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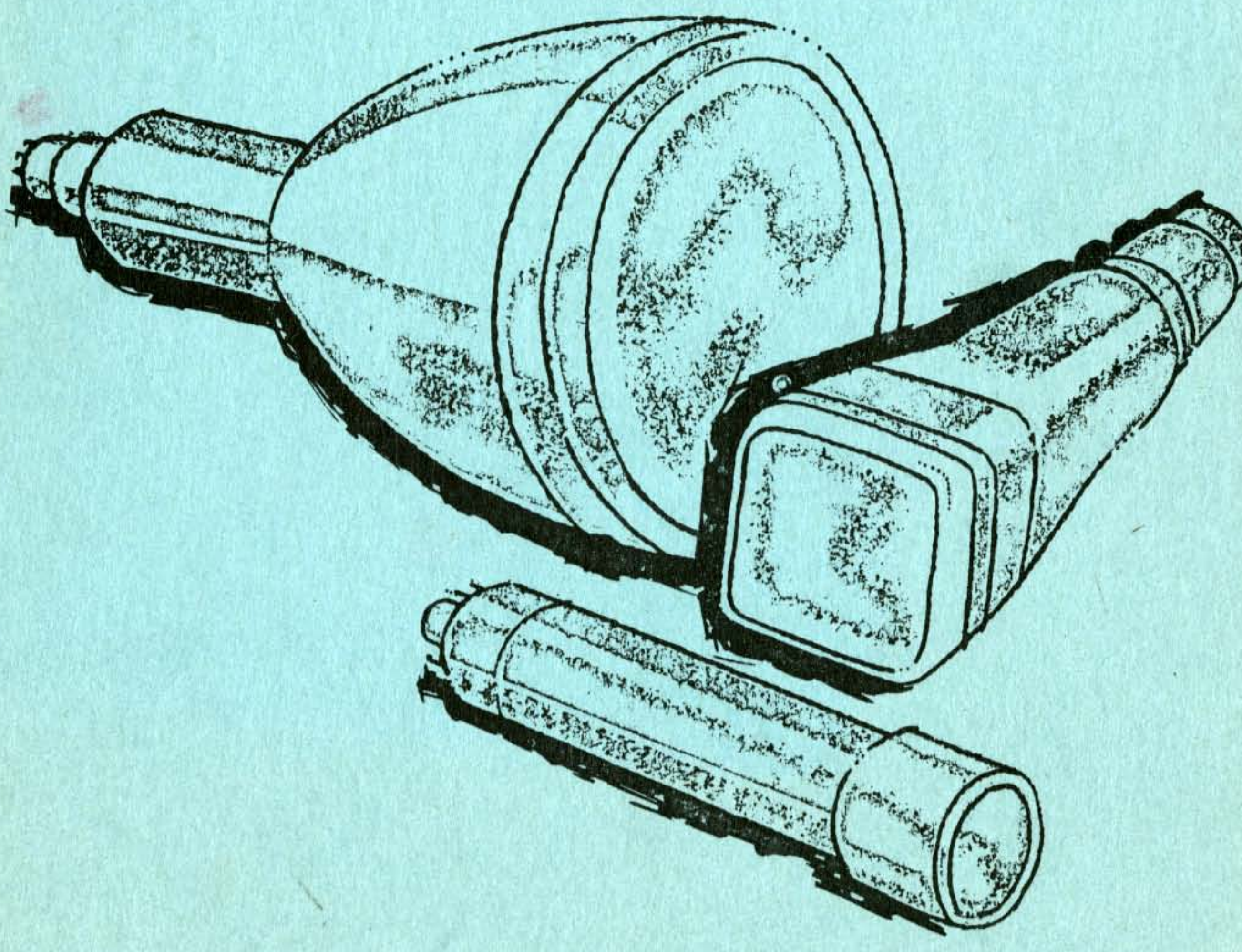
TECHNICAL INFORMATION SERIES

NUMBER R-62-ETC-3

AUTHOR D. L. CRAWFORD
R. J. NEY

TITLE LOW HEATER POWER CATHODE



GENERAL ELECTRIC

CATHODE RAY TUBE DEPARTMENT
ELECTRONICS PARK, SYRACUSE, N. Y.

GENERAL ELECTRIC

ELECTRONIC COMPONENTS DIVISION

CRT-705-85 (8-57)

TECHNICAL INFORMATION SERIES

Title Page

AUTHOR	SUBJECT CATEGORY	NO. R-62-ETC-3
D.L.Crawford R.J.Ney	Electron Tubes	DATE 3/28/62

TITLE Low Heater Power Cathode

ABSTRACT Heat balance is given on a 1/4 watt cathode. Parameters influencing the reliability of the heater-cathode is treated. Cycling and steady-state life data is given. The advantages of Rhenium-Tungsten filament over conventional Tungsten is demonstrated. An outline of the manufacturing process, and equipment is described.

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4	Technical Data Center Cathode Ray Tube Dept. Bldg. #6, Syracuse, N.Y.	36
GOV. CLASS None		

CONCLUSIONS

The manufacturing of a reliable quarter-watt heater-cathode is entirely feasible. There are experimental and theoretical indications that a 100 milliwatt cathode is also feasible.

By cutting out this rectangle and folding on the center line, the above information can be fitted into a standard card file.

For list of contents—drawings, photos, etc., and for distribution see page attached.

GE ACCOUNTING REFERENCE ______

COLLABORATORS ______

COUNTERSIGNED Dr.H.J.Hannam DEPT. C.R.T. LOCATION Syracuse, New York

INTRODUCTION

There has been considerable interest in low heater power cathodes in the past few years. Quarter-watt cathodes have frequently been mentioned.

The heat balance of a 50 mil diameter, 22 mil thick oxide coated cathode operating at 825°C, with reasonable structural support and with quite favorable heater lead losses, indicates a power requirement of .173 watts.

The heat balance obtained from curves 1 to 5 are as follows:

1.	Conduction loss by 3 mil tripod legs	32 milliwatts
2.	Conduction loss by .8 mil heater leads	9
3.	a. Radiation loss by cathode surface (E=.3)	31
	b. Radiation loss by back surface	31
4.	Radiation loss by side wall (E=.3)	50
	Total	153
5.	Heat generation loss by leads - 13% of total. (Coil length/lead length=10)	20
	Total heat loss from heater-cathode	173

In the actual devices tested, at least 230 milliwatts is required to obtain 825°C cathode temperature. The discrepancies between theoretical and actual values are probably due to errors in the values used for emissivities, and errors in cathode temperature measurements. However, stable cathode operation has been obtained at 125 milliwatts of heater power.

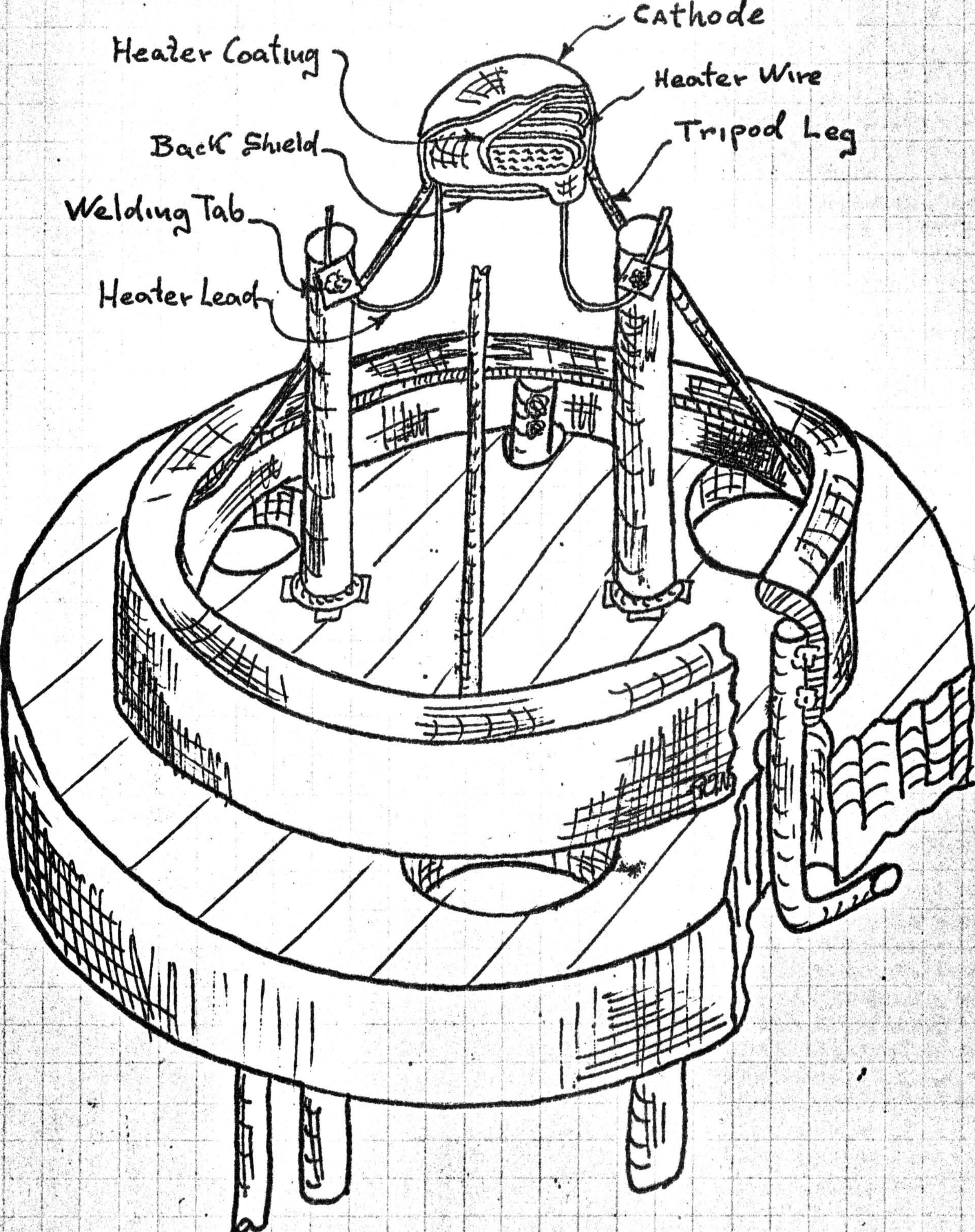
It will be exceedingly difficult to reduce the power requirement further if the present cathode area is maintained. The construction of the device is shown on Figure 1.

CATHODE SUPPORT

The cathode is supported by a tripod at approximately isosceles tetrahedral angles. The legs are made of 3 mil nilvar wires. This support structure gives nearly optimum rigidity in all directions, consistent with minimum heat-loss by the support, (Graph 1).

Low Heater Power Cathode.

fig. 1.



RADIATION LOSS FROM CATHODE

The cathode diameter is 50 mils in this design. The front surface is covered completely with cathode mix. The back surface is partially covered by a nickel tab which acts as a heat shield. The heat loss from these surfaces is given on Graph 4.

RADIATION LOSS FROM SIDE WALL

The side wall of the cathode is covered with cathode mix. It was found that heat losses are reduced when the side wall is covered with "fluffy" cathode mix. The adherence of the coating to the cap is also advanced by this method. The height of the side wall is determined by the thickness of the heater. The heat loss from the side wall is given on Graph 4.

