A RESEARCH REPORT ON DEACTIVATION EFFECTS IN TRIODES
RESULTING FROM EXCESSIVE ANODE HEATING by W. Nottingham 1940

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Requested by

Mr. H. W. Abbott, Director of Research
Speer Carbon Company
St. Marys, Pennsylvania



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*Wayne B. Nottingham* June 4, '40

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(Experimental Study  -    February 27 - May 3, 1940)


INTRODUCTION

After preliminary correspondence with Mr. H. W. Abbott,
a meeting was arranged in New York with Messrs. Abbott, Lacey,
and May of the Speer Carbon Company, and representatives of the
Amperex Electronics Products Company, Inc., (see report, March 1,
1940, by Mr. M. S. May).

During the New York conference two main problems were dis-
cussed.   These were (1) the deactivation of thoriated filaments
when operated with overloaded plates and, (2) faulty operation
due to the so-called "dusting" effect.

Under the first question it was pointed out that the evolu-
tion of gas, principally oxygen, or water vapor, within the tube
when subjected to excessive over-load, was probably responsible
for the deactivation effect.   In order to investigate this it
was proposed that a number of Amperex HF-100 "seals" (tubes as-
sembled but not exhausted) be taken to Cambridge for exhaust and
investigation.   In order to make certain checks as to the nature
of the gas, I proposed to attach an ionization gauge containing a
thoriated filament to one of the HF-100 seals and exhaust the two
tubes simultaneously.   This would serve two purposes, which were
(1) to give a means of calibrating the HF-100 tube so that it
would serve as an ionization gauge for future reference and, (2)
to find out whether or not the material responsible for deactiva-

tion would travel from the over-heated HF-100 into the ioniza-
tion gauge and deactivate that filament.   Under problem #2,
namely that of the "dusting" effect, I proposed that this might
be due to the presence of insulating material on the carbon
anode which might have a tendency to become positively charged
under electron bombardment and fly off of the anode onto the nega-
tive parts of the tube.   One reason for proposing this hypothesis
was that it is generally observed that the dusting effect comes
immediately after, or perhaps during the first few minutes of
operation of the tube.   Experiments which will be discussed be-
low seem to indicate a possibility that this insulating material
may come from the glass walls in the case of the HF-100, or even
the ceramic insulating parts which are used in the tube.   Ash
impurities in the carbon might also contribute.

A plan of attack as visualized at the time of the New York
conference thus included the items mentioned above and, in addi-
tion to these, I planned to study possible improvements in exhaust
schedule with the hope of separating the question of the de-
gassing of the anode from that of de-gassing the other parts in
the tube.

Also interest was expressed in determining comparative data
on tubes made by other manufacturers, containing carbon, tantalum,
and molybdenum anodes.   The types chosen for these comparative
tests were as follows:   Taylor 211-D (carbon); Taylor 203-A (car-
bon); Eimac 75-T (tantalum), and Western Electric 276-A (molybdenum).

# EXPERIMENTS ON TUBE WITH ION GAUGE
## Effect of Small Metallic Deposit on Thoriated Filaments

An Amperex tube, HF-100, (#12305), was attached by means of a 3/8" ID tube to an ionization gauge which was constructed of all molybdenum parts. These parts were thoroughly outgassed before the tube was assembled so as to avoid the objectionable effects of filament contamination when metallic parts are heated to a very high temperature. The reason for using molybdenum instead of tantalum was that I wanted to avoid having the material present which might react with or absorb hydrogen which, it was thought, might possibly be one of the gases evolving from the carbon anode. In spite of the precautions taken to eliminate the deposit of metallic impurities on the filament of the ionization gauge, just enough material became deposited on the gauge filament during the final exhausting of the tubes so that it became excessively sensitive and did not serve very effectively as an indicator of gas received in that part of the tube. The tube did serve as a means of calibrating the HF-100 so that it could be used as an ion gauge to measure the residual gas pressure left in any tube. The sensitivity turned out as follows: With 230 volts on the grid and -45 on the plate, the plate serving to collect ions, and a current to the grid of 20 milliamperes, the ion current to the plate was $10^{-8}$ amperes for a pressure of $10^{-8}$ millimeters.

Under these conditions the current in amperes to the plate is equal to the gas pressure in units of millimeters of mercury. Since in the normal operating circuit the plate is usually positive

and the grid negative, an HF-100 tube can serve as its own ion gauge with this arrangement just as well as with the one described above. It happens also to have the same sensitivity, that is, with 20 mils of current to the plate, the current now to the grid is a direct measure of the pressure in millimeters. For most practical purposes it may be assumed that the sensitivity is the same for any plate potential from 1000 volts to 2000 volts.

Gas pressures mentioned in the subsequent discussions were determined by using this scale of measurement.

Although the results using the thoriated filament as an "analyzer" of the gas evolved were not very satisfactory because of the above-mentioned experimental difficulty, it was not thought worth while to rebuild the tube so as to replace the filament because, as will be shown below, the principal source of gas in a well out-gassed HF-100 tube is the glass wall instead of the carbon. In order to make the analyzer of value as regards the carbons it would be necessary to build a tube with a larger envelope, preferably of Pyrex, so that the effect of the glass could be reduced sufficiently to allow gas effects from the carbon to dominate.

## EXPERIMENTAL METHODS

The diagram in Figure 1 shows the circuit arrangement used for testing the tubes. The filament was heated from a D.C. power line and the grid potentials were obtained by means of a potential divider from the same line. The plate potentials were furnished by a motor generator set with a 1-ampere capacity and an available voltage from 1000 to 2300 volts. The plate current and plate potential were observed at the tube with calibrated Rawson instruments. The grid currents were observed, using a Leeds and Northrup type "R" galvanometer and also a microammeter. The small condenser shown across the galvanometer and protective resistance was needed to eliminate oscillations, which otherwise might have interfered with the measurements. After operating the filament temperature at a proper value for activation, the saturation emission was measured by maintaining the plate at a potential of 1500 volts, or more, and the grid at -20. The filament heating current and voltage were raised until the standard emission arbitrarily taken as 30 mils, was observed. A slight decrease in the activation of the surface results in an increase in the filament voltage needed to deliver a saturation current of 30 mils. This method of measurement is more sensitive than the one used for standard comparisons by Amperex because in their case the current is partly limited by space charge and therefore small changes in the emission are not so prominent.

After having determined the minimum filament voltage for a

30-milliampere emission, the grid was made very negative and the filament voltage brought up to its normal operating value.

In order to start a run with a given plate dissipation the grid bias was lowered until the plate current increased to that required so that the product of the plate current and the plate potential equalled the required dissipation in watts. In nearly every case pyrometer measurements were made to determine the apparent temperature of the hottest part of the anode. No corrections were made for the light absorbed in the glass. For some of the measurements a blower was used to cool the glass envelope with a very strong stream of air. In the summary of results given below it may be assumed that the blower was not used unless special notation is made.

It is of course obvious from the circuit arrangement that the operation of the tubes is the equivalent of that used in a class A amplifier with no signal. As far as the evolution of gas from the anode is concerned it should not be any different in this case from that obtained when the tube is operating as an oscillator or class B or C amplifier.

The gas evolved from the grid in the latter cases might be greater since in actual operation the grid often receives considerable bombardment and therefore might run hotter than is the case in the circuit which I have used.

## TUBES TESTED AND DIVISION INTO GROUPS

The tubes tested may be divided into six groups.

GROUP I treats with 8 seals prepared at Amperex, but not evacuated. These all contained hydrogen treated anodes and thoriated filaments carbonized by Amperex in acetylene. There were six tubes in GROUP II. These contained anodes which were hydrogen treated but the filaments were not carbonized. Of these, only three were used.

GROUP III had three tubes containing anodes which had not been hydrogen treated and the filaments had not been carbonized. In GROUP IV there were six HF-100 tubes built and evacuated by Amperex. Three of these were tested.

In GROUP V there were four tubes built and evacuated by Taylor Tubes, Inc., Chicago, Illinois. Two of these were 203-A tubes and two of them were 211-D tubes.

In GROUP VI there were two tubes, one the 75-T Eimac tube, made by Eitel-McCullough, Inc., St. Bruno, California, and the other was the Western Electric 276-A vacuum tube produced by the Western Electric Company at Kearny, N. J.

The results of measurements taken on these six groups of tubes will be summarized by giving what might be called the "case history" of each tube.

## EXPERIMENTS CARRIED OUT ON TUBES OF GROUP I

The following table of general characteristics will serve as a description of this type of tube.

### TABLE I    GENERAL CHARACTERISTICS -- TUBE HF-100

Filament voltage . . . . . . . . . . . . . . . 10-10.5 v.

Filament current . . . . . . . . . . . . . . . . 2 amps.

Amplification factor . . . . . . . . . . . . . . . 23

Grid to plate transconductance at 100 m.a. . . . . 4,200 micro-mho

D.C. plate voltage maximum . . . . . . . . . . . 1,750 v.

Maximum plate current . . . . . . . . . . . . . 150 m.a.

Plate dissipation maximum . . . . . . . . . . . 75

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### TUBE #12304

This tube was evacuated on 3/9/40.    The heat given the grid under electron bombardment was so severe that the grid melted and the tube was of no service.

### TUBE #12305

The ionization gauge was attached to this tube after it had been completely rebuilt, following the spoiling of the gauge in connection with the evacuation of TUBE #12323, discussed below.

This tube was evacuated on 3/6/40 according to an evacuation schedule which started out with a baking at 500°C for $1\frac{1}{2}$ hours.

Following this the tube parts were heated, as indicated by TABLE II.

<div align="center">TABLE II</div>

| Conditions | Time | Temperature |
|---|---|---|
| Bomb | 5 min. | T  800 °C |
|  | 4 " | 830 |
|  | 7 " | 1000 |
|  | 4 " | 1160 |
| Off to make changes | 3 " |  |
| Bomb | 5 " | 1225 |
| Off | 3 " |  |
| Bomb | 5 " | 1261 |
| Off | 4 " |  |
| Grid heat | 5 " | 100 watts to grid |
| Bomb and grid | 3 " | 1270 to 1300°C |
| Grid heat | 10 " | 120 watts to grid |
| Heat capillary | 2 " |  |
| Preheat and finally flash getter | 14 " |  |
| Flash fil | 1 " | at 4.0 amp. (2850°K) |
| Bomb and grid | 2 " |  |
| Activation | 5 " | at 3.0 " |
| Test |  | $V_f$ = 5.8 standard conditions |
| Operate | 10 " | $150 \times 10^{-3}$  1500 volts (85°C) (225 watts) |
| Test |  | $V_f$ = 5.75 standard test |
| Seal off |  |  |

The pressures observed followed about the same as those listed below in connection with TUBE #12308, TABLE IV.    Just before seal-off the pressure was $1.8 \times 10^{-7}$ mm.    Just after seal-off it was $4 \times 10^{-6}$.    This is an abnormally large increase in pressure and is unexplained.    After a very short period of operation the pressure dropped to $2.5 \times 10^{-7}$ mm., which is about normal although a little larger than the best obtained in other tubes. Considerable difficulty was experienced in activating the thoriated

filament in the ionization gauge whereas the thoriated filament in the HF-100 tube was easily activated. This indicates that the ionization gauge filament probably received some contamination, probably molybdenum, during the outgassing process. After activating the ion gauge filament the tube filament was heated. This resulted in only a slight deactivation of the ion gauge filament but upon cooling the tube filament a very considerable deactivation of the gauge filament took place immediately. This was a rather unexpected phenomenon, although action similar to this has been observed in other cases and might serve as an interesting subject for further investigation.

