A COMPARISON OF THE BREAKING STRENGTH OF RESIN-FINISHED WITH UNFINISHED RAYON GABARDINES AS AFFECTED BY LIGHT, ABRASION AND CLEANING

by

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INTRODUCTION

Synthetic resins are coming to be more and more widely used in the textile industry. Their evolution has been the most important development in textile processing in the past two decades. Not only have many new finishes been developed, but also many new applications have been discovered for older finishing compounds. (15)

From time immemorial the natural textile fibers had served man well enough. But with man's progress his demand upon textile fabrics became increasingly difficult to meet. In the nineteenth century it became apparant that either new textile fibers would have to be developed or improvements and modifications be made upon the old. Outstanding success has been achieved in both fields. (5)

The development of spun rayon and the development of resin finishes have benefitted each other greatly. It is in the spun rayon field that these processes have become of greatest importance. (11)

For 60 years the science of dyeing had forged ahead while the science of finishing lagged far behind. Twenty years ago the principal finishing agents were sulphonated oils, starches, gums, soaps, waxes, and a few others. Finishers still relied upon certain mechanical treatments such as calendaring and beetling to produce the limited number of well known styles of finishes. (8) Today there are literally hundreds of finishing agents on the market. These new finishes are permanent, too. They no longer disappear in the first laundering. Today it seems as logical to expect permanent finishes as to expect fast colors.

For years resins had been used as coatings and lacquers on textile fibers and fabrics to produce oilcloth, tarpaulins, etc. In each case the fabric was just the backing or supporting material. However, in these new uses of resins for textile modification, the resin can be impregnated into the fiber without stiffening it. (13) Credit for the discovery goes to the research department of Tootal, Broadhurst, and Lee Company which developed and patented the process 14 years ago for the purpose of rendering materials crease resistant. They soon found that impregnation with resin not only increased the fabric's resistance to creasing but also increased its resilience and breaking strength, reduced its yarn slippage and shrinkage and made it more resistant to light degradation. (13)

Synthetic resins are an entirely new building tool, which must be taken into account by modern designers of fabrics and garments (12). By proper choice and use of resins they may be placed almost anywhere in or on the fiber and fabric. By their use it is possible to modify a fabric as much today as was formerly possible to change it through variation in thread count, twist, or type of fiber (13).

Resin-modified fabrics are now sold for many purposes for which they were formerly considered unsatisfactory. A great advantage to the consumer is the fact that these modifications and improvements may be wrought in the fabrics without greatly increasing their cost. While synthetic resins are not a cure-all for any and all textile problems, they are an important tool and have great possibilities. (12)

This study has been made to compare these resin-finished materials with materials not so treated in order to determine any differences between them and to ascertain how these differences were affected by light, abrasion and cleaning.

PRESENT STATUS OF KNOWLEDGE

Since the field of synthetic resin finishes is so new, the amount of research and the available literature are both limited. The research efforts have been directed toward finding best methods for application and use of resins rather than upon their advantages and disadvantages.

Of these resins the most popular are those of the urea-formaldehyde type, the original crease-proofing resin (9). These resins are clear, colorless, and light stable. Their only drawback lies in the difficulty of their application. If they are unskillfully applied they will stiffen the fabric. With proper handling, however, they are of great value.

These resins do not change the appearance of the fabric. There are fabrics today which are 30 percent resin and 70 percent fiber and yet have all the appearance, handle, and even microscopic characteristics, of a textile fabric made entirely of natural or synthetic fibers. (13)

An important feature of these new resin finishes is their permanence. Tests carried out by the American Institute of

Laundering show that the resistance to laundering of many of these finishes is excellent. One finish tested retained 80 percent of its finish after more than ten launderings. Further testing demonstrated that these finishes will withstand repeated dry cleanings. (10)

These resins appear to enter into the inter-micellar structure of the fiber and produce a stronger and more permanent lattice structure and thus a stronger yarn. Strength can be increased as much as 40 percent by proper application. (9)

The resins serve particularly to prevent loss of fiber strength upon exposure to sunlight and to prevent the decrease in the strength of viscose rayon when wet. In reporting investigations done by the research laboratory of Tootal, Broadhurst, Lee Company, Wood (18) stated that the resin-treated viscose samples tested dry were stronger than samples from the same fabric before treatment. The treated samples lost no strength on exposure to light, while the untreated samples decreased to one-fourth of their former breaking strength. Upon saturation with water the treated samples lost little strength in comparison to the amount lost by the untreated samples. The resin used in this treatment was urea-formaldehyde resin.

Hall (6) reported that fabrics treated with three to eight percent urea-formaldehyde resin lost only three percent wet breaking strength when exposed to summer sunshine for six months while the same fabric before treatment lost 68 percent. In these cellulosic fibers the resin seems to hinder the action of the sun which tends to catalyze the process of oxidation of cellulose to oxycellulose and carbon dioxide -- a process which weakens the fibers (1).

From the literature it seems evident that the resins are permanent to laundering and dry cleaning and that they improve the breaking strength of viscose rayons particularly when these fabrics are tested wet or after exposure to light.

METHOD OF PROCEDURE

Eight viscose rayon gabardines finished with synthetic resin and eight not finished with synthetic resin were used in this study. The colors included light and dark shades of red, blue, green, and brown. Fabrics having a price range from \$.355 to \$.59 were chosen from four different localities. All were 39 inches wide and were of 2/2 left twill weave. Mounted samples of these fabrics are shown in Plates I and II. The resin present on the finished fabrics was identified as urea-formaldehyde resin by the Rath method (14) and verified by the Skinkle method (16). The physical characteristics of these 16 fabrics are given in Table 1. This table is from Hay's thesis in which is given the methods used in obtaining the various characteristics (7).

Each fabric was divided into five parts. Of these, one part was kept as a control, one laundered five times, one laundered ten times, another dry cleaned five times, and the last dry cleaned ten times. The dry cleaning and laundering were done by the Manhattan Dry Cleaners, Manhattan, Kansas, a commercial firm which is a member of the National Dyers and Dry Cleaning Association. The fabrics were laundered in neutral

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. (7)

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

EXPLANATION OF PLATE I

Untreated rayon gabardines used in this study.

A Dark red

B Light red

D Dark blue

C Light blue

E Dark green

F Light green

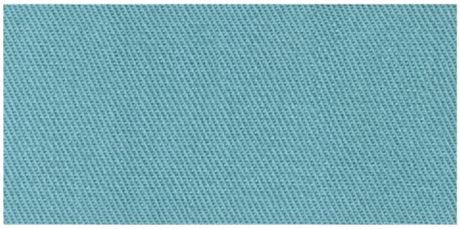
G Dark brown

H Light brown

PLATE I

A

B

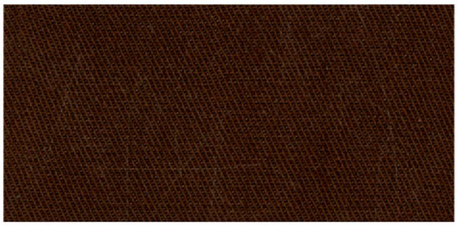


D

C

E

F



G

H

EXPLANATION OF PLATE II

Treated rayon gabardines used in this study.

I Dark red

J Light red

L Dark blue

K Light blue

M Dark green

N Light green

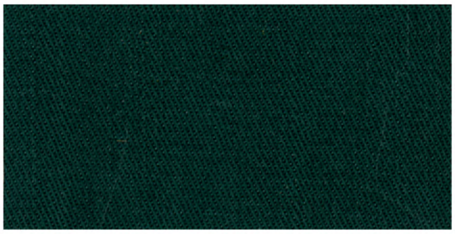
O Dark brown

P Light brown

PLATE II

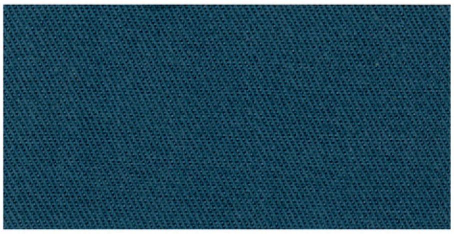
I

J



L

K



M

N

O

P

suds at 60^{o} F with water of zero hardness and powdered Texolive soap. As they came from the extractor, they were ironed dry in a roller press. The other group of fabrics was dry cleaned using Stoddard solvent and Sanitone detergent and were pressed in a steam flat press.

The type of dye which had been used on each of the 16 fabrics was determined according to the method described by Clayton (2).

Breaking strength and elongation determinations were made on the warp of the controls, of those laundered five and ten times, and of those dry cleaned five and ten times for each of the 16 fabrics according to the raveled-strip method outlined by Committee D-13 (3). Ten strips on the warp were prepared for each determination. Testing was done on a Scott tester at standard atmospheric conditions. Breaking strength specimens of the control fabrics and of the fabrics after each set of launderings and dry cleanings were exposed for 40 and 80 hours in an Atlas Fade-Ometer with temperature 150^{o} F and a humidity control. They were then tested on the Scott tester. Determinations were also carried out on dry samples and wet samples from the controls and after each set of launderings or dry cleanings for each of the fabrics.

To determine relative wearing qualities the breaking strengths of the original fabrics were compared with the same fabrics after abrasion on an M. I. T. model abrasion tester. The strips used in the abrasion determinations were six by 24 inches. They were abraded 500 strokes using a one-inch roller and crocus cloth as the abradant. The breaking strength and elongation determinations were made on raveled-strip samples cut from the abraded fabric (16).

The breaking strength results for each fabric were corrected to the thread count of the dry control as follows: The breaking strength was multiplied by the thread count of the control and the product was divided by the thread count of the sample broken. This was necessary because shrinkage and abrasion caused the thread count of the breaking strength samples to vary. In Table 2 are shown both the original and corrected breaking strength data of all 16 fabrics for dry, wet, abraded, and exposed samples before and after cleanings.

The elongation results for each fabric were changed from inches to percent as follows: The elongation was divided by three (the number of inches between the jaws of the Scott tester) and the result multiplied by 100. These data are shown in Table 3.

Table 2. Thread count, breaking strength, and corrected breaking strength of dry, wet, abraded, and exposed samples of control fabrics and after cleanings.

