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Title: Oxide-Coated and Thoriated Tungsten Filaments in a Small Thyratron

By

Electronic Tube Engg. Div.

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Date: July 21, 1943

72158

OXIDE-COATED AND THORIATED TUNGSTEN FILAMENTS IN A SMALL THYRATRON

Electronic Tube Engg. Div. July 17, 1943

Scope:

This data folder covers an investigation endeavoring to replace the present tungsten filament in a small thyratron by an oxide coated or thoriated tungsten filament. We hope to meet the following requirements with this change in filament design.

(1) The filament must draw not more than 0.150 amps. at a filament voltage of 1.35.

(2) The tube must have the ability to fire at least 20 times within .005 sec. and with a peak surge current of 5 amps. at a filament voltage of 1.0 v.

(3) The filament should be able to withstand a 20 minute life test at 1.4 volts without change in characteristics.

(4) Grid leakage must not be increased by the introduction of the coated filament.

Conclusions:

Tubes having oxide coated filaments had much better emission, resulting in shorter firing times. Critical grid voltage was more positive than tungsten filament tubes. Best emission was obtained from our spray coated wire. It produced more consistent critical grid values also. RCA, Sylvania and Raytheon dip coated wire gave good emission but were less consistent. All filaments required 5 to 8 minutes filament aging to stabilize critical grid voltage. Cold cathodes have to be added to avoid filament burn-outs from cathode spotting.

Carbonized thoriated tungsten was too brittle for use at the high acceleration this tube is to meet. Uncarbonized thoriated filaments lost their initial emission rapidly as result of evaporation. The low emission was accompanied by grid to cathode leakage.

Torching of the condensation trap every four runs (with no tubes on the system) greatly improved emission and overall yield.

(5) Critical grid voltage must meet constancy requirements and should preferably meet present specification values.

(6) The filament must be able to withstand a very high acceleration.

(7) The use of a getter must be avoided if possible.

<u>Conclusions</u>:

Coated filaments greatly decreased firing time by virtue of their better emissive properties. Eg was made more positive presumably due to the lower operating temperatures of the coated filaments. This required that we use a coarser grid mesh. Mesh tolerances, becoming more important for the larger meshes, caused excessive variation of Eg.

Good emission was obtained from filament wire coated by Raytheon, Sylvania, and RCA. Results on these filaments were not as consistent as wire coated by ourselves.

It was found to be advantageous to include cold cathodes of anodized aluminum which decreased the danger of a cathode spot forming on the filament.

Torching the condensation trap was found to help emission, providing the tubes weren't on the manifold during torching. Data indicates that torching is necessary after every fourth run.

Drifting of Eg on life test was overcome by aging the filament for 5 to 8 minutes at Ef =1.35 v.

Grid leakage was not appreciable for the oxide coated filaments but was excessive for the thoriated tungsten filaments.

The thoriated tungsten filaments showed a tendency to decrease in emission with the life of the tube. Carbonizing the filament was suggested to stabilize the filament but was rejected because of its embrittling action. We conclude that the oxide coated filament would increase our yield of good tubes as compared with the plain tungsten filaments. This yield, however, would still be at best 60 or 70% which is far from ideal.

<u>Discussion:</u>

A brief discussion of the various filaments tried and the limitations and advantages involved are given below. Other variables in this investigation were size of grid mesh and the use of cold cathodes, i.e. cold cathodes were omitted from part of the tubes.

<u>Spray-Coated .71 Mg. Tungsten 200 Mils Long</u>

The filaments in this group were sprayed after mounting on yokes. 60 x 60 grid mesh was used in all tubes. The sintering schedule used was as follows:

(1) 2 minutes at 800°
(2) 2 minutes at 900°
(3) 2 minutes at 1100°
(4) With +225 volts on the grid, filament power was regulated so that the emission current was .0001 amps. This condition was maintained until emission stabilized and emission data was recorded. (E_f and I_f for .1 mil. emission)

Very good emission was obtained on the third attempt at coating and the tubes were within limits on firing times and surge current. Grid voltages, however, were too positive and the average life of the filaments at E_f=1.4 v. was too short. This suggests that we try a little longer filament on the next group and a coarser grid mesh.