The gauge filament was again activated and the emission current in the Hf-100 was raised to give a 48 watt plate dissipation for 13 minutes. This resulted in complete deactivation of the gauge filament and a very slight deactivation in the tube filament with an increase in gas pressure from $10^{-7}$ mm to $2.5 \times 10^{-7}$ mm. The wattage was then increased to 120 watts for 10 minutes, with no further deactivation of the tube filament.

In TABLE III the first series of 9 runs is tabulated. Experiments with this tube served also to calibrate the HF-100 tube so that it could be used for determining the pressure as described above under "Experiments on Tube with Ion Gauge."

TABLE III.    POWER RUNS MADE ON 3/8/40

| Run | Watts | Time (min.) | Temperature | Best Vacuum (mm) | Worst Vacuum (mm) | Remarks |
|---|---|---|---|---|---|---|
| 1 | $120^B$ | 10 | | $4.4 \times 10^{-6}$ | $17 \times 10^{-6}$ | No deactivation |
| 2 | $150^B$ | 10 | 780°C | .7 | 1.4 | " " |
| 3 | $203^B$ | 10 | 830 | 1.1 | 1.7 | " " |
| 4 | $225^B$ | 10 | 850 | 1.1 | 1.9 | " " |
| 5 | $250^B$ | 10 | 890 | .9 | 1.9 | " " |
| 6 | $275^B$ | 10 | 925 | 1.1 | 2.9 | " " |
| 7 | $300^B$ | 10 | 925 | 1.2 | 4.6 | " " |
| 8 | $350^B$ | 10 | 990 | 2.0 | 15.2 | Some " |
| | | | | | | Full recovery normal fil.V. in 30 min. |
| 9 | $400^B$ | 15 | 1025 | 2.5 | 31.5 | Some deactivation Recovery in 35 min. |
| 10 | 150 | 30 | 780 | $2.8 \times 10^{-6}$ | $15.7 \times 10^{-6}$ | No deactivation 3/9/40 |

B  -  Indicates that a strong air blast was used to cool the tube.


## TUBE #12306

Evacuated in 1 hour, 23 minutes on 3/12/40.    The filament springs in this tube lost their power to keep the filament taut and therefore the sagging of the filament caused a short circuit to the grid making the tube unsatisfactory for further tests.

## TUBE #12308

The ion gauge described above was attached to this tube
and evacuation undertaken on 3/4/40.    After baking, the anode
was heated by high frequency and the following table (TABLE IV)
will serve to indicate the gas pressures observed as a function
of the time and temperature of anode heating.

### TABLE IV

| Time (min.) | Temperature | Maximum Pressure | Pressure at end of Period |
|---|---|---|---|
| 8 | 770°C | $6 \times 10^{-4}$ mm | $2 \times 10^{-4}$ mm |
| 5 | 900 | $1.8 \times 10^{-3}$ | $1 \times 10^{-3}$ |
| 10 | 950 | $1.3 \times 10^{-3}$ | $2.4 \times 10^{-4}$ |
| 7 | 1017 | $9 \times 10^{-4}$ | $3.5 \times 10^{-4}$ |
| 4 | 1132 | $2.5 \times 10^{-3}$ | $8.6 \times 10^{-4}$ |

Within 15 to 45 seconds after turning on the high frequency,
at each of the steps indicated in TABLE IV,  the gas pressure rose
to a maximum and then gradually declined to the value shown in the
fourth column.    This shows that at any given temperature the rate
of evolution of gas is at first high, and then gradually decreases,
but even at the end of a few minutes the pressure is still very
high in the tube.   Of course the faster the pumps and the larger
the pumping lead by which the tube is connected to the vacuum sys-

tem, the more effectively the pumps can carry away this gas.

Upon cooling, a large part of the gas that may be in the tube at the moment the high frequency heating current is turned off is likely to be reabsorbed in the graphite anode.   After having carried on the evacuation as far as indicated by TABLE IV, the anode temperature was raised to 1230°C and, owing to the lack of sufficient cooling of the glass, it softened and punctured.

## TUBE #12320

This tube was evacuated on 3/9/40 and served as a basis for the formulation of a new pumping schedule, shown on page 24 of my notebook.   A modification of this pumping schedule is included under a separate heading below.

This tube was evacuated in 1 hour, 46 minutes and after the seal-off and a short time of operation the pressure observed in the tube was $2.8 \times 10^{-8}$ mm.   This vacuum was far superior to that obtained in connection with the evacuation of #12305.  The following table shows the results obtained on a series of runs made with this tube.

## TABLE V

| | Run | Watts | Time | Plate Temp. | Test $V_f$ before run | Test $V_f$ after run | Remarks |
|---|---|---|---|---|---|---|---|
| | 1 | 225[B] | 15 min. | 830 | 5.15 | 5.2 | O. K. |
| | 2 | 225[B] | 1 hr. 8 " | | 5.20 | 5.05 | " |
| | 3 | 300[B] | 47 | 910 | 5.05 | 5.05 | " |
| | 4 | 300[B] | 1 hr. | 915 | 5.05 | 5.15 | " |
| 3/11/40 | 5 | 350[B] | 1 hr. | 950 | 5.15 | 5.3 | Slight deactivation. Reactivated in 20 min. |

No air blast

| | Run | Watts | Time | Plate Temp. | Test $V_f$ before run | Test $V_f$ after run | Remarks |
|---|---|---|---|---|---|---|---|
| 3/12/40 | 6 | 260 | 15 min. | 910 | 5.2 | 6.6 | More deactivation than for 350 watts above. Recovery by activation in 3 min. at 13 volts. $V_f$. |
| | 7 | 300 | 15 | 950 | 5.25 | 6.8 | Deactivation. Recovery 3 min. at 13.5 |
| | 8 | 350 | 10 | 1000 | 5.3 | 6.7 | Deactivation. |
| | | | | | 6.7 | 6.1 | 7 min. 10.5 |
| | | | | | 6.1 | 5.2 | 3 " 13 |

Blower on

| | Run | Watts | Time | Plate Temp. | Test $V_f$ before run | Test $V_f$ after run | Remarks |
|---|---|---|---|---|---|---|---|
| | 9 | 400[B] | 10 | 1035 | 5.05 | 5.05 | O. K. |
| | 10 | 475[B] | 10 | 1110 | 5.05 | 5.07 | Less deactivation than for 260 above in Run 6. |
| | 11 | 515[B] | 10 | 1140 | 5.2 | 6.95 | About the same as 8 above. |
| | | | | | 6.95 | 5.4 | 25 min. at 10.5 |
| | | | | | 5.4 | 5.1 | 50 " at 10.5 |

Full recovery

B — indicates glass cooling with strong air blast

$V_f$ — indicates filament voltage for standard emission conditions described under "experimental methods"

Attention should be called to the fact that the degree of deactivation for Runs #6, 7, and 8 is greater than that of Run #9 or 10, and that the deactivation in Run #11 is very little greater than that found with the lower plate dissipation and no air blast. These data serve as one of the first indications of the fact that the graphite anode can be sufficiently outgassed so that it becomes unimportant in comparison with the glass as a source of filament contamination.

## TUBE #12322

This tube was evacuated on 2/28/40 and was the first one to be pumped in connection with this study. It was first baked for 30 minutes at 500°C and after cooling the anode was heated for three minutes with high frequency current. At the time the importance of cooling the glass was not fully realized and at the end of three minutes a visible gray deposit could be seen. Previous discussion with Messrs. Abbott and Anton led me to understand that this gray deposit was usually associated with a gas discharge phenomenon taking place while the high frequency heating was first carried out. The pumping speed of my pumps was such that at no time was there any gas discharge visible. I am therefore inclined to think that the gray deposit perhaps should be interpreted as a deterioration of the glass when it is heated to an excessively high temperature. In the absence of gas discharges this may take place simply as a result of the heat absorbed from the high temperature graphite anode. It is largely avoided if a strong air blast is used to cool the glass.

This was not done in this particular case. If an air blast is used and an excessively high gas pressure generated, then the glass may still be disrupted because of the heating brought about by the ion bombardment which may take place.

The object in discussing this point in such detail is that it seems to me that the so-called "dusting" phenomena are probably associated with the deterioration of the glass or the ceramic insulating parts in the tube.

After the initial high frequency heating, the grid and plate were connected together and electron bombardment at high voltage was started. With 2000 volts and 20 watts being dissipated, the filament emission remained constant, but at 4000 volts and 30 watts the emission dropped off somewhat. At this potential fluorescence could be observed upon the grid and grid posts as well as on the glass walls of the tube. The color of the fluorescent spectrum seemed to be the same at all points at which it was visible. This might indicate that the disrupted glass and the deposit on the grid and grid wires were essentially the same material. At 8000 volts and 20 milliamperes (160 watts) the filament suddenly deactivated and its resistance decreased about 12%. This is clearly the phenomenon of dusting as I understand it. It was found that the material which had deposited upon the filament did change its optical emissivity in the direction to increase the power radiated at a given temperature. This material left the filament rather slowly at the normal filament voltage of 10.5 volts. It was found necessary to raise the filament voltage to 15 volts to bring about a

rapid evaporation of the material condensed on the filament. Following the 15-volt treatment the filament returned to normal.

In order to test the reproducibility of this effect the voltage was again increased to 8000 volts and again the sudden filament deactivation and dusting took place. This time the decrease in resistance was 16% but after three minutes of heating with 15 volts on the filament the resistance returned to normal. After additional oven baking and high frequency heating the tube was sealed off. Its general behavior under test was quite normal and with the voltages used under operating conditions, no further effects of the dusting were observed.

## TABLE VI

| Run | Watts | Time | Temp. | Test $V_f$ Before run | Test $V_f$ After Run | Remarks |
|---|---|---|---|---|---|---|
| 1 | $315^B$ | 10 min. | 940 | 5.5 | 5.5 | Blast on |
| 2 | 315 | 10 | " | 5.5 | 5.65 | " off. Shows slight deact.with no air |
| 3 | $420^B$ | 10 | | 5.65 | 5.7 | Blast on. Shows little add. deact. |
| 4 | $500^B$ | 10 | | 5.7 | 6.9 | Blast on - Deact. Easy to reactivate to 5.65 |
| 5 | 360 | 10 | | 5.65 | 6.2 | No blast.Some deactivation |
| 6 | 300 start 255 finish | 13 hrs. | | 5.7 | 6.0 | Some deact. Full recovery in 1 hr. normal $V_f$. |
| 7 | $400^B$ | 27 min. | | 5.5 | 6.7 | Deact. set in after 20 min. |

Run #4 of TABLE VI compares quite favorably with Run #11 of TABLE V, showing that a 500 watt plate dissipation for as long a time as 10 minutes can be withstood without serious difficulty when an air

blast is used to cool the glass.   Direct comparisons with cases for which the air blast was not used were not made for this particular tube.

TUBE #12323

A new filament was mounted in the ionization gauge since the exposure of the first filament to air at the time Tube #12308 was punctured caused serious oxydization of the filament.   The gauge was then connected to this tube and again measurements were made of the pressure as a function of the anode temperature.   These results are tabulated in TABLE VII.

### TABLE VII

| Temperature | Maximum Pressure | Pressure at end of Period |
|---|---|---|
| 841 | $6.5 \times 10^{-4}$ | |
| 897 | $8 \times 10^{-4}$ | |
| 965 | $1.6 \times 10^{-3}$ | |
| 1035 | $1.4 \times 10^{-3}$ | $9 \times 10^{-4}$ for 5 min. |
| Cooling | $2 \times 10^{-4}$ | $4 \times 10^{-6}$ in 2 min. |
| 1126 | $5 \times 10^{-3}$ | $1.7 \times 10^{-3}$ |
| Cooling | $2 \times 10^{-4}$ | $3.8 \times 10^{-6}$ in 4 min. |
| 1159 | $2.4 \times 10^{-3}$ | $2 \times 10^{-3}$ |
| 1270 | $2.9 \times 10^{-3}$ | |
| 1270 | $1 \times 10^{-3}$ | sucked in due to insufficient air blast |

Owing to an insufficiently strong air blast for the cooling of this tube the glass punctured after the anode had run for a few minutes at 1270°C. This resulted in the spoiling of the ionization gauge, which had to be completely rebuilt.

