

CHAPTER - II

EXPERIMENTAL TECHNIQUE

Apparatus utilised.

1. Arc tube.
2. D.C. ammeter.
3. High Current rheostats.
4. A number of electric fans.
5. An electronic multimeter with high input impedance.
6. A double-stage rotary vacuum pump.
7. Pirani gauge.
8. Needle valve.
9. A radio-frequency oscillator.
10. Stabilised D.C. Power supply.
11. Radio-frequency milliammeter.
12. A variable condenser supplemented with a vernier condenser.
13. Digital counter-timer.
14. Absorption wave meter.
15. An L.C.R. Bridge.
16. Meter Bridge.
17. P.O. Box.
18. Solenoid coils of an electromagnet (without pole pieces).
19. Gaussmeter.

Determination of azimuthal radio-frequency conductivity and its radial distribution function in an arc plasma.

Arrangements:

In the present diagnostic study a new radio-frequency coil probe technique has been developed to find the azimuthal radio-frequency conductivity and its radial distribution function ⁱⁿ of a mercury arc plasma. The arc has been produced in an arc tube (Fig.2.1) made of Pyrex glass. Besides the two tungsten electrodes at its two ends, the tube also consists of two tungsten probes (immersed upto the axis of the tube) stuck in the positive column region with a separation of 6.35 cms. between them and a small coil of length 6 cms. has been wound around the body of the tube in this probe-to-probe gap. This coil serves the purpose of radio-frequency power induction from the externally used high frequency oscillator which has been fed from a D.C. Stabilized power supply. Analytical quality of tripple-distilled mercury has been used here to produce the mercury arc. A double-stage rotary vacuum pump has been utilised to maintain the system a desired vacuum mark and a needle valve has been used in the line to control the degree of vacuum. In case any quantity of mercury comes up and contaminates the pump fluid, precautions have been taken by using several glass traps in the vacuum line. A Pirani Gauge was kept always fitted with the system to relay the vacuum situation. The arc has been operated by a high current D.C. voltage Generator.

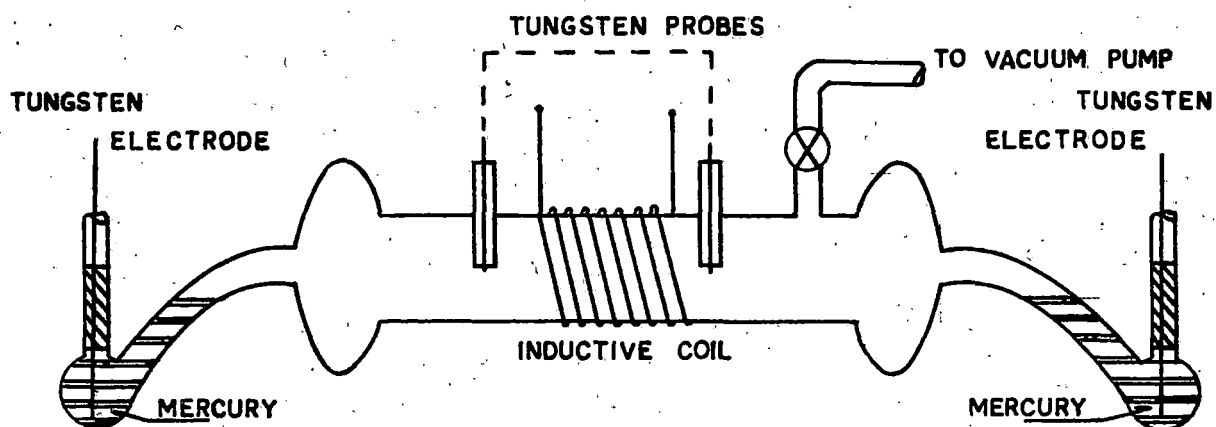


FIG.2'1. DIAGRAM OF A MERCURY ARC TUBE.

To control the arc current several high current rheostats have been used in series with a D.C. ammeter (Range: 0 - 5A). A radio-frequency milliammeter ranging 0 - 120 mA (Thermocouple type, made by Weston Instruments, Inc., U.S.A. Model No. 508) in series with a microcondenser kept for the purpose of tuning have been connected at the two leads of the coil wound around the arc tube. These three elements connected in series serve the purpose of the secondary circuit in the present study.

It will be seen in the subsequent chapter that when r.f. power is induced in the coil inside which the arc is produced, the effective resistive impedance of the coil can be written as

$$R' = R_0 + \frac{E_2^2 C^2}{(C_0 + C)^2 + \omega^2 R_2^2 C_0^2} + \frac{\omega^2 M^2}{R_1^2 + \omega^2 L_1^2} R_1$$

where R_0 = Coil resistance (ohm); C_0 = value of the tuning capacitor (farad); C = Stray capacitance (Farad) formed between the coil and the plasma column; R_2 = axial plasma resistance (ohm); R_1 = azimuthal plasma resistance (ohm); ω = angular frequency (radian); L_1 = eddy secondary inductance (Henry); L = Coil inductance (Henry); M = Mutual inductance (Henry), of L and L_1 . The last term expresses the reflected resistance in the coil due to the eddy current flowing through the plasma.

In case of arc phenomena, the above expression reduces to,

$$R' = R_0 + \frac{\omega^2 M^2}{R_1}$$

i.e., the azimuthal conductance may be given by,

$$G_1 = \frac{1}{R_1} = \frac{R_0}{\omega^2 H^2} \left[\frac{R_1}{R_0} - 1 \right]$$

So, if i_0 and i_1 be the tuned radio-frequency currents through the coil before and during the discharge respectively, the azimuthal conductance may alternatively be written as,

$$G_1 = \frac{R_0 (\alpha - 1)}{\omega^2 H^2}, \text{ where } \alpha = \frac{i_0}{i_1}$$

From this expression the azimuthal conductivity (G_s) simply comes out to be,

$$G_s = \frac{\pi}{l} \frac{R_0}{\omega^2 H^2} (\alpha - 1), \text{ } l \text{ being the length of the coil.}$$

Thus, only knowing the value of α i.e., only noting down the two tuned radio-frequency currents before and during the discharge, it is possible to calculate the azimuthal conductivity of an arc plasma and the same observation can be repeated for different discharge currents.

It will be revealed afterwards that the same measurement of ' α ' will lead also to find the radial distribution function for the azimuthal conductivity of an arc plasma.

Circuit constants:

Length of the arc tube = 30 cms.

Outer diameter of the tube = 1.9 cms.

Anode - Cathode Spacing = 20 cms.

Coil length = 6 cms.

Coil diameter = 1.9 cms.

Wire diameter = 1 mm.

Number of turns in the Coil = 50

Probe to Probe Separation = 6.35 cms.

