PHOTOMETRIC TEST FOR REFLECTIVE MATERIALS

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This report describes the photometric equipment and procedure employed by the Michigan Department of State Highways Research Laboratory for testing reflex-reflective materials, updating Research Report No. 243 (Dec. 27, 1955). Photographs of the testing and control equipment are also included.

Test Equipment

The components of the photometer include a light source to illuminate the reflector, a photoelectric receptor to measure the reflected beam, a goniometer to mount the reflector, and other related control and calibration apparatus (Fig. 1).

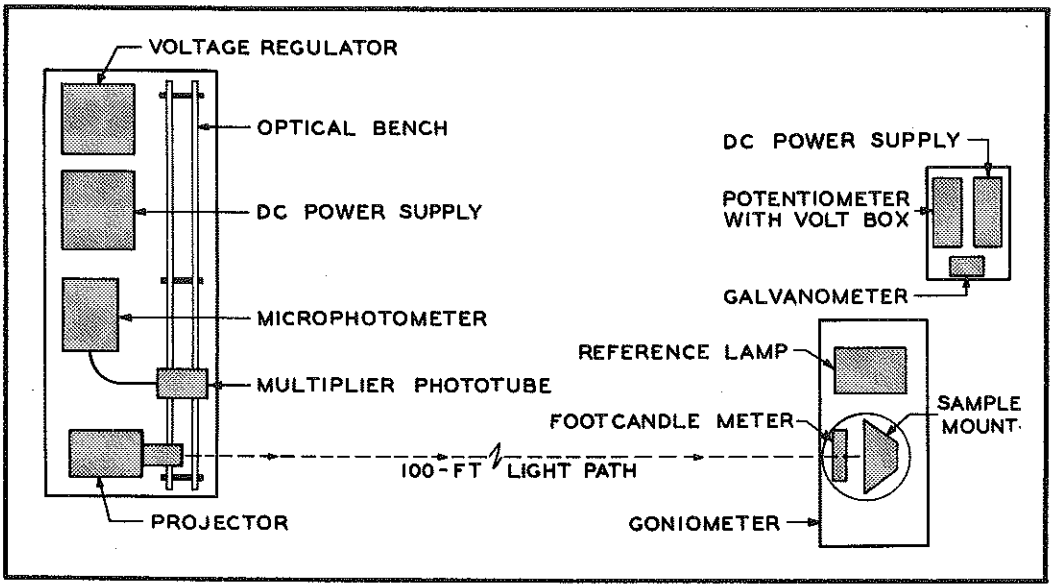


Figure 1. Arrangement of test apparatus.

Since reflectors are measured in terms of specific intensity or candlepower per foot-candle of illumination, the test procedure generally consists of measuring light intensity at various angles of incident illumination. Light incident on a reflector is reflected back to a multiplier phototube, and the phototube response is indicated on a meter previously calibrated with a candlepower reference lamp. In this manner, candlepower can be

measured at various divergence or observation angles by varying the distance between the source and phototube, and can be measured at various entrance angles by rotating the reflector about an axis perpendicular to the incident light beam. Finally, foot-candles of illumination are measured at the reflector position with a foot-candle meter.

The equipment used in the test includes:

1. Projector (Fig. 2)

a. Projector Housing: Bell and Howell 16-mm movie projector. The projector was dismantled and only the projector housing, condensing optics, blower, and film gate were retained. A 1/32-in. diam aperture is mounted in the film gate when measuring reflective samples smaller than 6 in. and a 3/32-in. diam aperture is used for larger samples. The projector is fixed to a stable and permanent mounting at the optical bench.

b. Projector Lens: Luxtar 1, 7-in., f 4.5 anastigmat. The lens was commercially produced by Viewlex inc., Long Island City, N. Y., for use in 35-mm slide projectors. Effective diameter of the light source at the lens is 1-7/16 in.

c. Projector Lamp: 750 w, T 12 projection lamp with a C13D filament, base down, 120 v. The lamp is operated from a regulated d.c. voltage supply to stabilize lamp intensity.