## TUBE #12330

Evacuation on this tube was started on 3/12/40. During the high frequency heating the air blast was not turned on sufficiently soon and the tube punctured.

## EXPERIMENTS CARRIED OUT ON TUBES OF GROUP II

There were six tubes under GROUP II which were prepared by Amperex with hydrogen treated graphite anodes but with filaments which had not been carbonized.  Only three of these tubes, as noted below, were evacuated and tested - the three numbering #12472, #12473, and #12474 have not been evacuated as yet.

### TUBE #12489

This tube was evacuated on 3/17/40 in one hour and 28 minutes following closely the new schedule mentioned above (page 24 of my notebook).  The pressure just after sealing off was $6.4 \times 10^{-8}$ mm.

On my pumping system between the second mercury pump and the mechanical pump, a Geisler tube is attached to determine very roughly the type of gas which may be trapped in a large reservoir at this point.  The tubes of GROUP I gave out a gas mixture which showed up in the Geisler tube discharge with a distinct blue color. It was noted that the gas trapped from this tube (#12489) gave a pale blue discharge instead of the darker blue one observed previously.  This is probably to be associated with the absence of acetylene in the graphite anode since the filament of this tube was not carbonized.  In spite of this lack of carbonization, and the feeling on the part of Mr. Anton and others that a noncarbonized filament could not be expected to stand up under test, this tube did perform very satisfactorily, as is indicated in TABLE VIII.

## TABLE VIII

| Run | Watts | Time | Temperature | $V_{f1}$ | $V_{f2}$ | Remarks |
|-----|-------|------|-------------|------|------|---------|
| 1 | 150 | 4 hrs.35 m. | | 4.9 | 4.8 | No blower |
| 2 | 250 | 4 " 10 m. | 860°C | 4.8 | 4.75 | No change in activation |
| 3 | 300 | 10 " 30 " | 933 | 4.75 | 4.8 | " " |
| 4 | 350 | 5 " 15 " | 965 | 4.8 | 5.9 | Some deactivation. Recovery to 5.3 in 18 min. at 10.5 |
| 5 | 400 | 35 " | 1030 | 5.3 | 6.4 | No air blast. Some deactivation |
| 6 | 400[B] | 2 " 11 " | | 5.3 | 6.3 | Air blast on. Same deactivation as in 35 min. of 5. |
| 7 | 550[B] | 10 " | 1100° | 5.3 | 7.5 | Started at 550 watts. Started falling in 3 min. React. to 5.25 easy. |

Again the importance of the cooling of the glass makes itself apparent in connection with this study since it will be noted that at 400 watts the deactivation in 35 minutes is greater than that observed in 2 hours and 11 minutes when, in the latter case, the blower was used.

## TUBE #12496

This tube had an anode which was hydrogen treated but the cathode was not carbonized. It was evacuated on 4/16/40 with a pumping time of 2 hours and 7 minutes. A Geisler tube was connected to the outlet of the mercury pump in order to take a sample of the gas

which was evolved during the high temperature heating of the anode after the tube was oven-baked. Extra time was used in the evacuation in order to study a deactivation effect which had been observed a few days previous in connection with the pumping of TUBE #12495. The details of this effect are given under this tube number in GROUP III below. It suffices to say here that the effect was not observed in this tube. A series of five runs was made after the tube was sealed off and the results are tabulated in TABLE IX.

## TABLE IX

| Run | Watts | Time | Temp. | $V_{f1}$ | $V_{f2}$ | Remarks |
|-----|-------|------|-------|----------|----------|---------|
| 1 | 80 | 90 | | 4.75 | 5.7 | Leakage effect and deactivation |
| 2 | 160 | 60 | 780°C | 4.6 | 4.7 | Very little leakage |
| 3 | $300^B$ | 65 | 910 | 4.7 | 5.15 | "       "        " |
| 4a | $500^B$ | 18 | 1060 | 4.55 | | Vacuum $8 \times 10^{-8}$ |
| 4b | 500 to $455^B$ | 12 | | | 7.25 | Much leakage now |
| 5 | 110 | 30 | | 4.65 | 4.7 | |

The run lasting 30 minutes and starting out at 500 watts with the blower is plotted as CURVE I of Figure 2. This shows that this tube was capable of operation for 18 minutes before the cathode emission was reduced as a result of poisoning to the point at which it was not possible to deliver 500 watts to the plate. When this tube was first connected to the measuring system it showed no appreciable leakage current from the anode to grid over the insulating grid-anode support. After the first run of 90 minutes at

80 watts a very noticeable leakage current was observed which was at least 10 times as large as normal and more than 100 times larger than the original current before the run. This seems to be a part of the dusting phenomenon.

After the second run the leakage was still larger but following the third run it returned to normal and remained nearly normal for the rest of the tests. This might be interpreted to indicate that the material which leaves the anode when it "dusts" carries with it a large amount of carbon. This settles on negatively charged surfaces such as the insulators in question and causes a large leakage current. I still think that the reason the carbon is torn off the anode is to be associated with a previous deterioration of the glass or the ceramic insulators. This presumably becomes embedded on the surface of the carbon and finally flies off, carrying with it a certain amount of graphite material.

## TUBE #12497

This tube contained an anode which was hydrogen treated at Amperex and the filament which was not carbonized there but was carbonized here in acetylene. The carbonization raised the room temperature resistance of the filament from 0.377 ohm to 0.437 ohm. This tube was evacuated in exactly 90 minutes, following very closely the schedule which is described below. The important modification which was introduced here is that of allowing the anode to cool very much more slowly after it had been at the highest temperature. The results shown in TABLES IV (page 12) and VII (page 18) show that at high anode temperatures the gas pressure is of the order of $10^{-3}$ mm. In this tube a temperature of 1325°C was attained and at this tem-

perature the pressure must have been well above $10^{-3}$ millimeters. If the anode had been suddenly cooled off then, it would tend to absorb a good deal of the gas in the tube more quickly than the pump would be able to pump it away through the small seal-off constriction.   By dropping the temperature slowly to about 1300, then 1250, and so on, it seems likely that the pump would be able to carry the gas off with less of it going back into the anode. The dusting leakage effect was looked for in this tube and although it was there to a very small extent, it was decidedly less noticeable than was the case in TUBE #12496.

Four runs were made for this tube, the last of which started at 500 watts and continued at this high dissipation for 18 minutes. The wattage as a function of the time is shown by CURVE 2, Fig.2. The other data are summarized in TABLE X.

## TABLE X

| Run | Watts | Time | Temp. | $V_{f1}$ | $V_{f2}$ | Remarks |
|-----|-------|------|-------|------|------|---------|
| 1 | 150 | 45 | | 5.7 | 5.35 | $8 \times 10^{-8}$ mm. Vacuum |
| 2 | $400^B$ | 60 | 1035°C | 5.3 | 5.8 | Slight deactivation |
| 3 | 300 | 60 | 950 | 5.4 | 7.3 | Shows poison from glass. Pressure still $8 \times 10^{-8}$ |
| 4a | $500^B$ | 18 | 1110 | 5.2 | Cont. | |
| 4b | $500^B$ to 450 | 12 | | Cont. | 7.7 | Not much worse deactivation than 3 |

Reactivate to 5.25

## EXPERIMENTS CARRIED OUT ON TUBES OF GROUP III

There were three tubes in GROUP III which were sent without having had the anodes hydrogen treated at Amperex and without carbonization of the filaments.

### TUBE #12471

Although the filament of this tube was not acetylene treated at Amperex, I gave it a very slight carbonization which raised its resistance from .375 to .384 ohm.

This tube was evacuated on 3/16/40. The time required was 2 hours and 25 minutes, after having started on the regular schedule. The schedule was not followed throughout because it became apparent that the evacuation was proceeding less satisfactorily than that experienced when the anodes were hydrogen treated. This seems to indicate that the hydrogen treatment does displace certain heavier gas molecules, such as nitrogen and oxygen, and that this hydrogen will actually remain in the carbon for a considerable time and thus inhibit the reabsorption of heavier atoms. I think this has been the opinion generally held and these experiments simply confirm it. The runs taken with this tube were not very extensive, but the summary of observations is tabulated in TABLE XI.

### TABLE XI

| Run | Watts | Time | Temperature | $V_{f1}$ | $V_{f2}$ | Remarks |
|-----|-------|------|-------------|----------|----------|---------|
| 1 | 150 | 11 m. | 830°C | 4.9 | – | Cont. to 2 |
| 2 | 340$^B$ | 10 | 1060 | – | 5.2 | " from 1 |
| | | | | | | Very little deactivation. Vac. better than 10$^{-7}$. |
| 3 | 260 | 30 | 990 | 4.8 | 5.8 | (Blower off) |
| 4 | 260 | 60 | 990 | 5.8 | 6.0 | " " |
| | | | | 6.0 | 5.6 | In 5 min. at 10 V. |
| | | | | 5.6 | 4.8 | " 30 " " 10 V. |
| | | | | | | Full recovery. |

## TUBE #12488

This tube was evacuated on 3/15/40 in 1 hour, 26 minutes with a pressure at the time of seal-off of $4.8 \times 10^{-6}$ mm. Considerable deactivation was observed even with only 150 watts to the plate. I suspected that one of the metal-to-glass seals was leaking. This suspicion was verified by the fact that after 20 hours (mostly without voltages applied) a test was made and the gas pressure was so high that an arc-over took place destroying the tube.

## TUBE #12495

The filament of this tube was carbonized here to raise its resistance from .373 to .545 ohm. The tube was evacuated on 4/13/40 with a required time of $3\frac{1}{2}$ hours. This was longer than would have been necessary had it not been for an effect of gas poisoning which made its appearance. After some heating with high frequency and while the filament was hot and being used to bombard the grid, the filament activated to a certain extent with the anode at 1335°C. The emission from the filament at the time was 80 mils. As soon as the high frequency heat was removed and the anode started to cool, the current dropped very quickly to only 15 mils and then, after some little time, rose again to 68 mils. This experiment was repeated a number of times and an additional experiment was made, in which after having maintained the anode at 1335°C for a short time it was maintained at about 1000°. At this temperature apparently the deactivation effect was a maximum.

There are some cases for which the gas evolved from the surface

is not the greatest at the highest temperature.   These cases have
not been particularly well authenticated but it looks as though
this might be an example.   It would be very interesting to follow
up this effect because of the fact that under an overload of the
order of 350-400 watts these tubes operate with anodes at the tem-
perature at which they seem to give out this poisoning gas most
readily.   This effect was not observed in the hydrogen treated
tubes, although as mentioned above in connection with TUBE #12497,
special attention was given to see whether or not the effect was
there.   The fact that hydrogen seems to eliminate this deactiva-
tion effect points again to the advantage of its use and to the
importance of having the hydrogen as pure as it is reasonably pos-
sible to have it.   In spite of this difficulty it was nevertheless
possible to produce a good tube with a residual pressure of the
order of $6 \times 10^{-8}$ mm.

The first tests showed a considerable leakage due to "dusting."
The original leakage was quite small but after a few operations fol-
lowing which the filament was suddenly cooled off, the leakage was
very large.   After the series of runs summarized in TABLE XII the
"dusting" leakage disappeared.