Spray-Coated .71 Mg. Tungsten 215 Mils Long With 30 x 30 Grid Mesh. (.0065" Wire)

Cold cathodes were omitted from 50% of these tubes. Although the sintering schedule that produced good tubes in the previous group was followed, the results in this case were much poorer. This suggests that our coating or coating technique is faulty and that we should improve our coating method and also obtain some wire coated by another source.

Coating Techniques:

Two methods have been tried for improving our coating. First, a device was built which would alternately dip and bake the filament wire as it was run through a system of pulleys driven by syncronous motors. We found that our wire did not pick up sufficient coating to be practical. It is believed, however, that this method would prove to be successful if the proper coating and binder were found. Time has limited our investigation along this line.

The second method was more successful. Wire wound on a frame was passed in front of the spray-gun several times. Both sides of the wire was treated in this manner. This technique gave us good coatings and with proper attention to methods (with a continuous feed mechanism to draw a strand of wire between two opposing spray-guns), could be used to coat wire evenly and continuously in fairly large quantities. Coating weight could be varied by varying either the density of the spray or speed of wire.

R.C.A Coated .802 Mg. Nickel, 300 Mil. Filaments

30 x 30 grid was used and the anodized aluminum cathodes were omitted from 50% of the tubes.

The sintering schedule used was as follows:

(1) 30 seconds at 1000 to 1100°
(2) 900° until emission stabilized

The emissivity did not appear to be too dependent upon a critical sintering procedure as considerable flexibility of the above schedule was allowed without any apparent effort on the emission of various tubes.

The fact that 100% of these tubes had very good emission confirms our suspicion that our coating or coating technique has been defective.

These filaments drew too high currents to be suitable for our use and also were too long to be mechanically stable.

<u>Spray-Coated .50 Mg. Wire, 160 Mils Long</u>

These tubes were built in an attempt to work toward a shorter filament which would be better suited to stand high acceleration. Several different weights of coating were used ranging from 2 mg/cm^2 to about 11 mg/cm^2. Two grid meshes were used, 30 x 30 and 20 x 20.

These tubes had good emissive qualities, firing within the required time and surge current limits for filament voltages below .9 volts. Filament currents were satisfactory averaging about .55 inches at Ef=1.35 v. Critical grid voltage varied widely and also lacked the desired degree of stability on life test. Several of the filaments burned out at Ef=1.4 v. before the end of the 20 minute life test. This would indicate that a little longer filament is necessary. Grid leakage was not excessive as measured by noting the change in grid voltage due to a change in the value of the grid resistor.

<u>Raytheon-Coated .46 Mg. Wire</u>

The first filament length tried was .160 inches which proved to be much too short. In the second run of tubes, a .215 inch filament was used and in the third run, this was increased to .230 inches. A sintering schedule equivalent to that used by the Buffalo Tube Works on the same wire was tried. Slight variations were made in an attempt to find the closest approach to the Buffalo schedule.

These filaments required more aging in order to obtain good emission than any previous filaments tried. Grid voltages were positive even with grid mesh as coarse as 30 x 30. Results in general were much poorer than those obtained by E. J. Lawton on the same filament. Evidence has since been obtained which points to the condition of the moisture trap on our exhaust system as a likely source of this inconsistancy. These findings are described im more detail later in this report.

