# REPORT No. 36.

## THE STRUCTURE OF AIRPLANE FABRICS.

By E. Dean Walen.

This report was prepared at the Bureau of Standards for the National Advisory Committee for Aeronautics. The Third Annual Report of the National Advisory Committee for Aeronautics contained a progress report by the author on the development of cotton airplane fabrics, in which it was concluded that cotton fabric could be made which would be suitable for airplane fabrics, notwithstanding the fact that previous experimenters had believed that it was impossible to use successfully airplane fabrics made of cotton. Since that time it has been demonstrated practically that cotton airplane fabrics are satisfactory, and they are giving service results equal to if not better than the conventional linen fabrics. It is thought that a brief history of the development and service of the cotton airplane fabrics may be of interest.

On request of the National Advisory Committee for Aeronautics the Bureau of Standards began experimenting as early as January, 1916, to determine the feasibility of substituting cotton for the linen airplane fabrics. A thorough study of the properties of the linen airplane fabric was made, together with a more or less general consideration of the distribution of stresses in an airplane-wing covering. It was not until March, 1917, that we were able to issue instructions for the manufacture of experimental fabrics, which proved to be very satisfactory. The first fabrics of this series were received on or about the first of April, 1917, and as the series progressed changes were suggested; and during the early part of May, 1917, a fabric had passed the requirements of our laboratory tests. The next important problem was to determine the actual performance of these fabrics. To that end, samples were placed on Army airplanes at Langley field and on Navy airplanes at Pensacola during August, 1917. Similar fabrics were later sent by the Signal Corps to the Canadian Aeroplane Co., of Toronto, Canada, and they were placed on airplanes by the middle of October.

The results of the service tests demonstrated that the fabrics were satisfactory and that service results could be reliably predicted in the laboratory. In view of this, we felt justified in changing the structure of the experimental fabrics; and the result is the present grade A cotton fabric.

On August 24, 1917, a conference held between the military authorities and representatives of the bureau resulted in the Signal Corps equipment division ordering that the Bureau of Standards supply the necessary specifications covering the purchase of 500,000 yards of cotton airplane fabric. The specifications were transmitted by the Bureau of Standards on September 5, 1917, covering the fabrics known as grade A and B. A few days later the bureau supplied the necessary information regarding the apparatus and methods of testing and inspecting.

The Department of Agriculture was invited to assist in further development of cotton airplane fabrics; and they began their experiments during September, 1917. In April, 1918, the Signal Corps submitted samples which were understood to be the result of these investigations; these dealt with the use of the various cottons and the results are appended.

It is understood that the British Government is now using the grade A fabric with a good degree of satisfaction.

The study of aircraft fabrics, which has been an entirely new one, may be divided into three parts:

1. The determination of what properties should be studied.
2. The development of methods of determining the desired properties.
3. The determination of the factors of manufacture, which influence the properties, together with the magnitude of the influence.

## THE DETERMINATION OF THE PROPERTIES TO BE STUDIED.

A consideration of the method of covering an airplane wing and subsequently treating it with dope, together with the consideration of the airplane in flight under normal and abnormal conditions, leads to the conclusions that the following properties should be studied, and that the most advantageous combination of the properties is the most satisfactory fabric.

1. The weight (maximum allowable being 4 to 4.5 ounces per square yard).
2. The factor of safety of the covering:
   (a) When subjected to pressure.
   (b) When subjected to tear stresses.
   (c) When subjected to vibration.
   (d) When subjected to wing deflection.
   (e) When subjected to combinations of (a), (b), (c), and (d).
3. The preservation of the contour lines of the wing.
4. The surface friction.
5. The tightness to air.
6. The dope consumption.
7. The ease of application to the wing.
8. The ease of manufacture.

The problem of constructing apparatus to determine all these properties experimentally has by no means been solved, but it is thought that the test methods discussed, together with a consideration of the mechanics of the problem, are sufficient to predict with a reasonable degree of certainty the relative value of the fabrics experimented with.

## TEST METHODS.

*Moisture.*—It is a well-known fact that the properties of all textile materials are influenced by the moisture conditions to which they are exposed; for instance, the vegetable fibers increase in strength with an increase of moisture content, and the animal fibers are influenced in the reverse direction. For the purpose of laboratory testing, it is considered best to test these materials after they have been exposed to a constant condition of atmosphere which may be taken to be representative of the average conditions throughout the year. In this paper all physical determinations are made after the material has been subjected to an atmosphere of 65 per cent relative humidity at 70° F. for a period of three hours. It has been found that at the end of this time the moisture content of the material is sensibly in equilibrium with that of the atmosphere.

