V.C. Campbell

RTD-1048-21 (4-54)

TECHNICAL INFORMATION SERIES

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AUTHOR	SUBJECT CLASSIFICATION	NO. / DATE
Arthur T. Devlin	Cathode-Ray Tube	NO. DF55ETC8 DATE August 31, 1955

TITLE

Cathode-Ray Tube Cathode Temperature Measurements

ABSTRACT

The temperature of the cathode was measured using platinum-platinum 10% rhodium thermocouples during processing and at various standard test conditions.

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CONCLUSIONS

Cathode temperatures measured are 25 to 50°C higher then is considered normal for oxide coated cathodes in cathode ray tubes. Techniques used in making these measurements proved to be reliable after numerous cross-checks. If the cathode of the present product could be operated at a lower temperature, tube life may increase.

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 next page (FN-610-2).

INFORMATION PREPARED FOR Cathode Ray Tube Sub-Department

TESTS MADE BY A. T. Devlin

COUNTERSIGNED Geo. L. Case DIV. Cathode-Ray Tube

DIVISIONS Electronics LOCATION Syracuse, New York

GENERAL ELECTRIC COMPANY
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Introduction:

Before this investigation was started there were no accurate data available for the temperature of the cathode during processing and at normal operation. As part of an emission build-up and tube life improvement investigation on monochrome tubes a program was outlined for measuring the temperature of the cathode within $\frac{1}{2}$ of 1%. Since work of a similar nature was being done in Schenectady, a trip was made to the Research Laboratory where Dr. V. L. Stout suggested the thermocouple techniques used in making the measurements in this report.

Equipment:

Pyrometry instruments used in measuring the temperature of the cathode were the Brown one point recorder Model No. Y 153X11(R)-X-27 and the Leeds and Northrup potentiometer Model No. 8657-C and optical pyrometer Model No. 8622-C. The Brown recorder and the Leeds and Northrup potentiometer were calibrated at the Electronics Laboratory, Syracuse, New York before this investigation started. The same laboratory checked several platinum-platinum 10% rhodium thermocouples, similar to the ones used, against standard thermocouples and they were accurate to 0.3%.

Unless otherwise stated, gun parts used are the same as those of mount assembly NN16034AC less upper structure with the exception of the cathode. The cathodes used are ceramic with holes, except where stated; they are solid ceramics N16000DD. Heaters are N16000FG except where stated. Mounts were sealed in neck tubing. This is simply the neck tubing of a bulb with the top rounded off in order to seal as shown in Fig. 1 and 2.

Design:

The first group of two tubes had a 2 mil platinum-platinum 10% rhodium thermocouple spot welded to the cathode cap just below the cathode coating and is shown in Fig. 1. These thermocouple wires were brought out through the small holes in the ceramic disk and the cathode shield to a point $\frac{1}{4}$" below the grid #1 cup. At this point the 2 mil pt. and the pt. 10% rh. were spot welded to 20 mil pt. and pt. 10% rh. respectively. The 20 mil wires extended $3\frac{1}{2}$", where they were spot welded to the Ni stem leads. When ready for test, the tube was placed in a distilled water bath in order to keep the cold junction (20 mil pt. to nickel and the 20 mil pt. 10% rh. to nickel) at room temperature. Cathode temperature measurements were made with a Leeds and Northrup potentiometer and recorded with a Brown one point recorder.

Group #2 consisted of 3 tubes made and measured the same as those described in group #1. The measurements are listed in Fig. 3. All heaters were operated at 0.6 amps.

The first five cathode temperature measurements were higher than anticipated. For this reason several methods were devised to cross-check the temperature range. The first cross-check was the three tubes of group #3. These had slots (1/16"X 3/16") cut in the grid #1 cup and spacer in order to measure the cathode temperature with the optical pyrometer. A correction factor of .36 for the emissivity of nickel was added to the optical pyrometer readings using a temperature factor correction curve.

A Fourth group of two tubes was made and measured, having a thermocouple spot-welded to the cathode as described in group #1 and slots cut in the grid #1 cup and spacer as described in group #3. In addition, a clear glass window was formed in the neck tubing for viewing the cathode. The average of the measurements made with the optical pyrometer are within 15°C of the average of the measurements made with the Leeds and Northrup potentiometer. This correlation tends to substantiate the previous temperature measurements.

Another possible source of error investigated was the cold junction of pt. to nickel and pt. 10% rh. to nickel. If the cold junction's temperature changed from room temperature an error would be introduced depending on the conditions. In order to be sure that such an error was not being introduced, the cold junction was moved outside the tube. This was done by bringing the pt.-pt. 10% rh. extension leads out through the side of the neck tubing so that the cold junction was now at the instrument. This design is shown in Fig. 2. Group V are of this design and are within the range of previous readings.

Independent of this work, Dr. V. L. Stout of the Research Laboratory measured the temperature of 5 CRT cathodes using an optical pyrometer. He left his cathode exposed using no assembly or grid #1 cup and his measurements averaged 818°C. Dr. Stout was of the opinion that the radiation losses of his exposed cathodes were sufficient to make the difference and was not surprised at the temperature measurements listed in this report.

Temperature of G.E. and Competitors' cathodes

None of the several cross-checks made disproved the original temperature measurements. With this information a comparison could now be made of the cathode temperature of G.E. and competitors' cathodes. The ranges and averages for the particular groups, made as shown in Fig. 2, are as follows:

Tubes (5)
G.E. Cathodes and Sylvania Heaters
Range 861°C to 913°C
Ave. 898°C

Tubes (5)
Sylvania Cathodes, Heaters and Retainers
Range 869°C to 915°C
Ave. 891°C

Tubes (6)
G.E. Cathodes with solid ceramics and G.E. Heaters
Range 815°C to 880°C
Ave. 852°C

Tubes (2)
Sylvania Cathodes and G.E. Heaters
Range 824°C to 879°C
Ave. 851°C

Tubes (5)
RCA Cathodes, Heaters and Retainers
Range 779°C to 870°C
Ave. 829°C

The cathode temperatures are 25 to 50°C higher than that recommended by design standards.

Measurements tend to indicate that the cathodes where Sylvania heaters were used are higher in cathode temperature. This is attributable in part to the construction of the heater. Sylvania heaters have an additional turn and are 1/16" shorter than G.E. heaters; so they do not extend below the cathode sleeve.

Lots of 50 G.E., RCA, and Sylvania cathodes were measured for the thickness of the cathode caps and the average results are as follows:

	Average Thickness of Cap	Measured Tolerance
G.E.	.0039	± .0002
RCA	.0037	± .0006
Sylvania	.0029	± .0002

No correlation can be made between the thickness of the cap and cathode temperature. The reason for the lower temperature of RCA cathodes might be the method used by RCA in "crimping in" the ceramic to the nickel sleeve. G.E. and Sylvania cathodes are assembled differently than RCA's cathodes.

