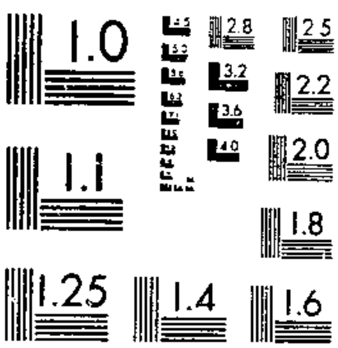
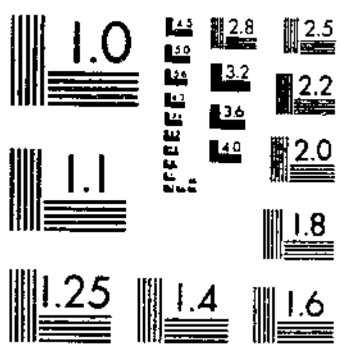
TB-645 (1938) USDA TECHNICAL BULLETINS UPDATA
MANUFACTURING AND SERVICEABILITY TESTS ON SHEETINGS MADE FROM TWO
ROGERS, R E., HAYS, M B., WIGINGTON, J T 1 OF 1

START



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Technical Bulletin No. 645 February 1939

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

MANUFACTURING AND SERVICEABILITY TESTS ON SHEETINGS MADE FROM TWO SELECTED MILL TYPES OF COTTON [1]

By RUTH ELMQUIST ROGERS, *associate textile chemist*, MARGARET B. HAYS, *associate textile physicist, Textiles and Clothing Division, Bureau of Home Economics*, and JOHN T. WIGINGTON,[2] formerly *cotton technologist, Bureau of Agricultural Economics*

CONTENTS

INTRODUCTION

Fiber and spinning studies are of great value in determining the relative and absolute quality of cotton, but they do not as yet give a full and accurate picture of the serviceability of a given cotton when it is used for a specific purpose. In order to broaden the scope and extend the value of such investigations, fiber studies, including physical, chemical, and X-ray measurements, together with manufacturing and serviceability tests, are going forward in the Department of Agriculture on cottons differing widely in respect to the various

[1] Submitted for publication June 10, 1938.

[2] This is a cooperative project of the Bureaus of Agricultural Economics and Home Economics. The Bureau of Agricultural Economics supervised the manufacture of the cottons into sheets and studied the manufacturing and yarn properties of the cottons. The Bureau of Home Economics made service as well as laboratory tests on the fabrics. G. L. Crawford, formerly senior agricultural economist, the Bureau of Agricultural Economics, gave general supervision and helpful suggestions in the planning of this project. Appreciation is also expressed to the management of the Pequot Mills for making the facilities of that mill available for the manufacturing tests and to the Danvers Bleachery for its cooperation during the bleaching, finishing, and fabricating of the sheetings. Acknowledgment is made to M. E. Campbell, senior cotton technologist, for his assistance in preparing the report of the manufacturing tests. Mary Lindsley, former manager of the Dodge Hotel, Washington, D. C., kindly extended the facilities of the hotel for this study, and the staff of that institution generously cooperated in the serviceability phase of the project.

100480°—39——1

fiber properties. Through studies of the various types of data derived from this work it is hoped eventually to develop more rapid and accurate methods and a more effective basis for recognizing cotton quality as it is related to manufacturing and service performance.

At present, the most reliable means of determining the suitability of one or more cottons for a specific use seems to be to manufacture the fibers into yarns, cords, and fabrics, and subject these materials to service and related tests, under as nearly controlled conditions as it is feasible to secure.

In a previous study by the Department of Agriculture (*18*) [3] sheetings made from American upland cotton, selected to represent the Good Middling, Middling, and Strict Good Ordinary grades, were submitted to laboratory and wearing tests. According to a classification for sheeting proposed by Hays (*15*), the materials used were mediumweight muslin.

This bulletin reports similar work on two selected mill types of American upland cotton ranging from Middling to Strict Middling grade when made into heavyweight muslin sheets. In the present study, more sheets of each lot were put into service, and a larger sample was taken each test period. Additional laboratory tests were also performed. These two investigations are believed to be the only ones in which cotton of known grade and staple length have been manufactured into fabrics and the resultant serviceability of the materials evaluated by actual wear studies.

THE COTTONS AND THEIR MANUFACTURE INTO YARNS AND FABRICS

The cottons (designated A and B) used in these tests were selected from several hundred bales stored in the warehouse of the Pequot Mills, as being representative of two types grown in widely separated locations and used regularly by the mill. While classification and spinning data are presented in this report only for these two cottons when manufactured separately, at the time this test was conducted the mill was using a mixture of 20 percent of cotton A and 80 percent of cotton B. In addition to material manufactured separately from each of the two cottons, samples of gray and finished fabric were also obtained from this mixture of the two for use in the serviceability tests.

From an examination of the tags and identification marks on each bale the following information was collected concerning the origin of the cotton tested: Cotton A was compressed at Calexico, Calif. Six of the ten bales were grown in the vicinity of Somerton, Ariz., whereas the remaining 4 bales came from Calexico, Calif. Cotton B was grown in Arkansas and was concentrated at Texarkana for shipment.

As the bales were opened samples were taken from the top, middle, and bottom of each bale of cotton to be tested. Ten bales of cotton A, 5 for warp yarns and 5 for filling yarns, and 10 bales of cotton B, 5 for warp yarns and 5 for filling yarns, were used in this test.

The bales were weighed and then the bagging and ties were removed and weighed. The difference between gross weight and tare gave the net weight of cotton used in the tests. Five bales were placed on the floor beside the long apron that feeds the bale breaker. Approxi-

[3] Italic figures in parentheses refer to Literature Cited, p. 30.

mately 20 pounds from each bale was placed on the apron at one time, thus affording as nearly a uniform mix as possible. The cotton was opened and passed in succession through a bale breaker, a vertical opener, and two lattice cleaners. From here it was passed through a pneumatic conveyor pipe to the picker room of the mill. At this point the cotton was fed to a breaker picker with two beaters, the first a three-blade and the second a two-blade, then to the finisher picker equipped with a Kirschner beater, after which it was delivered to the card room.

In the card room the cotton was passed through the cards, evener drawing frames, finisher drawing frames, slubber, intermediate, and fine frames.

The roving was next trucked to the spinning room where it was spun into two counts of yarn: 21s warp yarn and 22s filling yarn. The warps were prepared with the use of an automatic spooler and high-speed warper, operating at a speed of 42 yards per minute, and a 2-drum slasher. A corn starch sizing mixture was used.

The filling yarns, after spinning, were put through a steam conditioning process to set the twist in the yarn and prevent kinking during weaving.

The sheeting material was woven on two 72-inch plain looms, running at the rate of 119 picks per minute.

In weaving the gray goods, the following specifications were followed as closely as possible: Width in gray, 72 inches; ends per inch, 68; picks per inch, 72; weight, 1.55 linear yards per pound; warp-yarn number, 21s; filling-yarn number, 22s.

Prior to processing the test cottons each cleaning machine to be used was emptied of waste and stock, and thoroughly cleaned. The bales were weighed, tare deducted, and the net weight of cotton recorded. At each cleaning machine weighings were made of stock fed, stock delivered, and each type of waste removed.

When the samples of cotton had been spun, representative samples of yarn were collected and marked for identification, to be used for strength and sizing tests. Twenty-five bobbins of yarn were selected from each test lot.

The two cottons, as well as the mixture, were manufactured on the same equipment and under similar atmospheric conditions. The cottons were carefully observed as they passed through the various machines during the spinning and weaving processes. There were no noticeable differences in the manufacturing behavior of the test samples.

Upon the completion of the weaving of the test cottons the gray fabrics were taken to the Danvers Bleachery where they were bleached, finished, and made into sheets. Particular attention was given to the marking of the gray fabrics after they reached the bleachery. Each lot was marked with indelible ink, making its identity easily observed at any time during the bleaching and finishing processes.

Bleaching of the fabrics was accomplished by subjecting them to the following processes, in the order listed: Singe, kier boil, wash, acid sour, wash, kier boil, chemic, bleach, sour, wash, and antichlor. To finish the fabrics, they were passed through a water mangle, starch mangle, drier, and tenter frame. The starch solution used consisted of a mixture of corn and potato starches.

After the fabrics had been bleached, starched, and finished they were carried to the fabricating department to be inspected, torn to the proper length, and made into sheets. At this point particular attention was also paid to the marking of the test fabrics. Each sheet was properly marked, packed, and shipped to the Bureau of Home Economics for wear and laundering tests.

WEAR AND LABORATORY PROCEDURES

WEARING TEST

The finished sheets were subjected to the same service conditions in the cooperating Washington hotel as previously reported for sheeting made from the three grades of cotton (*18*). The hotel maintains its own laundry and the staff cooperated to control the conditions both of use and of laundering.

Fifty-eight sheets of each of the three lots made from cotton A, cotton B, and a mixture of 20 percent of A with 80 percent of B which is designated throughout as a commercial mixture were marked with an identifying number. All were laundered once and put into service on a transient-guest floor of the hotel.

Two sheets were used per bed per day, the wide hem always being placed at the head of the bed. All sheets except those removed for testing were used as long as serviceable.

The used sheets were collected each morning and sent to the hotel laundry where they were held until a worker from the Bureau of Home Economics arrived to check the laundry procedure. Usually sheets were washed three times weekly but in slack periods only twice a week. A record was kept of the time required for each suds, rinse, extraction, and ironing for every day that any of the sheets were laundered. A daily record of the identifying number of each sheet washed was obtained at the time of folding.

For the first 2 years the laundry procedure was essentially a cold break-down of 4 minutes, a hot suds (approximately 160° F.) of 10 minutes, three hot rinses (120° to 130°) each of 3 to 6 minutes, and one or two cold rinses (90° to 100°) of 3 to 5 minutes. For the remainder of the study, after the installation of automatic valves to give a definite quantity of water, the method was changed by substituting a 15-minute suds at 140° for the break-down and the 10-minute suds. The water temperatures reported are approximate since they were not controlled automatically.

Soap chips were used throughout in sufficient quantity to give a good suds. No bleach was ever added and bluing was used only for a period of a few weeks in the spring as is usual hotel practice.

The sheets were extracted 7 to 12 minutes, then ironed selvage to selvage through a four-roller mangle heated with steam at 65 to 70 pounds pressure (approximately 300° F.). A record was kept of the few times a sheet was ironed hem to hem. All were folded by hand.

Ordinary stains were removed by washing again or by soaking in the soap tank and then washing. Any other necessary stain-removal treatment was recorded and sheets so treated were never used for testing.

LABORATORY TESTS

Sheets were tested in the unbleached state, when finished, and at regular intervals of 25 washes, constituting a period, up to and including 275 times laundered. Two sheets were tested at each period through the 150 times laundered, three at the 175 and 200 periods, and four at the 225, 250, and 275. The size of sample was increased at the end of the study because the variation between sheets became larger as wear progressed.

Shrinkage, weight per square yard, yarns per inch (thread count), thickness, bursting strength, breaking strength, elongation, fluidity in cuprammonium hydroxide, copper number, methylene blue absorption, and ash content were determined at each test period. The starch content was evaluated for the new sheetings and for those laundered 1, 3, 5, 10, 25, and 50 times. The percentage of moisture was determined for the new fabrics and for those laundered 75, 150, and 275 times.

Physical tests were made in a laboratory maintained at 70° F. and 65 percent relative humidity on samples conditioned at least 4 hours at this temperature and humidity. The chemical tests were made on cotton thoroughly conditioned, but the results of the analyses were calculated on the basis of the dry weights.

SAMPLING

Since all these sheets were used on single beds, the area 22 inches wide and 71 inches long most probably occupied by the body was chosen for sampling. This area which undoubtedly received the greatest amount of wear was divided into four sections designated as A, pillow; B, shoulder; C, hip; and D, leg (*18, fig. 11*).

Five warp and five filling strips were taken from each of the four sections. Section A supplied one sample for weight per square yard and one for bursting strength; sections B and C, each one for weight and three for bursting strength; and section D furnished two weight-per-square-yard and three bursting-strength samples. Thickness and yarns per inch were determined on the same pieces as were used for the weight per square yard. All four sections were sampled for the methylene blue absorptions, while a composite sample of the four sections was used for fluidity in cuprammonium hydroxide and copper number measurements. The sides supplied material for the starch and ash determinations. Three determinations were made for the fluidity, copper number, methylene blue absorption, and starch measurements and two for those of ash and moisture.

