I. PHYSICAL ELECTRONICS

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A. ELECTRON-EMISSION PROBLEMS

1. Thermionic Work Function and Conductivity of Oxide-Coated Cathodes

A combination of research on thermionic emission and conductivity enables one to investigate the electron band structure of oxide-coated cathodes. During the past year W. E. Mutter carried out on a well-activated cathode some experiments which reveal a thermionic work function of 1.40 ev and a conductivity activation energy of 1.22 ev. Below 650°K a low temperature slope of 0.13 ev was observed on his conductivity curve. A similar low temperature slope of 0.1 - 0.2 ev for temperatures in the range between 600°K and 800°K has been reported by the Philips Laboratories (1). To explain this break, Vink, the experimenter, thinks that there are two conduction processes going on. Below 800°K, electron conduction through adjoining particles of the coating dominates. Above 800°K, conduction by electrons passing in the pores between the particles dominates.

In disagreement with this hypothesis Mutter found no changes in conductivity measurements made with the cathode in vacuum and in helium at a pressure of one atmosphere, where the mean free path of low energy electrons is only 10^{-4} cm. This indicates that the conductivity takes place through the coating particles and not by thermionic emission between the particles. In this case a possible explanation for the break can be that electron traps have two electrons associated with them and give up the first electron to correspond with the low temperature slope, and the second electron to produce the larger slope.

An anomaly observed by Mutter in the case of an oxygen-deactivated oxide-coated cathode has led to an experiment wherein the relation between the thermionic work function and the conductivity activation energy will be studied as the degree of activation of the cathode is varied. Mutter employed a split-cathode to measure the conductivity. He found that the thermionic work function was 2.36 ev, while the conductivity activation energy was 3.40 ev for the deactivated state.

In the present case conductivity will be measured using both the

split-cathode and the probe methods in the same tube. These measurements will be compared over a wide temperature range including the region extending far below the observed low temperature break.

The tube to be used is almost completed. It involves a gravity-controlled sliding anode and a cylindrical cathode. The cathode has a ring gap in the base metal as well as a probe wire running half-way along the coating. The cathode remains the only unfinished element of the tube.

R. T. Watson

2. Thermionic Emission from Ultrafine-Grain Oxide-Coated Filaments

Two projection tubes have been completed for visual study of thermionic emission from the filaments described in the Progress Report of October 15, 1949. These tubes have cylindrical geometry. The phosphor is coated on the inside of a 50-mm pyrex envelope. The emitter is held under tension at the axis of the tube; the collector is parallel to the axis and near the edge of the envelope.

The general experimental procedure which has been used is as follows. The emitter is a polished tungsten wire in which single crystals have been grown by heating. A photograph is taken of the tungsten emission pattern. The tungsten wire is removed, coated cataphoretically with barium and strontium carbonates, then returned to the tube. After activation a photograph is made of the emission pattern from the oxide coating. The purpose of these steps is to find whether or not the emission from the coating is influenced by the crystallographic structure of the base metal.

The phosphor used is zinc sulphide, silver-activated. This material has a peak in its emission spectrum at about 440 mμ. In order to apply the phosphor, the inside surface of the cleaned pyrex envelope is first washed with a 10-percent solution of potassium silicate. After a 5-minute drying in air the surface becomes sufficiently tacky, and the powdered phosphor is blown in. The coating is then hardened by baking in air at 300°C. This process may be repeated if a thicker coating is desired.

The collector is a 1/4-inch spring of 15-mil tungsten with a pitch of 40 turns to the inch. This spring is stretched between two press leads which are 4.5 in. apart. The construction is such that the spring may be outgassed by passing current through it. The emitter (or base metal in the coated cases) is of No. 218 tungsten wire. This wire is 5 mils in diameter originally but, after polishing, the diameter has decreased to about 4 mils. The oxide coating is about 1 mil thick.

Tube No. 1 was given a single coating of phosphor. The single crystals were grown in the tungsten wire by passing an a-c current through it. The temperature was raised to 1800°K for an hour, 1900°K for an hour, and so on to 2600°K. The pattern was observed by applying 4000 volts to the collector. This heat treatment resulted in two single crystals of about 3.5 in. and 1.5 in., respectively. Using Nichol's data one could recognize the peaks of emission from the 111 and 116 planes, and the minima from the 110 and 112 planes. No minimum was seen at the 100 direction. Photographs were made using Verichrome film and a Wratten C4 (deep-blue) filter. After coating the wire, further photographs were made, this time with no filter. The emission observed was reasonably uniform and showed no evidence whatsoever of the tungsten pattern.