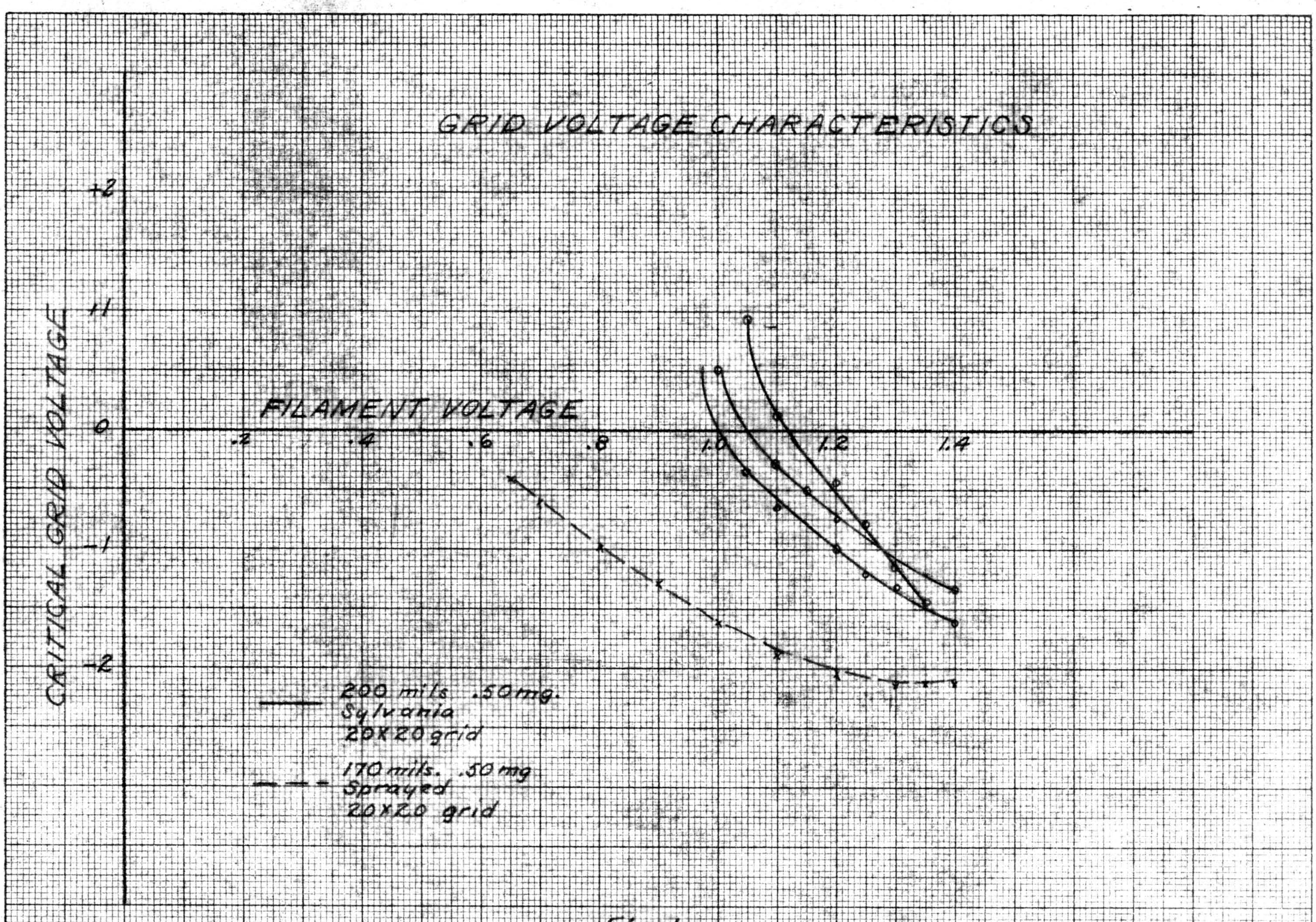

GRID VOLTAGE CHARACTERISTICS
CRITICAL GRID VOLTAGE
FILAMENT VOLTAGE
+2
+1
0
-1
-2
.2
.4
.6
.8
1.0
1.2
1.4
200 mils .50mg.
Sylvania
20X20 grid
170 mils. .50 mg
Sprayed
20X20 grid
1-11-43
AER

