Technical Bulletin 104 January 1935

University of Minnesota
Agricultural Experiment Station

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The Relationships Between Physical Properties and Cost of Staple Wool Materials

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SUMMARY

Wool dress flannels, serges, and gabardines have been studied (1) to show what relationships may exist between price and certain measurable properties which are associated with service, and (2) to show what relationships may be found among these several properties which might aid the consumer in selection when service is desired. The properties or variables measured were thickness, weight per square yard, number of yarns per inch, tensile strength of fabric, bursting strength, elongation of fabric under stress, shrinkage, resistance to abrasion, twist of yarns, size of yarns, tensile strength of yarns, and elongation of yarns under stress. Shrinkage was calculated for area, as well as for both the warp and filling directions.

Actually, only a few significant relationships were found between price per square yard and the variables measured. These few were scattered and were different for all three groups of fabrics with one exception, percentage shrinkage in area decreased with increasing price for flannels and gabardines. It must be concluded, therefore, that price, in the case of these three kinds of fabrics, is not an adequate guide in selection on any basis except cost to the consumer.

The number of significant relationships among the variable properties for each of the three groups were not uniform, and about twice as many were found for flannels as for either serges or gabardines. Those significant relationships which were common to all three types of fabrics may be summarized briefly, and indicate a lack of constant structural relationships among the properties of staple wool materials.

1. The thickness of these fabrics increased with the size of the warp yarns, but this relationship may be masked by the influence of the number of warps per inch.
2. The number of fillings per inch increased as the number of warps increased.
3. Fabric strength increased with the number of yarns per inch when yarn strength was eliminated, and also with yarn strength if the influence of the number of yarns per inch was removed.
4. The bursting strength of these fabrics increased with tensile strength in the direction of the warp.
5. The percentage fabric elongation in the direction of the filling increased with the percentage elongation of the filling yarns.
6. Area shrinkage increased with fillingwise shrinkage.
7. The coarsest yarns were the strongest.
8. The finest warps had the greatest unit elongation under stress.
9. The strongest warps had the lowest unit elongation under stress and the highest percentage elongation.

Certain test methods were evaluated and compared.

A STUDY OF WOOL FLANNELS, SERGES, AND GABARDINES

THE RELATIONSHIPS BETWEEN PHYSICAL PROPERTIES AND COST OF STAPLE WOOL MATERIALS[1]

ETHEL L. PHELPS, ROSLYN GIRAUD,
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INTRODUCTION

Price is considered by many persons to be the most objective criterion of quality available to the consumer when purchasing textile fabrics. They believe that quality increases with increasing price, and that the greater the amount of money spent for a textile commodity, the greater will be the return. Undoubtedly the term "quality" often is used in a very general sense, so that it may not have the same meaning to two different persons or if applied to two different fabrics or types of fabrics by the same person. In the case of cotton batiste or wool challie high quality might imply fine yarns and sheer fabric, whereas for canvas the same term will suggest marked compactness and thickness of fabric. It is evident that quality is not necessarily commensurate with strength or resistance to wear, since it must be referred to the use intended for the fabric. In connection with use, in some cases quality may be associated more closely with finish or with uniformity or character of yarns and weave structure than with strength or other similar factors.

In certain cases fashion is placed before service in choosing fabrics for outer garments. In such cases appearance is probably the most important factor in determining choice of material. However, in other situations, service may be desired instead of fashion for specific garments, such as children's outdoor winter clothing, men's and women's suits and coats, uniforms, and other garments where fashion is not always a dominating influence in selection. Little is known specifically about the factors which influence serviceability of wool fabrics. The information gathered from experience by any one individual user is in-

[1] The authors are greatly indebted to Dr. Alan E. Treloar, assistant professor of biometry, for his assistance with the statistical analyses of these data, and to Miss Marion Weller, Miss Ethel Gorham, and Mrs. Mertie Buckman, of the Division of Home Economics, for criticism of the manuscript.

[2] Deceased.

adequate, since it must necessarily cover only a limited variety of fabrics over a long period of time.

Wool is an important agricultural product in certain regions and wool fabrics fill a very definite need in the clothing requirements of people living in climates where cold weather is experienced. Therefore, in view of this and of the foregoing, three staple types of wool fabrics have been studied in an attempt to determine, if possible, what measurable factors influence the serviceability of such materials and how variable such factors may be. Six serges, nine gabardines, and fourteen dress flannels were purchased in 1927 and 1928 in Minneapolis and Saint Paul from representative retail stores, jobbers, and mail order houses, representing three types of wool fabrics then available to city or country dwellers of Minnesota and the surrounding territory. Similar fabrics are in use at the present time, and it is not unlikely that inferences drawn from a study of these materials also would hold true for others of similar nature.

A fabric is a highly complex structure, varying with the character of the raw material used and influenced or modified in character and behavior by all of the processes to which either fiber or fabric are subjected in the course of manufacture. An attempt has been made to determine relationships and interrelationships among some of the measurable variables or distinguishing features of these fabrics. Thirteen such variables have been studied. These variables are: price per square yard, thickness, weight per square yard, number of yarns per inch, tensile strength of fabric, bursting strength, elongation of fabric under stress, shrinkage, resistance to abrasion, twist of yarns, size of yarns, tensile strength of yarns, and elongation of yarns under stress.

All of these factors are not equally important in determining the suitability of a wool fabric for any one purpose. However, each factor is important, directly or indirectly, in connection with some of the many uses to which such fabrics are subjected and also as a measure of the characteristics of the fabric. It is difficult to select any one fabric from a group as "best" in every respect, a situation which undoubtedly results from variations in manufacturing procedure, but the consumer, consciously or unconsciously, mentally weighs some of these varying features in the process of selection.

A picture of these fabrics from the aspect of each of the variable factors studied is presented here. The statements of relationships found among these variables refer to the three types of fabrics investigated, as determined by the particular fabrics of each type which were studied. It is hoped that this information may give to the purchaser a clearer understanding of the nature of, and afford assistance in the purchase of, wool fabrics.

GENERAL FINDINGS

A greater number of general statements can be made for flannels than for either serges or gabardines, since approximately twice as many significant relationships between the variables studied were found for flannels as for the other two types of fabric. This may be due to greater uniformity of construction in flannels. At the same time, there is a possibility that the finishing process known as "fulling," to which all flannels are subjected, may act as a coordinating force among the various components of the fabric in such a way that each affects the other to a greater extent than would be the case otherwise.

The general statements of relationships found among the flannels, serges, and gabardines studied, as indicated by statistical methods of analysis, have been summarized under some of the commonly recognized properties or variable factors measured. Each of these variables is discussed in an attempt to point out its value as a measure of other factors which may or may not be desired by the consumer of these textile fabrics.

Price.—After adjusting the prices of fabrics purchased from jobbers to comparable retail levels, price per square yard of these flannels, serges, and gabardines was compared with the other variables studied, and but few significant relationships were found. Based on these findings, only general statements can be made.

Increasing price of dress flannels was accompanied by an increase in fineness of warp yarns, which in turn was accompanied by an increase in number of yarns per inch. Fewer twists per inch in filling yarns, which may result in cloth of softer handle, were found as price per square yard increased. Also, there was less tendency to shrink in the direction of the warp and in area as price per square yard increased.

Tensile strength of serges in the direction of the warp increases as price per square yard increases.

Higher-priced gabardines were found to be most closely woven and to shrink least in the direction of the filling and in area. The three highest-priced gabardines were woven with a five-shaft, warp-faced, uneven twill weave, and it so happened that these were all purchased at retail stores.

Since only a few relationships were observed between price per square yard and other factors, it would appear that price is an inadequate guide in the evaluation and selection of wool flannels, serges, and gabardines on any basis other than cost to the consumer. In this connection it should be noted that retail prices to a certain degree reflect wholesale prices and may not be identical for similar fabrics if such have been purchased on a rapidly changing wholesale market. However, this possible variation in price is met in every-day practice by the retail consumer of yard goods.

Width.—Wool fabrics are commonly sold in widths varying from 36 to 54 inches. Of the fourteen flannels purchased, one measured barely 27 inches, two barely 36 inches, one slightly more than 36 inches, one barely 50 inches, one slightly more than 50 inches, two approximately 53 inches, and six more than 54 inches. Of six serges purchased, one fabric measured barely 40 inches, one slightly more than 42 inches, and four more than 54 inches. All nine gabardines purchased were more than 54 inches in width and six of the nine exceeded 55 inches in width.

Width is an important factor to consider in relation to price when purchasing fabrics. If the prices of fabrics of different widths were uniform, a relationship such as that shown below would prevail:

Width in inches	Square inches per running yard	Price per square yard
27	970	$1.31
36	1,296	1.00
40	1,440	0.90
50	1,800	0.72
54	1,944	0.67

Thus, if three fabrics—one 27 inches wide, one 36 inches wide, and one 54 inches wide—were each priced at $1 per linear yard, the narrowest fabric would cost twice as much as the widest and a third more than the medium-width fabric.

Width of fabric is also an important factor to consider in relation to the pattern of the garment to be made. A particular pattern of given size can often be placed upon the fabric with less waste of material if the fabric width has been chosen in accordance with the size and shape of the various pattern pieces. In this connection the relation of price to width is especially significant.

Weave structure and number of yarns per inch.—Weave structure may be an important factor in contributing to the properties of a piece of cloth. It varies with the manner of interlacing, which determines the length of floats on the surface, as well as the magnitude of the "binding effect" of the yarns. No one weave structure can be expected to produce a fabric that is superior in wearing quality and tear resistance as well as in tensile strength and elongation or elasticity. It is generally believed that, other factors being equal, a closely woven fabric with short floats will have high tensile strength and elongation and good wearing quality. On the other hand, high tear resistance requires freedom of movement of the yarns in the direction of the tear and strong yarns at right angles to the tear.

Of the fabrics studied, the flannels and serges were all woven with a four-shaft even twill weave, as shown in Figure 1, weave A. The gabardines were woven with three different weaves, as shown in Figure 1, weaves B, C, and D. With one exception, weaves B, C, and D correspond to the price range and are, respectively: a satin weave which tends to be more loosely woven than the other two; a simple three-shaft, warp-faced, uneven twill weave; and a compact, five-shaft, warp-faced, uneven twill weave which is more characteristic of gabardines than are the other two.

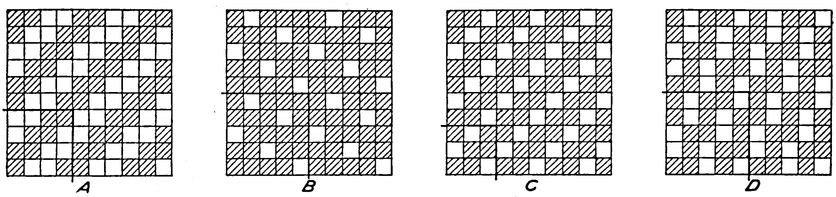

Fig. 1. Weave Structures Used in Wool Flannels, Serges, and Gabardines Studied

The only measurable descriptions of these types of weave structure are number of yarns per inch and twill angle, i.e., the slope of the diagonal line seen on the surface of the cloth, the latter tending to vary with the former. All of the flannels and serges were woven so as to have a normal, or 45-degree angle, twill, and the gabardines were all woven with a steep twill, that is, with a diagonal line forming an angle with the filling which measures more than 45 degrees.

Number of yarns per inch seems to be an important factor in contributing to the properties of these flannels. As the number of warps and fillings per inch is increased, the warpwise fabric strength increases, and both the warp and filling yarns are finer; the strength of filling yarns decreases and the filling yarns have greater twist; and there is a trend toward a thinner fabric with less resistance to wear by friction and less elongation under stress.

In the case of serges, as the number of warps per inch is increased, the number of fillings per inch increases correspondingly and the filling yarns are finer.

Since gabardines with the five-shaft, warp-faced, uneven twill weave (D) were woven with the greatest number of warps and fillings per inch, relationships found for the whole series of these fabrics may be colored by the effects of weave structure. However, an increase in the number of warps and fillings per inch was found to be accompanied by less tendency to shrink in area, by more tightly twisted yarns (hence less pliable yarns), and by an increase in price per square yard. By examining the original data it may be observed that gabardines with weave D have the largest number of warps per inch, were spun with the highest twist, are strongest in the filling direction, are medium in warpwise fabric strength, and shrink little if at all in width.

The fabrics with weave C were woven with strong two-ply warps and have fewest fillings per inch. They are strongest of all the gabardines in the direction of the warp and are most uniform in strength in the direction of the filling.

Gabardines with weave B were woven with the weakest filling yarns, are thinnest, and are weakest and most uniform in fabric strength in the direction of the warp.

Thickness.—Thickness may or may not be a characteristic desired when purchasing wool fabrics, depending on the uses intended for them. For warmth (resistance to transfer of heat) a maximum amount of dead air space built into the yarn and fabric is desirable and results in a thick fabric; for resistance to wind a closely woven, compact fabric is needed. For dresses to be worn in buildings with modern heating a thin, loosely woven fabric may be most comfortable.

The thickest wool flannels and serges are made with the coarsest yarns. Thick flannels are heavy and are made with less twist in the filling yarns. They have high resistance to wear by friction, but shrink considerably in both directions and in area.

The effect of thickness of serges on service factors could not be determined, but the yarns of the thickest fabrics are strongest and therefore probably would offer high resistance to tearing.

Like the flannels, thickest gabardines are also heaviest. They offer considerable resistance to bursting forces and to tension applied in the warp direction, and, unlike the heavy flannels, shrink less than the lighter weight gabardines in the direction of the filling.

Weight.—The heaviest flannels, serges, and gabardines were found to be thickest. Warpwise shrinkage increased with weight of flannels. Heavy serges are strongest in both directions and heavy gabardines are strongest in the direction of the warp, while both heavy serges and gabardines are most resistant to bursting forces. Heaviest gabardines are most closely woven in the direction of the warp.

Wearing quality of textile fabrics is a composite factor, which includes resistance to bursting forces, to tension imposed in a longitudinal or transverse direction and recovery from such stresses, and to wear by friction.

Recovery from stress was not studied in this investigation, but resistance to bursting forces, tension, and abrasion (friction) were studied in some detail.

Resistance to bursting forces increases as tensile strength of flannels in the direction of the warp increases and as strength of gabardines and serges increases in both directions. It also increases with weight of serges and gabardines and with thickness of gabardines. Bursting strength of flannels and gabardines increases with a decrease in shrinkage in the direction of the filling and in area. It also increases as the filling yarn strength of flannels decreases, as the filling yarn strength of gabardines increases, and as the warp yarn strength of serges increases.

Resistance to tension (tensile strength) of flannels, serges, and gabardines increases fundamentally in both directions as the yarn strength or the number of yarns per inch is increased. Thick, heavy gabardines are strongest in the direction of the warp. Heavy serges are strongest in both directions. Weight and thickness are not important in determining the strength of flannels, except as thickness results from the use of coarse yarns, which, in turn, are strongest and produce a strong fabric in the direction of the filling. Fine warps are found in gabardines that are strong in the warp direction, and coarse fillings in gabardines that are strong in the filling direction. Serges that are strong in the direction of the warp have more loosely twisted filling yarns. Strong flannels stretch less in the direction of the warp before rupture than do weaker flannels. Flannels that are strongest in the direction of the warp shrink little in width and in area, but lose much strength in the filling direction when abraded. Gabardines are stronger than flannels in both directions, while serges are stronger than flannels in the direction of the filling. Serges and gabardines are not widely different in strength.

Resistance to abrasion, contrary to popular acceptance, was not observed to be related to weight or twist of yarns for flannels and serges. Factors that influence the resistance of serges to abrasion could not be determined, but it was noted that those most resistant to abrasion in the direction of the warp are less likely to shrink in width and in area. The thinnest flannels, which were also closely woven of fine yarns, lost most strength when subjected to abrasion. Flannels showed a greater fillingwise elongation after abrasion than before. Also, flannels most resistant to abrasion in the direction of the filling shrank less in area and were most resistant warpwise.

Fabrics that have been fulled, i.e., finished by a process that works up a mat of fibers of variable thickness on the surface of the cloth, as in the case of flannels, do not lose as much strength fillingwise with a given amount of wear as do hard-finished fabrics of similar weave, such as serges. A probable reason is that the fundamental yarn does not begin to lose strength until the mat of fibers is worn off, while serge yarns are exposed immediately to the destructive action of the abradant.

Altho the serges studied were stronger than the flannels in the direction of the filling before being abraded, during abrasion they lost enough strength so that finally the two types of fabric were not significantly different in strength. Neither were they significantly different in elongation after being abraded.

Shrinkage.—Shrinkage is an important factor in the selection of wool fabrics, especially those to be used for children's garments which frequently come in contact with water. Also, since shrinkage may in some cases result from accidental wetting of wool fabrics, the shrinkage of wool materials used for outer garments is important to the consumer whether the garments are laundered or dry cleaned.

No marked difference in amount of shrinkage was observed for the three types of fabrics studied. Relationships for shrinkage in area are not identical with those for shrinkage in the direction of the warp or of the filling, altho area shrinkage is based upon both warp and filling shrinkage. As determined by shrinkage in area, marked shrinkage of serges is associated with marked shrinkage in width and with loss of strength warpwise after abrasion. A difference in factors affecting shrinkage of flannels and gabardines is apparent. Thick flannels made with coarse yarns set relatively far apart and loosely woven gabardines may be expected to shrink considerably. Such fabrics are low-priced and have low bursting strength. In addition, flannels that have low warpwise fabric strength and few twists in the filling, that lose strength fillingwise after abrasion, and that shrink most in length and in width shrink most in area.

METHOD

Conditioning.—Relative humidity and temperature are important factors in textiles testing. Outstanding effects of variation in atmospheric conditions have been noted in the case of weight, tensile strength, and elasticity. In general, weight and elasticity of animal fibers will increase, while their tensile strength will decrease, with increasing humidity (Shorter, 1923). In general, for a given relative humidity, the regain is less at a high temperature than at a low temperature but does not vary in a constant ratio (Hartshorne, 1918). Since many properties of textile materials vary with changes in relative humidity and temperature, two conditions, (1) testing after drying to constant weight at 100 degrees to 110 degrees C. and (2) testing under artificially maintained, standard conditions of temperature and relative humidity, are possible where comparisons of data are to be made. In the case of tensile strength of certain cotton fabrics, correction formulae have been developed so that testing can be carried out under prevailing atmospheric conditions and the values obtained corrected to standard regain.

In this study, in determining weight per square yard and yarn number, samples were dried to constant weight at 100 degrees C. ± 1 degree C. and the final values corrected for standard moisture regain. Shrinkage and yarn count determinations were made under prevailing atmospheric conditions, the latter being facilitated by the use of a light table. All other tests were made in a conditioning room after the material had reached equilibrium with the standard atmosphere, 70 degrees F. ± 2 degrees and 65 per cent relative humidity ± 2 per cent (American Society for Testing Materials, 1933).

Sampling.—All samples were taken far enough from the selvage to eliminate differences that might result from closer packing of the warp yarns in the selvage region. As far as possible, all samples for a given test were cut so as to contain a different set of both warp and filling yarns in order to insure random sampling. This arrangement was impossible in a few instances, but in such cases the samples all contained a different set of yarns in the direction of test. This alternate method corresponds to that described in the specification promulgated by the Federal Specifications Board (Bureau of Standards, 1925) and to that of the American Society for Testing Materials (1933), both of which require that all samples be cut with a different set of yarns in the direction of test only.

Width.—Width was determined at five different places uniformly distributed along the length of the fabric which was placed flat and without tension upon a table. Measurements were taken from edge to edge at right angles to the warp and read to the nearest sixteenth of an inch. The mean of the five measurements was taken as the width of the fabric (Federal Specifications Board, 1933).

Price per square yard.—Inasmuch as the fabrics chosen were of various widths as purchased, the price per square yard was determined in order that price might be expressed in comparable terms. Also for the sake of comparison, materials purchased from jobbers were marked up 50 per cent, which corresponds to 33⅓ per cent of the retail price, the customary retail mark-up for such fabrics. Each group of fabrics was finally arranged in the order of ascending price per square yard.

Thickness.—The fabrics were measured for thickness with a Starrett thickness gage. An interval of five seconds was allowed to elapse after the pointer ceased to move before the thickness was read on the dial to the nearest thousandth of an inch (Haven, 1932), and the mean of ten measurements was taken as the thickness of the fabric.

Weight per square yard.—Three samples, three inches by three inches, were used for the determination of weight (American Society for Testing Materials, 1933). These were dried to constant weight in a vacuum oven at a temperature of 100 degrees C. ± 1 degree C. A regain amounting to 11 per cent was added to the dry weight to allow for standard moisture regain (Matthews, 1924) and the weight per square yard was calculated by the following formula:

$$\text{Weight per square yard in ounces} = \frac{\text{weight of one square inch in grams}}{45.71}$$

$$\text{where } 45.71 = \frac{1{,}296 \text{ (square inches per square yard)}}{28.35 \text{ (grams per ounce)}}.$$

Yarn number.—Yarn number is a measure of the size of yarn, the number increasing as the size decreases. For woolen yarns, according to the "run" system, No. 1 yarn measures 1,600 yards (one "run") to the pound, No. 10, 16,000 yards to the pound. The numbering of worsted yarns is based on the number of 560-yard "hanks" in one pound of yarn, there being one "hank" in one pound of No. 1 worsted yarn, 10 "hanks" in one pound of No. 10 yarn (Matthews, 1924). To determine the yarn number of these fabrics, two samples totaling nine yards each of warp and of filling were raveled from representative places in each fabric. These were dried to constant weight at 100 degrees C. ± 1 degree C. and weighed in grams. The average of the two dry weights was taken as the weight of the yarn. Twelve per cent of the dry weight was added to the dry weight of the woolen yarns, and 15 per cent to the dry weight of the worsted yarns in order to allow for standard moisture regain (Matthews, 1924). Yarn number was calculated by the following formula:

$$\text{Yarn number} = K \times \frac{\text{length of sample in yards}}{\text{weight of sample in grams}}$$

where K = 0.28 for woolen yarns, and 0.81 for worsted yarns

$$\text{and } 0.28 = \frac{453.6 \text{ (grams per pound)}}{1{,}600 \text{ (yards per pound of No. 1 woolen yarn)}}$$

$$\text{and } 0.81 = \frac{453.6 \text{ (grams per pound)}}{560 \text{ (yards per pound of No. 1 worsted yarn)}}.$$

Twist.—Twist was determined with a Precision twist counter with the clamps set one inch apart. In the case of two-ply yarns, the ply twist was first determined, after which one ply was cut away and the singles twist was counted for the remaining strand, which had been adjusted exactly to a one-inch gage length. The mean of 10 values was taken as the twist of the yarn and was recorded as the number of twists per inch.

