THE EFFECT OF WEAR UPON SELECTED PERFORMANCE FACTORS OF COTTON SHEETINGS

by

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This study was planned to determine the effects of use upon the performance of sheetings manufactured from cottons with specific properties of length and strength. One group of sheets was laundered only while a similar group was used and laundered. Sheets from both groups were withdrawn for testing after established numbers of launderings. Measurements of fabric weight and tearing strength, the test results used in this study, were considered good indices of the effects of wear.

It was assumed that a comparison of sheets that were used and laundered with those that were laundered only gives an indication of the effects of use. The data included results from the original or unlaundered sheetings and from sheetings after five and fifteen launderings.

The specific objectives of this study were as follows:

1. To determine the mean and percentage differences at stated intervals between a.) sheets used and laundered and b.) sheets laundered only.

2. To determine the significance of differences in the fiber properties of sheets that were used and laundered with those that were laundered only.

The results from fabric weight and tearing strength tests were studied statistically by means of an analysis of variance. A program for the analysis was developed so that the data might be analyzed using a Remington Rand Univac 1105 digital computer.

The results of this study indicated the following conclusions:

1. After five and fifteen launderings sheets which had been used and laundered had a greater tear resistance than those which had been laundered only.

2. Fabric weight did not vary greatly whether the sheets had been used and laundered or laundered only.

3. Sheets made of long staple length cottons had a greater tear strength than those made of short staple length cottons.

4. Sheets made of high strength cottons had a greater tear strength than those made of low strength cottons.

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E. J. H.

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CHAPTER I

INTRODUCTION

Fibers properties as related to the growth and processing of cotton are well defined. There is a recognized lack of knowledge, however, related to the effect of fiber properties upon the performance of the end-product.

As a contribution to this need for information, the Southern Regional Textile Research Project, SM-18, is being conducted under the sponsorship of the U. S. Department of Agriculture by the home economics research personnel of the Agriculture Experiment Stations of six Southern states. The project will provide information about the relation of fiber properties to end-product performance. This regional project has as its major objective the study of the relation of the specific fiber properties length and strength to the end-product performance.[1]

To achieve this objective, strains of cotton having specific length and strength properties were made into sheets and subjected to use in women's dormitories. After stated numbers of launderings, sheets were withdrawn to be tested. Of the sheets being tested, some had been used and laundered while

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[1]Technical Committee Project SM-18, "The Relation of Fiber Properties to End-Product Performance." (Manual of Procedures, Southern Regional Research Project SM-18).

others were laundered only.

With consideration of end-product performance, the question arises as to whether fabric performance features are affected more by the combination of use and laundering or by laundering only. A comparison of performance data from sheets that were used and laundered with comparable data from sheets laundered only may show how great a factor use is in performance.

Tests of fabric weight and tearing strength have been used to give a measurement of the effects of laundering and the combination of use and laundering. Other studies have obtained results for fabric weight and tearing strength tests that show the fabrics have been affected by periods of use and laundering.

The specific objectives of this study are as follows:

1. To determine the mean and percentage differences at stated intervals between a.) sheets used and laundered and b.) sheets that were laundered only.

2. To determine the significance of differences in the fiber properties of sheets that were used and laundered with those that were laundered only.

The results of tests of fabric weight and tearing strength before use or laundering and at the fifth and fifteenth intervals of use and laundering were used. The program by which the data were processed by a digital computer, a Remington Rand Univac 1105, was developed as a part of this study.

Symbols and Terms Used in the Study

Some of the symbols and terms adopted need clarification.

a. (W) is the symbol which designates the sheets which have been laundered only.

b. (WW) is the symbol which designates the sheets which were used and laundered.

c. (U) is the symbol which designates the universities in the four participating states where the sheets were used in women's dormitories.

d. (S) is the symbol which designates strength, one of the two fiber properties under investigation in this study.

e. (L) is the symbol which designates the fiber property length.

f. The sheetings were made from eight varieties of cotton having different combinations of length and strength properties.

Cottons 1 and 2 have short staple length and low strength.

Cottons 3 and 4 have short staple length and high strength.

Cottons 5 and 6 have long staple length and low strength.

Cottons 7 and 8 have long staple length and high strength.

Organization of the Remainder of the Study

In Chapter II a review of the literature pertaining to other studies concerning the effects of use and laundering upon cotton fabrics and studies concerning fabric weight and tearing strength is presented. The procedures for the use of the sheets, the testing of the sheets, and the statistical comparison of results are described in Chapter III. The compilation of data and the statistical significance of the differences between the laundered only and the used and laundered sheets are presented in Chapter IV. In Chapter V the summary, conclusions, and recommendations for further study are presented.

CHAPTER II

REVIEW OF LITERATURE

I. STUDIES RELATED TO FABRIC PERFORMANCE IN USE

The Launderability and Serviceability of Cotton Fabrics

Cotton fabric has been widely used, largely because of its launderability and hygienic properties. How serviceable that fabric will be in use is influenced by the wear it receives in use and in laundering.

There is extensive information pertaining to the serviceability of fabrics in use. However, little of this information indicates the performance characteristics as they relate to the effect of use alone.

Consumer Reports frequently give information concerned with the serviceability of sheets and pillowcases. The importance of fabric care has been emphasized as a factor in determining the amount of serviceability that can be expected.[1]

Kaswell, in describing the reaction of cotton to laundering, states that alkaline soaps and bleaches and high temperatures have little effect on cotton. "The fact that cotton is stronger when wet than dry is of obvious advantage in

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[1] "Muslin and Percale Sheets and Pillowcases," *Consumer Reports*, 26 (January, 1961), p. 19.

resisting mechanical stresses encountered in laundering."[2] Kaswell writes of a study of cotton-linen union fabric conducted by Honnegger and Schnyder that showed that laundering with alkaline bleach over a period of time will result in greater chemical damage than mechanical damage, but if no bleach is used, more mechanical damage will result. However, when chemical damage occurs in a fabric, more rapid mechanical breakdown may be expected.[3]

Before considering more fully the effects of laundering upon cotton fabrics, it is necessary to review the nature of the cotton fiber itself. According to Mauersberger, the cotton fiber is "a hair which grows out of a single epidermal cell in the cottonseed coat."[4] Microscopic study shows that the structure of the fiber can be classified as having three parts - the cuticle, the primary wall, and the secondary wall. However, many authorities make no distinction between the cuticle and the primary wall.[5] A study conducted by Chippindale gives a description of these parts. The primary wall is made up of cellulose fibrils. The secondary wall which constitutes the major portion of the

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[2]Ernest R. Kaswell, Textile Fibers, Yarns, and Fabrics: A Comparative Survey of Their Behaviour with Special Reference to Wool (New York: Reinhold Publishing Corporation, 1953), p. 416.

[3]Ibid.

[4]Herbert R. Mauersberger, Matthew's Textile Fibers (New York: John Wiley and Sons, Inc., 1947), p. 230.

[5]Ibid., p. 233.

fiber is also made up of fibrils which are in bundles in definite layers.[6] These two parts are often studied using the electron microscope to determine the effects various treatments have had upon them.

Chippindale states more precisely the effect of laundering on cotton fabrics.

> In the past, the fundamental difference between wet and dry abrasion has not been always fully appreciated. Laundering, whether by hand or by washing machine, is a form of low-load wet abrasion - milder than the wet abrasion of the test machines, but, nevertheless, of the same nature, leading to some form of fibrillation.
>
> Cotton-fabric samples (some as made-up garments) were subjected to wet abrasion in a washing machine without having suffered any dry abrasion. It was found that, almost invariably, the primary wall was removed . . . .
>
> . . . No yarns were broken, nor was wear visible to the eye observed . . . . Considerable fibrillation has taken place and many individual fibrils have been torn out of the fibre surface. In many places, the primary wall has been removed, revealing the parallel structure of the secondary wall. Remnants of disintegrated primary wall remain on the fibre surface. In addition to individual fibrils, there are small groups or bundles of fibrils lying on the fibre surfaces.[7]

Chippindale, as he studied the effects of laundering and wear, came to the following conclusion:

> The process of breakdown of cotton fabrics in wear and in laundering is completely different; that is, it depends to a very large extent on whether the fibres are wet or dry when abraded.

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[6] P. Chippindale, "Wear, Abrasion, and Laundering of Cotton Fabrics. Part I: Wear of Fabrics during Actual Service and Laundering," *Journal of the Textile Institute,* 54 (November, 1963), p. T446.

[7] *Ibid.*, p. T447.

In the dry state, the fibre surfaces are worn away by erosion of cellulosic material and the mechanism appears similar whether the fibres are resin-treated or not. In either case, the fibre behaves as though it were homogeneous throughout its volume.

In the wet state, the fibre swells and the fibrillar structure is loosened. When abrasive forces are applied, fibrils break away usually as individuals, whereas, with resin-treated fibres, they are cemented together by resin and the fibre tends to break down into larger fragments, these being sheaves of fibril bundles.

A garment in frequent use and requiring frequent laundering, for example, a cotton dress or shirt, is subject to wet and dry abrasion alternately.[8]

Perdue, in discussing some of the pitfalls encountered when the effect of chemical damage on a used and laundered fabric is considered, reported the following:

> Unless a sample of new fabric from the same piece is available, the strength of the fabric in a used article gives no indication of the extent of the chemical damage which has occurred. Even when a comparison of this sort can be made, it is not safe to assume that any loss of strength is due to chemical damage; it may have arisen through physical wear.
>
> The only method of ascertaining from strength tests alone that chemical damage has occurred to cotton or linen articles, is to make the tests with fabric in the dry state and then in the wet state. Chemically undamaged cotton or linen shows much the same strength whether wet or dry; in fact, with fabrics in particularly good condition the wet strength is greater than the dry strength. Chemical damage results in a fall in dry strength, but there is a greater fall in wet strength so that fabric with appreciable chemical damage has wet strength distinctly below its dry strength. This may be made the basis of a rough and ready test for serious chemical damage because a fabric which tears much more easily in the wet state than in the dry state has certainly suffered considerable chemical damage.[9]

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[8] Ibid., p. T448.

[9] G. R. Perdue, The Technology of Washing (London: The British Launderer's Research Association, 1961), pp. 11-12.

Pollitt, recognizing that fabrics suffer mechanical and chemical damage, suggests that the tears which finally result begin at a point of such damage. Decrying the fact that many people choose a fabric because it is stronger than another initially, he states that strength is not always an advantage to durability unless "the effects of the destructive actions proceed at the same rate"[10] for the fabrics being compared. He does state that strength is an advantage for a fabric. He made a distinction between yarn strength and fabric strength. These two are influenced in different ways by fiber strength. The geometry of cloth construction can allow a relatively low strength yarn to make up into a stronger fabric. As a result, it seems that fiber strength is the more important factor to be considered; however, it was suggested that fiber strength should be determined using a particular length of the fiber; a length determined by the closeness of the weave.[11]

The serviceability of fabrics is considered also by Fred De Armond. He describes a study conducted by the Bureau of Home Economics of the United States Department of Agriculture. Sheets of the same brand that were discarded by a Washington hotel were examined for indications of wear. Usually the filling yarns showed wear more readily than warp yarns, suggesting that

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[10]E. Pollitt, "Factors Affecting the Performance in Use of Cotton Fabrics," Textile Weekly, 59 (September 25, 1959), p. 587.

[11]Ibid.

longer use might have been expected if the filling yarns had been stronger.[12]

De Armond states:

> There can be no gainsaying the fact that improper laundering methods, whether conducted under home or commercial conditions, can shorten the life of any washable article. However, a study of numerous repeatedly worn and laundered articles demonstrates conclusively that wear, localized in many cases, is the most important factor. The action of laundering is uniform and can be checked by test-piece control methods. Localized weakening, such as results from the rubbing of a wrist watch on the edge of a shirt cuff, can result only from wear.
>
> Further, it is fallacious to conclude that when an article has been test-laundered successively, say 100 times, its life in use will average from two to four years, depending upon how many times it is laundered yearly. Laundering is a constant factor; wear is not.[13]

II. LITERATURE RELATED TO FACTORS BEING STUDIED

The Use of Fabric Weight in Serviceability Tests

Fabric weight is used widely for quality control and is often used in conjunction with other tests in performance testing. Grover and Hamby describe two methods employed to determine fabric weight. One method requires having the specimen in an oven-dry condition; the other suggests that the specimen be allowed to return to moisture equilibrium from the oven-dry state. The second method is the one most generally used in quality control.[14]

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[12]Fred De Armond, The Laundry Industry (New York: Harper and Brothers, 1950), p. 51.

[13]Ibid., pp. 52-53.

[14]Elliott B. Grover and D. S. Hamby, Handbook of Textile Testing and Quality Control (New York: Textile Book Publishers, Inc., 1960), p. 521.

