THE EFFECT OF COMMERCIAL LAUNDERING PROCESSES UPON SERVICE QUALITIES OF CERTAIN COTTON FABRICS

by

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INTRODUCTION

Laundering is a cleaning process that is repeated frequently whether it be done at home or commercially. The question arises as to whether or not service qualities of fabrics may be influenced by the laundering processes employed.

Most laundering processes require a detergent to remove soil efficiently. A detergent is a substance that is soluble in water, lowers surface tension and forms an emulsion to give a suds. Soap is one of the common detergents.

Cotton fabrics, such as ginghams and percales, are suitable for a variety of clothing and household uses. They are frequently sent to commercial laundries.

The lack of permanence of color in comparatively inexpensive cotton materials presents definite problems both to the consumer of the materials and those entrusted with their care. Of the several methods of applying color to cloth, the three that are commonly employed in the dyeing of cotton fabrics are yarn dyeing, piece dyeing and printing. In yarn dyed fabrics, the yarns themselves are dyed and then woven into cloth. In piece dyed, the cloth is dyed in the piece by immersing in or passing through a dye bath. In printed fabrics, the color is applied and fixed to the surface of the cloth.

The purpose of this study was to observe the effect of commercial laundry processes upon the service qualities of six blue cotton fabrics representative of yarn dyed, piece dyed and

printed materials.

PRESENT STATUS OF KNOWLEDGE

Few studies have been made that bear directly upon the subject of the effect of laundry methods on cotton fabrics. Ginter, Shadduck, Partlow and Pearson (4) studied the effects of commercial and home laundry methods on five plain weave fabrics. The results were analyzed to show both the effects due to washing and those due to ironing. The commercial washing methods studied caused less decrease in the strength of the fabrics during the first 15 launderings, but more thereafter than did the home laundry method. Commercial washing seemed to be slightly easier than home methods on new material but this was not true on materials that were washed frequently. Ironing by commercial methods tended to weaken material more than home methods. Commercial laundering weakened material more than home laundering.

To determine whether the dye in cloth would bleed when subjected to various laundry methods, Schaenger and Hardy's (12) study included both home and commercial laundering processes. One-inch squares of white muslin were sewed to one corner of each test sample. The pieces were then placed in separate jars and washed according to methods suggested by the Commercial Standard except instead of making up the stock soap and bleach solutions, they were obtained from a local commercial laundry. In some cases commercial laundering affected the colors less than, and in other cases as much as home laundering. In all

cases the commercial process weakened the fibers to a greater degree than the home process.

Howarth (8) studied the effect of various methods of power and home laundering on certain cotton fabrics. Chambray and broadcloth were used and the percentage loss in breaking strength and the amount of shrinkage per yard were determined. Results indicated that power methods were no more severe on the strength of these fabrics than home methods and that power methods had slightly less effect on the loss of color. All fabrics showed some change in color by all laundering methods.

The effects of washing agents on linen and cotton was studied by Turnbull and Supple (16). The fabrics were laundered 10, 25, 40, and 50 times by ordinary home processes in distilled water, and in solutions of two washing powders and a neutral soap. Neutral soap and washing powders had a decided strengthening effect upon cotton fabrics during 1 to 25 washings and thereafter they weakened them markedly. Soap and the washing powders produced a marked discoloration in the fabrics.

A comparison of service qualities on certain cotton fabrics was made by Dennis (3). Methods of applying color and the effect of pleating and starching in laundering were studied. The study showed that laundering was a greater factor in deterioration of strength than sunlight, and sunlight a greater factor in fading than laundering.

Snyder and Winegar (14) used pillow cases of three qualities and prices in their study to determine whether there is any real basis for the belief that wear on clothing is greater with com-

mercial than home laundering. In every case washing by the commercial laundry decreased the strength of the threads more than washing by home methods. An explanation suggested was that in the commercial laundry a greater number of suds and rinses were used than in most homes.

A study was made by McTavish (9) to determine the relative shrinkage and wearing qualities of different priced ginghams. The materials chosen were placed in three groups ranging in price from 10 to 35 cents. The study concluded that the number of threads per inch had no direct bearing on the wearing qualities of ginghams but influenced the shrinkage. The price of material was proportional to the number of threads per inch.

The purpose of a study by Coles and Kirkpatrick(1) was to find a simple and reliable household method of testing the color of cotton fabrics for fastness to laundering and light. Also to determine the relative fastness of color in guaranteed and non-guaranteed cotton fabrics. Tests were made on nine pieces of suitings and ginghams. These materials were tested according to washable A tests as set up by American Society of Textile Chemists and Colorists. The fabrics were also washed 50 times with a neutral soap solution and luke warm water. Results showed that guaranteed fabrics were in general more reliable than non-guaranteed and that there was a wide variation in the reliability of fabrics guaranteed as fast color. In most cases there was a close relation between fastness to laundering and fastness to light.

The study by Ginter and others (5) on the durability of cotton garments as affected by laundering and wear was done to show the effects of wear as made by physical changes on a group of cotton garments which were worn and laundered until worn out. The fabrics used in this study included 5 medium weight muslins ranging in price from 10 to 29 cents. Results showed that warpwise, the material was more weakened than fillingwise. In regard to durability, material tested after artificial abrasion in the laboratory did not rank in the same order as the same material subjected to body wear and laundering.

Factors controlling fading were reported by Sch (11). The factors studied were intensity of light falling on dyed material, the relative humidity of the air in contact with the dyed material at the time of exposure to the light, the temperature of the air and the temperature of the exposed surface of the cloth. It was found that fading during a certain length of time at 90 per cent relative humidity was the same as when exposed three times as long at 30 per cent relative humidity.

METHOD OF PROCEDURE

Six cotton fabrics, medium blue in color, of plain weave, two each of piece-dyed, yarn dyed, and printed materials, were selected for study (Plate I). The price range was from 19 to 59 cents a yard. One yard from each fabric was used as a control. Then each of the six fabrics was divided into three three-yard pieces, making three similar groups of fabric samples. The three groups were laundered under different conditions by commercial

EXPLANATION OF PLATE I

Fig. 1 Yarn dyed, fabric 1

Fig. 2 Yarn dyed, fabric 2

Fig. 3 Piece dyed, fabric 3

Fig. 4 Piece dyed, fabric 4

Fig. 5 Print dyed, fabric 5

Fig. 6 Print dyed, fabric 6

PLATE I

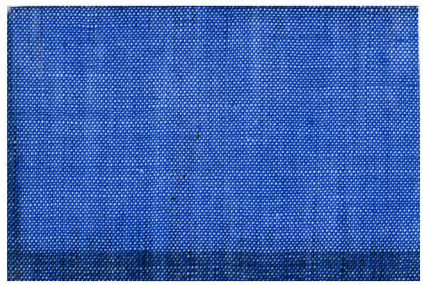


Fig. 1

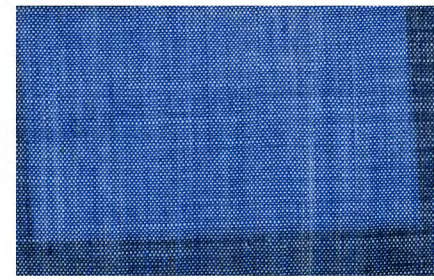


Fig. 2

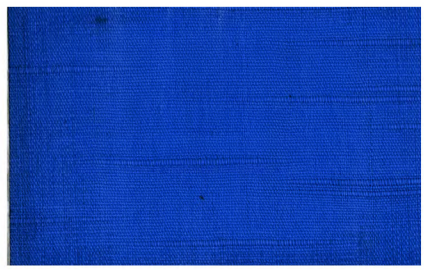


Fig. 3

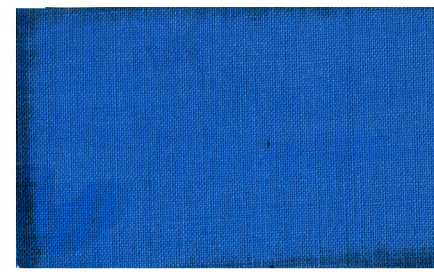


Fig. 4

Fig. 5

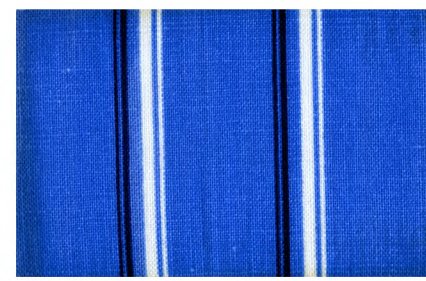


Fig. 6

laundries. Water at 100°F. and a high titer soap were used by a laundry in Wichita; water at 160°F. and a high titer soap, by a laundry in Manhattan; and water as drawn from the tap and a low titer soap by the same laundry in Manhattan. The fabrics were laundered in two suds and rinsed four times. The first rinse was in water of the same temperature as the water used for the suds. Subsequent rinses were gradually cooled until the last was the temperature of water as drawn from the tap. Ironing was done by a flat work roller press.

The controls were tested for thread count, breaking strength and elongation before and after abrasion, percentage sizing and finishing, thickness, twist, crimp, weight per square yard, yarn counts and color (Table 1).

Color change was measured at the end of the tenth laundering. After both five and ten launderings, tests were made for thread count, breaking strength, elongation and shrinkage.

The following tests were made on the fabric after it was laundered 25 and 35 times: Thread count, breaking strength and elongation before and after abrasion, shrinkage, and thickness At the conclusion of the laundering period of 35 times, color change was again measured.

The raveled strip method as set up by Committee D 13 (2) was used to determine the breaking strength and elongation. Ten strips on both warp and filling were prepared for this study.

Tests for abrasion were made after material was abraded three hundred times on the M.I.T. model of abrasion tester. The abradant used was crocus cloth. Rules set up for the use of the

Table 1. Physical characteristics, price and place of purchase of six plain weave, Z twist, cotton fabrics.

Fabric	Method of dyeing	Place of purchase	Price	Width of material	Crimp per cent		Twist turns per inch		Yarn counts cotton system		Weight per square yard ounces dry weight	Per cent of weight of finishing and sizing
					Warp	Filling	Warp	Filling	Warp	Filling		
1	Yarn	Geo. Innes Wichita, Ks.	$ .59	36 1/2	6.5	11.3	28.0	20.6	39.98	44.56	2.99	3.01
2	Yarn	Pelletiers Topeka, Ks.	$ .49	36	7.2	9.5	26.6	23.1	46.11	26.32	2.61	2.15
3	Piece	J.C. Penny Manhattan, Ks.	$ .29	35 3/4	12.2	10.7	22.4	25.8	40.22	41.81	3.41	1.24
4	Piece	Pelletiers Topeka, Ks.	$ .19	36	5.9	5.9	36.1	30.4	31.62	28.66	3.17	3.45
5	Print	James A. Poole Emporia, Ks.	$ .19	35 3/4	7.2	16.4	22.2	24.0	36.06	41.61	3.21	3.63
6	Print	Pelletiers Topeka, Ks.	$ .19	36 3/4	6.6	9.6	30.5	25.1	36.70	41.75	2.98	3.00

machine were followed. After abrasion, ten strips on the filling and ten strips on the warp were prepared for tests of breaking strength.

A quantitative analysis of the cotton fabrics was made to remove all non-fibrous constituents, sizing, and finishing added by the manufacturer. Approximately five grams of material were taken for the test. After constant weight was reached the specimen was extracted for two hours with carbon tetrachloride. The specimen was completely immersed in a three to eight per cent aqueous solution of a starch and protein solubilizing enzyme for one hour at a temperature of 122 to 140°F. then rinsed 12 times, then dried and weighed (Committee D 13, 2).

Qualitative tests were made to determine the presence of dextrin, glucose, cane sugar, glycerine, starch and egg albumin. Analysis was made according to methods accepted by the American Society of Textile Chemists and Colorists (17). A test for dextrin was made with a dilute iodine solution. A reddish violet or brown coloration indicated the presence of dextrin. Fehling's solution was used to test for glucose. If glucose was present, a red or yellow precipitate (cuprous oxide or hydroxide) separated out at once. The presence of cane sugar was found by using dilute sulfuric acid, then neutralizing with sodium hydroxide and Fehling's solution. If cuprous oxide was formed, cane sugar was present. A test for glycerine was made by using potassium hydrogen sulfate, then passing the gas evolved into Schiff's reagent. When glycerine was present, Schiff's reagent

developed a purplish color.

The twist of yarn was determined on a Suter twist counter. A 10-inch length was inserted in the jaws of the twist counter and twisted under tension until it broke. Another ten-inch length was inserted in the jaws of the twist counter and the yarn was then untwisted and retwisted in the opposite direction until it ruptured. The yarn twist was calculated by using the following formula (7):

$$\frac{N_1 - N_2}{2L} = t$$

N_2 = Number of turns of twist to rupture

N_1 = Number of turns to untwist and retwist to rupture

t = Total number of turns in one inch

L = Length of yarn

Shrinkage was measured by marking off with a thread a 10-inch square whose sides were parallel with the warp and filling yarns. The sample was taken at least three inches from the selvage (2).

The weight per square yard of fabric was calculated on the basis of the weight of five pieces two inches square or 20 square inches of material as set up by Committee D-13 (2).

Thickness was determined with a thickness gauge according to the method accepted by Committee D-13 (2). The gauge was equipped with a dial graduated to read directly to 0.001 inch.

A camera lucida was used to determine the crimp. The curves were traced on a sheet of paper. A straight line was drawn across the top of the curves. Both curved and straight lines

were stepped off with a compass. The percentage of crimp was calculated from the following formula:

$$\text{Percentage of crimp} = \frac{\text{Length of curved line} - \text{Length of straight line}}{\text{Length of straight line}} \text{ x } 100$$

An eight inch square of each fabric was used to determine yarn counts. These eight-inch squares were dried and weighed. The warp and filling yarns were raveled and counted and then weighed separately. The combined weights of the warp and filling yarns were subtracted from the original sample. The difference was divided between warp and filling. The number of yarns in the specimen, both warp and filling, was multiplied by the length of the specimen. After computing the crimp, it was added to this length. The following formula was used to calculate the cotton system (6):

$$\text{Yarn Counts} = \frac{\text{Total length in inches}}{36} \text{ x } \frac{453.6 \text{ (Grams in pound)}}{\text{Weight of sample}} \text{ x } \frac{1}{840 \text{ (Number of yards in hank)}}$$

The H S B Color Analyzer was used to measure the change in color. Colors were analyzed by the method described by the Bausch and Lomb Optical Company (15) according to the Munsell system. After the percentages of sector color and neutrals were determined, the color specifications of hue, saturation and brilliance were calculated. The following formula was used to express color in its primary attributes in figures for the sector percentage of colors and neutrals, using balanced illumination:

$$H(\text{hue}) = Z - \frac{Ax\ Px}{Ax\ Px + Az\ Pz}\ (Z - X)$$

where X = Number of first hue (clockwise in the hue circle)

Z = Number of the second hue (clockwise in the hue circle)

A = Area (expressed in sector percentage)

P = Power number (brilliance x saturation)

H = Resulting hue

S = Saturation or chroma = $\frac{A_1S_1 + A_2S_2}{100}$

B = Brilliance or value = $\sqrt{\frac{A_1\ B_1 + A_2\ B_2 + A_3\ B_3 + A_4\ B_4}{100}}$

To express colors in figures so that color change may be visualized, Nickerson's formula was used (9) with adjustments suggested by Subcommittee A-7 of Committee D-13 of the A.S.T.M. for color tolerance.

