THE EFFECTS OF TWO TYPES OF DOMESTIC SIZING ON A PERCALE FABRIC

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I. INTRODUCTION

The purpose of a domestic sizing is to provide a temporary finish for fabrics. There are two general classes of domestic sizings on the market today, vegetable starches and synthetic starches. The synthetic starches may further be divided into the semi-permanent types which are retained in the fabric through several washings and those which have to be added to the fabric at each laundering.

This study is primarily concerned with the differences produced in percale by treatment with a corn starch and a temporary plastic starch.

The objectives of this investigation were to:

1. Determine the change in certain properties of percale at various periods of laundering when treated with two types of sizing.
2. Analyze the results statistically in order to find the relationship between certain properties of the fabric which are due to its treatment.

II. REVIEW OF LITERATURE

The ideal domestic sizing not only stiffens the fabric but also adds to its attractiveness by making it smooth and pliable. Proper starching helps to keep garments clean for a longer period of time by covering and holding down the surface fibers that catch the dust. The dirt that does collect can usually be removed more easily from starched than unstarched fabrics.

The effects of starch on the serviceability of textiles depends considerably upon how the fabric is used. The life of fabrics which are subjected to abrasion are extended by treatment with starch since it assists the fabrics to resist abrasion, but if the fabrics are subjected to flexing it tends to shorten their life since the starch tends to make the fibers more brittle.

The finish which is applied to fabrics also affects its permeability to air. Besides the finish, the permeability of a fabric to air is dependent upon the actual area between the yarns, the number of open spaces per unit area, and the thickness of the fabric.[1]

While permeability to air is not desirable for fabrics used for such purposes as vacuum cleaner bags, sailcloths, and balloon cloth it is desirable in most clothing fabrics since the question of heat losses by convection is closely allied with air permeability.

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[1] F. H. Clayton, "The Measurement of the Air Permeability of Fabrics," The Journal of the Textile Institute, XXVI (1935), T172, T180.

Several methods have been proposed to measure the air permeability of fabrics. Haven[2] has described an apparatus which measures the back pressure which is developed when air is forced through a fabric at a constant rate; however this apparatus is complex and rather expensive.

Other apparatus have been designed to measure the rate of flow of air when it is forced through a fabric at a constant pressure. The Frazier machine is often used for this process. It has a suction fan which draws the air through a known area of fabric which is clamped over an orifice. The speed of the fan can be regulated and orifices of different sizes are supplied to take care of fabrics of different degrees of permeability.[3]

A third method measures the time required to force a known volume of air at a standard pressure through a fabric. A device which uses this principle was designed by Skinkle[4] and is called an Apermeter. This apparatus was selected to determine the air permeability of the fabric in this study since it was simple to build and to operate.

As stated previously, one of the reasons for starching fabrics is to add stiffness or body to the fabrics. Numerous methods of measuring the stiffness of a fabric have been proposed. MacNicholas and Hedrich have suggested a method which measures the thickness of a folded sample. A strip of fabric 3 inches by 9 inches in size is folded back on itself, and the height of the fold when compressed by various loads is measured.[5]

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[2] George B. Haven, Mechanical Fabrics, New York: (1932), 313-315.

[3] John H. Skinkle, Textile Testing, Brooklyn: (1949), 93.

[4] Ibid., p. 95.

[5] Ibid., p. 123

A method originated by Peirce[6] is called the hanging heart or heart-loop method. A strip of fabric is folded back on itself and clamped so that it hangs in a heart shaped loop. The length of the loop is measured, and the stiffness is inversely proportional to the length of the loop.

A method developed by Dreby[7] measures the distortion angle through which a fabric may be distorted in its own plane without producing wrinkles in the fabric. The apparatus for this method is called a Planoflex.

Several methods which use the principle of projecting a strip of fabric from a horizontal plane, have been suggested. Chu, Cummings, and Teixeira[8] proposed such a method in which the overhang of the fabric corresponding to a given angle is measured rather than the angle corresponding to a given overhang, the latter method being that suggested by Peirce.[9] From Bickley's data, it was found that the bending length is one-half the length of the overhang when an angle of dip of 41° is used.[10] The method of Chu, Cummings, and Teixeira with the constant angle being 41° was adopted for measuring the stiffness of the specimens in this experiment since it simplified the calculations and also the equipment required.

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[6] F. T. Peirce, "The Handle of Cloth as a Measurable Quantity," _The Journal of the Textile Institute_, XXI (1930), T377-T416.

[7] Edwin C. Dreby, "The Planoflex," _American Dyestuff Reporter_, XXX (November 24, 1941), 651-654, 665-666.

[8] C. C. Chu, C. L. Cummings, and N. A. Teixeira, "Mechanics of Elastic Performance of Textile Materials," _Textile Research Journal_, XX (August, 1950), 548.

