CHAPTER II

EXPERIMENTAL TECHNIQUE USED IN THE INVESTIGATION.

A. BREAKDOWN OF AIR IN CROSSED RADIO FREQUENCY AND D.C. ELECTRIC FIELD.

APPARATUS:-

(1) R.F. Oscillator, (2) V.T.V.M., (3) D.C.Voltage Source, (4) Pirani Gauge, (5) Gas purification system, (6) Exhaust Pump and (7) Needle Valve.

The r.f. oscillator is a Colpitts Oscillator. A tube of the type 811 has been used to obtain a large output voltage of 1000 volts r.m.s. at the operating frequency of 5.7 MHz. To eliminate the harmonics and parasitic oscillations that is present in the oscillator, when operated in the high power level, a coupled circuit arrangement that had been used by Gill and von Engel (1948) has been followed. The r.f. voltage that has been applied across the discharge tube is taken across the coil L of the coupled circuit L-C, tuned by the condenser C to the frequency of the oscillator, the coil L being loosely coupled to the oscillator coil. The plate voltage of the oscillator tube has been supplied from a full wave rectifier circuit using a tube of the type 5R4GY. The input of the circuit is made variable by means of a variac connected between the mains and input terminals of the transformer used in the rectifier circuit. By this arrangement the plate voltage of the

r.f. oscillator is made variable from zero and hence the r.f. output. The composite circuit in its simplest form is as shown in Fig. 2.1. The frequency of the oscillator has been measured with an absorption type wave meter as well as with a communication receiver. The r.f. voltage is applied to two parallel plate electrodes, each of area 10 cm. x 10 cm. between which the discharge tube has been placed. The discharge tube is a rectangular parallelopiped made of glass with internal dimension 20.0 cm. x 2.5 cm. x 2.5 cm. The two rectangular electrodes each of area 25 cm. x 5 cm. have been used to apply transverse uniform electric field. The arrangement is as shown in Fig. 2.2.

The r.f. breakdown voltage has been measured with a V.T.V.M. The plate voltage of the oscillator is gradually increased and hence the r.f. applied voltage across the discharge tube. At some r.f. voltage it has been observed that the reading of the V.T.V.M. has shown an abrupt fall with a simultaneous glow in the discharge tube. The r.m.s. value of the r.f. voltage, that is indicated by the V.T.V.M. has been taken as the breakdown voltage.

Air has been passed through dilute solution of caustic potash to remove traces of CO_2 and is then washed with water by passing through series of wash bottles containing cold water to remove traces of caustic potash,

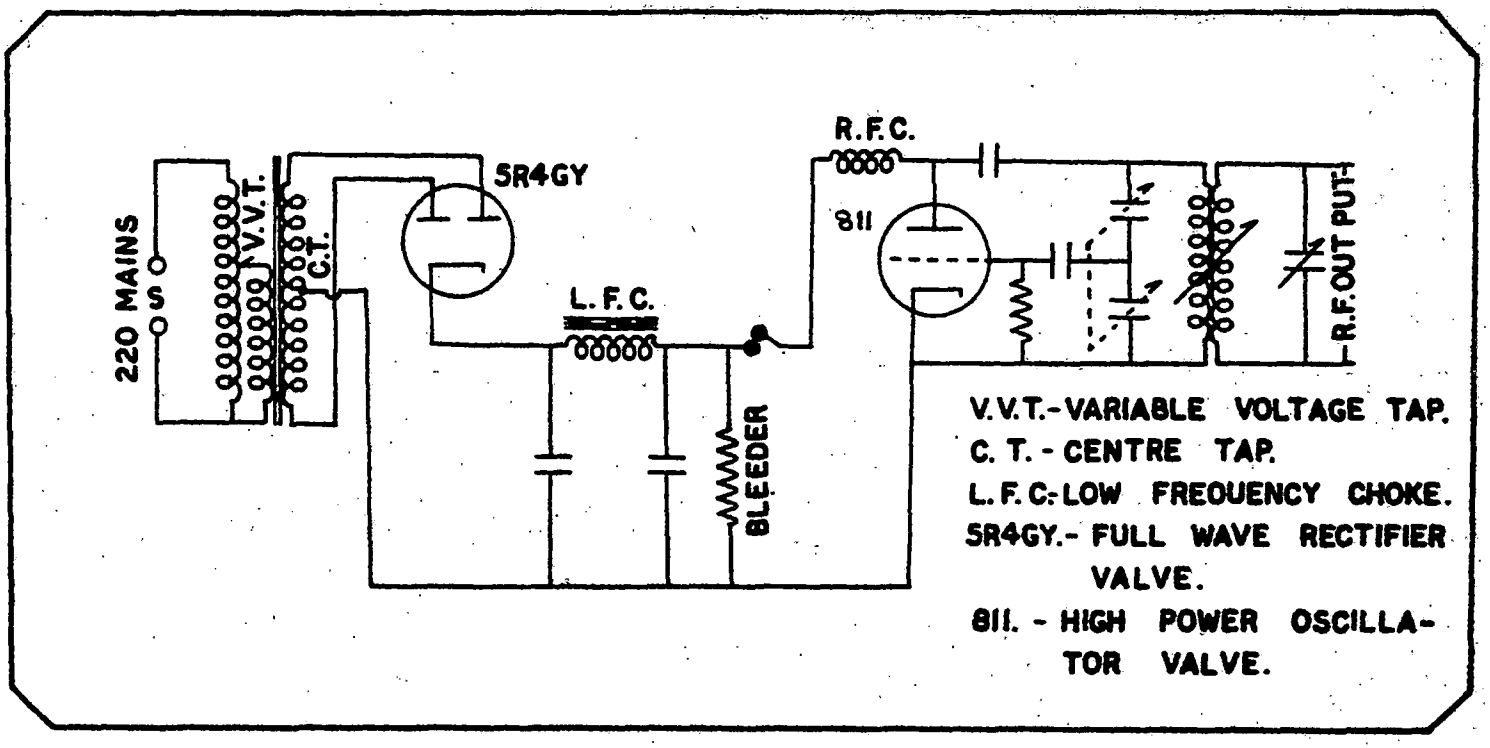
220 MAINS
V.V.T.
C.T.
5R4GY
L.F.C.
BLEEDER
R.F.C.
811
R.F.OUT PUT
V.V.T.-VARIABLE VOLTAGE TAP.
C. T. - CENTRE TAP.
L. F. C.-LOW FREQUENCY CHOKE.
5R4GY.- FULL WAVE RECTIFIER VALVE.
811. - HIGH POWER OSCILLATOR VALVE.

FIG. 2.1.

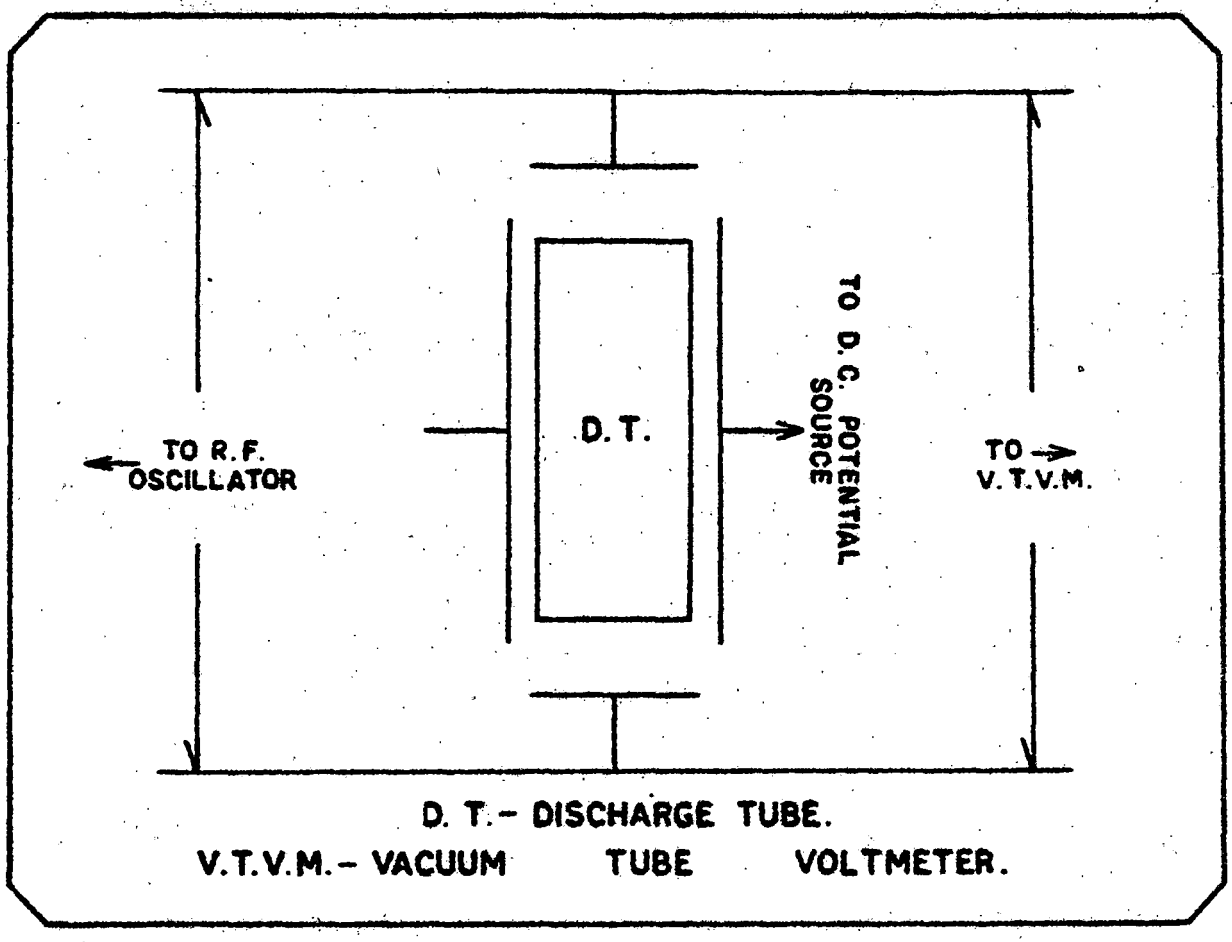
TO R.F. OSCILLATOR
D.T.
TO D.C. POTENTIAL SOURCE
TO V.T.V.M.
D. T.- DISCHARGE TUBE.
V.T.V.M.- VACUUM TUBE VOLTMETER.