Fabrics (Rayon gabardines)	No. of launderings and dry cleanings	Warp thread count: Before abrasion	Warp thread count: After abrasion	Breaking strength of warp, Pounds: Dry	Pounds: Wet	Pounds: After abrasion	Pounds: 40 hrs. exposure	Pounds: 80 hrs. exposure	Pounds corrected*: Dry	Pounds corrected*: Wet	Pounds corrected*: After abrasion	Pounds corrected*: Faded 40 hrs.	Pounds corrected*: Faded 80 hrs.
Unfinished:													
A Dark red	Control	134	130	87.8 ± .5	40.4 ± 1.6	50.9 ± 3.2	77.2 ± .7	67.5 ± 1.6	87.8	40.4	52.4	77.2	67.5
	5 D. C.	132	130	91.0 ± .6	38.7 ± .5	80.0 ± 1.8	78.2 ± .7	71.4 ± 1.1	92.3	39.2	82.4	79.4	72.5
	10 D. C.	130	132	87.6 ± .7	35.3 ± .5	70.0 ± 2.4	76.0 ± 1.4	65.0 ± 1.8	90.2	36.4	71.0	78.3	67.0
	5 L.	137	137	71.8 ± 1.3	28.4 ± .5	58.6 ± 2.4	72.2 ± .7	64.3 ± 1.5	70.2	27.8	57.3	70.6	62.9
	10 L.	138	134	56.9 ± .6	29.8 ± .7	56.2 ± 1.2	53.4 ± 1.0	52.2 ± 2.3	55.2	28.9	56.2	51.9	50.7
B Light red	Control	137	131	78.4 ± .6	28.9 ± 1.0	53.2 ± .9	71.6 ± .6	61.2 ± 1.0	78.4	28.9	55.6	71.6	61.2
	5 D. C.	138	135	83.8 ± .8	28.2 ± .3	70.2 ± .9	70.0 ± 1.2	64.7 ± .7	83.2	28.0	71.3	69.5	64.2
	10 D. C.	134	134	78.4 ± .8	22.1 ± .4	60.6 ± 2.0	66.4 ± 1.3	57.7 ± 1.9	80.0	22.5	61.8	67.7	58.9
	5 L.	136	136	76.2 ± .7	21.8 ± .5	52.8 ± 1.5	71.4 ± 1.1	65.3 ± .6	76.7	22.0	53.2	71.9	65.8
	10 L.	135	136	58.4 ± .5	20.0 ± .8	45.8 ± 1.5	60.1 ± 1.2	56.8 ± .9	59.3	20.3	46.1	61.0	57.7
D Dark blue	Control	124	119	94.5 ± 1.9	49.8 ± 1.0	81.6 ± .9	84.2 ± 1.0	71.9 ± 1.8	94.5	49.8	84.9	84.2	71.9
	5 D. C.	122	123	96.0 ± .7	40.5 ± .7	85.0 ± 2.8	84.9 ± 1.2	77.7 ± 1.5	97.9	41.3	85.8	86.6	79.3
	10 D. C.	120	120	94.6 ± 1.1	39.6 ± .7	78.0 ± .5	87.4 ± .3	71.6 ± 3.2	97.4	40.8	80.3	90.0	73.7
	5 L.	123	128	82.3 ± 1.1	30.6 ± 1.0	75.6 ± 1.9	76.5 ± .7	62.8 ± .7	83.1	30.9	73.3	77.3	63.4
	10 L.	122	122	65.8 ± 1.2	27.2 ± .7	42.6 ± 1.5	64.2 ± 1.7	53.7 ± 1.3	67.1	27.7	43.5	65.5	54.8
C Light blue	Control	135	137	85.4 ± 1.0	37.0 ± 1.6	76.9 ± 1.2	75.7 ± .7	67.4 ± .9	85.4	37.0	75.8	75.7	67.4
	5 D. C.	138	134	90.2 ± .7	38.8 ± .4	74.7 ± 1.3	75.2 ± .4	65.8 ± 1.1	88.2	37.9	75.2	73.5	64.4
	10 D. C.	136	134	82.8 ± 1.1	31.8 ± .4	47.6 ± 1.0	77.8 ± 1.0	62.1 ± 1.5	82.2	31.6	47.9	77.3	61.7
	5 L.	137	130	72.0 ± 1.2	24.3 ± 1.0	48.4 ± 2.1	68.8 ± 1.3	58.8 ± .5	70.9	23.9	50.3	67.8	57.9
	10 L.	139	136	56.2 ± 1.2	22.2 ± .6	57.1 ± 1.4	55.8 ± 1.3	48.2 ± 2.3	54.6	21.6	56.7	54.2	46.8

* Pounds corrected = (breaking strength x thread count of control) ÷ thread count of sample broken

Table 2. (continued).

Fabrics (Rayon gabardines)	No. of launderings and dry cleanings	Warp thread count: Before abrasion	Warp thread count: After abrasion	Breaking strength of warp, Pounds: Dry	Pounds: Wet	Pounds: After abrasion	Pounds: 40 hrs. exposure	Pounds: 80 hrs. exposure	Pounds corrected*: Dry	Pounds corrected*: Wet	Pounds corrected*: After abrasion	Pounds corrected*: Faded 40 hrs.	Pounds corrected*: Faded 80 hrs.
	Control	134	129	72.5 ± .6	28.0 ± .9	56.2 ± 1.7	62.7 ± 1.3	52.8 ± .3	72.5	28.0	58.4	62.7	52.8
	5 D. C.	133	132	74.5 ± .8	26.6 ± .5	68.4 ± 1.2	64.6 ± 1.5	59.2 ± 1.0	75.2	26.9	69.4	65.2	59.8
E	10 D. C.	131	131	74.6 ± .5	23.8 ± .6	60.0 ± 1.4	64.0 ± 1.0	57.2 ± .9	76.1	24.3	61.2	65.3	58.3
Dark green	5 L.	132	134	69.8 ± 1.0	26.2 ± .4	53.3 ± 2.0	61.1 ± .8	52.7 ± .4	70.8	26.6	53.3	62.0	53.5
	10 L.	130	130	53.2 ± .8	23.8 ± .4	49.8 ± 1.5	50.0 ± .9	50.0 ± 1.0	54.8	24.5	51.3	51.5	51.5
	Control	134	130	79.6 ± 1.1	40.5 ± .9	63.5 ± 2.3	68.2 ± 1.0	56.0 ± 1.7	79.6	40.5	65.4	68.2	56.0
	5 D. C.	134	136	83.8 ± .7	35.4 ± .2	77.2 ± 1.1	60.0 ± 2.5	60.0 ± 1.1	83.8	35.4	76.0	60.0	60.0
F	10 D. C.	132	130	74.2 ± .6	34.1 ± .6	69.4 ± 3.2	66.0 ± .4	54.2 ± 1.3	75.3	34.6	71.5	67.0	55.0
Light green	5 L.	137	134	66.8 ± 1.0	24.3 ± .7	60.8 ± 1.8	59.0 ± .6	53.5 ± .8	65.3	23.8	60.8	57.7	52.3
	10 L.	136	136	51.4 ± .6	25.6 ± .6	45.5 ± .9	46.8 ± .8	45.8 ± .8	50.6	25.2	44.7	46.1	45.1
	Control	137	133	80.6 ± .9	36.5 ± 1.1	67.2 ± 1.8	71.5 ± 1.2	61.2 ± 1.5	80.6	36.5	69.2	71.5	61.2
	5 D. C.	135	136	86.6 ± .6	36.4 ± 2.3	56.0 ± 2.8	68.4 ± 1.9	56.8 ± 2.2	87.9	36.9	56.4	69.4	57.7
G	10 D. C.	132	135	76.4 ± .9	36.1 ± .6	77.9 ± 2.5	76.2 ± .6	55.8 ± 2.5	79.5	37.5	79.1	79.2	58.0
Dark brown	5 L.	137	134	78.4 ± 1.1	35.7 ± .4	51.8 ± 2.5	69.3 ± .5	58.2 ± 1.5	78.4	35.7	52.8	69.3	58.2
	10 L.	134	133	58.5 ± .7	22.7 ± 1.0	53.9 ± 1.2	59.2 ± .9	57.2 ± 1.2	59.7	23.2	55.5	60.4	58.3
	Control	138	134	89.2 ± .8	45.3 ± .4	71.0 ± 3.7	79.2 ± .6	71.6 ± 1.1	89.2	45.3	73.1	79.2	71.6
	5 D. C.	138	136	91.0 ± .8	40.3 ± .9	85.6 ± 1.0	78.4 ± .9	73.3 ± 1.2	91.0	40.3	86.9	78.4	73.3
H	10 D. C.	137	136	83.6 ± .6	39.8 ± .9	77.8 ± 2.5	75.2 ± 3.1	66.1 ± 1.5	84.2	40.1	79.0	75.7	66.6
Light brown	5 L.	138	133	85.4 ± 1.1	29.1 ± .5	59.3 ± 2.6	70.3 ± .9	65.1 ± 1.0	85.4	29.1	61.7	70.3	65.1
	10 L.	136	137	59.8 ± .6	26.1 ± .5	53.0 ± 2.2	67.6 ± 2.9	58.6 ± 1.2	60.7	26.5	53.4	68.6	59.5

* Pounds corrected = (breaking strength x thread count of control) ÷ thread count of sample broken

Table 2. (continued).