Fig. 1

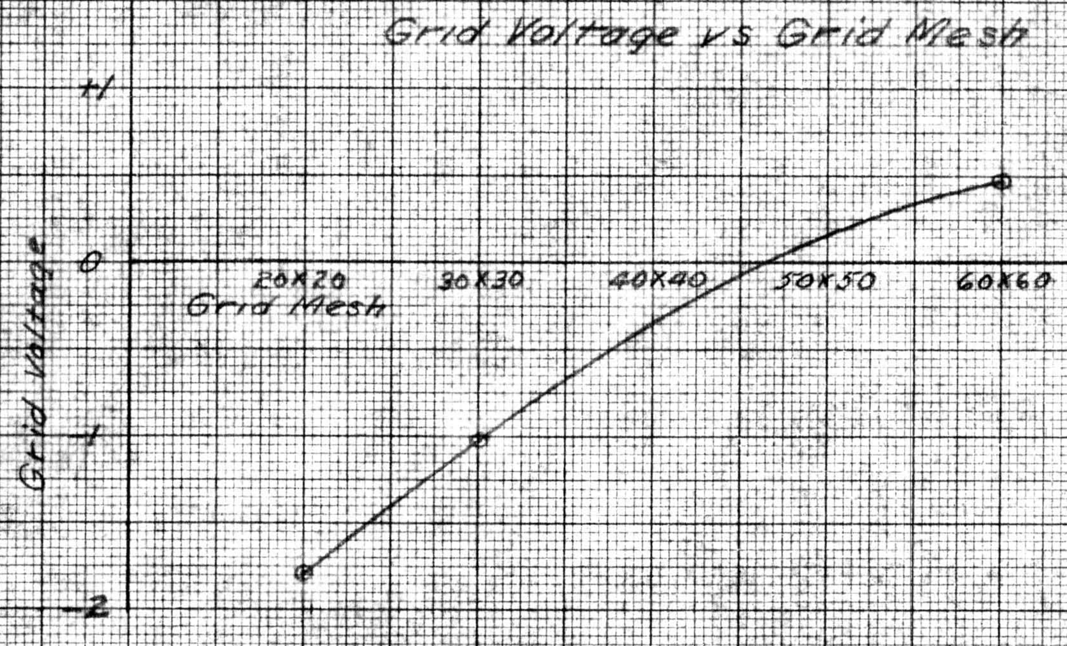


Fig. 2

2-3-43
AER

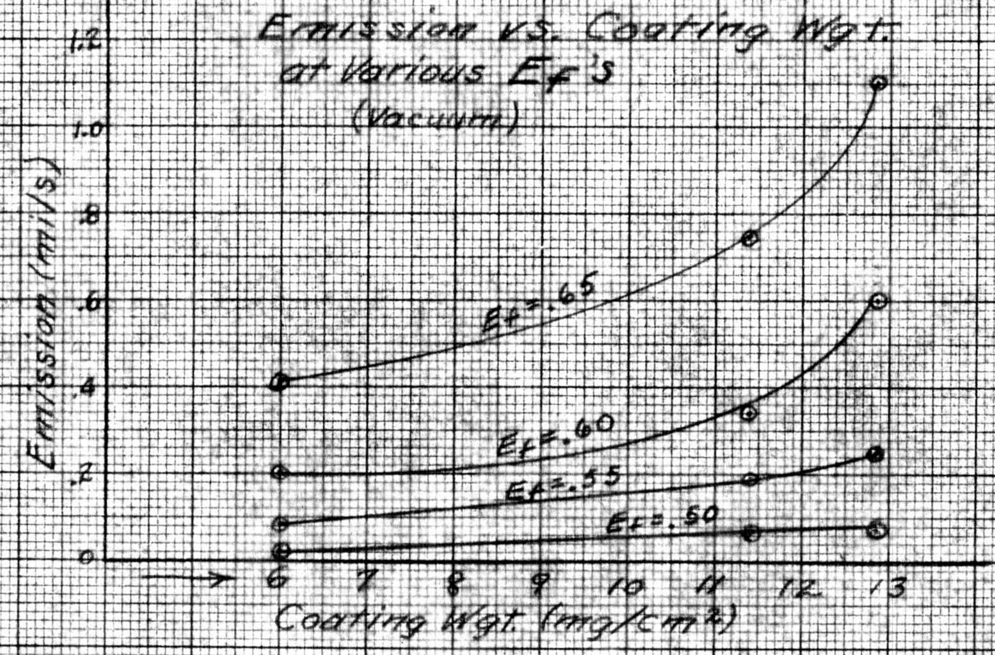


Fig. 3

2-20-43
AER

Effects of Varying Coating Weights

The .170 inch .50 mg. filament was used in this investigation. 30 x 30 grid was used in all tubes. These filaments were coated in the following approximate weights: 2 mg./cm^2, 6 mg./cm^2, 11.4 mg./cm^2, and 13 mg./cm^2. No emission could be obtained from the lightest-coated filament. Emission increased with coating weight for the other three samples. Evidence was obtained which indicated that Eg was more positive for the lighter coatings. The data on this point is not conclusive due to the fact that the shift is slight and could be linked with other factors such as the exhaust operation.

Curves in Fig. 3 show the variation of emission with coating weight.