Tests were made on a new sheet of each lot at the beginning of the study and on another at the end. In addition breaking strength, bursting strength, and fluidity were determined on stored samples at yearly intervals in order to evaluate the aging effect. On unlaundered sheets no samples were taken closer than 12 inches to the selvage and they were selected to be representative of the whole sheet.

PHYSICAL TESTS

Each sheet was measured before going into service and again when removed for testing, or at the time of discarding. The length was measured in three places and the width in five, to the nearest one-sixteenth inch. One sheet of each lot was measured after 5, 10, 15, and 20 times laundered to determine how soon the maximum shrinkage occurred.

A 2-inch square steel die was used to stamp out the fabric-weight samples, which were then weighed on a torsion balance calibrated to read directly in ounces per square yard (*18*). The number of threads or yarns in an inch of fabric was counted both warpwise and fillingwise with a micrometer thread counter (*1*). Thickness was measured on the same samples with a micrometer gage graduated to read to 0.001 inch, which exerted constant pressure on a given area of fabric.

Breaking strength was determined by the strip method (*18*) on samples cut 1¼ by 6 inches and raveled down to an inch. The motor-driven Scott tester was equipped with a recording-stretch attachment, and 3-inch jaws both front and back. The elongation was determined from the graphic record and was reported as percentage of stretch.

The ball-burst attachment was substituted for the jaws of the Scott tester to determine the bursting strength of the fabrics. Samples 4 by 4 inches in size were used for this test.

CHEMICAL TESTS

Fluidity determinations, which satisfactorily measure chemical tendering in worn cotton fabrics, were made on 0.5-percent solutions of cotton (on the dry-weight basis) in cuprammonium hydroxide at 25° C. with capillary-tube viscometers. The modified procedure developed at the Bureau of Home Economics (*18, p. 53*) was followed.

Copper-number determinations and methylene blue absorptions give additional information concerning the chemical deterioration of cellulosic material. For the copper-number determinations, 1.5 g of finely divided sheeting were treated with Braidy's solution and heated for 3 hours in an oil bath thermostatically controlled at 100° C. (*18, p. 56*). Methylene blue absorption measurements were determined on 0.3-g samples with a buffered methylene blue solution of pH 7 (*18, p. 29*).

The amount of starch in the sheetings was measured by the method of Fargher and Lecomber (*10*). Two and one-half gram samples of the fabrics were heated for 2½ hours with 1 N sulphuric acid at 100° C. to convert the starch present into glucose. The percentage of starch was calculated from the amount of iodine required to react with the glucose.

The ash content of the fabrics was estimated by igniting 5-g samples to constant weight in a muffle furnace. For moisture determinations 5-g samples of the conditioned fabrics were dried to constant weight at 105° C. in the bottles designed by Barritt and King (*2*). Dried air was passed through the bottles during heating.

RESULTS

CLASSIFICATION OF COTTON

The average results of the classification of cotton A and cotton B by the Appeal Board of Review Examiners of the United States Department of Agriculture are shown in table 1. A further tabulation of the classification data, giving the percentage distribution according to grade and staple length, is shown in table 2.

TABLE 1.—*Classification of cotton* [1]

Sample	Grade	Staple length (inches)	Character		
			Uniformity of length [2]	Fiber (body)	Strength [3]
Cotton A:					
Warp yarns	Middling Light Spotted to Strict Middling Light Spotted.	$\frac{15}{16}$ to 1	Irregular and wasty.	Light	Weak.
Filling yarns	do	$\frac{15}{16}$	do	do	Do.
Cotton B:					
Warp yarns	Middling to Strict Middling	$1\frac{1}{32}$	Regular	Fine	Normal.
Filling yarns	do	$\frac{31}{32}$ to $1\frac{1}{16}$	do	do	Do.

[1] Classification made by Appeal Board of Review Examiners of the U. S. Department of Agriculture. Average of 30 samples for each of the cottons tested.
[2] Irregular indicates slightly below the average. Wasty indicates mixed length of fiber.
[3] Weak indicates poor strength. Normal indicates average or good strength.

TABLE 2.—*Percentage distribution of the classification of cottons tested, by grade and staple length* [1]

Kind of cotton and grade	Distribution for staple length of—					Total
	$\frac{15}{16}$ inch	$\frac{31}{32}$ inch	1 inch	$1\frac{1}{32}$ inches	$1\frac{1}{16}$ inches	
Cotton A:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Strict Middling Spotted	43.4					43.4
Middling Light Spotted	20.0	16.7	3.3			40.0
Middling Spotted	3.3	13.3				16.6
Total	66.7	30.0	3.3			100.0
Cotton B:						
Strict Middling			3.3	10.0	10.0	23.3
Strict Middling Spotted			3.3			3.3
Middling		6.7	30.0	30.0	6.7	73.4
Total		6.7	36.6	40.0	16.7	100.0

[1] Data based on representative samples taken from 5,000 pounds of cotton used in manufacturing the warp and filling yarns.

It is rather difficult to make a simple comparison of the grades of cottons A and B in view of the fact that the individual samples of each covered a range of a full grade, and that cotton A was predominantly spotted whereas cotton B was not. However, it may be said that on an average, cotton B was lower in grade as regards foreign matter, but that cotton A was lower as regards the color component of grade. The classers found cotton B to be approximately one-sixteenth of an inch longer on an average, and to have a considerably more desirable character than cotton A. The cotton used for warp yarns was of the same grade and character but slightly longer in staple than that of the same type designation used for filling yarns.

MANUFACTURING WASTE

From the weighings of the amount of stock fed and the amount of stock delivered the percentages of total visible and invisible waste were calculated (table 3 and fig. 1).

TABLE 3.—*Percentages of the different types of waste removed by the pickers and the cards*

Kind of waste	Waste in [1]—			
	Cotton A, Middling Light Spotted to Strict Middling Spotted [2]		Cotton B, Middling to Strict Middling [2]	
	Warp	Filling	Warp	Filling
Kind of waste:				
Picker waste:				
Opener:	*Percent*	*Percent*	*Percent*	*Percent*
Vertical	0.98	0.52	0.63	0.36
Lattice cleaners	1.35	1.44	.98	.95
Sweepings	.12	.18	.10	.09
Total visible	2.45	2.14	1.71	1.40
Breaker:				
Hopper box	.02	.02	.02	.03
Damper box	.03	.08	.07	.09
Motes and fly	.78	.85	.81	.81
Sweepings	.01	.03	.01	.02
Total visible	.84	.98	.91	.95
Total invisible [3]	2.12	2.85	1.93	2.51
Finisher:				
Total visible	.42	.77	.31	.23
Total invisible	.88	[4] .05	.79	.75
Card waste:				
Flat strips	2.94	2.35	3.01	2.36
Cylinder and doffer strips	.68	.67	.67	.68
Motes and fly	1.69	1.57	.78	1.12
Sweepings	.11	.23	.11	.11
Total visible	5.42	4.82	4.57	4.27
Total invisible	.57	.56	1.12	1.01
Picker and card waste:				
Total visible	8.73	8.32	7.22	6.58
Total invisible	3.43	3.26	3.71	4.13

[1] The waste percentage for each cleaning machine is based on the net weight of cotton fed to that particular cleaning machine. The percentage of total visible waste removed by the pickers and card equals 100 times the sum of the pounds of waste removed by the pickers and card divided by the net weight fed to the opener picker. Invisible waste is figured similarly.
[2] See table 2 for the percentage distribution of the classification of cottons tested, by grade.
[3] Represents invisible waste for opener and breaker pickers.
[4] Invisible gain.

An examination of the percentages of waste removed by the different cleaning machines shows that more visible waste was extracted from the cotton A by the pickers and cards. On an average, this difference amounted to 1.62 percent, or 7.74 pounds of waste per 478-pound bale of cotton. From a consideration of the grades of the cottons, as shown in table 2, this finding is somewhat surprising, as the grade of cotton B (ignoring the color designation) was on an average slightly lower than that of cotton A. It may be seen in table 3 that the chief differences in quantity of waste removed were in the form of opener waste and card motes and fly. These particular types of waste consist largely of foreign matter, such as leaf, motes, shale, sand, etc.

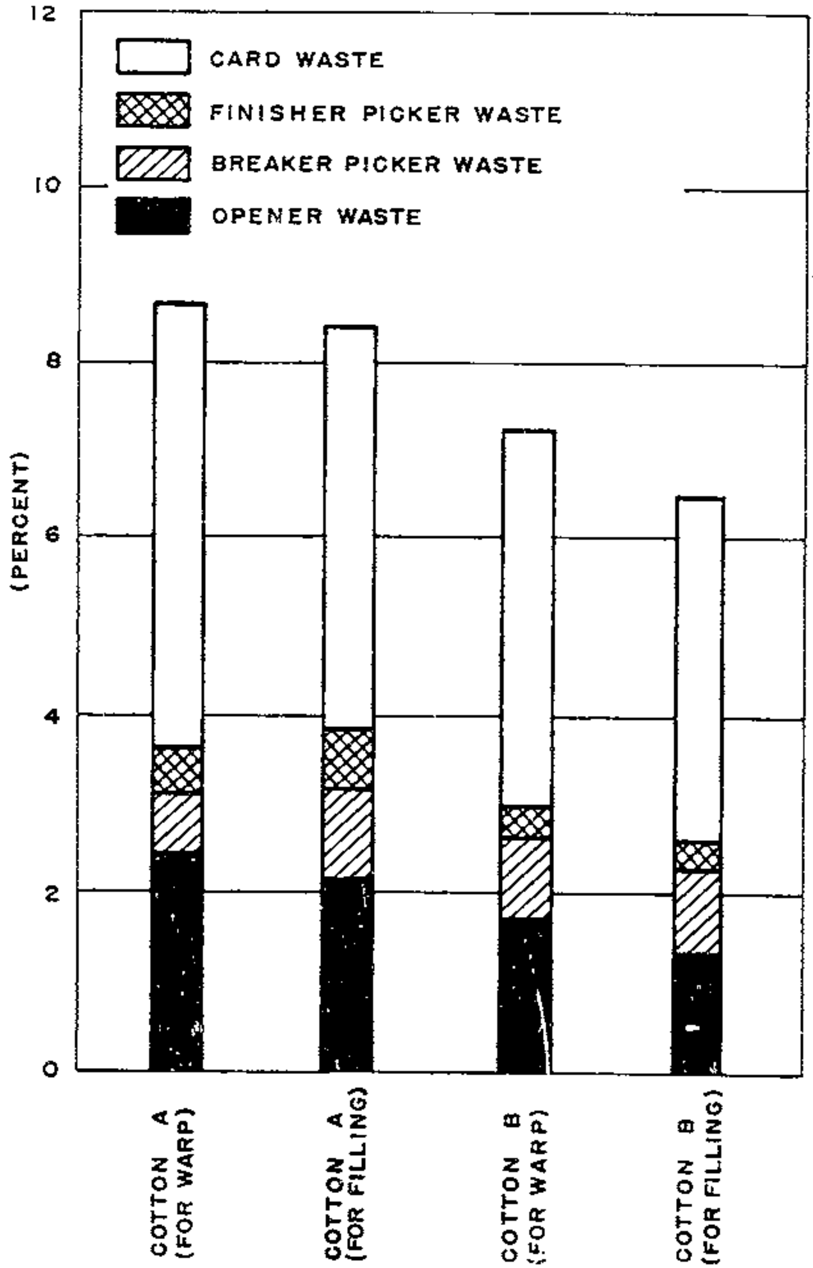


FIGURE 1.—Percentages of picker and card waste from cottons A and B.

STRENGTH OF YARN

The yarn-strength [4] and size data were then corrected to the specified yarn number, 21s warp yarn and 22s filling yarn, through the use of an improved method for converting an observed skein strength of cotton yarn to that of a specified yarn number as reported by Campbell (*5*).