HEATER

The important considerations in heater design are:

1. The heat loss due to heat generation and conduction in the heater leads,

2. The operating temperature of the coil,

3. The surge current in the heater.

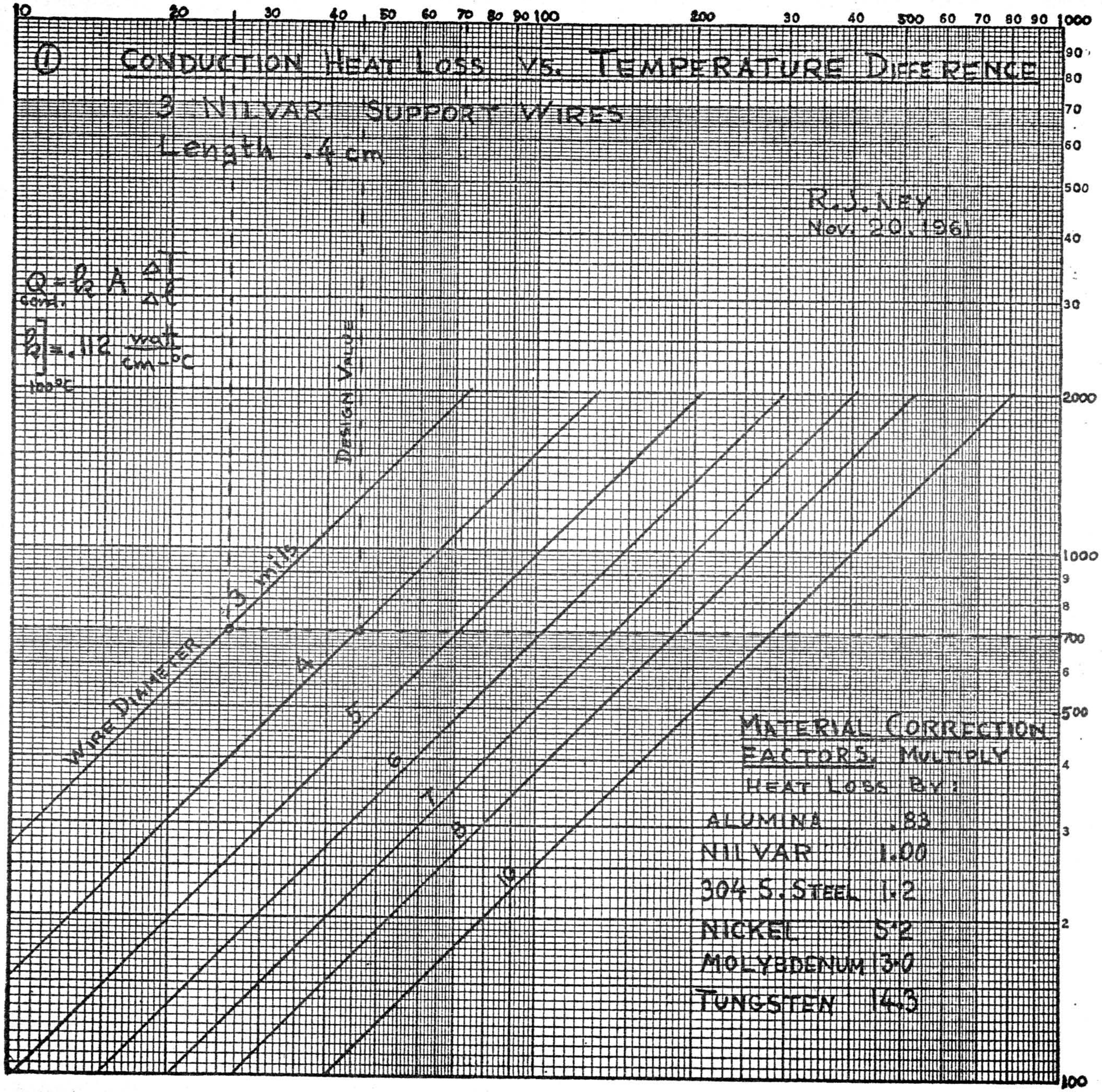
All of these considerations are enhanced by a long heater. The heat conduction loss by the heater leads is given on Graph 2. A mid-span temperature of 600°C is assumed.

The heat generation loss can be expressed simply in terms of heater coil length to lead length ratio. The relationship is given on Graph 5. A midspan temperature of 600°C, and a coil temperature of 1200°C is assumed. Radiation losses from the leads are neglected. In heaters concerned within this report, the radiation losses from the heater leads are less than .1% of the total heat loss.

Conduction and heat generation in the heater leads are independent phenomena provided that the thermal conductivity k and electrical resistivity ρ are not a function of temperature, and radiation losses are neglected. This becomes a fairly good approximation in this heater if the conductivity k and resistivity ρ are used consistently with the midspan temperature. If the phenomena can be superimposed, it is seen that one half of the heat generated in the leads will be lost

Low Heater Power Cathode

Graph 1.

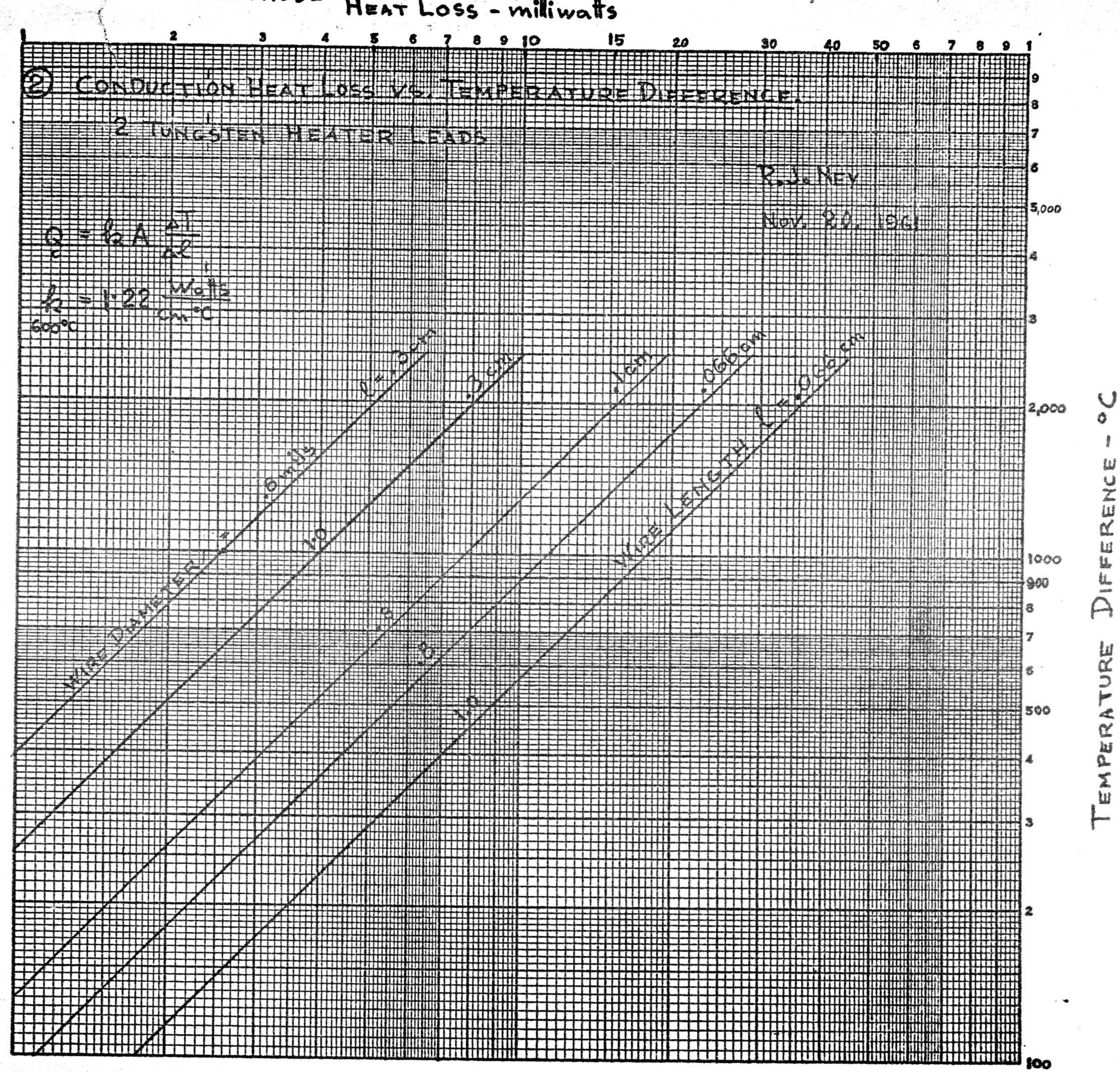


$Q_{cond.} = k A \frac{\Delta T}{\Delta l}$

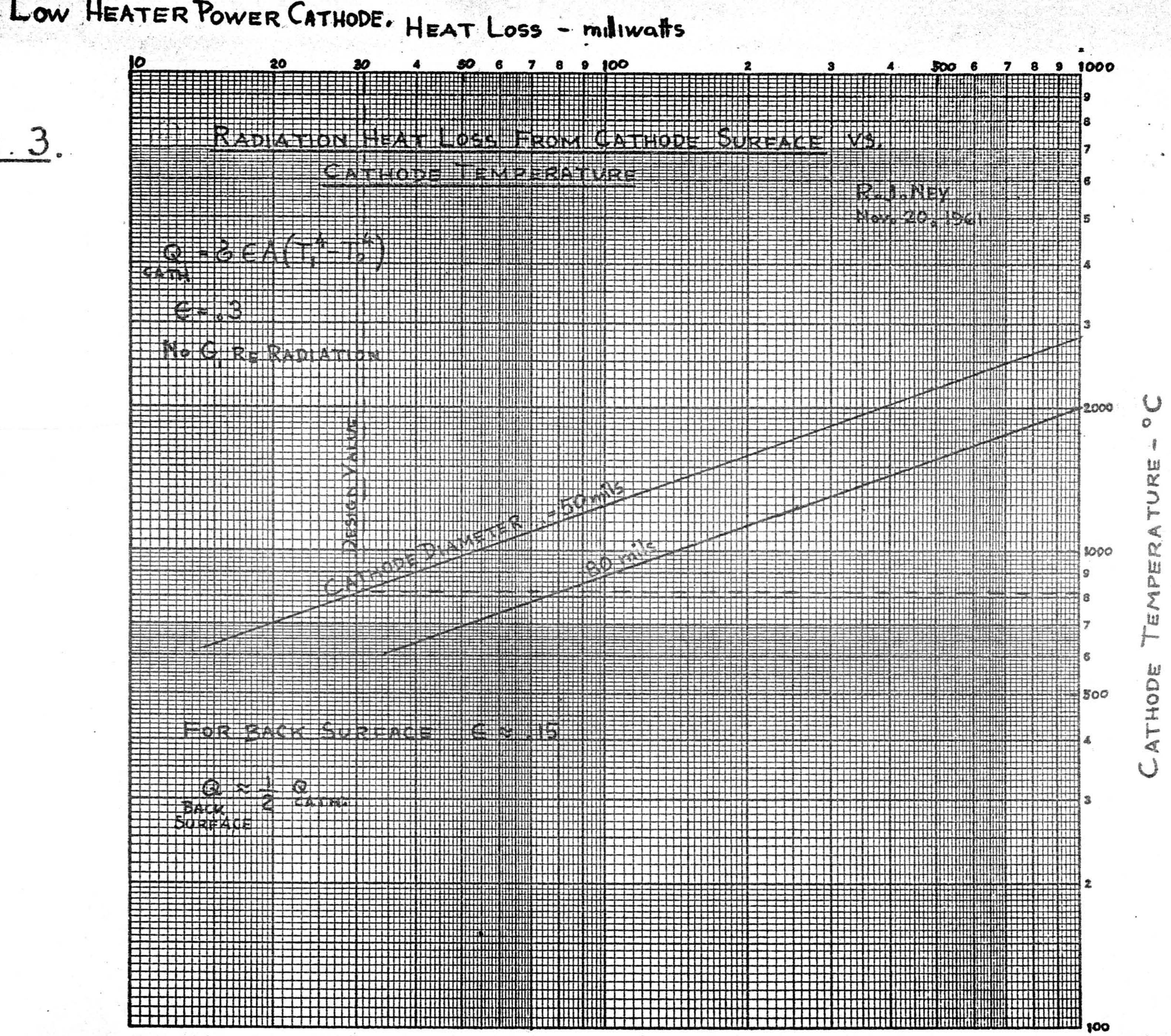
$k]_{100°C} = .112 \frac{watt}{cm - °C}$

GRAPH 2

LOW HEATER POWER CATHODE



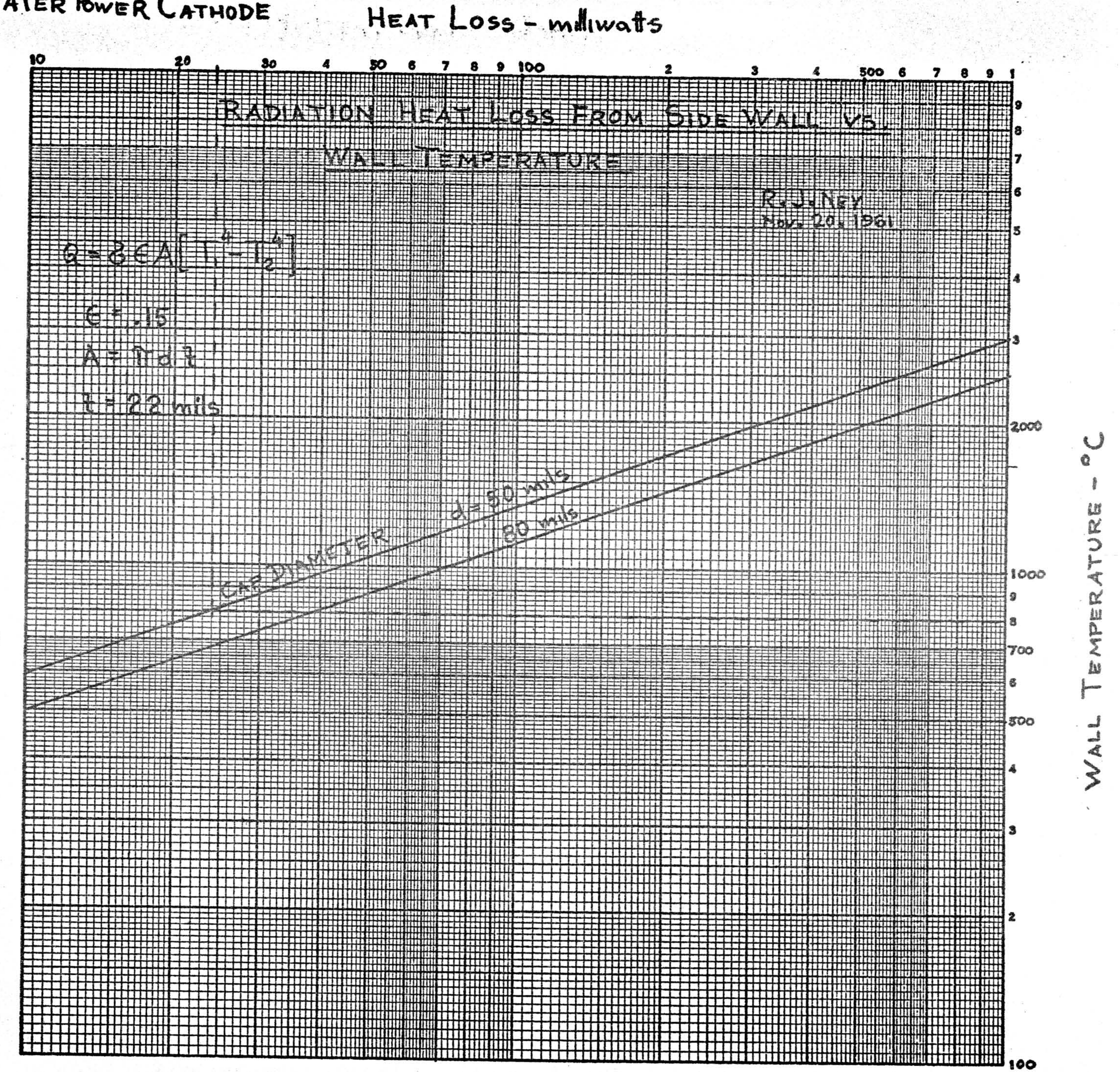
GRAPH. 3.



