CHAPTER II

EXPERIMENTAL ARRANGEMENT

2.1. Apparatus Utilised

1. Discharge Tubes of various dimensions
2. Arc tube of various dimensions
3. High voltage transformer
4. Variac
5. Milliammeter, Microammeter.
6. High current Rheostats
7. V.T.V.M.
8. D.C. Power supply (Stabilized).
9. D.C. Generator
10. A double stage Rotary vacuum pump.
11. Pirani Gauge
12. Needle valve
13. Gauss meter
14. Audio frequency generator
15. A.C.Microvoltmeter
16. Oscilloscope
17. High voltage power supply
18. Spectrograph
19. Audio frequency generator
20. Loudspeaker and Microphone.

2.2. Discharge tubes

All the discharge tubes in which measurements were carried out were constructed of pyrex glass. For glow discharge measurements the tubes were fitted with brass (80% Cu 20% Zn) and stainless steel electrodes and for low pressure mercury arcs, the arcs were struck in between mercury pools. The arc tubes are fitted to simple traps through standard joints. In this way the mercury vapour going out of the discharge tube could condense smoothly and could return to the tube. Otherwise it was observed that mercury would condense in the joining rubber tubes and a mercury plug would be formed in the passage and hereby would disturb the vacuum system.

The discharge tubes were thoroughly cleaned by chromic acid, petroleum ether and distilled water and dried on the pump. Then the tubes were heat baked in an electric oven in the usual way. Finally the tubes were heated and pumped off by rotary pump for several days (and for several hours before each set of observations) to degas them. For removing the occluded gases from the electrodes, both the electrodes were used as cathodes alternatively by reversing the currents through the discharge. The tubes were then flushed with the desired gas for two or three days and then the gas was introduced through a microleak of a needle valve to a desired pressure. (Ref FIG 2.2.(1), & 2.2(2))

2.3. Preparation of gases

For measurements in dry air, the air was passed through two U - tubes containing phosphorous pentoxide Powder and caustic potash pellets to remove traces of water vapour, then it was introduced to the discharge tube through a needle valve.

Hydrogen and oxygen gases were prepared from electrolysis of a warm solution of pure barium hydroxides in between platinum electrodes in a U-tube.

For hydrogen, the gas evolved from the cathode was passed through a hard glass tube containing copper spiral heated electrically. The gas was next passed through series of U-tubes containing phosphorous pentoxide powder and caustic potash pellets.

The oxygen gas evolved in the anode of the electrolysis tube was passed through a flask containing sulphuric acid.

The nitrogen gas was supplied by Indian Oxygen Ltd. and was passed through concentrated sulphuric acid

After purification has been done in the stated manners the gases were stored in a round bottom glass flask which is connected to the discharge tube.

For mercury arcs, triple distilled mercury was used. In course of experiments, occassionally the mercury in the tubes was replaced by fresh supply and the discharge tubes were cleaned and degassed.

2.4. Measurement of pressure

Pressure of the gas in the discharge tube was measured by a Mcleod gauge fitted with triple distilled mercury.

In some of the experiments the pressure in the discharge tubes could not be measured directly because the tube was placed in between the pole pieces of electromagnet, but a parallel line was used. At the junction between these two vacuum lines the pressure is the same and if the conductance of the two lines are identical, the pressure in the discharge tube would be equal to that at the Mcleod gauge. Dushman and Lafterty (1962) have discussed that effective pumping speed, S_{eff} is given

$$\frac{1}{S_{eff}} = \frac{1}{S} + \frac{1}{C}$$

where S is the speed of the pump (50 litres/min) and C is the total conductance of the line. For viscous flow, conductance of a line is given by

$$C = 2.84 \frac{a^4}{l} P_2 \text{ litre/Sec}$$

where 'a' and 'l' are the radius and length of the tubes and P_2 the upstream pressure. So the parallel tubes were identical as far as possible. The lines were made of rubber and polythene pressure tubes. For the same reason, the needle valve was placed in between the junction of identical lines and the pump. A pirani gauge was used in the discharge tube line and through it the pressure of air could be compared.

The pressure of mercury vapour was determined from standard tables (Hodgman 1956) after noting the inside wall temperature (T_W) of the discharge tube which is equal to the outside wall temperature increased by the temperature drop over the tube wall resulting from the energy which is dissipated in the tube and carried away via the tube wall (Verweij, 1960). The outside wall temperature was measured by a mercury in glass thermometer when the arc was in steady state. Generally the arcs were cooled by electric fans. So a steady state of an arc corresponded to a steady outer wall temperature. The temperature drop as calculated by Verweij can be estimated by assuming that the total energy dissipated $W = Ei$ per cm of tube length (E is the intensity of electric field, measured by noting the voltage across the arc minus standard cathode fall of 10 volts as determined by Lamar and Cromptor (1931), then divided by arc length and i is the arc current. This energy is carried away by thermal conduction through the surface area of 1 cm. of tube length, thus through $2\pi R$ cm^2 (R is the internal radius of the discharge tube), since the amount of energy which escapes as radiation through the tube wall is relatively small, the ultraviolet resonance radiation being absorbed within a very small penetration depth in pyrex glass wall. The temperature drop ΔT_ω is given by

$$W = 2\pi R K \frac{\Delta T_\omega}{d}$$

where d is the thickness of glass wall (0.14 cm) and K is the thermal conductivity of the glass (K pyrex = 11×10^{-3} Joule/cm/sec/$^\circ$C). For a typical operation of arc at a current of 2.5 amp., ΔT_ω amounted to 7 - 8°C. Since number density of ground state mercury atoms 'n_g' is directly related with p_{Hg} by the relation

$$n_g = 3.3 \times 10^{16} \frac{p_{Hg}}{T_\omega} 273$$

In all the arc measurement, dry air was admixed with mercury vapour. The pressure of dry air was measured by Mcleod gauge.

2.5. MAGNET and power supplies

In some of the experiments electromagnets were used. Depending upon the diameter and length of the discharge tube, the diameter of the pole pieces (10 cm x 8 cm square and 5 cm diameter) and length between them were adjusted. For a specific experiment, the pole pieces were so chosen that the magnetic field was uniform and without any radial component at the location of discharge tube. For measurements in axial magnetic field, the total discharge tube was placed in between the pole pieces. Transverse Mag field is applied at only certain portion of the discharge tube. [Fig 2.5(i)]

The magnetic fields were measured by a calibrated differential gauss meter. The electromagnets were powered by a stabilized d.c. supply.

The power supply for generating glow discharges was a stabilized electronic d.c. supply (0 - 1200 volts in steps of 105 volts). The supply was connected to discharge tubes via a high wattage balast resistor.

For a.c. glow discharges 50 Hz common supply was used through a step up transformer whose input was connected to an auto transformer.

The mercury arcs were struck by a d.c. generator (200 - 240V) whose voltage output could be adjusted to a constant value by a variable external resistor. For glow discharges, the discharge current was varied between 8 to 30 mA and arc current was varied between 1.5 to 5 Amp. [Ref FIG 2.5(1)]

2.6. Diagnostics by spectroscopic method

Spectroscopic method was utilized to determine electron temperature. The radiation of the axial regions of the discharge tube after passing through a vertical slit was focussed by a double convex lens on the vertical slit of the collimator of the spectrograph. In the spectrograph there was a Pellin - Broca prism for 90 degree deflection of the spectrum. Such a mounting was appropriate as a monochromator with fixed slit. The exit slit was in a direction of 90 degree with the plasma source. The wavelength is changed by rotating the prisms with a mechanical arrangement fitted with an accurately calibrated drum. The wavelengths of the radiations were further checked from standard values given in International Critical Tables (1926). The slit width which could be varied with a micrometer arrangement was varied from 0.2 mm to 1 mm depending on the response of lines chosen to the photomultiplier. For a set of observation however the slit width was fixed.

The collimator was focussed by rack and pinion arrangements, the selected line was focussed on the cathode of the photomultiplier RCA 931 operated at 1425 V. The surface open type photomultiplier which has low mean radiation equivalence of dark current was placed in a darkened chamber behind the exit slit. The power source of photomultiplier was made in two sections; the first was 1200 V stabilised pack to supply the dynode voltage while the second was used to furnish some 225 V, between the final dynode and the anode. The last voltage source was also used to operate the vacuum tube voltmeter, which consisted of two 6J7 tubes operating with about 32 V, on the plates and about 1.3 V negative grid bias. The grids were connected to the two ends of the resistor R_1 (600 K Ω) which was in series with the plate of the photomultiplier tube. When current flowed through this resistor, a voltage drop occured and one of the 6J7 tubes drew less current producing an imbalance in the plate circuit. A 0 $\sim$ 200 μA meter between the plates measured this imbalance.

When the signal approximated 3 V, the 6J7 reached cutoff and beyond this point there was no increase in the meter deflection. With no light on photomultiplier tube and a rough balance obtained with R_4, the meter was set to zero with R_2 (Fig.2.6.1). In this way the effect of photomultiplier dark current was eliminated completely. Then, with 3 V or more applied to resistor R_1, the meter was set to full scale deflection by means of control R_3. The micrometer at the output recorded the intensity of the spectral line. The slit was adjusted so that meter deflection corresponding to the line with strongest response to the photomultiplier was well within the range of full scale deflection.

The sensitivity of a photomultiplier depends on wavelength of incident radiation and on quantum efficiency of the cathode material (including the effect of photomultiplier's window material). Percentage Quantum efficiency was taken from Carl Zeiss brochure (reproduced in fig.2.6(2)).

