those derived from pines and other coniferous trees. Egypt produced no kinds of incense trees or shrubs. The common incenses were pine resin, ladanum, and myrrh, and all these were imported. It is difficult to believe that the ceremonial use of incense arose in Egypt.

These are a few of the questions raised by a study of the material relating to the origins of the ancient civilisation of Egypt. An immense vista has been opened out before our eyes by the discoveries of the last thirty years, and now, in Egypt better than in any other country in the world, we can see man passing

from the primitive hunter to the pastoral nomad, from the pastoral nomad to the agriculturist, and then on to the civilised life which begins with the art of writing. We can see in the Delta and in the Lower Nile Valley tribes becoming permanently settled in fixed abodes around primitive cult-centres, and then uniting with others into one community. We can trace the fusion of several communities into single States, and then, later, the uniting of States under a supreme sovereign. What other country in the world preserves such a record of its early history?

Rare Gas Discharge Lamps.

By J. W. RYDE, Research Laboratories of the General Electric Company, Ltd., Wembley.

A DISCHARGE of electricity through a gas at atmospheric pressure generally takes the form of a luminous spark which will pass only under a potential gradient of several thousand volts per centimetre. If, however, the pressure of the gas is reduced, the appearance of the discharge changes. First it spreads out into wavy streamers; the streamers then broaden until the discharge tube is filled with a diffuse luminous glow extending from the positive electrode to within a short distance of the cathode. This glow is known as the positive column. The cathode is now covered with a layer of bright luminosity called the negative glow, and on close inspection is seen to be not quite in contact with the electrode but separated from it by a thin and sharply defined region, known as the Crookes's dark space. Another less well-defined dark region, the Faraday dark space, is between the negative glow and the positive column. Further reduction of the pressure results in a widening of both dark spaces and the negative glow, the positive column at the same time becoming correspondingly shorter. At still lower pressures the Crookes's dark space increases until finally it fills the whole tube and there is no further luminosity of the gas.

The potential necessary to start the discharge depends on the pressure and nature of the gas, the form and material of which the electrodes are made, and also on the distance between them. In a given gas with given electrodes the starting potential is large at high pressures, but decreases, in an almost linear relation, with decrease of pressure, reaching a minimum at what is called the critical pressure, after which it rises again very rapidly. The pressure at which the minimum occurs depends on the form of the electrodes, their distance apart and the nature of the gas, but the minimum itself depends on the nature of the gas and the material and form of the cathode employed. It is about 200 volts for neon, 280 volts for hydrogen, 340 volts for air, and 420 volts for carbon dioxide. Small traces of impurity affect these values to a great extent; thus, the addition of only 0.5 per cent of pure hydrogen to neon reduces the minimum starting potential by nearly 50 volts, 5.0 per cent reduces it by about 60 volts, but if more than 5.0 per cent is added the hydrogen ceases to act as an impurity and begins to show its own characteristics, so that the starting voltage rises again. On the other hand, small quantities of other gases, such as oxygen, raise the starting potential instead of lowering it. The material of which the

cathode is made has also some effect. The figures given above refer to cathodes of ordinary metals such as iron, nickel, or copper, etc., between which there are only small differences, but with magnesium, barium, or the alkali metals the starting voltage is considerably reduced; in fact, with certain alloys of these metals, the glow discharge can be started in neon at a potential so low as 90 volts and may be maintained at 58 volts.

When once the discharge has started, the potential can be lowered somewhat before the discharge stops.

FIG. 1.

The curve connecting this "going out" voltage and the pressure is roughly similar to the starting voltage curve, but is displaced to a position somewhat below it on the voltage ordinate.

If the electrodes are only a short distance apart, so that the positive column is absent, the relation between the current flowing and the potential applied across the electrodes is that shown in Fig. 1. The states represented by the lower and upper parts of the curve are unstable, and can be observed only if there is in series with the discharge an appropriate resistance, by means of which the current may be varied. With this arrangement, when the current is only of the order of a micro-ampere, a faint glow is seen some distance from the cathode. The potential between the electrodes falls rapidly as the current is increased, and at the same time the glow becomes brighter and assumes the form of a sharply defined patch moving nearer and nearer to the cathode as the current rises. The voltage now remains sensibly constant, being that known as the normal cathode fall, which is the lowest potential at which

the unsupported discharge can be maintained. With a further increase of current, the glow spreads laterally over the cathode, its intrinsic brilliancy and the current density remaining practically constant. A value of the current is eventually reached at which the cathode becomes completely covered with a layer of glow separated from it by the Crookes's dark space, which is only a fraction of the width of the layer of glow itself. Any further increase in current brings us to the part *c* of the curve; the voltage now increases with increase of current and the glow becomes brighter and the dark space narrower. The curve eventually becomes very steep, following the path *cc'*, and currents of the order of several amperes per square centimetre of cathode surface can be passed. At some part of the curve *cc'* the cathode begins to heat up considerably, and if composed of a refractory metal such as tungsten, will become white-hot; thermionic emission then takes place and the glow discharge passes over to the arc discharge. As soon as this begins the potential difference between the electrodes begins to decrease as the current rises, and may finally drop to only a few volts.