2. Photomultiplier Microphotometer (Fig. 3): Model 10-210, purchased in 1951 from the American Instrument Co., 810 Georgia Ave., Silver Spring, Md. The phototube supplied with the microphotometer was replaced with a 1P22 multiplier phototube, which when mounted and shielded in the receptor housing has an effective surface masked to 15/16-in. height and 7/16-in. width. The housing is attached to an optical bench adjacent to the projector, which permits use of various divergence angles or observation angles down to $1/10^{o}$ or 2 in. at the 100-ft test distance. In front of the opening in the phototube shield is a mount to receive the Wratten 101 filter which corrects the spectral response of the phototube to match the spectral response of the eye (Fig. 4). The photomultiplier microphotometer is to be replaced with a Model 15 Recording Photometer available from Pacific Photometric Instruments, 3022 Ashby Ave., Berkeley, Calif.

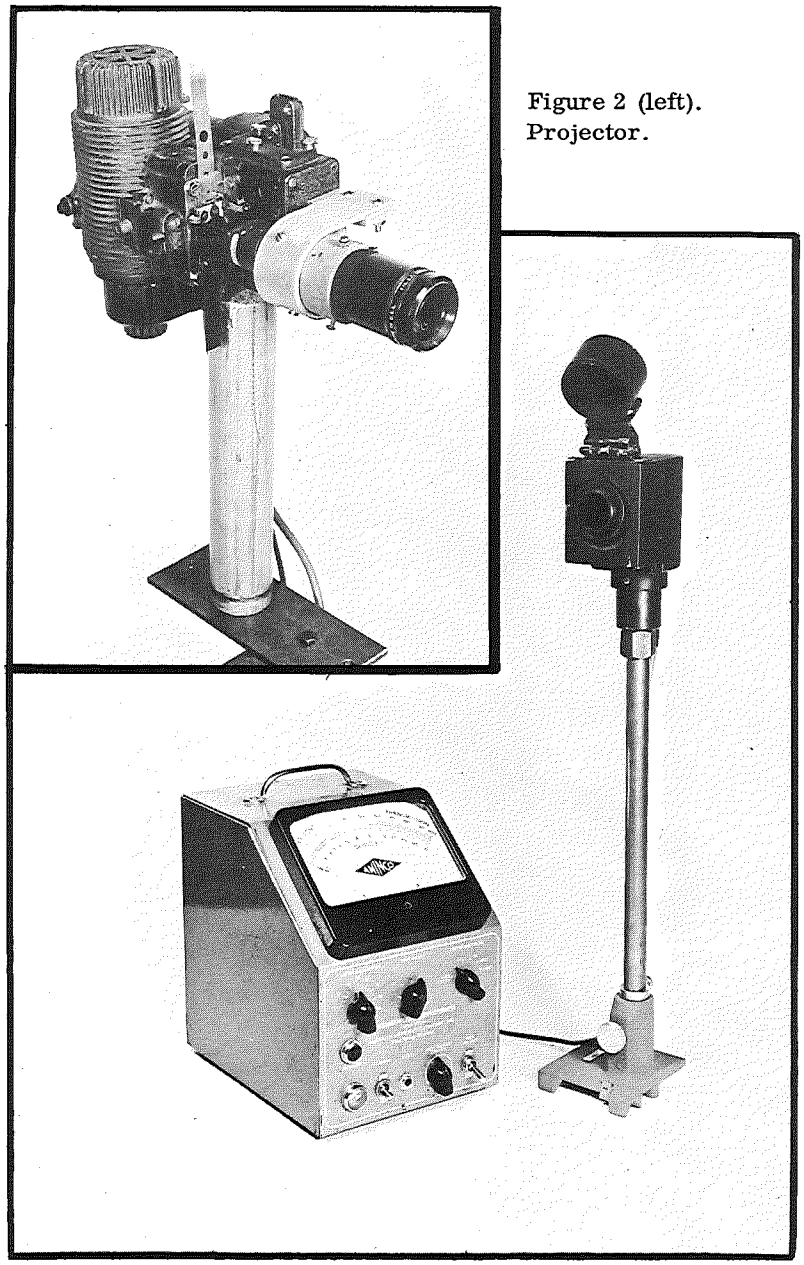


Figure 2 (left). Projector.

Figure 3. Microphotometer and phototube receptor housing.