LOW HEATER POWER CATHODE. HEAT LOSS - milliwatts
RADIATION HEAT LOSS FROM CATHODE SURFACE VS.
CATHODE TEMPERATURE
R. J. NEY
NOV. 20, 1961
$Q_{CATH} = \sigma \epsilon A (T_1^4 - T_2^4)$
$\epsilon = .3$
NO G_1 RE RADIATION
DESIGN VALUE
CATHODE DIAMETER = 50 mils
180 mils
FOR BACK SURFACE $\epsilon \approx .15$
$Q_{BACK SURFACE} \approx \frac{1}{2} Q_{CATH.}$
CATHODE TEMPERATURE - °C
10
20
30
4
50
6
7
8
9
100
2
3
4
500
6
7
8
9
1000
9
8
7
6
5
4
3
2000
1000
9
8
7
6
500
4
3
2
100

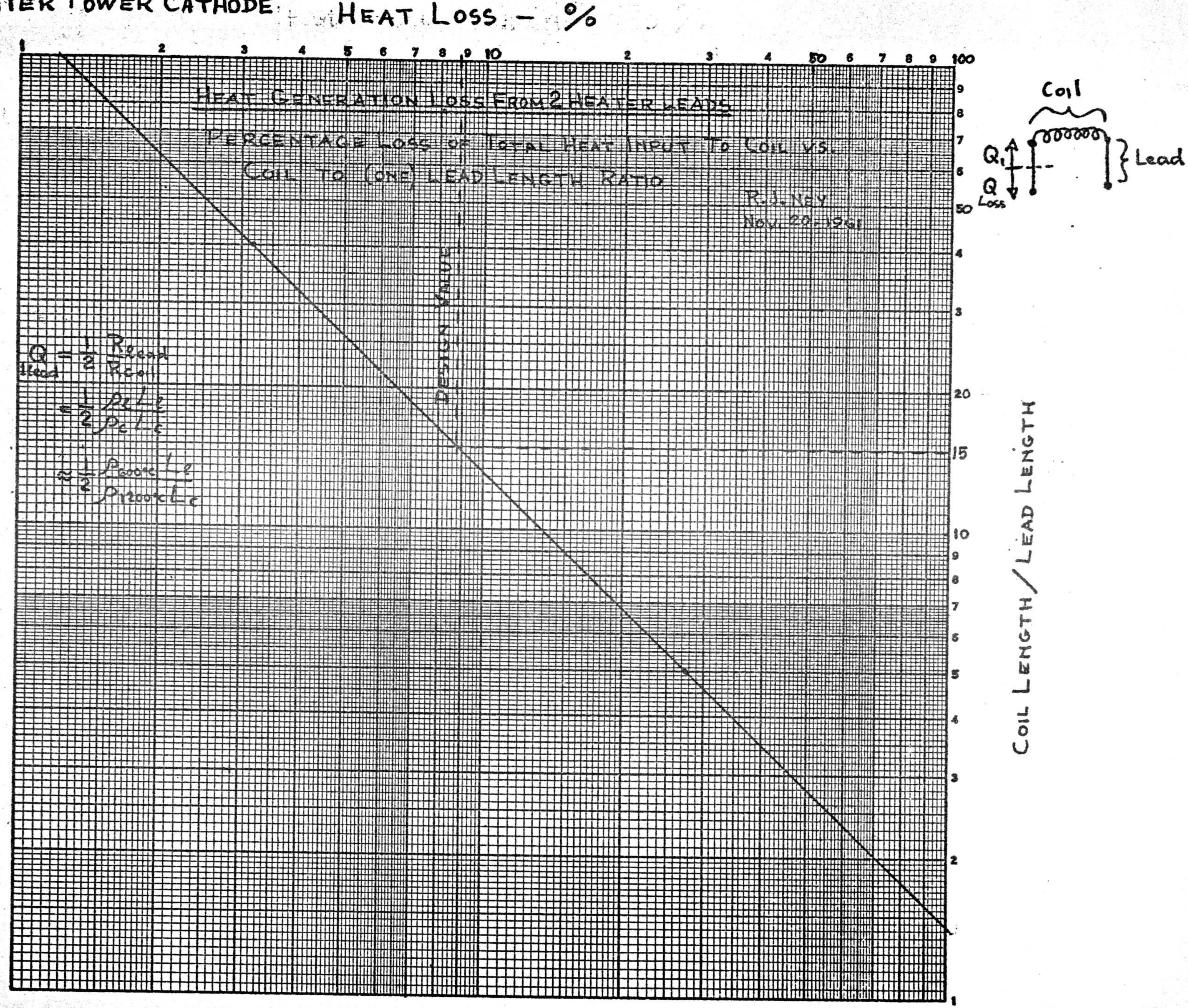
Low Heater Power Cathode

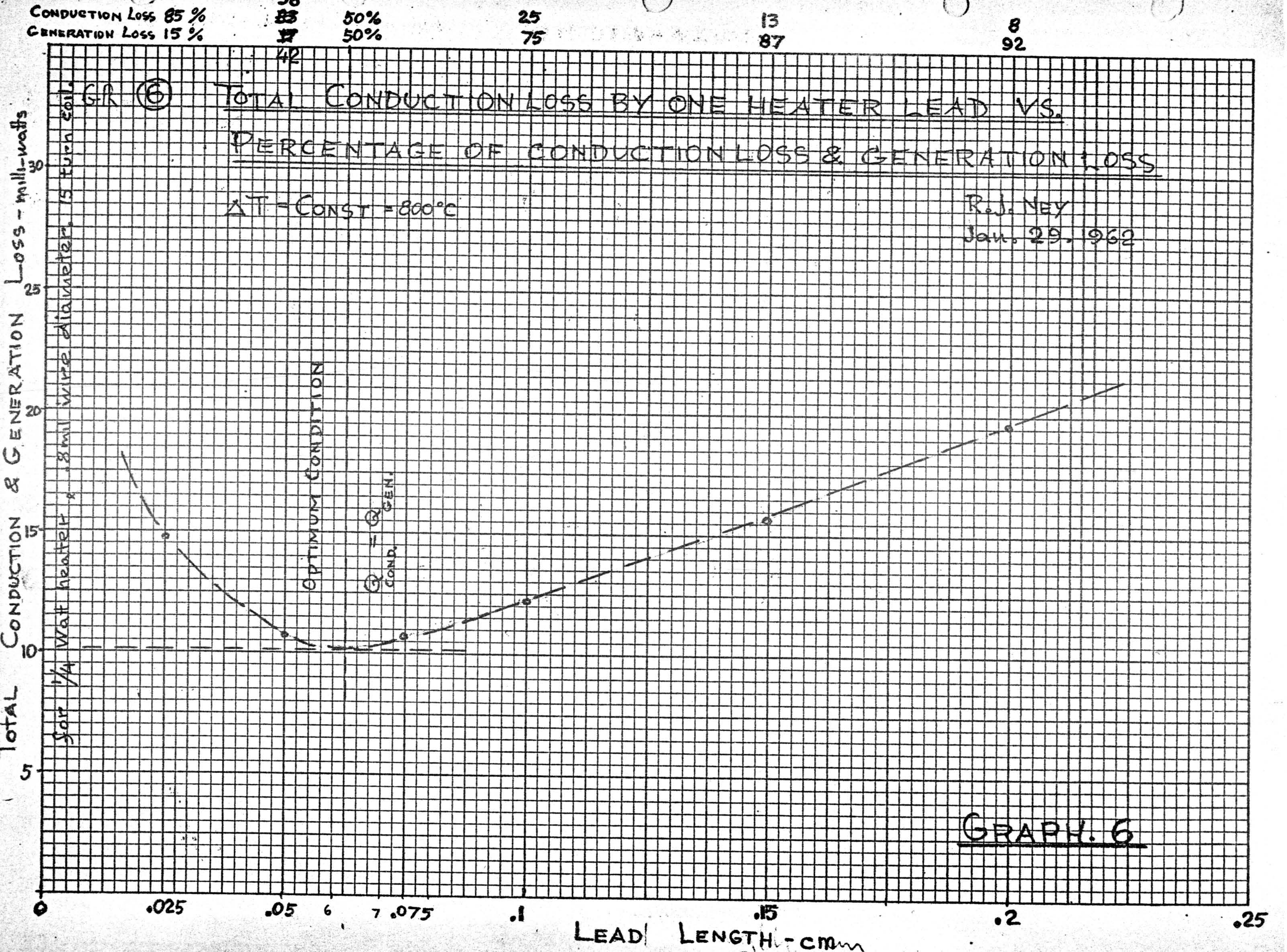
Graph 4



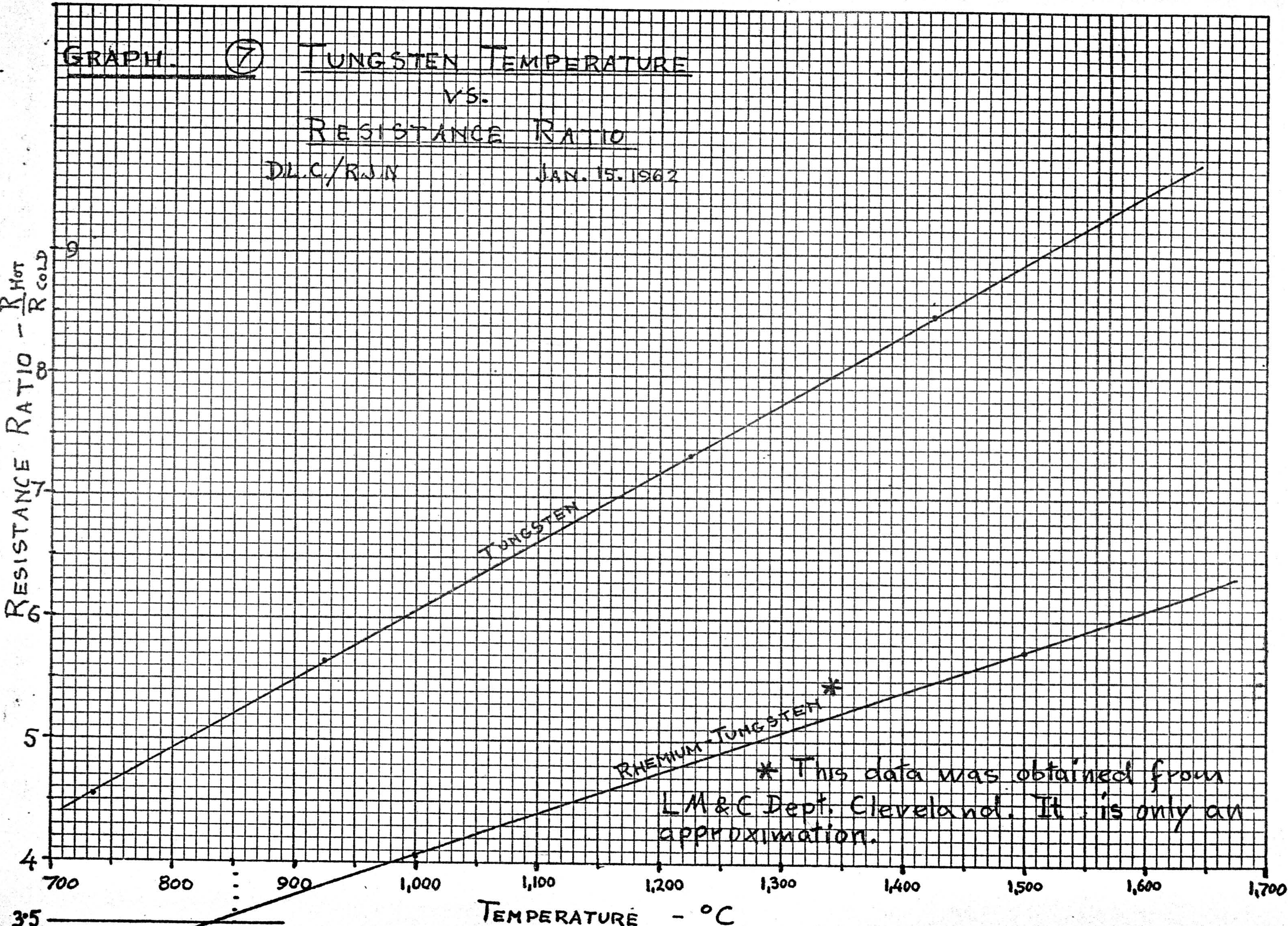
Low Heater Power Cathode

Graph 5





Conduction Loss 85 %
Generation Loss 15 %
50%
50%
25
75
13
87
8
92
42
GR ⑥ Total Conduction Loss by One Heater Lead vs.
Percentage of Conduction Loss & Generation Loss
ΔT - Const = 800°C
R.J. Ney
Jan. 29, 1962
Optimum Condition
Q COND. = Q GEN.
for 1/4 Watt heater & .8 mil wire diameter, 15 turn coil.
Total Conduction & Generation Loss - milli-watts
Lead Length - cm
0
.025
.05
6
7
.075
.1
.15
.2
.25
5
10
15
20
25
30
Graph. 6


GRAPH. 7 TUNGSTEN TEMPERATURE
VS.
RESISTANCE RATIO
DL.C./RJN
JAN. 15. 1962
RESISTANCE RATIO - R HOT / R COLD
9
8
7
6
5
4
3.5
700
800
900
1,000
1,100
1,200
1,300
1,400
1,500
1,600
1,700
TEMPERATURE - °C
TUNGSTEN
RHENIUM-TUNGSTEN *
* This data was obtained from LM&C Dept. Cleveland. It is only an approximation.

and one half will be transferred to the coil. It can be seen further that if the coil temperature is held constant and the total cathode heat loss is constant, the minimum heat loss by the lead occurs when the conduction and generation losses are equal. See Graph 6.