The original formula then became:

$$I = (C/5)\ \ d2H + 6dL + 3dC$$

where I = Index of fading

H = Hue

L = Lightness (brilliance or value)

C = Chroma (saturation)

d = Difference

FINDINGS AND DISCUSSION

Analysis of Controls

An analysis was made before laundering of the six cotton fabrics selected for study. No fabric was balanced as to thread count as in all cases the warp thread count exceeded that of the filling. The warp thread count varied from 85.8 to 132.7 per inch; the filling thread count, from 63.3 to 77.2 per inch. The lowest breaking strength of the warp yarns was 33.2 pounds; the highest 67.8. The lowest breaking strength of filling yarns was 16.5 and the highest, 33.2 pounds.

The greatest amount of sizing and finishing was found in fabric 5 and the least in fabric 3. Fabrics 1 and 3 contained a small amount of dextrin, fabric 5 contained a large amount. A small amount of starch was found in fabrics 2, 4, and 5. Fabric 6 contained a small amount of glucose, cane sugar and egg albumin.

The yarn twist in both warp and filling was Z for all fabrics. The number of turns per inch in both warp and filling varied from 20.6 to 30.4 in all fabrics. In fabrics 1, 2, 4, and 6 there were more turns per inch in warp yarns than in filling: fabrics 3 and 5 had more turns per inch in filling yarns. Fabric 4 had the highest twist in both warp and filling. The lowest twist occurred in the filling of fabric 1.

The weight per square yard of all materials varied from 2.61 to 3.40 ounces. Fabric 3 was the heaviest and fabric 2 the lightest.

The thickness varied from .008 to .001 inch.

The percentage of crimp in yarn ranged from 5.9 to 12.2 in the warp yarns and from 5.9 to 16.4 in the filling.

Thread count, crimp, twist, weight per square yard, thickness and sizing are shown in Tables 1, 2, 3, and 4.

General Effects of Laundering

Fabric 1 showed an increase from 91.0 in warp thread count to 93.1 after 25 launderings and then a decrease to 92.3 after 35 launderings. Filling thread count remained at 69.0 until after 35 launderings and then showed a thread count of 70.3. The breaking strength of warp yarns decreased when laundered by all the different processes. The breaking strength of filling yarns increased when laundered by process using water as drawn from tap but was not consistent when laundered by processes using water of 100°F. and 160°F. There was a slight increase in elongation in warp and filling yarns after all laundering processes. The percentage increase in thickness varied after laundering from 5.1 to 14.8.

Fabric 2 showed an increase from 93.1 in warp thread count to 96.9 after 25 launderings and then a decrease to 94.5 after 35 launderings. The filling thread count showed an increase from 73.0 to 78.0 after the fabric was laundered 35 times. The breaking strength of warp and filling yarns increased under all laundering processes after laundering 5 times and decreased under all laundering processes after laundering 25 times. There was a

Table 2. Thread count, amount and percentage of change in breaking strength and elongation of filling yarns of six cotton fabrics laundered 5, 10, 25 and 35 times before and after abrasion.

Fabric	Number of launderings	Temperature of water	Yarn dyed											
			Thread count		Breaking strength in pounds		Breaking strength in pounds corrected		Percentage of corrected breaking strength		Elongation		Percentage of elongation	
			Before abrasion	After abrasion	Before abrasion	After abrasion	Before abrasion	After abrasion	Before abrasion	After abrasion	Before abrasion	After abrasion	Before abrasion	After abrasion
1	0	Tap	69.0	68.5	29.9 ± 1.2	15.1 ± .3	29.9	15.2	100.0	- 49.1	.21 ± .01	.22 ± .01	7.0	7.3
	5		69.2		31.5 ± .9		31.4		4.9		.24 ± .01		8.2	
	10		69.4		32.6 ± .8		31.9		6.5		.25 ± .00		8.3	
	25		69.3	69.0	33.2 ± .4	31.3 ± .1	32.0	31.3	8.9	4.7	.25 ± .00	.25 ± .01	8.3	8.3
	35		70.0	68.6	33.5 ± .6	21.1 ± .7	32.9	21.0	10.7	- 29.8	.27 ± .02	.30 ± .00	9.2	10.0
	0	100° F.	69.0	68.5	29.9 ± 1.2	15.1 ± .3	29.9	15.2	100.0	- 49.1	.21 ± .01	.22 ± .01	7.0	7.3
	5		69.0		35.0 ± .5		35.0		16.9		.26 ± .01		8.6	
	10		69.2		32.9 ± .7		32.8		9.6		.28 ± .00		9.4	
	25		69.2	68.0	35.6 ± .4	28.5 ± .5	35.5	28.7	18.5	- 4.0	.27 ± .01	.27 ± .01	9.0	9.2
	35		70.3	68.4	33.4 ± .7	21.1 ± 1.6	32.8	21.1	9.5	- 29.4	.27 ± .01	.23 ± .01	9.2	7.7
	0	160° F.	69.9	68.5	29.9 ± 1.2	15.1 ± .3	29.9	15.2	100.0	- 49.1	.21 ± .01	.22 ± .01	7.0	9.3
	5		69.0		34.3 ± .5		35.1		17.4		.29 ± .01		9.6	
	10		69.0		32.3 ± .4		33.2		10.9		.29 ± .00		9.8	
	25		69.8	68.8	36.7 ± .5	33.6 ± .5	36.7	33.5	22.5	12.0	.25 ± .01	.30 ± .00	8.5	10.0
	35		70.1	70.5	34.1 ± .6	28.7 ± 1.1	34.0	27.8	13.5	- 7.0	.26 ± .00	.22 ± .01	8.9	7.6
2	0	Tap	73.0	71.6	33.2 ± 1.3	14.2 ± .3	33.2	14.5	100.0	- 56.3	.31 ± .06	.22 ± .16	10.4	7.3
	5		76.0		35.2 ± .3		33.9		2.1		.31 ± .01		10.0	
	10		76.9		33.6 ± .5		31.9		- 3.9		.32 ± .01		10.7	
	25		77.3	75.4	34.5 ± .3	30.0 ± .3	32.5	28.4	- 2.1	- 14.5	.32 ± .01	.27 ± .01	10.7	9.1
	35		78.0	77.1	34.4 ± .3	29.0 ± .7	31.2	27.5	- 6.0	- 17.2	.32 ± .01	.32 ± .01	10.7	10.7
	0	100° F.	73.0	71.6	33.2 ± 1.3	14.2 ± .3	33.2	14.5	100.0	- 56.3	.31 ± .06	.22 ± .16	10.4	7.3
	5		76.4		36.1 ± .3		34.4		- 3.6		.28 ± .01		9.6	
	10		76.8		34.4 ± .4		26.4		-20.5		.30 ± .00		10.1	
	25		76.7	74.9	35.7 ± .3	26.8 ± .6	33.9	25.6	2.1	- 22.9	.31 ± .01	.29 ± .00	10.6	9.8
	35		78.2	75.7	33.2 ± .4	25.6 ± .9	31.3	24.2	- 5.7	- 27.1	.24 ± .01	.28 ± .01	8.7	9.6
	0	160° F.	73.0	71.6	33.2 ± 1.3	14.2 ± .3	33.2	14.5	100.0	- 56.3	.31 ± .06	.22 ± .16	10.4	7.3
	5		76.2		35.1 ± .3		33.6		1.2		.31 ± .01		10.6	
	10		76.5		37.0 ± .9		35.4		6.6		.30 ± .01		10.0	
	25		77.1	75.6	35.2 ± .4	32.6 ± .4	33.4	30.9	0.6	- 6.9	.30 ± .00	.34 ± .01	10.3	11.3
	35		78.2	75.7	32.7 ± .3	32.7 ± .6	30.5	30.8	- 8.1	- 7.2	.30 ± .00	.29 ± .00	10.2	9.6

Table 2 (cont.)

Fabric	Number of launderings	Temperature of water	Thread count		Breaking strength in pounds		Breaking strength in pounds corrected		Percentage of corrected breaking strength		Elongation		Percentage of elongation	
			Before abrasion	After abrasion	Before abrasion	After abrasion	Before abrasion	After abrasion	Before abrasion	After abrasion	Before abrasion	After abrasion	Before abrasion	After abrasion
						Piece dyed								
3	0	Tap	63.3	63.2	16.5 ± .3	15.2 ± .6	16.5	15.1	100.0	- 9.5	.17 ± .01	.16 ± .01	6.3	5.3
	5		64.1		18.9 ± .7		18.7		13.5		.22 ± .00		7.6	
	10		63.6		21.3 ± 1.1		21.3		29.0		.21 ± .01		7.0	
	25		63.2	62.7	23.7 ± 1.2	21.9 ± .8	23.7	22.1	43.9	33.9	.24 ± .01	.23 ± .01	8.3	7.9
	35		63.8	63.2	18.9 ± .4	18.6 ± .5	18.8	18.6	14.0	12.7	.20 ± .00	.26 ± .01	6.9	8.7
	0	100° F.	63.3	63.2	16.5 ± .3	15.2 ± .6	16.5	15.1	100.0	- 9.5	.17 ± .01	.16 ± .01	6.3	5.3
	5		63.3		23.4 ± 1.6		23.4		42.1		.24 ± .01		8.1	
	10		63.5		17.9 ± .2		17.8		7.9		.15 ± .01		5.1	
	25		63.5	62.7	19.0 ± .6	20.0 ± .4	18.9	20.2	14.9	22.4	.21 ± .01	.22 ± .01	7.2	7.6
	35		64.6	63.8	24.0 ± 1.3	20.9 ± .7	23.6	20.8	43.0	26.0	.24 ± .01	.23 ± .01	8.3	7.7
	0	160° F.	63.3	63.2	16.5 ± .3	15.2 ± .6	16.5	15.1	100.0	- 9.5	.17 ± .01	.16 ± .01	6.3	5.3
	5		63.6		22.0 ± .8		21.9		33.0		.26 ± .01		8.7	
	10		63.8		19.5 ± .6		19.5		17.6		.21 ± .02		7.0	
	25		64.3	62.6	23.8 ± .9	20.3 ± .7	23.8	20.6	44.6	24.8	.23 ± .01	.23 ± .01	7.9	7.7
	35		64.0	62.9	20.9 ± 1.1	20.8 ± .5	20.8	20.8	25.2	26.0	.21 ± .01	.23 ± .01	7.1	7.8
4	0	Tap	77.2	76.7	32.5 ± .1	23.1 ± 1.6	32.5	23.3	100.0	-28.3	.34 ± .21	.35 ± .24	11.3	11.9
	5		79.6		33.2 ± .6		32.2		- 0.9		.35 ± .01		11.9	
	10		79.8		32.5 ± .6		31.5		- 3.0		.36 ± .01		12.2	
	25		79.9	79.9	32.4 ± .4	31.5 ± .8	31.3	30.3	- 3.7	- 6.8	.34 ± .01	.31 ± .01	11.6	10.4
	35		79.5	79.3	29.9 ± .5	26.6 ± .4	29.1	25.7	-10.5	-20.9	.31 ± .01	.33 ± .01	10.6	11.1
	0	100° F.	77.2	76.7	32.5 ± .1	23.1 ± 1.6	32.5	23.3	100.0	-28.3	.34 ± .21	.35 ± .24	11.3	11.9
	5		80.0		33.9 ± .3		32.7		0.6		.34 ± .01		11.6	
	10		80.5		32.4 ± .7		31.1		- 4.3		.32 ± .01		10.9	
	25		80.5	79.7	33.4 ± .4	29.4 ± .1	32.0	28.4	- 1.5	-12.6	.35 ± .01	.33 ± .01	11.7	11.5
	35		80.5	79.3	32.3 ± .5	26.9 ± .6	31.0	25.5	- 4.6	-21.5	.37 ± .01	.36 ± .01	12.3	12.2
	0	160° F.	77.2	76.7	32.5 ± .1	23.1 ± 1.6	32.5	23.3	100.0	-28.3	.34 ± .21	.35 ± .24	11.3	11.9
	5		80.0		32.0 ± .3		30.9		- 4.9		.33 ± .01		11.2	
	10		80.0		31.7 ± .6		30.6		- 5.8		.33 ± .01		11.0	
	25		80.0	79.5	32.4 ± .4	31.2 ± .5	31.3	30.1	- 3.7	- 7.4	.36 ± .01	.37 ± .01	12.1	12.6
	35		80.7	79.8	29.7 ± .7	27.7 ± .5	28.4	26.6	-12.6	-18.2	.30 ± .01	.32 ± .01	10.1	10.7

Table 2 (concl.)