The effect of moisture on the doped fabric is not so pronounced as on the undoped fabric in the case of both linen and cotton, but the effect of moisture on the doped silk fabric produces a very marked loss of tightness. Linen, when thoroughly soaked, is increased in strength by a larger percentage than is cotton; and, inasmuch as the materials are only occasionally in approximately this condition, it appears that the results are less misleading if determined from tests made upon materials which have been tested under normal conditions.

The effect of humidity upon the strength of linen and cotton has been published in the British Reports on Aeronautical Fabrics, but it is believed that the foregoing discussion is sufficient for this paper.

The properties of textile materials which have been determined in the past and which are of interest to this discussion are weight, thread count, yarn number, twist, and tensile strength, and for completeness these will be given brief consideration.

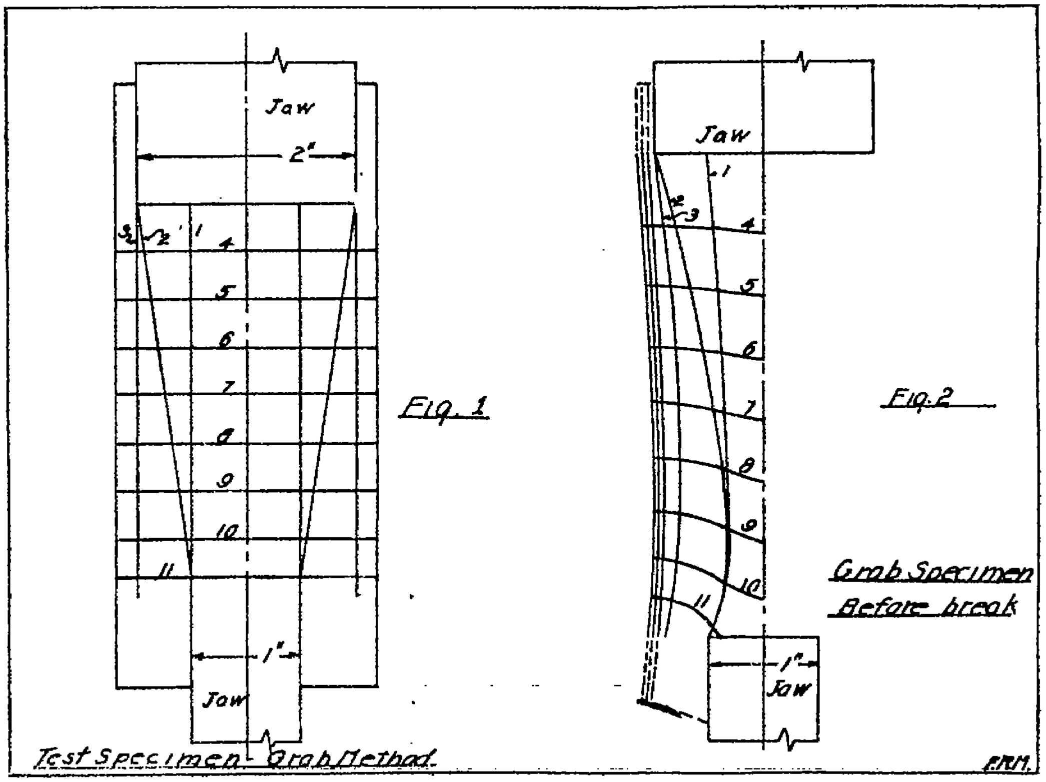
*Weight.*—The weight was determined by cutting several samples of 4 square inches by means of a die, and these samples were weighed on a torsion balance calibrated to read directly in ounces per square yard. The method of hand brushing of dope onto the fabric prevents the accurate determination of doped weights, and accordingly the weights given are only indicative of general tendencies.

*Thread count.*—The thread count is taken to mean the number of threads per inch in the warp or filling, and was determined by actually counting the threads with a suitable counter.

*The yarn number.*—The yarn number is the weight per unit length of the yarn, but it is expressed in terms of the number of standard length to weigh 1 pound. It was determined by weighing a known length of yarn and the number was subsequently calculated.

*Twist.*—The twist is the number of turns of twist which have been put into the yarn, and, in this paper, was determined by untwisting the yarn, and the turns per inch expressed in terms of the twisted length.

