PHYSICS AND CHARACTERISTICS OF GLOW LAMPS

CHAPTER 1

The neon glow lamp, which is also commonly referred to as a glow tube or neon bulb, is a cold-cathode, gas-discharge device. As well as having extensive use as a visual indicator, the neon bulb has characteristics which enable it to operate as a very versatile and inexpensive circuit component. This booklet is devoted to these characteristics and associated circuitry.

THEORY OF GASEOUS CONDUCTION IN THE NEON GLOW LAMP

The glow tube consists basically of two metallic elements spaced a short distance apart and immersed in neon gas at a moderately low pressure. The electrical conduction between these two elements is a very complicated phenomenon involving neutral atoms, excited atoms, positive ions, and electrons. In addition, the conduction mechanism in the neon bulb varies throughout the operating voltage-current range. A typical neon bulb characteristic is shown in Fig. 1.1.

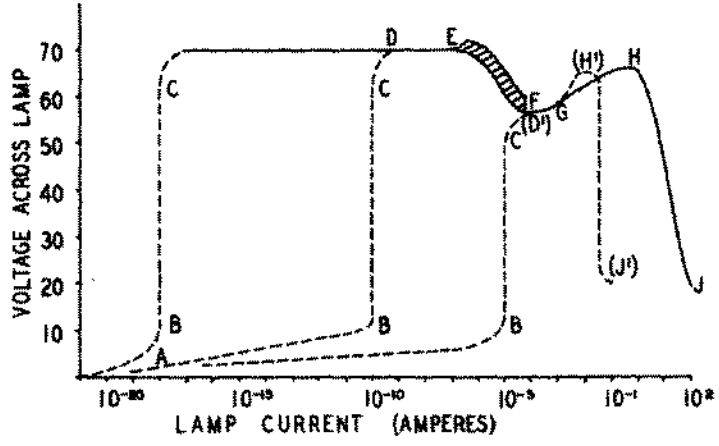

Fig. 1.1. Characteristic Curve of the Neon Lamp

Electrical conduction in the lamp requires the ionization of the neon gas, which consists of the separation of an electron from an atom resulting in a positively charged ion and a free electron. In order to break an electron away from an atom, energy must be supplied to it. This energy may be supplied by collisions between particles such as electrons or excited atoms; a process which requires the application of an electric field. Ionization may also be produced directly by external ionizing sources such as ultraviolet rays, x-rays, and cosmic rays. A third producer of ionization may be radioactive additives within the lamp.

The gas within the neon bulb is always in a state of partial ionization due to one or more of the ionizing sources just mentioned. As an increasing voltage is applied to the neon bulb there is a small increasing current flow due to the drift of electrons and ions which are made available by the action of these ionizing sources. The applied voltage produces an electric field which draws the positive ions to the cathode and the electrons to the anode. This current is indicated by one of the regions AB in Figure 1.1. A large portion of this current can be photoelectrons if the lamp is operating in ambient light.

As the voltage is increased, a point B is reached where all the available ions and electrons are being pulled from the gas and a further increase in voltage results in no further increase in current. This constant-current region is represented by the curves BC.

A further increase in the voltage across the lamp past the value represented by point C results in a rapid increase in current to the point D or D'. This discharge is called a non-self-maintained or a Townsend discharge. This increasing current is brought about through a phenomenon termed electron avalanche in which a moving electron (a so called primary electron) upon colliding with an atom may liberate another electron from the atom thus resulting in a positive ion and two electrons. These two electrons are now accelerated by the electric field and in turn may produce two more collisions. Thus there is an accumulating density of charge carriers available, and as they are attracted to the electrodes the current increase. If the external excitation which is producing the primary electrons should be removed the current will cease to flow, hence this discharge is termed non-self-maintained. The characteristic curve from A to D is dependent upon this external excitation.

When the voltage across the lamp is increased to a value represented by point D the gas in the lamp "breaks down" and begins to glow. This is defined as the breakdown or firing voltage. The current will increase to a value limited mainly by the resistance in the external circuit. If, after breakdown occurs, the external ionizing excitation source is removed, current will continue to flow and for this reason this type of discharge is referred to as a self-maintained discharge.

The voltage at which breakdown occurs is a function of the product of the interelectrode spacing and the gas pressure and does not depend upon these two parameters separately. This relationship between electrode spacing and gas pressure is known as Paschen's law. The breakdown voltage is also dependent upon the electrode material and the composition of the gas.

After breakdown occurs the lamp passes through a transition region EF which is an unstable region of operation. The shaded portion indicates the region in which oscillation can occur. This region is often referred to as the negative resistance region, since voltage decreases as current increase, contrary to normal behavior in a resistive element. In extremely high illumination the negative resistance region may be missing, as shown on the third curve, A to D'.

As current through the lamp is allowed to increase further, the lamp enters the normal glow discharge region represented by section FG in Figure 1.1 where voltage changes a minimum amount with a change in current. The operating voltage across the lamp at any point on the characteristic curve is termed its maintaining voltage and, of course, will vary with current. In the normal glow region the lamp maintaining voltage reaches its minimum value. (See section on Equivalent Circuits and General Formulae.) In the normal glow region the glow is confined to a portion of the cathode surface and the amount of cathode surface covered by the glow is somewhat proportional to the tube current.