[9] Peirce, _op. cit._, XXI, T377-T416.

[10] N. J. Abbott, "Measurement of Stiffness in Textile Fabrics," _Textile Research Journal_, XXI (June, 1951), 443.

III. THE EXPERIMENT

A. Introduction

Several tests were selected to determine the differences in percale as a result of treatment with two types of starch: a plastic starch, sold under the trade name "Glosstex," and Faultless Starch, a well known corn starch. The tests which were made included air permeability, stiffness, breaking strength, weight, and yarns per inch.

Percale was selected as the fabric on which the tests were made since it is a typical clothing material which is usually starched during the process of laundering. The percale was of the 80-square type, and no information concerning the probable shrinkage or color fastness was known.

The fabric was subjected to a series of launderings with the tests being made at specific intervals.

B. Selection and Preparation of Test Samples

In order to obtain as much uniformity in the samples as possible, the samples used for all the tests were taken from a single bolt of percale.

The samples, which were $8\frac{1}{2}$ inches by $8\frac{1}{2}$ inches, were marked off on the material, three samples being taken across the width of the cloth. A $2\frac{1}{2}$ inch border along one selvage was discarded, and the 8 inch strip along the other selvage was cut into squares and used for replacements for samples which were removed for testing at the laundry intervals.

In order to know the exact original location of each sample in the bolt, a special method of numbering the samples was employed. The number on each sample denoted the number of the row and the column from which it was taken. The samples were numbered with indelible ink after which they were hemmed on all sides to prevent raveling.

The samples were selected at random for the different tests. To do this, numbers from 1 to 399 (399 being the total number of samples) were assigned to the samples in consecutive order. These numbers were written on separate slips of paper $\frac{1}{2}$ inch by $\frac{1}{2}$ inch, shuffled, and drawn one at a time. As the numbers were drawn they were recorded in groups of five since all the tests required five samples. The tests were assigned at random to these groups and by matching these numbers with the corresponding numbers on the samples, it was possible to know the test for which each sample was to be used.

Although this procedure for sampling may appear on the surface to be unnecessarily laborious, it provided completely randomized sampling of the percale.

C. <u>Laundry Procedure</u>

All the samples were washed together during the forty launderings. As samples were removed from the washing routine for testing, they were replaced by pieces of the same fabric as the original, the pieces being the same size as the hemmed samples used in the experiment.

The samples were washed in a semi-automatic, agitator type machine for 10 minutes, using water at 52° C. (125.6° F.) and enough detergent to produce a good suds. After the washing period, they were allowed to spin dry for two minutes, followed by two one-minute rinses in water at 38° C. (100.4° F.); the final spin dry period being four minutes.

The samples were hung indoors to dry completely before they were starched. After they were dry, they were divided into three groups: one group consisting of samples which were starched with plastic starch, the second group consisting of samples which were starched with corn starch, and the third group consisting of control samples which were not starched.

A temperature of 38° C. (100.4° F) was used for the starch solutions, the concentration being one teaspoon to one pint of water for the corn starch and one part of starch to six parts of water for the plastic starch.

The starched samples were passed two at a time through a constant pressure and speed wringer to obtain a uniform saturation, after which they were hung inside to dry completely again before being sprinkled for ironing.

Water of the same temperature as that of the starch solutions was used for sprinkling the samples, with approximately the same amount being used each time. The sprinkled samples were allowed to set at least one hour, after which they were ironed with a mangle using the same setting for heat and speed each time. The direction in which the samples were ironed was alternated from warp to filling at each laundering.

D. Description of Apparatus

Air Permeability Apparatus:

A modification of the method used by Skinkle[1] was employed to determine the air permeability of the percale samples. The apparatus (see Fig. 1) was composed of a Water Reservoir (A), connected by rubber tubing to one outlet of a Condenser Jacket (B). The other outlet of

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[1] Skinkle, op. cit., 95.