*Tensile strength.*—The tensile strength is the breaking load of the material, and has in the past been determined according to many different modifications of two methods—the "grab" and the "strip." The kinds of machines used may be classed according to the method of applying the load, constant increment of load machines, and constant increment of stretch machines; and again further subdivided according to the type of load indicating head, those which have




extremely large inertia errors such as the inclination balance, and those which do not, such as a spring. The tensile strength determinations have been further complicated by various rates of load application and various rates of stretch increments. Inasmuch as there has existed a wide diversity of opinion as to method of determining tensile strength, it is proposed to discuss the reasons for adopting certain test methods before the tensibility properties of textile material are discussed.

*Strip and grab test.*—The grab test is the oldest of test methods and has a large number of adherents in this country. A very general form of grab test, as illustrated in figure 1, has one clamp much wider than the other. In this particular case the width of the upper clamp was 2 inches and the lower clamp was varied in width from $\frac{1}{4}$ to 2 inches. Lines were drawn on the specimens before being subjected to tension and the outside dimensions of the specimens and the distance between clamps kept constant. Figure 2 represents the distortion of the lines just before the rupture and shows very graphically the stress distribution. It will be noted that there is a concentration of stresses at or near the line 10; and, as would be expected, the sample ruptured at this line. The position of this line of concentration of stress approaches the line midway between the clamps as the width of the lower clamp is increased, and finally lies midway when the two clamps are of the same width. Hence, this test has a tendency to produce a fiber rupture rather than a fabric rupture. The curves shown in figure 3 are composite curves taken from tests on various fabrics. Curve D represents the relation between the strength and the width of lower clamp as outlined above. The strength is divided by the width, and the result, called the unit strength, is plotted against the width of strip. The curve H is the unit strength calculated from Curve D. It is seen that the relative strength of the fabric is a function of the dimensions of the clamps, and that it is approaching asymtotically a constant unit tensile strength.

