CHAPTER II

GENERAL EXPERIMENTAL ARRANGEMENT
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The general experimental set-up for the work presented in the thesis, consists of the following

(1) Vacuum unit
(2) Production of plasma
(3) Confinement of plasma
(4) Double probe arrangement
(5) Sonic probe arrangement.

2.1 VACUUM UNIT

The fundamental requirement for studying gaseous discharge and plasma state is the production of precisely controlled and accurately measurable low pressure (of the order of 1 Torr). This whole unit, is an assembly of a vacuum chamber, a vacuum pump and a pressure gauge to measure the pressure.\(^1\)\(^2\)

Vacuum Chamber

In the study presented here, three different vacuum chambers were used, one big glass chamber, one big steel chamber and a small glass chamber. These chambers were designed depending upon the specific experimental study. It was observed that there was no appreciable variation of parameters, unless the chamber was very much small, so that the plasma column touched the walls. Thus the chambers were made
as big as possible so that assembly of the apparatus could be kept inside it, without touching the walls.

The big glass chamber was fabricated by National Physical Laboratory, New Delhi, according to the given specific design and dimensions. The chamber was made of 4 mms thick glass. The inner diameter of the chamber was 25 cms, and its height was about 60 cms. The upper part of the chamber was closed with the help of a vacuum tight glass lid, which could be opened when required. Ten copper leads were sealed on the lid of chamber for electrical connections. Two of them were able to sustain high voltage and two of the others were shielded leads for the connection with loudspeaker and microphone. Each lead was insulated properly and was fixed at a sufficient distance. The chamber with appropriate rubber gasket was kept on a metal vacuum surface which was connected to a vacuum pump, and a Mc-leod gauge (Vacuoscope).

The steel chamber was fabricated in the workshop of the Government College of Engineering and Technology, Raipur. The inner diameter of the chamber was 20 centimeters and its height was 40 cms. The chamber was made of 1.0 cm thick cast iron. The upper portion of the chamber was covered by a sealing of perspex sheet (4 mms thick) with the help of Araldeite (adhesive). Electrical leads, for high voltage and other connections were also sealed with the help of Araldeite, after inserting them in the drilled holes on perspex sheet. The perspex sheet used was able to sustain
low pressure and it was transparent so that one can view the inside of the chamber. The chamber was kept on the platform (surface plate) and was made vacuum tight by applying vacuum grease locally around the base circumference of the chamber. The assembly of apparatus was kept inside the chamber. The platform was made of steel (diameter - 30 cms) and provided with three outlets. One of these was connected to the vacuum pump, the second was connected to the vacuouscope, and third was connected to the leak valve.

The third small glass chamber was designed specially for observations in the presence of magnetic field. It was fabricated in the glass blowing laboratory of Bhilai Steel Plant. The chamber was made of pyrex glass tube of internal diameter 10 cms and length 20 cms. Both ends of the tube were closed with perspex sheet, with the loudspeaker on one sheet and the microphone on other. Perspex sheet were sealed on the tube ends with the help of Araldelite. Holes were drilled on perspex sheets, for connecting leads. All the connection leads were sealed with Araldelite. Two diametrically opposite holes were drilled on the glass tube at its middle for leads to the aluminium electrodes. Electrodes were fixed in such a way that the microphone and the loudspeaker were perpendicular to the discharge column. The discharge tube was provided with three jet holes, for the connection with the vacuum pump, the vacuum gauge and the leak valve.

The present investigation was directly concerned with the production and measurement of sound waves pressure inside
the chamber. Hence it was of importance to make the vacuum chamber "anechoic", so that sound waves reaching the walls are completely absorbed and do not reflect from the walls/microphone etc., to interfere with newly produced sound waves, and to cause errors in measurements. This was achieved by coating the inner walls and other equipments in the chambers by glass wool and by porous/spongy materials.

Production of Low Pressure

In the present investigation experiments were performed at low pressure ranging from 0.5 to 1.7 torr. This range of pressure was obtained by a rotary oil vacuum pump\(^1,2,5\) (Model SSRR/30, Single stage, manufactured by Basic Synthetic Chemicals Calcutta -33). The chamber was first evacuated by the pump, later the experimental gas, which was dry air, was introduced [fig. (2.1)]. The air was dried by passing it through a u-tube containing calcium chloride. The desired pressure was maintained by adjusting the valve and the fine regulator.

Measurement of Pressure

The pressure inside the chamber was measured with the help of vacuoscope (Mc-leod gauge VG/2, Basic Synthetic Chemicals private Ltd., Calcutta-33). The vacuoscope was a miniature "McLeod gauge and working on the same principle. The range of the gauge was from .01 torr to 10 torr. The vacuoscope gave direct readings of the pressure on a calibrated scale, provided with it.
2.2 PRODUCTION OF PLASMA

The discharge was produced in between the two circular electrodes facing each other at various pressures ranging from 0.5 to 1.5 torr. Each electrode was made of 1 mm thick circular aluminium disc of diameter 2 cms and they were placed 4.5 cms (variable) apart. Aluminium was selected as the material for the electrodes because it gives small secondary emissions and shows little cathode sputtering. They were rounded off at the edge in order to avoid the distortion of the electric field. The electrodes were thoroughly cleaned and made smooth by machining in order to get a steady state discharge.

The discharge was excited by stabilized high voltage d.c., a.c. (50 Hz) and h.f. fields. A schematic circuit diagram with essential elements is shown in figure (2.2).

D.C. Discharge

A direct current high voltage was obtained by using a high voltage powersupply unit (Model HV 200, Max. voltage 2 KV at 1 mA, manufactured by Trombay Electronic Instruments). The voltage was varied with the help of a coarse and a fine variable knobs provided with powersupply unit. The voltage applied was measured with the help of a voltmeter provided with the unit.