Filament Temperature & Initial Surge Current

The heat transfer from the filament to the cathode is a function of the filament surface area and the mode of heat transfer to the cathode. By using long filaments, the wire temperatures can be reduced for the same wire size. Moreover, if the heater is bonded to the cathode cap by a thin layer of alumina slurry, the heat transfer is essentially by conduction.

In the existing heater - cathode configuration, the filament temperature is several hundred degrees lower when the heat transfer is by conduction rather than radiation (see Table 1).

It is advantageous from reliability and efficiency standpoints to operate the filament at a temperature approaching that of the cathode.

The initial surge current is a function of filament operating temperature. When the filament is cold, its resistance is lower by the factors indicated on Graph 7, compared to operating temperatures. The initial surge current can, hence, be read from this graph directly for a given coil operating temperature.

The initial surge current is also a function of the steady state current. As the filament length is increased, the steady state current requirement for the filament is decreased for the same total heat generation and wire diameter; hence, the surge current is also decreased.

Graph 7 also indicates the reduction that can be obtained in the surge current by the use of Rhenium-Tungsten wire.

Typical operating temperatures for various wire diameters and filament lengths for the quarter-watt cathode are given on Table 1.

Hot Spots

It is not possible at this state of the art to build heater filaments which are absolutely uniform, such that at an overload failure the complete filament would melt from one end to the other. Invariably in actual heater filaments, the failures occur at localized regions (hot spots).

Maximum temperatures occur at these "hot spots" when operating voltage is suddenly applied to the cold filament. A large percentage of the operating voltage is across these high resistance spots, which increases the temperature and, hence, increases the resistance even further. The damage potential due to these hot spots is determined by:

1. Electrical resistance gradient of the wire along wire axis,

2. Thermal conduction gradient to the insulation along wire axis,

3. Applied voltage and source impedances,

4. Ratio of the time constant of the hot spot to time constant of the total filament.

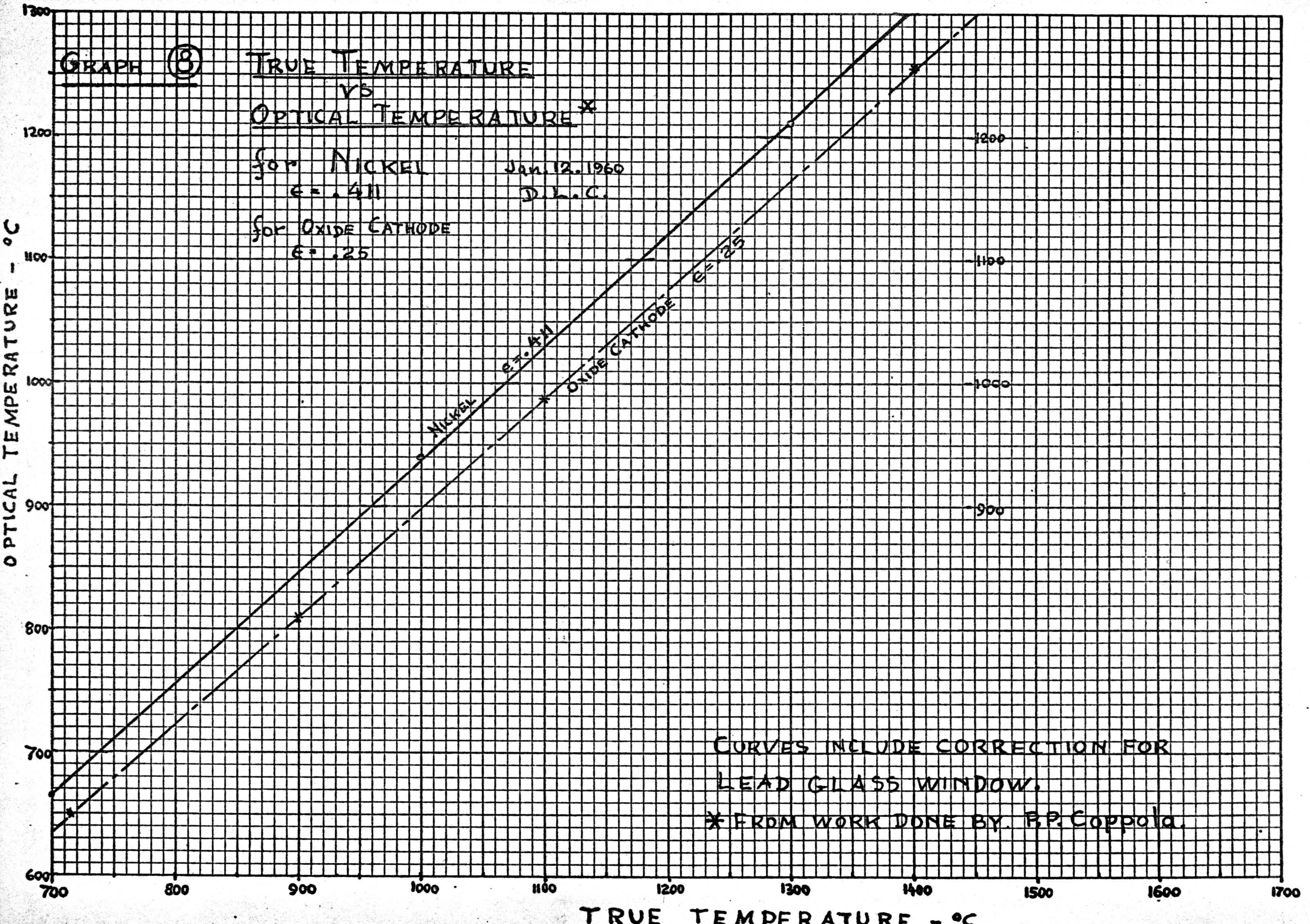
The above parameters determine the maximum temperature and the duration of excessive temperatures. Chemical reaction and evaporation at these hot spots increase the resistance gradient which aggravates the condition even further.

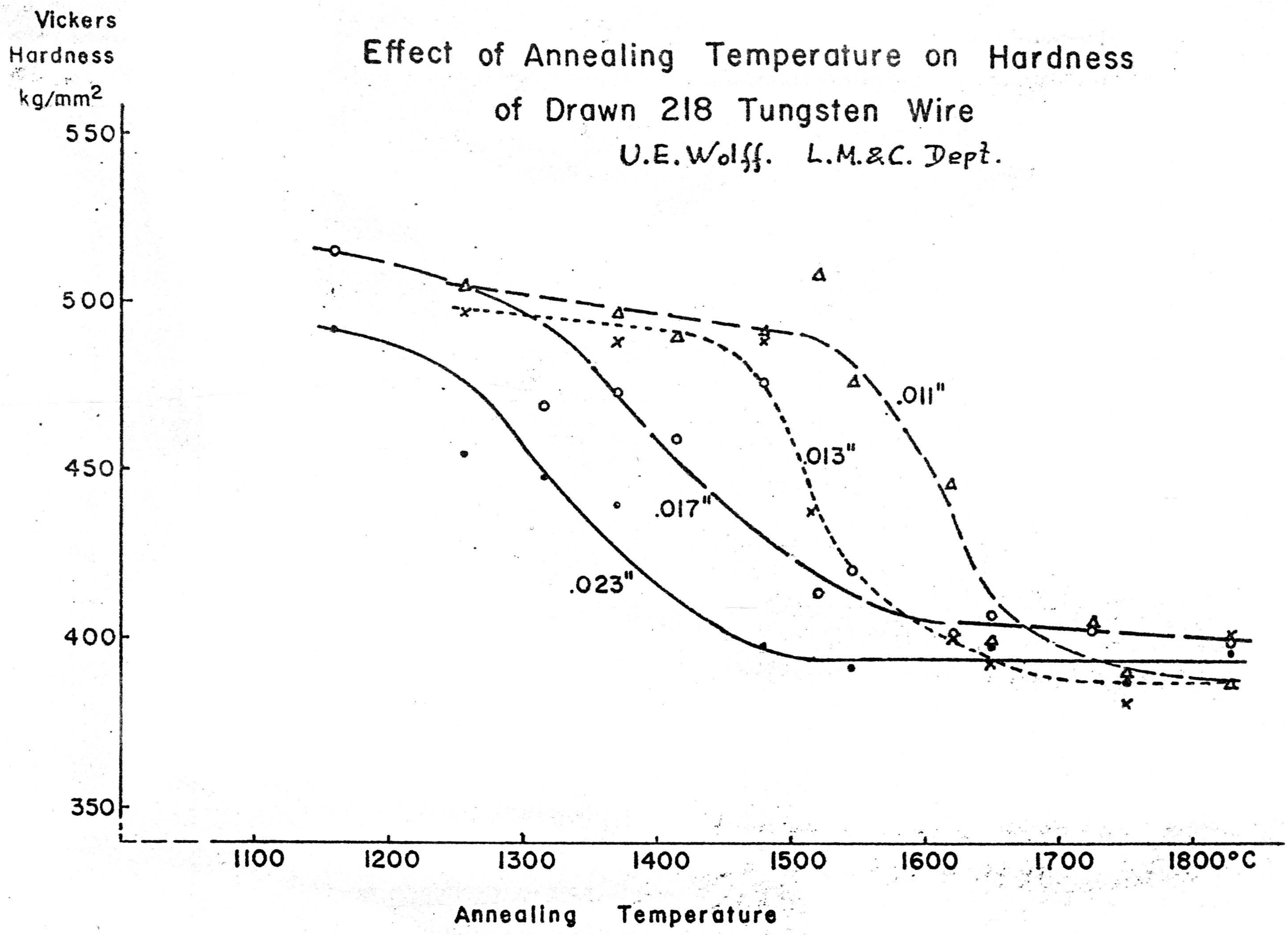
When temperatures reach the melting temperature of the alumina, a void appears around the wire. Failure occurs when the filament temperature reaches the melting temperature of the tungsten, usually at a cold start.

Recrystallization of Tungsten Filaments

Recrystallization is associated with enbrittlement of the tungsten. Practically all of the failures in the present design are due to the recrystallization and then an application of excessive stresses on the filament. This will result in brittle fracture of the filament.