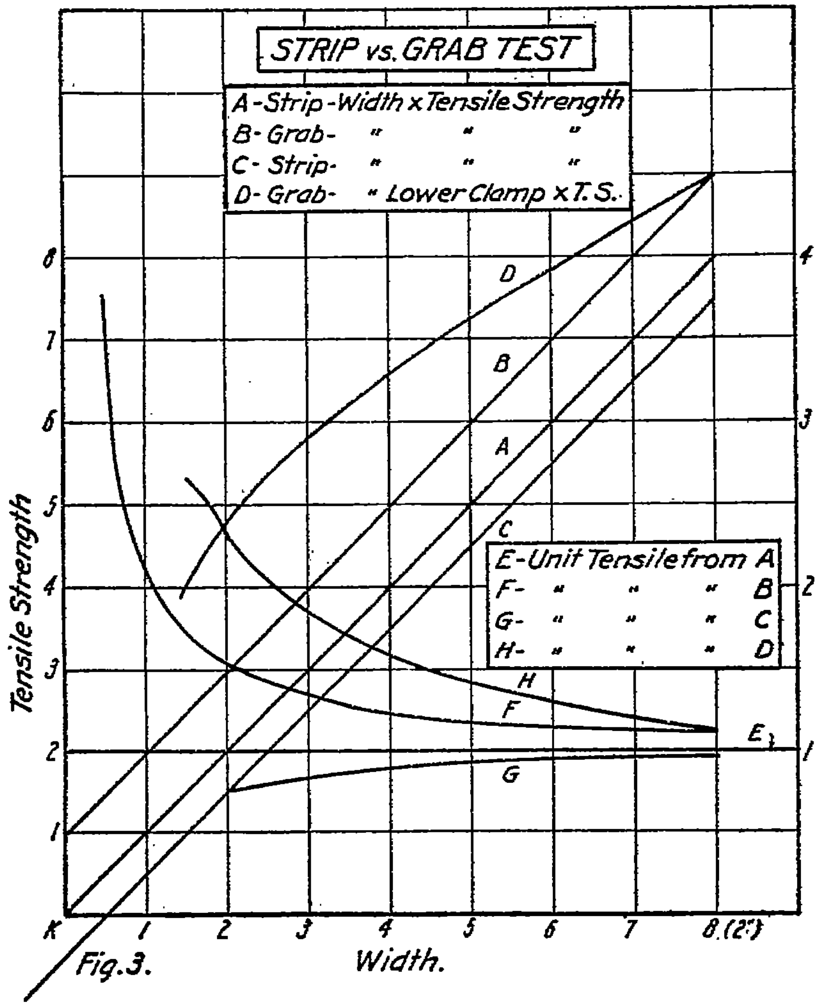
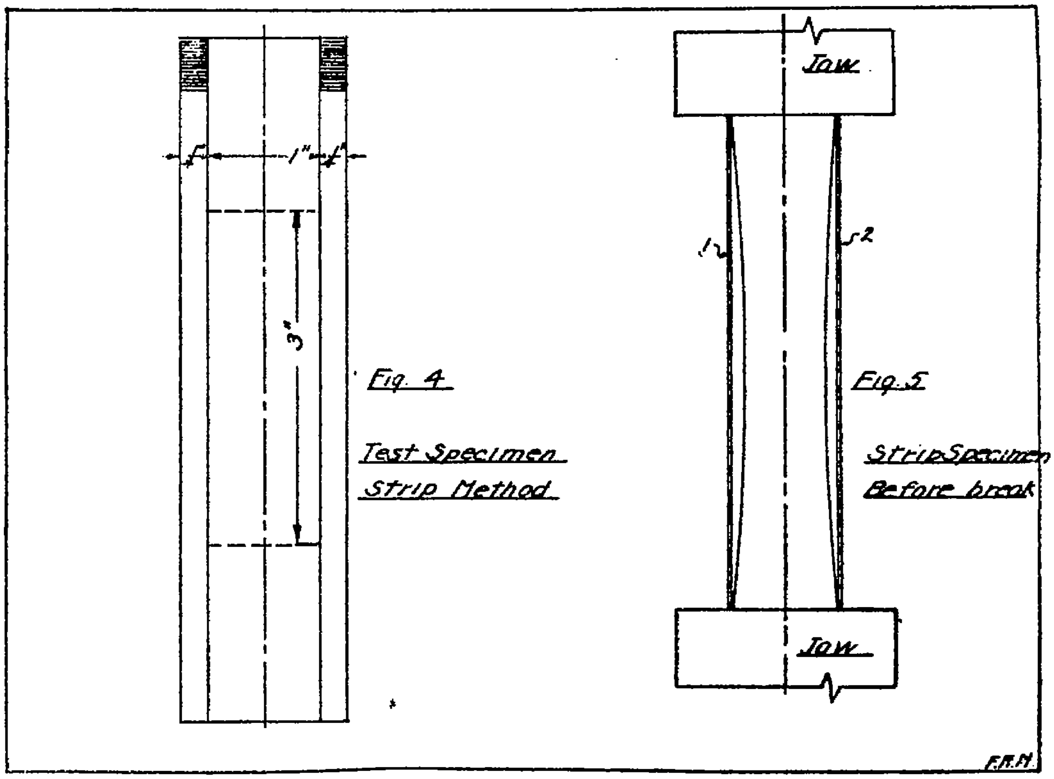



Fig. 3.

The curve A was obtained from plotting the result of tensile strength against the width of strip, using the strip test. The strips were prepared as shown in figure 4, and their appearance just before rupture is shown in figure 5. It will be observed that there are several threads, 1 and 2 (fig. 5), which become detached from the rest of the strip. This suggests that these threads do not carry their proportionate part of the load. An examination of the curve A shows that a straight line ratio exists between the width of the strip and the tensile strength, and that the unit strength is constant and independent of the specimen dimensions as shown by curve E. It was found in testing strips of widths between 1½ and 2 inches that it was extremely difficult to place the samples in the clamps evenly, and that very slight changes in the alignment of the clamps caused the strip to break at much lower strengths than is indicated, but if extreme care was used, the straight line ratio was preserved. From this it was concluded that the personal equation was so great in the case of the 2-inch sample that it was best to use a 1-inch sample.

The straight line ratio between width of strip and tensile strength does not hold for all fabrics. The curve C may be taken to represent the width of strip and strength relations of tests made upon the warp of a heavy duck. The curve (A) may be taken to represent the width of strip and strength relations of tests made on the same duck in the warp direction with the end threads held in place by tying them in with the filling fringe. It will be seen that, as would be expected, the two lines are parallel, and that the distance (K) is the correction factor to be added to the tensile strength of such materials. This condition will only occur in fabrics having a radically different crimp in one system of threads as compared with the other system of threads. For the class of material which is being considered in this report the condition will not occur.

The curve (B) represents the width of clamp and tensile strength relations of fabric tested by using a grab test having the upper and lower clamp of the same dimensions and increased




by a like amount. It will be observed that the line is parallel to the curve (A) and that the perpendicular distance between them is a measure of the constant force transmitted from one clamp to the other by the fabric surrounding the fabric between the clamps. The distance between the curves (A) and (B) depends not only on the width of the specimen but also upon the distance which the sample protrudes into the clamp.