In tube No. 2 the same procedure was followed with the exceptions that the glass envelope had a double coating of phosphor, and the single crystals were grown by maintaining the tungsten wire at 2000°K for 45 hours. In this case there were about six single crystals in the tungsten filament, varying in length from 1/2 in. to 1 in. The tungsten pattern could be recognized as in the case of tube No. 1. After coating the wire the emission pattern once again showed no evidence of an effect from the crystallographic structure of the base metal.

These results are judged sufficiently conclusive to make the projection-tube studies complete. A tube is now being designed for the purpose of making the velocity-distribution measurements mentioned in the Progress Report of July 15, 1949. C. P. Hadley

3. Deterioration of Oxide-Coated Cathodes under Low Duty-Factor Operation

The tubes described in the Progress Report of October 15, 1949 have been aged according to the plan outlined and show the following results:

a. Interface resistance

Up to 1557 hours, only four tubes had developed cathode interface resistance. Two of these were from panel III, the other two from panel IV.

b. Pulsed emission

The results of the pulsed emission measurements are plotted in Fig. I-1. They are normalized to the average currents at zero-hours life (approximately 0.5 amp/cm^2 at the reduced cathode temperature of 940°K and an anode voltage of 250 volts). The pulsed emission was measured at zero- and 284-hours life by a 1-msec, 250-volt pulse, repeated at a rate of one per

second. This was found to affect the state of the cathode, as was evidenced by the d-c emission measurements. All subsequent pulsed emission measurements were therefore made with a single 1-msec pulse, viewed on a long-persistence synchroscope.

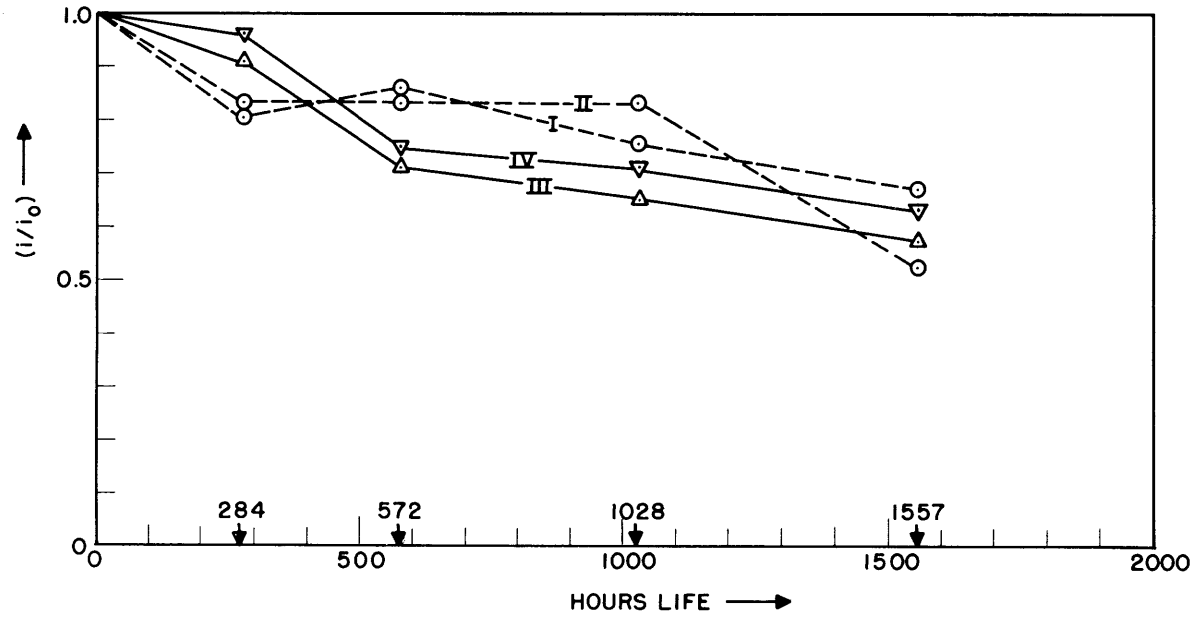


Fig. I-1 Results of pulsed emission measurements.

