school of experience ends only with his life. It is through these societies that the results of personal professional efforts are gathered and recorded. His thoughts are brightened, his best work is studied and appreciated by his colleagues. He is stimulated by healthy rivalry to do his best, and to honor the achievements of others.

We need have no apprehension as to the future of our great technical societies. There are the best of reasons for their continued existence and their healthy growth. Their foundations are deeply embedded and beyond the reach of those discordant elements which frequently revolutionize governments, divide our churches and overthrow the greatest financial undertakings.

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THE PHOTOMETRY OF INCANDESCENT LAMPS.

A SPECIAL PLAN FOR READILY PROCURING RESULTS, AND THE
APPARATUS NECESSARY FOR THE PURPOSE.

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In the industrial photometry of incandescent lamps, one of two things is always the object of measurement, *i. e.*, the candle-power which an incandescent lamp has at any applied E.M.F., or the E.M.F. which should be applied to produce a given candle-power. The first is the one with which users of lamps have to do; the last is a determination which the manufacturer of incandescent lamps has to make for his whole product. Strange as it may seem, the last is much the harder to obtain if ordinary photometric methods are used.

There are many sorts of photometers and many methods of using them. What I shall say will have reference to but

one sort, a Bunsen photometer, and to a certain plan of using one which makes it especially easy to work with.

A Bunsen photometer is a familiar instrument. In its simplest form it consists of a graduated bar, at the ends of which are located the lights to be compared, one of them being of known candle-power. Along the bar one moves the car, which holds, in a plane perpendicular to a line joining the lights in question, a paper with a grease spot on it. When a position is reached where the spot cannot be distinguished from the surrounding paper, one knows that the illumination of both sides of the sheet is alike; that is, since the illumination of a surface falls off with the square of the distance from the light source, by taking ratios of distances to lights from the car position squared, one has obtained the ratio of the candle-power of the lights.

In practice one has many obstacles to overcome in getting this simple result. In matters photometric there are such as:

(a) Too large a ratio between the candle-power of the light measured and that of the standard light. This causes a slight inaccuracy in the setting of the car to make a very disproportionate inaccuracy in the resulting candle-power calculated.

(b) A difference in the color of the lights which are being compared. This makes it impossible to find a place along the bar where the grease spot disappears.

(c) Reflection from surrounding objects. A distortion of the illumination of the paper in the car results, so no *true* ratio can be found.

(d) A difference in the quality of the sides of the paper with the grease spot on it. If the paper be turned side for side, quite a different setting of the car for "equal illumination" will be found.

(e) A difference in eye-sensitiveness. If one stood on the other side of the bar a different determination would have been had.

(f) A difference in mirrors used to enable one to see both sides of the paper at the same time, and so distortions, similar to those last mentioned, are produced.

A *D* *F* *C* *F* *E* *B*

FIG. 1.—The photometer set up ready for use.

In matters of manipulation there is the difficulty in keeping the E.M.F. on the lamps steady; in adjusting the E.M.F. within very close limits; in knowing the exact E.M.F. sending current through the lamp, due to the inaccuracy of voltmeters which have not been especially calibrated for the work. Any of these not right and errors in the results are found, so they become utterly unsatisfactory and unreliable. An inexperience in making readings or poor choice of conditions causes results to be procured which are equally valueless.

FIG. 2.—The photometer folded and ready to put into its carrying case.

In getting results in the usual way one has to labor through the tedious process of taking ratios of distances which must be squared, and must take enough readings to eliminate errors already mentioned by taking averages of candle-powers determined from a number of car settings.

So many of the difficulties are met and mastered in a portable photometer which has been loaned me by the Electric Motor and Equipment Company, Newark, N. J.,

that I will use it as a text in considering the special method of measurement I want to describe. In this photometer a grease spot car is used, and the standard is an 8 candle-power oil lamp, which practice shows to be of more than required constancy over a period of twenty minutes or more at a time.

Fig. 1 shows this photometer ready for use. The different parts may be described by reference to letters placed directly below them in the cut. At *A* is put the incandescent lamp whose candle-power is to be determined. Provision is made on each photometer for lamps having Edison, Westinghouse or Thomson-Houston bases. *Fig. 2* shows this detail better, one of the interchangeable parts for altering the style of the socket being shown on the table just in front of the packed photometer and to the right of the center of the cut. At *B*, at the other end of the instrument, some five feet from *A*, is the oil lamp. This holds enough oil to burn for four hours in use, and for an hour at a time with practically no change in its candle-power after once warming up and being set.

Since the standard is of fixed value, a direct reading scale can be used. It is shown directly below the car at *C*, and is marked off on celluloid from 7 candle-power to 34, marks being made for each half candle-power. In the car one can see the screen with grease spot, and the reflections of the two sides of the paper in the mirrors. The index for reading candle-power at any car setting shows on the scale just under the grease spot.