From this plot the cathode radiant sensitivity S in amperes per watt corresponding to a radiation of wavelength λ A° is calculated as

$$S = \frac{Q\lambda}{12395 \times 100}$$

here Q is the percentage quantum efficiency. From S the relative spectral sensitivity for two lines was calculated and the micro ammeter reading for total intensities of lines was corrected for relative spectral response of the photomultiplier. Moreover emission coefficient corresponding to a radiation with frequency

ν which is directly proportional to observed total intensity can be separated into a continuous and discrete part

$$\epsilon_{\nu} = \epsilon_{\nu c} + \epsilon_{\nu L}$$

$\epsilon_{\nu L}$ contains the desired spontaneously emitted energy within the line, $\epsilon_{\nu c}$ was eliminated by balancing the V.T.V.M. to the null of meter reading with resistors in the circuit when the continuum radiation at the near vicinity of the line was focussed on the photomultiplier tube cathode and the contribution for $\epsilon_{\nu c}$ was found to be negligible.

2.7 EXPERIMENTAL ARRANGEMENT

2.7.1. Heat Flow Process in the Positive Column of a Glow Discharge

Apparatus required: Discharge tube, High voltage transformer, Variac, Stabilised D.C. power supply, Pirani gauge, Needle valve, Microammeter, Separate arrangement for prep of H_2, O_2, N_2, Milliammeter, Oil Rotary pump.

Arrangement:- The discharge tube provided with four electrodes (A,B, C, D) (Fig. 2.7.1.(1)) of which the electrodes A and B connected to a source of high voltage are used to excite the discharge. The discharge tube was cleaned as per procedure mentioned in 2.2.

The pressure of the gas under investigation is measured with an accurately calibrated pirani gauge (Ref. 2.4).

An external variable voltage from a stabilized power supply is applied to the electrodes C & D. The plasma within the electrodes C & D acts as a conducting medium and with the plasma on, the current is measured in the microammeter (Fig. 2.7.1(2)) for different values of applied voltage.

The investigations were carried out first in air, For measurements in dry air the procedures were followed which is explained in 2.3.

After air, hydrogen and oxygen is introduced in the discharge tube separately. Preparation of hydrogen and oxygen is explained in 2.3.

Then nitrogen was introduced in the discharge tube and similar procedure of applying external variable voltage from a power supply is applied to C and D.

A representative curve is shown in Fig. (3·4) for hydrogen Fig. (3·5) for nitrogen, Fig. (3·3). for oxygen, From the linear portion of the curve the resistence and hence the conductivity of the plasma has been calculated.

2.7.2. Evaluation of Electron Temperature in Glow Discharge from Measurement of Diffusion Voltage:

Apparatus required -

1. Discharge tube
2. High voltage Transformer
3. Variac
4. Milliammeter
5. Oil Rotary pump
6. Pirani Gauge
7. Needle valve
8. Magnet with power supply
9. V.T.V.M.

Arrangement:-

The discharge tube of length 10 cm in which the ionized gas under investigation was produced by a high voltage source. The pressure under investigation is measured by an accurately calibrated Pirani gauge The discharge tube was cleaned as per procedure mentioned in 2.2.

Two cylindrical probes of length 1 cm and diamter 0.01 cm. are placed parallel to one another, one along the axis $r = 0$ and other at a distance $r = 0.9$ cm. from the axis (Fig. 2.7.2.(i)). The radius of the discharge tube is 1.6 cm.

The output voltage at the two probes is measured by a V.T.V.M. having an internal impedance of 100 M Ω

A filter circuit (Low pass filter) was designed and is connected at the output of the probes to prevent oscillations generated in the plasma from reaching the V.T.V.M.

The output voltage has been measured for different (E/P) values in air, where E is the axial field i.e., the voltage per cm. length of the positive column and P is the pressure in torr. The axial field E is determined by measuring the voltage between the two extra probes at a distance 5 cm. placed in the positive column.

The variation of T_e with (E/P) has been plotted in (Fig. 4.1.).

After that a transverse magnetic field was applied to the discharge tube. The details of the electromagnet and power supply are already discussed in 2.5. The magnetic field was varied from 0 to 100 gauss for a constant discharge current of 2.8mA.

2.7.3. Hall Effect in an Arc Plasma:-

Arrangements:- The arc has been produced in an arc tube made of pyrex glass. Besides the two tungsten probes (immersed upto the axis of the tube) stuck in the positive column region with a separation of

26.4 cms., between them. Two horizontal metallic plates (2.5 cm x 1 cm) at a distance of 0.8 cm. are introduced within the arc tube for measuring the Hall voltage.

Analytical quality of triple distilled mercury has been used here to produce the mercury arc. A double stage rotary vacuum pump has been utilized to maintain the system at 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.

To control the arc current several high current rheostats have been used in series with a D.C. ameter (range 0 - 5A).

Circuits constants:-

Radius of the tube = 1.32 cm.

Distance between mercury pool = 26.4 cm.

Horizontal metallic plates = 2.5 cm x 1 cm

Distance between two plates = 0.8 cm.

Experimental procedures:-

As a preparation to produce the mercury arc in the glass tube, 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 throughly. After completing these operations, triple 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 0.2 torr. [Ref FIG 2.7.3 (1)]

Arc is then produced inside the tube by following the tilting process. A number of fans have been used for cooling the arc and maintain a steady temperature.

Two horizontal metallic plates (2.5 cm x 1 cm) at a distance of .8 cm are introduced within the arc tube for measuring the Hall voltage. [FIG 2.7.3.(2), 2.7.3 (3)]

The magnetic field which is at right angles to both to the direction of the flow of current and measuring electrodes has been provided by an electromagnet. The power to run the electromagnet has been supplied by a stabilised power supply. The magnetic field which has been varied from zero to 550 gauss has been measured by an accurately calibrated gauss meter (Model EC GH 867). The gauss meter operates on the principle of the Hall effect. The Hall probe is made of a highly pure indium arsenide crystal and is encapsulated in a non magnetic sheath of approximately 500 mm x 5 mm x 2 mm and is connected to a three feet cable. A transparent cap is provided for the protection of the probe. The accuracy of the readings is ± 2.5 percent upto 10 kilogauss.

The Hall voltage developed in the arc plasma has been measured by a V.T.V.M. (Simpson Model N 321 - 1). The valve tube voltmeter is a versatile instrument designed for accurate measurement of voltage (both a.c. and d.c.). The d.c. voltage upto 1500 volts can be measured in seven stages, input impedance is 35 megaohms in all the ranges and and the accuracy of reading is ± 3 percent.

2.7.4. Determination of plasma parameters by sonic wave through an ionised gas:-

Apparatus required:-

1. Discharge tube
2. High voltage transformer
3. Variac
4. Milliammeter
5. Loudspeaker
6. Microphone
7. Audio frequency generator

8. Rotary pump
9. Pirani gauge and Niddle valve
10. Oscilloscope.

Experimental arrangement:

The discharge tube is made of pyrex glass of length 90 cm and 5.4 cm. in diamter. The discharge tube was cleaned as per procedure mentioned in 2.2. The electrodes of outer diameter 1.5 cm. and made of hollow cylindrical brass tubes (E, E) (Fig.2.7.4.a) are connected to high voltage transformer.

The discharge tube is fitted at one end with a loudspeaker (L) which is energised with a Philips Audio frequency generator (GM 2308) and the loudspeaker acts as a source of sonic waves.

At the other end a Microphone is fitted to receive the audio signal. Both the loudspeaker and the Microphone are fixed to the wall of the discharge tube through a sponge like material in the form of foam which effectively dampens the propagation of sound, so that no propagation of sound is possible through the body of the discharge tube.

This has been further tested by evacuating the discharge tube to a high degree of vacuum when it was observed that even for high input audio voltage, the output at the receiver was too low to be detected.

The output from the microphone has been detected by an a.c. microvoltmeter and then connected to an oscilloscope.

Pure and dry air was passed through the discharge tube using the procedure mentioned in 2.3.

The pressure inside the tube measured by a vacuoscope and was kept constant by a regulating needle valve.

2.7.5. Enhancement of electron temperature by Bank condenser discharge:-

Apparatus required:-

1. Discharge tube
2. Pirani gauge
3. Milliameter
4. Needle valve
5. Rotary vacuum pump
6. High voltage transformer
7. D.C. high voltage stabilised power supply
8. Spectrograph
9. Power supply for photomultiplier tube
10. D.C.Microammeter.

Arrangement:

The discharge tube was provided with four electrodes A, A,& B,B (Fig. 2.7.5.(i)) of which the electrodes A and A are connected to a source of high voltage which is used to excite the discharge. The discharge tube was cleaned throughly as per procedures mentioned in 2.2.

The discharge tube was evacuated by a double stage rotary vacuum pump and pressure was maintained to desired level by a fine needle valve and monitored by Pirani gauge. Dry air was passed through the discharge tube as per procedure mentioned in 2.3.

The glow discharge was maintained between the electrodes A and A.

The spectrograph slit was set accurately at the level of the discharge tube and dark current was adjusted before the observations (as per procedures mentioned in 2.6).

Two Sets of different lines were selected and at same [See chapter VI] discharge current, photomultiplier current for each specific line was noted (pressure was kept constant at 0.2 torr).

