THE EFFECT OF RESIN FINISHES ON THE COLOR FASTNESS OF RAYON GABARDINES

by

WILDA MARGUERITE HAY

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INTRODUCTION

Color fastness of textiles has long been an important serviceability requirement demanded by the consumer. In the past the kind of dye, method of dyeing, and affinity of fibers to dyes have been the most determining factors upon color fastness. Today the dyer and finisher as well as the ultimate consumer are concerned with the effect of the new finishes.

Prior to the last world war textile finishing was limited to cotton goods sized with starch with the addition frequently of oil, soap, glycerine and talc. The natural fibers were the principal ones used. Ornamental and utilitarian requirements of fabrics were achieved through fiber differences and by variation in method of construction. More recently there has been an ever increasing demand for luxury goods. Due to the cost of pure dye silk and defects of weighted silk, rayon has been developed to take their place to a very great extent.

Manufacturers are endeavoring to give rayon the desirable characteristics of silk, wool and linen. To accomplish this new finishes are used to improve such qualities of rayon as draping, hand, dull and bright finish, crease resistance and color fastness.

The year 1940 witnessed the production of a number of fabrics which never could have been sold on the market that they captured without the use of synthetic resin finishes. Today it is possible to alter a fabric as much by resin finishes as formerly required a fiber substitution of wool for cotton or silk for rayon (9).

These new finishes have fulfilled a great need of the consumer for low and medium priced fabrics that are attractive and comparatively durable. At the present time because of the shortage of wool, silk and linen in this country it is quite probable that the new finished rayons will replace them to a marked extent.

It is highly desirable that the rayon finished fabrics meet the demands that are placed upon them. The purpose of this study has been to ascertain the permanence of these finishes and their effect on color fastness of rayon garbardines.

PRESENT STATUS OF KNOWLEDGE

The field of synthetic resin finishes is comparatively new. The Tootal Broadhurst Lee Company of Manchester, England discovered the process about 15 years ago. These finishes have been introduced into the United States only within the past seven years. Consequently the research and literature upon the subject is limited.

There has been a rapid development in research by dye manufacturers and chemists upon finishes for textiles. The most popular of these finishes are the urea-formaldehyde resins and their closely allied products (9).

These resins were first used to give crease resistance to cellulosic materials. Their uses have now been extended to include wooly handle, increased warmth, resistance to slippage, reduction of shrinkage and fixation of other types of sizing (9).

Many of these resins form a sheath on the fiber which reflects the catalyzing rays of the sun and thus preserves the fabric and color. These finishes also set the dyestuffs causing them to be more resistant to light, laundering and perspiration (9). Roberts (13) and Powers (11) have found that resins increase the stability of color toward light.

The synthetic resins most commonly used are clear, colorless, light stable resins which can be dispersed or dissolved in water. Powers (11) stated that fabrics may have as much as 30 per cent synthetic resins added and still retain the appearance, feel and even microscopic characteristics of the original fabric.

The permanence of finishes is an important factor. The first finishes used were not permanent and were only expected to increase the draping qualities of fabrics in replacing weighted silks (9). According to Chase (2) a two per cent solution of hydrochloric acid applied over night to resin finished fabrics fails to remove the resin. It can be shown that clear glass like urea formaldehyde resins are completely insoluble in dry cleaning solvents. The permanence of resins is increased if properly set by baking subsequent to drying at lower temperatures (8). According to Le Brun (8), Powers (11), and Roberts (13), the resins used are permanent to laundering and dry cleaning.

Freedman (5) has recommended the use of Fade-Ometer tests on laundered and dry cleaned resin treated fabrics to determine

the effect of light on these fabrics.

There is a great demand today for rayon gabardines to be used in garments for sport wear. The use of these garments requires a dye that is resistant to severe treatment. In order to manufacture a medium priced material the dyes used are often of an inferior quality. This difficulty may be partly solved by the use of a protective urea-formaldehyde finish for light and medium dyeings (6).

The use of synthetic resins has assisted the promotion of rayon to a place where today it is a most important development in the suiting and dress field. The further application of resins will greatly increase the range of spun rayons into new fields (11).

It seems evident from the literature cited that resin finishes are quite permanent to laundering and dry cleaning and that the color fastness to light and laundering of materials treated with resin finishes is improved.

PROCEDURE

Materials

The materials used in this study were viscose rayon gabardines. They were purchased from retail and wholesale stores in different localities after a preliminary test for the resin finish had been made upon a sample of the material.

Eight rayon gabardines with a resin finish and eight without a resin finish were purchased in light and dark shades of red, blue, green and brown.

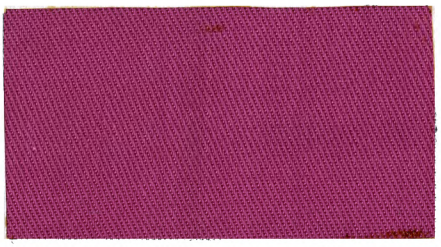
EXPLANATION OF PLATE I

Untreated rayon gabardines used in this study.

A	Dark red
B	Light red
C	Light blue
D	Dark blue
E	Dark green
F	Light green
G	Dark brown
H	Light brown

PLATE I

A



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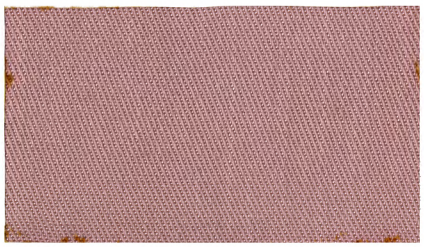

