The Stain Removal Index (SRI): A New Reflectometer Method for Measuring and Reporting Stain Removal Effectiveness

O.W. NEIDITCH, K.L. MILLS and **G. GLADSTONE,** Lever Brothers Company Research Center, 45 River Road, Edgewater, NJ 07020

ABSTRACT

The development of laundry stain removal test methods is currently receiving attention in task groups of 3 major standards developing organizations in the U.S. The need for such test methods is reflected in the proliferation of products for presoaking or pretreatment of stained laundry items prior to washing or for addition to the main wash solution to help insure complete removal of stains. Proposed test methods involve: (a) a standardized staining procedure, (b) pretreatment or presoaking of the stains, and/or (c) a wash in a detergent solution which may include an additive, (d) visual or instrumental evaluation of the degree of stain removal, and (e) calculation of percentage stain removal when instrumental evaluation is used. Calculation of percentage stain removal involves the use of the reflectance value of the applied stain. This can lead to anomalies in results due to the failure of reflectance readings to be directly proportional to the amount of stain applied. This paper describes the stain removal methodology developed by the authors including an instrumental method for reading and a procedure for calculating the stain removal effectiveness of any pretreatment, presoaking, and/or wash procedure. This instrumental method and the calculation described as the "Stain Removal Index" (SRI) overcomes many of the anomalies found with percentage stain removal calculations and presents results which parallel visual appearance. The "Stain Removal Index" defines the relationship of the appearance of the treated and washed stain fabric to the appearance of an unstained fabric of the same material.

INTRODUCTION

In general terms, a stain is any undesirable matter present on a substrate which has an adverse effect on the appearance of the substrate. When referring to fabrics, stains are usually caused by substances which are distinguished from soiling derived from normal use of the particular household article or item of clothing. Stains are often colored and are usually localized. Stains can be divided broadly into 2 types: (a) stains such as rust, ink and paint, which are not removed by normal or even abnormal wash treatment and require special chemical or solvent treatment; and (b) stains largely removed by appropriate wash treatment (1).

The reduction or elimination of phosphate in detergents because of environmental concerns and the reduction of water temperatures in the washing machine for both energy conservation and cost savings are contributing to increased stain removal problems in laundering (2-5). These stain removal problems are reflected in the proliferation of products for presoaking or pretreatment of stained laundry items prior to washing or for addition to the wash solution to help insure the complete removal of stains. Included among such products are (a) presoaks and detergency boosters, (b) prespotters, (c) bleaches, and (d) water softeners. In addition to these specialties, (e) heavy-duty liquid detergents and pastes prepared from detergent powders are used to a large extent to pretreat stains before laundering.

The importance of stain removal problems is further indicated by the great attention being given to this subject concurrently in task groups of the American Association of Textile Chemists and Colorists, The Chemical Specialties Manufacturers Association and The American Society For Testing and Materials—Committee D-12. Proposed test methods involve: (a) a standardized staining procedure, (b) pretreatment or presoaking of the stains, (c) a wash in a detergent solution which may include an additive, (d) visual or instrumental evaluation of the degree of stain removal, and (e) calculation of percentage stain removal when instrumental evaluation is used. One author has concluded, after being in the household cleaning field for more than 20 years, that every research laboratory involved in cleaning or bleaching evaluations has its own set of evaluatory procedures or test methods, and that these methods are based on varying histories of requirements and specialized experience (6).

MATERIALS AND METHODS

Fabric swatches were cut from garments purchased from normal commercial outlets. The swatches were cut 9 inches in the warp direction and 4½ inches in the fill direction. All swatches were prewashed 5 times at 130 F in 0 ppm hardness water using 0.14% concentration of a commercial anionic, phosphate detergent prior to application of staining materials. This was done to remove any residual spinning oils and any easily removed finish such as sizing.

Staining materials were chosen to represent a range of stains encountered by consumers. A standard amount of stain was applied to each fabric. This amount of stain was chosen to represent the minimal amount of material which could be evenly distributed over a 2-in. circle.

All staining materials were applied in the center of a 2-in. circle while the swatches were suspended between racks and allowed to wick until the stain covered the entire area of the circle. In all experiments, each stain was replicated on 4 swatches of each fabric type. Stains were aged for 1 hr prior to washing. This aging period was chosen as the minimal time necessary to obtain a difficult-to-remove stain.

After appropriate pretreatment, stained fabrics were washed in a Kenmore Model 90 washer using a normal cycle with a 12-min wash cycle followed by the normal spin, spray rinses and deep rinse. Washing machines were filled with 25.5 gallons of 100 F water having a water hardness of ca. 120 ppm. All washes were done with commercial detergents at the manufacturer's recommended use concentration. The washed swatches were dried in a heated drying cabinet.

REFLECTANCE MEASUREMENT

The reflectance and color of test swatches were measured on a Gardner XL-10a colorimeter, modified to include Noviol filters to eliminate fluorescence effects. Cloths were presented to the colorimeter in a stack of 4 replicates with the 2-in. stained circle centered in the aperture of the colorimeter. The stack of swatches was backed with a standard white, high-reflectance, backing plate.