A high voltage d.c. power supply was designed at this laboratory. A bank of condensers (Each condenser having capacitance 24 μ F and 2500 V and Total '8' condensers were connected in parallel) were charged at different voltages 2250 V, 2000V, 1750V, 1500 V from the high voltage power supply (Fig.2.7.5.(i)).

A special type of switch was also designed in our laboratory which connects the bank of condensers to power supply first (Fig.2·7.5(i)).

After the charging of condensers (Keeping the glow between A and A) the switch now connects the bank of condensers across the electrodes B & B).

Immediately the condenser bank was discharged between the electrodes B and B in presence of glow when the condenser bank discharges immediately discharge current and photomultiplier tube current increases. The discharge current and photomultiplier currents were recorded with great accuracy and the each set of experiment was repeated several times.

For a specific line, bank current discharge was varied from 2.25 KV to 1.50 KV.

Two sets of lines were choosen and similar procedure was repeated for each set.
The experiment was repeated with Air & hydrogen gas. For details of experimental set up, please refer chapter VI

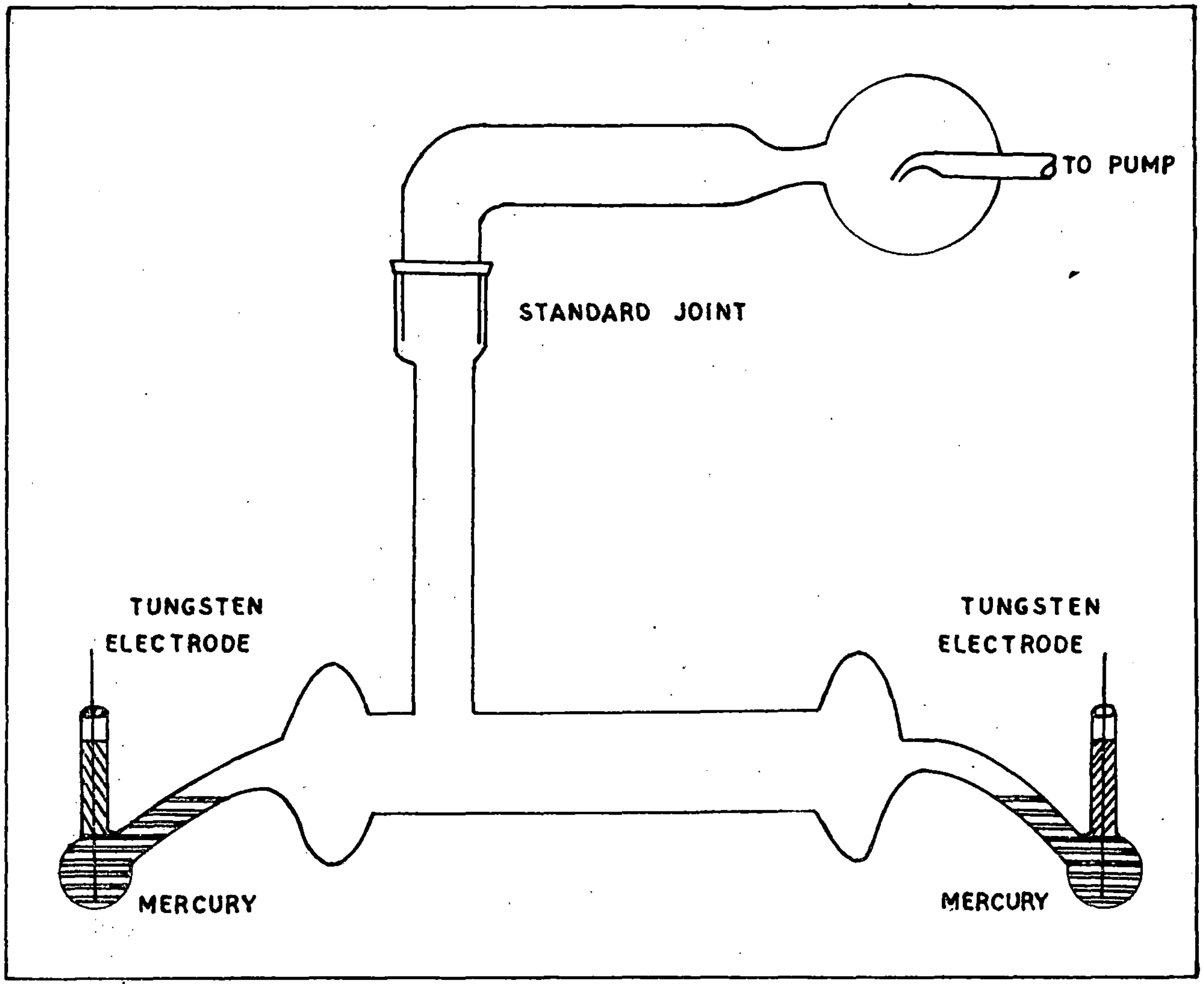

FIG. 2·2(1) DIAGRAM OF A MERCURY ARC TUBE

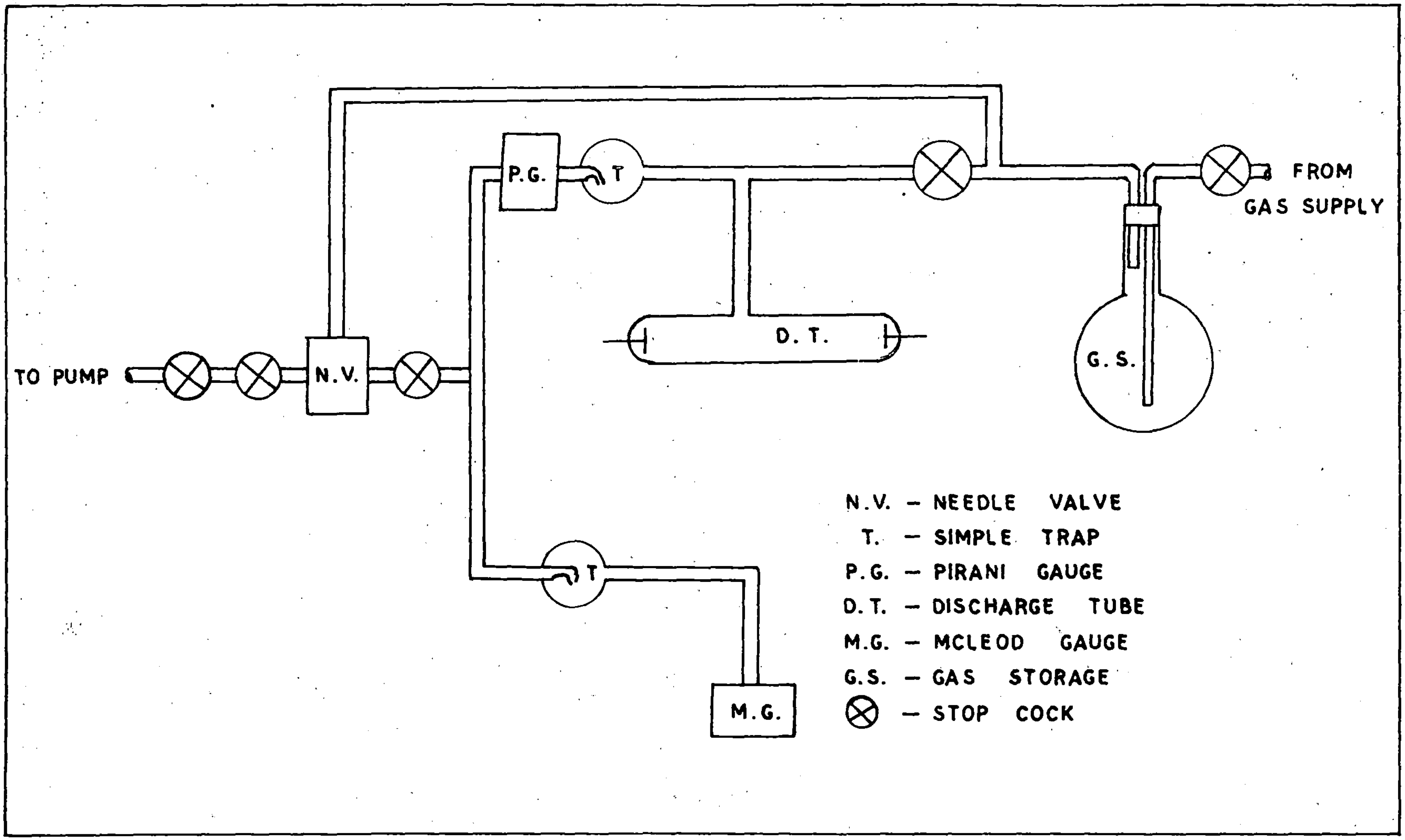

FIG. 2·2(2) DIAGRAM OF A GLOW DISCHARGE TUBE.