## TABLE XII

| Run | Watts | Time (in min) | Temp. | $V_{f1}$ | $V_{f2}$ | Remarks |
|---|---|---|---|---|---|---|
| 1 | $300^B$ | 10 | | 5.3 | 5.6 | Leakage increase |
| 2 | $300^B$ | 75 | 915°C | 5.5 | 6.3 | Some deactivation. Leakage gone after reactivation |
| 3 | 300 | 65 | 935 | 5.95 | 8.2 | More deactivation |
| 4 | $300^B$ | 75 | | 5.4 | 5.7 | Shows effect of glass. $p = 6 \times 10^{-8}$ |
| 5 | $500^B$ | 10 | 1090 | 5.4 | 7.1 | Less deactivation than 3 |
| 6 | 400 300 | 10 | 1042 | 5.5 | 8.2 | Glass effect again |

React. to 5.5 vac  $5 \times 10^{-8}$  no leakage

---

The comparison between runs 2 and 4 on one hand and 3 on the other indicates the importance of cooling the glass. Furthermore, a comparison between runs 5 and 6 shows the same effect. In fact, in the case of run 5 it was possible to maintain the 500 watt dissipation for 10 minutes, while in the case of run 6, which started out at 400 watts, it was not possible to maintain this the entire time and it fell to 300 before the end of 10 minutes.

## EXPERIMENTS CARRIED OUT ON TUBES OF GROUP IV

There were six tubes in GROUP IV, which were produced at Amperex on 2/28/40. Of these, only three have been tested and the results are given below. The tubes of this group which were not tested were #12325, #12326, and #12327.

### TUBE #12321

The first tests on this tube were made to determine the best working conditions by measuring the plate current as a function of the grid potential with 1200 volts on the anode at various filament potentials. It was found that a plate current of 30 mils flowing with the grid at -20 is a measure of the saturation current from the filament. Since the saturation current is a direct indication as to the state of activation of the filament, the voltage drop over the filament required to get a standard emission current then becomes an indicator of the state of activation of the filament. The lower the voltage drop the higher the state of activation.

Tests were also made to determine the voltage drop which would give a sufficiently high temperature of the filament to bring about activation. At the operating voltage of 10 to $10\frac{1}{2}$ volts activation takes place slowly. In fact, at this temperature the rate of arrival of thorium atoms from the inside of the thoriated tungsten filament is supposed to exactly offset the normal loss of thorium brought about by ion bombardment, gas adsorption (such as oxygen), and thorium evaporation. In case the first two losses exceed the rate of arrival, then deactivation takes place with a consequent

loss in electron emission. When no electron current is being emitted, fairly rapid activation takes place with filament voltages between 11 and 15 volts. The higher the voltage the more rapid the activation. With voltages higher than 15 volts the rate of evaporation of thorium from the filament is so great that the filament becomes deactivated when operated at such a high temperature.

The gas pressure in this tube was found to be $2.5 \times 10^{-7}$ before any extensive runs were carried out. After some time of operation the gas pressure was found to increase noticeably.

The results of the first series of measurements, taken 2/29/40, are tabulated in TABLE XIII.

## TABLE XIII

| Run | Watt | Time | $V_{f1}$ | $V_{f2}$ | Remarks |
|-----|------|------|------|------|---------|
| 1 | 175 | 10 | 5.4 | 5.8 | Some deactivation |
| 2 | 205 | 10 | 5.8 | 6.8 | More " |
| 3 | 0 | 9 hrs. at 10.5 V. | | | |
| 4 | 150 | 4 hrs. 15 min. | 5.5 | 5.7 | Slight " |
| 5 | 195 | 1 hour | 5.7 | 6.6 | Less deactivation than run 2. |
| 6 | 0 | 10 min. at $V_f$ = 14 volts | 6.6 | 5.5 | |
| 7 | 8 (to grid) | 10 | 5.5 | | Some deactivation |
| 8 | 15 | 20 | | | " " |
| 9 | 32 | 20 | | | More " |
| 10 | 50 | 2 | | | " " |
| 11 | 32 | 6 | | | " " |
| 12 | 60 | 1 | | 8.3 | Serious " |
| 13 | 0 | 9 at $V_f$ = 14 volts | 8.3 | 5.7 | Gas pressure 5 x 10-7 |

The runs above from 7 to 12 show the result of bombarding the grid. It will be noticed that the grid is a rather serious source of deactivating material in case it is bombarded. Even with as low as 8 watts to the grid for 10 minutes, measurable deactivation took place. The details for runs 7 to 12 are not filled in since the standard test conditions were not returned to between each run. The nature of these experiments involved a continuous measure of the emission properties of the filament and therefore the remarks given at each run are appropriate in spite of the lack of detail.

A second series of measurements was made on 3/11/40 with results as shown in TABLE XIV.

## TABLE XIV

| Run | Watts | Time | Temp. | $V_f$ before | $V_f$ after | Remarks |
|-----|-------|------|-------|--------------|-------------|---------|
| 1 | $225^B$ | 10 | 830 | 5.4 | 6.6 | Vac.before $2 \times 10^{-7}$ " after $8 \times 10^{-8}$ Recover from deact.in 25 min.normal $V_f$=10.5 to 5.7 volts. |
| 2 | $300^B$ | 10 | 920 | 5.7 | 6.25 | Deact.not as great as above. $V_f$=10.5 for 25 min. |
| 3 | $300^B$ | 50 30 min. $V_f$=10.5 to get 5.55 | | 5.55 | 6.3 | Very little greater deactivation |
| 4 | 150 | 10 | 770 | 5.55 | 5.5 | O.K. stand by 14 hours at $V_f$=10.5 |
| 5 | 200 | 30 | 840 | 5.3 | 5.4 | O.K. Vac. $1.3 \times 10^{-7}$ |
| 6 | 250 | 15 | 910 | 5.4 | 5.85 | Same deactivation |
| 7 | 300 | 15 | 965 | 5.85 | 7.5 | Deactivation |
| 8 | 0 | 1 min | | 7.5 | 6.9 | Activating $V_f$=14 V. |
| 9 | | 1 " | | 6.9 | 6.4 | " " |
| 10 | | 2 " | | 6.4 | 5.85 | " " |
| 11 | | 7 " | | 5.85 | 5.4 | " 13 V. |

It will be noted that the tube returned to normal activation and that in spite of the fact that after run 7 the vacuum was $17 \times 10^{-7}$ mm. it improved to $10^{-7}$, which was slightly better than the initial vacuum measured when the tube was first put into service.

A comparison might be appropriate between the results above and those obtained on TUBE #12320, TABLE V.   For example, runs 3 and 4, at 300 watts for a time of 1 hour and 47 minutes, show less deactivation than was observed in the Amperex tube when running at 300 watts for only 10 minutes.   Also, comparison might be made with runs 9 and 10 of TABLE V, summarizing measurements made at 400 and 475 watts, respectively.   Note that the deactivation is less than for the 300 watt runs 2 or 7 of TABLE XIV.

Referring also to TABLE VI, the deactivation found on the Amperex tube is definitely worse than that in TUBE #12322.  TABLES VIII and XI show similar results also.

The leakage current from grid to anode in this tube was at first quite small; it then increased showing the effect of "dusting" but finally decreased again to normal.   This phenomena has been discussed in detail above (TUBE #12496).

TUBE #12328

The results of observations on this tube are shown in TABLE XV.

TABLE XV

| Run | Watts | Time | $V_{f1}$ | $V_{f2}$ | Remarks |
|---|---|---|---|---|---|
| 1 | 250 | 5 | 5.4 | 7.35 | Considerable deactivation. Big leakage effect. |
| 2 | 250 | 5 | 5.1 | 5.6 | Deactivation not so bad |
| 3 | 250 | 10 | 5.2 | 6.25 | "          bad. |
| 4 | $250^B$ | 10 | 5.15 | 5.15 | Shows glass is source of poison. |
| 5 | 250 | 10 | 5.15 | 6.00 | Poison from glass. |
| 6 | $250^B$ | 3 hrs.8 m. | 5.2 | 5.15 | No poison with blower on. |

The comparison between runs 2, 3, and 5 on the one hand and 4 and 6 on the other shows the importance of outgassing the glass in a rather remarkable degree. Again, with this tube very serious leakage was observed at first but this finally cleared up.

## TUBE #12331

This tube, also pumped by Amperex at the same time as the one above, had an initial vacuum of $6 \times 10^{-9}$ which may be considered as very good. The results of three runs are shown in TABLE XVI.

TABLE XVI

| Run | Watts | Time | $V_{f1}$ | $V_{f2}$ | Remarks |
|---|---|---|---|---|---|
| 1 | 200 | 2 hrs.10 m. | 5.25 | 6.0 | Deactivation. Activation for 15 min. at $V_f=10.5$ |
| 2 | 250 | 2 " 20 " | 5.55 | 6.55 | Greater deactivation. 40 min. at $V_f=10.5$ |
| 3 | 300 | 20 " | 5.3 | 6.5 | Compare with runs 5 to 8, TABLE XX. |

Although the runs taken on this tube were not very exten-
sive, it seems that this performance is almost exactly the same
as TUBE #12321, as discussed on pages 29 and 30.

# EXPERIMENTS CARRIED OUT ON TUBES OF GROUP V

There were four tubes in this group, all manufactured by Taylor Tubes, Inc.   Two of these were 203-A and two were 211-D tubes.   The gas pressures mentioned below were estimated, assuming the same sensitivity of the tubes as ionization gauges as was used in connection with the HF-100 tubes above.

These Taylor tubes have physical dimensions distinctly larger than the HF-100 and yet their proportions are roughly the same. For that reason I think that it is legitimate to assume the same ionization sensitivity.   The manufacturer's tube ratings for these tubes are given in the following table.

### TABLE XVII.  GENERAL CHARACTERISTICS

|  | 203-A | 211-D |
|---|---|---|
| Filament Voltage, volts | 10 | 10 |
| Filament Current, amps. | 3.25 | 3.25 |
| Plate Resistance, ohms | 6000 | 3400 |
| Mutual Conductance, uMhos | 4200 | 3530 |
| Amplification Factor | 25 | 12 |
| Max. Plate Dissipation, watts | 100 | 100 |
| Nonex Glass | 50 Watt Base | 50 Watt Base |

## TAYLOR TUBE 203-A  U-21

This tube was put to test after the tube U-32, results of which are given in a section below.   Since it was obvious from the first run that this tube was worse than the U-32 rather than better, time was not taken for extensive tests.   The measurements taken are given, however, in TABLE XVIII.

## TABLE XVIII

| Run | Watts | Time | Temp. | $V_{f1}$ | $V_{f2}$ | Remarks |
|-----|-------|------|-------|----------|----------|---------|
| 1 | $300^B$ $210^B$ | 60 min. | 900 | 5.4 | 7.2 | Deactivation Reactivation to 5.55 |

### TAYLOR TUBE 203-A  U-32

The initial pressure in this tube when first tried was approximately $1.2 \times 10^{-7}$, which checks with what might be expected. The results of a series of runs are shown in TABLE XIX.

## TABLE XIX

| Run | Watts | Time | Temp. | $V_{f1}$ | $V_{f2}$ | Remarks |
|-----|-------|------|-------|----------|----------|---------|
| 1 | $157^B$ | 10 min. | | 5.3 | 5.3 | 50% overload |
| 2 | $250^B$ | 10 | | 5.3 | 5.3 | |
| 3 | $300^B$ | 10 | 900°C | 5.3 | 5.8 | Slight deactivation. Reactivation to 5.3 |
| 4 | ($300^B$ (250 | 1 hr. 4 min. | | 5.3 | 6.8 | Deactivation. Compare with run 6, TABLE VI. |
| 5 | 300 | 5 min | | 5.3 | 5.6 | Some deactivation with no blower. |
| 6 | 300 | 30 " | | 5.6 | 6.8 | |

It will be noticed that this tube shows a slight deactivation when running at 300 watts for 10 minutes. Run #4, which lasted for a longer time showed so much deactivation that with constant grid potentials the power dissipation dropped. In this particular case it does not mean that the maximum power this tube was capable of delivering was 250 watts since the grid was not changed in order to

bring up the current.    This run might be compared with that of #6 in TABLE VI, where a start was made at 300 watts and after 13 hours of operation the deactivation was less than that in TUBE 203-A U-32.

