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MICHIGAN
STATE HIGHWAY DEPARTMENT
Charles M. Ziegler
State Highway Commissioner

MICHIGAN STATE HIGHWAY DEPARTMENT PHOTOMETRIC TEST FOR REFLECTIVE MATERIALS

B. W. Preston

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SYNOPSIS

This report describes photometric equipment and procedures employed by the Michigan State Highway Department Research Laboratory, for testing reflective materials. A method for computing data, a sample data sheet, and photographs of the testing equipment are also given.

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Basically, the photometric equipment consists of a permanently mounted light source, a tri-axially adjustable sample-mounting device called a goniometer, and a photomultiplier tube receptor with necessary filters located adjacent to the light source. (Figure 1)

Light incident on the sample is reflected in its individual characteristic pattern back to the photomultiplier tube which transforms this light to electrical energy. This is then amplified and indicated on a meter. A standard lamp of known intensity is located near the sample. This is used to calibrate the photomultiplier-amplifier-meter combination as necessary. The distance between the projected light source and the adjacent receptor is variable permitting changes in the divergence angle. By adjusting the mounted sample to the desired entrance angle and using the appropriate divergence angle, actual field conditions can be simulated for any distance from 50 to 500 feet. The entire device is enclosed in a light-proof tunnel which is 50 feet long with small roomettes at each end for equipment and operators (Figure 2). Following is a list of the equipment used:

Projector, Bell and Howell, 16 mm; less lens, film driving mechanism, and shutter, using only condensing optics, projector housing and blower (Figure 3).

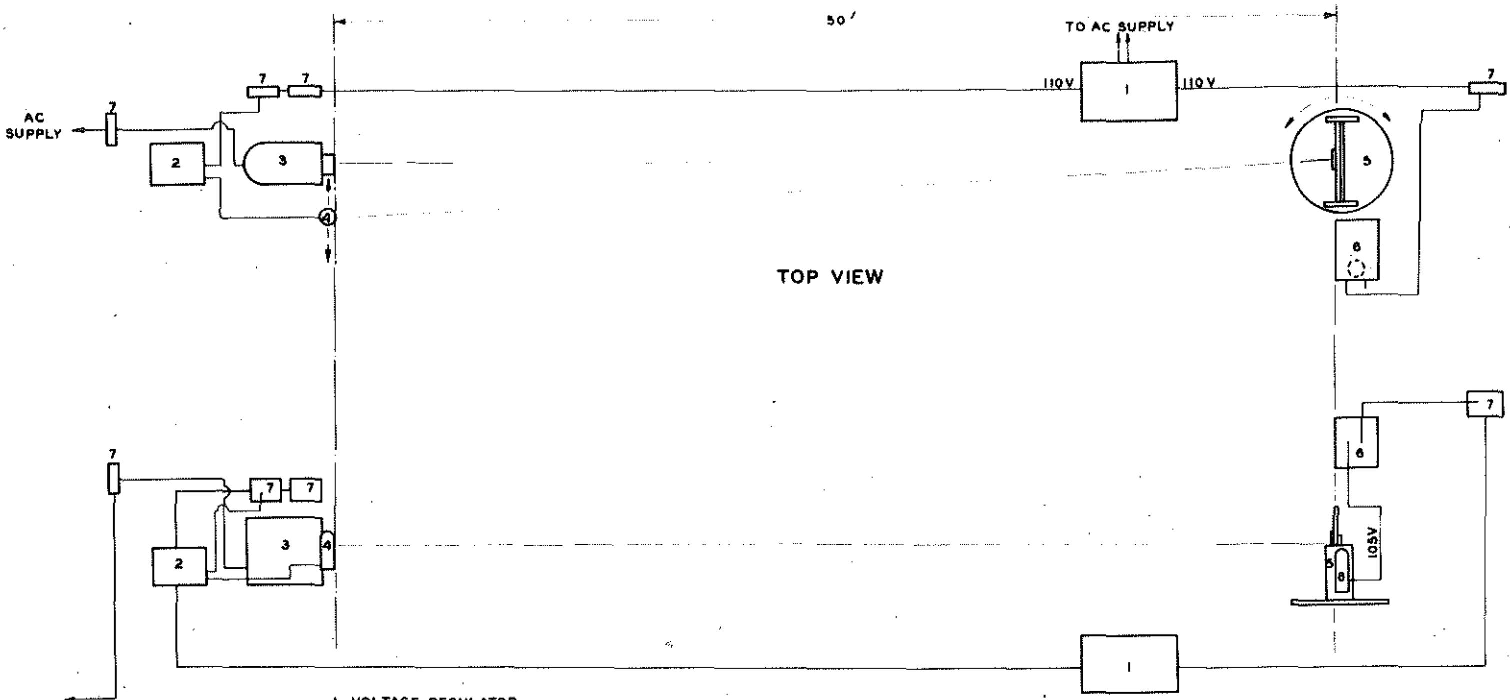
Lens, 7-inch f4.5 Luxtar I anastigmat, Viewlex Inc., Long Island City, N.Y. (This lens is designed for 35 mm. slide projectors).

