.

NO. 34-122 DIETZGEN GRAPH PAPER
LOGARITHMIC
2 CYCLES X 2 CYCLES

EUGENE DIETZGEN CO.
MADE IN U. S. A.

NO. 340 L22 DIETZGEN GRAPH PAPER
LOGARITHMIC
2 CYCLES X 2 CYCLES

Figure A18, Measured Plate Current, Tube 7296-1A, 500°C.

A24

Figure A19, Measured Transconductance, Tube 7296-1A, Room Temperature

ERNEST DIETZGEN
MADE IN U. S. A.

NO. 341-02 DIETZGEN GRAPH PAPER
LOGARITHMIC
2 CYCLES X 2 CYCLES

Figure A20, Measured Transconductance, Tube 7296-1A, 500°C.

Figure A21, Measured Plate Current, Tube 7296-2A, Room Temperature

EUGENE DIETZGEN CO.
MADE IN U. S. A.

NO. 341-L DIETZGEN GRAPH PAPER
LOGARITHMIC
2 CYCLES X 2 CYCLES

Figure A22, Measured Plate Current, Tube 7296-2A, 500°C.

NO. 34-122 DIETZGEN GRAPH PAPER
LOGARITHMIC
2 CYCLES X 2 CYCLES
EUGENE DIETZGEN CO.
MADE IN U. S. A.

Figure A23, Measured Transconductance, Tube 7296-2A, Room Temperature

GENE DIETZGEN
MADE IN U. S. A.

NO. 341-2 DIETZGEN GRAPH PAPER
LOGARITHMIC
2 CYCLES X 2 CYCLES

Figure A24, Measured Transconductance, Tube 7296-2A, 500°C.

EUGENE DIETZGEN CO.
MADE IN U. S. A.

NO. 341-L
DIETZGEN GRAPH PAPER
LOGARITHMIC
2 CYCLES X 2 CYCLES

Figure A25, Measured Plate Current, Tube 7588-1A, Room Temperature

ROSE DIETZGEN CO.
MADE IN U. S. A.

NO. 341-02 DIETZGEN GRAPH PAPER
LOGARITHMIC
2 CYCLES X 2 CYCLES

Figure 26, Measured Plate Current, Tube 7588-1A, 500°C .

Figure A27, Measured Transconductance, Tube 7588-1A, Room Temperature

Figure A28, Measured Transconductance, Tube 7588-1A, 500°C.

GENE DIETZGEN CO.
MADE IN U. S. A.

NO. 341-22 DIETZGEN GRAPH PAPER
LOGARITHMIC
2 CYCLES X 2 CYCLES

Figure A29, Measured Plate Current, Tube 7588-2A, Room Temperature

Figure A30, Measured Plate Current, Tube 7588-2A, 500°C .

A36

Figure A31, Measured Transconductance, Tube 7588-2A, Room Temperature

Figure A32, Measured Transconductance, Tube 7588-2A, 500°C.

APPENDIX B
RESISTOR TEST DATA

APPENDIX B - DALE WIRE WOUND RESISTORS ΔR_T VERSUS TIME

(ΔR_T = Percent change in resistance from 25 to 500C)

