NATIONAL BUREAU OF STANDARDS REPORT

7410

A Survey of the Equipment and Procedures for the Photometry of Projectors at the National Bureau of Standards

By

L. Chernoff

NBS

U. S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

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L. Chernoff
Photometry & Colorimetry Section
Metrology Division

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A Survey of the Equipment and Procedures for the Photometry of Projectors at the National Bureau of Standards

L. Chernoff

1. PURPOSE

The object of this report is to describe the procedures used and equipment available for projection photometry at the National Bureau of Standards. This paper, besides serving as a guide for making this type of measurements, will make a detailed description of the procedures for photometric measurement of projectors unnecessary in future NBS test reports.

2. EQUIPMENT

2.1 Ranges

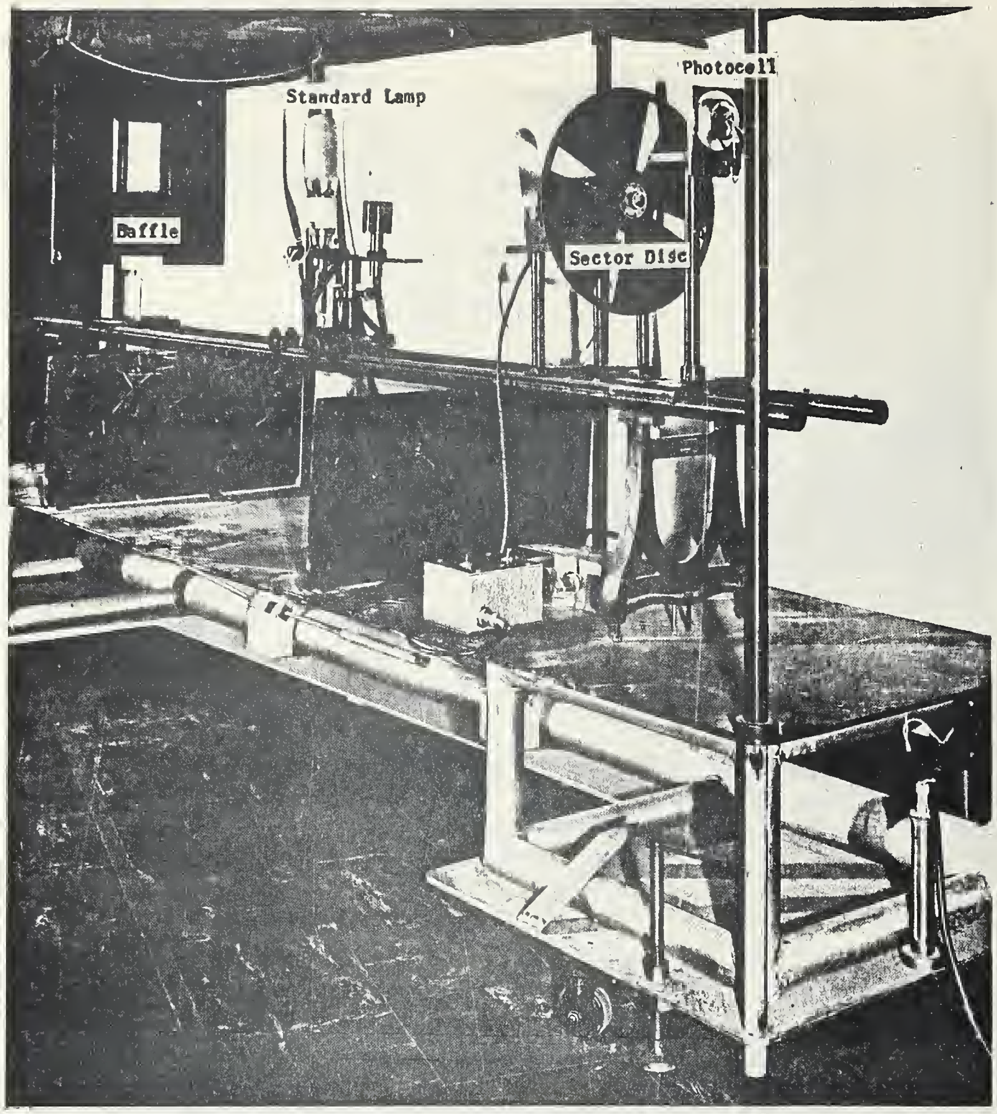
There are two ranges for the photometry of projectors at the National Bureau of Standards. The choice of range and the actual photometric setup are determined by the intensity, size, shape, and type of the unit to be tested.

a. 30-Meter Range

Smaller units are in general tested on the 30-meter range, which is located in the attic of the East Building of the National Bureau of Standards. The photocell and standard lamp for calibrating it are mounted on a movable "photometer bar," shown in figures 1A and 1B. By moving the photometer bar, a maximum distance of 30 meters can be obtained between the unit under test and the photocell. The standard lamp can be moved in and out of the calibration position by remote control.

The goniometer, which is located at one end of the 30-meter range, is shown in figure 2. Units mounted on it can be rotated about a horizontal axis through two pivot points on the U-shaped inner frame. There are two rotary tables for horizontal traverses which permit the goniometer to be used as either a class A or class B goniometer. The inner table on which the test unit is mounted is used almost exclusively, however. This table provides rotations about a secondary axis corresponding to the vertical, perpendicular to the horizontal axis which in this case is fixed; when the goniometer is operated in this manner, it is a type A goniometer.

Horizontal traverses obtained by rotating the larger table on which the outer frame is mounted result in rotations about a fixed vertical axis; when the goniometer is operated in this manner, it is a type B goniometer [1].



THE PHOTOMETER BAR OF THE 30-METER RANGE- Mounted on the bar is the equipment used in calibrating, however the shielding for stray light between the standard lamp and the photocell has been removed, and a white background has been substituted for the normally black one.

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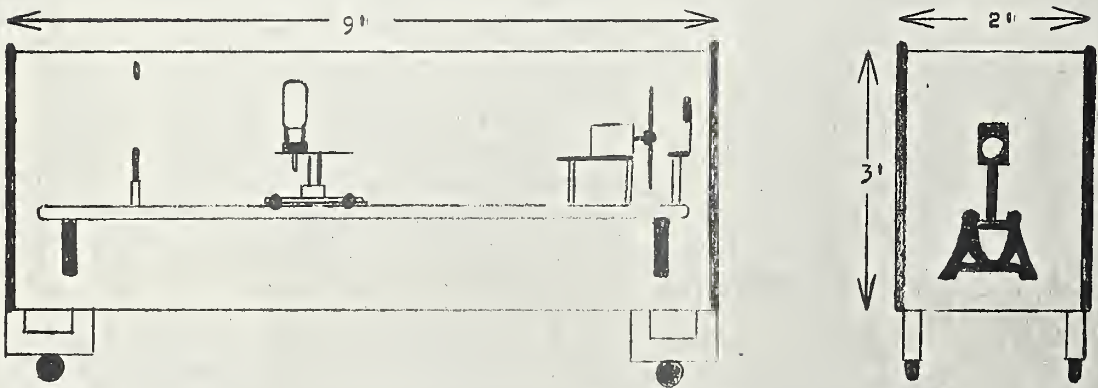
Figure 1A