The discharge circuit, as illustrated in fig. (2.2), was made by connecting the high tension terminal to one electrode and the second electrode was connected to the
negative (earthed) terminal of the power supply, through a resistance of 10 $\text{K}\Omega$ to limit the current. The discharge current was measured with the help of a calibrated reflection type moving coil galvanometer with lamp and scale arrangement.

**A.C. Discharge**

An alternating high voltage was obtained with the help of step-up transformer (Type A717, Pri. Voltage 230 volts, Sec. Voltage 10 KV, Radio Sound, Bombay). The voltage to the primary of the transformer was fed by a variable (0 - 250 volts) auto-transformer (Dimmerstat, Type T 1264/7731, AEPL, Bombay). The a.c. discharge circuit consisted of similar elements as those in d.c. discharge circuit. The electrodes were directly connected to the step-up terminals of the transformer, through a resistance of 10 $\text{K}\Omega$. The discharge voltage was measured with the help of a high impedance vacuum tube voltmeter (V.T.V.M. GM 6009, Philips, India). The discharge current was measured by a calibrated galvanometer in the circuit containing a rectifier 0470 across the resistance of 10 $\text{K}\Omega$ as shown in the fig. (2.2).

**H.F. Discharge**

The high frequency voltage was obtained with the help of a Tesla coil (Type VT-65, S.No. 274, Polytronic, Bombay), capable of giving fixed high frequency of the order of 300 MHz with variable output voltage. The high frequency terminal of the Tesla coil was directly connected to one electrode and the second electrode was connected to the earth. The discharge voltage was measured with the help of a V.T.V.M.
2.3 **PLASMA CONFINEMENT**

The plasma was confined longitudinally with the help of a uniform magnetic field applied parallel to the electric field. The magnetic field was produced with the help of a pair of Helmholtz's coils and varied between 0 to 250 Gauss.

The Helmholtz pairs [fig. (2.3)] are two similar wire bounded coils of same radius separated by a distance $r$, equal to the radius of the each coils. The coils were connected in series so that current flows in both of these coils in the same direction. Thus a fairly constant magnetic field around a distance $r/2$ was obtained.

The magnetic field was varied by varying the current in the coils, and was measured with the help of a search coil and a galvanometer. The measurement of magnetic field at different points showed that field was fairly uniform around $r/2$.

2.4 **DOUBLE PROBE ARRANGEMENT**

A schematic diagram of the double probe method is shown in fig. (2.4). It consists of two identical metallic probes, a dry battery of 30 volts, a d.c. voltmeter and a precise reflection type galvanometer to measure current.

Two identical copper wires of same diameter and length were used as probes. The probes wires were shielded by a capillary glass tube of small diameter and only a very small length (about 1 mm) of the copper probes was exposed to the discharge. They were cleaned thoroughly by pre-heating.
and rubbing. The probes were fixed diametrically opposite to each other in the discharge column. The distance between the tips of the probes was kept about one centimeter, so that the potential on one probe might not disturb that on the other probe.

The voltage to the probes was supplied by a 30 volts d.c. supply of dry batteries and was measured by a V.T.V.M. The probe current was measured by a sensitive reflection type galvanometer with lamp and scale arrangement which was calibrated to measure current (1 div = 2 µA).

At first, the probe P₁ was made positive and P₂ negative. The probe current was measured by varying the probe voltage. The probe current increased with applied voltage till a saturation value was obtained (saturation ion current). Similar observations were taken by changing the polarity of the probes i.e. by making P₂ positive and P₁ negative. A graph was plotted with the probe voltage as abscissa and the probe current as the ordinate. Electron temperature was calculated from the graph following the logarithmic plot method of Johnson and Malter,¹¹-¹³ as explained fully in Chapter III and VI. Further more, the radius and length of the probe were also measured by using travelling microscope to evaluate the electron density of the plasma. The method of evaluating electron density is given in Chapter VII.

2.5 SONIC PROBE ARRANGEMENT

The sonic probe technique¹⁴,¹⁵ consists of essentially two parts, the first part of which involves
generation and transmission of sound signals, and the second part involves reception and measurement of pressure amplitude of the transmitted signal, as shown in the Fig. (2.5).

Sinusoidal sound waves were generated with the help of an audio frequency oscillator (Advance type H, model 1, made in U.K.) with output voltage between 0 to 25 volts and frequency range from 20 Hz to 20 KHz. They were amplified with the help of an audio frequency amplifier (Type 6503, Philips, India). Amplified sound waves were fed to a small size moving coil loudspeaker kept at right angle to the discharge column.

A moving coil microphone kept in the line of the loudspeaker received the transmitted waves. The waves were amplified by a second audio frequency amplifier (Type 201-A, Redart). The amplified waves were detected and measured by a V.T.V.M. after due amplification.

The procedure of measurement of sound wave pressure in air and with the plasma is as follows -

(i) **In Air** :- A suitable sound wave pressure was read at the receiving end by adjusting the output of the audio-oscillator and the two amplifiers. Let the voltage as read by V.T.V.M. be \( V_1 \) (volts).

(ii) **In Plasma** :- The plasma was created by passing an electrical discharge through air. Let the magnitude of the voltage now as recorded by V.T.V.M. be \( V_2 \) (\( V_2 < V_1 \) ).
The experiment was repeated by changing, 1) the frequency of the audio signal and 2) the state of ionization by changing the voltage at the electrodes.

Using $V_1$ and $V_2$ the percentage attenuation of sound waves was calculated. This gave the value of characteristic impedance, $r$. From the knowledge of $r$ the value of electron temperature was calculated, as described in the Chapter III.
REFERENCES


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