earth. The capacity as usually computed requires that the potential of one wire shall be as much above earth potential as the other is below earth potential. To make sure that this requirement is fulfilled in practice, a special network is arranged in which there are two indicating instruments, both of which must show zero current. Although somewhat complicated, this method gives satisfactory results in those cases where the capacity to earth is an important factor.

The methods here outlined have been found to give satisfactory results with resistances from 1 to 10,000 ohms. With coils, the resistance of which lies between 1 and 1000 ohms, it was possible to measure the inductance with such accuracy that the error in the time constant (L/R) deduced from this measurement is not more than 10^{-9} second. For coils with a resistance of more than 1000 ohms the corresponding limit is 10^{-8} second.

HELIUM TUBES AS LIGHT STANDARDS.

By P. G. Nutting, Bureau of Standards.

THE investigation of the properties of electrically conducting gases with a view to their possible use as primary standards of luminous intensity has been in progress at the Bureau of Standards for the past six years. A summary of the results obtained is given below; this includes a report of a recent reproducibility test here given for the first time.

Of the available gases and vapors, helium is the only one emitting light of a suitable color and having reasonable lasting qualities. The light is of a yellowish-white approximately that of the Hefner flame and of an old type carbon filament glow lamp. The useful life of a helium tube is from 5 to 100 hours, depending on its construction and operation. The next best gases would be carbon dioxide and sulphur, but these emit a snow-white light and disappear rapidly in carrying a current.

The form of tube found most suitable has a capillary portion of 2-mm. bore, 2-mm. thickness of wall, and about 7 cm. long. The terminal bulbs are 35 mm. in diameter and spherical, while the electrodes are aluminum disks 1 mm. thick and 25 mm. in

diameter. Recent results indicate that possibly a slightly increased bulb diameter might give longer life to the tubes.

The relation between current and light emitted is very nearly linear over a wide range of intermediate currents, 10 to 35 m.a. Twenty-five milliamperes was chosen as the most suitable standard current.

The ratio of light emitted to internal energy, current times potential gradient, is not quite constant. The minimum watts per candle for a tube of 2-mm. base, namely, 3.8 w./c.p., occurs at a current between 25 and 30 m.a. Owing to the large and uncertain variations in the potential gradient and the difficulties in its precise determination, attention was directed toward expressing light in terms of current and bore rather than in terms of internal energy.

The light emitted by a helium tube as a function of current was later determined line by line for each of the six prominent spectrum lines. These all behave nearly alike, increasing with current sensibly as does the total light. Helium shows no trace of any secondary spectrum in the visible region.

Neither the voltage nor frequency of alternation of the exciting current affects the light emission by a measurable amount. Voltages of 1, 2, 5, and 10 thousand were used, and direct, alternating 60-cycle and 900-cycle current.

Gas density does not affect the specific light emission over a range from 3 to 8 mm. pressure, provided the bore of capillary is not much over 2 mm. With 25 m.a. current through 2 mm.-bore, the light is sensibly independent of gas density from 3 to 8 mm. pressure. Chiefly for this reason these specifications and 4 to 7 mm. pressure were adopted for the standard tubes, inasmuch as gas density is difficult to control and determine in such tubes.

The correction to the light emitted by a centimetre length of capillary for slight departures from 2 mm. in the bore was carefully determined. It is—0.010 c.p./cm. for each $\pm$ 0.1 mm. difference in bore from 2.00 mm.

A test for reproducibility was made on a set of forty tubes. The capillary portions of these tubes were specially prepared and selected by Baudin to secure the utmost possible uniformity of bore and wall and freedom from striations. The tubes were made up and filled at the Bureau of Standards.

Color reproducibility was determined by intercomparing the spectra of these tubes line by line with a spectrophotometer. The slight variations observed were well within the errors of observation.

Photometric observations on the mean horizontal candle-power per centimetre length of capillary were made by four experienced observers. The computed probable error in the c.p./cm. for all observers and all the tubes was 0.16 per cent. The average deviation of the tubes from their mean value was 1.15 per cent., the maximum deviation 3 per cent. The four different observers read on an average 1.2 per cent. below, 0.1 per cent. above, 1.5 per cent. above, and 0.5 per cent. below the mean of the four.¹

THE EFFECT OF ADDED FATTY AND OTHER OILS UPON THE CARBONIZATION OF MINERAL LUBRICATING OILS.²

By C. E. Waters.

THE author determined, by a method published some time ago,³ the relative amounts of "carbonized" matter formed by heating two similar mineral engine oils and mixtures of these oils with various fatty oils, soap, asphalt, sulphur, etc. Samples of 10 grams each were heated in Erlenmeyer flasks to 250° C. for 5 hours. The flasks were carefully matched in size, for it was shown that the "carbonization" is an oxidation phenomenon, depending in amount upon the area of the oil surface exposed to the air. The flasks were heated in a special air-bath so arranged as to allow perfect freedom of diffusion of oil vapors and air.

The loss by evaporation was first determined; then measured volumes of petroleum ether were added, and next day the "carbonized" material which was precipitated was filtered off, washed free of oil with petroleum ether and weighed. The flasks were also weighed to determine the amount of "varnish," the closely

¹ The report on reproducibility tests is to be published in the *Bulletin of the Bureau of Standards*. The preliminary work was reported on in the *Bureau of Standards Bulletin* 4, 511, 1908; the relation between line intensity and current in same journal, 7, 65, 1911.

² Bureau of Standards, Technologic paper, 4.

³ *Bull. Bur. Standards*, 7, 365 (1911); *J. Ind. Eng. Chem.*, 3, 233 (1911).