CHAPTER II

EXPERIMENTAL SET UP

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2.1. Collision loss factor:

Apparatus and Accessories: (1) Glow discharge tube for diffusion voltage measurement (2) High voltage power supply (3) Constant current generator (4) Digital Voltmeter (Model No. Hill 205) (5) Ammeter (Sett & Dey) (6) R.C. filter (7) McLoyd Gauge (8) Pirani Gauge (9) Two stage Rotary Pump.

2.1.1. The discharge tube is cylindrical in shape and made of corning glass with two circular brass electrodes fitted symmetrically at two ends inside the tube and in such a way that they face parallel to each other. To stop any spurious discharge with the back side of the electrodes, the backside of the electrodes are tightly covered with teflon cap and the connecting tungsten rods are sealed with thin glass coating. So the chance of any spurious discharge resulting in sudden undesired fluctuation of discharge current was thus totally eliminated. In absence of such sealing, there is face to face discharge between the electrodes for low values of E/p, but when E/p is gradually made high, there is sudden rise of discharge current showing luminious glow behind the electrodes. Such a change in discharge current cannot occur when only the front surfaces of the electrodes are open to discharge.

2.1.2. The probes for the measurement of diffusion voltage were made of very thin tungsten wire of diameter 0.2 mm and placed

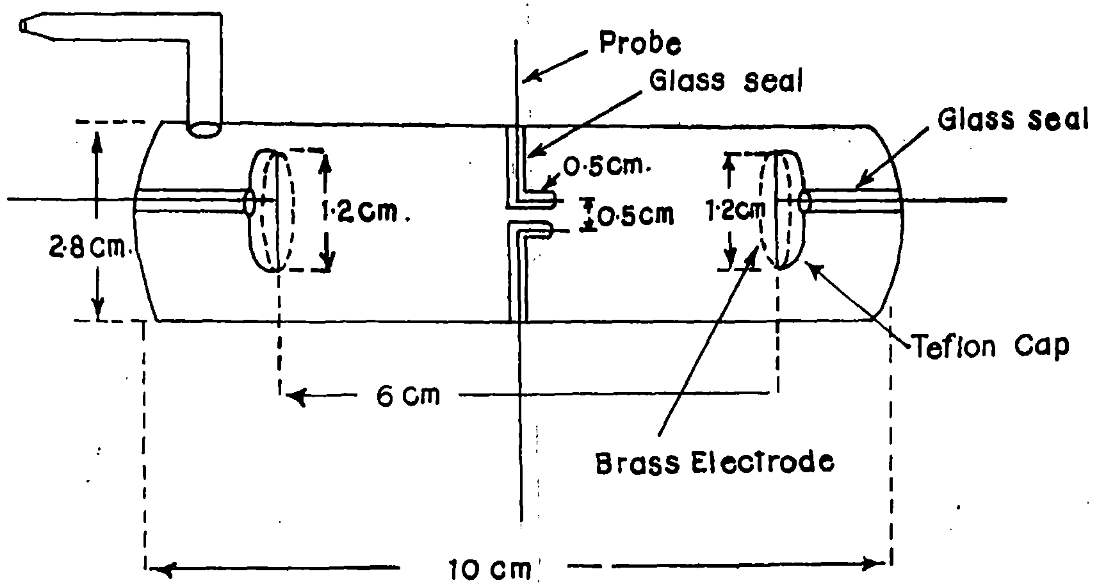

Probe
Glass seal
Glass seal
0·5cm.
0·5cm
1·2cm.
1·2cm
2·8cm.
Teflon Cap
6 cm
Brass Electrode
10 cm

Fig.2.1.

parallel to the electric field, of which one is placed along the symmetry axis of the plasma column while the other one is placed 5 mm away from the axis. The length of each probe is 5 mm and the electrodes are sealed with thin glass coating except at the ends of each. The length of the open portion of the probes are no more than 0.2 mm each. Both of the electrodes point towards the same direction in the discharge tube. The Schematic diagram of the complete discharge tube is shown in Fig. 2.1.

2.1.3. The gases used in the experiment were at least analytically pure. Three gases are used in this experiment, vide, air, hydrogen and nitrogen. Air was made pure by passing first through caustic potash solution removing carbon dioxide and then through distilled water and finally through highly concentrated sulphuric acid followed by several U tubes filled up with caustic potash pellet. The rate of flow through the purification system was kept extremely small to ensure the purification process to be complete. Finally pure air is stored in a five litre vessel connected with the purification system.

Pure hydrogen is produced by electrolysis of dilute barium hydroxide solution. To remove any trace of impurity present in the hydrogen, the prepared gas is allowed to pass through heated platinum net followed by caustic potash pellet and phosphorus pentoxide.

Nitrogen is produced by controlled heating of sodium chloride and ammonium nitrite solution mixed in a round bottom flask. This nitrogen contains little chlorine, ammonia, nitric oxide and water vapour. To remove these impurities from the nitrogen, the gas is allowed to pass through concentrated solution of caustic potash and then through concentrated sulphuric acid. Finally the gas is made to pass through highly heated copper turnings to remove nitric oxide by reducing it into nitrogen. This is pure nitrogen and has been used in the present experiment.

2.1.4. Pressure during discharge is measured with the help of a McLoyd gauge and a Pirani gauge simultaneously so that correctness of the pressure measured is assured. The calibration curves for the Pirani gauge in air, hydrogen and nitrogen were supplied by the manufacturer.

2.1.5. High voltage power supply is designed to have a supply of voltage maximum upto 2.5 KV and a current maximum upto 10 mA (HV 4800D).

2.1.6. To ensure the discharge current to be constant in a particular set of experiment a series current controller is designed and connected in series with the discharge tube in addition to a high watt resistance (51.3 K. Ohm) in series. After fixing the current in the discharge circuit, the current controller and the high voltage power supply is gradully adjusted in such a way that the drop across the current controller is within the specified limit. Under this condition

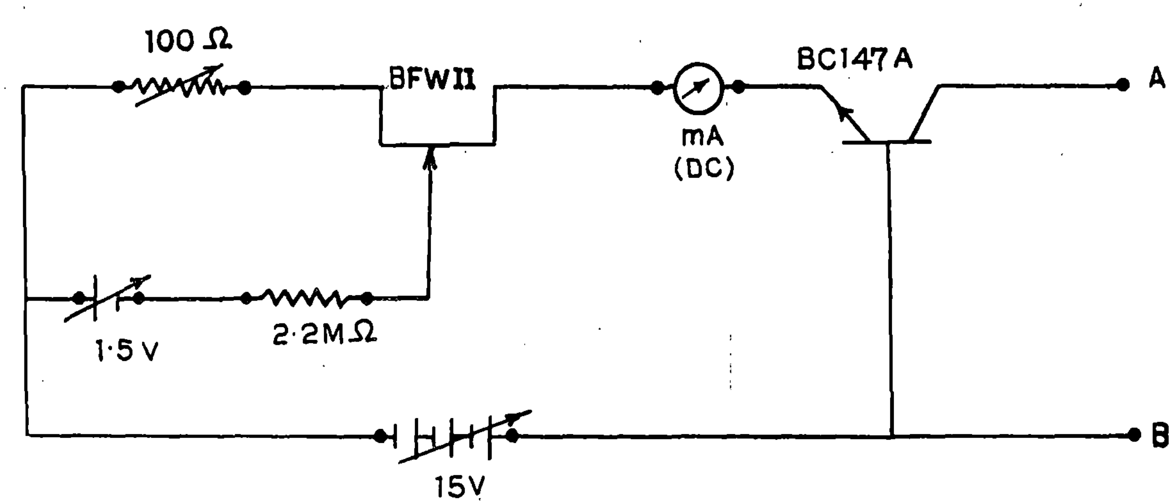


Fig. 2·2. CKt - Current Controller

the current through the discharge tube remains fairly constant against any spurious fluctuation in the system . Circuit diagram is shown in Fig. 2.2.