The wire is received in soft annealed condition with a Vickers hardness of about 400 Kg/M^2. (See Graph 9.) The wire is wound at about 10,000 psi tensile stress (about 1 gm force on .5 mil wire). The smallest bend in the coil has a radius of curvature of 7½ mils; the bending stresses associated with this are much less than that due to the winding tension. The lead wires get additional "handling stresses" which is not practical to evaluate. The heater assembly is hydrogen fired

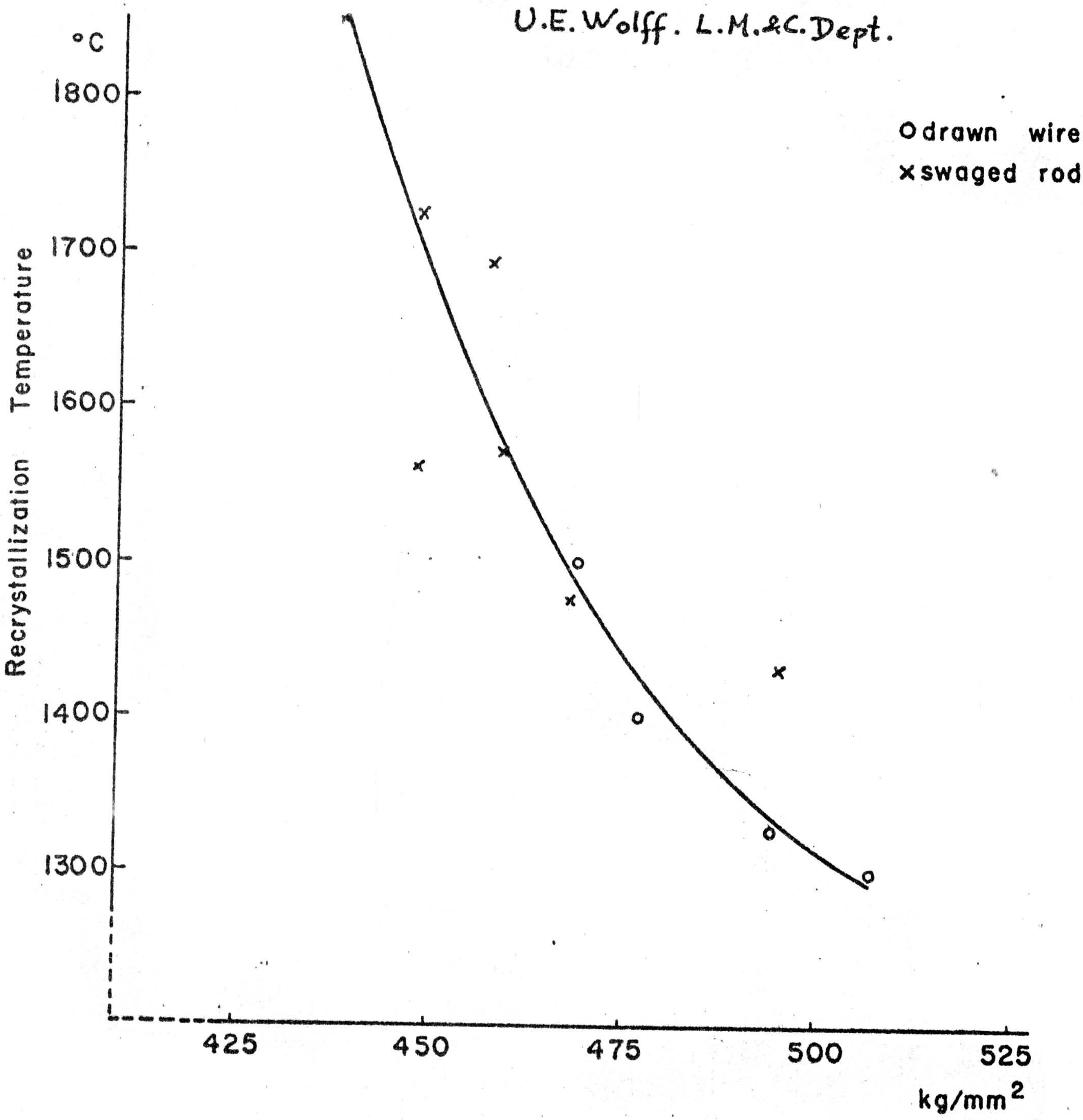

GRAPH (8)
TRUE TEMPERATURE
VS
OPTICAL TEMPERATURE*
for NICKEL
ϵ = .411
for OXIDE CATHODE
ϵ = .25
JAN. 12. 1960
D.L.C.
NICKEL ϵ = .411
OXIDE CATHODE ϵ = .25
CURVES INCLUDE CORRECTION FOR
LEAD GLASS WINDOW.
* FROM WORK DONE BY R.P. Coppola.
OPTICAL TEMPERATURE - °C
TRUE TEMPERATURE - °C
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700


Effect of Annealing Temperature on Hardness
of Drawn 218 Tungsten Wire
U.E. Wolff. L.M.&C. Dept.
Vickers
Hardness
kg/mm2
550
500
450
400
350
1100
1200
1300
1400
1500
1600
1700
1800°C
Annealing Temperature
.011"
.013"
.017"
.023"

GRAPH . 9.

Recrystallization Temperature
vs. Hardness before Recrystallization
in 218 Tungsten

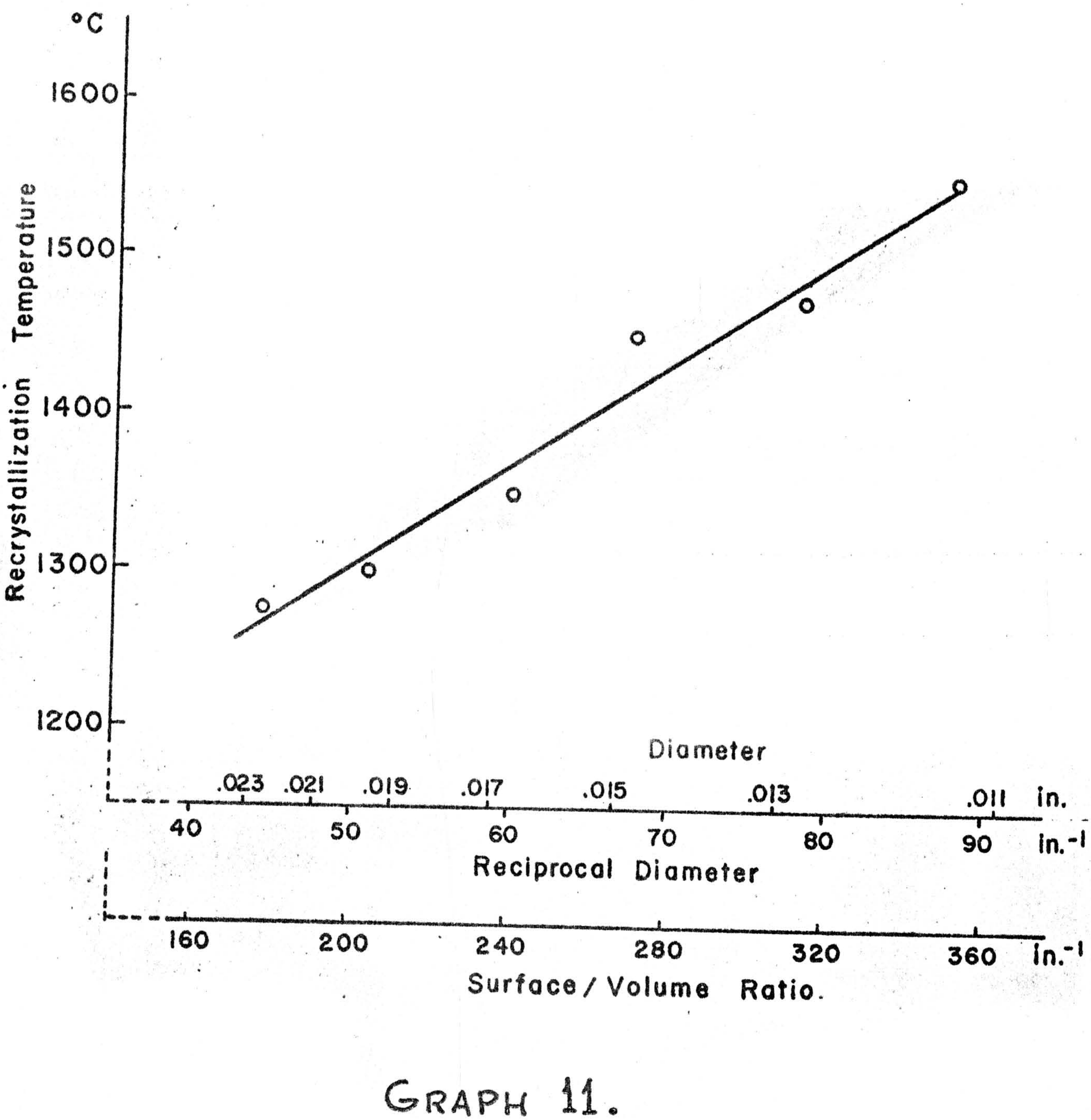
U.E. Wolff. L.M.&C. Dept.



GRAPH .10.

Recrystallization Temperature vs. Size of Thin 218 Tungsten Wire

U.E. Wolff. L.M.&C. Dept.



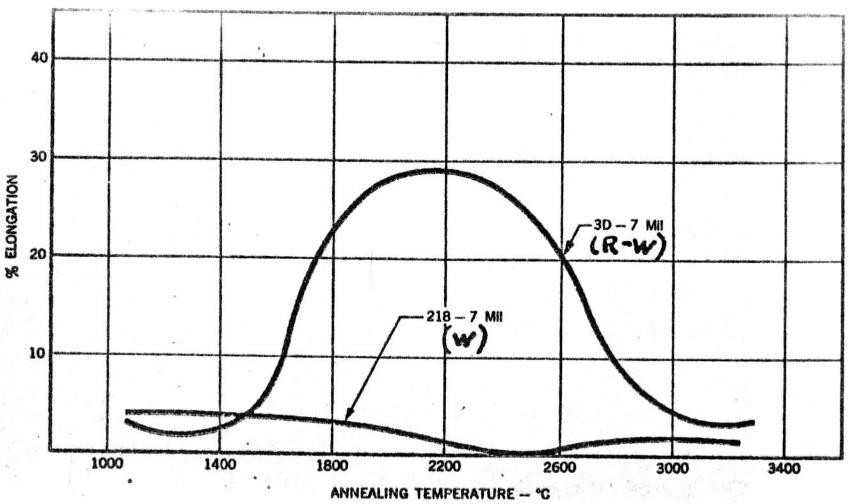
GRAPH 11.

GRAPH. 12.

Tungsten vs.
Rhenium Tungsten

Room Temperature Elongation After Annealing

Specimens were annealed for 3 minutes in hydrogen prior to testing.



G.E. LM&C Dept.
2C (A-H) 12/5000

at 1,350°C. The recrystallization temperatures vs. Vickers hardness is given on Graph 10. If the hardness was not increased over about Vickers 480 due to cold working, the tungsten will not be recrystallized.

According to G. E. Report 59-LMC-132 by U. E. Wolff, the temperature range between start to complete recrystallization is approximately 200°C. It is noted that when wet hydrogen is used in the furnace, the brittleness curve is shifted up by several hundred degrees centigrade.

In the present design, recrystallization occurs in the heater leads at lower temperatures than in the coil. Recrystallization temperature is also a function of the wire size, as indicated on Graph 11.

A number of properties, including recrystallization temperatures are improved by the use of Rhenium-Tungsten wire. There is only very limited data available on this alloy; an elongation curve is given on Graph 12. Experience with this heater indicates that Rhenium-Tungsten wire remains soft under conditions where 218 tungsten is fully recrystallized.

Thermal Efficiency

If one bases the thermal efficiency of the cathode on the heat loss by radiation from the useful cathode area at operating temperature, the efficiency of the standard 3.8 watt cathode is .84%. This is based on a useful area of 50 mil diameter, at 825°C with E=.3 (see Graph 3). The efficiency of the $\frac{1}{4}$ watt cathode is 13%, while at 50% thermal efficiency the power requirement is 64 milliwatts.

Thermal Expansion Within the Heater

The thermal expansion of tungsten is $40 \times 10^{-7}/°C$ at room temperature, while the thermal expansion of alumina is about $90 \times 10^{-7}/°C$, resulting in considerable expansion mismatch. During the heating cycle, the tungsten expands first, then the ceramic comes up to temperature gradually and expands more than the tungsten. There is usually no danger of fracturing the tungsten in the heating cycle, since it is hot and consequently ductile.

During the cooling cycle however, due to the heat transfer parameters the tungsten cools first, while the core ceramic is still in expanded condition. Since the tungsten is cold and more brittle than when it is hot, fracture of the tungsten tends to occur exclusively during the cooling cycle. Experiments with heaters substantiate this conclusion. The tungsten may take a large number of cycles before complete fracture occurs.

There are three parameters that are adjusted to control the thermal-fatigue problem in this design:

1. Undercoating - The maximum thermal expansion difference between the tungsten coil and alumina ceramic is 1.5×10^{-4} inches. A layer of nitro-cellulose of about 2×10^{-4} inches is placed on the core ceramic before winding. During hydrogen firing the nitro-cellulose layer disappears, and a gap is produced to take up the expansion of the core ceramic.

2. Winding Tension - If the coil winding stress is reduced, the absolute stress during the cooling cycle is also reduced. In this design, the winding stress is reduced to the bare minimum, which is about 10,000 psi.

3. "Soft" Alumina Coating - The coating ceramic is fired at only 1350°C, which leaves it relatively soft. The ability to use soft ceramic is made possible by the integral potting of the heater into the cathode cap. The coating has a much lower strength than the tungsten; hence, it tends to crumble locally rather than fracture the tungsten filament.

Life tests indicate that the heater can only take several hundred "on-off" cycles when it is wound at 100,000 psi winding stress. At 10,000 psi winding stress, the life is extended to 120,000 to 130,000 cycles. All heaters (4) with undercoating and reduced winding tension are still operating after 135,000 cycles.

The use of Rhenium-Tungsten wire should increase the fatigue life of the heater, since it is more ductile than pure tungsten. There is no life data on this alloy wire heater at this time.

Flashing of the Heater Leads

If the heater lead is much longer than the specified value (75 mils for .4 mil wire and 20 turn coil), the lead will glow bright when voltage is applied. The glow will diminish when the heater comes up to temperature. Flashing of the lead can occur also when the coating is cracked near the first coils. If flashing condition occurs, the heater should be rejected, since it will last no more than a few hundred cycles.