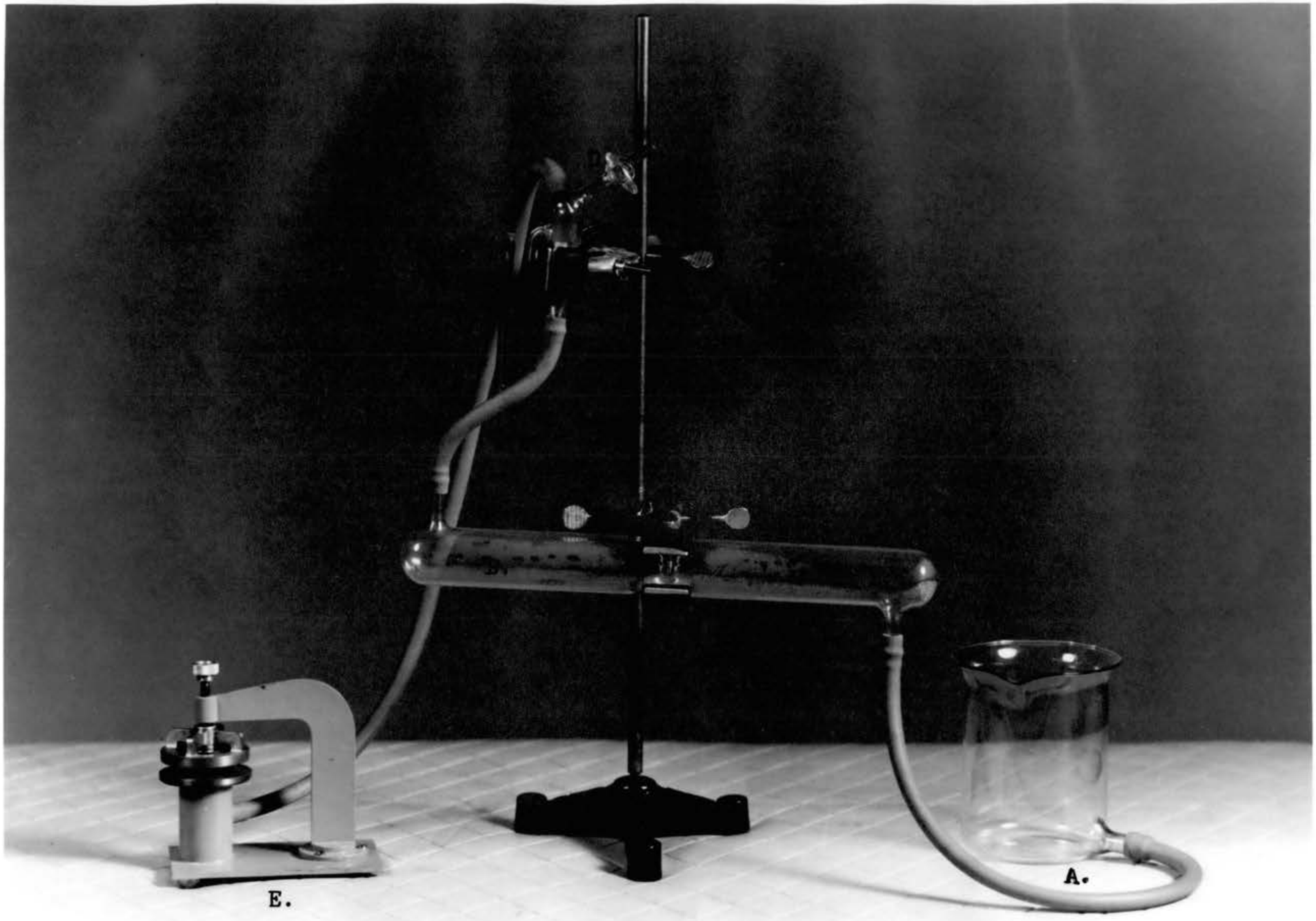

Fig. 1 Apparatus for Air Permeability Test

the condenser jacket was connected by rubber tubing to a Glass Funnel (C). One outlet of the funnel contained a Glass Stopcock (D), a second outlet being connected by rubber tubing to the Sample Holder (E). The sample holder had two concentric three-eighths inch orifices in the plates between which the samples were placed. These orifices allowed the air to pass through the fabric when a sample was clamped in place.

Stiffness Apparatus:

The apparatus used to determine the stiffness of the specimens consisted of a block of wood $3\frac{1}{2}$ inches wide, $5\frac{1}{4}$ inches high, with an overall length of $11\frac{1}{2}$ inches. The top of the block consisted of a $7\frac{1}{2}$ inch horizontal platform, at the end of which was a second plane slanted at a 41° angle to the horizontal plane. An architect's ruler was used to measure the degree of stiffness of the specimens.

E. Test Procedure

Fifteen samples of percale, five each of control, corn starch, and plastic starch were used for the air permeability test. The samples were marked off in three-fourths inch squares, making a total of 81 squares on each sample. Only one test was made on each square.

The test for air permeability was made on the new fabric and before and after the samples were starched following one, ten, twenty, thirty, and forty washings.

To make the test, a sample was clamped in the sample holder with the orifices in the plates placed over a square on the sample. The stopcock was opened and the water bottle was raised until water flowed into the funnel leaving the distilling jacket completely filled with water. The stopcock was then closed and the water bottle was placed on the table. A stop watch was used to time the flow of the water from the jacket. The stopwatch was started when the water was level with the entrance to the jacket and stopped when it passed the exit of the jacket. The time was recorded and the sample was taken from the sample holder. The square which had been tested was crossed out, and the sample was then reinserted and tested on a different square, the squares being selected at random. A total of seven tests were made on each sample at each test period.