The study conducted by Saville to determine the effects of various drying methods used measurements of fabric weight. The muslin fabric used in this study suffered its greatest loss in weight during the first ten launderings. This loss in weight was largely a loss of sizing and finishing materials. After ten launderings the loss leveled off; however, decrease in fabric weight was noted throughout the forty launderings.[15]

A study carried on at Cornell University, considering the effect of laundering and dry cleaning on certain resin-treated cotton fabrics, showed an increase in fabric weight after washing in an agitator-type automatic washer. In some cases changes in weight tended to correspond to changes in dimension.[16]

The Use of Tear Strength in Serviceability Tests

Tear strength tests are often used in evaluating the serviceability and durability of a fabric. Consumer Reports pointed out that the sheets which were studied were:

> . . . inspected for such fabric characteristics as weight, yarn count, weave, and whiteness, and each was examined for quality of design and workmanship. In addition all were tested after nine launderings and tumble dryings, for such performance properties as tensile strength, tear strength, abrasion resistance, and shrinkage.[17]

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[15]Dorothy Saville, "A Comparison of Five Methods of Drying Cotton Fabrics," Oklahoma State University Experiment Station Bulletin B-510 (Department of Home Economics Research, Oklahoma State University, October, 1950), p. 16.

[16]Evelyn E. Stout, Carol L. Zillgit and Muriel R. Ferraro, "Effect of Laundering and Drycleaning on Laboratory Performance of Certain Resin-finished Winter Cottons," Journal of Home Economics, 49 (March, 1957), pp. 198-99.

[17]"Sheets and Pillowcases," Consumer Reports, 29 (January, 1964), p. 11.

There are various test methods that may be employed to determine tear resistance. Grover and Hamby indicate that it is often the case that differences in test methods yield differing results.[18]

Stavrakas and Platt have recognized the multiplicity of results and have stated that there is a "real need for more thorough comprehension of the mechanism of tear."[19] In their study of tear strength Stavrakas and Platt have stated that "the complete mechanism of the tearing action is not known, and whatever portion is known must be described principally in general terms."[20]

In this study Stavrakas and Platt have presented some important relationships that help clarify the effect of yarn and fabric properties upon tear strength.

> . . . One such relationship suggests that the principal determinant of the level of tear strength when other factors are held constant is the strength of the cross yarns. Another relationship shows the ability of a fabric to overcome a deficiency in yarn strength by permitting greater mobility of the yarns in the plane of the fabric. A third relationship suggests that the crimp interchange occasioned by a filling-wise stretching action, namely the increase in warp crimp with a concomitant decrease in filling crimp, will enhance the tear resistance of a fabric. The most encouraging information obtained from this analysis demonstrated the possibility of achieving a considerable degree of fabric crease resistance

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[18]Grover and Hamby, op. cit., pp. 544-45.

[19]E. James Stavrakas and Milton M. Platt, "Investigations on the Modifications of Yarn and Fabric Structure Needed to Improve Tear Strength of Cotton Fabrics," ARS 72-19, (Washington: United States Agriculture Research Service, January, 1961), p. 5.

[20]Ibid.

(140° Monsanto crease angle) with a 20% loss in yarn tensile strength, while still achieving a 16% increase in tear strength.[21]

They came to the following conclusion:

> . . . tear strength of cotton fabrics may be improved by incorporating one or both of the following structural variations: Utilization of weaves with longer floats or of more open-textured fabrics, or both, to increase yarn mobility in the fabric; by utilization of coarser yarns, stronger fiber, improved preparation, or any combination thereof to increase yarn strength.[22]

This study answers in part the problem recognized by Kaswell; "the problem of lower abrasion and tear resistance resulting from the application of crease resisting resins may be a serious one."[23]

Louis, Fiori, and Sands have stated that tear strength is augmented by using cotton fibers with higher elongation.[24] Another study by Tallant, Fiori, and Sands has shown that short staple cotton fibers have detrimental effect on most fabric properties including tear strength.[25]

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[21]Ibid., p. 15.

[22]Ibid., p. 16.

[23]Kaswell, op. cit., p. 280.

[24]Gain L. Louis, Louis A. Fiori, and Jack E. Sands, "Blending Cottons Differing in Fiber Bundle Break Elongation, Part II: Effect on Properties of a Combed Broadcloth, " Textile Research Journal, 31 (May, 1961), p. 483.

[25]John D. Tallant, Louis A. Fiori and Jack E. Sands, "The Effect of the Short Fibers in a Cotton on its Processing Efficiency and Product Quality, " Textile Research Journal, 32 (January, 1962), p. 55-56.

III. SUMMARY

A study of the literature shows that very little has been done to study the effects of wear alone. There is also little information comparing fabrics that have been laundered only with those that have been used and laundered. Chippindale and Perdue have recognized the need for more knowledge about the wear factor. The consideration of chemical and physical damage, fiber properties and the geometry of cloth construction are also presented in the literature related to wear and serviceability.

The information related specifically to fabric weight was quite limited. The studies cited obtained differing results after periods of laundering.

Tearing strength has been pointed out to be a factor which needs more clarification. It is recognized that tearing strength is affected by fiber properties and cloth construction.

CHAPTER III

METHOD OF PROCEDURE

This thesis, as a contributing part of the regional project, makes use of portions of the data obtained in the Southern Regional Textile Research Project, SM-18.[1] The data obtained from the project are compared in this thesis to show the differences between sheetings that were used and laundered and those that were laundered only. By using the test results that were obtained for the project, this thesis has a wider scope than would have been possible otherwise.

I. REVIEW OF PROCEDURES FOLLOWED IN THE SOUTHERN REGIONAL TEXTILE RESEARCH PROJECT SM-18

Description of Fibers and Fabrics

For this phase of the regional project eight varieties of cotton were chosen for their length and strength characteristics. Four bales were classified as long staple length fibers and the other four as short staple length fibers. Within each of these classifications, fibers were also classified as high or low

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[1]Technical Committee Project SM-18, "The Relation of Fiber Properties to End-Product Performance," (Manual of Procedures, Southern Regional Research Project SM-18).

strength. The classifications were as follows:

Cotton 1 Cotton 2	short staple length, low strength.
Cotton 3 Cotton 4	short staple length, high strength.
Cotton 5 Cotton 6	long staple length, low strength.
Cotton 7 Cotton 8	long staple length, high strength.

The eight bales of cotton were made into type 140 muslin sheeting in the form of single sheets. Different colored yarns were woven into the selvage as a means of identification of the cotton type used. One fourth of the total number of sheets of each type (248 sheets) was sent to each of four states - Alabama, Missouri, North Carolina, and Oklahoma. Six sheets of each type were withheld to serve as controls or to supply samples at the 0 interval of use or laundering. These six sheets were marked for the tests being performed.

Procedure for In-Service and Laboratory Testing

One hundred sixty of the 248 sheets were subjected to use in women's dormitories at Auburn University, The University of Missouri, The University of North Carolina at Greensboro, and Oklahoma State University. After a week of use as bottom sheets, the sheets were collected and sent to a commercial laundry. The remaining 88 sheets which were laundered only were laundered on regular schedule with those that were used and laundered.

Testing was done at specified intervals of use and laundering. Three sheets were tested at the control or 0 interval. Sets of three sheets that were used and laundered and sets of two sheets that were laundered only were withdrawn for laboratory testing at the fifth, the fifteenth, the thirtieth, the forty-fifth and sixtieth intervals of use and laundering. Sixteen sheets that were used and laundered and eight sheets that were laundered only were carried through the laundering intervals as spares, to be used as replacements in case of the loss or withdrawal of a sheet for some reason. Table I shows the plan for withdrawal for testing of sheets of one cotton type. This procedure was followed with the eight experimental cottons in each of the four states performing service testing.

TABLE I

PLAN FOR WITHDRAWAL OF SHEETS FOR TESTING
(ONE COTTON CLASSIFICATION)

Treatment	Intervals						Spares	Total
	0	5	15	30	45	60		
Used and laundered	3	3	3	3	3	3	2	20
Laundered only	-	2	2	2	2	2	1	11
							TOTAL*	31

*Total for eight cottons is 248 sheets used at each station.

Standard templates were used for marking testing areas so that uniformity in the portion of the sheets being tested might be maintained. Experiment stations at the University of Tennessee and Louisiana State University, in addition to those at the four universities previously mentioned, were responsible for performing specific tests for all sheets from all states. The tests performed were: (1) thread count, (2) fabric weight, (3) dimensional change, (4) tearing strength, (5) breaking strength, (6) fabric elongation, (7) Stoll abrasion, (8) Taber abrasion, (9) stiffness, (10) Monsanto wrinkle recovery, (11) Celanese wrinkle recovery and (12) fluidity.

II. PROCEDURES IN THIS STUDY

Since this thesis considers the effects of wear upon cotton sheetings, tests of fabric weight and tearing strength were chosen as good indices of the effects of wear. It is assumed that the effects of wear which occurs from use can be determined by comparing sheets that were used and laundered with sheets that were laundered only.

Fabric Weight

The sample used for fabric weight was a rectangle 17 inches by 22.5 inches with the longer dimension in the direction of the filling yarns. In the upper right corner of the specimen parallel to the top of the sheet and the right selvage, a notch one inch by two inches was cut. The longer dimension of the notch was always in the direction of the warp. A template was used to mark the test area. The fabric was spread smooth and tensionless on a horizontal surface. The template was placed on the fabric so that the top was 24 inches from the hem and the side was parallel to the selvage. After the specimen was marked according to the template, it was cut from the sheet. The sample was hung free for 24 hours in a conditioning room with the standard temperature and humidity of $70 \pm 2^{\circ}$ F. and 65 ± 2 percent relative humidity. The specimen was then folded or rolled and weighed to .01 gram.

For each specimen two readings were taken not more than 15 minutes apart and these two were not to differ more than 0.02 grams, so that the test might be within the tolerance of 0.1% of the weight of 380.5 square inches of fabric. In order to express the weight in ounces per square yard, the weight obtained was multiplied by the constant factor .1200. Fabric weight was reported to the nearest 0.01 ounce.[2]

From the specimen used for fabric weight, samples were later cut for the tests of tearing strength, breaking strength, fabric elongation, Monsanto wrinkle recovery, and stiffness. Figure 1 is a diagram of the template used for fabric weight, showing the placement of the other test samples.

Tearing Strength

Tearing strength was determined by the procedures proposed by the American Society for Testing and Materials given in the *ASTM Standards on Textile Materials*, D1424-59, 1961. The test using the Elmendorf Tester required that five samples of both warp and filling specimens be cut 102 mm.

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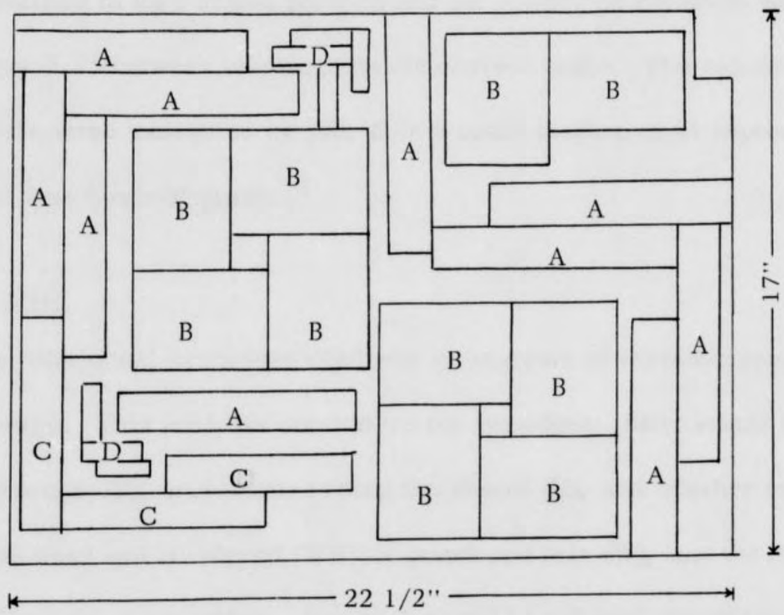
[2] *Ibid*., p. 25.

FIGURE 1

DIAGRAM OF THE TEMPLATE USED FOR FABRIC WEIGHT SAMPLES SHOWING THE PLACEMENT OF OTHER TEST SAMPLES[a]

Key: A = Breaking Strength and Elongation Samples
B = Tearing Strength Samples
C = Stiffness Samples
D = Monsanto Wrinkle Recovery



[a]Manual of Procedures, Southern Regional Research Project, SM-18, op. cit., p. 14.

long and 75 mm. wide. A notch 12 mm. square was cut in the middle of one of the long sides. After the pendulum was raised to the starting position and the pointer returned to position against its stop, the straight long side of the specimen was fastened securely in the clamps so that the notched edge was parallel to the top of the jaws and the widthwise yarns were perpendicular to the clamps. A slit extending 20 mm. from the bottom edge was cut in the specimen using the knife blade. The sector release was pressed and held down as the pendulum was allowed to swing one complete swing. The pendulum was then caught by hand and returned to its starting position and the pointer on the scale was read to the nearest 0.25 between markings on the correct scale. The values read from the scale were multiplied by 100, thus a scale reading of 64 represented six thousand four hundred grams.[3]

Analysis of Data

The statistical procedure used was an analysis of variance using a split plot design. This analysis considered the variables: fiber staple length (L), fiber strength (S), universities using the sheets (U), and whether or not the sheet was used and laundered (WW) or laundered only (W), and the interaction effects of these variables. For each variable and each interaction an F value was computed as a basis for accepting or rejecting the null hypothesis. The pattern of analysis, developed by the project statistician and members of the technical committee, is presented in Table II.

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[3] Ibid., pp. 33-34.