Fabric	Number of launderings	Temperature of water	Thread count		Breaking strength in pounds		Print dyed: Breaking strength in pounds corrected		Percentage of change in breaking strength		Elongation		Percentage of elongation	
			Before abrasion	After abrasion	Before abrasion	After abrasion	Before abrasion	After abrasion	Before abrasion	After abrasion	Before abrasion	After abrasion	Before abrasion	After abrasion
5	0	Tap	75.5	74.6	26.5 ± .3	23.8 ± .6	26.5	24.1	100.0	- 9.1	.32 ± .01	.35 ± .00	10.6	11.6
	5		76.6		31.3 ± .5		30.4		14.7		.40 ± .00		13.3	
	10		78.8		31.0 ± .5		29.6		11.7		.39 ± .00		13.0	
	25		78.5	77.9	29.3 ± .4	22.8 ± .7	27.4	21.8	3.2	-17.7	.38 ± .01	.33 ± .00	12.6	11.1
	35		79.3	78.5	27.9 ± .8	23.3 ± .5	26.6	24.9	0.2	- 9.5	.36 ± .01	.38 ± .00	12.0	12.8
	0	100° F.	75.5	74.6	26.5 ± .3	23.8 ± .6	26.5	24.1	100.0	- 9.1	.32 ± .01	.35 ± .00	10.6	11.6
	5		77.7		33.2 ± .3		32.2		21.3		.40 ± .00		13.3	
	10		78.5		31.0 ± .5		29.8		12.2		.38 ± .00		12.6	
	25		78.5	77.8	27.2 ± 1.8	26.9 ± .8	26.1	25.7	- 1.4	- 3.0	.36 ± .01	.33 ± .00	12.3	11.3
	35		79.5	77.6	31.7 ± 6.3	26.7 ± .4	30.2	23.3	13.7	-12.1	.38 ± .01	.34 ± .00	12.7	11.6
	0	160° F.	75.5	74.6	26.5 ± .3	23.8 ± .6	26.5	24.1	100.0	- 9.1	.32 ± .01	.35 ± .00	10.6	11.6
	5		78.4		28.9 ± .4		27.8		4.8		.28 ± .00		9.3	
	10		78.6		29.5 ± .9		28.3		6.8		.35 ± .01		11.6	
	25		78.4	77.8	31.9 ± .2	28.8 ± .5	30.7	28.8	15.6	-17.2	.36 ± .01	.38 ± .00	12.0	12.9
	35		79.8	78.3	31.5 ± .4	28.8 ± .4	29.8	28.9	12.2	-17.1	.35 ± .01	.33 ± .00	11.6	11.1
6	0	Tap	72.1	73.5	23.0 ± 1.3	13.8 ± 1.0	23.0	13.5	100.0	-41.3	.35 ± .02	.27 ± .15	11.6	9.0
	5		76.0		29.4 ± .6		27.9		21.3		.37 ± .00		12.5	
	10		76.7		29.4 ± .6		27.6		20.0		.36 ± .01		12.0	
	25		76.9	76.1	30.0 ± .5	26.0 ± .9	28.1	28.0	22.2	-11.5	.35 ± .01	.33 ± .01	11.6	11.1
	35		78.0	76.9	26.7 ± .7	23.1 ± 1.2	24.6	25.7	7.0	- 1.3	.31 ± .01	.32 ± .01	10.3	10.9
	0	100° F.	72.1	73.5	23.0 ± 1.3	13.8 ± 1.0	23.0	13.5	100.0	-41.3	.35 ± .02	.27 ± .15	11.6	9.0
	5		75.9		30.2 ± .5		28.7		24.8		.40 ± .00		13.3	
	10		76.2		30.5 ± .1		28.9		25.6		.47 ± .00		15.8	
	25		76.3	76.1	32.2 ± .5	26.6 ± 1.0	30.4	26.7	32.2	14.5	.35 ± .01	.35 ± .01	11.6	11.8
	35		78.5	77.7	32.2 ± .5	28.7 ± .1	29.6	28.2	28.7	9.6	.34 ± .01	.31 ± .01	11.5	10.3
	0	160° F.	72.1	73.5	23.0 ± 1.2	13.8 ± 1.0	23.0	13.5	100.0	-41.3	.35 ± .02	.27 ± .15	11.6	9.0
	5		76.8		28.5 ± .8		26.4		14.8		.33 ± .00		11.0	
	10		76.7		30.5 ± .4		28.7		24.8		.35 ± .00		11.6	
	25		76.9	76.1	29.5 ± .8	27.4 ± .4	27.2	26.1	18.3	13.5	.33 ± .01	.32 ± .01	11.0	10.6
	35		78.2	77.2	30.0 ± .4	28.6 ± .6	27.7	28.7	20.4	7.4	.35 ± .01	.33 ± .00	11.6	11.0

Table 3. Thread count, amount and percentage of change in breaking strength and elongation of warp yarns of six cotton fabrics laundered 5, 10, 25, 35 times before and after abrasion.

Fabric	Number of launderings	Temperature of water	Thread count		Breaking strength in pounds		Breaking strength in pounds corrected		Percentage of change in breaking strength		Elongation		Percentage of elongation	
			Before abrasion	After abrasion	Before abrasion	After abrasion	Before abrasion	After abrasion	Before abrasion	After abrasion	Before abrasion	After abrasion	Before abrasion	After abrasion
			Yarn dyed											
1	0	Tap	91.0	89.6	41.2 ± .3	38.6 ± .2	41.2	38.2	100.0	- 7.3	.24 ± .00	.27 ± .01	8.0	9.0
	5		92.9		41.0 ± .3		40.3		- 2.1		.24 ± .00		8.0	
	10		93.0		41.2 ± .3		40.4		- 4.9		.22 ± .00		7.3	
	25		93.1	91.0	39.6 ± .3	35.4 ± .7	38.8	34.8	- 3.5	-15.5	.27 ± .00	.25 ± .01	9.2	8.5
	35		92.3	89.5	38.5 ± .3	36.2 ± .2	37.9	36.3	- 5.7	-11.9	.30 ± .00	.30 ± .00	10.0	10.3
	0	100° F.	91.0	89.6	41.2 ± .2	38.6 ± .2	41.2	38.2	100.0	- 7.3	.24 ± .00	.27 ± .01	8.0	9.0
	5		92.2		42.5 ± .3		41.9		1.7		.25 ± .00		8.6	
	10		93.0		42.8 ± .3		37.5		- 5.6		.22 ± .01		7.8	
	25		93.0	91.0	41.2 ± .3	39.1 ± .5	40.3	38.4	- 2.1	- 6.8	.27 ± .01	.27 ± .01	9.3	9.2
	35		92.4	90.0	39.9 ± .2	38.3 ± .4	39.3	38.1	- 2.0	- 7.5	.27 ± .01	.27 ± .01	9.1	9.2
	0	160° F.	91.0	89.6	41.2 ± .2	38.6 ± .2	41.2	38.2	100.0	- 7.3	.24 ± .00	.27 ± .01	8.0	9.0
	5		92.8		40.0 ± .3		39.2		- 4.7		.25 ± .00		8.7	
	10		92.0		40.1 ± .2		39.6		- 3.9		.26 ± .00		8.7	
	25		92.7	91.0	40.9 ± .2	40.8 ± 1.7	40.2	40.2	- 2.4	- 2.4	.26 ± .00	.29 ± .01	8.7	9.7
	35		91.5	90.0	36.9 ± .3	35.7 ± .9	36.9	35.5	-10.4	-13.8	.29 ± .00	.29 ± .00	9.7	9.7
2	0	Tap	93.1	91.1	33.3 ± .7	18.4 ± .06	33.3	18.8	100.0	-43.5	.21 ± .12	.16 ± .21	7.0	5.3
	5		96.1		35.8 ± .4		34.8		4.5		.24 ± .00		8.1	
	10		96.0		34.0 ± .2		33.3		10.0		.28 ± .00		9.3	
	25		96.2	94.0	33.6 ± .2	25.4 ± .1	32.5	24.6	- 2.4	-26.1	.25 ± .00	.26 ± .01	8.6	8.8
	35		94.0	91.6	29.4 ± .2	26.3 ± .9	29.2	26.2	-12.3	-21.3	.29 ± .00	.29 ± .00	9.8	9.8
	0	100° F.	93.1	91.1	33.3 ± .7	18.4 ± .1	33.3	18.8	100.0	-43.5	.21 ± .12	.16 ± .21	7.0	5.3
	5		95.3		35.7 ± .4		34.9		4.8		.26 ± .01		8.8	
	10		95.3		34.1 ± .5		33.3		0.0		.26 ± .01		8.9	
	25		95.3	93.5	34.1 ± .5	24.3 ± 1.8	33.7	24.4	1.2	-26.7	.27 ± .00	.24 ± .01	9.2	8.2
	35		94.2	92.1	35.1 ± .4	21.6 ± 1.1	34.7	21.4	4.2	-35.7	.31 ± .00	.24 ± .01	10.0	8.2
	0	160° F.	93.1	91.1	33.3 ± .7	18.4 ± .1	33.3	18.8	100.0	-43.5	.21 ± .12	.16 ± .21	7.0	5.3
	5		94.5		33.9 ± .3		33.2		- 0.3		.25 ± .01		8.6	
	10		96.4		34.0 ± .3		32.8		- 1.5		.27 ± .01		9.1	
	25		96.0	93.0	34.0 ± .4	28.6 ± .6	33.0	39.2	- 0.9	-17.7	.28 ± .00	.27 ± .01	9.4	9.1
	35		94.5	91.2	30.0 ± .5	27.6 ± .9	29.6	27.5	-11.1	-17.4	.28 ± .01	.30 ± .00	9.3	10.0

Table 3 (cont.)

Fabric	Number of launderings	Temperature of water	Thread count: Before abrasion	Thread count: After abrasion	Breaking strength in pounds: Before abrasion	Breaking strength in pounds: After abrasion	Breaking strength in pounds corrected: Before abrasion	Breaking strength in pounds corrected: After abrasion	Percentage of change in breaking strength: Before abrasion	Percentage of change in breaking strength: After abrasion	Elongation: Before abrasion	Elongation: After abrasion	Percentage of elongation: Before abrasion	Percentage of elongation: After abrasion
			Piece dyed											
3	0	Tap	132.7	130.6	67.8 ± .7	21.7 ± 2.4	67.8	22.1	100.0	-67.4	.24 ± .01	.16 ± .01	8.0	5.3
	5		133.7		70.7 ± .8		70.2		3.5		.30 ± .00		10.1	
	10		134.8		68.8 ± .5		67.7		- 0.1		.28 ± .00		9.5	
	25		134.1	131.3	66.7 ± .9	32.4 ± 2.1	66.0	32.3	- 2.7	-52.5	.31 ± .00	.21 ± .01	10.5	7.1
	35		133.3	131.4	62.4 ± .7	38.8 ± .6	62.2	38.5	- 3.8	-43.2	.30 ± .00	.23 ± .00	10.0	7.8
	0	100° F.	132.7	130.6	67.8 ± .7	21.7 ± 2.4	67.8	22.1	100.0	-67.4	.24 ± .01	.16 ± .01	8.0	5.3
	5		134.1		71.5 ± .6		70.6		4.3		.30 ± .00		10.1	
	10		134.3		71.2 ± 1.3		70.5		4.0		.28 ± .00		9.6	
	25		134.7	131.9	70.0 ± .5	42.5 ± 1.2	69.1	42.1	1.9	-37.9	.29 ± .01	.22 ± .01	9.8	7.4
	35		132.5	131.3	65.2 ± .6	37.8 ± 1.0	65.2	37.0	- 3.8	-45.4	.28 ± .01	.22 ± .01	9.6	7.3
	0	160° F.	132.7	130.6	67.8 ± .7	21.7 ± 2.4	67.8	22.1	100.0	-67.4	.24 ± .01	.16 ± .01	8.0	5.3
	5		133.7		69.7 ± 4.5		69.3		2.1		.28 ± .01		9.4	
	10		134.3		67.6 ± .9		66.7		- 1.5		.26 ± .01		8.7	
	25		134.0	131.4	66.2 ± .2	56.9 ± 2.3	65.7	56.6	- 3.0	-16.5	.27 ± .01	.26 ± .01	9.2	8.9
	35		133.0	131.4	63.1 ± .5	44.7 ± 1.7	62.9	44.3	- 7.3	-34.7	.32 ± .01	.24 ± .01	10.9	8.2
4	0	Tap	87.9	85.1	47.2 ± .5	41.9 ± .5	47.2	43.3	100.0	- 8.3	.22 ± .02	.22 ± .03	7.3	4.4
	5		88.2		45.6 ± .6		45.1		- 4.4		.23 ± .01		7.7	
	10		88.8		43.7 ± .6		43.2		- 8.5		.24 ± .01		8.2	
	25		88.8	86.2	44.4 ± .3	39.1 ± .3	43.9	38.6	- 7.0	-18.2	.26 ± .00	.25 ± .01	8.7	8.6
	35		88.0	85.2	40.4 ± .4	41.4 ± .1	40.4	41.3	-14.4	-12.5	.25 ± .01	.25 ± .00	8.6	8.4
	0	100° F.	87.9	85.1	47.2 ± .5	41.9 ± .5	47.2	43.3	100.0	- 8.3	.22 ± .00	.22 ± .02	7.3	4.4
	5		88.8		44.7 ± .4		44.0		- 6.8		.24 ± .00		8.0	
	10		88.8		44.4 ± .3		44.0		- 6.8		.24 ± .00		8.0	
	25		88.8	86.6	43.9 ± .4	39.6 ± .5	43.4	38.9	- 8.1	-17.6	.26 ± .00	.23 ± .00	8.9	7.9
	35		88.1	86.4	43.0 ± .5	40.2 ± .2	42.9	39.7	- 9.1	-15.9	.26 ± .00	.24 ± .00	8.8	8.3
	0	160° F.	87.9	85.1	47.2 ± .5	41.9 ± .5	47.2	43.3	100.0	- 8.3	.22 ± .02	.22 ± .02	7.3	4.4
	5		88.8		47.2 ± .5		46.7		- 1.1		.24 ± .00		8.1	
	10		88.4		44.9 ± .3		44.7		- 5.3		.25 ± .00		8.6	
	25		88.5	86.2	43.8 ± .6	41.3 ± .4	43.6	40.8	- 7.6	-13.6	.24 ± .02	.27 ± .01	8.1	9.0
	35		88.0	85.0	40.3 ± .2	38.6 ± .4	40.3	38.6	-18.2	-18.2	.27 ± .01	.23 ± .01	7.3	7.4

Table 3 (concl.)