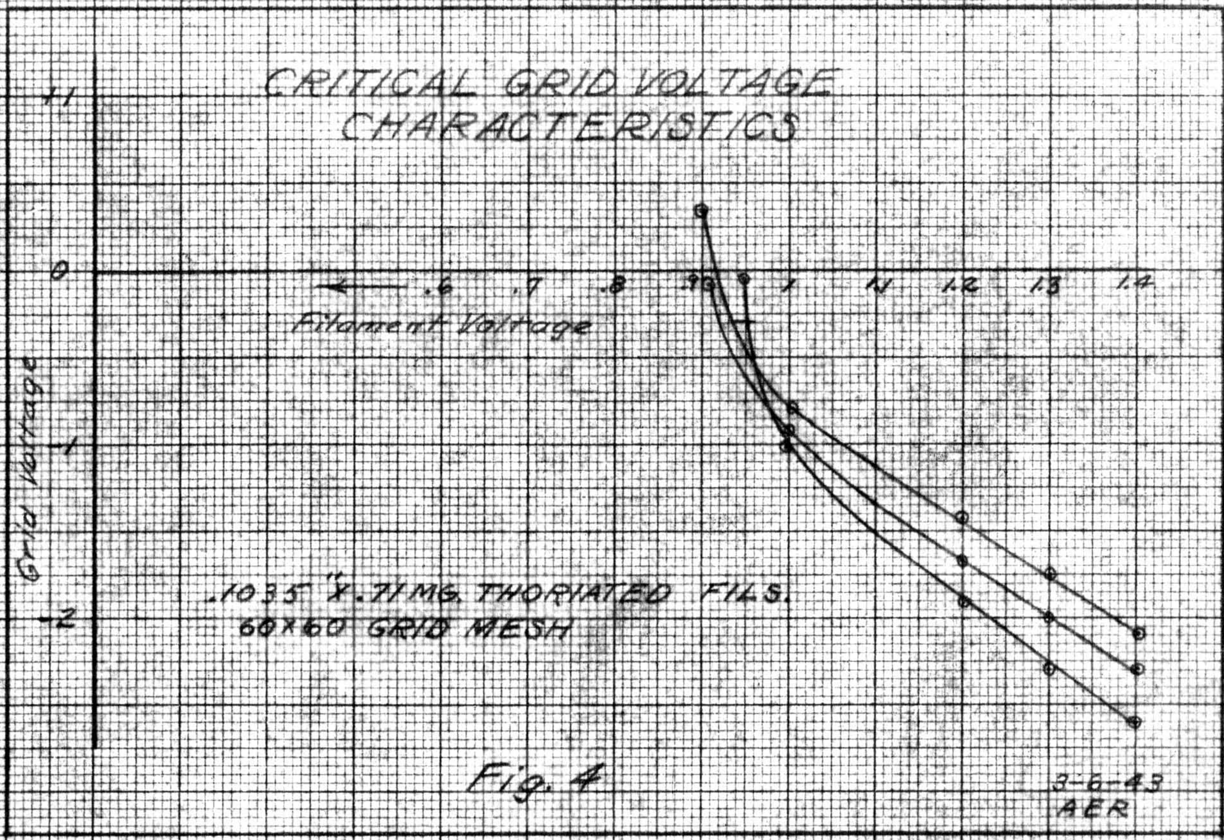
Thoriated Tungsten Filaments

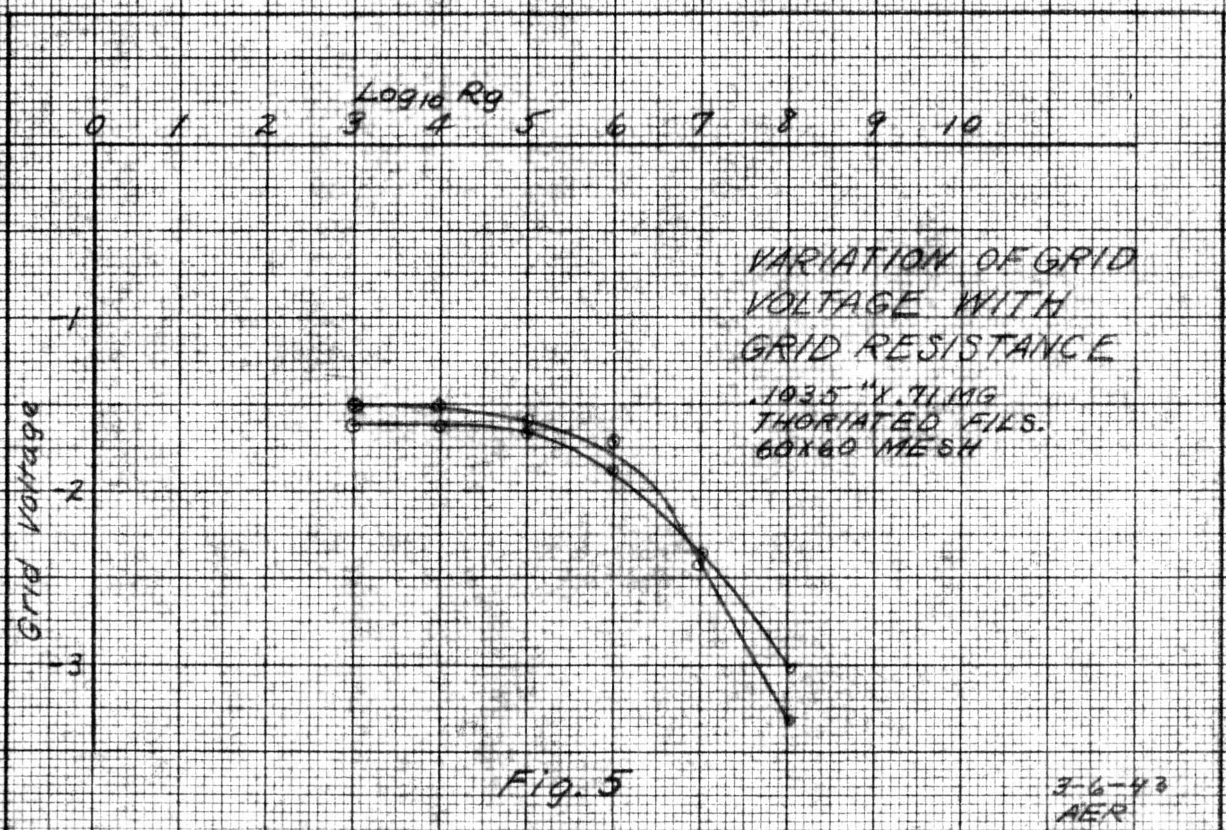
The only available thoriated tungsten wire was 1 mil. in diameter. Accordingly, while awaiting the arrival of a smaller wire, .200 inch filaments were built of this wire. Good emission was obtained from these filaments but Eg varied widely with Ef. A drop in Ef from 1.35 v. to 1.45 v. made Eg about 1 v. more positive.

Some .72 mg. wire was obtained and a length of .122 inches was tried. Eg characteristics were much more satisfactory but firing times were noted to lengthen appreciably with age. The filament was thought to run a little cool suggesting that a shorter filament be tried.