DIMENSIONAL DIAGRAM OF THE PHOTOMETER BAR

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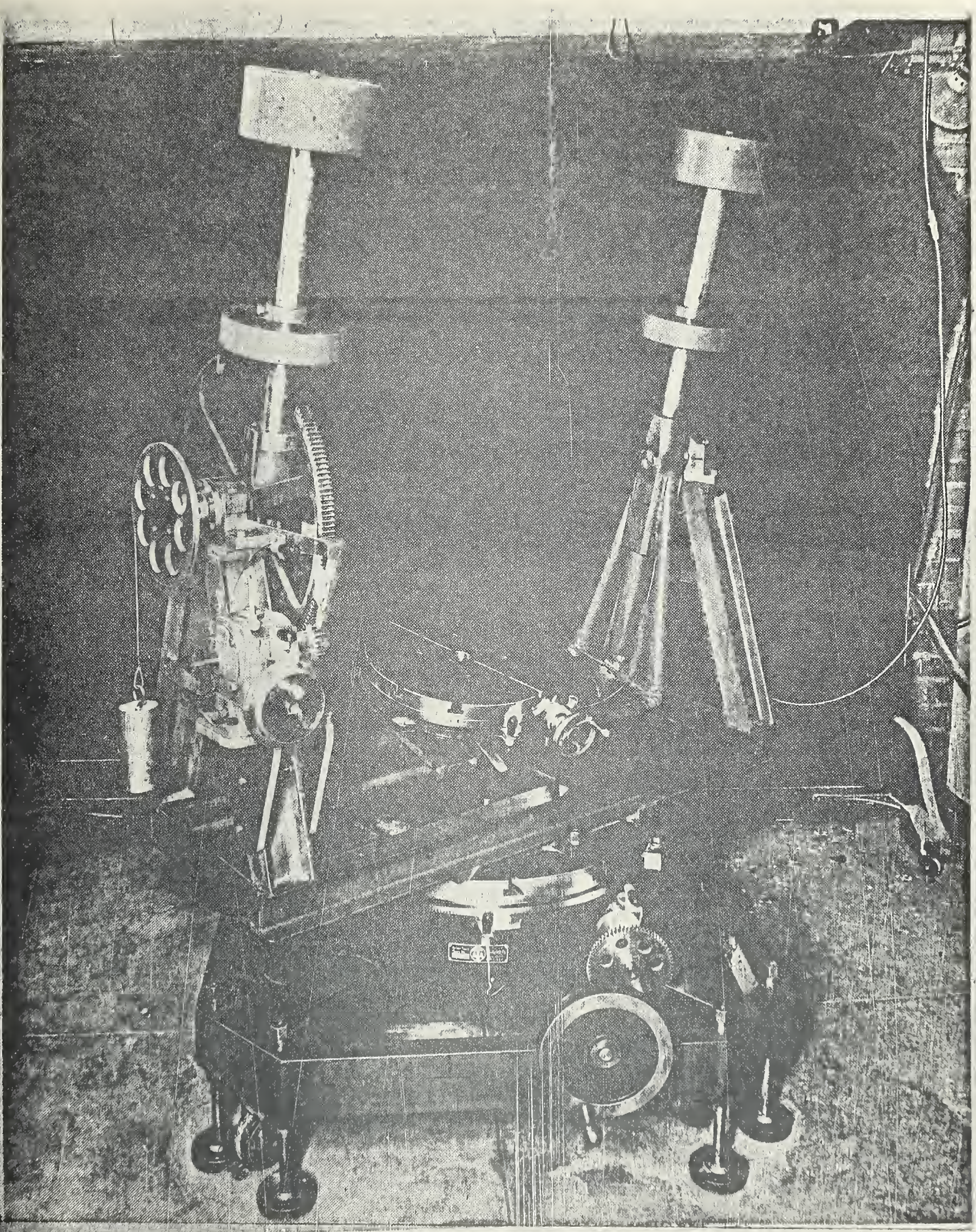
Figure 1B



THE GONIOMETER OF THE 30-METER RANGE

The goniometer is gear-driven in both the horizontal and vertical directions and is generally turned by means of synchronous motors. When a self-balancing recording potentiometer is used, the recorder chart is driven by another synchronous motor which is powered from the same source as is the goniometer motor. Gear ratios for the recorder and the goniometer can be varied to make available several choices of speed of rotation and chart speed, and hence provide a range of angular scales (degrees per division) on the chart.

One source of error in goniometry is the backlash of the driver gears. For horizontal traverses, the errors due to backlash are minimized by running traverses in only one direction. In the vertical direction, backlash can result from inconstant torque and from the goniometer cradle passing through a balance point in the course of the traverse. To minimize these effects, with the test unit mounted on the goniometer, the pinion gear on the vertical drive is disengaged, and the inner frame is balanced by means of the counterweights at the top of the goniometer. After this balancing, a constant torque is applied by means of a small weight at the end of a cable, which passes over a pulley connected to the vertical drive shaft[1]. The pulley and weight are seen to the left of the goniometer (figure 2).

In order to minimize the errors caused by stray light, the photometer bar is provided with a series of shields. One of these shields is seen in figure 1. In addition, there are adjustable screens situated along the range between the goniometer and the photometer bar. The goniometer and the background of the photometer bar are black.

The minimum test distance which can be used in photometry is called the "minimum inverse-square distance."[2] The illumination from the light unit, measured at distances greater than this minimum, obeys the inverse-square law. The photometric distance is made greater than this minimum distance. The minimum inverse-square distance is determined by the type and size of the light source, lens, reflector, etc., and must be considered individually for each unit. If this distance is more than 30 meters (100 feet), the 30-meter range can not be used.

The case of the photometry of a searchlight emitting a parallel beam is shown in figure 3. For this case, the angle subtended by the optic (reflector) of the searchlight at the photocell must be greater than the angle subtended at the point on the reflector farthest from the light source by the smallest projected dimension of the light source. If the reflector is viewed through a telescope at the position of the photocell, the reflector will then appear bright over all the aperture.

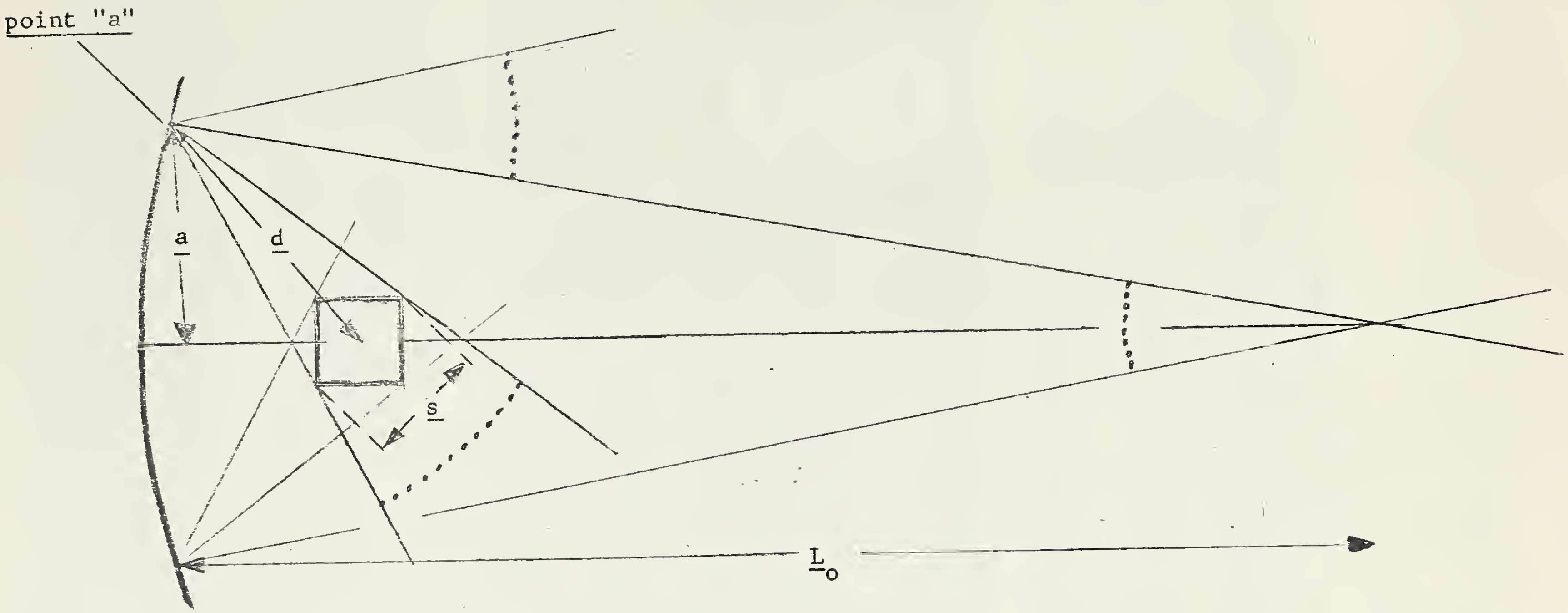


DIAGRAM FOR THE DETERMINATION OF THE "MINIMUM INVERSE SQUARE DISTANCE"-
The dotted lines subtend equal angles.

Figure 3

From these considerations, the minimum inverse-square distance, L_o, is given by

$$L_o = \frac{ad}{6s}$$

where

L_o is the minimum inverse-square distance (in feet),

a is the distance from the point on the reflector that is farthest from the light source to the axis of the searchlight (in inches),

d is the distance from the light source to point "a" (in inches), and

s is the smallest projected dimension of the light source as viewed from point "a" (in inches).

To illustrate, these considerations may be applied to the photometry of two different type PAR-64 lamps, one with a 300-watt, 6.6-ampere filament, and the other with a 120-watt, 6-volt (20-ampere) filament. These lamps have the same overall dimensions and differ only in the size and construction of the filaments. Both lamps have clear covers and employ parabolic reflectors, and both emit a parallel beam of light. For both lamps, the dimension a is 3.7 inches and the dimension d is 3.8 inches.

The filament of the 300-watt lamp is of the CC-6 type; that is, the filament wire is wound in a helix and the helix is again wound into a larger helix. The axis of the larger helix is perpendicular to the axis of the reflector. The smaller helix is wound so tightly that its diameter can be considered the smallest dimension of the light source, and its projected dimension, dimension s, is this diameter, 0.033 inch. L_o is therefore 70 feet, which permits the lamp to be photometered on the 30-meter range.