A study of the data in table 4 shows that there is a difference in the corrected breaking strengths of the yarns spun from the two samples, cotton B producing yarns with a higher corrected breaking strength than cotton A. However, these differences in breaking strengths may be attributed to the fact that the cotton B was about one-sixteenth of an inch longer in staple length than cotton A. In order to determine the extent to which this difference in staple length alone might be expected to account for such a difference in the strengths of the warp yarns comparisons have been made with corresponding values obtained with the use of Campbell's empirical formula.[5] This formula gives the average skein strengths of carded warp yarn that may be expected to be obtained, under certain manufacturing conditions, from cottons of various staple lengths and a range of yarn numbers. The strengths of warp yarns thus estimated for the staple lengths of cotton and yarn numbers under consideration are shown in table 4.

TABLE 4.—*Corrected skein breaking strength and estimated strength of yarns*

Strength	Average corrected skein strength of [1]—							
	Cotton A				Cotton B			
	Warp yarn (4.84 twist multiplier) 31/32 inch [2]		Filling yarn (3.71 twist multiplier) 15/16 inch [2]		Warp yarn (4.84 twist multiplier) 1 1/32 inches [2]		Filling yarn (3.71 twist multiplier) 1 inch [2]	
	Average	*SEm*±	Average	*SEm*±	Average	*SEm*±	Average	*SEm*±
	Pounds		*Pounds*		*Pounds*		*Pounds*	
Corrected	95.3	1.01	74.8	0.77	101.4	0.82	80.02	0.68
Estimated [3]	98.3				104.0			

[1] Average of 25 observations.
[2] See table 2 for the percentage distribution of the classification of cotton tested by staple length.
[3] Bureau of Agricultural Economics formula for determining yarn strength from staple length of cotton and number of yarn.

Examination of the data in table 4 shows that the warp yarn spun from cotton B was 6.4 percent higher in breaking strength than that spun from cotton A. The estimated breaking strength of 21s warp yarn spun from cotton with a staple length of 1 1/32 inches is found to be 5.8 percent higher in strength than the same count of yarn spun from cotton of 31/32-inch staple length. Thus it is seen that the difference between the strengths of the warp yarns spun from cotton A and cotton B in this test may be accounted for almost entirely by the difference in staple length.

[4] The yarns were tested at the cotton testing laboratory of the Bureau of Agricultural Economics, Washington, D. C., where they were reeled into skeins of 120 yards each, and allowed to condition for at least 4 hours in an atmosphere of 65 percent relative humidity at a constant temperature of 70° F. The yarns were then broken on a standard type inclination-balance skein tester and sized on a direct yarn numbering quadrant.

[5] CAMPBELL, MALCOLM E. THE RELATION OF STAPLE LENGTH OF COTTON TO THE SKEIN STRENGTH OF CARDED WARP YARN. U. S. Bur. Agr. Econ. Unpublished.

SHRINKAGE

All the sheets shrank lengthwise but increased in width with wear and laundering. The average change in dimension for sheeting made from cotton A was −9.4 percent warpwise and +2.6 percent fillingwise. The cotton B sheet shrank 9.1 percent and gained 2.3 percent in width. For the sheeting made from the commercial mixture the changes were −9.0 percent and +1.9 percent, respectively. The variations for the three fabrics are not significant. A comparison of these shrinkage values with those of the earlier wear study (*18, p. 36*) shows that these sheets shrank more lengthwise and gained somewhat less in width than those previously tested.

A sheet made of cotton A, which originally measured 103.6 by 64.4 inches, was 96.5 by 66.5 inches after five washes. Further variations in width were insignificant, but at 10, 15, and 20 washes the length was 95.6, 94.7, and 95.1 inches, respectively. At the time of discarding, after 327 washes, this sheet measured 94.5 inches in length.

These and similar measurements for the sheets of the other two lots show that the greater part of the shrinkage occurs in the first 5 washes and that the changes in dimensions after 15 washes are negligible. A small increase lengthwise was noted at 20 washes for the sheet from cotton A because one time it was ironed hem to hem. In normal hotel practice sheets are ironed selvage to selvage. McClew (*16*) also observed the relationship of percentage of shrinkage to direction of ironing.

WEIGHT

The weight per square yard (tables 5 and 6) as plotted in figure 2 shows that there was an appreciable loss in weight upon bleaching and finishing, and an equivalent gain at the end of 25 washes as a result of shrinkage.

TABLE 5.—*Physical analysis of three lots of unbleached sheetings*

Material	Weight per square yard	Yarns per inch		Thickness	Bursting strength	Breaking strength	
		Warp	Filling			Warp	Filling
	Ounces	*Number*	*Number*	*Inches*	*Pounds*	*Pounds*	*Pounds*
Cotton A	5.11	68.8	72.1	0.014	76	54.9	61.5
Cotton B	5.10	69.8	72.4	.013	81	60.4	68.2
Commercial mixture	5.08	69.4	72.3	.014	80	59.8	68.9

When finished and throughout the major portion of this study, the sheets made from cotton A were lighter in weight than were those from the other two lots. Since the curves in figure 2 for the fabrics of cotton B and the mixed cottons show no consistent difference, it is evident that the addition of 20 percent of cotton A did not appreciably lower the weight of the sheeting. Service did not produce so great a reduction in the weight of these heavy muslin sheets (table 6) as the 0.8-ounce loss reported for mediumweight muslin sheeting of the previous study (*18, p. 29*).

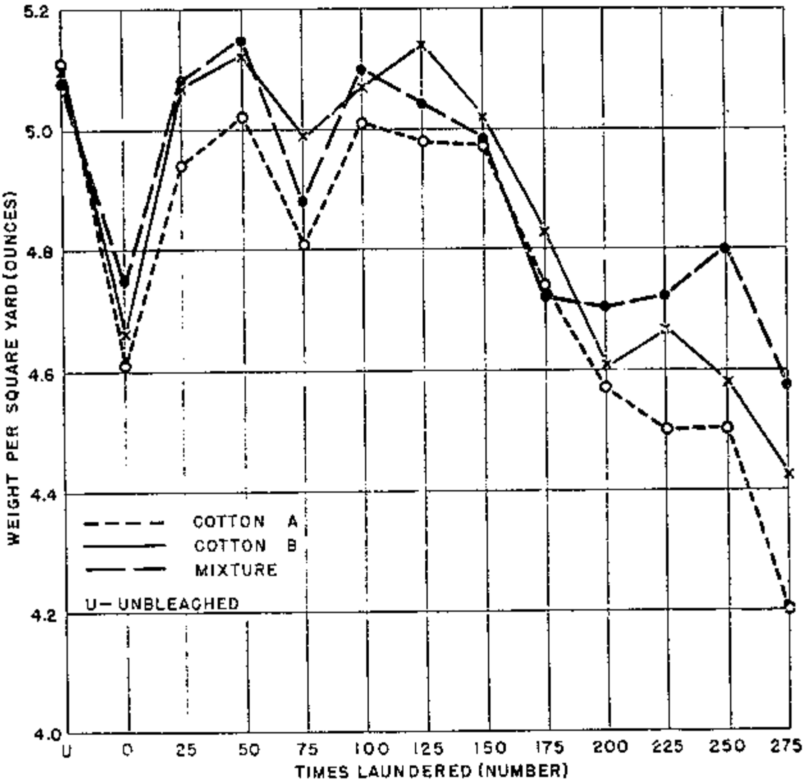


FIGURE 2.—Weight per square yard of the three lots of unbleached sheetings and of the bleached sheetings laundered various numbers of times.

YARNS PER INCH AND THICKNESS

The unbleached sheetings had 69 yarns per inch warpwise and 72 yarns fillingwise (table 5), which is a standard mill construction. After bleaching, all three sheetings had more warp yarns per inch and fewer filling yarns (table 6). According to the classification proposed by Hays (*15*), these sheets are heavyweight muslin, since they have a finished count fillingwise between 66 and 76 yarns per inch. As shown in table 6, the number of yarns decreased warpwise and increased fillingwise with service until there was approximately the same number in both directions.

From a comparison of the thickness values (tables 5 and 6), it is evident that all three materials changed similarly during bleaching and finishing. There was a slight gain with laundering, but after 75 washes all three sheetings measured 0.011 inch in thickness and showed no further changes throughout the remainder of the study.

BURSTING STRENGTH

Figure 3 shows that the bursting strength decreased with increasing amounts of service, and that the sheeting of this study made from cotton A (table 6) had lower values throughout than did the other two materials.

TABLE 6.—*Weight, yarns per inch, thickness, and bursting strength of three lots of sheetings after repeated laundering and wear*

Material	Times laundered	Weight per square yard	Yarns per inch		Thickness	Bursting strength
			Warp	Filling		
	Number	*Ounces*	*Number*	*Number*	*Inches*	*Pounds*
Cotton A	[1] 0	4.61	77.0	67.4	0.010	78
	25	4.94	76.2	72.0	.013	66
	50	5.02	76.0	72.2	.012	62
	75	4.81	75.1	73.9	.012	64
	100	5.01	74.9	74.8	.011	52
	125	4.98	74.4	75.0	.011	48
	150	4.67	74.1	73.1	.011	40
	175	4.74	74.8	73.9	.011	33
	200	4.57	74.5	73.9	.011	31
	225	4.50	74.8	73.6	.011	26
	250	4.50	74.5	73.6	.011	20
	275	4.20	73.4	73.6	.011	18
Cotton B	[1] 0	4.66	76.8	68.4	.010	78
	25	5.07	76.0	72.9	.012	77
	50	5.12	75.9	74.3	.012	72
	75	4.99	75.3	73.7	.011	73
	100	5.07	75.4	74.1	.012	56
	125	5.14	74.8	74.6	.011	53
	150	5.02	74.5	73.5	.011	41
	175	4.83	75.0	74.1	.011	36
	200	4.61	74.6	74.4	.011	32
	225	4.67	74.8	74.4	.011	30
	250	4.58	74.5	74.8	.011	24
	275	4.43	74.5	73.8	.011	22
Commercial mixture	[1] 0	4.75	76.5	69.0	.011	83
	25	5.08	76.0	74.0	.012	76
	50	5.15	75.8	74.3	.011	66
	75	4.88	75.4	75.7	.011	73
	100	5.10	75.2	75.3	.011	56
	125	5.04	74.7	75.7	.011	52
	150	4.98	73.9	73.7	.011	42
	175	4.72	74.9	75.3	.011	35
	200	4.70	75.1	74.8	.011	33
	225	4.72	75.4	75.2	.011	30
	250	4.80	74.7	75.4	.011	28
	275	4.57	74.0	75.5	.011	22

[1] Average for 5 test periods.

BREAKING STRENGTH

The values for breaking strength are given in table 7. In general, the sheeting made from cotton A was slightly weaker than the other two materials between which no significant difference existed. It should be noted that cotton B had a somewhat longer staple length (table 1) than cotton A. The average breaking-strength values, as plotted in figure 4 for each of the three sheetings, show a progressive loss with service. A comparison of the warpwise results indicates that there was approximately as great a loss in breaking strength with the first 50 washes as was produced by the following 225 launderings. Fillingwise the reduction at 50 washes was equivalent to that produced by the next 100.

Whitin *(21)*, in his report of the Cotton Textile Institute wear study on 24 mill brands of sheeting, gives the loss in breaking strength for sheets of the heavyweight, 68 by 72 construction, at the end of 65 washings in the Westchester Hospital as 53.25 percent. The materials made from cotton B and from the mixture of the two cottons showed this percentage reduction in strength between 125 and 150 washes, and the cotton A sheeting between 100 and 125 times laundered.

