CHAPTER - II

THE EXPERIMENTAL TECHNIQUES

CHAPTER - II

2.1 DETERMINATION OF AZIMUTHAL RADIO-FREQUENCY CONDUCTIVITY AND ITS RADIAL DISTRIBUTION FUNCTION IN AN ARC PLASMA (REF: CHAPTERS III & IV)

2.1.1 Apparatus

Arc tube (Fig. 2.1)

D.C. ammeter (Sett and Dey, 0-5 Amps.)

High current rheostats (Sett and Dey)

A number of electric fans

An electronic multimeter with high input impedance (Philips, FET input)

A double-stage rotary vacuum pump (Basynth)

Pirani gauge

Needle valve (Hind-Hi-Vac. precision type)

A radio-frequency oscillator (Hartley type, made in the laboratory)

Stabilized D.C. Power Supply (made in the laboratory)

Radio-frequency milliammeter (Weston, thermocouple type, 0-120mA)

A variable condenser supplemented with a Vernier condenser

Digital Counter-timer (Systronics, Model No.701)

Absorption wave meter

An L.C.R. Bridge (Marcony Instruments)

2.1.2 <u>Experimental Arrangements</u> :

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 of a mercury arc plasma. The arc has been produced in an arc tube made of Pyrex glass (Fig. 2.1)and also(Fig. 3.3 Chapter III). Besides the two tungsten electrodes at its two ends, the tube also consists of two tungsten probes (immersed upto the axis of the tube) fitted in the positive column region with a separation of 6.35/4.55 cms. between them and a small coil of length 6 cms. has been wound around the tube within this probe-to-probe gap. This coil serves the purpose of radio frequency power induction from the externally used r.f. 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 utilized to maintain the system a desired vacuum mark and a needle valve has been used in the vacuum 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 (15 amps.) d.c. generator. 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.308) in series with a Vernier condenser 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 tank circuit in the present study.

It will be seen in the next 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,

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

where R_0 = coil resistance (ohm); C_0 = value of the tuning capacities (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,

$$R' = R_0 + \omega^2 M^2 / R_1$$

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

$$\sigma_1 = \frac{1}{R_1} = \frac{R_0}{\omega^2 M^2}\left[\frac{R'}{R_0} - 1\right]$$

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,

$$\sigma_1 = \frac{R_0(\alpha - 1)}{\omega^2 M^2} \quad \text{where } \alpha = i_0/i_1$$

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

$\sigma_s = \frac{\pi}{l} \cdot \frac{R_0}{\omega^2 M^2}(\alpha - 1)$, l 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 out the radial distribution function for the azimuthal conductivity of an arc plasma.

2.1.3 Arc Tube Dimensions and 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/4.55 cm.
Coil diameter	=	1.9 cms
Wire diameter	=	1 mm
Number of turns in the coil	=	50
Probe-to-probe separation	=	6.35 cms.

2.1.4 Experimental Procedure :

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 sodium hydroxide (NaOH) solution. Then the tube has been washed several times with distilled water and after that with dehydrated pure benzene and then dried thoroughly. A suitable quantity of tripple-distilled mercury has then been poured into the tube. 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. After producing the arc the relative position of the oscillator coil and the work coil is so adjusted that the r.f. meter reading becomes moderately high so as to achieve the highest sensitivity in one hand and to ascertain, on the other hand, that the meter pointer does not cross the scale when the arc is extinguished. A number of fans have been used for cooling the arc to obtain a stable condition. The r.f. meter reading is then noted as 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 pointer again shifts from its foregoing position. The circuit is then retuned by the variable condenser. The tuned current and the value of the capacitance (i.e. C_0) are noted. The 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. 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 (Philips FET input) with high input impedance. The purpose of keeping these voltage readings is to compare the values of azimuthal conductivity found by the present process with the axial conductivity values measured, using the relation,

$$\sigma_z = I_z / \pi r^2 E_z$$

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 chapter IV. It is worthwhile to mention here that extreme precautions have been taken such that no element of the apparatus is disturbed during each set of observations. A very good care has also been taken during the whole observations such that no mercury droplet could appear inside the tube in the coil region, the presence of which changes the situation quite a lot. The above experiment is repeated several times for a given discharge current and oscillator frequency. 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 'γ' is measured for a single frequency. Now varying the frequency of the oscillator the whole experiment is repeated for different discharge currents.

2.1.5 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 figure (2·2a). It has been designed to cover a frequency 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, 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 . Another variable condenser C is placed in parallel with the inductance L, 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 stabilized power supply, through a radio frequency choke. The blocking capacitor 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 improving the tuning accuracy) and a radio frequency milliammeter, all connected in series (Fig. 2.2b). The dials of both the condensers in the receiver circuit have been calibrated in terms of capacitance with the help of a L.C.R. bridge.

The dial readings against capacitance values are shown in figs. (2.3) and (2.4).

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 Vernier condenser in the receiver circuit :

Dial reading	Capacitance in pF	Dial reading	Capacitance in pF
0	10.5	13	43.2
1	10.6	14	46.3
2	11.8	15	48.5
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	73.8

Table 2.3

Dial calibration of the condenser in the oscillator tank circuit against frequency (Fig. 2.5) :

Dial reading of the condenser	Frequency in Mc/S	Dial reading of the condenser	Frequency in Mc/S
2	1.45	20	2.58
4	1.50	22	2.75
6	1.60	24	3.13
8	1.70	26	3.44
10	1.79	28	3.81
12	1.90	30	4.17
14	2.02	32	4.53
16	2.15	34	4.95
18	2.32	36	5.16

2.1.6 Measurements of Inductances L & 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,

$$L = \frac{c.\ a^2 n^2}{b}\,k$$

where c = Const.
= 0.039 48 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 a function of $\frac{2a}{b}$
= .8781 in this case.