FIG. 2.2.

dust particles and organic matters. It has then been dried by passing through a tower of fused $CaCl_2$ and finally through P_2O_5.

The discharge tube has been continuously evacuated by a rotary pump which is capable to evacuate the system to a pressure of 10^{-3} mm. Hg. and has properly been baked to remove occluded gas. The operation has continued for a considerable time and then pure and dry air has been introduced into the discharge tube. The system has been flushed a number of times with pure and dry air to ensure the atmosphere of pure and dry air inside the discharge vessel. The pressure of the gas has been kept constant by means of a needle-valve and is measured by a Edward Pirani Penning Vacuum Gauge. Keeping the pressure at a constant value and without any transverse d.c. field, the breakdown voltage has been measured by the V.T.V.M. Observations at different pressures have been repeated for several times and the mean values of breakdown potentials have been noted against the corresponding pressures.

The transverse d.c. voltage has been applied from a d.c. voltage source. The d.c. voltage source is an electronic voltage stabilizer with output voltage from 0 to 300 volts and with ripple only 0.01%. With different values of the superimposed transverse d.c. field the breakdown voltage have been measured for different pressures. The observations have been repeated and mean values are obtained.

B. RADIO FREQUENCY ELECTRIC FIELD BREAKDOWN OF GASES IN PRESENCE OF TRANSVERSE MAGNETIC FIELD (LOW INTENSITY).

APPARATUS:-

(1) R.F.Oscillator, (2) V.T.V.M., (3) Mercury Manometer, (4) Electromagnet, (5) Gas Generation and Purification System and (6) Exhaust Pump.

The r.f. oscillator used in the experiment is the same as described in the previous experiment with the exception that the frequency of oscillation is 6.2 MHz. The r.f. voltage has been applied to two external circular parallel plate electrodes each of radius 4.0 cm. ~~each~~. The two electrodes have been attached externally to the flat ends of a cylindrical discharge tube made of glass and of length 0.7 cm. and radius 2.0 cm. The discharge tube has been placed between the pole pieces of an electromagnet with the length of the discharge tube perpendicular to the magnetic field lines produced by the electromagnet as shown in Fig. 2.3. The distance between the pole pieces of the electromagnet is 10.0 cm. and the maximum field that can be produced by the magnet is 1.2 K.Gauss.

The pressure of the gas has been measured with the help of a mercury manometer. The manometer has been connec-

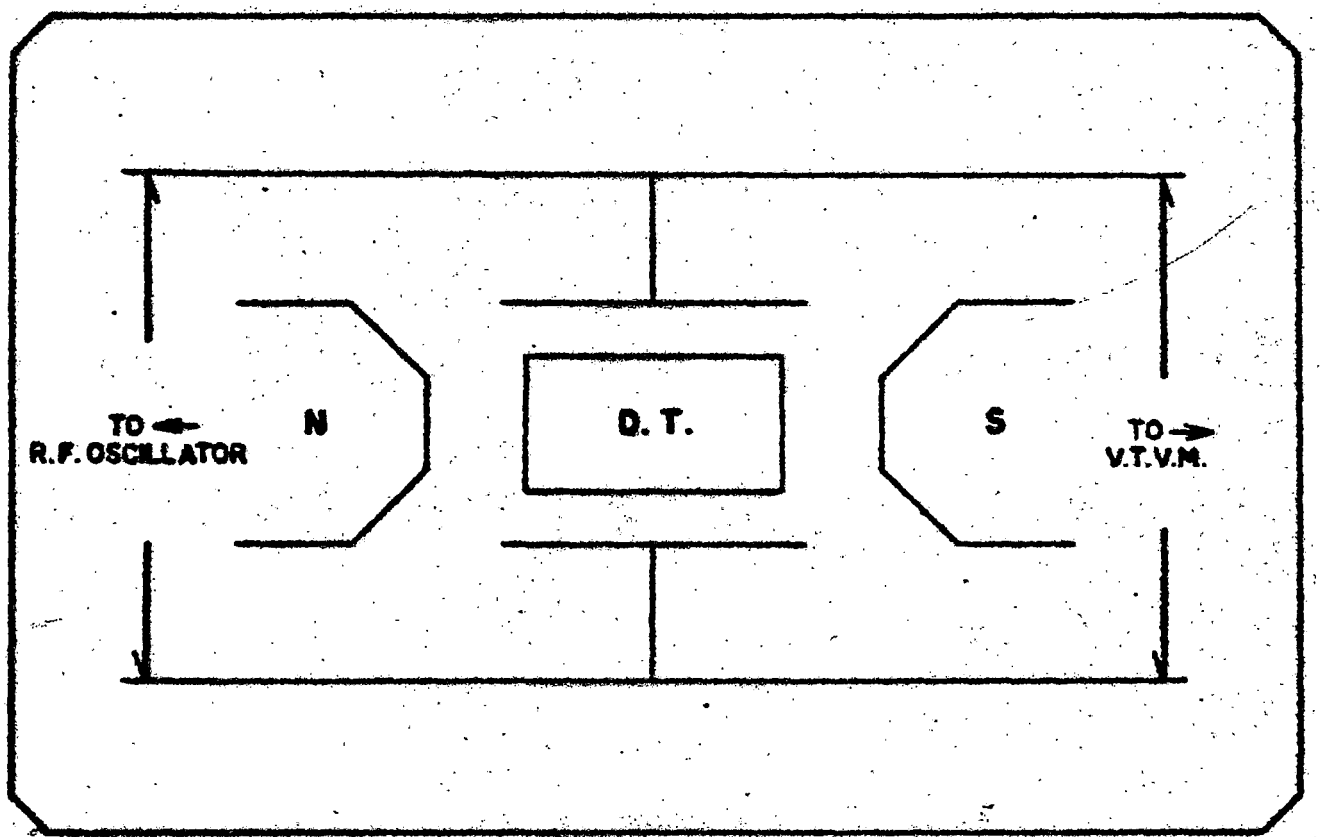

FIG. 2.3.

ted to the system and the mercury vapour from the manometer has been prevented from entering the discharge tube by means of a trap immersed in a bath containing freezing mixture of ice and common salt. The mercury level in the two limbs of the manometer has been measured with the help of a travelling microscope.

Hydrogen gas has been prepared by the electrolysis of warm barium hydroxide solution, taken in a hard glass U-tube, with nickel electrodes. Traces of oxygen present in the gas so formed has been removed by passing the gas over heated platinum gauge to burn out any traces of oxygen. The gas has then been dried by passing the gas through a U-tube containing re-distilled phosphorous pentoxide. Oxygen gas has been prepared by heating pure potassium permanganate taken in a conical flask. The oxygen gas so formed has been washed with water in a wash bottle. Oxygen gas has then been dried by passing it through a tower containing fused calcium chloride, through a U-tube containing pellets of potassium hydroxide and finally through another U-tube containing re-distilled phosphorous pentoxide. Air has been purified and dried by methods as mentioned in the previous experiment.

The electromagnet has been calibrated by means of a gaussmeter. The gaussmeter consists of a rectangular coil rotated along the axis passing through the plane of the coil by a synchronous motor of revolution 50 c/s. By placing the coil perpendicular to the uniform magnetic field, the induced e.m.f. that is generated in the coil has been measured by an a.c. milli-voltmeter. An e.m.f. of 0.18 mV. is induced in the coil when the coil is rotating in a magnetic field of one gauss. * This constant has been supplied by the manufacturer of the gaussmeter. The current through the coil of the electromagnet has gradually been increased in steps of 0.5 Amp. and the corresponding induced e.m.f. in the gaussmeter coil has been noted from the a.c. milli-voltmeter. The results are given in Table-2.1. The calibration have been repeated thrice and the results are plotted in Fig. 2.4. Dividing the a.c. milli-voltmeter reading by 0.18, the magnetic field has been obtained in gauss for the corresponding current in the electromagnet.