TABLE 7.—*Breaking strength and elongation of three lots of sheeting after repeated laundering and wear*

Material	Times laundered	Breaking strength (strip)								Elongation							
		Section A		Section B		Section C		Section D		Section A		Section B		Section C		Section D	
		Warp	Filling	Warp	Filling	Warp	Filling	Warp	Filling	Warp	Filling	Warp	Filling	Warp	Filling	Warp	Filling
	Number	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Cotton A	[1] 0	63.7	56.4	63.5	54.2	63.9	54.9	-------	-------	6.7	17.6	7.2	18.2	7.1	18.6	-------	-------
	25	49.0	49.6	48.6	49.7	50.2	50.1	50.3	53.3	11.7	15.4	12.3	15.0	11.6	16.1	12.7	16.8
	50	40.6	42.1	38.6	41.4	42.5	38.9	40.5	42.4	10.8	13.2	10.9	13.9	10.8	13.5	10.9	13.9
	75	40.1	39.5	37.9	38.1	40.5	40.7	41.1	42.5	9.0	10.1	8.7	10.2	8.6	10.3	9.0	10.0
	100	29.2	30.7	31.3	27.2	32.0	32.9	30.8	31.7	10.5	12.0	10.4	11.5	10.5	13.2	10.7	11.9
	125	25.9	24.0	23.4	22.3	28.8	27.1	29.7	27.1	7.8	8.4	7.8	8.4	8.9	10.3	8.9	9.1
	150	25.7	23.9	23.0	20.0	28.0	26.5	30.0	27.7	7.8	7.7	7.3	7.0	7.6	8.3	8.9	8.6
	175	22.5	15.9	18.1	13.8	25.4	21.1	26.6	22.3	8.8	7.6	7.6	7.3	9.3	9.1	9.1	8.6
	200	20.6	16.6	17.2	12.0	25.1	19.0	26.0	21.2	7.9	7.7	7.7	7.3	8.5	9.0	9.3	8.4
	225	17.6	11.9	12.6	8.0	21.6	14.0	21.8	17.1	8.4	7.8	7.6	6.3	8.6	8.2	9.2	8.4
	250	15.8	11.6	13.9	8.1	20.0	15.5	20.7	17.7	7.1	5.5	6.3	4.7	7.5	7.4	8.4	7.6
	275	14.4	8.9	9.8	6.8	17.5	11.9	19.9	15.5	7.7	5.9	5.8	5.8	8.3	7.3	9.8	7.8
Cotton B	[1] 0	65.8	58.7	66.0	60.6	65.4	61.4	-------	-------	7.7	16.4	8.2	16.8	8.1	16.7	-------	-------
	25	52.6	53.1	49.9	52.6	53.8	53.0	52.4	54.0	13.0	16.0	12.7	16.9	13.6	18.1	13.7	17.6
	50	39.9	43.7	40.5	42.2	41.9	41.0	39.5	41.3	10.4	12.4	10.9	13.3	11.2	13.6	11.5	12.1
	75	41.6	44.1	40.5	39.9	43.4	44.6	42.7	43.4	8.5	9.5	8.5	9.3	8.7	10.7	8.9	9.8
	100	33.7	33.9	30.6	27.8	34.3	34.5	35.4	35.8	10.3	12.1	10.3	11.0	11.1	12.0	10.8	11.7
	125	31.9	28.9	27.6	23.8	31.2	31.8	31.4	31.7	8.7	7.8	8.4	8.8	8.8	9.8	9.1	8.5
	150	29.2	25.0	24.7	20.8	29.8	29.7	32.5	29.9	8.6	8.0	7.8	7.3	8.2	9.1	9.0	8.6
	175	22.1	19.4	19.8	13.2	26.5	19.9	28.0	24.4	9.2	8.7	8.4	7.4	9.4	9.1	10.0	9.8
	200	20.3	19.3	19.6	13.9	26.2	19.9	26.8	24.1	8.8	8.5	8.2	7.0	9.5	9.4	10.0	9.2
	225	19.2	15.5	15.3	10.2	24.9	19.3	24.9	20.8	9.4	8.1	8.2	6.8	9.3	9.2	10.0	9.2
	250	15.3	12.1	11.6	8.6	18.9	12.3	19.1	15.8	7.6	6.1	6.2	4.7	7.4	6.3	8.3	7.2
	275	15.6	10.9	12.3	6.8	19.2	14.9	20.6	19.0	7.7	6.9	6.7	4.8	8.1	7.9	9.6	8.6
Commercial mixture	[1] 0	64.5	60.6	66.3	63.0	65.9	63.6	-------	-------	8.1	17.6	8.7	18.1	8.3	17.5	-------	-------
	25	50.7	55.9	48.7	54.0	49.0	48.6	46.3	54.7	14.7	17.5	13.2	16.8	12.7	16.4	13.5	15.9
	50	37.2	42.5	38.2	41.0	40.3	45.8	42.1	44.0	10.6	13.0	10.6	13.2	11.1	13.9	11.1	13.1
	75	39.7	46.4	39.0	45.0	42.7	45.8	39.3	45.4	9.2	11.1	8.9	10.8	9.2	11.5	9.1	10.7
	100	32.0	30.6	29.5	30.2	34.7	31.7	35.9	39.0	11.5	12.1	11.0	13.1	10.9	13.5	11.0	13.5
	125	28.2	28.4	25.2	25.1	32.5	32.6	32.9	33.8	8.3	9.4	8.1	9.2	8.9	10.1	9.3	9.8
	150	26.6	26.3	24.5	21.3	32.2	28.4	30.5	29.2	7.5	8.3	7.6	7.8	9.1	9.3	9.6	8.8
	175	24.4	20.1	20.2	16.2	26.9	23.2	28.5	25.4	9.0	9.1	8.8	8.2	8.8	9.4	9.3	9.3
	200	20.7	16.4	18.2	11.9	26.6	20.6	25.9	22.3	8.9	8.0	7.7	7.0	9.0	9.7	8.7	9.4
	225	18.6	14.6	14.4	9.8	24.9	18.0	25.3	20.3	8.8	8.2	7.9	7.3	9.2	9.7	9.7	9.7
	250	15.6	12.9	12.8	9.2	20.3	16.2	21.3	18.4	7.3	6.[illegible]	6.4	5.3	8.0	7.5	8.5	7.9
	275	15.5	11.8	12.2	6.5	19.0	14.5	21.8	18.1	7.8	6.[illegible]	6.8	5.2	8.7	8.1	10.0	8.7

[1] For unlaundered sheeting, 3 sections were taken on a diagonal instead of 4 sections representing areas of wear as was the method of sampling laundered sheets. The value is an average for 5 test periods.

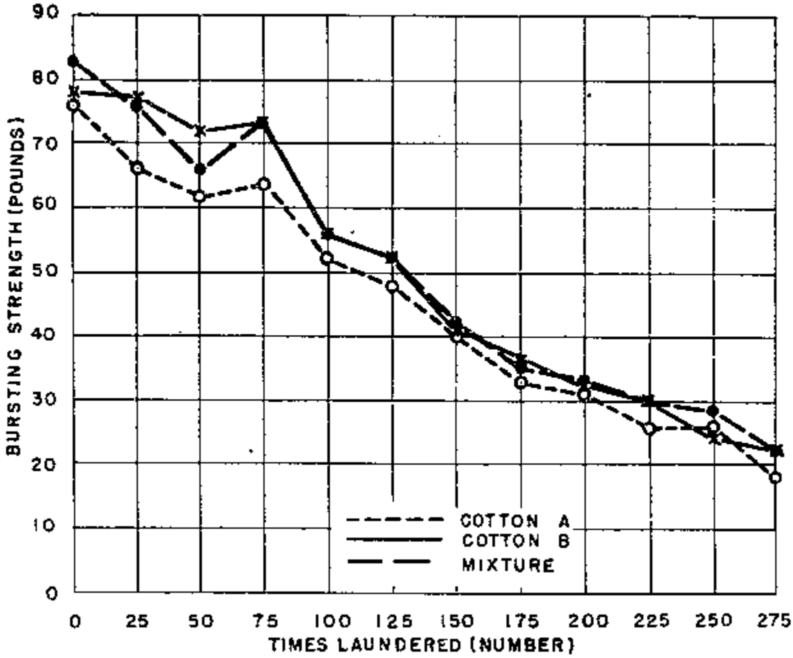


FIGURE 3.—Bursting strength of the three lots of sheetings removed from service at intervals throughout their wear life.

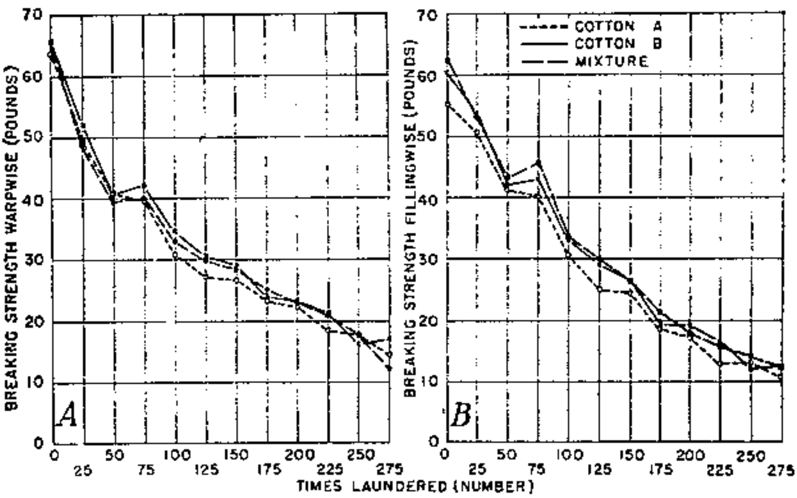


FIGURE 4.—Breaking strength of three lots of laundered sheets: *A*, Warpwise; *B*, fillingwise. The average of the four sections was plotted.

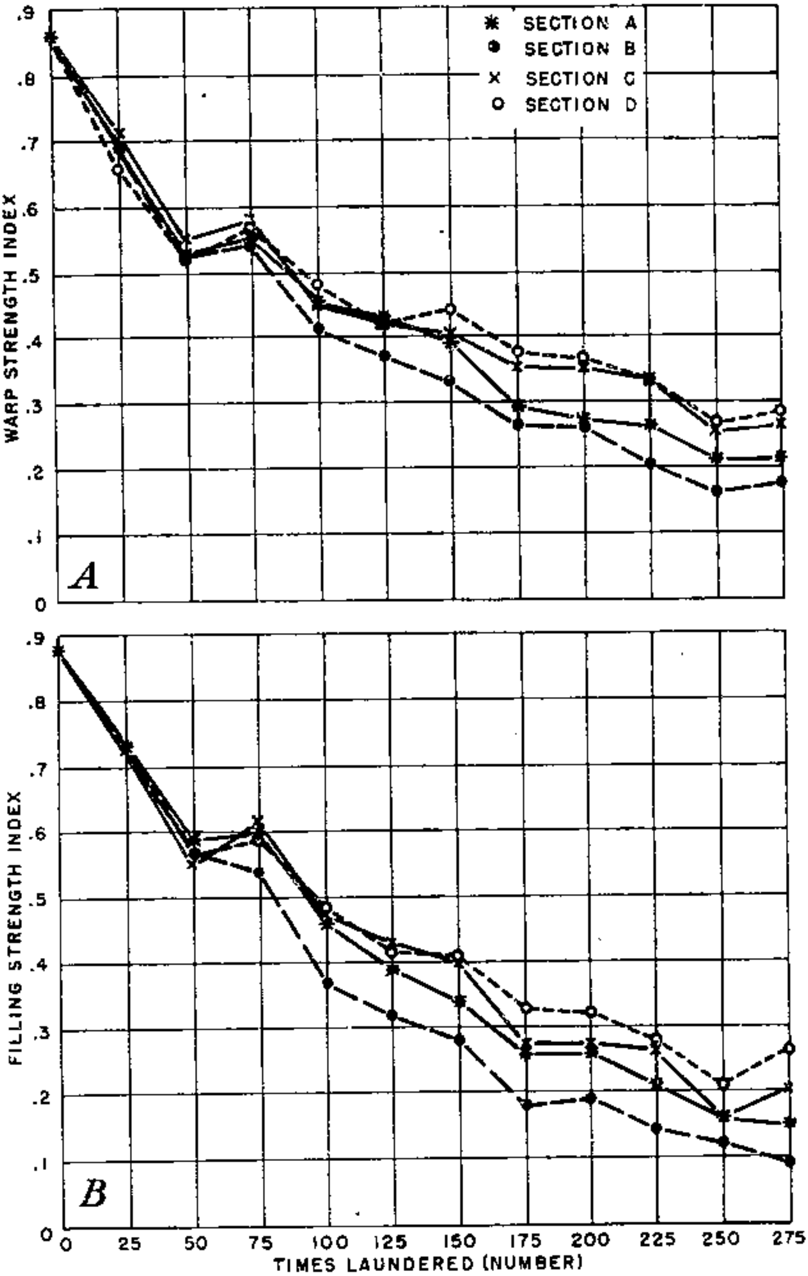


FIGURE 5.—The strength-index values, i. e., $\frac{\text{breaking strength}}{\text{number of yarns}}$, of the four sections of the sheets made from cotton B and given various amounts of wear: *A*, Warpwise; *B*, fillingwise.