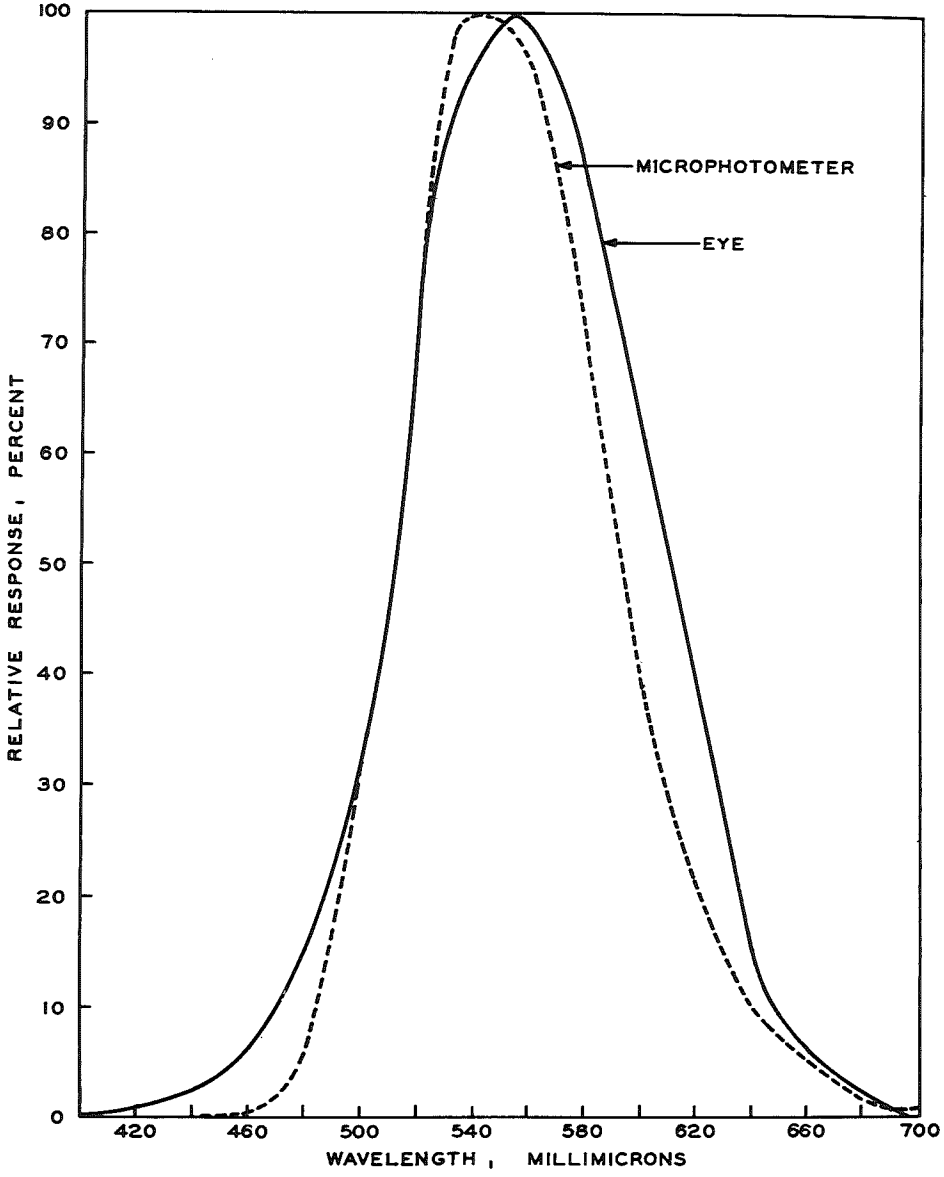


Figure 4. Comparison of spectral responses of eye and microphotometer (with phototube and filter).

3. Voltage Regulator (Fig. 5): Sorensen Model FRLD 750, available from Sorensen and Company, Inc., Richards Ave., South Norwalk, Conn. This is an a.c. regulator used to power the microphotometer.

4. Power Supply (d.c.) (Fig. 6): Sorensen Model DCR, 0 to 150 v, 15 amp, available from Sorensen and Co., Inc. This is used to stabilize the projector lamp.

5. Optical Bench (Fig. 7): Gaertner No. L361, 2-m double rod, available from the Gaertner Scientific Corp., 1201 Wrightwood Ave., Chicago Ill. The bench is used to mount the multiplier phototube housing.