Results of Callibration of Electromagnet:-

Amplitude of the output a.c. voltage/gauss = 0.18 mV.
Distance between the pole-pieces of the electromagnet = 10.0 cm.

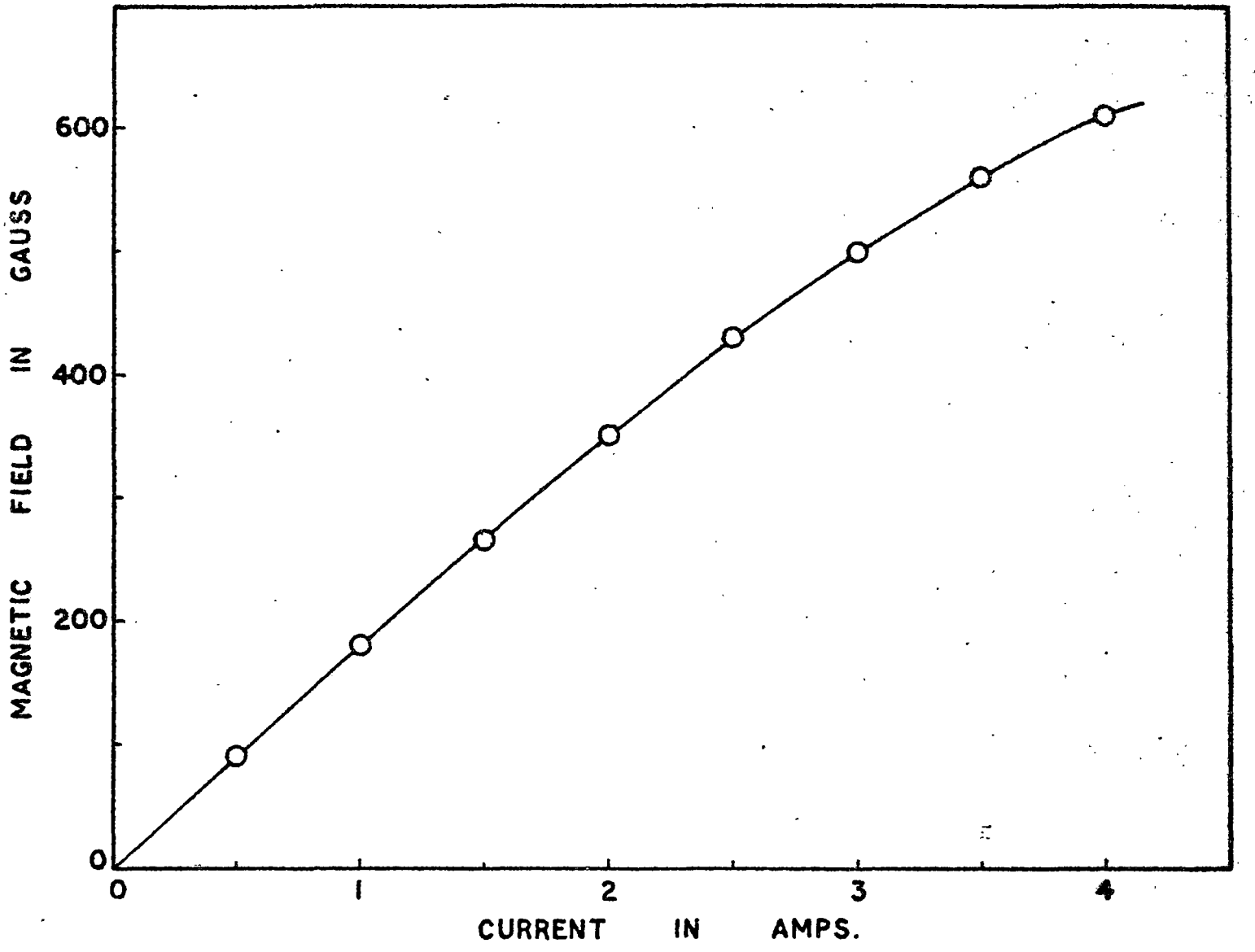

FIG. 2.4.

TABLE-2.1

Current through the coil of the magnet (Amps.)	A.C.output voltage of the gaussmeter (mV.)	Magnetic field (gauss)
0	0	0
0.5	16.2	90
1.0	32.4	180
1.5	47.7	265
2.0	63.0	350
2.5	77.7	430
3.0	90.0	500
3.5	100.8	560
4.0	109.8	610

Before starting measurement of breakdown potential with variable pressure and superimposed transverse steady magnetic field, the whole system of discharge vessel has been exhausted by a rotary pump and has simultaneously been baked for a considerable time. Then the system was flushed several times by the experimental gas to ensure the atmosphere of the gas within the discharge tube. Keeping the pressure within the discharge tube constant by

adjusting the needle-valve and with zero magnetic field, the r.f. voltage has gradually been increased until the breakdown of the gas has occured which is noted by the appearance of a bright glow and slight fall of applied voltage called the breakdown voltage. The breakdown voltage has been measured by the V.T.V.M. The measurements have been repeated for a particular pressure and the mean value has been taken as the breakdown potential at that pressure. Keeping the pressure of the gas at different values, the corresponding breakdown potentials have been noted. The whole procedure have been repeated in presence of transverse steady magnetic field of different field intensities. Identical measurements have then been repeated for different gases. The gases that have been investigated in the present experiment are hydrogen, oxygen, and dry air.

C. RADIO FREQUENCY ELECTRIC FIELD BREAKDOWN OF GASES IN PRESENCE OF TRANSVERSE MAGNETIC FIELD (HIGH INTENSITY).

APPARATUS:-

(1) R.F.Oscillator, (2) V.T.V.M., (3) Pirani Gauge, (4) Electromagnet, (5) Gas Generation and Purification System, (6) Exhaust Pump and (7) Needle Valve.

The r.f. oscillator that has been used in the experiment is the same as described in the previous experiments. The frequency of the oscillator is 8.9 MHz. and and the maximum output voltage that can be obtained is 500volts r.m.s. The r.f. voltage has been applied to two rectangular parallel plates kept separated by a distance 1.0 cm. The two parallel plates have served the purpose of external electrodes. The discharge tube is a rectangular parallelopiped of internal dimension 0.6 cm.x2.0cm. x 2.2 cm. The discharge tube has been placed between the electrodes with sides 2.0 cm x 2.2 cm. parallel to the electrodes. The magnetic field has been produced by an electromagnet and the magnetic field lines are perpendicular to the sides 0.6 cm. x 2.0 cm. of the discharge tube. The distance between the pole pieces of the electromagnet is 5.0 cm. and the maximum field that the magnet is capable to produce is 5 K.Gauss.

Gas generation and purification process is the same as described in the previous experiment. The pressure of air has been measured by an Edward Pirani Penning Vacuum Gauge while the pressures of hydrogen and oxygen have been measured by a Pirani Gauge which has previously been calibrated by a Mc Leod Gauge. The

results of calibration are given in Table-2.2 and 2.3 and are plotted in Figs.2.5 and2.6 for hydrogen and oxygen respectively. The r.f. breakdown voltage has been measured by a V.T.V.M. The electromagnet has been calibrated by a gaussmeter in the same procedure as described in the previous experiment and also by calibrated Hall-probe. The results are given in Table-2.4 and are plotted in Fig.2.7.

Results of Calibration of Pirani Gauge for Hydrogen & Oxygen.

TABLE-2.2

Pirani Current in μA.	Pressure in Torr.
10	.90
14	.63
21	.42
29	.31
41	.23
51	.18
62	.15
80	.11
101	.08