2.1.7. The probes are connected with the input of a π-type RC fiter whose time constant is 2.4 sec. The value of R is 100 kilo ohm and that of the two condensers are 24 μF. The aim of such filter is to stop any spurious ac voltage to appear at the output of the filter. Particularly the low frequencies which are frequently present in such glow discharge tubes, disturb the measurement of diffusion voltage. Because the probes in addition to dc diffusion voltage also peak up such spurious ac voltages present during the discharge. The impedence between the probes is high because of extremely small surface area open to the discharge and comparatively high distance between the open tips of the probes and also due to low conductivity in case of low density plasma formed in a glow discharge tube.

Also because of small surface area open, the power picked up by the probes against diffusion voltage is quite small. So it has to be assured that the circuit measuring diffusion voltage does not consume any appreciable power which may result in faulty measurement of diffusion voltage.

Thus the condensers in the R-C filter are selected in such a way that leakage current does not exceed nano-Ampere and to ensure that any change in voltage between the probes can immediately effect the output of the filter in a linear way, high quality rapid discharge condensers are used in this construction.

Use of L-C filter in such cases has been tested in the laboratory, which shows that such use is inconvenient because of large size of the filter required to prevent any low frequency to appear at the output of the filter.

2.1.8. The voltmeter connected at the output of the filter for the measurement of the diffusion voltage under the stated condition, as described, needs to have high input impedence.

Also since the diffusion voltage is a floating voltage in a discharge tube where both probes are immersed in high voltages, the voltmeter must be isolated with respect to the main discharge voltage source, otherwise irratic and impossible voltages may be shown by the voltmeter. To prevent such problem, it is convenient to use battery operated digital voltmeter whose input impedence is also high in addition to the ability to measure any such floating voltage. In this experiment the digital voltmeter Hill 205 has been used whose input impedence is more than 10 Meg ohm.

2.1.9. The pressure inside the discharge tube is maintained with the help of a double stage rotary pump and one needle valve. The needle valve which has adjustable microleak allows

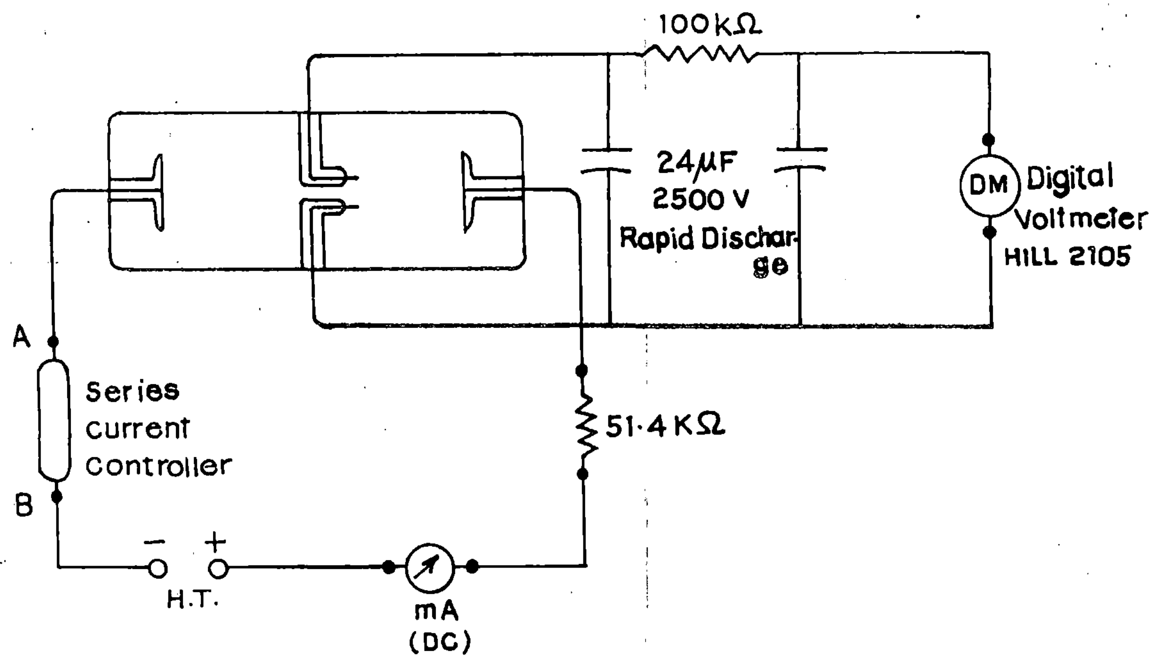


Fig. 2. CKt. Diffusion voltage Measurement

Fig. 2·3

one to control the flow of experimental gas into the discharge tube. When pressure and temperature of the system come to equilibrium after some time of operation of the discharge, the reading can be recorded. The complete block diagram of the discharge system is shown in Fig. 2.3.

2.1.10. The diffusion voltage is related to the electron temperature (Sen, Ghosh and Ghosh, 1983) by relation

$$\frac{kT_e}{e} = \frac{V_R}{\log_e\left[J_o\left(2{\cdot}405\,\frac{r}{R}\right)\right]} \tag{2.1}$$

where V_R is the diffusion voltage, and T_e is the electron temperature, r is the distance between the probes, R is the tube radius, J_o is the zeroth order Bessel's function, k is the Boltsman constant and e is the electronic charge.

Thus in this system we are able to measure electron temperature from the measurement of diffusion voltage with different pressure and discharge current (i_D). Since T_e, i_D and collision loss factor K is related with E/p as shown in the theory developed in the present work, we can measure mean collision loss factor for the electrons.

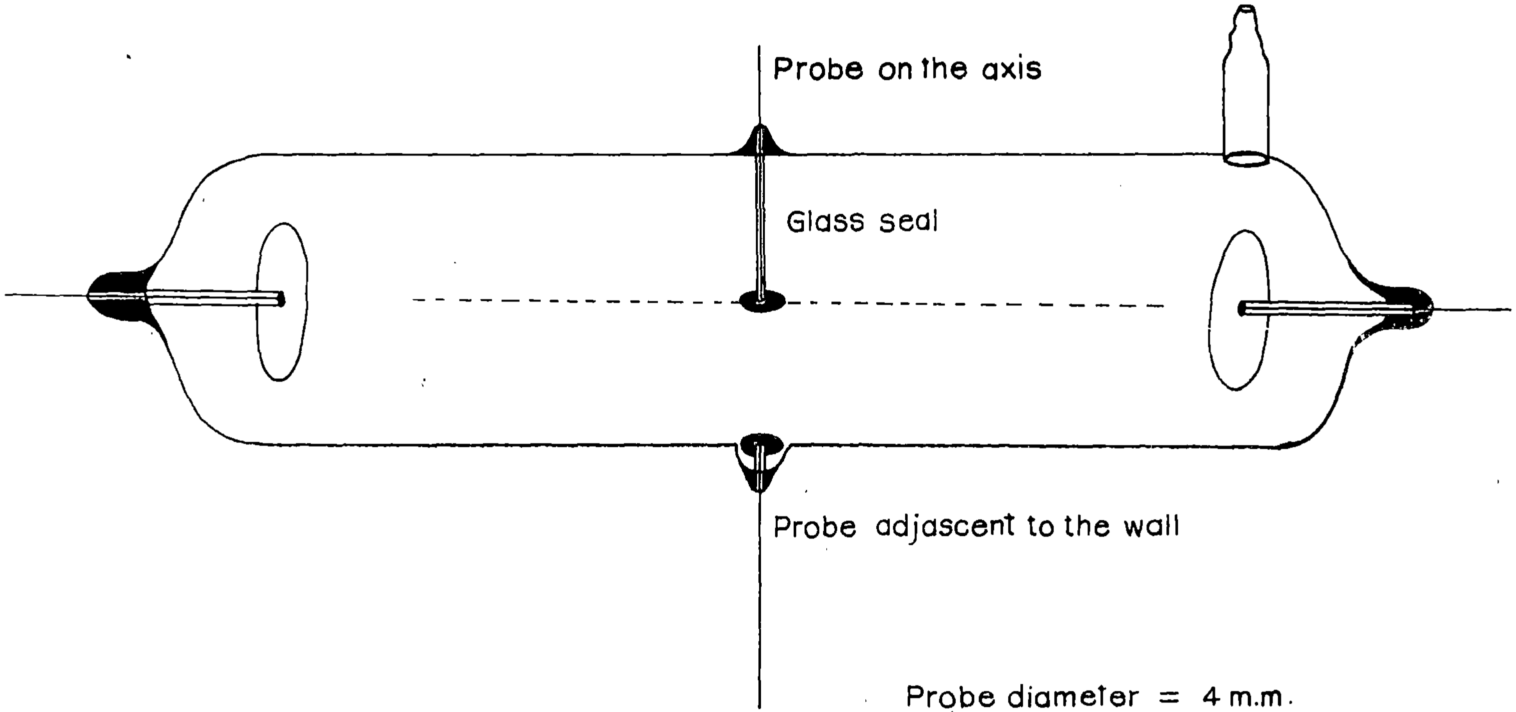
2.2. Hall voltage and diffusion voltage in transverse magnetic field in case of a low density discharge plasma.