Experimental Procedures:

As a preparation to produce the mercury arc in the glass tube, firstly the tube has been thoroughly washed with dilute chromic acid and then with NaOH Solution. After these chemical baths the tube has been washed several times with distilled water and after that with dehydrated pure benzene and then dried thoroughly. Finishing these operations, tripple-distilled mercury has been poured into the tube to the desired level. The tube is then connected to a double-stage rotary vacuum pump. Time was allowed to pass till the system reaches a vacuum of the order of 10^{-2} Torr.

Now the oscillator Coil is placed near the work Coil i.e., the Coil wound around the tube and the induced r.f. voltage is tuned with the variable condenser which is supplemented by a vernier condenser placed in the secondary circuit in series with a r.f. milliammeter and the work coil.

Arc is then produced inside the tube by following the tilting process. Obviously the meter indicator shifts from its previous position. The tuning condition is once more checked by the condenser. A number of fans have been used for cooling the arc and maintain a steady temperature. The r.f. meter reading is then noted as far accurately as possible. This current reading is then noted as far accurately as possible. This current reading is i_1 . At the same time the dial reading of the variable condenser i.e., the value of the capacitance (Say C') is noted down. Now without disturbing any element of the experiment, the arc is then switched off. The meter indicator again shifts from its foregoing position. The ~~wiring~~ tuning condition is again checked by the variable condenser. The tuned current and the value of the capacitance (i.e., C_0) are noted. This current reading is i_0 . It will be seen afterwards that the difference between C' and C_0 gives the value of the stray capacitance (i.e., C). At every stage of the experiment the voltage across the two probes fitted in the positive column of the arc tube has been noted with the help of an electronic multimeter with high input impedance. The purpose of keeping these voltage readings is to compare the value of azimuthal conductivity found by the present process with the axial conductivity values measured, using the relation,

$$\sigma_z = \frac{I_z}{\pi r^2 E_z}$$

where E_z is the field in the positive column, I_z is the discharge current and r is the internal radius of the tube. The further importance of measuring the probe-to-probe voltage will be found in the subsequent chapters.

It is worth while to mention here that once the arc is formed, the tube ^{placed} ~~stranded~~ and the secondary circuit tuned, extreme precautions have been taken such that no element is disturbed any more till one set of observations is over. A very good care has been taken such that no mercury droplet could appear inside the tube in the coil region during the whole observation, the presence of which changes the situation quite a lot. The above experiment is repeated several times keeping the discharge current and the frequency of the oscillator in a fixed position. The discharge current is then varied to some other value with the help of rheostats connected in series with the D.C. supply and the experiment is repeated as described above. Thus for different discharge currents the ratio α' is measured for a single frequency. Now varying the frequency of the oscillator the whole experiment is repeated for different discharge currents.

R.F. Oscillator circuit and calibration of its condenser dial with frequency.

The radio frequency oscillator used here is of Hartley type and the circuit diagram is shown in the Fig.(2.2a). It has been designed to cover a range of 1.45 MC/Sec. to 5.16 MC/Sec. The inductance L of the tank circuit is divided into two parts L_1 and L_2 and their common point is connected to the Cathode terminal of the vacuum tube 6L6. The end of L_1 is connected to the grid through the parallel combination of R_g and C_g .

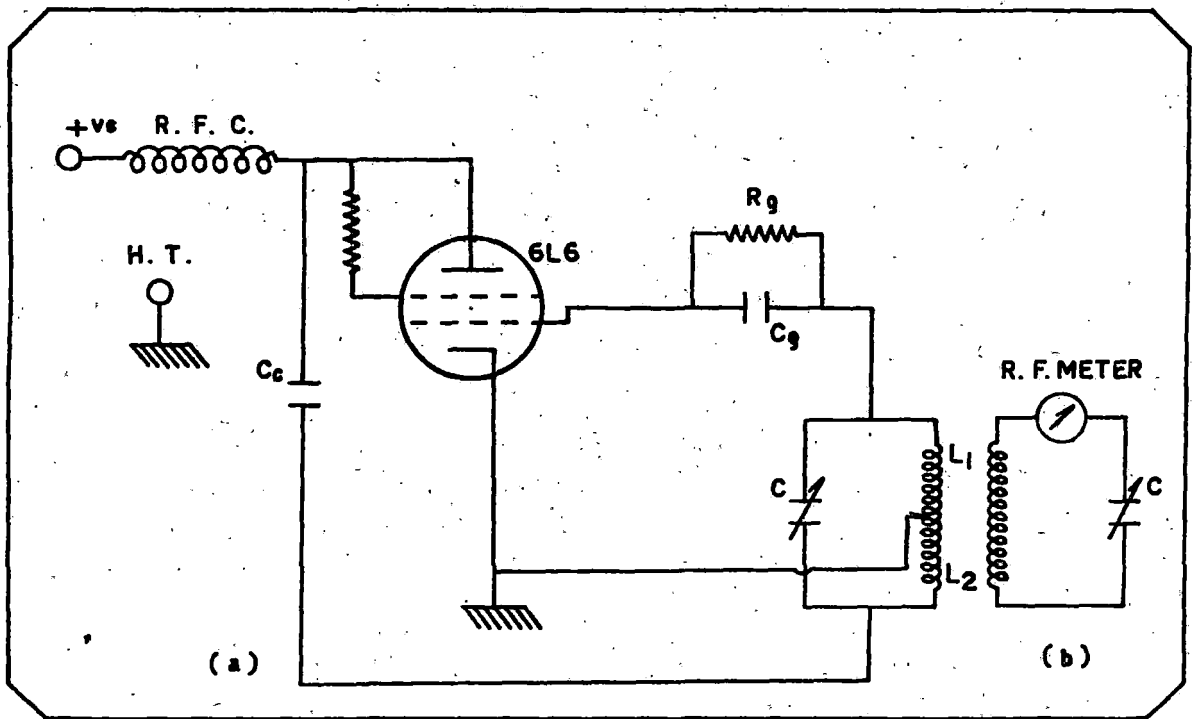


FIG.2'2. RADIO FREQUENCY OSCILLATOR CIRCUIT - (a).
 SECONDARY TUNING CIRCUIT - (b).

which provides the grid bias voltage. The end of L_2 is connected to the plate of the oscillator valve 6L6 through the blocking condenser C_c . Another variable condenser C is placed in parallel with the inductance L_1 , thereby making a complete tank circuit. The current circulating in the resonant circuit passes through both portions of the inductance and develops a voltage for the grid excitation. The connection of the plate voltage supply is known as the shunt feed. The direct component of the plate current is supplied from a stabilized¹ power supply through a radio frequency choke. The blocking capacitor C_c , which has a small reactance compared with the load impedance, allows a path to the a.c. component, while the d.c. from the power supply is prevented. The gang condenser dial has been calibrated against frequency by the help of a digital counter-timer (Model 701, made by "Systronics", India) as well as checked further by an absorption wavemeter. The secondary receiving circuit, as discussed earlier, consists of the coil wound around the arc tube, a variable tuning condenser (supplemented by a vernier condenser ^{for} ϵ improving the tuning accuracy) and a radio frequency milliammeter, all connected in series (Fig. 2.2b). The dials of both the condenser in the receiver circuit have been calibrated in terms of capacitance by the help of an L.C.R. bridge. The dial readings against capacitance values are shown in Figs. (2.3, 2.4) and 2.5).