When measuring the reflectance of fabrics, the background is important since some light is transmitted and reflected or absorbed by the background. To avoid back reflection, one can use a dull black backing or use enough layers of fabric to reduce the effect of the backing. The result of studies comparing single swatches and 4 replicate swatches backing each other showed less variability within products when the 4-fabric thickness was used. This, in turn, led to better differentiation between products when colored stains were tested. With the uncolored oil stains on a white fabric, single thickness readings with a dull black background are preferable. The use of an indicator dye can help in the reflectance measurements when evaluating otherwise colorless oil stains.

FORMULA 1. Percent stain removal calculation based on reflectance (lightness) change.

$$\% \text{ Stain removal} = \frac{L_W - L_S}{L_C - L_S} \times 100$$

L_S = stained swatch
L_W = stained and washed swatch
L_C = clean swatch prior to staining
L = lightness = $10\sqrt{Rd}$ or $10\sqrt{Y}$ or $10\sqrt{G}$

FORMULA 2. Percent stain removal calculation based on total color difference (ΔE).

$$\Delta E = [(\Delta L)^2 + (\Delta a_L)^2 + (\Delta b_L)^2]^{1/2}$$

$$\% \text{ Stain removal} = \frac{\Delta E_1}{\Delta E_2} \times 100$$

$$\Delta E_1 = [(L \text{ washed} - L \text{ stained})^2 + (a_L \text{ washed} - a_L \text{ stained})^2 + (b_L \text{ washed} - b_L \text{ stained})^2]^{1/2}$$

$$\Delta E_2 = [(L \text{ clean} - L \text{ stained})^2 + (a_L \text{ clean} - a_L \text{ stained})^2 + (b_L \text{ clean} - b_L \text{ stained})^2]^{1/2}$$

RESULTS AND DISCUSSION

Calculation of percentage stain removal based on reflectometer data has been widely used as a method of evaluating stain removal (Formula 1).

ΔE is another calculation based on color difference meter readings which is used for colored stains and colored fabrics (Formula 2).

Over a period of years, we have noted a number of problems in using these methods of calculation. Some examples of these problems are the following: (a) percentage stain removal may not describe the relative performance of products (Table I). Although the washed reflectance of the cloths in Table I indicates that the products were about equal in reflectance, percentage stain removal indicates a considerable difference in stain removal. This is due to the fact that both the clean and stained fabrics for these products had slight differences in reflectance, although they were in the range of normal variability. (b) Percentage stain removal is subject to low sensitivity when fabric or stain reflectances are low (Table II). Because of the low clean reflectance of the colored fabric in Table II, small differences in reflectance translate into a large difference in percentage stain removal. In general, dark-colored fabrics have a small range in reflectance between clean and stained readings and suffer from this problem. (c) Percentage stain removal tends to exaggerate differences between products (Table III). Table III demonstrates that a 1.7 unit reflec-

TABLE I

Cooking Oil Stain on Yellow Polyester

Product	L Clean	L Stained	L Washed	% Stain removal (L)
A	72.1	66.5	72.7	115.1
B	72.6	66.5	72.8	102.6
C	73.7	67.8	73.4	94.1

TABLE II

Cooking Oil Stain on Brown Polyester

Product	L Clean	L Stained	L Washed	% Stain removal (L)
A	44.2	28.5	43.8	97.1
B	44.4	31.6	41.8	79.5
C	44.2	33.6	39.0	51.2

TABLE III

Cooking Oil Stain on Tan Polyester

Product	L Clean	L Stained	L Washed	% Stain removal (L)
A	44.1	38.0	44.2	102.8
B	44.1	35.3	43.4	90.9
C	44.0	37.8	42.5	72.7

TABLE IV

Deep Olive Make-Up—Commercial Detergent

Fabric	L Clean	L Stained	L Washed	% Stain removal (L)
Cotton	96.2	50.5	57.3	11.1
Polyester/cotton 65/35 Permanent press	94.7	52.0	50.3	-2.8
Polyester	96.3	51.0	46.6	-6.4

tance difference translates into a difference of 30% in stain removal. (d) Percentage stain removal values greater than 100% can be obtained. This often is an indication that something other than the stain material, such as finish or dye, has been removed from the fabric. This can result in a value for "L washed" higher than for "L clean" and a calculated percentage stain removal greater than 100%. Examples of this also have been shown in Tables I and III. (e) Percentage stain removal can give values which are negative (Table IV). Negative results can occur when a stain is not removed but changes to a darker color. (f) Percentage stain removal does not describe the final appearance of stained fabrics. This has been demonstrated in Table IV and will be shown in more detail in the experiments which are discussed later in this paper.

To overcome the problems with stain removal calculations, we propose use of the expression "contrast," the formula of which is shown in Formula 3. In this calculation, the color values of the stained swatch are eliminated and the ΔE is calculated for the difference between the color values of the clean and the stained/washed swatch. The use of this expression depends on uniform staining of the swatches to minimize variability.