TABLE II

THE PATTERN FOR AN ANALYSIS OF VARIANCE USING A SPLIT PLOT DESIGN

Source	Degrees of Freedom
Length (L)	1
Strength (S)	1
Universities (U)	3
L x S	1
L x U	3
S x U	3
L x S x U	3
Bales treated alike = Error a	16
W vs WW	1
W vs WW x L	1
W vs WW x S	1
W vs WW x U	3
W vs WW x L x S	1
W vs WW x L x U	3
W vs WW x S x U	3
W vs WW x L x S x U	3
Error b	16
TOTAL	63

Programming the Analysis for Univac

The investigator translated the statistical design into an elementary type of program for analyzing the data by means of the Remington Rand Univac 1105 Data Automation System in the Research Computation Center of the Consolidated University of North Carolina. A reproduction of the program in NUIT (New Internal Translator) language is included as Appendix A. The data were assigned Y values as shown in Table III and sent to the computer center on forms like to one in Appendix B. The key for decoding the analysis is given in Appendix C.

TABLE III

ASSIGNMENT OF Y VALUES FOR DATA PROCESSING

	Alabama		Missouri		North Carolina		Oklahoma	
Cotton	W	WW	W	WW	W	WW	W	WW
1	Y1	Y33	Y2	Y34	Y3	Y35	Y4	Y36
2	Y5	Y37	Y6	Y38	Y7	Y39	Y8	Y40
3	Y9	Y41	Y10	Y42	Y11	Y43	Y12	Y44
4	Y13	Y45	Y14	Y46	Y15	Y47	Y16	Y48
5	Y17	Y49	Y18	Y50	Y19	Y51	Y20	Y52
6	Y21	Y53	Y22	Y54	Y23	Y55	Y24	Y56
7	Y25	Y57	Y26	Y58	Y27	Y59	Y28	Y60
8	Y29	Y61	Y30	Y62	Y31	Y63	Y32	Y64

CHAPTER IV

PRESENTATION OF DATA

I. FABRIC WEIGHT AND TEARING STRENGTH OF COTTONS BEFORE AND AFTER TREATMENT

The test results, which were taken from the data of the regional project for study, were in the form of mean values for eight cottons at four locations. The results were first studied in this form for obvious trends or patterns in the performance of the eight cottons as indicated by measurement of fabric weight and tearing strength.

Fabric Weight

Table IV gives the mean values for fabric weight. Test results at all intervals indicated that cotton 7 tended to be the heaviest while cotton 4, with exceptions, tended to be the lightest in weight. There was evidence of differences in the weight of sheets serviced in the different universities. The results for the North Carolina cottons were lowest in weight. The results from the Alabama and Oklahoma stations tended to be similar in weight; these results were usually highest. The range of weights varied little with treatment. The weights of the unlaundered sheets (0 interval) ranged from 4.87 to 5.38 ounces per square yard. At the fifth interval, weights for sheets that were laundered only ranged from 4.90 to 5.34 ounces per square yard as compared to a range

TABLE IV

FABRIC WEIGHT BEFORE AND AFTER LAUNDERING TREATMENTS
(Expressed in Ounces per Square Yard)

	Alabama		Missouri		N. Carolina		Oklahoma	
INTERVAL 0								
Cottons								
1	5.18		5.07		4.94		5.17	
2	5.18		5.03		4.87		5.16	
3	5.30		5.09		4.96		5.23	
4	5.12		5.01		4.93		5.11	
5	5.28		5.13		5.01		5.22	
6	5.20		5.05		4.97		5.18	
7	5.38		5.27		5.09		5.35	
8	5.22		5.02		4.89		5.11	
INTERVAL 5	W[1]	WW[2]	W	WW	W	WW	W	WW
Cottons								
1	5.22	5.19	5.06	5.05	4.94	5.03	5.14	5.16
2	5.15	5.21	5.09	5.09	4.98	5.05	5.20	5.22
3	5.28	5.29	5.21	5.21	5.20	5.17	5.26	5.32
4	5.08	5.09	4.97	4.99	4.90	4.91	5.14	5.14
5	5.28	5.25	5.24	5.21	5.13	5.10	5.07	5.22
6	5.24	5.26	5.08	5.15	5.08	5.10	5.22	5.22
7	5.28	5.36	5.24	5.31	5.17	5.19	5.34	5.33
8	5.12	5.12	4.96	5.03	4.94	4.96	5.14	5.15
INTERVAL 15								
Cottons								
1	5.10	5.40	5.15	5.14	4.98	4.97	5.14	5.13
2	5.45	5.33	5.14	5.09	4.91	4.96	5.18	5.13
3	5.35	5.36	5.29	5.13	5.06	5.12	5.25	5.28
4	5.40	5.30	5.07	5.04	4.91	4.90	5.05	5.08
5	5.50	5.30	5.26	5.18	5.02	5.06	5.26	5.26
6	5.30	5.30	5.20	5.14	5.01	5.04	5.12	5.18
7	5.45	5.43	5.34	5.31	5.10	5.20	5.36	5.29
8	5.30	5.20	5.12	5.02	4.86	4.87	5.10	5.10

[1]W = Laundered only.
[2]WW = Used and Laundered.

of 4.91 to 5.36 ounces per square yard for those that were used and laundered. At the fifteenth interval, sheets laundered only ranged from 4.86 to 5.50 ounces per square yard and those which were used and laundered ranged from 4.87 to 5.43 ounces per square yard.

Tearing Strength

Warp tearing strength. The mean values for warp tearing strength, or tear resistance, are presented in Table V. These values showed greater differences among the eight cottons than were evident in the data for fabric weight. In most cases cotton 8 tended to have the highest tearing strength while cottons 1 and 2 were lowest. Differences among sheets which were serviced in the different universities were also apparent. The mean tear strength of the sheets used at the Alabama and Oklahoma stations tended to be similar and showed the highest resistance to tearing. The results from the North Carolina station were again somewhat lower than those of the other states. Differences due to treatment were also shown in the data. At the control or 0 interval, results from all states and all cottons ranged from 922 to 1573 grams. At the fifth interval, the results ranged from 730 to 1310 grams for sheets which were laundered only and from 970 to 1648 grams for those that were used and laundered. At the fifteenth interval, the results ranged from 752 to 1155 grams for sheets that were laundered only and from 917 to 1492 grams for sheets that were used and laundered.

Filling tearing strength. The mean filling tearing strength results are

TABLE V

WARP TEARING STRENGTH BEFORE AND AFTER LAUNDERING TREATMENTS (Expressed in Grams)

	Alabama		Missouri		N. Carolina		Oklahoma	
INTERVAL 0								
Cottons								
1	1073		922		947		1075	
2	1057		953		957		1058	
3	1218		1003		1003		1163	
4	1158		1040		977		1207	
5	1308		1210		1070		1160	
6	1255		1230		1193		1248	
7	1318		1275		1152		1303	
8	1475		1420		1165		1573	
INTERVAL 5	W[1]	WW[2]	W	WW	W	WW	W	WW
Cottons								
1	942	1050	800	1018	730	1002	938	1065
2	912	1055	835	1060	758	970	892	1040
3	1025	1185	930	1167	862	1152	1005	1193
4	1010	1155	902	1120	820	1085	1020	1175
5	1158	1308	950	1208	928	1120	1058	1275
6	1050	1303	1002	1248	948	1223	1120	1330
7	1220	1392	1028	1385	902	1310	1150	1360
8	1310	1600	1075	1648	1052	1432	1088	1543
INTERVAL 15								
Cottons								
1	752	917	830	1040	838	1048	828	918
2	802	917	865	1047	862	1038	815	940
3	895	1033	960	1163	915	1150	855	1062
4	942	997	922	1140	848	1147	885	1007
5	1032	1170	962	1273	928	1195	935	1145
6	1155	1115	980	1253	952	1225	940	1155
7	1072	1173	1018	1300	932	1237	1000	1218
8	1135	1338	1018	1492	985	1342	1072	1335

[1]W = Laundered only.
[2]WW = Used and Laundered.

presented in Table VI. The results obtained for filling tearing strength tests were similar to those obtained for warp tearing strength. The means of filling tearing strength test results showed noticeable differences among cottons. Cotton 8 tended to be highest in strength and cottons 1 and 2 tended to be lowest. Differences were evident in the tear resistance of sheets serviced in the different universities. Differences due to treatment also showed in these results. The tearing strength of the control or unlaundered sheets ranged from 920 to 1530 grams. At the fifth interval, results ranged from 712 to 1382 grams for sheets laundered only and from 942 to 1580 grams for those used and laundered. At the fifteenth interval, sheets in laundered only groups ranged from 710 to 1178 and those that were used and laundered ranged from 845 to 1438 grams.

A study of the data for both warp and filling tearing strength tests indicated that the fabrics obtained greater strength with use and laundering than with laundering only. In some cases the strength of the used and laundered fabric exceeded the strength recorded for the unlaundered sample.

II. COMPARISON OF STATISTICAL SIGNIFICANCE OF DIFFERENCES DISREGARDING DIFFERENCES DUE TO TREATMENT

In this section the test results were studied in terms of length and strength properties and locations of servicing. The eight cotton types from which sheets were made were selected on the basis of length and strength. The cottons are classified according to staple length in the following groupings:

Short staple:	Cottons 1, 2, 3, and 4.
Long staple:	Cottons 5, 6, 7, and 8.

TABLE VI

FILLING TEARING STRENGTH BEFORE AND AFTER LAUNDERING TREATMENTS
(Expressed in Grams)

	Alabama		Missouri		N. Carolina		Oklahoma	
INTERVAL 0								
Cottons								
1	1002		920		937		990	
2	975		922		920		1030	
3	1083		942		992		1108	
4	1058		1018		968		1132	
5	1238		1222		1077		1153	
6	1167		1207		1137		1217	
7	1260		1280		1130		1307	
8	1495		1410		1160		1530	
INTERVAL 5	W[1]	WW[2]	W	WW	W	WW	W	WW
Cottons								
1	928	1000	715	942	712	972	875	1018
2	892	1058	782	1010	762	970	902	1013
3	975	1150	855	1078	862	1065	960	1118
4	990	1133	822	1023	795	1055	995	1103
5	1152	1295	935	1188	920	1112	955	1228
6	1045	1352	888	1208	920	1185	1092	1272
7	1190	1422	952	1327	912	1290	1162	1308
8	1382	1580	1000	1487	1032	1410	1125	1523
INTERVAL 15								
Cottons								
1	710	872	820	1018	910	1032	755	850
2	795	893	868	1003	910	1038	782	845
3	835	953	955	1092	888	1115	795	938
4	935	922	918	1080	885	1113	800	900
5	1058	1187	972	1248	975	1208	918	1113
6	1145	1118	992	1242	942	1220	860	1088
7	1082	1148	1070	1328	985	1238	965	1137
8	1178	1277	1155	1438	1000	1350	1055	1228

[1]W = Laundered only.
[2]WW = Used and Laundered.

The classification according to strength is made in the following groupings:

Low strength:	Cottons 1, 2, 5, and 6.
High strength:	Cottons 3, 4, 7, and 8.

The mean results according to property were considered and the percentage change from the original was also studied. The analysis considered only the statistical significance of differences within a specific interval of a specific test and not differences between intervals. Differences were considered statistically significant when the analysis yielded F values at the five per cent level of probability. Appendix D shows the significance of the F values obtained.

Fabric Weight

Length (L). Means values according to length and strength properties with percentage change from the original are shown in Table VII. Both short and long staple cottons increased in weight with laundering. The long staple cottons were slightly heavier than the short staple cottons. The differences in weight between short and long staple cottons were not great at any interval, the greatest difference being only 0.05 ounces per square yard. The analysis of variance at the fifth and fifteenth intervals yielded F values for the length variable which were not significant (Appendix D).

Strength (S). Cottons of low and high strength also increased in weight with laundering. High strength cottons were slightly heavier than low strength cottons. The difference between low and high strength cottons was relatively

TABLE VII

MEAN FABRIC WEIGHTS AND PERCENTAGE CHANGE ACCORDING TO LENGTH AND STRENGTH PROPERTIES

Property	Intervals			Percentage Change	
	0	5	15	0-5	0-15
	(oz./sq. yd.)				
LENGTH					
Short Staple	5.08	5.12	5.15	+0.79	+1.38
Long Staple	5.12	5.17	5.19	+0.98	+1.37
STRENGTH					
Low Strength	5.10	5.14	5.17	+0.78	+1.37
High Strength	5.13	5.15	5.18	+0.39	+0.97

small; the greatest difference was only 0.03 ounces per square yard. These differences were not significant statistically (Appendix D).

Universities (U). Table VIII shows the mean fabric weights obtained from sheets serviced in the different universities or locations and the percentage differences between intervals. There was considerable variation in the results obtained. However, the importance of the variation was difficult to ascertain since at no interval did the difference exceed 0.34 ounces per square yard. At all intervals, the sheets serviced at the North Carolina station were the lightest in weight. Sheets serviced at the Alabama station were the only ones with a mean weight at the fifth interval lower than the original mean weight. At the fifteenth interval, only the sheets serviced at the Oklahoma station were lower in weight than the original. The analysis of variance showed the differences due to location to be significant at the five per cent level for the fifth interval and at the one per cent level for the fifteenth interval (Appendix D).