Fabric	Number of launderings	Temperature of water	Thread count: Before abrasion	Thread count: After abrasion	Breaking strength in pounds: Before abrasion	Breaking strength in pounds: After abrasion	Print dyed: Breaking strength in pounds corrected: Before abrasion	Print dyed: Breaking strength in pounds corrected: After abrasion	Print dyed: Percentage of change in breaking strength: Before abrasion	Print dyed: Percentage of change in breaking strength: After abrasion	Print dyed: Elongation: Before abrasion	Print dyed: Elongation: After abrasion	Print dyed: Percentage of elongation: Before abrasion	Print dyed: Percentage of elongation: After abrasion
5	0	Tap	89.3	86.4	42.2 ± .3	41.4 ± .3	42.3	42.8	100.0	1.2	.17 ± .00	.19 ± .01	5.7	6.3
	5		91.0		45.9 ± .3		45.1		6.6		.21 ± .00		7.0	
	10		91.0		43.7 ± .7		42.9		1.4		.23 ± .01		7.8	
	25		90.4	87.5	44.7 ± .4	39.3 ± .4	44.1	38.8	4.3	- 8.3	.21 ± .00	.22 ± .01	7.3	7.5
	35		89.3	86.4	41.1 ± .3	41.3 ± .3	41.1	41.3	- 2.8	- 2.4	.26 ± .01	.24 ± .01	8.5	8.0
	0	100° F.	89.3	86.4	42.2 ± .3	43.4 ± .3	42.3	42.8	100.0	1.2	.17 ± .00	.19 ± .01	5.7	6.3
	5		90.5		46.1 ± .4		45.5		7.6		.22 ± .01		7.6	
	10		91.2		46.4 ± .6		45.4		7.3		.23 ± .00		7.7	
	25		90.5	87.6	45.0 ± .3	42.7 ± .6	44.4	42.1	5.0	- 0.5	.24 ± .01	.20 ± .00	8.2	6.8
	35		89.8	86.9	44.9 ± .4	40.2 ± .5	44.7	39.9	5.8	- 5.7	.24 ± .01	.21 ± .01	8.3	7.2
	0	160° F.	89.3	86.4	42.5 ± .3	43.4 ± .4	42.3	42.8	100.0	1.2	.17 ± .00	.19 ± .01	5.7	6.3
	5		90.8		45.7 ± .4		44.9		6.1		.25 ± .01		8.5	
	10		89.2		46.4 ± .6		46.4		9.7		.25 ± .01		7.5	
	25		89.3	86.6	44.3 ± .7	41.6 ± .4	44.3	41.6	4.7	- 1.7	.22 ± .01	.22 ± .00	7.6	7.4
	35		89.2	86.2	41.9 ± .4	39.8 ± .4	41.9	39.9	- 0.9	- 5.7	.22 ± .00	.22 ± .00	7.6	7.4
6	0	Tap	85.8	83.5	45.4 ± .1	32.6 ± .2	45.4	38.1	100.0	-16.1	.19 ± .17	.17 ± .17	6.3	5.6
	5		89.9		45.1 ± .5		43.1		- 4.0		.21 ± .06		7.0	
	10		90.0		43.8 ± .4		43.8		- 3.5		.25 ± .00		8.6	
	25		89.6	76.1	42.8 ± .4	39.7 ± .4	41.1	38.1	- 8.8	-16.1	.25 ± .00	.23 ± .00	8.3	7.4
	35		87.7	76.9	38.6 ± .5	40.0 ± .4	37.8	39.4	-16.7	-13.2	.24 ± .00	.24 ± .00	8.0	8.2
	0	100° F.	85.8	83.5	45.4 ± .1	32.6 ± .2	45.4	38.1	100.0	-16.1	.19 ± .17	.17 ± .17	6.3	5.6
	5		89.1		45.8 ± .6		44.2		- 2.6		.23 ± .01		7.1	
	10		89.6		44.7 ± .5		42.8		- 5.7		.23 ± .01		7.1	
	25		88.9	86.0	44.1 ± .4	40.6 ± .4	42.6	39.3	- 6.2	-13.4	.22 ± .01	.21 ± .01	7.1	7.0
	35		87.2	86.6	41.2 ± .3	38.6 ± .5	40.6	37.1	-10.6	-18.3	.27 ± .00	.24 ± .04	9.1	8.0
	0	160° F.	85.8	83.5	45.4 ± .1	32.6 ± .2	45.4	38.1	100.0	-16.1	.19 ± .17	.17 ± .17	6.3	5.6
	5		89.1		42.9 ± .6		40.1		-11.7		.25 ± .00		8.5	
	10		89.7		44.4 ± .3		42.5		- 6.4		.26 ± .00		8.8	
	25		89.0	86.0	44.1 ± .5	40.1 ± .5	42.5	27.7	- 6.4	-30.0	.24 ± .00	.27 .01	8.0	9.2
	35		87.6	85.6	40.5 ± .5	38.7 ± .3	39.7	37.5	-12.6	-17.4	.28 ± .00	.22 .01	9.6	7.5

Table 4. Thickness and shrinkage of six cotton fabrics.

Yarn dyed								
Fabrics	Temperature of water	Number of launderings	Thickness in inches		Shrinkage in inches		Shrinkage in per cent	
			Before abrasion	After abrasion	Warp	Filling	Warp	Filling
1	Tap	0	.009	.009				
		5			.125	.314	1.3	3.1
		10			.563	.314	5.6	3.1
		25	.010	.010	.563	.314	5.6	3.1
		35	.010	.010	.563	.355	5.6	3.8
	100° F.	0	.009	.009				
		5			.250	.318	2.5	3.1
		10			.250	.355	2.5	3.8
		25	.010	.009	.314	.355	3.1	3.8
		35	.010	.010	.314	.355	3.1	3.8
	160° F.	0	.009	.009				
		5			.188	.355	1.9	3.8
		10			.314	.355	3.1	3.8
		25	.011	.009	.314	.355	3.1	3.8
		35	.011	.010	.314	.355	3.1	3.8
2	Tap	0	.008	.009				
		5			.563	.355	5.6	3.8
		10			.563	.355	5.6	3.8
		25	.010	.010	.563	.355	5.6	3.8
		35	.010	.010	.563	.355	5.6	3.8
	100° F.	0	.008	.009				
		5			.500	.450	5.0	4.4
		10			.500	.450	5.0	4.4
		25	.010	.010	.500	.450	5.0	4.4
		35	.010	.010	.500	.450	5.0	4.4
	160° F.	0	.008	.009				
		5			.450	.355	4.4	3.8
		10			.500	.450	5.0	4.4
		25	.010	.009	.563	.450	5.6	4.4
		35	.010	.010	.563	.450	5.6	4.4

Table 4 (cont.)

Fabrics	Temperature of water	Number of launderings	Piece dyed: Thickness in inches: abrasion	Piece dyed: Thickness in inches: abrasion	Shrinkage in inches: Warp	Shrinkage in inches: Filling	Shrinkage in per cent: Warp	Shrinkage in per cent: Filling
3	Tap	0	.011	.010				
		5			.000	.188	0.0	1.9
		10			.000	.188	0.0	1.9
		25	.011	.011	.000	.188	0.0	1.9
		35	.011	.011	.000	.188	0.0	1.9
	100° F.	0	.011	.010				
		5			.000	.188	0.0	1.9
		10			.000	.188	0.0	1.9
		25	.011	.011	.000	.188	0.0	1.9
		35	.011	.010	.000	.188	0.0	1.9
	160° F.	0	.011	.010				
		5			.000	.188	0.0	1.9
		10			.000	.188	0.0	1.9
		25	.012	.010	.000	.188	0.0	1.9
		35	.011	.011	.000	.188	0.0	1.9
4	Tap	0	.010	.010				
		5			.314	.250	3.1	2.5
		10			.355	.250	3.8	2.5
		25	.011	.010	.355	.250	3.8	2.5
		35	.011	.010	.355	.250	3.8	2.5
	100° F.	0	.010	.010				
		5			.355	.250	3.8	2.5
		10			.355	.250	3.8	2.5
		25	.011	.011	.355	.250	3.8	2.5
		35	.011	.011	.355	.250	3.8	2.5
	160° F.	0	.010	.010				
		5			.355	.250	3.8	2.5
		10			.355	.250	3.8	2.5
		25	.011	.009	.355	.250	3.8	2.5
		35	.011	.011	.355	.250	3.8	2.5

Table 4 (concl.)

Fabrics	Temperature of water	Number of launderings	Thickness in inches		Shrinkage in inches		Shrinkage in per cent	
			Before abrasion	After abrasion	Warp	Filling	Warp	Filling
			Print dyed					
5	Tap	0	.010	.010				
		5			.355	.355	3.8	3.8
		10			.355	.355	3.8	3.8
		25	.011	.010	.450	.355	4.4	3.8
		35	.011	.010	.450	.355	4.4	3.8
	100° F.	0	.010	.010				
		5			.314	.125	3.1	1.3
		10			.355	.125	3.8	1.3
		25	.011	.011	.355	.188	3.8	1.9
		35	.011	.011	.450	.188	4.4	1.9
	160° F.	0	.010	.010				
		5			.314	.355	3.1	3.8
		10			.450	.355	4.4	3.8
		25	.011	.011	.450	.500	4.4	5.0
		35	.011	.011	.450	.500	4.4	5.0
6	Tap	0	.009	.009				
		5			.450	.355	4.4	3.8
		10			.500	.355	5.0	3.8
		25	.011	.011	.500	.355	5.0	3.8
		35	.011	.011	.500	.355	5.0	3.8
	100° F.	0	.009	.009				
		5			.355	.314	3.8	3.1
		10			.450	.355	4.4	3.8
		25	.011	.011	.500	.355	5.0	3.8
		35	.011	.012	.500	.355	5.0	3.8
	160° F.	0	.009	.009				
		5			.314	.355	3.1	3.8
		10			.450	.450	4.4	4.4
		25	.011	.009	.450	.450	4.4	4.4
		35	.011	.011	.564	.450	5.6	4.4

slight increase in elongation of warp yarns. The percentage of shrinkage varied from 1.9 to 5.6 and the increase in thickness in inches varied from .008 to .010.

Fabric 3 showed an increase from 132.9 warp thread count to 134.7 after 25 launderings and then a decrease to 133.3 after 35 launderings. The fabrics fillingwise showed no significant change in thread count after laundering. The breaking strength of warp yarns showed an increase after 5 launderings and a decrease after 25 launderings. The filling yarns showed an increase in breaking strength after 5 launderings. There was an increase in elongation in both warp and filling yarns after 5 launderings in all laundering methods. There was no shrinkage warpwise but the shrinkage fillingwise was 1.9 per cent. There was no apparent change in thickness after any laundering process.

Fabric 4 showed no variation in warp thread count, but an increase in filling thread count from 77.2 to 80.7 after 35 launderings. The breaking strength of filling threads showed little or no increase under all laundering methods but a decrease after laundering 25 times. The warp yarns showed a decrease after each period of testing. The warp and filling yarns showed a slight increase in elongation but were not always consistent in this respect. The percentage of shrinkage varied from 3.1 in filling yarns to 3.8 in warp. The increase in thickness varied from .01 to .011 inch.

Fabric 5 showed an increase from 89.3 to 90.5 warp yarns after 25 launderings and then a decrease to 89.3 after 35 launderings. The filling thread count showed an increase from 75.5

to 79.3 after 25 launderings. Breaking strength of warp yarns showed an increase after 5 to 25 launderings and then a decrease after 25 launderings. Breaking strength of filling yarns showed a gradual increase after each laundering. There was an increase in elongation in warp and filling yarns in most cases after each method of laundering. The percentage of shrinkage varied from 3.8 to 4.4. The increase in thickness varied from .01 to .011 inch.

Fabric 6 showed an increase from 85.8 to 89.6 in warp yarns after 25 launderings and then a decrease to 87.7 after 35 launderings. Filling yarns increased from 72.0 to 78.2. Breaking strength in pounds in filling yarns increased after each period of testing. Breaking strength of warp yarns showed a decrease after each period of testing. There was a slight increase in elongation of warp yarns but little change in filling yarns. Percentage of shrinkage varied from 3.8 to 5.6. The increase in thickness varied from .009 to .011 inch.

Effects of Laundering Processes

The results of the laundering process shown in Table 2 using water at a temperature as drawn from the tap showed that in fabrics 4 and 6 the breaking strength of yarns decreased after five launderings. In fabrics 1, 2, 3, and 5 there was an increase in breaking strength. All but fabric 3 showed a decrease in warp thread count after 35 launderings. The filling yarns of fabrics 1, 2, 3, 5, and 6 showed an increase in breaking strength after five launderings. The percentage elongation remained nearly the

same for all fabrics. The percentage shrinkage was greater warpwise in fabrics 1 and 2 than in the other fabrics. Thickness was not apparently affected by the various laundering processes.

The results of the laundering process in water at a temperature of 100°F. showed that fabrics 1, 2, 3 and 5, both warpwise and fillingwise, increased in breaking strength after laundering five times. The warp yarns of fabrics 2, 3, 4 and 6 and the filling yarns of fabrics 1, 2, 4 and 6 showed a decrease in breaking strength at the end of 25 launderings. The percentage elongation of all fabrics remained nearly the same laundered by this process. Shrinkage was less by the laundering process using water at 100°F. than by the process using water as drawn from the tap and by water at 160°F. The different laundering processes did not seem to affect thickness.

The results of the laundering process using water at a temperature of 160°F. showed that the warp yarns of fabrics 1, 4 and 6 and the filling yarns of fabric 4 decreased in breaking strength after laundering five times. The warp yarns of fabrics 2 and 3 and the filling yarns of fabrics 2 and 5 showed a very slight increase in breaking strength after laundering five times.

Warp threads in all fabrics but fabric 6 and filling threads in all fabrics showed a sharp decrease in breaking strength at the end of 25 launderings. The percentage elongation of all fabrics remained nearly the same. There was a greater percentage shrinkage in most cases due to this laundering process. The thickness apparently was not affected by this laun-

dering process (Figs. 7-12).

Analysis of Abraded Fabrics

Fabric 1 showed a decrease in both warp and filling thread count after abrasion as compared with the unabraded fabric. There was an increase in thread count after 25 launderings and a decrease at 35 launderings. There was a 7.3 per cent decrease in breaking strength warpwise and 49.1 per cent decrease fillingwise after abrasion. The breaking strength increased after 25 and 35 launderings warpwise but decreased fillingwise. Elongation was greater in both warp and filling after abrasion. There was no apparent change in thickness due to abrasion after laundering 25 and 35 times.

Fabric 2 showed a decrease in thread count in both warp and filling after abrasion as compared with the unabraded fabric. There was an increase in thread count of both warp and filling after 25 launderings and then a decrease at 35 launderings. There was 43.5 per cent decrease in breaking strength warpwise after abrasion and 56.4 per cent decrease fillingwise. The breaking strength increased after 25 and 35 launderings in both warp and filling. Elongation was greater in both warp and filling. There was no apparent decrease in thickness after abrasion of fabrics laundered 25 and 35 times.