Number of yarns per inch.—The number of yarns per inch was counted on the strip and modified serigraph samples. The samples were raveled to exactly one inch, then placed over a light table and the yarns counted with the use of a Lowinson counter. The counts recorded are means of 10 determinations (American Society for Testing Materials, 1933).

Bursting strength.—Determinations of bursting strength test the resistance of a fabric to forces applied over a given area. This factor was measured both with pressure under a rubber diaphragm (Mullen tester) and with pressure exerted by a steel ball (ball-burst tester attachment used on a Scott universal tester). In the latter case force was applied at a rate of 12 inches per minute, and a 1-inch ball with a 1¾-inch ring was employed. A mean of 10 determinations was taken as the bursting strength by the diaphragm method for all correlations, except the comparison with bursting strength by the ball-burst method. Since only five determinations were made by the ball-burst method, the mean of the first five measures was taken as the bursting strength by the diaphragm method for all comparisons of these two tests.

Tensile strength and elongation of fabric.—Tensile strength and elongation of fabric were determined with a Scott universal tester of the inclination-balance type, set for a maximum capacity of 150 pounds, equipped with an autographic recorder, and having a pulling jaw speed of 12 inches per minute. Both the grab and the strip tests were used. For the grab test, samples were cut four inches by six inches in size and fastened in the machine so that tension was applied to the central one-inch by three-inch portion only. Specimens for the strip test were cut 1¼ inches wide if the number of yarns per inch was more than 50, and 1½ inches wide if the number per inch was less than 50. In both cases the samples were cut six inches long. They were raveled to exactly one inch in width, and placed in the tester so that tension was applied on the central three-inch portion. For comparison with the three-inch test, another strip test was made on samples cut long enough to provide six inches of fabric between the jaws. Strength was read on the dial of the machine and elongation from the autographic record marked on a chart at the time of test. The mean of five determinations for each was taken as the strength and elongation in both warp and filling directions (Federal Specifications Board, 1933).

Tensile strength and elongation of yarn.—Yarn strength was measured on a Scott single-strand tester with a possible maximum capacity of 500, 1,000, or 2,000 grams and equipped with an autographic recorder. Five strips of cloth in both warp and filling directions were cut 1 inch by 12 inches and five yarns for testing were raveled from each side of each strip. The jaws were set 15 centimeters apart, and the pulling jaw speed was six inches per minute. The force in grams necessary to break the yarn was read on the dial of the machine and also recorded on a chart from which elongation was read. A mean of the 50 tests each of warp and filling yarns was taken as the strength and elongation of warp and filling.

Tensile strength and elongation by modified serigraph test.—For the serigraph test 80 parallel yarns, three or four inches long, are fastened at the ends with a knot or piece of gummed paper and are broken as a unit. It has been used to test the strength of fine slippery yarns, such as those made of silk and rayon. Haven (1932) believes that it should give a good average of the strength of yarn. A modification of this test was devised by Hess (1932) to make possible its application to yarns woven into cloth, and this modification has been used in this study. It provides that specimens shall be cut 1¼ inches by 6 inches and the central three-inch portion of crosswise yarns removed. The strip is then raveled to exactly one inch in width. This procedure gives a one-inch strip of parallel yarns three inches in length, held together at each end by 1½ inches of original fabric. The specimens were broken in the Scott universal tester, being clamped in the jaws so that the inside edges of the jaws were exactly at the ends of the raveled central portion. The breaking force in pounds was read from the dial, and elongation in inches from a chart. The mean value of five such tests in each direction was taken as the modified serigraph strength and elongation for warp and for filling.

Abrasion.—Fabrics were abraded on an abrasion machine of the type designed by Haven (1932). Specimens were cut 6½ inches by 26 inches. Three such specimens cut in the direction of the warp and three in the direction of the filling permitted the testing of the fabric in both directions after it had been abraded both with the warp and the filling yarns under tension. Methods of operation of the machine as recommended by Haven (1932) were followed. No. 3/0 emery cloth was employed as the abradant, a new piece being used for each sample, and a pressure in ounces equal to the weight of the fabric per square yard placed on the abradant; a ¼-inch flexing roller was used, and a speed of 55 double strokes per minute was maintained. Altho a tension of 1½ to 2½ pounds is suggested by Haven (1932), a tension of four pounds was found to be more satisfactory in keeping the fabric flat upon the flexing roller, and this tension was used throughout the testing, inasmuch as all of the fabrics weighed less than seven ounces per square yard.

The number of rubs given a fabric must necessarily depend upon the nature of the material under test and has not been standardized. Preliminary tests were made on samples cut from some of the light-, medium-, and heavy-weight fabrics, thus attempting to establish the number of rubs necessary to reduce the strength of the medium-weight fabric about 50 per cent, while leaving sufficient strength in the lightest fabrics to permit a reliable test after abrasion, and at the same time to have a significant effect on the heaviest fabrics. One thousand double rubs were chosen, but owing to the wide variation in the fabrics studied, and to some unexpected reactions to abrasion, the aims of the preliminary tests were not fully realized. However, since the fabrics were all given the same treatment, and since the results were used only for comparative purposes, 1,000 double rubs proved to be fairly satisfactory for producing wear on this type of material. After being rubbed, the fabrics were allowed to rest over night before being broken by the grab method with the Scott universal tester. The means of five tests made in the direction of abrasion, and the means of five tests made opposite the direction of abrasion were taken as the strength and elongation of the fabric (a) after abrasion in the direction of test and (b) after abrasion opposite the direction of test, respectively.

When the data from this test were analyzed, it was found that a greater loss in strength was caused when the fabrics were rubbed opposite the direction of test than when they were rubbed with the testing direction under tension and that the loss in the latter case was statistically significant only for the flannels. For this reason those data were disregarded, and the analyses of losses due to abrasion were based on data from the samples abraded opposite the direction of test.

Shrinkage.—For the determination of shrinkage, the central six-inch by nine-inch area was marked with basting thread on seven-inch by ten-inch samples. Shrinkage was induced by immersing the samples in water at an initial temperature of 75 degrees C. and allowing them to soak over night. They were removed from the water without squeezing, hung over a rod until nearly dry, and pressed with a uniform number of vertical movements of the iron upon the fabric in such a way that distortion was avoided. The steaming samples were dried thoroly before the central area was measured. The difference in size due to shrinkage was measured in inches. Three such determinations were made on each fabric and the mean of the three values taken as the shrinkage in inches. The percentage shrinkage, warpwise, fillingwise, and in area, was calculated from the original dimensions of the sample.

Statistical treatment.—Altho exact methods for the analysis of data seem not to have been used as widely in this type of textile research as in some older fields, Tippett (1930) believes that their application is direct and recommends them for the evaluation of textile data. Statistical analyses have been used in this case since it is believed that conclusions drawn from such are more reliable than those drawn from visual analysis.

Throughout this study the assumption has been made that the distribution of the variables is normal. Slater (1932) has shown that the distribution of variables studied by him in a textiles testing laboratory are somewhat skewed, but not seriously so, and the use of "normal" theory is therefore appropriate for the discussion of means. The samples have been considered as "small," since in every case the number of samples studied was less than 25.

The measurement of type has been achieved by the arithmetic mean, $\overline{x}$, since this value represents the summation of a proportionate part of every individual in the series. In the formula

$$\overline{x} = \Sigma\,(x)\ /\ N$$

Σ is the summation sign, x the variable,[3] and N the number of variates in the series.

The deviation from type has been portrayed by the use of the standard deviation, s. This statistic has proven the most desirable description of variability. Its magnitude increases from zero, for complete agreement of all variates, to larger numbers as the dispersal increases. The fundamental formula used is

$$s_x = \sqrt{\Sigma\,(x - \overline{x})^2\ /\ (N - 1)}.$$

The -1 is a correction factor, effectively drawn to the attention of biologists by Fisher (1932), to take into account the fact that the mean of a sample may not exactly equal the mean of the supply, and hence the standard deviation of the sample would tend to be smaller than that of the supply.

The coefficient of correlation, r, serves as a measure of the interdependence of two series of correlated variables. It compares the association of two variables in relation to their relative deviation about their means. The magnitude of the correlation coefficient varies from plus one for perfect relationship, through zero for none, to minus one for perfect inverse relationship. The fundamental formula used herein is

$$r_{xy} = \frac{\Sigma_{xy}\ /\ N - \overline{x}\overline{y}}{[(N-1)\ /\ N]\ s_x s_y}$$

where x represents one series of variates and y the other series. The use of the correction factor $(N-1)\ /\ N$ in the denominator is neces-

[3] There is much confusion in the use of the terms variable and variate. Herein the character measured will be designated as the variable and the individual measures of that character as the variates.

sary since the formula for s employed involves $(N - 1)$ degrees of freedom instead of N. To decide whether a given value of r was significantly different from zero, Fisher's (1932) Table V.A. of the values of the correlation coefficient for different levels of significance was used. A level of significance of 0.05 was chosen, to accord with customary usage.

The relationship between two variables when the influence of other variables is eliminated was determined by the use of the partial correlation coefficient, r. The formula used for the elimination of the influence of one variable[4] is

$$r_{1,2.3} = \frac{r_{1,2} - (r_{1,3}\ r_{2,3})}{\sqrt{(1 - r^2_{1,3})\ (1 - r^2_{2,3})}}.$$

The formula employed for the elimination of the influence of two variables is

$$r_{1,2.3.4} = \frac{r_{1,2.4} - (r_{1,3.4}\ r_{2,3.4})}{\sqrt{(1 - r^2_{1,3.4})\ (1 - r^2_{2,3.4})}}.$$

Fisher t test was used for the determination of the probability of occurrence of the difference between two means (Fisher, 1925) in cases where the variables were paired. The formula used is

$$t = \bar{d}\ \sqrt{N}\ /\ s_d$$

$$\text{where } \bar{d} = \bar{x} - \bar{y} \text{ and } s_d = \sqrt{s_x^2 + s_y^2 - (2r_{xy}s_xs_y)}.$$

From t, P was found from the "Table of the Probability Integral of 'Students' Distribution" ("Student," 1925), and P' calculated from the formula

$$P' = 2\ (1 - P).$$

If the value of P' was less than 0.05, the difference between the means was considered to be significant.

To determine the significance of the difference between means of unpaired variables (values from different types of fabrics), Fisher's (1932) method for the application of "Students" distribution was used. In this case

$$t = \frac{(\bar{x}_1 - \bar{x}_2)\ \sqrt{N_1 + N_2 - 2}}{\sqrt{(N_1 - 1)\ s_1^2 + (N_2 - 1)\ s_2^2}} \sqrt{\frac{N_1N_2}{N_1 + N_2}}.$$

The -1 in the denominator is a correction factor introduced to compensate for the use of Fisher's s. Since $(N_1 + N_2 - 2)$ was less than

[4] A comma is used to separate the numerals indicating the variables involved, since some variables are represented by numerals containing two digits.

30 in every case, the probability integral tables of t ("Student," 1925; or Fisher, 1932) were used to determine the significance of the value obtained.

To test for the significance of the difference in the variability of two series of data, Fisher's (1932) logarithmic transformation, z, of the quotient of the two standard deviations was used.

$$z = 2.3026 \log_{10} \frac{s_1}{s_2}$$

Table VI, "Table of one per cent points of the distribution of z" (Fisher, 1932) was used in the determination of the significance of the difference.

In all cases the magnitude of the variate reported is the average of a series of determinations made on sub-samples from each fabric. From such records the average precision of the testing method employed may be estimated as a standard deviation, σ, by dividing the mean standard deviation (Pearsonian formula) of the replicates by the factor (Table 17 of Pearson, 1931) appropriate to the number of replicates. Assuming a normal distribution of these errors, the central 99 per cent (approximately) of range of error may be secured by multiplying σ by the factor 5. The mean of N replicates on an "average" fabric may then be expected to vary over the range $5\sigma / \sqrt{N}$. If a maximum permissible range of accuracy (or tolerance, T) be established, then the number of replicates necessary to confine the variation in the means to this range is given by the expression

$$N = 25\sigma^2 / T^2.$$

DISCUSSION OF DATA AND CORRELATIONS

Complete data for the fabrics studied are found in the Appendix, together with calculated means, standard deviations, correlation coefficients, and results of tests for significance and precision. These will supplement the following discussion. Significant correlations are listed in summary form at the beginning of each section, followed by a brief comparison of results obtained with those recorded in the literature.

Price Per Square Yard

Flannels — Price per square yard increases as—
- yarn number of warps increases
- number of twists per inch of filling yarns increases
- percentage shrinkage in warp direction decreases
- percentage shrinkage in area decreases

Serges — Price per square yard increases as—
- tensile strength of fabric in warp direction increases

Gabardines Price per square yard increases as—
- number of warps per inch increases
- number of fillings per inch increases
- percentage shrinkage in filling direction decreases
- percentage shrinkage in area decreases

In other words, the most expensive flannels were made with the greatest number of warps per inch, had less tightly twisted filling yarns, and shrank the least; the most expensive serges were strongest in the direction of the warp; and the most expensive gabardines were most closely woven and shrank the least. Such relationships are not mentioned in the literature, but Griffith and Strow (1932) found weight and thickness of cotton fabrics to be closely related to price; Halgrim (1930) reported a direct relationship between price of women's coats and resistance to abrasion and weathering of the fabric of which they were made, and Cranor and Rice (1924) found a direct relationship between price and weight of serges. Tensile strength of serges in both directions was found to increase with weight per square yard (see page 25), and thus the direct relationship between price of serges and tensile strength in the direction of the warp may indicate a possible similar relationship with weight if a larger sample were studied.

Thickness

Flannels Increasing thickness is associated with—
- increasing weight per square yard
- increasing shrinkage in warp and filling directions and in area, depending upon number of yarns per inch
- increasing size of yarns in both directions, relationship with warps irrespective of number of warps per inch, but relationship with fillings depending upon number of fillings per inch
- decreasing number of yarns per inch in both directions, depending upon yarn size
- decreasing percentage loss of strength after abrasion in both warp and filling directions, depending upon size of yarn and number of yarns per inch
- decreasing filling twist, irrespective of size of filling yarns

Serges Increasing thickness is associated with—
- increasing yarn size in both directions, relationship with warps irrespective of number of warps per inch, with fillings depending upon number of fillings per inch
- increasing yarn strength in both directions, yarn strength in turn related to size of yarns
- increasing twist of both warps and fillings, if effect of size of yarn is eliminated

Gabardines Increasing thickness is associated with—
- increasing tensile strength of fabric in warp direction
- increasing bursting strength

increasing weight per square yard
increasing size of warp yarns, if influence of number of warps per inch is eliminated
decreasing shrinkage in filling direction

The inverse correlation obtained between thickness and filling twist in flannels, when the influence of yarn size is eliminated, corresponds to a statement by Herzfeld (1920): "In woolen yarns of equal number the thickness will vary in different samples on account of the differences in the twist." An opposite relationship between thickness and yarn twist was found for both warps and fillings from serges. It will be noted that for all three fabrics, increasing thickness is accompanied by coarser yarns, which, in turn, influence certain relationships between thickness and other factors, as also does the relationship, for flannels, between thickness and number of yarns per inch.

A relationship between thickness and weight of wool dress fabrics is indicated here, since significant positive correlation was found for flannels and gabardines, and the corresponding correlation for serges was only slightly under the adopted level of significance.

Weight Per Square Yard

Flannels Increasing weight per square yard is associated with—
increasing shrinkage in warp direction
increasing thickness
decreasing twist of filling yarns

Serges Increasing weight per square yard is associated with—
increasing fabric strength warpwise and fillingwise
increasing bursting strength
increasing yarn strength of warps and fillings
increasing size of warps, if number of warps per inch is eliminated

Gabardines Increasing weight per square yard is associated with—
increasing thickness
increasing fabric strength in warp direction
increasing bursting strength
increasing number of warps per inch, if size of warps is eliminated
increasing twist of warp yarns, if size of warps is eliminated

One might expect to find weight of fabric influenced by size of yarns and number of yarns per inch. Such relationship was found with size of yarns only in serges, and with number of yarns per inch only in gabardines. However, since a relationship between weight and thickness has been indicated, and since thickness and size of yarn are closely related, as are size of yarn and number of yarns per inch for flannels and serges, it is probable that in other cases significant correlation may be obtained when comparing weight per square yard with size of yarn and with number of yarns per inch.

Relationships between weight per square yard and number of warps per inch correspond to the observations of Barker and Midgley (1922), that weight of cloth can be varied by closeness of weaving. They also mention a relation between weight and thickness which likewise has been noted above. Wardell (1931) shows that weight increases with twist of cotton yarn at an increasing rate. Cranor and Rice (1924) report, from a study of 66 serges, that "twist varied with . . . . the weight of the cloth," and a relationship between weight and price. The inverse relationship found between weight per square yard and twist of flannel and gabardine fillings indicates merely that in these two cases the heaviest fabrics were made with loosely twisted filling yarns.

Number of Yarns Per Inch

Flannels — Increasing number of yarns per inch in both directions is accompanied by—
- increasing loss of strength after abrasion in both directions
- increasing tensile strength of fabric in warp direction
- decreasing size of warps and fillings
- decreasing shrinkage in both directions and in area
- decreasing thickness
- decreasing strength of filling yarns

Increasing number of warps per inch is accompanied by—
- decreasing number of twists per inch in filling yarns
- decreasing fabric elongation per inch per pound

Increasing number of fillings per inch is accompanied by—
- increasing number of twists per inch in filling yarns
- decreasing fabric elongation per inch per pound
- decreasing percentage fabric elongation

Serges — Increasing number of warp yarns per inch is accompanied by—
- increasing number of filling yarns per inch
- increasing fabric strength warpwise, if yarn strength of warps is eliminated
- increasing warp yarn strength, if warpwise fabric strength is eliminated
- decreasing size of filling yarns

Increasing number of filling yarns per inch is accompanied by—
- increasing number of warps per inch
- increasing fabric strength fillingwise, if strength of filling yarns is eliminated

Gabardines — Increasing number of warp yarns per inch is accompanied by—
- increasing price per square yard
- increasing number of filling yarns per inch
- increasing number of twists per inch of warp yarns
- increasing fabric strength in warp direction, if strength of warps is eliminated

decreasing shrinkage in area, irrespective of thickness

Increasing number of filling yarns per inch is accompanied by—
- increasing price per square yard
- increasing number of twists per inch of warp yarns
- increasing number of twists per inch of filling yarns
- increasing number of warps per inch
- increasing fabric strength in filling direction, if filling yarn strength is eliminated
- increasing shrinkage in filling direction, if thickness or size of filling is eliminated
- decreasing shrinkage in area, irrespective of thickness or size of filling

Priestman (1917), discussing certain worsted fabrics, states that fabric strength increases with increased number of yarns per inch, and Schiefer et al. (1933) report that a firm, closely woven cotton fabric has greater strength than one which is sleazy and open. Such a relationship was found for these fabrics, with the exception of flannels, in the direction of the filling. Essam (1928) reported an increase in extensibility of cotton fabrics with greater number of yarns per inch and Schiefer et al. (1933) made a similar observation for closely woven, firm fabrics. The opposite was observed in this study in the case of flannels, while no relationship was found for serges and gabardines.

Morton and Turner (1928) found closely woven cotton fabrics to be most resistant to friction. However, Simon (1933), who studied rayon lining fabrics, states that this relationship is not nearly as obvious and fixed as might be expected. In this study, the resistance of flannels to abrasion in both directions was found to increase as fewer yarns were used. Those flannels woven with fewest yarns per inch were also made of coarsest yarns, which was responsible for part of these relationships (see discussion on resistance to abrasion).

The inverse relationships found between number of yarns per inch and percentage shrinkage for flannels and gabardines were not surprising, since greater shrinkage might be expected of loosely woven fabrics.

Tensile Strength (strip test, 3-inch gage length)

Flannels — Warpwise fabric strength increases with—
- increasing bursting strength
- increasing number of warps per inch, irrespective of strength of warps
- increasing number of fillings per inch
- increasing yarn number of fillings
- increasing warp yarn strength, if influence of number of warps per inch is eliminated
- increasing loss of strength in filling direction after abrasion
- decreasing filling yarn strength

decreasing fabric elongation per inch per pound in direction of the warp
decreasing yarn number of warp yarns, if number of warps per inch is eliminated
decreasing shrinkage in filling direction and in area

Fillingwise fabric strength increases with—
increasing filling yarn strength, irrespective of number per inch
increasing number of fillings per inch, if filling yarn strength is eliminated

Serges — Warpwise fabric strength increases with—
increasing price per square yard
increasing weight per square yard
increasing bursting strength
increasing warp yarn strength, irrespective of number of warps per inch
increasing number of warps per inch, if warp strength is eliminated
increasing fabric elongation as percentage of original length
decreasing twist per inch of fillings
decreasing yarn number of warps, if number of warps per inch is eliminated

Fillingwise fabric strength increases with—
increasing weight per square yard
increasing number of fillings per inch, if filling yarn strength is eliminated
increasing bursting strength
increasing strength of filling yarns, irrespective of number of fillings per inch

Gabardines — Warpwise fabric strength increases with—
increasing thickness
increasing weight per square yard
increasing bursting strength
increasing yarn number of warps, irrespective of number of warps per inch
increasing warp yarn strength, irrespective of number of warps per inch
increasing number of warps per inch, if strength of warps is eliminated
increasing fabric elongation as percentage of original length

Fillingwise fabric strength increases with—
increasing bursting strength
increasing filling yarn strength, irrespective of number of fillings per inch
increasing number of fillings per inch, if filling yarn strength is eliminated
decreasing yarn number of fillings, depending on number of fillings per inch

From the above significant correlations, it may be stated that tensile strength of wool fabrics is closely related to other strength factors, such as bursting strength and yarn strength. Since strong yarns are also coarse, then greatest strength might be expected from those fabrics made wtih the coarsest yarns, but such was found only in flannels and serges in the warp direction, and gabardines in the direction of the filling. Strong serges and gabardines (in the warp direction) are also heaviest, but this relationship would not necessarily be expected for flannels, since the entangled fibers on the surface of the fulled cloth could increase the strength of the fabric regardless of its weight.