The strength index or breaking strength per yarn, obtained by dividing the breaking strength by the number of yarns per inch, makes it possible to compare strength independent of variations in the number of yarns per inch. As measured by strength index, the warpwise strength was not affected by bleaching and only a small reduction occurred in the filling strength per yarn. The filling strength index for the fabric of cotton B was reduced from 0.94 in the unbleached state to 0.88 in the bleached and finished condition; of the cotton A material, from 0.85 to 0.82; and the mixture, from 0.95 to 0.90.

The values for strength index plotted by sections in figure 5 for the cotton B material show that the order of decreasing deterioration for the four sections was B, A, C, and D. The same order prevailed for the fabrics made from cotton A and the mixture. A similar finding was reported previously for sheetings made from Strict Good Ordinary, Middling, and Good Middling cottons (*18, p. 30*).

This and the previous study show that wear as well as laundering affect the life of a fabric. Many investigators have attempted to evaluate the durability of fabrics by merely laundering them repeatedly. Since this procedure does not simulate the conditions of actual use, it cannot reveal the changes that occur during service.

The effect of body wear, which includes such factors as mechanical abrasion and absorption of perspiration, is also shown by the breaking strength of the material at 250 washes when tests were made on the sides of the sheet, areas not normally subjected to this wear. For the cotton B fabric the breaking strength was 22.4 pounds warpwise and 17.1 pounds fillingwise. Similarly, the values were 21.9 and 18.2 pounds for cotton A, and 23.4 and 19.5 pounds for the mixture. A comparison of these values for the sides of the sheets laundered 250 times with those in figure 4, show that they approximate the average values of the four sections for the respective materials at 200 washes. Body wear has an appreciable effect on sheeting since 50 extra periods of use were necessary to give the sides of the sheets the same breaking-strength values as the centers at 200 washes. The role played by wear was even greater in a study reported by Ginter and others (*11*) for muslin garments than in this investigation on sheeting.

ELONGATION

Warpwise elongation increased at 25 washes, then gradually decreased, but after 125 washes the values remained essentially the same (table 6). The fillingwise elongation decreased with service to values between 6 and 8 percent. Figure 6 in which the elongation curves for cotton A are plotted, shows the same order of the sections as given by breaking strength, namely, B, A, C, and D. Section B, the most deteriorated, had the lowest percentage elongation while section D, the least damaged, had the highest percentage. Undoubtedly, fabric deterioration and the percentage of stretch at break are related.

LENGTH OF SERVICE

The time of the first break and of removal from service, as measured by the number of times laundered, is given in table 8. The sheets lost in the hotel were omitted in compiling this table. If a sheet had been tested before a break occurred it was not considered in computing the time of first break and all test sheets were omitted from the time of removal from service. In these computations, no distinction was made between breaks due to accidents or to stain removal and those resulting from normal wear. Sheets were withdrawn when in the judgment of the workers they were too weak to patch or darn.

The average time of first break for these three sheetings is lower than that previously reported for Middling cotton in another study (*18*), although the upper limits of the range are higher. For all three

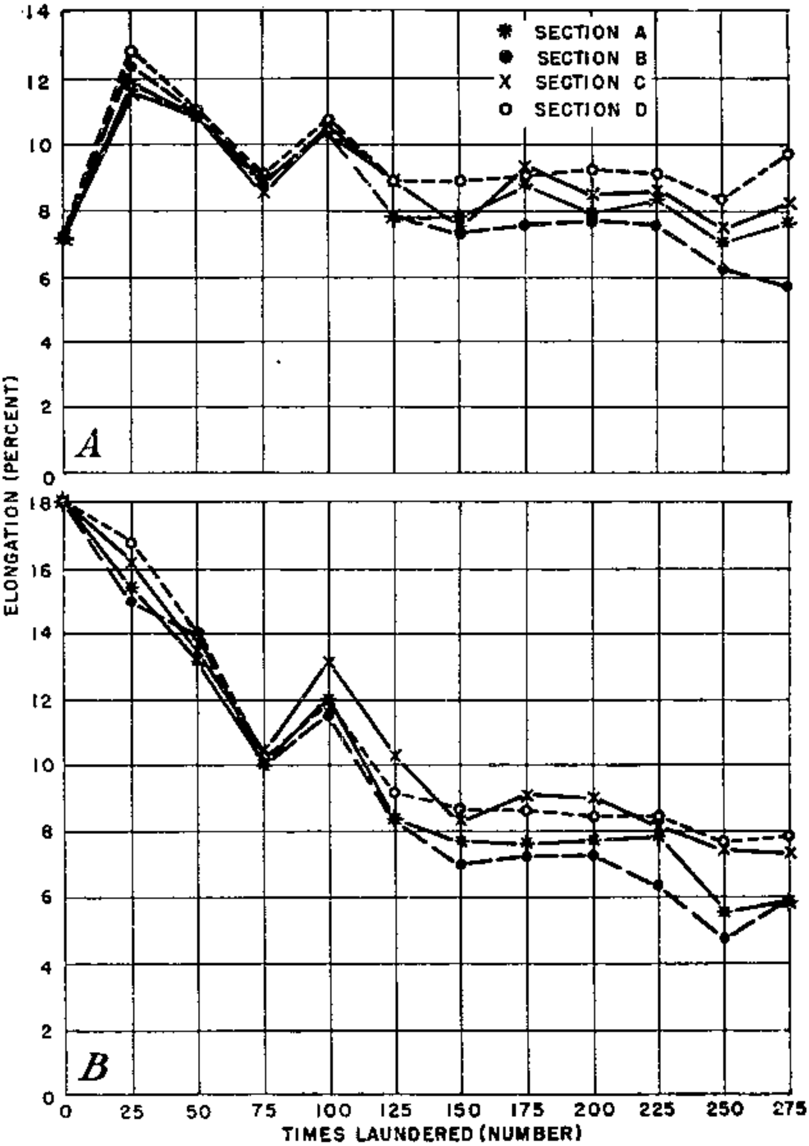


FIGURE 6.—Elongation of four sections of cotton A sheeting given various amounts of service: *A*, Warpwise; *B*, fillingwise.

heavyweight sheetings, the low value in the range of time of first break (table 8) is below 102 times laundered, the lowest value previously reported for medium weight muslin. However, it was noted that the 43, 46, and 54 low values in table 8 were for some sheets that had been badly stained and had been treated to remove these stains.

TABLE 8.—*Range, average, and standard deviation of time of first break and of removal from service for three lots of sheetings*

Material	First break occurred				Removed from service			
	Times washed		Sheets averaged	Standard deviation	Times washed		Sheets averaged	Standard deviation
	Range	Average			Range	Average		
	Number	*Number*	*Number*	σ	*Number*	*Number*	*Number*	σ
Cotton A	46–224	156	46	38	152–350	281	26	58
Cotton B	54–227	156	48	42	62–359	276	25	78
Commercial mixture	43–240	154	49	52	93–362	278	21	84

As shown in table 8, there was no significant difference in the average time of removal from service for the three fabrics. A comparison of the length of service of sheets in this study with those of the previous wear study (*18*) shows that the grade of cotton and the sheeting construction are more important than the differences in these two cottons. Mediumweight sheets as previously reported (*18*) had an average length of service of 208 times laundered when made from Strict Good Ordinary cotton, whereas from Middling cotton they averaged 239 times. The cotton of approximately Middling grade made into heavy muslin sheeting averaged 281 for cotton A, 276 for cotton B, and 278 for a mixture of the two cottons.

Haley (*14*) reports 50 weeks' service from sheeting of an undesignated construction. His wear factor was greater since sheets were used seven times instead of once before laundering. It is impossible to make direct comparisons between studies when both the service conditions and the fabric construction vary.

FLUIDITY

The fluidities of the cuprammonium solutions of the bleached and finished sheetings are higher than those of the unbleached materials (tables 9 and 10). The bleached fabrics have lower yield values (*18, p. 59*), indicating that the solutions of bleached cotton in cuprammonium were more truly viscous fluids than were those of the unbleached. Noncellulosic impurities are present in the unbleached materials and may interfere with the accuracy of the results.

The fluidity results for the fabrics from cotton A are higher in general than those from cotton B and the mixed cottons (table 10 and fig. 7). This shows that the material made from cotton A was more deteriorated chemically than the other two sheetings. The values for the fabrics from cotton B and the mixture of the cottons are approximately equal.

As service progressed the fluidity for each of the three sheetings increased. The yield value for each material decreased with wear until it became zero at approximately the 150-wash period. Thus, the abnormality measured by the yield value became less accentuated with increasing deterioration of the cotton.

On the basis of a system devised by Ost (*17*) for rating cotton deterioration by fluidity, the values of the unlaundered finished sheetings are approximately equal to that of a cotton fabric bleached by a process somewhat more severe than is normal commercial practice.

TABLE 9.—*Fluidity in cuprammonium hydroxide, copper number, methylene blue absorption, moisture, and ash of the three lots of unbleached sheetings*

Material	Fluidity	Copper number [1]	Methylene blue absorption [2]	Moisture	Ash
	Reciprocal poises			*Percent*	*Percent*
Cotton A	10.5	1.22	6.1	6.93	1.17
Cotton B	8.0	.68	5.9	6.78	.99
Commercial mixture	8.9	.62	5.6	6.82	.97

[1] Grains of copper reduced by 100 g of dry cotton.
[2] Millimols of methylene blue absorbed by 100 g of dry cotton.

TABLE 10.—*Fluidity in cuprammonium hydroxide, copper number, methylene blue absorption, and ash content of the three lots of sheetings after repeated laundering and wear*

Material	Times laundered	Fluidity	Copper number [1]	Methylene blue absorption [2]					Ash
				Section A	Section B	Section C	Section D	Average	
	Number	*Reciprocal poises*							*Percent*
Cotton A	0	11.2	0.24					1.3	0.04
	25	13.1	.45	4.9	4.8	4.6	4.5	4.7	.32
	50	14.5	.49	7.4	7.6	7.4	7.2	7.4	.64
	75	15.0	.56	9.3	9.2	9.1	8.4	9.0	.81
	100	16.0	.71	11.5	11.5	10.9	10.6	11.1	.92
	125	16.5	.80	13.2	13.5	12.4	12.2	12.8	1.00
	150	18.1	.84	14.2	14.5	14.0	13.8	14.1	1.05
	175	19.4	.89	14.2	14.2	13.9	14.0	14.1	1.18
	200	20.1	.94	14.7	14.8	14.1	13.9	14.4	1.33
	225	21.3	.97	15.8	16.1	15.6	15.5	15.8	1.48
	250	22.0	1.00	15.9	16.5	15.8	15.6	16.0	1.50
	275	22.5	1.06	17.5	17.7	17.4	17.3	17.5	1.76
Cotton B	0	10.9	.20					1.3	.04
	25	12.5	.42	4.7	4.8	4.5	4.3	4.6	.32
	50	14.4	.40	7.1	7.2	7.0	6.7	7.0	.58
	75	14.6	.52	8.0	8.3	8.2	8.2	8.2	.71
	100	15.8	.69	10.9	11.4	10.8	10.6	10.9	.89
	125	16.3	.76	12.5	12.7	12.5	12.3	12.5	.97
	150	17.9	.82	13.2	13.4	12.9	12.9	13.1	1.00
	175	18.7	.85	13.9	14.3	13.7	13.7	13.9	1.11
	200	20.1	.93	14.3	14.0	14.1	14.0	14.3	1.15
	225	21.0	.95	15.1	15.3	14.9	14.6	15.0	1.42
	250	21.8	1.00	16.3	16.4	16.0	15.8	16.1	1.53
	275	22.2	1.03	16.6	16.9	16.4	16.0	16.5	1.63
Commercial mixture	0	10.9	.23					1.2	.03
	25	12.7	.43	4.3	4.4	4.2	4.1	4.3	.30
	50	14.4	.49	6.9	7.2	7.1	6.8	7.0	.54
	75	14.6	.55	8.9	9.0	8.6	8.4	8.7	.73
	100	15.6	.69	11.4	11.3	10.8	10.3	10.9	.86
	125	16.5	.75	12.4	12.8	11.9	11.7	12.2	.96
	150	18.0	.83	12.6	13.1	12.4	12.2	12.6	.99
	175	18.9	.86	13.7	13.9	13.3	13.3	13.6	1.04
	200	19.9	.91	14.2	14.3	13.9	13.8	14.1	1.28
	225	21.2	.96	15.5	15.9	15.5	15.4	15.6	1.44
	250	22.2	1.02	16.6	16.8	16.5	16.3	16.6	1.64
	275	22.5	1.04	17.0	17.2	16.9	16.5	16.9	1.68

[1] Grams of copper reduced by 100 g of dry cotton.
[2] Millimols of methylene blue absorbed by 100 g of dry cotton.