The filament of the 120-watt lamp is of the C-6 type. The filament wire is wound into a single helix. This helix is wound so loosely that the single turns of the coil can be discerned. Therefore the diameter of the filament wire itself, 0.020 inch, is considered its smallest projected dimension. L_o is 120 feet, and on this basis this lamp should be photometered on the 279-meter range described below.*

* The separate turns of the helix cannot, however, be discerned from the extreme regions of the reflector. For the region of the reflector where the separate turns of the helix can just be discerned, both a and d are about 2.2 inches and L_o computed for this region is 40 feet. At the extreme regions of the reflector, the diameter of the (footnote continued at top of page 7.)

helix, 0.083 inch, is the smallest projected dimension of light source, and L_0 is 28 feet. This lamp would therefore be photometered on the 30-meter range. See Walsh, J.W.T., Photometry, London (Constable & Company Ltd., 1953). Chapter XIV.

b. 279-Meter Range

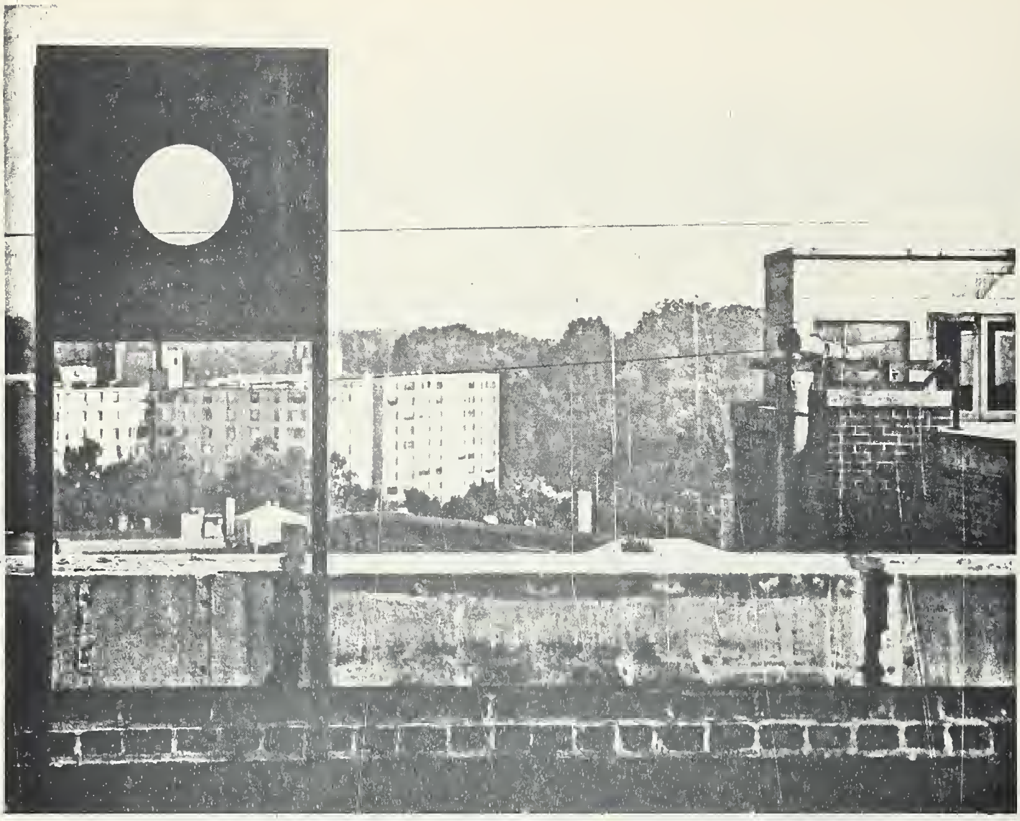
Larger lights are, in general, tested on the 279-meter range. The photocell and the standard lamp are located in a hut on the roof of the Industrial Building at the National Bureau of Standards. The range has been designed with the photocell facing south so that during the day the photocell views the shaded side of the building in which the goniometer is located and of the intervening stray-light shields. A baffling tube and two additional stray-light shields are also situated on the roof of the Industrial Building. Figures 4A and 4B are photographs showing the hut, together with the shielding for stray light.

The goniometer, recording potentiometer, and all electrical controls are located in a room on the top floor of the Computer Laboratory. The distance between the photocell and the goniometer is fixed, 279.0 meters.

This goniometer was constructed from a 60-inch coast-defense searchlight and is shown in figure 5. In order to obtain greater precision in the angle settings, the old gearing was removed, and more precise gearing was installed. Tests have shown that the angles for small traverses can be set with an error of less than 0.03° in both horizontal and vertical settings.[3]

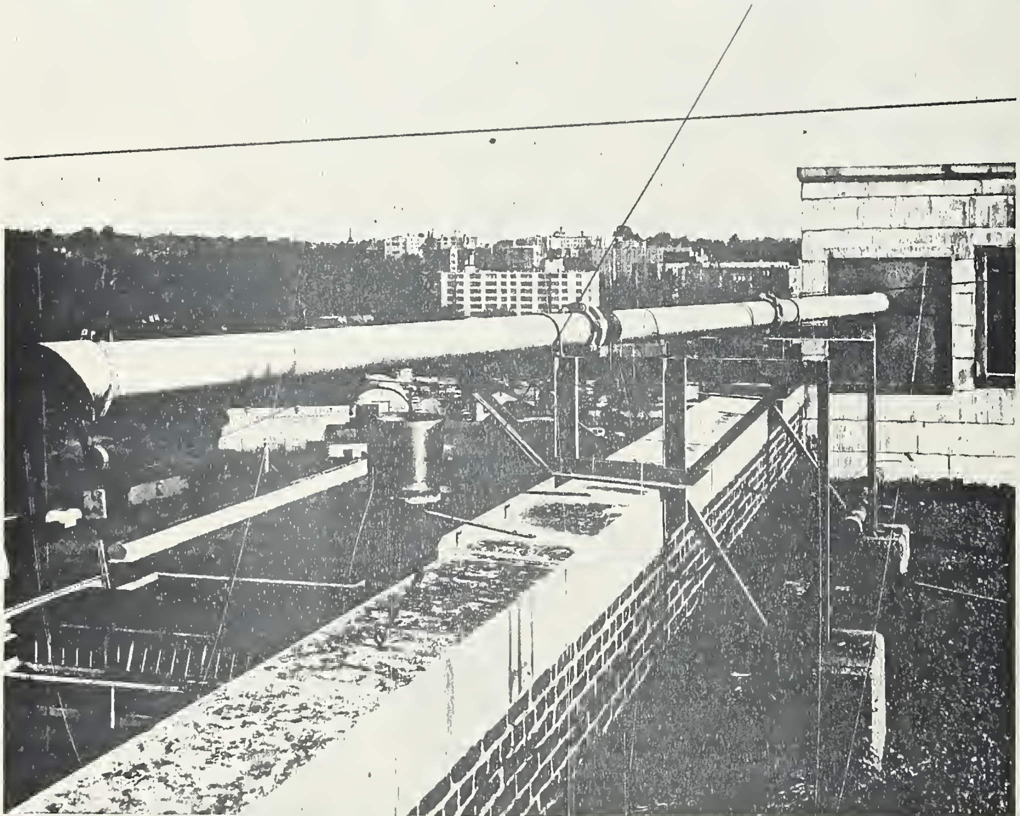
Units mounted on this goniometer can be rotated about a fixed vertical axis and about a secondary axis, corresponding to the horizontal, perpendicular to the fixed axis. Errors resulting from inaccurate vertical centerings of the test unit are generally negligible; e.g., if a unit is mounted 2 feet below or above the center of rotation of the goniometer, for a vertical rotation of 30° there will be an error of 0.2 percent in the candlepower reading due to the change in photometric distance, and a corresponding error in the vertical angle readings of 0.015°. The goniometer is so sturdy that there is minimum backlash of the driver gears resulting from inconstant torque. It was found that under an extremely asymmetrical loading of a test unit the error resulting from backlash was within 0.04°.[3]

This goniometer is generally driven by hand although motor drives are installed. An "x-y" recorder is used and the chart drive of the recorder is controlled by a self-balancing potentiometer (the y-axis amplifier). A voltage signal from a potential divider attached to the drive mechanism of the goniometer is connected