Tearing Strength

Length (L). The means results of tearing strength tests, according to length and strength properties, and the percentage differences between intervals are presented in Table IX. The results from long staple length cottons were higher than those from short staple length cottons. Both the long and short staple length cottons showed a decrease in strength with laundering.

Strength (S). Both high and low strength cottons decreased in strength

TABLE VIII

MEAN FABRIC WEIGHTS AND PERCENTAGE CHANGE

ACCORDING TO UNIVERSITIES

University	Intervals			Percentage Change	
	0	5	15	0-5	0-15
	(oz./sq. yd.)				
Alabama	5.23	5.21	5.34	- 0.38	+2.10
Missouri	5.08	5.12	5.16	+ 0.79	+1.57
North Carolina	4.96	5.05	5.00	+ 1.81	+0.81
Oklahoma	5.19	5.20	5.18	+ 0.19	- 0.19

TABLE IX

MEAN TEARING STRENGTH AND PERCENTAGE CHANGE ACCORDING TO LENGTH AND STRENGTH PROPERTIES

Property	Intervals			Percentage Change	
	0	5	15	0-5	0-15
		(grams)			
STAPLE LENGTH					
Short					
Warp	1051	996	949	- 5.23	- 9.70
Filling	1000	954	913	- 4.60	- 8.70
Long					
Warp	1272	1210	1128	- 4.87	- 11.32
Filling	1249	1183	1122	- 5.28	- 10.17
STRENGTH					
Low					
Warp	1107	1040	996	- 6.15	- 10.03
Filling	1070	1009	981	- 5.70	- 8.32
High					
Warp	1216	1166	1081	- 4.11	- 11.10
Filling	1180	1128	1055	- 4.41	- 10.59

with laundering. The high strength cottons were consistently stronger than the low strength cottons. The percentage change from the original was greater for the low strength cottons at the fifth interval, but greater for the high strength cottons at the fifteenth interval. The length and strength variables were highly significant at the fifth and fifteenth intervals (Appendix D).

Universities (U). The differences in results, according to the locations at which sheets were used, are shown in Table X. The mean results of tearing strength from all universities decreased with laundering. Although the means for sheets serviced at the Alabama and Oklahoma stations were highest initially, the percentage decrease in strength was also greatest for them. This variable was highly significant at both the fifth and fifteenth intervals (Appendix D).

Summary

A study of the results, considering only the effects of differences in length, strength, and universities performing testing, showed that fabric weight tended to increase with laundering. Differences in length and strength had little effect on fabric weight and were not statistically significant. Differences due to location of servicing were statistically significant for fabric weight. Warp and filling tearing strength followed similar patterns. Tearing strength tended to decrease with laundering. Long staple cottons and high strength cottons yielded fabrics with greater tearing strength. The variables length and strength were highly significant statistically. The differences in tearing strength results from sheets used in the different universities were also

TABLE X

MEAN TEARING STRENGTH AND PERCENTAGE CHANGE ACCORDING TO UNIVERSITIES

University	Intervals 0	5	15	Percentage Change 0-5	0-15
	(grams)				
Alabama					
Warp	1233	1167	1028	- 5.35	- 16.63
Filling	1160	1160	1007	0.00	- 13.19
Missouri					
Warp	1132	1086	1079	- 4.06	- 4.68
Filling	1115	1013	1075	- 9.15	- 3.59
North Carolina					
Warp	1058	1018	1040	- 3.78	- 1.70
Filling	1040	998	1050	- 4.04	+ 0.96
Oklahoma					
Warp	1223	1141	1007	- 6.70	- 17.66
Filling	1183	1103	939	- 6.76	- 20.62

apparent and these were highly significant (Appendix D).

III. COMPARISON OF STATISTICAL SIGNIFICANCE OF DIFFERENCES CONSIDERING DIFFERENCES DUE TO TREATMENT

This section was primarily concerned with the effects of treatment and how the treatments influenced the variables of length, strength and universities discussed in the preceding section. The differences between the sheets used and laundered and those laundered only were selected as the criterion for judging the effects of wear.

Fabric Weight

Treatment (W vs WW). The mean fabric weight for sheets used and laundered and for those laundered only is presented in Table XI and compared graphically in Figure 2. Both groups of sheets increased in weight with laundering. The difference between these groups was not great, not more than 0.02 ounces per square yard at any interval. The difference was highly significant at the fifth interval, but not significant at the fifteenth interval (Appendix D).

Treatment and length (W vs WW x L). The mean fabric weights and percentage change according to treatment and length are presented in Table XII and are presented graphically in Figure 3. The means for all groups increased with laundering. The means of long staple cottons were highest for both the sheets used and laundered and those laundered only. Generally, the highest means were recorded at the fifteenth interval for all classifications. An

TABLE XI

MEAN FABRIC WEIGHTS AND PERCENTAGE CHANGE ACCORDING TO TREATMENT

Treatment	Intervals			Percentage Change	
	0	5	15	0-5	0-15
	(oz./sq. yd.)				
Laundered only	5.12	5.14	5.18	+0.39	+1.17
Used and laundered	5.12	5.16	5.16	+0.78	+0.78

FIGURE 2

MEAN FABRIC WEIGHTS AND PERCENTAGE CHANGE
ACCORDING TO TREATMENT

Key: Used and Laundered (WW) ● ———

Laundered only (W) o - - - - - -

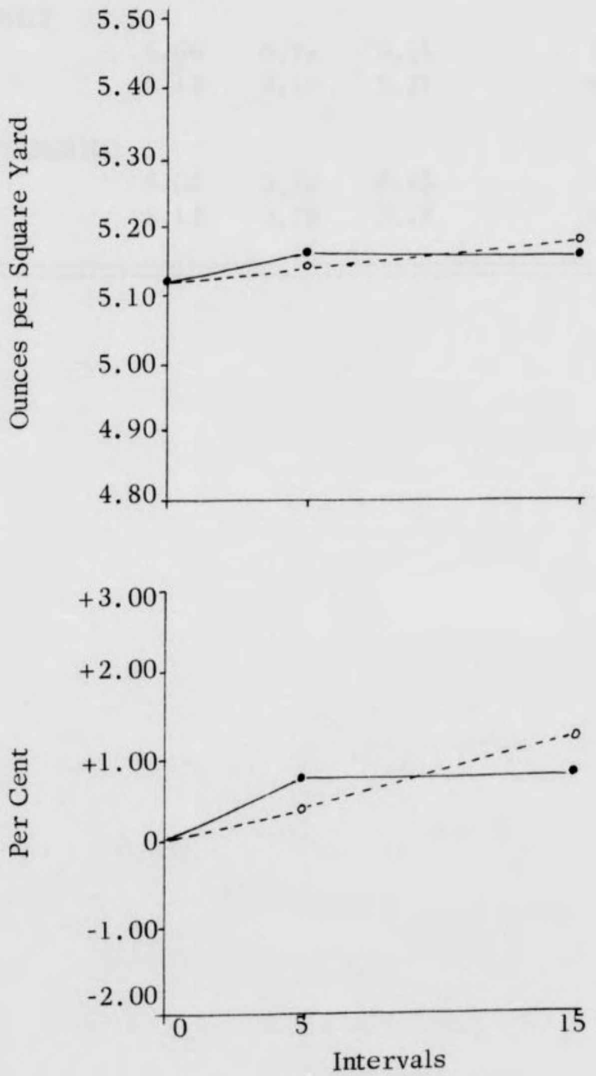


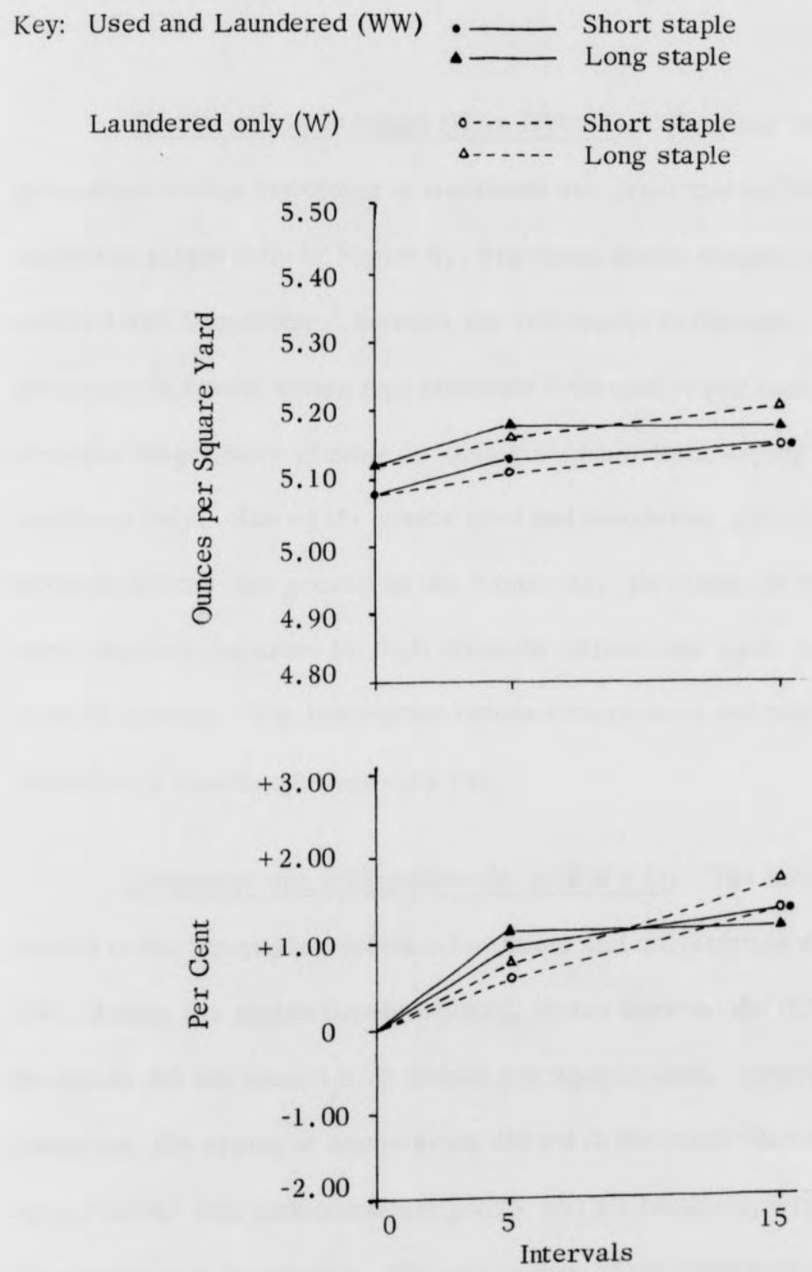
TABLE XII

MEAN FABRIC WEIGHTS AND PERCENTAGE CHANGE ACCORDING TO TREATMENT AND LENGTH

Variable	Intervals			Percentage Change	
	0	5	15	0-5	0-15
	(oz./sq. yd.)				
LAUNDERED ONLY					
Short staple	5.08	5.11	5.15	+0.59	+1.38
Long staple	5.12	5.16	5.21	+0.78	+1.76
USED AND LAUNDERED					
Short staple	5.08	5.12	5.15	+0.98	+1.38
Long staple	5.12	5.18	5.18	+1.17	+1.17

FIGURE 3

MEAN FABRIC WEIGHTS AND PERCENTAGE CHANGE
ACCORDING TO TREATMENT AND LENGTH



exception was the mean for long staple cottons for sheets used and laundered which was the same at the fifth and fifteenth intervals. The interaction between treatment and length was not significant at the fifth or fifteenth interval (Appendix D).

Treatment and strength (W vs WW x S). The mean fabric weights and percentage change according to treatment are presented in Table XIII and are presented graphically in Figure 4. The mean fabric weights for all groups increased with laundering. Between any two means in the table, there was no difference in fabric weight that exceeded 0.09 ounces per square yard. Means of fabric weight were greater for high strength cottons among the sheets laundered only. Among the sheets used and laundered, the mean for high strength cottons was greater at the 0 interval. However, at the fifth and fifteenth interval the mean for high strength cottons was equal to the mean for low strength cottons. The interaction between treatments and strength was not statistically significant (Appendix D).

