A Method for Measuring the Reflectance of Cloth Samples in Detergency Tests

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THE common laboratory detergency test consists in washing artificially soiled cloth swatches by hand or in an Atlas Launderometer. The reflectances of the swatches before and after washing are measured. The reproducibility of the reflectance change in such tests is poor, and a statistical analysis of the data usually indicates that a large number of test swatches would be necessary to determine a reliable average value. Woodhead, Vitale, and Frantz (1) developed a test in which the average change in reflectance of 20 swatches was obtained with a reproducibility of $\pm 6\%$. The swatches, which were selected from stocks of various ages of soil, were machine-washed in a single batch. Five reflectance measurements were made on each side of every washed swatch with a Lange type reflectometer. The average of 200 readings was taken as the reflectance of the washed set. This procedure requires much work and time.

With the Hunter multipurpose reflectometer, the number of readings per swatch can be reduced to one for each side for an over-all reproducibility of 6.0% in the average reflectance change. However, more time is required to make a reflectance measurement with the Hunter reflectometer than with the direct reading Lange instrument. Forty readings with the Hunter reflectometer required more time than 200 readings with the Lange reflectometer.

We have developed a simple method of measuring the average reflectance of the 20 swatches where only two reflectance measurements are required. Consequently little more work or time is required for a detergency test using 20 swatches than for a test based on one or two swatches. The principle of the method is similar to that of disc colorimetry technique (2). We shall describe the method as applied to 1½ x 2-inch swatches laundered in a small laboratory washing machine.

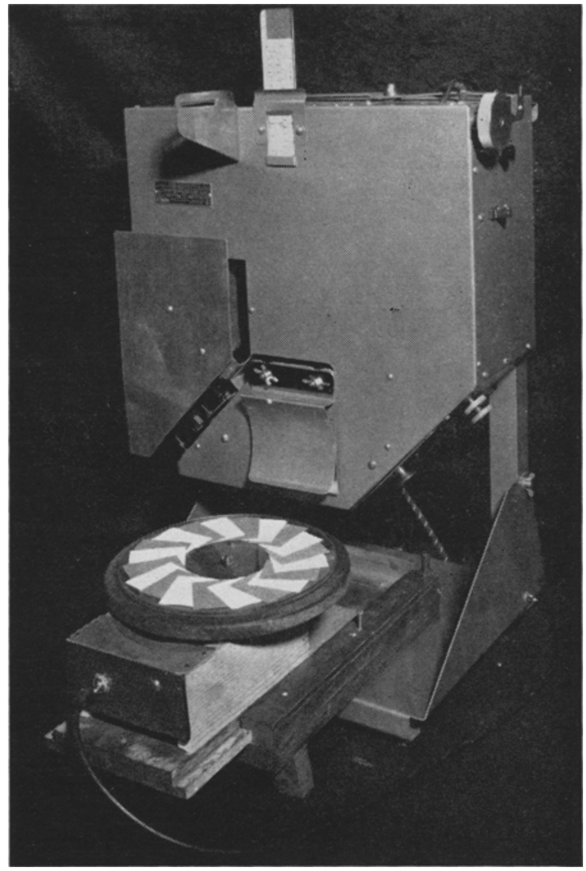

FIG. 1. Phonograph turntable on sliding track under Hunter reflectometer.

Alternate white and soiled pieces of cloth have been placed on the turntable to show individual swatches.

Experimental

I. *Apparatus and Materials.* Reflectance measurements were made with a Hunter multipurpose reflectometer (3). The green filter was used in the incident beam. A lens supplied by the manufacturer was used to reduce the incident beam area from approximately 4½ square inches to ⅔ square inch. A Rubicon galvanometer with a period of 5.1 seconds and sensitivity of 0.0025 microamperes per millimeter was used to indicate the balance point. A phonograph turntable was mounted under the reflectometer as shown in Figure 1. In order to show the individual swatches on the turntable alternate white and soiled swatches have been used for this photograph. The distance between the turntable surface and the reflectometer opening was $^3/_{10}$ inch (0.76 cm.).

Circular glass plates $^3/_{32}$ inch thick and 8 inches in diameter had holes drilled in their centers to fit the peg on the turntable. These discs were matched so that readings of the reflectance standards supplied with the Hunter reflectometer were reproduced within 0.001 Hunter reflectance units when the standards were read through the discs. In the preparation of secondary reflectance standards, as described below, a sheet of $^1/_{32}$-inch cardboard and gray flint papers were used.

A small laboratory washing machine was used in which 20 swatches were free to move about in a liter of detergent solution agitated at constant speed. The swatches were cut from a single batch of cotton fabric artificially soiled by the process described by Van Zile *et al.* (4). Two synthetic detergents and a soap were selected to illustrate the use of the method of reflectance measurement. Detergent A was of the sodium monoglyceride sulfate type. Detergent B was of the sodium alkyl aryl sulfonate type. The soap was an unbuilt tallow soap of about 40° titre. Distilled water solutions were used for all the tests.