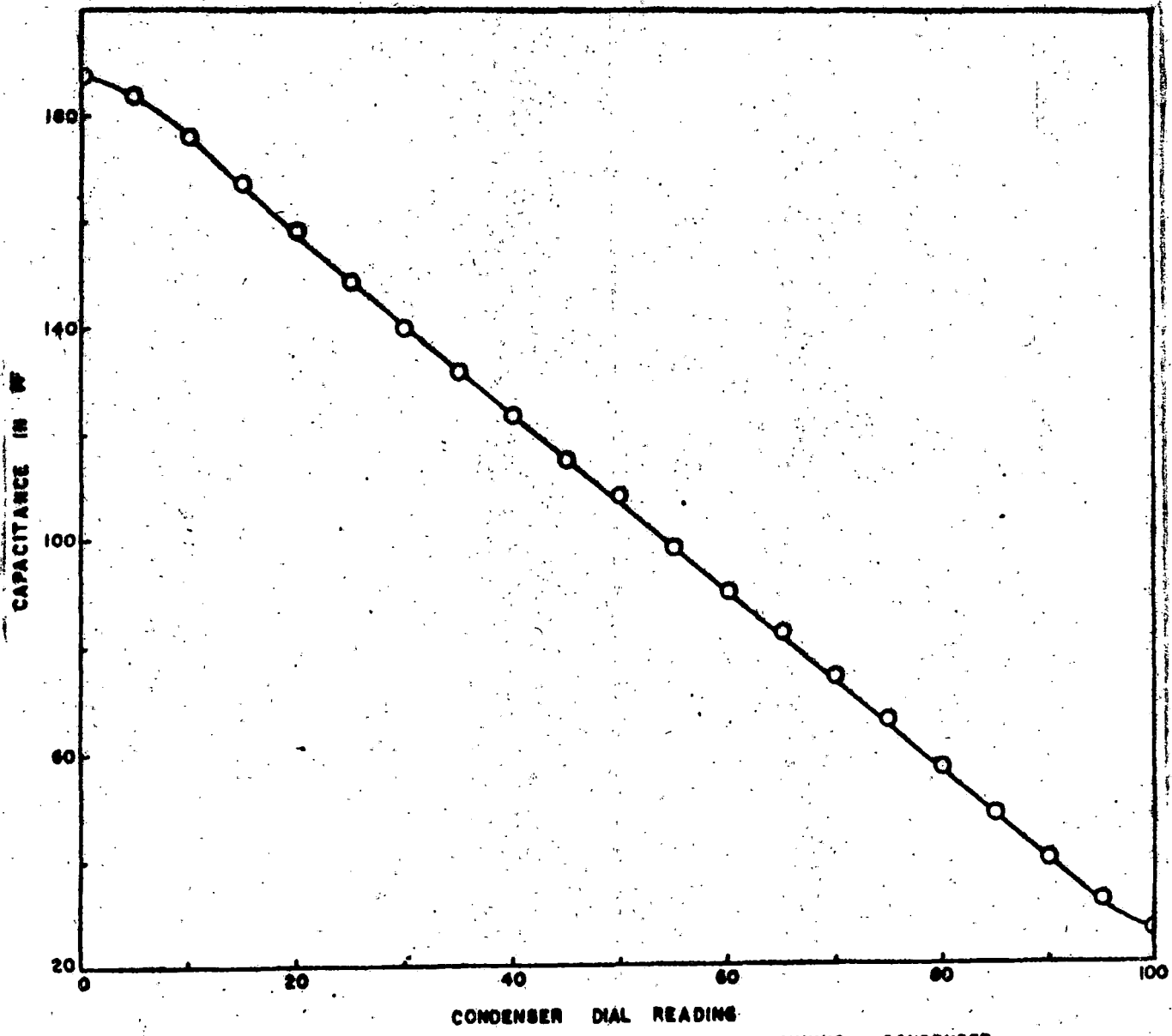


FIG. 2'3. CALIBRATION OF THE VARIABLE TUNING CONDENSER IN THE RECEIVER CIRCUIT.