Lamp, standard, and mount; available from Photometry and Colorimetry Section, Optics and Metrology Division, National Bureau of Standards, Washington, D. C.

Goniometer, steel, made in the MSHD Research Laboratory shop (Figures 4A and 4B).

Photomultiplier Microphotometer, model 10-210, complete with 1P22 multiplier tube and Corning filters No. 3307 and No. 4308 (available from American Instrument Company, 810 Georgia Avenue, Silver Spring, Maryland). Cost is about $550.

Voltage Regulator, Sorenson Model 1000 S. Sorenson & Co., Stamford, Connecticut.



1 VOLTAGE REGULATOR
2 PHOTOMULTIPLIER
3 LIGHT SOURCE (BELL & HOWELL)
4 PHOTOMULTIPLIER TUBE
5 GONIOMETER
6 VARIABLE TRANSFORMER
7 OUTLETS
8 STANDARD LAMP

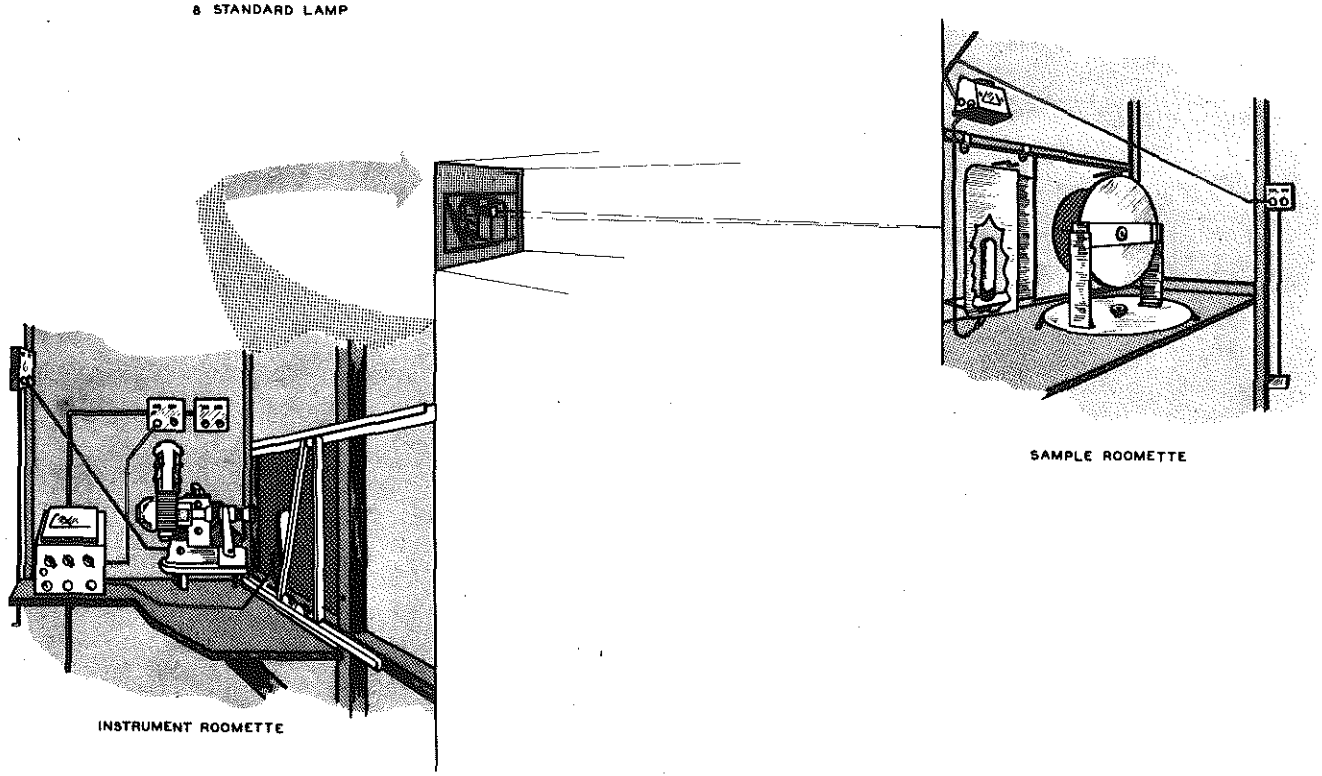


FIGURE I
SCHEMATIC DIAGRAM OF THE PHOTOMETRIC TESTING EQUIPMENT

Transformer, variable with voltmeter; Superior Electric Company, Type UC1M; Superior Electric Co., Bristol, Connecticut.

Filter, 10-percent neutral density; American Optical Company (specially made).

Foot-Candle Meter, Weston Model 614; Weston Electrical Instrument Co., Newark, New Jersey.

The roomette which contains the goniometer is referred to as the "sample" end of the light tunnel (Figure 5). This sample end contains the goniometer with the test sample attached to its face. Adjacent to the goniometer is the standard lamp in its mount with shield. The lamp voltage is set at the specified voltage with the variable transformer. This variable transformer is connected to the voltage regulator to assure a uniform light output from the lamp. The standard lamp is shielded so as to prevent any light from striking the sample. A system of hinged black doors is arranged in front of the lamp and sample which permits the exposure of either device to the tunnel or the complete masking of both.

The roomette containing the projector and microphotometer is referred to as the "instrument" end of the light tunnel (Figure 6). This instrument end contains the converted projector with the specially attached 7-inch focal length lens. The projector film gate mask was removed and replaced with a new mask having a circular aperture which produces a circular light pattern which is the diameter of the goniometer face at the 50-foot distance. Power for the projector is supplied directly from the power line and not from the voltage regulator as to the other equipment. Starting the projector in mid test, which is necessary, was found to disrupt the adjustments of the standard lamp and microphotometer.