Apparatus and Accessories: (1) Glow discharge tube for the measurement diffusion voltage as well as Hall voltage with the same pair of probes. (2) Voltmeter (3) Magnet power supply

(4) Electromagnet (5) High voltage power supply (6) Current meter (7) McLoyd Gauge (8) Pirani Gauge. (9) R-C filter (10) Needle valve (11) Double stage Rotary Pump (12) Air Purification arrangement.

2.2.1. The discharge tube in this case has the same design except for the probes which, in this discharge tube, are two thin circular brass plates connected face to face parallel to each other, one along the axis while the other at the periphery of the discharge tube. The connecting tungsten rods are sealed with thin glass coating. Thus the electrodes form the same configuration as the circular parallel plate condenser, besides the fact that the medium inside is a partially conducting medium. Thus the probes including the partially conducting medium inside forms a semi-metal and hence under the influence of magnetic field in a direction transverse to the direction of discharge current through the space between the probes must result in the appearance of Hall voltage, which means the separation of charges in the plasma which has a strong tendency against the formation of any such charge separation. So there must be strong diffusion under this circumstances which will try to resist the Hall voltage. So these two voltages should act opposit to each other under such arrangement and condition.

Also it has been shown in the theory that under the placement of the probes as stated, i.e., one on the axis and other at the periphery of the discharge tube, there will be no initial diffusion voltage between the probes. Thus such a design of the



Probe diameter = 4 m.m.
Electrode diameter = 2·0 c.m.
Discharge tube diameter = 2·4 c.m.
Probes' seperation = 1·2 cm.
Electrodes' seperations = 6 cm.
Tube length = 12 cm.

Fig. 2·4.

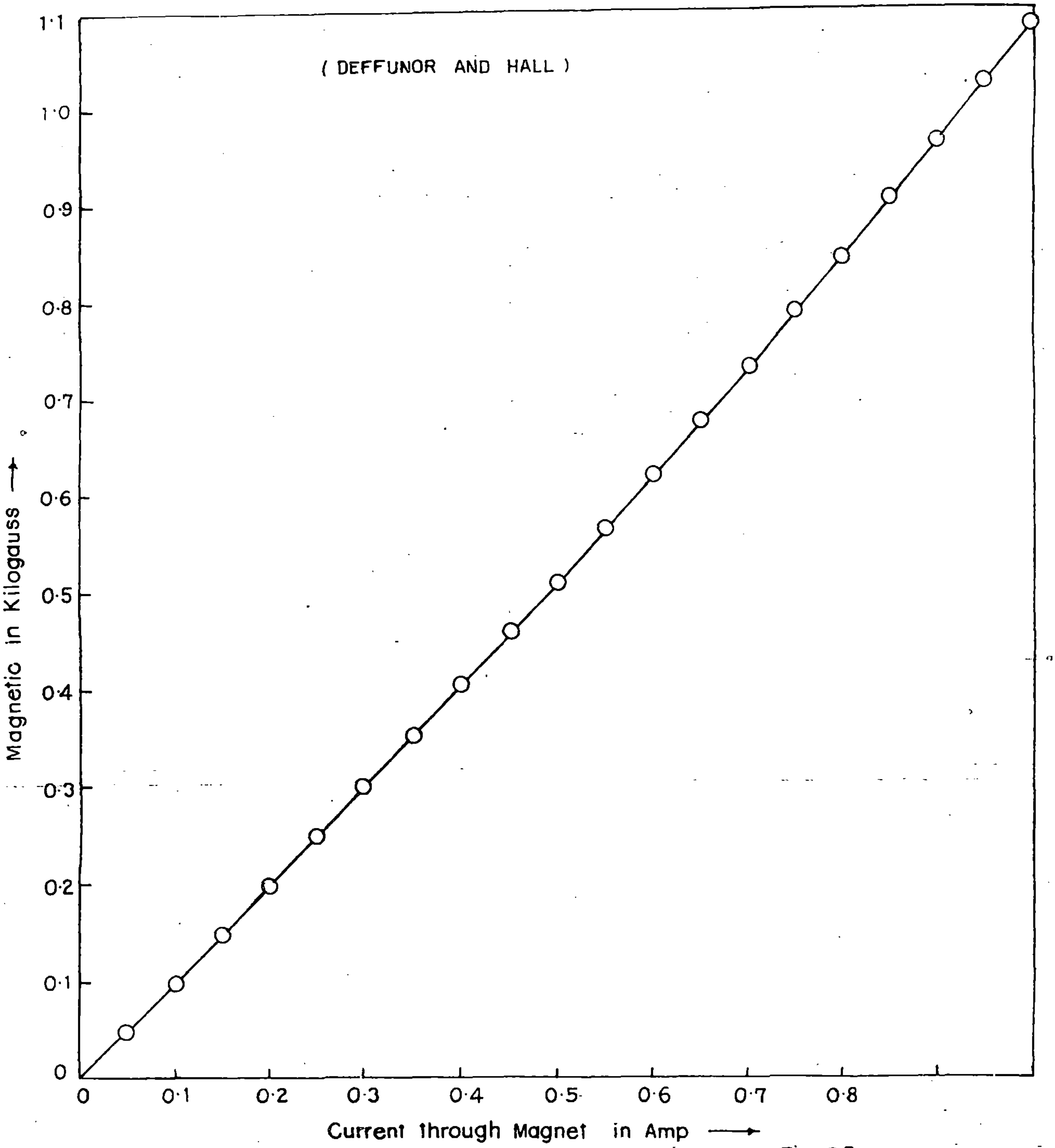

(DEFFUNOR AND HALL)
Magnetic in Kilogauss
0
0·1
0·2
0·3
0·4
0·5
0·6
0·7
0·8
0·9
1·0
1·1
0
0·1
0·2
0·3
0·4
0·5
0·6
0·7
0·8
Current through Magnet in Amp

Fig. 2·5 .

discharge tube will enable one to measure Hall voltage in combination with the diffusion voltage in presence of transverse magnetic field. The diagram of the discharge tube is shown in Fig. 2-4.

2.2.2. The **electromagnet** is calibrated with the help of a Hall probe electronic gauss meter. The result of calibration is shown in the table 2a and Fig. 2.5 .

Table 2a

Current through the magnet in Amp	Magnetic field in K.Gauss: When current in one direction	Magnetic field in K.Gauss: When current in reversed direction	Mean Magnetic field in Kilo Gauss
0	0	0	0
0.05	0.05	0.05	0.05
0.10	0.10	0.10	0.10
0.15	0.15	0.15	0.15
0.20	0.20	0.20	0.20
0.25	0.25	0.25	0.25
0.30	0.30	0.30	0.30
0.35	0.36	0.35	0.355
0.40	0.41	0.40	0.405
0.45	0.46	0.46	0.46
0.50	0.51	0.51	0.51
0.55	0.56	0.57	0.565
0.60	0.62	0.62	0.62
0.65	0.67	0.68	0.675
0.70	0.73	0.73	0.73
0.75	0.79	0.79	0.79
0.80	0.85	0.84	0.845
0.85	0.90	0.91	0.905
0.90	0.97	0.96	0.965
0.95	1.02	1.03	1.025
1.00	1.08	1.09	1.085

2.2.3. Magnet power supply is a constant current power source.

This enables one to keep the current through the magnet at a constant value and hence the magnetic field across the discharge tube for the time until the system comes to thermal equilibrium with new arrangement of distribution of current.