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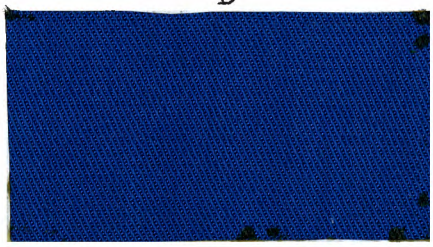
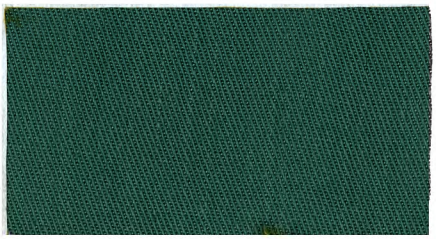
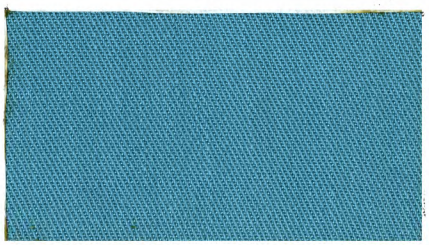


C

E

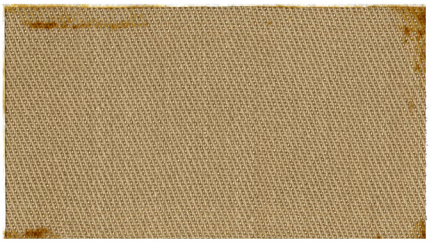


F



G

H



EXPLATATION OF PLATE II

Treated rayon gabardines used in this study

I Dark red

J Light red

K Light blue

L Dark blue

M Dark green

N Light green

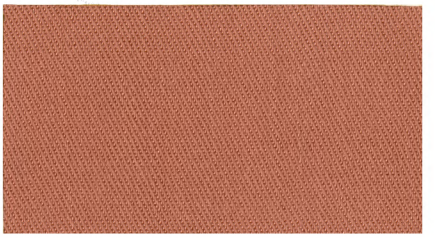
O Dark brown

P Light brown

PLATE II

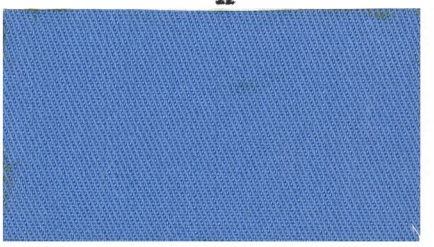
I

J



L

K



M

N

O

P

Identification of Finish

To determine the presence of formaldehyde resin the method by Rath (12) was used in which a sample of the material was boiled in a distilling flask with water containing some sulphuric acid. After cooling the distillate it was introduced into a 0.1 per cent sulphuric acid solution of carbazole. The development of a blue color indicated the presence of formaldehyde. The identification of urea formaldehyde resin was further verified by the Skinkle method (15) in which a few crystals of phloroglucinol were added to the distillate. Upon neutralizing with sodium hydroxide, a deep red color developed if formaldehyde was present.

Physical Tests

The weave, thread count, twist, crimp, yarn counts, weight per square yard and thickness were determined. The thickness, thread count and weight per square yard were determined by method approved by Committee D-13 (3). The crimp was determined by the Schwarz microscopic method using the camera lucida (14).

The twist of the single ply yarns was determined with the Suter twist counter. A ten inch length of yarn under a known tension was placed in jaws of the twist counter and twisted up until it was broken. A second piece of yarn of the same length was untwisted and retwisted in the opposite direction until

ruptured. The twist was calculated by the formula

$$t = \frac{N_1 - N_2}{21}$$

where t = turns per inch

N_1 = number of turns to untwist and retwist to rupture

N_2 = number of turns to twist to rupture

1 = length of yarn

The yarn counts were determined by drying and weighing eight inch squares of fabric after which the warp and filling yarns were raveled, counted, dried, and weighed. The combined weights of warp and filling were compared with weight of the original sample. Any small discrepancy in weight was divided equally between the warp and filling. The total length was calculated from the per cent crimp and lengths of warp and filling in the fabric. The yarn counts were determined from the total length and weight in the worsted system. The results of these tests are shown in Table 1.

Preparation of Materials

Controls were taken from all of the fabrics. Each of the fabrics was divided into four equal lengths. The fabrics were laundered five and ten times and dry cleaned five and ten times by the Manhattan Dry Cleaners, Manhattan, Kansas who are members of the National Dyers and Dry Cleaning Association. The fabrics were laundered in tap water at 60° F. and zero hardness. The soap used was powdered Texolive. They were sorted for laundering according to classification of color, amount of soil and kind of

Table 1. Place of purchase, cost and physical characteristics of the fabrics tested; all fabrics 39 inches wide, with weave (2/2)L and Z direction of twist.

Fabrics	Place purchased	Cost (per yd.)	Thread count		Thickness	Weight per sq. yd. (oz. dry wt.)	Crimp		Yarn counts (deniers dry wt.) worsted		Twist per inch	
			Warp	Filling	(in.)		Warp	Filling	Warp	Filling	Warp	Filling
A Dark red	J. C. Penny Manhattan, Ks.	$ .39	135.0	61.9	.0135	4.2	5.6	4.7	50.8	55.2	22.5	18.4
B Light red	Montgomery Ward Manhattan, Ks.	$ .39	134.4	63.1	.0150	4.2	5.3	4.7	46.4	50.4	21.7	20.4
C Light blue	Montgomery Ward Manhattan, Ks.	$ .39	133.6	62.2	.0157	4.4	4.7	6.4	47.3	54.5	20.6	19.7
D Dark blue	Walkers Wichita, Ks.	$ .59	121.6	65.5	.0178	5.6	8.8	8.8	38.4	43.1	19.1	17.5
E Dark green	J. C. Penny Manhattan, Ks.	$ .39	134.1	61.4	.0172	4.4	6.1	8.1	48.7	51.1	21.1	17.9
F Light green	Walkers Wichita, Ks.	$ .59	136.7	64.8	.0158	4.4	5.5	4.8	50.1	47.9	18.3	19.5
G Dark brown	Gimbles Milwaukee, Wis.	$ .49	133.0	63.8	.0157	4.6	6.6	7.1	47.5	48.0	20.3	21.2
H Light brown	Gimbles Milwaukee, Wis.	$ .49	133.4	63.7	.0151	4.5	7.7	5.2	48.9	51.6	20.9	19.6
I Dark red	Cohn Hall Marx New York	$ .355	131.0	61.0	.0154	4.9	7.3	6.8	45.6	40.7	17.7	19.1
J Light red	Cohn Hall Marx New York	$ .355	134.4	61.0	.0150	4.5	6.2	6.5	48.4	48.8	20.5	18.0
K Light blue	Cohn Hall Marx New York	$ .355	130.0	63.0	.0145	4.7	8.8	6.5	47.4	44.2	19.4	17.5
L Dark blue	Cohn Hall Marx New York	$ .355	121.0	63.0	.0148	4.7	6.5	7.8	46.9	45.0	20.2	18.3
M Dark green	Cohn Hall Marx New York	$ .355	125.0	62.0	.0142	4.6 ~~5.3~~	4.6	7.4	49.0	44.0	19.8	19.1
N Light green	Cohn Hall Marx New York	$ .355	137.0	64.0	.0158	4.9	7.3	6.0	45.4	42.3	20.2	17.3
O Dark brown	Cohn Hall Marx New York	$ .355	132.0	60.0	.0148	5.2	6.1	8.6	46.4	43.7	18.1	19.7
P Light brown	Cohn Hall Marx New York	$ .355	131.0	62.0	.0154	4.8	6.3	4.7	45.8	38.6	19.9	19.0