The values for the sheetings laundered 275 times correspond to Ost's values for a material that showed a serious loss in breaking strength.

Fluidity measurements were made on material from the sides of the sheets laundered 250 times to obtain some estimate of the chemical deterioration caused by body wear. For cottons A, B, and the mixture these results were 21.5, 21.1, and 21.4, respectively. A comparison of these values with those in table 10 shows that the fluidity results for the sides at this test period are approximately the same as those for the center at the 225 launderings, indicating that body wear produced chemical deterioration. It is possible that this chemical action was produced by body secretions such as perspiration. Haley (*14*) has stated that wear either has a chemical action or so changes the physical condition of a fabric that the chemical effect of laundering is enhanced.

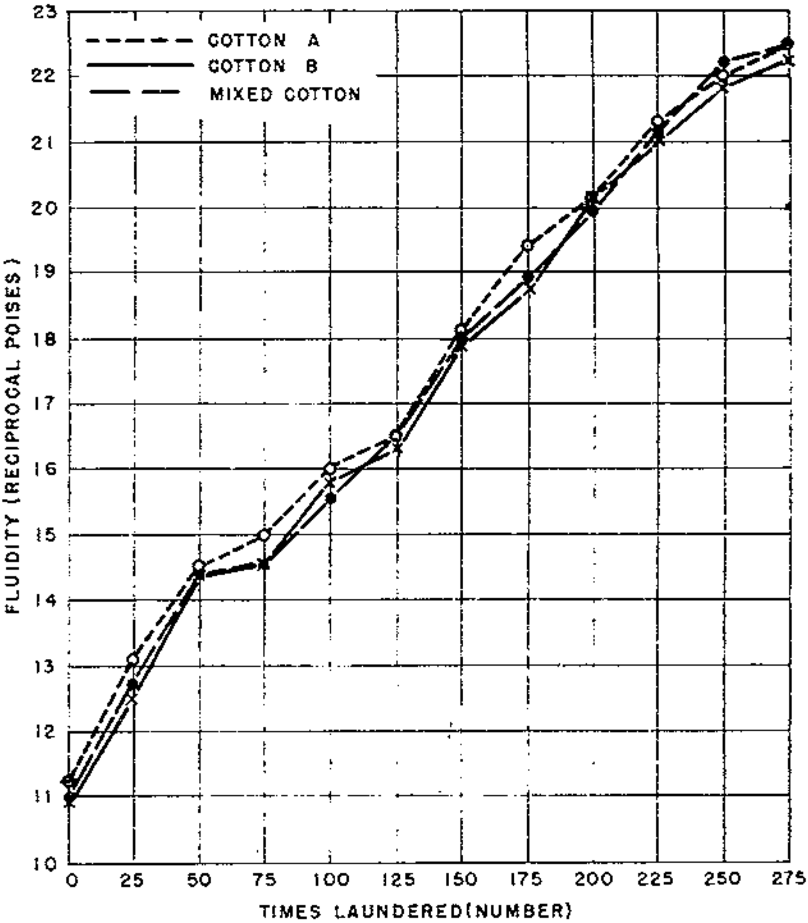


FIGURE 7.—Fluidity values of cuprammonium solutions of the three lots of sheetings removed from service at intervals of their wear life.

At the beginning of this investigation, samples of the unlaundered sheetings were placed in envelopes and stored in a file case in an office. Fluidity measurements were made on these stored fabrics once each year for the 4-year period while the sheets were in service in the hotel. Figure 8 shows that the fluidity values for each sheeting increase with storage. The slopes of the curves in this figure indicate that the rate of the chemical deterioration of the cotton becomes greater with time. Grimes (*13*) found that for raw cotton the rate of loss of strength increased as the storage period was extended.

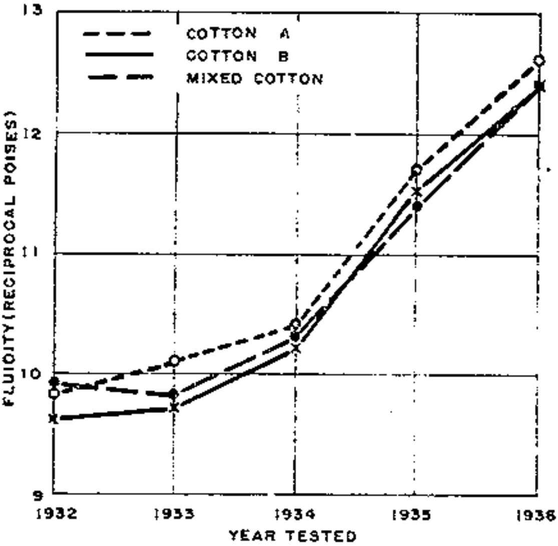


FIGURE 8.—Fluidity values of cuprammonium solutions of the three lots of unlaundered sheetings tested after various periods of storage.

Although storage caused a rise in fluidity, no loss in breaking or bursting strength was obtained. Clibbens and Ridge (*8*) state that any chemical process accompanied by a considerable rise in fluidity reduces the fabric strength actually or after a mild alkaline treatment, such as even an ordinary laundering process. In the present study samples that had been stored 5 years and then laundered once showed a loss in breaking strength. However, since there were no values for an unstored fabric laundered once it is impossible to know whether this reduction in strength is due to latent damage or merely to a loss of starch.

COPPER NUMBER

The copper-number results for the unbleached sheetings are appreciably greater than those for the bleached (tables 9 and 10) and agree with the findings of Clibbens and Geake (*6*) that bleaching caused a reduction in copper number. The high values for the cotton in the gray state show that the noncellulosic impurities present in the raw cotton possessed reducing properties. The sheeting from cotton A contained considerably more impurities of this type than did the other two materials.

For the major part of this study, the copper-number values for the sheeting from cotton A are higher than those for the other two lots of fabrics (table 10 and fig. 9). As with breaking strength and fluidity, there is relatively little difference between the values for the materials from cotton B and the mixture.

The copper numbers increased steadily as wear progressed. This rise, however, becomes less rapid with service. For example, the

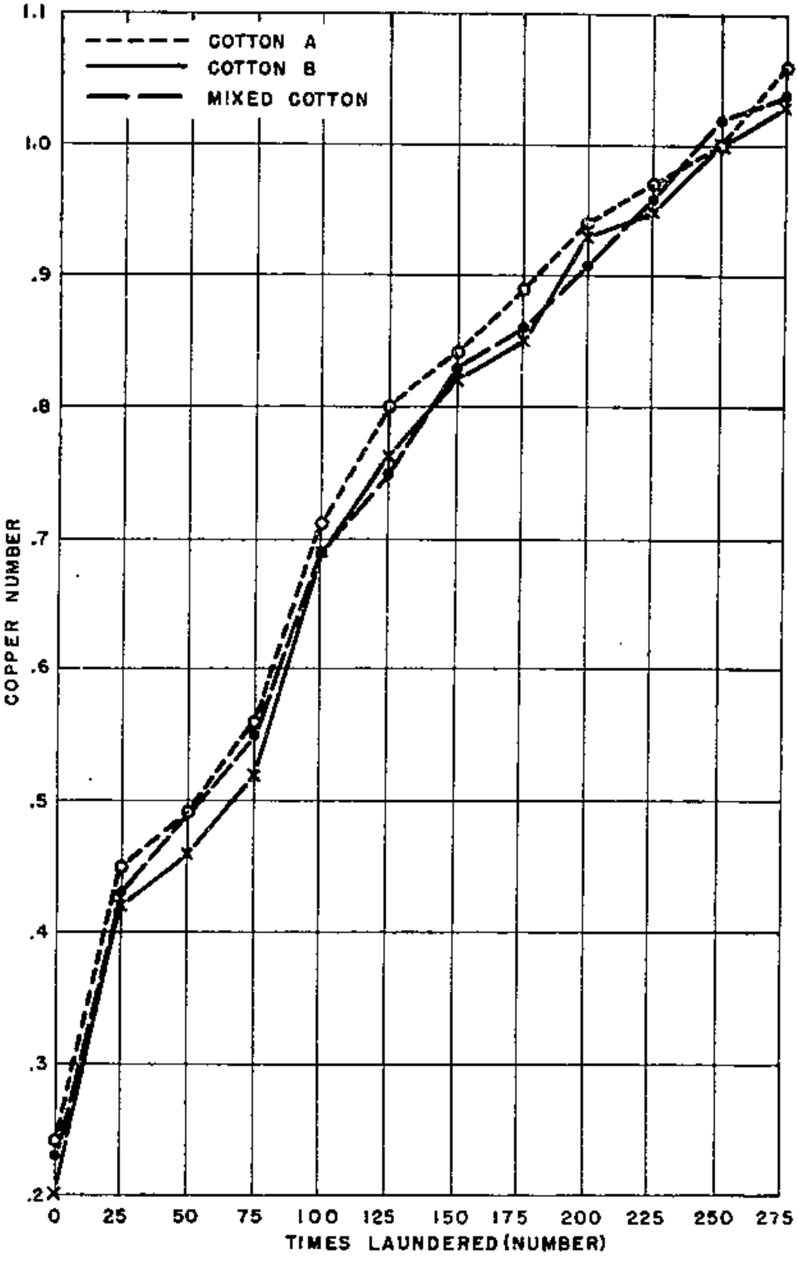


FIGURE 9.—Copper numbers of laundered sheets made from the three lots of fabrics.