Temperature Versus Emission and Time

Cathode temperature versus time was recorded on a Brown one point recorder with a 4 second response time for full scale for G.E., Sylvania, and RCA cathodes. Plots of these curves are shown in figures 5, 6, and 7. The per cent of the maximum temperature reached in 20 seconds for each group was averaged and Sylvania cathodes were at 82%, RCA 70%, and G.E. 78%.

Temperature limiting and space charge limiting emission curves were plotted for G.E. and competitors' cathodes and are shown in Fig. 8, 9, and 10. The knee of the curve is the point where space charge limiting starts and temperature limiting ends. Normally the voltage applied to a tube is such that the operating point is just to the right of the knee of the curve.[1] It can be seen that for G.E. and competitors' cathodes this is approximately 700°C. This is over 100°C less than the measured operating temperature.

Cathode Temperature During Processing

Before cathode temperatures were measured during processing, an R.F. filter was designed to protect the recorder from the R.F. energy of the high frequency heating coils. A special group of tubes was made with thermo-couples welded to the grid #1 cup and cathode as shown in Fig.11. A plot of cathode temperature versus heater current and grid #1 temperature taken from recorder measurements is shown in Fig. 12. Cathode temperatures during aging may be found in the same Fig. (12). The temperature of the grid #1 cup was measured for these special tubes at standard operating conditions and the average temperature was 320°C.

[1] Cathode-Ray Tubes, M. G. Say (Editor)

Discussion

Authorities recommend an operating range of 775 to 825°C for oxide coated cathodes in cathode ray tubes.[1] It is well known that the life of a tube is directly dependent upon cathode temperature.[2] Therefore, increasing the temperature means an increased rate of evaporation of barium causing rapid loss of emission and thus short life. However, the high temperatures of the present product may be necessary because of the form of the envelope and the materials used which make it more susceptible to contamination. In order to overcome the contamination and obtain sufficient emission the cathode has to be operated at a higher temperature.

Conclusion

The average cathode temperature of G.E. and competitors' cathodes is from 25 to 50°C higher than is considered normal for oxide coated cathodes. Work is continuing in order to evaluate the effect of operating at a lower cathode temperature.

[2] "Design Factors that Extend Electron Tube Life", J. H. Wyman, Tele-Tech, Nov. 1953.