The voltmeter is a digital voltmeter which can measure floating voltage without interaction with the main discharge system.

The current meter in this case is required to be sensitive since there is a change in discharge current with magnetic field even if the supply voltage and other impedences in the circuit remain same. In this experiment, "Sett & Dey" current meter has been used.

McLoyd gauge, Pirani gauge, R-C filter and High voltage power supply are same as described in 2.1.

2.3. Cathode fall measurement in a metal arc for different pressure and discharge current.

Apparatus and Accessories: (1) Discharge tube with movable electrode arrangement (2) Water cooling system for discharge tube (3) 350 volt power supply (4) Series current controller (5) Ammeter (6) Voltmeter (7) Two needle valves (8) Mercury Manometer for measurement of pressure from a few mm of Hg to 76 cm of Hg pressure (9) Double stage rotary Pump.

2.3.1 The discharge tube for the measurement of cathode fall at various pressure needs to have arrangement for the adjustment of electrode separation from outsice the discharge tube. So at the two ends of the discharge tube there are two B34 standard joint socket. B34 inner counterpart forms the lid of the discharge tube. A pair of tungsten rods are sealed with each of the lids. The tungsten rods help electrical connection from out to within the tube. In addition, each pair of tungsten rods on each lid can support an electrode holder. The electrode holder each on the other open end has inside thread which allows the fitting of the experimental electrodes tightly and which at their one end has outer thread which fits well into the thread of the electrode holder. One of the electrode holder is formed of two parts connected by screw system. One part is fixed with a pair of tungsten fused on one lid while the other part passes through a socket which allows the electrode pass through it but prevents any rotation of the electrode. As a result, when the corresponding lid of the discharge tube is manually rotated from outside the electrode moves forward or backward. To record the amount of displacement of the electrode, the lid is connected with a large "protractor" which has 360 degree uniform graduation. The "protractor" is again connected with another screw through gear system, such that the screw moves parallel to a linear scale when the circular scale is rotated. Screw pitch for the electrode screw and the outer screw are same. So just like screw gauge one can read the displacement of the electrode

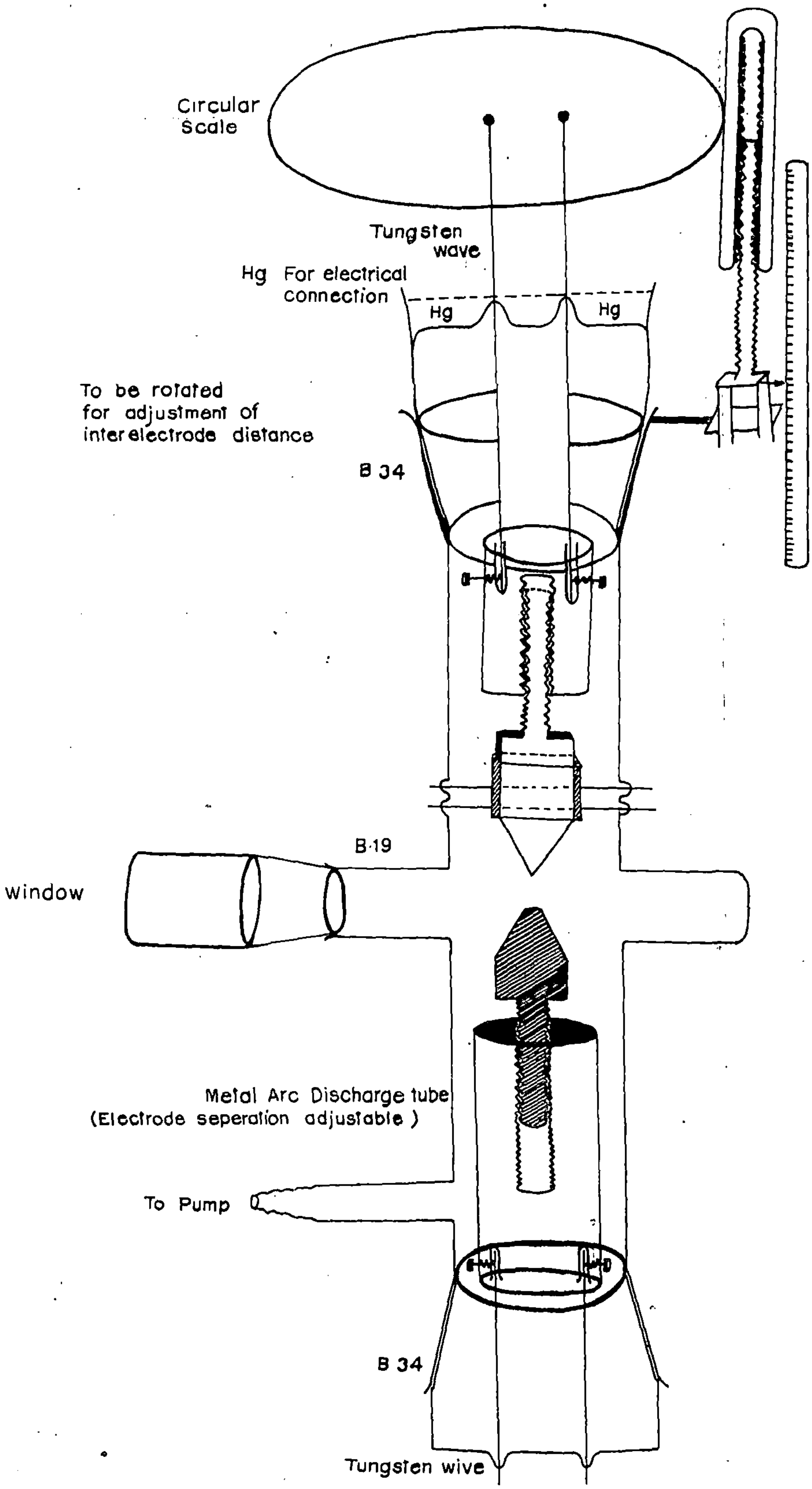
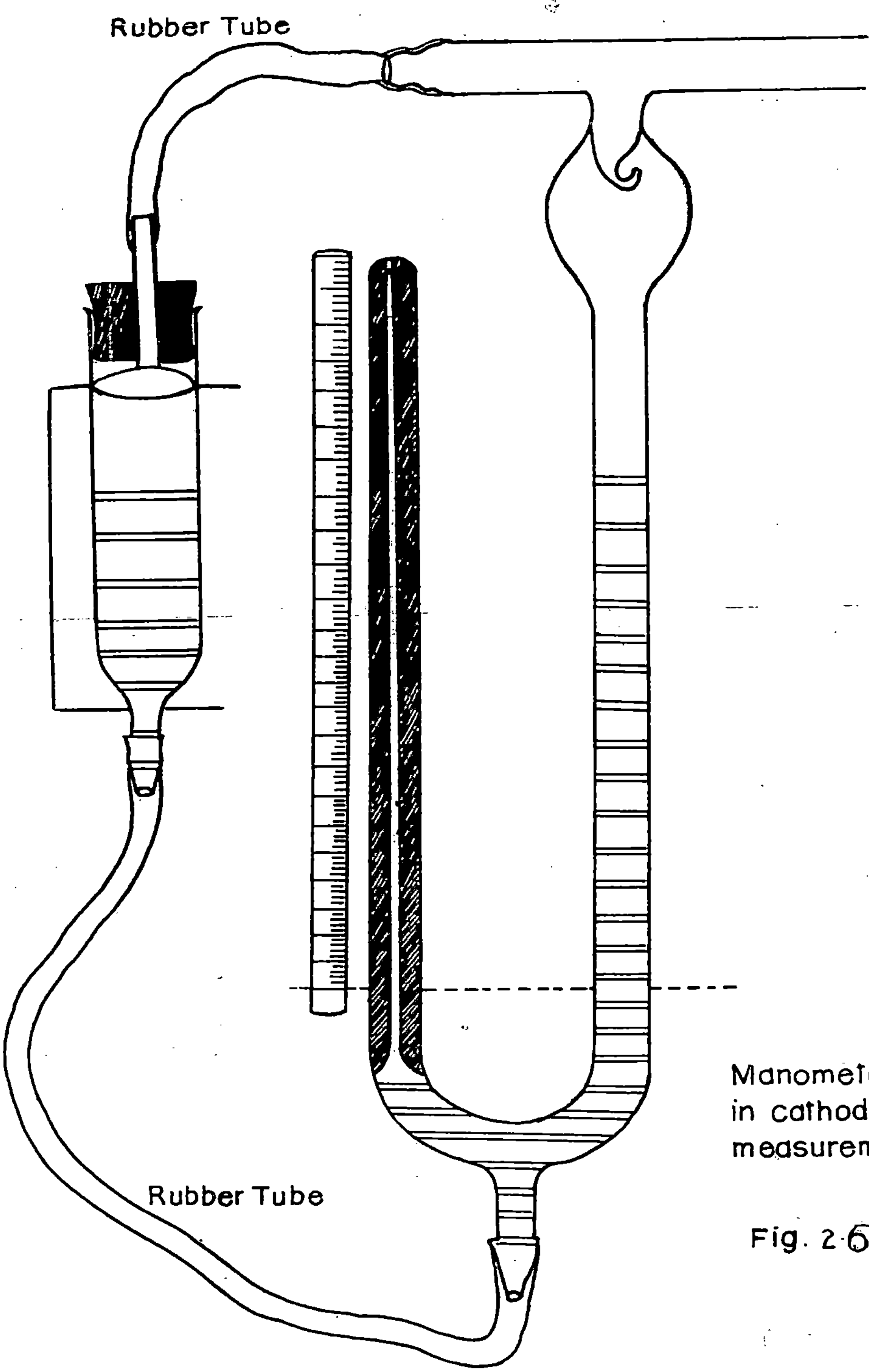