Fabrics (Rayon gabardines)	No. of launderings and dry cleanings	Warp thread count: Before abrasion	Warp thread count: After abrasion	Breaking strength of warp — Pounds: Dry	Pounds: Wet	Pounds: After abrasion	Pounds: 40 hrs. exposure	Pounds: 80 hrs. exposure	Pounds corrected*: Dry	Pounds corrected*: Wet	Pounds corrected*: After abrasion	Pounds corrected*: Faded 40 hrs.	Pounds corrected*: Faded 80 hrs.
Finished:													
I Dark red	Control	129	133	98.2 ± 1.2	53.4 ± .5	46.0 ± 2.1	88.0 ± .5	87.6 ± 1.1	98.2	53.4	44.6	88.0	87.6
	5 D. C.	133	134	96.0 ± 1.0	45.8 ± 1.8	67.0 ± 2.2	98.3 ± 1.2	87.8 ± 1.3	93.1	44.4	64.5	95.3	85.1
	10 D. C.	132	132	86.9 ± .8	45.4 ± .3	74.8 ± 3.4	93.0 ± 1.6	87.9 ± 1.2	84.9	44.3	73.0	90.8	85.9
	5 L.	133	136	93.4 ± .8	52.3 ± .6	71.1 ± 4.3	95.4 ± .9	89.6 ± 1.2	90.6	50.7	67.5	92.5	87.0
	10 L.	133	132	84.5 ± 1.0	43.2 ± .9	78.4 ± 2.6	87.8 ± 1.0	75.9 ± 1.7	82.0	41.9	76.6	85.2	73.6
J Light red	Control	138	136	102.0 ± .9	60.3 ± 1.2	74.9 ± 1.7	92.3 ± .9	87.9 ± 1.0	102.9	60.3	76.0	92.3	87.9
	5 D. C.	137	137	97.2 ± 1.4	49.8 ± 1.5	83.8 ± 1.4	94.9 ± .4	83.3 ± 1.3	97.9	50.2	84.5	95.6	83.9
	10 D. C.	136	136	85.0 ± 2.5	51.9 ± .3	65.6 ± 5.3	86.0 ± 1.1	76.8 ± 1.6	86.3	52.7	66.6	87.3	78.0
	5 L.	135	136	93.6 ± 1.2	55.8 ± .9	61.7 ± 1.9	93.6 ± 1.0	93.4 ± 1.3	95.5	57.0	62.6	95.5	95.4
	10 L.	136	139	84.2 ± .9	49.2 ± 1.1	66.4 ± 2.1	82.8 ± .6	79.8 ± 1.4	85.5	50.0	65.8	84.0	81.0
L Dark blue	Control	132	136	96.0 ± .6	55.6 ± 2.8	59.6 ± 1.6	92.8 ± 1.1	91.2 ± .8	96.0	55.6	57.8	92.8	91.2
	5 D. C.	133	136	93.8 ± 1.5	51.6 ± .6	85.6 ± .7	93.2 ± 1.0	80.3 ± .8	93.0	51.2	83.1	92.5	79.7
	10 D. C.	134	138	90.2 ± 1.3	49.3 ± .9	74.2 ± 3.0	87.1 ± 1.2	78.8 ± 1.4	88.8	48.6	71.0	85.1	77.6
	5 L.	135	136	93.2 ± 1.2	59.6 ± .4	62.1 ± 2.4	94.8 ± .8	92.8 ± 1.2	90.9	58.1	60.3	92.5	90.8
	10 L.	133	133	85.4 ± .8	50.8 ± .9	68.6 ± 4.8	83.8 ± .7	80.8 ± 1.0	84.7	50.4	68.2	83.1	80.1
K Light blue	Control	134	135	105.1 ± 1.0	59.8 ± 1.5	83.4 ± 1.0	96.9 ± 1.4	98.2 ± .7	105.1	59.8	82.8	96.9	98.2
	5 D. C.	134	136	107.2 ± 1.0	54.6 ± .4	86.0 ± 3.3	97.5 ± 1.2	87.0 ± .7	107.2	54.6	84.7	97.5	87.0
	10 D. C.	133	134	101.0 ± 1.0	51.6 ± .4	70.0 ± 1.6	90.2 ± .8	81.5 ± .9	102.0	52.1	70.0	91.1	82.3
	5 L.	133	136	94.6 ± 1.2	58.2 ± .9	80.6 ± 1.3	96.4 ± 1.0	94.1 ± 1.3	95.5	58.8	79.4	97.4	95.0
	10 L.	134	132	87.6 ± 1.1	50.7 ± 1.1	79.4 ± 2.8	89.2 ± .7	81.4 ± .9	87.6	50.7	80.6	89.2	81.4

* Pounds corrected = (breaking strength x thread count of control) ÷ thread count of sample broken

Table 2. (concluded).

Fabrics (Rayon gabardines)	No. of launderings and dry cleanings	Warp thread count: Before abrasion	Warp thread count: After abrasion	Breaking strength of warp — Pounds: Dry	Pounds: Wet	Pounds: After abrasion	Pounds: 40 hrs. exposure	Pounds: 80 hrs. exposure	Pounds corrected*: Dry	Pounds corrected*: Wet	Pounds corrected*: After abrasion	Pounds corrected*: Faded 40 hrs.	Pounds corrected*: Faded 80 hrs.
	Control	138	134	90.4 ± .8	52.4 ± .6	64.2 ± 1.4	86.7 ± .9	85.6 ± 1.4	90.4	52.4	66.1	86.7	85.6
	5 D. C.	137	137	91.8 ± .5	47.1 ± .3	73.6 ± 1.1	83.0 ± .9	74.1 ± 2.1	92.4	47.4	74.1	83.6	74.6
	10 D. C.	138	135	82.0 ± 1.1	39.6 ± 1.0	39.6 ± 1.2	86.4 ± 1.1	74.0 ± 1.6	82.0	39.6	40.4	86.4	74.0
M	5 L.	135	133	89.2 ± .7	47.8 ± .3	57.7 ± 1.4	86.6 ± .8	81.5 ± 1.4	91.0	48.8	60.0	88.3	83.1
Dark green	10 L.	134	137	74.6 ± .8	42.6 ± 1.9	60.3 ± 1.3	74.4 ± .8	65.7 ± 2.0	76.8	43.9	60.7	76.6	67.7
	Control	135	133	100.1 ± 1.0	63.9 ± 3.1	59.7 ± 1.4	99.2 ± 1.3	96.4 ± 1.1	100.1	63.9	60.6	99.2	96.4
	5 D. C.	132	135	102.5 ± .9	55.6 ± .7	65.7 ± 1.2	93.6 ± 2.2	86.9 ± 1.4	104.6	56.7	65.7	95.5	88.6
N	10 D. C.	134	136	92.4 ± 2.5	50.4 ± .9	77.2 ± 1.4	91.8 ± 1.6	85.1 ± 2.6	93.0	50.8	76.7	92.4	85.7
Light green	5 L.	134	136	102.0 ± .6	52.6 ± .6	87.5 ± 1.3	96.4 ± 1.5	96.2 ± 1.4	102.7	53.0	86.9	97.1	96.9
	10 L.	134	130	89.1 ± .9	59.3 ± 1.1	76.4 ± 2.2	89.8 ± .9	85.8 ± .9	89.7	59.7	79.5	90.4	86.4
	Control	138	136	100.9 ± .8	60.4 ± .7	74.4 ± 1.2	102.6 ± 1.1	102.7 ± 1.0	100.9	60.4	75.5	102.6	102.7
	5 D. C.	136	136	103.4 ± 1.1	53.0 ± .7	69.0 ± 1.4	96.8 ± 1.3	93.3 ± 1.1	105.0	53.8	70.0	98.3	94.7
O	10 D. C.	134	134	91.8 ± 1.0	50.8 ± .5	87.6 ± 1.8	96.7 ± 1.5	95.2 ± .8	94.6	52.3	90.2	99.6	98.1
Dark brown	5 L.	133	136	98.2 ± 1.7	57.7 ± .4	79.9 ± 4.0	97.0 ± 1.0	97.3 ± 1.5	102.1	60.0	81.1	100.9	101.2
	10 L.	134	139	88.3 ± 1.0	54.8 ± 1.3	82.4 ± 2.5	90.4 ± 1.3	89.4 ± 1.1	90.9	56.4	81.8	93.1	92.1
	Control	132	131	90.6 ± .4	51.6 ± .4	79.7 ± 1.7	90.6 ± 1.2	91.9 ± .6	90.6	51.6	80.3	90.6	91.9
	5 D. C.	132	134	89.4 ± 1.3	46.5 ± 1.6	46.8 ± 2.0	87.4 ± 1.2	85.5 ± 1.0	89.4	46.5	46.1	87.4	85.5
P	10 D. C.	132	133	83.2 ± 1.5	45.4 ± .4	58.1 ± 2.5	90.6 ± .9	87.0 ± .9	83.2	45.4	57.7	90.6	87.0
Light brown	5 L.	135	132	93.3 ± .8	44.0 ± .6	33.6 ± 1.5	89.6 ± .7	86.4 ± 1.2	91.2	43.0	33.6	87.6	84.5
	10 L.	134	138	81.2 ± .6	51.9 ± .9	53.5 ± 2.7	84.2 ± .6	83.6 ± .6	80.0	51.1	51.2	82.9	82.3

* Pounds corrected = (breaking strength x thread count of control) ÷ thread count of sample broken

Table 3. Elongation in inches and percent of dry, wet, abraded, and exposed fabrics on the controls and after cleanings.

Fabrics (Rayon gabardines)	No. of launderings and dry cleanings	Elongation of warp									
		Dry		Wet		After abrasion		40 hrs. exposure		80 hrs. exposure	
		Inches	Percent	Inches	Percent	Inches	Percent	Inches	Percent	Inches	Percent
Unfinished:											
	Control	.70 ± .00	23.3	.71 ± .02	23.7	.53 ± .01	17.7	.66 ± .01	22.0	.59 ± .01	19.7
	5 D. C.	.71 ± .01	23.7	.76 ± .01	25.3	.70 ± .01	23.3	.60 ± .01	20.0	.58 ± .01	19.3
A	10 D. C.	.77 ± .00	25.7	.63 ± .01	21.0	.64 ± .02	21.3	.61 ± .01	20.3	.54 ± .02	18.0
Dark red	5 L.	.85 ± .01	28.3	.77 ± .01	25.7	.81 ± .03	27.0	.77 ± .01	25.7	.76 ± .02	25.3
	10 L.	.72 ± .01	24.0	.83 ± .02	27.7	.78 ± .00	26.0	.72 ± .01	24.0	.65 ± .05	21.7
	Control	.68 ± .00	22.7	.63 ± .02	21.0	.52 ± .01	17.3	.66 ± .01	22.0	.62 ± .01	20.7
	5 D. C.	.71 ± .00	23.7	.67 ± .02	22.3	.65 ± .01	21.7	.59 ± .01	19.7	.54 ± .01	18.0
B	10 D. C.	.74 ± .00	24.7	.45 ± .02	15.0	.67 ± .02	22.3	.57 ± .01	19.0	.50 ± .01	16.7
Light red	5 L.	.75 ± .01	25.0	.56 ± .01	18.7	.62 ± .01	20.7	.72 ± .01	24.0	.69 ± .01	23.0
	10 L.	.68 ± .01	22.7	.52 ± .01	17.3	.73 ± .02	24.3	.70 ± .02	23.3	.62 ± .01	20.7
	Control	.78 ± .00	26.0	.82 ± .02	27.3	.68 ± .01	22.7	.64 ± .02	21.3	.61 ± .01	20.3
	5 D. C.	.80 ± .01	26.7	.84 ± .01	28.0	.74 ± .02	24.7	.66 ± .01	22.0	.60 ± .01	20.0
D	10 D. C.	.76 ± .01	25.3	.78 ± .01	26.0	.73 ± .01	24.3	.71 ± .01	23.7	.62 ± .02	20.7
Dark blue	5 L.	.80 ± .01	26.7	.80 ± .01	26.7	.79 ± .01	26.3	.74 ± .01	24.7	.67 ± .01	22.3
	10 L.	.83 ± .01	27.7	.72 ± .01	24.0	.63 ± .02	21.0	.71 ± .01	23.7	.71 ± .01	23.7
	Control	.66 ± .01	22.0	.65 ± .03	21.7	.71 ± .01	23.7	.62 ± .01	20.7	.60 ± .01	20.0
	5 D. C.	.69 ± .01	23.0	.71 ± .02	23.7	.61 ± .01	20.3	.60 ± .00	20.0	.54 ± .01	18.0
C	10 D. C.	.72 ± .01	24.0	.56 ± .01	18.7	.50 ± .01	16.7	.65 ± .01	21.7	.51 ± .01	17.0
Light blue	5 L.	.72 ± .01	24.0	.61 ± .02	20.3	.64 ± .02	21.3	.67 ± .01	22.3	.62 ± .02	20.7
	10 L.	.67 ± .01	22.3	.54 ± .01	18.0	.76 ± .01	25.3	.73 ± .01	24.3	.60 ± .01	20.0