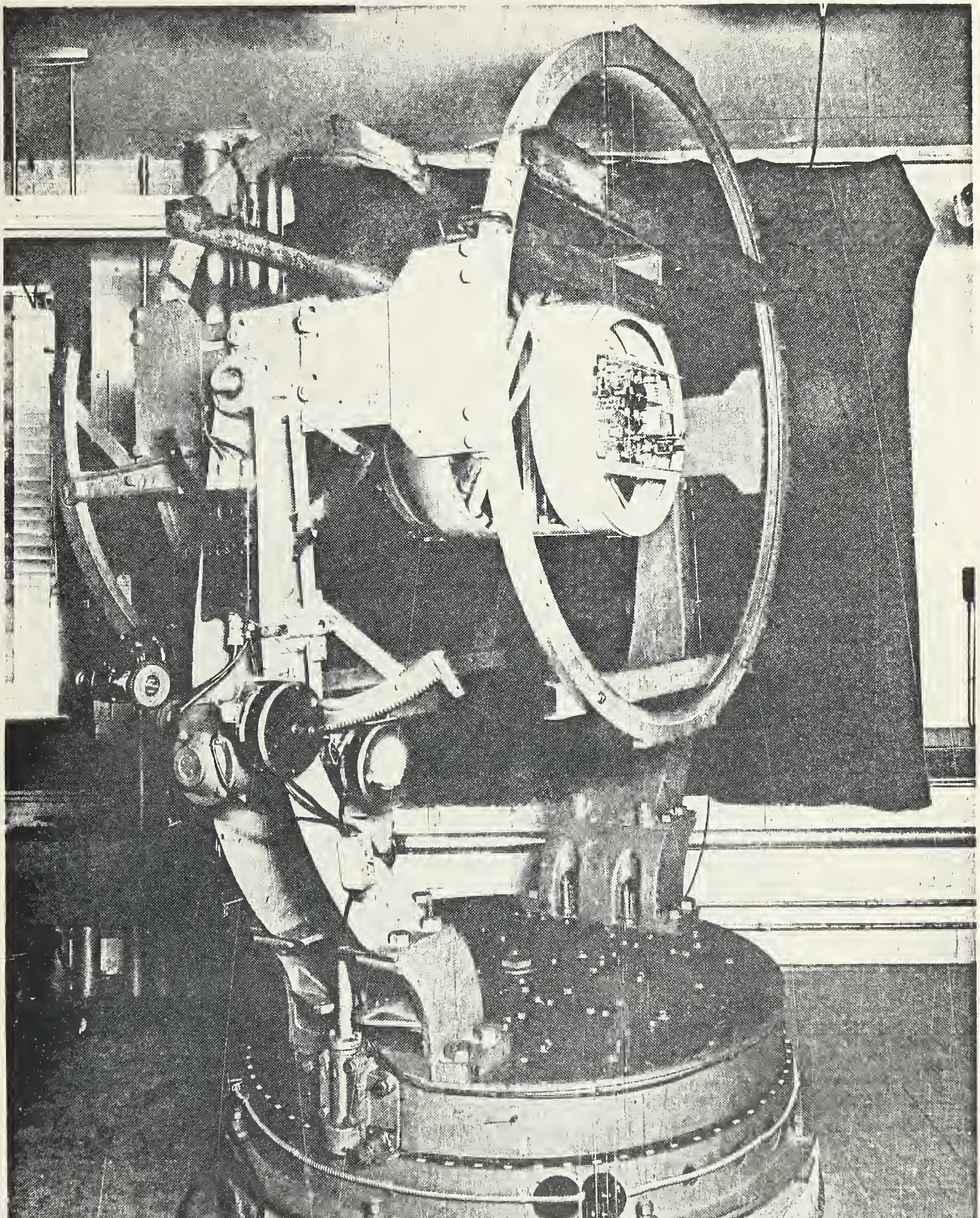
THE BAFFLING TUBE OF THE 279-METER RANGE- Seen are the baffling tube and one of the two other baffles.

Figure 4A



A CLOSE-UP VIEW OF THE BAFFLING TUBE- The front of the tube is covered with a removable protective shield.

Figure 4B



THE GONIOMETER OF THE 279-METER RANGE- An aircraft searchlight is mounted on the goniometer to the input of the y-axis amplifier, thus making the chart position a function of the goniometer angle.

The baffling tube and some of the other stray-light shielding seen in figures 4A and 4B block out all but a 6-foot-diameter area of view at the goniometer. This baffling is effective enough to permit much of the photometry on the 279-meter range to be carried out during the day. The illumination from the background is equivalent to that of a light with an intensity of about 1 kilocandle, and as a general rule any light whose peak intensity is over 100 kilocandles can be photometered during daylight.

As shown in figure 6 the standard lamp and photocell are so arranged that they do not have to be moved for calibration or test measurements. The photometric axes from the standard lamp and from the test unit are respectively 5° left and right of an axis perpendicular to the face of the photocell. The response of the photocell used in the 279-meter range is symmetric with respect to the angle of incidence of the light illuminating it. Therefore, such an arrangement introduces no experimental errors.

The distance of the test unit to the photocell on the 279-meter range is so large that correction for the transmission of the air path must be made. The transmittance at the time of photometry is measured by means of a National Bureau of Standards Transmissometer[4] and is used as a correction in the calibration of the photometer.

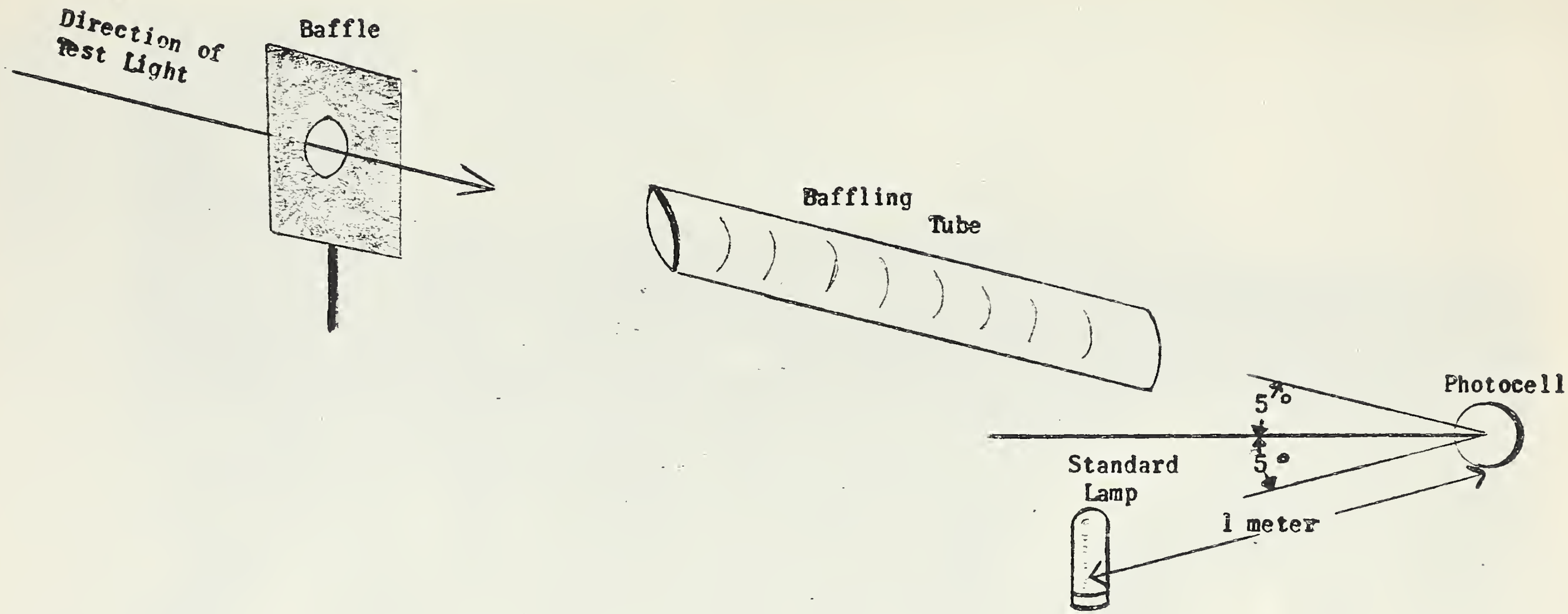
2.2. PAR Lampholder

A holder for PAR-type lamps is used to facilitate the mounting of lamps of this type. Since PAR-type lamps are generally tested on the 30-meter range, the PAR lampholder has been designed to be easily mounted on the goniometer of this range and is shown in figure 7. A set of removable mounting rings makes it possible to mount any of the various sizes of PAR lamps on the PAR lampholder.

The holder contains a telescope with cross hairs which is used to align the holder with a mark at the other end of the range so that the axis of the PAR lamp reflector will coincide with the photometric axis. It is therefore possible to remove the PAR lampholder from the goniometer and to replace it at some future time with the PAR lamp aligned as before.