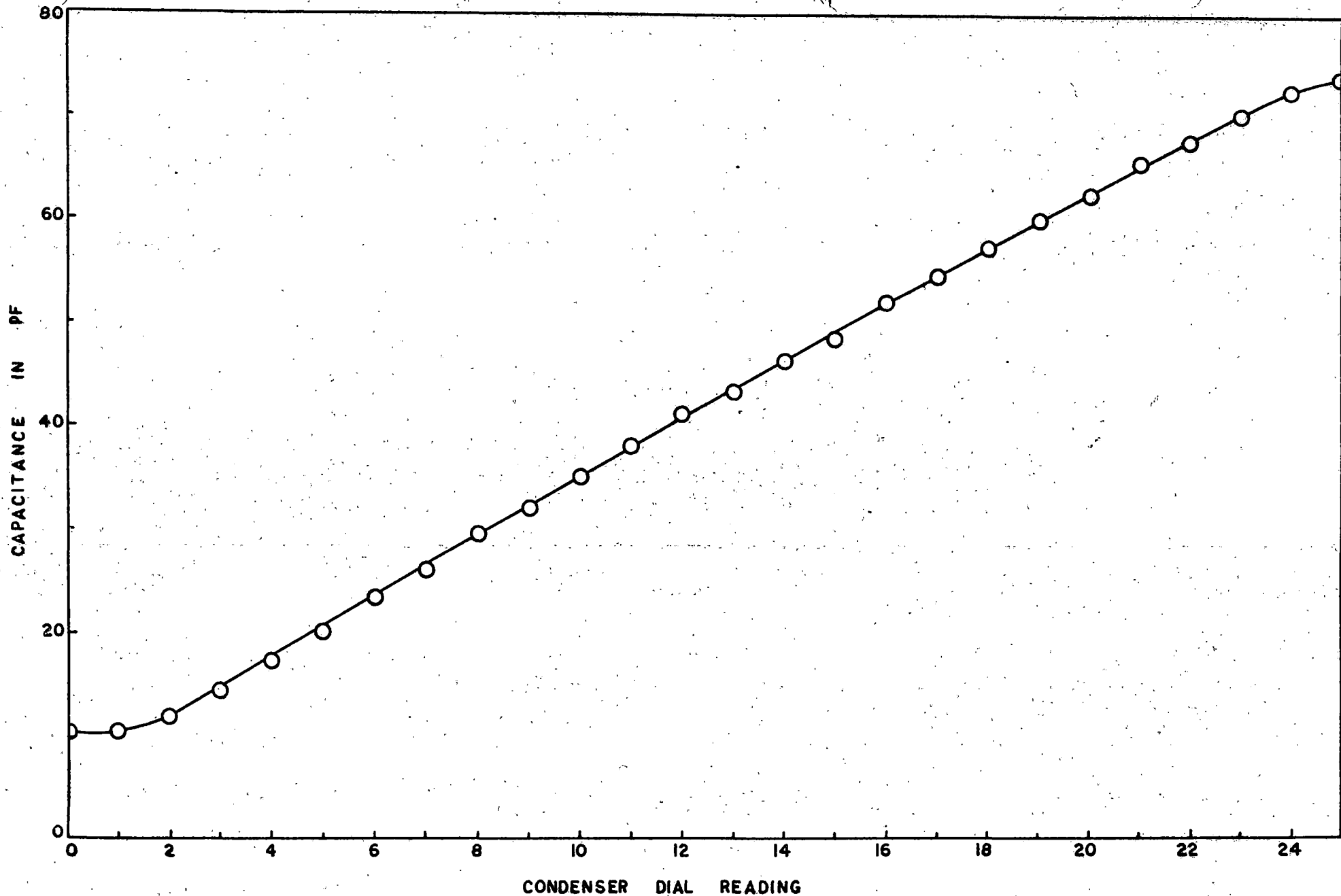


FIG. 24. CALIBRATION OF THE VERNIER CONDENSER IN THE RECEIVER CIRCUIT.

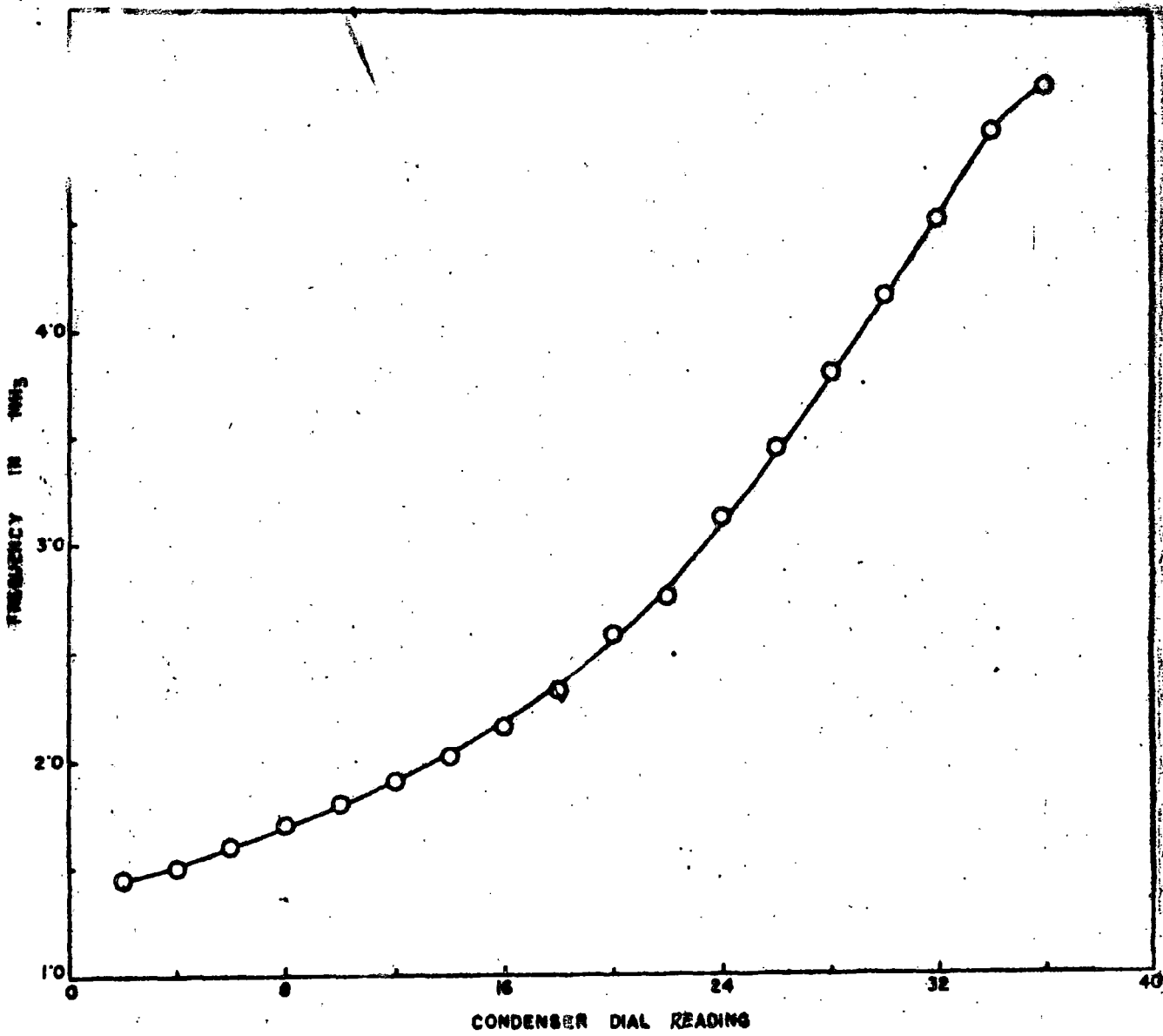


FIG. 2'S. OSCILLATOR FREQUENCY CALIBRATION.

Table 2.1

Dial Calibration of the variable tuning
condenser in the receiver circuit.

Dial reading in degree	Capacitance in PF	Dial reading in degree	Capacitance in PF
00	187.3	55	98.8
05	183.8	60	90.0
10	176.0	65	82.5
15	167.2	70	74.0
20	158.0	75	66.0
25	148.7	80	57.0
30	140.0	85	48.0
35	131.5	90	39.8
40	123.2	95	32.0
45	115.0	100	26.3
50	108.0		

Table(2.2)

Dial Calibration of the variable condenser
in the receiver circuit.