(1) Pulse shapes

For panels I and II, the emission pulses have been observed to be square; the emission shows no time variation during the pulse. For nearly all tubes of panels III and IV, however, the emission is observed to increase during the pulse, as in Fig. I-2. A plot of $\log \left\{ i_\infty^2 - i^2 \right\}$ vs. time, as in

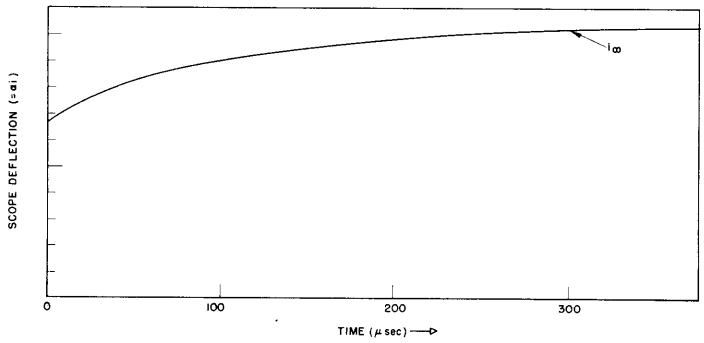


Fig. I-2 Pulsed emission vs. time. Tube IV-9 (1557 hours).

Fig. I-3 yields a straight line within the experimental uncertainty.

When we recall that the theoretical expression for the emission current from an oxide-coated cathode may be expressed as

$$j = A(T)\, n_b^{1/2}\, e^{-e\phi/kT}$$

where n_b is the number of activation centers per unit volume, we see that the behavior observed could be explained if n_b varied with time during the pulse as

$$n_b = n_{bo} + C(1 - e^{-\lambda t})$$

where $C = 0$ for $t < 0$, but $C =$ constant independent of time for $t \geqslant 0$. In the simple semiconductor model of the oxide-coated cathode, the conductivity is given by an expression of the form

$$\sigma = A'(T)\, n_b^{1/2}\, e^{-\Delta\epsilon/2kT} \quad .$$

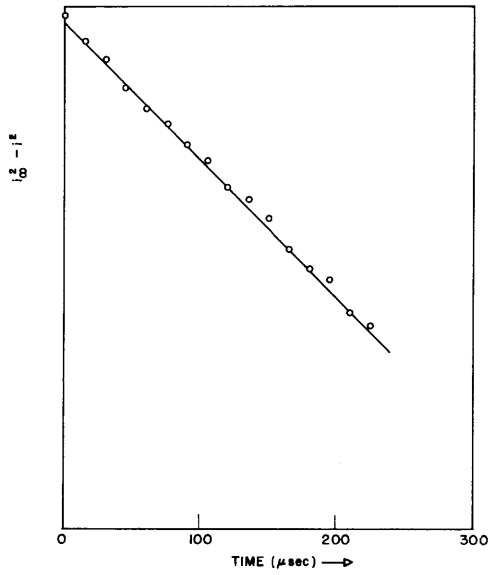


Fig. I-3 Log $\left\{i_\infty^2 - i^2\right\}$ vs. time (from Fig. I-2). Tube IV (1557 hours).

Thus, if n_b were varying with time,

$$E = j/\sigma = \frac{A(T)\, e^{-e\phi/kT}}{A'(T)\, e^{-\Delta\epsilon/2kT}}$$

is independent of n_b and hence independent of time. The constant C could therefore be proportional to E, since the field in the cathode coating is zero when no emission current is being drawn.

It appears, therefore, that some process, dependent on the field, occurs

in these cathodes, increasing the number of activation centers per unit volume where current is drawn.

c. D-C emission

The d-c emission has been measured before and after the pulsed emission measurements. The results are plotted in Fig. I-4 normalized to the average zero time currents. Note that at 284 hours, for panels III and IV, the pulse test caused a large change in the d-c emission; after modification of the pulse test, it has caused no significant change in the d-c emission at any measurement.