Steady State Heater Life

There are three phenomena that are considered here in regards to heater life.

1. Burn Out Voltage - When heater voltage is increased, at a relatively slow rate, at some voltage the heater will burn out. The ratio of the Operating Voltage to Burn Out Voltage $\left(\frac{V_B}{V_O}\right)$ is dependent on the tungsten temperature; hence, the thermal impedance between the heater and its heat sink.

It is noted that when the heater is not potted into the cap, the voltage ratio $\frac{V_B}{V_O} \approx 1.5$. When the heater is potted into the cathode cap, the ratio $\frac{V_B}{V_O} \approx 3$. The failure in the potted heaters occur after the top of the cathode cap has been melted, and the heat transfer "circuit" is thus altered. It is expected that if a higher melting cap were to be used, the true ratio $\frac{V_B}{V_O}$ would be found considerably higher than 3.

2. Decreasing Heater Resistance During Life - When this phenomenon occurs, the heater will increase its power consumption and temperature at constant applied voltage. This will tend to accelerate the process until failure due to an open heater will occur.

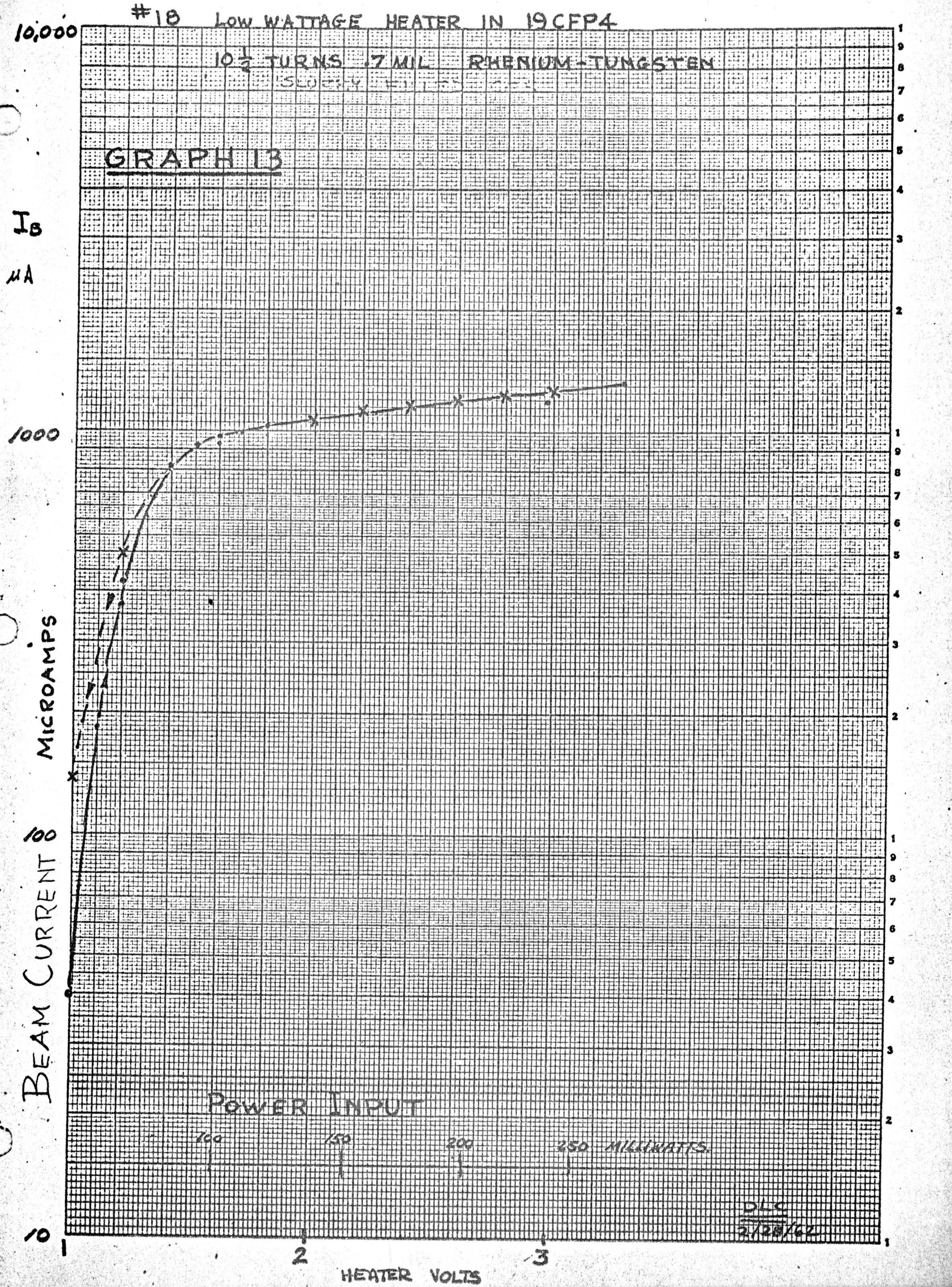
This type of failure was found to be caused by the shorting out of adjacent heater coils. The problem was eliminated by increasing the drying time of the heater spray slurry and by spacing the coils no closer than one wire diameter.

Two heaters were operated at 40% over voltage, or about 100% power overload for 5 weeks continuously. No change in heater resistance was observed.

3. Increasing Heater Resistance During Life - This type of failure has been mentioned in the literature. It is suspected that the ultimate failure of the heater at steady state operation would be due to this cause. This phenomenon, however, was not observed in this heater under the applied test conditions.

Firing of the Alumina

A relatively pure grade of alumina (Nortons 38-900) is


#18 LOW WATTAGE HEATER IN 19CFP4
10 1/2 TURNS .7 MIL RHENIUM-TUNGSTEN
GRAPH 13
I_B
μA
BEAM CURRENT MICROAMPS
10,000
1000
100
10
POWER INPUT
100
150
200
250 MILLIWATTS
1
2
3
HEATER VOLTS
DLC
2/28/62

used in order to eliminate long-term chemical reaction problems. The fusing temperature of this grade of alumina is relatively high. It is advantageous to use "soft" fired alumina since it will crumble locally rather than fracture the heater filament. This is especially important at the region where the heater lead enters the ceramic.

On the other hand, if the ceramic is exposed to handling, it must have sufficient strength to be able to take the handling. In this design the ceramic is potted into position, and the heater leads are connected before firing. The ceramic receives no handling whatever after firing.

<u>100 Milliwatt Cathodes</u>

Experiments and analysis indicate that radiation shielding within the cathode structure can result in cathodes with power requirements of about 100 milliwatts.

The diagram of such a cathode is given on Figures 2 and 3.

A desirable feature of this type of cathode is its insensitivity to applied voltage variations. This results from the heat transfer characteristics of the system. When relatively low power is applied, only the cathode surface directly above the heater will "glow" and the major portion of the heat loss is by radiation from this surface. As more heat is applied, the side wall will also become red and the major portion of the heat loss is by radiation from a much larger area than the cathode surface alone. This effect tends to keep the cathode surface cool when over voltage is applied. One must keep in mind that in this structure, radiation heat loss becomes important only above 500-600°C, (see Graphs 1-5).

A cathode, which was only a partially modified $\frac{1}{4}$ watt type, (Graph 13) showed a cathode emission of 900 microamps at 1.5 volt heater voltage and 1,400 microamps at 3.5 heater voltage.

100 MILLIWATT CATHODE

fig. 2

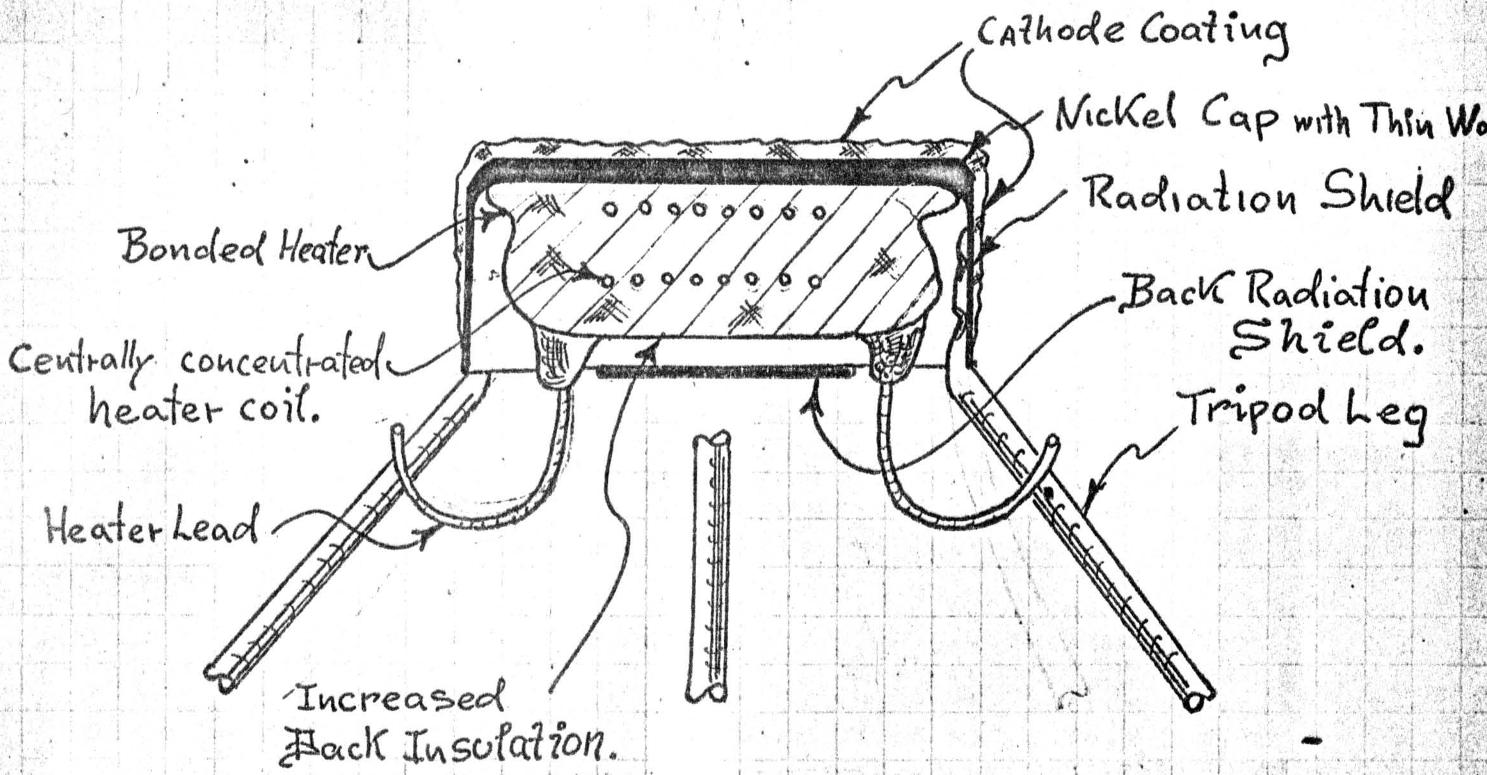
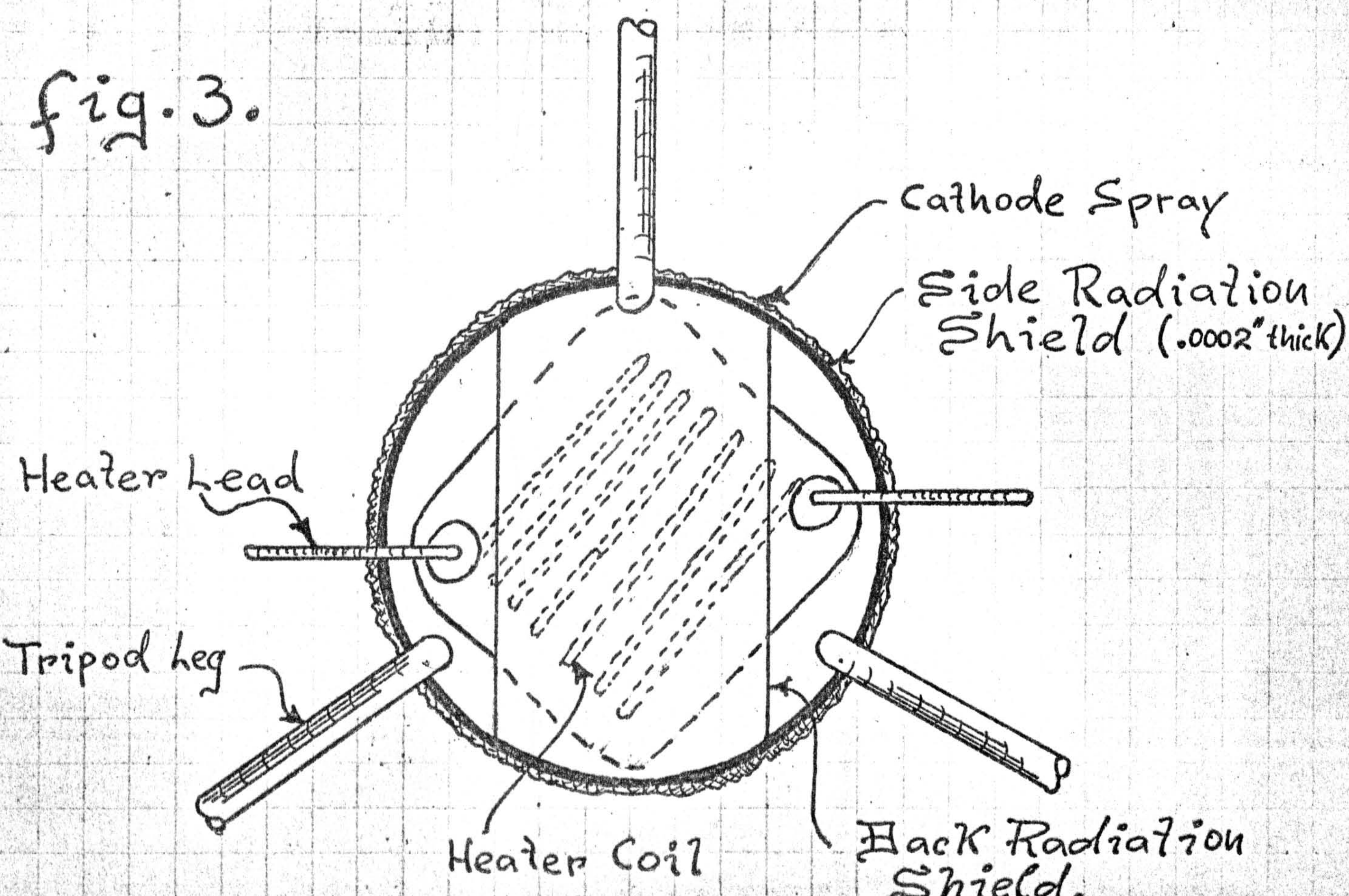


fig. 3.