Priestman (1917), working with worsted cloths, and Morton and Turner (1928), with cotton fabrics, agree that the number of yarns per inch is a contributing factor to the tensile strength of a fabric as found here. Also Schiefer et al. (1933) claim yarn strength to be an important factor in the strength of cotton fabrics, as has been shown for these wool fabrics. Altho in but one case was relationship found between twist and tensile strength of the fabrics studied, references in the literature indicate such relationship (Priestman, 1917, 1920). Other important contributing factors mentioned in the literature are fiber elasticity, crimp, and scale structure of wool (Van der Merwe, 1923), and fiber strength of cotton (Goldthwait, 1929). It has been stated that cotton fabrics with high tensile strength have low tear resistance (Schiefer et al., 1933), and that serviceability or durability are not necessarily measured by tensile strength (Meredith, 1928; Laboratoriums Serivalor, 1932).

Bursting Strength

Flannels	Increasing bursting strength is accompanied by—
	increasing tensile strength of fabric in warp direction
	decreasing shrinkage in filling direction and in area
	decreasing strength of filling yarns
Serges	Increasing bursting strength is accompanied by—
	increasing weight per square yard
	increasing tensile strength of fabric in both directions
	increasing strength of warp yarns
Gabardines	Increasing bursting strength is accompanied by—
	increasing thickness
	increasing weight per square yard
	increasing tensile strength of fabric in both directions
	increasing strength of filling yarns
	decreasing shrinkage in filling direction and in area

Warpwise fabric strength of flannels is inversely related to strength of filling yarns, hence bursting strength may appear to increase as filling strength decreases. For this type of material, bursting strength does not automatically test the weaker of the two sets of yarns in a fabric, as Haven (1932) claims. Undoubtedly in this case the effect of finishing processes on strength must be taken into consideration. Further, the bursting strength of serges and gabardines is related to tensile strength of fabric both in warp and filling directions, while no relationship was found for either of these two types of fabric between warpwise fabric strength and fillingwise fabric strength. This would indicate that the bursting test measures cloth as a composite structure and does not separate and test the components of a fabric with one operation. Besides tensile strength, the bursting strength of serges and gabardines appears to depend also upon weight per square yard.

Elongation Under Stress

Two methods of expressing elongation under stress are recommended in the literature. In one case elongation is to be calculated as percentage increase in length of specimen (American Society for Testing Materials, 1933, and Federal Specifications Board, 1933). A second method expresses it as elongation per unit of gage length per unit of load applied (Haven, 1932). In this investigation, both methods have been used. However, to visualize clearly comparative elongation, it seems necessary to consider it in the light of the force applied in producing a given stretch. For example, if two specimens with a three-inch gage length be subjected to tension in a tensile strength machine, one breaking at 60 pounds and one at 90 pounds, and both show a total elongation of three-quarters inch at the point of rupture, a difference in behavior is obvious. The former yielded to elongation more readily than the latter since less force was required to stretch it a given distance. Calculating elongation as percentage increase in length does not show this real difference, since the percentage increase in length is the same for both specimens, i.e., 25 per cent. Using the second method, the elongation of the first specimen is found to be 0.00417 inch per inch of specimen per pound of load, while that of the second is 0.00278 inch per inch per pound of load. The first specimen thus appears to be one and one-half times as yielding as the second. In using this method it must be assumed that elongation is proportionately greater as the gage length of the specimen increases. If this assumption is erroneous, then the method could properly be used for comparative purposes only, if the data compared had been collected from samples of equal gage length, in which case nothing would be gained by expressing stretch in terms of unit length of specimen. Moreover, if the elongation were expressed simply as stretch per sample per unit of load, the advantage of the second method would be retained, while the variate would be a less extended decimal and thus easier to handle in calculation.

References to elongation in the literature are not extensive and are concerned principally wtih discussions of theory of stretch and of the effect of humidity and twist on elongation, while little concern is given to the effect of weave structure, size of yarns, number of yarns per inch, or finishing processes on elongation, or to the relationship between elongation of fabric or yarn and service factors.

Altho elongation expressed in terms of unit load may seem to give a truer picture of this factor, correlation coefficients were also calculated with elongation expressed as percentage increase in length, since this method is prescribed by the American Society for Testing Materials and the Federal Specification for Test Methods for Textiles, and since New and Gregson (1926), Turner (1928), Essam (1929), Ball (1932), Schiefer et al. (1933), and others have used this method.

Fabric Elongation, per unit of force per unit of gage length

Flannels — Warpwise fabric elongation increases with—
- decreasing number of warps per inch
- decreasing fabric strength in warp direction

Fillingwise fabric elongation increases with—
- decreasing number of fillings per inch
- decreasing warp yarn elongation

Serges — Fillingwise fabric elongation increases with—
- increasing twists of filling yarns

Gabardines — Fillingwise fabric elongation increases with—
- increasing twist of filling yarns
- increasing filling yarn elongation

The above significant correlations are so scattered that only two general statements may safely be made. In those fabrics which had been fulled (flannels), fabric elongation per unit of force is associated with a decreasing number of yarns per inch. In those fabrics which had not been fulled (serges and gabardines), fillingwise fabric elongation is associated with an increasing number of twists per inch in the filling yarns.

Fisher's *t* test indicates that flannels are significantly more yielding in the filling direction than are serges or gabardines. Since the difference between elongation of serges and of gabardines is not significant, and since serges and flannels are made with the same type of weave structure, the expectation that weave structure would have a marked influence on elongation of the fabrics studied is not supported.

Fabric Elongation, percentage increase in length

Flannels — Fillingwise fabric elongation increases with—
- increasing loss in percentage elongation after abrasion in warp direction
- increasing filling yarn elongation
- decreasing number of fillings per inch

Serges Warpwise fabric elongation increases with—
- increasing fabric strength in the same direction
- increasing fillingwise fabric elongation
- increasing warp yarn elongation

Fillingwise fabric elongation increases with—
- increasing warpwise fabric elongation
- increasing warp yarn elongation
- increasing filling yarn elongation
- decreasing twist of filling yarns

Gabardines Warpwise fabric elongation increases with—
- increasing fabric strength in the same direction
- increasing fillingwise fabric elongation
- increasing warp yarn elongation
- increasing filling yarn elongation (probably due to relation between warp and filling yarn elongation)

Fillingwise fabric elongation increases with—
- increasing warpwise fabric elongation
- increasing twist of filling yarns
- increasing warp yarn elongation (probably due to relation between warp and filling yarn elongation)
- increasing filling yarn elongation

It may be observed that the relationships between percentage elongation of fabric and other factors are almost identical for serges and gabardines in the direction of the warp, while in the direction of the filling, correlations with twist of filling yarns have opposite signs.

Essam (1928, 1929) and Schiefer et al. (1933) report that closeness of weave is important in determining the extensibility of cloth, and find that the percentage extensibility of cotton fabrics increases directly with number of yarns per inch. In this study, the opposite relationship was observed for flannels in the direction of the filling and no relationship was noted in any other case. Except for flannels, in the direction of the warp, an increase in fabric elongation was accompanied by a similar increase in yarn elongation. It has been stated that elongation and tensile strength of fabric are not necessarily directly related (Haven, 1932). Two such relationships were observed in this study, one for gabardines in the direction of the warp, and one for serges in the same direction.

According to Essam (1928), elongation of cotton fabrics depends in part upon twist of yarns. Such a relationship was observed for gabardines in the filling direction, but the opposite relationship was obtained for serges in the direction of the warp. Fabric elongation is said to be related also to wearing quality of acetate rayon fabrics (Simon, 1933), to weave of cotton fabrics (Essam, 1929), to regain of yarns in cotton fabrics (Essam, 1928), and to tear resistance of cotton fabrics (Schiefer et al., 1933). Regain and tear resistance were not included in this study, and but one significant correlation was obtained between fabric elongation and resistance to abrasion (flannel filling).

Shrinkage

Flannels — Shrinkage in area increases with—
- increasing thickness, depending on number of yarns per inch
- increasing shrinkage in warp direction
- increasing shrinkage in filling direction
- increasing size of warp yarns, depending on number per inch
- increasing size of filling yarns, depending on number per inch
- decreasing price per square yard
- decreasing number of warp yarns per inch, depending on thickness and size of warps
- decreasing number of filling yarns per inch, depending on thickness and size of filling yarns
- decreasing tensile strength of fabric in warp direction
- decreasing bursting strength
- decreasing loss of strength in filling direction after abrasion
- decreasing number of twists per inch in warp yarns, if size of warp yarns is eliminated
- decreasing number of twists per inch in filling yarns

Shrinkage in warp direction increases with—
- increasing thickness, depending on number of warps and fillings per inch
- increasing weight per square yard
- increasing shrinkage in area
- increasing size of warps, depending on number of warps per inch
- decreasing price per square yard
- decreasing number of warps per inch, depending on thickness and size of warps
- decreasing number of fillings per inch, depending on thickness
- decreasing number of twists per inch of filling yarns, irrespective of size of fillings

Shrinkage in filling direction increases with—
- increasing thickness, depending on number of warps and fillings per inch
- increasing shrinkage in area
- increasing size of filling yarns, depending on number per inch
- decreasing number of warps per inch, depending on thickness
- decreasing number of fillings per inch, depending on thickness and size of fillings
- decreasing fabric strength in direction of warp
- decreasing bursting strength
- decreasing number of twists per inch in filling yarns, depending on size of fillings

Serges — Shrinkage in area increases with—
- increasing shrinkage in filling direction
- increasing loss of strength after abrasion in warp direction

Shrinkage in filling direction increases with—
- increasing shrinkage in area
- increasing loss of strength after abrasion in warp direction

Gabardines Shrinkage in area increases with—
- increasing shrinkage in filling direction
- decreasing price per square yard
- decreasing number of filling yarns per inch, irrespective of size of filling yarns or thickness
- decreasing number of warps per inch, irrespective of thickness but depending on size of warps
- decreasing bursting strength
- decreasing size of filling yarns, if number of fillings per inch is eliminated

Shrinkage in warp direction increases with—
- decreasing twist of warp yarns, if size of warps is eliminated

Shrinkage in filling direction increases with—
- increasing shrinkage in area
- decreasing price per square yard
- decreasing thickness, irrespective of number of warps or fillings per inch
- decreasing number of fillings per inch, if thickness or size of filling yarns is eliminated
- decreasing bursting strength

In spite of the large number of significant simple correlations obtained when comparing shrinkage with other factors, none of these hold true for all three types of fabric studied except that shrinkage in area increases with shrinkage in the filling direction. Many depend upon interrelationships with other factors. A few relationships with increasing area shrinkage are common for flannels and gabardines. These are decreasing price per square yard, decreasing number of warp and filling yarns per inch, and decreasing bursting strength.

No significant difference in amount of shrinkage was noted between serges, gabardines, or flannels studied in this investigation. However, since they were all finished cloths when purchased, the exact character of manufacturing processes used could not be known, but the flannels had undoubtedly been fulled and the serges and gabardines not fulled.

The literature on the subject of shrinkage of wool fabrics is largely concerned with discussions of cause, which are directed toward the finishing process known as milling or fulling. From a study of unfinished wool fabrics, B(arker) and B(arker) (1926) conclude that worsted fabrics shrink more during a milling process than do woolen fabrics. This is of interest in view of the discussions of milling by Shorter (1923) and by Speakman and Stott (1931) insofar as parallel fibers are well arranged for traveling along each other in the direction of the root end. In this connection it should be noted that warpwise shrinkage of gabardines increases as the number of twists per inch of the warps is decreased, as does fillingwise shrinkage of flannels with decreasing filling twist.

To a limited extent, shrinkage may be expected from the release, by wetting, of strains resulting from manufacturing processes, as suggested by Shorter (1923) and by Speakman and Stott (1931). Therefore, uniform relationships might not necessarily be expected even with similar fabrics.

Resistance to Abrasion

Flannels Percentage loss of strength in the warp direction after abrasion increases as—
- number of warps and fillings per inch increases, relationships with warps irrespective of yarn number
- fillingwise loss of strength after abrasion increases
- yarn number of warps and fillings increases, depending on thickness
- thickness decreases, depending on number per inch or size of warps

Percentage loss of strength in the filling direction after abrasion increases as—
- number of warps and fillings per inch increases, relationship with fillings depending on yarn number
- tensile strength of fabric in warp direction increases
- percentage loss of strength in warp direction after abrasion increases
- yarn number of fillings increases, depending on thickness
- thickness decreases, depending on number per inch or size of fillings
- shrinkage in area decreases

Serges Percentage loss of strength after abrasion in the warp direction increases as—
- shrinkage in filling direction increases
- shrinkage in area increases

Gabardines Loss of strength after abrasion was not statistically significant in the filling direction, and reliable breaks on only four fabrics were obtained in the warp direction before abrasion. Therefore no correlations involving data from loss of strength after abrasion have been calculated.

Relationships of loss of strength after abrasion of flannels in both directions with number of warps per inch are not significant if number of fillings per inch is elimited, and neither are those with number of fillings per inch if number of warps is eliminated. Since relationships are indicated between the number of warps and the number of fillings per inch, between number of yarns per inch and size of warp and filling yarns, and between size of warp and filling yarns and thickness, it would seem that these factors, for flannels, are so closely connected that none of them can be eliminated from calculation without distorting the whole picture.

No reference is found in the literature to relationships between resistance to abrasion and size of yarns, or between resistance to abrasion and thickness. However, Simon (1933), working with rayon lining fabrics, found that such fabrics may sometimes wear better if not closely woven. In explanation he suggests that in closely woven fabrics yarns may rub together and so weaken each other. Kapff (1923), working with wool fabrics, observed an increase in resistance to wear as the twist of the yarn was increased to a certain limit. New (1927), working with flax yarns, also noted a direct correlation between resistance to wear and number of twists per inch, and indicates that this may be due to more complete binding of fiber strands with high twist. Rosenzweig (1932) states that excessive twist adversely affects elasticity and, therefore, durability. Morton and Turner (1928) report that cotton fabrics giving the greatest resistance to wear were made of yarns spun with soft singles twist and medium two-fold twist. No relationship between resistance to wear and twist of yarns of wool flannels, serges, and gabardines was found, even when the influence of size of yarn was eliminated.

Lewis and Cleary (1917) observed that, of four wool flag buntings, the heaviest offered the greatest resistance to the action of wind and weather in an exposure test. Both Rosenzweig (1932), comparing fabrics made from the five major textile fibers, and Matthew (1932), after studying linen fabrics, mention cloth structure, or weave, and the effects of finishing processes as important factors in determining durability. Apparently resistance to abrasion is markedly influenced by finishing processes, type of weave being constant, since in comparing loss of strength after abrasion of flannels and serges it has been found that, altho the losses were not uniform, flannels are more resistant to abrasion than are serges. The flannels lost a mean of 26.6 per cent of strength in the direction of the warp and 30.8 per cent of strength in the direction of the filling, while corresponding losses for serges were 41.6 per cent and 60.1 per cent, respectively.

Rosenzweig (1932) and Simon (1933) suggest that elongation at break is a factor in wearing quality. Halgrim (1930) found that higher-priced women's coats tested 33 per cent better in an abrasion test and 48 per cent better in a weathering and abrasion test than did lower-priced coats which were comparable in type. Morton and Turner (1928), Matthew (1930), Heerman and Herzog (1931), the Laboratoriums Serivalor (1932), and Simon (1933) agree that high tensile strength does not necessarily indicate high resistance to abrasion. Morton and Turner (1928) also report that fabrics with a high tearing strength are not necessarily satisfactory from the standpoint of wearing quality.

Effects of abrasion have been variously stated and are summarized as: a loss of tensile strength, loss in thickness and weight, change in luster, and an increase in porosity to air (U. S. Institute for Textile Research, 1932). In this connection, luster refers to the sheen of a finished fabric and should not be confused with the "shine" that often develops on worsted fabrics after a period of service. Effects of abrasion on thickness, weight, luster, and porosity to air were not determined in this study, but a statistically significant decrease in tensile strength resulting from abrasion was observed in flannels and serges in both directions. Effects of abrasion on elongation were found to be contradictory, and statistically significant only for serges in both directions and for flannels in the filling direction. Elongation in the direction of the filling in both types of fabric increased, and in the direction of the warp of serges decreased, with increased abrasion.

Twist

Flannels
- Increasing twist of warp yarns is associated with—
  - decreasing shrinkage in area, if size of warp yarns is eliminated
- Increasing twist of filling yarns is associated with—
  - increasing price per square yard
  - increasing number of fillings per inch
  - increasing fineness of warp yarns
  - decreasing thickness
  - decreasing weight per square yard
  - decreasing number of warp yarns per inch
  - decreasing fabric shrinkage in warp direction, irrespective of size of fillings
  - decreasing fabric shrinkage in filling direction, depending on size of fillings
  - decreasing shrinkage in area

Serges
- Increasing twist of warp yarns is associated with—
  - increasing thickness, if influence of warp yarn number is eliminated
- Increasing twist of filling yarns is associated with—
  - increasing thickness, if influence of filling yarn number is eliminated
  - decreasing tensile strength of fabric in warp direction

Gabardines
- Increasing twist of warp yarn is associated with—
  - increasing price per square yard
  - increasing number of warps and fillings per inch
  - increasing weight per square yard, if size of warps is eliminated
  - decreasing shrinkage in warp direction, if warp size is eliminated
- Increasing twist of filling yarns is associated with—
  - increasing number of fillings per inch
  - increasing elongation of filling yarns per unit of force, if size of fillings is eliminated

Relationships between twist of yarns and elongation have been mentioned by other investigators. New and Gregson (1926) working with flax yarns, Wardell (1931) with cotton yarns, and Rudolph (1925) with jute yarns, state that extension, or elongation, increases with twist. Shinn (1930) and Möller (1930) make similar statements. On the other hand, English (1925) reports finding no evidence of twist influencing the extensibility of cotton yarns. Cranor and Rice (1924) observed that twist varied with finish and weight of serges. Wardell (1931) found that weight of yarn increased with increased twist, but not in the same ratio.

It will be noted that increasing twist of filling yarns was accompanied by decreasing thickness of flannels, while increasing twist of both warp and filling yarns from serges was accompanied by increasing thickness of fabric, if the influence of yarn number is eliminated. Less thickness with greater twist might be expected of yarns spun from fibers of the same diameter and with the same number of fibers in the cross section. If the influence of these two factors is ignored, such relationships would not necessarily be obtained. The positive correlation between twist of yarns and thickness, obtained for serges only when yarn size was theoretically held constant, cannot be explained either from the literature or from available experimental data.

Relationships observed between twist and number of yarns per inch in flannels and gabardines indicate that flannels and gabardines made of filling yarns of highest twist were most closely woven in the filling direction, and that gabardines made of warps of highest twist were most closely woven in both directions.

An indication, from scattered relationships, of less shrinkage with increased twist of yarns is entirely plausible. The twist of yarns used in these fabrics ranged from 8.8 to 21.3 turns per inch, and therefore none can be considered as very tightly twisted yarns which might shrink because of take-up due to twist and hence be expected to give a positive correlation between number of twists per inch and shrinkage.

Altho Schiefer et al. (1933) state that twist and strength of yarns from cotton fabrics are closely related, no such relationships were found for yarns from these flannels, serges, and gabardines. Brandt (1934) reports that the influence of number of twists per inch on the strength of cotton yarns varies with the size of the yarn. His data show that strength increases rapidly with twist of coarse yarns until a maximum is reached, beyond which point increased twist has slight effect, while opposite results were noted for fine yarns. Such relationships as these would not be indicated by methods of correlation analysis.

Yarn Number

Flannels As warp yarns become coarser—

- thickness increases, irrespective of number of warps per inch
- tensile strength of fabric in direction of warp increases, if number of warps per inch is eliminated
- shrinkage increases in warp direction and in area, depending on number of warps per inch
- resistance to abrasion in warp direction increases, depending on thickness
- filling yarns become coarser
- warp yarn strength increases, irrespective of twist
- price per square yard decreases
- number of yarns per inch decreases in both directions, the decrease in the warp direction depending on thickness
- twist of filling yarns decreases
- elongation per unit length of warp yarns decreases

As filling yarns become coarser—

- thickness increases, depending on number of filling yarns per inch
- resistance to abrasion increases in both directions
- warp yarns become coarser
- filling yarn strength increases, irrespective of twist
- number of warp yarns per inch decreases
- number of filling yarns per inch decreases, irrespective of thickness
- warpwise fabric strength decreases
- shrinkage in both filling direction and area, depending on number of fillings per inch, decreases
- elongation per unit length of filling yarns decreases, but percentage elongation increases

Serges As warp yarns become coarser—

- thickness increases, irrespective of number of warps per inch
- warp yarn strength increases, irrespective of twist per inch of warps
- filling yarn strength increases, probably because warp and filling strength are directly related
- unit elongation of warp yarns decreases, but percentage elongation increases
- weight per square yard increases, if influence of number of warp yarns per inch is eliminated
- tensile strength of fabric in warp direction increases, if influence of number of warps per inch is eliminated

As filling yarns become coarser—

- thickness increases, depending on number of fillings per inch
- number of warps per inch decreases
- filling yarn strength increases, irrespective of twist of fillings

Gabardines As warp yarns become coarser—

- tensile strength of fabric in warp direction decreases, irrespective of number of warps per inch
- warp yarn strength increases, irrespective of twist of warps

unit elongation of warp yarns decreases, but percentage elongation increases
thickness increases, if influence of number of warps per inch is eliminated

As filling yarns become coarser—
tensile strength of fabric in filling direction increases, depending on number of fillings per inch
shrinkage in area decreases, if number of fillings per inch is eliminated
yarn strength of fillings increases, irrespective of twist of fillings
unit elongation of fillings decreases

The relationships observed between size of yarn and yarn strength are comparable to those observed for worsted yarns by Ball (1932) and for cotton yarns by Sheldon (1927). Ball also noted a decrease in percentage elongation of worsted yarns as the yarn number increased, while the opposite relationship was observed for flannel fillings, and serge and gabardine warps.

