Fermilab

$\bar{p}$ Note #352

TEV I ELECTRODES FORMED MICROWAVE ASSEMBLY KICKER COOLING EVALUATION

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12/1/83

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TEV I Electrodes
Formed Microwave Assembly
Kicker Cooling Evaluation

Summary

Cooling of the "formed" version of the TEV I Electrode microwave assembly when operated as a kicker has been evaluated with a series of tests incorporating engineering models of the microwave assembly. The major objective of the evaluation was to determine the operating temperatures of the resistor (component lifetime) and the combiner board (outgassing). A nominal resistor power of 7 watts and water cooling were assumed.

The evaluation consisted of the following three elements:

I. <u>Resistor Cooling Tests</u>
Details as per the attached memorandum "Resistor Cooling Tests", MF/RN/DV, 6/1/83. Summary is as follows:

A. <u>Objective</u>
The test objective was to evaluate the effectiveness of resistor cooling of the "formed" version of the Tev I electrode microwave assembly. Variables of the evaluation were coolant, materials and geometry.

B. <u>Test Arrangement</u>
The test samples consisted of a formed 1-2 GHz cavity, resistor socket, resistor stud, resistor and pin, heat sink and cooling clip. One sample incorporated a stainless steel resistor socket and another sample incorporated a copper resistor socket. The sample assembly permitted the the installation of a stainless steel Belleville washer between the resistor socket and the heat sink.

C. <u>Conclusions</u>
1. The resistor sockets will be stainless steel. The very small performance improvement offered by copper does not overcome stainless steel's advantage of offering a reliable tack welded joint between the socket and the cavity.
2. A Belleville washer will be installed between the heat sink and the cooling clip. The small, as measured, thermal impedance of the washer does not overcome the advantage of improved joint reliability, and thus electrical continuity, between the resistor stud and the cavity.

3. The resistor temperature, at an operating power of 7 watts, can be maintained below the required maximum of 50°C with water as a coolant.
4. A comparison of the cooling performances of the "formed" and "machined" cavity configurations, at a power level of 7 watts, is as given below:

TEMPERATURE (°C)

Configuration	Tip	Socket	Δ
Machined	72	45	27
Formed	39	18	21

II. Single Pair Kicker Tests

Details are per the attached memorandum "Single Pair Kicker Tests", MF/RN/DV, 10/24/83. Summary is as follows:

A. Objective

The test objective was to conduct an evaluation of the cooling of the "formed" version of the TEV I electrode microwave assembly when operated as a kicker with water cooling.

B. Test Arrangement

The test article corresponds to a single cavity pair slice of a 1-2 GHz formed microwave array. The test article incorporated a loop that corresponds to the current LBL 1-2 GHz loop design. The circuit board was etched with a pattern to yield the approximate RF power dissipation in the board when operated in the DC test mode. A circuit board connector of the soldered blade type was employed. Only the upper half of the test article had a loop, etched circuit board and connector.

C. Conclusions

For an operating power level of 7 watts, the resistor steady state operating temperature is greater than 50°C, the specified maximum allowable value based on component performance and life time considerations.

The previous evaluation of the resistor cooling in which the cooling configuration consisted of the cooling tube, cooling clip, heat sink, cavity resistor socket, resistor stud, resistor and resistor pin indicated a lower operating temperature; i.e., 39°C, at an operating power level of 7 watts. A comparison of the two data sets is as follows:

	Power Level [W]	Water Flow [gpm]	Water Inlet Temp. [°C]	Resistor Temp. [°C]
Previous test	7	1	14	39
This test	7	1.5	21	52
	0	+0.5	+ 7	+13

Since this test has shown that resistor temperature is insensitive to flowrate in the 1-2 gpm range, the major cooling variable difference other than test article and instrumentation is the inlet temperature of the cooling water.

If a 50°C maximum resistor operating temperature is to be an operational criteria, the use of chilled water appears to be necessary.

D. Cooling water flowrate in the range of 1-2 gpm is adequate.

E. Since the circuit board temperatures is slightly higher than that of the adjacent sideplane, it appears that circuit board cooling by means of emissivity control on the board and side plane surfaces would not be effective.

F. Since the array structure temperatures are closely grouped and moderately; i.e., 7 - 15°F, above that of the cooling water, thermal distortion of the array during operation should not be a problem. Also a straight cooling tube configuration can be employed due to the small differential thermal contraction over the array length. This may not be the case, however, if a rapid heating of the structure for the purpose of bakeout is accomplished by flow of large volumes of high temperature; i.e., 150°C, gas through the cooling tube. Heating at moderate rates is appropriate to reduce cooling tube complexity.

G. Resistor solder joints should survive operation at power; i.e., 7 watts, without coolant flow.

III. Single Pair Kicker tests with Chilled Water

Details are per the attached memorandum "Single Pair Kicker Tests", MF/RN/DV, 11/27/83. Summary follows:

A. Objective

The test objective was to continue the evaluation of the cooling of the "formed" version of the TEV I electrode microwave assembly when operated as a kicker with chilled water cooling.

B. <u>Test Arrangement</u>

The test arrangement and procedure is as per the previous kicker cooling evaluation. The principal variable was to evaluate the effectiveness of chilled water in maintaining the resistor operating temperature below the required 50°C upper limit at an operating power of 7 watts. The chilled water supply, which was improvised to permit testing, resulted in a minimum water supply temperature of approximately 10°C.

C. <u>Conclusion</u>

For the specified kicker operating power of 7 watts, the resistor steady state operating temperature can be maintained below 50°C with the use of moderately chilled; i.e., 10°C, water.

Attachments

MF/RN/DV
6/1/83

Tev I Electrodes
Formed Microwave Assembly
Resistor Cooling Tests

I. Objective

The test objective was to evaluate the effectiveness of resistor cooling of the "formed" version of the Tev I electrode microwave assembly. Variables of the evaluation were coolant, materials and geometry.

II. Samples

The test samples consisted of a formed 1-2 GHZ cavity, resistor socket, resistor stud, resistor and pin, heat sink and cooling clip. The physical relationship of these components is as shown by Figure 1. One sample incorporated a stainless steel resistor socket and the other sample incorporated a copper resistor socket. The sample assembly permitted the installation of a stainless steel Belleville washer between the resistor socket and the heat sink.

III. Procedure

A. Preparation

The tests were performed in a vacuum chamber to approximate the electrode operating environment.

The two samples, one with a stainless steel resistor socket and one with a copper resistor socket, were mounted on a 3/8 inch O.D. stainless steel coolant tube. The mounting was by means of mechanical clamping the tube between the heat sink and cooling clip, followed by soft soldering.

The sample and coolant tube assembly were instrumented with thermocouples for temperature monitoring. Temperatures monitored included coolant inlet and outlet, cavity near resistor socket, resistor pin and shield. Power connections were provided to each resistor.

The instrumented samples were surrounded by a copper thermal shield which was heat sinked to the coolant tube. The shield was wrapped with super insulation.

The physical arrangement of the samples is as shown by Figure 2.

The shielded samples were installed in a vacuum chamber that was actively pumped by a mechanical vacuum pump.

B. Variables

1. Geometry
   a. Stainless steel resistor socket with and without Belleville washer.
   b. Copper resistor socket with and without Belleville washer.
2. Coolant
   a. Liquid nitrogen (-196°C)
   b. Water (≈ 14°C)
3. Power
   a. For liquid nitrogen: 5W, 7W, 10W, 13W and 15W
   b. For water: 5W, 7W and 10W
4. Sequence
   a. Evacuate vacuum chamber to minimum pressure obtainable with pumping system; i.e., 1-5 microns Hg.

b. Establish coolant flow and monitor until thermal equilibrium is reached.
c. Apply power and monitor resistor warm and cold and temperatures until thermal equilibrium is reached. Remove power.
d. Allow thermal equilibrium to be reached and proceed with next power setting.

IV. Results

A typical transient heating curve is as shown by Figure 3.
The steady state liquid nitrogen coolant results are as shown by Figures 4 and 5. No attempt was made to monitor the flow rate.
The steady state water coolant results are as shown by Figures 6 and 7. The flow rate was maintained at 1 gpm.

V. Discussion

A. General

In general, the copper socket provides better cooling than the stainless steel socket. At the predicted operating power level; i.e., 7 watts, The difference, as measured by the resistor tip temperature without a Belleville washer is small; i.e., 1°C for liquid nitrogen and 2° for water coolant

In general, the addition of a Belleville washer between the heat sink and the cooling clip impedes resistor cooling. At the predicted operating power level; i.e., 7 watts, the difference as measured by the resistor tip temperature is as given by the table below:

TIP TEMPERATURE (°C)

Geometry	LN_2 Coolant	Water Current
Copper w/washer	-168°C	40°C
Copper w/o washer	-168°C	37°C
SST w/washer	-168°C	39°C
SST w/o washer	-169°C	39°C

The data indicates that the net effect is small.

B. Liquid Nitrogen

At the predicted operating power level; i.e., 7 watts, the effects of geometry and material have small effects on the steady state operating temperatures. Representative values for tip, socket and Δ temperatures are -167°, -185° and 18°.

C. Water

At the predicted operating power level; i.e., 7 watts, the effects of geometry and material have small effects on the steady state operating temperatures. Representative values for tip, socket and Δ temperatures are 39°C, 18°C and 21°C. The tip temperature is maintained below the required operational maximum of 50°C.

VI. Conclusions

A. Socket Material

The resistor sockets will be stainless steel. The very small performance improvement offered by copper does not overcome stainless steel's advantage of having a very reliable tack welded joint between the socket and the cavity.

B. Belleville Washer

A Belleville washer will be installed between the heat sink and the cooling clip. The small, as measured, thermal impedance of the washer does not overcome the advantage of improved joint reliablility, and thus electrical continuity, between the resistor stud and the cavity.