Circular Scale
Tungsten wave
Hg For electrical connection
Hg
Hg
To be rotated for adjustment of interelectrode distance
B 34
B·19
window
Metal Arc Discharge tube (Electrode seperation adjustable)
To Pump
B 34
Tungsten wive

Fig. 2·7.



Manometer used in cathod Fall measurement

Fig. 2·6.

by taking the circular scale reading and linear scale reading. The discharge tube is shown in Fig. 2.7.

2.3.2 The manometer is about 80 cm long and made of capillary tube of 1.5 mm diameter. Its one end is sealed and space above mercury is perfectly vacuum. The inside of the manometer is cleaned with chromic acid and then with caustic soda and finally with distilled water. Then highly distilled mercury is poured inside the manometer. The bottom of the manometer has opening which is connected with the lower end of a large container by a rubber tube. The upper end of the container is connected to the open limb of the manometer with another rubber tube. The container can be moved up and down so that the mercury level inside the open limb, which is in the same level as in the container, can be adjusted. A linear scale is fitted parallel to the closed limb. The scale reads gradually higher from the bottom to the top. Thus when the mercury level in the open limb is brought to a particular mark, the mercury level in the closed limb directly reads the pressure inside the discharge tube which is also connected with the open limb of the manometer. The Manometer is shown in the Fig. 2.6.

2.3.3 Constant current controller is designed with several power transistors in parallel such that the current capacity reaches the desired current level. The voltage tolerance of the controller is 90 volt. So it is set at 45 volt at the required

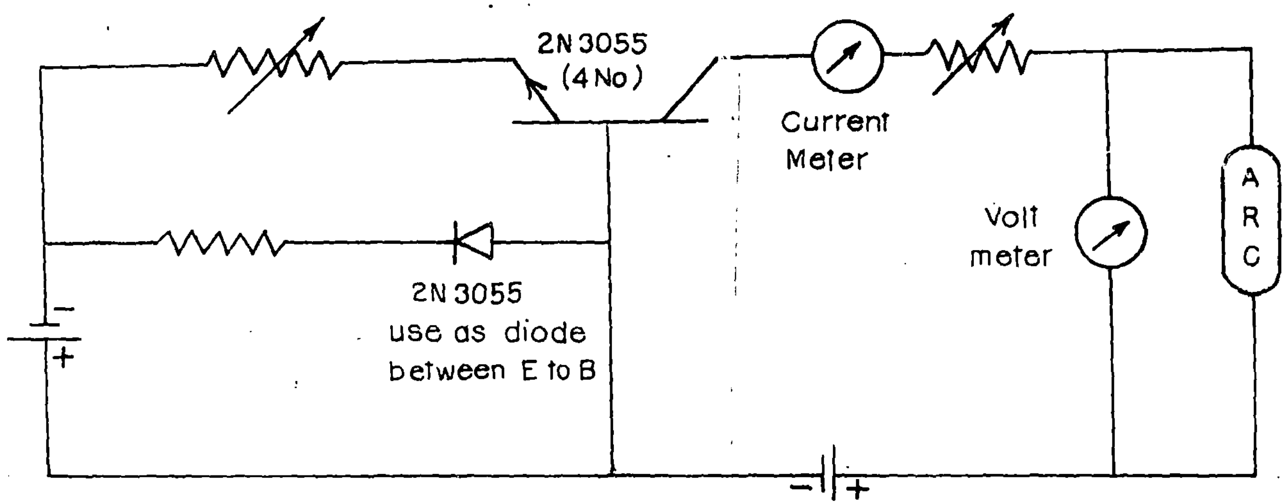


Fig. 2·8. : Series current controller used in arc circuit discharge current. So, any voltage fluctuation or impedance fluctuation in the arc will be compensated upto $\pm$ 45 volt at the same discharge current level. The circuit diagram is shown in Fig. 2.8.

2.3.4 Digital voltmeter is used to record the burning voltage of the arc for electrode separation varying from 0 to several mm.

2.3.5 Due to intense heating in the arc in addition to the electrodes, the glass container may undergo some cracks unless some efficient cooling is provided. So the discharge tube is dipped upto its neck in water which runs through another container. Thus the life of the discharge tube is much lengthened.

2.3.6 The experiment is performed upto a pressure of one atmosphere, so to maintain the pressure inside the discharge tube with a double stage rotary pump two needle valves are required. One needle valve is connected just after the pump, so that the pump cannot draw much gas from the system and another needle valve is connected with the discharge tube which allows the desired gas to enter the system through its leak. Thus the pressure inside the system can be increased either by increasing the leak of the needle valve with the discharge tube or by decreasing the leak size of the needle valve close to the pump. And the pressure inside the discharge tube can be reduced by decreasing the leak size of the needle valve which allows