6. Goniometer (Fig. 8): Designed by the Michigan Department of State Highways Research Laboratory. The various assemblies of the goniometer were custom-made to rough tolerances and then finished and assembled in the laboratory's machine shop. The goniometer will accept any lighting or lighted samples essentially producing a horizontal light beam up to maximum sample size of 42-in. wide and 36-in. high. Mounting devices or jigs (Fig. 9) were built to attach either reflector buttons or reflective sheeting to the goniometer. The jigs not only facilitate sample mounting but also provide a simple means of aligning the samples in the light path center. Individual reflector buttons are tested while spinning to eliminate or average orientation effects, and thus this jig has a mounted 1725-rpm motor.

7. Foot-Candle Meter (Fig. 10): General Electric Model SL 480, Ranges 0-2, 0-6 and 0-20, available from General Electric Large Lamp Dept., Cleveland, Ohio. This meter is used to measure the illumination from the projector incident on the reflector. It is held perpendicular to and facing the projector by means of a bracket on the goniometer.

8. Reference Lamp (Fig. 11): 100 w, T 8-1/2 microscope lamp with a CC13 filament, medium screw base, base down, 120 v. (G. E. No. 100T8-1/2/9-120v). The reference is calibrated at 105v in the Research Laboratory from candlepower standards obtained from the Electrical Testing Laboratories, N.Y., N.Y. The lamp is mounted in a housing at the goniometer and is operated at a constant and readily monitored 105-v d.c. (Fig. 12). An aperture on the front of the housing permits use of the lamp as required during the test.

9. Power Supply (d.c.): Sorensen Model T 120-2.5, 0- to 120-v d.c., 2.5 amp (Fig. 11), available from Sorensen and Company, Inc. This is used to supply stable power to the reference lamp.

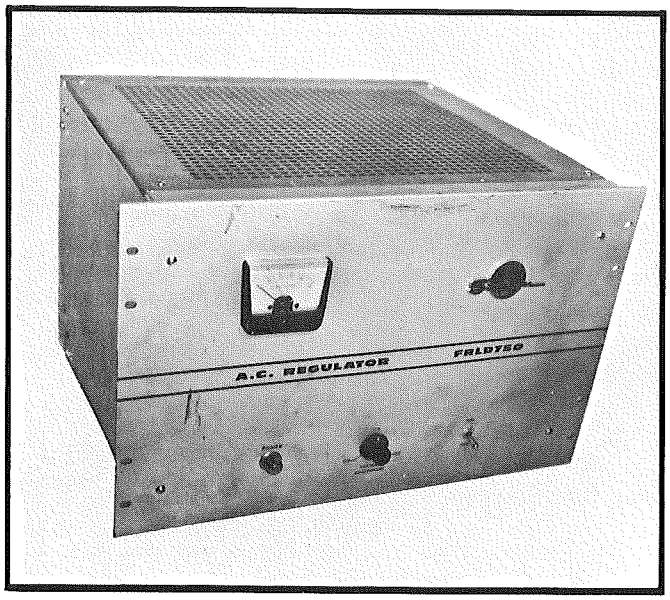


Figure 5. Voltage regulator.

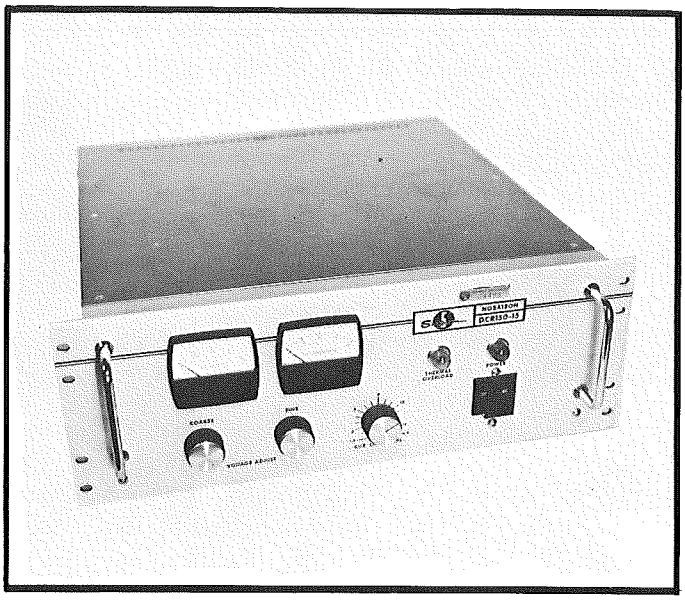


Figure 6. Power supply (d.c.) for projector lamp.