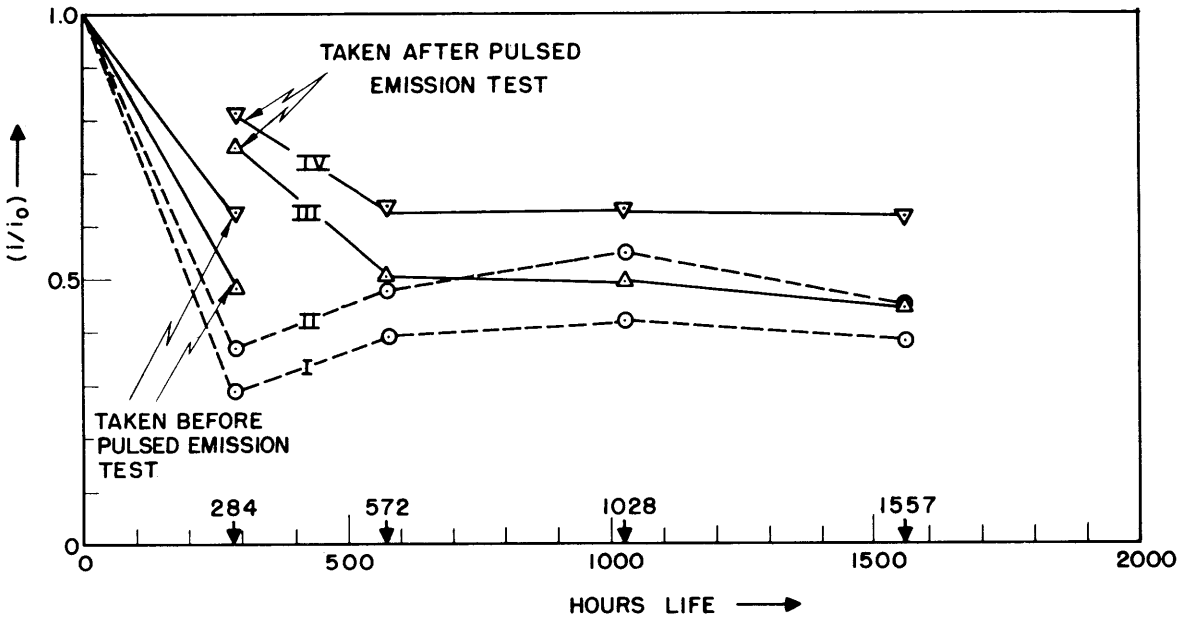


Fig. I-4 Results of d-c emission measurements.

So far, only six tubes of the forty can be classified as failures. They can be broken down as follows. Two tubes from panel II exhibited low emission which apparently was due to loss of active material. Two tubes from panel III and two tubes from panel IV showed interface resistance. Evidently, interface-resistance formation is favored by low duty-factor; however, the rate of incidence is much lower than previous work on commercial tubes with No. 699 Ni cathode alloy would lead one to expect. This leaves open the possibility that impurities in other electrodes of the tube play a significant part in this type of deterioration.

Up to the present, there appears to be no significant difference between the 100-percent duty-factor panels and 0-percent duty-factor panels as far

as emission is concerned. However, a visual inspection of the tubes indicates that evaporation of active material is much greater in the conducting tubes than in the nonconducting ones. They would therefore be expected to be the first to fail due to loss of emission.

The life test herein described is being continued. When it has been carried to completion, the plates and cathodes of the tubes will be subjected to spectrochemical analysis to ascertain the difference in impurity content, if any, of failures and nonfailures. In addition, a method is being devised whereby more accurate measurements than heretofore possible may be made on the cathode interface voltage drop as a function of current and temperature so that quantitative inferences on the nature of the interface may be made from its electrical characteristics.

4. Purified Standard Diodes

These diodes have been aged as follows:

Tube	Activated by	Aging condition	T_k
N – 1	drawing emission current	I_b = 12 ma	~1100°K
N – 2	drawing emission current	I_b = 12 ma	~1100°K
N – 4	drawing emission current	I_b = 0	~1100°K
N – 5	methane	I_b = 12 ma	~1100°K
N – 7	methane	I_b = 0	~1100°K

Tubes N – 1, N – 2, N – 4 were aged 572 hours, and were forwarded to Professor Lark-Horowitz, Purdue University, for attempt at activation by neutron bombardment. Their history was as follows:

a. No interface resistance was shown.

b. Pulsed emission (940°K, 250 volts E_b)

Tube	284 hrs	572 hrs
N – 1	0.12 amp	0.16 amp
N – 2	0.06	0.09
N – 4	(sparked)	0.22

c. D-C emission (650°K, 4.5 volts E_b)

	0 hours	284 hrs		572 hrs	
Tube		before pulse test	after pulse test	before pulse test	after pulse test
N – 1	<0.01 μa	8.1 μa	10.5 μa	20.0 μa	14.0 μa
N – 2	<0.01	0.05	0.5	0.02	0.3
N – 4	21.5	19.2	1.6	19.5	38.0

Tubes N – 5 and N – 7 have been aged 1557 hours with the following results:

a. Interface resistance

Neither tube shows interface resistance; however, N – 7 appears to have a high coating resistance, in that its plot of current vs. voltage departs from the space-charge line at the origin, yet it has at least as good an emission under pulse conditions as any of the other tubes.