C. Coolant

The resistor temperature, at an operating power of 7 watts, can be maintained below the required maximum of 50°C with either liquid nitrogen or water as a coolant. Liquid nitrogen offers a large margin of safety in this area.

D. Comparison with Machined Cavity

A comparison of the cooling performances of the "formed" and "machined" cavity configurations, at a power level of 7 watts, is as given by the data below:

TEMPERATURE (°C)

Configuration	LN$_2$ Tip	LN$_2$ Socket	LN$_2$ Δ	Water Tip	Water Socket	Water Δ
Machined[1,2]	-94	-120	26	72	45	27
Formed[3,4]	-168	-186	18	39	18	21

E. Cooling Improvements

Heat transfer to the resistor stud can be improved by increasing the thread size and increasing the length of engagement. These two areas will be pursued.

Heat transfer to the resistor stud can be improved by filling the voids of the threaded connection and between mating surfaces with a conductive material such as solder. This area will not be pursued for reasons of assembly and disassembly, bakeout and vacuum performance.

[1] Data per LBL Engineering Note, "Stochastic Cooling, Kicker Resistor Test (100 ohm), Preliminary Power Tests in Vacuum", T. Henderson and F. Voelker, March 3, 1983.

[2] Water temperature = 12°C. Flow rate estimated to be 1 gpm.

[3] Data for stainless steel socket with Belleville washer.

[4] Water temperature = 14°C, flow rate 1 gpm.

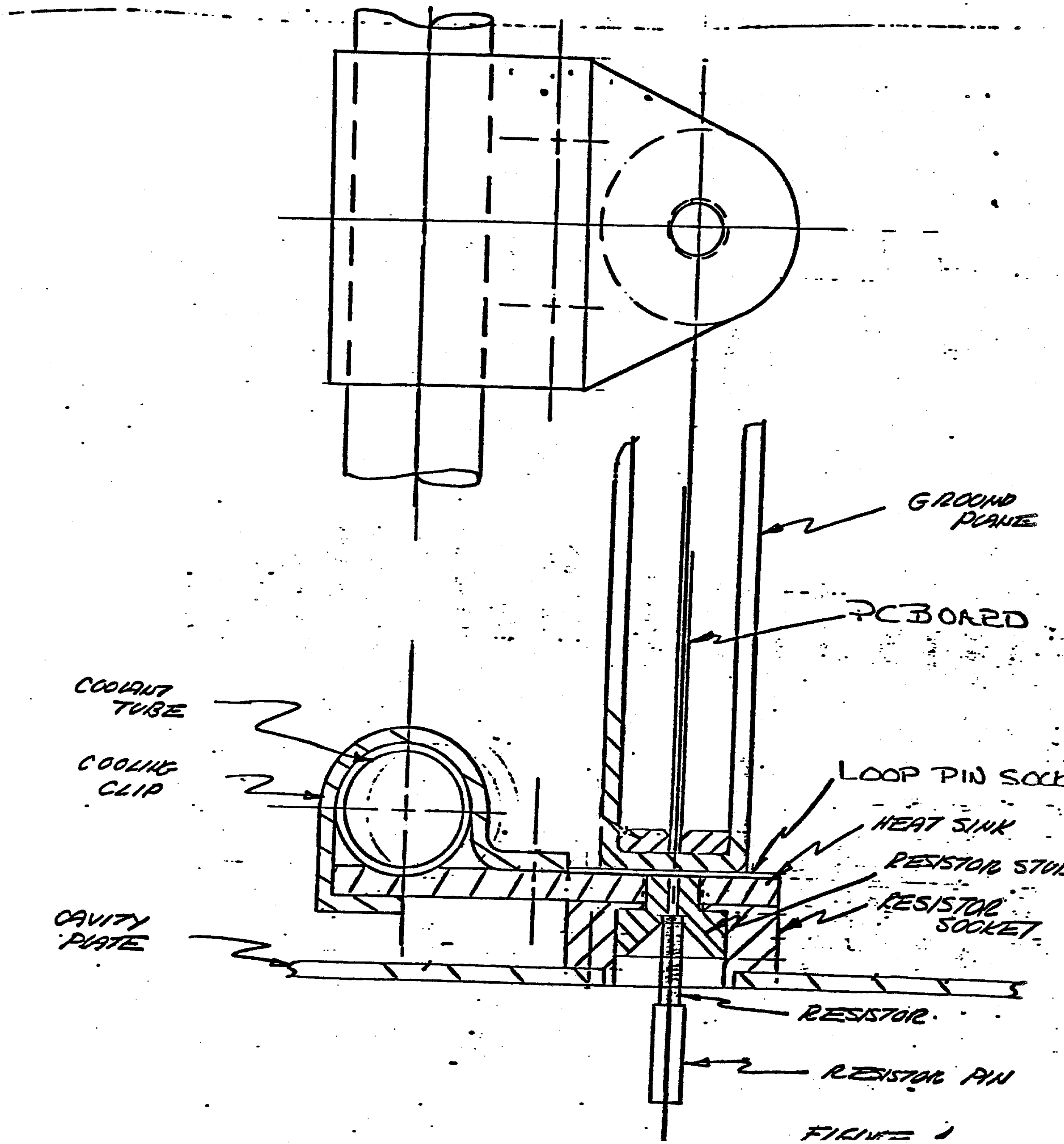
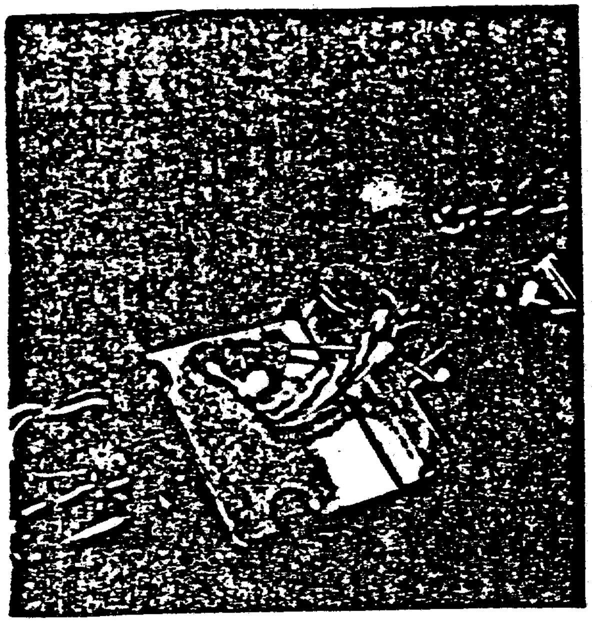
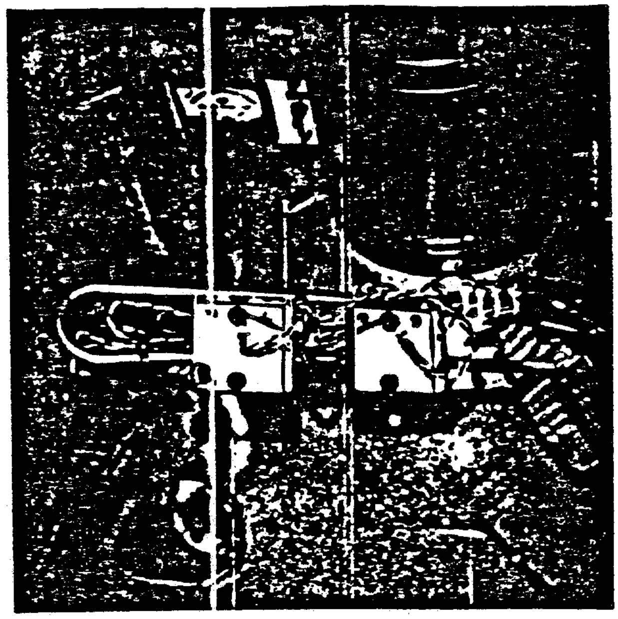

GROUND PLANE
PC BOARD
COOLANT TUBE
COOLING CLIP
LOOP PIN SOCK
HEAT SINK
RESISTOR STU
RESISTOR SOCKET
CAVITY PLATE
RESISTOR
RESISTOR PIN

FIGURE 1





SINGLE CAVITY SHOWING
HOOK-UP OF POWER LEAD
AND THERMOCOUPLE

DOUBLE CAVITY
ON COOLING LINE

BACK SIDE OF CAVITY
WIRE THERMOCOUPLE WIRES

MORE PICTURES
ON P. 12 YELLOW

FIGURE ?

