NEON LIGHTING.

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It is certainly unnecessary for me to tell English engineers how neon was discovered, since they all know that the discovery of those remarkable rare gases, which were contained in the air unsuspected by anybody, was due to Sir William Ramsay. It was the fractional distillation of liquid air which led Ramsay to his results, and these were the more remarkable since they were obtained with small resources and with apparatus capable of supplying only one or two litres of liquid air per hour.

I thought that with infinitely greater resources at my disposal, and by using apparatus capable of liquefying 10,000 cubic metres of air per day, I should be able to obtain new results. But I had to admit that after Ramsay there was nothing more to be done.

But although I was unable to add to the list of rare gases, I was able, on the other hand, to obtain them, particularly neon, in greater abundance. Indeed, the arrangement of my oxygen apparatus is such that neon constitutes the residue of the progressive liquefaction of air, and it is thus obtained as a by-product in the commercial manufacture of oxygen ; and in spite of the fact that there is only one part of neon in 66,000 parts of air, my modest apparatus giving only 50 cubic metres of oxygen per hour can yield 100 litres of neon per day, which can be used to fill balloons, such as I have here. These balloons can rise in the air since the density of neon is two-thirds of that of the latter. Neon is therefore really a commercial product freely obtainable, and I have been investigating its applications, directing my attention particularly to its use for lighting.

I need not mention the very serious disadvantages of modern sources of light, their increasing brilliancy and their greater and greater glare, and all engineers know the hopes that have been aroused in connection with diffused lighting, which without fatiguing the eyes can provide the marvellous soft glow of the rarefied atmosphere of Geissler tubes. Unfortunately, the latter have so far proved disappointing, since the luminous properties of ordinary gases are not very marked. Only nitrogen has been employed, thanks to the perseverance of Mr. McFarlane Moore, and its efficiency is not very high, namely 1·72 watts per candle. On the other hand, the rare gases are distinguished by their tendency to become luminous, and their spectra are remarkable. That of neon in particular is excellent. It contains numerous fine rays in the red, orange, and yellow, and three important lines in the green. Unfortunately, however, it has no rays in the blue or violet. Of course the absence of blue rays is a serious disadvantage for a source of light, but I believed that it would be possible to remedy this defect, and so I continued my experiments.

There were other features besides the richness of its spectrum which made me concentrate my attention on neon. The most important of all is that neon possesses a remarkable aptitude for becoming luminous. A long time ago Sir James Dewar obtained neon tubes which became luminous at the loops of a resonator, and which were non-luminous at the nodes, in such a way that these detectors provided an ingenious method of measuring the wave length of a wireless telegraph installation.

It was again a colleague of Ramsay, namely, Professor Collie, who with the neon which I had sent to Ramsay made the following interesting experiment. The sealed glass tube contained a small quantity of mercury in a rarefied atmosphere of neon; on shaking the tube in a dark room the mercury appeared like a rain of fire. The explanation of this curious phenomenon followed from the experiments of Bouty, who had noticed that neon allows electric discharges to pass with extraordinary ease. Thus, where a pressure of 1,000 volts would be necessary in the case of air, 13 volts is sufficient with neon. The Collie phenomenon is thus explained: the electrification of the tube caused by shaking the mercury is sufficient to bring about the discharges in the gas.

Possessing such properties, neon must evidently be taken into account for producing light. I therefore directed my attention towards the use of this gas in very large Geissler tubes similar to Moore tubes.

The first difficulty which I encountered is rather curious. Rare gases, as is well known, have another name, viz. noble gases, but it seems that neon has a very high idea of its dignity. Although capable of remarkable effects when isolated, it absolutely refuses to do anything when in contact with common gases such as hydrogen or nitrogen. Such gases are infinitely inferior to it, and minute traces of them mixed with neon are sufficient to upset its luminous property and luminous efficiency so completely that not a single line of its spectrum is to be found in the light produced.