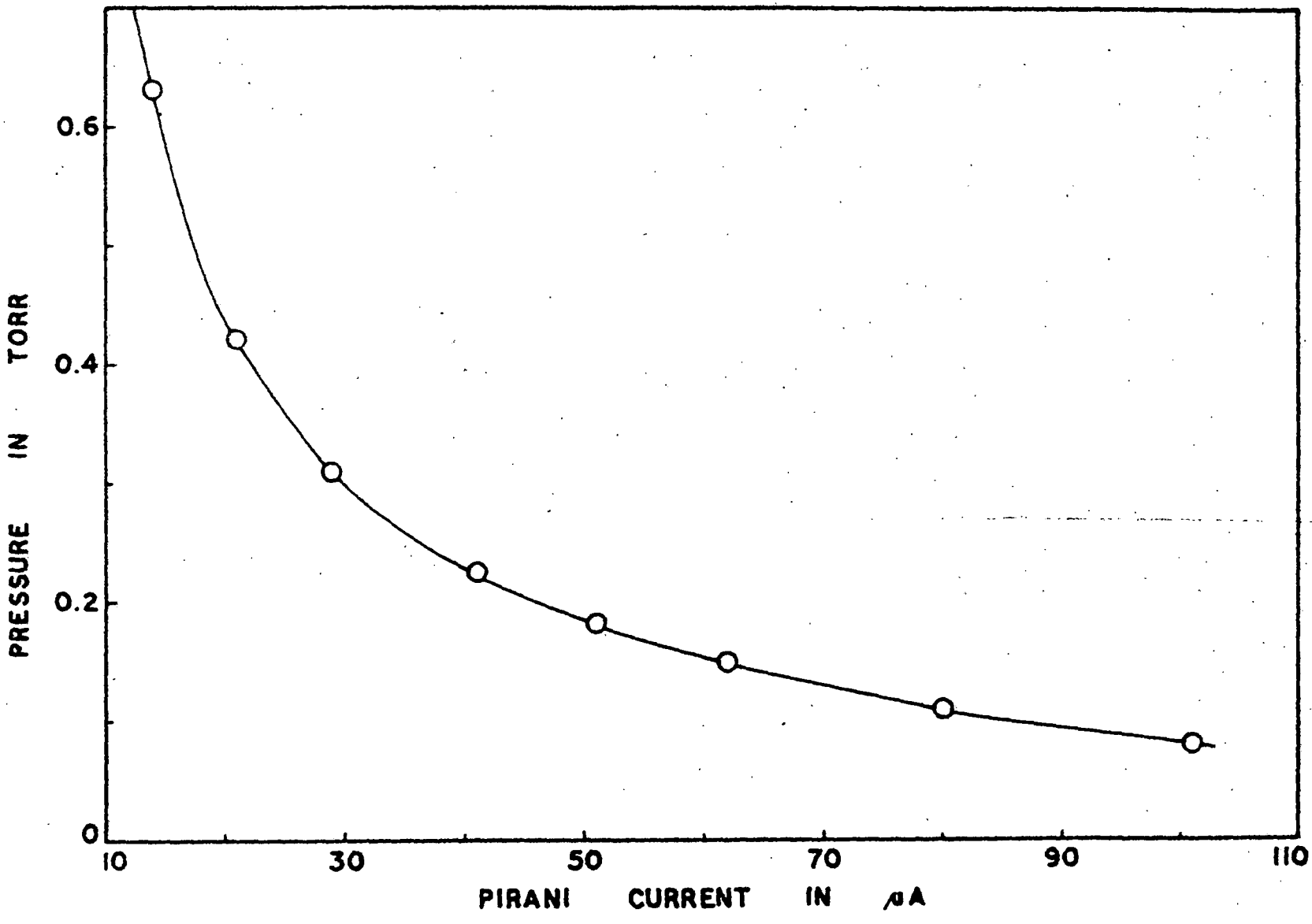
PRESSURE IN TORR
0.6
0.4
0.2
0
10
30
50
70
90
110
PIRANI CURRENT IN μA

FIG. 2.5.

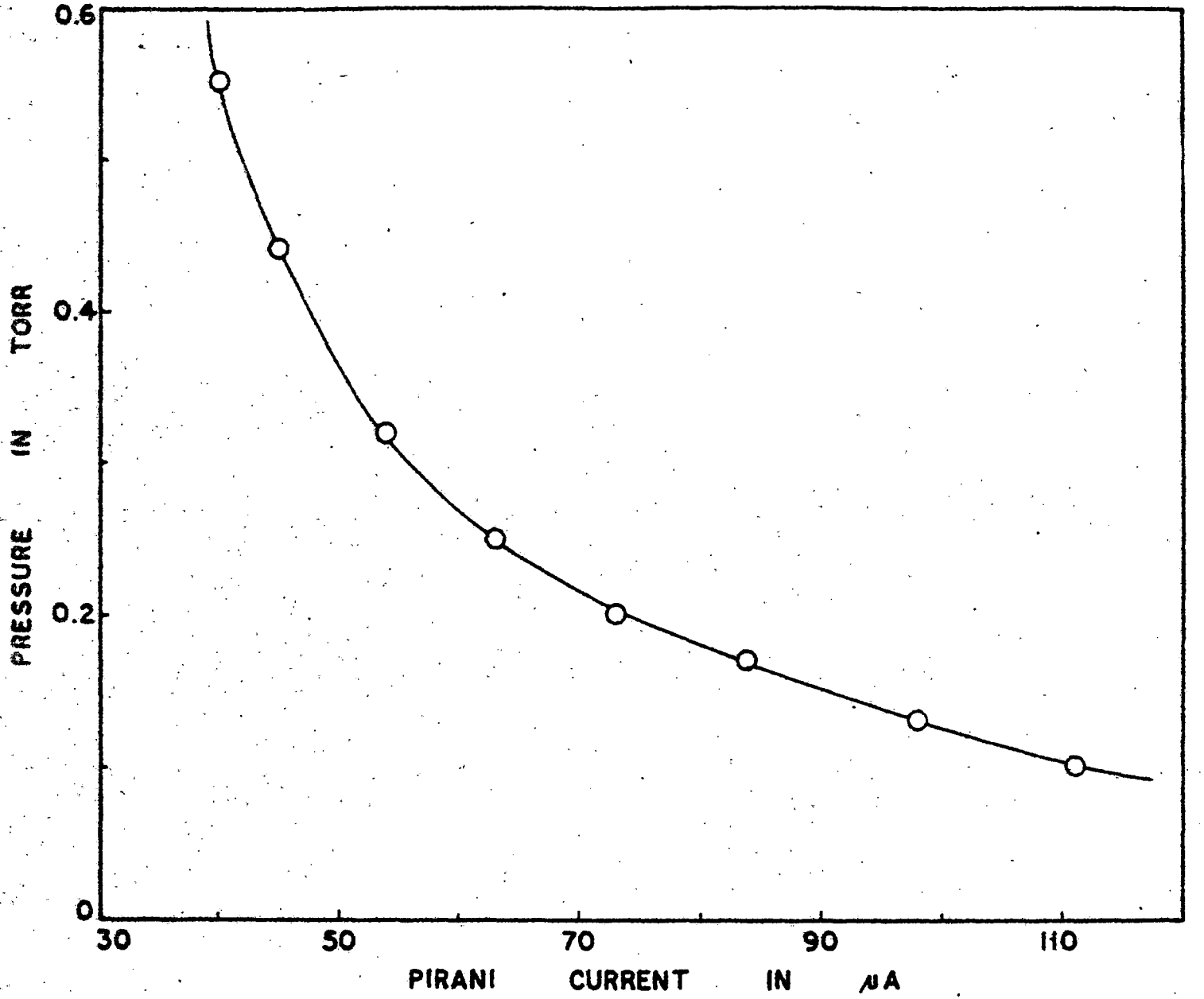

FIG. 2.6.

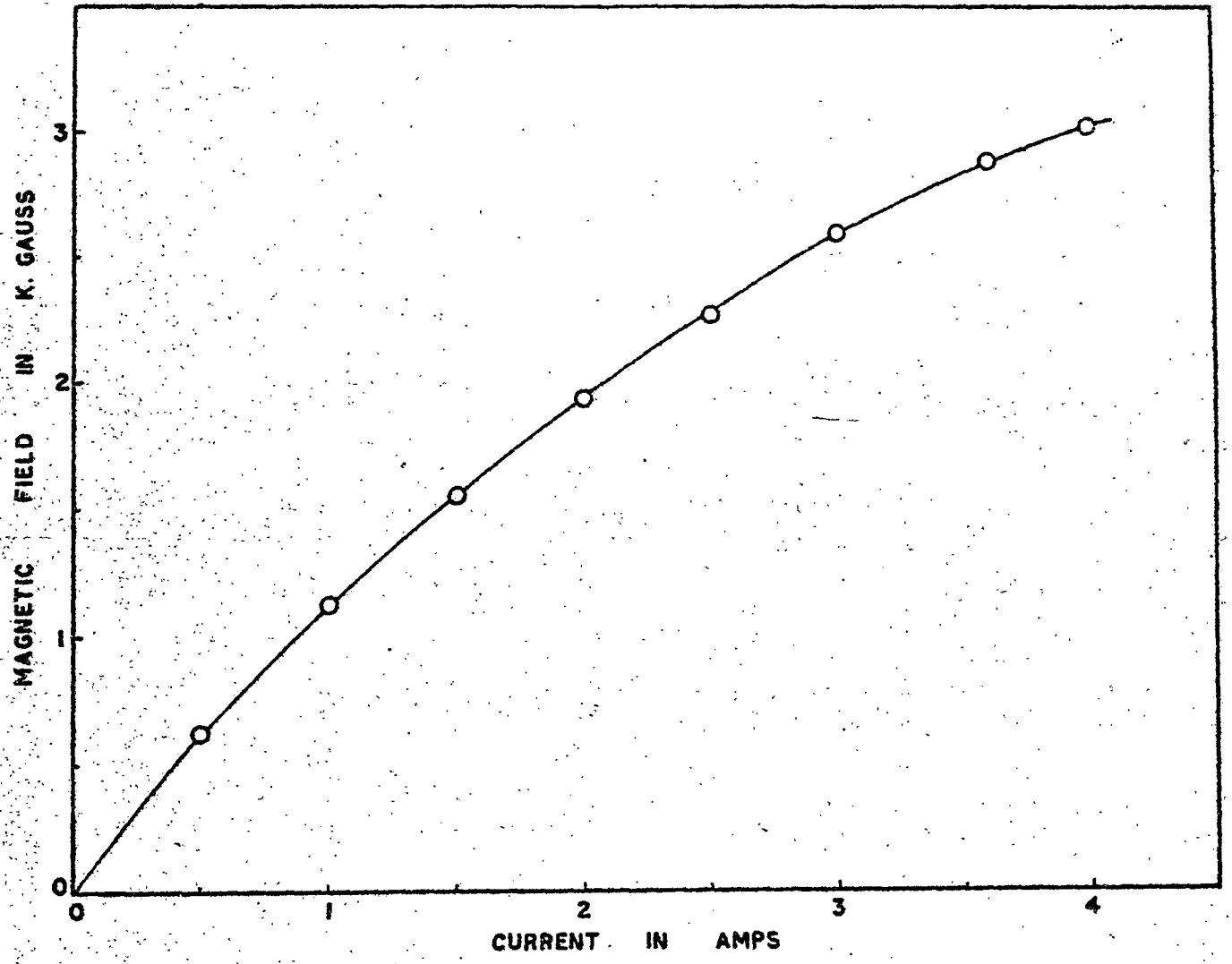

FIG. 2.7.