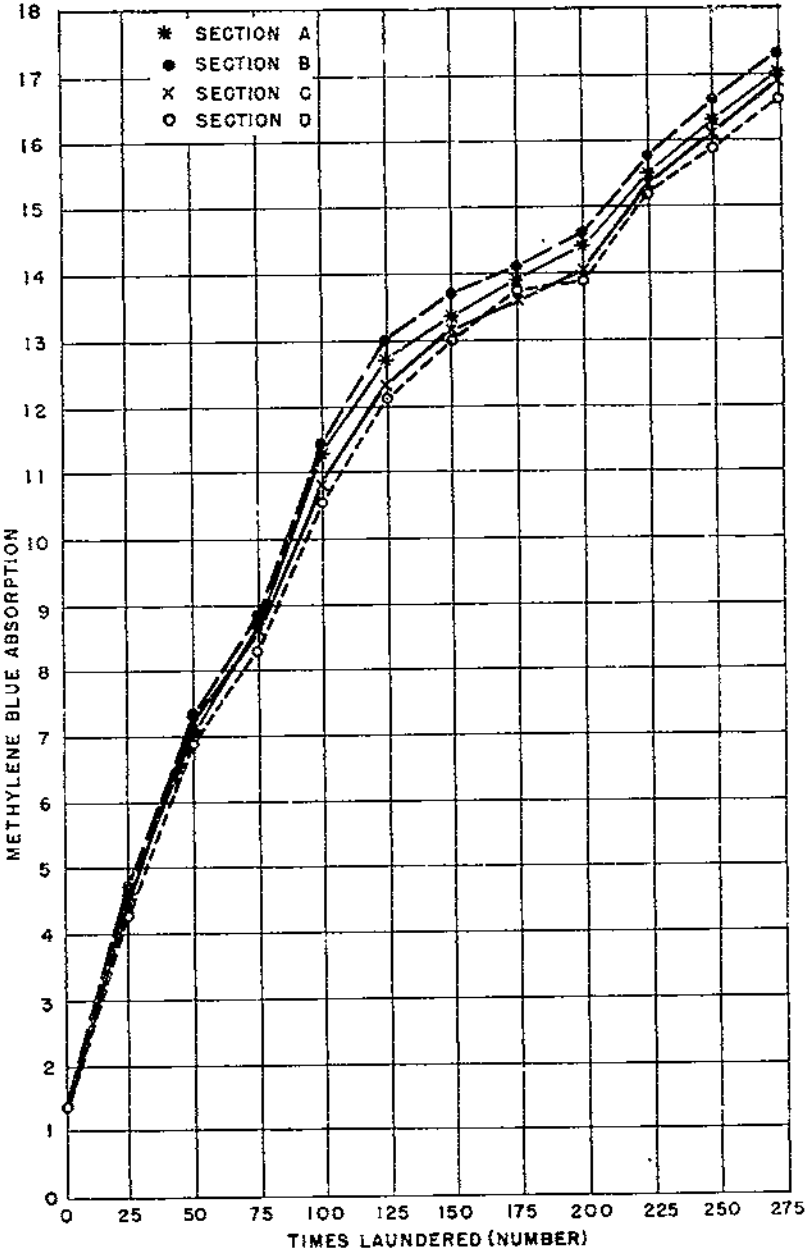


FIGURE 10.—Methylene blue absorption of different sections of cotton sheetings laundered various numbers of times. The value for each section is the average of that for the three lots of sheetings.

deterioration that occurred during the first 75 washes is approximately equivalent to that for the next 175 launderings. A similar tendency was noted for breaking strength.

The copper-number values of the sides of the sheets laundered 250 times are 0.97, 0.96, and 0.98 for cottons A, B, and the mixed cottons, respectively. As with fluidity, these values are approximately the same as those found for the center of the sheets after only 225 washes (table 10). Since strength-index values for the sides of the sheets laundered 250 times are approximately equal to those of the center after 200 washes, wear apparently has a greater effect on the physical properties of the sheeting than on the chemical.

The copper numbers for the unlaundered, bleached sheets of these three lots of fabrics are slightly lower than those reported for the sheets of Middling cotton in the investigation on the effect of grade of cotton (*18*). The fabrics for this project may have been somewhat more carefully finished than those for the previous investigation, or the raw cotton used may have been less deteriorated chemically. With service, the copper-number values for the sheeting of the present study increased slightly more rapidly than those for the previous one.

METHYLENE BLUE ABSORPTION

Tables 9 and 10 show that the bleached sheetings absorbed considerably less methylene blue than did the unbleached fabrics. Clibbens and Geake (*7*) also found that after a normal bleach, cotton had a decidedly lower absorption than in the gray state.

The absorption values as well as the copper numbers and the fluidities indicate that in general cotton A sheeting in this study was deteriorated more chemically than were the other two materials. The methylene blue results for these three lots of sheets were somewhat lower originally but higher during the greater part of the investigation than were those for the fabric from the Middling cotton in the study on the grade of cotton.

Wear and laundering caused a progressive increase in absorption. The large rise in the methylene blue absorption and the relatively small increase in copper number with service shows that the type of oxidized cellulose formed is the same as that produced by Birtwell, Clibbens, and Ridge (*4*) when they treated cotton with alkali hypobromite.

It is apparent from figure 10, where the absorption values for the different sections of the sheetings are plotted against the number of times laundered, that the order of increasing chemical deterioration of the sections is D, C, A, and B. This again shows that wear has a chemical effect. Strength index and elongation ranked the sections in this same order.

STARCH

The percentages of starch found in the new sheetings and in those laundered 1, 3, 5, 10, and 25 times are shown in figure 11. Although a small amount of starch remained in the fabrics after 25 washings, none was present after 50. It is evident from this graph that more starch was removed during the first 3 launderings than during the next 22, and that the greatest loss occurred during the first wash.

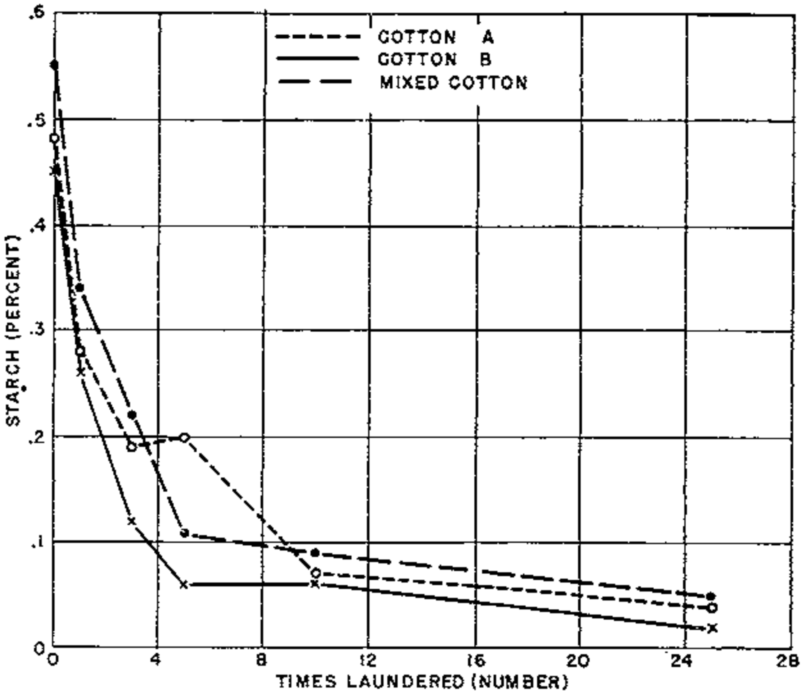


FIGURE 11.—Starch content of the three lots of sheetings laundered a various number of times.

ASH

The ash content of each of the three unbleached fabrics is approximately 1 percent and that of the bleached less than 0.05 percent (tables 9 and 10). This conforms with the statement of Birtwell, Clibbens, and Ridge (*3*) that in general the ash content of unbleached cotton is about 1 percent and that of cotton that has received a full bleach less than 0.1 percent.

The unbleached sheeting made from cotton A had the highest ash content of the three unbleached fabrics. It also had the greatest fluidity in cuprammonium hydroxide, the highest copper number, and the largest methylene blue absorption. The percentage of ash in the bleached fabric made from cotton A was greater for the major part of this study than that in the other two materials (fig. 12).

With continued laundering, the amount of ash in the three sheetings increased. The gain in ash content is greater for the first half of the wear life of the fabrics than for the second. The percentage of ash found for the washed sheetings is higher than that reported by Griffith and others (*12*) who repeatedly laundered a bleached-cotton sheeting without subjecting it to wear. Their fabric contained 0.07 percent of ash after 1 washing and 0.44 percent after 200 washings. However, the water used by these workers was of zero hardness while the water employed in the present investigation had an average hardness of approximately 5 grains per gallon.

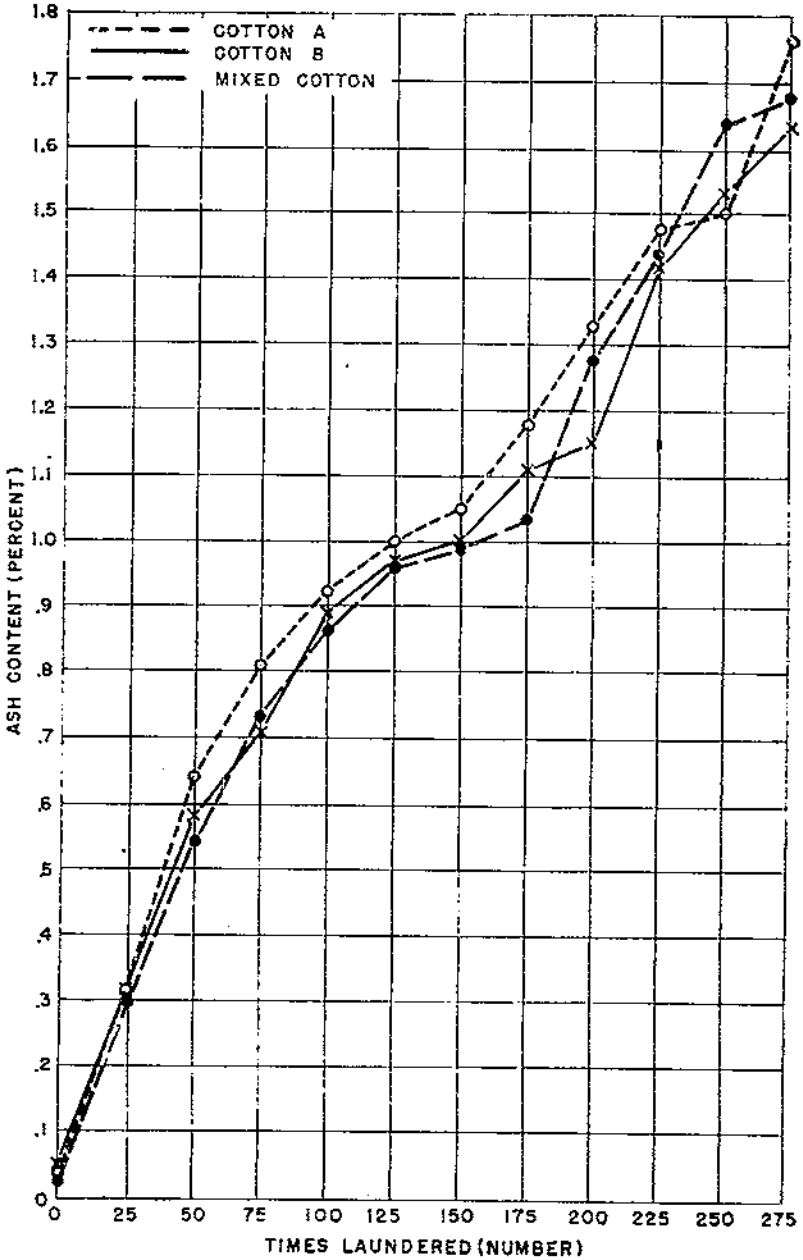


FIGURE 12.—Ash content of the three lots of sheetings laundered a various number of times.

MOISTURE

The moisture content of the unbleached materials is higher than that of the bleached (tables 9 and 10), agreeing with the findings of Urquhart, Bostock, and Eckersall (*20*) that the hygroscopicity of cotton decreases as its noncellulosic constituents are removed. The unbleached cotton A sheeting contains more moisture than the other two materials.

Figure 13 shows that as service continued the percentages of moisture in all three fabrics decreased. It should be noted that the

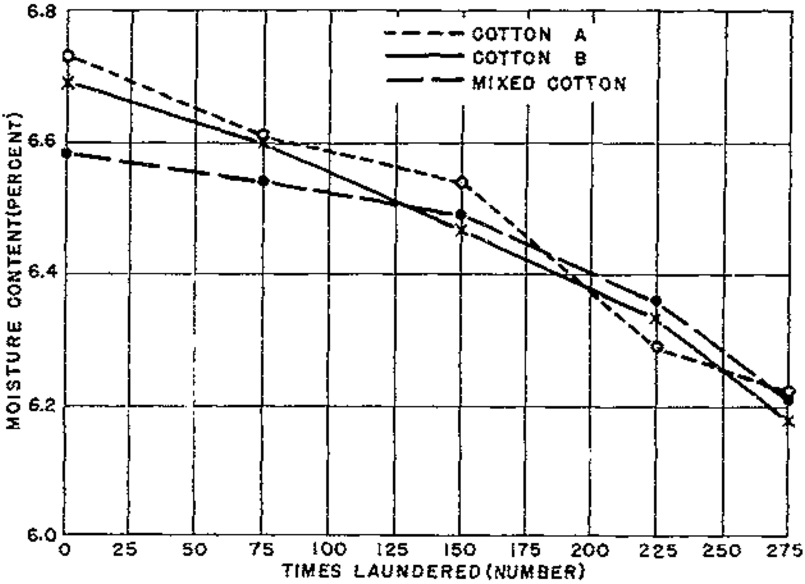


FIGURE 13.—The moisture content of the three lots of sheetings given various amounts of wear.

unlaundered bleached materials were desized and that the insoluble soaps in the laundered materials were removed before determining moisture content.

