SOME METHODS OF PHOTOMETRY AS APPLIED TO INCANDESCENT LAMPS.

BY J. T. MARSHALL.

For fifteen years or more the Edison General Electric Company and its predecessor, the Edison Lamp Company, have tested lamps for voltage on a so-called sliding scale photometer. This type of photometer is an adaptation of the ordinary form of a Bunsen grease spot photometer, by which the voltage of the lamp at rated candle-power is determined from the candle-power it gives at a given voltage.

If two lamps of the same candle-power and voltage be placed one at each end of the photometer and the same voltage be applied to them, they will give the same candle-power and the photometer screen will balance at the middle of the photometer. If the two lamps are of different voltages, they will give different candle-powers and the screen will balance at some other point than the middle of the photometer. The relative candle-power of the two lamps, as indicated by the point at which the screen balances, will determine their relative voltage. The voltage of one lamp being known, the voltage of the other lamp may be read directly from a scale on the photometer made to suit the lamp.

The sliding scale photometer does not require a volt-meter—an advantage which, before the introduction of reliable dead-beat volt meters, was more apparent than at present. This type of photometer has a further advantage, in that its readings are not materially affected by changes of several volts in the line—for the reason that these changes similarly affect both lamps, and do not alter the balancing point of the screen.

Fig. 1 is a simple diagram showing the electrical connections of a photometer.

A is the working standard, or lamp of known voltage. B is the lamp to be tested, and c is the movable screen, the position of which at the balancing point indicates the voltage of the lamp B. The volt scale is made by a combination of the curves of the candle-power scale of a Bunsen photometer and a curve showing the change of candle-power due to change of voltage.

Fig. 2 is a curve of a candle-power scale of a Bunsen photometer. It is derived from the formula:

$$\frac{100}{x^2} = \frac{y}{(100 - x)^2}$$

Fig.1

x is the distance of the screen from the standard lamp, expressed in per cents. of the photometer length, and y is the candle-power expressed in per cents. of the candle-power of the standard lamp.

Fig. 3 is a curve showing the change of candle-power due to change of voltage. The candle-powers and voltages are expressed in per cents. of the candle-power and voltages at 3.1 w.p.c.

Fig. 4 is a curve of the volt scale of a sliding scale photometer. The voltages are expressed in per cents. of the voltage of the standard lamp, and the distances from the standard lamp in per

cents. of the photometer length. This curve is derived from the curves of Figs. 2 and 3.

For instance: A lamp with a voltage 105 per cent. of the voltage of the standard lamp will, when burned at the voltage of the standard, be burning at 95.24 per cent. of its true voltage. In Fig. 3 the percentage candle-power corresponding to 95.24 per cent. voltage is 71.2 per cent., and in Fig. 2, the per cent. distance corresponding to 71.2 per cent. is 54.28 per cent; so that the distance corresponding to 105 per cent. volts is 54.28 per cent. The

projection of the integral per cent. volt points of the curve on the length scale gives the volt scale.

The length of the volt divisions for any length photometer and voltage of standard lamp will be directly as the length of the photometer, and inversely as the voltage of the standard lamp.

There is a source of error in the use of the sliding scale photometer, in that the curve in Fig. 3 is not the same for all lamps. This difference is due to the fact that the law of change of resistance of filaments with change of temperature or candle-power varies—depending on how much of the filament is base carbon and how much is treatment.

Fig. 5 shows change of candle-power due to change of voltage

for lamps made with filaments of only base carbon, and filaments which have been treated respectively to 75, 50, $37\frac{1}{2}$ and 25 per cent. of the resistance of the base carbon. The voltages and candle-powers are expressed in per cents. of the voltage and candle-power at 3.1 w.p.c.

Fig. 6 shows the volt scales derived from each of the curves referred to in Fig. 5.

The curves of Figs. 3 and 4 are derived from the lamps treated to $37\frac{1}{2}$ per cent. of the initial resistance. This is about an average treatment.

It will be seen in general that the volt scale is contracted more and more as the treatment on the filament thickens. If any one of these scales is used for reading variously treated filaments, it will be necessary to restrict the readings to a few volts either side of the middle point.

These scales were derived from a few lamps, made and measured since I was asked to prepare this paper. Measurements made on a larger number of lamps would probably modify these scales somewhat. The scale actually in use at our factory is shown on Fig. 6 by round dots.

In using the sliding scale photometer it is the practice to select a scale whose middle voltage is very nearly the average voltage of the lamps to be tested; to select for a working standard a well-seasoned lamp of the same candle-power as the lamps to be tested and of a slightly lower voltage than the middle point of the scale; to have a few ohms resistance in series with the working standard, so that its candle-power may be reduced or slightly changed; to read only a few volts either side of the middle point

of the scale, and to keep the voltage of the line nearly the same as the middle point of the scale.