After calculating the value of L, 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, Chapter III).

2.1.7 Measurement of Radio Frequency Resistance (R_p) 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. 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, (Hartley type), which is the driving oscillator (Fig. 2.2). 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_o 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 (I_1) in the r.f. meter becomes $1/\sqrt{2}$ times of the resonant current I_o i.e. 70.7% of I_o. 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_o.

$$\text{Therefore, } E_o = I_o \times R_o \qquad \ldots \quad (2.1)$$

where R_o 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, $(R_o + j\,\Delta x)$ corresponding to the r.f. current I_1.

This leads to,

$$\frac{I_o}{I_1} = \frac{\sqrt{R_o^2 + (\Delta x)^2}}{R_o} \qquad \ldots \quad (2.2)$$

$$\text{or} \quad \frac{I_o^2 - I_1^2}{I_1^2} = \frac{(\Delta x)^2}{R_o^2} \qquad \ldots \quad (2.3)$$

$$\text{or} \quad R_o^2 = (\Delta x)^2 \cdot \frac{I_1^2}{I_o^2 - I_1^2} \qquad \ldots \quad (2.4)$$

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

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

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

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

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

Putting this value of Δx in equation (2.4)

$$R_o^2 = \left(\frac{C_2 - C_1}{2\omega C_1 C_2}\right)^2 \left(\frac{I_1^2}{I_0^2 - I_1^2}\right)$$

$$\text{or,} \quad R_o = \frac{C_2 - C_1}{2\omega C_1 C_2} \sqrt{\frac{I_1^2}{I_0^2 - I_1^2}} \quad \ldots \quad (2.8)$$

Thus knowing the values of C_2, C_1, I_1 and I_0, 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 appreciably with frequency for the frequency range indicated by the manufacturer. And in fact, it has been found that the value of the r.f. resistance of the whole network, measured by the resistance variation method, is only slightly, greater than the d.c. resistance value of the meter. This is quite in good agreement with our expectations.

2.2 INVESTIGATION OF THE HEAT FLOW MECHANISM ACTIVE IN THE POSITIVE COLUMN OF A LOW PRESSURE MERCURY ARC (REF: CHAPTER VI)

2.2.1 Apparatus :

Specially designed arc tube; Meter bridge; P.O. Box; Mercury thermometer; and all the equipments mentioned in section 2.1.

2.2.2 Experimental Arrangements and Procedures :

The experimental arrangements for this investigation remain almost the same as discussed in Section 1 of this chapter except with slight modification in the design of the mercury arc tube (Fig.6.1 of Chapter VI). 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 unaltered so that some experimental data from the previous works can be used here without error. A glass condenser of length 20 cms. is fitted along the mid-portion of the tube with an aim to obtain a stable arc with water cooled walls. The temperature of this outflowing water is measured with an ordinary mercury thermometer fitted with the condenser. Besides this, a thin 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 discussed in the next section.

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 thermometer 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 $\dot{Q}_o$ is calculated by knowing the discharge current and the voltage across the plasma column under study. The significance of these measurements will be revealed in Chapter VI.

2.2.3 Electron Temperature Measurement by an Electrostatic (Langmuir) Probe :

The method for determination of electron temperature by an electrostatic probe is based on the prolarization of a plasma. A metal probe P (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. In the same figure the source of the voltage applied to the probe and a potentio-meter arrangement to vary the voltage, is also shown.

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 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 $V - V_0$, where 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, one obtains a straight line over a wide range, of the form as shown in Fig. 2.8. The slope of this line allows one to determine the electron temperature T_e.

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

2.3 GENERATION OF ION-ACOUSTIC WAVE IN A GLOW DISCHARGE PLASMA BY SONIC TRANSDUCER : A NEW NONIMMERSIVE SONIC PROBE DIAGNOSTIC METHOD.

2.3.1 Apparatus :

A discharge tube (made of Pyrex glass, 1 meter long dia. 6 cm.)

Two hollow cylindrical brass electrodes with tungsten wire fittings.

D.C. power supply (0 - 2 kV, 100 mA) made in the laboratory.

Variable auto-transformer (0 - 260 V, 8 Amps.)

Step-up transformer (230:4000 V, 200 mA)

Sonic transducer (1) : Loudspeaker (dia. 4 cm.)

Sonic transducer (2) : Microphone (dia. 4 cm.)

Two stage rotary vacuum pump (Basynth)

Miniature McLeod Gauge (Vacuscope: Basynth; 1-.001 Torr).

Needle Valve

Double beam oscilloscope (Philips;PM3230; 0-10 MHz).

Audio oscillator, beat frequency type (Philips; GM 2308).

Solid state a.c microvoltmeter (Systronix; type 411; 1 Hz-3 MHz) used as amplifier.

Rogow ring - multilayer coil made of copper wire wound around an "O" type laminated iron core.

Decade condenser box.

Milliammeter and voltmeter.