Fabric 3 showed a decrease in thread count in warp yarns after abrasion but no change in filling yarns when compared with the unabraded fabric. A decrease of 67.4 per cent was shown in the breaking strength warpwise after abrasion and 9.5 per cent

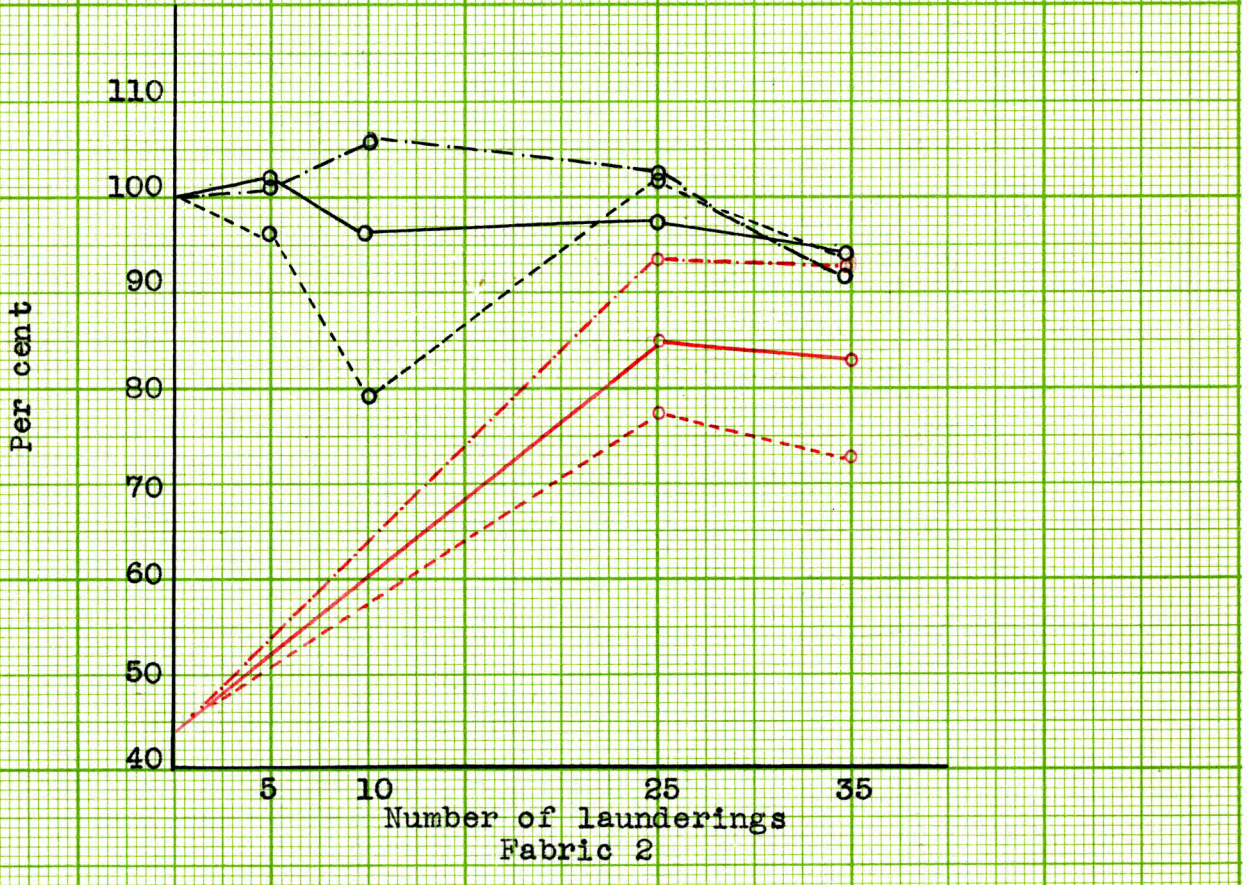
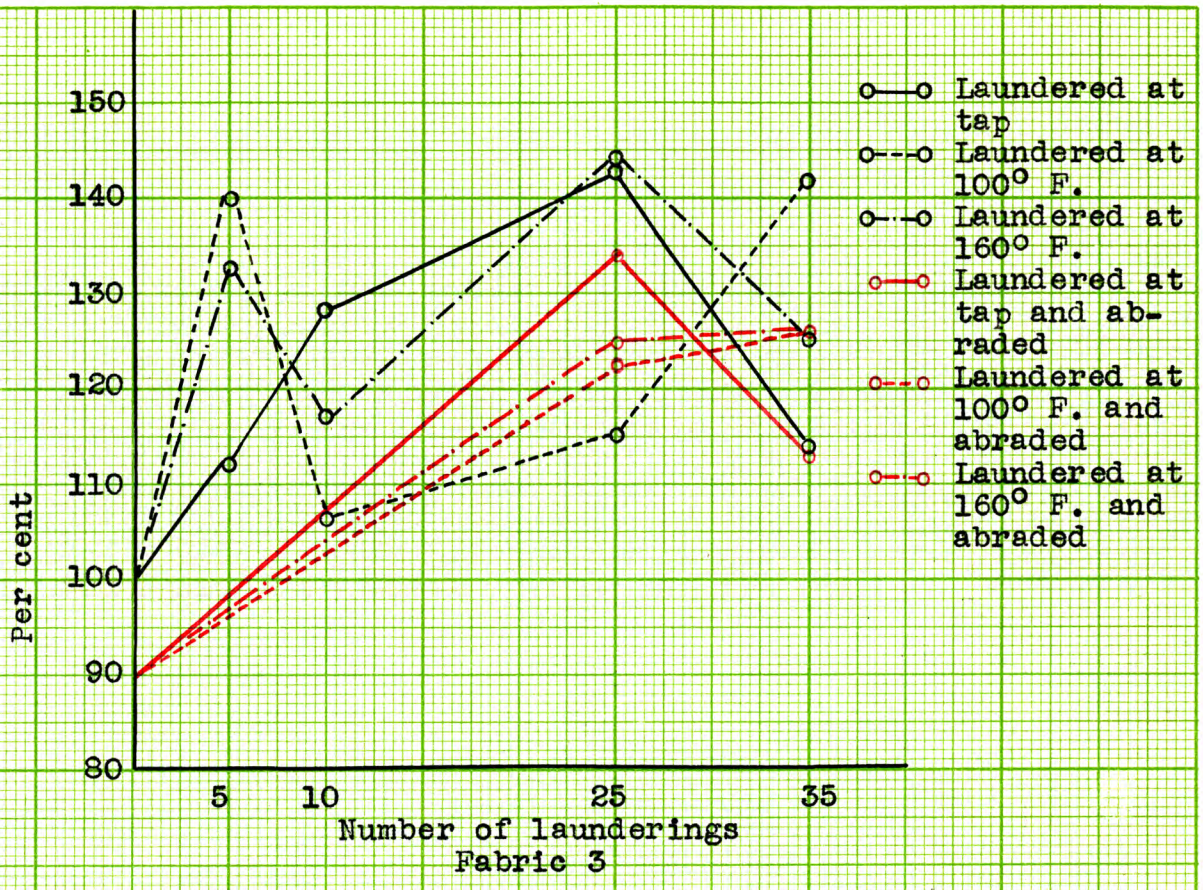


Fig. 7. Breaking strength of two yarn dyed fabrics laundered 5,10, 25 and 35 times before and after abrasion.



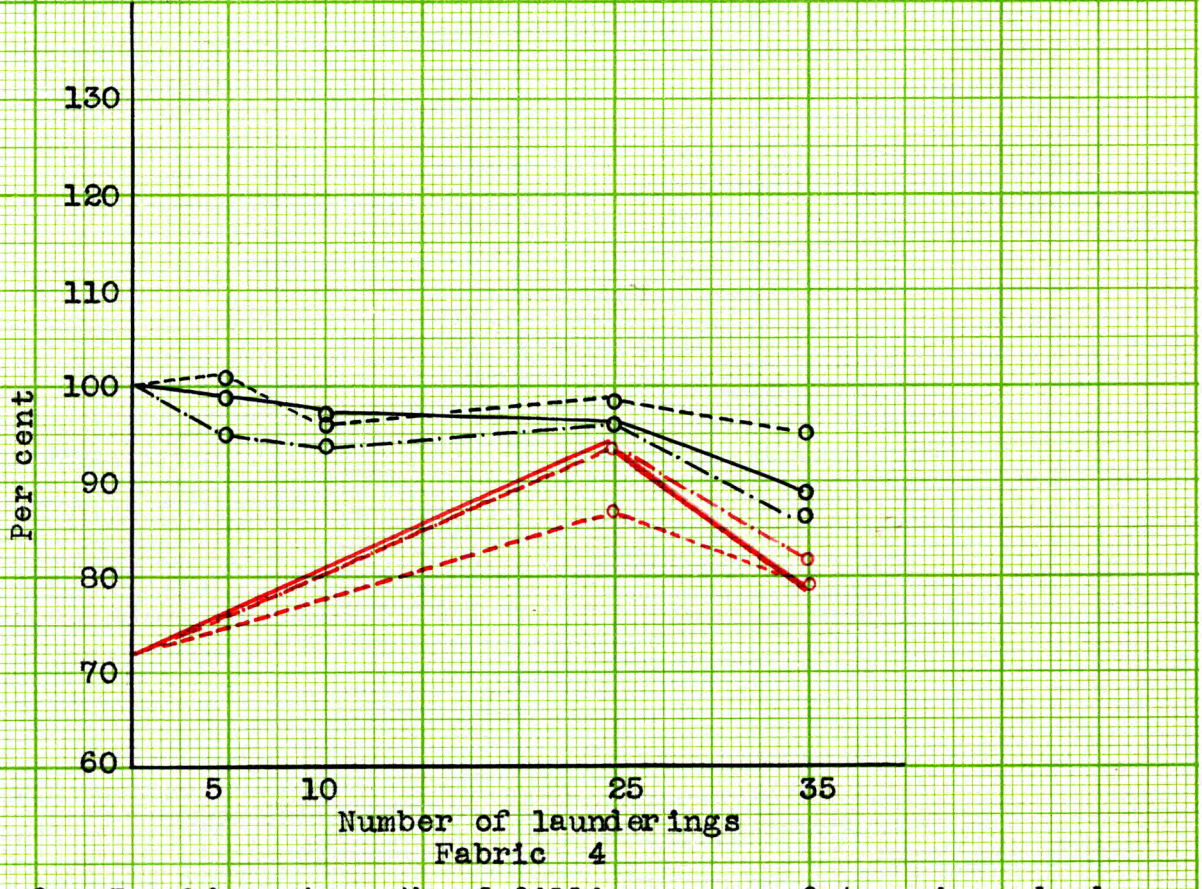
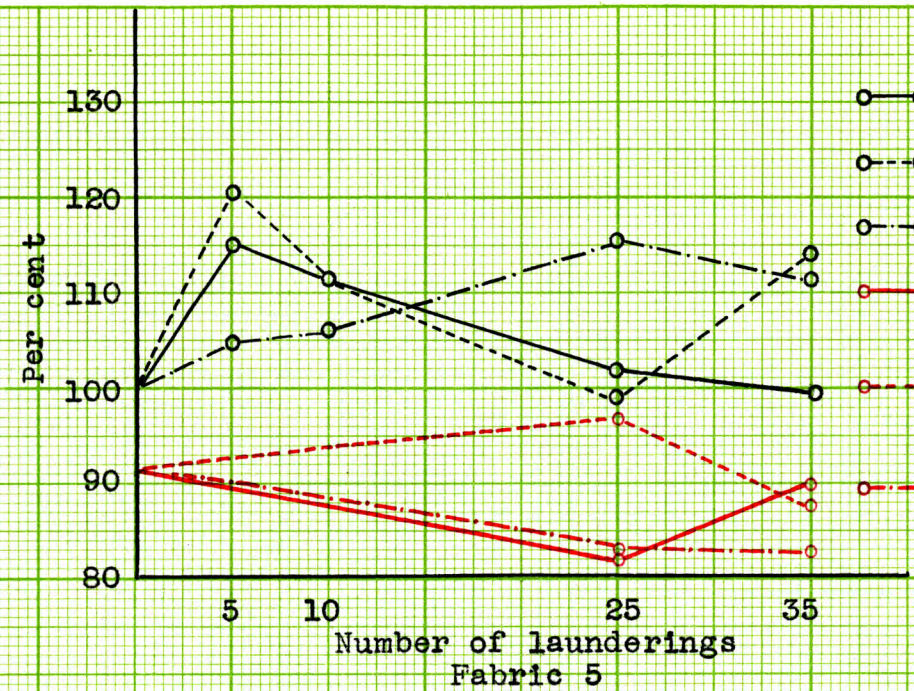


Fig. 8. Breaking strength of filling yarns of two piece dyed fabrics laundered 5, 10, 25 and 35 times before and after abrasion.