It is thus not sufficient, as one might imagine, to fill a tube with absolutely pure neon; for although the tube glows magnificently, impurities set free from the electrodes when the current passes, quickly cause its luminous properties to disappear.

To get over this serious difficulty I have therefore had to devise a method of purifying neon in the tube itself as the impurities are being set free by the current; and with this object I have made use of one of the most curious features of liquid air, namely, that carbon absorbs air very vigorously when it is cooled to the temperature of liquid air. But it is under very special conditions that I have made use of this property. Carbon, in fact, behaves differently with different gases. The more difficult these are to liquefy, the less easily are they absorbed. Absorption is thus very much less with neon than with the various gases which accompany it.

The method which I invented for purifying the atmosphere of my neon tubes will thus at once be evident. The tube is connected to a carbon receiver immersed in liquid air, and this carbon slowly absorbs the gases set free when the current is passing, but leaves the neon. It is thus a pump, but an intelligent pump which takes up the inconvenient molecules and leaves the others.

After a lengthy process extending over a number of hours the neon remains victorious and the tube is ready. Separated by means of a blow-pipe from the carbon receiver it will then show the fine neon glow, and this will not fall off.

Having got over this difficulty, another was encountered. I noticed that neon tubes obtained in this way had a very short life. After the potential difference at their terminals had rapidly increased they began to flicker and then to go out. Moore has found that the atmosphere of his tubes gradually became more rarefied and that the tubes then ceased to glow. This curious fact frustrated all his efforts until he conceived the idea of introducing nitrogen into his tubes, by means of an ingenious electromagnetic valve, as rarefaction proceeded. Unfortunately such a remedy was inapplicable in the case of neon, for if Moore's observations are correct the amount of nitrogen absorbed by his tubes is absurd, namely 200 litres per year for a 50-metre tube. If my neon tubes were as absorbent, my liquid air apparatus would be insufficient.

I have thus found it necessary to ascertain the conditions which would render the absorption of neon negligible, so that a single charge of neon will enable a tube to have a very long life comparable with that of glow lamps. For that purpose it was necessary first to ascertain how absorption takes place. I noticed that the electrodes of the first tubes, which were very small, became incandescent when the current flowed and volatilized rapidly, a metallic deposit composed of scales and particles being produced near the electrodes. I thought that it was this metallic deposit which absorbed the neon, and indeed gas containing neon was given off on dissolving the deposit in nitric acid. It is thus without doubt the volatilization of the electrodes which is the trouble, and in order to get rid of this it ought to be sufficient to use large electrodes that will only be heated slightly by the current. Experience has confirmed these precautions so completely that with electrodes having 500 sq. centimetres per ampere, volatilization is practically prevented and the tubes have a very long life.

This life naturally increases as the tubes are made longer, since there are only two electrodes to absorb the neon, and the longer the tube the greater the amount of neon it contains. With tubes 6 metres long it is easily possible to obtain a life of 1,000 or 1,200 hours, and I have tubes

20 metres long which are in excellent condition after burning 2,000 hours. This is a better result than is obtained with glow lamps. The problem has thus been solved in an unexpectedly simple manner. We now have tubes capable of showing the spectrum of absolutely pure neon, and these tubes, which are valveless, as in the case of the most recent automobile engines, are very much simpler than any manufactured up to the present time, and have a very satisfactory life.