2.3.2 Experimental Arrangements :

The schematic diagram of the experimental arrangement is shown in Fig. 2.9. The glow discharge plasma is generated in a glass tube (length 1 meter approx., diameter 6 cm.) by applying d.c. voltage to two hollow cylindrical brass electrodes (C and D) (electrode separation, 48 cm.), the tungsten wire fittings of which are protruding from the tube wall. The plasma forms a column of about 50 cm. long and 5.5 cm. in diameter (i.e. the inner diameter of the tube, since no radial confinement has been done by utilizing longitudinal magnetic field). The necessary d.c. power required for the discharge is obtained from a self-made solid state unstabilized power supply with π-type filter arrangements. The input of the supply has been drawn from the a.c. line through a variable auto-transformer and a step-up transformer (230 V/4000 V). The discharge voltage and current may be varied smoothly by the use of an auto-transformer. The power supply ripple does not disturb the measurement due to the tuning arrangements which will be discussed later. The necessary vacuum is obtained with a two stage rotary vacuum pump and the air pressure may be varied, by adjusting a leak in the vacuum line through a needle valve.

As the exciter of acoustic waves, we have used an electrodynamic loudspeaker (A) which has been placed within the discharge tube at one end, such that the acoustic wave is excited in the direction of the longitudinal axis of the discharge. Arrangements have been made so that the sonic wave passing through the discharge space might be picked up by means of the electrodynamic microphone (B) placed at the other end of the tube. This provision has been made keeping in view the idea (suggested by some authors) that the effect of reflection of sonic wave at the plasma neutral gas interfaces on its propagation characteristics might lead to a good diagnostic technique. But our detailed theoretical calculations (Chapter VIII) has enabled us to believe that for ordinary laboratory glow discharge plasma, the reflection of sonic waves at the interfaces would produce little effect on its propagation characteristics. Hence the electrodynamic pick-up device, though depicted in the figure remains unused for the present diagnostic studies. As will be discussed in Chapter IX, the wave mode (later detected as ion acoustic mode), which would propagate in the medium of ionized particles might produce an interfering alternating current of the same frequency. Keeping this in view a Rogowasky loop or ring (Golovin et al, 1958, Cooper 1963 of Chapter I) has been constructed. The ring consists of a multi-layer coil (3000 turns) made of copper wire wound around an 'O' type laminated iron core (average dia. 14 cm. approx.), the plane of which being always perpendicular to that of each loop of the coil. The rogow ring is then placed around the discharge tube in the form of a girdle such that the axes of the both coincide and the ring may be moved freely along the discharge tube. The ring thus constructed becomes able to pick up magnetic field, at a given cross-section of the positive column, arising from any perturbation current within the plasma. The ring in effect serves the purpose of the secondary of a current transformer, the primary of which being the positive column carrying alternating perturbation current.

Proper electromagnetic shielding arrangement has been made by surrounding the loudspeaker by the shielding box G, thereby the direct spurious pick up by the Rogow ring from the exciter is minimized.

The inductance of the Rogowaski ring has been utilized to form a tank circuit with a decade condenser box and the output is taken across the variable condenser so that in one hand, the greater sensitivity of the pick-up apparatus is obtained and on the other hand, it becomes possible to filter out the required output from the actual discharge noise emitted and also from the slight a.c. ripples in the discharge current. The output thus obtained is first amplified [a solid state a.c. microvoltmeter, which has a provision for an output terminal for independent display has been used] and then fed to an input channel of a double beam oscilloscope F, the other channel of which is fed by the audio-signal directly from the audio-oscillator (Philips : beat frequency type) which excites the electrodynamic loud-speaker. The reasons for application of the signal directly to the second channel of the C.R.O. are two fold. Firstly it sets the triggering sequence independent of the pick-up ring output thus avoiding spurious triggering (which may arise due to the emitted discharge noises) and secondly this signal can be used as the reference signal so that the phase shifts may be obtained faithfully.

2.3.3 Experimental Method :

Using the experimental device as described above (Fig.2), the phase velocity of the wave mode propagating in the medium of the charged particles has been measured. The pick-up ring has been placed around the discharge tube for picking up the information of the alternating perturbed signal at different positions along the positive column of the glow discharge. The voltage induced in the ring, at different positions along the discharge tubes, are found mutually phase shifted because of the finite propagation velocity of the wave. The phase shifts are calculated by measuring the horizontal displacement of a peak of the sinusoidal wave-form from its original positions. These displacements can easily be read from the scales of the oscilloscope screen. These shifts in spatial units can easily be converted into temporal units since the frequency of the signal is known. This point is further discussed in Chapter IX. The induced voltage in the ring can also be measured with the use of the microvoltmeter used for the purpose of amplification, but this is not done because for the present study the peak to peak height in spatial units of the oscilloscope screen served our purpose adequately.