The screens, *F F*, are to shield the eyes of the observer from direct light from either source. His eyes must be protected thus so they may be adapted to distinguish small differences in tint of spot and field as he views the reflections in the mirrors. This arrangement makes "taking readings" much less fatiguing than the common and older plan of using an eye screen fast to the car, such as is used with fluoroscopes.

At *E* is a rack to hold the standard lights. They are here out of the way, and yet conveniently placed to carry about or use.

A very refined adjustment of the E.M.F. on the lamp terminals is provided for by the rheostat shown at *D*. This is a solenoid of resistance wire along which a contact piece is arranged to be moved, so varying the E.M.F. on a 16 candle-power lamp through a range of 15 or 20 volts by steps so small as not possible to detect with a first-class voltmeter. Thus one has at command the adjustment of the E.M.F. on the lamp under test to the exact value required, and a cause of errors of considerable magnitude is eliminated. At its marked E.M.F. a 16 candle-power 110 volt lamp will vary in candle-power as much as $6\frac{1}{2}$ per cent. for a 1 per cent. change in E.M.F. applied, it must be remembered.

Between the incandescent lamp and rheostat there are some simple switching devices provided, and the connecting cords to use at them to bring current to the photometer and to connect voltmeter, ammeter, wattmeter or all of them at once to the circuit, as one chooses.

The 8 candle-power oil lamp is set to the value it must keep through a set of readings in a fashion which at once eliminates nearly all the difficulties in making satisfactory photometer measurements, which I have mentioned. The method of proceeding to a candle-power measurement is as follows: The oil lamp is lighted and warmed up. A standard incandescent lamp at an E.M.F. about like that on the circuit to be used is put in its "standard position" (that for which its candle-power is known), and its terminal difference of potential made that demanded on its label. It is now 16 candle-power from a direction down the photometer bar. The car is next set at the 16 candle-power mark and the light from the oil lamp adjusted until the grease spot disappears. The standard incandescent lamp is next removed and others, whose candle-power it is required to know, put in its place, one after the other, the car being shifted to a point where the grease spot disappears for each one, and their candle-power thus read directly. After a little practice one can make such readings on a 16 candle-power lamp so that the widest range of values determined will not be more than $\frac{4}{10}$ of a candle-power. And if all are

averaged, no reading differs from this value by more than $\frac{2}{10}$ of a candle-power. In other words, an accuracy in a single reading will be within $1\frac{1}{2}$ per cent. of the truth. This is a very satisfactory result for a determination of candle-power on a commercial photometer. It is to be understood as applying to readings made at different times upon the same lamp.

Or, for other purposes, the car is left at 16 candle-power, for example, and the E.M.F. on the lamp varied until the spot is gone. The determination of this last can be made by a practised observer with quite remarkable accuracy, considering the shortness of the bar.

The oil-lamp standard can be checked at any instant by a return to the incandescent standard at the other end of the bar, setting the index on the car at the 16 candle-power mark and observing whether the grease spot is now invisible, as it should be.

Without going into a detailed explanation, one has, by this method, done away with all difficulty due to reflection, difference in quality of the sides of the greased paper, difference of eye-sensitiveness, etc., and done away with them all to such an extent that a real dark room is not required to get satisfactory results. If only the light is not shining in the observer's eyes, a room not so dark but that common newspaper print can be read in it is satisfactory for ordinary work. By putting the real standard at the same end as the lamp whose candle-power is measured, all distortions come into every measurement in exactly the same way, and so are negligible. I am not informed whether or not this plan of working is original with the company above named, but it is certainly a plan of greatest possible value to any one who has many measurements of candle-power to make, and wants them procured in as rapid and yet accurate a way as possible.

It will be seen that really the candle-power of the oil lamp never becomes known. It is simply a steady light, the value in candle-power of which need not concern one.

The oil-lamp flame is not noticeably different in color from many incandescent lamp filaments, especially if the

incandescent lamps are not perfectly new and burning at high incandescence; and, by using it, rather than a second incandescent lamp, one does away with the necessity for a second voltmeter and its separate and accurate calibration.

It cannot be denied that, if there are incandescent lamps at both ends of the bar, having the same efficiency and candle-power, any fluctuations of E.M.F. on the circuit after that on both lamps has been set will not interfere with the candle-power determinations, since the ratio of candle-powers will keep the same. But any advantage so obtained is more than offset in most commercial work by the necessity of having voltmeters for both lamps, and accurate ones, too.

Since the photometer I am using to illustrate these remarks is a portable one, it lacks certain accessories, like a rotating socket, by the use of which the mean horizontal or rated candle-power becomes known at once.

Fig. 2 shows the instrument packed and ready to be put in its carrying case, shown in the background. There is no question as to the exceeding portability of the instrument, not only because it can be used without a dark room, but also because it can be put together so compactly to carry around.

Considering the purpose for which it was designed, therefore one can forgive the lack of a rotating socket.

I have described the instrument, not because it is a perfect one for *all* requirements of up-to-date photometry, but because it seems to me, a disinterested party, to embody very many points which must make a commercial photometer a satisfactory instrument, and so to be worthy of presentation to the members of the Institute.