Treatment and universities (W vs WW x U). The fabric weight data related to the interaction between treatment and universities are shown in Table XIV. Among the sheets laundered only, at any interval the difference between the means did not exceed 0.38 ounces per square yard. Among sheets used and laundered, the means at any interval did not differ more than 0.31 ounces per square yard. For both treatment groups and all locations, fabric weight tended to increase with laundering. The interaction of the variables treatment and

TABLE XIII

MEAN FABRIC WEIGHT AND PERCENTAGE CHANGE
ACCORDING TO TREATMENT AND STRENGTH

Variable	Intervals			Percentage Change	
	0	5	15	0-5	0-15
	(oz./sq. yd.)				
LAUNDERED ONLY					
Low strength	5.10	5.13	5.17	+0.59	+0.37
High strength	5.13	5.14	5.19	+0.19	+1.17
USED AND LAUNDERED					
Low strength	5.10	5.16	5.16	+1.18	+1.18
High strength	5.13	5.16	5.16	+0.58	+0.58

FIGURE 4

MEAN FABRIC WEIGHTS AND PERCENTAGE CHANGE
ACCORDING TO TREATMENT AND STRENGTH

Key: Used and Laundered (WW) • ——— Low strength
▲ ——— High strength

Laundered only (W) ○ - - - - - - Low strength
△ - - - - - - High strength

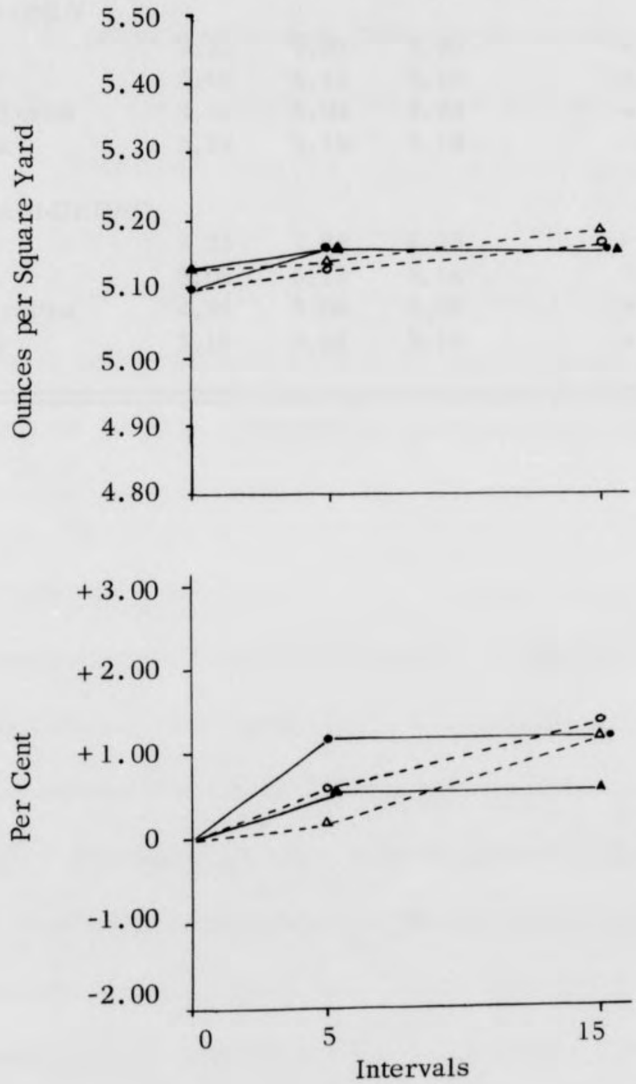


TABLE XIV

MEAN FABRIC WEIGHTS AND PERCENTAGE CHANGE ACCORDING TO TREATMENT AND UNIVERSITIES

Treatment	Intervals			Percentage Change	
	0	4	15	0-5	0-15
	(oz./sq. yd.)				
LAUNDERED ONLY					
Alabama	5.23	5.21	5.36	- 0.38	+ 2.48
Missouri	5.08	5.11	5.20	+0.59	+ 2.36
North Carolina	4.96	5.04	4.98	+1.61	+ 0.40
Oklahoma	5.19	5.19	5.18	- 0.00	- 0.19
USED AND LAUNDERED					
Alabama	5.23	5.22	5.33	- 0.19	+ 1.91
Missouri	5.08	5.13	5.13	+0.98	+ 0.98
North Carolina	4.96	5.06	5.02	+2.02	+ 1.21
Oklahoma	5.19	5.22	5.18	+0.58	- 0.19

location was not significant (Appendix D).

Tearing Strength

Treatment (W vs WW). Both warp and filling tearing strength, as shown in Table XV, yielded results that indicated obvious differences between sheets that were used and laundered and those that were laundered only. A graphic presentation of the differences in mean tearing strength and percentage change from the original is given in Figure 5. The sheets that were laundered only lost strength with laundering, but those that were used and laundered had greater tearing strength at the fifth interval and had slightly less strength at the fifteenth interval than they had originally. The variable treatment was significant at the one per cent level for warp and filling tests at the fifth interval and for filling tests at the fifteenth interval and at the five per cent level for warp tear strength tests at the fifteenth interval (Appendix D).

Treatment and length (W vs WW x L). The mean tearing strength and percentage change according to treatment and length are presented in Table XVI, and are presented graphically in Figure 6. There was a noticeable difference between the short staple cottons of the laundered only group and the used and laundered group. A similar difference was noted in the long staple cottons. The long staple cottons in both treatment groups had the greatest strength at all intervals. The used and laundered group had a higher mean tear resistance at the fifth and fifteenth intervals than the laundered only group. The used and laundered group had increased in strength at the fifth interval, but had a mean

TABLE XV

MEAN TEARING STRENGTH AND PERCENTAGE CHANGE ACCORDING TO TREATMENT

Treatment	Intervals			Percentage Change	
	0	5	15	0-5	0-15
		(grams)			
LAUNDERED ONLY					
Warp	1162	982	938	- 15.49	- 19.28
Filling	1124	953	935	- 15.21	- 16.81
USED AND LAUNDERED					
Warp	1162	1224	1142	+ 5.34	- 1.72
Filling	1124	1184	1101	+ 5.34	- 2.05

FIGURE 5

MEAN TEARING STRENGTH AND PERCENTAGE CHANGE ACCORDING TO TREATMENT

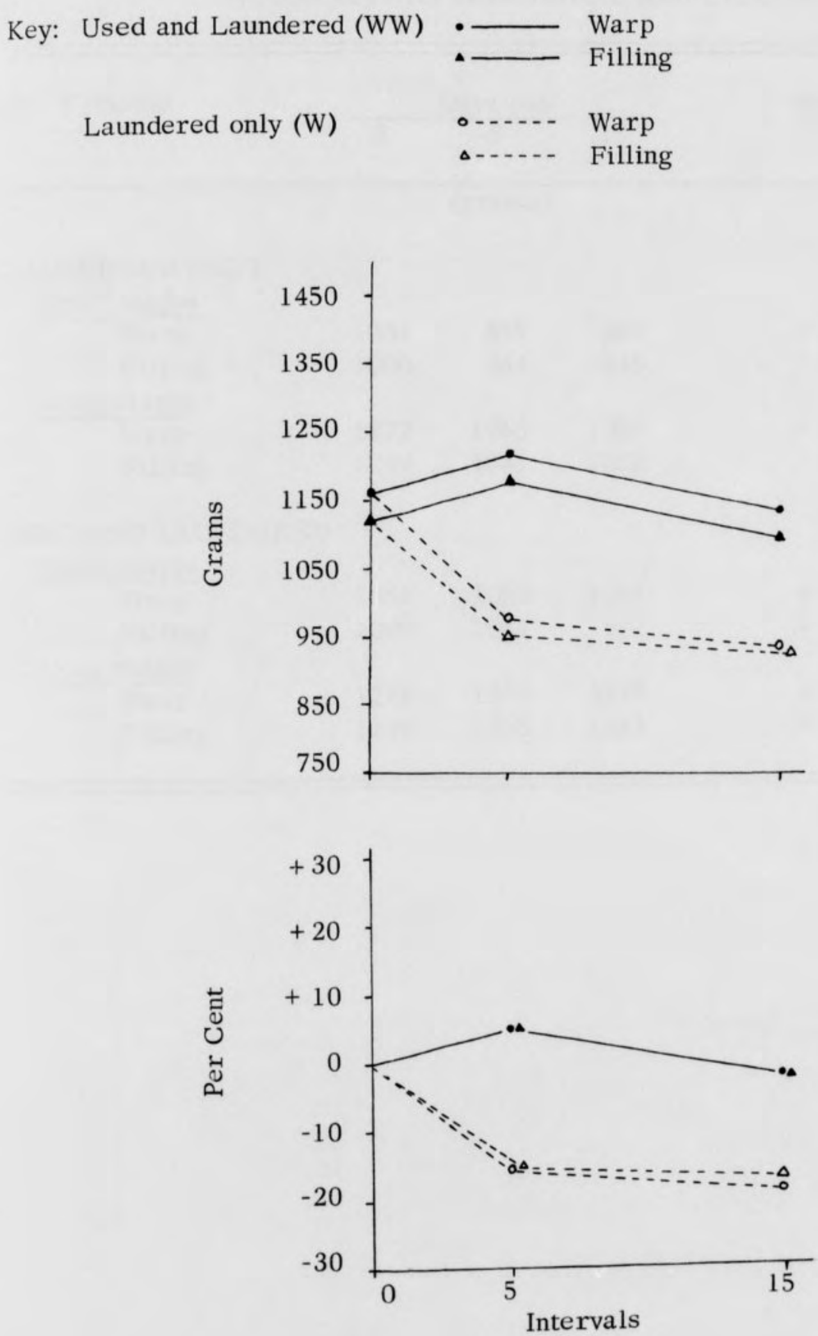


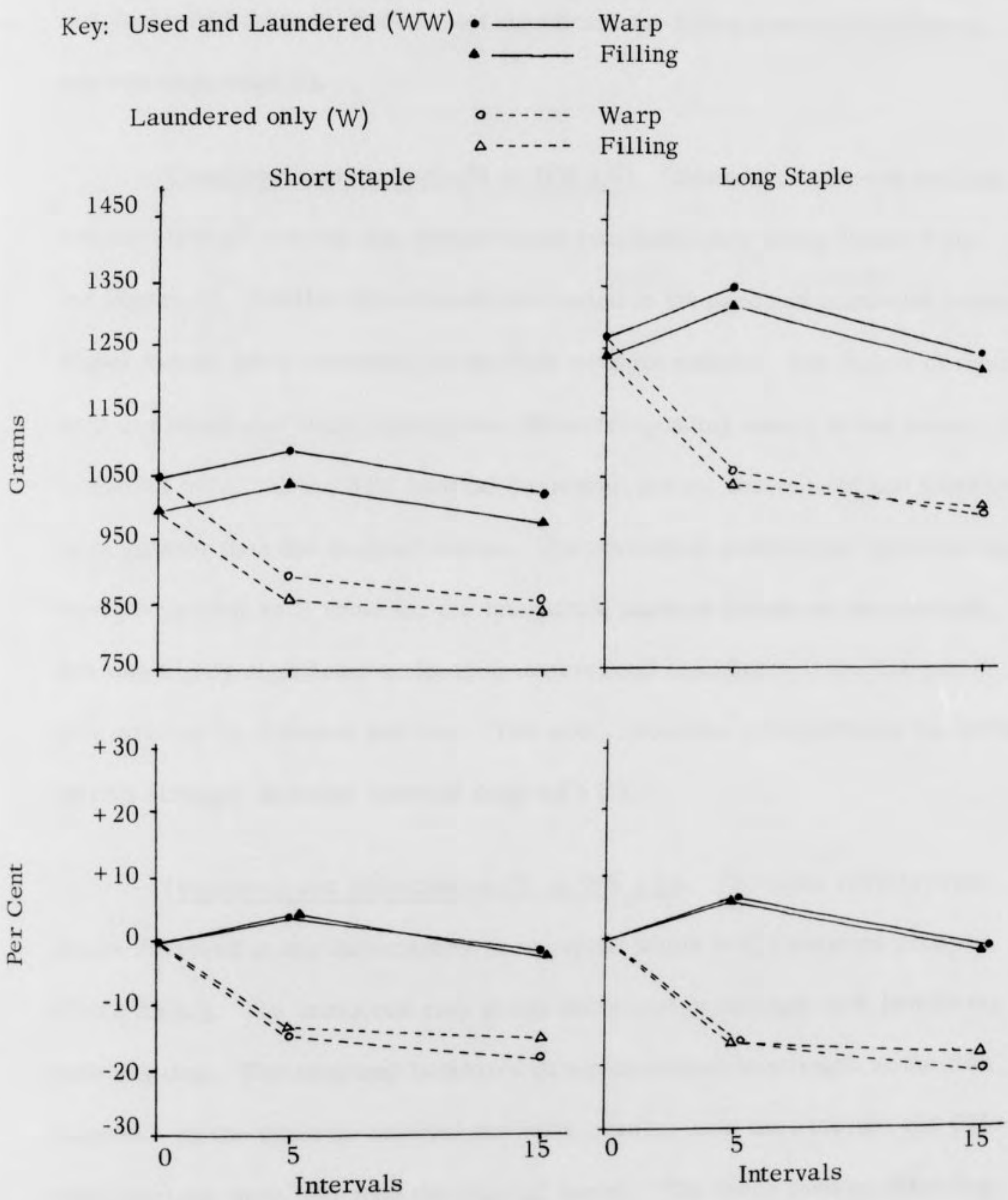
TABLE XVI

MEAN TEARING STRENGTH AND PERCENTAGE CHANGE
ACCORDING TO TREATMENT AND LENGTH

Variable	Intervals			Percentage Change	
	0	5	15	0-5	0-15
	(grams)				
LAUNDERED ONLY					
Short staple					
Warp	1051	899	863	- 14.46	- 17.89
Filling	1000	864	848	- 13.60	- 15.20
Long staple					
Warp	1272	1065	1007	- 16.27	- 20.83
Filling	1249	1041	1022	- 16.65	- 18.17
USED AND LAUNDERED					
Short staple					
Warp	1051	1093	1035	+ 4.00	- 1.52
Filling	1000	1044	979	+ 4.40	- 2.10
Long staple					
Warp	1272	1355	1248	+ 6.52	- 1.89
Filling	1249	1325	1223	+ 6.08	- 2.08

FIGURE 6

MEAN TEARING STRENGTH AND PERCENTAGE CHANGE ACCORDING TO TREATMENT AND LENGTH



strength at the fifteenth interval slightly less than the original mean. The interaction of treatment and length was highly significant for the warp tear strength tests at the fifth and fifteenth intervals and for the filling tear strength test at the fifth interval but was not significant for filling tests at the fifteenth interval (Appendix D).