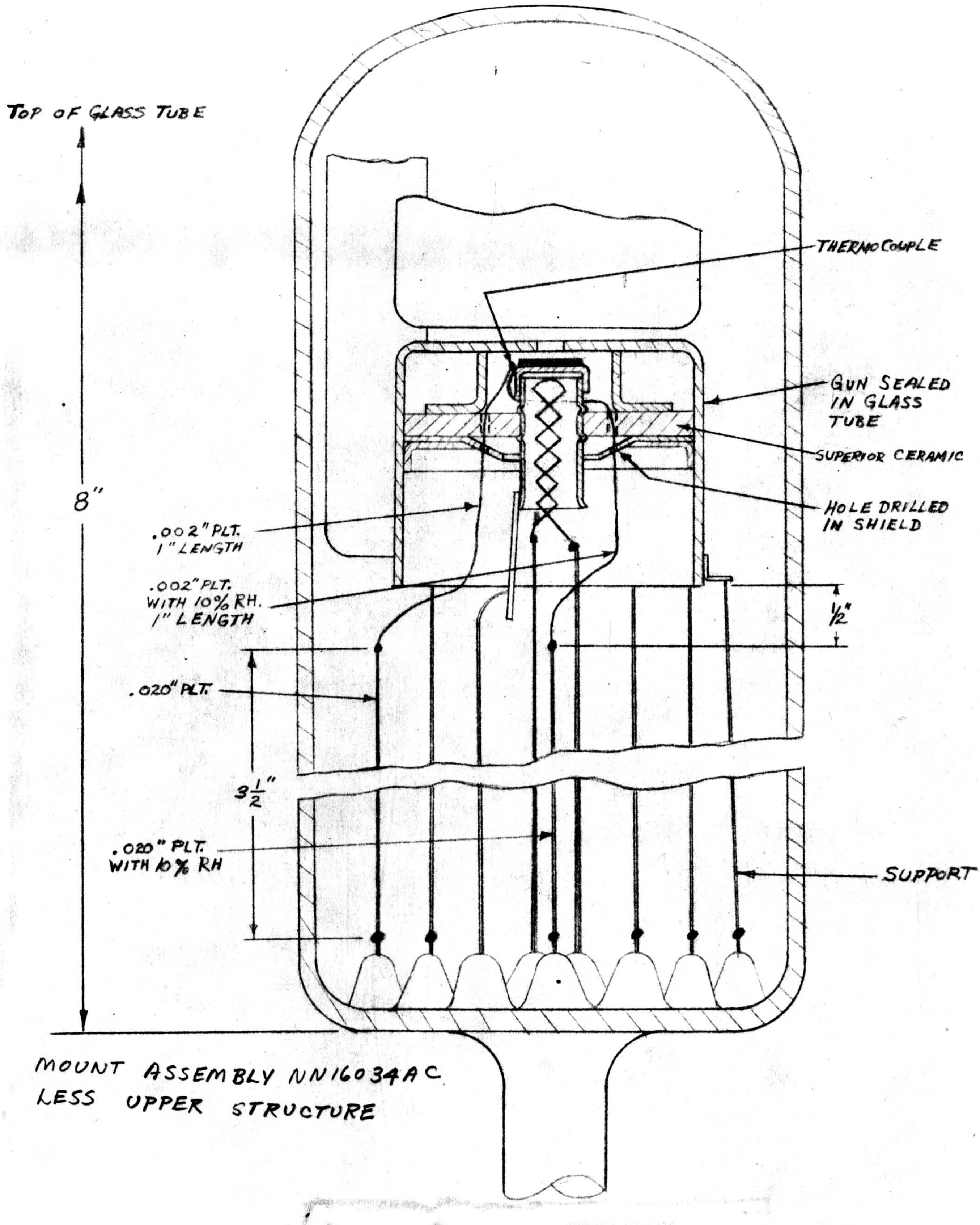


FIG.#1

THERMOCOUPLE CONSTRUCTION FOR CATHODE TEMPERATURE MEASUREMENT

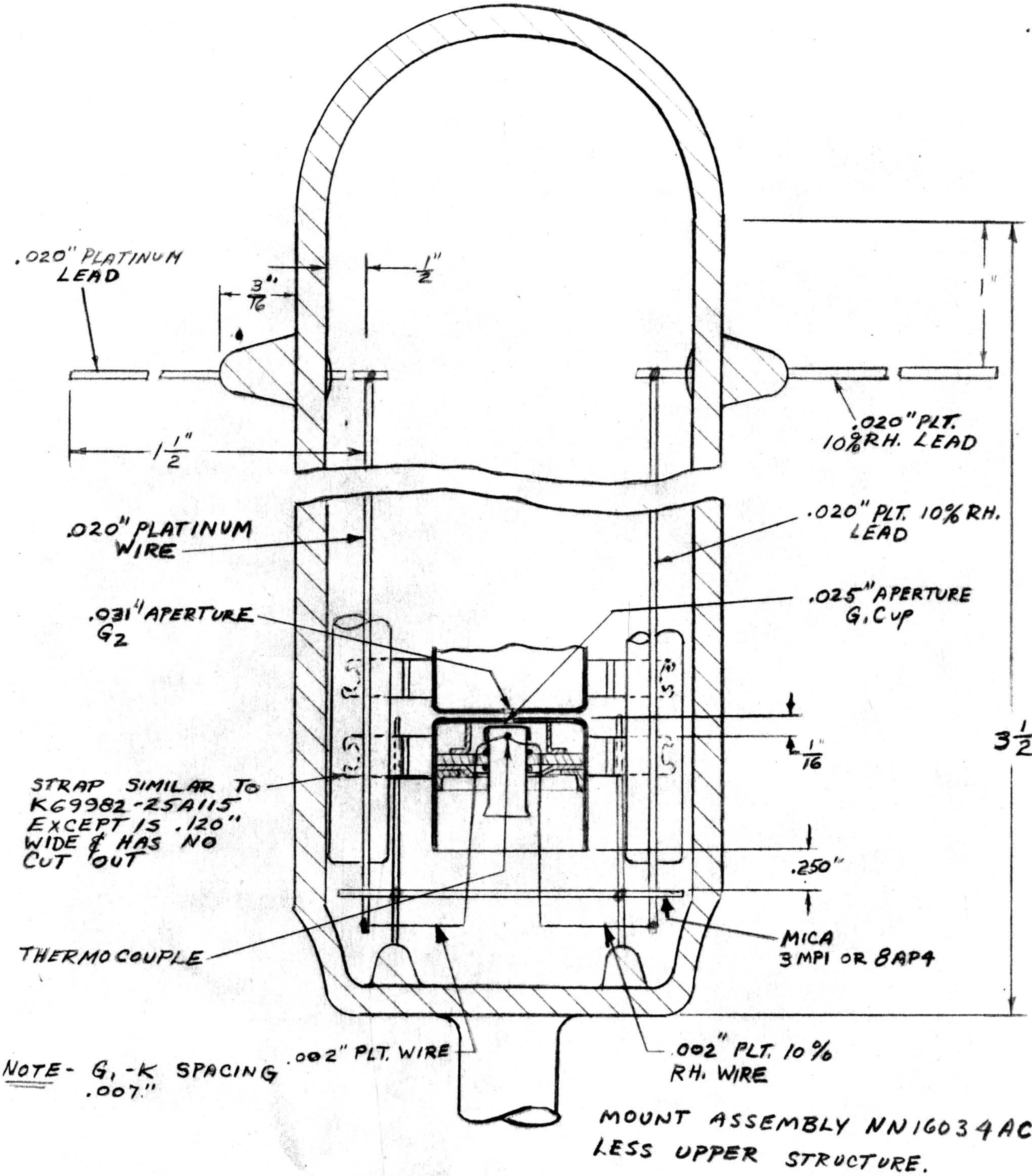


FIG. 2

THERMOCOUPLE CONSTRUCTION FOR CATHODE TEMPERATURE MEASUREMEMT

FIG. 3

CATHODE TEMPERATURE MEASUREMENTS

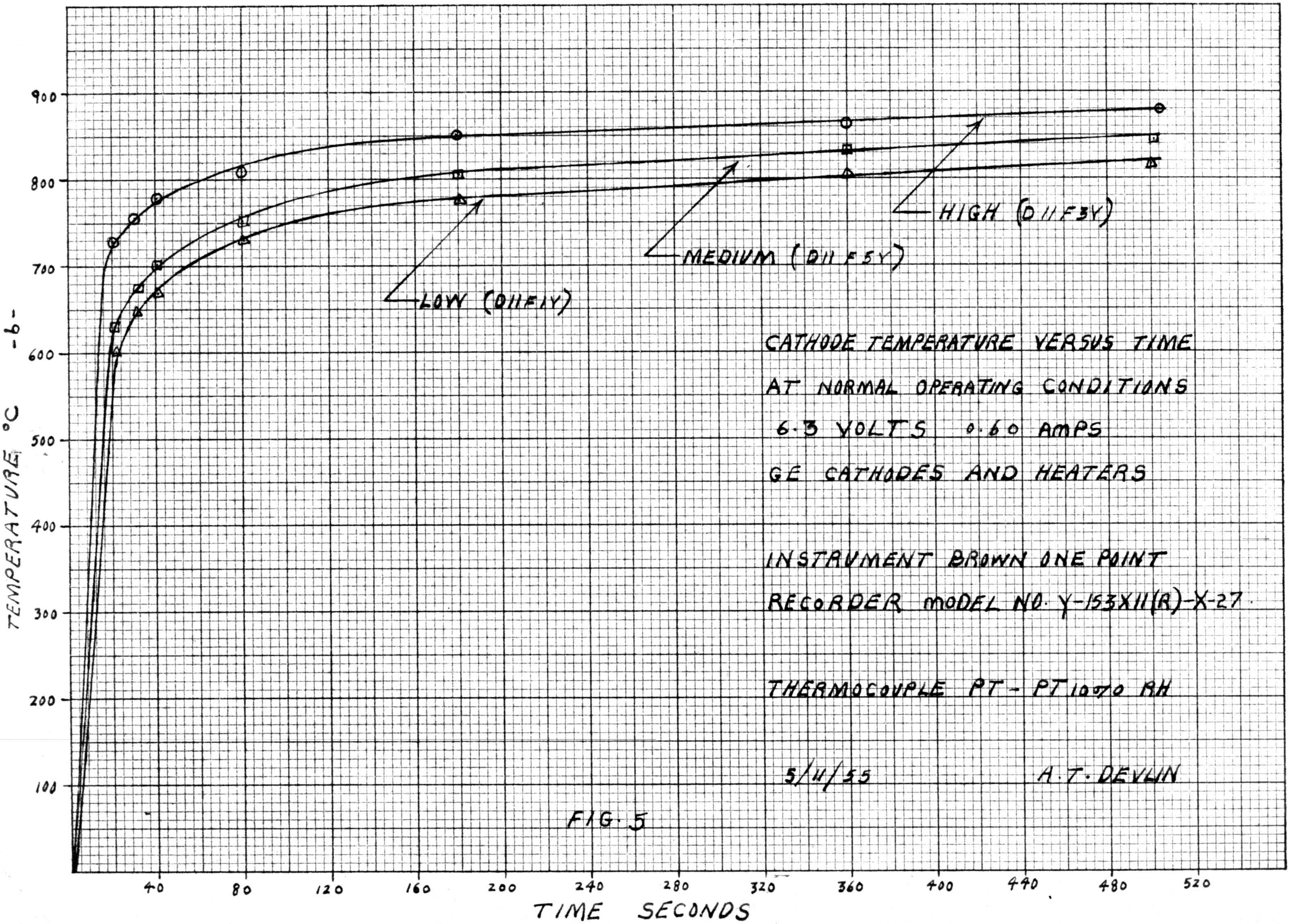
	Temp. Leeds & Northrup Potentiometer	Temp. Optical Pyrometer	Amps	Volts	zero bias Em(20 sec)ua	zero bias Em(30 sec)ua	zero bias Em ua	c.o.	Heater Warmup Time sec. Standard Test
Group #1 - standard GE mount (N16034AC) - Cold junction pt.-pt. 10% rh to nickel									
1)B9F1V	896°C		0.6	6.4		740	920	35	9.6
2)B10F1V	873°C		0.6	6.3		N C	N C		9.8
Group #2 - standard GE mount (N16034AC) - Cold junction pt.-pt. 10% rh to nickel									
3)C1F1V	906°C		0.6	6.2		1380	1690	51	9.0
4)C1F2V	870°C		0.6	6.1		1400	1550	53	9.6
5)C1F3V	879°C		0.6	6.0		960	1240	41	9.8
Group #3 - standard GE mount (N16034AC) - Readings made through curvature of glass									
6)C7F1V		829°C	0.6	5.8		500	920	41	10.2
7)C7F2V		890°C	0.6	5.8		1200	1460	47	9.8