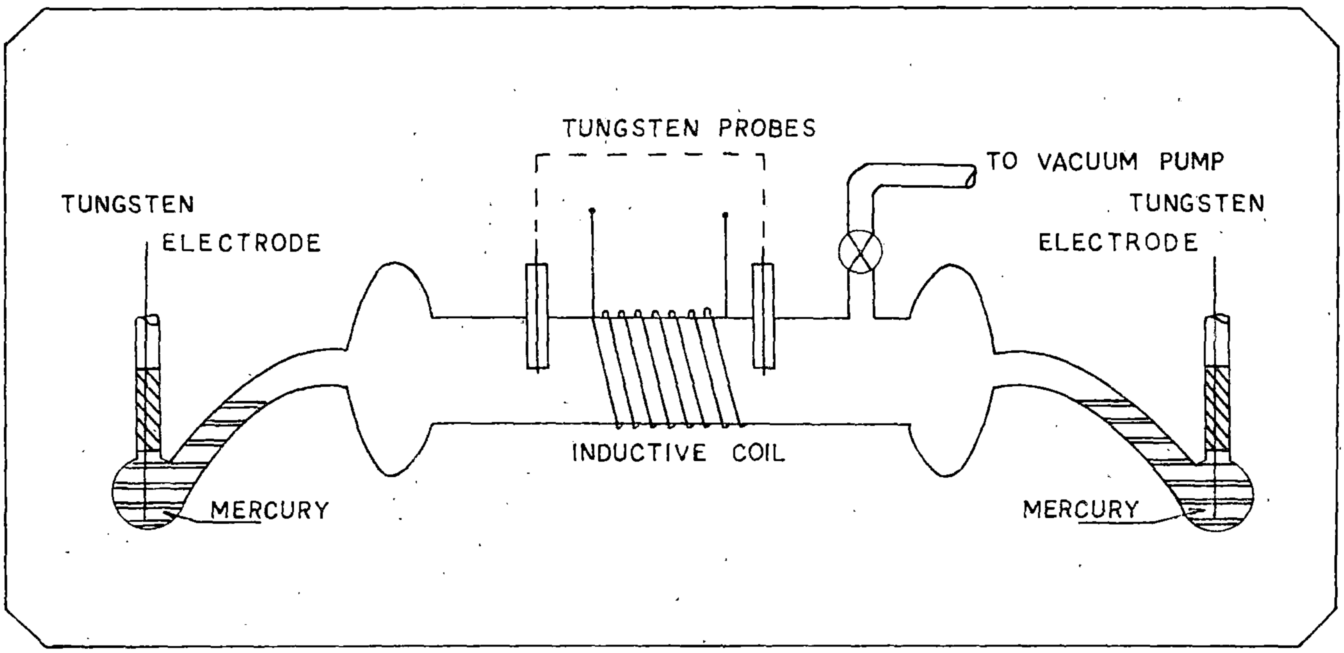

FIG. 2·1. DIAGRAM OF A MERCURY ARC TUBE.

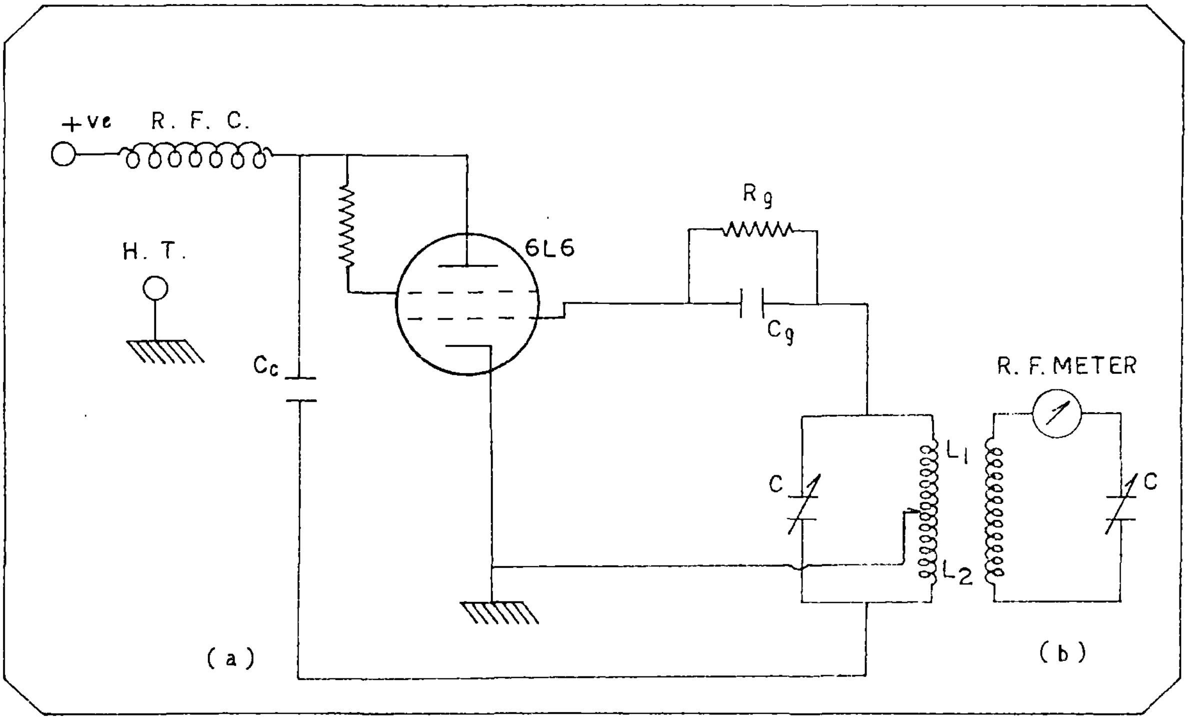

FIG.2·2. RADIO FREQUENCY OSCILLATOR CIRCUIT - (a).
SECONDARY TUNING CIRCUIT - (b).