Treatment and strength (W vs WW x S). Differences between the high and low strength cottons are evident in the laundered only group (Table XVII and Figure 7). Similar differences were noted in the used and laundered group. Higher means were recorded for the high strength cottons. The means of sheets used and laundered were greater than the corresponding means of the sheets laundered only. At the fifth interval the means for the sheets used and laundered were greater than the original means. The statistical analysis for warp tearing strength yielded an F value for the interaction between treatment and strength that was highly significant at the fifth interval and significant at the five per cent level at the fifteenth interval. The interaction was not significant for filling tearing strength at either interval (Appendix D).

Treatment and Universities (W vs WW x U). The mean results from sheets serviced at the universities were varied within both treatment groups (Table XVIII). The laundered only group decreased in strength with laundering at each location. The used and laundered group increased in strength at the fifth interval. At the fifteenth interval the mean results from the Alabama and Oklahoma stations were less than the original mean. The mean results of tearing

TABLE XVII

MEAN TEARING STRENGTH AND PERCENTAGE CHANGE ACCORDING TO TREATMENT AND STRENGTH

Variable	Intervals			Percentage Change	
	0	5	15	0-5	0-15
		(grams)			
LAUNDERED ONLY					
Low strength					
Warp	1107	939	905	- 15.18	- 18.25
Filling	1070	905	901	- 15.42	- 15.79
High strength					
Warp	1216	1025	966	- 15.71	- 20.56
Filling	1180	1000	969	- 15.25	- 17.88
USED AND LAUNDERED					
Low strength					
Warp	1107	1142	1087	+ 3.16	- 1.81
Filling	1070	1114	1061	+ 4.11	- 0.84
High strength					
Warp	1216	1306	1196	+ 7.40	- 1.64
Filling	1180	1255	1141	+ 6.36	- 3.30

FIGURE 7

MEAN TEARING STRENGTH AND PERCENTAGE CHANGE
ACCORDING TO TREATMENT AND STRENGTH

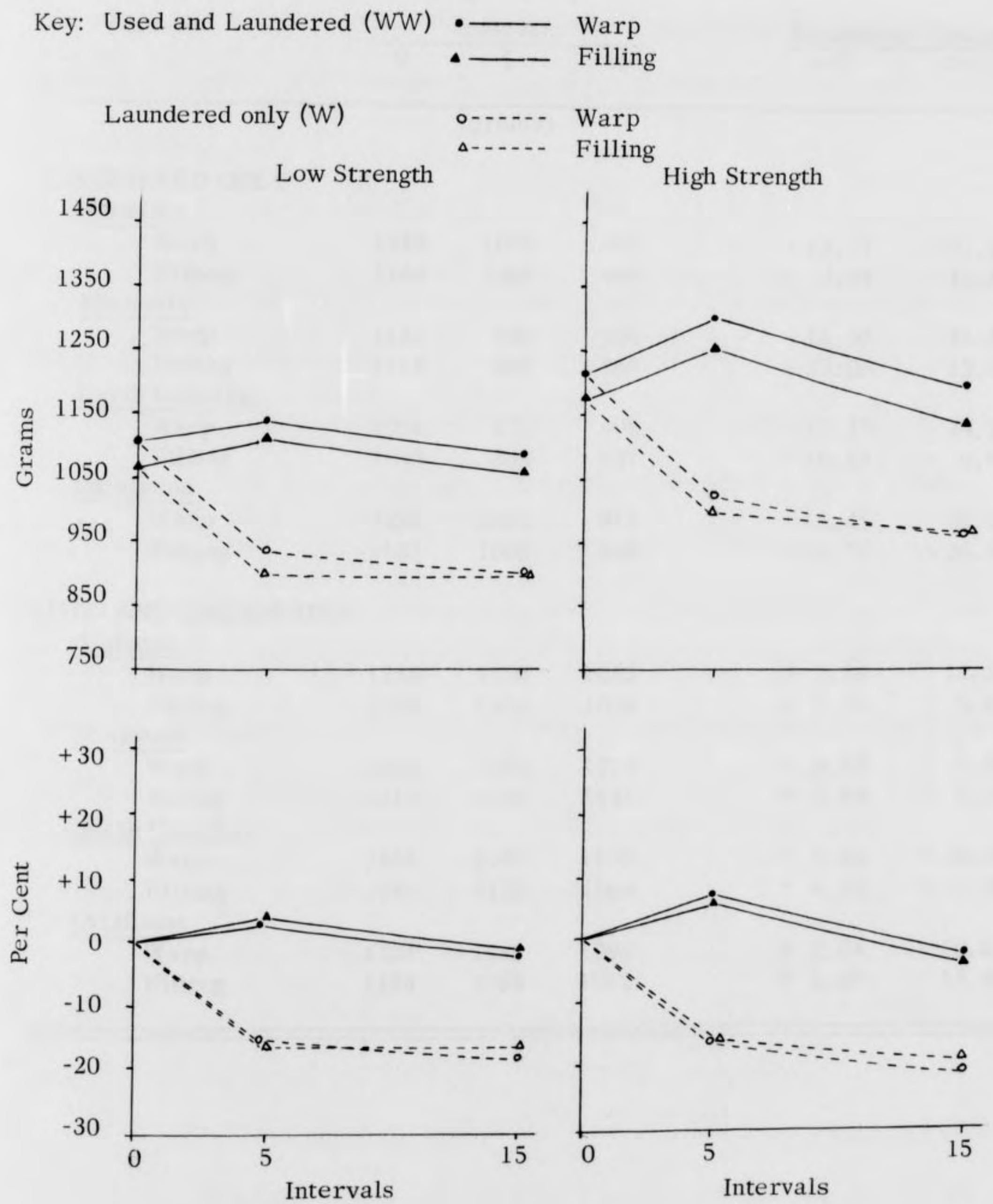


TABLE XVIII

MEAN TEARING STRENGTH AND PERCENTAGE CHANGE
ACCORDING TO TREATMENT AND UNIVERSITIES

Variable	Intervals			Percentage Change	
	0	5	15	0-5	0-15
		(grams)			
LAUNDERED ONLY					
Alabama					
Warp	1233	1073	973	- 12.57	- 21.09
Filling	1160	1069	967	- 7.84	- 16.64
Missouri					
Warp	1132	940	956	- 16.96	- 15.55
Filling	1115	869	969	- 22.06	- 13.09
North Carolina					
Warp	1058	875	908	- 17.30	- 14.18
Filling	1040	865	937	- 16.83	- 9.90
Oklahoma					
Warp	1223	1034	916	- 15.45	- 25.10
Filling	1183	1008	866	- 14.79	- 26.80
USED AND LAUNDERED					
Alabama					
Warp	1233	1256	1082	+ 1.86	- 12.25
Filling	1160	1250	1046	+ 7.76	- 9.83
Missouri					
Warp	1132	1232	1214	+ 8.83	+ 7.24
Filling	1115	1158	1181	+ 3.86	+ 5.92
North Carolina					
Warp	1058	1162	1173	+ 9.83	+ 10.87
Filling	1040	1132	1164	+ 8.85	+ 11.92
Oklahoma					
Warp	1223	1248	1098	+ 2.04	- 10.22
Filling	1183	1198	1012	+ 1.27	- 14.45

strength data from the North Carolina stations continued to increase at the fifteenth interval. The mean results from the Missouri station was greater at the fifteenth interval than the original mean but less at the fifth interval than the original mean. The interaction of the variable treatment and universities was highly significant at both the fifth and fifteenth interval for warp and filling tests (Appendix D).

Summary

The trends toward significant differences in fiber properties and universities which were found in the preceding section were also apparent when the effects of treatment were studied. Treatment did not affect fabric weight as greatly as it did tearing strength. The differences noted in fabric weight were of no practical significance and, in most cases, of no statistical significance since the differences were small. Both warp and filling tearing strength at the fifth interval had increased with use and laundering. The effects of treatment as applied to tearing strength were significant for many of the variables and interactions studied.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR FURTHER STUDY

I. SUMMARY

A great deal has been learned about the cotton fiber and its properties, but there is little information about the effects of the fiber properties on the end-product performance. The personnel of the Southern Regional Textile Project, SM-18, have been considering the effects of the fiber properties staple length and strength upon the performance of cotton sheetings. The cotton sheetings made from cotton fibers having specific length and strength characteristics were subjected to two different treatments. One group was laundered only while a similar group was used and laundered. The sheets in the last group were subjected to use in women's dormitories in four universities - at Auburn University, the University of Missouri, the University of North Carolina at Greensboro, and Oklahoma State University. Sheets from both groups were withdrawn for testing after established numbers of launderings. Measurements of fabric weight and tearing strength, the test results used in this study, were among the many tests used to indicate serviceability.

One of the performance features that has not been adequately described is the effect of wear through use. It is known that use will affect fabrics and that laundering will also affect fabrics. Most studies have considered the effects of use and laundering together, however. This study was planned to determine the effects of use alone. It was assumed that a comparison of sheets that were used and laundered with those that were laundered only gives an indication of the effects of use.

The results from tests of fabric weight and tearing strength were selected for consideration in this study because these tests were considered good indices of the effects of wear. The data, taken from the regional project, included results from the original or unlaundered sheetings and from sheetings at the fifth and fifteenth intervals of laundering. Data from sheets serviced at all four universities were used.

The specific objectives of this study were as follows:

1. To determine the mean and percentage differences at stated intervals between a.) sheets used and laundered and b.) sheets laundered only.

2. To determine the significance of differences in the fiber properties of sheets that were used and laundered with those that were laundered only.

The results from fabric weight and tearing strength tests were studied statistically by means of an analysis of variance. A program for the analysis was developed so that the data might be analyzed using the Remington Rand 1105 digital computer in the Computation Center of the Consolidated University of North Carolina.

Fabric Weight

Fabric weight tended to increase with launderings. The weights for sheets laundered only seemed to have an even increase in weight throughout the fifteen launderings. The sheets used and laundered had their greatest increase in weight by the fifth laundering and changed only slightly between the fifth and fifteenth interval.

It was found that there were differences statistically significant at the five per cent level of probability among sheets serviced at the different universities (U) at the fifth interval. The analysis of variance for fabric weight indicated differences significant at the one per cent level of probability between sheets used and laundered and those laundered only (W vs WW) at the fifth interval and among sheets serviced at the different universities (U) at the fifteenth interval.

Although the statistical evaluation did show some significant differences, these differences are of little practical significance since the range of values for the raw data was so small. Any increase in weight which was found was probably due to dimensional change, as noted in the study by Stout and others at Cornell University.[1] The loss in weight has probably come as the result of the abrasive forces of both use and laundering.

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[1]Evelyn E. Stout, Carol L. Zillgit and Muriel R. Ferraro, "Effect of Laundering and Drycleaning on Laborabory Performance of Certain Resin-finished Winter Cottons," Journal of Home Economics, 49 (March, 1957), pp. 198-99.

Tearing Strength

Study of both warp and filling tearing strength tests showed the unexpected result that sheets tended to increase in strength with use and laundering while sheets which were laundered only decreased in strength. A partial answer to the question of why this happened may be found in the study by Stavrakas and Platt.[2] This study stated that increased yarn mobility increases tearing strength. Subjecting the fabric to movement in use may have increased yarn mobility in the used and laundered sheetings, and as a result those sheets were stronger. The gain in strength may also be attributed to the fact that the fabric has been some what roughed up in use and has, as a result, a smaller distance between the points of interlacing of the yarns which make up the fabric. Since there would be more interlacings per inch and since fabrics are generally stronger with more interlacings per inch, it is likely that such a fabric would have greater tearing strength.

The number of launderings considered in this study probably does not give a true picture of the effects of use. The effects of use will probably be seen more clearly at the thirtieth interval.

Distinct differences were noted in the results when length and strength characteristics were considered. The sheets made from short staple length fibers had the lowest strength. These results are similar to the ones found by

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[2]E. James Stavrakas and Milton M. Platt, "Investigations on the Modifications of Yarn and Fabric Structure Needed to Improve Tear Strength of Cotton Fabrics," ARS 72-19, (Washington: United States Agriculture Research Service, January, 1961), p. 15.

Tallant, Fiori and Sands who stated that short staple length cotton fibers have a detrimental effect on most fabric properties.[3]

There seems to be a direct relationship between the strength of the fiber and the strength of the fabric. High strength cottons yielded stronger fabrics than low strength cotton fibers.

The analysis of variance for warp tearing strength indicated differences significant at the five per cent level of probability:

At the fifth interval

For the interaction among treatments and length and strength properties (W vs WW x L x S).

At the fifteenth interval

1. For the interaction between length and universities (L x U).
2. For treatments (W vs WW).
3. For the interaction between treatment and strength (W vs WW x S).