Only one significant correlation indicating change in yarn number with change in twist of yarns was obtained for flannels, serges, and gabardines. This observation is in accord with statements by Moeller (1929) who found that diameter of yarn, rather than size (as indicated by yarn number), decreased wtih increased twist. To determine whether or not twist varied with yarn number for yarns of equivalent strength, correlation coefficients of twist with yarn number, while eliminating the influence of yarn strength, were calculated, but all of the values so obtained were below the required level for significance.

Size of yarns apparently influences thickness in two of these fabrics. Coarseness of warp yarns in flannels and serges is accompanied by increasing thickness, irrespective of number of warps per inch, while a similar relationship with coarseness of fillings depends on number of fillings per inch. In the case of gabardines coarse warps are associated with thick fabrics only if number of warps per inch is eliminated, and no relationship is found for fillings.

Yarn Strength

Flannels Warp yarn strength increases with—
increasing warpwise fabric strength, if number of warps per inch is eliminated
increasing size of warp yarn, irrespective of twist
decreasing unit elongation of warps depending on size of warps, but increasing percentage elongation of warps, irrespective of size

Filling yarn strength increases with—
increasing fabric strength in filling direction, irrespective of number of fillings per inch

increasing size of filling yarns, irrespective of twist
increasing unit elongation of fillings, if size of filling yarns is eliminated and increasing percentage elongation, irrespective of size of filling yarns
decreasing number of warps and fillings per inch
decreasing fabric strength in warp direction
decreasing bursting strength
decreasing elongation per unit length of filling yarns, depending on size of filling yarns

Serges — Warp yarn strength increases with—
increasing thickness
increasing weight per square yard
increasing number of warps per inch, if warpwise fabric strength is eliminated
increasing fabric strength in warp direction, irrespective of number of warps per inch
increasing bursting strength
increasing size of warp yarns, irrespective of twist
increasing strength of filling yarns
decreasing unit elongation of warp yarns, irrespective of size, but increasing percentage elongation depending on size

Filling yarn strength increases with—
increasing thickness
increasing weight per square yard
increasing fillingwise fabric strength, irrespective of number of fillings per inch
increasing size of warp and filling yarns, irrespective, for fillings, of twist of fillings
increasing strength of warp yarns
increasing percentage elongation of filling yarns, depending on size of fillings

Gabardines — Warp yarn strength increases with—
increasing warpwise fabric strength, irrespective of number of warps per inch
increasing size of warps, irrespective of warp twist
decreasing unit elongation, but increasing percentage elongation of warps, both depending on warp yarn number

Filling yarn strength increases with—
increasing fillingwise fabric strength, irrespective of number of fillings per inch
increasing bursting strength
increasing size of fillings, irrespective of filling twist

In the serges, warp and filling yarn strength were directly related and showed corresponding relationships with other factors. This uniformity was not observed for flannels or gabardines.

For these three types of fabrics yarn strength increases with size of yarn, irrespective of twist. Sheldon (1927), working with cotton yarns, also found a relationship between yarn strength and size of yarn, altho the two did not increase at the same rate. Ball (1932) reports a rapid increase in strength of worsted yarns with an increase in size.

Altho twist was not found to be a factor in the strength of yarns from the fabrics studied, other investigators have observed these two factors to be definitely related. Mercier and Schoffstall (1928), Mauver (1924), and Möller (1930) state that twist is an important factor contributing to the strength of yarn, while Essam (1928) reports that cotton yarn strength increases directly with twist, and Mercier and Schoffstall (1928) further point out that if twist of cotton yarns is continued beyond a certain limit, the strength of the yarn decreases. As a result, it can be said that the strength of a yarn may be unsatisfactory either because of excessive or insufficient twist. Mercier and Schoffstall (1928) and Moeller (1929) also indicate that maximum strength is obtained when the amount of twist imparted to the yarn is just enough to prevent slipping of fibers over each other, with minimum fiber strain, when force is applied to the yarn in a longitudinal direction. The above investigators apparently worked with yarns which had never been woven into cloth. It is not surprising to find that results obtained from a study of yarns raveled from fabrics do not agree closely with these. Moreover, Ball (1933) states that "there is no exact correlation between average twist, as usually determined, and minimum breaking strength."

Increasing strength of warp yarns is accompanied by decreasing unit yarn elongation, depending on yarn number in flannels and gabardines, but irrespective of this factor in serges. On the other hand, increasing warp yarn strength is accompanied by increasing percentage yarn elongation, depending on size of yarn in serges and gabardines, but irrespective of size in flannels. Yarn strength follows fabric strength, irrespective of number of yarns per inch, in every case except flannel warps, where the relationship is not significant unless number of warps is eliminated.

Yarn Elongation, per unit of length per unit of strength

Flannels — Warp yarn elongation increases with—
- decreasing fillingwise fabric elongation
- decreasing size of warp yarn, depending on strength of warps
- decreasing warp yarn strength, depending on size of warps

Filling yarn elongation increases with—
- increasing filling yarn strength, if influence of size of filling yarns is eliminated
- decreasing size of filling yarns, depending on strength of fillings
- decreasing filling yarn strength, depending on size of fillings

Serges — Warp yarn elongation increases with—
- decreasing size of warp yarns, depending on strength of warps
- decreasing warp yarn strength, depending on size of warps

Gabardines Warp yarn elongation increases with—
- increasing twist of warp yarns, irrespective of size of warps
- decreasing size of warp yarns, depending on strength of warps
- decreasing warp yarn strength, depending on size of warps

Filling yarn elongation increases with—
- increasing fabric elongation fillingwise
- increasing twist of filling yarns, irrespective of size of fillings
- decreasing fabric loss in elongation per unit by abrasion fillingwise
- decreasing size of filling yarns, depending on strength of fillings

By eliminating the effect of either yarn strength or size of yarn in correlations between elongation and either one of these two factors it is shown that these two variables are so closely related that they must be considered together in predicting the probable elongation of warp yarns from flannels, serges, and gabardines, and of filling yarns from flannels. In other words, for yarns of equal strength but varying size, no relationship is found between elongation and size of yarn; and for yarns of equal size but varying strength, no relationship is found between elongation and strength. However, as the factors of strength and size are both increased in a yarn, the elongation of that yarn will decrease proportionately. An interesting aspect of these interrelationships is noted in the case of the flannels, where it is indicated that, for filling yarns of equal size, elongation will increase as the yarns are made stronger, while if the stronger yarns are also coarser, elongation will be proportionately less.

Yarn Elongation, percentage increase in length

Flannels Warp yarn elongation increases as—
- warp yarn strength increases, irrespective of size of warps
- loss in elongation after abrasion in warp direction decreases

Filling yarn elongation increases as—
- fabric elongation in filling direction increases
- loss in elongation after abrasion in warp direction increases
- size of filling yarns increases, irrespective of strength of fillings
- filling yarn strength increases, irrespective of size of fillings

Serges Warp yarn elongation increases as—
- fabric elongation in warp and filling directions increases
- filling yarn elongation increases
- size of warps increases, depending on strength of warps
- warp yarn strength increases, irrespective of size of warps

Filling yarn elongation increases as—
- fabric elongation in filling direction increases
- warp yarn elongation increases
- filling yarn strength increases, depending on size of fillings

Gabardines Warp yarn elongation increases as—
- fabric elongation in both directions increases
- filling yarn elongation increases

size of warp yarns increases, depending on strength of warps
warp yarn strength increases, depending on size of warps
Filling yarn elongation increases as—
fabric elongation in both directions increases
warp yarn elongation increases
twist of filling yarns increases

It will be observed that relationships indicated here are not identical with those found when elongation is expressed in centimeters per gram per centimeter. In the case of the relationship between yarn elongation and yarn strength, a positive correlation, irrespective of size of yarn, with percentage elongation is obtained for flannel warps and fillings and for serge warps, but depending on size for serge fillings and gabardine warps. As previously noted, a negative correlation with yarn strength, depending on size of yarn, is found in four cases when elongation is expressed as per unit of force. Ball (1932) reports an increase in percentage elongation as size of yarn increases. However, only three such relationships were observed in this investigation, flannel fillings, and serge and gabardine warps. The reverse is seen to be true for unit yarn elongation with the exception of serge fillings. As noted under twist (page 35), several investigators have reported a relationship between yarn elongation and twist. A positive relationship between elongation of filling yarns from gabardines and the number of twists per inch of these yarns was observed with both methods of expressing elongation, and a similar relationship was found for gabardine warps with unit elongation.

Relationships That Are Constant For Flannels, Serges, and Gabardines

Correlations that are significant for all three types of fabrics studied are listed below, with the appropriate sign indicating positive or negative correlation.

Thickness and yarn number of warps, when number of warps per inch is eliminated	—
Number of warps per inch and number of fillings per inch	+
Warpwise fabric strength and number of warps per inch, when strength of warps is eliminated	+
Fillingwise fabric strength and number of fillings per inch, when strength of fillings is eliminated	+
Warpwise fabric strength and warp yarn strength, when number of warps per inch is eliminated	+
Fillingwise fabric strength and filling yarn strength, whether or not number of fillings per inch is eliminated	+
Warpwise fabric strength and bursting strength	+
Percentage fabric elongation in filling direction and percentage filling yarn elongation	+

Fillingwise shrinkage and area shrinkage	+
Yarn number of warps and warp yarn strength	−
Yarn number of fillings and filling yarn strength, whether or not twist is eliminated	−
Yarn number of warps and unit elongation of warps	+
Warp yarn strength and unit elongation of warps	−
Warp yarn strength and percentage elongation of warps	+

From the above correlations the following relationships hold true for each of these three types of wool fabrics:

Thickness of fabric increases with size of warp yarns, but the relationship may be masked by the influence of the number of warps per inch.

The number of fillings per inch increases as the number of warps increases.

Fabric strength increases with number of yarns per inch when yarn strength is eliminated, and vice versa.

Bursting strength of fabric increases with tensile strength in the direction of the warp.

Percentage fabric elongation in the direction of the filling increases with percentage elongation of filling yarns.

Area shrinkage increases with fillingwise shrinkage.

Coarsest yarns are strongest.

Finest warps have greatest unit elongation.

Strongest warps have lowest unit elongation under stress and highest percentage elongation.

The limited number of general statements which can be made for wool flannels, serges, and gabardines, fabrics which are suitable for similar uses, indicates the lack of constant relationship to be found among properties of wool fabrics, and the variability among fabrics which results from variations in raw material or manufacture.

Fabric Breaking Strength Tests

1. Three-inch Gage Length vs. Six-inch Gage Length, with Strip Method

From a comparison of tensile strength data, using a three-inch gage length and a six-inch gage length, it was found that strength values for the three-inch gage length were of greater magnitude than those for the six-inch gage length, but that their dispersal was not significantly different. A high correlation was obtained between the two series of variates, as well as identical relationships with other factors studied, with few exceptions.

In spite of the fact that the means of elongation at the breaking point in inches per pound per inch obtained by the two tests are not significantly different from each other in any case, significant correlation coefficients were obtained between the two series of data only for flannels in the warp direction and for serges and gabardines in the filling direction. In this connection it should be noted that the dispersal of the elongation data using the three-inch gage length was significantly greater than that using the six-inch gage length in the case of flannels in the filling direction and of gabardines in the warp direction, while the reverse was found in the case of serges in the warp direction.

2. Strip Method (three-inch gage length) vs. Grab Method

Testing the warpwise tensile strength of gabardines by the grab method involved considerable difficulty. Five of the fabrics (2, 5, 6, 8, 9) consistently broke at the jaw, which made it impossible to collect warpwise data on those fabrics by this method. Fabrics 2, 5, and 6 were woven with a simple three-shaft, warp-faced, uneven twill weave, and Nos. 8 and 9 were woven with a five-shaft, warp-faced, uneven twill weave. All five fabrics stretched considerably before breaking at the jaw. The three fabrics woven with a satin weave broke in the usual manner in the region between the jaws and with less stretch than those discussed above.

With five exceptions, all in the direction of the filling (flannel 13, serge 3, gabardines 2, 4, 7), the dispersal of the grab strength values about their means was greater than the corresponding dispersal of the strip strength values about their means. None of the exceptions noted above were significant at Fisher's 1 per cent point, but that of gabardine 7 was significantly different at the 5 per cent point. Of the 48 cases in which the grab test dispersal was greater than that of the strip test, 13 were significantly greater at the 1 per cent point, and 9 at the 5 per cent point.

Considering these two methods as applied to groups of flannels, serges, and gabardines, greater precision was obtained with the strip test than with the grab test, as is shown in Table 1, since the maximum deviation of any single break from the mean of the five, considering all samples in the series, is considerably less for the strip than for the grab method.

TABLE 1.—PRECISION OF TENSILE STRENGTH TESTS IN POUNDS (σ)

		Strip method	Grab method
Flannels	Warpwise	1.3	3.3
	Fillingwise	1.6	3.8
Serges	Warpwise	2.2	6.1
	Fillingwise	1.9	4.4
Gabardines	Warpwise	2.1	*
	Fillingwise	1.9	2.9

* Only 4 variates obtained.

Tensile strength values by the grab method are greater than the corresponding strip test values, but the greater precision found for the strip test is further indicated if deviations from the mean are considered as percentages of the mean of the group, as is shown in Table 2. For flannels and serges such values for the grab test are more than 50 per cent greater than those for the strip test.

TABLE 2.—PRECISION OF TENSILE STRENGTH TESTS IN PERCENTAGE DEVIATION FROM MEAN (σ)

		Strip method	Grab method
Flannels	Warpwise	5.0	8.8
	Fillingwise	11.8	18.5
Serges	Warpwise	6.6	12.6
	Fillingwise	8.3	14.4
Gabardines	Warpwise	4.7	*
	Fillingwise	9.9	11.5

* Only 4 variates obtained.

Furthermore, in order to obtain a precision of 1.5 pounds, it would have been necessary to break the number of samples indicated in Table 3.

TABLE 3.—NUMBER OF SAMPLES REQUIRED FOR PRECISION OF 1.5 POUNDS IN TENSILE STRENGTH TESTS

		Strip method	Grab method
Flannels	Warpwise	4	25
	Fillingwise	6	33
Serges	Warpwise	11	84
	Fillingwise	9	44
Gabardines	Warpwise	10	*
	Fillingwise	8	19

* Only 4 variates obtained.

Yarn Breaking Strength Test

Fifty yarns were broken in determining the strength of yarns from flannels, serges, and gabardines. This number is enough to give an approximately uniform average for yarns from this type of material and also provides a fairly uniform degree of precision as is seen in Table 4.

TABLE 4.—PRECISION OF TENSILE STRENGTH TESTS ON YARN, IN GRAMS (σ)

	Flannels	Serges	Gabardines
Warps	17.8	20.8	17.9
Fillings	13.4	18.9	14.6

In order to obtain a precision either of ten grams or of twenty grams, it would have been necessary to break the number of samples listed in Table 5.

TABLE 5.—NUMBER OF BREAKS REQUIRED FOR A GIVEN PRECISION IN YARN STRENGTH DETERMINATION

		Precision of 10 grams	Precision of 20 grams
Flannels	Warps	158.0	39.5
	Fillings	90.0	23.0
Serges	Warps	216.0	54.0
	Fillings	178.0	45.0
Gabardines	Warps	160.0	40.0
	Fillings	107.0	27.0

Bursting Strength Tests

1. Rubber Diaphragm vs. Ball-burst

Bursting strength data for wool flannels, serges, and gabardines using a tester with a rubber diaphragm have been compared with similar data using a ball-burst attachment on a tensile strength tester. A series of five breaks on each fabric was used for this comparison.

TABLE 6.—MEANS AND STANDARD DEVIATIONS FOR BURSTING STRENGTH DATA

	Flannels		Serges		Gabardines	
	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Rubber diaphragm	80.90000	5.2207	94.73333	19.8483	95.44444	12.4885
Ball-burst	51.37143	2.9278	63.60000	16.0286	58.35555	10.9925
Correlation between data for two tests	0.887		0.994		0.980	

______ Coefficient equal to or above required level for significance.

As is seen in Table 6, values for the rubber diaphragm test are approximately one-third higher than those for the ball-burst test in the case of all three of the fabrics studied, but they are not significantly different in dispersal as determined by Fisher's z test. Pickles (1931) states that "strength varies according to the diameter of the ball and not according to the area of the cross section of the ball" in a ball-burst test. Hence the size of the steel ball, and possibly the difference in size of clamps and rings used in the two tests, may have influenced the actual magnitude of the values obtained.

A significant correlation is observed between the two series of data in the case of all three fabrics. Deviations (in pounds) from the mean

TABLE 7.—DEVIATION FROM MEANS OF BURSTING STRENGTH VALUES

	Rubber diaphragm		Ball-burst	
	Pounds	Per cent	Pounds	Per cent
Flannels	4.5	5.6	3.9	7.6
Serges	4.3	4.5	5.0	7.9
Gabardines	5.2	5.4	5.0	8.6

of values for flannels and gabardines obtained by using the ball-burst test do not differ greatly from those obtained by using the rubber diaphragm test (Table 7). Deviations from the means as percentages of the total means for the two methods are also listed.

Modified Serigraph Test

The modification of the serigraph test used in this study has been recommended for the determination of the strength of yarns that have been woven into cloth, if equipment is not available for single yarn breaks. Results from this investigation show that the test as run is in reality a fabric rather than a yarn test and it compares favorably with the strip test.

When the values for each of these tests (serigraph and strip) are correlated with the values for other factors measured, significant coefficients of approximately the same degree are found for each with the same combination of factors and for the same type of fabric. In other words, with identical factors for comparison and approximately equivalent degrees of significance these methods of testing give identical results, except for a few scattered cases of low significance for the serigraph test in the direction of the filling.

On comparing significant relationships of the serigraph test with those of yarn strength, only a few cases are found where the correlation coefficient, with the same second variable and for the same group of fabrics, is significant. In these cases, with but one exception, the value of the correlation coefficient is lower for yarn strength, and only two of the scattered exceptions noted when comparing correlations of the serigraph and strip tests are included.

Strength per single yarn in grams may be calculated from the serigraph test by the following formula:

$$\text{Calculated yarn strength in grams} = \frac{\text{modified serigraph strength in pounds}}{\text{number of yarns per inch}} \times 453.6.$$

If such values are compared with those for observed yarn strength, it is seen that in every case the calculated values are greater than the observed values, the difference being approximatly 50 per cent and statistically significant. However, it should be remembered that the gage length of the serigraph samples was three inches, while that of the yarns broken on the single strand tester was 15 centimeters (5.9 inches). Therefore a difference between actual values is to be expected. A high correlation was obtained between the two sets of data. The standard deviations are not significantly different as determined by Fisher's z test using the 1 per cent point of the distribution of z.

Thus for flannels, serges, and gabardines the inference may be drawn that yarn strength values calculated from modified serigraph test values may be used satisfactorily instead of those from single strand tests in formulating a concept of yarn relationships, even tho the actual magnitude of the means is not identical.

Pickles (1931) reports the use of a method similar to this modified serigraph test to determine the effect of interlacing yarns on fabric strength. By examining the percentage difference in strength of flannels, serges, and gabardines as measured by the strip and serigraph tests, it may be observed that, with one exception (gabardine 8), interlacing of yarns has a greater effect on strength in the direction of the filling than in the direction of the warp. This may be due to the fact that in every case the number of warps per inch is greater than the number of fillings per inch, and hence a greater number of interlacings is disturbed when transverse yarns are removed prior to breaking the fabric in the direction of the filling. Weave structure, finish, and other factors are also important in this connection, as may be seen by an examination of the data. The gabardines with weave D are woven with more warps per inch than are those with weaves B and C. Yet the effect on total strength of the interlacing of warps in weave D was less than the effect of the interlacing of warps in weaves B and C. Furthermore, altho serges and flannels are woven with the same weave structure and the number of yarns per inch of the serges is higher in both directions than that of the flannels, the effect of interlacing is greater for flannels than for serges.

LITERATURE CITED

American Society for Testing Materials, Committee D-13. (1933) A. S. T. M. Specifications and Methods of Test for Textile Materials. Philadelphia: American Society for Testing Materials.

BALL, H. J. (1932) A Study of Single and Two-Ply Worsted Yarns. Bull. of Lowell Textile Inst. Series 35, No. 4, May.

———— (1933) Discussion of "Textiles as They Are." Rayon and Melliand Textile Monthly 14:34.

B(ARKER), A. F., and B(ARKER), K. C. (1926) The Shrinkage of Woollen and Worsted Cloths. J. Textile Science 1:79-82.

BARKER, A. F., and MIDGLEY, E. (1922) Analysis of Woven Fabrics. 2nd Rev. Ed. London. Scott, Greenwood and Son.

BRANDT, C. D. (1934) Twist and Strength. Textile World 84:247.

CRANOR, K. T., and RICE, J. V. (1924) Tests Leading Toward the Standardization of Serge. J. Home Econ. 16:314-20.

ENGLISH, W. (1925) Influence of Mule Spinning on Some Properties of Cotton Yarns. Part I—A Comparison of the Breaking Strength, Extensibility, and Regularity of Ring and Mule Spun Cotton Yarns. J. Textile Inst. 16:T97-113.

ESSAM, J. M. (1928) The Physical Properties of Fabrics: The Effect of Yarn and Weaving Structure. Part I. J. Textile Inst. 19:T37-58.

———— (1929) The Physical Properties of Fabrics: The Effects of Yarn and Weaving Structure. Part II. J. Textile Inst. 20:T275-93.

Federal Specifications Board (1933) Federal Specification for Textiles; Test Methods. Federal Standard Stock Catalog, Sec. IV, Part 5, CCC-T-191.

FISHER, R. A. (1925) Application of "Students" Distribution. Metron 5:3-17.

———— (1932) Statistical Methods for Research Workers. 4th Ed. London. Oliver and Boyd.

GOLDTHWAIT, F. (1929) Cotton—from Molecule to Mill. Textile Colorist 51:585-89.

GRIFFITH, M., and STROW, H. (1932) The Relation of Price to the Physical Characteristics of Some White Cotton Fabrics. Bimonthly Bulletin of the Ohio Agr. Expt. Station, No. 158, pp. 186-88.

HALGRIM, A. O. (1930) A Study of Women's Coats. S. Dak. Agr. Expt. Sta. Bull. No. 248, pp. 3-30.