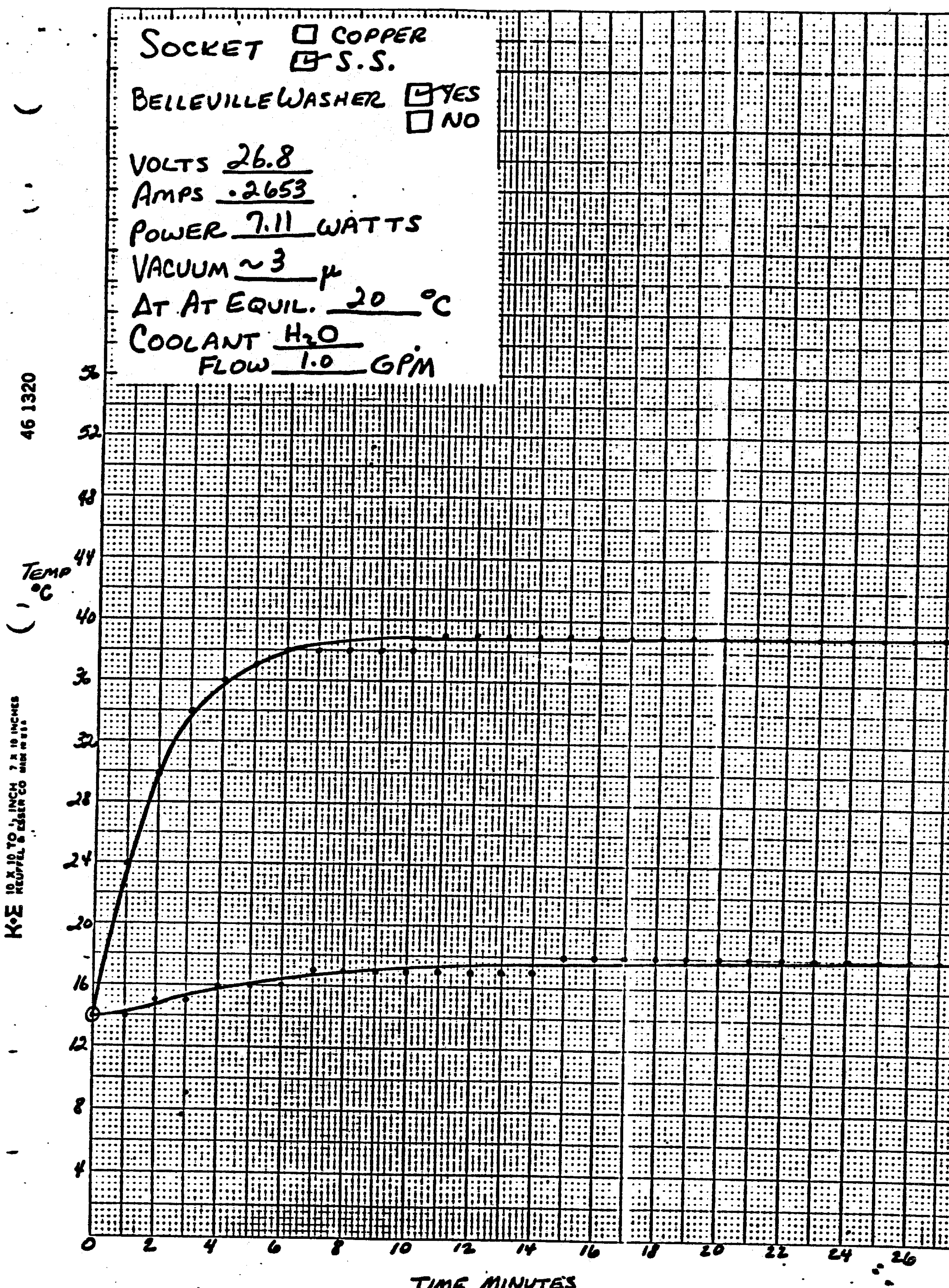

SOCKET
COPPER
S.S.
BELLEVILLE WASHER
YES
NO
VOLTS 26.8
AMPS .2653
POWER 7.11 WATTS
VACUUM ~3 μ
ΔT AT EQUIL. 20 °C
COOLANT H2O
FLOW 1.0 GPM
TEMP °C
56
52
48
44
40
36
32
28
24
20
16
12
8
4
0
2
4
6
8
10
12
14
16
18
20
22
24
26
TIME, MINUTES
46 1320
K·E 10 X 10 TO ½ INCH 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

FIGURE 3

LN_2 COOLED, TIP & SOCKET ΔT vs POWER

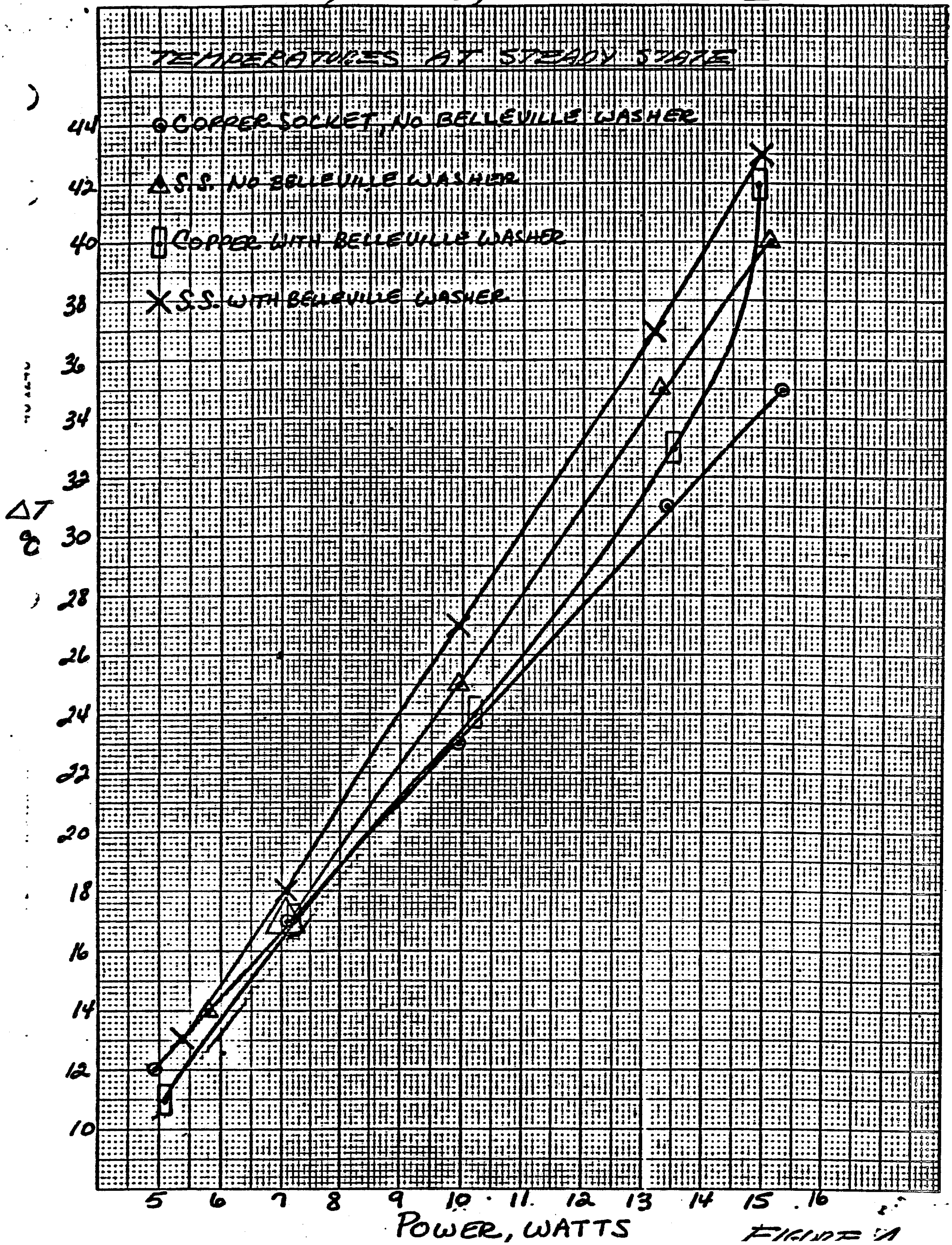
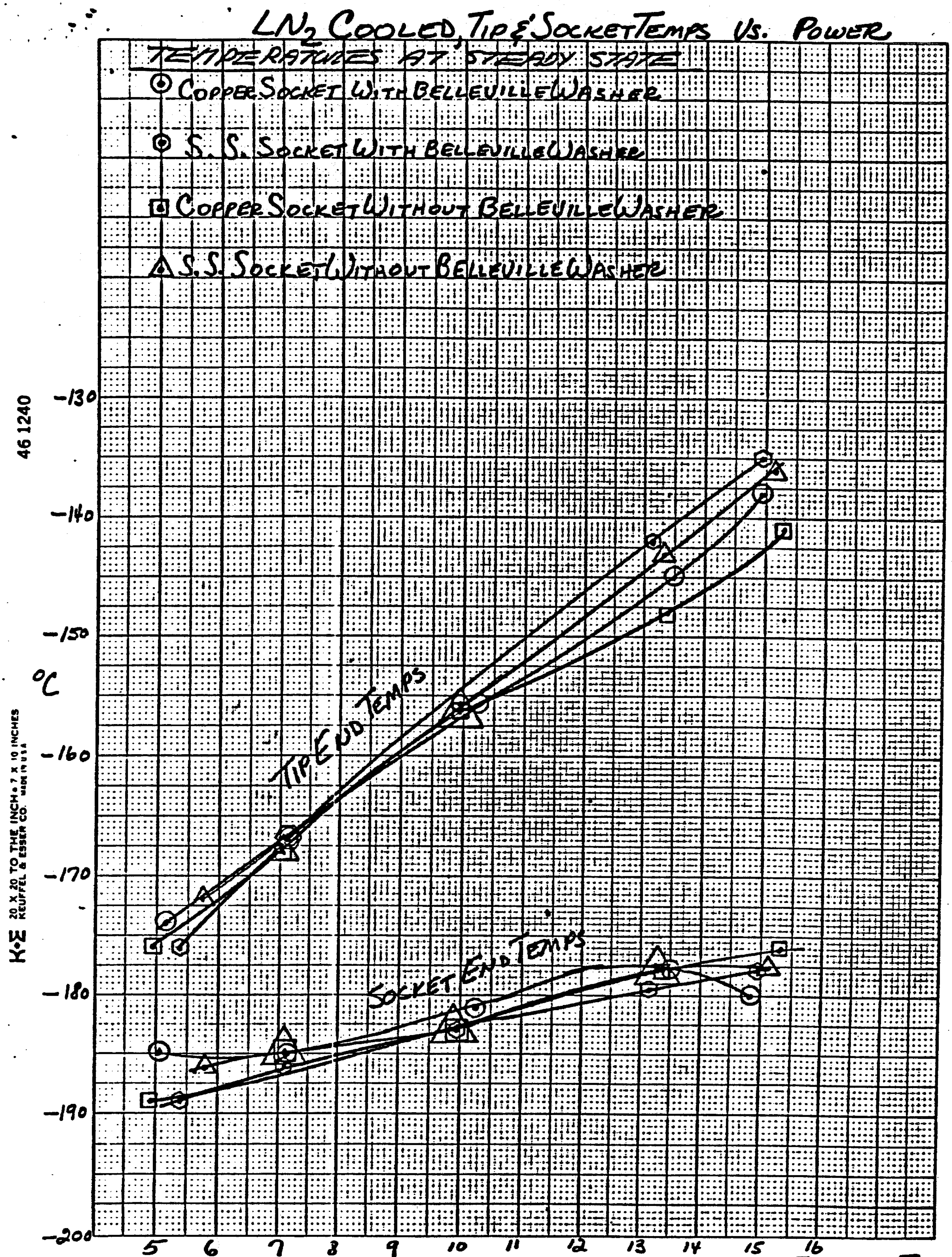