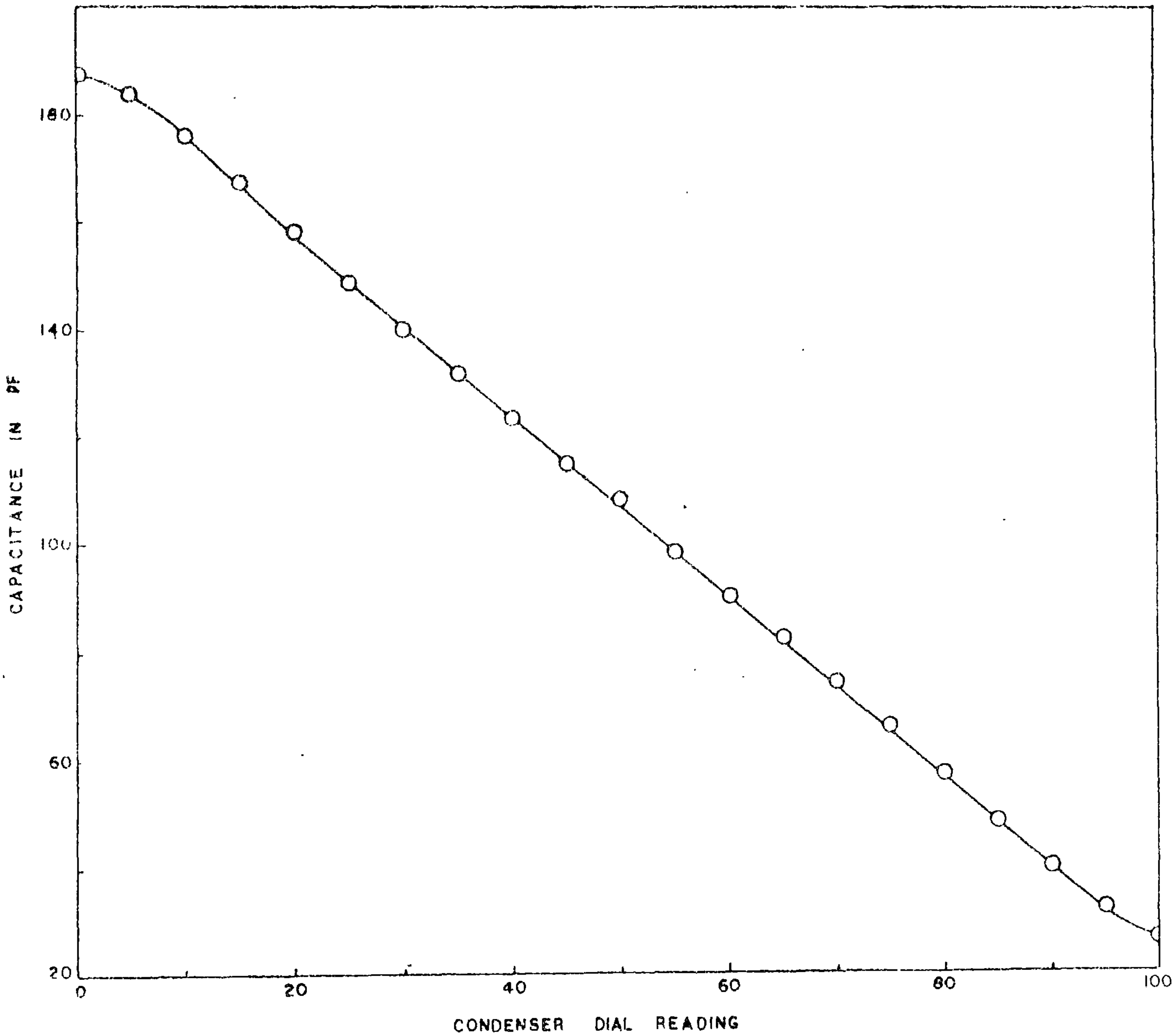

FIG. 2.3. CALIBRATION OF THE VARIABLE TUNING CONDENSER IN THE RECEIVER CIRCUIT.