The microphotometer is connected to the voltage regulator and mounted in the instrument end of the tunnel. The 1P22 photomultiplier tube is shielded and mounted on a trolley device beside the projector so that the distance between them is adjustable. This permits selection of divergence angles from $1/5^{o}$ to 2^{o} as desired. In front of the opening in the photomultiplier shield is a mount designed to receive standard 2-inch square filters. The two Corning filters (No. 3307 and No. 4308) are placed in this mount. These filters correct the spectral response of the photomultiplier tube so that it matches the spectral response of the human eye. The 10-percent neutral density filter is also placed in this filter mount as desired to increase the range of the instrument without making any electrical adjustments.

Other equipment used includes an inter-communication system between the sample end and instrument end of the tunnel, and darkroom type exhaust fans in each roomette. The voltage regulator is located outside the tunnel to facilitate heat dissipation.

Prior to actual testing procedures, all equipment except the projector is allowed to warm up and become stable for a period of at least one-half hour.

The actual test consists of four basic steps:

1. Calibration of microphotometer with the standard lamp.

2. Measurement of total reflected light from test sample and ambient secondary sources with the microphotometer.

3. Measurement of ambient light only.

4. Calibration check as in Step 1.

In detail, the test proceeds as follows. (Refer to the sample data sheet attached). After the equipment has warmed up sufficiently, the voltage of the standard lamp adjusted, and the microphotometer adjusted and zeroed out, the operators proceed with Step No. 1. With the projector off, the sample masked, and the standard lamp exposed, the number of galvanometer divisions on the microphotometer is recorded for the standard lamp. This figure, a similar figure obtained later by Step No. 4, and the known intensity of the standard lamp give the sensitivity of the device in terms of the average number of foot-candles of light received by the photomultiplier tube for each galvanometer division indicated. For Step No. 2, the projector is on, the standard lamp shielded, the sample exposed, and the microphotometer still operating as in Step No. 1. The goniometer is set to the desired entrance angle and the photomultiplier tube to the proper divergence angle to simulate the desired viewing distance (see sample data sheet). The galvanometer is read and the number of galvanometer divisions recorded in the "total" column. For Step No. 3, both the sample and the standard lamp are shielded; the projector is on. The galvanometer is again read and the number of galvanometer divisions recorded in the "basic" column. This "basic" figure represents that light which is incident on the photomultiplier tube face from sources other than the sample. Step No. 4 is identical to Step No. 1. These provide us with two things - the average instrument sensitivity for the test, and an indication of the stability of the apparatus for this period.