Table 3. (continued)

Fabrics (Rayon gabardines)	No. of launderings and dry cleanings	Elongation of warp: Dry: Inches	Dry: Percent	Wet: Inches	Wet: Percent	After abrasion: Inches	After abrasion: Percent	40 hrs. exposure: Inches	40 hrs. exposure: Percent	80 hrs. exposure: Inches	80 hrs. exposure: Percent
E Dark green	Control	.64 ± .01	21.3	.63 ± .01	21.0	.58 ± .01	19.3	.66 ± .01	22.0	.57 ± .00	19.0
	5 D. C.	.67 ± .01	22.3	.62 ± .01	20.7	.72 ± .01	24.0	.56 ± .01	18.7	.55 ± .01	18.3
	10 D. C.	.62 ± .01	20.7	.59 ± .01	19.7	.67 ± .01	22.3	.58 ± .01	19.3	.54 ± .01	18.0
	5 L.	.73 ± .01	24.3	.64 ± .01	21.3	.76 ± .02	25.3	.63 ± .01	21.0	.60 ± .01	20.0
	10 L.	.68 ± .01	22.7	.75 ± .01	25.0	.88 ± .02	29.3	.69 ± .01	23.0	.59 ± .01	19.7
F Light green	Control	.60 ± .01	20.0	.70 ± .01	23.3	.56 ± .03	18.7	.61 ± .01	20.3	.54 ± .01	18.0
	5 D. C.	.72 ± .01	24.0	.77 ± .01	25.7	.63 ± .01	21.0	.49 ± .02	16.3	.51 ± .01	17.0
	10 D. C.	.67 ± .00	22.3	.69 ± .01	23.0	.73 ± .02	24.3	.59 ± .01	19.7	.50 ± .01	16.7
	5 L.	.72 ± .01	24.0	.70 ± .02	23.3	.76 ± .01	25.3	.67 ± .01	22.3	.66 ± .01	22.0
	10 L.	.71 ± .01	23.7	.85 ± .01	28.3	.92 ± .02	30.7	.72 ± .02	24.0	.72 ± .01	24.0
G Dark brown	Control	.71 ± .01	23.7	.77 ± .02	25.7	.65 ± .02	21.7	.74 ± .01	24.7	.62 ± .01	20.7
	5 D. C.	.84 ± .01	28.0	.69 ± .03	23.0	.56 ± .03	18.7	.61 ± .00	20.3	.50 ± .02	16.7
	10 D. C.	.70 ± .00	23.3	.75 ± .01	25.0	.76 ± .02	25.3	.70 ± .01	23.3	.51 ± .02	17.0
	5 L.	.80 ± .01	26.7	.80 ± .01	26.7	.77 ± .04	25.7	.72 ± .01	24.0	.66 ± .02	22.0
	10 L.	.72 ± .01	24.0	.62 ± .02	20.7	.78 ± .02	26.0	.78 ± .01	26.0	.64 ± .02	21.3
H Light brown	Control	.71 ± .01	23.7	.79 ± .02	26.3	.62 ± .03	20.7	.74 ± .00	24.7	.65 ± .02	21.7
	5 D. C.	.75 ± .00	25.0	.81 ± .01	27.0	.74 ± .02	24.7	.61 ± .01	20.3	.60 ± .02	20.0
	10 D. C.	.73 ± .01	24.3	.76 ± .01	25.3	.80 ± .02	26.7	.67 ± .03	22.3	.59 ± .02	19.7
	5 L.	.81 ± .01	27.0	.60 ± .01	20.0	.84 ± .02	28.0	.75 ± .02	25.0	.72 ± .01	24.0
	10 L.	.76 ± .01	25.3	.67 ± .01	22.3	.73 ± .03	24.3	.76 ± .01	25.3	.75 ± .01	25.0

Table 3. (continued)

Fabrics (Rayon gabardines)	No. of launderings and dry cleanings	Elongation of warp									
		Dry		Wet		After abrasion		40 hrs. exposure		80 hrs. exposure	
		Inches	Percent	Inches	Percent	Inches	Percent	Inches	Percent	Inches	Percent
Finished:											
	Control	.32 ± .01	10.7	.50 ± .01	16.7	.23 ± .01	7.7	.40 ± .01	13.3	.37 ± .01	12.3
	5 D. C.	.48 ± .00	16.0	.57 ± .01	19.0	.29 ± .01	9.7	.47 ± .01	15.7	.40 ± .01	13.3
I Dark red	10 D. C.	.44 ± .01	14.7	.53 ± .01	17.7	.40 ± .02	13.3	.42 ± .01	14.0	.40 ± .00	13.3
	5 L.	.45 ± .00	15.0	.58 ± .00	19.3	.34 ± .01	11.3	.45 ± .01	15.0	.42 ± .01	14.0
	10 L.	.44 ± .00	14.7	.48 ± .01	16.0	.38 ± .01	12.7	.45 ± .01	15.0	.38 ± .01	12.7
	Control	.52 ± .01	17.3	.62 ± .01	20.7	.45 ± .02	15.0	.49 ± .01	16.3	.51 ± .01	17.0
	5 D. C.	.61 ± .00	20.3	.64 ± .01	21.3	.53 ± .01	17.7	.51 ± .00	17.0	.46 ± .01	15.3
J Light red	10 D. C.	.50 ± .01	16.7	.66 ± .01	22.0	.40 ± .03	13.3	.47 ± .01	15.7	.45 ± .01	15.0
	5 L.	.59 ± .01	19.7	.71 ± .01	23.7	.43 ± .01	14.3	.58 ± .01	19.3	.53 ± .01	17.7
	10 L.	.56 ± .00	18.7	.60 ± .01	20.0	.44 ± .01	14.7	.57 ± .01	19.0	.56 ± .01	18.7
	Control	.57 ± .01	19.0	.66 ± .02	22.0	.38 ± .01	12.7	.50 ± .01	16.7	.56 ± .01	18.7
	5 D. C.	.55 ± .01	18.3	.67 ± .01	22.3	.53 ± .01	17.7	.50 ± .00	16.7	.44 ± .00	14.7
L Dark blue	10 D. C.	.53 ± .01	17.7	.60 ± .01	20.0	.45 ± .02	15.0	.50 ± .00	16.7	.49 ± .01	16.3
	5 L.	.58 ± .01	19.3	.70 ± .00	23.3	.42 ± .02	14.0	.56 ± .01	18.7	.53 ± .01	17.7
	10 L.	.55 ± .00	18.3	.61 ± .01	20.3	.47 ± .03	15.7	.55 ± .01	18.3	.55 ± .01	18.3
	Control	.46 ± .00	15.3	.66 ± .01	22.0	.47 ± .01	15.7	.51 ± .01	17.0	.51 ± .00	17.0
	5 D. C.	.62 ± .01	20.7	.71 ± .01	23.7	.51 ± .02	17.0	.53 ± .01	17.7	.51 ± .03	17.0
K Light blue	10 D. C.	.60 ± .00	20.0	.59 ± .01	19.7	.46 ± .01	15.3	.50 ± .01	16.7	.51 ± .00	17.0
	5 L.	.60 ± .01	20.0	.66 ± .02	22.0	.54 ± .01	18.0	.56 ± .01	18.7	.54 ± .01	18.0
	10 L.	.58 ± .01	19.3	.64 ± .01	21.3	.62 ± .01	20.7	.59 ± .01	19.7	.55 ± .01	18.3

Table 3. (concluded)