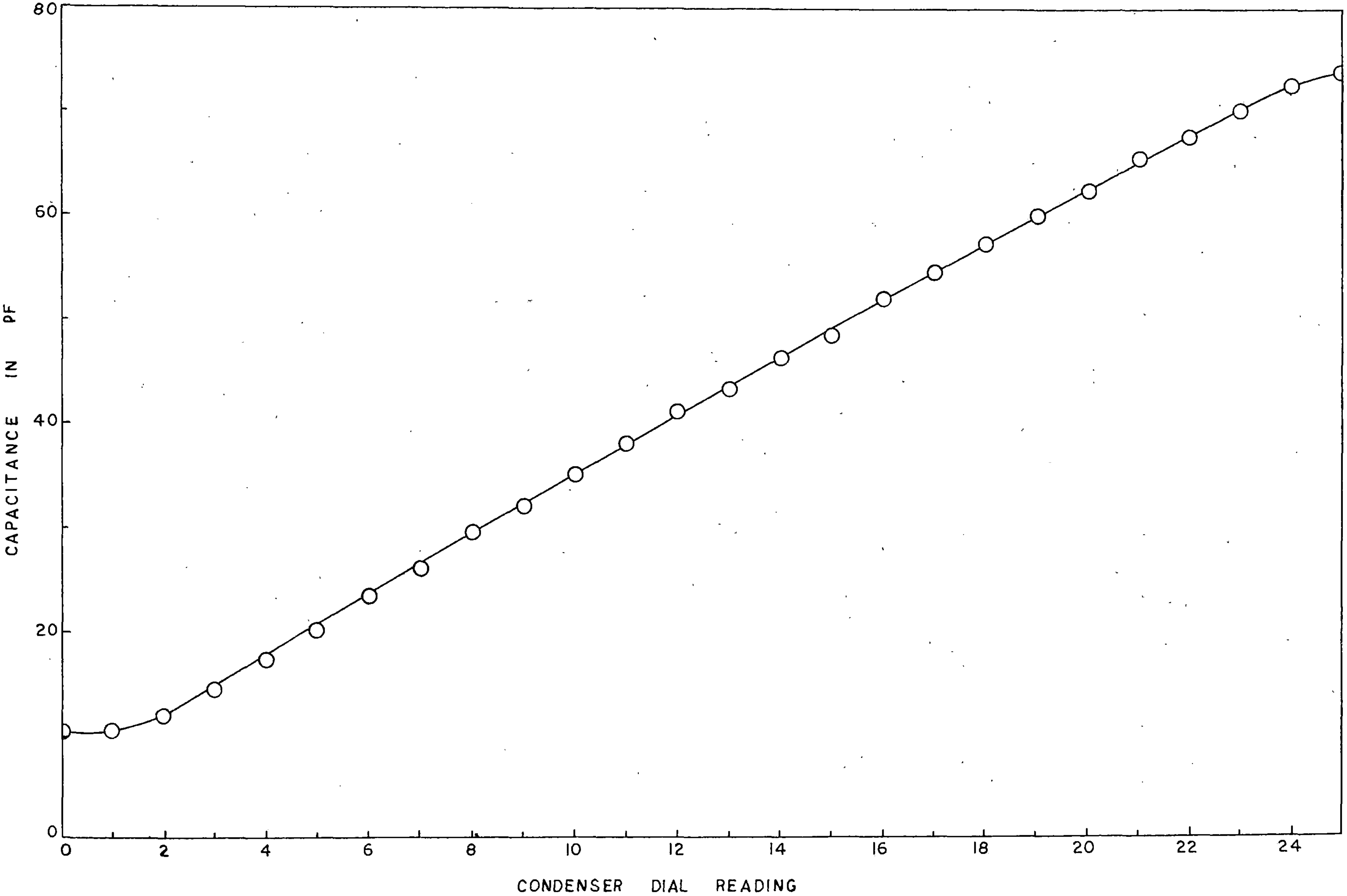

FIG. 2·4. CALIBRATION OF THE VERNIER CONDENSER IN THE RECEIVER CIRCUIT.