HARTSHORNE, W. D. (1917) The Moisture Content of Textiles and Some of Its Effects. J. Am. Soc. Mech. Eng. 39:905-12.

HAVEN, G. B. (1932) Mechanical Fabrics. New York. John Wiley and Sons, Inc.

HEERMANN, P., und HERZOG, A. (1931) Mikroskopische und mechanisch—technische Textiluntersuchungen. Berlin. Verlog von Julius Springer.

HERZFELD, J. (1920) Technical Testing of Yarns and Textile Fabrics. 3rd Rev. Ed. London. Scott, Greenwood and Son.

HESS, K. (1932) Modified Serigraph Method Proves Valuable for Testing Yarns in Woven Fabrics. Textile World 81:25.

KAPFF, v. S. (1923) Über den Einfluss Chemischer und physikaliseher Einwirkungen auf die Wolle und die Prüfung der Tuche aug ihre Tragfähigkeit. Melliands' Textilber. 4:237-40.

Laboratoriums Serivalor. (1932) Die relative und absolute Dauer der Webstoffe. Melliands' Textilber. 13:188-91.

Lewis, W. S., and Cleary, C. J. (1918) Comparative Service Tests of Cotton and Wool Bunting. Proc. Second Annual Textile Conference. Bur. Standards Miscel. Pub. No. 19, pp. 41-45.

Matthew, J. A. (1930) A Cloth Wear Testing Machine. J. Textile Inst. 21:T546-60.

——— (1932) The Testing of Linen Fabrics From the Point of View of Their Uses. J. Textile Inst. 23:P113-21.

Matthews, J. M. (1924) Textile Fibers. 4th Ed. New York. John Wiley and Sons, Inc.

Mauver, E. (1924) Die Widerstandsfähigkeit der Baumwallfäden und der Wollbänder. Abs. in Rev. Text. 22:555-57. (Original not seen) Melliands' Textilber. 6:441 (1925).

Mercier, A. A., and Schoffstall, C. W. (1928) Effect of Twist on Cotton Yarns. Bur. Standards J. Research 1:733-50.

Meredith, R. S. (1928) Economics of Adulteration of Some Textile Fabrics. J. Textile Inst. 19:P78-83.

Moeller, E. (1929) Tensile Strength, Elasticity and Elongation in Yarn. The Melliand 1:10-13.

Möller, E. (1930) Testing the Strength and Elongation of Yarns. The Melliand 2:658-60.

Morton, W. E., and Turner, A. J. (1928) The Influence of the Degree of Twist in Yarns on the Results of Yarn Mercerization, and on the Properties of Plain Fabrics Made from Grey or Mercerized Cotton Yarns. Part II. The Results of Various Strength Tests on the Fabrics. J. Textile Inst. 19:T189-222.

New, G. T. (1927) The Measurement of the Resistance of Flax Yarns to Wear. J. Textile Inst. 18:T595-605.

——— and Gregson, A. L. (1926) The Behavior of Flax Yarns Under Repeated Impacts. J. Textile Inst. 17:T437-52.

Pearson, K. (1931) Tables for Statisticians and Biometricians. Part II. London. Cambridge University Press.

Pickles, F. (1931) The Strength of Fibres, Yarns, and Cloths. J. Textile Sci. 4:36-39.

Priestman, H. (1917) Shalloons, Cream Serge or Shell Cloth, Lastings. Textile World 53:1345, 1349.

——— (1920) Yarn Twist and Cloth Strength. Textile World 57:2535.

Rosenzweig, A. (1932) How Durable Are Textiles? A Way To Determine It. Textile World 81:1686-88.

Rudolph, H. (1925) Untersuchung Über die Zusammenhänge Zwischen Festigkeit und Drehung bei Jutegarnen. Melliands' Textilber. 6:770-71.

Schiefer, H. F., Cleveland, S., Porter, J., and Miller, J. (1933) Effect of Weave on the Properties of Cloth. Bur. Standards J. Research. 11:441-51.

Sheldon, A. N. (1927) The Mathematical Relation of Yarn Strength to Staple Length and Yarn Count. Textile World 72:314-16.

Shinn, W. E. (1930) The Elongation Factor in Cotton Fabrics. The Melliand 2:370-71.

SHORTER, S. A. (1923) The Moisture Content of Wool—its Relation to Scientific Theory and Commercial Practice. J. Soc. Dyers Colourists **39**: 270-76.

SIMON, L. (1933) Wearing Qualities of Synthetic Yarn Lining Fabrics and Methods Used in Testing. Melliand Textile Mo. **5**:108-10.

SLATER, F. P. (1932) The Significance of Results in Textile Testing. J. Textile Inst. **23**:P170-79.

SPEAKMAN, J. B., and STOTT, E. (1931) A Contribution To the Theory of Milling. Part I—A Method for Measuring the Scaliness of Wool Fibers. J. Textile Inst. **22**:T339-48.

"Student." (1925) New Tables for Testing the Significance of Observations. Metron **5**:18-21, 26-32.

TIPPETT, L. H. C. (1930) Statistical Methods in Textile Research. The Analysis of Complex Variations. J. Textile Inst. **21**:T105-26.

TURNER, A. J. (1928) The Relation Between Atmospheric Humidity and the Breaking Strengths and Extensibilities of Textile Fabrics Before and After Weathering. J. Textile Inst. **19**:T101-68.

U. S. Bureau of Standards. (1925) United States Government General Specification for Textile Materials (Methods of Physical and Chemical Tests). Bur. Standards Circ. No. 293; U. S. Gov't. Gen. Specif. No. 345.

U. S. Institute for Textile Research, Inc. (1932) Textile Research. A Survey of Progress. Cambridge. Mass. Inst. Technology Press.

VAN DER MERWE, A. R. (1923) Quality and Character in Wool. J. Dept. Agr., Union S. Africa (Original not seen). Abs. in Textile World **64**:711.

WARDELL, W. A., (1931) Effects of Twist on Strength, Elongation, Contraction, Weight, and Uniformity of Cotton Yarn. Textile World **79**:980, 981.

APPENDIX

TABLE I.—VALUES FOR VARIABLES OF WOOL FLANNELS, SERGES, AND GABARDINES STUDIED

Identification number of variable				1			2	3	4	5	6	7
Fabric		Weave structure*	Market	Retail price in dollars per linear yard	Retail price in dollars per square yard	Width in inches	Thickness in 1/1000 inches	Weight in ounces per square yard	Number of yarns per inch warpwise	Number of yarns per inch fillingwise	Tensile strength of fabric in pounds, strip test, 3-inch gage length warpwise	Tensile strength of fabric in pounds, strip test, 3-inch gage length fillingwise
Flannel	1	A	Mail order	0.97	0.93	37.50	20.7	4.40	39.1	33.8	18.8	14.0
	2	A	Mail order	1.67	1.18	50.50	25.3	5.72	47.8	33.4	25.2	14.2
	3	A	Mail order	1.89	1.22	54.90	17.5	4.20	69.2	49.6	30.1	13.4
	4	A	Retail	1.49	1.47	36.07	16.0	4.55	51.4	41.8	21.9	14.0
	5	A	Jobber	2.39	1.62	53.07	22.0	4.08	48.9	35.3	21.0	11.6
	6	A	Jobber	2.48	1.65	54.25	14.3	3.74	91.9	70.2	27.2	13.5
	7	A	Jobber	1.25	1.66	26.97	18.0	4.24	71.6	49.9	29.4	12.7
	8	A	Retail	2.63	1.69	55.15	14.1	4.26	91.3	69.6	28.6	13.6
	9	A	Jobber	2.63	1.73	54.02	17.8	3.70	70.0	50.4	29.4	11.9
	10	A	Retail	1.88	1.87	35.95	17.2	3.77	51.3	42.6	18.1	14.7
	11	A	Jobber	2.95	1.90	55.10	14.8	4.59	86.2	61.9	32.2	12.4
	12	A	Retail	2.95	1.94	54.25	18.9	4.38	70.1	49.4	30.1	11.8
	13	A	Retail	2.95	1.98	53.35	19.2	4.86	62.4	46.3	20.9	17.2
	14	A	Retail	2.95	2.12	49.60	17.6	4.28	71.2	50.5	32.2	14.3
Serge	1	A	Mail order	1.19	1.00	42.86	14.6	3.37	59.8	48.9	21.0	14.5
	2	A	Mail order	1.75	1.14	55.50	12.9	3.98	77.2	65.8	24.3	26.9
	3	A	Retail	2.95	1.94	54.67	15.3	5.03	77.9	60.9	39.8	26.3
	4	A	Jobber	2.93	1.95	54.05	11.8	3.81	92.7	71.4	31.8	19.0
	5	A	Jobber	2.48	2.22	40.27	11.4	3.74	92.0	71.5	30.8	17.1
	6	A	Retail	4.50	2.88	56.22	18.1	5.73	65.5	64.1	50.9	32.6
Gabardine	1	B	Mail order	1.98	1.28	55.86	15.5	4.47	84.9	56.8	30.5	26.1
	2	C	Mail order	2.69	1.79	54.11	16.8	5.20	90.5	55.4	50.3	16.8
	3	B	Mail order	3.19	2.06	55.68	12.4	3.82	107.3	64.2	30.9	13.0
	4	B	Jobber	3.38	2.20	55.31	16.2	4.70	91.5	60.5	33.0	21.0
	5	C	Jobber	3.68	2.41	54.86	17.1	5.51	90.9	55.6	53.2	19.2
	6	C	Jobber	3.86	2.51	55.28	16.6	5.28	90.2	55.7	49.6	16.2
	7	D	Retail	4.95	3.16	56.42	17.0	4.76	116.8	61.9	39.7	14.4
	8	D	Retail	5.95	3.81	56.28	20.8	7.12	122.7	70.1	68.3	26.4
	9	D	Retail	5.95	3.86	55.48	16.2	5.50	151.4	77.6	48.1	20.4

* See Figure 1, p. 9.

TABLE I—*Continued*

Fabric		8	9	10	11	12	13	14	15	16	17	18
		Bursting strength in pounds		Elongation of fabric, strip test, 3-inch gage length inches per pound tension		per cent of original length		Shrinkage, per cent			Tensile strength of fabric after abrasion,* in pounds, grab test	
		diaphragm	ball-burst	warpwise	fillingwise	warpwise	fillingwise	warpwise	fillingwise	in area	warpwise	fillingwise
Flannel	1	72.6	47.7	0.0088	0.0148	16.60	20.73	13.00	13.67	24.90	†	†
	2	83.2	53.1	0.0101	0.0162	25.40	22.93	11.33	6.55	17.20	36.0	22.8
	3	85.6	53.6	0.0053	0.0158	15.87	21.13	4.22	3.78	7.90	31.0	11.2
	4	72.7	48.9	0.0065	0.0151	14.20	21.13	4.66	4.66	9.10	†	†
	5	76.5	49.0	0.0085	0.0194	17.87	22.47	5.55	15.33	20.00	29.7	13.9
	6	79.4	49.7	0.0061	0.0120	16.67	16.27	4.22	2.11	6.30	15.4	13.0
	7	84.8	53.1	0.0055	0.0170	16.27	21.60	5.55	4.22	9.50	35.5	15.8
	8	81.2	51.7	0.0052	0.0128	15.00	17.47	5.55	4.22	9.50	9.7	9.3
	9	84.6	52.0	0.0048	0.0174	14.20	20.67	4.22	3.22	7.30	29.8	10.6
	10	71.6	48.2	0.0080	0.0156	14.53	22.87	4.89	7.44	12.00	21.4	20.0
	11	82.0	50.6	0.0067	0.0131	21.60	16.27	5.77	3.55	9.10	25.9	8.6
	12	84.6	54.1	0.0050	0.0168	15.07	19.87	5.11	6.78	11.50	30.9	15.0
	13	82.0	53.1	0.0099	0.0134	20.67	23.00	8.11	2.77	7.80	31.1	25.1
	14	88.3	56.9	0.0048	0.0166	15.47	23.80	3.78	1.00	4.70	38.7	7.1
Serge	1	69.4	43.6	0.0053	0.0077	11.13	11.13	4.00	1.22	5.20	16.2	10.3
	2	85.8	55.7	0.0049	0.0044	12.00	11.93	4.44	4.89	9.10	17.0	10.3
	3	110.0	78.7	0.0032	0.0081	12.87	21.27	3.67	1.89	5.50	36.4	1.9
	4	91.9	58.7	0.0048	0.0084	15.40	15.87	3.22	4.00	7.00	27.8	9.5‡
	6	128.9	89.8	0.0047	0.0077	24.13	25.00	4.88	7.67	12.20	17.2	4.5
	5	82.7	52.8	0.0031	0.0078	9.53	13.27	5.56	3.44	8.80	59.8	43.3
Gabardine	1	95.8	61.5	0.0049	0.0035	16.27	9.13	4.44	3.22	7.50	24.1	26.0
	2	90.6	51.4	0.0044	0.0054	21.93	9.13	6.22	4.22	10.20	61.8	20.8
	3	75.2	41.7	0.0042	0.0076	12.87	9.93	3.67	6.22	9.60	19.0	14.0
	4	97.5	63.3	0.0052	0.0076	17.07	15.87	4.40	2.56	6.90	20.7	17.0
	5	100.1	59.6	0.0052	0.0059	27.47	12.93	3.89	4.67	8.40	57.1	25.7
	6	90.3	51.4	0.0046	0.0064	22.87	10.33	4.22	4.22	8.30	63.2	21.7
	7	87.4	51.1	0.0064	0.0063	25.40	9.13	5.11	1.44	6.50	30.8	18.4
	8	123.3	81.1	0.0084	0.0098	57.07	25.80	4.88	0.00	4.90	84.8	46.3
	9	102.4	63.7	0.0071	0.0074	34.13	15.00	3.67	1.22	4.80	37.5	28.5

* Opposite direction of test. † No material for abrasion. ‡ Mean of three breaks.

TABLE I—*Continued*

Fabric		19	20	21	22	23	24	25	26	27	28
		Loss of strength from abrasion* in pounds		Loss of strength from abrasion* per cent		Elongation of fabric after abrasion,* inches per inch per pound, grab test		Change in elongation after abrasion,* per cent inches per inch per pound		Change in elongation after abrasion,* per cent per cent of original length	
		warpwise	fillingwise	warpwise	fillingwise	warpwise	fillingwise	warpwise	fillingwise	warpwise	fillingwise
Flannel	1	†	†	†	†	†	†	†	†	†	†
	2	5.4	2.6	13.0	10.2	0.0062	0.0120	0.00	+ 4.35	−12.90	− 5.83
	3	8.0	6.2	20.5	35.6	0.0045	0.0140	−11.76	+21.74	−29.67	−21.33
	4	†	†	†	†	†	†	†	†	†	†
	5	2.0	2.0	6.3	12.6	0.0069	0.0174	− 6.76	+27.94	−11.43	+11.38
	6	23.5	7.6	60.4	36.9	0.0048	0.0115	− 5.88	+22.61	−63.00	−18.55
	7	4.3	4.2	10.8	21.0	0.0045	0.0137	+ 2.27	+14.60	− 9.71	− 7.43
	8	32.3	16.1	76.9	63.4	0.0050	0.0106	− 5.66	+28.30	−78.37	−50.67
	9	6.9	6.8	18.8	39.1	0.0042	0.0133	− 2.33	+24.06	−21.26	−19.62
	10	3.6	0.6	14.4	2.9	0.0070	0.0112	+ 4.48	− 4.46	−10.40	− 7.03
	11	21.8	8.0	45.7	48.2	0.0041	0.0105	−21.15	+ 4.76	−57.07	−45.60
	12	14.9	5.0	32.5	25.0	0.0043	0.0139	− 4.44	+10.07	−36.32	−16.80
	13	1.6	1.5	4.9	5.6	0.0075	0.0100	+ 8.69	+ 6.00	+ 3.41	0.00
	14	7.1	16.1	15.5	69.4	0.0041	0.0162	− 8.89	+31.48	−24.16	−55.35
Serge	1	8.3	6.8	33.9	40.0	0.0056	0.0080	+ 3.70	− 3.75	−32.00	−41.65
	2	16.9	15.0	49.9	59.3	0.0039	0.0064	−40.71	+30.61	−70.67	−47.20
	3	18.4	34.7	33.6	94.8	0.0034	0.0211	−32.00	+181.33	−54.91	−85.45
	4	17.6	17.2	38.8	64.4	0.0033	0.0074	−42.11	+ 7.25	−64.65	−61.82
	5	28.1	18.6	62.0	80.5	0.0028	0.0089	−30.00	+28.99	−73.45	−74.74
	6	27.4	11.7	31.4	21.3	0.0029	0.0054	−17.14	+ 1.89	−44.00	−20.23
Gabardine	1	18.7	2.6	43.7	9.1	0.0038	0.0041	−19.15	+28.13	−54.33	+17.09
	2	‡	−0.9§	‡	−4.5§	0.0031	0.0063	‡	+16.67	‡	+21.85
	3	22.1	0.4	53.7	2.8	0.0030	0.0065	−23.08	−19.75	−63.79	−21.71
	4	27.4	8.1	56.9	3.3	0.0040	0.0078	− 6.98	+47.17	−60.00	− 6.35
	5	‡	0.2	‡	0.8	0.0032	0.0065	‡	− 2.99	‡	− 4.76
	6	‡	−1.2§	‡	−5.9§	0.0034	0.0053	‡	0.00	‡	+ 6.46
	7	33.7	−0.3§	52.2	−1.7§	0.0035	0.0045	−22.22	−25.00	−62.97	−23.08
	8	‡	−1.3§	‡	−2.9§	0.0033	0.0054	‡	−14.29	‡	−11.76
	9	‡	−0.1§	‡	−0.4§	0.0029	0.0067	‡	−11.84	‡	−12.00

* Opposite direction of test. † No material for abrasion. ‡ Fabric broke at jaw before abrasion. § (—) signifies a gain in strength.

TABLE I—*Continued*

Fabric		29 Twist of warp yarns: ply	direction of twist: singles	direction of twist: ply	number per inch: singles	number per inch: ply	30 Twist of filling yarns: ply	direction of twist	number per inch	31 Yarn number (size of yarn): warps	32 Yarn number (size of yarn): fillings	33 Tensile strength of yarns in grams: warps	34 Tensile strength of yarns in grams: fillings
Flannel	1	1	L		11.4		1	L	9.1	6.0	5.0	145.2	87.8
	2	1	L		12.2		1	L	8.8	4.0	4.5	*	*
	3	1	L		12.5		1	R	11.1	9.9	9.5	109.1	42.5
	4	1	L		14.1		1	L	11.3	10.0	10.0	107.9	91.9
	5	1	L		9.9		1	R	10.0	9.0	5.0	77.8	33.7
	6	1	R		11.7		1	R	13.4	15.0	16.0	65.4	22.6
	7	1	L		10.4		1	R	10.2	9.5	9.0	92.0	37.4
	8	1	R		14.3		1	R	12.4	14.0	15.0	67.4	25.3
	9	1	L		11.3		1	R	11.8	10.0	10.0	101.9	31.4
	10	1	L		13.9		1	L	13.0	10.0	5.0	79.3	94.7
	11	1	L		14.7		1	R	10.8	12.0	17.0	98.0	29.0
	12	1	L		11.1		1	R	12.7	9.5	10.0	105.3	25.5
	13	1	L		12.3		1	L	11.6	12.0	5.0	63.5	96.2
	14	1	L		11.0		1	R	12.5	10.0	10.0	119.8	59.2
Serge	1	1	L		12.2		1	R	11.2	32.0	31.0	89.2	65.6
	2	1	R		13.4		1	R	12.3	42.0	33.0	62.1	83.4
	3	1	R		12.1		1	R	10.3	28.0	32.0	127.7	98.0
	4	1	R		12.3		1	R	11.0	42.0	48.0	73.5	38.9
	5	1	R		11.7		1	R	11.1	41.0	45.0	69.2	29.3
	6	2	R	L	9.5	10.4	1	R	10.0	20.0	29.0	246.5	131.4
Gabardine	1	1	L		12.6		1	R	9.9	37.0	25.0	83.5	114.3
	2	2	R	L	12.3	14.7	1	R	9.2	2/26.0	41.0	164.6	54.2
	3	1	L		16.0		1	R	11.7	44.0	45.0	60.9	30.5
	4	1	L		13.1		1	R	10.9	38.0	30.0	78.7	80.7
	5	2	R	L	13.9	17.0	1	R	10.8	2/25.0	35.0	180.4	81.2
	6	2	R	L	12.3	13.2	1	R	9.7	2/25.0	41.0	165.0	60.8
	7	2	R	L	11.1	17.8	1	R	9.8	2/38.0	36.0	87.3	47.9
	8	1	L		17.4		1	R	13.0	26.0	36.0	165.3	99.6
	9	1	L		21.3		1	R	12.0	41.0	41.0	76.4	51.3

* Impossible to ravel sample.