2.3 Photo-Sensitors

The photo-sensitors used in the photometric measurements are constant-current devices which produce currents proportional to the illuminance on their faces. All photo-sensitors used



THE ARRANGEMENT OF THE PHOTOMETRIC EQUIPMENT ON THE 279-METER RANGE

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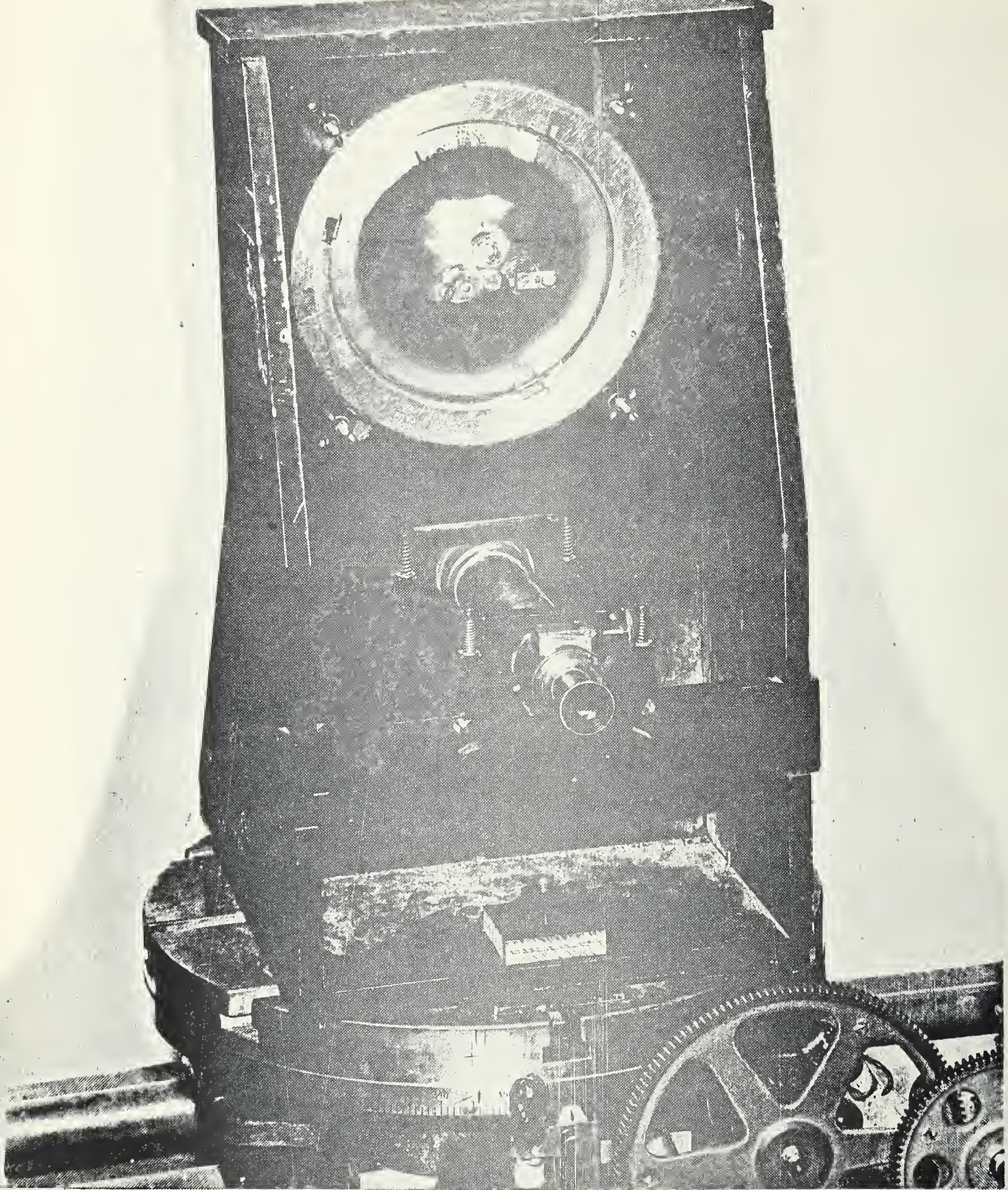
Figure 6



A REAR VIEW OF THE PAR LAMP HOLDER- Seen are the telescope for aligning, the mounting ring, and the back of a PAR-56 lamp which has been mounted on the holder.

are color-corrected by means of optical filters in order to make their response similar to the CIE spectral luminous efficiency function. Two different types of photo-sensitors are in general use, the barrier-layer photocell and the vacuum phototube. While photomultiplier tubes are available, there has been no occasion to use them for the photometry of projectors at the National Bureau of Standards laboratories in the last few years.

a. Barrier-Layer Photocell

The barrier-layer photocell is a solid state device, and is the type generally used. In the selection of a photocell for photometric testing, several cells which were color corrected by means of color correcting filters were examined for spectral response. In this process, the transmittance of several colored filters for light of a specified color temperature is measured with these photocells. These measurements are compared with transmittances determined from spectrophotometric measurements. The results of one such series of measurements are tabulated in table I.

The photocells with good color response are then tested for linearity; the one most linear in its response is selected for use. The response of the photocell being used at present, cell number 3 of table I, was found to be linear to better than 0.1% in the most useful range. This is sufficiently linear for photometric testing. The results of the linearity measurements of this photocell are shown in figure 8.

The barrier-layer photocell is used with two different circuits. For most photometric work with this photocell, an external shunt is used. The voltage drop across the shunt is amplified by means of a linear amplifier and the output of the amplifier is recorded on the recorder chart of a self-balancing potentiometer. This circuit is shown in figure 9. However, when greater precision is required in the measurements, or when the illumination on the face of the photocell is either very large or very low, a "zero-resistance" circuit is employed and intensity readings are made directly from a Kohlrausch potentiometer.[8,9]

b. Vacuum Phototube

For flashing lights of short flash duration such as the condenser-discharge light, and for lights of very low intensity, a type PJ-14B vacuum phototube is used.[5] The phototube with its power supply is housed in a metal box and is shown in figure 10. The phototube is color-corrected by means of a specially designed filter; the accuracy of this color correction is indicated in figures 11A and 11B.

Table I

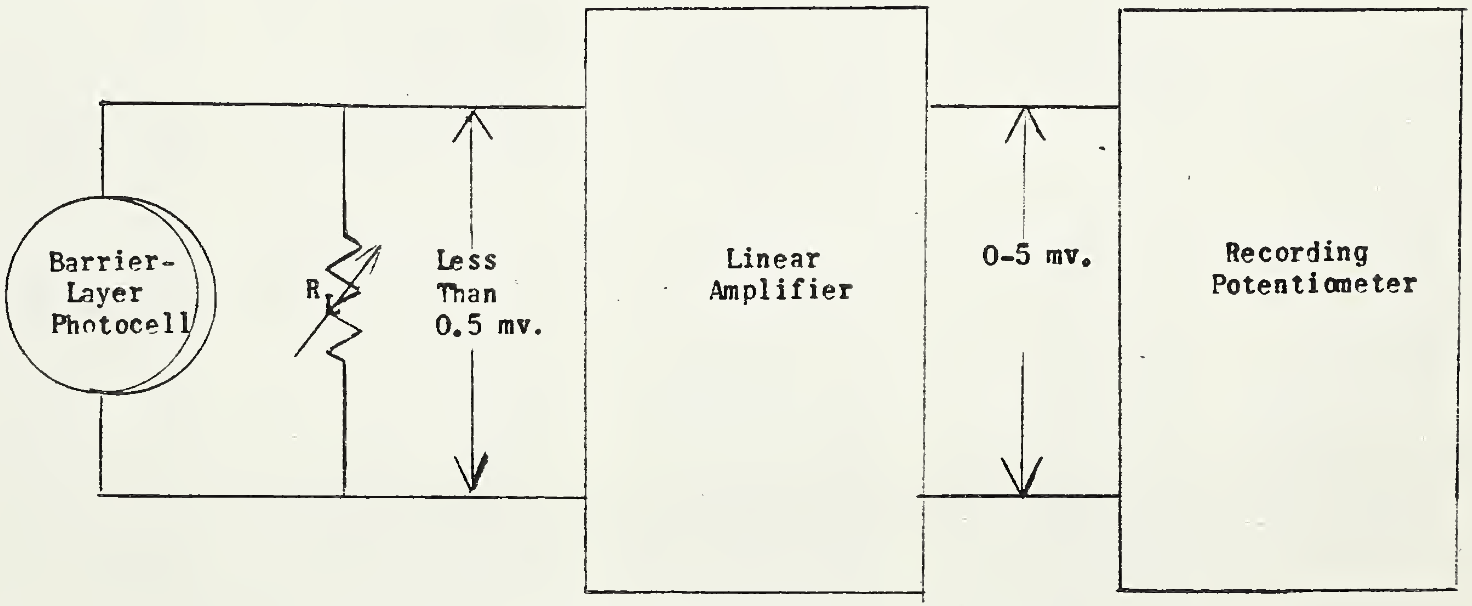
Color Response of a Group of Photovoltaic Cells with Filters