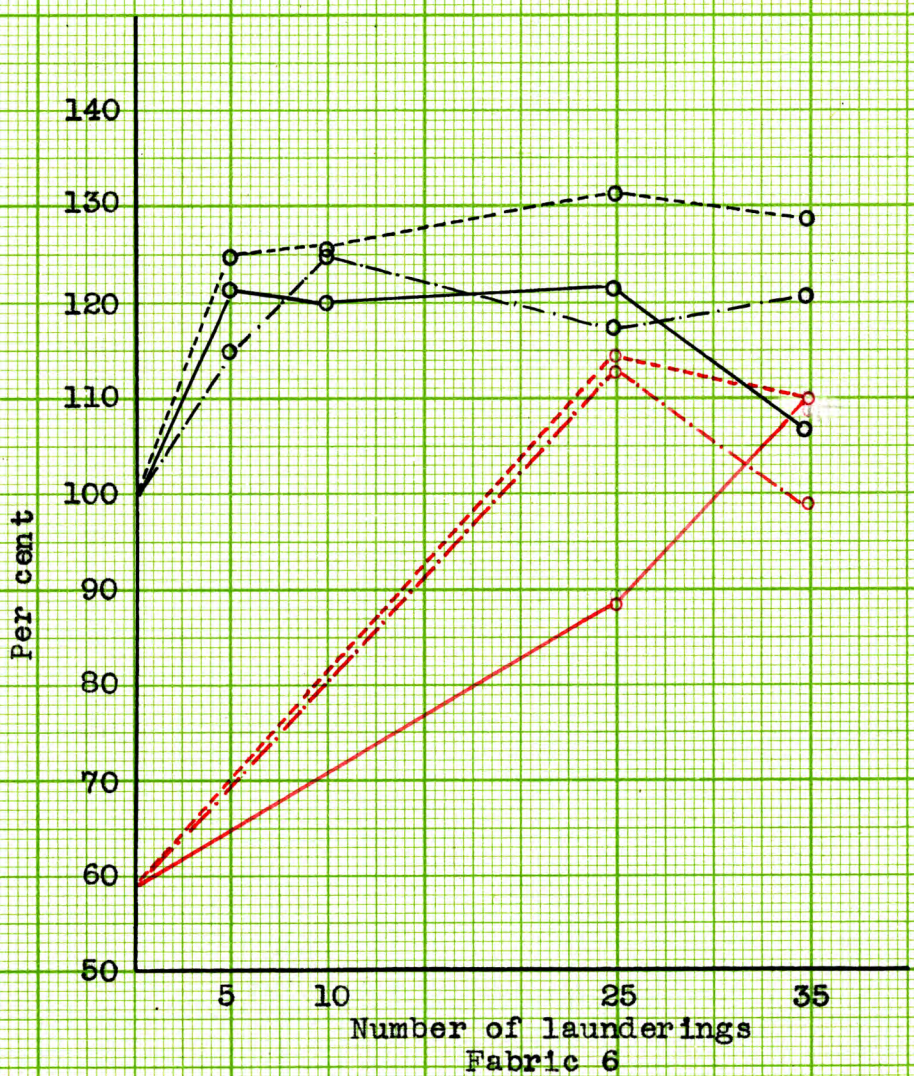
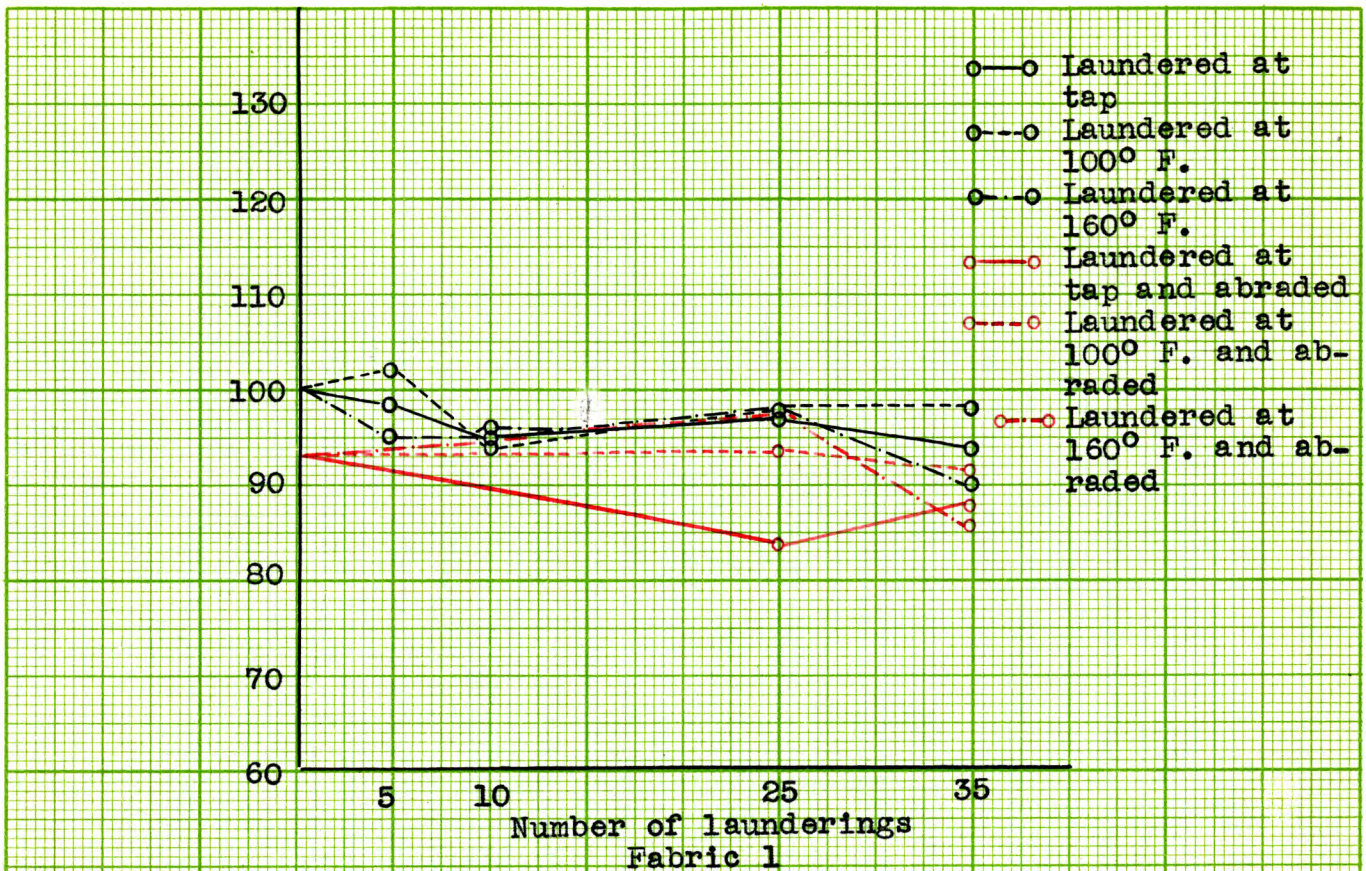


Fig. 9. Breaking strength of filling yarns of two print dyed fabrics laundered 5, 10, 25 and 35 times before and after abrasion.



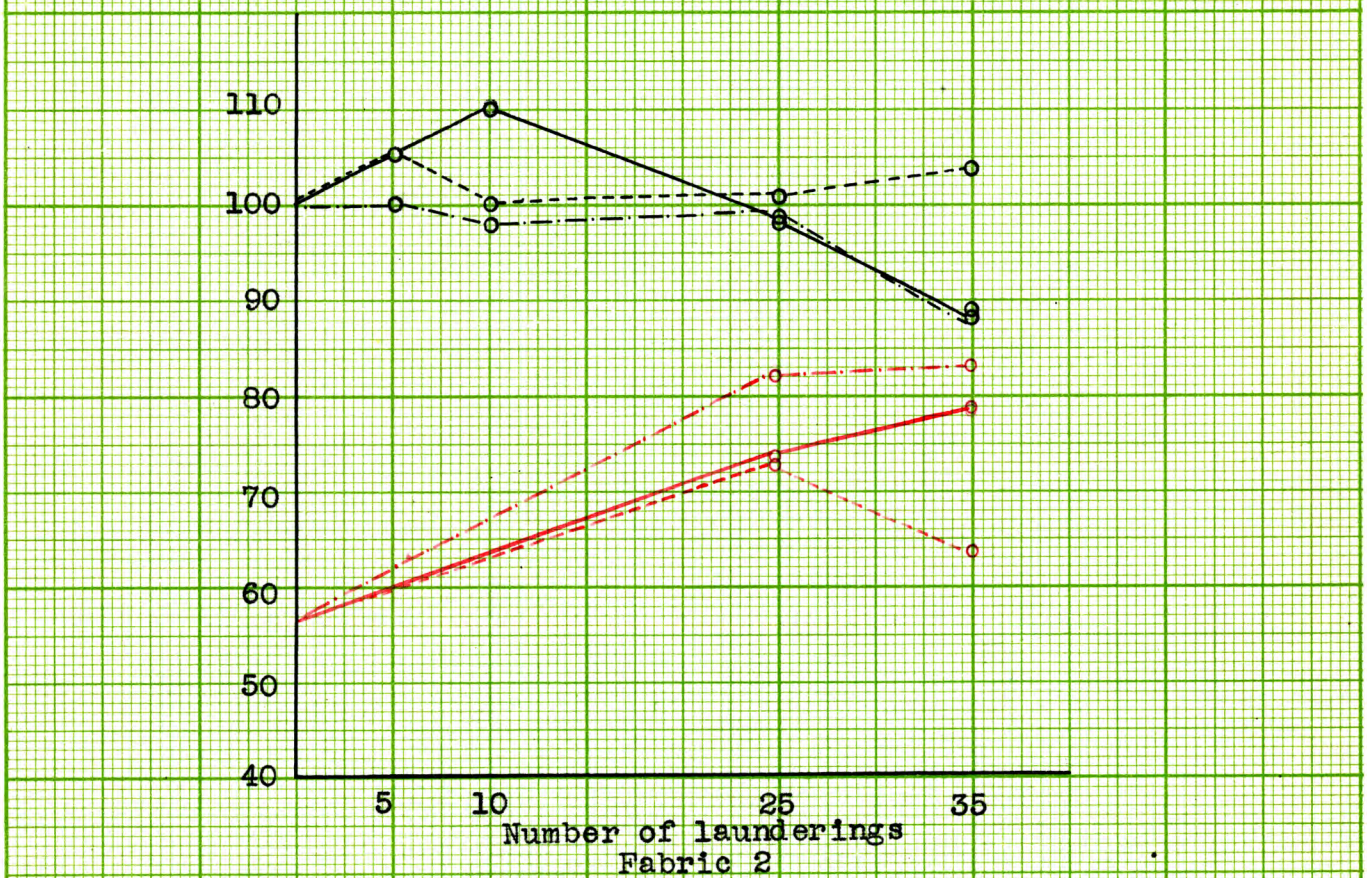
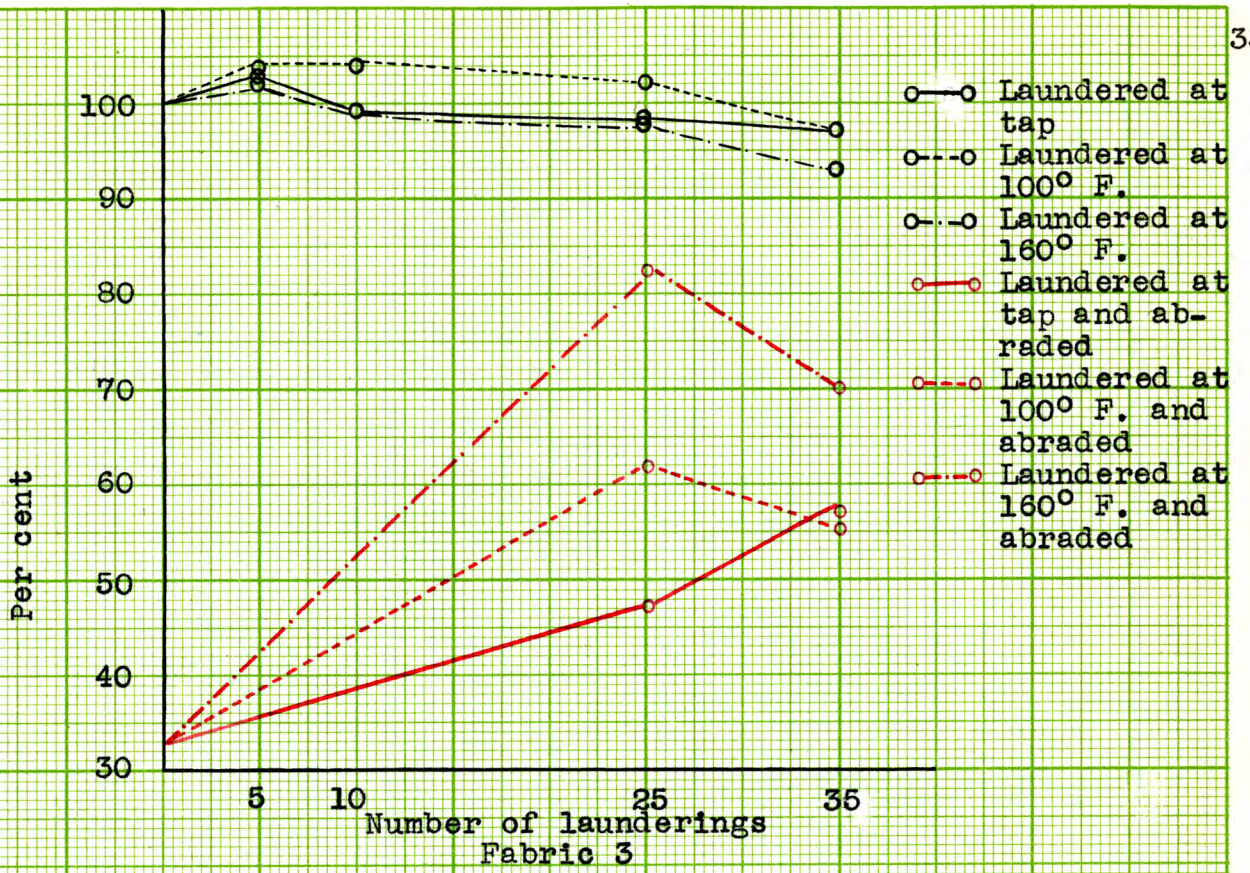


Fig. 10. Breaking strength of warp yarns of two yarn dyed fabrics laundered 5, 10, 25 and 35 times before and after abrasion.



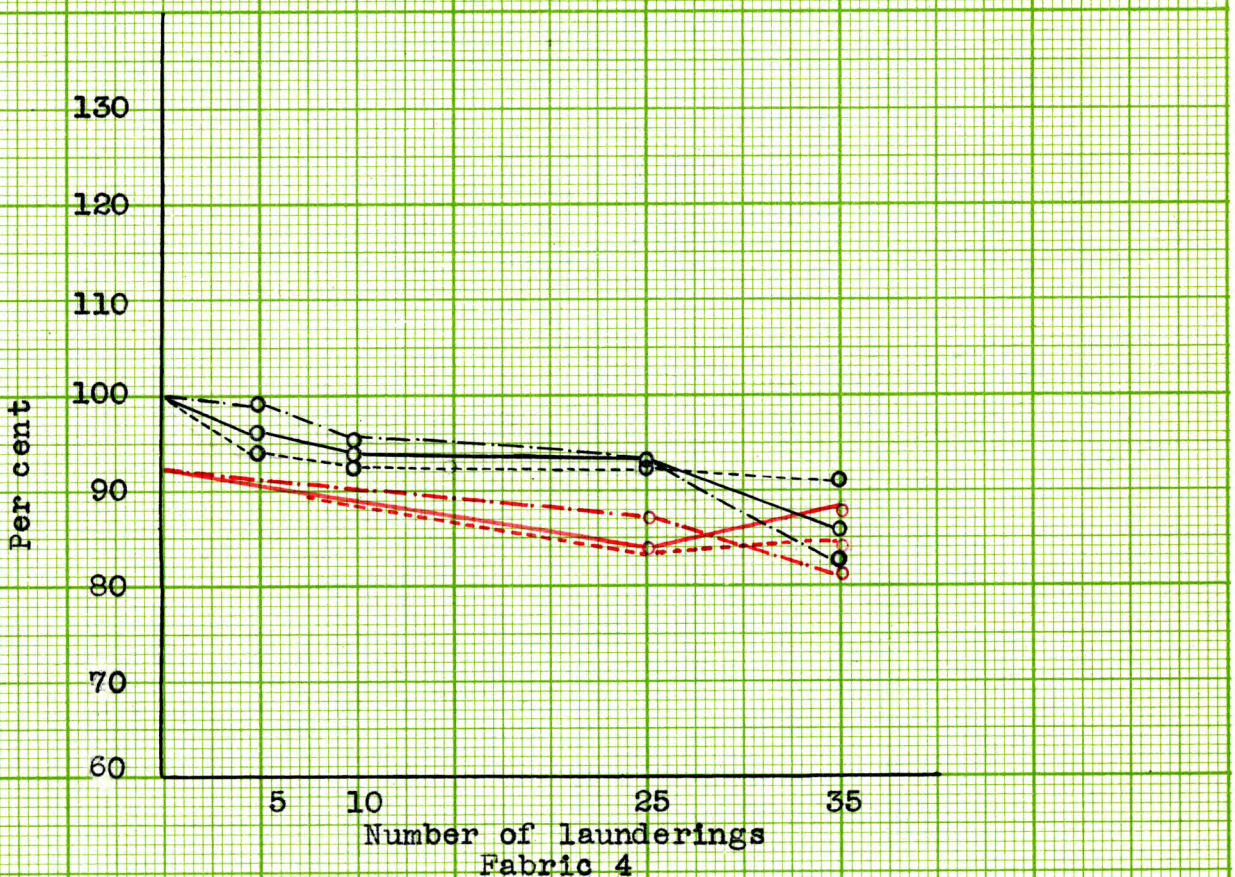


Fig. 11. Breaking strength of warp yarns of two piece dyed fabrics laundered 5, 10, 25 and 35 times before and after abrasion.