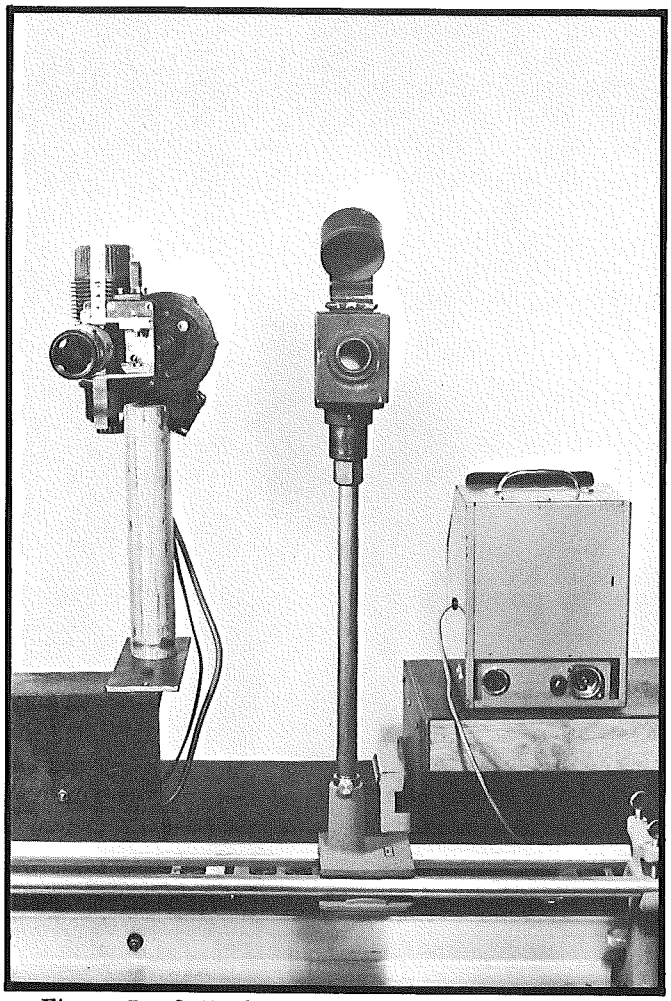


Figure 7. Optical bench with projector and photo-tube receptor.