Dial reading	Capacitance in pF	Dial reading	capacitance in pF
0	10.5	13	43.2
1	10.5	14	46.3
2	11.0	15	49.5
3	14.3	16	52.0
4	17.3	17	54.5
5	20.0	18	57.2
6	23.2	19	60.0
7	26.0	20	62.3
8	29.5	21	65.5
9	32.0	22	67.5
10	35.0	23	70.0
11	38.0	24	72.5
12	41.0	25	75.3

Table (2.3)

Dial calibration of the condenser in the oscillator tank circuit against frequency.

<u>Dial reading of the condenser</u>	<u>Frequency in MC/S</u>
2	1.45
4	1.50
6	1.60
8	1.70
10	1.79
12	1.90
14	2.02
16	2.15
18	2.32
20	2.53
22	2.75
24	3.15
26	3.44
28	3.81
30	4.17
32	4.53
34	4.95
36	5.16

Measurements of Inductances L and M.

Two methods have been used here to measure the value of the coil inductance (work coil). One of them is the direct measurement by an LCR Bridge and the other by using the formula,

$$L = \frac{C \cdot a^2 \cdot n^2}{b} \cdot k \quad \text{where } C = \text{const.}$$

= 0.039 for a single layer coil.

a = Radius of the coil in cm.

b = Length of the coil in cm.

n = Number of turns and ~~k~~ is

and k is a function of $\frac{2a}{b}$

= .8781 in this case.

After calculating the value of L, now the value of the mutual inductance M has been estimated assuming plasma inductance to be a secondary with turn unity and having an average cross-section equal to half the inner cross-section of the tube (Simpson 1960).

Measurement of radio frequency resistance of the secondary tuning circuit and its theory.

The method used here for determining the radio frequency resistance may be called as reactance variation method. The secondary tuning circuit consists of an inductance

(the coil wound around the positive column), a variable condenser and a radio-frequency milliammeter^a. All the components and r.f. meter are connected in series. A vernier condenser is fitted in parallel to the above condenser in order to note the capacitance value more accurately. The secondary receiving circuit is loosely coupled to the radio frequency oscillator, (Hartely type), which is the driving oscillator of desired frequency (Fig. 2.2a). The secondary tuning circuit is tuned to the desired frequency of the driving oscillator by proper adjustment of the tuning condenser. The resonant current I_0 in the r.f. milliammeter and the value of the capacitance of the tuning condenser are noted. Then the value of the capacitance in the condenser is changed to some other value C_2 by rotating its dial, so that the current in the r.f. meter I_1 becomes $\frac{1}{2}$ times of the resonant current I_0 i.e., 70.7% of I_0 . After that the capacitance value of the condenser is again changed to C_1 by rotating its dial in the opposite direction, so that the current in the r.f. meter becomes again equal to I_1 . The readings for C_2 and C_1 are noted.

When the secondary circuit is sharply tuned to the desired frequency, the induced voltage in the secondary circuit becomes equal to E_0 .

$$\text{Therefore, } E_0 = I_0 \cdot R_0, \quad (2.1),$$

where R_0 is the radio frequency resistance of the circuit. With the circuit in detuned condition, if the change in reactance value is Δx , the series impedance will be $(R_0 + j\Delta x)$ corresponding to the r.f. current I_1 .

This leads to,

$$\frac{I_0}{I_1} = \frac{\sqrt{R_0^2 + \Delta x^2}}{R_0} \quad (2.2)$$

or

$$\frac{I_0^2}{I_1^2} - 1 = \frac{R_0^2 + \Delta x^2}{R_0^2} - 1 \quad (2.3)$$

or

$$\frac{I_0^2 - I_1^2}{I_1^2} = \frac{\Delta x^2}{R_0^2}$$

or

$$R_0^2 = \Delta x^2 \left(\frac{I_1^2}{I_0^2 - I_1^2} \right) \quad (2.4)$$

The slight change of reactance at the upper half and lower half of the maximum power are respectively,

$$\Delta x = \omega L - \frac{1}{\omega C_2} \quad (2.5)$$

$$\text{and } \Delta x = \frac{1}{\omega C_1} - \omega L \quad (2.6)$$

where $\omega = 2 \pi f_r$, f_r = resonant frequency. Combining equations (2.5) and (2.6) we get,

$$\Delta x = \frac{C_2 - C_1}{2 \omega C_1 C_2} \quad (2.7)$$

Putting this value of Δx in equation (2.4)

$$R_o^2 = \left(\frac{C_2 - C_1}{2 \omega C_1 C_2} \right)^2 \frac{I_1^2}{I_o^2 - I_1^2}$$

or

$$R_o = \frac{C_2 - C_1}{2 \omega C_1 C_2} \sqrt{\frac{I_1^2}{I_o^2 - I_1^2}} \quad (2.8)$$

Thus knowing the values of C_2 , C_1 , I_1 and I_o , the radio-frequency resistance R_o of the circuit has been calculated by using the equation (2.8).

To have a check of this value of R_o , the d.c. resistance of the r.f. meter has been measured by an LCR Bridge with an apprehension that the resistive contribution of the other elements in the network will not be a significant amount (as their dimensions were negligibly small) and also keeping the fact in mind that the r.f. meter resistance does not alter with the frequency utilised. And in fact, it has been found that the value of the r.f. resistance of the whole network, measured by the reactance variation method, is only slightly greater than the d.c. resistance value of the meter, which was quite in good agreement with the expectation.

Investigation of the heat flow mechanism active in the positive column of a low pressure mercury arc.

The experimental arrangements set here remain almost same as the earlier ones except with slight modification in the design of the mercury arc tube. Though the present tube

has some other differences in its constructional features from the earlier one, the dimensions of the main tube have been kept same, so that some experimental data from the previous works can be used here without error. A glass^a condenser of length 20 cms. is fitted along the mid-portion of the tube with an aim to pass water around the positive column of the mercury arc. The temperature of this outflowing water has been measured with an ordinary mercury thermometer fitted with the condenser. Besides this, a glass capsule containing a small platinum wire coil has been placed at the axis of the tube, and the two leads of the coil are kept outside the tube. This arrangement combined with the use of a meter bridge and a P.O.Box served the purpose of a platinum resistance thermometer which measured the temperature at the axis of the arc tube at different discharge conditions. Here also a double-probe arrangement has been used to measure the voltage across the positive column, and one of these probes has been employed to measure the electron temperature following the standard technique.

The experimental procedure is quite straight forward. The platinum resistance thermometer is first calibrated and water is flown through the condenser. The arc is then drawn along the tube. Some time is allowed to pass to achieve the thermal equilibrium of the platinum thermometer at the axis. The temperature of the platinum reads T_{no} which is the temperature at the axis. The mercury thermometer reads the temperature θ of the outflowing water. Now due to finite conductivity of

glass this θ will not be the actual temperature of the plasma at the periphery. Knowing the thickness and conductivity of glass of the tube, the actual peripheral temperature T_{nw} is calculated. The same experiment is repeated for different discharge currents. In each case the rate of supply of heat \dot{q}_0 is calculated by knowing the discharge current and the voltage across the plasma column under study.

