EXPERIMENT NO. 2

Objective: To conduct experiment in the High Voltage lab. To observe the following.

a) Distinction between the types of electrostatic fields.

b) Different stages in gas breakdown.

Electrostatic field:

For a dielectric material to be used in insulation it should be able to store charge across the material without allowing charges to flow through. The positioning of the charges across the material results in the build-up of electrostatic field. With an increase in demand for electrical energy, transmission level voltages have gone up. In order to keep the size and weight of electrical equipment, the designers are forced to adequately design the insulation. This requires an understanding of the behaviour of the insulating material when exposed to electric fields; the first step towards that is knowledge of electric fields and methods of controlling electric stress.

Electric field E is defined as the force per unit charge. At any point in the field, E is defined as gradient of potential, i.e. $E = -\nabla\phi$

The simplest kind of electric field is **uniform** field. In this case, field is constant within the volume of the dielectric i.e. space independent. This kind of field is very difficult to achieve even with parallel plates. A **non uniform** field is space dependent. In this case, the potential gradient may be very high over a limited region. In a field map representing non-uniform fields, the field lines tend to be concentrated in certain regions but sparsely distributed elsewhere. The extend of non-uniformity may be measured by **field efficiency factor** defined as $\eta = \frac{E_{mean}}{E_{\max}}$. It is also called the **Schwaiger factor**. η equals unity for a uniform field and approaches zero with increase of non-uniformity.

The uniformity of a field is predominantly determined by the shapes of the electrodes used.

1. Uniform Fields may be obtained between two parallel plates provided stress control is applied at the ends.
2. Non-uniform Fields with high Schwaiger factor may be obtained between two coaxial cylinders.
3. Non-uniform Field with vey low Schwaiger factor may be obtained with a needle - plane geometry, i.e. at any sharp point, edge or a thin wire.

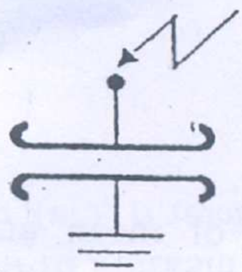
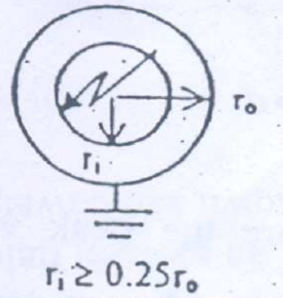
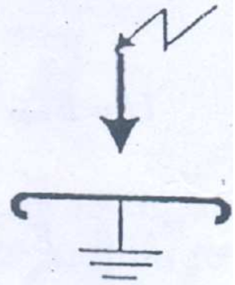
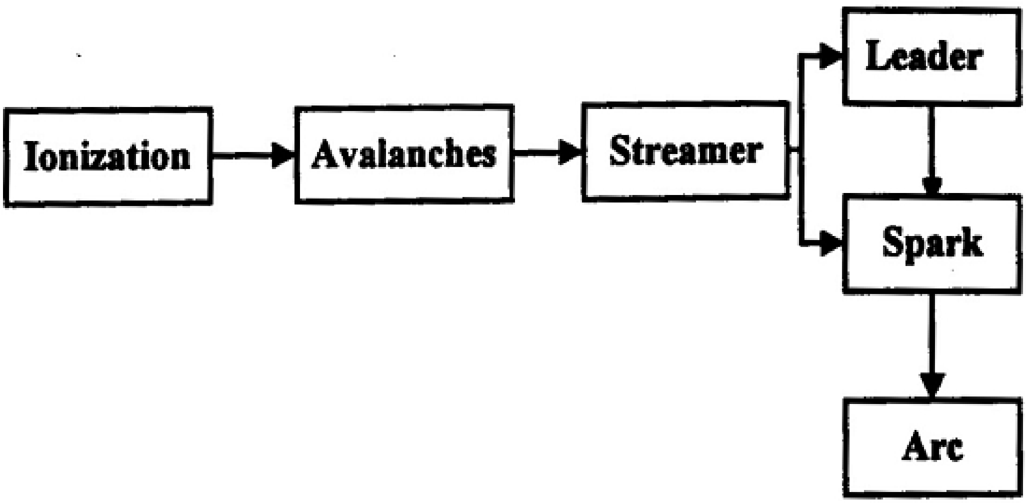
Field Classification	Uniform	Non-Uniform Field with high Schwaiger factor	Extremely No-uniform (with low Schwaiger factor)
Electrode Configuration	Parallel plate 	Concentric spheres  r_o, r_i, $r_i \geq 0.25 r_o$	Needle-plane 
η	1.0	0.25 for air	<<0.01

Fig.2.1: Typical electrodes configurations

As the voltage across uniform field increases, the applied field exceeds a critical value E_b the dielectric breakdown strength of the material. This is characteristic of the dielectric material. When field across the material exposed to uniform field exceeds the dielectric breakdown strength of the material, **breakdown** occurs i.e. the material loses its insulating property and allows conduction of high current. In a material exposed to non-uniform fields, only a small region may be stressed above the dielectric breakdown strength of the material, while the field elsewhere remains within safe bounds. This may result in localised breakdown of the material (only in the region of maximum field), which then becomes conducting without the conducting path being able to bridge the opposite electrodes. This is called **partial discharge**. Partial discharge in open air is called corona. Other forms of partial discharges occurring within materials or along gas-solid surfaces are internal discharges, tracking, surface flashover, etc.



