A DISTRIBUTION PHOTOMETER OF NEW DESIGN*

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SYNOPSIS: The field of usefulness of the distribution photometer is explained briefly. A review is made of the more common types of distribution photometers. The requirements which had to be met by the photometer described in this paper are outlined. This is followed by a detailed description of the above instrument, including the methods and features of design which were employed to meet the requirements. The ten foot integrating icosahedron is mentioned and an outline given of the methods employed for transferring lighting units of different types from icosahedron to distribution photometer, and vice versa, with a minimum of time and labor. The electrical supply and control system for the entire room, including the two above instruments, is described.

As the art of illumination advances, there is a constantly growing demand on the part of those interested in the purchase and installation of lamps and lighting units for more specific information regarding the performance of those units. Running parallel with this desire, there is naturally a demand for better and more scientifically designed combinations of lamp and accessory; for light sources and systems of illumination which will be more artistic, more restful to the eyes, and at the same time more efficient in their distribution of light. This development is helped along to a considerable extent by educational work on the part of the manufacturers of lamps and lighting equipment, as well as by the natural desire for improvement upon the part of all who are interested in the art.

It is, of course, in the development and measurement of sources which more efficiently distribute their light that the distribution photometer is found to be indispensable. Instruments of this sort have been made in a number of different forms. The photometer which is described in this paper will be seen to be of the

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same general type as that of some others already in use, but it is believed that it differs sufficiently from its predecessors, to be of interest.

Before going into a detailed description of this instrument, however, a brief review will be made of the most common types of distribution photometers.

In the instrument shown in Figure 1, the arm supporting the unit under test rotates about a horizontal axis. Direct readings on the light source are made by means of the photometer head,

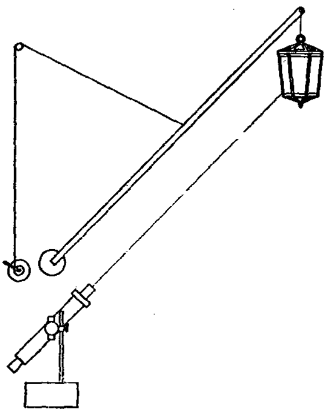

Fig. 1.—A simple photometer in which the unit is rotated about the measuring device.

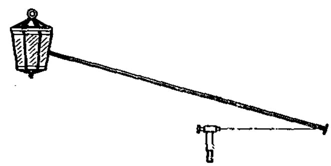

Fig. 2.—A simple photometer utilizing a spot plate which is rotated about the unit.

which can be adjusted to point directly toward the light when the latter is in any position. The axes of rotation are so arranged that the photometer and light source are separated by a constant distance. This would in most cases be ten feet, as that is the standard distance which is used in the great majority of distribution photometer readings. This method is obviously unsuited to handle work on a large scale.

The arrangement shown in Figure 2, and the one just described, probably represent the simplest types of distribution photometers. Referring to Figure 2, the arm, or rod, rotates about a horizontal axis passing through the center of the light source. At the movable end of the rod is fixed a small diffusing plate or reflector, whose surface is perpendicular to the center line of the rod. The intensity of illumination on the diffusing plate is measured with a portable illuminometer, and from these readings the candlepower of the source is determined. We have used this method in the past, but it is, of course, quite slow and inconvenient.

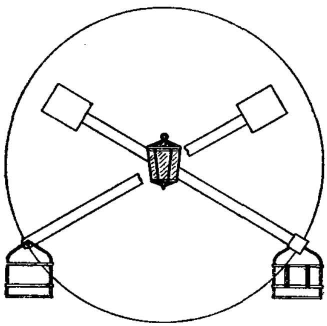

Fig. 3.—A "ferris wheel" type photometer.

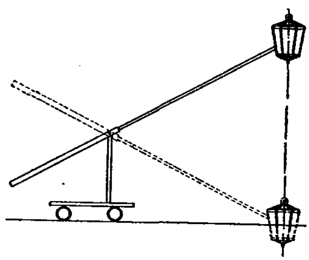

Fig. 4.—One form of the Dibden photometer.