Gas discharge lamps may be divided into three classes, namely: (1) Lamps in which practically all the light is emitted by the positive column, (2) negative glow lamps in which the positive column is absent, and (3) lamps in which the light is emitted not from the gas but from the cathode itself, which is rendered incandescent by the discharge.

Lamps of the Moore type belong to the first class. They consist of a long glass tube filled with gas to a pressure of a few millimetres and having an electrode at each end. On account of the distance between the electrodes, the operating potential usually amounts to several thousand volts and is inconveniently high. Recently, short tubes of this type containing neon, and having electrodes made of alkali metal alloys, have been developed which will run on 220 volt A.C. supply, but require a special device giving a higher voltage for starting. These lamps are very efficient; with some of the tubes an efficiency of 0.65 watts per candle is obtainable. The colour of the light, however, is a brilliant orange red, which for many purposes is objectionable.

The second class of lamp was developed to run directly on ordinary lighting circuits. The electrodes are placed a few millimetres apart in a small bulb, the distance between them being such that the positive column is absent; this is to enable them to start and run at ordinary supply voltages. The gas used for filling the lamps is neon with about 20 per cent. of helium, which is separated with it during the process of extraction from the air. The advantages of neon are threefold. In the first place, most of the energy radiated from the glowing gas lies in the visible spectrum; secondly, the starting potential is lower than in other gases; and thirdly, the colour of the light emitted, being a yellow orange, is more suitable for illumination purposes than that from any other gas. By using hydrogen to reduce the starting voltage as explained above, and by filling the lamps to about the critical pressure (10 mm.), it is possible to make lamps having iron electrodes in which the discharge will start at about 150 volts.

The whole of the light from these lamps comes from

the negative glow, which appears as a layer of bright orange luminosity about two millimetres thick completely covering the cathode, whatever its size or shape. The Crookes's dark space at the pressure used is only a fraction of a millimetre thick and is not easily seen. In consequence, the luminosity takes the form of the cathode, so that if this electrode is formed out of a sheet of metal in the shape of a letter, numeral, or similar sign, it will appear brilliantly illuminated when the discharge is passing. It is in this form that the tube is used for advertising purposes. In cases where the lamp is required for dim illumination, the cathode is made of a spiral of wire in the shape of a beehive, which ensures an approximately even distribution of light in all directions. The other electrode is either an iron wire hidden behind the letter, or a plate inside the spiral. On direct current only one electrode becomes illuminated, but on alternating current the small electrode also glows during the half cycle when it becomes the cathode.

On account of the rigidity of the mechanical construction, the lamps are robust and their life is limited only by their progressive blackening. This blackening is due to particles of the cathode which are shot off during the passage of the discharge and collect in the form of a film on the bulb. The rate at which the blackening takes place depends on the current passing through the lamp, and also varies very greatly with the particular metal used for the electrodes and the nature of the gas. The addition of impurities which lower the starting potential of the gas also considerably reduces the blackening. Thus, with iron electrodes and pure neon, the useful life of the lamp would only be about 80 hours, while with an addition of a small percentage of hydrogen the life becomes of the order of 1000 hours or more. A series resistance placed in the caps of the lamps makes them suitable for various voltages, and at the same time reduces the current to a value leading to a reasonable life.

These lamps, in common with all forms of Geissler discharge tubes, possess many properties which are valuable for purposes other than that of lighting. For example, when running on the part *ab* of the curve of Fig. 1 they can act as a negative resistance and can be used to generate oscillations. They are also sensitive detectors of current; the luminosity produced by a current of one microampere is easily seen if the lamp is shielded from direct daylight. But these other developments cannot be treated here.

In the third class of lamp, the electrodes are usually tungsten spheres about one millimetre in diameter and placed one millimetre apart. The bulb is filled with neon to about 50 mm. pressure. When first switched on, an intense glow discharge takes place which heats the cathode white-hot; a thermionic emission then ensues and the potential across the lamp drops to about 25 volts, the current being 1.0 to 1.25 amperes, the remaining volts being dropped in the series resistance. The lamp at this final stage operates in the region *e* of the current voltage curve shown in Fig. 1. The white-hot tungsten ball acts as a very intense point source of light suitable for projection purposes. The Pointolite lamp is a variant of this form, in which the discharge is initiated by means of a tungsten spiral heated electrically, the heating current being cut off when the lamp has started.

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