Comparison with Other Low Power Cathodes

Sylvania and Philco are both active in this field. The diameters of all cathodes are 50 mils, including ours.

Table 2 compares the significant parameters of the three various designs.

All of the competitor's heaters are made of lamp filament coils. In order to maintain the coil, these heaters must be fired and fabricated in brittle condition. Yield and reliability are hence impaired. The Philco heater has the (molybdenum or tungsten) core wire left in the coil at the legs. The leads are used for support of the cathode. This adds complexity to the manufacturing, increases the heat loss over nilvar legs, and results in brittle, fracture-prone support legs.

The Sylvania heater requires a high pressure moulding operation on the fired heater coil; this probably results in partial fracturing of the wire. The Sylvania heater appears to be suspended on 1.1 mil tungsten wires and a foil tab in one plane only. It is prone to filament lead failure due to mechanical shock.

It is estimated that about 35% of the heat input to the Sylvania heater is lost by heat generation in the heater leads.

Table 2

	Wire Material	Voltage Volts	Nominal Current Milliamps	Wattage of Emission Knee Milliwatts	Wire Dia. Mils.	Heater Length inch	Heater to Lead Length	Wire Temperature (Cathode @ 750°C) °C	Current Density 10^3 amp/cm²	Surge Current Density 10^3 amp/cm²	Max. Bend Dia. to Wire Dia.
G.E.	Rhe-W	6.3	20	80	.4	2.20	31:1	≈770	25	80	15:1
G.E.	Rhe-W	3.0	75	175	.8	.95	15:1	≈800	25	85	20:1
G.E.	W	3.0	75	175	.7	.95	15:1	800	31	170	20:1
Philco	W	2.4+	105+	200+	1.0!	.60!!	Post Lead	≈800!!	21	105	4:1!!
Sylv.	W	1.5+	150+	210+	1.1+	.40*	4:1*	≈800**	27	135	2:1*

+ Published Data.
* Calculated from Published Data.
** Calculated from Published Filament Geometry & Not Resistance.
! Measured on Sample Tubes.
!! Calculated from Measurements & Published Data.

MANUFACTURING

HEATER

Core Ceramic - The heater wire is wound on a core ceramic. The core ceramic is an extruded A-12 alumina, supplied at 6-inch long stalks. It is 15 mils thick and has a full $7\frac{1}{2}$ mil radius of curvature on the two sides in order to reduce stresses in the wire wound on it, also to obtain more uniform coil pitch.

The extruded ceramic stalk is coated with a layer of nitro-cellulose. This is done in order to minimize thermal stresses in the wire, as described previously. The coating also improves the chucking operation of the ceramic into the winding mandrel. Moreover, a more uniform coil is obtained when the core is coated, since the wire sinks into the coating to some extent and does not roll over as it is being laid down. The cross section of the fractional mil size wire is far from being circular; hence, in certain orientation it tends to roll when it is laid down on a hard uncoated core ceramic. The coating solution consists of:

2 gm. of Nitro-Cellulose (RS-600) made by Hercules Powder Company
3 gm. Butyl Acetate

The ceramic stalk is dipped into this solution and soaked for 10 minutes. It is then pulled out of the solution with the stalk oriented vertically, at a rate of about 6 inches/minute. When the first coating dries, the ceramic is immersed again and pulled out immediately at the same rate. The coating dries sufficiently in 10 minutes. A well adherent and mirror-like layer of about .05 to .1 mils thickness is obtained. A new batch of ceramic should be coated each week. This maintains proper "working" softness and adherence of the coating.

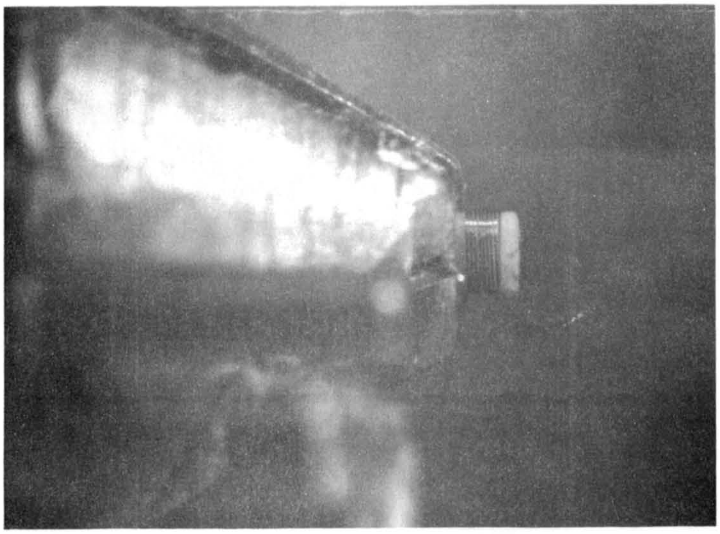
The ceramic stalk is then inserted into an indexing fixture and scribed with a diamond needle at 30 mil intervals, and then broken off at the scribe marks.

Coil Winding

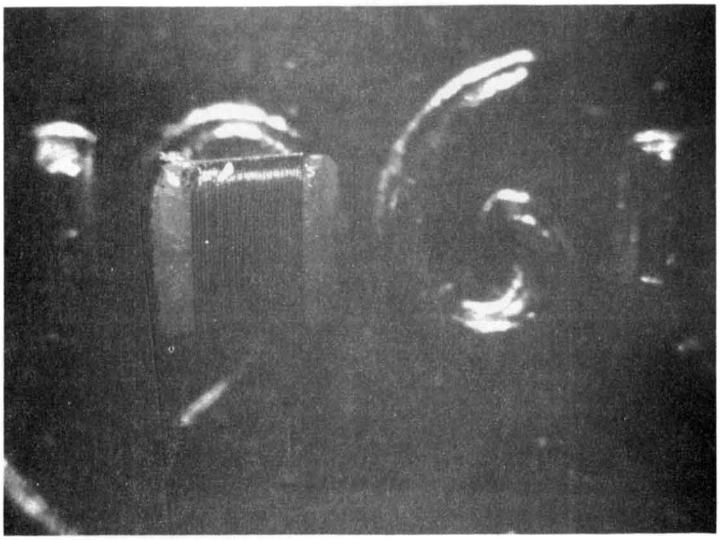
A coil winding lathe was built for the specific purposes of this particular heater. A photograph of the lathe and winding mandrel is shown on photographs No's 1 and 2. The core ceramic is inserted into the mandrel with forceps, under 30X magnification. The wire is led from the reel through the stationary and rotating guide posts, and then secured to the tie clamp.

Wire Tension

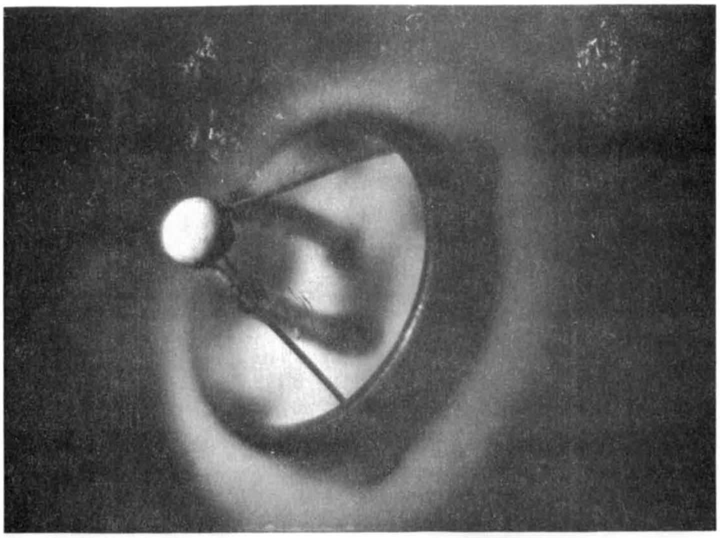
A torque is obtained on the supply reel by a chord and



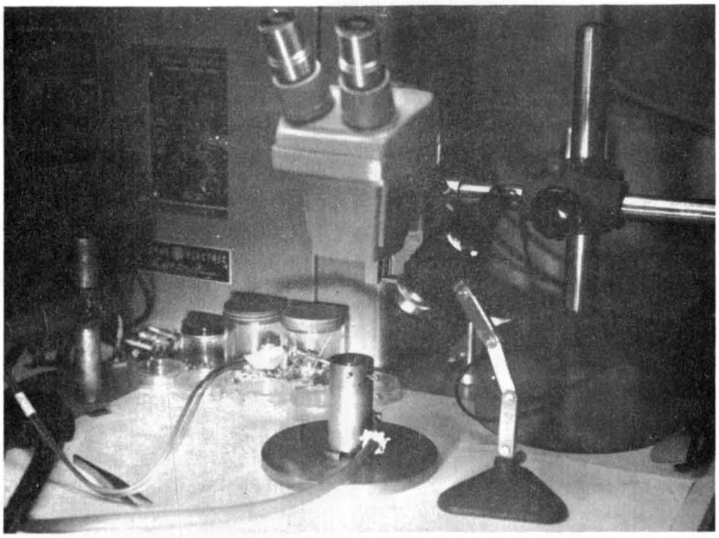
Low Heater Power Cathode: Churck and Heater.



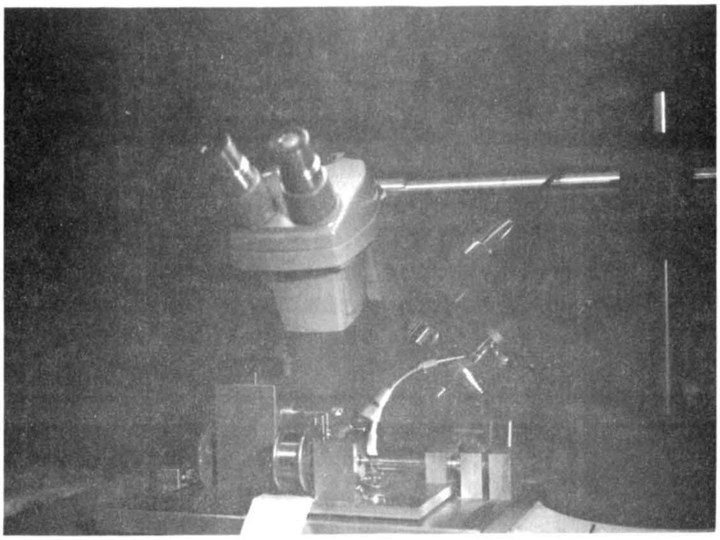
Low Heater Power Cathode: 30 Turn Coil on 1961 Penny.



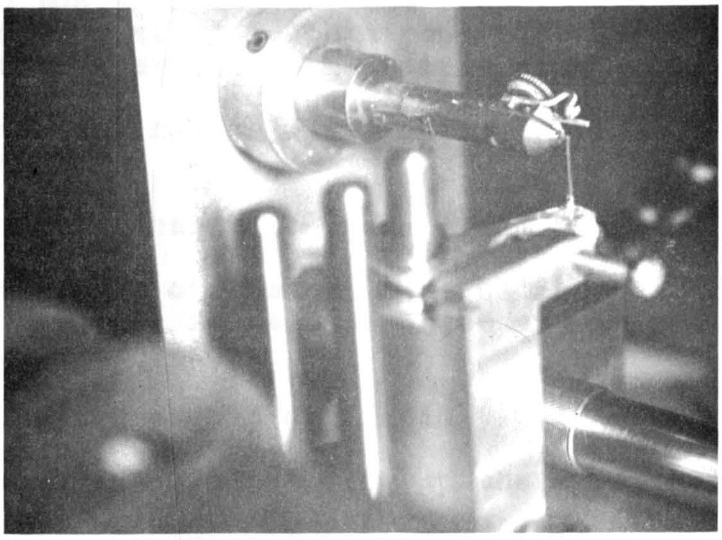
Low Heater Power Cathode: Cathode and Tripod Support.