The apparatus shown in Figure 3 represents what might be termed the ferris wheel type of photometer. Two arms rotate in a vertical plane about opposite sides of the lighting unit. Each of these arms carries on one end a basket arrangement, or car, in which a photometer operator is seated. In each car is mounted a photometer capable of measuring the candlepower of the source when viewed from any direction. At the opposite end of each arm are mounted suitable counterweights. The arms are moved to form equal angles with the vertical, and simultaneous readings are taken from each position.

In Figure 4 is given a schematic drawing of one form of the Dibden photometer. The lighting unit can be moved vertically. From this unit an arm extends to the car, which travels on a horizontal track. The arm is pivoted where it is fastened to the car, so that, as the unit is raised and lowered the car travels forward and backward along the track. The photometer head is attached to the arm in such a manner that it always points toward the light. This apparatus can be set for any angle between the two extreme positions where the car is either directly above or directly below the unit. The Dibden photometer has been very satisfactory in certain cases, but was not suited for our needs because of the required height of more than 20 feet.

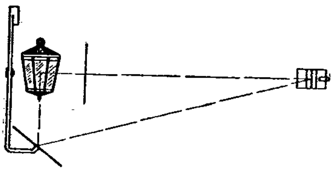

Fig. 5.—A simple single mirror selector type photometer.

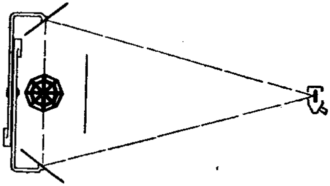

Fig. 6.—The Matthews double mirror selector type photometer.

The simplest mirror type photometer is that shown in Figure 5. The mirror rotates on an arm, about the axis which passes through the center of the light source and the center of the photometer head. For any position of the mirror, light emitted by the source in that direction will be reflected to the photometer head. A screen prevents direct light from the source from striking the photometer head. The light enters the photometer head at a large angle with the normal, bringing in certain uncertainties, and causing some difficulty in shielding.

The Matthews double mirror selector, Figure 6, operates in the same manner as the single mirror type described above. It has the advantage, however, that the source is viewed simultaneously from opposite sides at equal angles from the vertical. This eliminates, to a certain extent, errors which may be encountered due to the fact that the candlepower of the source is not uniform about a vertical axis.

Another form of single mirror selector is that shown in Figure 7. The distance between the axis of rotation of the upper gear, and the axis of the horizontal portion of the arm supporting the lighting unit, is the same as the distance between axes of the upper and lower gears. By means of the train of gears, the unit is rotated about the mirror at a constant distance. The mirror, at the same time, is rotated just the correct amount to throw the reflected light along its horizontal axis of rotation, to

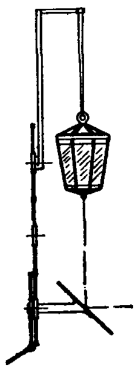

Fig. 7.—Another single mirror selector type photometer.

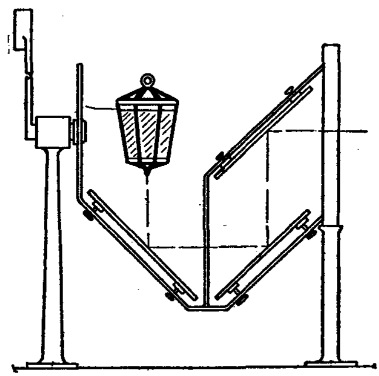

Fig. 8.—A three mirror selector type photometer.

a photometer head. In this device it is very difficult to rotate the unit under test.

A three mirror selector is shown in Figure 8. The three mirrors rotate as one unit about a horizontal axis passing through the center of the light source. At every position of the mirrors, light is reflected horizontally to a photometer head. This method has certain advantages, but also certain mechanical disadvantages.