fiber. They were ironed dry as they came from the extractor. The fabrics were dry cleaned in a continuous flow of the Stoddard solvent and Sanitone detergent.

Samples, one inch by 12 inches, of the control, laundered five and ten times and dry cleaned five and ten times were prepared for fading by clipping to cardboard cards. The samples were subjected to light from a carbon arc lamp in the Atlas Fade-Ometer with humidity control. Samples of the fabrics were exposed in the Fade-Ometer at 100° F. for 40 hours. Samples of fabrics before and after laundering five and ten times and dry cleaning five and ten times were subjected to light at 150° F. for 40 and 80 hours.

Quantitative Determination of Finishing Materials

The finishing materials were removed by the carbon tetrachloride and enzyme method given in A. S. T. M. (3) and the nitric acid method of Howlet and Urquehart (7) in which a known weight of fabric was boiled in 400 ml. of .1 N nitric acid solution for ten minutes. The sample was rinsed in distilled water until neutral, dried to constant weight and the amount of finish was calculated.

Both the nitric acid and carbon tetrachloride and enzyme methods were used in determining the per cent of finishing material on the controls. The carbon tetrachloride and enzyme method was used on all untreated fabrics in determining the per cent of finishing after laundering and dry cleaning five times and after dry cleaning ten times. The nitric acid method was used on all

resin threated fabrics in determining the per cent of finishing after laundering five and ten times and dry cleaning five and ten times.

Color Analysis

The faded samples were analyzed for color by the use of the Bausch and Lomb Color Analyzer. The sector percentages of two neutrals and two colors were determined experimentally after which the color specifications of hue, saturation (chroma) and brilliance (lightness or value) were calculated according to Directions for Use of the Bausch and Lomb H S B Color Analyzer (1). The formulas used to calculate the color specifications follow:

$$H \text{ (hue)} = Z - \frac{A_x P_x}{A_x P_x + A_z P_z} Z - X$$

where x = number of first hue (clockwise in the hue circle)

z = number of second hue (clockwise in the hue circle)

A = area (expressed in sector percentage)

P = power number (brilliance x saturation)

H = resultant hue

$$S = \frac{A_1 S_1 + A_2 S_2 + A_3 S_3}{100}$$

where S = saturation or chroma

$$B = \sqrt{\frac{A_1 B_1^2 + A_2 B_2^2 + A_3 B_3^2 + A_4 B_4^2}{100}}$$

where B = brilliance or value

An example of the color analysis for fabric A was as follows:

Control A

Colors and neutrals	Area
95RP 4/12	30
5 R 4/9	41
N 3	18
N 6	11

$$H = 5 - \frac{30\ (4 \times 12) \cdot 10}{41\ (4 \times 9) + 30\ (4 \times 12)} = .06$$

$$S = \frac{(30 \times 12) + (41 \times 9)}{100} = 7.29$$

$$B = \sqrt{\frac{(30 \times 4^2) + (41 \times 4^2) + (18 \times 3^2) + (11 \times 6^2)}{100}} = 4.12$$

Color specification $.06\ R\ \frac{4.12}{7.29}$

Control A exposed 40 hr. 150° F.

Colors and neutrals	Area
95RP 4/12	19
5 R 4/9	34
N 3	18
N 6	29

$$H = 5 - \frac{19\ (4 \times 12) \cdot 10}{19\ (4 \times 12) + 34\ (4 \times 9)} = .73$$

$$S = \frac{(19 \times 12) + (34 \times 9)}{100} = 5.34$$

$$B = \sqrt{\frac{(19 \times 4^2) + (34 \times 4^2) + (18 \times 3^2) + (29 \times 6^2)}{100}} = 4.54$$

Color specification $.73\ R\ \frac{4.54}{5.34}$

The color spedifications were reduced to the indices of fading according to Nickerson's formula (10):

$$I = (C/5)\, d_2 H + 6dL + 3dC$$

where I = index of fading

H = hue

L = lightness (brilliance or value)

C = chroma (saturation)

d = difference

An example of the calculation of index of fading in fabric A follows:

Control A .06 R $\frac{4.12}{7.29}$

Control A 40 hr. exposure 150° F. .73 R $\frac{4.54}{5.34}$

Ave. chroma	dH	dL	dC	I
6.32	.67	.42	1.95	10.06

$$I = \frac{6.32}{5}\ (1.34) + 6\ (.42) + 3\ (1.95)$$

$$I = 10.06$$

The color specifications are given for all of the fabrics in Tables 2 and 3.

Table 2. Color specifications of untreated fabrics.