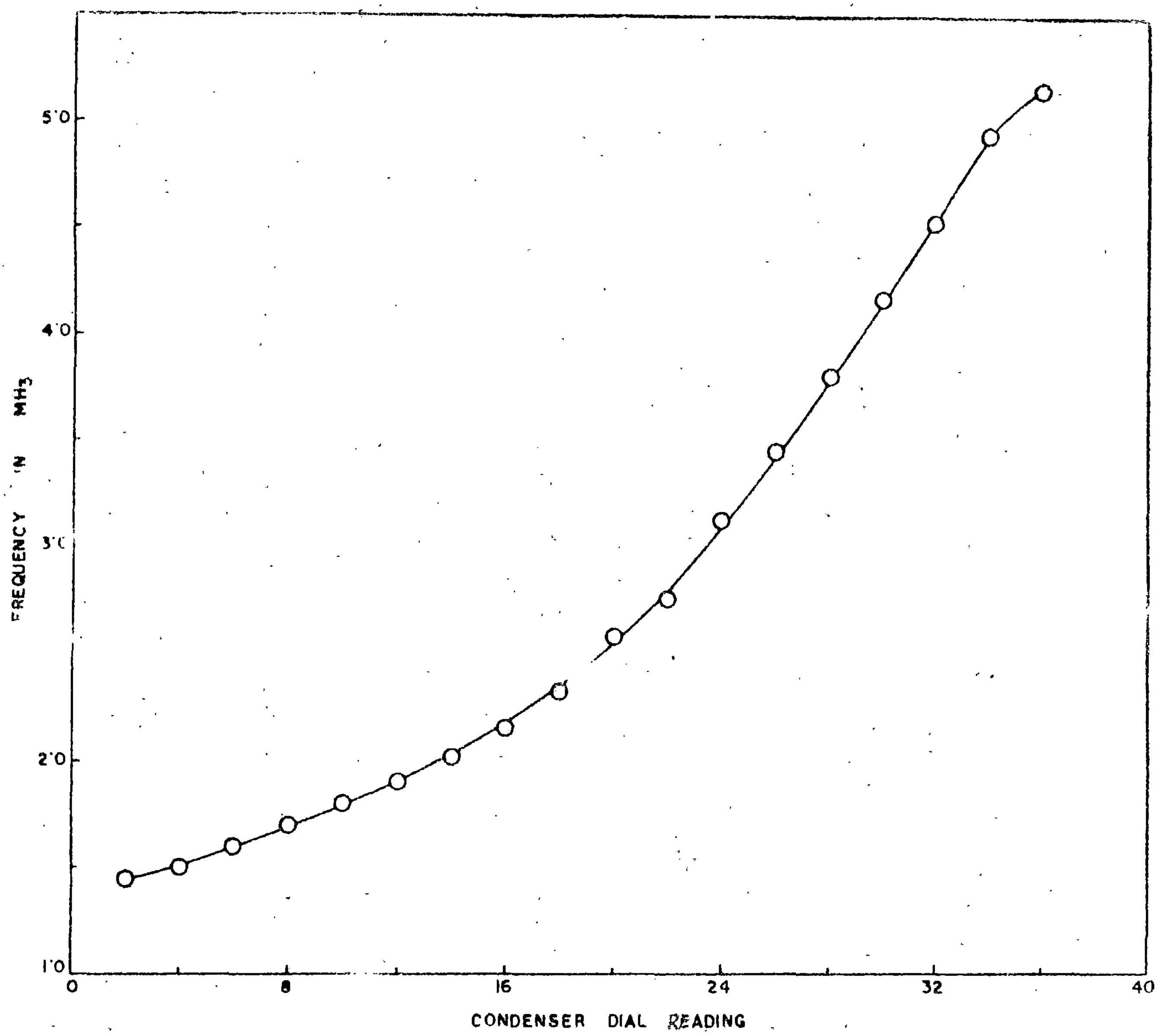

FIG. 2.5. OSCILLATOR FREQUENCY CALIBRATION

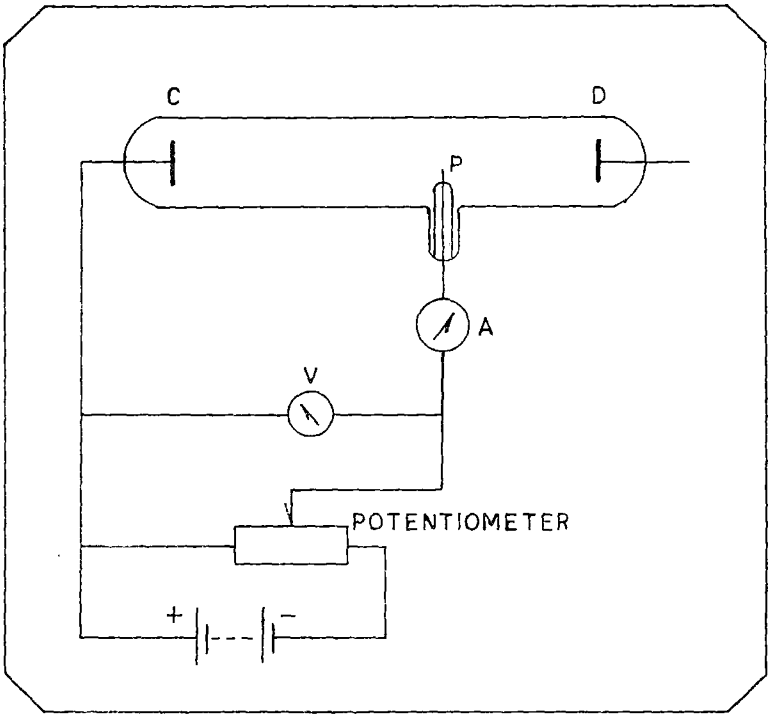

FIG. 2·6. SCHEMATIC EXPERIMENTAL ARRANGEMENT FOR MEASURING ELECTRON TEMPERATURE.

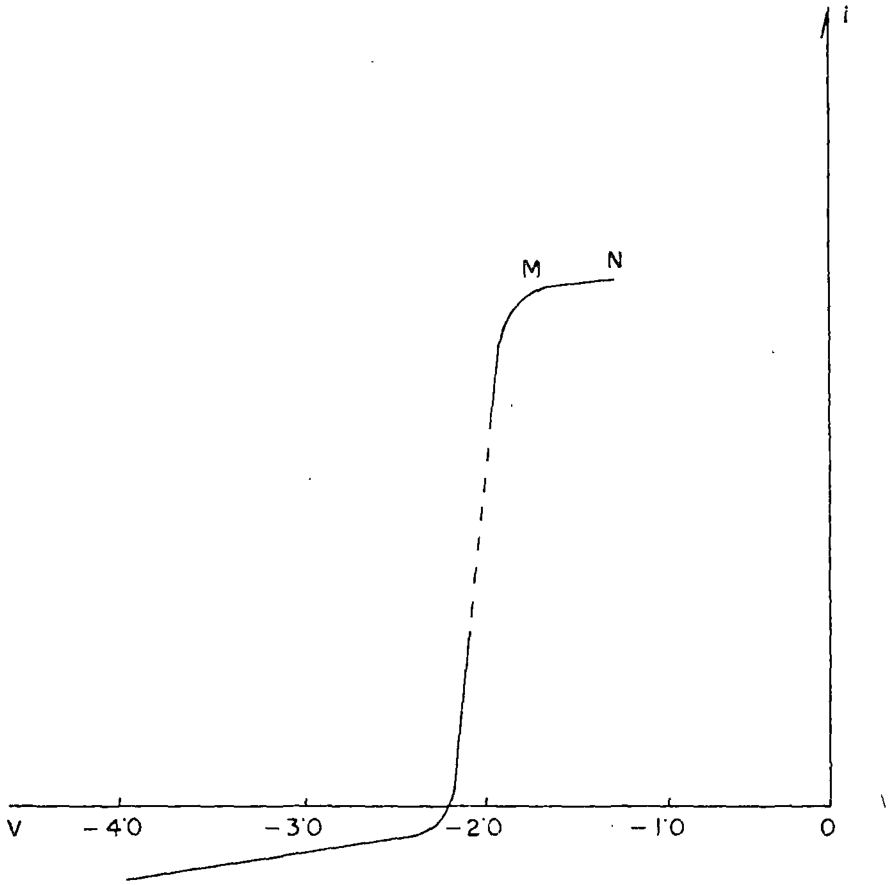

FIG. 2·7 . VOLT - AMPERE . CHARACTERISTIC OF A LANGMUIR PROBE.