Filter Characteristics				Transmittance Ratio #					
Color	x*	y**	T***	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6
Red	.725	.275	.0410	1.17	1.04	1.00	1.20	1.13	.98
"	.687	.313	.222	1.07	1.00	1.00	1.07	1.05	1.03
"	.648	.351	.324	.97	.95	.94	.94	.96	.94
Yellow	.630	.370	.427	1.02	1.00	.99	1.02	1.01	1.00
"	.578	.421	.612	1.02	1.01	1.01	1.02	1.01	1.01
"	.554	.444	.725	.97	.97	.97	.97	.96	.95
Green	.233	.679	.0370	.98	.98	1.01	.96	.94	.96
"	.310	.573	.201	.97	.97	1.00	.96	.94	.96
"	.350	.450	.409	1.00	1.01	1.02	1.00	.99	1.00
Blue	.160	.080	.020	1.01	.98	.99	.95	.96	1.00
"	.162	.293	.140	.90	.90	.92	.87	.88	.97
"	.320	.329	.250	.87	.88	.88	.88	.87	.87

Ratio of transmittance measured by photocell to transmittance determined from spectrophotometric measurements
* x-coordinate on the CIE chromaticity diagram
** y-coordinate on the CIE chromaticity diagram
*** Transmittance of the filter as determined by spectrophotometric measurements

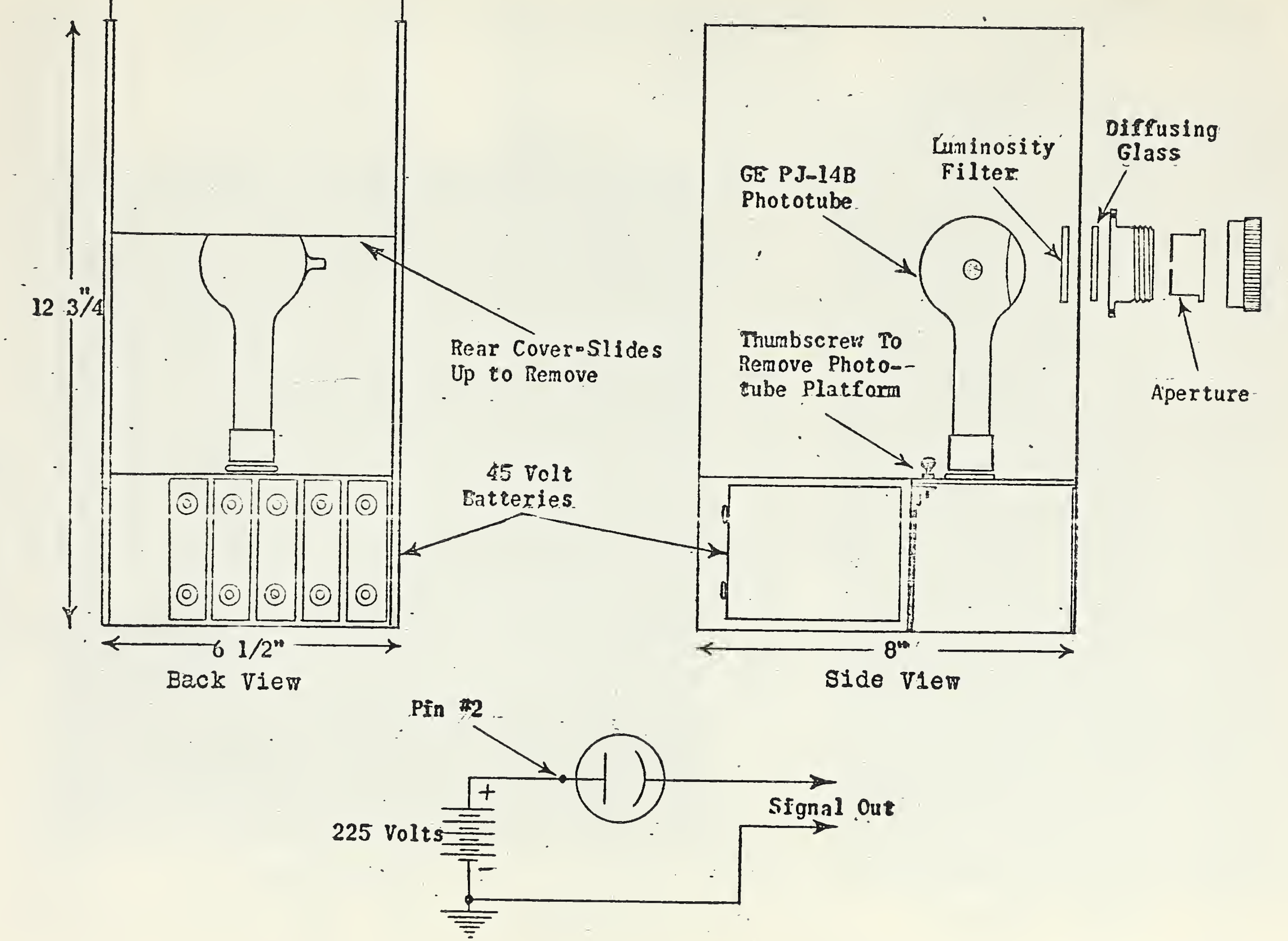
LINEARITY OF RESPONSE FOR SELECTED BARRIER-LAYER PHOTOCELL
Note-Voltage drop across photocell did not exceed 1 millivolt.