TABLE I—*Continued*

Fabric		35 Elongation of yarns, cm. per cm. per gram: warps	36 Elongation of yarns, cm. per cm. per gram: fillings	37 Elongation of yarns, per cent of original length: warps	38 Elongation of yarns, per cent of original length: fillings	39 Tensile strength in pounds, modified serigraph test: warpwise	40 Tensile strength in pounds, modified serigraph test: fillingwise	41 Difference in strength due to interlacing yarns*, warpwise: pounds	42 Difference in strength due to interlacing yarns*, warpwise: per cent	43 Difference in strength due to interlacing yarns*, fillingwise: pounds	44 Difference in strength due to interlacing yarns*, fillingwise: per cent
Flannel	1	0.0015	0.0021	21.68	18.89	15.0	8.1	3.8	20.21	5.9	42.14
	2	†	†	†	†	†	†	†	†	†	†
	3	0.0015	0.0036	16.52	15.44	26.0	7.6	4.1	13.62	5.8	43.28
	4	0.0015	0.0028	15.72	25.51	18.4	11.0	3.5	15.93	3.0	21.43
	5	0.0017	0.0048	12.89	16.09	11.9	4.1	9.1	43.33	7.5	64.65
	6	0.0021	0.0052	13.56	11.80	22.6	8.9	4.6	16.91	4.6	34.07
	7	0.0017	0.0039	15.85	14.71	23.7	7.1	5.7	19.39	5.6	44.09
	8	0.0023	0.0057	15.56	14.47	24.1	9.7	4.5	15.73	3.9	28.68
	9	0.0014	0.0048	14.43	14.95	23.9	7.0	5.5	18.71	4.9	41.18
	10	0.0019	0.0026	15.00	25.08	14.3	10.9	3.8	20.99	3.8	25.85
	11	0.0023	0.0045	22.21	12.93	26.9	8.7	5.3	16.46	3.7	29.84
	12	0.0016	0.0051	17.33	13.12	26.3	8.8	3.8	12.62	3.0	25.42
	13	0.0025	0.0029	16.03	28.19	14.6	12.4	6.3	30.14	4.8	27.91
	14	0.0016	0.0030	19.59	17.59	27.6	9.2	4.6	14.29	5.1	35.66
Serge	1	0.0015	0.0023	13.12	15.12	17.8	12 1	3.2	15.24	2.4	16.55
	2	0.0021	0.0014	13.19	11.81	18.3	18.4	6.0	24.69	8.5	31.60
	3	0.0015	0.0017	18.69	16.92	33.1	20.5	6.7	16.83	5.8	22.05
	4	0.0021	0.0027	15.27	10.60	27.0	12.5	4.8	15.09	6.5	34.21
	5	0.0017	0.0038	11.67	11.16	25.8	11.4	5.0	16.23	5.7	33.33
	6	0.0011	0.0018	27.83	24.13	43.4	25.1	7.5	14.73	7.5	23.01
Gabardine	1	0.0017	0.0009	14.32	10.64	24.9	19.5	5.6	18.36	6.6	25.29
	2	0.0012	0.0018	19.84	9.53	39.7	11.2	10.6	21.07	5.6	33.33
	3	0.0020	0.0033	11.96	10.20	24.0	8.7	6.9	22.33	4.3	33.08
	4	0.0019	0.0018	14.96	14.19	25.8	14.7	7.2	21.82	6.3	30.00
	5	0.0012	0.0016	21.71	13.09	44.8	13.1	8.4	15.79	6.1	31.77
	6	0.0012	0.0017	19.56	10.12	41.8	11.7	7.8	15.73	4.5	27.78
	7	0.0020	0.0020	17.21	9.43	33.2	11.5	6.5	16.37	2.9	20.14
	8	0.0020	0.0025	33.52	24.81	53.6	22.1	14.7	21.52	4.3	16.29
	9	0.0024	0.0028	18.43	14.59	38.0	16.1	10.1	21.00	4.3	21.08

* Strength (3-inch gage length)—modified serigraph strength.
† Impossible to ravel sample.

TABLE I—*Continued*

Fabric		45	46	47	48	49	50	51	52	53	54
		Calculated yarn strength* in grams		Elongation, modified serigraph test				Tensile strength of fabric in pounds			
				inches per inch per pound		per cent of original length		strip test (6-inch gage length)		grab test	
		warps	fillings	warpwise	fillingwise	warpwise	fillingwise	warpwise	fillingwise	warpwise	fillingwise
Flannel	1	174.2	108.9	0.0111	0.0206	16.67	16.67	17.3	12.7	26.2	18.3
	2	†	†	†	†	†	†	23.6	11.6	41.4	25.4
	3	170.5	68.0	0.0047	0.0219	12.33	16.67	28.0	12.4	39.0	17.4
	4	162.4	119.3	0.0063	0.0178	11.53	19.60	20.4	13.3	29.4	19.8
	5	110.2	52.6	0.0103	0.0406	12.33	16.67	19.8	10.3	31.7	15.9
	6	111.6	57.6	0.0058	0.0121	13.20	10.73	25.4	12.0	38.9	20.6
	7	150.1	64.4	0.0056	0.0235	13.20	16.67	27.3	11.3	39.8	20.0
	8	119.7	63.1	0.0051	0.0172	12.33	16.67	25.8	12.4	42.0	25.4
	9	155.1	63.1	0.0048	0.0213	11.53	14.93	27.5	11.3	36.7	17.4
	10	126.5	116.1	0.0086	0.0207	12.33	22.53	17.4	12.7	25.0	20.6
	11	141.5	64.0	0.0062	0.0142	16.67	12.33	29.9	11.9	47.7	16.6
	12	170.1	80.7	0.0053	0.0256	14.07	22.53	27.8	10.8	45.8	20.0
	13	106.1	121.6	0.0084	0.0174	12.33	21.53	20.3	16.1	32.7	26.6
	14	176.0	82.5	0.0042	0.0197	11.53	18.13	30.0	13.2	45.8	23.2
Serge	1	135.2	112.0	0.0056	0.0082	9.93	9.93	19.7	12.8	24.5	17.1
	2.	107.5	127.0	0.0067	0.0045	12.33	8.33	22.3	23.0	33.9	25.3
	3	192.8	152.9	0.0027	0.0060	9.13	12.33	36.4	24.8	54.8	36.6
	4	132.0	79.4	0.0037	0.0067	9.93	8.33	30.9	17.5	45.4	26.7
	5	127.0	72.1	0.0025	0.0080	6.60	9.13	28.4	14.8	45.3	23.1
	6	300.7	177.4	0.0038	0.0066	16.67	16.67	47.5	31.4	87.2	55.0
Gabardine	1	132.9	155.6	0.0040	0.0043	9.93	8.33	29.3	23.9	42.8	28.6
	2	199.1	91.6	0.0031	0.0036	12.33	4.00	49.0	14.1	‡	19.9
	3	101.6	61.2	0.0035	0.0096	8.33	8.33	29.7	11.8	41.1	14.4
	4	127.9	110.2	0.0032	0.0084	8.33	12.40	31.3	19.1	48.1	25.1
	5	223.6	107.1	0.0035	0.0064	15.80	8.33	52.1	17.4	‡	25.9
	6	210.0	95.3	0.0034	0.0071	14.07	8.33	48.5	14.7	‡	20.5
	7	128.8	84.4	0.0040	0.0057	13.20	6.60	37.3	13.8	64.5	18.1
	8	198.2	142.9	0.0047	0.0060	25.00	13.27	66.2	25.2	‡	45.0
	9	113.9	93.9	0.0032	0.0057	12.33	9.13	45.5	19.5	‡	28.4

* $\frac{\text{Modified serigraph strength}}{\text{Number of yarns per inch}} \times 453.6.$

† Impossible to ravel sample.

‡ Fabric broke at jaw.

TABLE I—*Continued*

Fabric		55	56	57	58	59	60	61	62
		Elongation of fabric, strip test, 6-inch gage length				Elongation of fabric, grab test			
		inches per inch per pound		per cent of original length		inches per inch per pound		per cent of original length	
		warpwise	fillingwise	warpwise	fillingwise	warpwise	fillingwise	warpwise	fillingwise
Flannel	1	0.0096	0.0144	16.63	18.30	0.0086	0.0118	22.50	21.67
	2	0.0097	0.0018	22.90	20.83	0.0062	0.0115	25.87	29.17
	3	0.0051	0.0155	14.13	19.17	0.0051	0.0015	20.00	20.00
	4	0.0051	0.0157	10.50	20.83	0.0059	0.0109	17.50	21.67
	5	0.0101	0.0181	20.00	18.67	0.0074	0.0136	23.33	21.67
	6	0.0053	0.0139	13.33	16.67	0.0051	0.0089	20.00	18.33
	7	0.0053	0.0207	14.33	23.33	0.0044	0.0117	17.50	23.33
	8	0.0063	0.0151	16.23	18.67	0.0053	0.0079	22.50	20.00
	9	0.0053	0.0188	14.50	21.23	0.0043	0.0101	15.83	17.50
	10	0.0072	0.0111	12.50	14.17	0.0067	0.0117	16.67	24.17
	11	0.0062	0.0105	18.67	12.50	0.0052	0.0100	25.00	16.67
	12	0.0045	0.0211	12.50	22.83	0.0045	0.0125	20.83	25.00
	13	0.0082	0.0139	16.67	23.37	0.0069	0.0094	22.50	25.00
	14	0.0048	0.0158	14.50	20.83	0.0045	0.0111	20.83	25.83
Serge	1	0.0061	0.0097	12.00	12.50	0.0054	0.0083	13.33	14.17
	2	0.0057	0.0049	12.83	11.27	0.0066	0.0049	22.50	12.50
	3	0.0035	0.0085	12.50	21.23	0.0050	0.0075	27.50	27.50
	4	0.0050	0.0081	15.40	14.10	0.0057	0.0069	25.83	18.33
	5	0.0048	0.0085	14.10	12.50	0.0040	0.0069	18.33	15.83
	6	0.0048	0.0084	22.83	26.33	0.0035	0.0053	30.83	29.17
Gabardine	1	0.0055	0.0035	16.23	8.33	0.0047	0.0032	20.00	9.17
	2	0.0041	0.0067	20.37	9.53	*	0.0054	*	10.83
	3	0.0042	0.0099	12.50	11.63	0.0039	0.0081	15.83	11.67
	4	0.0047	0.0057	14.50	12.50	0.0043	0.0053	20.83	14.17
	5	0.0047	0.0083	24.43	14.50	*	0.0067	*	17.50
	6	0.0043	0.0067	20.83	9.80	*	0.0053	*	10.83
	7	0.0061	0.0060	22.83	8.33	0.0045	0.0060	29.17	10.83
	8	0.0079	0.0091	52.07	22.83	*	0.0063	*	28.33
	9	0.0067	0.0101	30.83	19.57	*	0.0076	*	21.67

* Fabric broke at jaw.

TABLE II.—MEAN VALUES OF VARIABLES FOR THE SERIES OF WOOL FLANNELS, SERGES, AND GABARDINES

Variable		Number of variable	Flannels $N = 14$	Flannels $N = 13$ No. 2 omitted	Flannels $N = 12$ Nos. 1,4 omitted	Flannels $N = 11$ Nos. 1,2,4 omitted	Serges $N = 6$	Serges $N = 5$ No. 6 omitted	Gabardines $N = 9$	Gabardines $N = 5$ Nos. 2,5,6,7 omitted
Price per square yard, dollars		1	1.64000	1.67538	....	....	1.85500	....	2.56444	....
Thickness, 1/1000 inch		2	18.10000	17.54615	18.05833	....	14.01667	13.20000	16.51111	16.22000
Weight per square yard, ounces		3	4.34071	4.23462	4.31833	....	4.27667	3.98600	5.15111	5.12200
Number of yarns per inch	warpwise	4	65.88571	67.27692	69.32500	....	77.51667	....	105.13333	....
	fillingwise	5	48.90714	50.10000	50.75833	....	63.76667	....	61.97778	....
Fabric strength, pounds, strip test, 3-inch gage length	warpwise	6	26.07857	26.14615	27.03333	....	33.10000	29.54000	44.84444	42.16000
	fillingwise	7	13.52143	13.46923	13.44167	....	22.73333	20.76000	19.27778	21.38000
Bursting strength, pounds	diaphragm	8	80.65000	80.45385	81.98333	....	94.78333	....	95.84444	....
	ball-burst	9	51.37143	....	....	....	63.60000	....	58.35555	....
Fabric elongation, strip test, 3-inch gage length, inches per inch per pound	warpwise	10	0.0068000	0.0065461	0.0066583	....	0.0043333	0.0042600	0.0056000	0.0009600
	fillingwise	11	0.0154290	0.0153692	0.0155083	....	0.0073500	....	0.0066555	....
Fabric elongation, strip test, 3-inch gage length, per cent of original length	warpwise	12	17.10143	16.46308	17.38500	....	14.17667	12.18600	26.12000	27.48200
	fillingwise	13	20.72929	20.56000	20.69583	....	16.41167	....	13.02778	....
Shrinkage, per cent	warpwise	14	6.14000	5.74077	5.69167	....	4.29500	4.04200	4.50000	4.21200
	fillingwise	15	5.66429	5.59615	5.08083	....	3.85167	....	3.08555	....
	in area	16	11.20000	10.73846	10.23333	....	7.96667	7.80000	7.45556	6.74000
Fabric strength after abrasion,* pounds, grab test	warpwise	17	....	....	27.92500	....	29.06667	....	44.33333	....
	fillingwise	18	....	....	14.36667	....	13.30000	....	24.26667	....
Loss of strength due to abrasion,* pounds	warpwise	19	....	....	10.95000	....	19.45000	....	....	....
	fillingwise	20	....	....	6.39167	....	17.33333	....	0.83333	....
Loss of strength due to abrasion,* per cent of original strength	warpwise	21	....	....	26.64167	27.88182	41.60000	....	....	....
	fillingwise	22	....	....	30.82500	32.70000	60.05000	....	0.06667	....
Fabric elongation after abrasion,* grab test, inches per inch per pound	warpwise	23	....	....	0.0052580	....	0.0036500	....	....	....
	fillingwise	24	....	....	0.0128580	....	0.0095333	....	0.0059000	....
Change in elongation after abrasion,* per cent, inches per inch per pound	warpwise	25	....	....	−4.28583	−4.67545	−26.37667	....	....	....
	fillingwise	26	....	....	+15.95417	+17.00909	+41.05333	....	+2.01110	....
Change in elongation after abrasion,* per cent, per cent of original length	warpwise	27	....	....	−29.24000	−30.72545	−56.61333	....	....	....
	fillingwise	28	....	....	−19.73583	−21.00000	−55.18167	....	−3.80667	....

Number of twists per inch of yarn	warps	29	12.20000	12.20000	12.10833	....	....	12.34000	....	16.08000
	fillings	30	11.33571	11.53077	11.52500	....	10.98333	....	10.77778	....
Yarn number, (size of yarn)	warps	31	10.06428	10.53077	10.40833	....	34.16667	37.00000	33.33333	37.20000
	fillings	32	9.35714	9.73077	9.66667	....	36.33333	....	36.66667	....
Yarn strength, grams, observed	warps	33	....	94.81538	....	89.04545	111.36667	84.34000	117.98889	....
	fillings	34	....	52.09231	....	45.22727	74.43333	....	68.94444	....
Yarn elongation, centimeters per centimeter per gram	warps	35	....	0.0018154	....	0.0018727	0.0016667	0.0017800	0.0017333	0.0020000
	fillings	36	....	0.0039231	....	0.0041909	0.0022833	....	0.0020444	....
Yarn elongation, per cent of original length	warps	37	....	16.64385	....	16.27000	16.62833	14.38800	19.05667	18.63800
	fillings	38	....	17.59769	....	16.76091	14.95667	....	12.95555	....
Modified serigraph strength, pounds	warpwise	39	....	21.17692	....	21.99091	27.56667	....	36.20000	....
	fillingwise	40	....	8.73077	....	8.58182	16.66667	....	14.28889	....
Difference in strength due to interlacing yarns, pounds	warpwise	41	....	4.96923	....	....	5.53333	....	8.64444	....
	fillingwise	42	....	4.73846	....	....	6.06667	....	4.98889	....
Difference in strength due to interlacing yarns, per cent	warpwise	43	....	19.87538	....	....	17.13500	....	19.33220	....
	fillingwise	44	....	35.70769	....	....	26.79160	....	26.52889	....
Yarn strength, grams, calculated	warps	45	....	144.15385	....	....	165.86667	....	159.55555	....
	fillings	46	....	81.68462	....	....	120.13333	....	104.68889	....
Elongation, modified serigraph test, inches per inch per pound	warpwise	47	....	0.0066461	....	0.0062727	0.0041667	....	0.0036222	....
	fillingwise	48	....	0.0209692	....	0.0212909	0.0066667	....	0.0063111	....
Elongation, modified serigraph test, per cent of original length	warpwise	49	....	13.08077	....	12.89545	10.76500	....	13.25778	....
	fillingwise	50	....	17.35846	....	17.21727	10.78667	....	8.74667	....
Fabric strength pounds, strip test, 6-inch gage length	warpwise	51	24.32143	24.37692	25.23333	....	30.86667	....	43.21111	....
	fillingwise	52	12.28571	12.33846	12.16667	....	20.71667	18.58000	17.72222	....
Fabric strength, pounds, grab test	warpwise	53	37.29285	....	38.87500	....	48.51667	....	....	....
	fillingwise	54	20.51429	....	20.75833	....	30.63333	....	25.10000	....
Fabric elongation, strip test, 6-inch gage length, inches per inch per pound	warpwise	55	0.0066214	0.0063846	0.0065000	....	0.0050000	....	0.0053555	....
	fillingwise	56	0.0147429	0.0157385	0.0146917	....	0.0080167	....	0.0073333	....
Fabric elongation, strip test, 6-inch gage length, per cent of original length	warpwise	57	15.52786	14.96077	15.85500	....	14.94333	....	23.84333	....
	fillingwise	58	19.31429	19.19769	19.27250	....	16.32167	....	13.00222	....
Fabric elongation, grab test, inches per inch per pound	warpwise	59	0.0057214	0.0056846	0.0054667	....	0.0050333	....	....	....
	fillingwise	60	0.0109000	0.0108538	0.0108250	....	0.0066333	....	0.0059889	....
Fabric elongation, grab test, per cent of original length	warpwise	61	20.77571	20.38385	20.90500	....	23.05333	....	....	....
	fillingwise	62	22.14357	21.60308	22.22250	....	19.58333	....	15.00000	....

* Opposite direction of test.

TABLE III.—STANDARD DEVIATIONS OF VARIABLES FOR THE SERIES OF WOOL FLANNELS, SERGES, AND GABARDINES

Variable		Number of variable	Flannels N = 14	Flannels N = 13 No. 2 omitted	Flannels N = 12 Nos. 1,4 omitted	Flannels N = 11 Nos. 1,2,4 omitted	Serges N = 6	Serges N = 5 No. 6 omitted	Gabardines N = 9	Gabardines N = 5 Nos. 2,5,6,7 omitted
Price per square yard, dollars		1	0.3384	0.3242	......	......	0.6989	......	0.8838	......
Thickness, 1/1000 inch		2	3.0750	2.3645	3.1870	......	2.5167	......	2.1561	3.0037
Weight per square yard, ounces		3	0.5180	0.3464	0.5588	......	0.9050	......	0.9178	1.2682
Number of yarns per inch	warpwise	4	16.6634	16.4758	15.1969	......	13.4077	......	21.8660	......
	fillingwise	5	11.7925	11.3609	11.6305	......	8.3851	......	7.6429	......
Fabric strength, pounds,	warpwise	6	4.9957	5.1931	4.7007	......	10.8863	7.2861	12.4996	16.3189
strip test, 3-inch gage length	fillingwise	7	1.4593	1.5052	1.5710	......	6.9411	5.5694	4.7476	5.4499
Bursting strength, pounds	diaphragm	8	5.3392	5.5044	4.4849	......	21.3299	......	13.1024	......
	ball-burst	9	2.9278	......	......	......	16.0286	......	10.9925	......
Fabric elongation, strip test, 3-inch gage length,	warpwise	10	0.001905	0.001718	0.001973	......	0.009396	0.001031	0.004464	0.001736
inches per inch per pound	fillingwise	11	0.002052	0.002125	0.002221	......	0.001471	......	0.001751	......
Fabric elongation, strip test, 3-inch gage length,	warpwise	12	3.2785	2.3374	3.4390	......	5.2514	2.1795	13.2618	18.4883
per cent of original length	fillingwise	13	2.4691	2.4839	2.6813	......	5.5769	......	5.4685	......
Shrinkage, per cent	warpwise	14	2.7804	2.4408	2.1071	......	0.8481	0.6474	0.8152	0.5294
	fillingwise	15	4.1569	4.3185	3.7593	......	2.3075	......	1.9657	......
	in area	16	5.6866	5.6392	4.4422	......	2.6296	2.9043	1.8888	1.9957
Fabric strength after abrasion,* pounds,	warpwise	17	......	......	8.5782	......	17.0405	......	23.1871	......
grab test	fillingwise	18	......	......	5.7092	......	15.0986	......	9.4847	......
Loss of strength due to abrasion,*	warpwise	19	......	......	10.0867	......	7.3942	......	......	......
pounds	fillingwise	20	......	......	5.4492	......	9.5011	......	1.2281	......
Loss of strength due to abrasion,*	warpwise	21	......	......	22.8827	23.5728	12.0018	......	......	......
per cent of original strength	fillingwise	22	......	......	21.9158	21.9528	26.6414	......	4.5916	......
Fabric elongation after abrasion,* grab test,	warpwise	23	......	......	0.001272	......	0.001033	......	......	......
inches per inch per pound	fillingwise	24	......	......	0.002322	......	0.005797	......	0.001169	......
Change in elongation after abrasion,* per cent,	warpwise	25	......	......	7.8764	8.1387	......	......	......	......
inches per inch per pound	fillingwise	26	......	......	11.6497	11.6015	......	......	24.0473	......
Change in elongation after abrasion,* per cent,	warpwise	27	......	......	24.9625	25.6186	16.2078	......	......	......
per cent of original length	fillingwise	28	......	......	20.8256	21.3537	23.7116	......	15.9299	......