Treatments	Specifications																	
	A*			B			C			D			E			F		
Control	.064	R	4.12/7.29	99.70	PR	5.11/7.26	71.16	PB	4.65/7.04	73.77	PB	3.02/7.56	42.69	G	3.64/2.80	49.45	G	5.72/3.60
Control exposed 40 hr. 100° F.	1.18	R	4.36/5.97	99.70	PR	5.11/7.26	72.83	PB	4.71/7.00	73.48	PB	2.86/5.52	41.84	G	3.70/2.80	48.31	G	5.96/3.36
Control exposed 40 hr. 150° F.	.73	R	4.54/5.34	99.70	PR	5.11/7.26	72.26	PB	4.86/6.48	72.90	PB	3.02/5.32	41.36	G	3.84/2.56	48.22	G	5.99/3.30
Control exposed 80 hr. 150° F.	99.00	PR	4.69/5.58	99.86	PR	5.21/7.02	72.37	PB	5.32/5.10	71.22	PB	3.14/4.24	37.82	YG	4.36/2.68	51.23	BG	6.00/2.34
Control dry cleaned 5 times	96.43	PR	3.94/6.30	99.43	PR	5.15/7.11	70.84	PB	4.69/6.92	73.77	PB	3.02/7.56	42.33	G	3.67/2.80	49.45	G	5.72/3.60
Dry cleaned 5 times exposed 40 hr. 150° F.	97.51	PR	4.41/7.53	99.70	PR	5.11/7.26	72.52	PB	4.94/6.33	71.77	PB	3.07/4.96	41.36	G	3.84/2.56	48.22	G	5.99/3.30
Dry cleaned 5 times exposed 80 hr. 150° F.	99.12	PR	4.73/6.12	99.86	PR	5.21/7.02	72.71	PB	5.40/4.95	71.13	PB	3.21/3.72	37.82	YG	4.44/2.56	51.23	BG	6.00/2.34
Control dry cleaned 10 times	96.43	PR	3.94/6.30	99.43	PR	5.15/7.11	70.74	PB	4.69/6.92	73.77	PB	3.02/7.56	42.33	G	3.67/2.80	49.45	G	5.72/3.60
Dry cleaned 10 times exposed 40 hr. 150° F.	95.97	PR	4.47/7.56	99.43	PR	5.21/7.11	72.52	PB	4.94/6.33	71.77	PB	3.07/4.96	41.36	G	3.89/2.56	48.22	G	5.99/3.30
Dry cleaned 10 times exposed 80 hr. 150° F.	96.26	PR	4.69/7.85	99.42	PR	5.16/7.32	72.71	PB	5.40/4.95	71.13	PB	3.21/3.72	37.82	YG	4.44/2.56	51.23	BG	6.00/2.34
Control laundered 5 times	97.29	PR	4.15/6.69	99.86	PR	5.21/7.02	70.30	PB	5.01/6.00	73.77	PB	3.02/7.56	42.33	G	4.06/2.80	48.63	G	5.85/3.60
Laundered 5 times exposed 40 hr. 150° F.	98.60	PR	4.75/6.00	99.86	PR	5.21/7.02	72.16	PB	5.27/5.20	71.52	PB	3.10/4.60	38.44	YG	4.80/2.04	46.34	G	6.42/2.82
Laundered 5 times exposed 80 hr. 150° F.	96.54	PR	4.76/7.53	99.49	PR	5.12/7.62	72.35	PB	6.40/3.65	70.00	PB	3.24/3.12	36.30	YG	4.98/2.40	50.79	BG	6.09/2.04
Control laundered 10 times	96.72	PR	4.15/6.81	99.86	PR	5.21/7.02	70.30	PB	5.01/6.00	73.77	PB	3.02/7.56	42.33	G	4.06/2.80	48.63	G	5.85/3.60
Laundered 10 times exposed 40 hr. 150° F.	96.21	PR	4.76/6.69	99.86	PR	5.21/7.02	72.16	PB	5.27/5.20	71.52	PB	3.10/4.60	38.10	YG	4.87/1.92	46.34	G	6.42/2.82
Laundered 10 times exposed 80 hr. 150° F.	96.43	PR	4.89/7.44	99.49	PR	5.12/7.62	72.35	PB	6.40/3.65	69.28	B	3.30/3.08	36.30	YG	4.98/2.40	50.79	BG	6.09/2.04

Treatments	Specifications																	
	G				H													
Control	16.67	YR	1.80/1.32	22.99	Y	5.45/2.56												
Control exposed 40 hr. 100° F.	16.39	YR	1.88/1.38	23.09	Y	5.52/2.52												
Control exposed 40 hr. 150° F.	16.55	YR	1.90/1.42	23.09	Y	5.52/2.52												
Control exposed 80 hr. 150° F.	16.55	YR	1.90/1.42	23.09	Y	5.52/2.52												
Control dry cleaned 5 times	16.75	YR	1.77/1.26	22.99	Y	5.45/2.56												
Dry cleaned 5 times exposed 40 hr. 150° F.	16.55	YR	1.90/1.42	23.09	Y	5.52/2.52												
Dry cleaned 5 times exposed 80 hr. 150° F.	15.48	YR	2.54/2.58	23.18	Y	5.58/2.48												
Control dry cleaned 10 times	16.75	YR	1.77/1.26	22.99	Y	5.45/2.56												
Dry cleaned 10 times exposed 40 hr. 150° F.	16.55	YR	1.90/1.42	23.09	Y	5.52/2.52												
Dry cleaned 10 times exposed 80 hr. 150° F.	15.48	YR	2.54/2.58	23.18	Y	5.58/2.48												
Control laundered 5 times	16.08	YR	1.88/1.30	23.23	Y	5.58/2.54												
Laundered 5 times exposed 40 hr. 150° F.	16.25	YR	1.91/1.44	23.41	Y	5.66/2.54												
Laundered 5 times exposed 80 hr. 150° F.	15.44	YR	2.60/2.74	23.41	Y	5.66/2.54												
Control laundered 10 times	16.12	YR	1.91/1.42	23.23	Y	5.58/2.54												
Laundered 10 times exposed 40 hr. 150° F.	16.25	YR	1.91/1.44	23.41	Y	5.66/2.54												
Laundered 10 times exposed 80 hr. 150° F.	15.44	YR	2.60/2.74	23.41	Y	5.66/2.54												

* Explained in Table 1.