The two mirror selector shown in Figure 9 is the type which has been designed and installed in the Physical Laboratory of the Westinghouse Lamp Company. The lighting unit is suspended from, or mounted on, the rotating head B. This head can be moved vertically to bring the light center to the proper position on the photometer axis lined through bearings H and J. Light from the unit, striking the large mirror C, is reflected to the small mirror D, and from there to a diffusing screen placed between

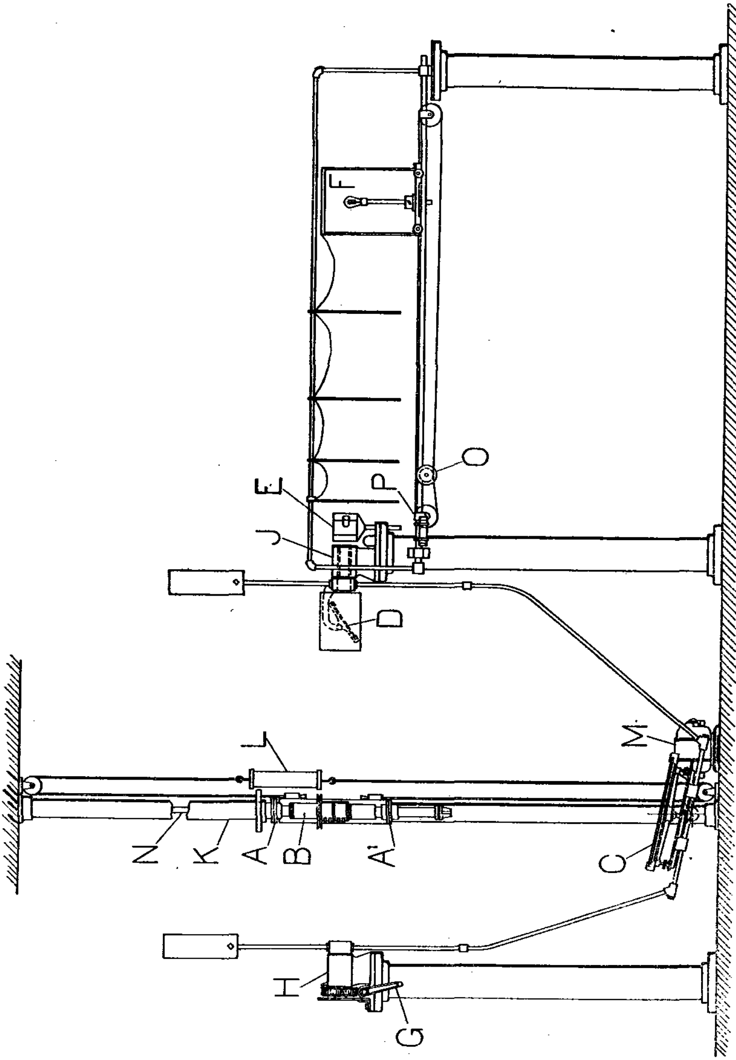

Fig. 9.—The two mirror selector type photometer designed by the Westinghouse Lamp Co.

it and the Lummer-Brodhun photometer head E. A working standard lamp in the housing at F, can be moved to a greater or less distance from the photometer head, to produce a brightness match. The mirrors C and D are rotated as a unit, about the axis which passes through the centers of bearings H and J, by turning the handle G.

Probably none of the photometers described is preeminently the best for all cases. However, a careful consideration of the problems of installation and required performance led to the adoption of this particular type as being the most desirable. It was required in this case that the photometer be installed on a building floor having approximately 10 feet head room. It was desirable to have the instrument take as small a floor space as might reasonably be arranged, although no definite limits were prescribed. It was necessary to build an instrument which could handle all kinds of luminaires from the smallest residential glass type to the largest street lighting units. In the latter case it was necessary to consider the weight of the unit as well as the size of the light source. Provision had to be made for mounting these units either in a pendent position or placed upright on a pedestal, as the case demanded. It was considered essential that a means be provided for rotating all units including the largest street lighting pendents and post tops. In addition to this it was desired that provision be made to transfer a complete unit from the distribution photometer to the ten-foot icosahedron,[1] or vice versa without disturbing the wiring, or the adjustment of the lamp in the unit. The distribution photometer room has been laid out to include a regular icosahedron 10 feet in height. The latter piece of apparatus is designed to be capable of measuring the total light output, and overall efficiency of any existing size of lighting unit by the same method as would be employed in using the Ulbricht sphere for this purpose.