FIGURE 1



LN2 COOLED, TIP & SOCKET TEMPS VS. POWER
TEMPERATURES AT STEADY STATE
COPPER SOCKET WITH BELLEVILLE WASHER
S. S. SOCKET WITH BELLEVILLE WASHER
COPPER SOCKET WITHOUT BELLEVILLE WASHER
S. S. SOCKET WITHOUT BELLEVILLE WASHER
TIP END TEMPS
SOCKET END TEMPS
°C
-130
-140
-150
-160
-170
-180
-190
-200
5
6
7
8
9
10
11
12
13
14
15
16
46 1240
K•E 20 X 20 TO THE INCH • 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.

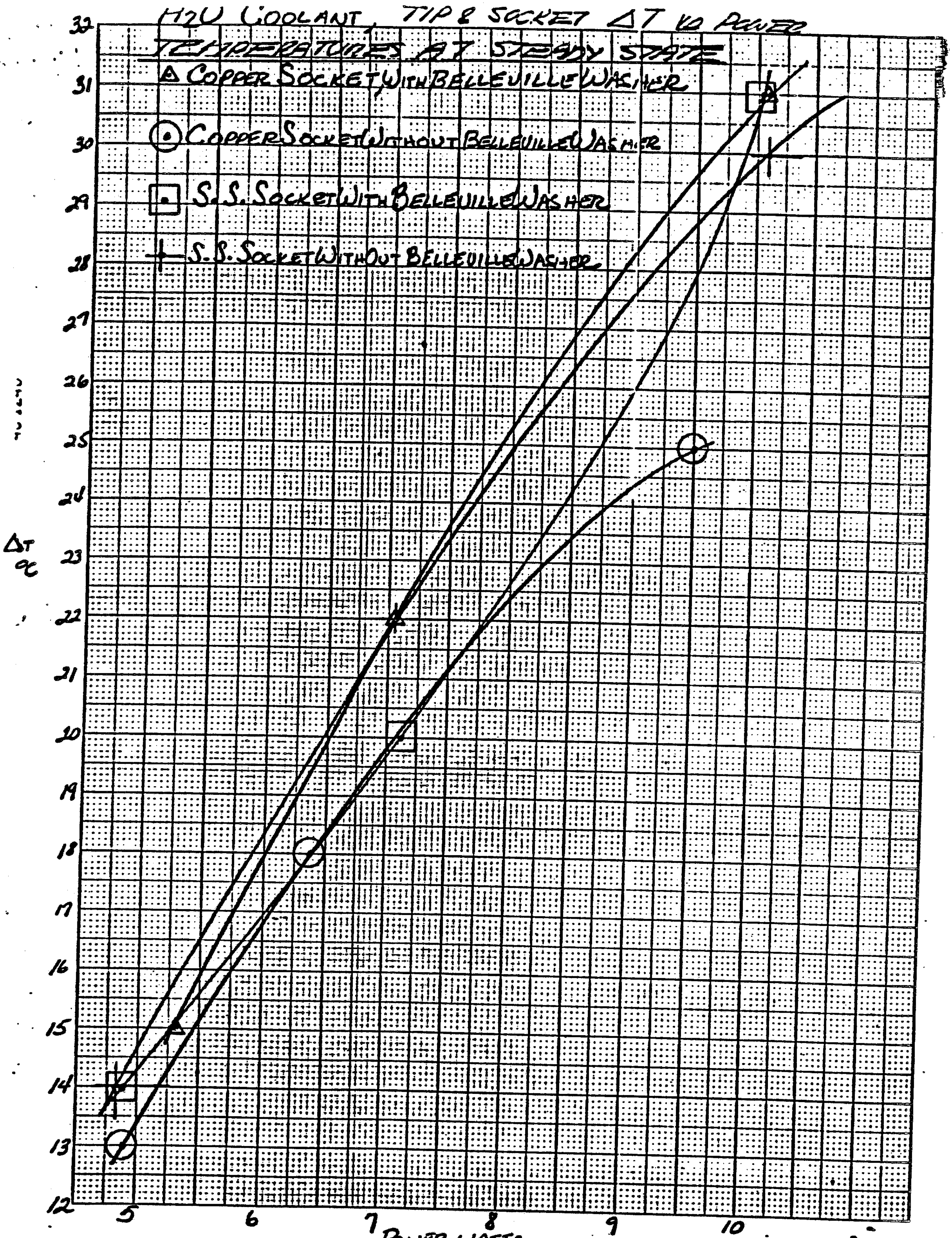
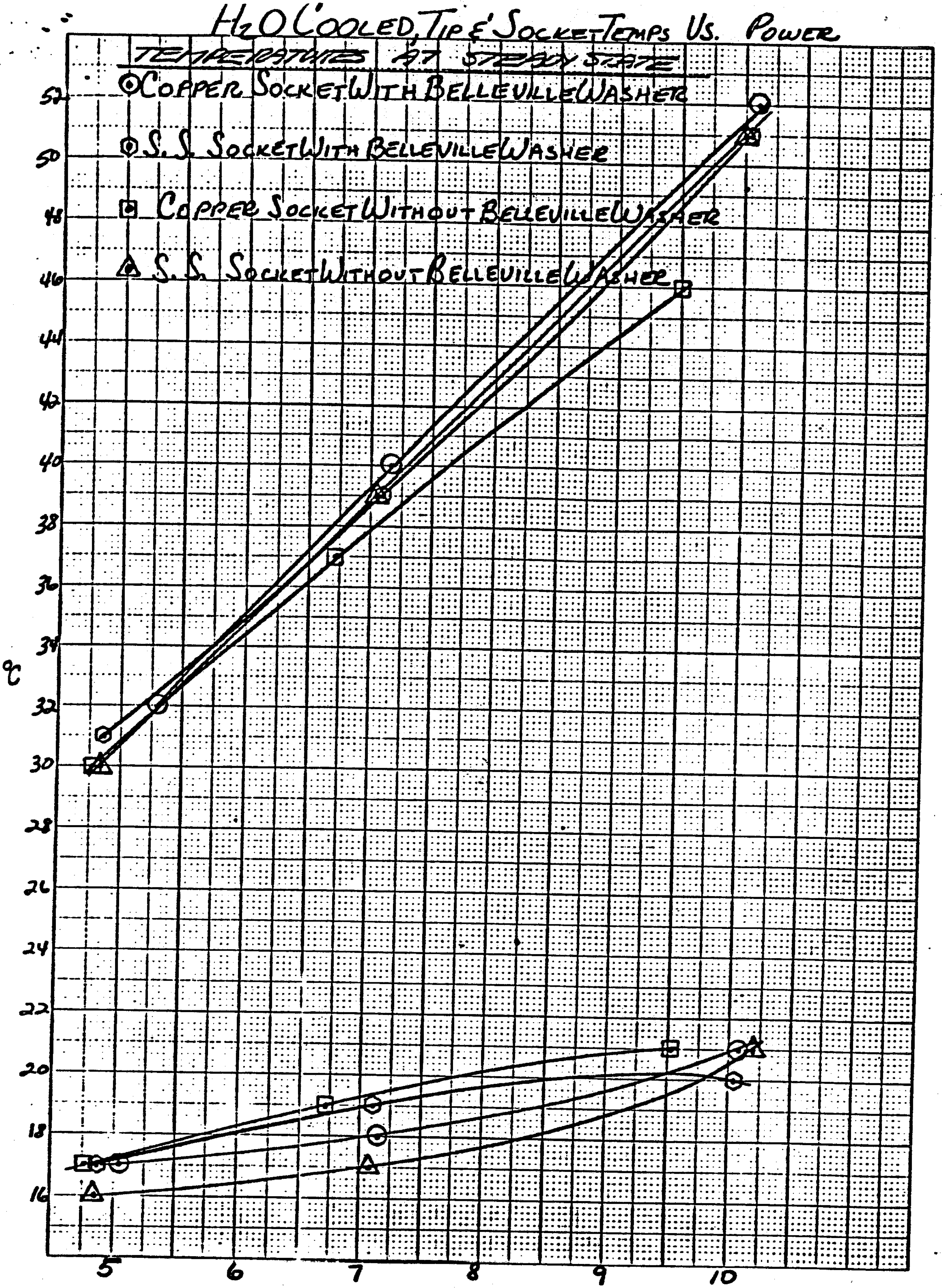

H2O COOLANT, TIP & SOCKET ΔT vs POWER
TEMPERATURES AT STEADY STATE
COPPER SOCKET WITH BELLEVILLE WASHER
COPPER SOCKET WITHOUT BELLEVILLE WASHER
S.S. SOCKET WITH BELLEVILLE WASHER
S.S. SOCKET WITHOUT BELLEVILLE WASHER
ΔT °C
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
5
6
7
8
9
10
POWER, WATTS

FIGURE 6



H_2O COOLED, TIP & SOCKET TEMPS VS. POWER
TEMPERATURES AT STEADY STATE
COPPER SOCKET WITH BELLEVILLE WASHER
S. S. SOCKET WITH BELLEVILLE WASHER
COPPER SOCKET WITHOUT BELLEVILLE WASHER
S. S. SOCKET WITHOUT BELLEVILLE WASHER
°C
52
50
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
5
6
7
8
9
10
POWER WATTS

FIGURE 7

MF/RN/DV
10/24/83

TEV I Electrodes
Formed Microwave Assembly
Single Pair Kicker Tests

I. Objective

The test objective was to conduct an evaluation of the cooling of the "formed" version of the TEV I electrode microwave assembly when operated as a kicker with water cooling.