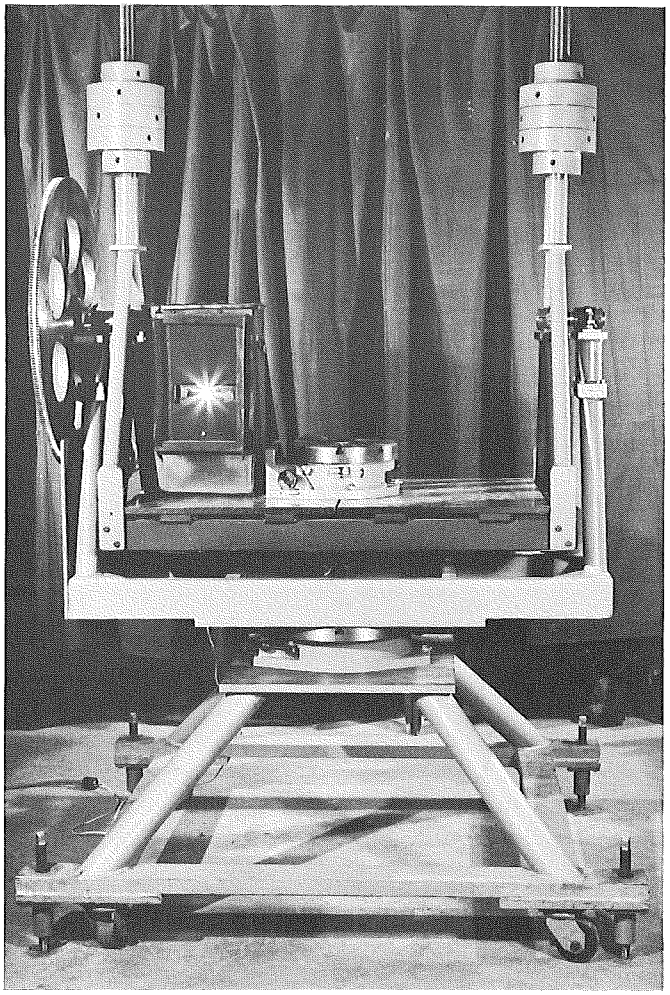
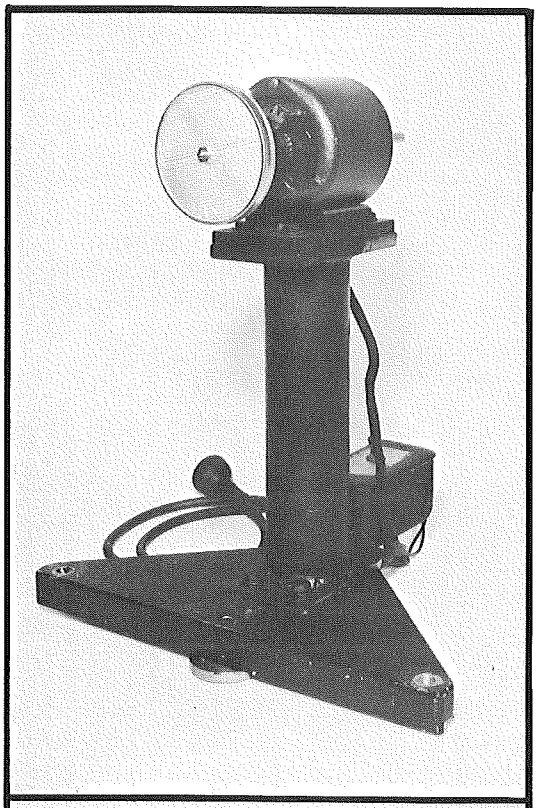


Figure 8. Goniometer.



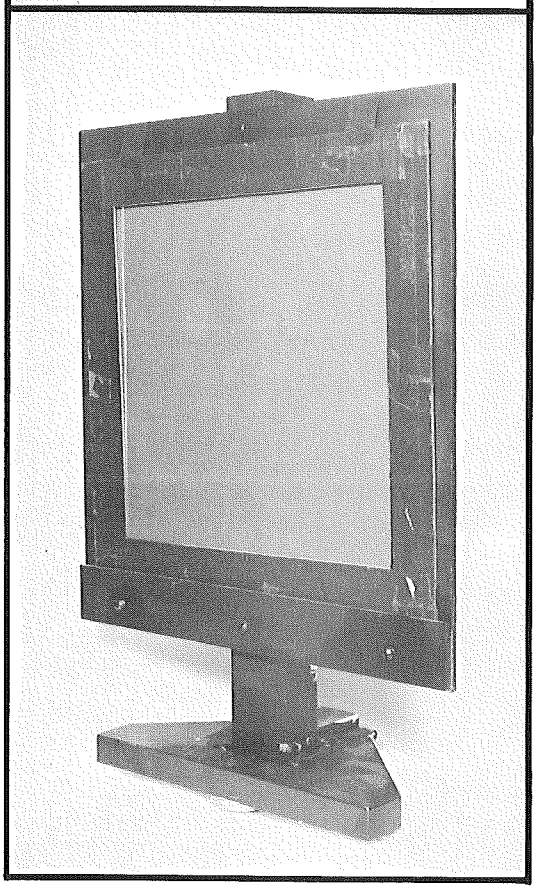


Figure 9. Reflector button and reflective sheeting jigs.