TABLE-2.3

Pirani Current in μA.	Pressure in Torr.
40	.55
45	.44
54	.32
63	.25
73	.20
84	.17
98	.13
111	.10

Results of calibration of electromagnet:-

Amplitude of the a-c output voltage of the gaussmeter/ gauss = 0.18 mV.

Distance between the pole pieces of the electromagnet = 5.0 cm.

TABLE-2.4

Current through the coil of the magnet (Amp.)	Measurement by Gaussmeter		Measurement by Hall-probe	Mean Magnetic field (K.Gauss)
	A.C.Output voltage of the Gaussmeter (mV)	Magnetic Field (K.Gauss)	Magnetic Field (K.Gauss)	
0	0	0	0	0
0.5	111.6	0.62	0.62	0.62
1.0	201.6	1.12	1.12	1.12
1.5	277.2	1.54	1.56	1.55
2.0	347.4	1.93	1.95	1.94
2.5	406.8	2.26	2.28	2.27
3.0	468.0	2.60	2.58	2.59
3.5	518.4	2.88	2.88	2.88
4.0	547.2	3.04	3.00	3.02

Before starting measurements of breakdown potential with superimposed magnetic field the whole system of discharge tube has been exhausted by a rotary vacuum pump and simultaneously baked for considerable time. Then the system was flushed several times by the experimental gas to ensure the atmosphere of the gas with the discharge tube.

The pressure of the gas within the discharge tube is kept constant by means of a needle-valve attached to the system. Keeping the pressure constant within the discharge tube and with a uniform d.c. magnetic field, transverse to r.f. field, the r.f. voltage has gradually been increased until the breakdown has occured. The r.f. breakdown voltage has been measured by the V.T.V.M. The r.f. voltage has then been slowly increased to find if the discharge extincts. The extinction of the glow has occured at high intensity of the magnetic field and the r.f. voltage at which extinction occured has been noted. The r.f. voltage at that condition has been further increased until the second breakdown has occured at a higher voltage which has also been measured by the V.T.V.M. Keeping the magnetic field constant, the measurement has been repeated a number of times. From these observations mean values of the first breakdown, extinction and second breakdown have been obtained at the corresponding values of the applied magnetic field. The experiment has been repeated for other gases. The gases used in the experiment are hydrogen, oxygen and pure dry air; the methods of preparation of the gases has already been stated in earlier experiments.

D. VARIATION OF GLOW DISCHARGE CURRENT IN LONGITUDINAL MAGNETIC FIELD

APPARATUS:-

(1) A High Voltage Stabilized Power Supply, (2) Pirani Gauge, (3) Electromagnet, (4) Exhaust Pump, (5) Discharge Tube, (6) Voltmeter, (7) Milliammeter, (8) Gas Generation and Purification System and (9) Needle Valve.

The high voltage d.c. power supply is an electronically regulated power supply with the output voltage varying from 150 to 1000 volts at 100 mA. maximum output current. The circuit diagram of the power supply is as shown in Fig. 2.8. The high voltage has been used to ionize the gas and to form a glow discharge in the discharge tube. The discharge tube is a cylindrical glass tube of radius 1.5 cm. fitted with parallel polished brass electrodes of radius 1.25 cm. kept separated by a distance 2.2 cm. Magnetic field has been produced by means of solenoid of 30 cm. length through which a d.c. current is passed. The discharge tube has been placed at the centre of the solenoid so that the magnetic field lines are parallel to the axis of the discharge tube.

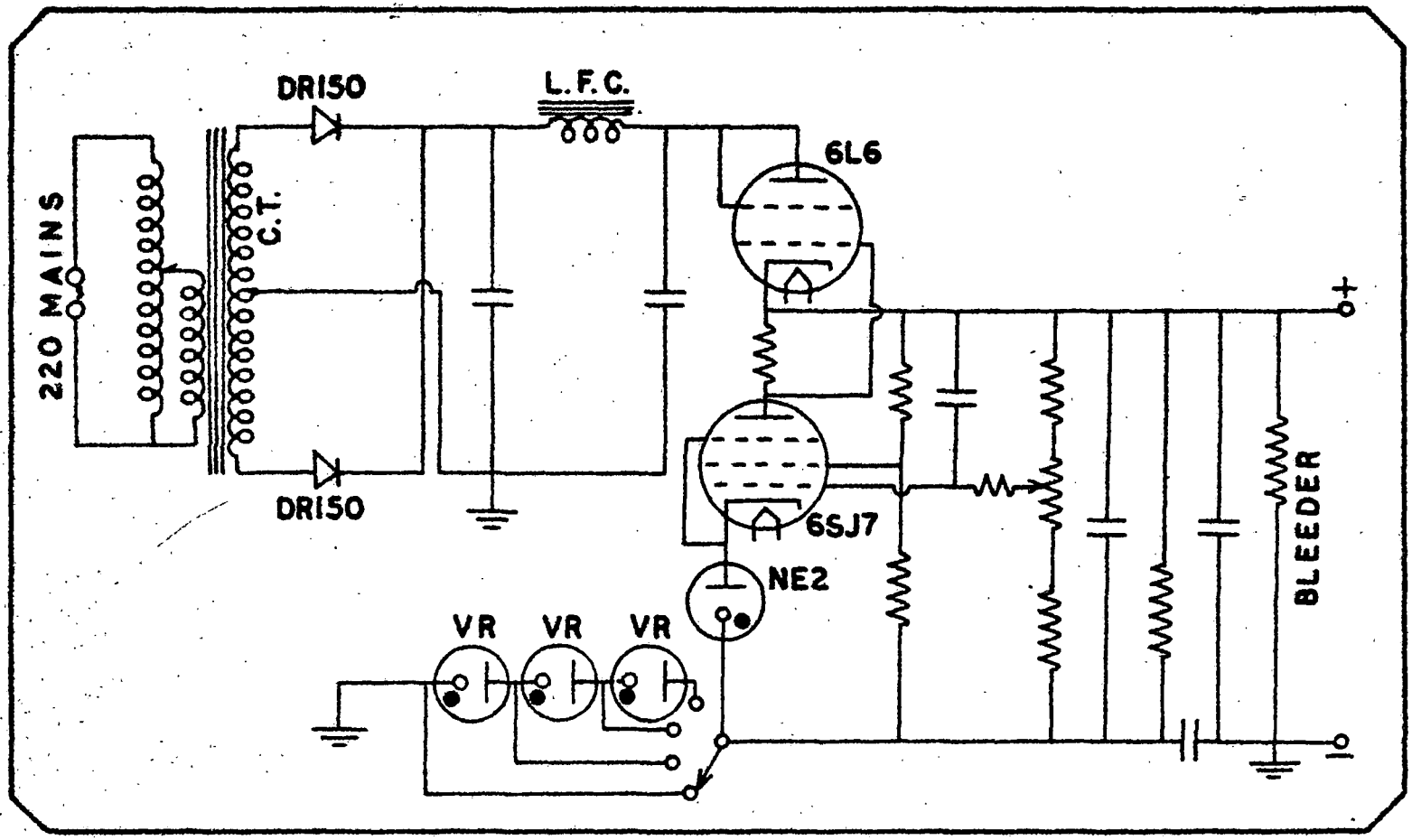

FIG. 2.8.

Hydrogen and oxygen have been prepared and dried and air has been purified and dried in the same methods as discussed in previous experiments. Nitrogen gas has been supplied by Indian Oxygen Company in cylinders. The nitrogen gas has been washed with water by passing the gas through wash bottles and then dried in the similar way as air has been dried.

Calibration of magnetic field produced by the solenoid has been made by using a ballistic galvanometer and a search coil. The gaussmeter method or Hall-Probe method has not been applied because the coil of the gaussmeter or the Hall-probe cannot be placed at right angles to the magnetic field lines within the coil where the discharge tube has to be placed. The results of calibration are given in Table-2.5 and are plotted in Fig. 2.9.