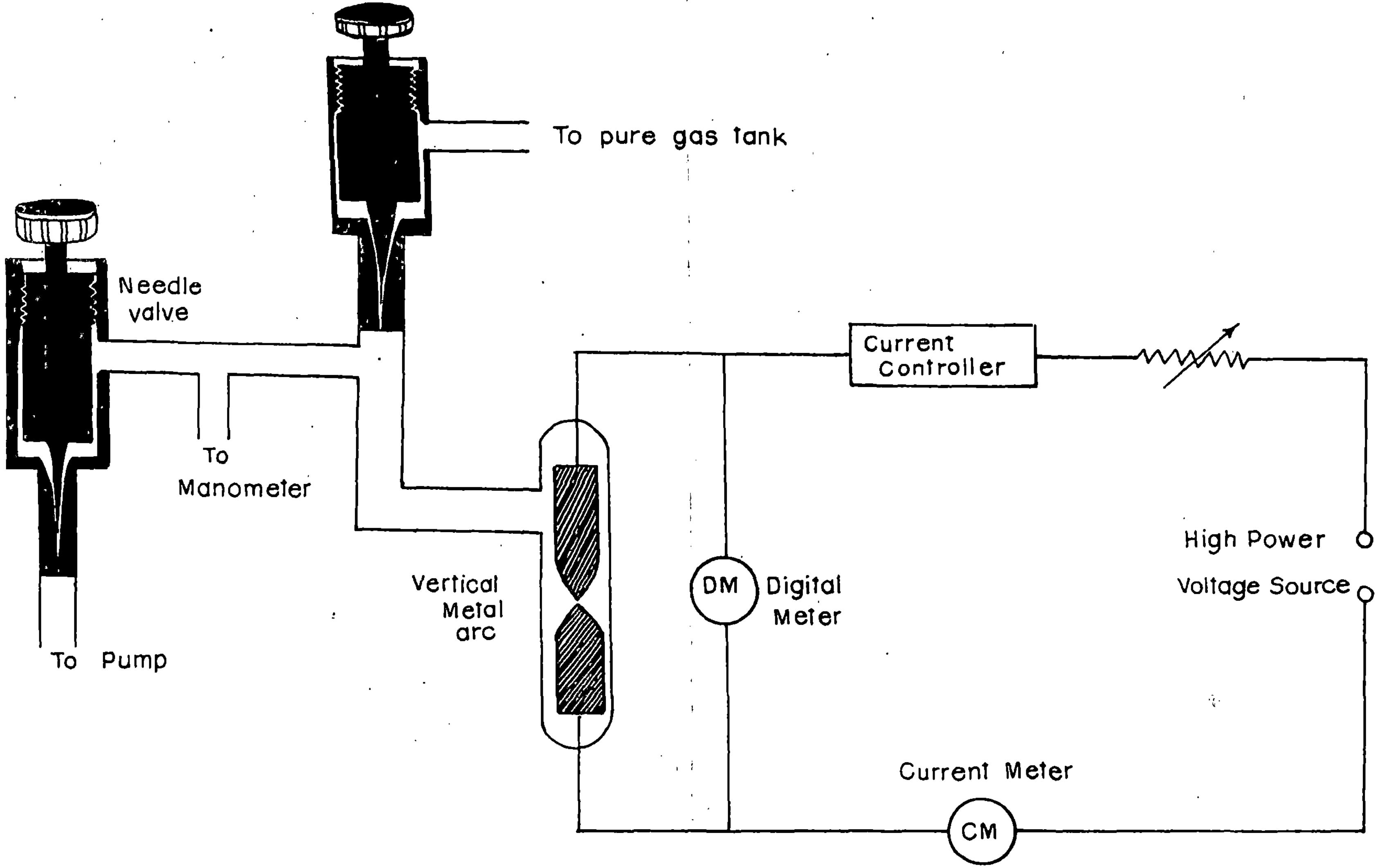
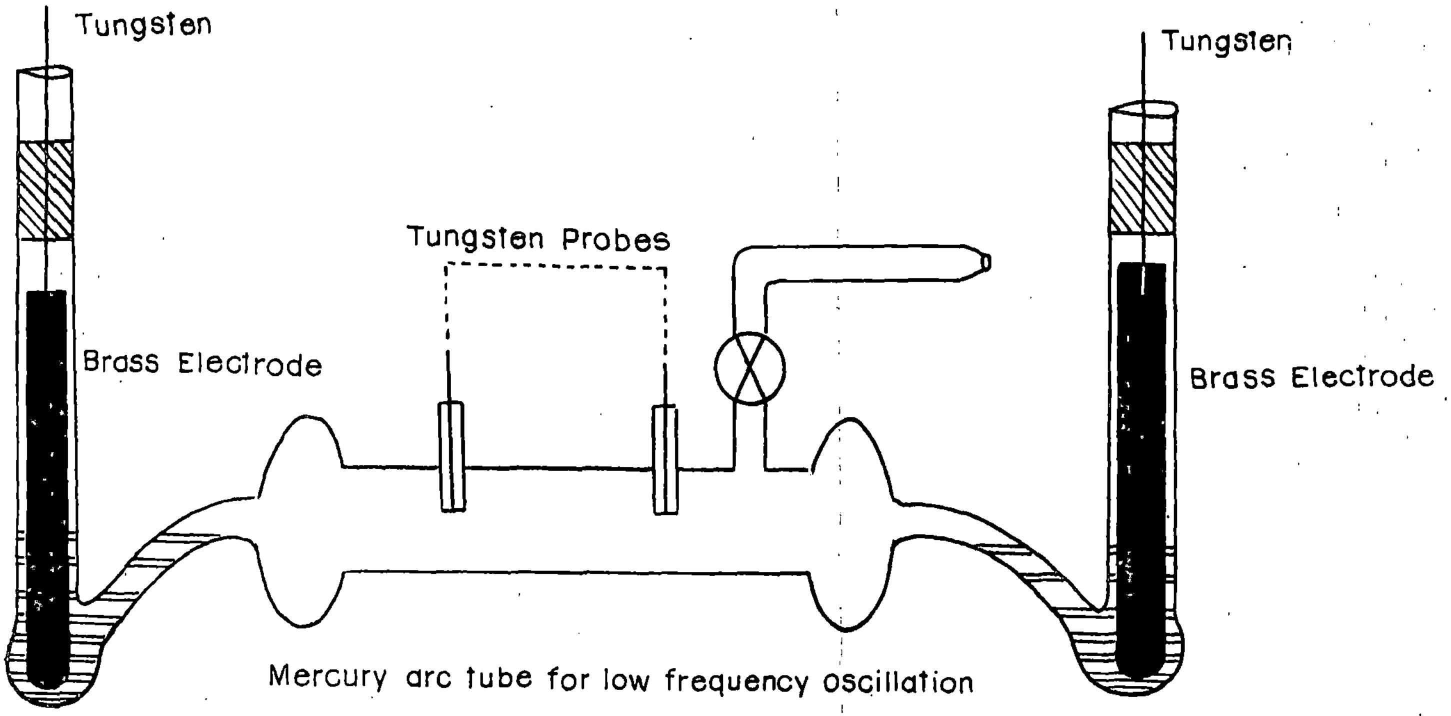


Fig. 2·9 : Fall voltage measurement (Metal Arc) gas into the discharge tube system and also by increasing the leak size of the needle valve close to the pump. Thus with the help of two needle valves and a rotary suction pump any desired pressure not exceeding atmospheric pressure can be maintained inside the discharge tube. The needle valves are adjusted in such a way that the rate at which the experimental gas enters the system is extremely low irrespective of the pressure inside the system. If this condition is not achieved, there may be a shortage of purified gas in the supply gas tank. The arrangement is shown in Fig. 2.9.

2.3.7 The cathode fall in an arc is determined by plotting the graph of arc burning voltage with electrode separation. [Sen, Gantait and Jana (1988)] Because of corrosion of the electrode surface, the measurement of the correct inter-electrode separation is difficult. So every time the electrode surface is to be rubbed to have a plane surface. And the reading has to be taken repeatedly and at a considerable swiftness. Particularly when the interelectrode distance becomes less than a millimeter, the arc is suddenly shorted because of the dense vapour and high temperature close to the cathode. Thus every set of experiment is required to be repeated to check the correct and repeatable results. Block diagram for the whole circuit and accessories is shown in Fig. 2.9.



Mercury arc tube for low frequency oscillation

Tube length 30 cm.
Tube Diameter 1·8 cm.
Brass eletrodediameter 0·8 cm.
Brass electrodelength 0·5 cm.

Fig. 2·10.

2.4 Low frequency oscillation in a Mercury arc Plasma.

Apparatus and Accessories: (1) Mercury arc discharge tube (2) CRO (3) Digital frequency meter (4) Variable inductance tank circuit (5) Voltmeter (6) Current meter (7) One needle valve (8) McLoyd Gauge (9) Pirani gauge (10) Power supply (11) Double stage rotary pump (12) Cooling arrangement (13) Thermometer (14) Magnet Power Supply (15) Electromagnet (16) Gas supply system (17) RF choke.