II. Test Arrangement

The test arrangement is as shown by Figure 1.

A. Test Article

The test article corresponds to a single cavity pair slice of a 1-2 GHz formed microwave array. The components have the geometry of the 1-2 GHz microwave array production design.

The test article incorporated a loop that corresponds to the current LBL 1 - 2 GHz loop design. The loop details are as shown by Figure 2. The circuit board was etched with a pattern to yield the approximate RF power dissipation in the board when operated in the DC test mode. A circuit board connector of the soldered blade type was employed. The circuit board and connector details are as shown by Figure 3.

Only the upper half of the test article had a loop, etched circuit board and connector.

B. Shield

The test article was contained in an supported from a shield. The shield consisted of a 1/16 inch thick copper cylindrical section, having a coolant flow loop, with removable circular end sections. The end sections consisted, from the exterior to the interior, of a 1/16 inch thick G10 disc, 25 layers of multilayer insulation, of a 1/16 inch thick copper disc. The copper disc was in thermal contact with the cylindrical portion of the shield. The test article was mounted to the shield by threaded fasteners on the horizontal centerline of the assembly. The fasteners were fabricated of G10 to provide thermal isolation of the array from the shield.

IV. Results

The array temperature distribution as measured by TC 1 through 11 versus power at a constant water flow rate is as shown by Figure 4.

The transient heating curves for the resistor; i.e., TC 11 at the resistor loop post upper end, versus power at constant water flow rate are as shown by Figure 5.

The effect of water flow rate on resistor temperature and circuit board temperature is as shown by Figure 6.

The array temperature distribution without water flow at a power level of 7 watts is as shown by Figure 7.

V. Discussion

A. The array temperature distribution is in three temperature groupings:
   1. Water inlet
   2. Array structure and combiner board
   3. Loop assembly

B. The array temperatures vary linearly with power for power levels from 3 to 10 watts.

C. The circuit board temperature is several degrees; i.e., less then 5°F, higher than the adjacent side plane surface.

D. The resistor temperature reaches its steady state value in a short; i.e., less than 1/2 hour, period of time. The steady state value for the as specified kicker operating power level of 7 watts is 125°F; i.e., 52°C. The temperature as measured should be somewhat lower than the actual resistor operating temperature since the resistor is connected to the resistor loop post through the resistor pin and a spring connector each of which having a resistance to the flow of heat from the resistor's lower end.

E. Resistor and circuit board temperatures are relatively insensitive to water flow rate for flow rates greater than 1 gpm.

F. Resistor temperatures can rise to the level of 300°F; i.e., 149°C, at an operating power level of 7 watts with no water flow.

VI. Conclusions

A. For the as specified kicker operating power level of 7 watts, the resistor steady state operating temperature is greater than 50°C which is the specified maximum allowable value based on component performance and life time considerations.

The previous evaluation[1] of the resistor cooling in which the cooling configuration consisted of the cooling tube, cooling clip, heat sink, cavity resistor socket, resistor stud, resistor and resistor pin indicated a lower operating temperature; i.e., 39°C, at an operating power level of 7 watts. A comparison of the two data sets is as follows:

	Power Level [W]	Water Flow [gpm]	Water Inlet Temp. [°C]	Resistor Temp. [°C]
Previous test	7	1	14	39
This test	7	1.5	21	52
	0	+0.5	+ 7	+13

Since this test has shown that resistor temperature is insensitive to flowrate in the 1 - 2 gpm range, the major cooling variable difference other than test article and instrumentation is the inlet temperature of the cooling water.

If a 50°C maximum resistor operating temperature is to be an operational criteria, the use of chilled water appears to be necessary.

B. Cooling water flowrate in the range of 1 - 2 gpm is adequate.

C. Since the circuit board temperatures is slightly higher than that of the adjacent sideplane, it appears that circuit board cooling by means of emissivity control on the board and side plane surfaces would not be effective. Cooling improvements could be achieved by actively cooling the side plane with chilled water.

1. "Resistor Cooling Tests," MF/RN/DV, 6/1/83

D. Since the array structure temperatures are closely grouped and moderately; i.e., 7 - 15°F, above that of the cooling water, thermal distortion of the array during operation should not be a problem. Also a straight cooling tube configuration can be employed due to the small differential thermal contraction over the array length[2]. This may not be the case, however, if a rapid heating of the structure for the purpose of bakeout is accomplished by flow of large volumes of high temperature; i.e., 150°C, gas through the cooling tube. Heating at moderate rates is appropriate to reduce cooling tube complexity.

E. Resistor solder joints should survive operation at power; i.e., 7 watts, without coolant flow[3].

2. $\Delta \ell = \ell \int \alpha dT = \ell \alpha \Delta T = 40 \text{ in} \times 0.6 \frac{\text{in}}{\text{in}°\text{F}} \times 10^{-5} \times 15°\text{F}$

$$= 0.0036 \text{ in}$$

$$\epsilon = \frac{\Delta \ell}{\ell} = \frac{.0036 \text{in}}{40 \text{in}} = 0.00009 \frac{\text{in}}{\text{in}}$$

$$\sigma = EG = 30 \times 10^6 \frac{\text{LB}}{\text{in}^2} \times 0.00009 \frac{\text{in}}{\text{in}} = 2700 \frac{\text{LB}}{\text{in}^2}$$

3. Solder melting temperature is approximately 162°C.

C. Vacuum Tank

The test article and shield assembly were installed in a vacuum tank. The unit was supported by G10 rods cantilevered from the tank flange.

The tank was evacuated with a turbomolecular pump.

D. Instrumentation

The article and shield were instrumented with Type T 28 gauge thermocouple wire. The junctions were made by welding and were fastened to the test article by mechanical clamping. Thermocouple locations are as given by Table 1.

The thermocouples were monitored with a commerical data logger having a built in reference junction. The calibration of the system was checked at the water boiling, ice melting and LN_2 boiling points.

The array coolant flow rates was monitored with a rotameter type flowmeter.

The tank vacuum was monitored with thermocouple type and ionization type vacuum gauges.

III. Procedure

A. Variables

A test plan was developed to evaluate several factors that could affect the operating temperatures of the resistor (component life) and the circuit board (outgassing).

B. Sequence

The vacuum tank was evacuated to the minimum pressure obtainable with the pumping system.

Baseline temperature measurements were made with the test article and ambient temperature and with no coolant flow.

Water coolant flow at approximately 20°C was initiated as per the test plan.

The array was operated at resistor DC power levels of 3, 5, 7 and 10 with a constant water flow rate. The array was operated at a power level of 7 watts with varying water flow. The array was operated at a power level of 7 watts with no water flow.

Data was taken until quasi steady state temperatures were reached.

MF/RN/DV
11/27/83

TEV I Electrodes
Formed Microwave Assembly
Single Pair Kicker Tests

I. Objective

The test objective was to continue the evaluation of the cooling of the "formed" version of the TEV I electrode microwave assembly when operated as a kicker with chilled water cooling.

II. Test Arrangement and Procedure

The test arrangement and procedure is as per the previous kicker cooling evaluation.[1]

The principal variable was to evaluate the effectiveness of chilled water in maintaining the resistor operating temperature below the required 50°C upper limit at an operating power of 7 watts.

The chilled water supply, which was improvised to permit testing, resulted in a minimum water supply temperature of approximately 10°C.

III. Results

The results of the previous[2] and this evaluation are as shown below:

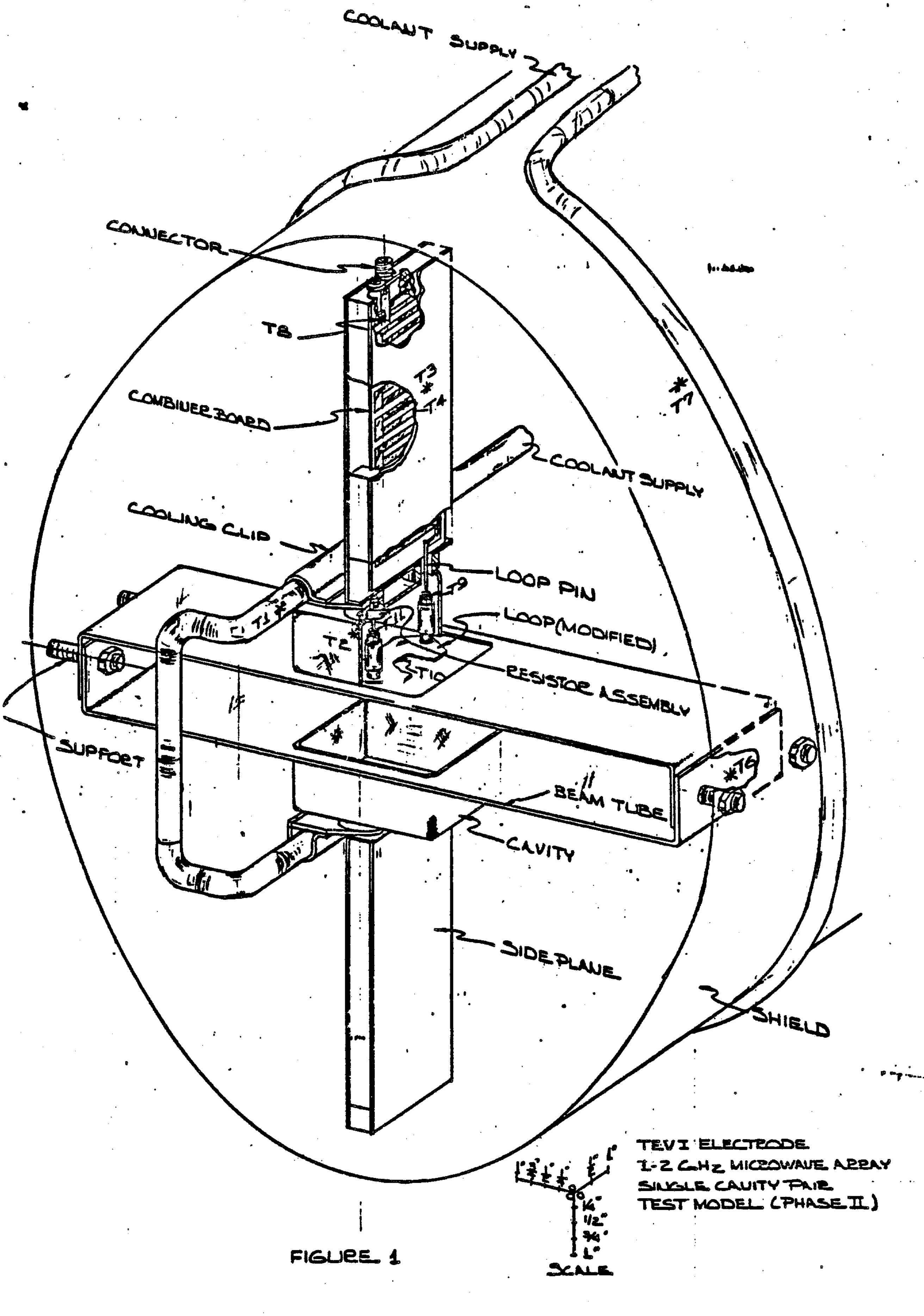
	Power Level [W]	Water Flow [gpm]	Water Inlet Temp. [°C]	Resistor Temp. [°C]
Previous Test	7	1.5	21	52
This Test	7	1	10	44
	7	1.5	10	44

IV. Conclusion

For the specified kicker operating power of 7 watts, the resistor steady state operating temperature can be maintained below 50°C with the use of moderately chilled; i.e.,10°C, water.

1 "Single Pair Kicker Tests", MF/RN/DV, 10/24/83

2 IBiD



TEV I ELECTRODE
1-2 GHz MICROWAVE ARRAY
SINGLE CAVITY PAIR
TEST MODEL (PHASE II)

FIGURE 1

TABLE 1
THERMOCOUPLE LOCATIONS

TC NO.	LOCATION
T1	Water Supply Tube
T2	Cavity wall near resistor assembly
T3	Side plane at geometric center
T4	Circuit board on conductor at geometric center
T5	Beam tube at halfway point between cavity edge and beam tube edge
T6	Beam tube side at horizontal centerline
T7	Cylindrical shield
T8	Circuit board connector blade at point of attachment to circuit board
T9	Circuit board loop post at upper end
T10	Loop plate at geometric center
T11	Resistor loop post at upper end

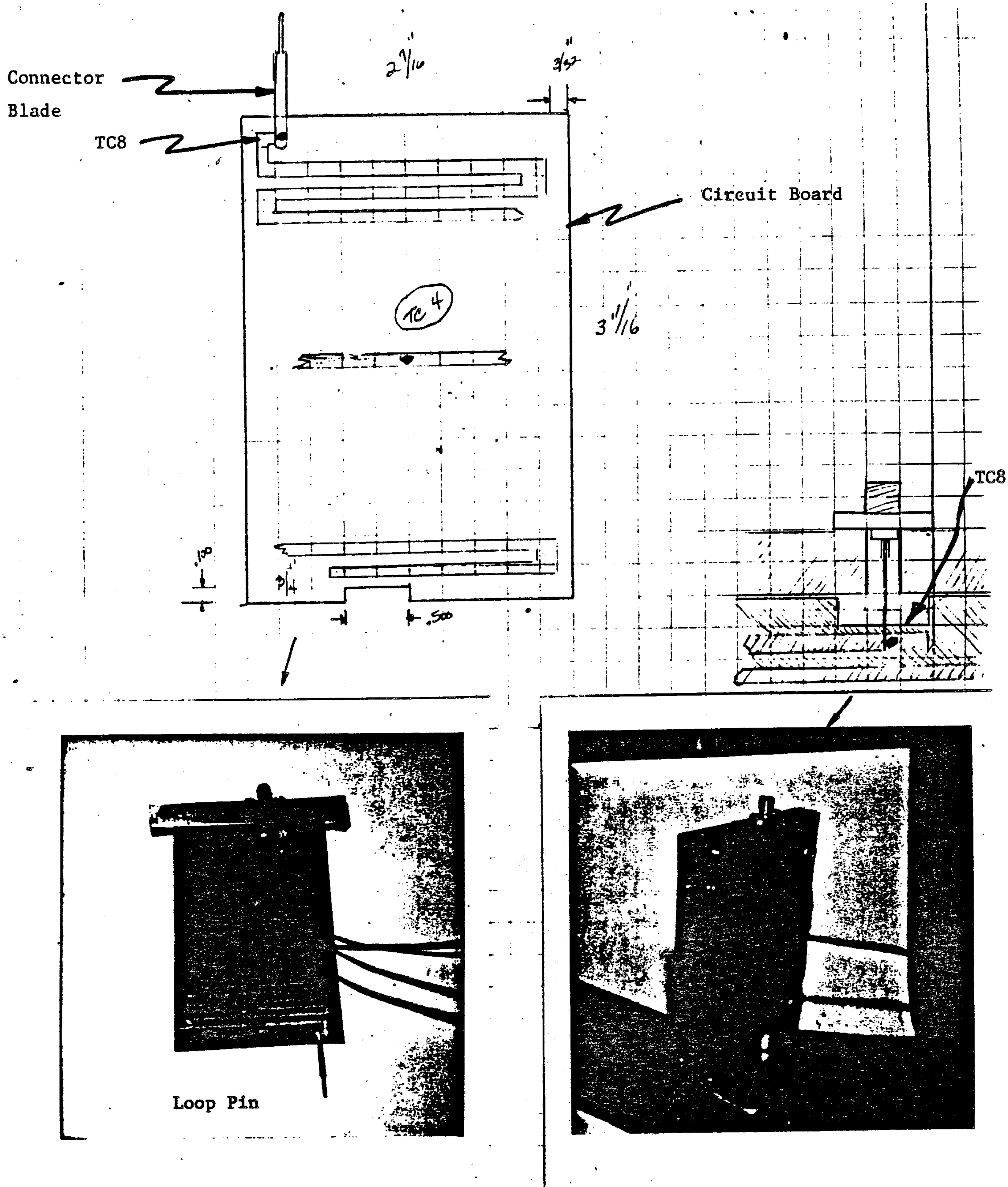
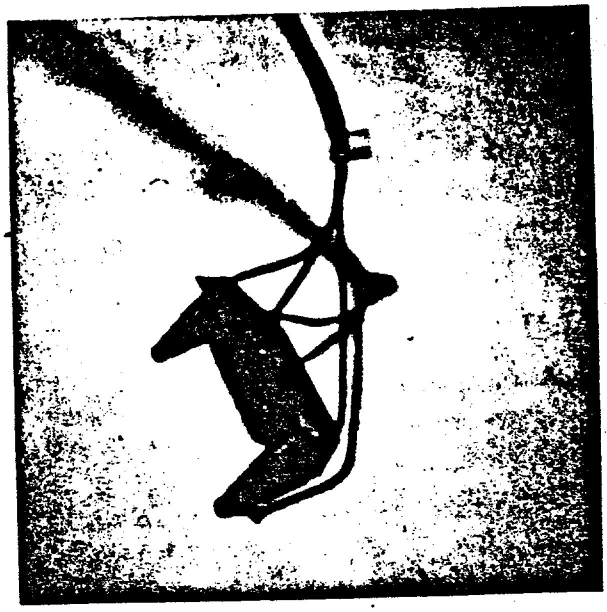
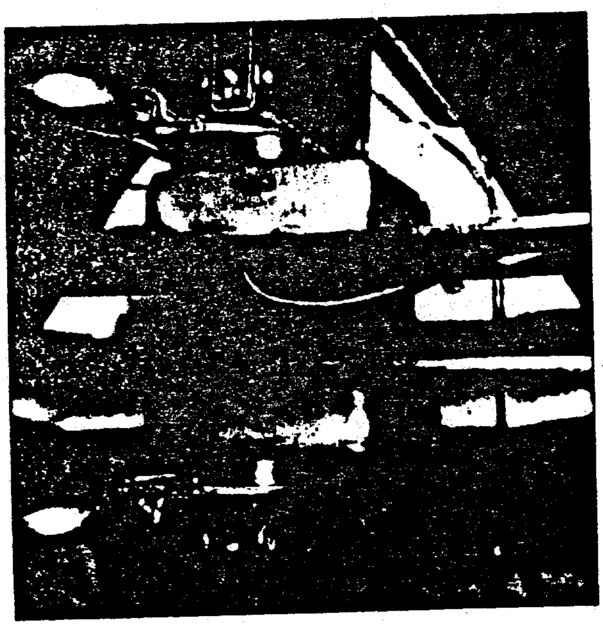

Connector
Blade
TC8
2 1/16"
3/32"
Circuit Board
TC 4
3 1/16"
.100
3/4"
.500
TC8
Loop Pin