The analysis showed significant differences at the one per cent level of probability:

At the fifth interval

1. Between sheets of long and short staple length cottons (L).
2. Between sheets of high and low strength cottons (S).
3. Among sheets used at the various universities (U).
4. For treatments (W vs WW).

---

[3]John D. Tallant, Louis A. Fiori and Jack E. Sands, "The Effect of the Short Fibers in a Cotton on its Processing Efficiency and Product Quality," Textile Research Journal, 32 (January, 1962), p. 55-56.

5. For the interaction of treatment and length (W vs WW x L).

6. For the interaction of treatment and strength (W vs WW x S).

7. For the interaction of treatment and universities (W vs WW x U).

At the fifteenth interval

1. Between sheets of short and long staple length cottons (L).

2. Between sheets of high and low strength cottons (S).

3. Among sheets serviced at the different universities (U).

4. For the interaction between treatments and length (W vs WW x L).

5. For the interaction between treatments and universities (W vs WW x U).

In summarizing the findings for filling tearing strength results, differences significant at the five per cent level of probability were noted:

At the fifth interval

1. Between sheets that were laundered only and those that were used and laundered (W vs WW).

2. For the interaction between treatments, length and universities (W vs WW x L x U).

Differences significant at the one per cent level of probability were found:

At the fifth interval

1. Between sheets of long and short staple length cottons (L).

2. Between sheets of high and low strength cottons (S).

3. Among sheets serviced in the different universities (U).

4. Between sheets used and laundered and those laundered only (W vs WW).

5. For the interaction of treatment and length (W vs WW x L).

6. For the interaction of treatment and universities (W vs WW x U).

At the fifteenth interval

1. Between sheets of long and short staple length cottons (L).

2. Between sheets of high and low strength cottons (S).

3. Among sheets used in the different universities (U).

4. For the interaction between length and strength properties (L x S).

5. Between sheets used and laundered and those laundered only (W vs WW).

6. For the interaction between treatment and universities (W vs WW x U).

II. CONCLUSIONS

The results of this study indicated the following conclusions:

1. After five and fifteen launderings sheets which had been used and laundered had a greater tear resistance than those which had been laundered only.

2. Fabric weight did not vary greatly whether the sheets had been used and laundered or laundered only.

3. Sheets made of long staple length cottons had a greater tear strength than those made of short staple length cottons.

4. Sheets made of high strength cottons had a greater tear strength than those made of low strength cottons.

III. RECOMMENDATIONS FOR FURTHER STUDY

Further investigation related to the effects of use would be desirable. The following recommendations are made for future study:

1. A study similar to this one be conducted considering the results through thirty launderings.

2. A study similar to this one be conducted comparing the results from tests of breaking strength and elongation with results from tests of tearing strength.

3. A study similar to this one be conducted comparing fabric weight with dimensional change.

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APPENDIX

APPENDIX A

ANALYSIS OF VARIANCE PROGRAM FOR REMINGTON RAND UNIVAC 1105

```
        N    020   Y   064   Z   325   S   020   W   050        H

1       2, NO, 1, 120                                           F
2       NNO:O                                                   F

3       KEENEY 3W HEADING AND 64 VAR. DATA INPUT                F
4       AT(33285996544)                                         F

5       ATN1  ATN20                                             F

6       T(O.)                                                   F

7       T(O.)                                                   F

        Z1:Y1+Y33                                               F
        Z2:Y2 +Y34                                              F
        Z3:Y3+Y35                                               F
        Z4:Y4+Y36                                               F
        Z5:Y5+Y37                                               F
        Z6:Y6+Y38                                               F
        Z7:Y7+Y39                                               F
        Z8:Y8+Y40                                               F
        Z9:Y9+Y41                                               F
        Z10:Y10+Y42                                             F
        Z11:Y11+Y43                                             F
        Z12:Y12+Y44                                             F
        Z13:Y13+Y45                                             F
        Z14:Y14+Y46                                             F
        Z15:Y15+Y47                                             F
        Z16:Y16+Y48                                             F
        Z17:Y17+Y49                                             F
        Z18:Y18+Y50                                             F
        Z19:Y19+Y51                                             F
        Z20:Y20+Y52                                             F
        Z21:Y21+Y53                                             F
        Z22:Y22+Y54                                             F
        Z23:Y23+Y55                                             F
        Z24:Y24+Y56                                             F
        Z25:Y25+Y57                                             F
```

Z26: Y26+ Y58	F
Z27: Y27 +Y59	F
Z28: Y28 +Y60	F
Z29: Y29 +Y61	F
Z30: Y30+Y62	F
Z31: Y31 +Y63	F
Z32: Y32 +Y64	F
Z33: Y1+Y5+Y9+Y13+Y17+Y21+Y25+Y29	F
Z34: Y2+Y6+Y10+Y14+Y18+Y22+Y26+Y30	F
Z35: Y3+Y7+Y11+Y15+Y19+Y23+Y27+Y31	F
Z36: Y4+Y8+Y12+Y16+Y20+Y24+Y28+Y32	F
Z37: Y33+Y37+Y41+Y45+Y49+Y53+Y57+Y61	F
Z38: Y34+Y38+Y42+Y46+Y50+Y54+Y58+Y62	F
Z39: Y35+Y39+Y43+Y47+Y51+Y55+Y59+Y63	F
Z40: Y36+Y40+Y44+Y48+Y52+Y56+Y60+Y64	F
Z41: Z1+Z5+Z9+Z13+Z17+Z21+Z25+Z29	F
Z42: Z2+Z6+Z10+Z14+Z18+Z22+Z26+Z30	F
Z43: Z3+Z7+Z11+Z15+Z19+Z23+Z27+Z31	F
Z44: Z4+Z8+Z12+Z16+Z20+Z24+Z28+Z32	F
Z200: (Y1xY1)+(Y5xY5)+(Y9xY9)+(Y13xY13)	F
Z201: (Y17xY17)+(Y21xY21)+(Y25xY25)+(Y29xY29)	F
Z45: Z200+Z201	F
Z202: (Y2xY2)+(Y6xY6)+(Y10xY10)+(Y14xY14)	F
Z203: (Y18xY18)+(Y22xY22)+(Y26xY26)+(Y30xY30)	F
Z46: Z202+Z203	F
Z204: (Y3xY3)+(Y7xY7)+(Y11xY11)+(Y15xY15)	F
Z205: (Y19xY19)+(Y23xY23)+(Y27xY27)+(Y31xY31)	F
Z47: Z204+Z205	F
Z206: (Y4xY4)+(Y8xY8)+(Y12xY12)+(Y16xY16)	F
Z207: (Y20xY20)+(Y24xY24)+(Y28xY28)+(Y32xY32)	F
Z48: Z206+Z207	F
Z208: (Y33xY33)+(Y37xY37)+(Y41xY41)+(Y45xY45)	F
Z209: (Y49xY49)+(Y53xY53)+(Y57xY57)+(Y61xY61)	F
Z49: Z208+Z209	F
Z210: (Y34xY34)+(Y38xY38)+(Y42xY42)+(Y46xY46)	F
Z211: (Y50xY50)+(Y54xY54)+(Y58xY58)+(Y62xY62)	F
Z50: Z210+Z211	F

Z212: (Y35xY35) +(Y39xY39)+(Y43xY43) +(Y47xY47) F
Z213: (Y51xY51) +(Y55xY55)+(Y59xY59) +(Y63xY63) F
Z51: Z212+Z213 F

Z214: (Y36xY36)+ (Y40xY40) +(Y44xY44)+ (Y48xY48) F
Z215: (Y52xY52)+ (Y56xY56) +(Y60xY60)+ (Y64xY64) F
Z52: Z214+Z215 F

Z53: Y1+ Y2+ Y3+Y4 F
Z54: Y33+Y34 +Y35+Y36 F
Z55: Z1+Z2+Z3+Z4 F
Z56: Y5+ Y6+Y7+Y8 F
Z57: Y37+Y38+ Y39+Y40 F
Z58: Z5+Z6+Z7+Z8 F
Z59: Y9+ Y10+Y11+Y12 F
Z60: Y41 +Y42+ Y43+Y44 F
Z61: Z9+Z10+Z11+Z12 F
Z62: Y13+Y14+ Y15+Y16 F
Z63: Y45+Y46+Y47+ Y48 F
Z64: Z13+Z14+Z15+Z16 F
Z65: Y17 +Y18+Y19+ Y20 F
Z66: Y49 +Y50+Y51 +Y52 F
Z67: Z17 +Z18+Z19 +Z20 F
Z68: Y21 +Y22+Y23 +Y24 F
Z69: Y53 +Y54+Y55 +Y56 F
Z70: Z21 +Z22+Z23 +Z24 F
Z71: Y25 +Y26+Y27+ Y28 F
Z72: Y57 +Y58+Y59+ Y60 F
Z73: Z25 +Z26 +Z27+ Z28 F
Z74: Y29+ Y30+Y31+ Y32 F
Z75: Y61+ Y62+Y63+ Y64 F
Z76: Z29+ Z30+Z31+Z32 F
Z77: Z33+ Z34 +Z35+ Z36 F
Z78: Z37+Z38 +Z39+Z40 F
Z79: Z41 +Z42+ Z43+Z44 F
Z80: Z45+Z46+ Z47+Z48 F
Z81: Z49+Z50+ Z51 +Z52 F

Z82: (Z79xZ79)/64. F

Z83: (Z80 +Z81)-Z82 F

Z216: Z55 +Z58 +Z61+ Z64 F
Z217: Z67 +Z70+Z73+ Z76 F
Z84: (((Z216xZ216)+(Z217xZ217))/32.)-Z82 F

Z218:Z55+Z58+Z67+Z70 F
Z219:Z61+Z64+Z73+Z76 F
Z85:(((Z218xZ218)+(Z219xZ219))/32.)-Z82 F
Z86:(((Z41xZ41)+(Z42xZ42)+(Z43xZ43)+(Z44xZ44))/16.)-Z82 F

Z220:Z55+Z58 F
Z221:Z61+Z64 F
Z222:Z67+Z70 F
Z223:Z73+Z76 F
Z224:((Z220xZ220)+(Z221xZ221)+(Z222xZ222)+(Z223xZ223))/16. F
Z87:Z224-Z82-Z84-Z85 F

Z225:Z1+Z5+Z9+Z13 F
Z226:Z2+Z6+Z10+Z14 F
Z227:Z3+Z7+Z11+Z15 F
Z228:Z4+Z8+Z12+Z16 F
Z229:Z17+Z21+Z25+Z29 F
Z230:Z18+Z22+Z26+Z30 F
Z231:Z19+Z23+Z27+Z31 F
Z232:Z20+Z24+Z28+Z32 F
Z233:(Z225xZ225)+(Z226xZ226)+(Z227xZ227)+(Z228xZ228) F
Z234:(Z229xZ229)+(Z230xZ230)+(Z231xZ231)+(Z232xZ232) F
Z88:((Z233+Z234)/8.)-Z82-Z84-Z86 F

Z235:Z1+Z5+Z17+Z21 F
Z236:Z2+Z6+Z18+Z22 F
Z237:Z3+Z7+Z19+Z23 F
Z238:Z4+Z8+Z20+Z24 F
Z239:Z9+Z13+Z25+Z29 F
Z240:Z10+Z14+Z26+Z30 F
Z241:Z11+Z15+Z27+Z31 F
Z242:Z12+Z16+Z28+Z32 F
Z243:(Z235xZ235)+(Z236xZ236)+(Z237xZ237)+(Z238xZ238) F
Z244:(Z239xZ239)+(Z240xZ240)+(Z241xZ241)+(Z242xZ242) F
Z89:((Z243+Z244)/8.)-Z82-Z85-Z86 F

Z245:Z1+Z5 F
Z246:Z2+Z6 F
Z247:Z3+Z7 F
Z248:Z4+Z8 F
Z249:Z9+Z13 F
Z250:Z10+Z14 F
Z251:Z11+Z15 F
Z252:Z12+Z16 F
Z253:Z17+Z21 F
Z254:Z18+Z22 F

Z255:Z19+Z23 F
Z256:Z20+Z24 F
Z257:Z25+Z29 F
Z258:Z26+Z30 F
Z259:Z27+Z31 F
Z260:Z28+Z32 F
Z261:(Z245xZ245)+(Z246xZ246)+(Z247xZ247)+(Z248xZ248) F
Z262:(Z249xZ249)+(Z250xZ250)+(Z251xZ251)+(Z252xZ252) F
Z263:(Z253xZ253)+(Z254xZ254)+(Z255xZ255)+(Z256xZ256) F
Z264:(Z257xZ257)+(Z258xZ258)+(Z259xZ259)+(Z260xZ260) F
Z265:Z82+Z84+Z85+Z86+Z87+Z88+Z89 F
Z90:((Z261+Z262+Z263+Z264)/4.)-Z265 F