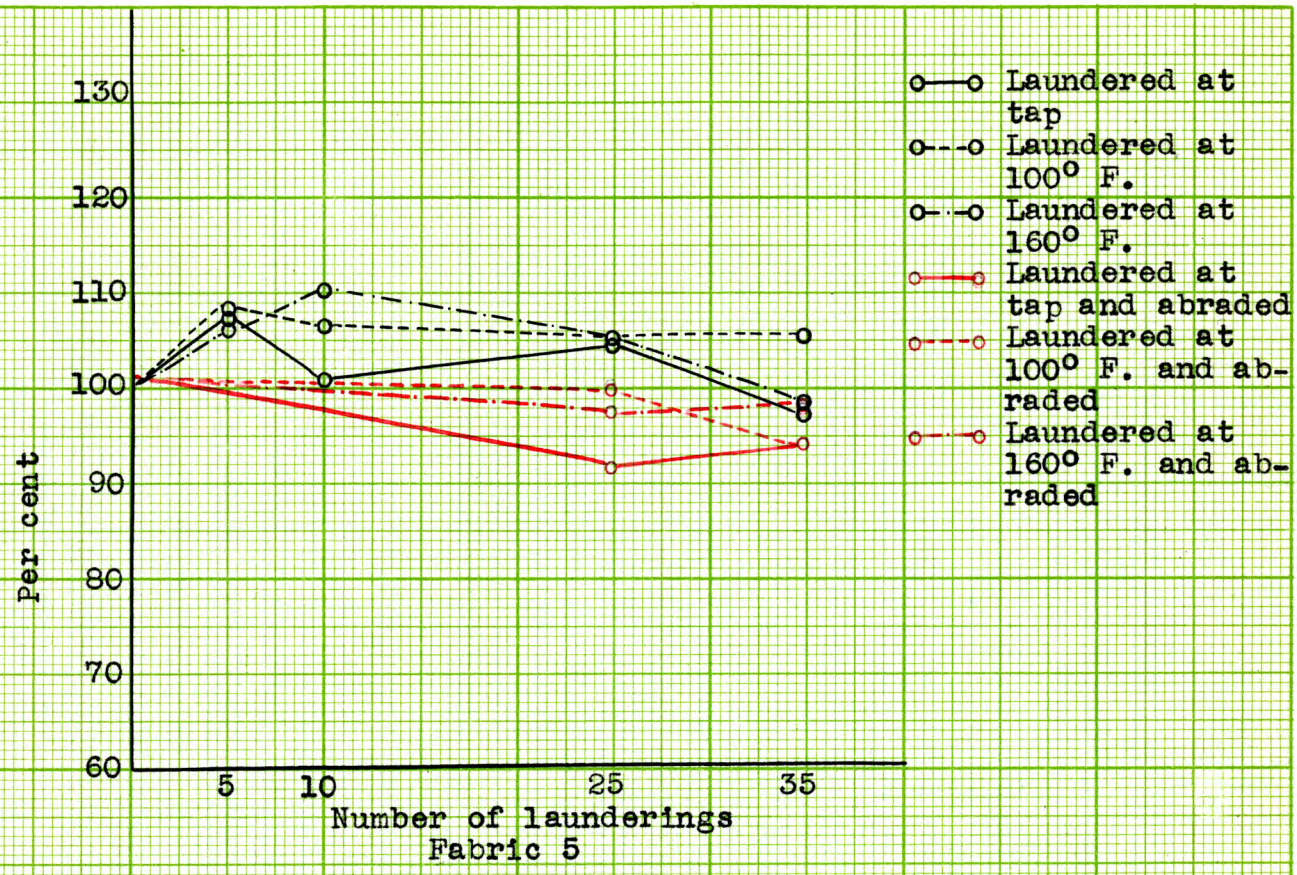


Fig. 12. Breaking strength of warp yarns of two print dyed fabrics laundered 5, 10, 25 and 35 times before and after abrasion.

decrease fillingwise. The breaking strength increased in both warp and filling after laundering. Elongation was less in both warp and filling after abrasion of fabrics laundered 25 and 35 times.

Fabric 4 showed a decrease in thread count in both warp and filling yarns after abrasion compared with the unabraded fabric. There was 8.3 per cent decrease in breaking strength warpwise and 28.3 per cent decrease fillingwise. There was little change in elongation before and after abrasion of fabrics laundered 25 and 35 times.

Fabric 5 showed a decrease in both warp and filling thread count after abrasion. There was 1.2 per cent decrease in warpwise breaking strength and 9.1 per cent decrease fillingwise. There was an increase in elongation after abrasion of fabrics laundered 25 and 35 times.

Fabric 6 showed a decrease in warp thread count after abrasion but no change in filling thread count. There was 16.1 per cent decrease in warpwise breaking strength and 41.3 per cent decrease in filling-wise breaking strength after abrasion. The breaking strength in both warp and filling increased after 25 and 35 launderings. There was a decrease in elongation after abrasion of fabrics laundered 25 and 35 times.

There was a decrease in both warp and filling thread count after abrasion of fabrics 1, 2, 5 and 6. A decrease in warp yarns was noted after abrasion of fabrics 3 and 4.

Effects of Abrasion after Laundering

In the laundering process using water at a temperature as drawn from the tap the effects of abrasion varied when compared with controls. After 25 launderings fabrics 1, 4, 5 and 6 showed a decrease in the warpwise breaking strength but after 35 launderings showed an increase. Fabrics 1, 2, 3, 4, and 5 showed an increase in breaking strength up to 25 launderings in filling yarns then a decrease after 35 launderings. The percentage elongation remained nearly the same.

In the laundering process using water of 100°F. the effect of abrasion on fabrics 1, 2, 3, and 6 showed an increase in warpwise breaking strength after laundering 25 times and a decrease after laundering 35 times. All fabrics showed an increase in fillingwise breaking strength after laundering 25 times then decreased after laundering 35 times. The percentage elongation before and after abrasion remained about the same.

In the laundering process using water at 160°F. the effect of abrasion on breaking strength was not consistent. There was a gradual increase in breaking strength up to 25 launderings and then a decrease. There was little or no change in elongation after abrasion (Figs. 13, 14, 15).

Changes in Color

After 10 launderings in the process using water at 100°F. the highest index of change in color was shown in fabric 2

Table 5. Index of color change after 10 and 35 launderings of six cotton fabrics using Nickerson's formula.

Fabrics	Number of launderings	Temperature of water	Sector percentage	Color specification	Average chroma	dh	dl	dc	I
				Yarn dyed					
1	0		75 PB 3/12 38 65 B 3/6 36 N 8 12 N 9.4 14	71.79 PB $\frac{5.17}{6.72}$					
	10	Tap	75 PB 3/12 44 65 B 3/6 34 N 8 10 N 9.4 12	72.21 PB $\frac{4.90}{7.32}$	7.02	.42	.27	.60	9.32
	35		75 PB 3/12 68 65 B 3/6 15 N 8 11 N 9.4 8	74.01 PB $\frac{4.65}{9.06}$	7.89	2.22	.52	2.34	45.17
	10	100° F.	75 PB 3/12 48 65 B 3/6 15 N 8 9 N 9.4 11	72.50 PB $\frac{4.76}{7.68}$	7.20	.71	.41	.96	15.56
	35		75 PB 3/12 46 65 B 3/6 15 N 8 24 N 9.4 15	73.60 PB $\frac{5.84}{6.42}$	6.57	1.81	.67	.30	28.70
	10	160° F.	75 PB 3/12 46 65 B 3/6 33 N 8 9 N 9.4 12	72.36 PB $\frac{4.85}{7.50}$	7.11	.57	.32	.78	12.37
	35		75 PB 3/12 64 65 B 3/6 10 N 8 20 N 9.4 6	74.28 PB $\frac{4.98}{8.28}$	7.50	2.49	.19	1.56	43.17
2	0		75 PB 3/12 13 65 B 4/8 84 N 8 7 N 9.4 16	66.48 B $\frac{5.76}{8.28}$					
	10	Tap	75 PB 3/12 8 65 B 4/8 71 N 8 6 N 9.4 15	66.13 B $\frac{5.40}{6.64}$	7.46	.35	.36	1.64	12.30
	35		75 PB 3/12 17 65 B 4/8 53 N 8 15 N 9.4 15	67.65 B $\frac{5.73}{6.28}$	7.28	1.17	.03	2.00	23.22
	10	100° F.	75 PB 3/12 6 65 B 4/8 73 N 8 6 N 9.4 15	65.84 B $\frac{5.41}{6.56}$	7.42	.64	.35	1.72	16.77
	35		75 PB 3/12 17 65 B 4/8 43 N 8 15 N 9.4 25	68.08 B $\frac{6.33}{5.48}$	6.88	1.60	.57	2.80	33.84
	10	160° F.	75 PB 3/12 4 65 B 4/8 75 N 8 6 N 9.4 15	65.57 B $\frac{5.43}{6.48}$	7.38	.91	.33	1.80	20.81
	35		75 PB 3/12 12 65 B 4/8 53 N 8 15 N 9.4 20	67.04 B $\frac{6.07}{5.68}$	6.98	.56	.31	2.60	17.48

Table 5 (cont.)

Fabrics	Number of launderings	Temperature of water	Piece dyed: Sector percentage		Color specification	Average chroma	dh	dl	dc	I
3	0		75 PB 3/12	57	71.96 PB 4.57/9.08					
			65 B 4/8	28						
			N 8	8						
			N 9.4	7						
	10	Tap	75 PB 3/12	62	72.52 PB 4.44/9.28	9.18	.56	.13	.20	11.66
			65 B 4/8	23						
			N 8	8						
			N 9.4	6						
	35		75 PB 3/12	71	73.89 PB 4.76/9.32	9.20	1.93	.19	.24	37.37
			65 B 4/8	10						
			N 8	9						
			N 9.4	10						
	10	100° F.	75 PB 3/12	64	72.66 PB 4.44/9.44	9.26	.70	.13	.36	14.82
			65 B 4/8	22						
			N 8	8						
			N 9.4	6						
	35		75 PB 3/12	69	73.47 PB 4.61/9.40	9.24	1.51	.04	.32	29.10
			65 B 4/8	14						
			N 8	9						
			N 9.4	8						
	10	160° F.	75 PB 3/12	66	72.88 PB 4.42/9.52	9.30	.92	.15	.44	19.33
			65 B 4/8	20						
			N 8	8						
			N 9.4	6						
	35		75 PB 3/12	70	73.77 PB 4.76/9.28	9.18	1.81	.19	.20	34.97
			65 B 4/8	11						
			N 8	9						
			N 9.4	10						
4	0		75 PB 4/10	73	73.51 PB 4.85/8.32					
			65 B 5/6	17						
			N 8	5						
			N 9.4	5						
	10	Tap	75 PB 4/10	65	73.36 PB 5.37/7.52	7.92	.15	.52	.80	7.90
			65 B 5/6	17						
			N 8	7						
			N 9.4	11						
	35		75 PB 4/10	79	73.83 PB 5.12	8.53	.32	.27	.42	8.34
			65 B 5/6	14						
			N 8	6						
			N 9.4	7						
	10	100° F.	75 PB 4/10	72	73.65 PB 5.05/8.10	8.21	.14	.20	.33	4.16
			65 B 5/6	15						
			N 8	5						
			N 9.4	8						
	35		75 PB 4/10	70	73.46 PB 5.07/8.02	8.17	.05	.22	.30	3.04
			65 B 5/6	17						
			N 8	5						
			N 9.4	8						
	10	160° F.	75 PB 4/10	75	73.47 PB 4.82/8.58	8.45	.04	.03	.26	1.64
			65 B 5/6	18						
			N 8	5						
			N 9.4	12						
	35		75 PB 4/10	71	73.63 PB 5.10/8.00	8.16	.12	.25	.32	4.42
			65 B 5/6	15						
			N 8	6						
			N 9.4	8						

Table 5 (concl.)