The photometer is set with a few lamps like those to be tested. They are first carefully seasoned and tested for voltage on a standard photometer, and kept for reference lamps. One of them is placed on the working end of the photometer, the screen is placed on the scale at the voltage marked on the reference lamp and the working standard is brought to a candle-power which balances the screen. The other reference lamps are then placed successively on the working end and their voltage read on the

scale by moving the screen. If the observed voltage averages the same as those marked on the reference lamps, the photometer is correctly set.

Attention has been called to the fact that the curves of candle-power and voltage are different for differently treated filaments. It is interesting to note that if curves were made showing the change of candle-power with w.p.c., they would be coincident for all the filaments of Fig. 5.

A brief account of the invention and early use of the sliding scale photometer may be interesting.

Some time in the early eighties, Mr. William Holzer, then

Superintendent of the Edison Lamp Company, sent to the life test photometer room several thousand 16 candle-power lamps, from which he asked us to select all that were above 115 volts. I began with the usual method of bringing the lamps up to candle-power and reading the volts with a Thompson galvanometer. Then it occurred to me that I could put in a standard lamp of 115 volts, connect it in multiple with the other lamp, and that all the lamps that were less than 16 candles would be more than 115 volts. The varying candle-powers of the successive lamps put on the photometer suggested the making of the volt scale; and, recalling that Mr. J. W. Howell had in his table drawer curves

like those in Figs. 2 and 3, I made a scale like that in Fig. 4, and the next day tested 1,500 lamps in four hours, something heretofore unprecendented in lamp testing. We were then making so few lamps that it did not seem worth while to change our regular photometer room to this method, particularly as the photometer required resetting for every different candle-power lamp. Mr. F. R. Upton, then General Manager of the lamp company, advised me to patent the invention, but I thought a publication of the method would only cause our competitors to appropriate it without compensation, and therefore did not do so. Soon afterwards, I was sent to our Canadian factory to put the lamp testing apparatus in order. I there found that the engine

regulation was so bad that the best way to obtain steady voltage was to turn the engine throttle while watching the voltmeter. I found that I could duplicate my results better with the sliding scale photometer, letting the engine race, than by trying to control it and read volts with a voltmeter. I therefore installed the sliding scale photometer and made up a full set of reference lamps. After this had been running for a year we commenced to install them in the Harrison factory, and are still using them.

We are using for inspection purposes a photometer connected as per Fig. 7. We call this the differential photometer.

The voltmeter reads the difference in voltage of the two

lamps, and has its point of no difference at the middle of the scale, which is marked with the voltage of the standard lamp. The scale is calibrated only a few volts either side of the middle point so that it is very open. One terminal of the voltmeter can be slid along the resistance in series with the standard lamp, so as to make the voltmeter read the voltage of the reference lamp used in setting the photometer. The advantage of this type of photometer over the sliding scale photometer for inspection is, that by changing the position of the screen it can be used with the same setting for lamps of all candle-powers, that come

Fig. 7

in the range of the voltage of the meter. The advantage over a standard photometer which reads the total voltage of the lamp, is that a more open scale can be used and changes in the voltage of the line produce smaller errors. For instance, if the standard lamp and the test lamp are the same voltage, a change in the line will make no change in the reading. But suppose that the test lamp is 100 volts, and that the line drops 10 per cent.; then the 10 volts difference will appear as 9 volts, and the lamp will read 109 volts instead of 110 volts, an error of less than 1 per cent., due to change of 10 per cent. in the line.

Our method of inspection with this photometer is to bring the test lamp to the volts marked on it and read the candle-power.

In this way a few lamps are inspected from about a third of all trays of lamps tested.

Mr. J. W. Howell first used the differential photometer as a means of testing lamps for volts, some time in 1897. We are now experimenting with it again for that purpose, and may possibly substitute it for the sliding scale photometer as a means of overcoming the error due to the different volt curves of differently treated lamps.

We are also experimenting on a photometer, using alternating current in a transformer having single volt steps. The test lamp will be brought to its rated candle-power by connecting it to the proper step, and its volts will be shown by the number of steps between the connections of the test lamp and the standard lamp. This method will have the triple advantage of dispensing with a voltmeter, overcoming the errors of the sliding scale photometer, and reading all lamps with one setting of the photometer. This method was suggested by Mr. H. B. Coolidge, of the Lamp Testing Bureau.