FIGURE 2. VIEW OF INSTRUMENT AND SAMPLE ROOMETTES AND CONNECTING 50 FOOT TUNNEL.

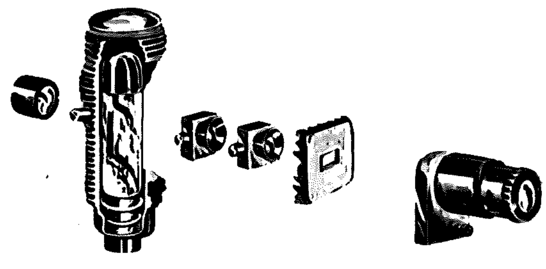


FIGURE 3. MODIFIED BELL AND HOWELL PROJECTOR LENS ASSEMBLY.

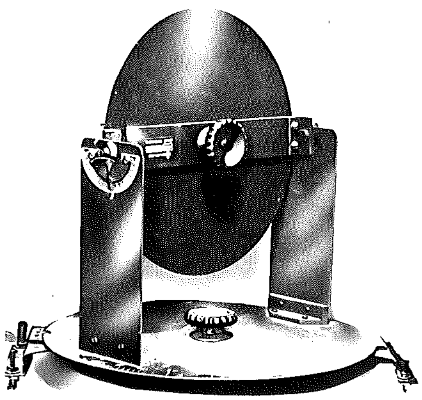


FIGURE 4A. BACK VIEW OF GONIOMETER.

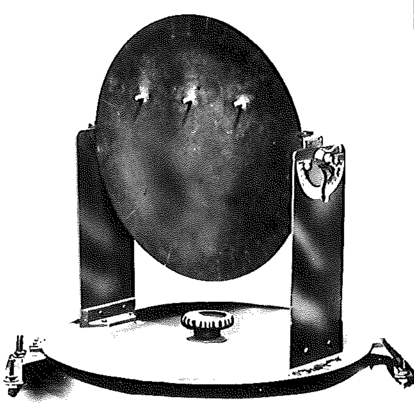


FIGURE 4B. FRONT VIEW OF GONIOMETER.

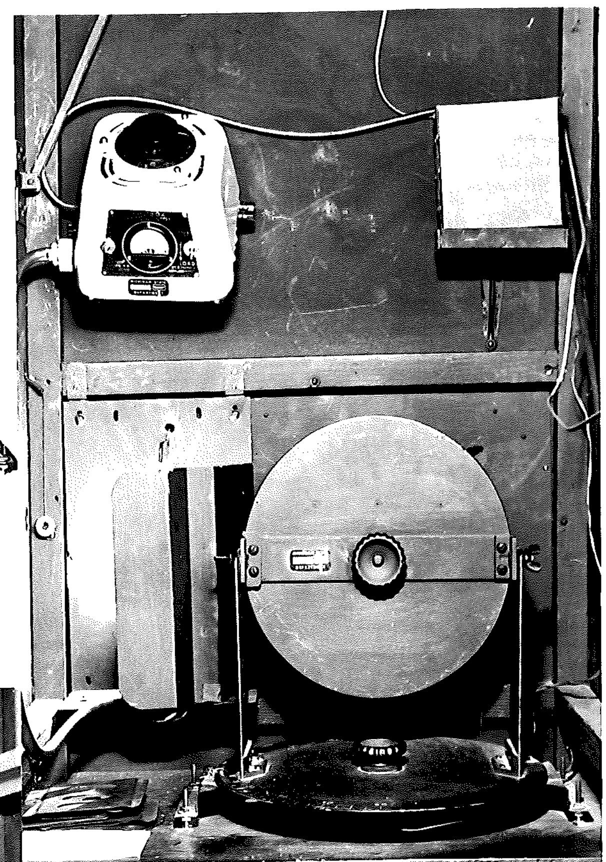


FIGURE 5. "SAMPLE" ROOMETTE, CONTAINING TRANSFORMER, STANDARD LAMP, AND GONIOMETER.