Fabrics (Rayon gabardines)	No. of launderings and dry cleanings	Elongation of warp									
		Dry		Wet		After abrasion		40 hrs. exposure		80 hrs. exposure	
		Inches	Percent	Inches	Percent	Inches	Percent	Inches	Percent	Inches	Percent
M Dark green	Control	.50 ± .00	16.7	.59 ± .01	19.7	.37 ± .01	12.3	.47 ± .00	15.7	.42 ± .01	14.0
	5 D. C.	.52 ± .00	17.3	.62 ± .01	20.7	.41 ± .00	13.7	.45 ± .01	15.0	.38 ± .01	12.7
	10 D. C.	.47 ± .01	15.7	.53 ± .02	17.7	.24 ± .01	8.0	.44 ± .01	14.7	.37 ± .01	12.3
	5 L.	.54 ± .01	18.0	.57 ± .01	19.0	.44 ± .01	14.7	.50 ± .00	16.7	.47 ± .01	15.7
	10 L.	.51 ± .00	17.0	.60 ± .01	20.0	.51 ± .02	17.0	.52 ± .01	17.3	.46 ± .01	15.3
N Light green	Control	.60 ± .01	20.0	.71 ± .02	23.7	.44 ± .01	14.7	.57 ± .01	19.0	.52 ± .01	17.3
	5 D. C.	.63 ± .01	21.0	.68 ± .01	22.7	.45 ± .01	15.0	.52 ± .02	17.3	.49 ± .01	16.3
	10 D. C.	.57 ± .02	19.0	.67 ± .02	22.3	.51 ± .01	17.0	.51 ± .01	17.0	.50 ± .01	16.7
	5 L.	.60 ± .00	20.0	.56 ± .01	18.7	.52 ± .01	17.3	.55 ± .01	18.3	.53 ± .01	17.7
	10 L.	.54 ± .01	18.0	.68 ± .01	22.7	.49 ± .01	16.3	.60 ± .01	20.0	.59 ± .01	19.7
O Dark brown	Control	.36 ± .01	12.0	.47 ± .00	15.7	.26 ± .01	8.7	.33 ± .01	11.0	.35 ± .00	11.7
	5 D. C.	.39 ± .00	13.0	.51 ± .00	17.0	.28 ± .01	9.3	.34 ± .00	11.3	.35 ± .00	11.7
	10 D. C.	.36 ± .00	12.0	.50 ± .01	16.7	.36 ± .01	12.0	.34 ± .00	11.3	.31 ± .00	10.3
	5 L.	.38 ± .01	12.7	.48 ± .01	16.0	.35 ± .01	11.7	.38 ± .01	12.7	.38 ± .01	12.7
	10 L.	.37 ± .01	12.3	.52 ± .01	17.3	.36 ± .01	12.0	.38 ± .01	12.7	.38 ± .01	12.7
P Light brown	Control	.40 ± .00	13.3	.46 ± .00	15.3	.39 ± .01	13.0	.37 ± .01	12.3	.40 ± .00	13.3
	5 D. C.	.41 ± .01	13.7	.49 ± .01	16.3	.22 ± .01	7.3	.37 ± .01	12.3	.36 ± .00	12.0
	10 D. C.	.38 ± .01	12.7	.49 ± .02	16.3	.29 ± .01	9.7	.39 ± .01	13.0	.40 ± .00	13.3
	5 L.	.29 ± .01	9.7	.41 ± .01	13.7	.17 ± .01	5.7	.39 ± .00	13.0	.38 ± .00	12.7
	10 L.	.39 ± .00	13.0	.52 ± .00	17.3	.29 ± .01	9.7	.40 ± .01	13.3	.41 ± .00	13.7

FINDINGS AND DISCUSSION

Analysis of Materials

As is shown in Table 2, variation in the thread count of the controls was from 129 to 138 for the resin-finished and from 124 to 138 for the unfinished materials. The range after five launderings was from 133 to 135 for finished and from 123 to 138 for unfinished; after ten launderings from 133 to 136 for finished and 122 to 139 for unfinished; after five dry cleanings from 132 to 137 for finished and 122 to 138 for unfinished; after ten dry cleanings from 132 to 138 for finished and 120 to 137 for unfinished. There was little difference in thread count between the controls and the dry cleaned fabrics. The increase in thread count with the number of launderings was due to shrinkage. A comparison of the control thread counts of the 16 fabrics shows little difference among them.

Dry cleaning had little effect on the appearance of either the resin-finished group or the unfinished group. Laundering changed the appearance of both groups somewhat. The change in appearance and handle, however, was noticeably greater in the case of the unfinished fabrics. These fabrics had less body and had lost their appearance of newness.

With some of the unfinished fabrics there was considerable yarn slippage evident after their abrasion of 500 strokes on the M. I. T. model abrasion tester. There was no noticeable yarn slippage of the resin-finished fabrics during abrasion.

Dry cleaning removed little finishing material from the untreated group of fabrics and removed no finishing material from the resin-treated group. Laundering removed almost all finishing material from the untreated fabrics, while it removed none from the resin-treated fabrics. Several color changes were apparent among the exposed samples, particularly those from fabrics not treated with resin. These changes are completely described by Hay. (7)

Dyes

When the fabrics were tested for the type of dye which had been used upon them, it was found that all materials reacted either to the substantive or acid dye tests or to both. They were no reactive to the tests for any other type of dye. Most of the fabrics were dyed with a combination of acid and substantive dyes according to Clayton's tests (2). Vat dyes were not found on any of these fabrics. This is of considerable interest in view of the fact that the eight resin-treated fabrics showed a high degree of fastness to light and laundering according to Hay (7). The resin finish apparently helped to give these acid and substantive dyes a degree of fastness ordinarily attributed only to vat dyes. Results of the acid and substantive dye tests are shown in Table 4.

Statistical Analysis of Results

Breaking Strength. The data on breaking strength and elongation were evaluated by the analysis of variance (4,17). In

Table 4. Identification of dyes on 16 viscose rayon gabardine fabrics.

Fabrics	Acid dye test (Boiling fabric in dilute ammonia, acidifying, adding piece of white wool)	Substantive dye test (Boiling fabric in 5% caustic soda, adding piece of white cotton)	Conclusion
A	Dyed white wool	Stained white cotton	Combination of acid and substantive
B	Dyed white wool	Cotton not affected	Acid
D	Dyed white wool	Stained white cotton	Combination of acid and substantive
C	Dyed white wool	Stained white cotton	Combination of acid and substantive
E	Dyed white wool	Stained white cotton	Combination of acid and substantive
F	Dyed white wool	Stained white cotton	Combination of acid and substantive
G	Dyed white wool gray	Stained white cotton pink	Combination of acid and substantive
H	Dyed white wool	Cotton not affected	Acid
I	Dyed white wool	Stained white cotton	Combination of acid and substantive
J	Dyed white wool	Stained white cotton	Combination of acid and substantive
L	Dyed white wool	Stained white cotton	Combination of acid and substantive
K	Dyed white wool	Stained white cotton	Combination of acid and substantive
M	Dyed white wool	Stained white cotton	Combination of acid and substantive
N	Dyed white wool	Stained white cotton	Combination of acid and substantive
O	Wool not affected	Stained white cotton	Substantive
P	Dyed white wool	Cotton not affected	Acid

the interpretation of differences by the analysis of variance a five percent probability was regarded as significant, a one percent as highly significant, and a 0.1 percent as very highly significant.

Table 5 shows the data on breaking strength for all 16 fabrics. The results of the statistical analysis of the data is shown in Table 6.

The sum of squares was calculated by the following method:

Correction term: $C = \frac{(SX)^2}{n} = \frac{(27835.2)^2}{400} = 1936995.9$

Total: $SX^2 - C = 2099409.42 - C = 162413.5$

Fabrics: $\frac{(12155.5)^2}{200} + \frac{(15679.7)^2}{200} - C = 31049.9$

Cleanings: $\frac{(5885.0)^2}{80} + \frac{(5886.9)^2}{80} + \frac{(5622.3)^2}{80} + \frac{(5515.3)^2}{80} + \frac{(4925.7)^2}{80} - C = 7755.7$

Treatments: $\frac{(6813.5)^2}{80} + \frac{(3359.3)^2}{80} + \frac{(5317.9)^2}{80} + \frac{(6433.3)^2}{80} + \frac{(5911.2)^2}{80} - C = 91983.8$

Fabrics x cleanings:

$$\left[\frac{79158205.22}{40} - C\right] - \left[31049.9 + 7755.7\right] = 3153.6$$

Fabrics x treatments:

$$\left[\frac{82603565.98}{40} - C\right] - \left[31049.9 + 91983.8\right] = 5059.5$$

Cleanings x treatments:

$$\left[\frac{32623936.48}{16} - C\right] - \left[7755.7 + 91983.8\right] = 2260.6$$

Colors within fabrics (variation within a group):

Correction term: $C_{(unfinished)} = \frac{(12155.5)^2}{200} = 738780.90$

Table 5. Breaking strength data in pounds for finished and unfinished fabrics.

Fabrics (Rayon gabardines)	Control					5 times dry cleaned					10 times dry cleaned					5 times laundered					10 times laundered					Totals
	dry	wet	abraded	40 hrs. exposure	80 hrs. exposure	dry	wet	abraded	40 hrs. exposure	80 hrs. exposure	dry	wet	abraded	40 hrs. exposure	80 hrs. exposure	dry	wet	abraded	40 hrs. exposure	80 hrs. exposure	dry	wet	abraded	40 hrs. exposure	80 hrs. exposure	
Unfinished:																										
A. Dark red	87.8	40.4	52.4	77.2	67.5	92.3	39.2	82.4	79.4	72.5	90.2	36.4	71.0	78.3	67.0	70.2	27.8	57.3	70.6	62.9	55.2	28.9	56.2	51.9	50.7	1565.7
B. Light red	78.4	28.9	55.6	71.6	61.2	83.2	28.0	71.3	69.5	64.2	80.0	22.5	61.8	67.7	58.9	76.7	22.0	53.2	71.9	65.8	59.3	20.3	46.1	61.0	57.7	1436.8
D. Dark blue	94.5	49.8	84.9	84.2	71.9	97.9	41.3	85.8	86.6	79.3	97.4	40.8	80.3	90.0	73.7	83.1	30.9	73.3	77.3	63.4	67.1	27.7	43.5	65.5	54.8	1745.0
C. Light blue	85.4	37.0	75.8	75.7	67.4	88.2	37.9	75.2	73.5	64.4	82.2	31.6	47.9	77.3	61.7	70.9	23.9	50.3	67.8	57.9	54.6	21.6	56.7	54.2	46.8	1485.9
E. Dark green	72.5	28.0	58.4	62.7	52.8	75.2	26.9	69.4	65.2	59.8	76.1	24.3	61.2	65.3	58.3	70.8	26.6	53.3	62.0	53.5	54.8	24.5	51.3	51.5	51.5	1355.9
F. Light green	79.6	40.5	65.4	68.2	56.0	83.8	35.4	76.0	60.0	60.0	75.3	34.6	71.5	67.0	55.0	65.3	23.8	60.8	57.7	52.3	50.6	25.2	44.7	46.1	45.1	1399.9
G. Dark brown	80.6	36.5	69.2	71.5	61.2	87.9	36.9	56.4	69.4	57.7	79.5	37.5	79.1	79.2	58.0	78.4	35.7	52.8	69.3	58.2	59.7	23.2	55.5	60.4	58.3	1512.1
H. Light brown	89.2	45.3	73.1	79.2	71.6	91.0	40.3	86.9	78.4	73.3	84.2	40.1	79.0	75.7	66.6	85.4	29.1	61.7	70.3	65.1	60.7	26.5	53.4	68.6	59.5	1654.2
																									Total	12155.5
Finished:																										
I. Dark red	98.2	53.4	44.6	88.0	87.6	93.1	44.4	64.5	95.3	85.1	84.9	44.3	73.0	90.8	85.9	90.6	50.7	67.5	92.5	87.0	82.0	41.9	76.6	85.2	73.6	1880.7
J. Light red	102.9	60.3	76.0	92.3	87.9	97.9	50.2	84.5	95.6	83.9	86.3	52.7	66.6	87.3	78.0	95.5	57.0	62.6	95.5	95.4	85.5	50.0	65.8	84.0	81.0	1974.7
L. Dark blue	96.0	55.6	57.8	92.8	91.2	93.0	51.2	83.1	92.5	79.7	88.8	48.6	71.0	85.1	77.6	90.9	58.1	60.3	92.5	90.8	84.7	50.4	68.2	83.1	80.1	1923.1
K. Light blue	105.1	59.8	82.8	96.9	98.2	107.2	54.6	84.7	97.5	87.0	102.0	52.1	70.0	91.1	82.3	95.5	58.8	79.4	97.4	95.0	87.6	50.7	80.6	89.2	81.4	2086.9
M. Dark green	90.4	52.4	66.1	86.7	85.6	92.4	47.4	74.1	83.6	74.6	82.0	39.6	40.4	86.4	74.0	91.0	48.8	60.0	88.3	83.1	76.8	43.9	60.7	76.6	67.7	1772.6
N. Light green	100.1	63.9	60.6	99.2	96.4	104.6	56.7	65.7	95.5	88.6	93.0	50.8	76.7	92.4	85.7	102.7	53.0	86.9	97.1	96.9	89.7	59.7	79.5	90.4	86.4	2072.2
O. Dark brown	100.9	60.4	75.5	102.6	102.7	105.0	53.8	70.0	98.3	94.7	94.6	52.3	90.2	99.6	98.1	102.1	60.0	81.1	100.9	101.2	90.9	56.4	81.8	93.1	92.1	2158.3
P. Light brown	90.6	51.6	80.3	90.6	91.9	89.4	46.5	46.1	87.4	85.5	83.2	45.4	57.7	90.6	87.0	91.2	43.0	33.6	87.6	84.5	80.0	51.1	51.2	82.9	82.3	1811.2
																									Total	15679.7
Totals:	1452.2	763.8	1078.5	1339.4	1251.1	1482.1	690.7	1176.1	1327.7	1210.3	1379.7	653.6	1097.4	1323.8	1167.8	1360.3	649.2	994.1	1298.7	1213.0	1139.2	602.0	971.8	1143.7	1069.0	27835.2
Cleaning totals:			5885.0					5886.9					5622.3					5515.3					4925.7			