Table 3. Color specifications of treated fabrics.

Treatments	Specifications					
	I*	J	K	L	M	N	O	P
Control	1.25 R 1.63/.80	1.06 R 4.20/8.54	73.05 PB 4.08/7.80	74.00 PB 2.21/4.20	50.26 BG 2.07/1.60	53.63 BG 2.58/2.82	15.65 YR 2.66/2.08	22.76 Y 4.56/1.88
Control exposed 40 hr. 100° F.	1.25 R 1.63/.80	1.06 R 4.20/8.54	73.05 PB 4.08/7.80	74.36 PB 2.26/4.50	49.28 G 2.13/1.70	54.00 BG 2.60/2.80	15.48 YR 2.70/2.20	22.68 Y 4.55/1.84
Control exposed 40 hr. 150° F.	1.67 R 1.67/.90	1.06 R 4.20/8.54	73.03 PB 4.10/7.68	74.36 PB 2.26/4.50	48.63 G 2.18/1.78	54.00 BG 2.60/2.80	15.48 YR 2.70/2.20	22.68 Y 4.55/1.84
Control exposed 80 hr. 150° F.	1.81 R 1.69/.94	1.79 R 4.35/8.64	73.53 PB 4.11/7.72	74.68 PB 2.30/5.04	46.57 G 2.41/2.30	54.13 BG 2.62/2.88	15.27 YR 2.82/2.68	22.68 Y 4.55/1.84
Control dry cleaned 5 times	1.25 R 1.63/.80	1.06 R 4.20/8.54	73.05 PB 4.08/7.80	74.00 PB 2.21/4.20	50.26 BG 2.07/1.60	53.78 BG 2.60/2.90	15.65 YR 2.66/2.08	22.76 Y 4.56/1.88
Dry cleaned 5 times exposed 40 hr. 150° F.	1.67 R 1.67/.90	.54 R 4.26/8.08	73.53 PB 4.11/7.72	74.36 PB 2.26/4.50	48.63 G 2.18/1.78	54.00 BG 2.60/2.80	15.46 YR 2.73/2.32	22.68 Y 4.55/1.84
Dry cleaned 5 times exposed 80 hr. 150° F.	1.81 R 1.69/.94	1.33 R 4.30/8.84	73.62 PB 4.04/8.20	74.67 PB 2.34/5.30	46.18 G 2.61/2.40	54.16 BG 2.65/2.80	15.27 YR 2.82/2.68	22.68 Y 4.55/1.84
Control dry cleaned 10 times	1.25 R 1.63/.80	1.06 R 4.20/8.54	73.05 PB 4.08/7.80	74.00 PB 2.21/4.20	50.26 BG 2.07/1.60	53.78 BG 2.60/2.90	15.65 YR 2.66/2.08	22.76 Y 4.56/1.88
Dry cleaned 10 times exposed 40 hr. 150° F.	1.67 R 1.67/.90	1.33 R 4.30/8.84	73.53 PB 4.11/7.72	74.36 PB 2.26/4.50	48.63 G 2.18/1.78	54.00 BG 2.60/2.80	15.46 YR 2.73/2.32	22.68 Y 4.55/1.84
Dry cleaned 10 times exposed 80 hr. 150° F.	1.81 R 1.69/.94	1.56 R 4.36/8.74	73.62 PB 4.04/8.20	74.67 PB 2.34/5.30	46.18 G 2.61/2.40	54.26 BG 2.67/2.82	15.27 YR 2.82/2.68	22.68 Y 4.55/1.84
Control laundered 5 times	1.51 R 1.65/.86	1.56 R 4.30/8.74	73.05 PB 4.08/7.80	74.08 PB 2.26/4.56	49.85 G 2.09/1.64	54.22 BG 2.67/3.04	15.62 YR 2.70/2.24	22.76 Y 4.56/1.88
Laundered 5 times exposed 40 hr. 150° F.	1.81 R 1.69/.94	1.56 R 4.30/8.74	73.53 PB 4.11/7.72	74.36 PB 2.26/4.50	49.28 G 2.13/1.70	54.19 BG 2.62/2.92	15.46 YR 2.67/2.10	22.68 Y 4.55/1.84
Laundered 5 times exposed 80 hr. 150° F.	1.88 R 1.70/.96	2.32 R 4.46/8.04	73.53 PB 4.11/7.72	74.38 PB 2.27/4.62	46.57 G 2.41/2.30	54.13 BG 2.62/2.88	15.34 YR 2.85/2.74	24.78 Y 4.56/1.80
Control laundered 10 times	1.51 R 1.65/.86	1.56 R 4.30/8.74	73.05 PB 4.08/7.80	74.08 PB 2.26/4.56	49.85 G 2.09/1.64	54.22 BG 2.67/3.04	15.62 YR 2.70/2.24	22.76 Y 4.56/1.88
Laundered 10 times exposed 40 hr. 150° F.	1.81 R 1.69/.94	1.56 R 4.30/8.74	73.53 PB 4.11/7.72	74.36 PB 2.26/4.50	48.63 G 2.18/1.78	54.19 BG 2.62/2.92	15.46 YR 2.67/2.10	22.68 Y 4.55/1.84
Laundered 10 times exposed 80 hr. 150° F.	1.88 R 1.70/.96	2.54 R 4.51/7.80	72.81 PB 4.10/7.80	74.39 PB 2.29/4.74	46.57 G 2.41/2.30	54.13 BG 2.62/2.88	15.34 YR 2.85/2.74	24.78 Y 4.56/1.80

* Explained in Table 1.