A detailed description of the distribution photometer will show how the various conditions were fulfilled. This description follows:

[1] See paper presented at this convention by K. S. Weaver and B. E. Shackelford "The Regular Icosahedron as a Substitute for the Ulbricht Sphere" on page 290 of this issue.

The rotating head which supports the lighting unit can be moved up or down on the vertical shaft K. The counterweight L makes this a fairly easy matter. Two handles are provided for clamping the head to the shaft. This one head is universal in that it can be used for either pendent or pedestal units. A pendent unit may be suspended from a suitable holder attached to the head, and the latter moved up along the vertical shaft to the proper position. In the same manner, a pedestal, or post top unit may be mounted on a suitable holder on top of the adjustable support, and the latter moved down until the proper position is reached.

The head is rotated at any desired speed by means of a direct current motor M, driving a vertical keyed shaft N, immediately behind the main shaft. The rotary motion is transmitted to the head by means of a round belt and pulleys.

Electrical connections are made by means of two wide slip rings and four brushes. One brush on each ring carries the lighting current, while the other is used for a voltmeter connection. It is considered that the drop in voltage between slip ring and lamp will be negligible. The shaft to which the rings are connected is hollow, and contains the wires leading to the lamp.

At points A and A^1 are flange connections of the same size and shape. The pieces which are attached above and below these points are built to accommodate certain lighting units. If a different type of unit is to be mounted in place, it is only necessary to disconnect a pair of flanges and connect the proper piece to support that particular type of unit. Electrical connections are automatically made by means of plugs and receptacles built into the flanged pieces. A sufficient number of pieces have been made up to take care of all ordinary lighting units. These can be added to at any time to accommodate new types. If the unit in question has a light center exceptionally far from the point of support, the upper or lower flange piece can be removed, depending on which one is not in use. This will give sufficient clearance so that the head can be raised or lowered to provide for all existing types of units, with an ample margin for future developments.

The icosahedron is equipped with upper and lower flange supports of the same type as those on the distribution photometer. Any unit, therefore, when once adjusted in place with its lamp, can be readily transferred from one photometer to the other by merely removing the flange bolts on one instrument, and bolting the flange in its place on the other. Electrical connections are thus automatically made, and no adjustments are disturbed.

It was found that the mirror C would have to be of such size as to make advisable a double arm support. The double bearing design as shown in Figure 9 was therefore decided on. This mirror is of plate glass, 20 inches in diameter. It is inclined at the proper angle from the vertical to reflect the light to the elliptical mirror D. The frame for the circular mirror is held to the main arms by a ball and socket and helical spring device. Adjustment of the mirror position is made by means of three screws near the edges of the mirror frame.

The elliptical mirror D, reflects the light to a translucent screen at the left end of the hollow bearing J. The mirror is mounted on a large ball and socket joint and is held in place by a set screw when the proper adjustment is obtained

The sheet metal hood which encloses the small mirror is painted a flat black. An aperture is provided for admission of light from the large mirror, but the hood shuts out most of the extraneous light. If it is found that a system of screening is needed for the large mirror, it is proposed to place a strip of black velvet, several feet wide, along the floor from about two feet in front of the lighting unit, straight back to the rear wall, five feet behind the unit. This will be extended straight up the wall, and out along the ceiling directly over the floor strip. Practically no extraneous light can strike the large mirror at the proper angle for reflection to the photometer head, except that which is reflected from the black velvet. This will of course be negligible.