Evanohm 1K				Cupron 1K (Note 1)				Kanthal 7K		
Date	66	69	70	67	71	72	73	← Test Number		
2/9	-1.6	-1.1	-1.6	.77	.85	-.19	.85			
2/10	-1.6	-1.1	-1.6	.86	1.03	1.03	1.03			
2/11	-1.4	-.95	-1.4	-	-	.65	.65			
2/14	-1.5	-1.0	-1.5	1.26	1.4	1.5	1.5			
2/15	-1.4	-1.0	-1.3	1.36	1.51	1.50	1.5			
2/16	-1.5	-1.0	-1.4	1.35	1.70	1.60	1.6			
2/17	-1.3	-.76	-1.2	.58	.65	.65	.65			
2/21	-	-.76	-	.29	.47	.46	.42			
2/22										
2/23										
2/25	-1.2	-.7	-1.2	.9	.9	1.0	1.1			
2/28	-.7	-.4	-.8	-.1	.1	.1	.1			
3/1	-1.0	-.7	-1.0	.3	.5	.5	.5			
3/2	-1.2	-	-1.3	.3	.5	.5	.6			
3/3	-1.0	-.4	-1.0	.2	.5	.5	.5			
3/4	-1.3	-.4	-1.0	.3	.4	.5	.3			
3/7	-1.3	-.476	-1.13	.573	.74	.83	.83			
3/8	-.851	-.76	-.757	.765	.83	.83	.92			
3/9	-.99	-.48	-.76	.38	.92	.64	.64			
3/10	-.76	-.38	-.75	.48	1.11	.73	.73			
3/11	-.67	-.38	-.67	.57	.92	.92	1.01			
3/4	-.96	.09	-.86	.57	.82	.82	.82			
3/15	-.96	-.28	-.29	.47	.64	.82	.83	Test Number		
3/16	-.96	-.28	-.57	.18	.55	.55	.64	24	25	26
3/17	-.38	-.19	-.38	.37	.55	.55	.55	Coating		
3/18	-.38	-.09	-.29	.47	.82	.73	.82	none	thin	thick
3/21	-.38	-.09	.29	.57	.82	.81	-			
3/22	-.09	-.19	-.09	.09	.46	.45	.36	-1.63	-1.73	1.34
3/23	-.09	-.09	0	.76	.91	1.00	1.00	-.08	-.08	.03
3/24	-.096	.096	-.096	.47	.63	.73	.73	.1414	-.1557	-.0706
3/25	-.19	.096	-.096	.18	.55	.54	.54	.06	-.28	-.14
3/28	.096	.29	.096	.37	.64	.72	.72	.071	-.23	.26
3/29	-.096	.29	0	-5.0	.181	.27	.27	-.042	-.24	-.24
3/30	.096	.38	.10	.28	.45	.45	.54	.028	-.25	-.14
3/31	0	Open	Open	0	.36	.36	.37	.057	-.28	-.20
4/1	0	.10	.10	.10	.18	.27	.36	.07	-.33	-.21
4/4	0	.10	.10	1.05	1.6	1.2	1.3	.63	.16	.27
4/7	Board removed			.47	.73	.72	.72	.33	-.10	-.04

Note 1. All + except as noted.

APPENDIX B - DALE WIRE WOUND RESISTORS ΔR_T VERSUS TIME (Continued)

(ΔR_T = % change in resistance from 25 to 500°C)

Evanohm 1K				Cupron 1K				Kanthal 7K		
Date	66	69	70	67	71	72	73	24	25	26
4/14	.10	-.1	.10	.28	.63	.45	.54	.07	-.37	-.28
4/15	.19	.48	.19	.19	.54	.36	.54	.07	-.41	-.46
4/8	-.38	-.1	-.38	.19	.54	.45	.36	.03	-.35	-.32
4/19	.29	.68	.28	.28	.54	.45	.54	.08	-.03	-.30
4/22	.39	.39	.39	.09	.27	.27	.18	-.11	-.51	-.42
4/25	.19	.48	.19	.85	1.1	1.1	1.1 *	.58	.14	.21
4/27	-.19	.39	.10	END TESTS				.45	-.10	.03
4/29	.19	.39	.29	* BAD COMMON GROUND				.08	-.37	.23
5/2	.67	.39	.58	CONNECTION FOR 4/25				.08	-.23	.21
5/3	-.19	-	-.09	TESTS.				.98	.40	.57
5/6	END TESTS							.47	.19	.24
5/9								.50	.11	.23
5/11								END TESTS		

Dale Evanohm Tests to Accelerate Stabilization

Bake at 1000°F for 1 day and then cycle from 25 to 500°C everyday:

	84	85	86	87
	4K Ω		14K Ω	
	.31" dia.		.62" dia.	
4/20	5.2	5.1	4.5	3.9
4/21	-2.2	-2.2	-2.9	-2.9
4/22	-2.8	-	-4.0	-3.8
4/25	-2.9	-2.9	-3.8	-3.6
4/27	-2.8	-3.0	-4.0	-4.1
4/29	-2.9	-2.9	-3.3	-3.3
5/2	-1.9	-2.0	-2.8	-2.2
5/3	-2.1	-2.3	-2.9	-2.9
5/4	-3.9*	-	-	-
5/5	-.35	-3.2	-3.0	-1.03
5/6	-.57	-2.1	-2.7	-3.0
5/9	-5.7	-2.3	-3.0	-3.3
5/11	-.25	-1.9	-3.4	-3.1
5/13	-.29	-3.2	-2.9	-2.9
5/16	-.13	-1.8	-3.2	-2.6
5/17	-.25	-1.9	-2.9	-2.1
5/18	-.10	-1.8	-2.6	-2.7
5/19	0	-1.8	-2.6	-2.7
5/20	.03	-1.6	-2.3	-2.0
6/6	.26	-2.4	-2.3	-2.3
6/7	.22	-1.4	-2.4	-
6/8	.38	-1.8	-2.0	-
6/10	.26	-1.3	-1.9	-2.4

Continuation of Dale Evanohm Tests to Accelerate Stabilization

6/14	.29	-1.3	-1.9	-2.2
6/16	.19	-1.4	-2.0	-2.3
6/17	.22	-1.4	-2.2	-2.3
6/21	.22	-1.3	-2.0	-2.3
6/22	.19	-1.3	-2.0	-2.3

* 10W power put on resistor for 1 hour in oven at 930°F.