RESULTS

Finishes

As shown in Tables 4, 5, the untreated fabrics did not show an appreciable difference in amount of finish removed by the carbon tetrachloride and enzyme method and the nitric acid method. There was a large difference in amount of finish removed from resin treated fabrics by the two methods showing that only the nitric acid method removed the resin finish from the treated fabrics.

Nearly all the finish was removed from untreated fabrics by laundering five times. Dry cleaning five and ten times did not remove much finish from untreated fabrics. A small amount of finish was removed from treated fabrics by laundering and none by dry cleaning.

Table 4. Per cent of sizing of untreated fabrics.

Fabrics	Controls		CCl_4		CCl_4
	CCl_4	HNO_3	Dry cleaned 5 times	Laundered 5 times	Dry cleaned 10 times
A	2.2	2.2	2.5	.3	2.7
B	2.8	2.6	2.9	.2	3.3
C	2.4	2.5	3.0	.1	3.5
D	1.8	1.6	1.4	.1	1.9
E	2.0	2.7	2.8	.4	3.0
F	1.4	1.9	1.9	.3	1.8
G	2.6	3.1	4.9	.5	4.3
H	2.3	2.4	3.4	.4	3.6

Table 5. Per cent of sizing of treated fabrics.

Fabrics	Controls		HNO_3		HNO_3	
	CCl_4	HNO_3	Dry cleaned: 5 times	Laundered: 5 times	Dry cleaned: 10 times	Laundered: 10 times
I	2.2	13.7	13.2	11.8	11.9	11.4
J	1.2	5.7	6.0	4.9	6.0	4.4
K	1.3	6.1	6.1	5.1	6.5	5.6
L	1.7	6.7	7.1	6.3	7.5	5.6
M	2.1	6.9	7.8	5.6	7.8	5.6
N	1.6	7.9	7.7	6.5	8.5	6.7
O	1.9	15.2	16.5	16.4	17.2	15.1
P	1.3	13.6	13.1	13.1	13.7	13.4

Statistical Analysis of Data on Fading

The data on color fastness was evaluated by the analysis of variance (16, 4). The indices of fading are found in Table 6. Using these indices it was found that the variance of the treatments plotted against the means of the treatments gave a straight line and thus a correlation was shown. Consequently these indices did not form a normal population. A transformation was made by using $I' = \sqrt{I + .5}$. The transformed indices (I') are given in Table 7. The results of analysis are given in Table 8.

Table 6. Indices of fading (I).

	Fabrics	Exposure at 100° F. for 40 hr.	Exposure at 150° F.					Treatments and exposures at 150° F.								
			Control			5 times dry cleaned		10 times dry cleaned			5 times laundered			10 times laundered		
		Control	0 hr.	40 hr.	80 hr.	0 hr.	40 hr.	80 hr.	0 hr.	40 hr.	80 hr.	0 hr.	40 hr.	80 hr.	0 hr.	40 hr.	80 hr.
Untreated	A Dark red	8.38	0	10.06	9.14	13.93	10.01	9.69	13.93	15.02	16.58	9.74	11.53	14.97	11.05	16.43	15.75
	B Light red	0	0	0	1.78	1.46	0	1.78	1.46	1.83	1.30	1.77	1.77	1.76	1.77	1.77	1.76
	D Dark blue	7.84	0	8.96	16.70	0	13.10	18.63	0	13.10	18.63	0	14.85	22.70	0	14.85	24.64
	C Light blue	5.15	0	5.91	12.76	1.77	7.51	14.49	1.77	7.51	14.49	7.52	11.68	23.21	7.52	11.68	23.21
	E Dark green	1.29	0	3.33	10.02	0.56	3.33	10.76	.56	3.33	10.76	2.90	13.30	15.27	2.90	14.32	14.87
	F Light green	3.76	0	4.22	7.56	0	4.22	7.56	0	4.22	7.56	1.96	10.52	8.40	1.96	10.52	8.40
	G Dark brown	.81	0	.96	.96	.40	.96	9.16	.40	.96	9.16	.85	1.26	10.07	1.26	1.26	10.07
	H Light brown	.64	0	.64	.64	0	.64	1.21	0	.64	1.21	1.08	1.75	1.75	1.08	1.75	1.75
Treated	I Dark red	0	0	.68	.97	0	.68	.97	0	.68	.97	.38	.97	1.13	.38	.97	1.13
	J Light red	0	0	0	3.71	0	3.46	2.44	0	2.44	3.29	2.93	2.93	7.24	2.93	2.93	8.90
	L Dark blue	1.83	0	1.83	4.31	0	1.83	5.35	0	1.83	5.35	1.52	1.83	2.29	1.52	1.83	2.79
	K Light blue	0	0	.54	1.91	0	1.91	3.26	0	1.91	3.26	0	1.91	1.91	0	1.91	.87
	M Dark green	1.31	0	2.31	7.02	0	2.31	8.90	0	2.31	8.90	.50	1.31	7.02	.50	2.31	7.02
	N Light green	.60	0	.60	.99	.53	.60	1.07	.53	.60	1.24	1.90	1.18	.99	1.90	1.18	.99
	O Dark brown	.75	0	.75	3.12	0	1.31	3.12	0	1.31	3.12	.75	.28	3.42	.75	.28	3.42
	P Light brown	.24	0	.24	.24	0	.24	.24	0	.24	.24	0	.24	1.73	0	.24	1.73

Table 7. Transformed indices of fading (I').