Z266:Z1-Z5 F
Z267:Z2-Z6 F
Z268:Z3-Z7 F
Z269:Z4-Z8 F
Z270:Z9-Z13 F
Z271:Z10-Z14 F
Z272:Z11-Z15 F
Z273:Z12-Z16 F
Z274:Z17-Z21 F
Z275:Z18-Z22 F
Z276:Z19-Z23 F
Z277:Z20-Z24 F
Z278:Z25-Z29 F
Z279:Z26-Z30 F
Z280:Z27-Z31 F
Z281:Z28-Z32 F
Z282:(Z266xZ266)+(Z267xZ267)+(Z268xZ268)+(Z269xZ269) F
Z283:(Z270xZ270)+(Z271xZ271)+(Z272xZ272)+(Z273xZ273) F
Z284:(Z274xZ274)+(Z275xZ275)+(Z276xZ276)+(Z277xZ277) F
Z285:(Z278xZ278)+(Z279xZ279)+(Z280xZ280)+(Z281xZ281) F
Z91:(Z282+Z283+Z284+Z285)/4. F

Z92:(((Z77xZ77)+(Z78xZ78))/32.)-Z82 F

Z286:Z53+Z56+Z59+Z62 F
Z287:Z54+Z57+Z60+Z63 F
Z288:Z65+Z68+Z71+Z74 F
Z289:Z66+Z69+Z72+Z75 F
Z290:((Z286xZ286)+(Z287xZ287)+(Z288xZ288)+(Z289xZ289))/16. F
Z93:Z290-Z82-Z92-Z84 F

Z291:Z53+Z56+Z65+Z68 F
Z292:Z54+Z57+Z66+Z69 F

Z293:Z59+Z62+Z71+Z74 F
Z294:Z60+Z63+Z72+Z75 F
Z295:((Z291xZ291)+(Z292xZ292)+ (Z293xZ293) +(Z294xZ294))/16. F
Z94:Z294-Z82-Z92-Z85 F

Z200:((Z33xZ33)+ (Z34xZ34)+(Z35xZ35)+ (Z36xZ36))/8. F
Z201:((Z37xZ37) +(Z38xZ38)+ (Z39xZ39)+ (Z40xZ40))/8. F
Z95:Z200+Z201 -Z82-Z86-Z92 F

Z200:Z53+ Z56 F
Z201:Z54+Z57 F
Z202:Z65+Z68 F
Z203:Z66+Z69 F
Z204:Z59+Z62 F
Z204:Z60+Z63 F
Z206:Z71+Z74 F
Z207:Z72+ Z75 F
Z208:((Z200xZ200)+(Z201xZ201)+(Z202xZ202) +(Z203xZ203))/8. F
Z209:((Z204xZ204)+(Z204xZ205)+(Z206xZ206) +(Z207xZ207))/8. F
Z210:Z82+ Z84+Z85+Z87 +Z92+Z93+ Z94 F
Z96:Z208+ Z209 - Z210 F

Z200:Y1+ Y5 +Y9+ Y13 F
Z201:Y33+ Y37+Y41+ Y45 F
Z202:Y2+Y6+ Y10+Y14 F
Z203:Y34+Y38+Y42+ Y46 F
Z204:Y3+Y7 +Y11+ Y15 F
Z205:Y35+Y39+Y43+ Y47 F
Z206:Y4+Y8 +Y12+Y16 F
Z207:Y36+Y40+Y44+ Y48 F
Z208:Y17+Y21+Y25+ Y29 F
Z209:Y49+Y53+Y57+ Y61 F
Z210:Y18+Y22+Y26+ Y30 F
Z211:Y50+Y54+Y58+ Y62 F
Z212:Y19+Y23+Y27 +Y31 F
Z213:Y51+Y55+Y59 +Y63 F
Z214:Y20+ Y24+Y28 +Y32 F
Z215:Y52+Y56+Y60 +Y64 F
Z216:((Z200xZ200)+(Z201xZ201) +(Z202xZ202)+ (Z203xZ203))/4. F
Z217:((Z204xZ204)+(Z205xZ205) +(Z206xZ206)+ (Z207xZ207))/4. F
Z218:((Z208xZ208)+(Z209xZ209)+ (Z210xZ210)+ (Z211xZ211))/4. F
Z219:((Z212xZ212)+(Z213xZ213)+ (Z214xZ214)+ (Z215xZ215))/4. F
Z220:Z82+Z84+Z86+Z92 +Z93+Z95 F
Z97:Z216+Z217+Z218+ Z219 -Z220 F

Z200:Y1+Y5+Y17+Y21 F
Z201:Y33+Y37+Y49+Y53 F
Z202:Y2+Y6+Y18+Y22 F
Z203:Y34+Y38+Y50+Y54 F
Z204:Y3+Y7+Y19+Y23 F
Z205:Y35+Y39+Y51+Y55 F
Z206:Y4+Y8+Y20+Y24 F
Z207:Y36+Y40+Y52+Y56 F
Z208:Y9+Y13+Y25+Y29 F
Z209:Y41+Y45+Y57+Y61 F
Z210:Y10+Y14+Y26+Y30 F
Z211:Y42+Y46+Y58+Y62 F
Z212:Y11+Y15+Y27+Y31 F
Z213:Y43+Y47+Y59+Y63 F
Z214:Y12+Y16+Y28+Y32 F
Z215:Y44+Y48+Y60+Y64 F
Z216:((Z200xZ200)+(Z201xZ201)+(Z202xZ202)+(Z203xZ203))/4. F
Z217:((Z204xZ204)+(Z205xZ205)+(Z206xZ206)+(Z207xZ207))/4. F
Z218:((Z208xZ208)+(Z209xZ209)+(Z210xZ210)+(Z211xZ211))/4. F
Z219:((Z212xZ212)+(Z213xZ213)+(Z214xZ214)+(Z215xZ215))/4. F
Z220:Z82+Z85+Z86+Z89+Z92+Z94+Z95 F
Z98: Z216+Z217+Z218+Z219-Z220 F

Z200:Y1+Y5 F
Z201:Y2+Y6 F
Z202:Y3+Y7 F
Z203:Y4+Y8 F
Z204:Y9+Y13 F
Z205:Y10+Y14 F
Z206:Y11+Y15 F
Z207:Y12+Y16 F
Z208:Y17+Y21 F
Z209:Y18+Y22 F
Z210:Y19+Y23 F
Z211:Y20+Y24 F
Z212:Y25+Y29 F
Z213:Y26+Y30 F
Z214:Y27+Y31 F
Z215:Y28+Y32 F
Z216:Y33+Y37 F
Z217:Y34+Y38 F
Z218:Y35+Y39 F
Z219:Y36+Y40 F
Z220:Y41+Y45 F
Z221:Y42+Y46 F
Z222:Y43+Y47 F

Z223:Y44+Y48 F
Z224:Y49+Y53 F
Z225:Y50+Y54 F
Z226:Y51+Y55 F
Z227:Y52+Y56 F
Z228:Y57+Y61 F
Z229:Y58+Y62 F
Z230:Y59+Y63 F
Z231:Y60+Y64 F

Z232:((Z200xZ200)+(Z201xZ201)+(Z202xZ202)+(Z203xZ203))/2. F
Z233:((Z204xZ204)+(Z205xZ205)+(Z206xZ206)+(Z207xZ207))/2. F
Z234:((Z208xZ208)+(Z209xZ209)+(Z210xZ210)+(Z211xZ211))/2. F
Z235:((Z212xZ212)+(Z213xZ213)+(Z214xZ214)+(Z215xZ215))/2. F
Z236:((Z216xZ216)+(Z217xZ217)+(Z218xZ218)+(Z219xZ219))/2. F
Z237:((Z220xZ220)+(Z221xZ221)+(Z222xZ222)+(Z223xZ223))/2. F
Z238:((Z224xZ224)+(Z225xZ225)+(Z226xZ226)+(Z227xZ227))/2. F
Z239:((Z228xZ228)+(Z229xZ229)+(Z230xZ230)+(Z231xZ231))/2. F
Z240:Z82+Z84+Z85+Z86+Z87+Z88+Z89+Z90+Z92+Z93+Z94
+Z95+Z96+Z97+Z98 F
Z99:Z232+Z233+Z234+Z235+Z236+Z237+Z238+Z239-Z240 F

Z100:Z83-Z84-Z85-Z86-Z87-Z88-Z89-Z90-Z91-Z92-Z93-Z94
-Z95-Z96-Z97-Z98-Z99 F

Z101:Z84 F
Z102:Z85 F
Z103:Z86/3. F
Z104:Z87 F
Z105:Z88/3. F
Z106:Z89/3. F
Z107:Z90/3. F
Z108:Z91/16. F
Z109:Z92 F
Z110:Z93 F
Z111:Z94 F
Z112:Z95/3. F
Z113:Z96 F
Z114:Z97/3. F
Z115:Z98/3. F
Z116:Z99/3. F
Z117:Z100/15. F

Z118:Z101/Z108 F
Z119:Z102/Z108 F
Z120:Z103/Z108 F

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        Z121:Z104/Z108                                F
        Z122:Z105/Z108                                F
        Z123:Z106/Z108                                F
        Z124:Z107/Z108                                F
        Z125:Z109/Z117                                F
        Z126:Z110/Z117                                F
        Z127:Z111/Z117                                F
        Z128:Z112/Z117                                F
        Z129:Z113/Z117                                F
        Z130:Z114/Z117                                F
        Z131:Z115/Z117                                F
        Z132:Z116/Z117                                F

        8, NO, 1, 1, 132,                             F
0008    TNO  TZNO                                     F

        9, NO, 0, 1, 132,                             F
0009    ZNO:0.                                        F

        10, NO, 1, 1, 24,                             F
0010    YNO:O                                         F

0011    G1                                           FF
```

APPENDIX B

A SAMPLE DATA SHEET
TO BE SENT TO THE COMPUTER CENTER

TEST ______________________

INTERVAL ______________________

Y VALUES (W)		Y VALUES (WW)	
1.	______	33.	______
2.	______	34.	______
3.	______	35.	______
4.	______	36.	______
5.	______	37.	______
6.	______	38.	______
7.	______	39.	______
8.	______	40.	______
9.	______	41.	______
10.	______	42.	______
11.	______	43.	______
12.	______	44.	______
13.	______	45.	______
14.	______	46.	______
15.	______	47.	______
16.	______	48.	______
17.	______	49.	______
18.	______	50.	______
19.	______	51.	______
20.	______	52.	______
21.	______	53.	______
22.	______	54.	______
23.	______	55.	______
24.	______	56.	______
25.	______	57.	______
26.	______	58.	______
27.	______	59.	______
28.	______	60.	______
29.	______	61.	______
30.	______	62.	______
31.	______	63.	______
32.	______	64.	______

APPENDIX C

KEY FOR DECODING THE ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Length (L)	1	Z 84	Z101	Z 118
Strength (S)	1	Z 85	Z102	Z 119
Universities (U)	3	Z 86	Z103	Z 120
L x S	1	Z 87	Z104	Z 121
L x U	3	Z 88	Z105	Z 122
S x U	3	Z 89	Z106	Z 123
L x S x U	3	Z 90	Z107	Z 124
Bales Treated Alike=E a.	16	Z 91	Z108	
W vs. WW	1	Z 92	Z109	Z 125
W vs. WW x L	1	Z 93	Z110	Z 126
W vs. WW x S	1	Z 94	Z111	Z 127
W vs. WW x U	3	Z 95	Z112	Z 128
W vs. WW x L x S	1	Z 96	Z113	Z 129
W vs. WW x L x U	3	Z 97	Z114	Z 130
W vs. WW x S x U	3	Z 98	Z115	Z 131
W vs. WW x L x S x U	3	Z 99	Z116	Z 132
E b.	16	Z100	Z117	
TOTAL	63	Z 83		

Degrees of Freedom:		1-16	3-16
F at	.05 =	4.49	3.24
	.01 =	8.53	5.29

APPENDIX D

F VALUES AND LEVEL OF PROBABILITY FOR DIFFERENCES IN FABRIC WEIGHT AND TEARING STRENGTH AT THE FIFTH AND FIFTEENTH INTERVALS

Source	Degrees of Freedom	Fabric Weight		Tearing Strength-W		Tearing Strength-F	
		5th Int.	15th Int.	5th Int.	15th Int.	5th Int.	15th Int.
Length (L)	1	1.41	1.28	132.32**	48.88**	165.64**	42.86**
Strength (S)	1	.02	.06	45.22**	43.08**	44.38**	33.76**
Universities (U)	3	3.48*	13.86**	12.50**	5.49**	18.39**	21.77**
L x S	1	.20	.14	.78	.26	2.71	.63
L x U	3	.09	.09	.49	3.89*	1.27	6.28**
S x U	3	.13	.00	.26	.46	.16	1.16
L x S x U	3	.08	.04	.48	.55	.11	.87
Bales Treated Alike=E a.	16						
W vs. WW	1	9.08**	.83	75.06**	29.26*	71.86**	23.88*
W vs. WW x L	1	.30	.43	16.06**	11.07**	19.00**	4.86
W vs. WW x S	1	.07	.25	10.63**	5.28*	3.86	.55
W vs. WW x U	3	.20	1.57	5.46**	13.62**	5.35**	17.42**
W vs. WW x L x S	1	.88	.26	4.80*	1.13	2.63	.00
W vs. WW x L x U	3	.90	.68	.59	2.33	.44	3.75*
W vs. WW x S x U	3	1.28	.17	.56	.14	.34	1.72
W vs. WW x L x S x U	3	1.90	.87	.79	.97	1.07	1.75
E b.							
TOTAL	63						

*Significant at the five per cent level of probability.

**Significant at the one per cent level of probability.