Low Heater Power Cathode: Assembly Fixture for Tripod Support.



Low Heater Power Cathode: Heater Winding Lathe.



Low Heater Power Cathode: Chuck and Wire Guide Posts.

weight arrangement. The wire tension used is 2 grams for .8 mil wire and ½ gram for .4 mil wire. Winding tension is quite critical since this determines the final enbrittlement of the coil (1 gm tension is approximately 10,000 psi stress in .5 mil wire).

Coil Spacing

The lathe carriage has lead screw feed of 720 turns/inch. A finer coil is produced by using an additional manual adjusting screw. It is planned to increase the lead screw feed rate to about 1,500 turns/inch.

The required number of turns are wound by monitoring a counter on the lathe.

Forming the Coil Leads

After the last coil has been wound, a guide post is extended from the mandrel. The wire is wound on this post by turning the spindle backward several turns. This arrangement results in a lead orientation perpendicular to the plane of the core ceramic, and extending from diagonally opposite corners.

Coil Spray

This is one of the most critical operations in the whole process. When the spraying is done properly, a homogenous, strong and smooth coating is obtained. The important considerations in the heater spraying process are:

1. The coating has to flow freely in between the heater coils.

2. The coating has to be relatively dense.

3. The strength of the unfired coating has to be such that the coil is held in place and is protected from external handling.

4. The coating should dry rapidly.

5. The spray should not clog up the spray gun.

These conditions are met by the following mixture in conjunction with forced hot air drying:

13 cc Butyl Acetate

7 cc < 4 gm Nitro Cellulose / 3 gm Butyl Acetate

20 gm Nortons Alumina #38-900
5 cc acetone
3.5 cc Butyl Carbitol[1] (B.P. 230°C)

The ratio of Butyl Carbitol[2] to Butyl Acetate determines the flowing and drying characteristics of the coating. The coating should take at least 30 seconds to dry in air to insure proper flow. It should dry sufficiently in 15 seconds to hold the coil after forced air at about 100°C is applied.

The mix tends to settle and coagulate, so it should be stored on an agitating device.

A PASCHE Fine air brush, with a ½ ounce cup, is used for spraying at 25 psi line pressure. The spray nozzle should be adjusted to just above minimum spray.

<u>Lead Cleaning & Forming</u>

After the coat dries, the leads are cut with small surgical scissors to about 50 mils length. Care must be taken in this operation not to pull or deform the leads. The spray is pulled off the leads by small forceps. The leads are then curled diagonally outward by special forming forceps. The heater is removed from the chuck; then, it is ready for insertion into the cathode cap.

<u>Tripod Support</u>

The cathode cap and the support ring are clamped into the fixture; the tripod legs are placed into the locating grooves and welded in position.

Using a 15 mil diameter wire loop of 3 mil diameter wire, a drop of modified spray mixture is inserted into the bottom of the cap. The alumina content in the spray mixture is

---

1. Diethilene Glycol Monobutyl Ether.

2. The use of Butyl Carbitol was suggested by A. Kling of the Research Laboratory, Schenectady.

increased by 50% in order to increase the viscosity of the mix and obtain a relatively uniform coating. The coating is dried by a jet of hot air. An additional drop of spray mixture is placed into the bottom of the cup with a 10 mil diameter wire loop. The heater is inserted in the proper orientation, and bonded to the bottom of the cap. The back shield is then folded into position; about 10 mils away from the heater.

Heater Connection

The support ring is mounted on the "Heater Ceramic" in the proper orientation and is secured by folding the 3 extruding posts. The ends of the heater leads should now be within 1/32 inch of the ends of the heater posts. A small rectangular nickel foil is pinched at the tip of a fine forceps welder and tack welded to one tip. The foil is then placed over the intersection of the heater post and heater lead, and is welded. Low heat must be used in order not to oxidize or re-crystallize the tungsten near the weld.

Firing

The completed assemblies are placed in a firing boat and inserted into a hydrogen furnace. The following firing schdule is used:

10 min.	H_2 Purging
30 min.	180°C
30 min.	250°C
10 min.	1,350°C
10 min.	Cooling with H_2 ON

The lag characteristics of the system are such that the temperatures are obtained about 3 minutes after the heater setting. The hydrogen is bubbled through a jar of water in order to introduce oxygen.

Cathode Spray

The fired assemblies are placed in a spraying fixture with 80 mil aperture, and the cathode is oxide coated.

Continuity Check

Before the cathodes are inserted into the tube, the heater continuity is checked. Check should be made on the lowest (R x 1) scale on the ohm-meter, and contact should be made only for a fraction of a second. Otherwise, the heater may be partially oxidized. <u>The low scale must be used to check continuity on the finished tube also</u>.

Heater cathode cold resistance should be over 2 mega-ohms, and will run as high as 20 mega-ohms.

GENERAL ELECTRIC K-69087-262A180

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TITLE ASM

GRID-CATHODE LOW HEATER POWER

FIRST MADE FOR IMAGE ORTHICON

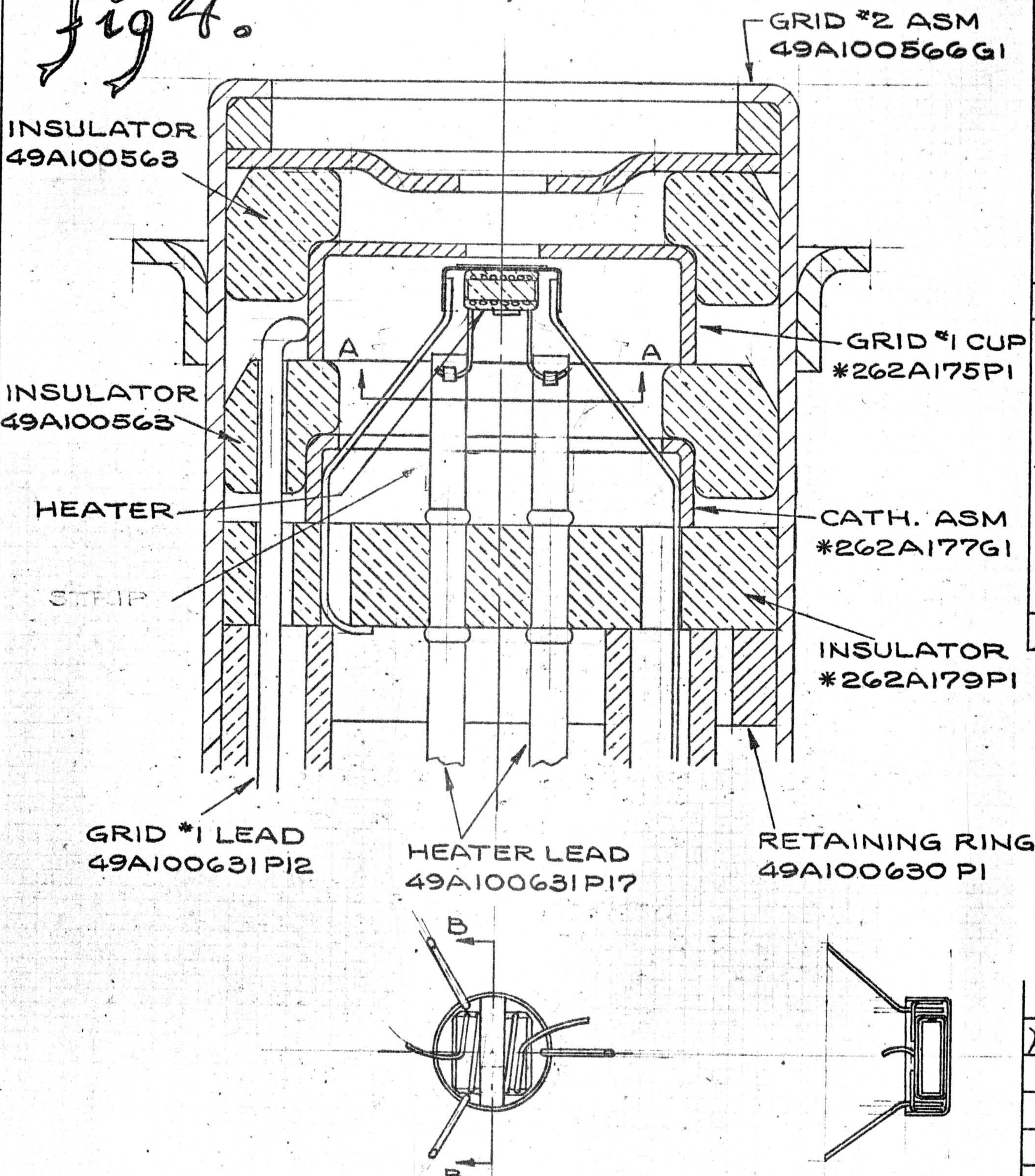
*: K-69087-

REVISION

2 MARCH 28/62 RJP

april 28 61 JVJ

fig 4.



10X SCALE

SECTION A-A

SECTION B-B

PRINTS TO

MADE BY N. LeWay Apr 20, 1961

ISSUED April 20, 61 JVJ

APPROVALS JN-11696

POWER TUBE DIV OR DEPT.

SCH'DY LOCATION

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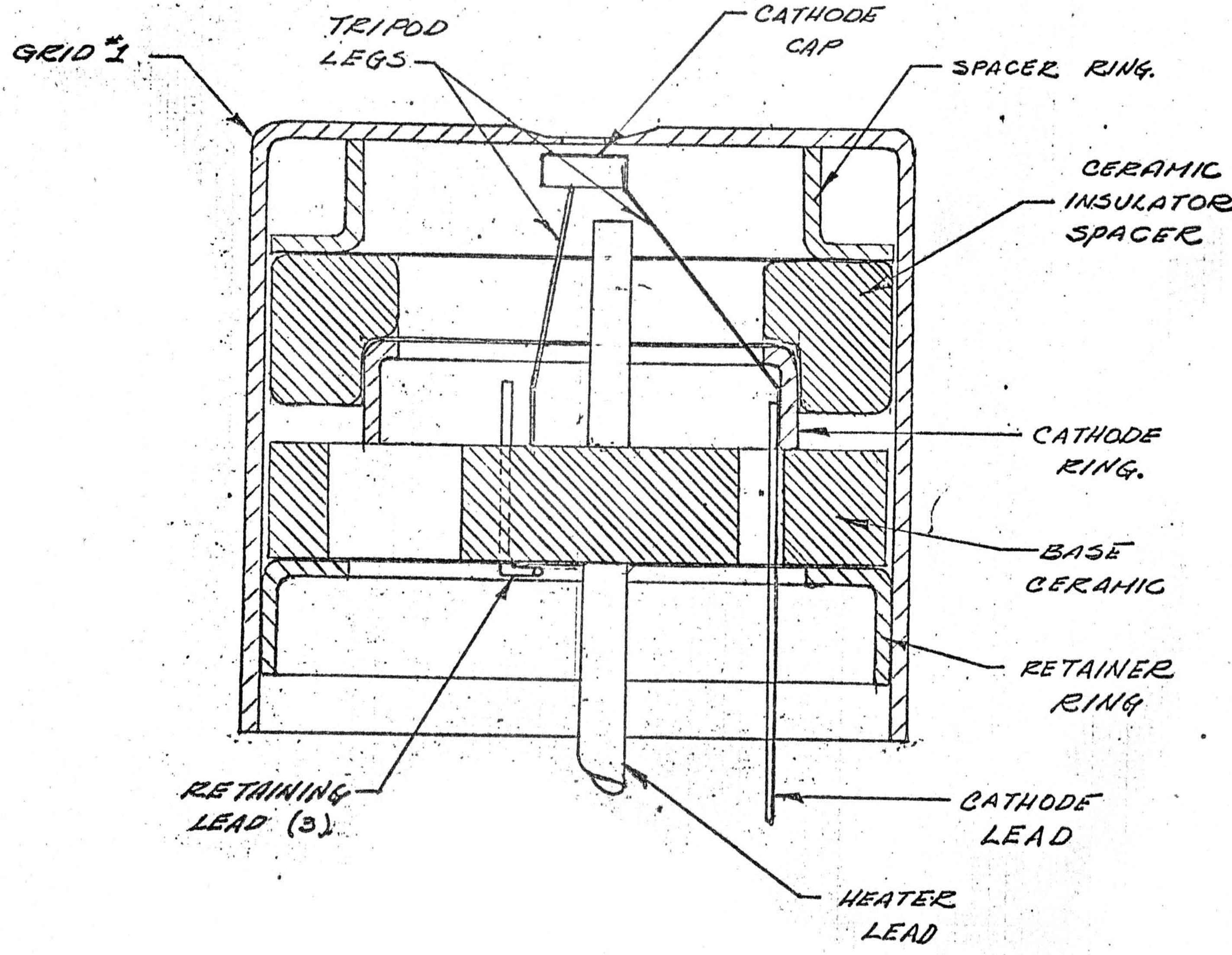
FIG. 5



CATHODE - GRID #1 ASSEMBLY
LOW WATTAGE HEATER

DLC/2-21-62