	Fabrics	Exposures at 150°F.			Treatments and exposures at 150° F.											Totals	
		Control			5 times dry cleaned			10 times dry cleaned			5 times laundered			10 times laundered				
		0 hr.	40 hr.	80 hr.	0 hr.	40 hr.	80 hr.	0 hr.	40 hr.	80 hr.	0 hr.	40 hr.	80 hr.	0 hr.	40 hr.	80 hr.		
Untreated	A Dark red	.707	3.26	3.10	3.79	3.24	3.19	3.79	3.94	4.14	3.19	3.46	3.94	3.41	4.11	4.02	51.287	
	B Light red	.707	.707	1.51	1.40	.707	1.51	1.40	1.53	1.34	1.51	1.51	1.50	1.51	1.51	1.50	19.851	
	D Dark blue	.707	3.08	4.15	.707	3.69	4.37	.707	3.69	4.37	.707	3.92	4.82	.707	3.92	5.01	44.555	
	C Light blue	.707	2.53	3.65	1.51	2.83	3.87	1.51	2.83	3.87	2.83	3.49	4.87	2.83	3.49	4.87	45.687	274.884
	E Dark green	.707	1.96	3.24	1.03	1.96	3.36	1.03	1.96	3.36	1.84	3.71	3.97	1.84	3.85	3.92	37.737	
	F Light green	.707	2.17	2.84	.707	2.17	2.84	.707	2.17	2.84	1.57	3.32	2.98	1.57	3.32	2.98	32.891	
	G Dark brown	.707	1.21	1.21	.949	1.21	3.11	.949	1.21	3.11	1.16	1.33	3.26	1.33	1.33	3.26	25.335	
	H Light brown	.707	1.07	1.07	.707	1.07	1.31	.707	1.07	1.31	1.26	1.50	1.50	1.26	1.50	1.50	17.541	
Treated	I Dark red	.707	1.09	1.21	.707	1.09	1.21	.707	1.09	1.21	.938	1.21	1.28	.938	1.21	1.28	15.877	
	J Light red	.707	.707	2.05	.707	1.99	1.71	.707	1.71	1.95	1.85	1.85	2.78	1.85	1.85	3.07	25.488	
	L Dark blue	.707	1.53	2.19	.707	1.53	2.42	.707	1.53	2.42	1.42	1.53	1.67	1.42	1.53	1.81	23.121	
	K Light blue	.707	1.02	1.55	.707	1.55	1.94	.707	1.55	1.94	.707	1.55	1.55	.707	1.55	1.17	18.905	160.771
	M Dark green	.707	1.68	2.74	.707	1.68	3.07	.707	1.68	3.07	1.00	1.35	2.74	1.00	1.68	2.74	26.551	
	N Light green	.707	1.05	1.22	1.02	1.05	1.25	1.02	1.05	1.32	1.55	1.30	1.22	1.55	1.30	1.22	17.827	
	O Dark brown	.707	1.12	1.90	.707	1.35	1.90	.707	1.35	1.90	1.12	.883	1.98	1.12	.883	1.98	19.607	
	P Light brown	.707	.860	.860	.707	.860	.860	.707	.860	.860	.707	.860	1.49	.707	.860	1.49	13.395	
	Totals	11.312	25.044	34.490	16.769	27.977	37.920	16.769	29.220	39.010	23.359	32.773	41.550	23.749	33.893	41.820		
			70.846			82.666			84.999			97.682			99.462			435.655
	Sum of squares		1077.080															

Table 8. Statistical analysis of fading.

Source of variation	Degree of freedom	Sum of squares	Mean square	F-function	Significance
Fabrics (treated and untreated)	1	54.267	54.267	161.19	***
Treatments (control, 5 times and 10 times dry cleaned, 5 times and 10 times laundered	4	11.522	2.880	8.59	***
Exposures (0, 40, 80 hr.)	2	66.345	33.172	99.02	***
Colors (red, blue, green, brown)	3	28.113	9.371	27.97	***
Shades (dark, light)	1	11.477	11.477	34.26	***
Fabrics x treatments	4	3.484	.871	2.60	
Fabrics x exposures	2	6.602	3.301	9.85	***
Fabrics x colors	3	12.362	4.121	12.30	***
Fabrics x shades	1	4.640	4.640	13.85	***
Treatments x exposures	8	.764	.096		
Treatments x colors	12	1.352	.113		
Treatments x shades	4	.590	.148		
Exposures x colors	6	14.659	2.443	7.34	***
Exposures x shades	2	5.486	2.743	8.19	***
Colors x shades	3	3.222	1.074	3.03	*
Error	183	61.381	.335		
Total	239	286.266			

* significant
** highly significant
*** very highly significant

The sum of squares was calculated as follows:

Correction: $C = \frac{(SI')^2}{N} = \frac{(435.655)^2}{240} = 790.814$

Total $SI^2 - C = 1077.080 - 790.814 = 286.266$

Fabrics: $\frac{(274.884)^2}{120} + \frac{(160.771)^2}{120} - 790.814 = 54.267$

Treatments: $\frac{(70.846)^2}{48} + \frac{(92.666)^2}{48} + \frac{(84.999)^2}{48} + \frac{(97.682)^2}{48} + \frac{(99.462)^2}{48} - 790.814 = 11.522$

Exposures: $\frac{(91.958)^2}{80} + \frac{(148.907)^2}{80} + \frac{(194.790)^2}{80} - 790.814 = 66.345$

Colors:

red	blue	green	brown

$\frac{(112.503)^2}{60} + \frac{(132.268)^2}{60} + \frac{(115.006)^2}{60} + \frac{(75.878)^2}{60} - 790.814 = 28.113$

Shades:

dark	light

$\frac{244.070}{120} + \frac{191.585}{120} - 790.814 = 11.477$

Fabrics x treatments:

$(\frac{20642.093}{24} - C) - (54.267 + 11.522) = 3.484$

Fabrics x exposure:

$(\frac{36721.134}{40} - C) - (54.267 + 66.345) = 6.602$

Fabrics x colors: $\left(\frac{26566.686}{30} - C\right) - (54.267 \not/ 28.113) = 12.362$

Fabrics x shades: $\left(\frac{51671.873}{60} - C\right) - (54.267 \not/ 11.477) = 4.640$