Let n = number of turns in the search coil

A = area of the search coil

H = magnetic field

R = total resistance in the circuit containing the ballistic galvanometer and the search coil

k = constant of the ballistic galvanometer

λ = logarithmic decrement

d = deflection of the spot of light

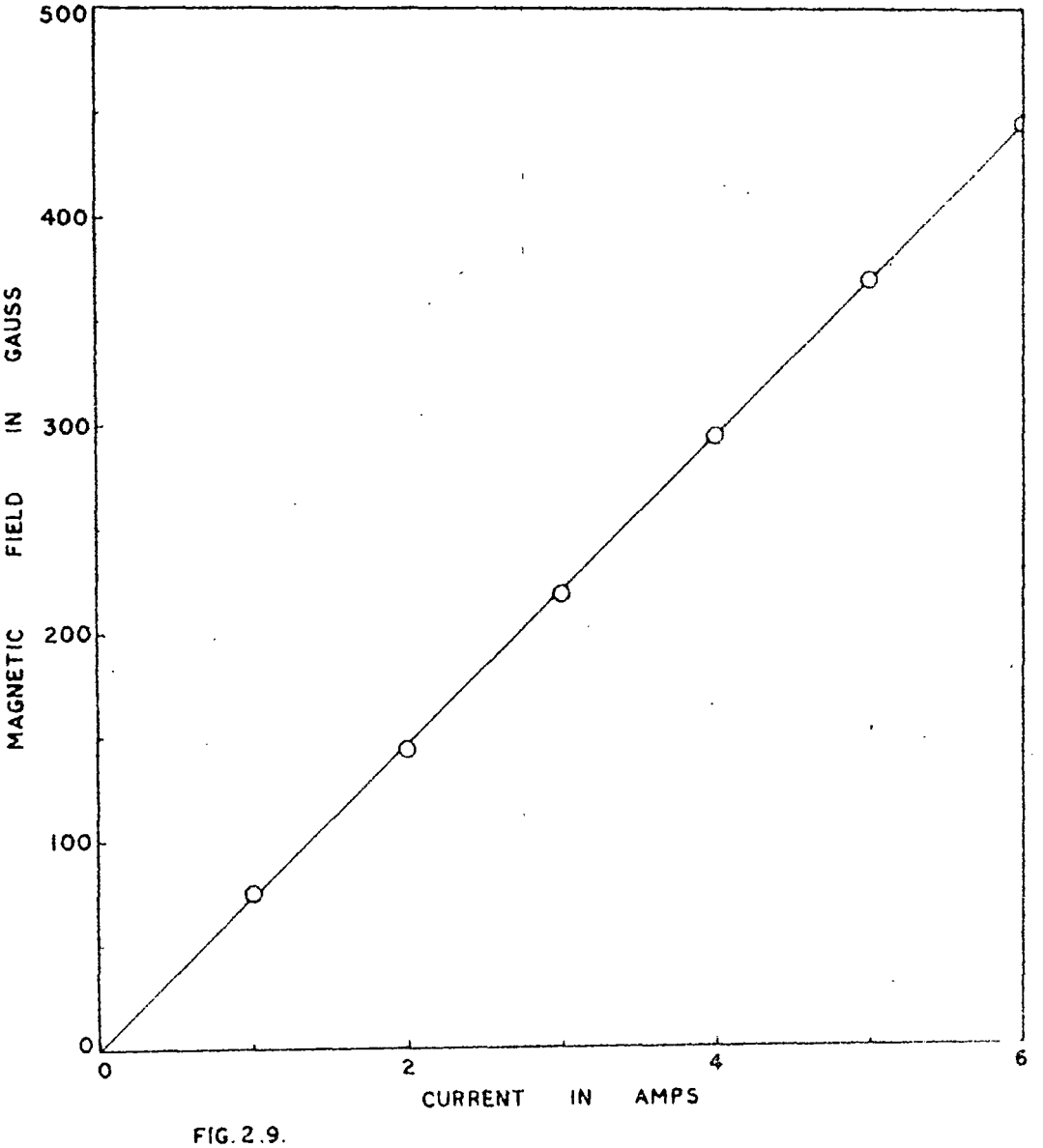
500
400
300
200
100
0
MAGNETIC FIELD IN GAUSS
0
2
4
6
CURRENT IN AMPS

FIG. 2.9.

D = distance between the mirror of the galvanometer and the scale

then $$H = \frac{kRd\ (1 + \frac{\lambda}{2})\ x\ 10^8}{2nAD}$$

Results of Calibration of Magnetic Field:-

No. of turns in the search coil = 203

Length of the wire forming the coil (L) = 820 cm.

Constant of the ballistic galvanometer (K) = 5.08×10^{-6}

Logarithmic decrement (λ) = 0.31526

Distance between the mirror and scale (D) = 82.2 cm.

Resistance of the search coil = 30.0 Ohm.

Resistance of the galvanometer = 90.0 Ohm.

Damping resistance in the galvanometer circuit = 500.0 Ohm.

So $$nA = \frac{L^2}{4\pi n} = 263.58 \text{ sq.cm.}$$

and R = 620.0 Ohms.

Hence H = 84.128 x d Gauss.

TABLE-2.5

Current through the Coil in Amps.	Deflection		Mean Deflection in cm.	Magnetic Field in Gauss.
	At make in cm.	At Break in cm.		
0 Direct	0	0	0	0
Reversed	0	0		0
1.0 Direct	0.9	0.9	0.9	75.71
Reversed	0.9	0.9		
2.0 Direct	1.7	1.7	1.7	143.02
Reversed	1.7	1.7		
3.0 Direct	2.6	2.6	2.6	218.72
Reversed	2.6	2.6		
4.0 Direct	3.5	3.5	3.5	294.44
Reversed	3.5	3.5		
5.0 Direct	4.4	4.4	4.4	370.15
Reversed	4.4	4.4		
6.0 Direct	5.3	5.3	5.3	445.88
Reversed	5.3	5.3		

Before starting the experiment, the discharge tube has properly been exhausted, baked and flushed a number of times by the experimental gas to ensure the atmosphere of the gas within the discharge tube. The pressure of the gas

within the discharge tube has been maintained constant at a suitable value by adjusting the needle-valve. The pressure of the gas has been measured by a calibrated Pirani gauge which has previously been calibrated by a Mc Leod gauge. The calibration of the Pirani gauge for hydrogen and oxygen are same as already been mentioned in previous experiments. The calibration curves for hydrogen and oxygen are given in Figs.2.5 &2.6 respectively. The results of calibration for nitrogen are given in Table - 2.6 and are plotted in Fig. 2.10.

TABLE-2.6

Pirani Current in μA.	Pressure in Torr.
24	.61
27	.52
31	.45
39	.35
49	.27
60	.20
75	.15
90	.11
112	.08