In order to determine the stiffness of the percale, three six inch by one inch specimens were cut from each of five warp and five filling samples of the new material and from each of the control and starched groups, after the first, tenth, twentieth, thirtieth, and fortieth launderings.

The specimen to be tested was placed on the horizontal plane of the wood block. A ruler was placed over the speciman with the zero even with the end of the speciman, both were moved slowly off the edge of the plane until the speciman dipped and touched a second plane which was slanted at a 41° angle to the horizontal plane.

The reading on the portion of the ruler which extended beyond the edge of the horizontal plane was recorded. Four readings for each specimen were taken, one from each end with the right side up, and one from each end with the reverse side up. In the analysis of the data, the four readings for each specimen were averaged, and each average was treated as a single measure of stiffness for each specimen.

In making the tests for weight, five each of the control, plastic starch, and corn starch samples were hemmed extra carefully to prevent any loss of weight due to raveling. The weight in grams was taken on the basis of the weight of the five samples from each group. The weights were taken after the samples had been conditioned at a standard atmosphere of 65 ± 2% relative humidity and 70 ± 2° F. for at least four hours. The samples were weighed when they were new and before they were starched at the same laundry intervals as the air permeability and stiffness tests were made.

Procedures of the American Society for Testing Materials were followed in making tests for the number of yarns per inch and for breaking strength.[2] The breaking strength (raveled-strip method) and number of yarns per inch were determined on the new fabric and before starching after the first, twentieth, and fortieth launderings.

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[2] American Society for Testing Materials, Committee D-13, A. S. T. M. Standards on Textile Testing, Philadelphia: (October, 1951), 139, 141.

IV. DISCUSSION OF RESULTS

Air Permeability Test

The analysis of variance (Table I) for air permeability shows there was a difference in the treatments of the percale. The breakdown of the treatments into the different comparisons showed that the within control, within corn starch, and within plastic starch among washes samples did not change significantly over the test periods, but there was a very significant difference in the air permeability of the corn starch compared to the plastic starch when they were averaged over all the test periods. The over-all mean for the corn starch was 14.83 seconds compared with 13.03 seconds for the plastic starch; thus the samples which were treated with corn starch were less permeable to air than those treated with plastic starch.

No differences were found in the residual effect between the control and starch samples; however the mean square, 37.44, indicated there was a significant difference in the residual effect between the two starches.

Further study of the over-all means for the plastic starch, before and after starching, showed that the samples which were starched were more permeable to air than those tested before they were starched. The over-all means for the corn starch, before and after starching indicated that just the opposite was true for the corn starch.

Since the starches had opposite effects on the air permeability of the percale, it is not possible to know, by this test, which set of samples retained the more starch from washing to washing even though the

TABLE I

AIR PERMEABILITY ANALYSIS OF VARIANCE

Source of Variation	Degrees of Freedom	Mean Square
Total	839	
Treatments[1]	23	21.62**
Control vs. starches (averaged over the washes)	1	11.69
Corn starch vs. plastic starch (averaged over the washes after starching)	1	284.22**
Residual effect (control vs. starches before starching ave. over washes)	1	7.85
Residual between starches (averaged over the washes before Starching)	1	37.44*
Within control among washes	4	7.28
Within corn starch among washes (after starching)	4	6.93
Within plastic starch among washes (after starching)	4	12.39
Between samples in treatments (experimental error)	96	6.28
Between specimens (sampling error)	720	2.89

Means
(In Seconds)

No. of Washings	Control	Corn Starch B. Starching	Corn Starch A. Starching	Plastic Starch B. Starching	Plastic Starch A. Starching
1	14.22	14.22	15.62	14.22	13.92
10	13.49	13.26	14.70	13.99	12.33
20	13.49	13.37	14.68	13.48	12.69
30	12.87	13.99	14.65	14.90	13.18
40	13.01	12.93	14.51	14.11	13.03
Total	68.08	67.77	74.16	70.70	65.15
Over-all Means	13.62	13.55	14.83	14.14	13.03

[1] The contrasts made in the breakdown for the sum of squares for treatments are not orthogonal; therefore some of the results are expected to be correlated.

** Denotes significance at the 1% level.

* Denotes significance at the 5% level.

mean square for this comparison was significant.

Yarns Per Inch Test

Warp Direction:

The analysis of the results of the yarns per inch test for the warp yarns is shown in Table II. There was a difference in the treatments as shown by the following contrasts: (1) new versus. others (averaged over the washes), (2) within control among washes, and (3) within corn starch among washes.

The mean for the yarns per inch of the new samples as compared to the others, indicates that this difference was due to shrinkage. Since the control means displayed a decrease at each test period after the first laundering, this difference can only be attributed to lengthening of the filling yarns. Further analysis showed that the response was a linear one, that is, the yarn count decreased at a uniform rate.