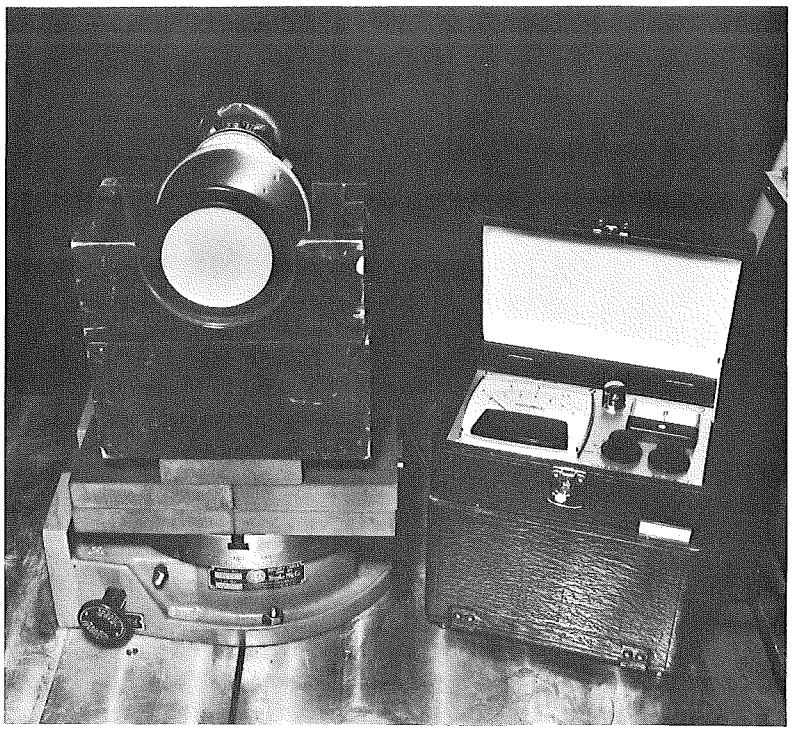


Figure 10. Foot-candle meter.

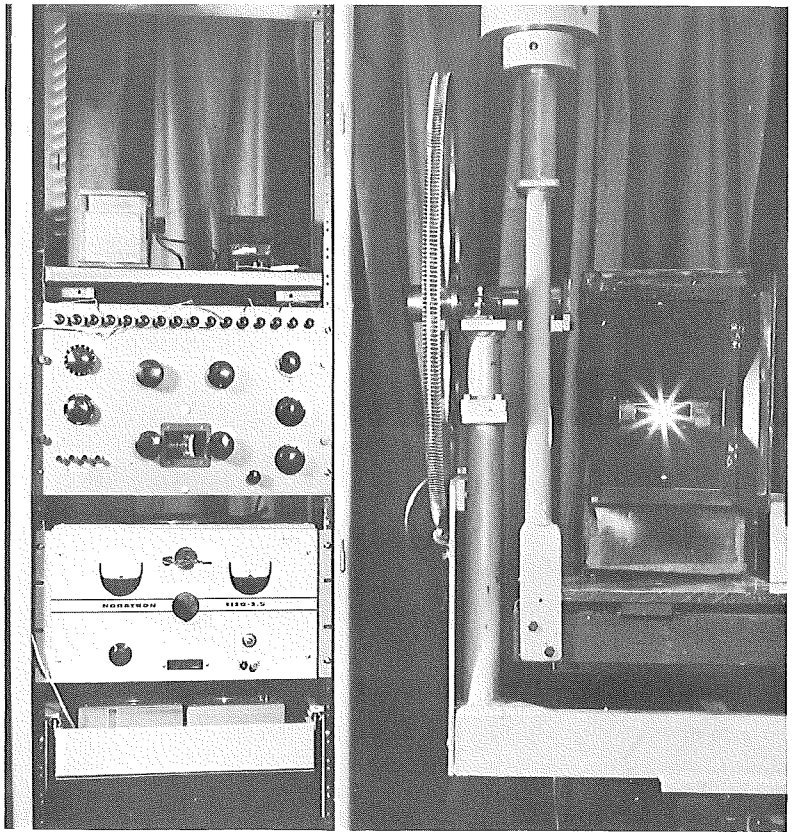


Figure 11. Reference lamp with power supply and voltage monitoring equipment.

10. Potentiometer with Volt Box: Leeds and Northrup, Model K-3 Potentiometer; with volt box, Catalog No. 7582, rated at 750 ohms per v (Fig. 11).

11. Galvanometer: Leeds and Northrup, Catalog No. 2420-C, having a sensitivity of 0.020 microamps per mm (Fig. 11). This is used as a readout for the potentiometer.