Figure 8

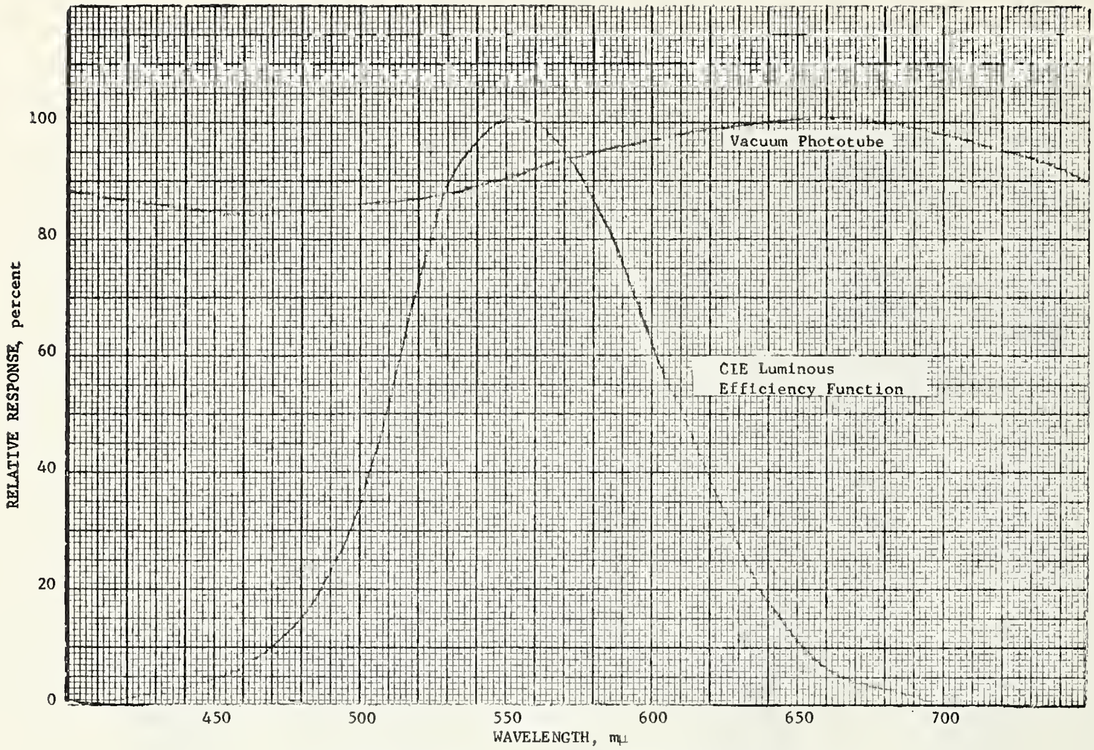


BLOCK DIAGRAM OF A BARRIER-LAYER PHOTOMETER

Figure 9



PJ-14B PHOTOTUBE PHOTOMETER HEAD



RELATIVE SPECTRAL RESPONSE OF UNCORRECTED PJ-14B VACUUM PHOTOTUBE AND CIE LUMINOUS EFFICIENCY FUNCTION

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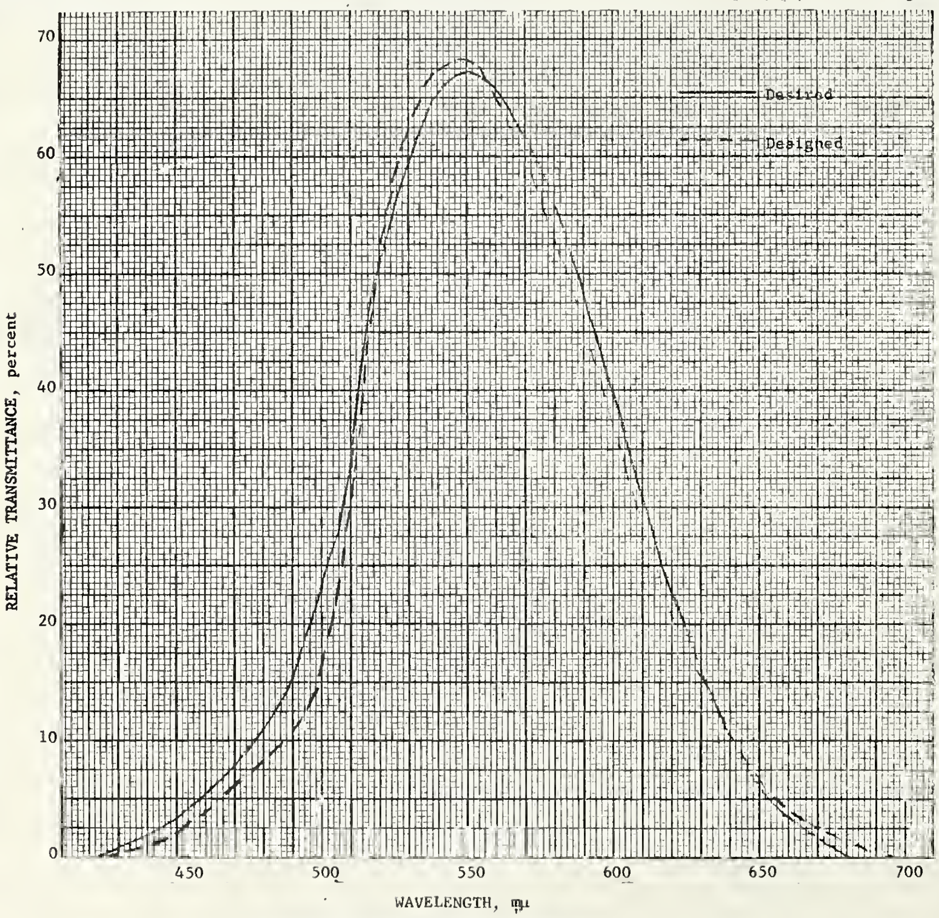
Figure 11A



SPECTRAL TRANSMITTANCE OF DESIRED AND DESIGNED COLOR-CORRECTING FILTER

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Figure 11B

A General Radio Type 1230A d-c amplifier is used to amplify the output of the phototube. This amplifer has been modified so that it may also be used as a potentiometer when greater accuracy is necessary.[6]

For the photometry of flashing lights, it is desirable to compute the effective intensity of the flash, which is determined from a measurement of the average intensity of the flash.[5] In order to read the average intensity, a resistance-capacitance network is placed across the phototube so that the photometer circuit will have a suitable time constant. A diagram of the photometer circuit employing the PJ-14B phototube, together with such a resistance-capacitance network, is shown in figure 12. The combination of d-c amplifier and phototube is useful in measuring steady illuminations as low as 0.00001 footcandle.

3. CALIBRATION OF THE PHOTOMETRIC SYSTEM

3.1 Introduction

Lamp standards of luminous intensity are used for calibrating the photometric testing equipment; a separate calibration is made before each test and a record is kept of the photometer sensitivity in order to detect any irregularities. The illumination on the photocell produced by the standard lamp is adjusted to some typical value of the illumination produced by the test light, generally in the range of 75% to 100% of the peak illumination from the test light. This procedure minimizes errors resulting from nonlinearity of the response of the photocell. The adjustment of the illumination of the standard lamp on the photocell is accomplished by varying the distance of the standard lamp from the photocell and by using optical attenuators. The photometer is usually calibrated so that it is direct reading.

3.2 Standard Lamps

The standard lamps used are "working standards" whose intensity has been determined at a given voltage.[7] Standard lamps are available ranging in intensity from about 8 to 900 candles. When a colored light is being tested, a filter is placed between the standard lamp and the photocell, which results in a standard lamp-filter combination having approximately the same spectral characteristics as those of the light to be tested. This procedure minimizes errors resulting from inadequate spectral correction of the photocell. In this procedure, a standard lamp of known intensity and color temperature is needed.

3.3 Attenuators

Sector disks are used almost exclusively for light attenuation, although neutral filters are also available. The sector disk is generally placed between the standard lamp and the photocell to obtain the proper range of calibration illumination; however, when the intensity of the light being photometered is unusually high, the sector disk may be used to attenuate the illumination from the test light. The range of sector disks available is from 1% to 80% transmittance.

When a sector disk is used, it is placed within a few inches of the photocell in order to reduce error from stray light. The disk is rotated at a few hundred revolutions per minute, which is fast enough to minimize error from apparent flicker. When a high illumination is attenuated by a sector disk of low transmittance there is an error due to only one part of the photocell being illuminated at a time; this error is successfully eliminated by placing a condenser of about 4 mfd. across the output of the photocell. (Care must be taken to obtain a capacitor which does not itself generate a small emf.)

3.4 Calibration Procedure

If:

$\underline{i}$ is the photocell current
$\underline{I}$ is the intensity of the light illuminating the photocell,
and $\underline{D}$ is the distance from the test unit to the photocell.

Then $$i = kI/D^2 \tag{1}$$
where $\underline{k}$ is the sensitivity of the photocell.

It is usually convenient to calibrate the photometer to be direct reading, so that

$$I = N\delta \tag{2}$$

where δ is the reading of the potentiometer of the measuring circuit, and where $\underline{N}$ is an integral power of 10 or the product of an integer, generally 2 or 5, and an integral power of 10.

The photometer is then calibrated using a standard lamp. If
$\underline{I}_s$ is the intensity of the standard lamp,
$\underline{D}_s$ is the distance of the standard lamp from the photocell,
$\underline{\delta}_s$ is the potentiometer reading and i_s is the photocell current when the photocell is illuminated by light from the standard lamp placed at the distance $\underline{D}_s$ from the photocell,

Then $$i_s = k\, I_s/D_s^2 \tag{3}$$

The potentiometer reading is proportional to the photocell current;

Therefore
$$i_s/\delta_s = i/\delta \tag{4}$$

Combining (1), (2), (3), and (4),

$$\delta_s = I_s D^2 / N D_s^{\,2} \qquad (5)$$

Calibration is accomplished by the following procedure: $\underline{I}_s$ and $\underline{D}_s$ are chosen so that I_s/D_s^2 will be approximately equal to $\underline{I}/D^2$, where $\underline{I}$ is some typical value of the intensity of the light to be tested. A suitable value of $\underline{N}$ is then selected. Calibration is completed, making the photometer direct reading, by one of the three following procedures, depending on the photometer circuit used.

a. External Shunt Circuit

A diagram of this circuit is shown in figure 9. In this circuit

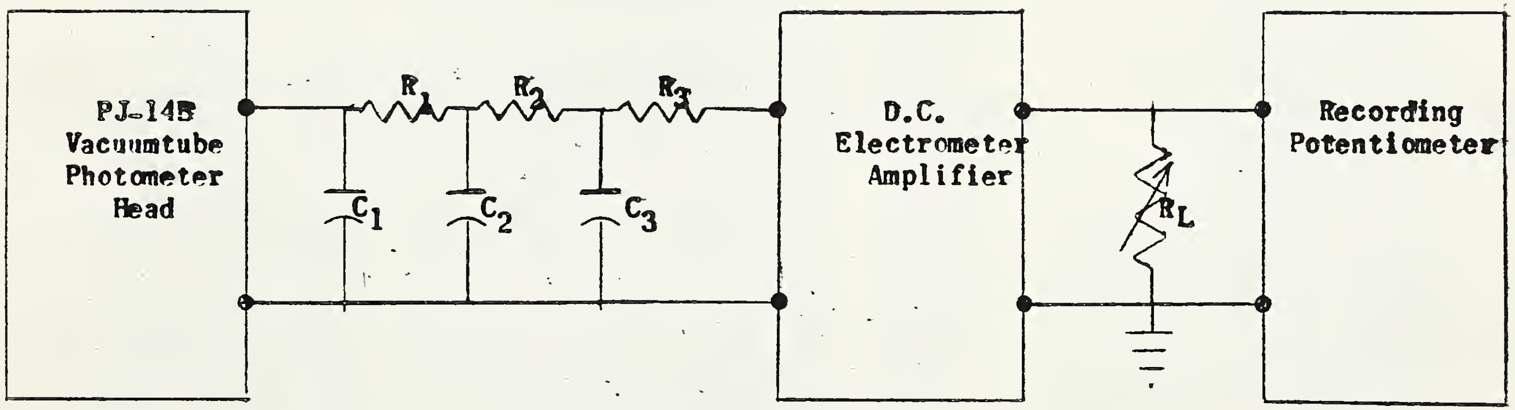
$$\delta_s = \frac{R_L S k I_s}{D_s^{\,2}} \qquad (6)$$

where $\underline{S}$ is the sensitivity of the photometer circuit and $\underline{R_L}$ is the resistance of the shunt.