Figure 2





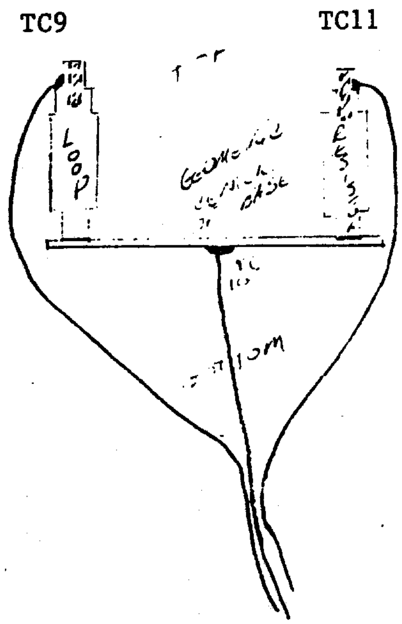
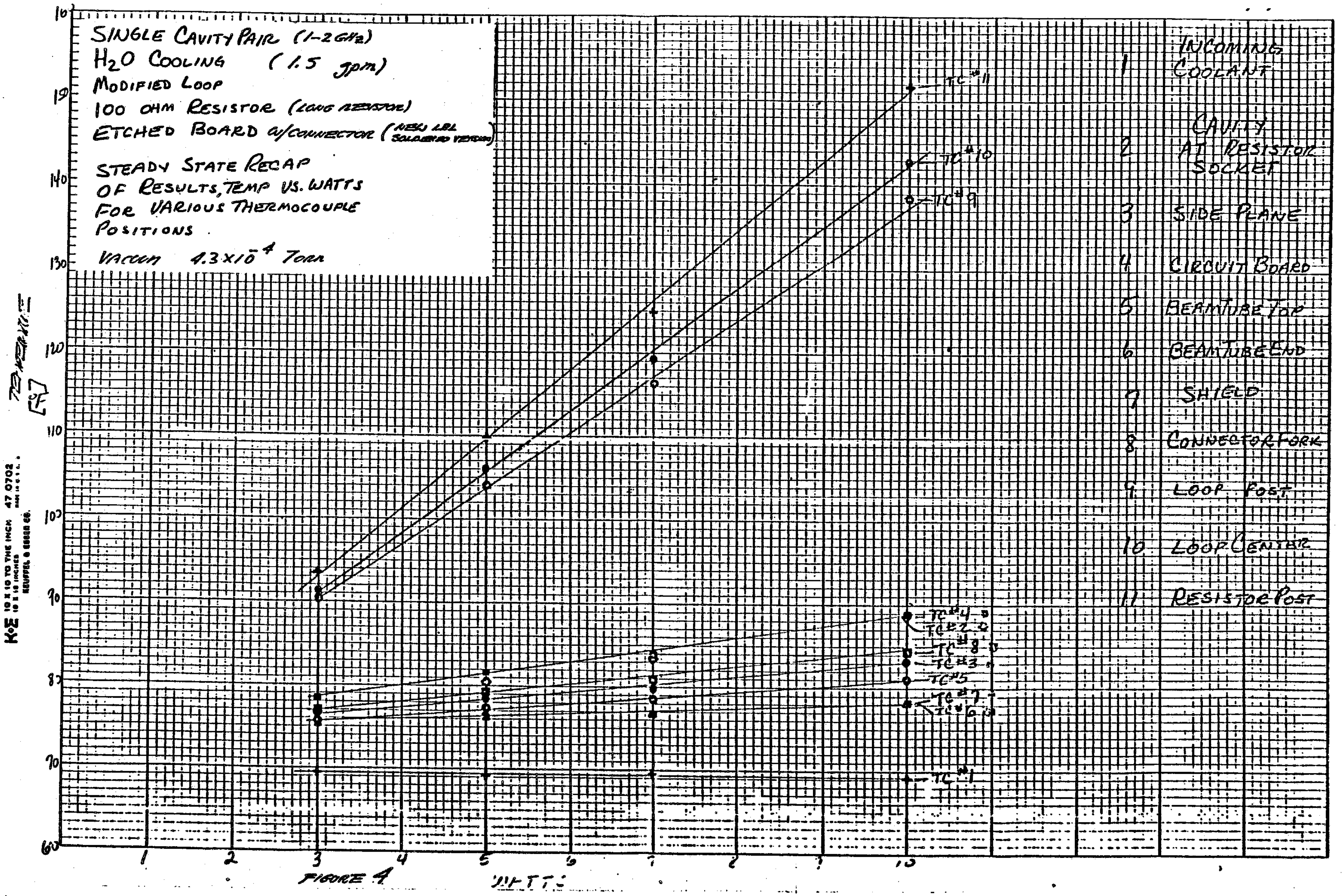
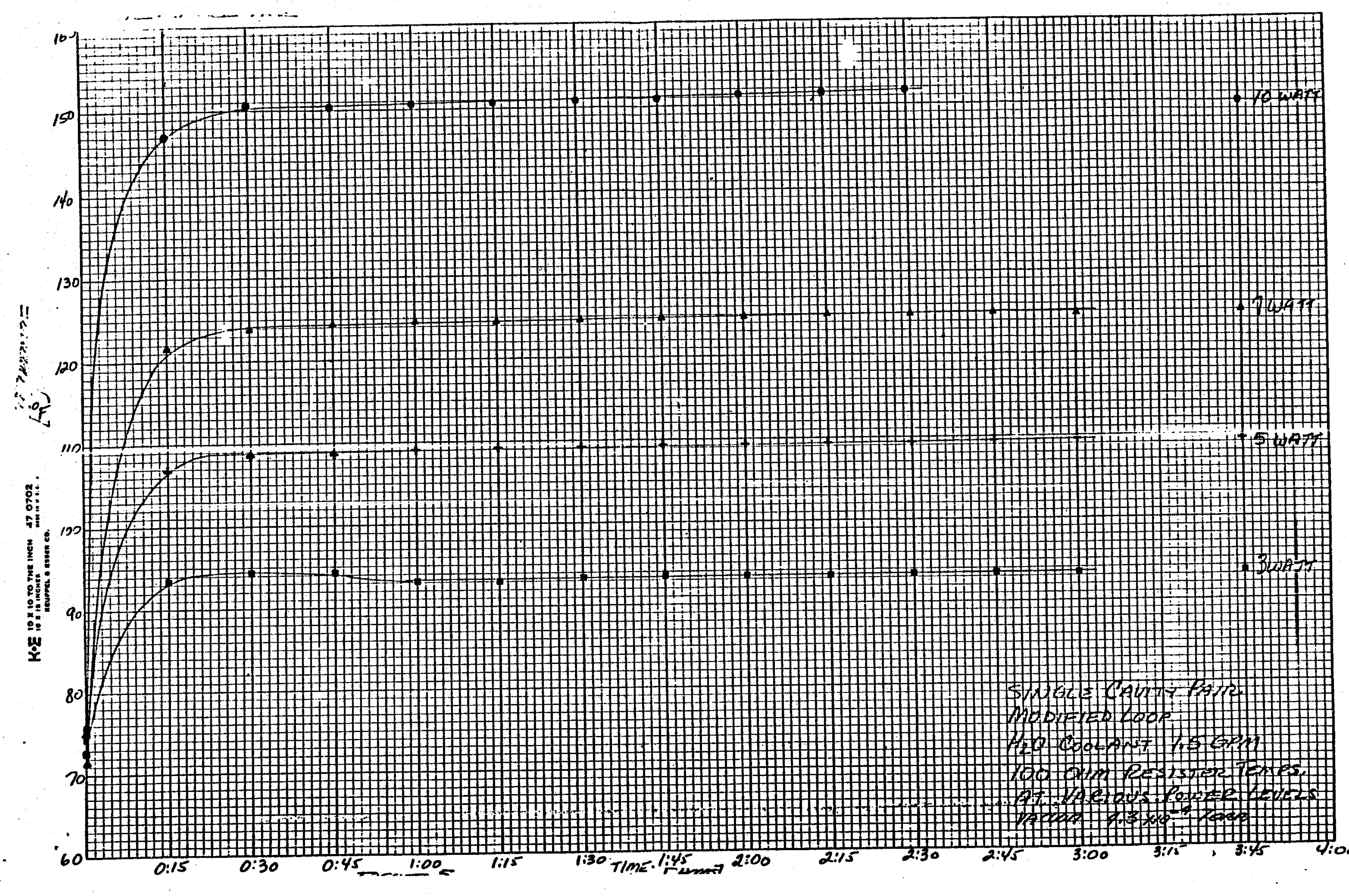
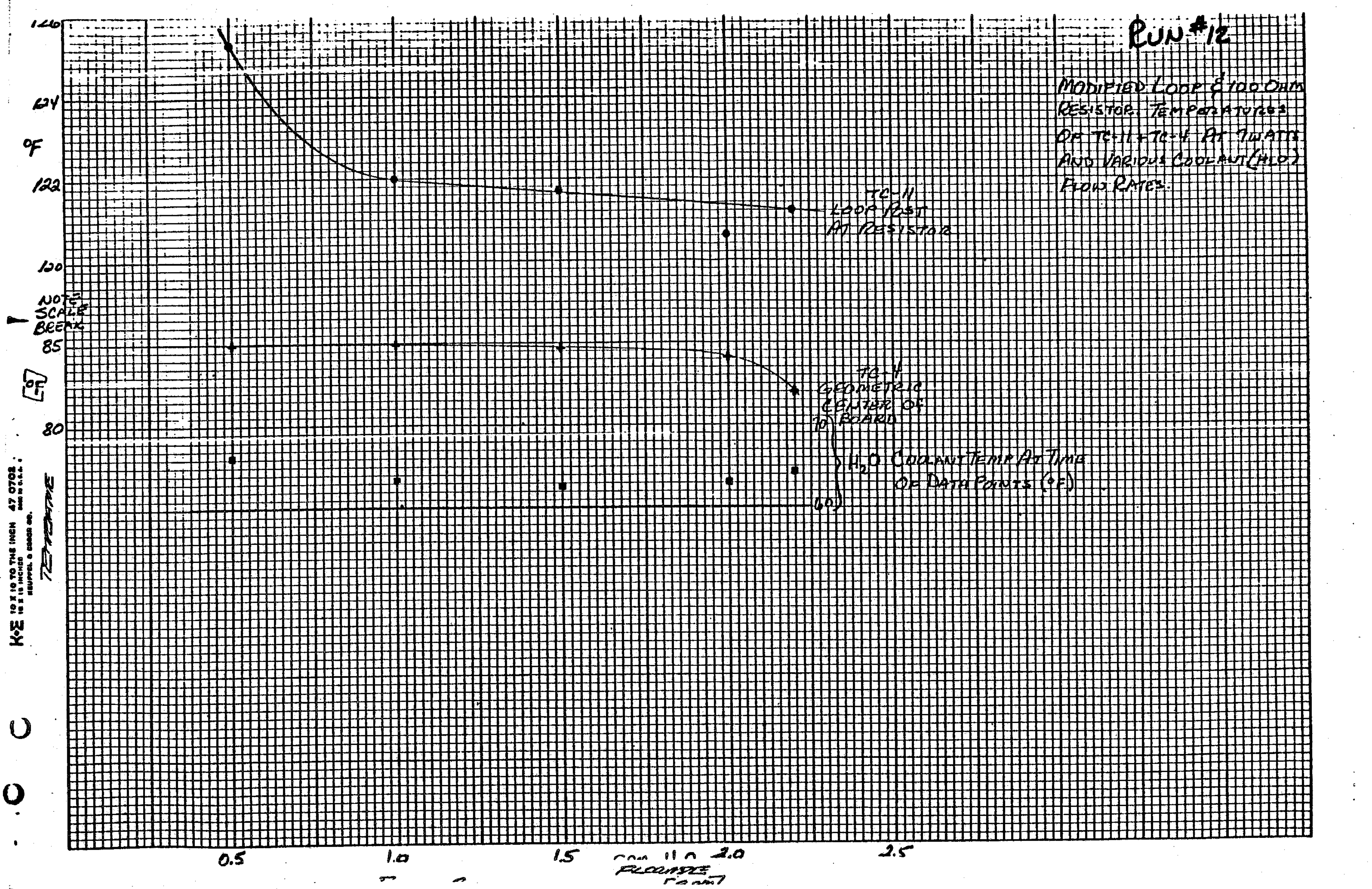


