ABSTRACT

The application of high voltages for transportation of electrical power in bulk quantities over long distances and in scientific research work e.g. nuclear particle accelerators and the like is on increase. For high voltage power apparatus along with solid insulation, gaseous insulation with its excellent arc quenching and recovery properties is an alternative to the conventional insulating oils used especially in transformers, circuit breakers, capacitors etc. Consequently research activity in the study of fundamental aspects of electrical breakdown and prebreakdown phenomena in gases is being continued as vigorously as in any other field of electrical engineering discipline. A knowledge of primary and secondary ionization coefficients, attachment and detachment coefficients and other electron swarm parameters which govern the electrical behaviour of gas insulators, is required for a proper understanding of the various breakdown processes involved, to exploit their potentialities as electrical insulators fully. This thesis is mainly concerned with the accurate determination of these parameters in certain gases (discussed below) under controlled experimental conditions using high vacuum techniques.
I. Measurement of sparking potentials, ionization and attachment coefficients in oxygen and nitrogen

The attractive features of molecular gases are the relatively small values of the secondary ionization coefficient and the attachment phenomena, the latter being the case only in the electronegative type (for example, oxygen) from the point of view of their electrical insulating properties. A survey of literature shows that reliable data on the ionization and attachment coefficients in oxygen and ionization coefficients in nitrogen are not available for gold-plated cathode electrode system in uniform electric fields in the range of $95.6 \leq \frac{E}{N} \leq 3503.7$ Td where $E$ is electric field strength (V cm$^{-1}$) and $N$ the gas number density (number of gas molecules per cm$^3$). The prebreakdown current growth phenomena in these two molecular gases is carefully investigated using the distance variation technique where prebreakdown currents are measured as a function of electrode separation (d cm) for constant values of $E/N$ keeping $N$ (the gas pressure) constant using a nonmagnetic stainless steel ionization chamber and the whole system completely free from even small traces of mercury.

The values of $\alpha/N$ and $\gamma$, the Townsend's primary and secondary ionization coefficients respectively
are experimentally determined in oxygen over a wide range $95.6 \leq \frac{E}{N} \leq 3503.7$ Td using gold-plated and aluminium cathode electrode systems both before and after glow discharge. The coefficient $\frac{\lambda}{N}$ is found to depend on $\frac{E}{N}$ only. Its variation at higher values of $\frac{E}{N}$ is observed to be less rapid with gold-plated cathode than with aluminium cathode. Similar observations are also found in the values of $\gamma$ for both electrode systems. Considerable spread is observed in the values of $\gamma$ determined from the up-curving portions of the current growth curves indicating a very unsystematic dependence of this coefficient on $\frac{E}{N}$. The attachment coefficient in oxygen is determined for $9.56 \leq \frac{E}{N} \leq 254.81$ Td. The type of dependence of $\frac{\gamma}{N}$ on $\frac{E}{N}$ is observed to be a sharp increase followed by an almost plateau region thereafter. Measurement of sparking potentials shows that Paschen's law is not obeyed in this gas.

Proceeding on similar lines, the values of $\frac{\lambda}{N}$ and $\gamma$ for nitrogen are determined over a range of $186.8 \leq \frac{E}{N} \leq 3112.7$ Td. Measurement of sparking potentials ($V_s$) shows that Paschen's law (i.e. $V_s$ depending only on the product Nd) is obeyed in nitrogen.
II. **Measurement of sparking potentials and ionization coefficients in dry air and artificial air**

Considerable data have become available on the growth of ionization currents in dry air over a wide range of $E/N$ but not much information in artificial air (oxygen 21 per cent plus nitrogen 79 per cent). Again a survey of literature reveals that reliable data in dry air free from contamination of mercury vapour and hardly any such data in artificial air are available for the ionization coefficients $\lambda/N$ and $\gamma$, only over a range of $E/N \leq 197$ Td. Not much information on these coefficients in dry air and no such data in artificial air are available using gold-plated electrode system at higher values of $E/N$. Hence the measurements of $\lambda/N$ and $\gamma$ are carried out in dry air as well as in artificial air over a wide range of pressure and $155.6 \leq E/N \leq 3424.0$ Td. The method that is employed is the pressure variation technique where ionization currents are measured with increase of pressure at various constant values of $E/N$ at constant electrode separation in uniform electric fields. Measurements of the sparking potentials shows that Paschen's law is not obeyed in dry air as observed by previous investigators. Townsend's primary ionization coefficient $\lambda/N$ is found to depend only on $E/N$ and a general increase in $\gamma$ with $E/N$ is observed.
Since there is no information available on the values of $\lambda/N$ for artificial air over the above mentioned range of $E/N$, values of $\lambda/N$ are calculated in the range using the semi-empirical equation suggested by Swamy and Harrison and the values are found to be accurate 5 per cent to 15 per cent less than those experimentally determined for dry air. The values of $\lambda/N$ are also measured in artificial air over a wide range of $E/N$ and these values are found to agree reasonably well with those calculated.

III. Measurement of sparking potentials, ionization and attachment coefficients in ammonia and water vapour

To the author's knowledge, published information on the ionization and attachment coefficients in ammonia and water vapour is not available in the literature except the one carried out by a recent worker a few years ago over a wide range of $E/N$ (for example, for $\lambda/N$, $70 \leq E/N \leq 2400$ Td in water vapour). Sparking potentials are measured with respect to $N_0$, the spark parameter and Paschen curves are drawn. Prebreakdown current growth is measured using the distance variation technique. The coefficients $\lambda/N$ and $\gamma$ are determined for $95.25 \leq E/N \leq 3322.76$ Td, using goldplated electrode system. These values are compared with those available in the literature (in certain ranges) and their agreement is found to be reasonable.
Attachment coefficient \( \eta/N \) is determined in ammonia and water vapour over a range of \( 28.48 \leq E/N \leq 132.91 \) Td and \( 47.47 \leq E/N \leq 167.72 \) Td respectively. The fall in \( \eta/N \) at higher values of \( E/N \) used in this investigation is found to be rapid. This is in agreement with the observations of the previous investigators.

IV. Measurement of sparking potentials, ionization and attachment coefficients in humid air

There is not much data available on the electron swarm properties of humid air except that of a few workers, that too, over a very limited range of the parameter \( E/N \) for three particular ratios of partial pressure of water vapour \( (p_w) \) to total pressure \( (p) \) of humid air. Hence, measurements of prebreakdown currents are carried out in humid air over the range \( 77.82 \leq E/N \leq 264.58 \) Td for different ratios of \( p_w/p = 1/30, 1/15 \) and \( 1/10 \) using the distance variation technique. The values of \( \lambda/N \) and \( \eta/N \) measured over the above mentioned \( E/N \) range are found to be higher than those of the previous workers obtained at the same \( p_w/p \) ratios. They are also found to have the same qualitative variation with \( E/N \) as obtained by previous workers. Sparking potentials are also measured
for the above mentioned ratios of \( p_w/p \) over the range 
\[ 2.5 \times 10^{16} \leq \frac{\Phi}{cm^2} \leq 149.17 \times 10^{16} \] using the pressure variation technique. \( V_s \) is found to increase with \( p_w/p \) as observed by previous investigators. New data on \( \alpha/N \) and \( \gamma \) over the range 
\[ 153 \leq E/N \leq 3423.94 \text{ Td} \] at \( p_w/p = 1/10 \) are measured for the first time using the pressure variation technique. These values of \( \alpha/N \) in humid air are compared with those in water vapour and dry air obtained in the present investigations under the same experimental conditions.