b. Pulsed emission

Tube	0 hours	284 hrs	572 hrs	1028 hrs	1557 hrs
N – 5	0.47 amp	0.51 amp	not obtained	0.40 amp	0.25 amp
N – 7	0.41	0.23	0.36	0.36	0.18

c. D-C emission

Tube	0 hours	284 hrs		572 hrs	1028 hrs	1557 hrs
		before pulse test	after pulse test			
N – 5	92 μa	26.0 μa	108 μa	65.3 μa	69.8 μa	60.0 μa
N – 7	190	0.08	0.05	0.02	0.02	0.01

From the foregoing results it appears that although methane activation yields a high initial activity for pure nickel cathodes, if they are operated nonconducting, they become unsatisfactory in a matter of a few hundred hours, as far as d-c emission is concerned. The exact mechanism of this failure is unknown at present, but is believed to be a high cathode coating resistance.

J. F. Waymouth, Jr.

5. Determination of the Field-Emission Properties of Single Tungsten Crystals by a Photometric Method

The first experimental tube has been completed and found to be unsatisfactory. As outlined previously the anode in the type of spherical projection tube used in this study has two purposes. It serves as the electrode to which the high voltage is applied and as the collector of secondary electrons emitted from the phosphor. In the first tube this anode was a circular ring of 15-mil tungsten wire with a diameter of 5 cm. It was found that this anode contained such a small surface area that it was not an efficient collector of secondary electrons. Hence the potential of the phosphor did not approach the potential applied to the anode but remained several thousand

volts lower. An attempt was made to improve this situation by painting lines of aquadag on the outside of the glass envelope and connecting the aquadag as an auxiliary anode. The field-emission patterns were observed at various stages as the point filament was heated and cleaned but these patterns were too weak to supply significant data.

The tube is now being used in the study of techniques required to obtain the extremely good vacuum necessary in an experimental project of this kind. The method now under consideration does not involve the use of a getter when the tube is sealed off the vacuum system. Instead, an ionization gauge is sealed off with the experimental tube, and the operation of this gauge serves to clean up the residual gases. More data are necessary before any conclusions can be drawn, but the results now available indicate that a very good vacuum can be obtained in this manner.

A second experimental tube is now under construction in which the anode will consist of tungsten springs. It is believed that these springs will collect the secondary electrons sufficiently well to eliminate the difficulties experienced in the first tube. M. K. Wilkinson

6. Photoelectric Emission

Work on the photoelectric emission from germanium was resumed in September. An experimental tube has been designed and is now under construction. The tube, possessing spherical symmetry, contains two spherical molybdenum cathodes as sub-strata on which germanium may be deposited, and a third to be used as a control. The anode is a graphite coating painted on the glass envelope. By means of side arms the cathodes are removed from the center of the spherical anode for outgassing by electron bombardment and germanium deposition.

Using spherical geometry, the distribution of total energies of the electrons

$$N(E) = 4\pi m^2/h^3 \, f(E) \int_0^E T(p_x) dE_x$$

where $f(E)$ is the Fermi factor, $T(p_x)$ is the transmission-transition probability and E_x is the energy associated with the component of momentum normal to the surface, may be determined by differentiating the current with respect to the retarding potential. This distribution function contains $T(p_x)$ under an integral sign, and a second derivative of the current would be needed to determine these unknown factors. However, using a tube possessing normal geometry these probabilities do not occur under this integral, i.e.

$$n(E_x) = a4\pi m^2 kT/h^3 \; T(p_x) \; \ln \left[1 + \exp -(E_x - E_o)/kT \right]$$

where a is a new factor containing surface roughness which is indeterminant. The general form of $T(p_x)$ could be found from data on the normal geometry tube and substituted into N(E). This substitution should yield the distribution obtained from the data on the spherical tube except for a multiplicative constant. By this method the transition-transmission probability may be determined and checked.

Future work will be the completion of the spherical tube and the design of a normal geometry tube. H. S. Jarrett

7. Effect of Impurity Surface States on the Photoelectric Threshold in Semiconductors

Experimental work has not yet been started on this project. It is proposed to study the change in the photoelectric threshold of the semiconductor germanium resulting from a surface layer of certain impurity atoms. The threshold is to be measured in the standard manner using plane parallel geometry (by a determination of the minimum retarding potential for zero photoelectric current combined with a simultaneous determination of the contact potential between the photoelectrically sensitive surface and the collecting anode). A P-type impurity atom is to be used. Within this classification lie most trivalent atoms containing closed inner shells. Aluminum has been chosen tentatively as the impurity. By using an effusion method (while keeping the surface to be contaminated at liquid-air temperatures) it is possible to deposit a desired amount of impurity with precision. The amount to be deposited will be of the order of a monolayer.