Number of twists per inch of yarn	warps	29	1.5226	1.5848	1.5312	......	......	0.6348	......	3.5351
	fillings	30	1.4281	1.2776	1.3844	......	0.8036	......	1.2587	......
Yarn number, (size of yarn)	warps	31	2.8073	2.2885	2.7718	......	9.0866	6.5553	7.7136	6.8330
	fillings	32	4.2582	4.1864	4.4227	......	8.0416	......	6.2249	......
Yarn strength, grams, observed	warps	33	......	23.8818	......	19.4114	70.2257	26.1747	48.9403	......
	fillings	34	......	29.6837	......	26.8242	38.1016	......	26.9286	......
Yarn elongation,	warps	35	......	0.000367	......	0.000372	0.000388	0.000303	0.000439	0.000255
centimeters per centimeter per gram	fillings	36	......	0.001168	......	0.001049	0.000875	......	0.000715	......
Yarn elongation,	warps	37	......	2.8831	......	2.6832	6.0048	2.7256	6.2297	8.6355
per cent of original length	fillings	38	......	5.3227	......	5.1768	5.1250	......	4.8721	......
Modified serigraph strength,	warpwise	39	......	5.5554	......	5.6320	9.6541	......	10.1073	......
pounds	fillingwise	40	......	2.1073	......	2.1794	5.5637	......	4.3054	......
Difference in strength due to interlacing	warpwise	41	......	1.5074	......	......	1.5306	......	2.7925	......
yarns, pounds	fillingwise	42	......	1.2823	......	......	2.0887	......	1.2216	......
Difference in strength due to interlacing	warpwise	43	......	8.3377	......	......	3.7828	......	2.7616	......
yarns, per cent	fillingwise	44	......	11.5136	......	......	7.2469	......	6.1961	......
Yarn strength, grams, calculated	warps	45	......	26.3783	......	......	71.9862	......	47.1769	......
	fillings	46	......	25.5773	......	......	41.0678	......	29.0839	......
Elongation, modified serigraph test,	warpwise	47	......	0.002229	......	0.001952	0.001658	......	0.000520	......
inches per inch per pound	fillingwise	48	......	0.006937	......	0.007524	0.001362	......	0.001872	......
Elongation, modified serigraph test,	warpwise	49	......	1.7513	......	1.4540	3.4273	......	5.0790	......
per cent of original length	fillingwise	50	......	3.5824	......	3.8507	3.2417	......	2.7791	......
Fabric strength, pounds,	warpwise	51	4.4811	4.6591	4.1163	......	10.1139	......	12.3850	......
strip test, 6-inch gage length	fillingwise	52	1.4027	1.4454	1.4834	......	6.9864	5.1742	4.6362	......
Fabric strength, pounds,	warpwise	53	7.3015	......	6.5897	......	21.6628	......	......	......
grab test	fillingwise	54	3.4413	......	3.6659	......	13.5141	......	8.8845	......
Fabric elongation, strip test, 6-inch gage length,	warpwise	55	0.001985	0.001849	0.001904	......	0.000894	......	0.001311	......
inches per inch per pound	fillingwise	56	0.004857	0.003244	0.005271	......	0.001623	......	0.002186	......
Fabric elongation, strip test, 6-inch gage length,	warpwise	57	3.2955	2.6244	3.2108	......	4.0551	......	11.9478	......
per cent of original length	fillingwise	58	3.1642	3.2619	3.3953	......	6.0650	......	5.1243	......
Fabric elongation, grab test,	warpwise	59	0.001292	0.001337	0.001070	......	0.001136	......	......	......
inches per inch per pound	fillingwise	60	0.001504	0.001555	0.001610	......	0.001300	......	0.001446	......
Fabric elongation, grab test,	warpwise	61	3.0788	2.8178	3.1525	......	6.4050	......	......	......
per cent of original length	fillingwise	62	3.5161	2.9938	3.8162	......	7.0670	......	6.3871	......

* Opposite direction of test.

TABLE IV.—COEFFICIENTS OF CORRELATION

Variables correlated		No. of variable	1	2	3	4	5	6	7	8	14
Price		1		−0.413	−0.274	−0.482	0.432	0.334	0.044	0.338	−0.619
Thickness		2			0.572	−0.746	−0.836	−0.365	0.507	0.002	0.651
Weight		3				−0.312	−0.383	−0.057	0.362	0.150	0.636
Number of yarns	W	4					0.974	0.744	−0.207	0.523	−0.567
per inch	F	5						0.607	−0.127	0.340	−0.539
Fabric strength,	W	6							0.440	0.847	−0.477
strip, 3-in.	F	7								−0.161	0.326
Bursting strength	§	8									−0.279
Shrinkage, per cent	W	14									
	F	15									
	A	16									
Loss of strength	W†	21									
due to abrasion	F†	22									
Twists per inch	W	29									
of yarn	F	30									
Yarn number	W	31									
	F	32									
Yarn strength	W‡	33									
	F‡	34									
Serigraph strength	W‡	39	0.267	−0.549	−0.024	−0.739	0.644	0.963	−0.357	0.778	−0.492
	F‡	40	0.302	−0.428	0.403	0.070	0.182	−0.212	0.798	−0.169	0.064
Fabric strength,	W	51	0.366	−0.352	−0.054	0.737	0.594	0.997	−0.421	0.865	−0.492
strip, 6-in.	F	52	0.165	−0.166	0.235	−0.073	0.006	−0.313	0.927	−0.102	0.162

* 14 variates, significant $r = 0.532$.
† Only 12 variates (no samples for Nos. 1 and 4), significant $r = 0.576$.
‡ Only 13 variates (no sample for No. 2), significant $r = 0.553$.
§ Tested with rubber diaphragm tester.
______ Coefficient equal to or above required level for significance.

BETWEEN VARIABLES OF WOOL FLANNELS*

15	16	† 21	† 22	29	30	31	32	‡ 33	‡ 34	No. of variable
−0.476	−0.639	0.051	0.263	0.047	0.681	0.563	0.302	−0.463	−0.150	1
0.564	0.670	−0.704	−0.600	−0.513	−0.703	−0.866	−0.814	0.314	0.275	2
0.017	0.267	−0.206	−0.225	0.149	−0.596	−0.529	−0.293	0.162	0.345	3
−0.680	−0.712	0.840	0.734	0.227	−0.582	0.810	0.896	−0.439	−0.714	4
−0.642	−0.674	0.882	0.679	0.338	0.645	0.874	0.910	−0.471	−0.616	5
−0.623	−0.603	0.388	0.782	−0.041	0.237	0.291	0.684	0.091	−0.737	6
−0.266	−0.129	−0.190	−0.231	0.296	0.077	0.048	−0.341	−0.197	0.758	7
−0.588	−0.536	−0.042	0.521	−0.305	0.103	0.092	0.283	0.003	−0.563	8
0.498	0.761	−0.248	−0.497	−0.071	−0.727	−0.648	−0.513	0.366	0.447	14
	0.933	−0.305	−0.527	−0.313	−0.538	−0.529	−0.559	0.227	0.153	15
		−0.300	−0.585	−0.244	−0.702	−0.679	−0.577	0.348	0.224	16
			0.601	0.521	0.458	0.677	0.856	−0.291	−0.561	21
				0.196	0.336	0.440	0.749	0.397	−0.496	22
					0.218	−0.324	0.393	−0.174	0.230	29
						0.757	0.473	−0.463	−0.153	30
							0.728	−0.767	−0.387	31
								−0.190	−0.653	32
									0.209	33
										34
−0.676	−0.634	0.434	0.770	0.090	0.327	0.307	0.727	0.198	−0.620	39
−0.496	−0.400	0.166	−0.041	0.622	0.478	0.346	0.047	−0.190	0.598	40
−0.647	−0.631	0.341	0.763	−0.055	0.247	0.292	0.663	0.072	−0.719	51
−0.375	−0.288	−0.122	−0.045	0.357	0.174	−0.160	−0.119	−0.119	0.722	52

TABLE V.—COEFFICIENTS OF CORRELATION

Variables correlated		No. of variable	1	2	3	4	5	6	7	8	14
Price		1		0.390	0.727	0.210	0.508	0.907	0.497	0.801	0.507
Thickness		2			0.803	—0.771	—0.478	0.679	0.669	0.716	0.457
Weight		3				—0.262	0.092	0.941	0.892	0.980	0.464
Number of yarns	W	4					0.864	—0.065	—0.238	—0.119	—0.318
per inch	F	5						0.265	0.178	0.236	0.090
Fabric strength,	W	6							0.742	0.971	0.448
strip, 3-in.	F	7								0.866	0.476
Bursting strength	†	8									0.396
Shrinkage, per cent	W	14									
	F	15									
	A	16									
Loss of strength	W	21									
due to abrasion	F	22									
Twists per inch	W‡	29									
of yarn	F	30									
Yarn number	W	31									
	F	32									
Yarn strength	W	33									
	F	34									
Serigraph strength	W	39	0.918	0.677	0.916	—0.072	0.242	0.996	0.686	0.950	0.432
	F	40	0.479	0.825	0.935	—0.426	—0.040	0.770	0.968	0.880	0.478
Fabric strength,	W	51	0.914	0.663	0.925	—0.048	0.282	0.998	0.723	0.966	0.423
strip, 6-in.	F	52	0.572	0.731	0.942	—0.260	0.150	0.818	0.990	0.923	0.460

* Six variates, significant $r = 0.811$.
† Tested with rubber diaphragm tester.
‡ Only 5 variates (double-ply twist omitted), significant $r = 0.878$.
_______ Coefficient equal to or above required level for significance.

Between Variables of Wool Serges*

15	16	21	22	‡ 29	30	31	32	33	34	No. of variable
0.288	0.398	−0.317	−0.120	−0.649	−0.765	−0.490	0.118	0.714	0.313	1
−0.593	−0.350	−0.478	−0.560	0.044	−0.650	−0.971	−0.824	0.916	0.927	2
−0.203	−0.025	−0.478	−0.205	−0.004	−0.715	−0.800	−0.500	0.893	0.851	3
0.698	0.478	0.629	0.670	−0.229	0.172	0.692	0.899	−0.509	−0.671	4
0.800	0.691	0.571	0.336	−0.014	0.063	0.456	0.708	−0.132	−0.325	5
−0.054	0.093	−0.395	−0.179	−0.417	−0.836	−0.732	−0.230	0.880	0.651	6
−0.089	0.073	−0.326	−0.246	0.599	−0.328	−0.568	−0.538	0.717	0.864	7
−0.134	0.009	−0.459	−0.189	−0.047	−0.738	−0.720	−0.337	0.866	0.761	8
0.379	0.636	0.207	−0.510	0.008	−0.188	−0.434	−0.380	0.592	0.452	14
	0.955	0.912	0.255	−0.078	0.322	0.563	0.613	−0.305	−0.488	15
		0.830	0.054	−0.066	0.212	0.332	0.387	−0.069	−0.265	16
			0.419	−0.037	0.562	0.721	0.553	−0.594	−0.633	21
				−0.369	0.107	0.449	0.440	−0.557	−0.452	22
					0.796	0.324	−0.380	−0.369	0.480	29
						0.792	0.180	−0.777	−0.445	30
							0.730	−0.921	−0.835	31
								−0.562	−0.854	32
									0.829	33
										34
−0.073	0.072	−0.418	−0.200	−0.529	−0.874	−0.744	−0.204	0.885	0.617	39
−0.279	−0.083	−0.488	−0.309	0.482	0.461	−0.745	−0.689	0.818	0.955	40
−0.057	−0.082	−0.411	−0.202	−0.427	−0.840	−0.717	−0.194	0.876	0.787	51
−0.152	0.015	−0.414	−0.269	0.492	−0.454	−0.653	−0.535	0.793	0.884	52

TABLE VI.—COEFFICIENTS OF CORRELATION

Variables correlated		No. of variable	1	2	3	4	5	6	7	8	14
Price		1		0.551	0.660	0.860	0.792	0.615	0.098	0.553	—0.162
Thickness		2			0.927	0.182	0.154	0.833	0.551	0.869	0.413
Weight		3				0.345	0.344	0.947	0.537	0.904	0.207
Number of yarns	W	4					0.954	0.299	0.034	0.314	—0.253
per inch	F	5						0.240	0.207	0.400	—0.341
Fabric strength,	W	6							0.287	0.731	0.241
strip, 3-in.	F	7								0.816	0.002
Bursting strength	‖	8									0.079
Shrinkage, per cent	W	14									
	F	15									
	A	16									
Loss of strength	W	21									
due to abrasion	F	22									
Twists per inch	W†	29									
of yarn	F	30									
Yarn number	W	31									
	F	32									
Yarn strength	W	33									
	F	34									
Serigraph strength	W	39	0.592	0.826	0.925	0.249	0.167	0.992	0.249	0.696	0.218
	F	40	0.299	0.637	0.629	0.220	0.365	0.378	0.968	0.867	0.007
Fabric strength,	W	51	0.582	0.822	0.939	0.261	0.204	0.999	0.283	0.720	0.242
strip, 6-in.	F	52	0.209	0.572	0.565	0.140	0.305	0.307	0.990	0.841	—0.060

* Nine variates, significant $r = 0.666$.
† Only 5 variates (double-ply twist omitted), significant $r = 0.878$.
‡ Only 4 variates.
§ Not a significant loss in strength.
‖ Tested with rubber diaphragm tester.
_______ Coefficient equal to or above required level for significance.

Between Variables of Wool Gabardines*

15	16	21	22	† 29	30	31	32	33	34	No. of variable
−0.718	−0.782	‡	§	0.865	0.636	−0.014	0.324	0.075	−0.160	1
−0.736	−0.548	‡	§	0.207	0.239	−0.664	−0.226	0.636	0.511	2
−0.647	−0.551	‡	§	0.460	0.464	−0.650	0.011	0.664	0.405	3
−0.595	−0.708	‡	§	0.996	0.641	0.382	0.387	−0.305	−0.323	4
−0.597	−0.746	‡	§	0.987	0.788	0.448	0.278	−0.385	−0.178	5
−0.430	−0.322	‡	§	0.582	0.364	0.748	0.261	0.794	0.185	6
−0.564	−0.559	‡	§	−0.170	0.369	−0.191	−0.693	0.124	0.912	7
−0.748	−0.706	‡	§	0.277	0.552	−0.438	−0.338	0.421	0.669	8
−0.196	0.230	‡	§	−0.435	−0.477	−0.418	−0.063	0.363	0.062	14
	0.909	‡	§	0.000	−0.394	0.009	0.310	0.031	−0.364	15
		‡	§	−0.564	−0.596	−0.177	0.275	0.193	−0.330	16
			§	‡	‡	‡	‡	‡	‡	21
				§	§	§	§	§	§	22
					0.722	0.029	0.714	0.149	−0.497	29
						0.207	0.160	−0.133	0.094	30
							−0.010	−0.987	−0.345	31
								0.122	−0.843	32
									0.256	33
										34
−0.393	−0.293	‡	§	0.576	0.293	−0.789	0.244	0.833	0.187	39
−0.713	−0.705	‡	§	0.012	0.467	−0.154	−0.598	0.097	0.835	40
−0.394	−0.285	‡	§	−0.566	0.347	−0.772	0.261	0.819	0.194	51
−0.637	−0.658	‡	§	−0.080	0.447	−0.137	−0.665	0.078	0.880	52

TABLE VII.—COEFFICIENTS OF CORRELATION BETWEEN ELONGATION FACTORS OF WOOL FLANNELS, SERGES, AND GABARDINES, PER UNIT OF GAGE LENGTH PER UNIT OF TENSION

Variables correlated		No. of variable	11	25	26	35	36	47	48	55	56	59	60
FLANNELS													
Fabric elongation, strip test,	warpwise	10	−0.491	0.433	−0.554	0.361	−0.493	0.901	0.168	0.888	−0.624	0.821	0.197
3-inch gage length	fillingwise	11		0.118	0.184	−0.702	−0.048	0.104	0.861	0.146	0.337	−0.024	0.820
Change in elongation after	warpwise†	25			−0.330	0.088	−0.375	0.351	0.087	0.295	0.003	0.336	0.028
abrasion,* per cent	fillingwise‡	26				−0.353	0.435	−0.370	0.230	−0.259	0.485	−0.334	−0.129
Yarn elongation	warps	35					0.234	0.078	−0.415	0.191	−0.546	0.095	−0.635
	fillings	36						−0.425	0.104	−0.270	0.329	−0.514	−0.295
Elongation by modified serigraph	warpwise	47							0.391	0.936	−0.259	0.955	0.394
test	fillingwise	48								0.450	0.545	0.261	0.791
Fabric elongation, strip test,	warpwise	55									−0.487	0.858	0.292
6-inch gage length	fillingwise	56										−0.325	0.170
Fabric elongation, grab test	warpwise	59											0.274
	fillingwise	60											
Fabric elongation after abrasion,*	warpwise	23										0.019	
grab test	fillingwise	24											0.006
SERGES													
Fabric elongation, strip test,	warpwise	10	−0.031	0.003	−0.068	0.013	−0.041	0.079	−0.010	0.076	−0.014	0.043	−0.017
3-inch gage length	fillingwise	11		0.265	0.127	−0.417	0.486	−0.774	0.703	−0.444	0.887	−0.577	0.657
Change in elongation after	warpwise‡	25			−0.293	0.671	−0.001	0.175	0.638	0.389	0.665	−0.328	0.469
abrasion,* per cent	fillingwise†	26				−0.098	−0.283	−0.423	−0.323	−0.823	0.002	0.031	0.230
Yarn elongation	warps	35					0.130	0.327	−0.373	0.278	−0.595	0.792	−0.117
	fillings	36						−0.538	0.738	0.056	0.434	−0.384	0.389
Elongation by modified serigraph	warpwise	47							−0.401	0.782	−0.533	0.688	−0.311
test	fillingwise	48								0.173	0.871	−0.525	0.699

Fabric elongation, strip test,	warpwise	55									−0.162	0.386	−0.076
6-inch gage length	fillingwise	56										−0.576	0.784
Fabric elongation, grab test	warpwise	59											−0.025
	fillingwise	60											
Fabric elongation after abrasion,*	warpwise	23										0.496	
grab test	fillingwise	24											0.469
GABARDINES													
Fabric elongation, strip test,	warpwise	10	0.195	§	0.111	0.187	0.091	0.197	−0.058	0.306	0.113	§	0.071
3-inch gage length	fillingwise	11		§	0.340	0.482	$\underline{0.729}$	0.281	0.509	0.486	$\underline{0.695}$	§	0.627
Change in elongation after	warpwise	25			§	§	§	§	§	§	§	§	§
abrasion,* per cent	fillingwise‡	26				−0.284	$\underline{-0.844}$	−0.350	−0.115	−0.372	−0.195	§	0.102
Yarn elongation	warps	35					0.598	0.251	0.246	0.638	0.346	§	0.394
	fillings	36						−0.022	0.533	0.220	$\underline{0.873}$	§	$\underline{0.899}$
Elongation by modified serigraph	warpwise	47							−0.144	$\underline{0.715}$	−0.053	§	−0.164
test	fillingwise	48								−0.255	0.385	§	0.514
Fabric elongation, strip test,	warpwise	55									0.245	§	0.104
6-inch gage length	fillingwise	56										§	$\underline{0.938}$
Fabric elongation, grab test	warpwise	59										§	
	fillingwise	60											
Fabric elongation after abrasion,*	warpwise	23										§	
grab test	fillingwise	24											0.496

* Opposite direction of test.
† Loss in elongation.
‡ Gain in elongation.
§ Only 4 variates.
_______ Coefficient equal to or above required level for significance.

TABLE VIII.—COEFFICIENTS OF CORRELATION BETWEEN ELONGATION FACTORS OF WOOL FLANNELS, SERGES, AND GABARDINES, PER CENT

Variables correlated		No. of variable	13	27	28	37	38	49	50	57	58	61	62
FLANNELS													
Fabric elongation, strip test,	warpwise	12	0.052	0.188	0.214	0.358	0.025	0.507	−0.266	0.838	−0.105	0.786	0.329
3-inch gage length	fillingwise	13		0.889	0.433	−0.134	0.618	−0.480	0.671	0.090	0.472	−0.144	0.735
Loss in elongation after abrasion,*	warpwise	27			0.683	−0.210	0.664	−0.394	0.559	−0.134	0.433	−0.198	0.582
per cent	fillingwise	28				−0.666	0.372	−0.190	0.302	0.184	0.222	−0.101	0.301
Yarn elongation	warps	37					−0.072	0.726	−0.073	0.215	−0.240	0.469	0.007
	fillings	38						−0.306	0.662	−0.221	0.108	−0.203	0.506
Elongation by modified serigraph	warpwise	49							−0.301	0.388	−0.430	0.553	−0.265
test	fillingwise	50								−0.353	0.392	−0.219	0.822
Fabric elongation, strip test,	warpwise	57									−0.120	0.817	0.214
6-inch gage length	fillingwise	58										−0.192	0.481
Fabric elongation, grab test	warpwise	61											0.207
	fillingwise	62											
SERGES													
Fabric elongation, strip test,	warpwise	12	0.812	0.346	0.661	0.941	0.798	0.871	0.813	0.937	0.822	0.760	0.716
3-inch gage length	fillingwise	13		0.236	0.168	0.934	0.811	0.562	0.089	0.737	0.981	0.871	0.982
Loss in elongation after abrasion,*	warpwise	27			0.517	0.413	0.641	0.381	0.525	0.192	0.394	−0.132	0.304
per cent	fillingwise	28				0.506	0.562	0.847	0.459	0.637	0.276	0.099	0.057
Yarn elongation	warps	37					0.921	0.798	0.946	0.858	0.961	0.790	0.883
	fillings	38						0.744	0.982	0.721	0.907	0.524	0.798
Elongation by modified serigraph	warpwise	49							0.685	0.760	0.617	0.576	0.444
test	fillingwise	50								0.770	0.955	0.610	0.873

Fabric elongation, strip test,	warpwise	57									0.741	0.658	0.626
6-inch gage length	fillingwise	58										0.780	<u>0.972</u>
Fabric elongation, grab test	warpwise	61											<u>0.798</u>
	fillingwise	62											
GABARDINES													
Fabric elongation, strip test,	warpwise	12	<u>0.849</u>	†	−0.228	<u>0.939</u>	<u>0.879</u>	<u>0.934</u>	0.481	<u>0.998</u>	<u>0.839</u>	†	<u>0.904</u>
3-inch gage length	fillingwise	13		†	−0.292	<u>0.788</u>	<u>0.987</u>	<u>0.737</u>	<u>0.821</u>	<u>0.838</u>	<u>0.891</u>	†	<u>0.922</u>
Loss in elongation after abrasion,*	warpwise	27			†	†	†	†	†	†	†	†	†
per cent	fillingwise	28				−0.016	−0.256	−0.110	−0.378	−0.207	−0.363	†	−0.359
Yarn elongation	warps	37					<u>0.818</u>	<u>0.979</u>	0.390	<u>0.937</u>	<u>0.706</u>	†	<u>0.792</u>
	fillings	38						<u>0.779</u>	<u>0.792</u>	<u>0.875</u>	<u>0.895</u>	†	<u>0.931</u>
Elongation by modified serigraph	warpwise	49							0.366	<u>0.936</u>	<u>0.667</u>	†	<u>0.760</u>
test	fillingwise	50								0.466	0.657	†	0.655
Fabric elongation, strip test,	warpwise	57									<u>0.830</u>	†	<u>0.893</u>
6-inch gage length	fillingwise	58										†	<u>0.986</u>
Fabric elongation, grab test	warpwise	61											†
	fillingwise	62											

* Opposite direction of test.
† Only 4 variates.
_______ Coefficient equal to or above required level for significance.