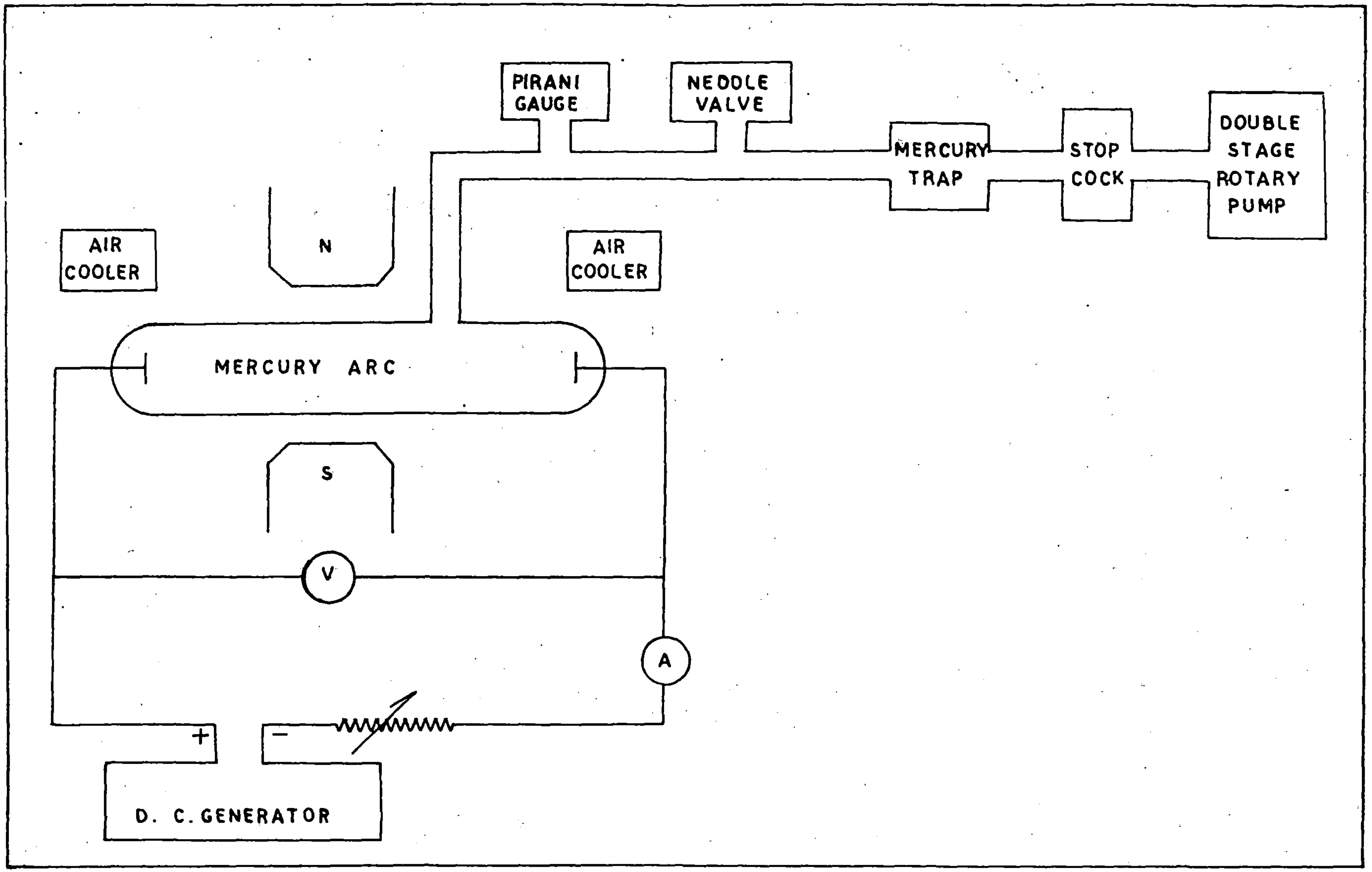

FIG. 2·5(i) SCHEMATIC DIAGRAM OF EXPERIMENTAL SET UP IN A TRANSVERSE MAGNETIC FIELD.

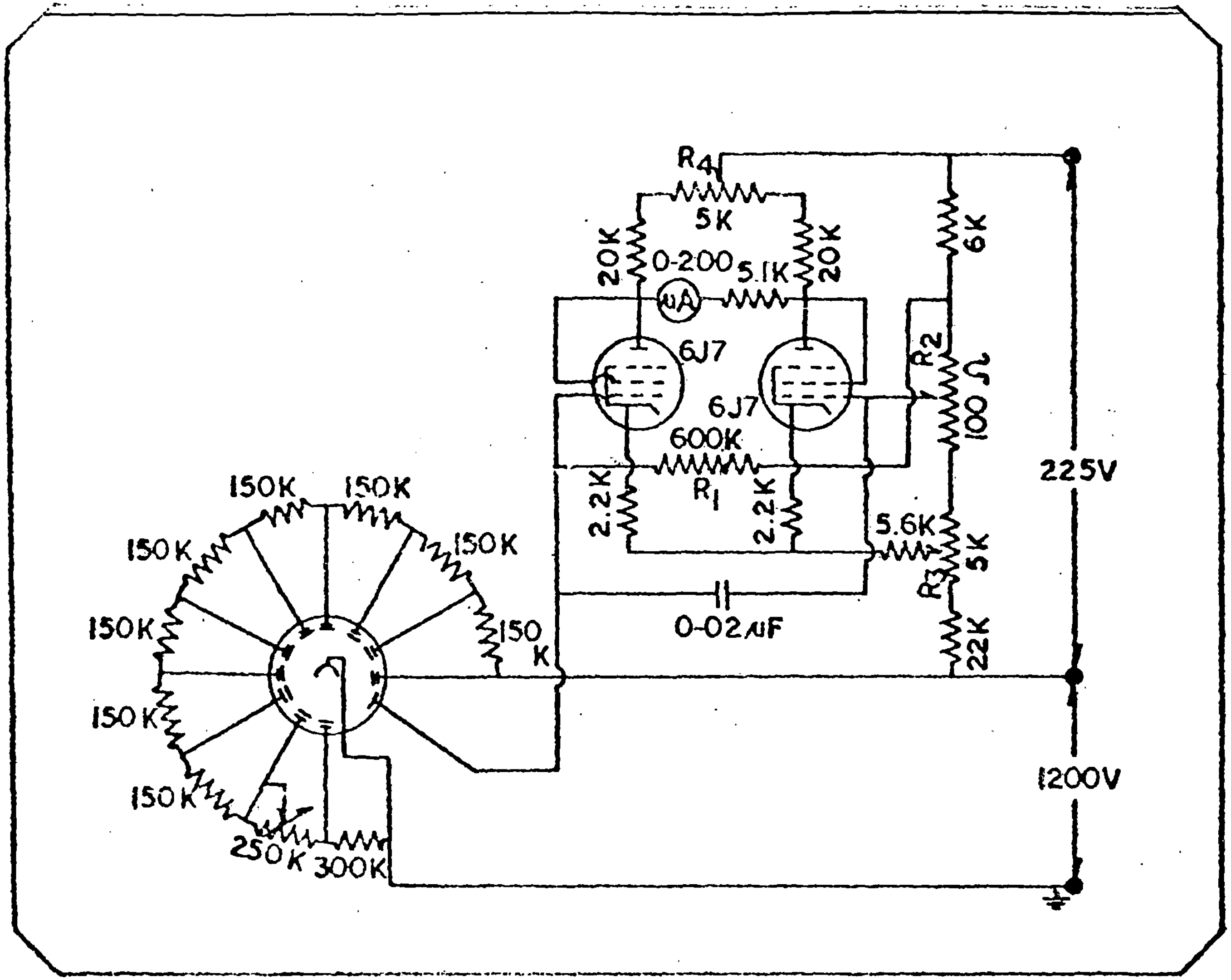

FIG. 2:6(1) PHOTOMULTIPLIER CIRCUIT.