103.5 inch filaments were tried next with 60 x 60 grid mesh. The behavior of Eg with Ef was satisfactory but Eg became excessively negative as the grid resistance was increased. (see Fig.'s 4 and 5) This would indicate that there is a greater amount of leakage due to condensed thorium than we can tolerate. Emission decreased greatly with life as before.

It is believed that carbonizing the filament would be necessary to obtain stable emission. This would tend to embrittle the tungsten however. In view of the small diameter of the wire and the high acceleration it must stand, we would be unable to tolerate any brittleness of the filament.


CRITICAL GRID VOLTAGE
CHARACTERISTICS
+1
0
-1
-2
Grid Voltage
.6
.7
.8
.9
1
1.1
1.2
1.3
1.4
Filament Voltage
.1035" X .71MG THORIATED FILS.
60X60 GRID MESH
3-6-43
AER
Fig. 4


Log10 Rg
0
1
2
3
4
5
6
7
8
9
10
-1
-2
-3
Grid Voltage
VARIATION OF GRID
VOLTAGE WITH
GRID RESISTANCE
.1035" X .71MG
THORIATED FILS.
60X60 MESH
3-6-43
AER
Fig. 5

Attempt to Make Tubes in Quantity

The filament selected for this project was the .170 inch .50 mg. tungsten, spray-coated. Several runs were made totaling 163 tubes. Yields varied widely for the various runs ranging from 5% to 63%. Evidence was obtained indicating that the condensation trap must be torched after every fourth run but must not be torched while tubes are on the manifold. This evidence is graphically presented in Fig. 6. The chief cause rejection was positive grid voltage. The next two important causes which could be readily reduced with proper attention to methods and inspection are leakers and open filaments. A wide variation occurred in grid voltages probably due to irregularities in the 30 x 30 x .0065" grid mesh.

In order to prevent the negative drift of grid voltage during life, it was necessary to age the filament from 5 to 8 minutes at E_f=1.35 v. The majority of these tubes would pass life test of 20 minutes at 1.35 v. Of 6 tubes life tested at E_f=1.4 v., only 3 passed life test indicating that we could expect about 50% to be good for 20 minutes life at 1.4 v.

Because of the variations in E_g, it is estimated that we could expect no better yields than 60 or 70% unless the tolerance specifications on E_g were relaxed.

Summary:

None of the filaments tried were entirely satisfactory in all respects. At best, we cannot predict a yield greater than 70% for coated filaments in this application. Coated filaments in general fire at a less negative grid value than plain tungsten or thoriated tungsten filaments, probably because of the lower operating temperature. This necessitates the use of a coarser grid mesh. Mesh tolerances become important for the larger mesh and produce wide variations in grid voltage which account for the greatest number of rejects.

With proper attention to methods, small diameter wire can be successfully coated by spray. Our attempts to dip coat were not successful due to lack of a proper binder.

Cold cathodes were found to reduce the danger of a cathode spot forming on the filament, destroying it.