TABLE IX.—COEFFICIENTS OF CORRELATION BETWEEN MISCELLANEOUS VARIABLES OF WOOL FLANNELS, SERGES, AND GABARDINES

Variables correlated	No. of variable	No. of yarns per inch W 4	No. of yarns per inch F 5	Fabric strength, strip, 3-in. gage W 6	Fabric strength, strip, 3-in. gage F 7	Loss of strength after abrasion, per cent W 21	Loss of strength after abrasion, per cent F 22	Twists per inch of yarn W 29	Twists per inch of yarn F 30	Yarn number, size of yarn W 31	Yarn number, size of yarn F 32	Yarn strength W 33	Yarn strength F 34	Fabric strength, grab test W 53	Fabric strength, grab test F 54
FLANNELS															
Fabric strength, strip test, 3-in. gage length	W 6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.922	.....
	F 7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.718
Fabric elongation, strip test, 3-in. gage length, inches per inch per pound	W 10	−0.644	.....	−0.747	.....	−0.424	.....	0.029	.....	.....	.....	.....	.....	.....	.....
	F 11	.....	−0.638	.....	−0.473	.....	−0.278	.....	−0.328	.....	.....	.....	.....	.....	.....
Fabric elongation, strip test, 3-in. gage length, per cent of original length	W 12	−0.132	.....	−0.034	.....	−0.184	.....	0.063	.....	.....	.....	.....	.....	.....	.....
	F 13	.....	−0.777	.....	0.368	.....	−0.446	.....	−0.278	.....	.....	.....	.....	.....	.....
Fabric strength after abrasion,* grab test, pounds	W 17	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.054	.....
	F 18	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.469
Yarn elongation, centimeters per centimeter per gram	W 35	.....	.....	.....	.....	.....	.....	0.458	.....	0.721	.....	−0.720	.....	.....	.....
	F 36	.....	.....	.....	.....	.....	.....	.....	0.320	.....	0.634	.....	−0.910	.....	.....
Yarn elongation, per cent of original length	W 37	.....	.....	.....	.....	.....	.....	0.224	.....	−0.331	.....	0.670	.....	.....	.....
	F 38	.....	.....	.....	.....	.....	.....	.....	−0.028	.....	−0.630	.....	0.936	.....	.....
Fabric strength, strip test, 6-in. gage length	W 51	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.940	.....
	F 52	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.546
SERGES															
Fabric strength, strip test, 3-in. gage length	W 6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.985	.....
	F 7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.870
Fabric elongation, strip test, 3-in. gage length, inches per inch per pound	W 10	−0.052	.....	−0.030	.....	−0.042	.....	0.576	.....	.....	.....	.....	.....	.....	.....
	F 11	.....	−0.028	.....	−0.304	.....	0.109	.....	−0.815	.....	.....	.....	.....	.....	.....
Fabric elongation, strip test, 3-in. gage length, per cent of original length	W 12	−0.324	.....	0 817	.....	−0.583	.....	0.245	.....	.....	.....	.....	.....	.....	.....
	F 13	.....	0.128	.....	0.757	.....	−0.163	.....	−0.856	.....	.....	.....	.....	.....	.....

Fabric strength after abra-	W	17	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.955	.....
sion,* grab test, pounds	F	18	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.785
Yarn elongation, centimeters	W	35	.....	.....	.....	.....	.....	.....	0.629	.....	0.932	.....	−0.843	.....	.....	.....
per centimeter per gram	F	36	.....	.....	.....	.....	.....	.....	.....	−0.028	.....	0.766	.....	−0.795	.....	.....
Yarn elongation, per cent of	W	37	.....	.....	.....	.....	.....	.....	−0.061	.....	−0.862	.....	0.975	.....	.....	.....
original length	F	38	.....	.....	.....	.....	.....	.....	.....	−0.728	.....	−0.727	.....	0.886	.....	.....
Fabric strength, strip test, 6-in.	W	51	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.985	.....
gage length	F	52	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.925
GABARDINES																
Fabric strength, strip test, 3-in.	W	6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	†	.....
gage length	F	7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.882
Fabric elongation, strip test, 3-in. gage length, inches per	W	10	0.234	.....	0.193	.....	†	.....	0.622	.....	.....	.....	.....	.....	.....	.....
inch per pound	F	11	.....	0.644	.....	0.047	.....	‡	.....	0.808	.....	.....	.....	.....	.....	.....
Fabric elongation, strip test, 3-in. gage length, per cent	W	12	0.556	.....	0.876	.....	†	.....	0.555	.....	.....	.....	.....	.....	.....	.....
of original length	F	13	.....	0.560	.....	0.616	.....	‡	.....	0.809	.....	.....	.....	.....	.....	.....
Fabric strength after abra-	W	17	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	†	.....
sion,* grab test, pounds	F	18	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.950
Yarn elongation, centimeters	W	35	.....	.....	.....	.....	.....	.....	0.951	.....	0.764	.....	−0.739	.....	.....	.....
per centimeter per gram	F	36	.....	.....	.....	.....	.....	.....	.....	0.675	.....	0.748	.....	−0.652	.....	.....
Yarn elongation, per cent of	W	37	.....	.....	.....	.....	.....	.....	0.093	.....	−0.686	.....	0.706	.....	.....	.....
original length	F	38	.....	.....	.....	.....	.....	.....	.....	0.813	.....	−0.124	.....	0.476	.....	.....
Fabric strength, strip test, 6-in.	W	51	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	†	.....
gage length	F	52	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.909

* Opposite direction of test.
† Only 4 variates.
‡ Not a significant difference in strength after abrasion.
_______ Coefficient equal to or above required level for significance.

TABLE X.—COEFFICIENTS OF CORRELATION BETWEEN CERTAIN VARIABLES OF WOOL FLANNELS, SERGES, AND GABARDINES, WITH CERTAIN FABRICS OMITTED. USED IN CALCULATING COEFFICIENTS OF PARTIAL CORRELATION

Variables correlated	Number of variable	Flannels No. 2 omitted	Flannels Nos. 1,4 omitted	Serges No. 6 omitted	Gabardines Nos. 2,5,6,7 omitted
Thickness	[illegible]				
Weight per square yard	3		0.619		
Number of warps per inch	4		−0.856		
Number of fillings per inch	5		−0.905		
Yarn number of warps	31		−0.891	−0.929	−0.941
Yarn number of fillings	32		−0.811		
Number of warps per inch	4				
Number of fillings per inch	5		0.980		
Fabric elongation, per unit, warpwise, strip, 3-in.	10		−0.639		
Yarn number of warps	31		0.796		
Number of fillings per inch	5				
Fabric elongation, per unit, fillingwise, strip, 3-in.	11		−0.753		
Yarn number of fillings	32		0.930		
Yarn number of warps	31				
Weight per square yard	3			−0.501	−0.865
Per cent shrinkage warpwise	14			0.282	−0.907
Per cent shrinkage in area	16			0.706	0.599
Loss in strength after abrasion,* per cent, warpwise	21			0.686	
Twists per inch of warps	29	0.414	0.327		
Tensile strength of warps	33			−0.933	−0.975
Elongation of warps, per unit	35	0.721		0.856	0.215
Yarn number of fillings	32				
Twists per inch of fillings	30	0.376	0.400		
Elongation of fillings, per unit	36	0.634			

* Opposite direction of test.

_______ Coefficient equal to or above required level for significance.

TABLE XI.—COEFFICIENTS OF PARTIAL CORRELATION

Variables correlated	Flannels	Serges	Gabardines	Variables correlated	Flannels	Serges	Gabardines
2,31. 4*	−0.670	−0.951	−0.807	2,32. 5	−0.234	−0.783	−0.283
2, 4.31	−0.152	−0.574	−0.104	2, 5.32	0.395	0.263	0.232
2,29.31	−0.491	0.985†	0.693†	2,30.32	−0.621	0.900	0.286
2,14. 4	0.416	0.351	0.483	2,15. 4	0.118	−0.120	−0.943
2,16. 4	0.297	0.331	−0.603	2,16. 5	0.263	−0.031	−0.658
2,14. 5	0.433	0.571	0.501	2,15. 5	0.065	−0.400	−0.813
2, 4.14	−0.603	.....	.....	2,22. 4	0.081‡	−0.092	.....
2,21. 4	0.054‡	−0.529	.....	2,22. 5	0.046‡	−0.483	.....
2,21. 5	0.470‡	−0.657	.....	2,22. 4,5	0.033‡	0.469	.....
2,21. 4,5	0.469‡	−0.705	.....	2,22.32	0.019‡	−0.388	.....
2,21.32	.....	−0.582	.....				
2, 4. 5	0.037‡	−0.809	.....				
2,21.31	−0.302‡	.....	.....				
3,29.31	−0.028	0.193†	0.967†	3,30.32	−0.543	−0.734	0.468
3, 4.31	0.234	0.673	0.845	3, 5.32	−0.293	0.428	0.355
3,31. 4	−0.496	−0.888	−0.597	3,32. 5	0.145	−0.618	−0.094
3,21. 2	−0.412‡	0.308	.....	3,22. 2	0.233‡	0.496	.....
4,31. 2	0.492	−0.372	0.329	5,32. 2	0.720	0.631	0.325
4, 6.33	0.876	0.937	0.935	5, 7.34	0.661	0.963	0.915
4,33. 6	−0.558	0.953	−0.117	5,34. 7	−0.803	−0.345	0.027
4,14. 2	−0.161	0.061	−0.199	5,14. 2	0.013	−0.423	−0.450
4,15. 2	−0.471	0.469	−0.693	5,15. 2	−0.376	0.730	−0.723
4,16. 2	−0.429	0.349	−0.739	5,16. 2	−0.279	0.636	−0.801
4,14.31	−0.114	−0.027	−0.111	5,15.32	−0.388	0.656	−0.748
4,16.31	−0.376	0.365	−0.704	5,16.32	−0.440	0.640	−0.891
4,21. 5	0.026‡	0.328	.....	5,21. 4	0.545‡	0.067	.....
4,21.32	.....	0.361	.....	5,21.32	0.436‡	0.305	.....
4,22. 5	0.469‡	0.801	.....	5,22. 4	−0.298	−0.650	.....
4,22.32	.....	0.698	.....	5,22.32	−0.072	0.039	.....
4,21.31	0.676‡	.....	.....				
4,22.31	0.706‡	.....	.....				
6,33. 4	0.696§	0.986	0.974	7,34. 5	0.870§	0.991	0.986
6,31. 4	−0.795	−0.954	0.719	7,32. 5	−0.548	−0.622	−0.676
6,10. 4	−0.524	−0.027	0.133	7,11. 5	−0.513	−0.304	−0.115
21,10. 4	0.270‡	−0.012	.....	22,11. 5	0.483‡	0.126	.....
21,29.31	0.431‡	0.269†	.....	22,30.32	0.060‡	0.031	.....
21,31. 2	0.149	.....	.....	22,32. 2	0.561	.....	.....
29,35.31	0.253	0.719†	0.968†	30,36.32	0.114	−0.262	0.848
29,14.31	−0.390	−0.243†	−0.971†	30,15.32	−0.375	0.285	−0.473
29,16.31	−0.668	−0.440†	−0.726†	30,17.32	−0.596	0.157	−0.674
				30,14.32	−0.640	.....	.....
31,29.33	0.444§	−0.061†	0.793†	32,30.34	0.369§	−0.429	0.447
31,35.33	0.379§	0.743	0.320	32,36.34	0.127§	0.276	0.575
31,37.33	0.384§	0.415	0.095	32,38.34	−0.705§	0.123	0.586
31,14. 4	−0.391	−0.313	−0.359	32,15. 5	−0.079	0.110	0.618
31,16. 4	−0.248	0.002	0.143	32,16. 5	0.119	−0.200	0.754
33,29.31	0.246§	−0.196†	0.798†	34,30.32	0.132§	−0.569	0.431
33,31.29	−0.775§	−0.925†	−0.991†	34,32.30	−0.650§	−0.879	−0.842
33,35.31	−0.375§	0.109	0.145	34,36.32	0.847§	−0.421	−0.060
33,37.31	0.687§	0.917	0.247	34,38.32	0.892§	0.742	0.696

* Coefficient of correlation between thickness and yarn number of warps, with influence of number of warps per inch eliminated.
† Five variates.
‡ Twelve variates.
§ Thirteen variates.
______ Coefficient equal to or above required level for significance

TABLE XII.—PROBABILITY OF THE OCCURRENCE OF THE DIFFERENCE BETWEEN MEANS OF VARIABLES OF FLANNELS, SERGES, AND GABARDINES* WHERE N_1 EQUALS N_2 AND VARIABLES ARE PAIRED

Variables compared	Flannels		Serges		Gabardines	
	W	F	W	F	W	F
Fabric strength, strip test, 3-in. vs. 6-in. gage length	0.0000	0.0000	0.0030	0.0042	0.0000	0.0002
Fabric strength, strip (3-in. gage l.) vs. grab.....	0.0000	0.0000	0.0192	0.0698	†	0.0094
Fabric strength, strip (3-in. gage l.) vs. mod. serigraph	0.0000	0.0000	0.0002	0.0010	0.0000	0.0000
Fabric strength, grab, before vs. after abrasion....	0.0032	0.0008	0.0012	0.0064	†	0.4468
Yarn strength, calculated vs. observed...........	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Fabric elongation, per unit, 3-in. vs. 6-in. gage length	0.4962	0.5588	0.8494	0.0790	0.8464	0.2298
Fabric elong., per unit, strip (3-in. gage l.) vs. grab	†	0.9218	‡	‡	‡	‡
Fabric elong., per unit, grab, before vs. after abrasion	0.9222	0.0296	0.0268	0.0002	†	1.9228

* If probability of occurrence was less than 0.05, the difference between the means of the variables was considered to be significant.
† Only 4 variates.
‡ Value of t secured too small to use table—probability of occurrence of difference very high.
________ Probability low enough to indicate significant difference between means at 5 per cent level.

TABLE XIII.—VALUES OF t SHOWING SIGNIFICANCE OF DIFFERENCE BETWEEN MEANS OF VARIABLES OF WOOL FLANNELS, SERGES, AND GABARDINES* WHERE N_1 DOES NOT EQUAL N_2 AND VARIABLES ARE NOT PAIRED

Variables compared	Flannels vs. serges	Flannels vs. gabardines	Serges vs. gabardines
Fabric strength, strip test, 3-in. gage length, warpwise........	2.01605	5.07279	1.87177
Fabric strength, strip test, 3-in. gage length, fillingwise.......	4.88736	4.28100	1.15184
Fabric strength after abrasion, grab test, warpwise	0.19206	2.26890	1.37700
Fabric strength after abrasion, grab test, fillingwise...........	0.21849	2.98030	1.73980
Loss in strength due to abrasion, per cent, warpwise	1.48656	†	†
Loss in strength due to abrasion, per cent, fillingwise........	2.48778	‡	‡
Fabric elongation, per unit, strip test, 3-in. gage length, warpwise	0.97028	0.89548	0.35352
Fabric elongation, per unit, strip test, 3-in. gage length, fillingwise	8.67539	10.56933	0.79913
Fabric elongation after abrasion, grab test, warpwise	0.02824	0.14310	0.00867
Fabric elongation after abrasion, grab test, fillingwise........	0.01908	0.08597	0.02032
Change in elongation, per unit, after abrasion, per cent, warpwise	3.79370	†	†
Change in elongation, per unit, after abrasion, per cent, fillingwise	1.00990	1.76200	1.56220
Shrinkage, per cent, warpwise	1.57233	1.71002	0.46975
Shrinkage, per cent, fillingwise............................	0.99426	1.73022	0.69097

* If value of t secured was greater than that which might be expected as a result of random causes at the chosen level, the difference between the means was considered to be significant.
† No data for gabardines.
‡ Loss very slight for gabardines.
_______ Value of t secured large enough to indicate significant difference between means at 5 per cent level.

TABLE XIV.—VALUES OF z SHOWING SIGNIFICANCE OF DIFFERENCE BETWEEN STANDARD DEVIATIONS OF VARIABLES OF FLANNELS, SERGES, AND GABARDINES*

Variables compared	Flannels		Serges		Gabardines	
	W	F	W	F	W	F
Fabric strength, strip, 3-in. vs. 6-in. gage length	0.10867	0.03951	0.07363	0.07362	0.00925	0.02372
Fabric elongation, unit, 3-in. vs. 6-in. gage length	0.04114	0.86159	2.35234	0.09831	1.22525	0.22186
Yarn strength, calculated vs. observed.......	0.09941	0.14891	0.02475	0.07496	0.03669	0.07699
Bursting strength, diaphragm vs. ball-burst...	0.57836		0.21374		0.12760	

* If value of z secured was greater than that which might be obtained by random causes, the difference between the standard deviations was considered to be significant.

______ Value of z secured large enough to indicate a significant difference between standard deviations at 1 per cent point (approximately 2 per cent level).

TABLE XV.—STANDARD DEVIATIONS (PEARSON'S) OF TENSILE STRENGTH VALUES OF INDIVIDUAL FLANNELS, SERGES, AND GABARDINES USED IN CALCULATING PRECISION

Fabric		Fabric strength				Bursting strength		Yarn strength	
		Strip test 3-in. gage length		Grab test					
		warp-wise	filling-wise	warp-wise	filling-wise	dia-phragm	ball-burst	warps	fillings
Flannel	1	1.1225	0.8367	2.4207	1.7776	1.8330	1.9849	26.3241	31.5620
	2	0.7483	1.1662	2.5573	1.4967	2.2271	1.8330	*	*
	3	0.4899	0.6633	1.3038	0.8000	2.4166	1.6733	26.3949	20.4756
	4	0.3742	0.6325	0.5831	0.7483	2.4000	1.9900	27.2780	16.3368
	5	0.6325	0.8025	1.6309	1.0198	1.7436	2.0347	31.5143	17.9301
	6	0.6782	0.9487	1.2000	1.2000	2.5768	2.4413	21.5833	12.6695
	7	0.2000	0.7483	0.2449	1.5811	1.8547	1.7436	21.8632	14.3958
	8	0.5831	0.4899	1.2649	7.8064	1.2000	1.0488	18.4185	13.8733
	9	0.7348	0.5831	1.1662	1.2000	1.0198	1.1576	24.7364	15.9386
	10	0.3742	0.4000	1.4491	1.2000	2.5613	0.9165	23.9794	18.0557
	11	0.6000	0.3742	1.7205	0.8000	2.1909	1.0000	21.5639	12.2474
	12	0.5831	0.6000	1.4353	0.8944	1.8974	1.7321	23.5034	17.4141
	13	0.2000	0.8124	1.8868	0.7348	1.4967	1.6553	18.8481	20.2623
	14	0.4000	0.2449	0.6782	1.3267	1.3267	1.7436	21.4467	20.9370
	Mean	0.5515	0.6645	1.3958	1.6313	1.9103	1.6396	23.6503	17.8537
Serge	1	0.8944	0.3162	1.3784	1.2000	0.8944	2.0396	27.1359	21.8550
	2	0.7483	0.8000	3.9799	1.1662	3.4000	1.5033	20.0771	25.6796
	3	0.8124	1.5362	2.7313	1.2410	3.0594	2.4617	28.8998	29.3598
	4	1.2083	0.6325	1.8547	2.5219	1.0955	2.4819	20.5244	15.3717
	5	0.5099	0.6633	2.3580	1.4966	0.7483	0.8000	21.9854	11.3141
	6	0.9695	0.5831	2.0396	2.7386	1.9391	2.4207	34.6590	35.4970
	Mean	0.8571	0.7552	2.3903	1.7274	1.6895	1.9512	25.5469	23.1795
Gabardine	1	0.8367	1.0198	1.2083	3.1369	3.0067	2.5179	18.5540	32.8178
	2	1.0770	0.6782	†	0.3742	2.1541	3.0232	31.5696	14.0840
	3	0.8000	0.5477	1.4967	0.8000	1.3565	1.5684	16.4222	14.9081
	4	0.8367	1.7607	1.5621	1.3565	1.7205	1.6553	20.0202	23.3454
	5	1.0296	0.7483	†	1.5621	0.0000	3.0757	30.8032	20.1633
	6	0.3742	0.5099	†	0.6325	4.7917	1.7436	27.0740	20.6000
	7	0.4000	0.5831	2.5298	0.3742	3.0331	1.0770	16.9473	12.5734
	8	1.5362	0.4899	†	1.3416	1.6000	2.1817	29.8565	18.4076
	9	0.6633	0.4899	†	1.1576	1.6000	2.1307	16.5239	13.3720
	Mean	0.8393	0.7586	1.6992	1.1928	2.1403	2.1082	23.0857	18.9191

* Impossible to ravel sample.
† Fabric broke at jaw.

TABLE XVI.—VALUES OF z SHOWING SIGNIFICANCE OF DIFFERENCE BETWEEN STANDARD DEVIATIONS OF TENSILE STRENGTH VALUES BY STRIP TEST (3-INCH GAGE LENGTH) AND GRAB TEST OF FLANNELS, SERGES, AND GABARDINES*

Fabric	Flannels		Serges		Gabardines	
	warpwise	fillingwise	warpwise	fillingwise	warpwise	fillingwise
1........	0.76849	0.75354	0.43250	1.33372	0.36749	0.39562
2........	1.22892	0.24951	1.67122	0.37693	†	0.59466
3........	0.97882	0.18739	1.21254	0.21342	0.62642	1.62392
4........	0.44360	0.16814	0.42853	1.38310	0.62434	0.26083
5........	0.94721	0.23965	1.53136	0.81373	†	0.73597
6........	0.57064	0.23500	0.74375	1.54685	†	0.21543
7........	0.20253	0.74807			1.84444	0.86509
8........	0.77441	2.76854			†	1.00742
9........	0.46191	0.72174			†	0.85990
10........	1.35391	1.09862				
11........	1.05345	0.76213				
12........	0.90078	0.39925				
13........	2.24433	0.10030				
14........	0.52798	1.68961				

* If value for z secured was greater than that which might be obtained by random causes, the difference between the standard deviations was considerd to be significant.

† Fabric broke at jaw in grab test.

———— Difference significant at 1 per cent point (approximately 2 per cent level).

.... Difference significant at 5 per cent point (approximately 10 per cent level).