8)C7F3V		829°C	0.6	6.0		940	1200	55	10.2
Group #4 - standard GE mount (N16034AC)-Readings made through clear glass window formed in tubing-cold junction pt.-pt. 10% rh to nickel									
9) ——	843°C	860°C	0.6	5.9	800	1125	1475	47	8.7
10)C10F1V	863°C	862°C	0.6	6.1	1100	1350	1700	47	9.8
Group #5 - standard GE mount (N16034AC) - Cold junction pt.-pt. 10% rh.									
11)C16F1V	842°C		0.6	5.9	525	1025	1440	48	8
12)C16F3V	857°C		0.6	5.9	700	1100	1550	50	9.2
13)C30F3V	841°C		0.6	5.8	850	1010	1100	53	8.2
Group #6 - Sylvania cathodes, GE heaters and shields* - Cold junction pt.-pt. 10% rh.									
14)C24F1V	824°C		0.6	5.8	800	925	1200	45	10.8
15)C24F2V	879°C		0.6	5.9	1100	1150	1380	39	10.8
Group #7 - Sylvania cathodes, heaters and retainers* - Cold junction pt.-pt. 10% rh									
17)C29F12		891°C	0.6	5.9	800	870	1000	43	12
18)C29F2V		915°C	0.6	6.2			N C	N C	
19)C30F1V	869°C		0.6	6.0	1150	1200	1160	47	10.5
20)C30F2V	897°C		0.6	6.0	300	325	880	42	11.3
21) ——	881°C		0.6	5.9	1050	1150	1500	41	10.5