Treatment totals: Dry - 6813.5 Wet - 3359.3 Abraded - 5317.9 40 hrs. exposure - 6433.3 80 hrs. exposure - 5911.2

Sum of squares: 2099409.42

Table 6. Analysis of data on breaking strength.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Fabrics (finished, unfinished)	1	31049.9	31049.9	37.3^{***}
Cleanings (control, 5 and 10 times dry cleaned, 5 and 10 times laundered)	4	7755.7	1938.9	4.2^{**}
Treatments (dry, wet, abraded, 40 and 80 hr. exposures)	4	91983.8	22996.0	44.8^{***}
Interactions:				
Fabrics x cleanings	4	3153.6	788.4	25.2^{***}
Fabrics x treatments	4	5059.5	1264.9	40.4^{***}
Cleanings x treatments	16	2260.6	141.3	4.5^{***}
Colors within fabrics	14	10134.4	723.9	23.1^{***}
Remainder	352	11016.0	31.3	
Totals	399	162413.5		

* Significant
** Highly significant
*** Very highly significant

Unfinished fabrics: $\frac{18589743.41}{25} - C_{(\text{unfinished})} = 4808.8$

Correction term: $C_{(\text{finished})} = \frac{(15679.7)^2}{200} = 1229265.0$

Finished fabrics: $\frac{30864765.73}{25} - C_{(\text{finished})} = 5325.64$

$$4808.8 + 5325.6 = 10134.4$$

In obtaining the error terms for the first three sources of variation in Table 6, the interactions concerned with that source of variation were pooled with the "colors within fabrics" variation. To obtain the error term used in testing the "fabrics" mean square, the sums of squares for the "fabrics x cleanings" and "fabrics x treatments" interactions were pooled with the sums of squares for "colors within fabrics" variation. To get the error mean square that pooled sum of squares was divided by the aggregate degrees of freedom contributed by these three sources of variation as illustrated below:

Error term for fabrics: $\frac{3153.6 + 5059.5 + 10134.4}{4 + 4 + 14} = 833.4$

In a similar manner the error term used for the F-test on the "cleanings" mean square was obtained by pooling the "fabrics x cleanings" and "cleanings x treatments" sum of squares with the "colors within fabrics" sum of squares as illustrated:

Error term for cleanings: $\frac{3153.6 + 2260.6 + 10134.4}{4 + 16 + 14} = 457.3$

Also for "treatments" the error term was obtained by pooling the "fabrics x treatments" and "cleanings x treatments" sum of squares with the "colors within fabrics" sum of squares as shown:

Error term for treatments: $\frac{5059.5 + 2260.6 + 10134.4}{4 + 16 + 14} = 513.4$

The "remainder" was used as the error term in testing the three interactions and the "colors within fabrics" variation for significance.

The analysis of variance showed very highly significant differences in breaking strength between the two groups of fabrics (finished and unfinished) and among the five treatments (dry, wet, abraded, 40 hours exposure, and 80 hours exposure). It showed highly significant differences among the cleanings (control, five times dry cleaned, ten times dry cleaned, five times laundered, and ten times laundered). All three interactions, "fabrics x cleanings", "fabrics x treatments", and "cleanings x treatments", were very highly significant. Also the "colors within fabrics" variation was very highly significant. It was the very high significance of this variation within a fabric group which made necessary the pooling of this term with the interactions in obtaining the error terms as described previously.

The t-test on the arithmetic means was used in testing the differences between fabric groups, treatments, cleanings, and the interactions. In Table 7 are the means for the t-test of the "fabrics x cleanings" interaction and of the variation due to "cleanings". In Table 8 are the least significant differences between means for the .05, .01, and .001 probability levels used in the t-test.

The sampling variances used in obtaining these least significant differences for the t-test were obtained in this way. The variance used in obtaining the differences in Table 8 for testing between fabrics within a cleaning was found by pooling the sum of the squares for "colors within fabrics" with the sum of the squares of the interaction not concerned with cleaning, namely, "fabrics x treatments". The pooled sum of the squares was divided by the pooled degrees of freedom which were 18. The resulting estimate of variance was 844.1, found as follows:

$$\frac{5059.5 + 10134.4}{4 + 14} = 844.1$$

The variance for a single mean of a fabric (either finished or unfinished) within a cleaning treatment, such as control or dry cleaned five times, was found by dividing the sampling variance by the number of samples used in obtaining that mean. In this case the number of samples used in obtaining the mean was 40, thus the operation was as follows:

V, sampling variance for fabrics within cleanings = 844.1

$\frac{V}{40} = \frac{844.1}{40} = 21.1 = V_{\bar{x}}$, variance of the mean for finished or unfinished fabrics.

The variance of the difference between means is equal to the sum of the variances of the means, when the number of samples in the two means are equal. In equation form this is:

$$V_{\bar{d}} = V_{\bar{x}_1} + V_{\bar{x}_2}$$

$V_{\bar{d}} = 21.1 + 21.1 = 42.2$, variance of differences between finished and unfinished fabrics means.

The standard deviation, $s_{\bar{d}}$ of the variance of the difference is found by taking the square root of the variance.

$$\sqrt{V_{\bar{d}}} = \sqrt{42.2} = 6.49 = s_{\bar{d}}$$

The least significant differences between the means can then be found from the formula:

$$t = \frac{\bar{d}}{s_{\bar{d}}} \quad \text{or } \bar{d} = t \times s_{\bar{d}} \, ,$$

where $\bar{d}$ is the least significant difference between means and $s_{\bar{d}}$ is the standard deviation of the differences between means as evaluated above. The t is found in the table of distribution of t from the Fisher-Yates tables (4).

Also the sampling variance used in obtaining the least significant differences in Table 8 for testing between cleaning means within a fabric group was found by pooling the sums of squares for "colors within fabrics" with the sums of squares for the interaction not concerned with fabrics, namely, "cleanings x treatments". The resulting estimate of variance was 413.2 and the accompanying degrees of freedom were 30. The same procedure for finding the least significant differences was followed for this as was followed for obtaining the differences for testing between fabrics within a cleaning. The estimate of sampling variance used in obtaining the least significant differences for testing between the means of the cleaning totals was 457.3, the variance or mean square used as the error term for the F-test on the "cleanings" mean square.

Table 9 shows the means for the t-test of the "fabrics x treatments" interaction and of the variation due to "treatments". Table 10 is the accompanying table of least significant differences between means.

Table 7. Means of breaking strength for t-test of fabrics x cleaning interaction and of cleaning variation.

Fabrics	Cleanings				
	Control	5 times dry cleaned	10 times dry cleaned	5 times laundered	10 times laundered
Unfinished	65.2	67.6	64.6	57.7	48.8
Finished	81.9	79.6	76.0	80.2	74.4
Means for cleaning totals	73.6	73.6	70.3	68.9	61.6

Table 8. Least significant differences in means for breaking strength in Table 7 for various levels of probability.

Difference for testing between	Probabilities		
	.05	.01	.001
Fabrics within a cleaning	13.6	18.7	25.5
Cleanings within a fabric	9.3	12.5	16.6
Means of cleaning totals	6.9	9.2	12.2

Table 9. Means of breaking strength for t-test of fabrics x treatments interaction and of treatments variation.

Fabrics	Treatments: Dry	Wet	Abraded	40 hrs. Exposure	80 hrs. Exposure
Unfinished	77.4	31.9	64.0	69.5	61.1
Finished	93.0	52.0	68.9	91.4	86.7
Means for treatment totals	85.2	42.0	66.5	80.4	73.9

Table 10. Least significant differences in means for breaking strength in Table 9 for various levels of probability.

Difference for testing between	Probabilities: .05	.01	.001
Fabrics within a treatment	12.8	17.4	23.8
Treatments within a fabric	9.3	12.5	16.6
Means of treatment totals	7.3	9.8	12.9

Table 11 shows the means for the t-test of the "cleanings x treatments" interaction. Table 12 is the accompanying table of least significant differences between means. The variances used in finding the least significant differences for Tables 10 and 12 were calculated in a similar manner to those for Table 8.

Table 11. Means of breaking strength for t-test of cleanings x treatments interaction.