Appendix B (Continued)

Caddock and Omnitronics Resistors ΔR_T Versus Time

(ΔR_T = Percent change in resistance from 25 to 500°C)

Caddock, Flat, Thick Film, Coated			Omnitronics WW Coated		Caddock, Cyl. Thick Film, Uncoated		
Test # →	68A	75	74			77	81
Start Date	12/20	1/12	Date	10KΩ	Date	28KΩ	317KΩ
Resistance Ω	22K	500K	12/20	1.4	2/9	5.4	
Day No.	$\Delta R_T, \%$		12/21	- 1.1	2/10	5.4	
1	2.6	3.7	12/22	- 1.6	2/11	5.4	6.9
2	2.2	2.3	12/23	- 2.1	2/14	5.5	9.4
3	.90	.50	12/28	- 2.2	2/15	5.6	6.9
4	0	-	12/29	- 2.1	2/16	5.9	9.2
5	0	5.2	1/4	- 2.7	2/17	4.3	4.9
6	-	.50	1/5	- 2.6	2/21	1.2?	3.9
7	9.4	1.0	1/6	- 2.6	2/25	4.9	-
8		1.0	1/7	- 2.6	2/28	4.5	-
9		1.1	1/12	- 2.6	3/1	4.7	-
10		- 2.1	1/13	- 2.7	3/2	5.2	2.1
11		- .8	1/14	- 2.7	3/3	5.2	- .6
12		- 6.9	1/17	-	3/4	5.2	- .7
13		-33	1/18	- 2.2	3/7	4.8	- 4.8
14		-19	1/19	- 2.7	3/8	5.1	- 3.2
15		-19	1/20	- 2.6	3/9	5.0	- 3.8
16		-29	1/21	- 2.4	3/10	4.9	- 2.3
17		-25	1/24	- 2.9	3/11	5.1	- 2.2
18		-33	1/25	- 2.8	3/14	5.0	- 7.8
19			1/26	- .10	3/15	4.8	-10.3
20			1/27	- 2.3	3/16	4.8	-10.3
21			1/28	- 2.5	3/17	4.7	-11.0
22			1/31	- 2.6	3/18	4.5	-10.4
23			2/1	- 2.7	3/21	4.7	- 9.3
24			2/3	- 2.5	3/22	4.5	-13.8
25			2/4	- 2.2	3/23	4.3	- 9.9
26			2/7	- 2.6	3/24	4.2	-19.2
27			2/8	- 2.6	3/25	4.2	-20.7
28			2/9	- 2.4	3/28	3.4	-20.7
29					3/29	3.9	-23.7
30					3/30	4.0	-32.0
31					3/31	3.9	-29.0
32					4/1	4.0	-32.0
33					4/4	4.0	-23.9
34					4/7	-	-27.1
35					4/8	4.2	-

APPENDIX B - CADDOCK THICK FILM RESISTORS ΔR_T VERSUS TIME.

(ΔR_T = Percent Change in Resistance)

Caddock Flat TK133 Uncoated, .2 x .25 x .1"			
Date	#95, 2.7K	#96, 2.8K	
5/18	-.48	-.68	
5/19	-.96	-1.9	
5/20	.49	-.17	
5/23	2.2	1.3	
5/24	---	1.0	
5/25	---	.53	
5/26	.97	.45	
5/27	1.3	.49	
5/31	1.5	.72	
6/2	1.4	.56	
6/3	2.0	1.0	
6/6	2.0	1.1	
6/7	1.9	.83	
6/8	2.0	.79	
6/10	1.7	.64	
6/14	1.7	.66	
6/15	1.7	.60	
6/16	1.8	.64	
6/17	1.8	.75	
6/21	1.8	.75	
6/22	1.8	.79	
6/23	1.7	.75	