*Sylvania cathodes used were discolored pink before processing

FIG. 4

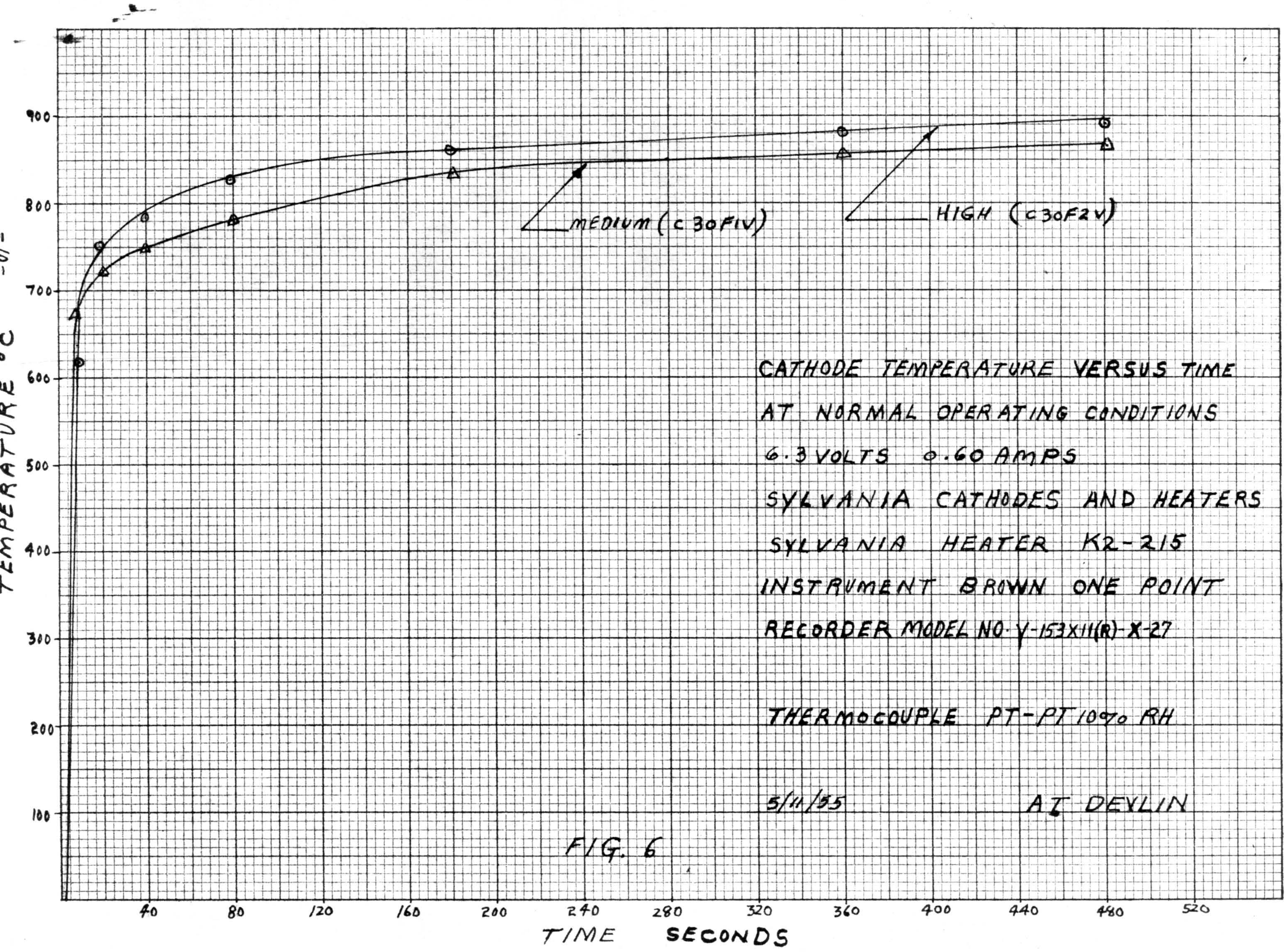
CATHODE TEMPERATURE MEASUREMENT

	Temp. Leeds & Northrup Potentiometer	Temp. Optical Pyrometer	Amps	Volts	zero bias Em(20 sec)ua	zero bias Em(30 sec)ua	zero bias Em ua	c.o.	Heater Warmup Time sec. Standard Test
Group #8 - GE Cathodes and Sylvania heaters - cold junction pt. - pt. 10% rh.									
D7F1V	908°C	925°C	0.6	6.2			1280	48	11.2
D7F3V	899°C	898°C	0.6	6.3	900	1050	1060	39	11.2
D7F2V	861°C		0.6	6.3	600	750	900	37	11.2
D7F4V	913°C		0.6	6.3	800	870	1050	37	11.2
D7F5V	907°C		0.6	6.4	780	840	1250		11.0
Group #9 - RCA Cathodes, heaters, and retainers- cold junction pt.-pt. 10% rh.									
C31F1V		844°C	0.6	6.0	550	850	1450	49	—
D13F2V	842°C		0.6	6.1	1000	1100	1400	45	9.6
D21F1V	806°C		0.6	6.0	450	650	1200	40	8
D21F2V	779°C		0.6	6.0	600	740	1000	40	10.4
D21F3V	870°C		0.6	6.3	690	850	1200	—	—
D21F4V	827°C		0.6	6.3	150	360	710	35	9.4
Group #10 - GE Cathodes with solid ceramics and GE heaters - cold junction pt.-pt. 10% rh.									
D11F1V	815°C		0.6	6.0	300	350	520	27	10
D11F4V	865°C		0.6	6.0	800	1400	1200	45	9.8
D11F2V	867°C		0.6	6.1			590	35	10.4
D11F5V	833°C		0.6	6.1	500	640	860	35	9.8
D11F3V	880°C	894°C	0.6	6.2	1150	1220	1450	47	9.8



HIGH (D11F3Y)
MEDIUM (D11F5Y)
LOW (D11F1Y)
CATHODE TEMPERATURE VERSUS TIME
AT NORMAL OPERATING CONDITIONS
6.3 VOLTS 0.60 AMPS
GE CATHODES AND HEATERS
INSTRUMENT BROWN ONE POINT
RECORDER MODEL NO. Y-153X11(R)-X-27
THERMOCOUPLE PT - PT 10% RH
5/11/55
A.T. DEVLIN
TEMPERATURE °C
100
200
300
400
500
600
700
800
900
40
80
120
160
200
240
280
320
360
400
440
480
520
TIME SECONDS

FIG. 5



900
800
700
600
500
400
300
200
100
TEMPERATURE °C
40
80
120
160
200
240
280
320
360
400
440
480
520
TIME SECONDS
MEDIUM (C30F1V)
HIGH (C30F2V)
CATHODE TEMPERATURE VERSUS TIME
AT NORMAL OPERATING CONDITIONS
6.3 VOLTS 0.60 AMPS
SYLVANIA CATHODES AND HEATERS
SYLVANIA HEATER K2-215
INSTRUMENT BROWN ONE POINT
RECORDER MODEL NO. Y-153X11(R)-X-27
THERMOCOUPLE PT-PT 10% RH
5/11/55
AT DEVLIN

FIG. 6

FN-521-B (8-50) GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y., U.S.A. 100X140 7/100 Inch Divisions