Although the runs made do not bring out the effect of cooling the glass as clearly as might be of interest, experiment shows that glass cooling is a little less important in the Taylor tubes than in the Amperex tubes.

Three reasons for this might be offered - first, the bulb of the Taylor tube is larger, secondly, the Taylor anodes were probably less thoroughly outgassed and therefore are a source of poisoning comparable with that of the glass, and third, Taylor places the getter pellet so that most of the getter falls on the glass where it must receive a very considerable amount of radiant energy from the anode which it must re-radiate.    Getter activity increases with the temperature and therefore the gas which might otherwise be given off to deactivate the filament is rapidly absorbed by the getter.    Although this method of mounting the getter may be successful to counteract over-heating, it is not considered good practice in my opinion because of the danger of evaporating the getter over the other parts of the tube when the tube is operated for long periods of time with an overload condition.    The method of mounting used by Amperex is very superior from the point of view of long life.

TAYLOR TUBE 211-D-1D9

This tube turned out to be the best of the four Taylor tubes. In fact, it was slightly better than any of the tubes pumped by

Amperex, although not as good as the tubes which I evacuated. Even though this tube was better than the Amperex tubes because of the fact that it has a larger plate area, it should be better and therefore I consider this one really on a par with Amperex.

Measurements were taken on this tube on two different dates but are summarized all together in TABLE XX.

## TABLE XX

Series I    4/5/40

| Run | Watts | Time | Temp. | $V_{f1}$ | $V_{f2}$ | Remarks |
|-----|-------|------|-------|------|------|---------|
| 1 | $300^B$ | 1 hr. 45 m. | 906°C | 5.3 | 5.9 | Some deactivation |
| 2 | $350^B$ | 35 | 1000 | 5.3 | 5.7 | "        " |
| 3 | $400^B$ | 35 | 1040 | 5.3 | 5.95 | "        " |
| 4 | 400 | 37 | 1060 | 5.5 | 5.9 | "        " |

Series 2    4/9/40

| Run | Watts | Time | Temp. | $V_{f1}$ | $V_{f2}$ | Remarks |
|-----|-------|------|-------|------|------|---------|
| 5 | 300 | 10 | | 5.3 | 5.25 | Compare with 1 |
| 6 | 300 | 1 hr.10 | | 5.25 | 5.1 | "      "  " |
| 7 | 300 | 2 " 10 | | 5.1 | 5.2 | "      "  " |
| 8 | 300 | 15 " 0 | | 5.25 | 5.15 | "      "  " |

(18 " 30 m. total of Runs 5 to 8)

| Run | Watts | Time | Temp. | $V_{f1}$ | $V_{f2}$ | Remarks |
|-----|-------|------|-------|------|------|---------|
| 9 | 400 | 30 | 1075°C | 5.2 | 5.7 | "      "  3 |
| 10 | 400 | 35 | | 5.7 | 7.0 | Increase in gas content |

(65 min. total of Runs 9 and 10)

| Run | Watts | Time | Temp. | $V_{f1}$ | $V_{f2}$ | Remarks |
|-----|-------|------|-------|------|------|---------|
| 11 | $400^B$ | 65 | 1035 | 5.15 | 6.75 | Compare 10 and 3 |
| 12 | $(500^B$ (320 | 10 | 1100 start | 5.05 | 7.95 | See curve sheet, Fig.2. Curve III. |

The initial pressure in this tube was $1.2 \times 10^{-7}$ and the final pressure was $3.6 \times 10^{-7}$. This is an increase by a factor of 3. The results of run 12 are shown as one of the curves in Fig. 2. It will be noted that the tube was incapable of giving the full 500-watt plate dissipation for more than 5 minutes.

## TAYLOR TUBE 211-D 1D-11

Runs taken on this tube are shown in TABLE XXI.

### TABLE XXI

| Run | Watts | Time | Temp. | $V_{f1}$ | $V_{f2}$ | Remarks |
|-----|-------|------|-------|----------|----------|---------|
| 1 | 300 | 15 | 900* 980** | 5.3 | 6.05 | Deactivation |
| 2 | 350)$^B$ 300) | 15 | 940* 1020** (temp. at start of run) | 5.25 | 7.00 | " |
| 3 | 350) 278) | 10 | | 5.2 | 7.55 | " |
| 4 | 350)$^B$ 325) | 15 | | 5.2 | 6.85 | |
| 5 | 113$^B$ | 25 | | 5.2 | 5.2 | |
| 6a | 500$^B$ | 3 | 1080 | 5.2 | | |
| 6b | 500)$^B$ 283) | 27 | 950 | | 8.2 | See Fig.2. Curve IV. |
| 7a | 500$^B$ | 4 | | 5.2 | | "   "   "  V. |
| 7b | 500) 270) | 16 | | | 8.2 | |

\* Temp. on side away from getter deposit.
\*\* Temp. on side toward getter deposit.

There was a slight increase in pressure to $2 \times 10^{-7}$ mm; throughout these runs the pressure was less than that in TUBE 1D9 above and yet the deactivation was a little bit more severe. This can be interpreted as indicating a thing that is well known and that is that at these low pressures it is not the pressure per se which is important but the composition of the gas which controls the degree of deactivation.

## EXPERIMENTS CARRIED OUT ON TUBES OF GROUP VI

### EIMAC 75-T TUBE

The runs were made on the EIMAC tube on 4/19/40 and as a result I can say that from the point of view of overload capacity this tube was the best of all measured. The general characteristics of the tube are tabulated below.

### TABLE XXII

#### GENERAL CHARACTERISTICS OF EIMAC 75-T

| | |
|---|---|
| Filament voltage | 5 volts |
| Filament current | 6.5 amperes |
| Amplification factor | 10.6 |
| Maximum plate current | 225 milliamperes |
| Plate dissipation | 75 watts |

Tube must be operated vertically with ample ventilation provided.

The results of my measurements are summarized in TABLE XXIII

### TABLE XXIII

| Run | Watts | Time | Temp. | $V_{f1}$ | $V_{f2}$ | Remarks |
|---|---|---|---|---|---|---|
| 1 | $150^B$ | 18 min. | 1300°C | 2.6 | 2.6 | No deactivation |
| 2 | $300^B$ | 10 | 1560 | 2.6 | 2.6 | "        " |
| 3 | $300^B$ | 90 | | 2.6 | 2.6 | "        " |
| 4 | $400^B$ | 15 | 1680 | 2.5 | 2.5 | "        " |
| 5 | $500^B$ | 10 | 1750 | 2.5 | 2.5 | "        " |
| 6 | 400 | 60 | | 2.5 | 2.6 | Slight " |
| 7 | $500^{FAN}$ | 30 | 1740 | 2.5 | 2.65 | "        " |

It will be noticed that no deactivation was observed through the first five runs.   Run 6, however, at 400 watts without a blower showed a slight deactivation and Run 7 at 500 watts, with only a small fan instead of an air blast, showed also a slight deactivation.   These runs, 5, 6, and 7, are truly remarkable for a tube with a 75-watt rating.   The success in this matter may be attributed to two factors - first, a reasonably thorough out-gassing of the tantalum anode and, second, the use of Pyrex glass of adequate diameter for the envelope.   Within the tube there are no ceramic insulators since the tube  elements are supported by their lead-in wires.   This eliminates the ceramic material as a source of gas since in the other tubes this material does get exceedingly hot.   Pyrex is a somewhat harder glass than Nonex and is possibly more transparent to infrared radiation.   This point is discussed in a little more detail below.

One of the really serious objections to the properties of this Eimac tube is that the grid emission is exceedingly large be-cause of the very high temperatures attained within the anode structure.   At the highest wattage this grid emission was 1.2 milliamperes.   Such large grid currents interfere with the appli-cation of potential to the grid through a relatively high resis-tance.   If the full bias potential is not applied then the tube is likely to "run away."   For example, if the grid of this tube became disconnected for a moment during operation, the anode would probably melt within a very few seconds.   If it is possible in the circuit employed to use sufficiently small current fuses, it might be possible to save the tube in case of "run-away."   This diffi-

culty is not encountered in the graphite anode tubes because de-
activation of the cathode takes place before permanent damage is
caused.    The reason for this is not that the graphite is neces-
sarily a worse source of gas but that the temperature to which
the graphite will rise in order to dissipate the required number
of watts is so much lower than that for tantalum.    I think this
is a point of considerable importance and yet if, in practice,
users of tubes properly fused their circuits the disadvantage
in the tantalum tube may not be serious.

## WESTERN ELECTRIC TUBE #276-A

This Western Electric tube is rated at 100 watts and contains
a molybdenum plate within a Nonex envelope.    The characteristics
of this tube are shown in TABLE XXIV.

### TABLE XXIV

| | |
|---|---|
| Filament voltage | 10 volts |
| Filament current (nominal) | 3 amps. |
| Average thermionic emission | 1.25 amp. |
| Max. direct plate voltage | 1250 volts |
| Max. direct plate current | 125 milliamp. |
| Max. Plate dissipation | 100 watts |
| Plate resistance | 3000 ohms |
| Grid to plate transconductance | 4000 micromhos |
| Amplification factor | 12 |

This tube turned out to be the poorest of all tubes studied.
The runs taken are summarized in TABLE XXV.

## TABLE XXV

| Run | Watts | Time | Temp. | $V_{f1}$ | $V_{f2}$ | Remarks |
|-----|-------|------|-------|----------|----------|---------|
| 1 | 110 | 10 min. | 830°C | 5.4 | 5.35 | No deactivation |
| 2 | 210 | 10 | 1000 | 5.35 | 5.25 | "        " |
| 3 | 320) 250) | 4 10 total | 1150 | 5.2 | 7.9 | Considerable " Reactivate to 5.3 volts |
| 4 | 320)<sup>B</sup> ) 245) | 6 | 1130 | 5.3 | 7.8 | Considerable deactivation |
| 5 | 500<sup>B</sup> 350 | 10 secs. 1 min. total | | 5.1 | 7.5 | Reactivate to 5.1 volts Considerable deactivation |

It will be noted that a 10-minute run at 210 watts, or approximately ~~three~~ two times normal load, resulted in no deactivation and yet a run which started at 320 watts resulted in very serious deactivation.   In fact, the current could not be maintained more than four minutes.   This was without a blower.   Run 4, with a blower, showed no observable difference.   This indicates that the molybdenum was so inadequately outgassed that it was more important as a source of poisoning than the glass because there was considerable difference in the glass temperature for these two runs, 3 and 4.

Run 5, which might be compared with many of the other runs listed above, shows this tube incapable of operating for more than a few seconds with a 500-watt plate dissipation.   In fact, in one minute's time the filament was so completely deactivated that only 350 watts could be delivered to the anode.   The original gas pressure

in the tube was about $3 \times 10^{-7}$.   This was also the highest pressure of all of the commercial tubes tested.   After the final run of the above table the pressure had increased to $10^{-6}$ mm.   The grid emission was also objectionably large.   Leakage current, when the tube was cold, was the largest of all tubes measured.   In spite of the serious deactivation and the increase in gas pressure, it was nevertheless possible to reactivate the filament to normal activity.   There ware no exceptions to this rule in all of the tubes tested.

# COMPARISONS

Some comparisons have been made in connection with the individual summaries of data taken.    Perhaps it would be worth while to review some of these.