The corn starch samples also showed a uniform decrease in the warp yarns per inch, but it is not known whether this was due entirely to the lengthening of the filling yarns or whether the corn starch had a tendency to spread the yarns apart, thus causing a lower count.

The plastic starch means also exhibited a decrease in the number of yarns per inch, but the decrease was not significant.

Filling Direction:

The analysis of the yarns per inch for the filling yarns (Table 3) indicated a significant difference in the treatments.

The differences which were exhibited in the (1) new versus others; (2) within control among washes; (3) within corn starch among washes; and (4) within plastic starch among washes are attributed to shrinkage of the percale.

TABLE II

YARNS PER INCH (WARP) ANALYSIS OF VARIANCE

Source of Variation	Degrees of Freedom	Mean Square
Total	119	
Treatments[1]	7	20.29**
Control vs. starches (averaged over the washes)	1	1.42
Corn starch vs. plastic starch (averaged over the washes)	1	1.31
New vs. others (averaged over the washes)	1	98.06**
Within control among washes	2	8.09**
Linear	(1)	16.13**
Quadratic	(1)	0.044
Within corn starch among washes	2	18.60**
Linear	(1)	36.30**
Quadratic	(1)	0.90
Within plastic starch among washes	2	3.76
Linear	(1)	5.63
Quadratic	(1)	1.88
Between samples in treatments (experimental error)	32	1.18
Between counts (sampling error)	80	0.97

Means
(In Yarns Per Inch)

No. of Washings	New	Control	Corn Starch	Plastic Starch
0	86.20			
1		90.00	90.00	90.00
20		89.33	88.60	89.13
40		88.53	87.80	89.13
Total	86.20	267.86	266.40	268.94
Over-all Means	86.20	89.29	88.80	89.65

[1] The contrasts made in the breakdown for the sum of squares for treatments are not orthogonal; therefore some of the results are expected to be correlated.

** Denotes significance at the 1% level.

* Denotes significance at the 5% level.

TABLE III

YARNS PER INCH (FILLING) ANALYSIS OF VARIANCE

Source of Variation	Degrees of Freedom	Mean Square
Total	119	
Treatments[1]	7	73.98**
Control vs. starches (averaged over the washes)	1	11.76**
Corn starch vs. plastic starch (averaged over the washes)	1	0.60
New vs. others (averaged over the washes)	1	378.69**
Within control among washes	2	30.49**
Linear	(1)	58.80**
Quadratic	(1)	2.18
Within corn starch among washes	2	45.07**
Linear	(1)	70.53**
Quadratic	(1)	19.60*
Within plastic starch among washes	2	59.27**
Linear	(1)	116.03**
Quadratic	(1)	2.50
Between samples in treatments (experimental error)	32	2.80
Between counts (sampling error)	80	11.17

Means
(In Yarns Per Inch)

No. of Washings	New	Control	Corn Starch	Plastic Starch
0	75.20			
1		78.13	78.13	78.13
20		80.00	81.07	80.60
40		80.93	81.20	82.07
Total	75.20	239.06	240.40	240.80
Over-all Means	75.20	79.69	80.13	80.27

[1] The contrasts made in the breakdown for the sum of squares for treatments are not orthogonal; therefore some of the results are expected to be correlated.

** Denotes significance at the 1% level.

* Denotes significance at the 5% level.

The yarns per inch in the within control and within plastic starch samples exhibited a linear response, while the within corn starch samples displayed significance in both the linear and quadratic effects.

The other mean square which exhibited significance was the control versus starches (averaged over the washes) comparison. As shown in Table III, the over-all mean for yarns per inch of the control samples was 79.69 as compared to 80.20, $\frac{(80.13 + 80.27)}{2}$, the average for the corn starch and plastic starch samples. These means indicate that the control samples did not increase in filling yarn count as much as the average of the plastic and corn starch samples.

Breaking Strength Test

Warp Direction:

The analysis of the breaking strength test for the warp yarns is shown in Table IV. The treatments were found to be significantly different at the one percent level. The variations in the treatments in this test were attributed to the: new versus others; within control among washes; within corn starch among washes; and within plastic starch among washes comparisons.

The mean for the breaking strength of the new specimens was 46.09 lbs. This was higher than the over-all mean for any of the other groups, indicating that washing and starching the fabric did decrease its strength.

The breaking strength of the control, corn starch, and plastic starch specimens decreased significantly between the first and fortieth washing, but as shown by the means at the different laundry intervals, only the plastic starch specimens exhibited a linear response. Both the linear and quadratic responses were significant for the control and corn starch specimens, which indicates that they did not change in a uniform manner.