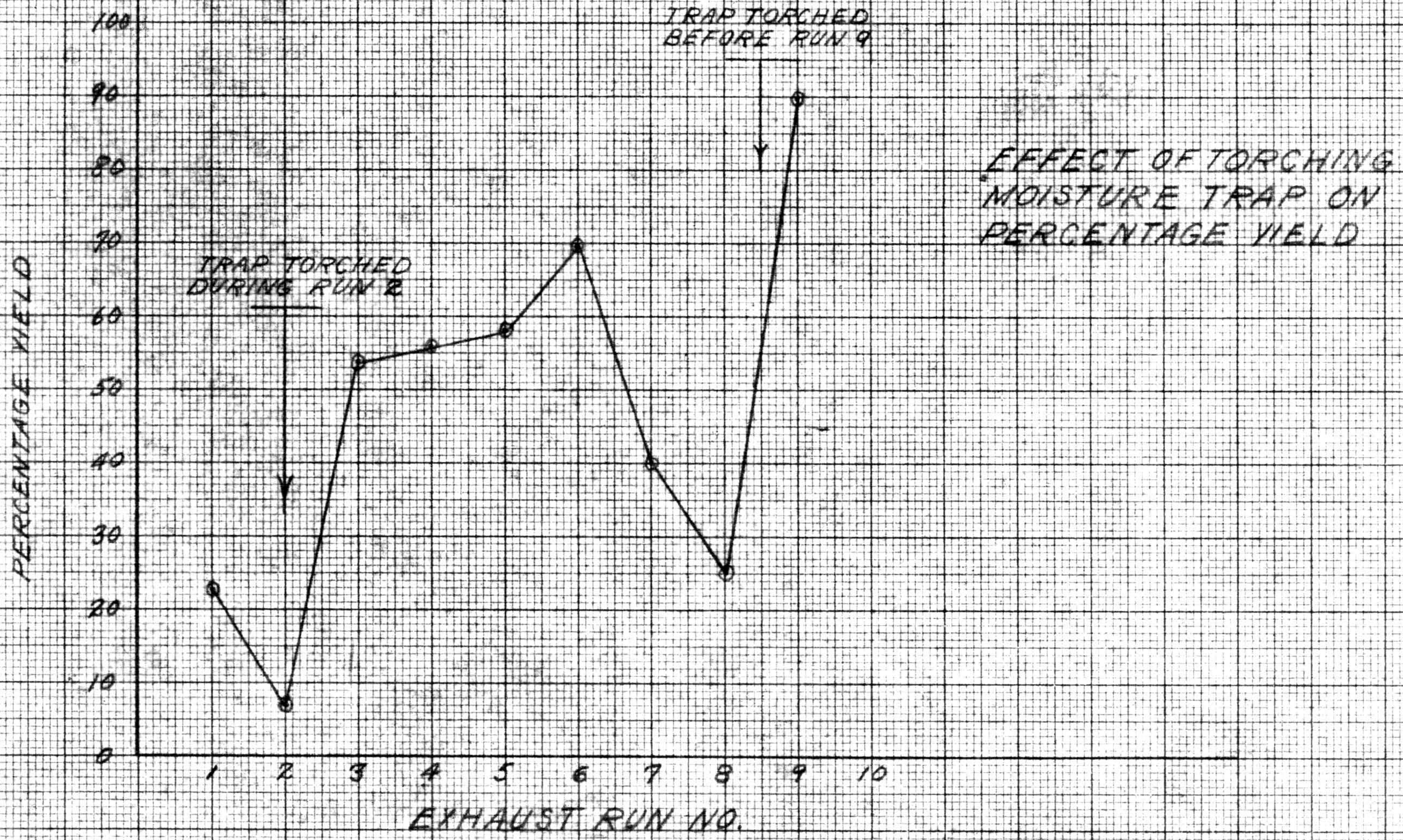

TRAP TORCHED BEFORE RUN 9
EFFECT OF TORCHING MOISTURE TRAP ON PERCENTAGE YIELD
TRAP TORCHED DURING RUN 2
PERCENTAGE YIELD
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
EXHAUST RUN NO.

Fig 6

It was found to be necessary to torch the trap after every fourth run. This torching must take place with no tubes on the manifold, otherwise emission is damaged by driving contamination from the trap into them.

Aging the filaments before life test was found to be necessary in order to stabilize Eg. Emission aging was found to be helpful in improving emission in most cases but was, apparently, unnecessary for our spray-coated filaments as emission improved only slightly with aging.

The sintering schedule was not too critical on these filaments. In general, it consisted in a degassing period of 15 seconds to 1 minute at 800° C for 30 seconds to 2 minutes. Many variations were tried with no apparent effect.

Condensation of coating material on other elements and the walls of the tubes was not excessive as indicated by low grid leakage.

The chief disadvantage of using thoriated tungsten is the high rate of evaporation of the emissive coating resulting in high leakage due to condensation, as well as in a depreciation of emission. Carbonizing the filament would probably stabilize emission by allowing an increase in the rate of restoration of the surface coating. This would not overcome the leakage problem, however, and would moreover cause some embrittlement of the filament which would be intolerable in view of the small diameter of the wire and the high acceleration it must stand.

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July 21, 1943

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