2.4.1 The arc tube is a conventional mercury arc tube of high length (about 30 cm, end to end) and 1.8 cm diameter with one difference that the electrical connection between the mercury inside and outside of discharge tube uses two thick (diameter 0.8 cm) and long brass electrodes in between the tungsten rod and the mercury at both ends of the discharge tube. If in place of such thick and long electrodes we use only tungsten rods (diameter 1 mm) for electrical connection, it appears in case of study of oscillation that the rod undergoes some physical change with time and after some hour of study of oscillation sometime a red spot starts forming frequently somewhere along the length of the tungsten rod and when such spot is formed the arc undergoes immediate extinction. And thus to remove such trouble we have introduced the above mentioned thick and long rods in between the tungsten and Mercury. The whole diagram is shown in Fig. 2.10

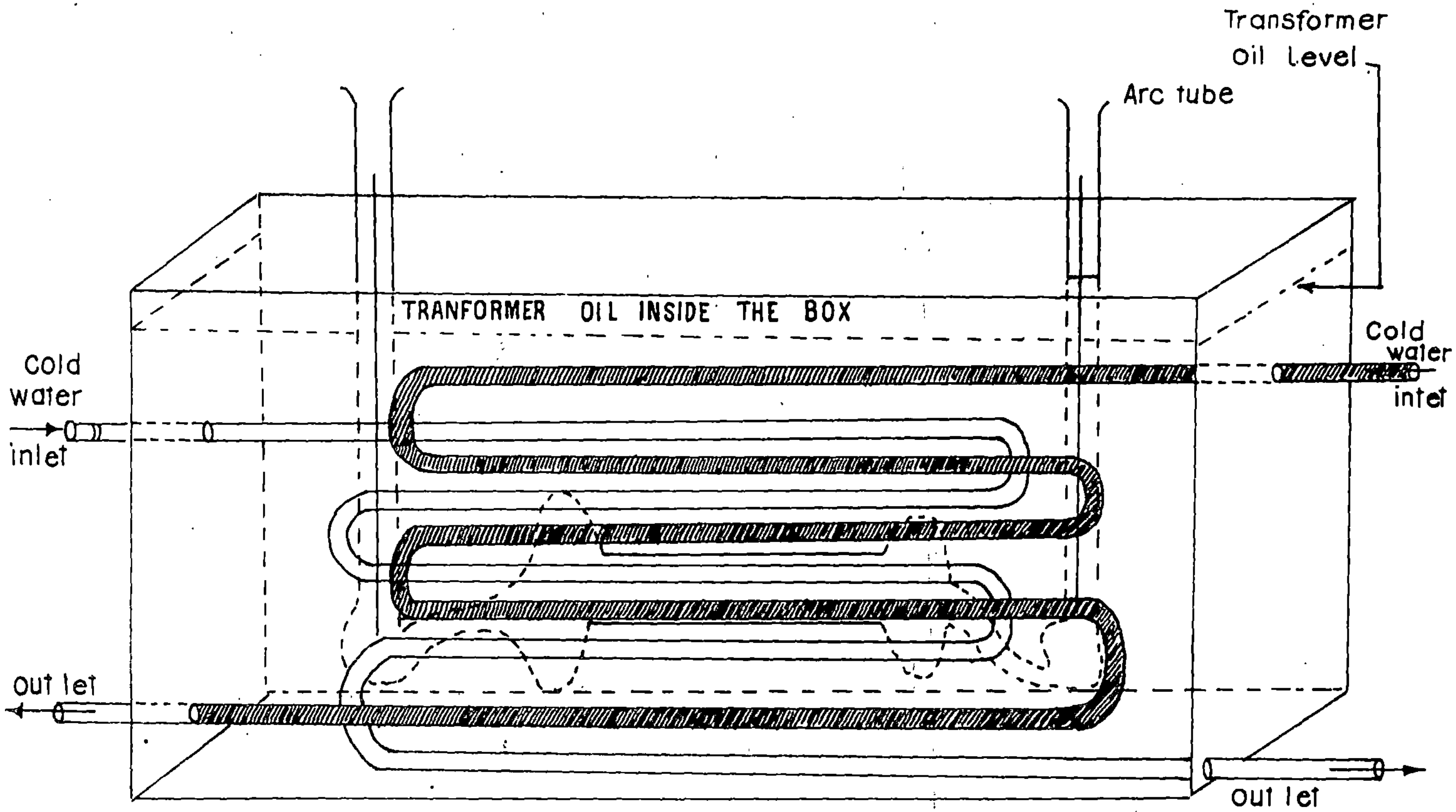


Fig. 2·11. Oil cooling box for Hg - Arc.

2.4.2 To study such a low frequency oscillation the arc tube is to be operated for large time until the tube is perfectly conditioned. This will make the characteristic of the arc to be stable and the tube will operate at a particular operating point on its characteristics curve and hence frequency and amplitude of oscillation will be stable, which is a funaamental utility of any oscillator. But such a long time operation with a perfect thermal equilibrium is very difficult for arcs which consumes high power resulting in either instability in thermal equilibrium or fracture of the tube. So an oil cooling arrangement is provided. This cooling system utilises transformer oil inside a metallic box which contains two array of thin walled copper tubes through which cold water is continuously allowed to pass. In between these two array of pipes inside the oil, the discharge tube is dipped. In this system the arc can be made to run for long time with perfect thermal equilibrium of the discharge tube with surrounding transformer oil. The temperature of the oil in the present case is about $55^{o}C$. The diagram of this cooler is shown in Fig. 2.11.

2.4.3 The tank circuit in parallel to the discharge tube utilises one variable air core choke and a 4 μF condenser and a variable resistance. It was initially intended to construct a negative resistance oscillator, but it did not really occur as per the plan. Reason behind this is probably embeded in the discharge tube. The theory suggests, in this case, that the d.c.

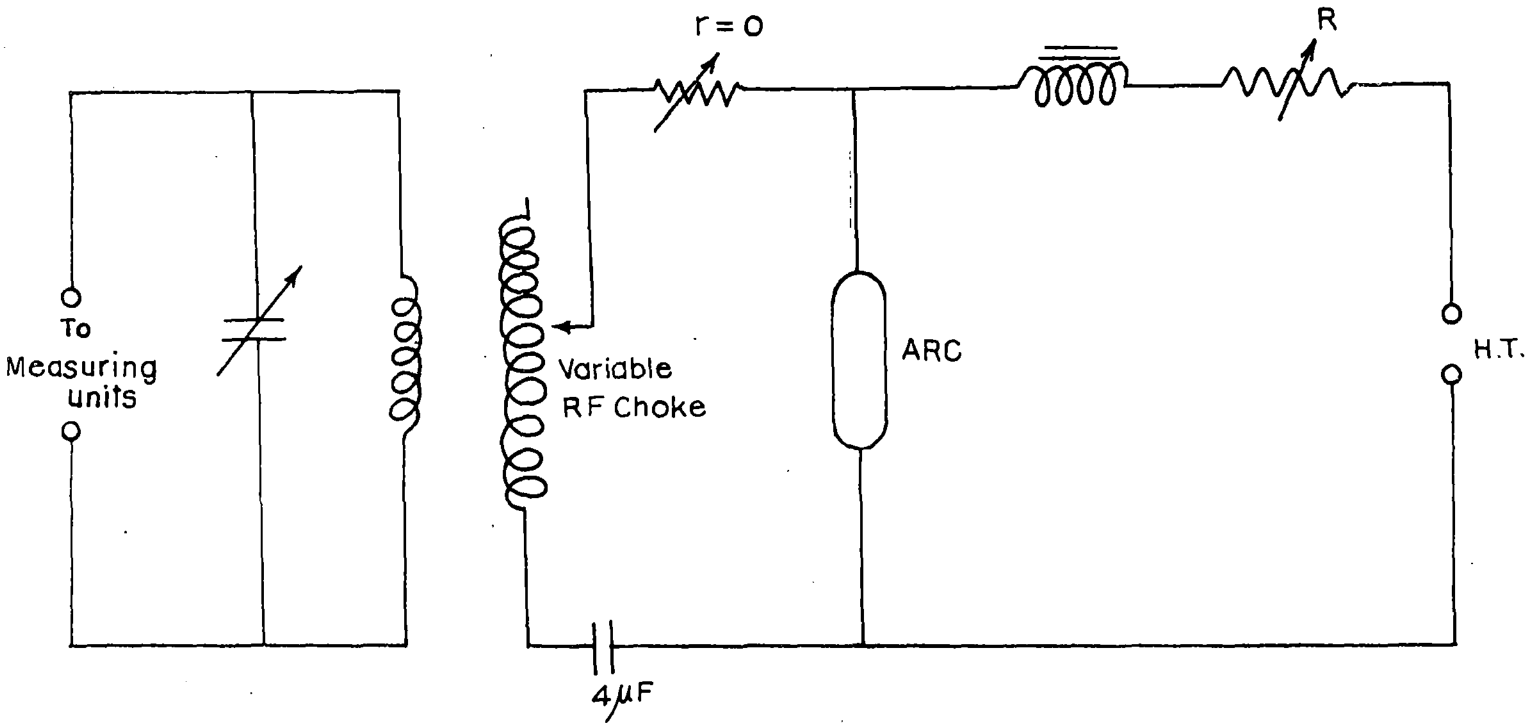


Fig.2·12. Circuit for study of oscillation.