	Treatments				
Cleanings	Dry	Wet	Abraded	40 hrs. Exposure	80 hrs. Exposure
Control	90.8	47.7	67.4	83.7	78.2
5 times dry cleaned	92.6	43.2	73.5	83.0	75.6
10 times dry cleaned	86.2	40.8	68.6	82.7	73.0
5 times laundered	85.0	40.6	62.1	81.2	75.8
10 times laundered	71.2	37.6	60.7	71.5	66.8

Table 12. Least significant differences in means for breaking strength in Table 11 for various levels of probability.

	Probabilities		
Difference for testing between	.05	.01	.001
Treatments within a cleaning	21.5	29.5	40.1
Cleanings within a treatment	20.2	27.6	37.6

The results of the t-test for breaking strength on the means of "fabrics", "treatments", and "cleaning" totals are shown below in tabular form in Table 13.

Table 13. Results of the t-test for breaking strength on the means of the totals.

Source of variation	Difference	Significance
Fabrics (unfinished, finished)	Finished greater than unfinished	***
Cleanings (control, 5 and 10 times dry cleaned, 5 and 10 times laundered)	No significant difference between control and 5 or 10 times dry cleaned.	
	No significant difference between control and 5 times laundered.	
	10 times laundered smaller than control.	***
	10 times laundered smaller than 5 times dry cleaned.	**
	10 times laundered smaller than 10 times dry cleaned.	*
	10 times laundered smaller than 5 times laundered.	*
Treatments (dry, wet, abraded, 40 hrs. exposure, 80 hrs. exposure.)	Dry greater than wet	***
	Dry greater than abraded	***
	Dry greater than exposed 80 hrs.	**

* Significant
** Highly significant
*** Very highly significant

Fabrics. No actual t-test was carried out on the means of the "fabrics" totals since that source of variation has but one degree of freedom and therefore the F-test sufficed to show the very highly significant difference.

In further testing the differences between the two groups of fabrics some significant differences were found between fabric means in the "fabrics x cleanings" interaction as shown in Table 7. These differences were found by applying the least significant differences between fabric means within a cleaning from Table 8 to the differences of the means in the interaction table. In the control fabrics, the finished and unfinished fabrics were just significantly different, the finished being greater than the unfinished. In the fabrics dry cleaned five and ten times there was no significant difference between the finished and unfinished group. In both cases, however, the differences of the means just escaped significance. Then in the five times laundered group there was a highly significant difference between the finished and unfinished fabrics, the finished being the greater. The finished fabrics were also the greater in the ten times laundered group where the difference is very highly significant. All of this indicated that neither the finished nor the unfinished fabrics lost strength in dry cleaning, but the unfinished fabrics lost strength rapidly with successive launderings while the strength of the finished fabrics was not appreciably decreased through laundering.

Significant differences between the two groups of fabrics were also found in the "fabrics x treatments" interaction as shown in Table 10 by applying the t-test to fabrics within a treatment. In the group of fabrics tested dry there was a significant difference between the finished and unfinished fabrics; the finished group showing the greater breaking strength. For the wet treatment the difference between the finished and unfinished fabrics was highly significant; the finished having much the greater breaking strength. This shows, therefore, that the finished fabrics tended not to become as weak when wet as the unfinished. Wet strength is essential to satisfactory laundering. There was no significant difference between the finished and unfinished groups for those fabrics tested after abrasion. Since the breaking strength of the finished fabrics was significantly greater than that of the unfinished in the original (dry) test, this lack of significant difference here probably showed that the finished fabrics did not resist abrasion as well as the unfinished in proportion to the original strength of each. There was a highly significant difference in the breaking strength between the finished and unfinished fabrics for those exposed 40 hours and a very highly significant difference between the fabrics for those exposed 80 hours. This indicated, then, that exposure to light weakened the unfinished fabrics a great deal more than it did the finished fabrics. This agrees with the research reported by Wood (18).

Cleanings. By inspection of the results in Table 13 of the t-test on the "cleaning" totals it is seen that the greater part of the variation shown by the F-test on the "cleanings" to be highly significant lies in the difference between the ten times laundered samples and the other four groups (control, five times dry cleaned, ten times dry cleaned, and five times laundered). So it can be concluded that the second five launderings did more to decrease the breaking strength of the fabrics than did any of the other cleaning treatments.

Almost no significant differences between cleanings within a treatment were found by applying the least significant differences in Table 12 to the "cleaning x treatments" interaction, Table 11. The one significant difference which is present agrees with the above statement. This significant difference was between the ten times laundered mean and the five times dry cleaned mean within the dry treatment. The difference between the ten times laundered mean and the control just missed significance. Both the control and the five times dry cleaned breaking strength means were considerably greater than the ten times laundered mean.

Examination of the "cleaning x fabrics" interaction in Table 7 discloses that most of the decrease in breaking strength due to numerous launderings lies in the unfinished group of fabrics and almost none in the finished group. For by applying the t-test to cleaning means within a fabric in Table 7 it was found that the ten times laundered unfinished mean differed highly significantly from the unfinished control mean, very highly significantly from the unfinished five times dry cleaned mean, and highly significantly from the unfinished ten times dry cleaned mean. On the other hand the ten times laundered finished group did not differ significantly from the mean of any other finished group mean. These results would indicate then, that the finished fabrics, as interpreted by breaking strength, resisted repeated launderings better than the unfinished fabrics.

Treatments. The results of the t-test on the means of the "treatment" totals in Table 13 showed that the breaking strength of the fabrics tested dry was greater than that of the fabrics tested wet or after abrasion by a very highly significant amount.

It was also greater than the breaking strength of the fabrics after exposure in an Atlas Fade-Ometer for 80 hours by a highly significant amount.

Significant differences can be found between the treatment means in the "fabrics x treatments" interaction, Table 9, by applying the t-test to treatment means within a fabric. By this means it was found that the dry breaking strength mean differs by a very highly significant amount from the wet breaking strength mean in the case of both the resin-finished and the unfinished fabric groups. In the resin-finished fabrics the dry breaking strength mean also differs from the abraded by a very highly significant amount. But in the unfinished fabrics the dry and abraded breaking strength means differ by just a highly significant amount. (The dry breaking strength mean was the greater, of course, in all these cases). This would lead to the same conclusion as has been drawn before -- that the breaking strength of the resin-finished fabrics decreased under abrasion more than did that of the unfinished fabrics in proportion to the original (dry) strength of each. When the dry breaking strength mean of the unfinished fabric group was compared with the mean of the samples exposed 80 hours, a highly significant difference was found, the dry again being the greater. However, with the resin-finished fabrics no significant difference was found between the dry breaking strength mean and the mean of the samples after exposure for 80 hours. This would indicate that the unfinished fabrics decreased in strength with exposure to light while the resin-finished fabrics were affected little or none at all in strength by exposure to light.

The differences between the treatment means in the "cleanings x treatments" interaction, Table 11, were found by applying the t-test. There was a very highly significant difference between the breaking strength means of the dry samples and the wet samples for each of the five cleaning treatments (control, dry cleaned five and ten times, laundered five and ten times). The dry means, of course, were higher than the wet. Saturation with water always decreases the breaking strength of rayon.

<u>Elongation</u>. A statistical analysis was made of data on elongation similar to that made of the data on breaking strength. Table 14 shows the data on elongation for all the fabrics. Table 15 shows the results of the statistical analysis of the data.

The error mean squares used in the F-test on the "fabrics", "cleanings", and "treatments" mean squares were obtained by the same method as was outlined in the breaking strength analysis.

The F-tests of significance in Table 15 showed very highly significant differences between the finished fabrics and unfinished fabrics. It showed highly significant differences between the various treatments. The F for the "cleanings" variation, however, was not significant. One of the interactions, "fabrics x treatments" was very highly significant. Another, "cleanings x treatments" was highly significant. The third, "fabrics x cleanings" was non-significant. The "colors within fabrics" variation again was very highly significant.

As in the breaking strength analysis, the t-test on arith-

Table 14. Elongation data in percent for finished and unfinished fabrics.