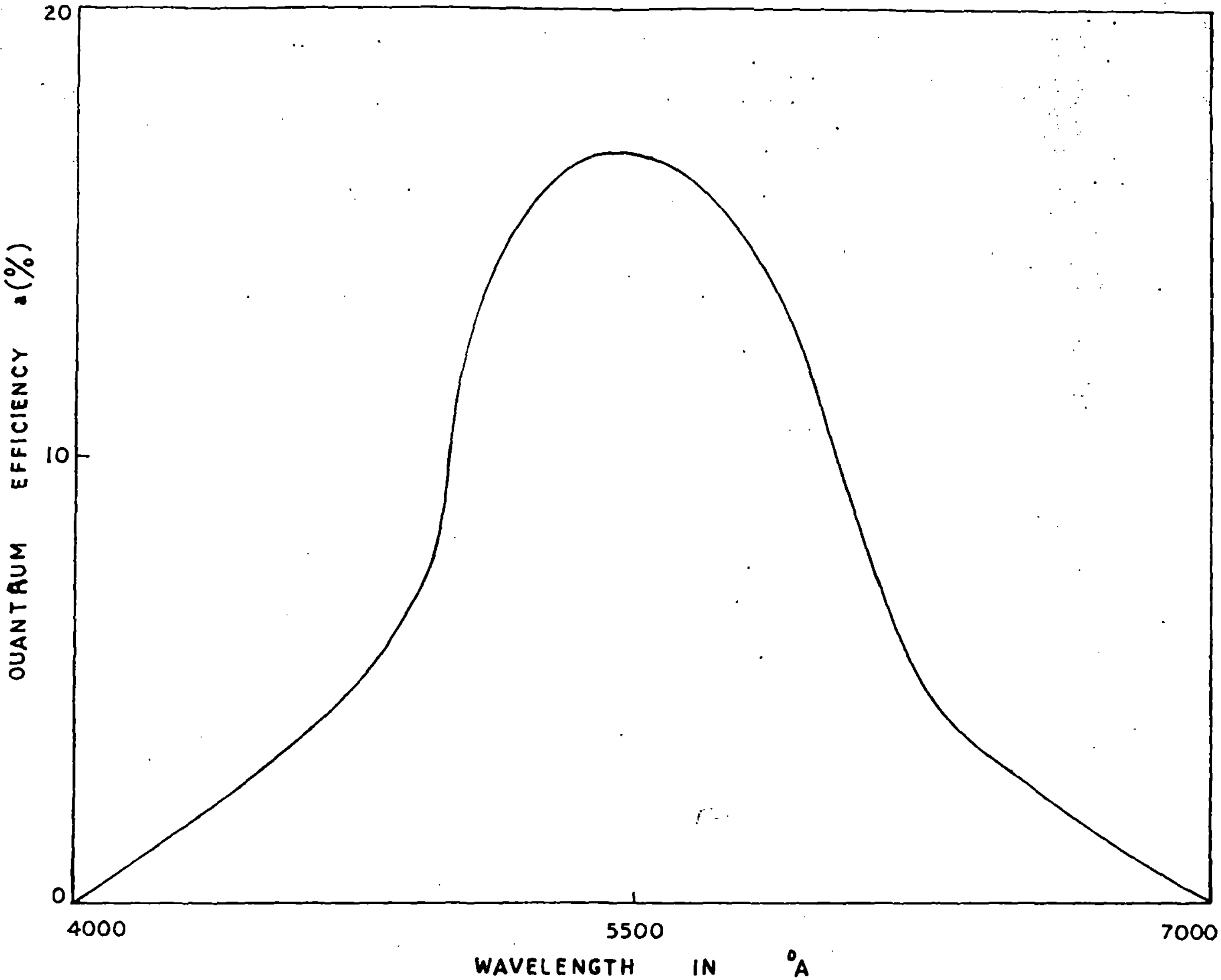

FIG. 2.6(2) QUANTUM EFFICIENCY IN % OF PHOTOMULTIPLIER M 10F 529 V_λ
(VEB CARLZEISS JENA BROCHURE NO. 40 – 637 – 2).

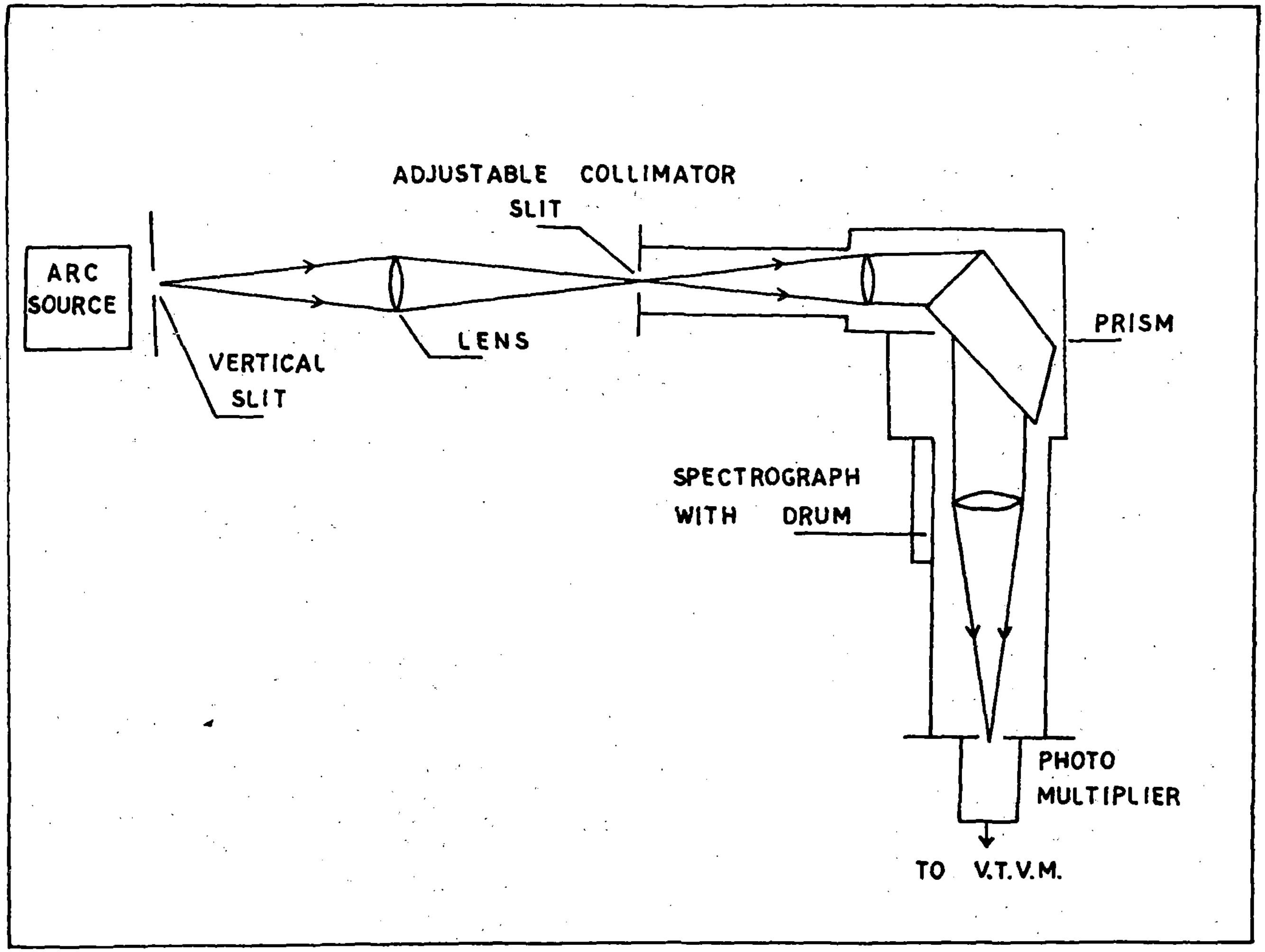

FIG. 2·6(3). EXPERIMENTAL SET UP FOR SPECTROSCOPIC MEASUREMENTS.