Calibration, therefore, requires that, with the photocell illuminated by light from the standard lamp, the external shunt resistance is set so that the potentiometer indicates the value δ_s given in equation (5). The other parameters of the calibration are usually adjusted so that the shunt resistance will be of the order of a few ohms. This order of resistance value is used since it is large enough to be set accurately, and it is small enough so that there will not be so great a voltage developed across the photocell that the photocell will respond nonlinearly. The practice is to maintain the sensitivity of the recorder at a fixed value of 5 millivolts for full-scale deflection. The sensitivity of the preamplifier is therefore set in order that this recorder sensitivity and desired range of resistance may be used.

b. Phototube With General Radio Amplifier

The procedure for calibration is the same as that for procedure a. (see figure 12) The load resistor on the photocell and the controls of the amplifier are adjusted for the optimum performance range of the amplifier. Also, the output of the amplifier should not exceed 5 milliamperes. Hence, other parameters are adjusted so that $\underline{R_L}$ is greater than 1 ohm.



C_1, C_2, C_3: 0.05 mfd., 1200 volt Mica

R_1, R_2, R_3: 2.2 megohms

R_L: Calibration Adjusting Resistor, Decade Box 9x(10+1+0.1+0.01)

PJ-14B PHOTOTUBE PHOTOMETER- The resistance-capacitance network between the photometer head and the amplifier is used in the photometry of flashing lights and is otherwise removed.

Figure 12

c. Zero-Resistance Circuit

A diagram of this circuit is shown in figure 13. In this circuit, if the photometer is balanced so that no current flows through the galvanometer

Then
$$i = i_a a/r_x \tag{7}$$

where

i is the photocell current,
i_a and a are the current through and resistance of the slidewire between 0 and A respectively (figure 13), and
r_x is the resistance of the resistor, r_x.

Assuming the slidewire is graduated from 0 to 100, the reading of the indicator of the slidewire is

$$\delta = a/a_o \tag{8}$$

where a_o is the total resistance of the slidewire (the resistance between 0 and B in figure 13.).

Then, combining (1), (7), and (8),

$$\delta = \frac{r_x kI}{i_a a_o D^2} \tag{9}$$

In the calibration of the zero-resistance circuit, i_a is generally kept constant and r_x is varied.

When the photocell is illuminated by light from the standard lamp, r_x is adjusted to obtain a zero reading of the galvanometer when the slidewire is set at the value δ_s of equation (5) for a given test distance, D. With the photometer thus calibrated, the intensity of the test light is given by equation (2).

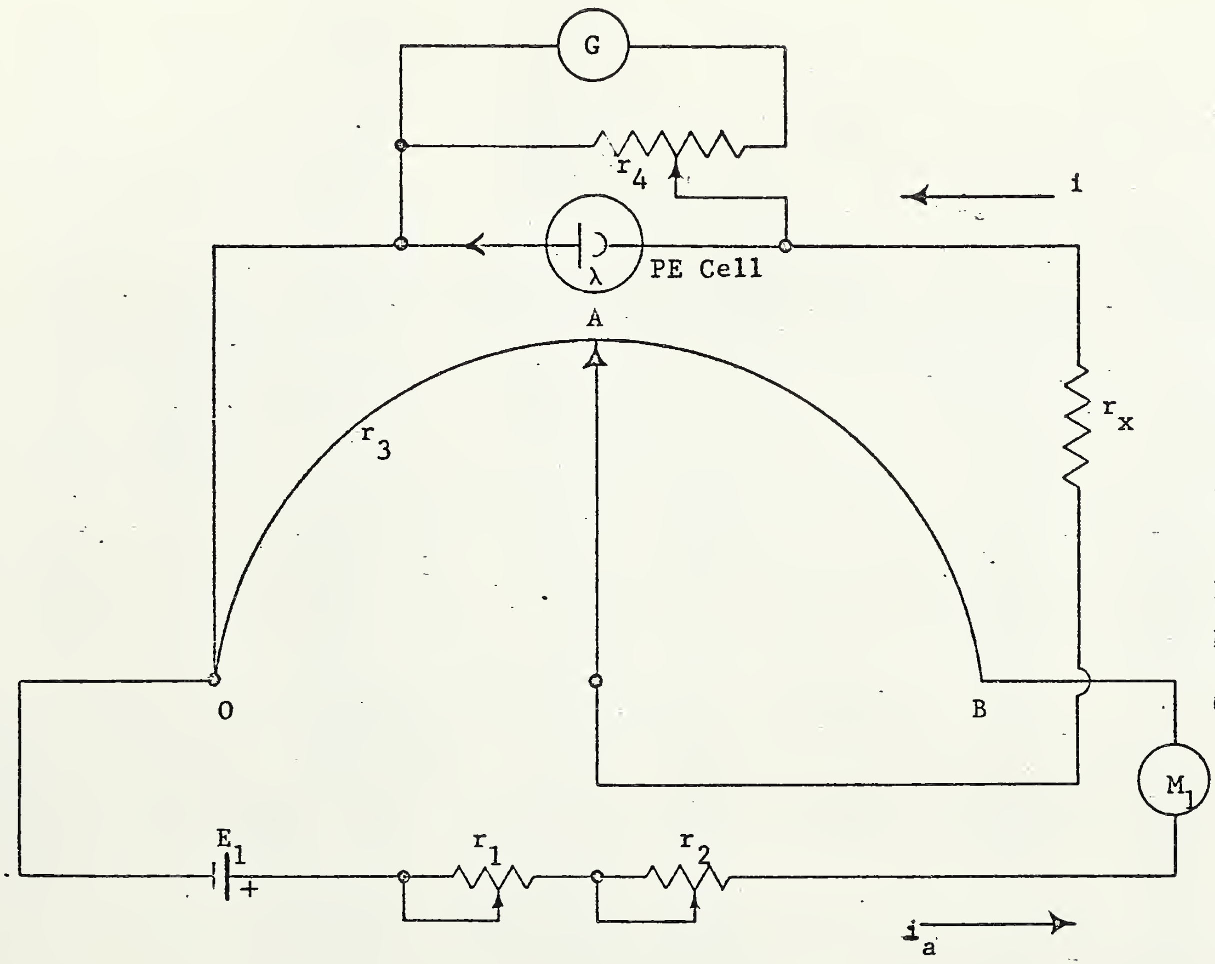
d. Special Procedures

Photometry of the test light under operating conditions other than the design condition is sometimes desirable. Equation (5) can be generalized, taking into account this condition as well as the transmittance of any filters or sector disks used in calibrating, so that

$$\delta_s = \tau_c \tau_s FI_s \frac{D^2}{ND_s^2} \tag{5a}$$

where

τ_c is the transmittance of the color filter at specified color temperature,
τ_s is the transmittance of the sector disk,



r_1	100-ohm rheostat
r_2	5-ohm rheostat
r_3(OAB)	10-ohm precision potentiometer or slidewire
r_4	galvanometer sensitivity control, resistance equal to critical damping resistance of galvanometer
r_x	4-decade resistance box o-100,000 ohms
E	1 1/2-volt dry battery
M_1	milliammeter, 10ma full scale, 30 ohms resistance.
G	galvanometer, sensitivity about 0.004 μamp/mm

"ZERO-RESISTANCE" PHOTOMETER CIRCUIT

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Figure 13

F is the ratio of the output of the light under test when it is operated under the design conditions to the output of the light when it is operated under test conditions. This ratio may be, for example, the ratio of the rated lumen output of the test lamp to the output of the lamp at the test voltage. It also may be the ratio of the intensity in a given direction at the operating voltage to the intensity in this direction at the test voltage.

In the case of flashing lights on which photometric measurements are made with the light burning steadily at a selected voltage, the factor F is the ratio of the effective intensity of the flash in a given direction to the steady intensity at the selected voltage in this direction of view.

4. TESTING PROCEDURE

The photometer is first calibrated as described under "Calibration Procedure" (Section 3.4) to some useful range determined by the intensity of the light being tested and the information desired. The test unit is mounted on the goniometer and is aligned. The angular settings of the goniometer are adjusted so that the origin of the goniometer settings will correspond to the desired axis. This axis usually is chosen with respect to either the seating plane of the unit or some characteristic of the beam such as its peak.

The proper shielding for stray light is put into place. The photocell is removed, and the eye is placed in the position normally occupied by the photocell. Examination can then be made to insure that the shielding is properly placed, and that no obstructions exist between the lamp and the photocell. When using the 279-meter range, the baffling tube is periodically checked to insure that it is not being obstructed by birds. The photocell is then replaced into its proper position.

If a sealed-reflector lamp is being photometered, the lamp is generally operated at either rated voltage or rated current. Other lamps, such as those used in combination with an optical system, are generally operated at or corrected to rated lumen output. Power for the test and standard lamps is usually obtained from storage batteries, which are periodically recharged. Voltage and current are measured on a potentiometer, and photometric measurements are not made until the lamp has reached stability.

If the goniometer is to be motor driven, the gear ratios are chosen so that the traverse will be slow enough to insure the accurate recording of the characteristics of the light. All information pertinent to the photometric measurements is recorded at the time the measurements are being made.

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