Treatments x exposures:

$$\left(\frac{13911.127}{16} - C\right) - (66.345 \not/ 11.522) = .764$$

Treatments x colors: $\left(\frac{9981.613}{12} - C\right) - (11.522 \not/ 28.113) = 1.352$

Treatments x shades: $\left(\frac{19545.676}{24} - C\right) - (11.522 \not/ 11.477) = .590$

Exposures x colors: $\left(\frac{17998.626}{20} - C\right) - (28.113 \not/ 66.345) = 14.659$

Exposure x shades: $\left(\frac{34964.887}{40} - C\right) - (66.345 \not/ 11.477) = 5.486$

Colors x shades: $\left(\frac{25000.877}{30} - C\right) - (28.113 \not/ 11.477) = 3.222$

In the analysis of variance a probability of five per cent was regarded as significant, one per cent as highly significant and one tenth per cent as very highly significant in the interpretation of differences. The F-test of significance in Table 8 showed a very highly significant difference in fabrics treated and untreated, treatments, exposures, colors and shades. There were very highly significant interactions of fabrics by exposures, colors and shades and exposures by colors and shades. A significant difference was found in the interaction of colors by shades. No interactions were found in fabrics by treatments or treatments

by exposures, colors and shades.

To test the difference between specific fabrics, treatments, exposures, colors and shades the t-test was used on the arithmetic means given in Table 9.

Table 9. Means of I' for fabrics, treatments, exposures, colors and shades.

Fabrics, treatments : exposures, colors and shades :	Means
Fabrics	
Untreated	2.29
Treated	1.34
Treatments	
Controls	1.47
5 times dry cleaned	1.72
10 times dry cleaned	1.77
5 times laundered	2.03
10 times laundered	2.07
Exposures	
0 hr.	1.15
40 hr.	1.86
80 hr.	2.43
Colors	
Red	1.88
Blue	2.20
Green	1.92
Brown	1.26
Shades	
Dark	2.03
Light	1.59

Table 10 shows the difference of means of I' for probabilities of .05, .01 and .001 used in the t-test.

Table 10. Differences of means of I' for .05, .01 and .001 probabilities.

Differences between	Probabilities		
	.05	.01	.001
Fabrics (untreated and treated)	.254	.336	.426
Treatments (controls, 5 and 10 times dry cleaned and 5 and 10 times laundered)	.232	.306	.389
Exposures (0, 40, 80 hr.)	.180	.238	.302
Colors (red, blue, green, brown)	.207	.273	.347
Shades (dark, light)	.147	.194	.246

The results of t-test are given in Table 11.

Table 11. Results of t-test of I'.

Source of variation	Differences	Significance
Fabrics (untreated and treated)	Treated faded less than untreated	***
Treatments (controls, 5 and 10 times dry cleaned and 5 and 10 times laundered)	5 and 10 times laundered faded more than 5 and 10 times dry cleaned	**
	No significant difference between 5 and 10 times laundered or between 5 and 10 times dry cleaned	
	Dry cleaned faded more than control	*
	Laundered faded more than control	***
Exposures (0, 40, 80 hr.)	80 hr. exposure faded more than 40 hr. and 40 hr. more than 0 hr.	***

Table 11 (concl.)

Sources of variation	Differences	Significance
Color (red, blue, green, brown)	Blue faded more than green or red	**
	Brown faded less than green, blue and red	***
Shades (dark, light)	Dark faded more than light	***

* significant
** highly significant
*** very highly significant

In the very highly significant interaction of fabrics x exposures there was a very highly significant difference in the zero and 40 hours of untreated fabrics but only a highly significant difference in the treated fabrics. In the interaction of fabrics x colors there were very highly significant differences between all colors of untreated except red and green which had no significant difference. Blue faded the most and brown the least in these fabrics. However, in treated fabrics there were no significant differences between colors except in green and brown, and blue and brown, both of which had significant differences. Brown faded the least of the treated. In the interaction of fabrics x shades the dark shades of untreated faded more than the light shades by a very highly significant amount. There was no significant difference in shades of the treated fabrics.

The analysis of fading of I which is given in Table 6 for the controls of fabrics at 100° F. for 40 hours is shown in Table 12.

Table 12. Analysis of I of the controls at 100° F. for 40 hours.

Source of variation	Degree of freedom	Sum of squares	Mean square	F
Fabrics (treated and untreated)	1	33.467	33.467	6.072*
Colors (red, blue, green, brown)	3	19.641	6.547	1.188
Shades (dark, light)	1	8.733	8.733	1.584
Fabrics x colors	3	17.743	5.914	1.073
Fabrics x shades	1	2.044	2.044	
Error	6	33.075	5.512	
Total	15	114.703		

* significant

As shown in above table there was a significant difference in fabrics treated and untreated. There were no interactions of fabrics by shades or colors. The sum of indices for untreated fabrics in Table 6 was 27.87 and for treated 4.73. This fact showed that there was considerable more fading on the controls of untreated than of treated at a temperature of 100° F. for 40 hours.

SUMMARY

The treated fabrics had a firmer handle than the untreated fabrics and had a better appearance after dry cleaning and laundering. These fabrics did not become sleazy after repeated dry cleanings and launderings.

Laundering removed most of the finish from untreated fabrics; while dry cleaning removed only a small amount. The resin

finish on treated fabrics was not removed by either dry cleaning or laundering.

The resin treated fabrics faded less than the untreated by a very highly significant amount. There was little difference in fading between the different colors in treated fabrics; however, there was considerable difference in the untreated fabrics. In the entire group of fabrics blue faded the most and brown the least. There was no significant difference in fading between light and dark shades in the treated; on the other hand, the fading of dark shades in the untreated fabrics was greater by a very highly significant amount.

Laundering produced fading of a very highly significant amount; dry cleaning produced just significant fading. Increased exposure caused a very highly significant increase in fading on all fabrics.

It is evident from this study that resin finished fabrics are more color fast than non-resin finished fabrics. The resin finishes are permanent to laundering and dry cleaning.

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