I propose next to consider the advantages of these tubes compared with tubes containing nitrogen.* First, the potential difference necessary is only one-third of that required by nitrogen. This is an important advantage from the point of view of safety, since neon tubes 6 metres long require a pressure of less than 800 volts at their terminals, and three tubes can be connected in series with a controlling induction coil and supplied from a 3,500-volt transformer. On the other hand, the intensity of the light is much higher, namely, 200 candles per metre instead of 60. For a given amount of light much shorter, and therefore more economical, tubes can be used. A further advantage is that these short tubes can be manufactured and sent in their finished state to purchasers. Finally, and this is the most important point, the luminous efficiency of 0·5 watt per candle is obtained with long tubes as against 1·7 watts per candle for nitrogen tubes. Perhaps it will be thought that this is not a very remarkable efficiency compared with that of a flame arc lamp, but it must be remembered that we are referring above to spherical and not hemispherical candle power; moreover, no expensive carbons are required, nor does the maintenance cost anything. Indeed, taking everything into consideration, I think that with the exception of the horrible light given by mercury lamps, neon tubes provide the most economical means of lighting.

Again, in the interesting experiments carried out at the Laboratoire Centrale d'Electricité, Messrs. Broca and Laporte showed that the neon light is physiologically excellent on account of its very low intensity, and with it visual acuity is increased by 20 per cent.

In all the above respects the neon light is thus perfect, but the question of its colour has still to be considered. Obviously it is much too red since it does not contain any blue rays. Undoubtedly this predominance of the red gives superb illuminating effects, such as, for example, those obtained at the Grand Palais des Champs-Elysées, which was lighted with neon tubes in 1910 on the occasion of the Automobile Exhibition, and at the church of Saint Ouen at Rouen, where 50 neon tubes were used during the Normandy millenary fêtes.

There is no doubt that in many cases of industrial lighting this very economical and convenient light would be welcomed in place of mercury lamps, and here let me point out how easily one becomes so accustomed to this ruddy light as only to retain an impression of

* Further particulars are given in the *Bulletin de la Société Internationale des Électriciens*, vol. 1 (3rd series), p. 505, 1911.

a warm shade of golden yellow in which the red is almost entirely absent. But again it must be recognized that this pronounced red is scarcely acceptable in the majority of cases, and I have been endeavouring to improve the light.

One solution at once suggests itself, namely, to intermingle the livid mercury light and the ruddy neon tube. Two difficulties, however, arise; first, if the mercury and neon are placed in the same tube they will not work together; and second, if we wish to associate blue tubes and red tubes, the mercury vapour tubes of the Cooper-Hewitt type require low-tension continuous current, whilst neon tubes require high-tension alternating current. They can thus not be run together. I have therefore manufactured "correcting" tubes, consisting of ordinary neon tubes containing a drop of mercury. These tubes glow with alternating current like ordinary neon tubes, but the mercury proceeds to volatilize and the blue mercury light is distributed throughout the whole tube.

Unfortunately, however, the efficiency of these tubes containing a drop of mercury is much lower than that of neon tubes and is about 1 watt per candle. This, however, is still acceptable, and it will be seen that with an equal number of such tubes and ordinary red tubes very agreeable diffused lighting without shadows can be obtained with an overall efficiency of 0·8 watt per spherical candle. This is a much better result than any lighting by tubes containing rarefied gases.

In conclusion, if a red light is often undesirable there are, on the other hand, certain cases in which it will prove undoubtedly superior, such as in the illumination of monuments, or in gala lighting, which I have already mentioned, and also perhaps publicity lighting, where the more dazzling and attractive a light the more suitable it is.

Neon fulfills the above requirements admirably. With my collaborator, Mr. de Beaufort, I have made tubes of small diameter which can be bent, easily twisted, and made into any shape desired, and which can provide either red or blue light. It might be expected that the minute quantity of neon in these tubes would only give them an ephemeral life, but I have had the pleasant surprise of finding that where a low current density is used at the electrodes small tubes last as long as large tubes.

A tube which I have here has lasted 1,400 hours, and requires a current of 30 milliamperes. These small tubes work with a simple alternating-current transformer, which is replaced in the case of continuous current by a rotating or Wehnelt interrupter.

The first cost of the installation is not much higher than that of ordinary apparatus, and a smaller amount of energy is consumed for an increased lighting effect. It therefore undoubtedly provides new scope for the industry as regards publicity lighting.