The data reported in Tables I and II were obtained with the 8-inch turntable described above. For over two years a 16-inch turntable with another Hunter reflectometer has been used for routine detergency tests. The full reflectometer beam (unreduced) is utilized with the larger turntable.

II. *Reflectometer Calibration.* The sample holder supplied with the Hunter reflectometer was removed to allow the installation of the phonograph turntable. Consequently, the reflectance standards supplied with the reflectometer were not suitable for routine calibration of the instrument. Reflectance measurements were to be made on cloth samples sandwiched between glass discs 8 inches in diameter and 3/32 inch thick. It was desirable to calibrate the apparatus so that measurements on the cloth surface under the 3/32-inch glass plate would correlate closely with data obtained by the usual measurements made in the absence of the glass.

For calibration of the reflectometer a secondary standard sandwich was prepared by permanently binding two gray flint paper discs, 8 inches in diameter, between two of the glass discs. Each gray paper was selected to match one of the primary standards supplied with the reflectometer. The papers were backed with a single sheet of 1/32-inch cardboard and the assembled secondary standard was permanently bound with lantern slide tape. The glass surfaces protect the gray papers from soil. A reflectance value for each side of this secondary standard assembly was determined as the average of 20 random readings made as usual with the Hunter reflectometer except that the turntable was not used and the photometer scale was adjusted to give a correct value for each primary standard read through another matched glass disc.

When this secondary standard was placed on the turntable, one of the gray paper discs was in the plane ordinarily occupied by the surface of the cloth samples in their glass sandwich. The reflectometer sample opening to glass plate clearance was 0.06 inch. The turntable was set in rotation at 120 r.p.m., and the reflectance scale was reset to fit the known reflectance value for the gray paper surface. The galvanometer showed a slight oscillation under these operating conditions. The reflectometer was adjusted until the oscillation was symmetric about the center of the scale.

By turning the secondary standard sandwich upside down, another point on the photometer scale may be readily calibrated. Two of these secondary standard assemblies furnishing four known reflectance values were used for routine calibration of the reflectometer. This method of calibration minimizes the effect on data of turntable libration or any slight increase in the spacing between the turntable and the reflectometer sample port due to extensive turntable wear.

III. *Washing of the Swatches and Reflectance Measurement.* Twenty soiled swatches were washed for 20 minutes at 110°F. in each run. Five runs each were made with 0.25% Detergent A, 0.25% Detergent B, and 0.3% soap. The rinsed and dried swatches were trimmed to remove all frayed edges. The swatches were arranged on one of the glass discs in the pattern shown in Figure 3, with the edges overlapping in the manner indicated. A second glass disc was placed over the swatches and the two plates with the cloth between them were transferred to the turntable in position for measurement as shown schematically in Figure 2. Individual reflectance readings were made with the incident beam at the center of each swatch, and another series of individual readings with the incident beam at the edge where the two cloths overlapped. The difference between the average of these "center" and "edge" readings was small. For example, 200 centers of swatches washed with Detergent A had an average reflectance of 0.322 Hunter units, whereas the corresponding edges averaged 0.325 units. After taking individual readings, the phonograph turntable was set in rotation at a speed of 120 r.p.m. and the reflectance remeasured. By turning the plates upside down the other side of the swatches was placed in position for measurement.

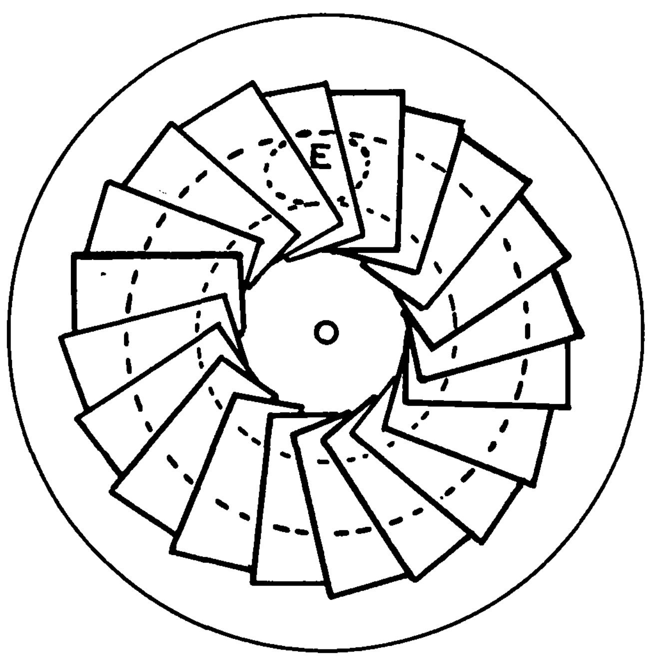

FIG. 3. Pattern of Swatches on glass disc. The area scanned during rotation is included between the dotted circles.
E—elliptical area illuminated by incident beam.