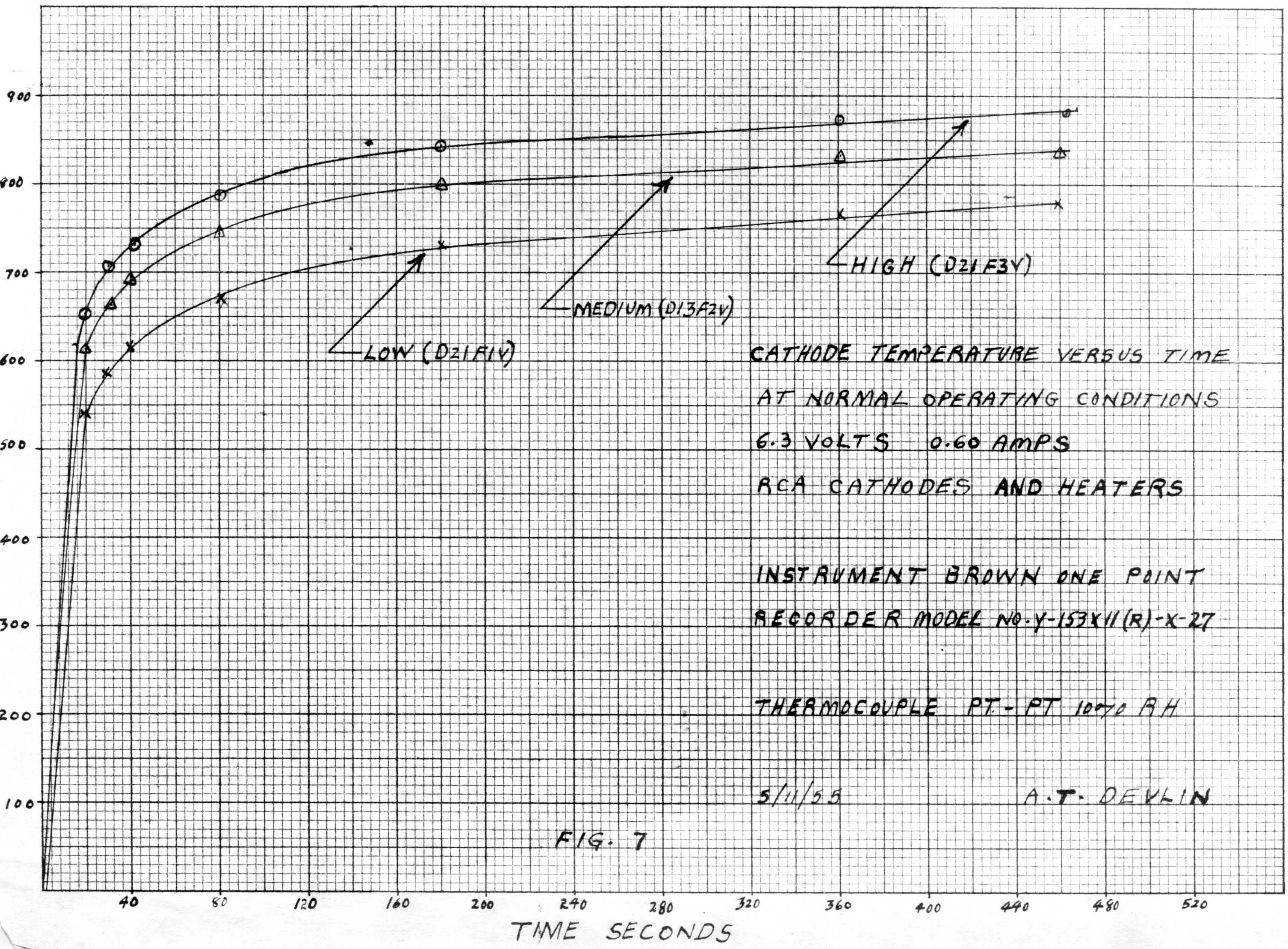
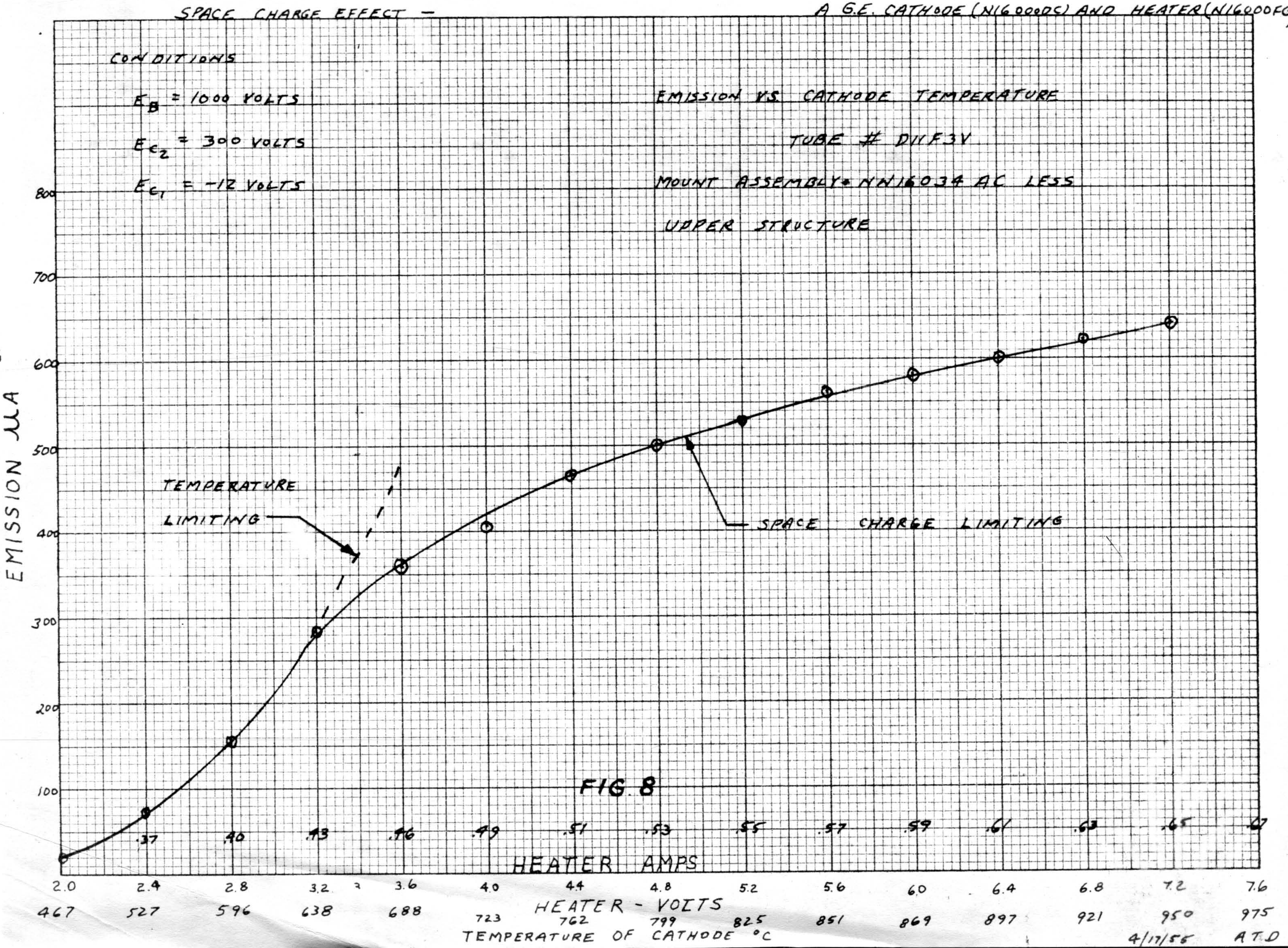


FIG. 7


SPACE CHARGE EFFECT –
A G.E. CATHODE (N16000DC) AND HEATER (N16000FG)
CONDITIONS
E_B = 1000 VOLTS
E_{C_2} = 300 VOLTS
E_{C_1} = -12 VOLTS
EMISSION VS. CATHODE TEMPERATURE
TUBE # D11F3V
MOUNT ASSEMBLY NN16034 AC LESS
UPPER STRUCTURE
TEMPERATURE LIMITING
SPACE CHARGE LIMITING
EMISSION µA
800
700
600
500
400
300
200
100
.37 .40 .43 .46 .49 .51 .53 .55 .57 .59 .61 .63 .65 .67
HEATER AMPS
2.0 2.4 2.8 3.2 3.6 4.0 4.4 4.8 5.2 5.6 6.0 6.4 6.8 7.2 7.6
HEATER - VOLTS
467 527 596 638 688 723 762 799 825 851 869 897 921 950 975
TEMPERATURE OF CATHODE °C
4/17/55
A.T.D
FIG. 8