It is hoped that such an experiment will be helpful in checking current theories of surface states in semiconductors. R. H. Parmenter

Reference

(1) E. S. Rittner, F. K. du Pre and R. A. Hutner, Suggestion regarding emission phenomena in (Ba-Sr)O cathodes, Phys. Rev. 76, 996 (1949).

B. STUDIES WITH GASEOUS DISCHARGE

1. Investigation of Low-Pressure Mercury Arcs

Measurements of probe characteristics in the plasma of the mercury arc have been partially completed. Most of the data has been taken using a plane tantalum probe whose axis can be set parallel or perpendicular to the axis of the tube. The probe is located at the center of the discharge and the supporting stem of the probe is surrounded by a cylindrical tantalum guard. Voltage-current curves are obtained for the probe, and the results are analyzed according to the customary Langmuir-probe method.

In order to control accurately the pressure of the mercury vapor in the tube it was found necessary to submerge the entire tube in a cooling bath of water, instead of merely submerging the bulb containing the mercury-pool cathode as is usually done. With all the tube walls at the same temperature it is found that small droplets of mercury condense on the walls while the discharge is going on, thus insuring that the pressure of the mercury gas in the plasma is the vapor pressure of mercury at the wall temperature. In this manner probe data were taken for water-bath temperatures of 11°C to 62°C, corresponding to mercury-vapor pressures of 6×10^{-4} mm to 3×10^{-2} mm.

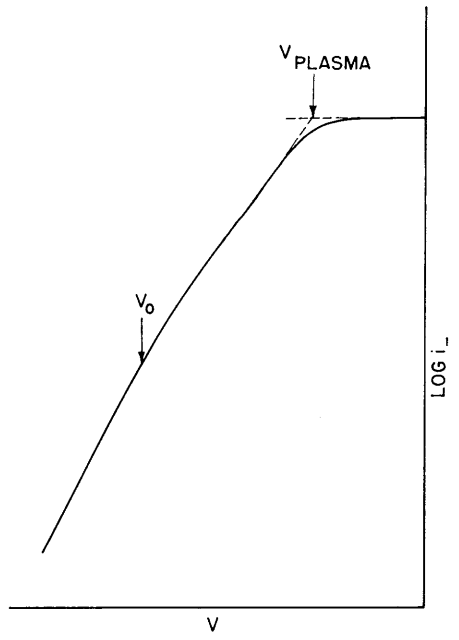


Fig. I-5 Typical probe characteristic curve.

If the distribution of electron energies in the plasma is Maxwellian, then a plot of the logarithm of the electron current i_- to the probe vs. the probe potential V should be a straight line of slope e/kT_- for probe voltages negative with respect to the plasma potential. Over the above range of pressure the actual log i_- vs. V curves exhibit a double slope, as shown in Fig. I-5. This indicates that the actual distribution of electron energies is non-Maxwellian, being characterized by a depletion of the high-energy electrons. The potential V_o of the breakpoint relative to the plasma potential varies from 12 volts at 6×10^{-4} mm pressure to 3 volts at 3×10^{-2} mm. The wide variation of V_o for different pressures would seem to discourage an explanation

of this depletion of fast electrons on the basis of inelastic collisions with mercury atoms resulting in excitation or ionization. It should be remarked too that the probe-characteristic curves were practically independent of the orientation of the probe surface, indicating the predominance of random currents in the plasma.

Measurements were also taken using a second plane probe at the center of the discharge. In this case the probe was surrounded by a guard ring as before; the gap between the edge of the probe and the guard ring was several tenths of a millimeter. The log i_- vs. V curves for this probe were the same as those previously described.

It is interesting to note that the current to the probe for any given probe voltage is found to be independent of the voltage applied to the surrounding guard (at least as long as the guard potential is negative enough with respect to plasma potential that the guard does not collect more than about one-tenth of the saturation electron current and hence noticeably deplete the plasma). This indicates that the probe is surrounded by a very thin sheath, and that outside the sheath the plasma is undisturbed by the presence of the probe, regardless of the probe potential.