APPENDIX C
CAPACITOR TEST DATA

APPENDIX C - CAPACITOR TEST DATA

ΔC_T = % change in capacitance from 25 - 500°C

DF = Dissipation factor at 500°C, percent

Date	Sandia thick film No. 68		Sandia thick film No. 78		El Menco mica No. 65		Semetex BN/Au #76		El Menco mica #80	
	ΔC_T	DF	ΔC_T	DF	ΔC_T	DF	ΔC_T	DF	ΔC_T	DF
12/29	5.9?	-								
1/4	69	31								
1/5	61	31								
1/10	58	32								
1/12	62	34								
1/13	57	32								
1/14	56	32								
1/18	55	50?			7.5	7.6				
1/19	57	37			6.4	7.7				
1/21	52	33			4.7	7.5	-61	1.6		
1/24	57	34			-5 ?	8.1	-43	-		
1/25	62	35	54	37	2.7	8.3	-4.5	1.0		
1/26	65	37	74	37	20?	9.5	48	1.4		
1/27	63	34	70	38	7.8	10	15	1.2		
1/28	66	37	71	38	-1.0	9.5				
1/31	68	35	66	37	-1.0	9.5				
2/1	65	37	69	39	11.7	9.4				
2/3	64	37	66	38	5.8	9.5				
2/4	55	35	63	37	15	7	El Menco mica #79			
2/7	67	35	70	37	13	10				
2/8	63	37	-		8	15				
2/9	63	37	61	38	24	15	26	11	16	6.7
2/10	64	38	61	39	17	17	7	15	25	21
2/11	63	38	65	39	20	21	16	27	17	20
2/14	64	38	65	39	18	21	28	40	19	19
2/15	62	38	65	39	34	29	33	38	26	20
2/16	63	38	65	39	36	35	36	40	22	20
2/17	58	37	65	40	129	70	53	44	27	19
2/21	62	37	-	-					Simmonds mica #1 No. 80A	
2/25	61	36	65	38					28	16
2/28	51	33							28	15
3/1	56	35							36	20
3/2	59	35							37	20
3/3	59	35							37	20
3/4	58	35							36	20
3/7	60	35							38	21
3/8	61	36							45	25
3/9	63	38							48	26
3/10	68	39							48	26
3/11	68	39							46	27
3/14	68	39							46	26
3/15	68	39							50	27
3/16	69	39							51	28
3/17	68	39							51	28
3/18	69	39							-	
3/21	70	40							49	26*
3/22	72	40							Simmonds mica #2 No. 80B	
3/23	72	40							36	19
3/24	61	37							34	18
3/25	60	38							26	35
3/28	60	39							36	24
3/29	64	35							35	26
3/30	59	34							36	16
3/31	55	37							36	16
4/1	55	37							36	16
4/4	55	37							35	16
4/12	59	38							51	30*

* Hermetic seal was found to be leaking when tested by immersing in hot water.

APPENDIX C - CAPACITOR TEST DATA, CONTINUED

(ΔC_T = % Change in Capacitance from 25-500°C)

(DF = Dissipation Factor at 500°C, percent)

Date	El Menco EMJ Mica #97, 100 Pf		
	ΔC_T	DF	
5/18	10.0	7.8	
5/19	.7	6.8	
5/20	2.2	6.5	
5/23	1.9	6.4	
5/24	.4	6.5	
5/25	6.9	6.2	
5/26	3.0	6.5	
5/27	7.0	6.7	
5/31	- .5	10.0	
6/2	-56.8*	5.7	
6/3	-4.4	---	
6/6	---	7.0	
6/7	2.2	6.0	
6/8	-25.8*	5.0	
6/10	4.4	6.5	
6/14	3.3	6.0	
6/15	4.3	6.2	
6/16	4.8	6.0	
6/17	3.7	6.0	
6/21	3.6	6.0	
6/22	3.6	6.0	
6/23	4.3	6.0	
*Believed to be due to corroded connection.			