The first point is that hydrogen treated anodes are more easily outgassed than the non-hydrogen treated anodes, although the latter can be outgassed and tubes with the same overload characteristics produced.    As far as these experiments go, there seems to be no difference in performance between the carbonized and non-carbonized filaments.    This cannot be said to be evidence that carbonization is not desirable since there are other experiments which have been made in the past demonstrating the superiority of carbonized filaments as regards their ability to hold thorium.

The tubes pumped at the Amperex plant were slightly inferior in load-carrying capacity to the ones pumped here.    The average of the Amperex tubes though is no doubt better than the average of the Taylor tubes although the best Taylor tube is a little better than the best Amperex tube.    Considering only the question of plate dissipation, the Eimac tube with the tantalum anode and the Pyrex envelope was undoubtedly the best of all tubes measured. The Western Electric tube with a molybdenum anode was very definitely the poorest tube of all those measured.

# RADIANT ENERGY ABSORBED BY THE GLASS

It is obvious that the radiation from a graphite anode dissipating a large number of watts will have its energy distributed over longer wavelengths than that from the metallic anodes. Without having detailed knowledge as to the transmission characteristics of Nonex and Pyrex glass it is well known that both of them absorb practically all of the infrared radiation of wavelengths longer than about 4 microns.

The transmission characteristic of Nonex glass has, as far as I can find, never been measured. The Corning Glass Company and also Dr. Coblentz, of the Bureau of Standards, had no information as to the infrared properties of this glass. Dr. Coblentz has measured the transmission of the so-called "chemical Pyrex" which is the general type used for tube construction. Fig. 3 shows the transmission characteristic of Pyrex for a sample 2 mm. in thickness. Also in this figure are two curves designated 2200°K and 1400°K. These curves have been adjusted to have the same maximum height, although for a more accurate comparison one should perhaps adjust them to have the same area underneath the respective curves. Since any estimation of the energy absorbed is only a rough approximation, because of the lack of detailed information as to the spectral emissivity of graphite as compared with tantalum, for example, in the infrared, the calculation of the curves in Fig. 4 was accomplished by taking the product of the energy distribution curve and the absorptivity. It is clear that a much larger frac-

tion of the energy radiated from a 1400° source is absorbed in the Pyrex glass. The absorptivity was determined by the relation A = 1-T where T is the transmission.

If the strong absorption in Nonex begins between 2 and 2.5 microns, then the relative amounts of absorption in the glass will be even still greater in the direction of more absorption for the graphite anode. Also, if the graphite anode is operating at a temperature considerably less than 1400°K, the normal value being in the neighborhood of 1000 or 1100°K, a very large fraction of the energy must be re-radiated by the glass. This very approximate analysis only serves to indicate the nature of the problem and could be carried with profit a little farther only at a rather considerable expense in determining additional transmission characteristics for Nonex glass after it has been heat-treated in the way it actually is in practice and also determining the spectral emissivity of graphite in the infrared.

## SPECTROSCOPIC ANALYSIS OF EXHAUST GAS

In order to get an idea as to whether or not it would be worth while to examine the exhaust gas in detail to determine its composition, Geisler tubes were attached to the exhaust manifold of the vacuum system during the evacuation of tubes #12495 and #12496. The report given on the spectroscopic analysis is summarized in TABLE XXVI.

# TABLE XXVI

| #12495 | | #12496 |
|---|---|---|
| CN | < | CN |
| CO | < | CO |
| CH | = | CH |
| $N_2$ | < | $N_2$ |
| $H_g$ | << | $H_g$ |
| H | > | H |
| O | > | O |
| N | = | N |

These comparisons are very inconclusive since my inspection of the Geisler discharge before the analysis was run and my inspection after the analysis was run showed that the running of the tubes had actually changed the relative proportions of the materials present in that the color in one tube was originally a pale blue, while in the other a definitely darker blue; after the tubes had been run for the analysis both tubes had a very much stronger red component than was initially the case. The composition found included of course most of the elements that one might suspect without running the analysis.

Without carrying a study of this kind very considerably farther than was originally intended, it is unlikely that anything of value could be obtained. In the first place the Geisler tube would perhaps have to be made of quartz so that it would not give off gas during the time required for exposing the photographic plate and the effects of various refrigerants on the trap should be considered since a certain fraction of the gas liberated by the graphite must be adsorbed in the trap and this proportion would be different for different molecules.

## METHODS OF EVACUATION RECOMMENDED

In order to produce tubes which are capable of withstanding large over-loads without deterioration, the tube must be well evacuated and the components heated to temperatures well in excess of any value which is likely to be reached under the anticipated overload condition. To get a good vacuum, the vacuum pumps must be fast and the connecting manifold must be as large as it is feasible to make it, right up to the point at which the tube is sealed on the manifold. The seal-off constriction of the tube should be made as large in diameter as is consistent with the mechanical requirements of the tube structure.

In the tube design every attempt should be made to make this constriction large and short. The pumping resistance of the constriction increases in proportion to its length and is proportional to the reciprocal of the cube of the diameter. Thus a small increase in the diameter of this tubing may make a very considerable increase in the pumping speed. Arrangements should be made so that the entire manifold, including the liquid air trap in case mercury pumps are used, can be baked at a relatively high temperature (430°C for Nonex and 500°C for Pyrex).

The oven in which the tubes are to be baked should be so arranged that it can be removed quickly and brought up to temperature quite rapidly. The temperature should be accurately known and controlled and should be as uniform as it is practically possible to make it.

The proper use of air blasts to cool off the liquid air trap
and to cool tubes under construction during the high frequency heat
treatment is very essential.

The evacuation schedule, which is summarized in TABLE XXVII
is one which has been found to be very suitable for the HF-100
tubes and this same schedule should be useful for other tubes of
the same general construction.

The following schedule is built on the assumption that the
tube being evacuated is connected through a large manifold and
liquid air trap to fast mercury diffusion pumps, and thence to a
mechanical pump.    In our case the mercury pumps are single-stage
pumps, the first of which has a speed of about 15 to 20 liters per
second and must be backed up by a "jet pump" which has a much
lower speed but is capable of operating against a much higher fore
pressure.    This second mercury pump is backed up by a Cenco me-
chanical pump.

TABLE XXVII

EVACUATION SCHEDULE USED ON HF-100 TUBES

Time (in minutes)

0       Seal tube to pumping manifold and start mechanical pump.

1       Apply heat to mercury pumps and turn on ovens.  (Main
        baking oven should have been pre-heated to 500°C.)

6       (a)  Remove baking oven.
        (b)  Test for leaks at "seal-on" junction.
        (c)  Start high frequency heating of anode using strong
             air blast to cool glass.
        (d)  Within one minute after starting, bring anode up
             to 1260°C and hold for three minutes.  During the
             next minute lower the temperature in 50° steps to
             1000°C.

TABLE XXVII -- continued                                                    52

12    Baking oven on, hold at 515°C for 30 minutes.

42    Liquid air trap oven off; air blast blower to cool trap.
      Lower temperature of baking oven to 480°C.

44    Put liquid air on trap with flask 2" below maximum height.
      (This is done so that later the liquid air level can be
      raised above the starting level.)

52    Baking oven removed after cooling to near 460°C.   If
      gauge is attached to system pressure at this time should
      be about $3 \times 10^{-7}$ mm.

53    High frequency heating of anode to approximately 1250°C
      with air blast on and filament heating connections made
      but power not supplied.   Anode connected to filament
      and grid connected to +800 to 1000 volts D.C.

62    Filament current turned on and gradually increased until
      80 milliamperes of emission current flows to the grid.
      Keep the high frequency heat on all of the time.

64    Anode temperature should now be about 1300°C and the
      vacuum $2 \times 10^{-4}$ or better.

68    During the following 2 minutes reduce the anode tempera-
      ture gradually to 900°C and then turn off high frequency
      and grid and filament power.

70    Pre-heat getter to maximum temperature for which only a
      slight getter deposit is made in 3 minutes' time. (800°C
      for getter used by Amperex.)

75    Flash filament one minute at 4.2 amperes for HF-100 tube.
      Temperature should be approximately 2900°K.

76    High frequency and grid heat applied, as above, at 62 min.

79    Gradually reduce anode heat to 900° during ensuing minute.

80    Soften seal-off capillary sufficiently to lose approximately
      half its diameter.

81    Flash getter complete.  Raise liquid air level.

82    Re-apply high frequency heat and grid power as above.

88    Reduce anode temperature gradually during ensuing $1\frac{1}{2}$ minutes
      to 1000°C.

90    Seal off tube with anode red hot.

The above vacuum schedule may seem to be rather too detailed for some manufacturers. Naturally it can be modified in ways that local experience indicate are satisfactory. I think it is possible that an extra 15 minutes added to the oven baking would be an advantage. If the tube design were such that the insulating ceramic parts or the springs which hold the filament taut would not over-heat, and the glass wall itself not over-heat, then an increase in the anode temperature to 1400 or 1500°C would be an advantage. With the design as now used by Amperex, the temperatures recommended above are, I think, the absolute maximum that can be used without having excessive loss of tubes during the evacuation process. In fact it might be necessary to reduce some of the temperatures slightly if there were much likelihood that conditions in all of the tubes on a given manifold were not reasonably uniform.

This schedule is incorporated to serve as a sort of skeleton plan which should be modified to suit local circumstances.

## SUMMARY

The following summary has been prepared so that it may serve along with the Table of Contents as an index to the information contained in this report.

1. Experimental Factors

Mention is made of certain experimental factors which had to do with the setting up of standard test conditions.   These are given on pages 5 and 29.   The circuit arrangement is discussed on page 6.   The calibration of the tubes tested as ionization gauges is discussed on pages 3 and 35.   Experiments were made to determine the range of voltage drop over the filament for which activation or deactivation takes place as the result of heating.   This discussion is on pages 29 and 30.

2. Pressure During and After Exhaust

Two sets of measurements are recorded for the pressure measured during the exhaust.   These are on page 12 for TUBE #12308 and page 18 for TUBE #12323.   Mention is made of the pressure before and after seal-off in the rather exceptional tube, #12305, on pages 9 and 10.   Further information on this tube during an overload run may be found on page 11.   The advantage in having hydrogen-fired anodes is mentioned on page 25.   Data on the gas pressure in other tubes may be found as indicated in the following table.

1. State problem
2. Discuss method
3. " Tube design factors
4. Glass effect results
5. 500 watt over load tests.

Thoriated fil
sen ind. of gas.

Over load
  Structured changes.
  gas
      (a) Discharge phe.
      (b) Deactivation effects
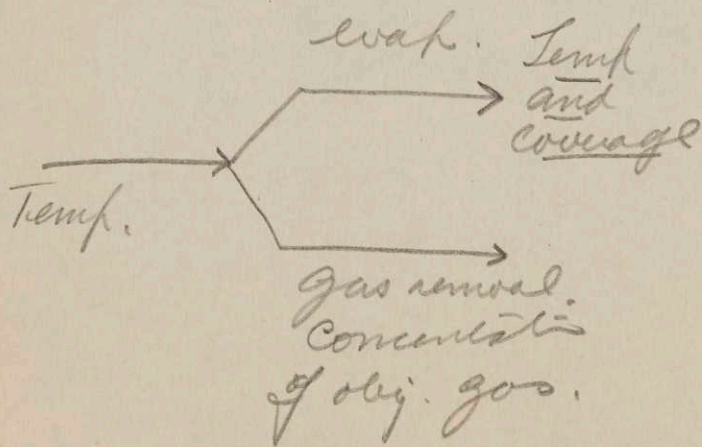
---

Deactivate effects,
  (1) Space charge limit
          emission
  (2) Temp limited
          emission.