This method of reporting stain removal results offers the following advantages: (a) Contrast describes how close the stained and washed fabric is to the clean fabric. (b) Contrast allows color measurements into the stain removal calculation. (c) Contrast provides a better treatment of stain removal on colored fabrics. (d) Contrast provides better agreement with visual evaluation of differences between fabrics. (e) Contrast provides a more efficient way of conducting stain removal tests.

Final results are reported in terms of a stain removal index which is simply defined as 100 minus contrast.

$$SRI = 100 - \text{contrast}$$

In this expression, the higher number indicates the better appearance and is more understandable.

Some examples of how the use of stain removal index can improve the reporting of stain removal results are shown in Tables V-XI.

In Table V, percentage stain removal had indicated that the products were quite different, while in truth, the final appearance values of the cloths were quite similar. The stain removal index also indicates that the 3 products perform similarly, and confirms visual observations that the stains were virtually eliminated with all 3 products.

In Table VI, percentage removal calculations indicate that nearly half of the stain remains after washing in product C, whereas the stain removal index shows that most of the stain has been removed. The stain removal index judgement is in better agreement with visual observations.

In Table VII, results demonstrate that SRI can be applied to a very dark stain with no loss in discrimination.

In Table VIII, the results demonstrate that SRI can be applied to a colored stain, also on a fabric other than polyester.

In Table IX, the results indicate that SRI eliminates negative percentage detergency results.

In Table X, while percentage stain removal indicates that the comparable results were obtained on both fabrics, SRI indicates that the blue polyester is closer to the original than the yellow.

FORMULA 3. The contrast formula.

$$\text{Contrast} = [(L_C - L_W)^2 + (a_C - a_W)^2 + (b_C - b_W)^2]^{1/2}$$

L = lightness
a = redness (+) - greenness (-)
b = yellowness (+) - blueness (-)
C = clean
W = stained and washed

TABLE V

Cooking Oil on Yellow Polyester

Product	L Washed	% Stain removal (L)	SRI
A	72.7	115.1	98.1
B	72.8	102.6	98.1
C	73.4	94.1	97.9

TABLE VI

Cooking Oil on Brown Polyester

Product	L Washed	% Stain removal (L)	SRI
A	43.8	97.1	99.5
B	41.8	79.5	96.3
C	39.0	51.2	92.6

TABLE VII

Blue-Colored Cooking Oil on White Polyester

Product	L Clean	L Stained	L Washed	% Stain removal (L)	SRI
A	90.7	52.0	85.0	85.4	93.6
B	90.4	49.5	80.5	75.8	87.7
C	92.2	45.5	77.0	67.5	80.6

TABLE VIII

Red Lipstick on White Dacron/Cotton 65/35 Permanent Press

Product	L Clean	L Stained	L Washed	% Stain removal (L)	SRI
Y	93.0	39.3	91.0	95.2	96.3
Z	93.5	38.0	88.7	88.4	91.1

TABLE IX

Deep Olive Make-Up—Commercial Detergent

Fabric	% Stain removal (L)	SRI
White cotton	11.1	57.3
White dacron/cotton 65/35 Permanent Press	-2.8	52.1
White polyester	-6.4	47.4

TABLE X

Cooking Oil Stain

Fabric	% Stain removal (L)	SRI
Blue polyester	50.9	83.5
Yellow polyester	52.2	73.4

TABLE XI

Spaghetti Sauce on White Cotton—Commercial Detergent

Stain level (g)	% Stain removal (ΔE)	SRI
.11	83.4	94.8
.22	85.5	94.1
.44	86.3	92.0
.66	87.4	88.4

In Table XI, different levels of a stain were applied to a 100% cotton fabric. Percentage stain removal based on color difference readings showed an increase in percentage stain removal as a result of an increase in stain level, whereas the opposite is shown in using the SRI and also using visual examination.

REFERENCES

1. Neiditch, O.W., in "Detergency-Theory and Test Methods, Part I," edited by W.G. Cutler and R.C. Davis, Marcel Dekker, Inc., NY, 1972, pp. 5-29.
2. "Cost of Home Laundry," Homemaker Testing Corporation, Washington, DC, October 1974.
3. "Phosphate Detergents Ban Effects on Indiana Housewives," Walker Research, Inc., Morristown, NJ, W.R. #199-02, March 1976.
4. Olson, W.W., "Results of a Consumer Perception Survey on Laundry Procedures and Results," Department of Family Sciences, University of Minnesota, presented at 29th National Appliance Conference, Denver, CO, November 10, 1978.
5. Lyng, A.L., JAOCS, 55:170 (1978).
6. McClain, C.P., in "Detergency-Theory and Test Methods, Part II," edited by W.G. Cutler and R.C. Davis, Marcel Dekker, Inc., NY, 1975, pp. 519-612.

[Received June 12, 1980]