APPENDIX D
COMPONENT TEST RECORD
Chronological Order

APPENDIX D

Component Test Record - Chronological Order

Test No.	R or C	Component	Valued R or C	Start Test	End Test
65	C	El Menco mica cap #1.	67 Pf.	1/18	2/17
66	R	Dale Evanohm res.	1 K Ω	1/18	5/3
67	R	Dale Cupron w w res.	1 K Ω	12/14	4/25
68A	R	Caddock thick film, coated, #1.	22 K	12/20	1/10
68B	C	Sandia thick film cap. #2	10 ³ Pf.	12/29	4/25
69	R	Dale Evanohm w w res.	1 K Ω	1/18	5/3
70	R	Dale Evanohm w w res.	1 K Ω	1/18	5/3
71	R	Dale Cupron w w res.	1 K Ω	12/16	4/25
72	R	Dale Cupron w w res.	1 K Ω	12/16	4/25
73	R	Dale Cupron w w res.	1 K Ω	12/16	4/25
74	R	Omitronics w w res.	10 K Ω	12/20	2/10
75	R	Caddock thick film, coated, #2.	500 K	1/12	2/9
76	C	Semetex BN/Au Capac.		1/20	1/28
77	R	Caddock thick film res. (cyl. #1).	28 K	1/21	5/31
78	C	Sandia thick film cap. #21	10 ³ Pf.	1/25	2/21
79	C	El Menco mica cap #2		2/9	2/21
80	C	El Menco mica cap #3		2/9	2/21
81	R	Caddock thick film, res. (cyl. #2)	317 K	2/11	4/25
82	R	Hoskins Mfg. Co. alloy 815 res. wire.	12 Ω	2/17	4/25
65A	C	El Menco capac. thin coat	60 Pf.	2/25	2/26
79A	C	El Menco capac. thick coat	60 Pf.	2/25	2/26
80A	C	Simmonds capac. #1	.03 Mfd.	2/25	3/22
-	-	3 Continental insul. wire samples	-	3/8	3/15
-	-	Res. test of 6" dia. Mykroy disc.		3/14	3/16
-	-	Res. test of Simmonds 2 pin connector		3/21	3/30
65B	C	El Menco capac. new coating		3/15	3/15
79B	C	El Menco capac. new coating		3/15	3/15

APPENDIX D Component Test Record - Chronological Order (Cont'd)					
Test No.	R or C	Component	Valued R or C	Start Test	End Test
24	R	Dale Kanthal A-1, no coating		3/21	6/1
25	R	Dale Kanthal A-1, thin coat		3/21	6/1
26	R	Dale Kanthal A-1, thick coat		3/21	6/1
-	-	Res. test, Swagelok/Insul. wire		3/21	3/30
-	-	Res. test, 2 insulated wires in paral.		3/21	3/30
<u>Inert Gas Test Fixture</u>					
80B	C	Simmonds cap. #2	.03 Mfd.	3/23	4/6
0	C	Simmonds cap. #3	.03 Mfd.	4/7	4/8
9	C	Simmonds cap. #4	.03 Mfd.	4/7	4/8
1	R	Caddock thick film res. }	30 K	4/7	4/8
2	R	Caddock thick film res. } round	30 K	4/7	4/8
4	R	Caddock thick film res. } Round	30 K	4/7	4/8
8	R	Caddock thick film res. } Matched	30 K	4/7	4/8
6	R	Caddock thick film res., flat		4/7	4/8
3	R	Caddock thick film res., flat		4/7	4/8
<u>Components Continued</u>					
65D	R	Caddock thick film flat, 5x1.5"	7MΩ	4/14	5/3
79C	R	Caddock thick film flat, .2x.2"	3 K	4/14	6/1
83	R	Caddock thick film cyl., 25" dia.	30K	4/8	5/31
84	R	Dale Evanohm, .26" dia.	3 K	5/11	6/23
85	R	Dale Evanohm, .26" dia.	3 K	5/11	6/23
86	R	Dale Evanohm, .26" dia.	14 K	5/11	6/23
87	R	Dale Evanohm, .26" dia.	14 K	5/11	6/23
88	R	Caddock, flat, 3/16" x 3/16"	1.5 M	5/11	5/31
89	R	Caddock, cylindrical, .25" dia.	100 Ω	5/11	5/31
90	R	Dale Evanohm, .26" dia.	334 K	5/11	6/8
91	R	Dale Evanohm, .26" dia.	342 K	5/11	6/8
92	R	Dale Evanohm, .26" dia.	3 K	5/11	6/23

APPENDIX D Component Test Record - Chronological Order (Cont'd)

Test No.	R or C	Component	Valued R or C	Start Test	End Test
93	R	Dale Evanohm, .26" dia.	3 K	5/11	6/23
94	R	Dale Evanohm, .26" dia.	3 K	5/11	6/23
95	R	Caddock flat	2.7 K	5/16	6/23
96	R	Caddock flat	2.8 K	5/18	6/23
97	C	El Menco EMJ	112 Pf	5/18	6/23