SPACE CHARGE EFFECT- A SLYVANIA CATHODE AND HEATER

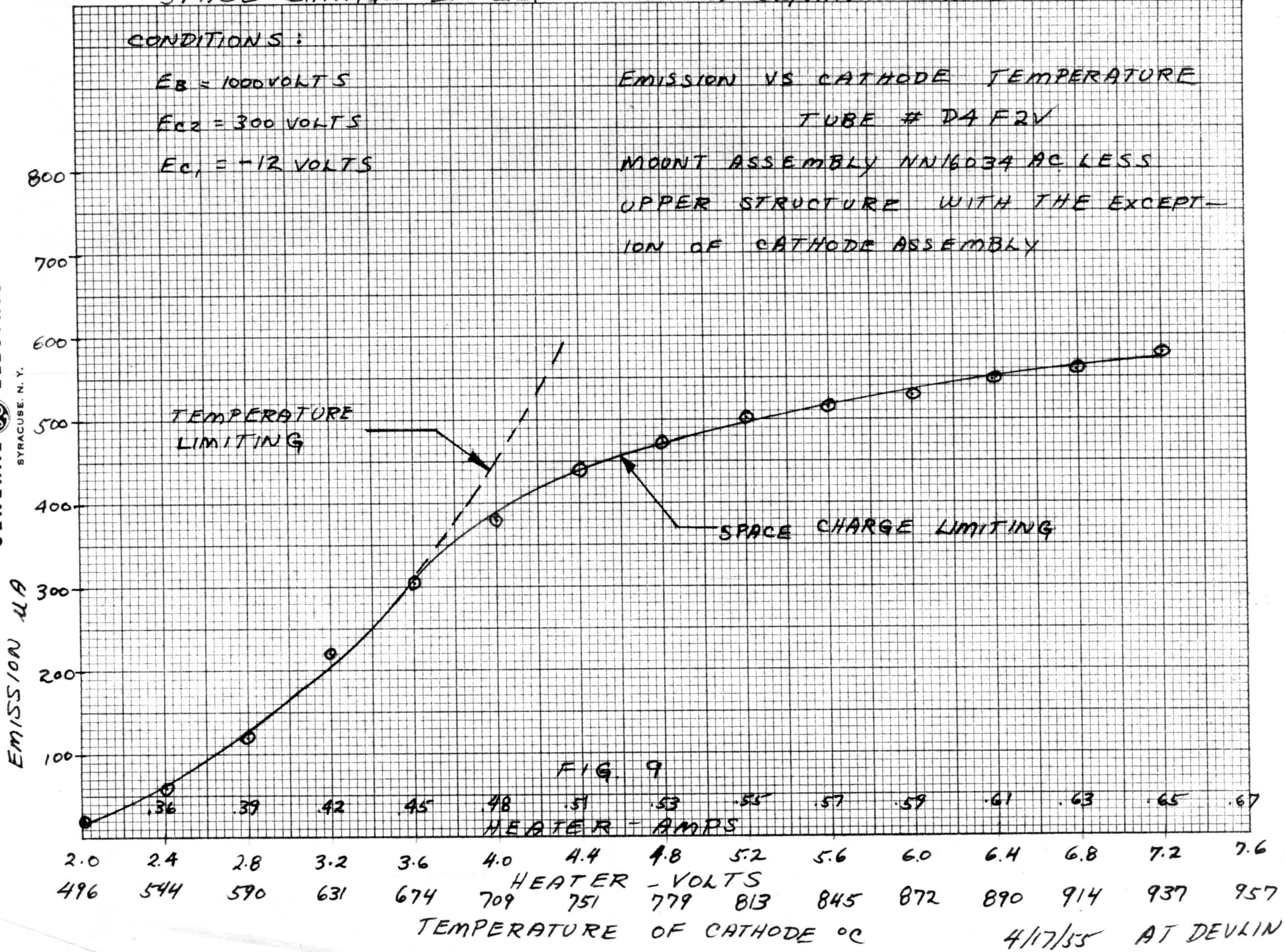
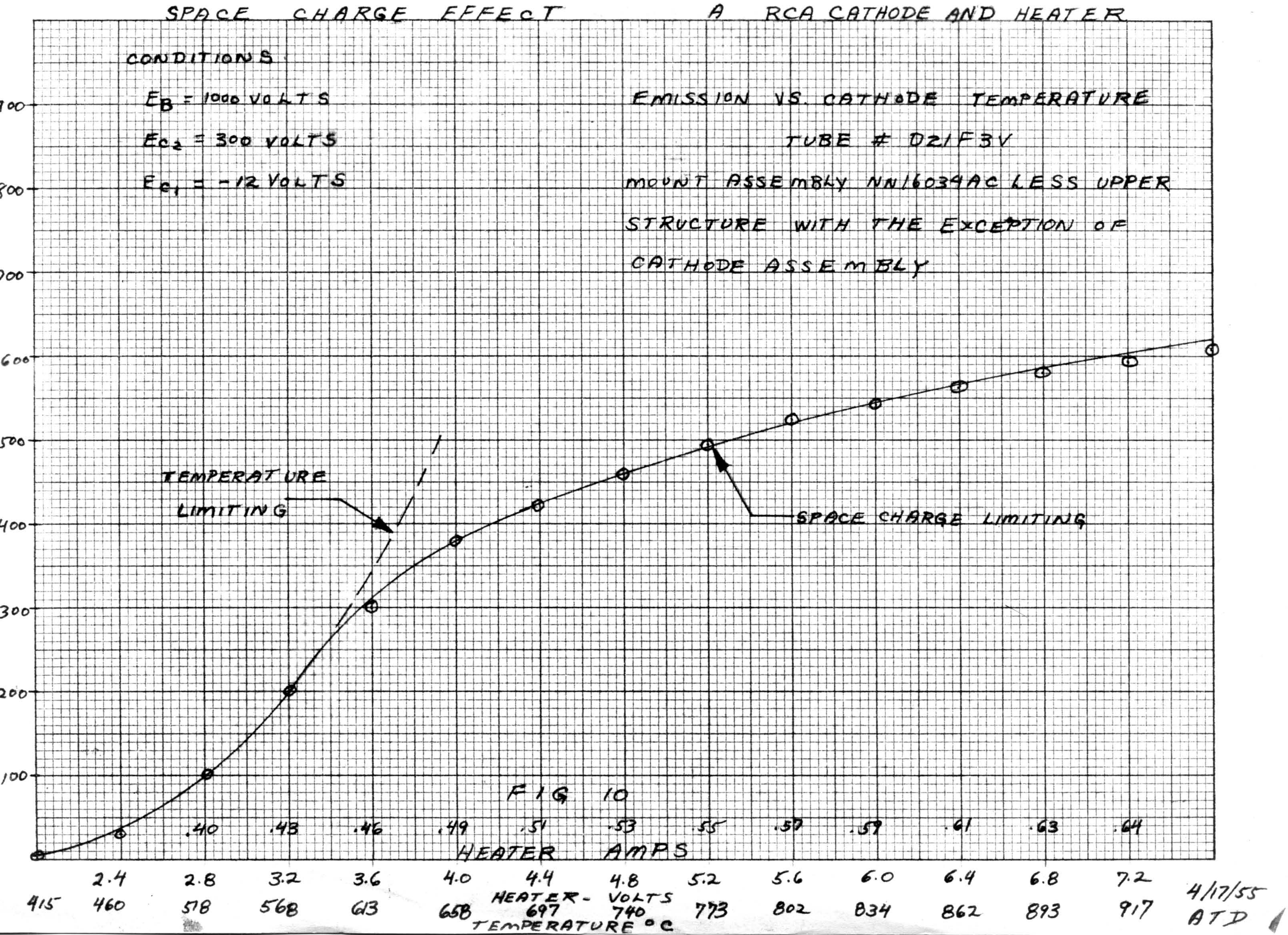