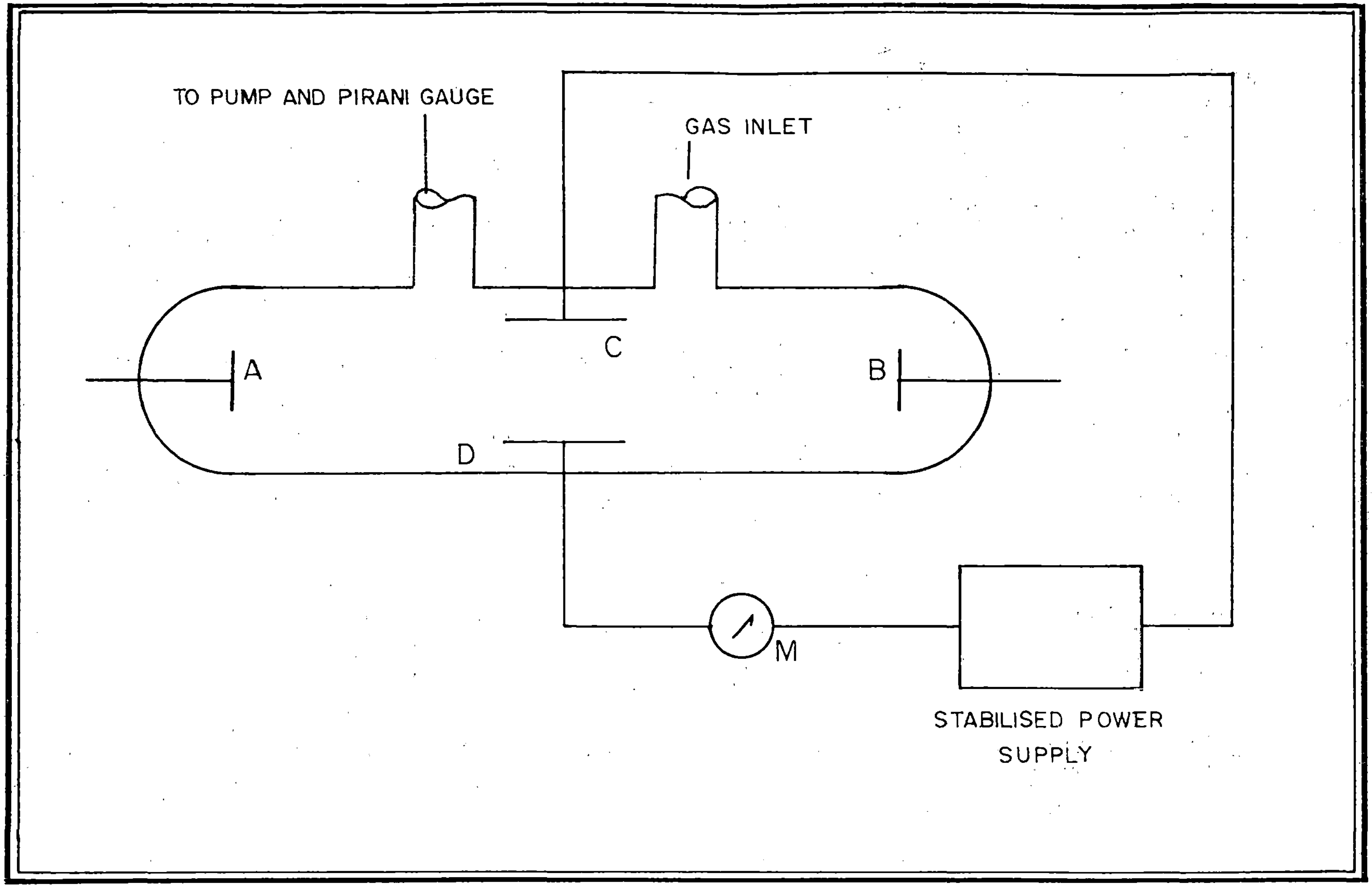

FIG 2.7.1.(1) EXPERIMENTAL SET UP

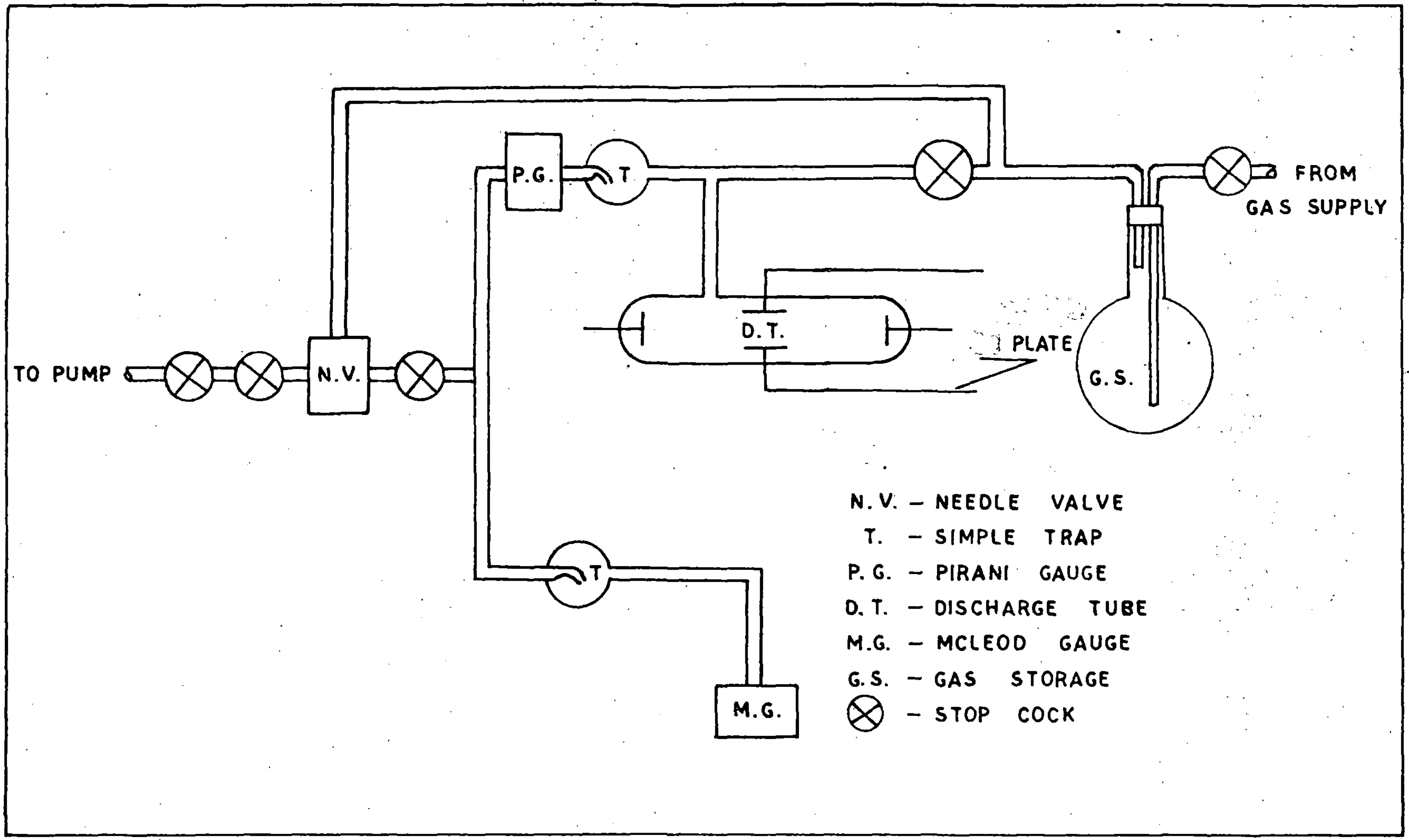

FIG. 2·7.1.(2). EXPERIMENTAL SET UP

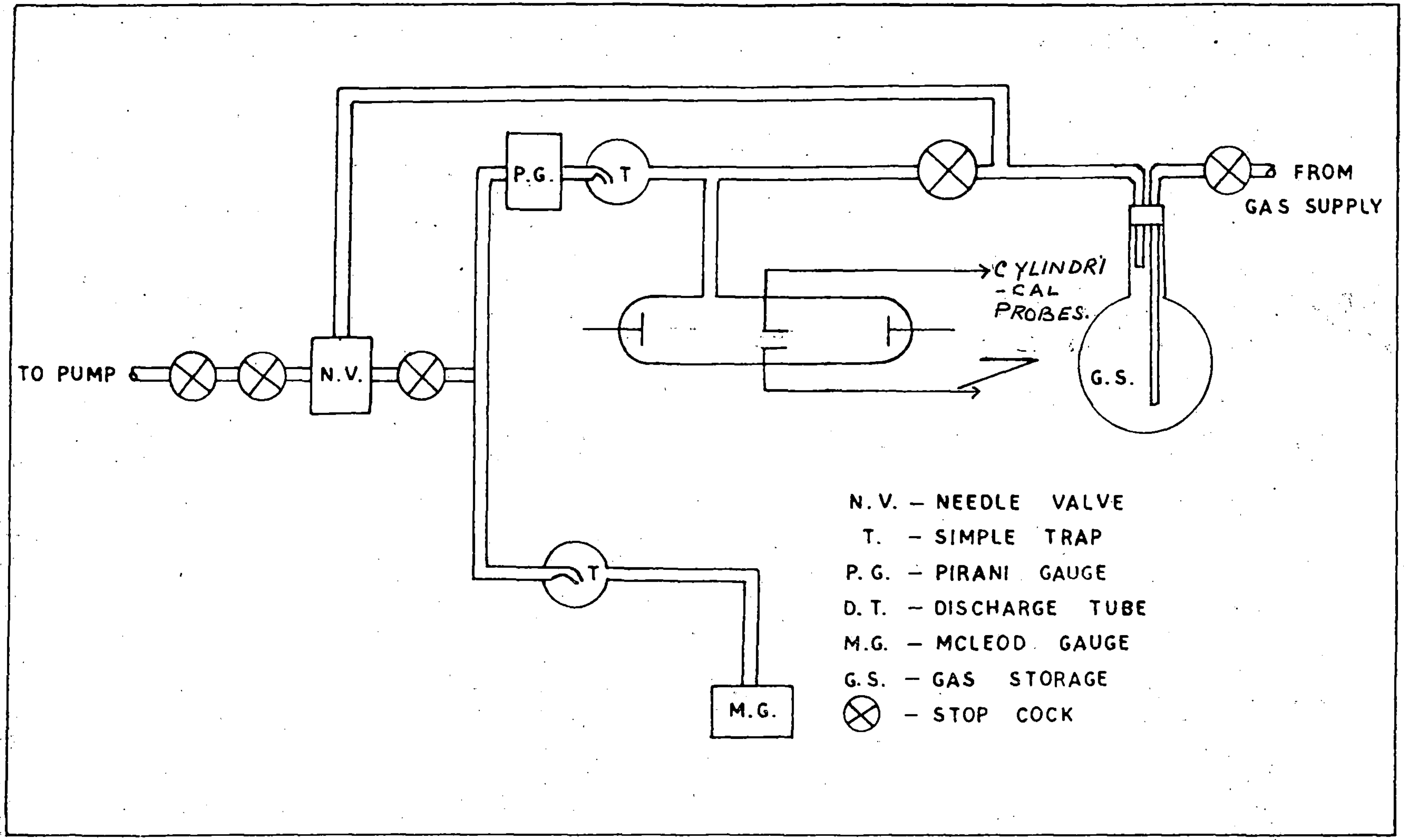

FIG (2.7.2(1)) EXPERIMENTAL ARRANGEMENT