TABLE IV

BREAKING STRENGTH (WARP) ANALYSIS OF VARIANCE

Source of Variation	Degrees of Freedom	Mean Square
Total	119	
Treatments[1]	7	74.38**
Control vs. starches (averaged over the washes)	1	2.79
Corn starch vs. plastic starch (averaged over the washes)	1	15.00
New vs. others (averaged over the washes)	1	147.50**
Within control among washes	2	129.30**
Linear	(1)	183.52**
Quadratic	(1)	75.08*
Within corn starch among washes	2	55.48*
Linear	(1)	54.95*
Quadratic	(1)	56.01*
Within plastic starch among washes	2	53.34*
Linear	(1)	97.20**
Quadratic	(1)	9.47
Error	112	13.70

Means
(In Pounds)

No. of Washings	New	Control	Corn Starch	Plastic Starch
0	46.09			
1		44.95	44.95	44.95
20		45.22	41.23	44.13
40		40.01	42.25	41.35
Total	46.09	130.18	128.43	130.43
Over-all Means	46.09	43.39	42.81	43.48

[1] The contrasts made in the breakdown for the sum of squares for treatments are not orthogonal; therefore some of the results are expected to be correlated.

** Denotes significance at the 1% level.

* Denotes significance at the 5% level.

Filling Direction:

As in the analysis of the warp breaking strength test, the treatments for the filling specimens were found to be different. The comparison, corn starch versus plastic starch (averaged over the washes), indicated a difference in breaking strength (Table V).

The over-all mean for the corn starch was 34.50 lbs. as compared to 32.98 lbs. for the plastic starch; therefore the percale which was treated with corn starch gained more strength than that which had been treated with plastic starch.

The analysis also displayed a difference within the control, corn starch, and plastic starch specimens. They all increased in strength between the first and fortieth launderings, but they did not all gain at a uniform rate. Since it was shown that the yarns per inch increased over the test periods, it may be surmised that the increase in strength was due in part to the increase in the yarn count, the rest being due to the treatment of the fabric; however the amount of increase contributed by each of these factors cannot be shown separately since they were confounded in this experiment.

Stiffness Test

Warp Direction:

The analysis of variance (Table VI) for the warp stiffness test, showed a significant difference for the treatments at the one percent level. With the exception of the linear effect of the within plastic starch, all the mean squares in the breakdown of the treatment sum of squares proved to be significant.

The over-all mean for the control specimens, 1.83 inches, was much lower than the over-all mean for the average of the corn starch and

TABLE V

BREAKING STRENGTH (FILLING) ANALYSIS OF VARIANCE

Source of Variation	Degrees of Freedom	Mean Square
Total	119	
Treatments[1]	7	40.90**
Control vs. starches (averaged over the washes)	1	12.48
Corn starch vs. plastic starch (averaged over the washes)	1	78.43*
New vs. others (averaged over the washes)	1	24.51
Within control among washes	2	44.98*
Linear	(1)	89.10**
Quadratic	(1)	0.841
Within corn starch among washes	2	42.38*
Linear	(1)	40.37
Quadratic	(1)	44.38
Within plastic starch among washes	2	44.64*
Linear	(1)	36.52
Quadratic	(1)	52.75*
Error	112	12.68

Means
(In Pounds)

No. of Washings	New	Control	Corn Starch	Plastic Starch
0	35.65			
1		32.64	32.64	32.64
20		34.07	35.91	31.45
40		36.09	34.96	34.85
Total	35.65	102.80	103.51	98.94
Over-all Means	35.65	34.27	34.50	32.98

[1] The contrasts made in the breakdown for the sum of squares for treatments are not orthogonal; therefore some of the results are expected to be correlated.

** Denotes significance at the 1% level.

* Denotes significance at the 5% level.

TABLE VI

STIFFNESS (WARP) ANALYSIS OF VARIANCE

Source of Variation	Degrees of Freedom	Mean Square
Total	239	
Treatments[1]	15	3.65**
Control vs. starches (averaged over the washes)	1	41.04**
Corn starch vs. plastic starch (averaged over the washes)	1	3.83**
New vs. others (averaged over the washes)	1	8.34**
Within control among washes	4	1.02**
Linear	(1)	1.20**
Quadratic	(1)	2.54**
Remainder	(2)	0.17**
Within corn starch among washes	4	0.343**
Linear	(1)	0.450**
Quadratic	(1)	0.730**
Remainder	(2)	0.045
Within plastic starch among washes	4	0.298**
Linear	(1)	0.0053
Quadratic	(1)	0.289**
Remainder	(2)	0.498**
Error	224	0.0297

Means (In Inches)

No. of Washings	New	Control	Corn Starch	Plastic Starch
0	1.95			
1		2.27	2.84	3.04
10		1.70	2.50	2.67
20		1.70	2.46	2.88
30		1.62	2.53	2.97
40		1.86	2.55	2.92
Total	1.95	9.15	12.88	14.48
Over-all Means	1.95	1.83	2.58	2.90

[1] The contrasts made in the breakdown for the sum of squares for treatments are not orthogonal; therefore some of the results are expected to be correlated.