The equipment is located in a dark room 10-ft high, 14-ft wide, and 125-ft long, providing a maximum light path length of 100 ft. The room is painted black and has black cloth baffles at 20-ft intervals along one wall and on the floor. The other wall is a black curtain with folds to trap stray light.

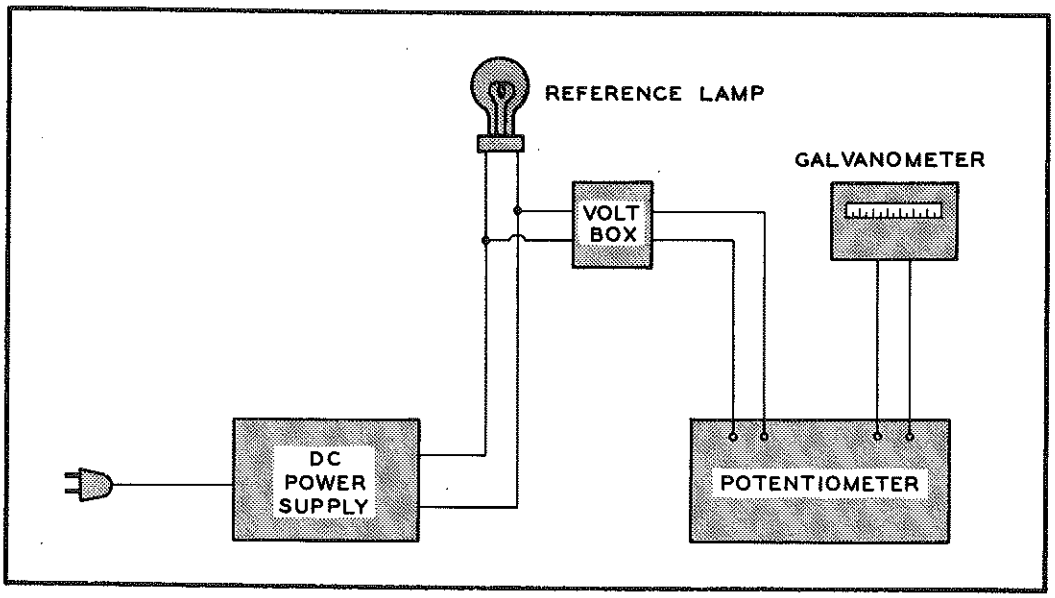


Figure 12. Circuitry for reference lamp operation and voltage measurement.

Test Procedure

The photometric test proceeds as follows:

1. Allow microphotometer, reference lamp, and power supply to stabilize for at least 30 min.

2. Adjust reference lamp to operate at calibration voltage.

3. Mount sample in goniometer.

4. Position phototube mount on optical bench to obtain desired observation angle.

5. Mask the phototube and zero the microphotometer.

6. Open the aperture on the reference lamp housing, remove the mask from the phototube, and record the microphotometer scale reading.

7. Close the aperture at the reference lamp.

8. Mask phototube, turn on projector, and after approximately 1 min re-zero the microphotometer.

9. Rotate goniometer to desired sample entrance angle and remove mask from phototube.

10. Record microphotometer scale reading.

11. Repeat Steps 9 and 10 for other entrance angles.

12. Cover sample with black velvet, record microphotometer scale reading, and then turn projector "off."

13. Check microphotometer calibration by repeating Steps 2, 5, 6, and 7.

14. Measure illumination at the sample with the foot-candle meter.

Calculations

Calculations in order of testing, are as follows:

a. Since the candlepower of the reference lamp is known, the candlepower per scale division of the microphotometer can be obtained after completing Step 6.

b. Determine the corrected microphotometer scale reading for the reflector at each angle by subtracting the reading obtained in Step 12 from the reading obtained in Step 10.

c. Determine the apparent candlepower of the reflector at a given angle by multiplying results of calculations "a" and "b."

d. Determine the specific intensity of the reflector by dividing the apparent candlepower (calculation c) by the incident foot-candles (Step 14) and the area of the reflector:

$$\text{specific intensity} = \frac{\text{apparent candlepower}}{\text{incident foot-candles x area}}$$

e. Report specific intensity of reflector buttons on the basis of area in square inches, and the specific intensity of reflective sheeting on the basis of area in square feet.