The translucent screen at the left end of the hollow bearing is exactly ten feet from the light center of the source. This screen becomes a secondary source of light, illuminating one half of the Lummer-Brodhun photometer field. The other half of the photometer field is illuminated by means of the working standard lamp. The familiar arrangement of movable carriage and screens is shown. Neutral light filters may be inserted in holders provided approximately an inch from the photometer head, on either side of the latter.

The carriage is moved by turning the knurled handle O, which actuates the former through a string passing over pulleys. Photometer readings are taken at point P on a graduated metal tape

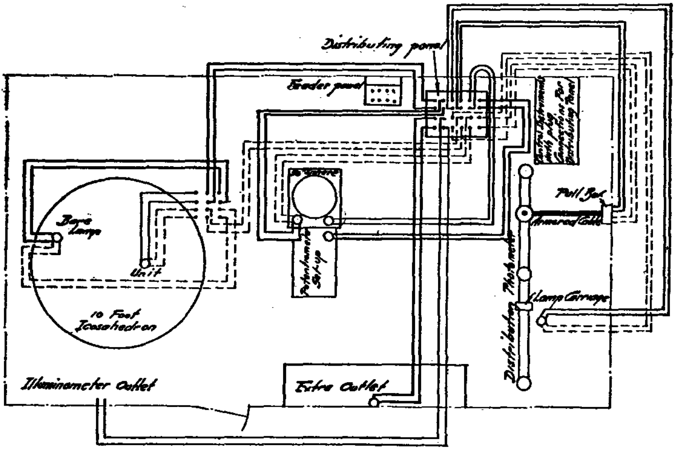

Fig. 10.—Layout of electrical control and supply system for the distribution photometer room. No. 14 wire, current leads,———, No. 8 wire, current leads,_____, No. 16 wire, voltage leads, - - - - -.

which also passes over suitable pulleys, and moves with the lamp carriage. This tape is graduated to read directly in candlepower.

The mirror arm is rotated by means of the handle G, which is connected to a worm and gear. The electrical control and meter table is placed immediately to the left of this point. The operator at this position can therefore rotate the mirror arm, and also read the angle between mirror arm and the vertical by means of a protractor on the left face of the worm gear.

The foregoing is probably a sufficiently detailed description of the distribution photometer proper. It may now be of interest

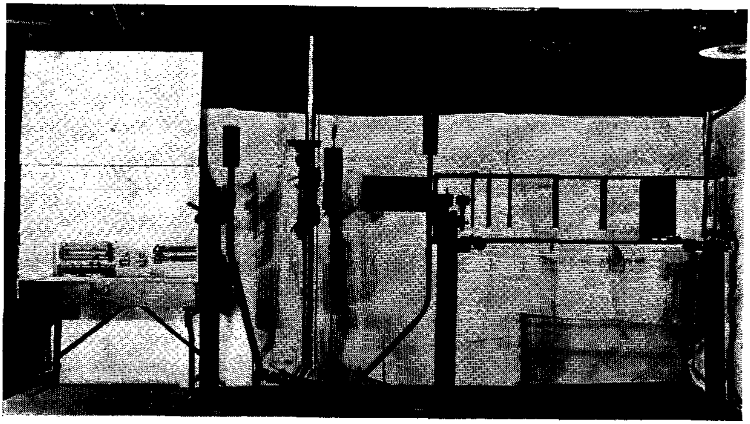

Fig. 11.—General view of Westinghouse two mirror selector type photometer.

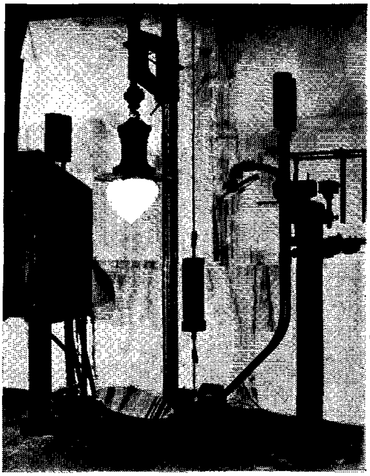

Fig. 12.—Pendent type street lighting unit in position for test.