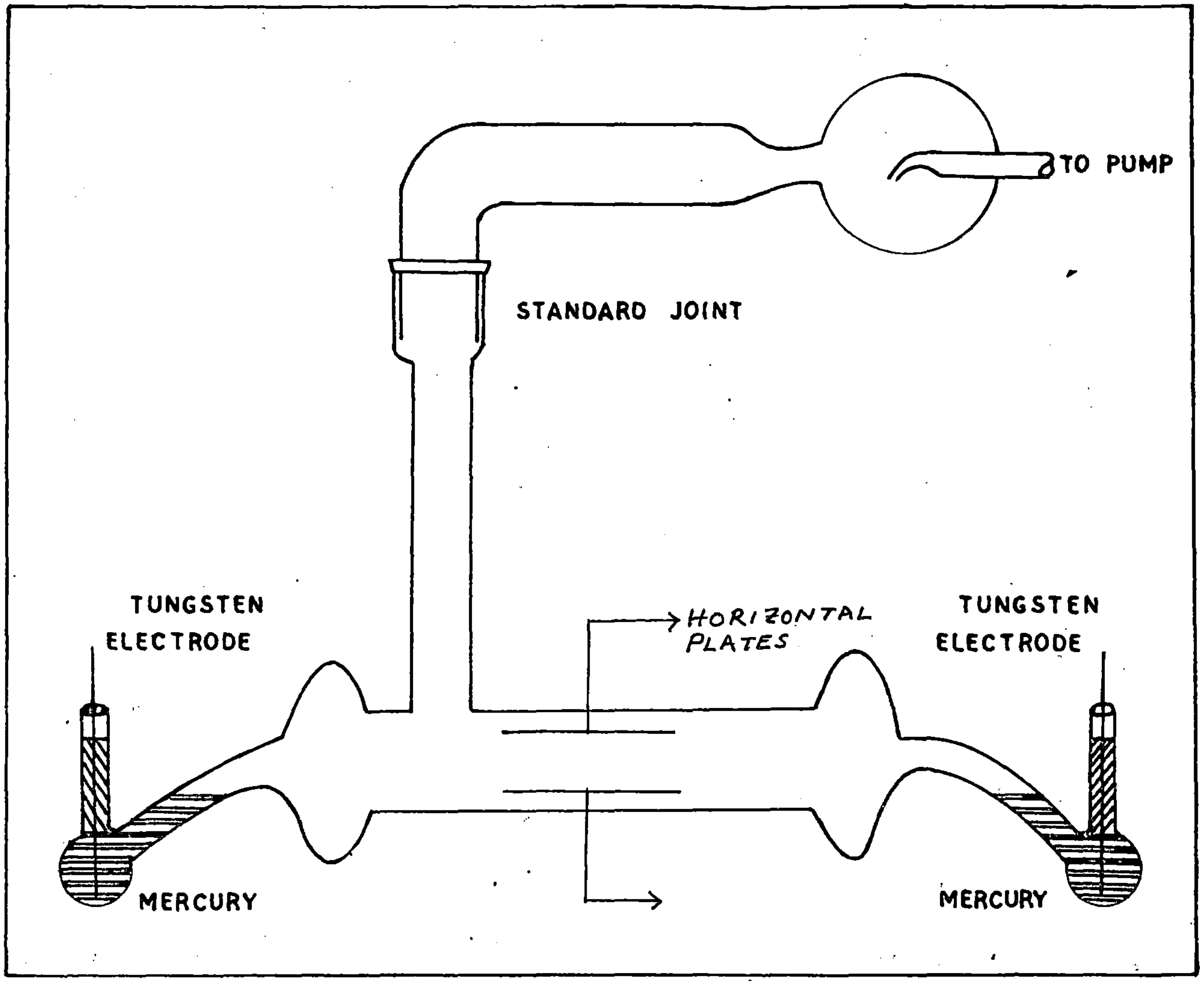

FIG 2.7.3.(1) DIAGRAM OF A MERCURY ARC TUBE

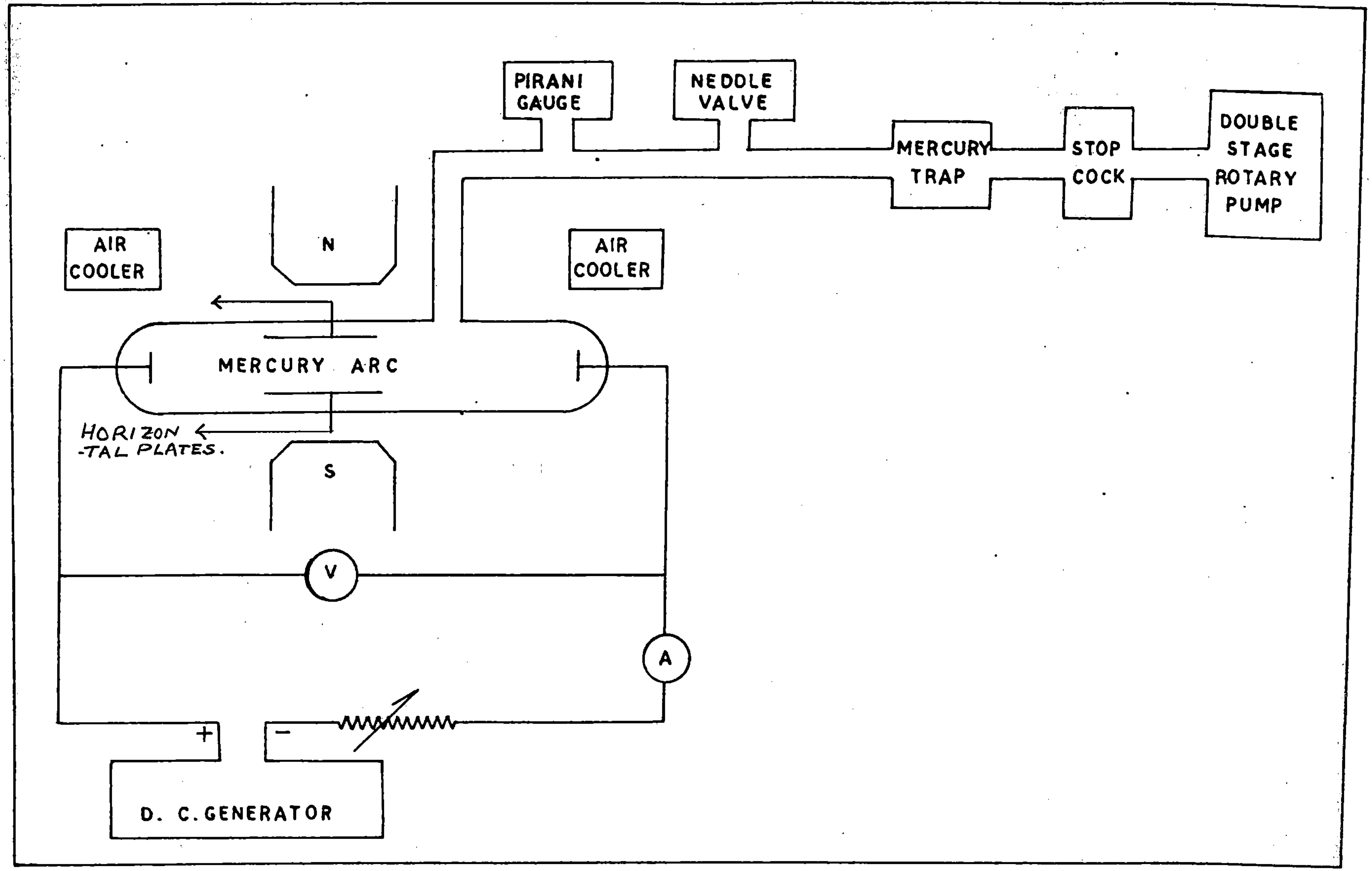

FIG.2·7.3.(2) SCHEMATIC DIAGRAM OF EXPERIMENTAL SET UP IN A TRANSVERSE MAGNETIC FIELD.