Electron temperature measurement by an electrostatic (Langmuir) Probe.

The method for determination of electron temperature by an electrostatic probe is based on the polarization of a plasma. A metal probe (viz., tungsten) is inserted into the plasma (Fig.2.6) and the current to the probe is measured as a function of the probe potential (volt-ampere characteristic, Fig.2.7). In Fig.2.6, C and D are two electrodes (anode and cathode) of the discharge tube in which the gas discharge is excited, P is the electric probe, V and A are the voltmeter and ammeter respectively which give the volt-ampere characteristics. Below the figure is the source of the voltage applied to the probe and a potentiometer arrangement to vary the voltage.

An important property of plasmas emerges clearly in the probe method: Plasmas do not obey Ohm's law. The current is determined simply by the magnitude of the charge which is transported by the positive potential. The current is found to approach a limiting value, called the saturation current, which is independent of potential and is determined by the charge which is transported by the electrons that strike the surface

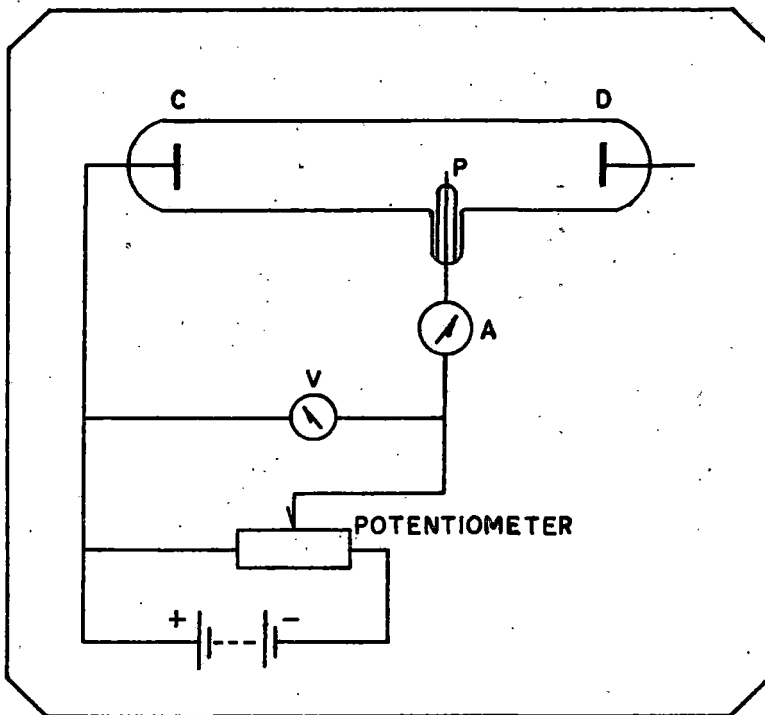


FIG. 2'6. SCHEMATIC EXPERIMENTAL ARRANGEMENT FOR MEASURING ELECTRON TEMPERATURE.

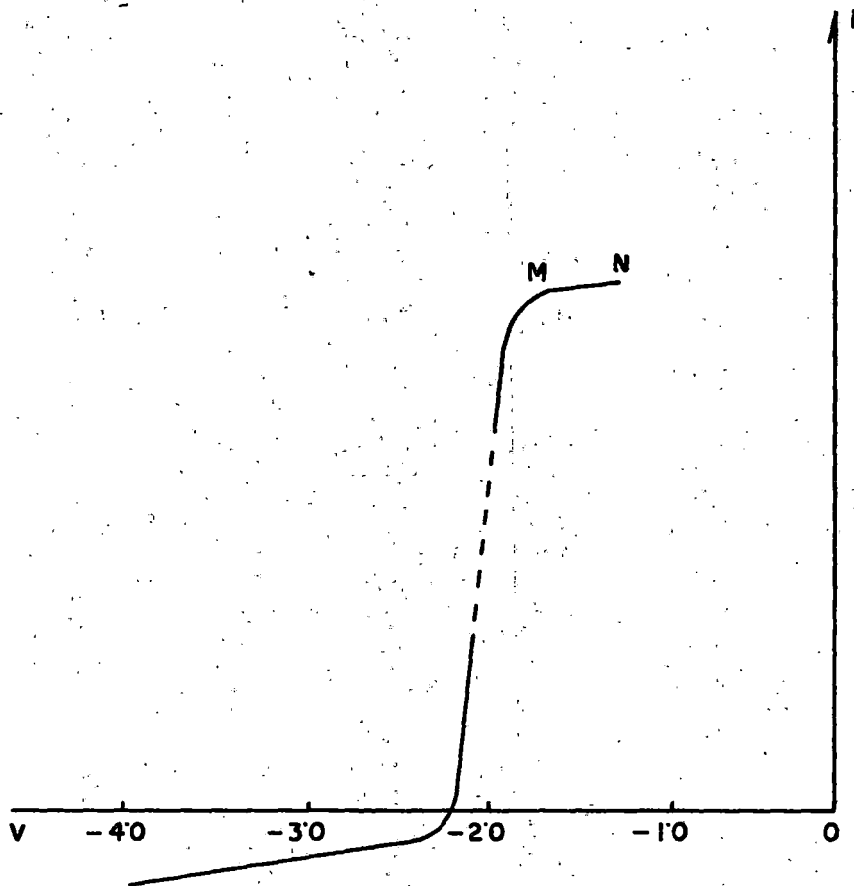


FIG. 2'7 . VOLT - AMPERE CHARACTERISTIC OF A LANGMUIR PROBE.

of the probe in their thermal motion. This nature of the current of being saturated may be seen from the figure of volt-ampere characteristic (Fig. 2.7) where i is the current to the probe and v is the potential relative to the anode. The segment MN represents the saturation current. The electron temperature can be determined with respect to the volt-ampere characteristic in the region in which the probe has a negative potential relative to the plasma. In this region the probe repels the electrons and the surface of the probe can be reached by only those electrons in the Boltzmann distribution which have energies sufficient to overcome the potential difference $V - V_0$, V is the probe potential and V_0 is the plasma potential. Hence,

$$\ln i = \frac{e}{T_e} V + \text{Const.},$$

where e is the charge of the electron and T_e is the electron temperature in energy units.

By plotting the current i as a function of the potential v on a logarithmic scale, we obtain a straight line over a wide range (Fig. 2.3). The slope of this line allows us to determine the temperature T_e .