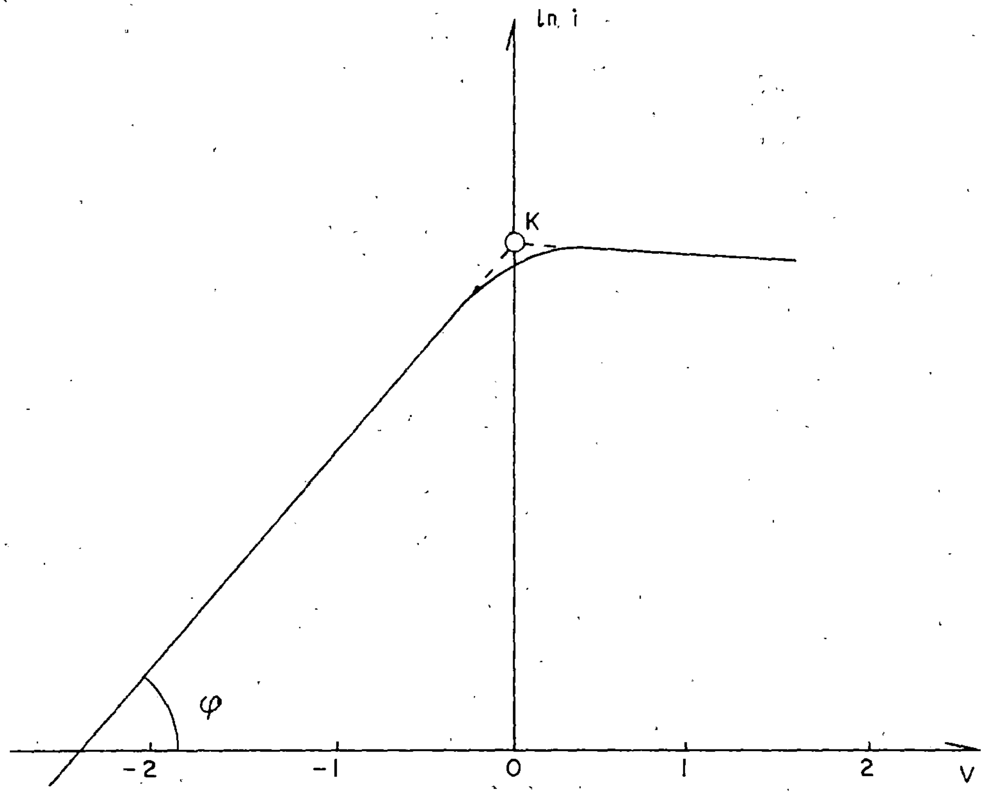

FIG. 2·8 . VOLT - AMPERE CHARACTERISTIC OF A LANGMUIR PROBE AS PLOTTED ON A LOGARITHMIC SCALE.

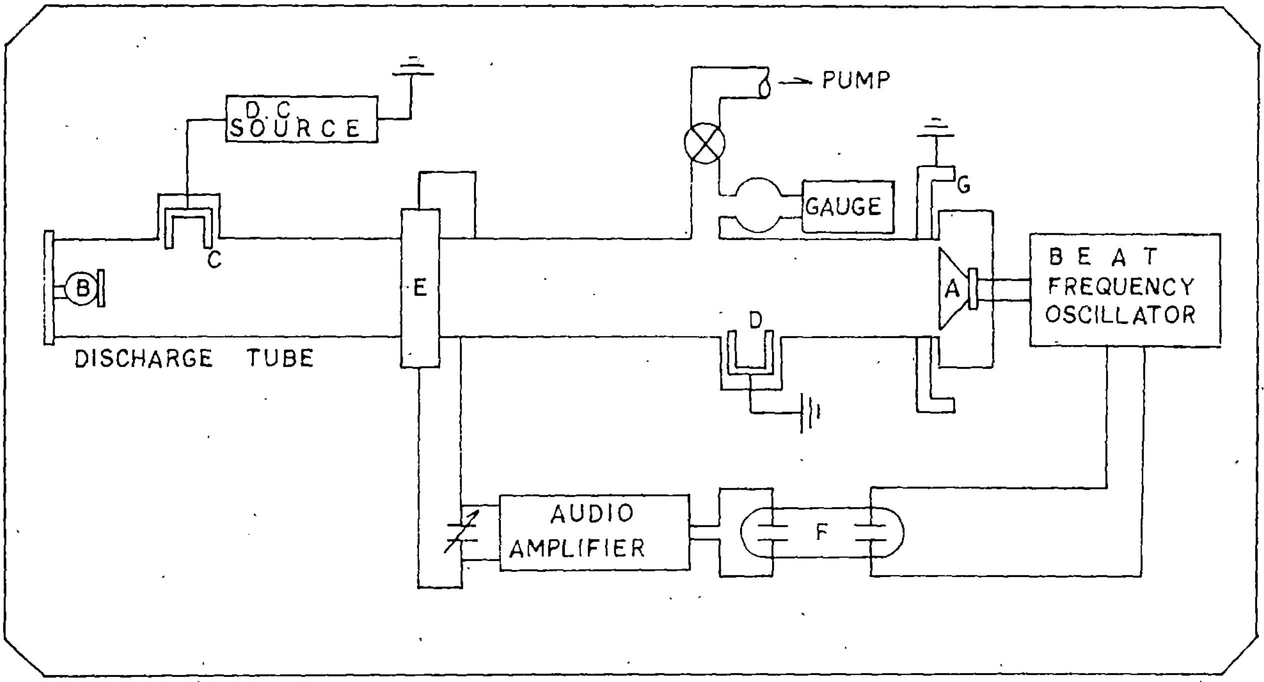

FIG. 2.9 SCHEMATIC EXPERIMENTAL ARRANGEMENT: ION-ACOUSTIC WAVE.