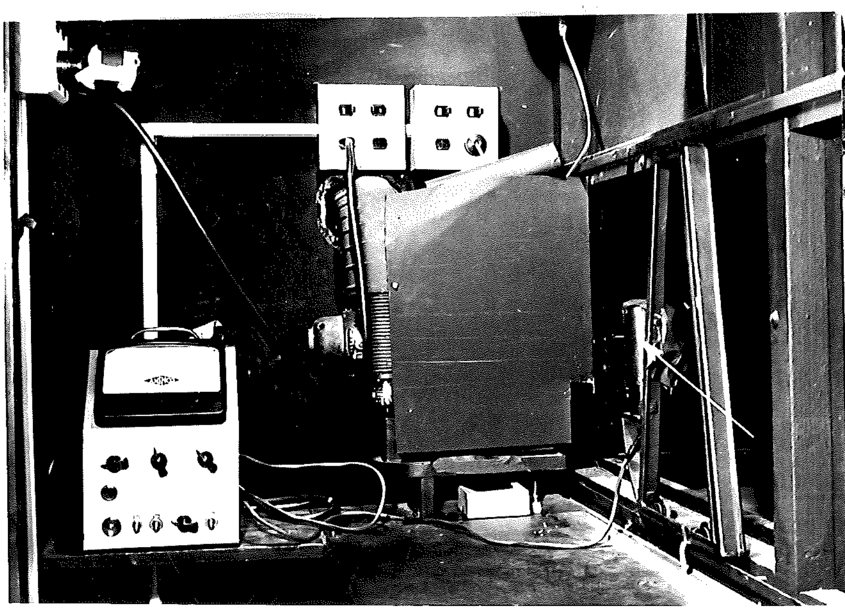


FIGURE 6. "INSTRUMENT" ROOMETTE, CONTAINING A PROJECTOR, PHOTOMULTIPLIER MICROMETER, AND A MULTIPLIER TUBE (SEE ARROW).

In many cases, Steps 2 and 3 are repeated for various entrance and divergence angle settings before proceeding with Step No. 4. This has been done with the example shown on the sample data sheet. In this example, six sets of readings were taken consecutively, the calibrations being made only at the beginning and conclusion of the series. This procedure is found to be quite satisfactory.

The incident light measurement is made with the foot-candle meter in the position of the sample with only the projector on. This is done at any convenient time since it is quite stable.

Calculation of this data to determine the specific intensity in terms of candle power of light reflected from each square foot of the sample for each foot-candle of incident light are as follows:

actual galvanometer div's. = total div's. - basic div's.

apparent candle power = actual div's. x (0.000439 ft. c./div.) x (test distance)^2

$$\text{specific intensity} = \frac{\text{apparent candlepower}}{\text{incident ft. c. x area}}$$

For reflectorized sheet materials, reflector area in the specific intensity unit is expressed in terms of square feet; for reflector buttons, which are usually of a higher order of brightness, unit area is the square inch.

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SUPPLEMENTARY LABORATORY NOTES

Effective Distance	Entrance Angle	Divergence Angle	Galvanometer Divisions Total	Basic	Actual	Apparent Candlepower	cp. / ft.c. x sq. ft.
500 ft	2^o	$1/5^o$	11.8	0	11.8	12.95	5.7
300 ft	3^o	$1/3^o$	9.3	0.5	8.8	9.66	4.2
200 ft	5^o	$1/2^o$	6.2	0.5	5.7	6.26	2.7
100 ft	10^o	1^o	5.8	0.3	5.5	6.04	2.6
75 ft	15^o	$1\text{-}1/2^o$	3.3	0.2	3.1	3.40	1.5
50 ft	20^o	2^o	1.6	0.1	1.5	1.65	0.7

Standard lamp intensity = 0.0358 ft. candle at 50 ft.

Calibration = $\frac{81 + 82}{2}$ = 81.5 galv. divisions average

= 0.000439 ft. c./galv. division

Sample area = 0.327 sq. ft.

Incident light = 7.0 ft.c.

Microphotometer Adjustments:

Meter calibration = 26

Meter multiplier = 0.1

High voltage = maximum

Test distance = 50 feet