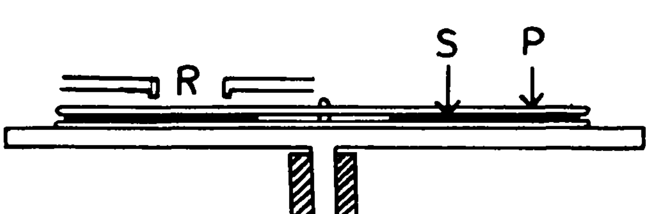

FIG. 2. Side view of turntable in position for measurement. P—upper glass plate. R—reflectometer opening. S—cloth swatch.

IV. *Precision of Measurements.* The cotton fabric used in the above tests showed an increase in the distance between the glass plates after washing. This change was 0.002 units on the portion of reflectometer scale used. Other errors have been eliminated by proper calibration of the apparatus. Without calibration the total cumulative errors seldom exceed 2% of the reflectance value. The precision of the readings with or without calibration is entirely adequate for the present detergency tests.

Data. The minimum and maximum individual reflectance readings for each run are listed in the first two columns of Table I. These values show the order of reproducibility which may be expected from detergency tests which use a single swatch. In the third

TABLE I

Reflectance Values for Individual Sets of Twenty Swatches (Values in Hunter Units × 1,000)

Swatch Set	Minimum Value in Set	Maximum Value in Set	(a) Average Value of the 20 Swatches in Set	(b) Average Value of Both-Sides Read with Rotating Turntable	% Deviation of b from a
Random soiled samples (unwashed)	195	217	210	210	0
	193	221	204	208	2
	195	216	205	207	1
	198	217	208	208	0
	196	220	207	209	1
Samples washed in 0.25% detergent A solution	289	368	319	320	0.3
	294	360	324	324	0
	291	358	323	324	0.3
	298	370	325	327	0.6
	296	360	325	326	0.3
Samples washed in 0.25% detergent B solution	340	402	359	359	0
	324	392	356	357	0.3
	328	390	356	357	0.3
	322	418	363	364	0.3
	314	380	353	352	0.3
Samples washed in 0.3% soap solution	317	406	374	375	0.3
	350	397	372	367	1.3
	334	399	367	369	0.5
	347	410	368	370	0.5
	320	401	366	371	1.4

column are shown the averages of all individual reflectance readings made on both sides of the 20 swatches. In calculating these averages, a summation was made of the values obtained with the incident beam at the centers of the swatches and values measured with the beam at the edges between overlapping swatches. The remaining columns of Table I show the agreement between the average reflectance value of the individual readings and the value read from the rotating samples. The excellent agreement between the average of individual swatch readings of all five runs and the average of the corresponding values obtained with rotation is evident from the data shown in Table II. This comparison is a fairly critical test of the method since the probable error of an entry in the first column of Table II is 0.002 Hunter reflectance units or less.

TABLE II

Average Reflectance Values for Five Consecutive Runs (Values in Hunter Units × 1,000)

	Average Reflectance from Individual Readings	Average Reflectance from Rotating Turntable
Random soiled samples (unwashed)	207	208
Samples washed in detergent A solution	323	324
Samples washed in detergent B solution	357	358
Samples washed in soap solution	369	370

Discussion

The glass plate over the samples does not interfere with the (45°, 0°) reflectance measurement. The terminology (45°, 0°) as defined by Hunter (3) means that the incident beam strikes the sample at an angle of 45° with the normal to the surface, and that the reflected beam is observed in a direction coinciding with the normal. Virtually none of the light reflected by the glass is present in the 0° beam. The constant proportion of light lost due to transmission through the glass is automatically compensated by the usual adjustment of light incident on the photocell of the reflectometer.

No shielding was necessary to keep stray light from entering the reflectometer under ordinary indoor illumination with 0.06 inch (1.5 mm.) clearance between the glass discs and the reflectometer opening. Within the reflectance range of the above data, background reflectance under the swatches did not affect the measurement. Some sort of pattern is advisable for placing the swatches on the disc. If the angle between the fabric warp and the plane of the 45° and 0° beams is varied, a 10% change in the reflectance occurs for the cotton fabric used in the above tests. It is useless to add this variation due to angular orientation to the statistical variations already present.

It will be noted in Figure 3 that the swatches overlap in a clockwise pattern. This arrangement was adopted because the 45° incident beam is directed on the disc from the left of the ellipse E. The overlapped edge is not illuminated from this direction, and the edge appears almost invisible when viewed from a position directly over E where the photocell scans the sample.

In the present work the change in reflectance was negligible for turntable speeds between 78 and 200 r.p.m. A slower speed of 33⅓ r.p.m. was not satisfactory.

Summary

The scanning of a number of swatches on a turntable rotating at 78 r.p.m. or faster, with a Hunter reflectometer yields the average reflectance of the set. The use of a glass plate to cover the cloth samples does not affect the reflectance measurement. Much time and work can be saved by application of the scanning technique to detergency tests employing multiple swatches of cloth.

Acknowledgments

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