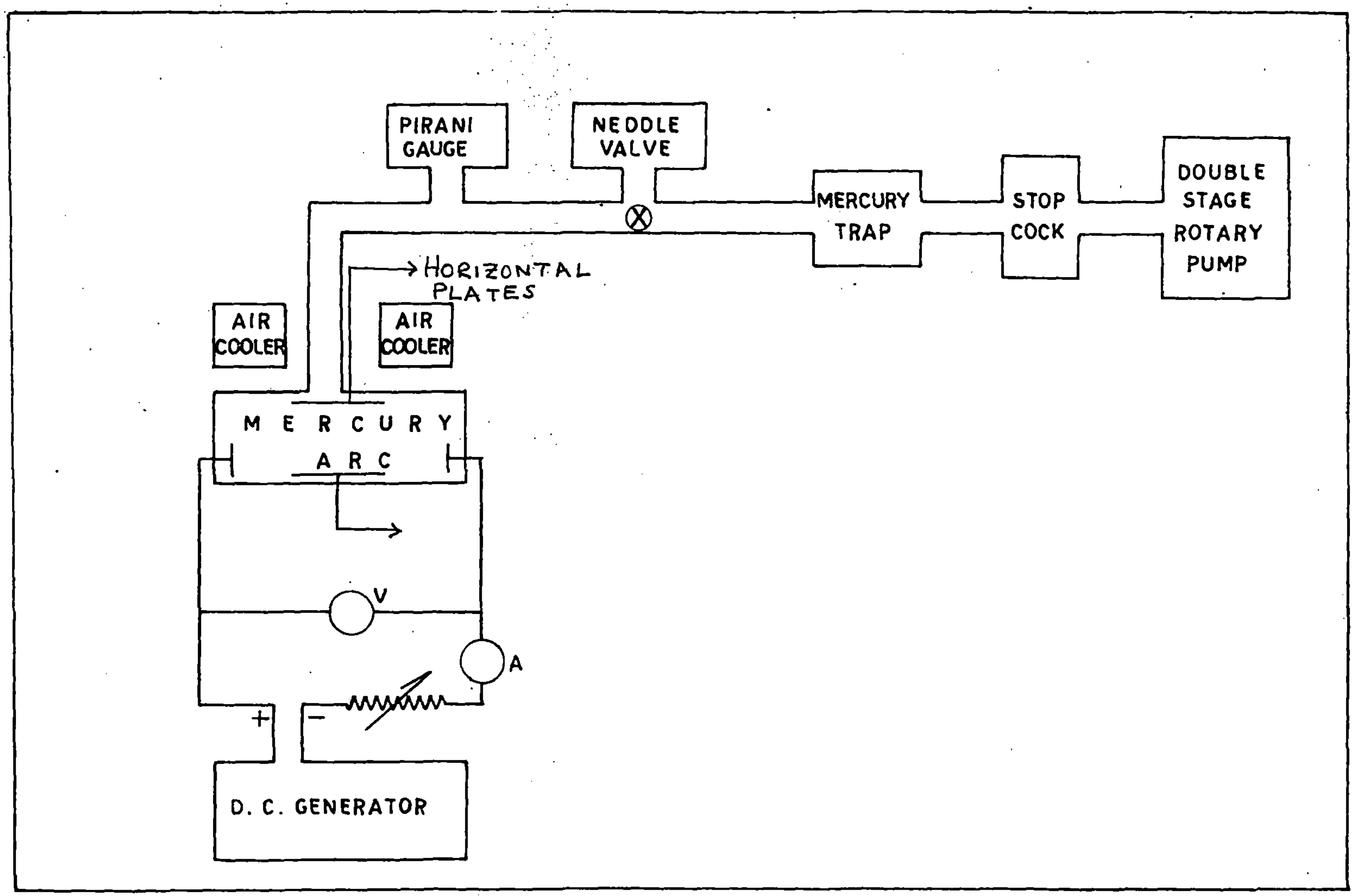

FIG. 2·7.3(3) SCHEMATIC DIAGRAM OF EXPERIMENTAL SET – UP

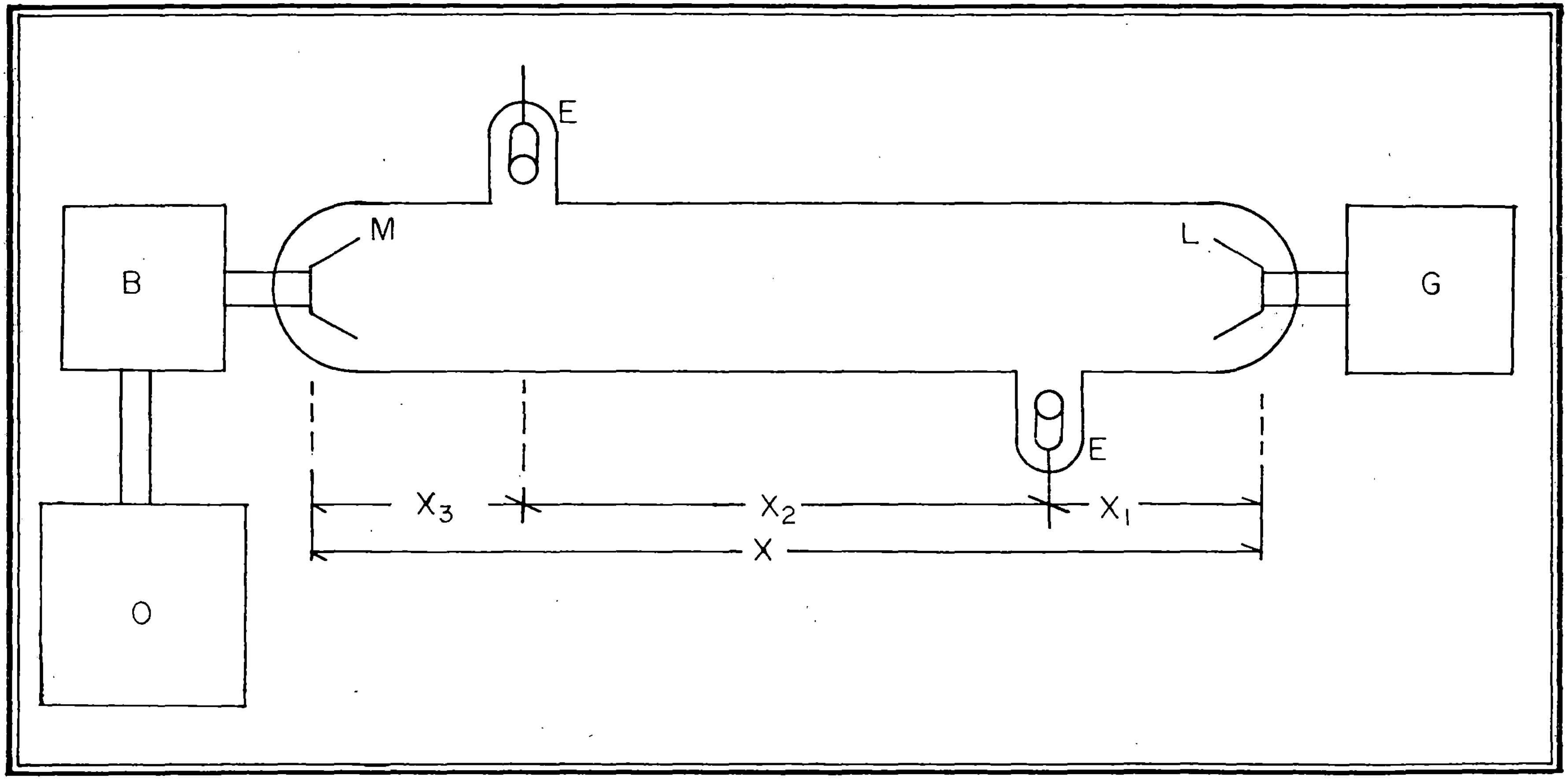

Fig 2·7.4(1) EXPERIMENTAL SET UP

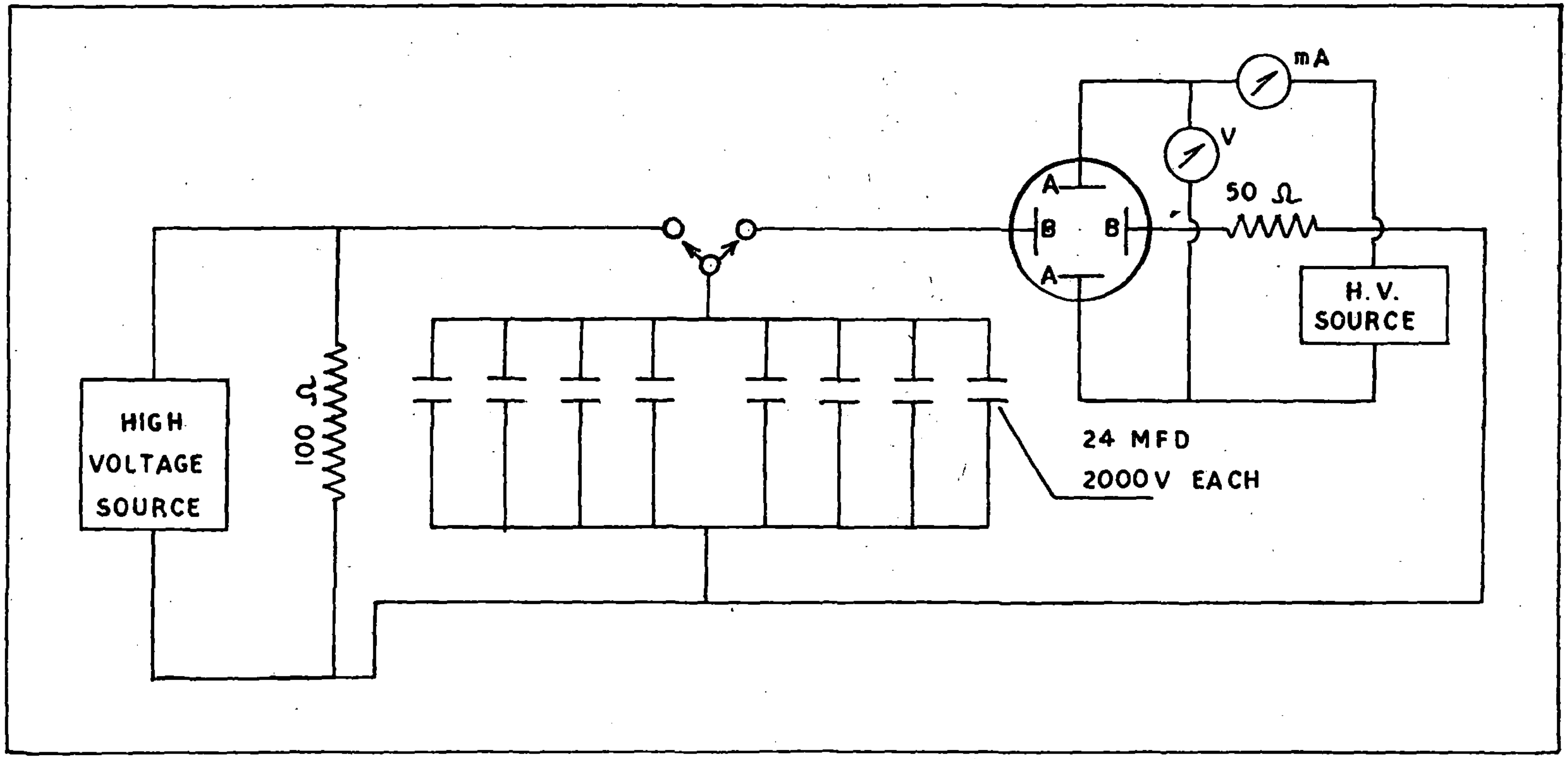

FIG. 2.7.5.(i) ENHANCEMENT OF SPECTRAL INTENSITY BY BANK CONDENSER DISCHARGE.