** Denotes significance at the 1% level.

* Denotes significance at the 5% level.

plastic starch specimens (2.74); hence starching did increase the stiffness of the percale, which accounts for the significance of the mean square, 41.04 for the control versus starches comparison.

The mean square for the corn starch versus the plastic starch (3.83) was also significant, showing there was a difference in the stiffness produced by the two starches. Although the average for the plastic starch specimens at the first washing (3.04) was greater than that for the corn starch (2.84), the over-all means showed that the plastic starch specimens did not lose as great a percentage of their stiffness as those treated with corn starch.

The over-all means readily explain the significance of the mean square (8.34) for the new versus others comparison. Even though the control mean, (1.83), is less than that for the new fabric (1.95) the means for the starched specimens increase the average of the three enough to cause the mean square for this comparison to be significant.

As shown in Table VI, the mean squares for the within control, within corn starch and within plastic starch tests all displayed significance at the one percent level. The means show that in each case the significance was due to loss of stiffness over the launderings. Upon further analysis, it was shown that these decreases did not follow a straight line regression.

Filling Direction:

The treatment mean square and each of the main effects in the breakdown of the treatments for the stiffness test in the filling direction were found to be significant with one exception. The exception as shown in Table VII was the within corn starch mean square; thus the fabric which was treated with corn starch did not change in stiffness over the

TABLE VII

STIFFNESS (FILLING) ANALYSIS OF VARIANCE

Source of Variation	Degrees of Freedom	Mean Square
Total	239	
Treatments[1]	15	2.02**
Control vs. starches (averaged over the washes)	1	23.28**
Corn starch vs. plastic starch (averaged over the washes)	1	0.760**
New vs. others (averaged over the washes)	1	8.66**
Within control among washes	4	0.283**
Linear	(1)	0.388**
Quadratic	(1)	0.662**
Remainder	(2)	0.040*
Within corn starch among washes	4	0.033
Linear	(1)	0.0027
Quadratic	(1)	0.035
Remainder	(2)	0.046*
Within plastic starch among washes	4	0.095**
Linear	(1)	0.309**
Quadratic	(1)	0.020
Remainder	(2)	0.026
Sampling error	224	0.0118

Means (In Inches)

No. of Washings	New	Control	Corn Starch	Plastic Starch
0	1.31			
1		1.65	2.04	2.04
10		1.36	2.08	2.19
20		1.35	1.97	2.16
30		1.31	2.01	2.22
40		1.43	2.06	2.25
Total	1.31	7.10	10.16	10.86
Over-all Means	1.31	1.42	2.03	2.17

[1] The contrasts made in the breakdown for the sum of squares for treatments are not orthogonal; therefore some of the results are expected to be correlated.

** Denotes significance at the 1% level.

* Denotes significance at the 5% level.

launderings.

The rest of the significance shown in Table VII can be explained in the same manner as that for the warp stiffness test; however it should be noted that the response of the plastic starch among the washes was a linear one and as shown by the means at the different test periods, the stiffness increased instead of decreased over the forty launderings.

The error terms in each of the breaking strength and stiffness analysis of variance are biased. The sampling error and experimental error sum of squares could not be separated due to the design of the experiment.

By noting the comparison of the sampling error with the experimental error in each of the other tests in the experiment, it will be seen that the experimental error is about twice the sampling error. Using this as a guide it might follow that one could expect the same thing to happen in these experiments. Therefore the error term in these experiments is too low, thus giving a significance when in reality the difference may not exist.

Weight Test

As in the other tests, the treatment mean square for weight was significant. As shown in Table VIII, both of the comparisons which were made also exhibited significance at the five percent level.

The over-all mean for the loss of weight for the control samples was 0.578 grams, while the loss for the plastic starch samples was only 0.388 grams. The negative mean for the corn starch samples, -0.158 indicated that this group of samples did not lose weight but actually gained weight. Since the control samples lost more weight than either

TABLE VIII

WEIGHT ANALYSIS OF VARIANCE[1]

Source of Variation	Degrees of Freedom	Mean Square
Total	14	
Treatments	2	0.7299*
Control vs. starches (before starching averaged over the washes)	(1)	0.7145*
Corn starch vs. plastic starch (before starching, averaged over the washes)	(1)	0.7453*
Between washings	4	0.020
Error	8	0.075

Weight in grams of 5 new samples for each treatments and their loss or gain at each test period.