Apparently the moisture content of a cotton fabric decreases as it becomes deteriorated by wear, washing, and ironing. Downey and Elmquist (*9*) found that the amount of moisture in sheetings which had been damaged by ironing temperatures was reduced. In general the material from cotton A contained more moisture than did the other two sheetings.

APPEARANCE OF FABRICS

Figure 14 shows that as wear progresses the interstices between the yarns of the fabrics become larger. When viewed under the microscope, the worn fabrics illustrated in figure 14 showed broken protruding fibers which were not visible in the new material. The fabric deterioration, as illustrated by these photomicrographs, is revealed as occurring progressively by all the physical and chemical tests reported here which measure damage.

SUMMARY AND CONCLUSIONS

The cotton used in these tests was selected from several hundred bales stored in the warehouse of the Pequot Mills, and was representative of two types being used regularly by the mill and obtained from widely separated points. Cotton A was grown in the vicinity of Somerton, Ariz., and at Calexico, Calif. Cotton B was grown in Arkansas.

According to the classification by the Appeal Board of Review Examiners, cotton A ranged from Middling Light Spotted to Strict Middling Spotted in grade and ranged from $^{15}/_{16}$ to 1 inch in staple length. Cotton B was classed as Middling to Strict Middling in grade, and ranged from $^{31}/_{32}$ to $1\frac{1}{16}$ inches in staple length.

The test cottons and a commercial mixture consisting of 20 percent of cotton A and 80 percent of cotton B were spun, woven into heavyweight muslin sheeting, bleached, and finished under similar mechanical and moisture conditions. Although the average grade of cotton A, except for its color designation, was slightly higher than that of B, 1.62 pounds per hundred more waste, or 7.74 pounds per 478-pound bale, was extracted from this cotton by the pickers and cards, chiefly in the form of foreign matter. The yarn spun from cotton B was more than 6 percent stronger in skein strength than that spun from A. However, these differences in breaking strength can be accounted for by the fact that cotton B was found by the classers to be on an average about one-sixteenth of an inch longer in staple length than cotton A.

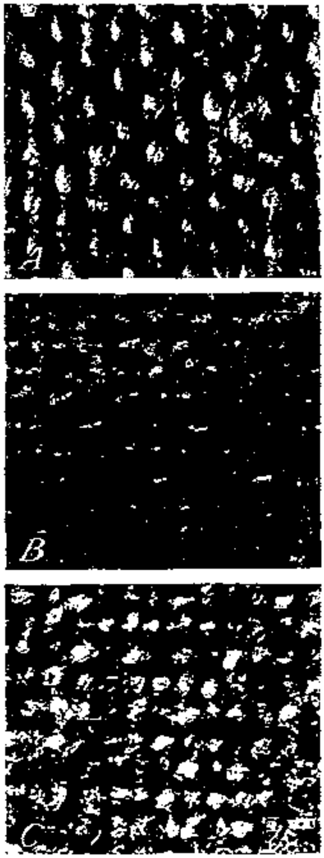


FIGURE 14.—Photomicrographs of cotton A fabrics: *A*, Unlaundered, bleached material; *B*, material worn and laundered 200 times; *C*, material worn and laundered 275 times. All ×10.

The sheets were put into use in a Washington hotel and their serviceability evaluated by physical and chemical determinations. Wear and laundering produced a progressive tendering in all three fabrics, as shown by all the tests measuring damage.

The first laundering removed the largest percentage of starch. A measurable amount was present after the twenty-fifth wash but not after the fiftieth.

The methylene blue absorption values for the different sections of the sheets show that the order of increasing chemical deterioration is section D, C, A, B. Such physical tests as breaking strength and elongation rank the sections in this same order.

Wear had more effect on the physical than on the chemical properties of the sheeting. This is indicated by the fact that the physical values for the sides of the sheets after 250 washes are similar to those of the center after 200 launderings while the chemical values of these sides are approximately equal to the centers after 225.

The fluidity values for each sheeting increase with storage. As the period of storing was extended the rate of chemical deterioration became greater. Storage produced no significant variations in breaking and bursting strengths.

The unbleached material made from cotton A which was of a somewhat shorter staple length, was more deteriorated as shown by breaking and bursting strengths, fluidity in cuprammonium hydroxide, copper number, methylene blue absorption, and ash, than were the other two unbleached sheetings between which there was no significant difference. Also the physical and chemical tests measuring damage showed in general that the bleached, finished fabric made from cotton A was more tendered originally and throughout use than the other two materials which gave approximately the same values.

The length of service of the sheetings from cottons A, B, and the mixture was practically equal, namely, 281, 276, and 278 periods respectively. Thus the differences in the deterioration of the two cottons were not great enough to affect the serviceability.

LITERATURE CITED

(1) American Society for Testing Materials.
1936. A. S. T. M. STANDARDS ON TEXTILE MATERIALS. 295 pp., illus. Philadelphia.

(2) Barritt, J., and King, A. T.
1926. THE SULPHUR CONTENT OF WOOL. PART I.—INHERENT VARIATIONS ACCORDING TO THE TYPE OF WOOL. Jour. Textile Inst. 17: T386–T395, illus.

(3) Birtwell, Constance; Clibbens, Douglas Arthur; and Ridge, Bert P.
1923. THE CHEMICAL ANALYSIS OF COTTON. I.—THE ABSORPTION OF METHYLENE-BLUE BY COTTON. Jour. Textile Inst. 14: T297–T313, illus.

(4) ——— Clibbens, Douglas Arthur, and Ridge, Bert P.
1925. THE CHEMICAL ANALYSIS OF COTTON—OXYCELLULOSE, PART I. Jour. Textile Inst. 16: T13–T52, illus.

(5) Campbell, Malcolm E.
1936. AN IMPROVED METHOD FOR CONVERTING AN OBSERVED SKEIN STRENGTH OF COTTON YARN TO THE STRENGTH OF A SPECIFIED YARN COUNT. U. S. Dept. Agr. Cir. 413, 19 pp., illus.

(6) Clibbens, Douglas Arthur, and Geake, Arthur.
1924. THE CHEMICAL ANALYSIS OF COTTON. II.—THE DETERMINATION OF COPPER NUMBER. Jour. Textile Inst. 15: T27–T38, illus.

(7) ——— and Geake, Arthur.
1926. THE CHEMICAL ANALYSIS OF COTTON. XI.—THE ABSORPTION OF METHYLENE BLUE FROM BUFFERED SOLUTIONS. Jour. Textile Inst. 17: T127–T144, illus.

(8) ——— and Ridge, Bert Pusey.
1928. THE TENSILE STRENGTH AND FLUIDITY OF CHEMICALLY MODIFIED COTTON. Jour. Textile Inst. 19: T389–T404, illus.

(9) Downey, K. Melvina, and Elmquist, Ruth E.
1936. COTTON FABRICS AS AFFECTED BY VARIATIONS IN PRESSURE AND IN LENGTH OF EXPOSURE DURING IRONING. U. S. Dept. Agr. Tech. Bull. 517, 32 pp., illus.

(10) Fargher, Robert George, and Lecomber, Leslie Vincent.
1931. THE DETERMINATION OF STARCH IN SIZED AND FINISHED COTTON GOODS. Jour. Textile Inst. 22: T475–T487.

(11) Ginter, Adella Eppel; Adkins, Katie; Davison, Suzanne; and Pearlmutter, Sophie.
1937. THE DURABILITY OF COTTON GARMENTS AS AFFECTED BY LAUNDERING AND WEAR. Jour. Home Econ. 29: 326–332.

(12) Griffith, Marion; Sprague, Thelma; Berg, Vera; with Edgar, Rachel.
1929. THE INFLUENCE OF LAUNDERING ON SOME COTTON AND LINEN FABRICS. Iowa State Col. Jour. Sci. 3: 215–225, illus.

(13) Grimes, Mary Anna.
1936. THE EFFECT OF EXPOSURE IN THE FIELD ON GRADE, STRENGTH, AND COLOR OF RAW COTTON. Tex. Agr. Expt. Sta. Bull. 538, 35 pp., illus.

(14) Haley, L. B.
1935. EFFECT OF WEAR AND LAUNDERING ON COTTON SHEETING. Textile Research 5: 263–274, illus.

(15) Hays, Margaret B.
1937. CLASSIFICATION OF SHEETS AS AN AID TO CONSUMER BUYING. Rayon Textile Monthly 18 (3): 71–72.

(16) McClew, Jean.
1931. FIRST AID IN COTTON SHEET SHRINKAGE. RECENT EXPERIMENTS CONDUCTED AT THE UNIVERSITY OF WASHINGTON BRING TO LIGHT SOME INTERESTING FACTS AND SUGGEST A REMEDY FOR THIS PROBLEM. Natl. Laundry Jour. 102 (5): 30–31, illus.

(17) Ost, H.
1911. DIE VISCOSITÄT DER CELLULOSELÖSUNGEN. Ztschr. Angew. Chem. 24: 1892–1896, illus.

(18) United States Bureaus of Agricultural Economics and Home Economics.
1934. A STUDY OF THE RAW COTTON AND THE YARN AND SHEETING MANUFACTURED FROM THREE GRADES OF AMERICAN UPLAND COTTON. U. S. Dept. Agr. Tech. Bull. 406, 70 pp., illus.

(19) United States Federal Specifications Board.
1933. FEDERAL SPECIFICATIONS FOR TEXTILES; TEST METHODS. Federal Standard Stock Catalogue, sect. 4, pt. 5, CCC–T–191, 13 pp. Washington, D. C.

(20) Urquhart, Alexander Robert; Bostock, William; and Eckersall, Norman.
1932. THE MOISTURE RELATIONS OF COTTON. VIII.—THE EFFECT OF PROCESSING. Jour. Textile Inst. 23: T135–T149, illus.

(21) Whitin, E. S.
1936. A "USE BY USER" TEST. Mod. Hosp. 47 (3): 90–92.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE WHEN THIS PUBLICATION WAS LAST PRINTED

Secretary of Agriculture	HENRY A. WALLACE.
Under Secretary	M. L. WILSON.
Assistant Secretary	HARRY L. BROWN.
Coordinator of Land Use Planning and Director of Information.	M. S. EISENHOWER.
Director of Extension Work	C. W. WARBURTON.
Director of Finance	W. A. JUMP.
Director of Personnel	ROY F. HENDRICKSON.
Director of Research	JAMES T. JARDINE.
Solicitor	MASTIN G. WHITE.
Agricultural Adjustment Administration	H. R. TOLLEY, *Administrator.*
Bureau of Agricultural Economics	A. G. BLACK, *Chief.*
Bureau of Agricultural Engineering	S. H. MCCRORY, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Biological Survey	IRA N. GABRIELSON, *Chief.*
Bureau of Chemistry and Soils	HENRY G. KNIGHT, *Chief.*
Commodity Exchange Administration	J. W. T. DUVEL, *Chief.*
Bureau of Dairy Industry	O. E. REED, *Chief.*
Bureau of Entomology and Plant Quarantine	LEE A. STRONG, *Chief.*
Office of Experiment Stations	JAMES T. JARDINE, *Chief.*
Farm Security Administration	W. W. ALEXANDER, *Administrator.*
Food and Drug Administration	WALTER G. CAMPBELL, *Chief.*
Forest Service	FERDINAND A. SILCOX, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*
Bureau of Plant Industry	E. C. AUCHTER, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Soil Conservation Service	H. H. BENNETT, *Chief.*
Weather Bureau	F. W. REICHELDERFER, *Acting Chief.*

This bulletin is a joint contribution from

Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Textiles and Clothing Division	RUTH O'BRIEN, *Senior Textile Chemist, in Charge.*
Bureau of Agricultural Economics	A. G. BLACK, *Chief.*

U. S. GOVERNMENT PRINTING OFFICE 1939

For sale by the Superintendent of Documents, Washington, D. C. Price 10 cents

END