---

Activation & deactiv
  balance.
Life determine
by rate of arrival

Active gases
increase rate of
loss ∴ decrease
population until
rate of evaporation
is reduced.

Temp. → evap. Temp
and
coverage

gas removal.
Concentration
of obj. gas.

Conen tion of
oxy. gas.

Temp. of source

Prin history

Activity of getter

---

Exp to separate
some effects.

(1) Over load for
known time with
obs. of temp lim.
emiss before and

after run.

Plate dissipation
constant.

Differ in
fil heating voltage
for ~~jitter~~ ~~standard~~
predetermined emission
a measure of
activity.

Observe at different
overloads and
different cooling conditions

Extreme overload.
maintain power as
long as possible
and continue
at reduced power
for definite time
again compare.

Conclusion.
(1) Design tube to
operate with
glass cool
(2) Out gas Temode is

possible.

③ Con. of insulati—
input.

④ Normal operating
temp of graphite
anodes should
be raised.

⑤ Should a tube
be rated at
a specific fraction
of its max. overload
capacity as determin—
by 10 5 15 or 30 min run.

## 3. Tube Exhaust

On page 12 mention is made of the pumps and pumping lead, while on page 50 there is a general discussion of the pumping problem and mention of the desirable requirements for the seal-off connection. A detailed pumping schedule is given on page 51 and the desirability for slow cooling of the anode is discussed on page 24.

4. <u>Deactivation Effects Produced by Non-Overload Conditions</u>

A discussion is given on page 3 of the effect on activation stability resulting from small deposits of foreign material on the Tungsten filament. Deactivation brought about in the ionization gauge as a result of the liberation of an unknown gas upon cooling of the HF-100 filament is mentioned on page 10. Upon cooling the anode in <u>TUBE #12495</u> an unexpected deactivation effect was observed, as mentioned on pages 26 and 27. This tube was not hydrogen treated. The same effect was looked for but not found in the hydrogen treated <u>TUBE #12496</u>. Mention of this is made on pages 21 and 22.

5. <u>"Dusting" Effect</u>

The first really obvious case of "dusting" was observed after operation of <u>TUBE #12322</u>, with very high voltages applied. Fluorescence of the glass and the grid structure were observed. The discussion is on pages 16 and 17. In this tube the reduction in filament drop for a standard filament current was observed after "dusting." Details are on page 16. The grid deposit on the glass is associated with glass deterioration and is mentioned on page 15. A leakage current from grid to anode has been observed and associated with the "dusting" phenomenon. The discussion is on pages 23 and 27.

6. <u>Deactivation Due to Overload</u>

Severe deactivation was observed as a result of grid bombardment, as shown on pages 30 and 31. The heating of the anode and

the consequent heating of the glass resulted in deactivation ef-
fects, as indicated on pages 14, 21, 28, and 32.

Experiments made with Taylor tubes, with and without glass
cooling, indicate that the envelope here plays a much less im-
portant part than in the Amperex tubes.   The discussion is on
pages 37 and 38.   This reduction in the importance of the glass
in the case of the Taylor tubes may be partly attributed to the
location of the getter, as mentioned on page 37.   The gas liber-
ated from the molybdenum anode of the Western Electric tube, 276-A,
was so great that no effect of the glass could be observed.  See
page 44.

Throughout this report there are numerous tables showing the
extent of the deactivation observed under various load conditions.
Refer to the Table of Contents for these data.

7.   Some Comparisons

A general treatment of the comparative merits of the tubes is
given on page 46 while other comparisons, for example, that between
M.I.T. evacuated tubes and Amperex tubes, is on page 32.   A com-
parison between Amperex and Taylor is on page 33 and the Eimac
comparisons are on page 42.

8.   Grid Emission

The details as regard grid emission on the Eimac tube are
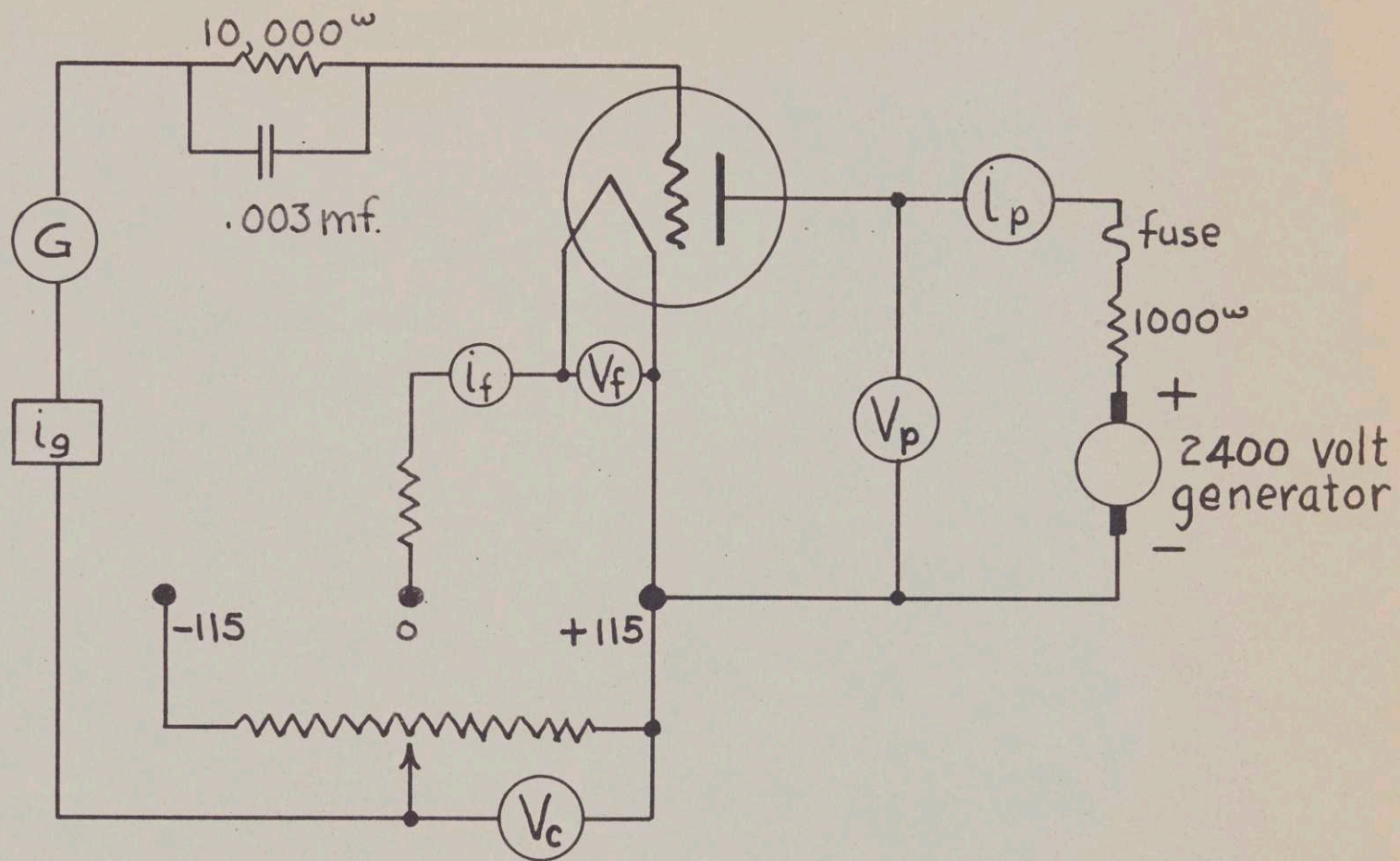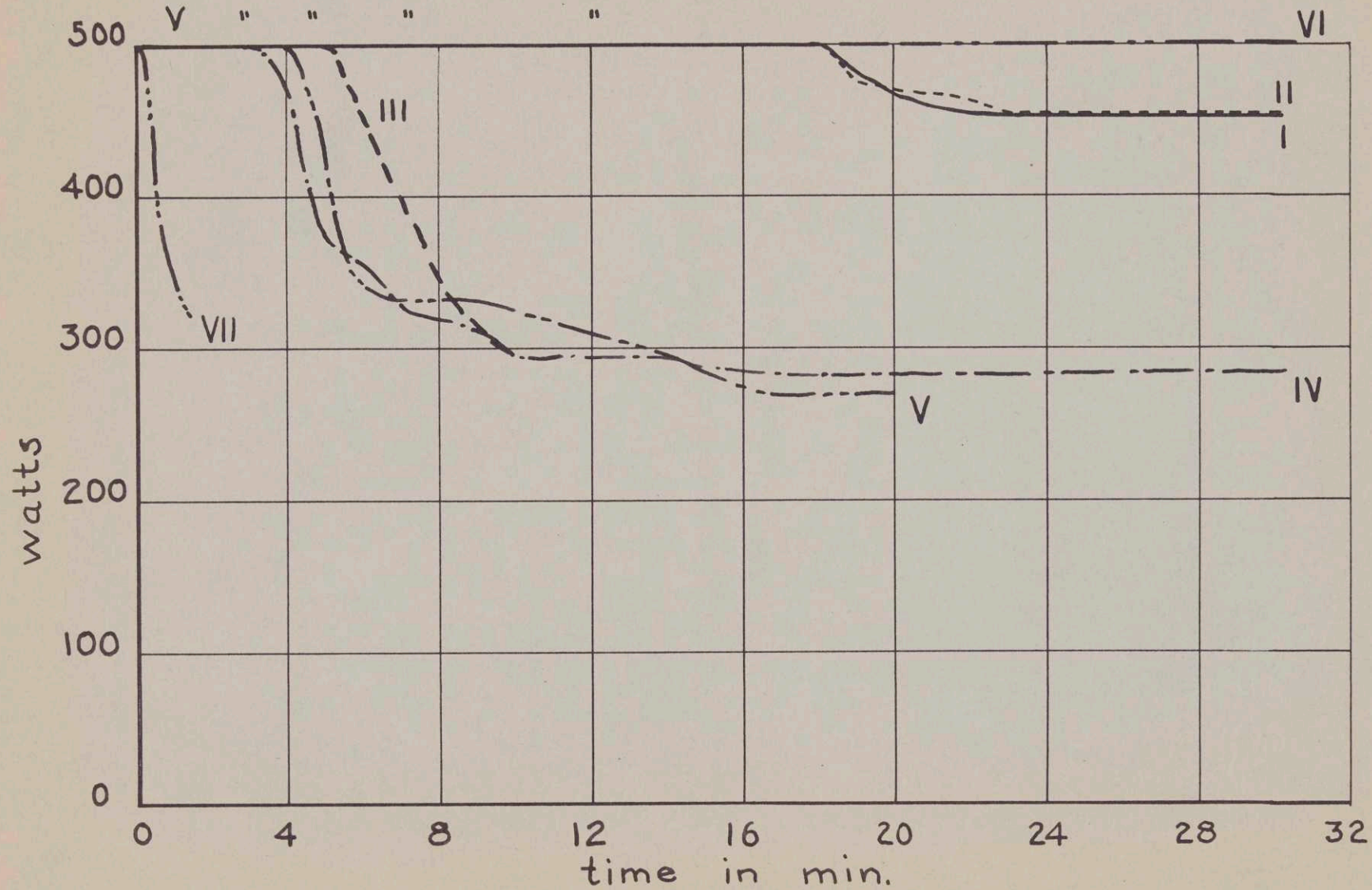given on page 42 and for the Western Electric tube on page 45.

Fig. 1

Fig 1.