The actual values of the electron temperature found in the present experiment may be seen in Chapter VI.

STUDY OF THE CONDUCTIVITY BEHAVIOURS OF A LOW PRESSURE MERCURY ARC PLASMA IN PRESENCE OF A LONGITUDINAL MAGNETIC FIELD

Measurements were made for a mercury arc plasma formed within the same arc tube which was used earlier for the determination of azimuthal radio frequency conductivity and radial distribution function through two tungsten probes fitted in the positive column and the coil wound around the

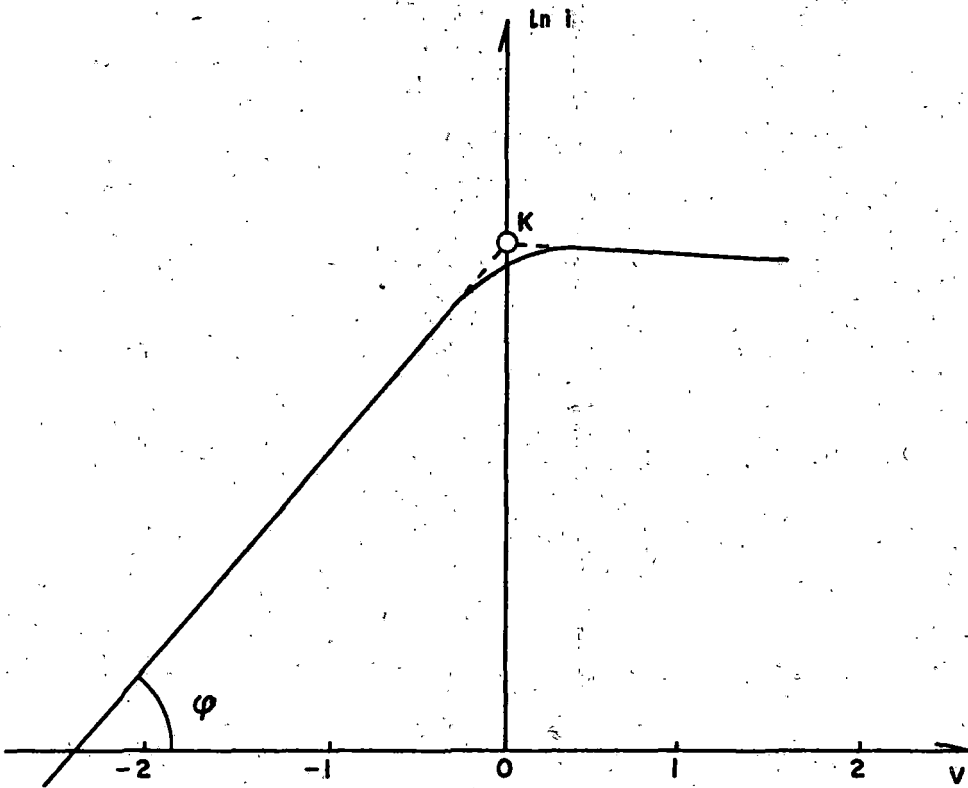


FIG. 2'8 . VOLT - AMPERE CHARACTERISTIC OF A LANGMUIR PROBE AS PLOTTED ON A LOGARITHMIC SCALE.

column. The only difference in the experimental arrangement from the previous one lies in the fact that here a longitudinal magnetic field has been applied along the positive column. For this purpose the two pole pieces of an electromagnet were taken out and the arc tube was placed inside the two coils with its axis parallel to that of the coils which were rested parallel to each other on the table, the distance of separation between the two coils being of the order of 15 - 20 cms. The power to the electromagnet coils was supplied from a D.C. source. A D.C. ammeter (0 - 5 amp.) and rheostats were kept connected in series to note and vary the current in the circuit. The circuitry corresponding to the arc tube was same as before. A schematic experimental arrangement has been shown in Fig. ~~2.9~~^{7.1.}. Before starting the experiment the magnetic field was first calibrated with respect to different currents (Fig. 2.10). Now at ^{the} ~~the~~ start of the experiment a Hall probe was placed perpendicular to the coil axis at the centre i.e. at a point midway between the magnet coils. After energising the coils the magnetic field was measured at different points on the off the axis by moving the Hall probe first along the axis and then across the axis in all directions. It was observed that the magnetic field remained fairly parallel and was uniformly extended upto at least 10 cms at the central position. After being ascertained of the above fact during the experiment the arc tube was placed between the magnetic coils co-axially and the geometry of the whole arrangement was such that the ends of the arc tube could be