Fabrics	Control					5 times dry cleaned					10 times dry cleaned					5 times laundered					10 times laundered					Totals
(Rayon gabardines)	dry	wet	abraded	40 hrs. exposure	80 hrs. exposure	dry	wet	abraded	40 hrs. exposure	80 hrs. exposure	dry	wet	abraded	40 hrs. exposure	80 hrs. exposure	dry	wet	abraded	40 hrs. exposure	80 hrs. exposure	dry	wet	abraded	40 hrs. exposure	80 hrs. exposure	
Unfinished:																										
A. Dark red	23.3	23.7	17.7	22.0	19.7	23.7	25.3	23.3	20.0	19.3	25.7	21.0	21.3	20.3	18.0	28.3	25.7	27.0	25.7	25.3	24.0	27.7	26.0	24.0	21.7	579.7
B. Light red	22.7	21.0	17.3	22.0	20.7	23.7	22.3	21.7	19.7	18.0	24.7	15.0	22.3	19.0	16.7	25.0	18.7	20.7	24.0	23.0	22.7	17.3	24.3	23.3	20.7	526.5
D. Dark blue	26.0	27.3	22.7	21.3	20.3	26.7	28.0	24.7	22.0	20.0	25.3	26.0	24.3	23.7	20.7	26.7	26.7	26.3	24.7	22.3	27.7	24.0	21.0	23.7	23.7	605.8
C. Light blue	22.0	21.7	23.7	20.7	20.0	23.0	23.7	20.3	20.0	18.0	24.0	18.7	16.7	21.7	17.0	24.0	20.3	21.3	22.3	20.7	22.3	18.0	25.3	24.3	20.0	529.7
E. Dark green	21.3	21.0	19.3	22.0	19.0	22.3	20.7	24.0	18.7	18.3	20.7	19.7	22.3	19.3	18.0	24.3	21.3	25.3	21.0	20.0	22.7	25.0	29.3	23.0	19.7	538.2
F. Light green	20.0	23.3	18.7	20.3	18.0	24.0	25.7	21.0	16.3	17.0	22.3	23.0	24.3	19.7	16.7	24.0	23.3	25.3	22.3	22.0	23.7	28.3	30.7	24.0	24.0	557.9
G. Dark brown	23.7	25.7	21.7	24.7	20.7	28.0	23.0	18.7	20.3	16.7	23.3	25.0	25.3	23.3	17.0	26.7	26.7	25.7	24.0	22.0	24.0	20.7	26.0	26.0	21.3	580.2
H. Light brown	23.7	26.3	20.7	24.7	21.7	25.0	27.0	24.7	20.3	20.0	24.3	25.3	26.7	22.3	19.7	27.0	20.0	28.0	25.0	24.0	25.3	22.3	24.3	25.3	25.0	598.6
																									Total	4516.6
Finished:																										
I. Dark red	10.7	16.7	7.7	13.3	12.3	16.0	19.0	9.7	15.7	13.3	14.7	17.7	13.3	14.0	13.3	15.0	19.3	11.3	15.0	14.0	14.7	16.0	12.7	15.0	12.7	353.1
J. Light red	17.3	20.7	15.0	16.3	17.0	20.3	21.3	17.7	17.0	15.3	16.7	22.0	13.3	15.7	15.0	19.7	23.7	14.3	19.3	17.7	18.7	20.0	14.7	19.0	18.7	446.4
L. Dark blue	19.0	22.0	12.7	16.7	18.7	18.3	22.3	17.7	16.7	14.7	17.7	20.0	15.0	16.7	16.3	19.3	23.3	14.0	18.7	17.7	18.3	20.3	15.7	18.3	18.3	448.4
K. Light blue	15.3	22.0	15.7	17.0	17.0	20.7	23.7	17.0	17.7	17.0	20.0	19.7	15.3	16.7	17.0	20.0	22.0	18.0	18.7	18.0	19.3	21.3	20.7	19.7	18.3	467.8
M. Dark green	16.7	19.7	12.3	15.7	14.0	17.3	20.7	13.7	15.0	12.7	15.7	17.7	8.0	14.7	12.3	18.0	19.0	14.7	16.7	15.7	17.0	20.0	17.0	17.3	15.3	396.9
N. Light green	20.0	23.7	14.7	19.0	17.3	21.0	22.7	15.0	17.3	16.3	19.0	22.3	17.0	17.0	16.7	20.0	18.7	17.3	18.3	17.7	18.0	22.7	16.3	20.0	19.7	467.7
O. Dark brown	12.0	15.7	8.7	11.0	11.7	13.0	17.0	9.3	11.3	11.7	12.0	16.7	12.0	11.3	10.3	12.7	16.0	11.7	12.7	12.7	12.3	17.3	12.0	12.7	12.7	316.5
P. Light brown	13.3	15.3	13.0	12.3	13.3	13.7	16.3	7.3	12.3	12.0	12.7	16.3	9.7	13.0	13.3	9.7	13.7	5.7	13.0	12.7	13.0	17.3	9.7	13.3	13.7	315.6
																									Total	3212.4
Totals:	307.0	345.8	261.6	299.0	281.4	336.7	358.7	285.8	280.3	260.3	318.8	326.1	286.8	288.4	258.0	340.4	338.4	306.6	321.4	305.5	323.7	338.2	325.7	328.9	305.5	7729.0

Cleaning totals: 1494.8 1521.8 1478.1 1612.3 1622.0

Treatment totals: Dry - 1626.6 Wet - 1707.2 Abraded - 1466.5 40 hrs. exposure - 1518.0 80 hrs. exposure - 1410.7

Sum of squares: 157773.92

metic means was used in testing the differences between "fabrics", "treatments", "fabrics x treatments" interaction, and "cleanings x treatments" interaction. The t-test could not be used on the "cleanings" variation since the F-test showed that any differences existing there were non-significant. The variances used in obtaining the least significant differences in the mean for the t-test were obtained by the same general method by which they were obtained in the breaking strength analysis.

Table 15. Analysis of data on elongation.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F
Fabrics (finished, unfinished)	1	4252.34	4252.34	105.80***
Cleanings (control, 5 and 10 times dry cleaned, 5 and 10 times laundered)	4	224.80	56.20	2.52
Treatments (dry, wet, abraded, 40 and 80 hr. exposures)	4	723.60	155.90	4.90**
Interactions:				
Fabrics x cleanings	4	44.96	11.24	1.89
Fabrics x treatments	4	372.04	93.01	15.60***
Cleanings x treatments	16	246.71	15.42	2.58**
Colors within fabrics	14	467.88	33.42	5.61***
Remainder	352	2097.99	5.96	
Totals	399	8430.32		

* Significant
** Highly significant
*** Very highly significant

Table 16 shows the means for the t-test for the "fabrics x treatments" interaction and of the "treatments" variation.

Table 17 is the accompanying table of least significant differences between means. Table 18 shows the t-test means for the "cleanings x treatments" interaction, and Table 19 is the accompanying table of least significant differences between means.

Table 16. Means of elongation for t-test of fabrics x treatments interaction and of treatments variation.

Fabrics	Treatments: Dry	Wet	Abraded	40 hrs. Exposure	80 hrs. Exposure
Unfinished	24.2	23.1	23.2	22.2	20.2
Finished	16.5	19.5	13.4	15.8	15.1
Means for treatment totals	20.3	21.3	18.3	19.0	17.6

Table 17. Least significant differences in means for elongation in Table 16 for various levels of probability.

Differences for testing between	Probabilities: .05	.01	.001
Fabrics within a treatment	2.51	3.43	4.68
Treatments within a fabric	2.22	3.00	3.98
Means of treatment totals	1.82	2.44	3.22

Table 18. Means of elongation for t-test of cleanings x treatments interaction.

Cleanings	Treatments: Dry	Wet	Abraded	40 hrs. Exposure	80 hrs. Exposure
Control	19.2	21.6	16.4	18.7	17.6
5 times dry cleaned	21.0	22.4	17.9	17.5	16.3
10 times dry cleaned	19.9	20.4	17.9	18.0	16.1
5 times laundered	21.3	21.2	19.2	20.1	19.1
10 times laundered	20.2	21.1	20.4	20.6	19.1

Table 19. Least significant differences in means for elongation in Table 18 for various levels of probability.

Differences for testing between	Probabilities: .05	.01	.001
Treatments within a cleaning	5.06	6.93	9.45
Cleanings within a treatment	3.95	5.42	7.38

The results of the t-test for elongation on the means of "fabrics" and "treatments" totals are shown in tabular form in Table 20. No t-test calculations were actually carried out on the "fabrics" totals means since this source of variation has only one degree of freedom and therefore the F-test sufficed to show the very highly significant difference.

Table 20. Results of the t-test for elongation on the means of the totals.

Source of variation	Difference	Significance
Fabrics (unfinished, finished)	Unfinished greater than finished	***
Treatments (dry, wet, abraded, 40 hrs. exposure, 80 hrs. exposure.)	Dry greater than 80 hrs. exposure.	**
	Dry greater than abraded.	*
	No significant difference between dry and wet.	

* Significant
** Highly significant
*** Very highly significant

Fabrics. It can be seen from Tables 16 and 20 that the elongation of the unfinished fabrics was greater than that of the finished by a very highly significant amount. The difference between finished and unfinished fabrics was further investigated through the "fabrics x treatments" interaction, Table 16. To find differences between fabrics the least significant differences for fabrics within a treatment from Table 17 were applied. Very highly significant differences were found between the finished and unfinished fabrics which had been tested dry, after abrasion, after 40 hours exposure and after 80 hours exposure in a Fade-Ometer. A highly significant difference was found between the finished and unfinished fabrics which had been tested wet. In each case the elongation of the unfinished fabrics was greater than that of the unfinished fabrics. In the case of the breaking strength the opposite was true. These data indicated that these two physical measurements varied inversely. Increased breaking strength was accompanied by decreased elongation or vice versa.

Treatments. In Table 20 it was stated that according to the "treatments" totals means the elongation of the dry samples was significantly greater than the abraded samples and was greater than those samples exposed 80 hours by a very highly significant amount. These differences were further investigated by applying the least significant differences from Table 17 to the treatments means within a fabric of Table 16. By this means it was found that in the unfinished fabrics there was a very highly significant difference between the elongation mean of the dry samples and that of the samples which had been exposed for 80 hours in a Fade-Ometer. The elongation of these fabrics decreased greatly on exposure to light. This difference was not found in the finished fabrics. In the finished fabrics, however, highly significant differences were found between the dry and the wet and between the dry and the abraded. The elongation of the dry samples was less than that of the wet and greater than that of the abraded. Since these differences were not present in the unfinished fabrics, it would indicate that the elongation of the finished fabrics tended to increase more when wet and decrease more when abraded than did the elongation of the unfinished fabrics.

In the "cleanings x treatments" interaction there were no significant differences either between treatments or between cleanings which would be of interest in this study.

SUMMARY AND CONCLUSIONS

This study was made to show the effect of resin finishes on the breaking strength and elongation of viscose rayon fabrics. Tests were made on finished and unfinished fabrics before and after laundering and dry cleaning, before and after abrasion and exposure to light.

Dry cleaning had little effect on the appearance of either the resin-finished or non-resin-finished group of fabrics. Both groups were somewhat changed in appearance by laundering, but the change was more evident in the unfinished fabrics. Some unfinished fabrics showed considerable yarn slippage after abrasion.

The dyes used on these 16 fabrics were shown to be acid or substantive or a combination of these two types.

The breaking strength of the resin-finished gabardines was greater than that of the non-resin-finished by a very highly significant amount. Very highly significant differences were also found for "cleanings". Most of this significance lay in the difference between the ten times laundered group and the other four cleaning treatments. Successive launderings decreased the breaking strength of the unfinished fabrics, but did not decrease the strength of the resin-finished group.

There were very highly significant differences among the breaking strengths of the treatments. The dry breaking strength was greater than the wet for both broups of fabrics by a very highly significant amount. However, the finished fabrics did not become as weak when wet as did the unfinished fabrics. Wet strength is a property which is essential to satisfactory laundering. Resin-finishing did not increase the resistance of the fabrics to abrasion. Exposure to light decreased the breaking strength of the non-resin-finished fabrics but not of the resin-finished.

The elongation of the non-resin-finished fabrics was greater than the resin-finished fabrics by a very highly significant amount. Breaking strength and elongation varied inversely in most cases. Neither dry cleanings nor launderings affected the elongation significantly. There were highly significant differences in elongation among the various treatments. In the unfinished fabrics there was no difference between the dry samples and those tested wet or after abrasion. In the finished fabrics, however, the elongation of the dry samples was less than that of the wet and greater than that of the abraded. The elongation of the unfinished fabrics, but not the finished, decreased upon exposure to light.

This study showed that the resin-finished fabrics used were stronger and less extensible than the unfinished fabrics and that the resin-finish protected the fabrics against yarn slippage and against loss of strength on wetting or on exposure to light.

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