Fig. 2.

transmission of chemical Pyrex 2 mm.
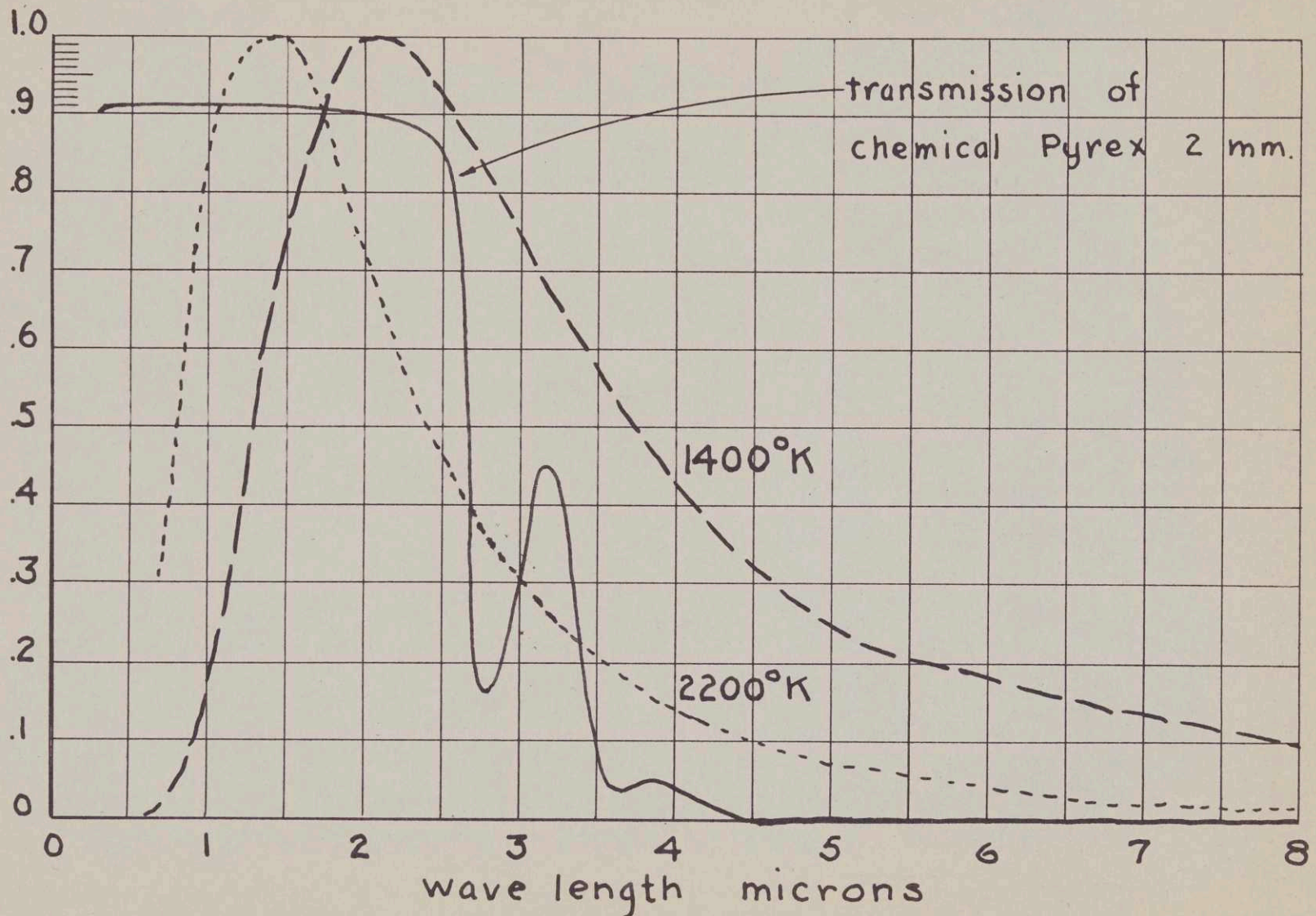
1400°K

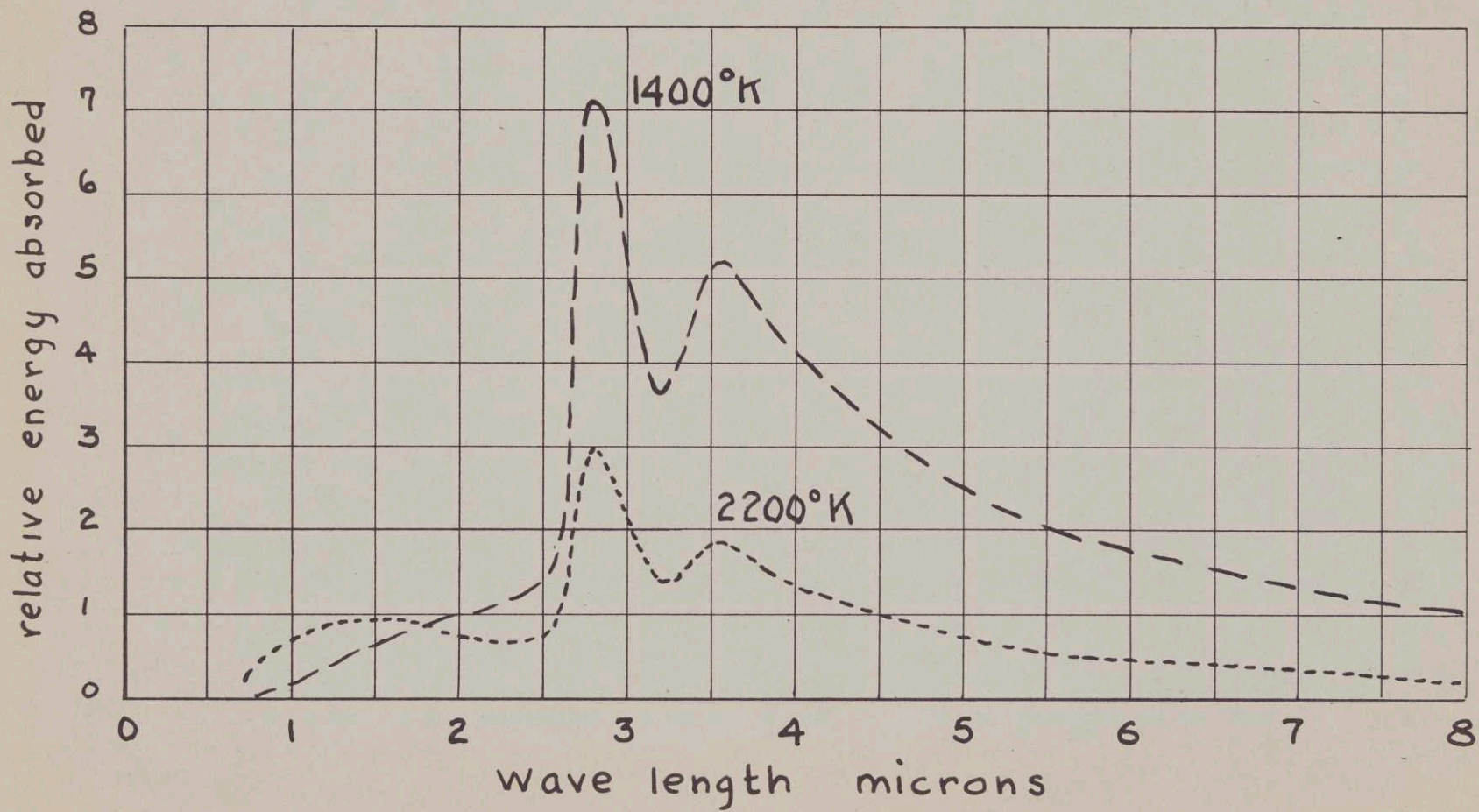2200°K

wave length microns

Fig. 3.

Fig 4.

During the past few months I have been interested in the overload characteristics of certain small transmitting triodes with thoriated filaments for cathodes.  Under extreme overload conditions tube failures generally result from structural changes due to the moving of the filament or the grid resulting in internal shorts, or else due to the effects of gas liberated by one or more of the electrodes, or by the glass wall of the envelope itself.  The liberation of gas may make itself objectionable in either of three ways.  First, the gas pressure may rise sufficiently to cause an actual gas discharge to take place; secondly, the gas pressure may be sufficient to result in deactivation of the filament by ion bombardment, or, third, deactivation of the filament may take place as a result of gas poisoning.  In reasonably well evacuated tubes the gas poisoning effect is generally the first one to be noticed.  In ordinary practice the triode is operated as a device in which the plate current is limited by space charge.  When this is the case and the design has been properly proportioned, noticeable changes in the thermionic emission may take place without altering the practical characteristics of the tube.  For test purposes, however, the operation of the tube in such a way that the current is limited by the temperature of the filament serves as a very sensitive indicator of the degree of thoriation and therefore as an indicator of the extent to which the deactivation effects from overload have decreased the true emission from the filament.

During normal operation activation is taking place con-
tinuously. If there are no poisoning effects and no cathode
bombardment, then the cathode takes on a value of surface
coverage of thorium which is probably between 70 and 80% of the
maximum thorium surface density which would be associated with
a monatomic layer of thorium on the surface. At this coverage
the rate of evaporation exactly equals the rate of arrival of
thorium at the surface, leaving it with the optimum coverage
from the point of view of obtaining a maximum thermionic emission
at the operating temperature.

The first effect of overload is to liberate poisonous gases
within the tube such as oxygen, for example, which react with
the filament at operating temperatures to remove some of the
thorium. Generally speaking, the so-called poison does not
stay on the filament at operating temperatures but combines the
thorium and leaves the filament, thus effectively increasing the
rate of removal of thorium atoms above that due to simple tem-
perature evaporation. This, of course, results in a decrease
in the surface coverage and in case this decrease goes far
enough the thermionic emission falls to a very small fraction
of its original value. The speed and extent of this deactivation
depends, of course, on the concentration of the objectionable gas,
which in turn depends upon the temperature of the source of the
objectionable gas and the activity of the getter used in the tube.

Experiments were carried out to determine to what extent the sources of poison could be eliminated and it was found in the case of graphite anodes that it was possible to out-gas the anodes sufficiently so that they became a relatively unimportant contributor to the deactivation process.  In these cases for which the anodes had been well out-gassed, the glass envelope became the dominating source of trouble.  This was demonstrated by operating the tubes with about 500% rated plate dissipation with and without an air blast to cool the glass wall.  The rate of deactivation was very greatly influenced by the effect of glass cooling.

Another type of run which was used to determine the effectiveness of the out-gassing procedure followed-the plan of adjusting the plate dissipation to 500 watts at the start and observing the time during which the tube was capable of delivering the 500 watts and then determining the maximum plate dissipation which could be obtained even after deactivation had set in.  Some of these results are shown in the second slide.

One might conclude from these studies that an important factor determining the ~~effect~~ extent to which a tube of given rating can be overloaded is that of the glass.  It is of course important to out-gas the anode as thoroughly as is practical.  Care must be exercised in the placing of such insulating parts as are necessary to hold the tube elements in their specified and proper positions.  Although it has been general practice to operate

tubes containing metal anodes with operating temperatures such that the anodes give off considerable intensity of visible radiation, the general practice with graphite anodes has been to operate them so that relatively little visible radiation is to be observed.   It seems altogether likely that a re-proportioning of the tube so that the anode is smaller relative to the glass envelope and running at a higher temperature would be an advantage.   The important point in this connection is that since a given total amount of radiation energy must be transmitted through the glass or re-radiated by the glass, the structure which results in the most uniform heating of the glass would be a distinct advantage.

Finally, it seems as though it might be worth while to specify the maximum overload wattage which a given tube can be expected to withstand for a period of, say, not more than ten or fifteen minutes, without permanent injury.   Of course all tubes of this particular type, when overloaded in the extreme, become temporarily injured because of the deactivation of the cathode but, as is well known, prolonged operation even at normal cathode temperatures without the application of the plate potential results in a reactivation;or a reactivation schedule can be used which will bring the tube back to its optimum condition within a very few minutes.

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