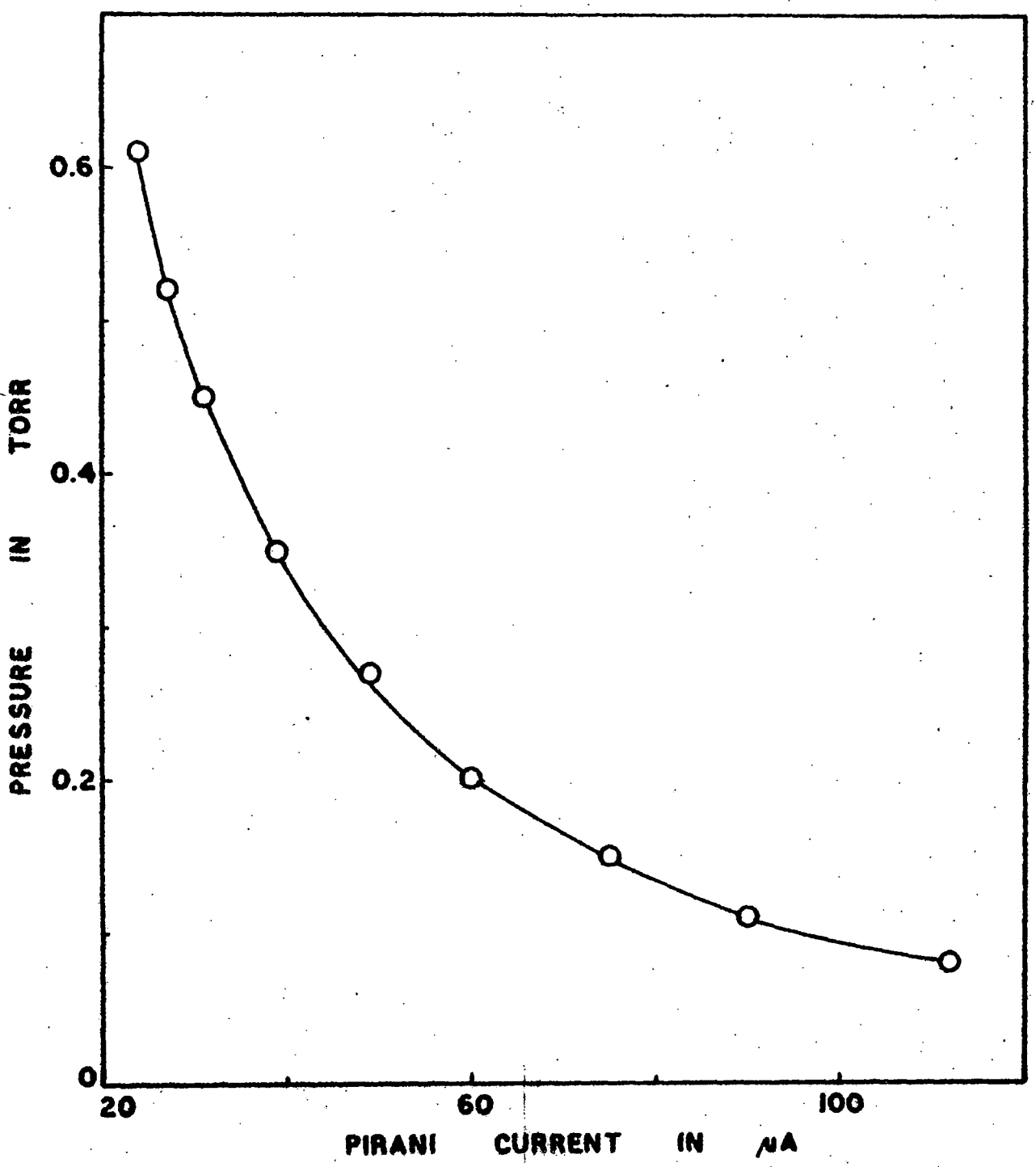

FIG. 2.10.

The output voltage of the high voltage regulated power supply which is connected to the discharge tube in series with a 100 K. Ohms resistance has gradually been increased to cause breakdown of the gas within the discharge tube and form a glow discharge. With zero magnetic field the discharge current has been measured by a milliammeter in series with the discharge tube and the applied voltage has been measured by a voltmeter as shown in Fig. 2.11. The magnetic field has then been gradually increased and the corresponding discharge current has been noted with the same applied voltage. Keeping the initial discharge current (with zero magnetic field) constant, the process have been repeated for several times and the mean of the discharge current values taken at any magnetic field. By changing the applied voltage the discharge current is changed for zero magnetic field to some other values and the change in discharge currents with magnetic fields have been noted for different initial discharge currents. Changing the pressure of the gas to some other values, the whole process have been repeated. The experiment was performed in different gases viz. hydrogen, oxygen, an air and nitrogen with their methods of preparation already been stated earlier.

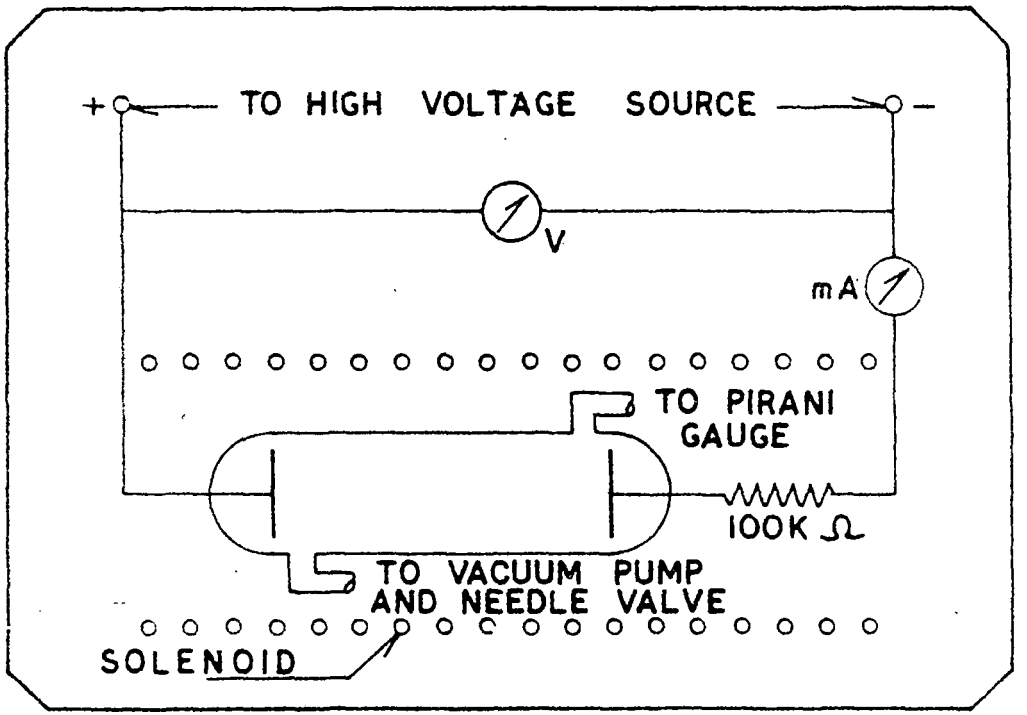
+
TO HIGH VOLTAGE SOURCE
−
V
mA
TO PIRANI GAUGE
100K Ω
TO VACUUM PUMP AND NEEDLE VALVE
SOLENOID

FIG. 2.11.

E. MEASUREMENT OF RADIO FREQUENCY CURRENT

APPARATUS:-

(1) R.F.Oscillator, (2) V.T.V.M., (3) Pirani Gauge, (4) Solid state a-c voltmeter, (5) Exhaust Pump and (6) Needle-Valve (7) Nitrogen gas cylinder.

The r.f. oscillator used in the experiment is the same as has been used in the previous measurements. The frequency of the oscillator is 1.378 MHz. and the maximum output voltage is 500 volts r.m.s. The r.f. discharge has been produced in a discharge tube made of pyrex glass fitted with two internal parallel aluminium electrodes of diameter 3.0 cm. and kept separated by a distance of 4.8 cm. The r.m.s. output voltage of the r.f. source has been measured by a vacuum tube voltmeter. The pressure within the discharge tube has been kept constant by means of a needle valve and the pressure has been measured with a Pirani gauge which has previously been calibrated by a Mc Leod gauge. The calibration curve is as shown in Fig. 2.10. By keeping the pressure and the applied voltage across the discharge tube constant, the total current through the discharge vessel has been kept at a constant value.

The circuit arrangement by which the gas discharge current has been measured is as shown in Fig. 2.12. The circuit has been fabricated to isolate the real part of the gas discharge current from the imaginary part. The discharge tube in series with a resistance R (= 200 Ohms) has been connected to the r.f. voltage source. The value of R is much smaller than the reactance of the capacitance formed between the electrodes of the discharge tube at the frequency of the r.f. source. A variable resistance R_1 (0 to 1 KΩ) in series with a 1MΩ resistance has been connected across the same r.f. voltage source. The voltage drop across the variable resistance R_1 has been applied to the input of the inverting amplifier A_1 which is a high speed operational amplifier of unit gain. The output of the amplifier A_1 and the voltage drop across R has simultaneously been applied to the input of the summing amplifier A_2 which is also a high speed operational amplifier with unit gain. The voltage drop across R_1 and the output of the amplifier A_2 have been measured by a solidstate a-c voltmeter whose frequency range is 0 to 3 MHz. For different values of R_1, the voltage drops across R_1 and the corresponding output voltages of A_2 have been measured. A plot of voltage drop across R_1 and the corresponding output voltage of A_2 show a