	Control	Corn Starch	Plastic Starch
New	27.47	28.05	27.62
No. of Washings			
1	0.14	0.17	0.10
10	0.52	-0.05	0.31
20	0.62	-0.19	0.38
30	0.77	-0.28	0.52
40	0.84	-0.44	0.63
Total	2.89	-0.79	1.94
Over-all Mean	loss 0.578	gain -0.158	loss 0.388

[1] The analysis of variance for the weight test was made by differences, that is the weight at each test period was subtracted from the new or original weight. These figures were then coded by adding 0.44 to each one in order to eliminate the negative numbers and to simplify the calculations.

* Denotes significance at the 5% level.

of the starch samples, the reason for the significance of the control versus starches (averaged over washes) comparison is obvious.

The difference in the over-all means for the corn starch and plastic starch was 0.546 (-0.158-0.388) which explains the significant difference of the corn starch versus plastic starch (averaged over washes) comparison.

The gain in weight by the corn starch samples indicated that not all the starch was being removed during the washing period; therefore a quantitative test for starch was made on three corn starch samples and it was found that the samples had retained an average of 1.7 percent of their weight in starch. The distilled water that had been used to desize the samples was tested for starch by the iodine test. A positive reaction was obtained. These tests proved that corn starch was remaining in the samples from washing to washing; thus explaining the increase in weight for this group of five samples.

It is not known whether there was also a residual effect in the plastic starch since the composition of the starch was not known.

Recommendations for Improving the Experiment

In the event that further study is made on this subject or related subjects, there are several recommendations that may be made to improve the design of the experiment.

1. Increase the number of specimens for the air permeability test.

   It was found that by increasing the number of specimens for the air permeability test from seven to ten, the efficiency of the test would be improved by 16 percent; furthermore if the number of specimens were increased from seven to twenty the efficiency of the test would be improved 31 percent.

2. Increase the number of counts for the yarns per inch test.

The efficiency of the yarns per inch test in the warp direction would be improved 26 percent by increasing the number of counts from three to four, and improved 50 percent by increasing the counts from three to five.

It was found in the filling yarns per inch test, that by doubling the number of counts, the efficiency of the test would also be doubled. This was true for the filling yarns since the variance between the samples was no more than that between the specimens.

3. Keep the breaking strength and stiffness specimens taken from each sample separate.

Since the specimens which were cut from each sample in the breaking strength and stiffness tests could not be identified, it was impossible to calculate an experimental error; therefore the error term for these tests are underestimated, which may have caused significance where differences may not have existed.

V. SUMMARY AND CONCLUSIONS

The effects of two types of sizing, a plastic starch and a corn starch, were determined by statistical analysis from results of tests which were performed on an 80-square percale fabric, samples of which were treated with one or the other of the starches. The tests were also made on samples which were not starched in order to provide a control for the experiment.

The tests which were made included: air permeability, stiffness, yarns per inch, breaking strength, and weight.

1. The air permeability test indicated that the permeability of the percale to air was decreased by treatment with corn starch and increased by treatment with plastic starch.

2. A significant increase was noted in the warp yarns per inch between the new fabric and the mean for the control, corn starch, and plastic starch samples when they were averaged over the test periods as a result of shrinkage of the fabric; however the yarns per inch in the control and corn starch samples decreased significantly between the first and fortieth launderings, indicating a uniform lengthening of the yarns. The yarns per inch for the plastic starch samples did not change significantly.

The number of yarns per inch in the filling continued to increase in the control, corn starch, and plastic starch samples at each test period throughout the entire 40 launderings, which indicated that the fabric had not reached the point of maximum shrinkage when the launderings were discontinued. The test also revealed that the samples which were starched shrunk more than the control samples.

3. The warp breaking strength of the control, corn starch, and plastic starch samples decreased significantly from the first to the fortieth laundering. The mean for these samples was also significantly less than the breaking strength of the new fabric. Starching did not affect the warp breaking strength of the fabric.

The control, corn starch, and plastic starch samples in the filling direction increased significantly in strength over the launderings. Since it was shown that the filling yarns per inch also increased, the increase in strength may be attributed to shrinkage.

Although both the plastic and corn starch samples gained strength, the corn starch gained a significantly greater amount than the samples which were treated with plastic starch.

4. The stiffness of the control, corn starch, and plastic starch samples in the warp direction decreased significantly among the washes, the plastic starch samples losing the least stiffness, and the corn starch losing less than the control samples.

The stiffness of the control samples for the filling yarns decreased significantly while the plastic starch samples increased significantly. There was no significant change in the corn starch samples.

5. The control and plastic starch samples decreased in weight over the forty launderings, while the corn starch increased in weight. The increase in weight of the corn starch samples was due to the retention of starch from washing to washing.

6. The experiment could have been improved by increasing the number of specimens for some of the tests and by making certain other changes in the experimental design.

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TYPIST SHEET

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