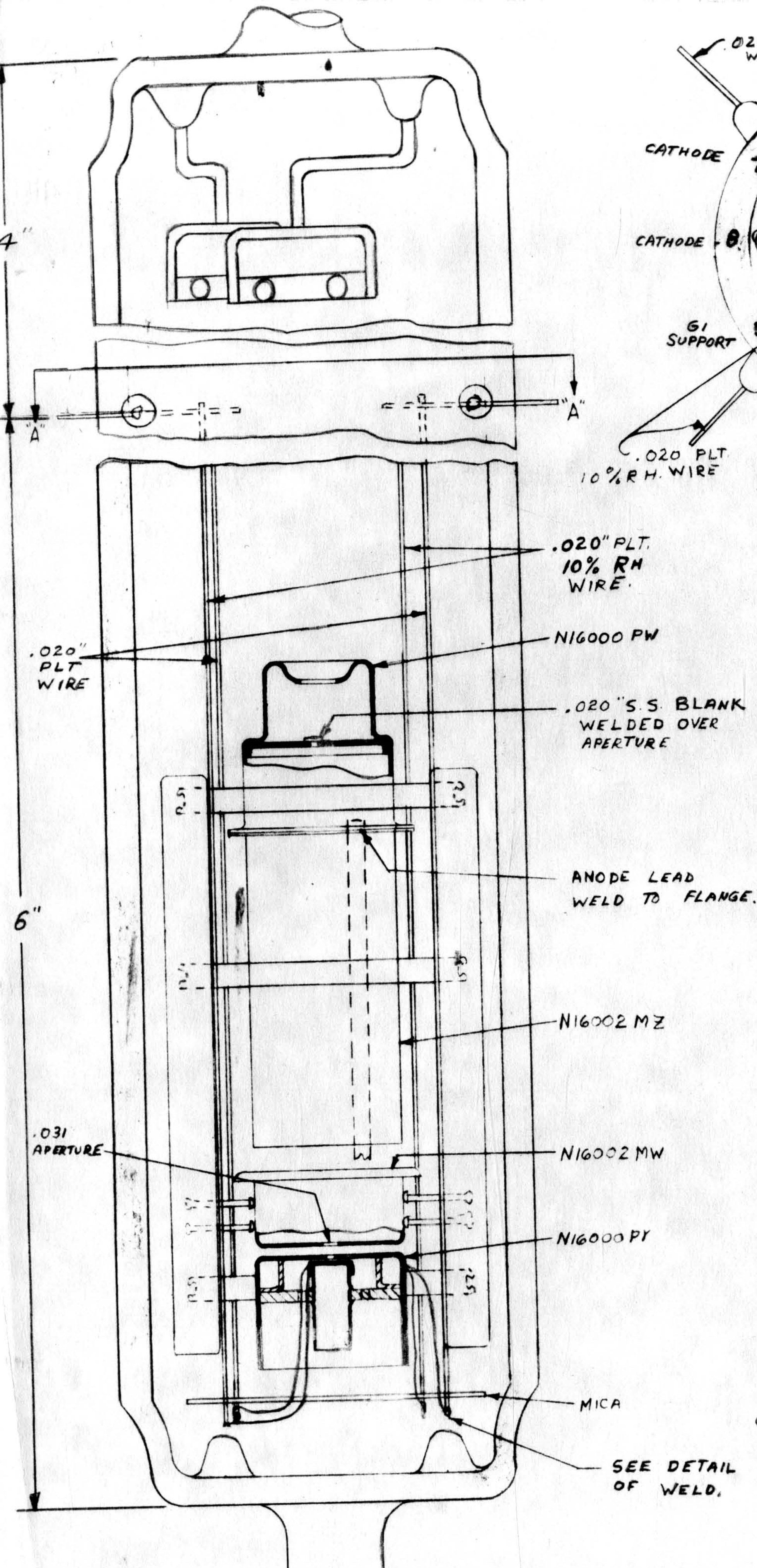
FIG. 9

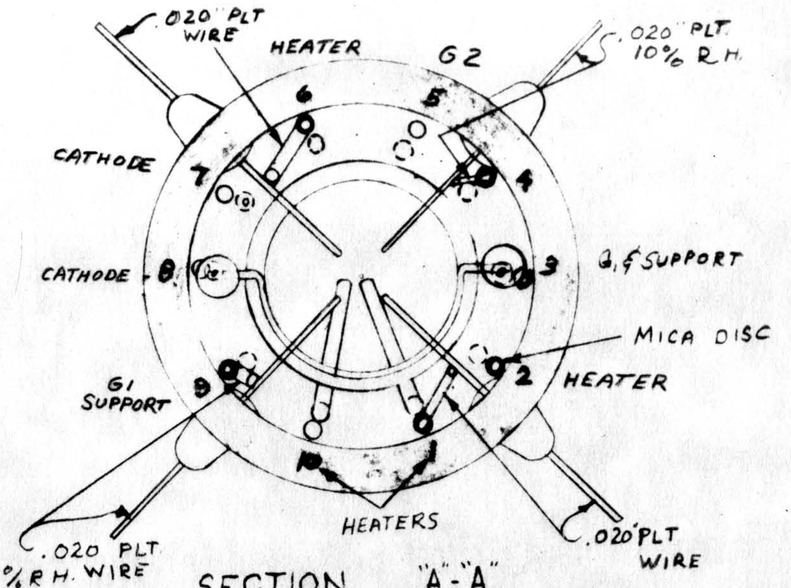
4/17/55 AT DEVLIN



SPACE CHARGE EFFECT
A RCA CATHODE AND HEATER
CONDITIONS
E_B = 1000 VOLTS
E_{c_2} = 300 VOLTS
E_{c_1} = -12 VOLTS
EMISSION VS. CATHODE TEMPERATURE
TUBE # D21F3V
MOUNT ASSEMBLY NN16034AC LESS UPPER
STRUCTURE WITH THE EXCEPTION OF
CATHODE ASSEMBLY
TEMPERATURE LIMITING
SPACE CHARGE LIMITING
100
200
300
400
500
600
.40 .43 .46 .49 .51 .53 .55 .57 .59 .61 .63 .64
HEATER AMPS
2.4 2.8 3.2 3.6 4.0 4.4 4.8 5.2 5.6 6.0 6.4 6.8 7.2
HEATER - VOLTS
415 460 518 568 613 658 697 740 773 802 834 862 893 917
TEMPERATURE °C
4/17/55
ATD

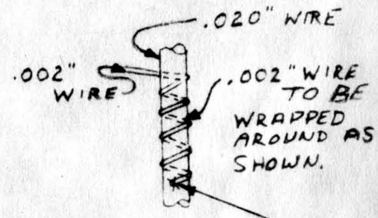
FIG 10





SECTION "A"-"A"
(PARTIAL)

PLT. - PLATINUM
RH. - RHODIUM



TYPICAL WELD

NOTES
1. G_1-K SPACING .007".
2. SHAPE PRIOR TO WELDING 4 THERMOCOUPLE LEADS.

MOUNT ASSEMBLY NN16034AC LESS UPPER STRUCTURE.

THERMOCOUPLE CONSTRUCTION FOR CATHODE & GRID #1 TEMPERATURE MEASUREMENT DURING ACTIVATION

FIG. 11