Fabrics	Number of launderings	Temperature of water	Print dyed: Sector percentage	Color specification	Average chroma	dh	dl	dc	I
5	0		75 PB 3/10 80 65 B 5/6 8 N 5 6 N 7 5	74.09 PB $\frac{3.63}{8.48}$					
	10	Tap	75 PB 3/10 80 65 B 5/6 7 N 5 7 N 7 5	74.20 PB $\frac{3.63}{8.42}$	8.45	.11	.00	.06	2.04
	35		75 PB 3/10 77 65 B 5/6 9 N 5 7 N 7 7	73.38 PB $\frac{3.79}{8.24}$	8.36	.71	1.63	.24	13.56
	10	100° F.	75 PB 3/10 78 65 B 5/6 7 N 5 N 7	74.18 PB $\frac{3.64}{8.22}$	8.35	.09	.10	.26	1.64
	3[illegible]		75 PB 3/10 77 65 B 5/6 8 N 5 7 N 7 8	74.06 PB $\frac{3.82}{8.18}$	8.3[illegible]	.03	.195	.30	1.85
	10	160° F.	75 PB 3/10 79 65 B 5/6 7 N 5 7 N 7 6	74.19 $\frac{3.68}{8.32}$	8.40	.10	.055	.16	2.49
	35		75 PB 3/10 78 65 B 5/6 8 N 5 7 N 7 7	74.07 PB $\frac{3.77}{8.18}$	8.33	.02	.142	.30	2.08
6	0		75 PB 3/10 8 65 B 5/10 72 N 8 10 N 9.4 10	65.63 B $\frac{5.83}{8.00}$					
	10	Tap	75 PB 3/10 9 65 B 5/10 64 N 8 11 N 9.4 16	65.78 B $\frac{6.16}{7.30}$	7.65	.15	.33	.70	6.38
	35		75 PB 3/10 11 65 B 5/10 65 N 8 9 N 9.4 15	65.92 B $\frac{6.02}{7.60}$	7.80	.29	.19	.40	6.86
	10	100° F.	75 PB 3/10 8 65 B 5/10 66 N 8 13 N 9.4 13	65.68 B $\frac{6.36}{7.40}$	7.70	.05	.53	.60	5.75
	35		75 PB 3/10 11 65 B 5/10 59 N 8 9 N 9.4 21	66.06 B $\frac{6.33}{7.00}$	7.50	.43	.50	1.00	12.45
	10	160° F.	75 PB 3/10 9 65 B 5/10 62 N 8 12 N 9.4 17	65.80 B $\frac{6.25}{7.10}$	7.55	.17	.42	.90	7.79
	35		75 PB 3/10 11 65 B 5/10 62 N 8 9 N 9.4 18	65.96 B $\frac{6.18}{7.30}$	7.65	.33	.35	.70	9.25

(Table 5). In fabric 3 when laundered 10 times by the process using water at 160°F. the change in color was greatest. After 10 launderings in water as drawn from the tap, fabric 2 showed the highest index of change in color.

The highest index of change in color was shown in fabrics 1, 3 and 5 after 35 launderings in the process using water as drawn from tap. When laundered 35 times by the process using water at 100°F. fabrics 3 and 6 showed the greatest color change. After 35 launderings in the process using water at 160°F. fabric 2 showed the highest index of color change.

The highest index of change in color in all materials by all laundering processes was in fabric 1 when laundered 35 times by the process using water as drawn from the tap.

SUMMARY

The findings of this study may be summarized as follows:

With all processes breaking strength tended to increase with five launderings and decrease with 35 launderings; elongation was greater after five launderings.

The number of launderings seemed to affect color change more than the various laundering processes.

There was no apparent relationship between method of dyeing and color fastness.

Under the conditions of this study there was no evident difference in the effect of laundering on the service qualities of the three groups of fabrics.

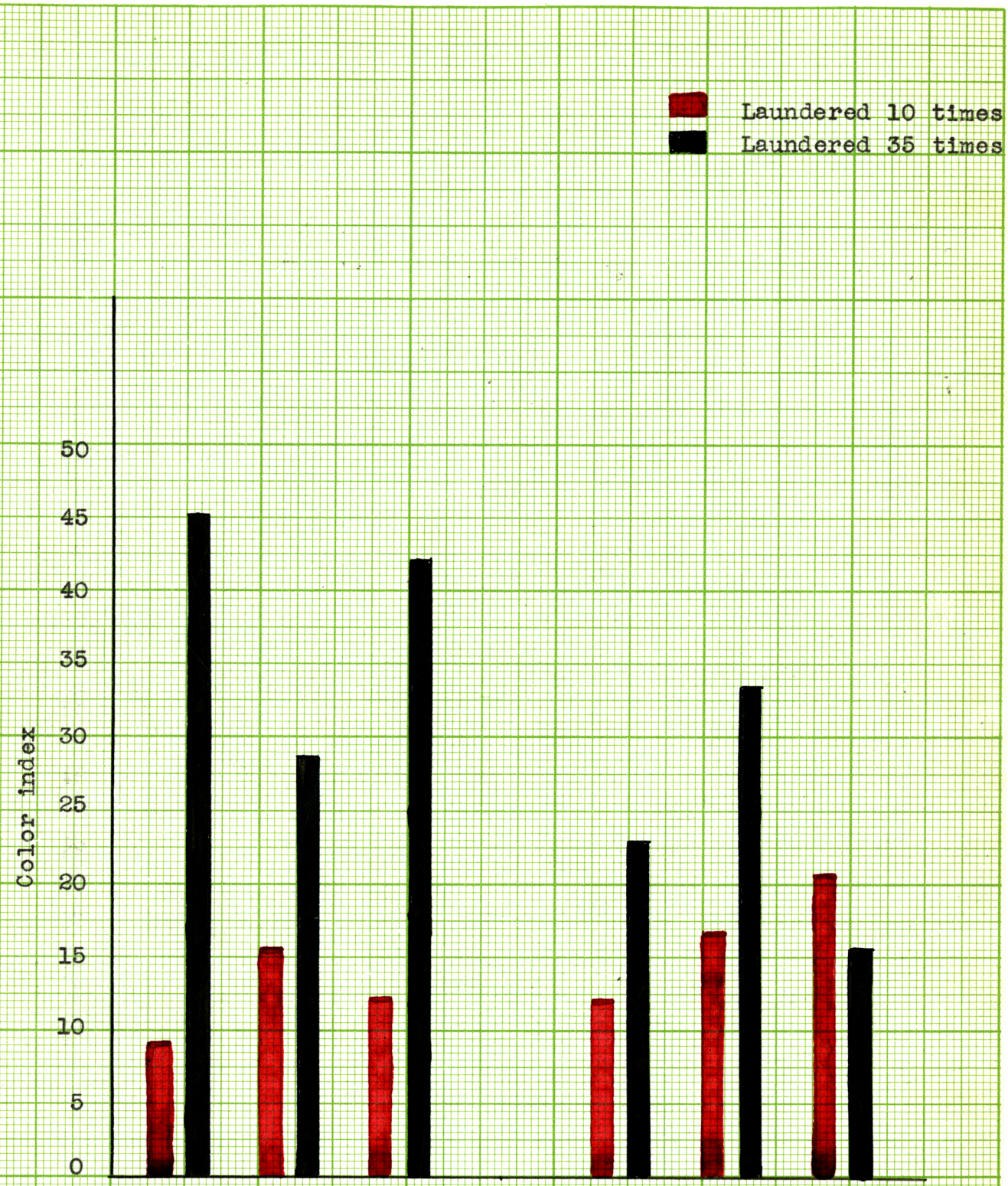


Fig. 13. Color indices of two yarn dyed fabrics at three temperatures.

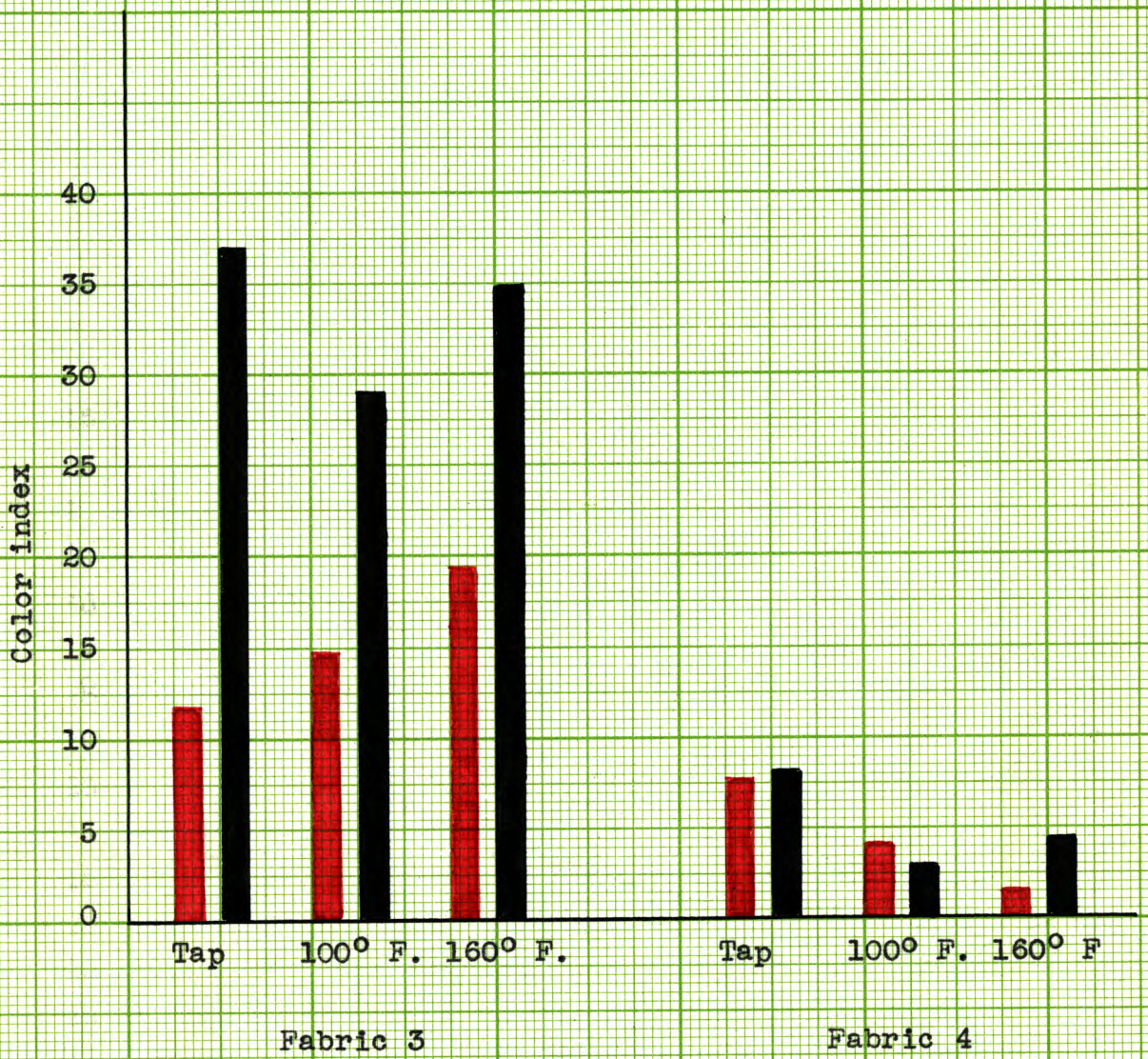


Fig. 14 Color indices of two piece dyed fabrics laundered at three temperatures.

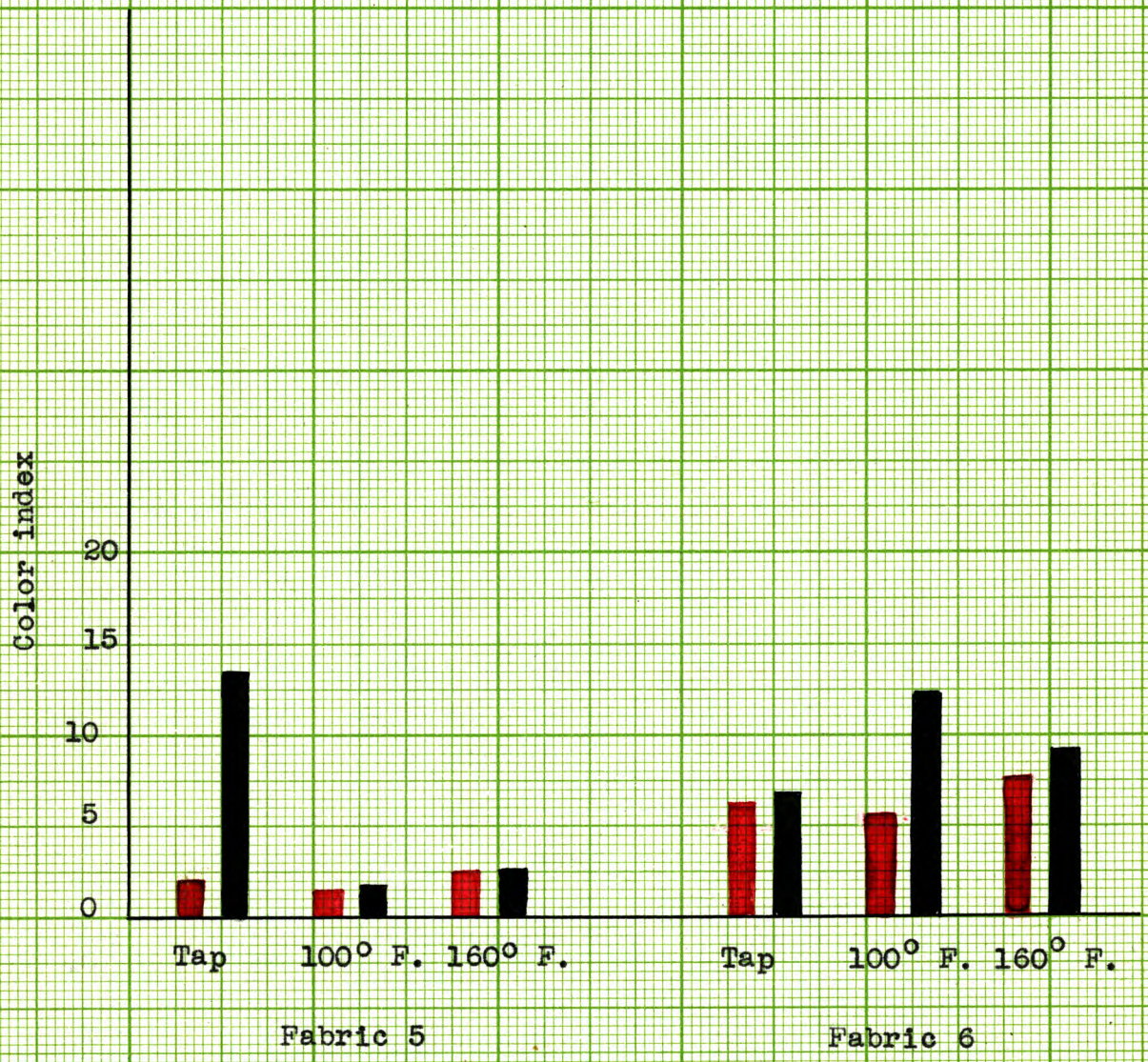


Fig. 15. Color indices of two print dyed fabrics laundered at three temperatures.

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