The mercury-arc tube, after having developed a leak, is now being reprocessed, and a cylindrical wire probe will be added in order to furnish additional data. R. M. Howe

C. EXPERIMENTAL TECHNIQUES

1. Spectral Emissivity of Tungsten

Some progress has been made in the construction of an experimental tube to be used in determining the spectral emissivity of tungsten. The tungsten sample is in the form of a right circular cylinder 3 15/16 in. long, 0.125 in. in diameter, and having a wall thickness of approximately 0.001 in.

The design of the tube requires that this cylinder be welded at each end to solid tungsten rods 0.125 in. in diameter which are tapered very slightly so that they will slide inside the cylinder and fit snugly. The cylinder thus laps over the ends of the rods for a distance of about 3/16 in. To prevent oxidation these welds must be made in an atmosphere of inert gas. Therefore the parts to be welded are mounted in a bell jar completely open at the bottom so that hydrogen can be fed in at the top and allowed to stream out continuously at the bottom while the welding is going on. The hydrogen is passed through concentrated sulphuric acid before being

admitted to the bell jar.

The work is heated by drawing an arc between a carbon electrode and the parts to be welded. We have been successful in making several of these welds so that they were quite strong and serviceable and the following points have been established as the result of considerable experimentation.

(a) It is best to use about 550 volts d-c and limit the current with suitable series resistances. With this voltage it is possible to draw an arc about 3/16 in. long which can be managed quite easily.

(b) Tungsten parts such as those described above can be welded best if the series resistances total 180 ohms. With this value of resistance the arc current is approximately 2.5 amp since the resistance of the wiring, the carbon electrode, and the resistance of the arc total about 40 ohms.

(c) The correct polarity is that which makes the carbon electrode negative with respect to the work.

(d) It is extremely important that the parts to be welded be shaped carefully so that they are in close contact with one another. There are several reasons for this. In the first place, very little free metal can be supplied for the joint, therefore the parts must be in close contact so that when they reach the melting point they will be able to fuse together without having to flow very far. Second, heat must be supplied to the thinner of the two parts, that is, to the cylinder, mainly by conduction across the boundary, and any gap between the two will prevent the cylinder from reaching its melting point. The arc must never be allowed to touch the cylinder. If it does, it will merely break away a small flake of it.

(e) Conduction of heat from the rod to the cylinder can be aided by wrapping 30 in. of 1-mil tungsten wire around each of the two joints so that it fits snugly half on the rod and half on the cylinder. This metal also supplies additional material for the joint.

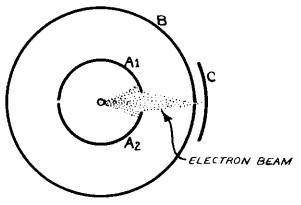
It is hoped that the tube may be completed soon so that preliminary data on the spectral emissivity of tungsten may be presented in the next quarterly report. W. B. Nottingham, L. E. Sprague, L. D. McGlauchlin

2. The Voltage Comparator Tube

The voltage comparator tube is a specialized type of vacuum tube designed to indicate precisely an output whenever two input voltages are equal. The input voltages each may be varying in a different manner with time, and their magnitudes may differ by as much as 300 volts. It is thought that such a tube might have practical application in certain types of analogue computers where an accurate time-marking pulse is desired to

indicate the instantaneous voltage equality of two inputs.

The voltage comparator tube uses a system of electron focusing as its principle of operation. A cylindrical, slotted electron lens structure is enclosed in a glass envelope of 1-in. diameter, which may be mounted on an octal tube base. A 40-mil nickel sleeve is surfaced with a narrow strip of oxide cathode coating. Concentric to the cathode are two anodes A and B (Fig. I-6). Anode A is split into two equal and insulated sections, A1 and A2, with a focusing aperture of about 30°. Anode B has an exit slit whose width is closely equal to the cathode width, about 0.05 cm. Finally, just beyond the exit slit is the collector anode C. If the interelectrode voltages are adjusted correctly, a beam of electrons leaving the cathode will be focused sharply at the exit slit and reach the collector anode; but if the voltage on anode A_1 is slightly different from the voltage on A_2, the beam will be deflected to one side of the exit slit and will no longer reach the collector anode.



TOP VIEW
OF THE VOLTAGE COMPARATOR TUBE

Fig. I-6 Top view of voltage comparator tube.