Stages in Discharge Development:

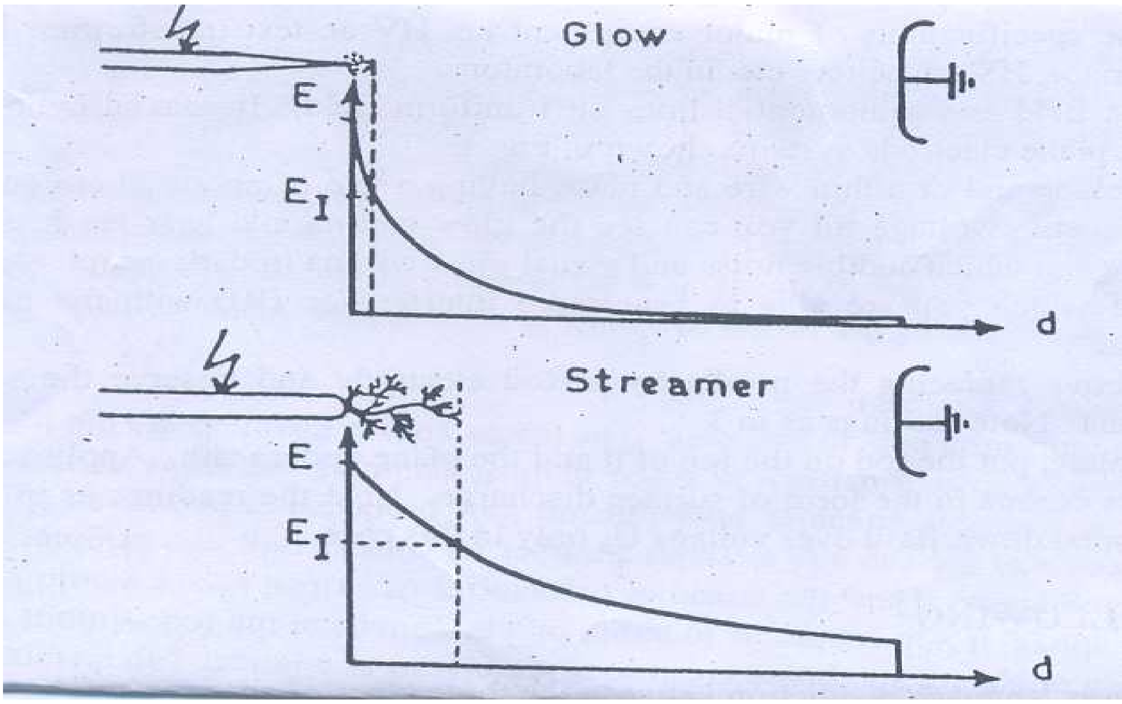
The visual nature of the corona can change according to the nature of the field. Some or all of the following different stages in the development of the discharge may be witnessed depending upon the field configuration.
Electric discharges develop due to ionization of atoms and molecules in regions of high electric field. With the production of a large number of electrons, electron avalanches are created. The following steps may occur next, depending on the nature of the field, and hence the electrode configurations.

1. **Glow**

   In highly non-uniform fields, where only a small region near the tip of an electrodes exceeds the breakdown strength of air, the PD is localised within a limited region close to the tip of the electrode. Depth of this region is so small that the ionization of air is not sufficient to create avalanches with a critical amplification. The optical impression of such a partial discharge process is a weak, bluish "Glow", seen adjacent to the sharp electrode. The electrons at high energy levels emit quantum of light and fall back to the original state of lower energy level. It appears in dark like a star at the tip of any point electrode.

2. **Streamer**

   If the non-uniform field exceeding the breakdown strength of air extends over a larger region, electron avalanches may be produced which progress from the tip of the electrode in steps towards the other electrode. The visual impression is similar to that of lightning. Streamers are essentially electron avalanches, typically lasting a few nanoseconds. Streamers redistribute charge within the surrounding gas.



Where E_1 is the minimum field intensity required for impact ionization.

Fig.2.2: Variation of field intensity at needle and rod – plane electrode configurations.

3. Leader

Streamers can lead to the development of a single leader channel. The projecting channel of hot plasma is called a leader and it can have electrical conductivity approaching that of an arc. The function of a leader is similar to introducing a short length of wire into a gap. The Leaders are the brightest channels and produce a "cracking" audible noise. A leader channel arises from the stem of the discharge where the gas is heated to the maximum by the total current flowing in from all streamer bursts. The total streamer current provides the leader its power, heats it and maintains the plasma conductivity. In our laboratory the Leader corona discharge is produced in the form of "Surface Discharge" on a glass plate to the limitation of the magnitude of HV available.

Sometimes this may develop into a spark or an arc. A **spark** is a discharge capable of passing high current typical of short circuit conditions. The final spark stage is the **arc** flash. After this breakdown is generally complete.

Laboratory work:

1. Note down the specifications of major equipment i.e. HV ac test transformer, Impulse Voltage Generator (IVG), HV capacitors etc. in the laboratory.

2. Sketch electric field and equipotential lines on (i) Uniform Field, (ii) Coaxial cylinder, and (iii) needle and plane electrode systems shown in Fig.1.

3. Take Needle-Plane and or a thin wire and plane having a gap of about 20 cm and apply ac, power frequency voltage till you can see the Glow Corona and hear the HISS sound. Note the voltage at which audible noise and visual Glow Corona in dark incept. Also note the voltage at which you are able to hear radio interference (RI) with the help of a transistor radio.

4. Repeat the above replacing the needle by a rod electrode and observe the same for Streamer Corona. Note readings as in 3.

5. Take a glass plate and put the rod on the top of it and the plane underneath. Apply voltage to observe Leader Corona in the form of Surface Discharge. Note the readings as in 3. Also measure the breakdown/flash over voltage U_b only in this case.

Answer the Following:

1. Describe the various stages in a discharge.
2. What are the various ways to detect corona.
3. How may corona be reduced?