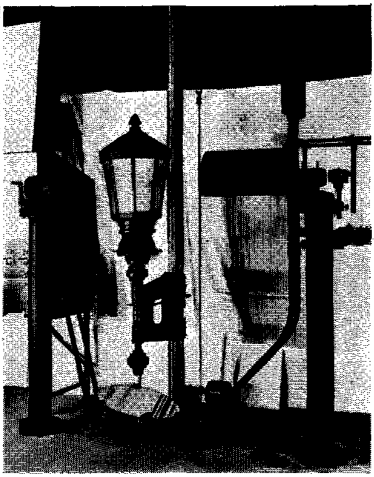

Fig. 13.—Post top type street lighting unit in position for test.

to describe, in a more general way, the layout of the entire photometer room, as there are several elements of flexible control which are considered to be worthy of mention here.

The electrical control and instrument table, shown in Figure 10, controls circuits running to the distribution photometer, 10-foot icosahedron and 30-inch sphere; and may be used to control a circuit to the miscellaneous work table and to the potentiometer table.

This control table is enclosed in a box, whose top and sides are painted a flat white on the inside. Four concealed show case lamps illuminate these white inside walls causing the meters to be indirectly illuminated by a soft, thoroughly diffused light. Space is provided for three large laboratory standard voltmeters or ammeters, or more of a smaller type. A system of rheostats of various capacities, with suitable switches, makes it possible to handle a wide range of currents and voltages without resorting to special connections.

Current is obtained from the feeder panel, and carried to the distribution panel, control table, and room circuits by means of wires terminating in plug connectors. The feeder panel in turn can be supplied with any desired form of current from the main laboratory switchboard.

Flexible wires, terminating in plugs, run from the control table to the distributing panel. From the latter are run the various circuits to carry current to the different pieces of apparatus. From suitable points, voltage leads run back from the photometric apparatus to the panel. At the icosahedron, a double pole double throw knife switch enables the operator to throw current on either the lighting unit or the bare lamp. A similar switch connects the voltmeter wires to the proper point.

With this system, it is possible to feed current at the voltages desired, to the various test and comparison lamps about the room. It is possible to regulate the current and take voltmeter and ammeter readings accurately. Tests can be made on lamps and units of widely different sizes and characteristics. This can be done with a minimum of labor required for mounting and adjusting test units and apparatus.

As these instruments are now designed, any sized unit which it is possible to handle on the distribution photometer will be within the capacity of the icosahedron, both in size of light source and in weight.

This means that practically any unit of ordinary proportions, not exceeding 30 inches in diameter nor 150 pounds in weight, can be readily accommodated. This will take care of all present sizes of lighting units of the type which would ordinarily be measured on a distribution photometer, and allow a considerable margin for possible future development.

Certain of the mechanical features of the distribution photometer described in this paper have been designed by Mr. H. I. Knecht of our Experimental Equipment Division.

DISCUSSION

W. F. LITTLE: A distribution photometer which has been in use at the Electrical Testing Laboratories for the past eight years is very similar to that described by the author. This photometer consists of adjustable rotator, two mirrors, hollow shaft through which the light is reflected, simple Lummer cube and photometer bar. It was originally designed as a recording photometer but experience showed a loss of time in interpreting the results. The rotator is moved up and down with a worm and gear, and the light source is brought to the photometer axis by projecting the filament onto an enlarged scale. All measurements are made from the light center; in this way the dimensions of the luminaire and the location of the glassware or accessory can be quickly and accurately determined in place.

The rotating arm which supports the French plate mirror is made of triangular construction in order to eliminate sag. In this way the double suspension is not necessary. In using the single suspension the mirror can be rotated through 360 degrees which is of considerable aid in measuring asymmetric reflectors or luminaires which cannot be rotated.

The reflection from the suspension arms is eliminated by the use of corrugated rubber matting with the corrugations running around the tubing.