An approximate formula for the focal length of such a cylindrical lens system as employed here was stated by Davisson and Calbick as

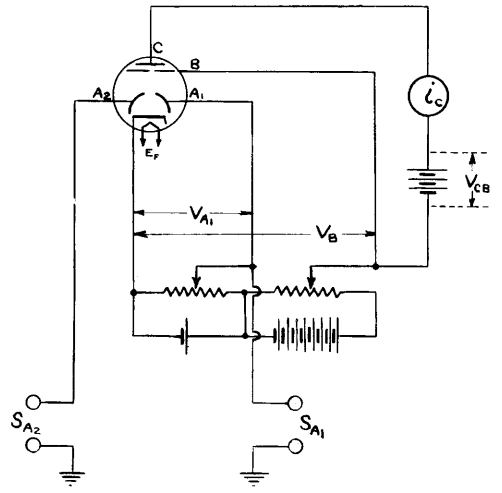
$$f = \frac{2V_A}{E_A - E_B}$$

where (considering for simplicity of explanation that the cylinders are not yet slotted) V_A is the difference of potential between anode A and cathode; E_A is the electric field intensity at the inside surface of anode A resulting from the difference of potential between anode A and cathode; and E_B is the electric field intensity at the outside surface of anode A resulting from the difference of potential between anode B and anode A.

The basic test circuit for the voltage comparator tube is shown in Fig. I-7. Note that the entire tube rides above ground by whatever voltage value signal S_{A1} takes on instantaneously. When $S_{A1} = S_{A2}$, an output current i_c may be observed in the collector circuit.

The determination of the conditions for optimum focusing requires much experimentation because of the number of parameters involved, i.e. heater voltage and the three anode voltages. It was found necessary, for example, to operate the heater at a voltage well below the normal value of 6.3 volts in order to avoid excessive space charge which would broaden the

apparent object of the electron lens system and consequently the all important image itself. For best sensitivity V_{A1} is kept small (less than a volt) so that any difference of voltage between A1 and A2 will more readily deflect the low-energy electrons. To determine optimum focusing conditions for particular values of voltages on the heater, anode A and anode C, curves were plotted of $i_c/i_c + i_B$ vs. V_B; hence, there was found a particular value of anode B voltage for which this ratio was a maximum.



BASIC TEST CIRCUIT

Fig. I-7 Basic test circuit.

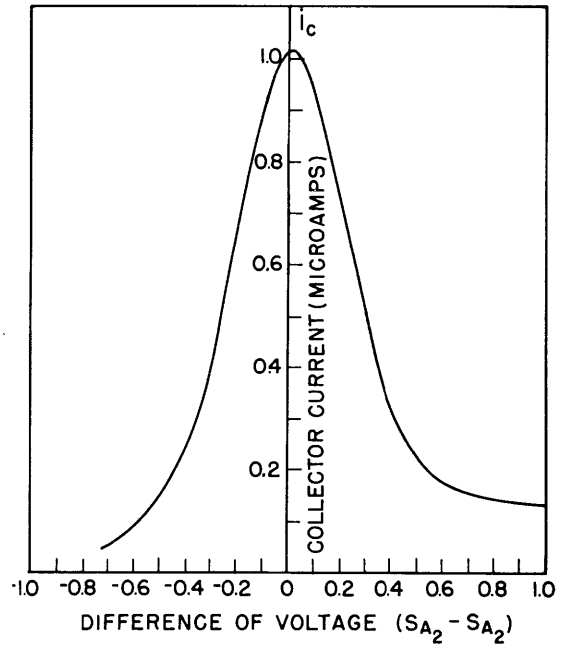


Fig I-8 Sensitivity curve. E_F = 3.5 volts V_{a1} = 0.75 volts V_B = 9.0 volts V_{CB} = 20.7 volts.

At conditions of optimum focusing a sensitivity curve may be plotted — collector current as a function of the difference of voltage between anode A1 and anode A2. A typical sensitivity curve is shown in Fig. I-8. If, now, in place of the i_c meter in the test circuit, a load resistor is inserted and the voltage developed across this resistor is fed through a two-stage d-c amplifier, the sensitivity curve may be clipped preferentially at the top with the final output from the amplifier indicating voltage equality of signals S_{A1} and S_{A2} within one-tenth of a volt.

The static characteristics of this voltage comparator tube have been quite completely determined. It was felt that rather than proceed further with the design of practical circuits demonstrating the timimg precision for which the tube may be adapted, it would be better to make an attempt to modify the original tube design in order to improve certain characteristics. The focusing aperture will be reduced in

width so as to improve resolution and will have the engineering refinement of edges bent in slightly toward the center. Anode A will be a solid element rather than split as before. A pair of very narrow deflection plates will be located just outside of the focusing aperture and shielded from the direct beam of electrons by anode A; thus the input resistance will be increased. The other electrodes will be similar to those of the first tube.

B. T. Joyce

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