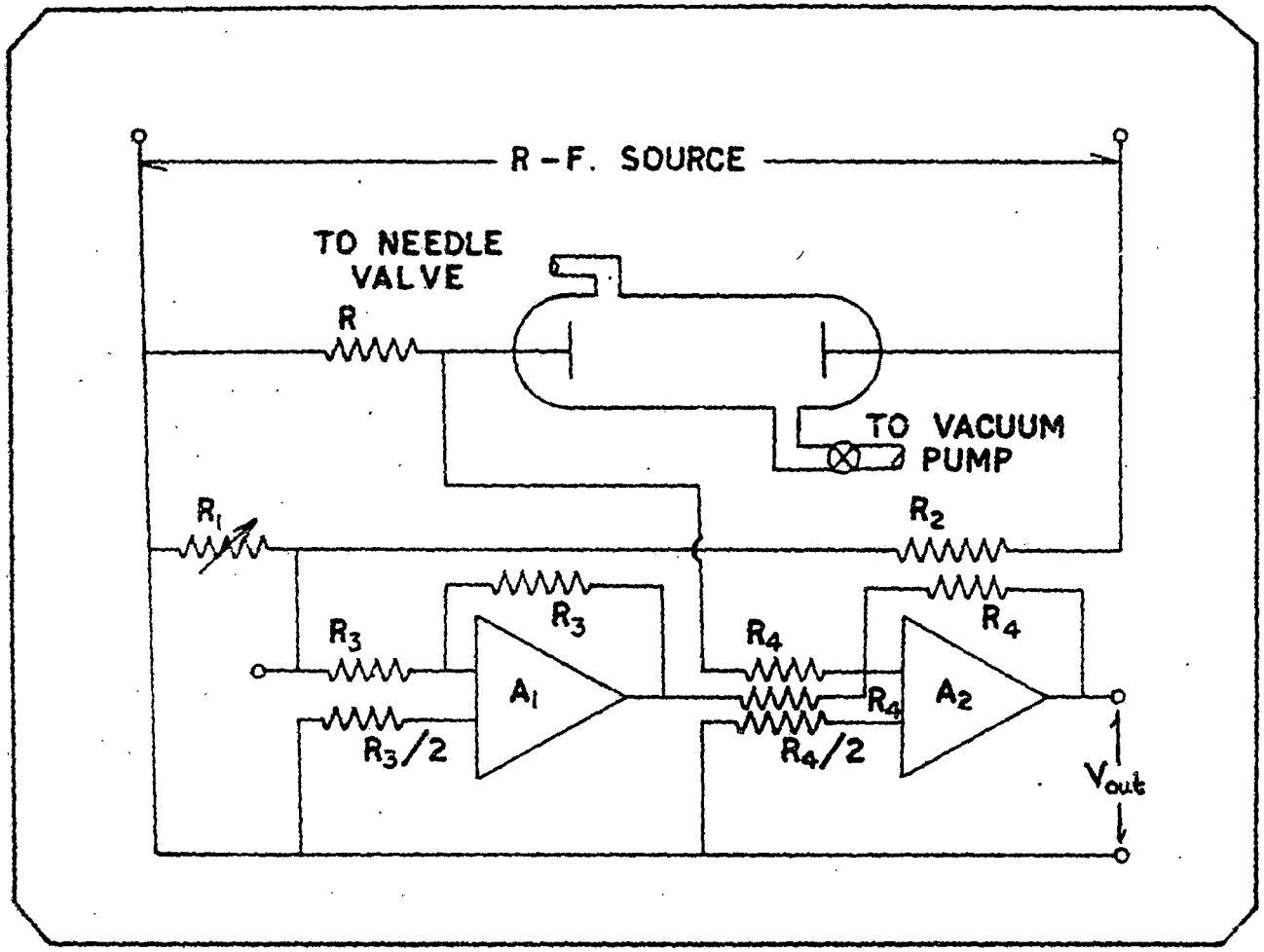
R - F. SOURCE
TO NEEDLE VALVE
R
TO VACUUM PUMP
R1
R2
R3
R3
R4
R4
R3/2
R4/2
A1
A2
Vout

FIG. 2.12.

minimum. The value of the voltage drop across R_1 corresponding to the minimum point in the plot of voltage drop across R_1 and the output voltage of A_2 gives the voltage drop across R due to the real part of the discharge current. The output voltage of the oscillator has then been changed to some other values to give different discharge current at constant pressure. The above procedure have been repeated to measure the different discharge currents at constant pressures and then repeated for different values of gas pressures. The measurement of current has been made in pure and dry nitrogen. The nitrogen gas has been supplied by Indian Oxygen Company in cylinders. The gas has been dried by methods as mentioned in the previous experiment.

F. MEASUREMENT OF PLASMA PARAMETERS BY ELECTRICAL PROBES

APPARATUS:-

(1) A centre-tapped step-up Transformer, (2) Pirani Gauge, (3) Solenoid, (4) Exhaust Pump, (5) Discharge Tube (6) Needle Valve.

The discharge tube is a long cylindrical glass vessel of length 25.0 cm. and diameter 5.5 cm. as shown in Fig. 2.13.

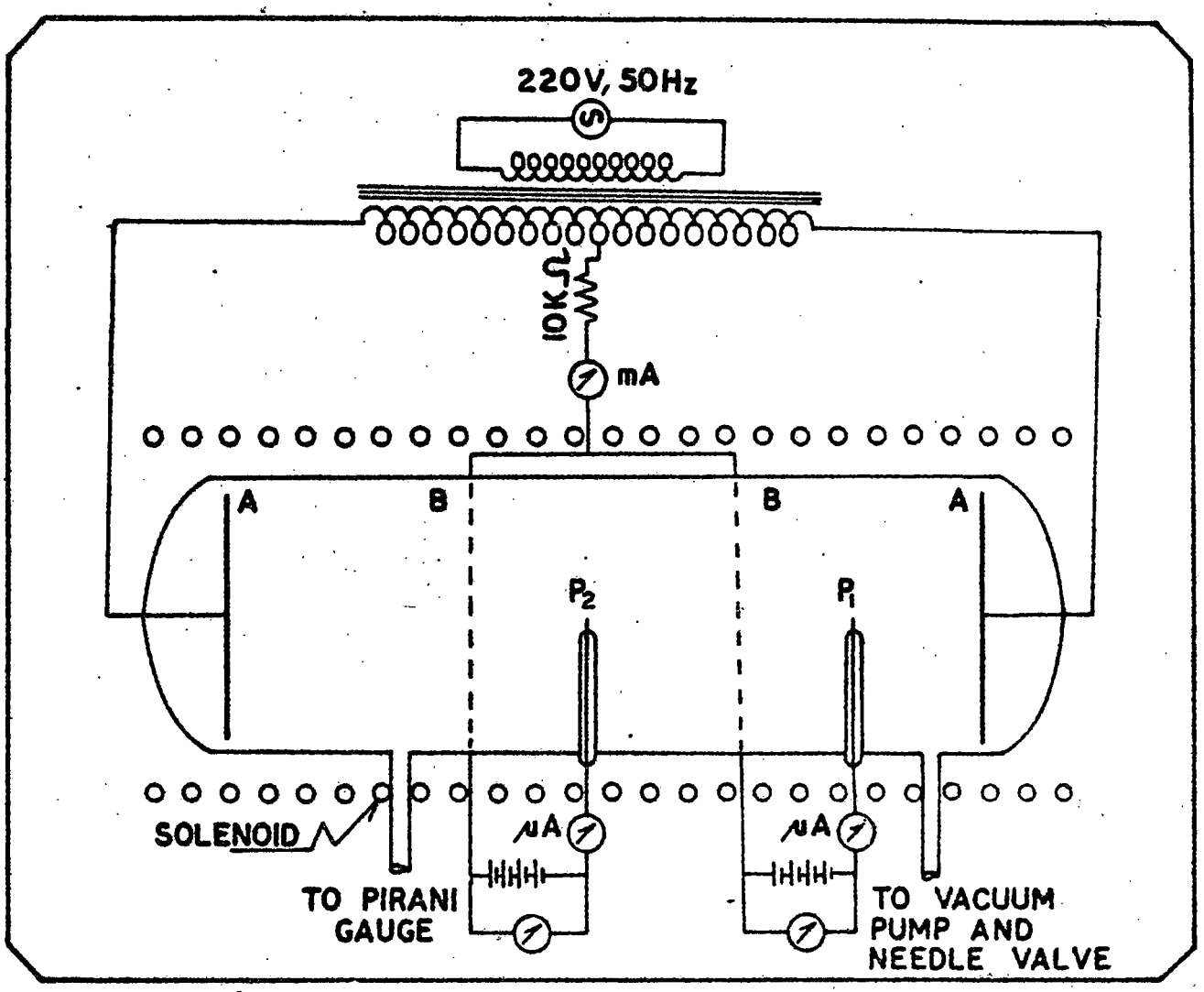
220V, 50Hz
10KΩ
mA
A
B
B
A
P2
P1
SOLENOID
μA
μA
TO PIRANI GAUGE
TO VACUUM PUMP AND NEEDLE VALVE

FIG. 2.13./7.1.

Four brass electrodes of diameter 5.0 cm. are fitted into the discharge tube. Two of the internal electrodes are at the two side walls while the other two are at distances 8.0 cm. from the end electrodes each and all the four electrodes are in parallel planes and co-axial. The two inner electrodes have number of perforations of diameter 0.4 cm. giving the transparency of the electrodes about 40% each. An electrical probe of diameter 0.025 cm. and length 0.2 cm. is placed on the axis of the discharge tube and at equal distances from the two perforated electrodes. Identical probes are also inserted within the active discharge sections, the tips of the probes being on the axis of the tube. The discharge tube is placed within a solenoid of 30.0 cm. long to produce an axial magnetic field by passing current through the solenoid. The callibration curve of the magnetic field produced by the solenoid is as shown in Fig. 2.9.

The discharge is produced in the discharge tube by connecting the two end electrodes to the extreme output terminals of the centre-tapped transformer while the two inner perforated electrodes are connected to the centre-tapping of the transformer. Quiscent diffused

plasma is produced in the middle portion of the discharge tube due to passage of electrons through the perforated electrodes to the field free space.

The probe is connected to another variable d.c. power supply in series with a d.c. micro-ammeter while the other terminal is connected to the inner perforated electrodes. The variable power supply to the probe is obtained by the series connections of a number of dry cells.

The pressure of the gas within the discharge tube is kept constant by the use of a needle-valve and the discharge current is also kept constant by adjusting the voltage of the transformer by a variac. With zero magnetic field and with the probe +ve the probe voltage is gradually increased in steps of 0.5 volts. The probe current is noted for each probe voltage. With the probe -ve, the probe current is noted for each probe voltage increased in steps of 0.5 volt initially and then of 9.0 volts to obtain ion saturation current. The same process is repeated with different axial magnetic fields.

REFERENCES

1. Gill, E.W.B. & von Engel, A. (1948), Proc. Roy. Soc., A192, 446.