Figure 3

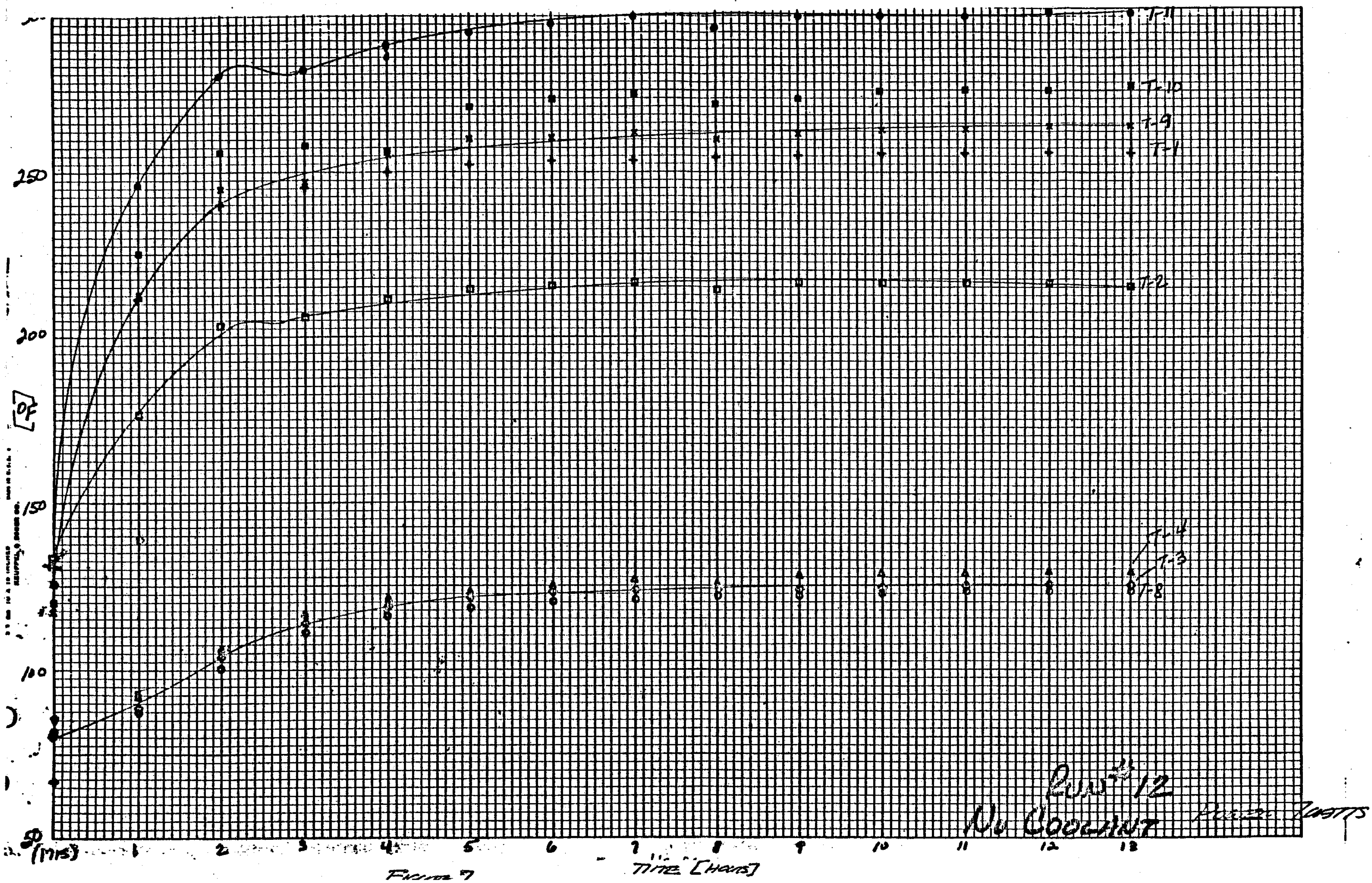

SINGLE CAVITY PAIR (1-2 GHz)
H2O COOLING (1.5 gpm)
MODIFIED LOOP
100 OHM RESISTOR (LONG RESISTOR)
ETCHED BOARD w/CONNECTOR (NEW LRL SOLDERED VERSION)
STEADY STATE RECAP OF RESULTS, TEMP VS. WATTS FOR VARIOUS THERMOCOUPLE POSITIONS
VACUUM 4.3X10-4 TORR
1 INCOMING COOLANT
2 CAVITY AT RESISTOR SOCKET
3 SIDE PLANE
4 CIRCUIT BOARD
5 BEAMTUBE TOP
6 BEAMTUBE END
7 SHIELD
8 CONNECTOR FORK
9 LOOP POST
10 LOOP CENTER
11 RESISTOR POST
TC#11
TC#10
TC#9
TC#4
TC#2
TC#8
TC#3
TC#5
TC#7
TC#6
TC#1
WATTS
K+E 10 X 10 TO THE INCH 47 0702
KEUFFEL & ESSER CO.
FIGURE 4



K·E 10 X 10 TO THE INCH 47 0702
10 X 15 INCHES
KEUFFEL & ESSER CO.



RUN #12
MODIFIED LOOP & 100 OHM RESISTOR. TEMPERATURES OF TC-11 + TC-4 AT 7 WATTS AND VARIOUS COOLANT (H_2O) FLOW RATES.
TC-11 LOOP POST AT RESISTOR
TC-4 GEOMETRIC CENTER OF BOARD
H_2O COOLANT TEMP AT TIME OF DATA POINTS (°F)
NOTE SCALE BREAK
°F
126
124
122
120
85
80
70
60
0.5
1.0
1.5
2.0
2.5
FLOWRATE



250
200
150
100
50
°F
(MIS)
1
2
3
4
5
6
7
8
9
10
11
12
13
TIME [HOURS]
T-11
T-10
T-9
T-1
T-2
T-4
T-3
T-8
Run #12
No Coolant

FIGURE 7

MF/RN/DV
11/27/83

TEV I Electrodes
Formed Microwave Assembly
Single Pair Kicker Tests

I. Objective

The test objective was to continue the evaluation of the cooling of the "formed" version of the TEV I electrode microwave assembly when operated as a kicker with chilled water cooling.

II. Test Arrangement and Procedure

The test arrangement and procedure is as per the previous kicker cooling evaluation.[1]

The principal variable was to evaluate the effectiveness of chilled water in maintaining the resistor operating temperature below the required 50°C upper limit at an operating power of 7 watts.

The chilled water supply, which was improvised to permit testing, resulted in a minimum water supply temperature of approximately 10°C.

III. Results

The results of the previous[2] and this evaluation are as shown below:

	Power Level [W]	Water Flow [gpm]	Water Inlet Temp. [°C]	Resistor Temp. [°C]
Previous Test	7	1.5	21	52
This Test	7	1	10	44
	7	1.5	10	44

IV. Conclusion

For the specified kicker operating power of 7 watts, the resistor steady state operating temperature can be maintained below 50°C with the use of moderately chilled; i.e.,10°C, water.

1 "Single Pair Kicker Tests", MF/RN/DV, 10/24/83

2 IBiD