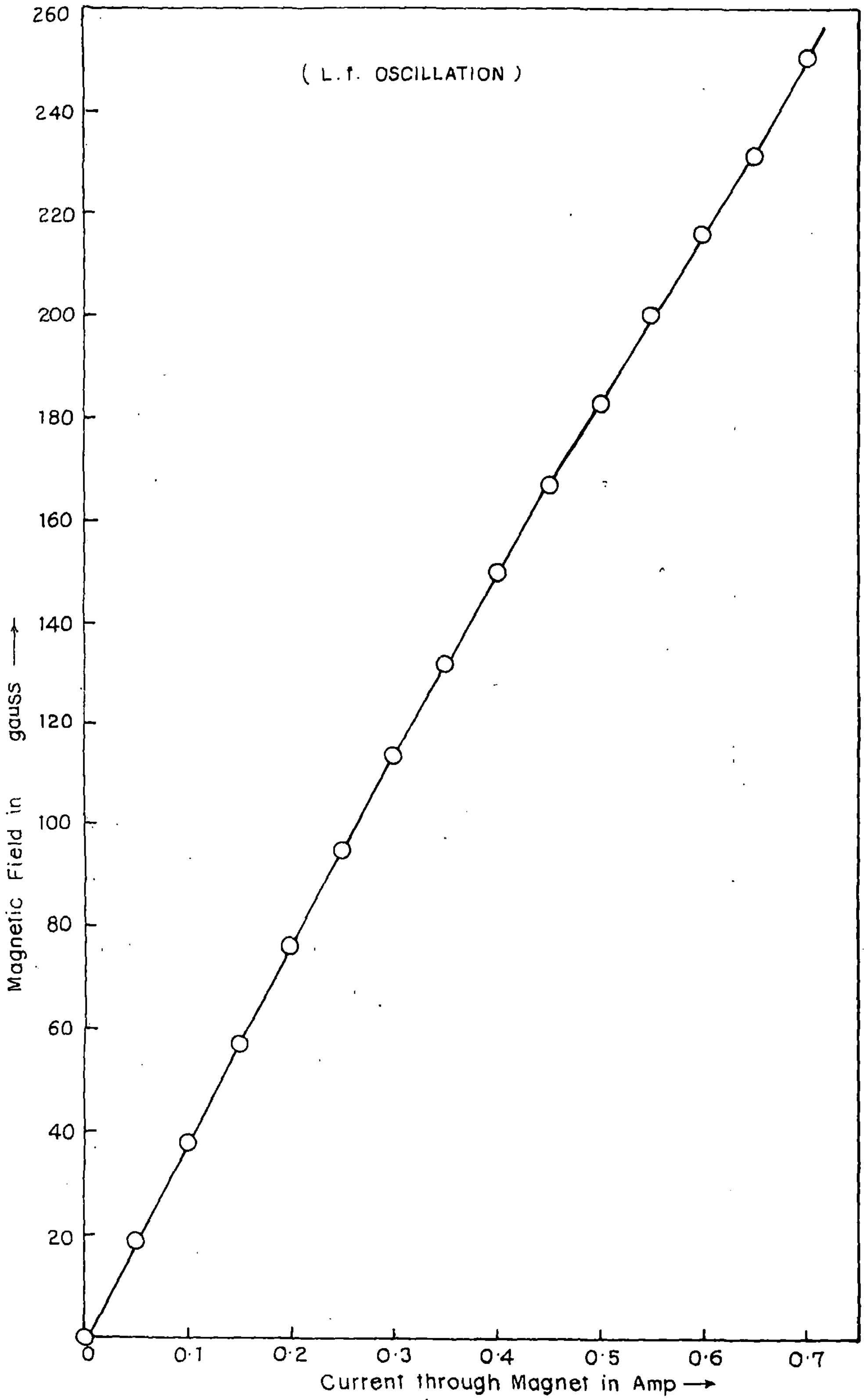

(L.f. OSCILLATION)
260
240
220
200
180
160
140
120
100
80
60
40
20
0
0·1
0·2
0·3
0·4
0·5
0·6
0·7
Magnetic Field in gauss →
Current through Magnet in Amp →

Fig. 2·13.

resistance and a.c. resistance both work in series in case of oscillation, unlike the case of the dynatron oscillator where only a.c. resistance works behind the oscillation. However, the resistance is found to be coupled and the sum of these two resistance for the present discharge tube is positive. So negative resistance oscillator could not be constructed.

On the other hand, it is found that a low frequency a.c. appears in the tank circuit whose frequency does not change with change in the value of inductance and the amplitude becomes maximum when the resistance that is inserted in the tank circuit is reduced to zero. The higher value of condenser increases the amplitude of the ac in the circuit without any change in frequency. These observation suggests that the ac is self generated inside the tube. Complete circuit diagram is shown in Fig. 2.12. The ac is picked up by loosely coupled secondary coil used in the measurement of amplitude and frequency.

2.4.4 The transverse magnetic field applied to mercury arc column is supplied by an electromagnet. The calibration data is shown in table "2b" and the curve in Fig. 2.13.

Table 2b

Magnet current in Amp	Magnetic field in Gauss: When current in one direction	Magnetic field in Gauss: When current in reversed direction	Mean Magnetic field in Gauss
0	0	0	0
0.05	19	19	19
0.10	38	38	38
0.15	57	57	57
0.20	76	76	76
0.25	95	95	95
0.30	114	114	114
0.35	132	132	132
0.40	150	150	150
0.45	167	167	167
0.50	183	182	182.5
0.55	200	200	200
0.60	216	216	216
0.65	332	231	231.5
0.70	250	251	250.5
0.75	265	265	265

2.4.5 The voltmeter in such experiment is required to be capable of measuring fraction of a volt correctly. Because the oscillation builds up only within a very small range of discharge current and to measure the correct value of ac resistance, within a small discharge current limit, the fraction of a voltage change in arc burning voltage must be recorded properly. The situation with change of magnetic field is more critical because the arc undergoes extinction for a magnetic field of the order of 150 gauss only as soon as the oscillation is allowed to develop in the LCR circuit parallel to the arc. So to know the ac resistance for a magnetic field not exceeding 150 gauss for which arc burning voltage changes only a few volt which is only 4 to 5 percent of the total arc burning voltage. So we have used a digital voltmeter which is capable of recording change in voltage in the second decimal place.

2.4.6 The characteristic curve in presence of transverse magnetic field is to be drawn to know the value of ac resistance, for a particular value of initial discharge current and different value of magnetic field applied to the arc. By the initial discharge current we mean the discharge current in absence of magnetic field. For this initial discharge current we gradually change the value of transverse magnetic field and go on recording the value of discharge currents and arc burning voltages for different value of magnetic fields. Thus we get a new characteristic curve for the arc with various transverse magnetic field. The initial discharge current for this new characteristic curve becomes a parameter which should remain essentially constant when the data for the new curve with transverse magnetic field is recorded. Most interesting fact is that sum of the ac and dc resistances for $H = 0$ and for $H \rightarrow 0$ are found to have fairly different values.

2.4.7 Change in frequency with change in pressure of discharge current or magnetic field is not more than a few percent. So a digital frequency meter will enable one to record such a small change in frequency. Such a record of frequency is essential to verify the theory which predicts that,

$$f = \frac{1}{\pi(r_{ac}+r_{dc})C}$$

i.e., the frequency is directly proportional to the inverse of the sum of the ac and dc resistances, which change a little for change in either of the factors like pressure, discharge current and magnetic field.

2.4.8 A CRO is used for visual observation and record of the amplitude of the ac developed. Photograph is also taken from the CRO screen for analysis and measurement of ac amplitude.

2.4.9 Pure air is preapred as described in 2.1 and allowed to enter the system through the needle valve. The pressure is measured with McLoyd Gauge and Pirani Gauge as described in 2.1.