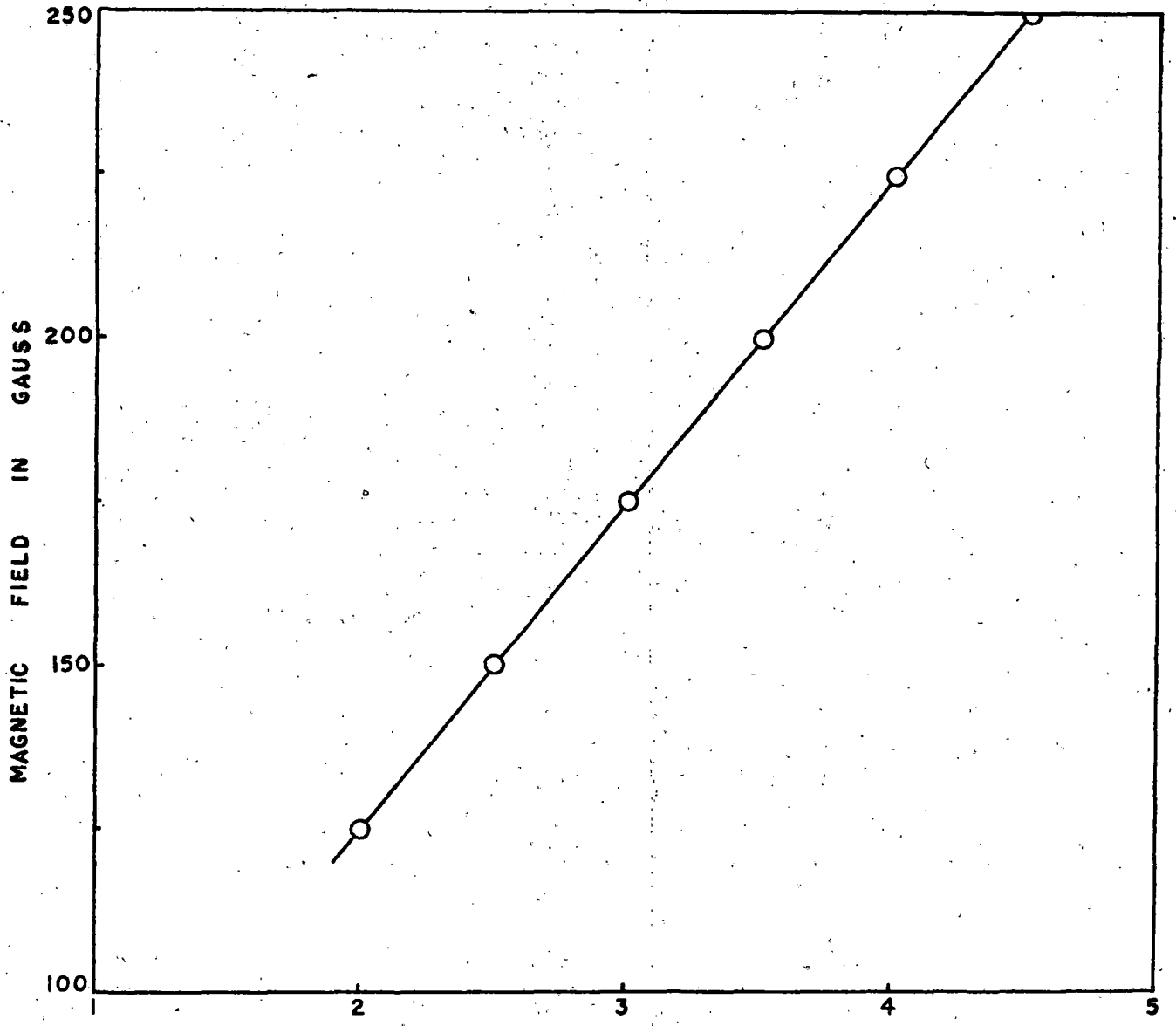


FIG. 2'10. CALIBRATION OF ELECTROMAGNET.

introduced into the bobbin holes and the positive column region which was to be probed, occupied the space where the magnetic fields were parallel and uniform.

Both the magnetizing current and arc current were obtained through the same D.C generator and the currents could be varied by two different sets of rheostats. The coil probe currents ~~on the~~ were noted, as was done previously, both with arc current on and off conditions and also in presence and in absence of magnetic field. It is now worthwhile to describe the sequence of observations and measurements.

(1) The solenoid coils were widely separated so that the arc tube may be tilted freely to get it struck.

(2) As soon as the arc was on, the arc tube and the solenoid coil assembly were replaced in the "proper position".

(3) Rheostats were adjusted to maintain the desired discharge current I in absence of magnetic field.

(4) Magnetising current circuit was turned on and the current was adjusted by rheostats to its desired value I_m and then turned off.

(5) The probe coil was tuned and the r.f. current i , (i.e. the coil probe current in arc-on condition and in absence of magnetic field) was noted.

(6) The probe-to-probe voltage E was also noted in the above condition.

(7) Magnet was turned on/and it was observed that the probe-to-probe voltage and discharge current decreased.

(8) The above quantities (E_B , I_B) were noted and simultaneously the coil probe current i_B (in presence of magnetic field) was also noted. For lower discharge current to avoid extinction of the arc, after sequence (7) the discharge current I_B was immediately adjusted to its previous value I in presence of magnetic field and again E_B and i_B were noted simultaneously.

(9) Operation (7) to (8) were repeated for different magnetic fields.

(10) Both the magnet and the arc were turned off.

(11) The coil probe was re-tuned and the tuned current i_0 (i.e. the coil probe current in absence of plasma) was noted.

The above sequence was then repeated for different arc currents (I). The sequence (7) - (9) was performed within a very short period of time so that the "arc condition" remained unaltered during those sequence of operations. It is now worth while to elaborate the term "arc condition". When the arc is turned on, it soon reaches an equilibrium maintaining a steady current and positive column field depending on the supply voltage, the resistance in series with the arc and the ~~the~~ ambient conditions; the latter determines the temperature and hence the mercury vapour pressure of the arc. It is evident that if the current is varied by changing the resistance (R) in series with the arc, or by some other means, the arc temperature and mercury vapour pressure continue to change until the arc re-establishes its new equilibrium condition. We then say that the "arc condition" has changed. This gradual change of "arc condition" is accompanied by

gradual change in the positive column electric field E (or the probe-to-probe voltage E) ; but if the probe - to- probe voltages are measured immediately after changing the arc currents it is observed that the electric field practically remains constant over a wide range of current variations (2-5 amps), whereas the current-voltage characteristics does not show this type of flatness if the probe voltages are measured in equilibrium conditions. This is because the later measurements are in varying " arc conditions".

It has been observed by experience that if the arc current (2-5 amps) be varied (< 3 amps) the " arc condition" remains practically unaltered for at least 15 seconds from the instant when the change of arc current has taken place. Within this period of time the probe-to-probe voltage remains constant.

Now with regards to coil-probe measurements also, the variation of the quantity $(\alpha - 1)$ (Chapter III) with arc current shows different behaviours depending on whether the measurements are made in the same " arc condition" (fast measurements) or in varying " arc conditions" (slow measurements). In the former case it has been found that $(\alpha - 1)$ is proportional to the arc current 'I'. This situation corresponds to the results discussed in Chapter III. In the next experiment (Chapter IV), every time the arc current was changed, sufficient time was allowed to pass to ensure equilibrium, before any measurements (E and $(\alpha - 1)$) were made. Thus in this case the measurements were made in varying arc conditions and as may be seen, $(\alpha - 1)$ and I did not show the proportionality behaviour.

In the former case since E remains constant for variation of arc currents and since $(\alpha - 1)$ is proportional to I , the quantity $(\alpha - 1) \frac{E}{I}$ and hence the constriction parameter (equations 7.17 and 7.18) becomes independent of I . Now if the magnetic field is turned on the arc current changes; apart from the intrinsic reasons for the change of arc currents there were extraneous reasons also for the present experiment. In our experiment both the arc and the magnet coil was energised by the same power supply. Thus when the magnet was turned on, the supply voltage decreased due to the extra load and the arc current fell and even if the magnetic confining effect is negligible one cannot put $a_p = a'$ to arrive at equation (7.30) provided one assumes that the constriction parameter is independent of current. Of course this assumption may be made, as discussed previously, if the measurements are made in the same "arc condition". Performing the operations (6) - (9) within very short period of time ensures the validity of the last assumption made in arriving at equation (7.30).

The above discussions also indicate that the operation (8) may be performed without questioning the validity of the assumption described by the equation (7.29), provided the "arc condition" is not disturbed. It was found that if the arc currents were in the lower side, the reduction of current due to the application of magnetic field sometimes caused extinction of the arc. To avoid this, immediately after applying the magnetic field, the arc current was adjusted to its original value (operation 8), when necessary.