The grab test in all of its modifications gives results which are a function of the dimension of the test specimen and clamps, and the results approach asymtotically the results of the strip test. The strip test gives a constant value for the strength of the material, provided it is of such dimensions that the personal equation is eliminated. The strip test applied to fabrics made of extremely nonuniform yarns will probably give a lower unit strength using a 2-inch strip than if a 1-inch strip were used. Such fabrics should not be considered for airplane-wing coverings; and, if they are considered, a frequency curve of tensile strength plotted from tests made on considerably narrower strips would be of much greater value than tests made on the wider strips.

*Testing machine.*—The tensile strength of fabrics depends somewhat upon the rate of load application. It has been observed that there are limits between which a change in the rate of load application produces a very slight change in the properties of the material. This condition is attained by stressing the specimen at a very slow rate; and, provided the rate of stress application is kept below the upper limit, the results will be the same whether the sample is stressed in equal increments of load or is stressed by causing it to be stretched at a constant increment of stretch. Within the limitations of the mechanical features of the testing machine the slow application of load is the most severe one.

The inertia errors of the indicating head are reduced in value so as to be within the variations of the fabric, if the head is operated at very slow speeds. An inclination balance type of testing machine equipped to cause the sample to be stressed by stretching it at a constant rate and operated at a speed of 5 inches per minute was used to determine the tensibility properties.

*Crimp.*—The crimp of a yarn is the increased length of the yarn taken from the fabric over the length of the fabric. The difference is caused by the interlacings of the yarns. The length of the yarn taken from the fabric is determined from the load-stretch diagram of the yarn. The yarn is stressed in small increments and the stretch plotted against the load. The time allowed between the increments is such that a further increase of time of application will produce only a very slight increase in the elongation. It was found that, after the crimp of the yarn and fibers was taken out, the load-stretch curve followed a straight line. This line was projected to intersect the zero load coordinate and that length taken to be the length of the yarn when straight and under no tension.

*Tensibility properties.*—The tensibility properties of textile material may be defined as the behavior of the material when subjected to tensile stresses acting parallel to and at the center plane or line of the material. These may be divided into the following: (*a*) Load-stretch relations; (*b*) tensile strength; (*c*) restitution and hysteresis.

The determinations were made on an inclination balance type of testing machine operated at very low speeds and having a small angular displacement of the balance arm. The machine was fitted with an autographic device for recording the load-stretch relations of the specimen. The device consisted of a drum revolved by the pendulum arm and a dotting pen moving in a vertical line parallel to the center line of the drum. The dotting pen was given its motion from the lower or pulling clamp of the testing machine. Correction for the motion of the top clamp was made by the use of skew coordinate paper. The drum was mounted in conical ball bearings, and the motion-transmitting parts were of flat brass ribbons. With these precautions it was found that the device contained no mechanical backlash or instrumental hysteresis.

The samples of fabrics were prepared by cutting strips 25 centimeters (10 inches) long by 3 centimeters (1¼ inches) wide and raveled to 2.5 centimeters (1 inch) width. The samples of doped fabric were prepared by cutting the samples directly to 2.5 centimeters (1 inch) width. The distance between the clamps was 20 centimeters (8 inches) and the pulling clamp was operated at the speed of 13 centimeters (5 inches) per minute for the more careful work of hysteresis and at 30 centimeters (12 inches) per minute for the ordinary tensile strength and elongation tests.

*Tear resistance (tensibility method).*—Specimens 25 centimeters (10 inches) wide and 36 centimeters (14 inches) long were clamped in the testing machine with 30 centimeters (12 inches) between clamps. Slits were previously cut at the center perpendicular to the line of pull; the fabric was stressed at the rate of 13 centimeters (5 inches) per minute; and a record made of the load necessary to start the tear. This method was not rigidly adhered to, as in many cases time and circumstances made it necessary to deviate therefrom. This method of test is more carefully defined in the British Reports on Aeronautical Fabrics and is referred to as the wound test.

*Tear resistance (rip method).*—The rip tear, or sometimes called the tongue test, has several modifications. The English investigators favor a tongue test made on the doped fabric detached from the frame. A rectangle is cut on three sides at or near the center of the specimen. The tongue which is produced is turned down and clamped in the pulling jaw, and the other

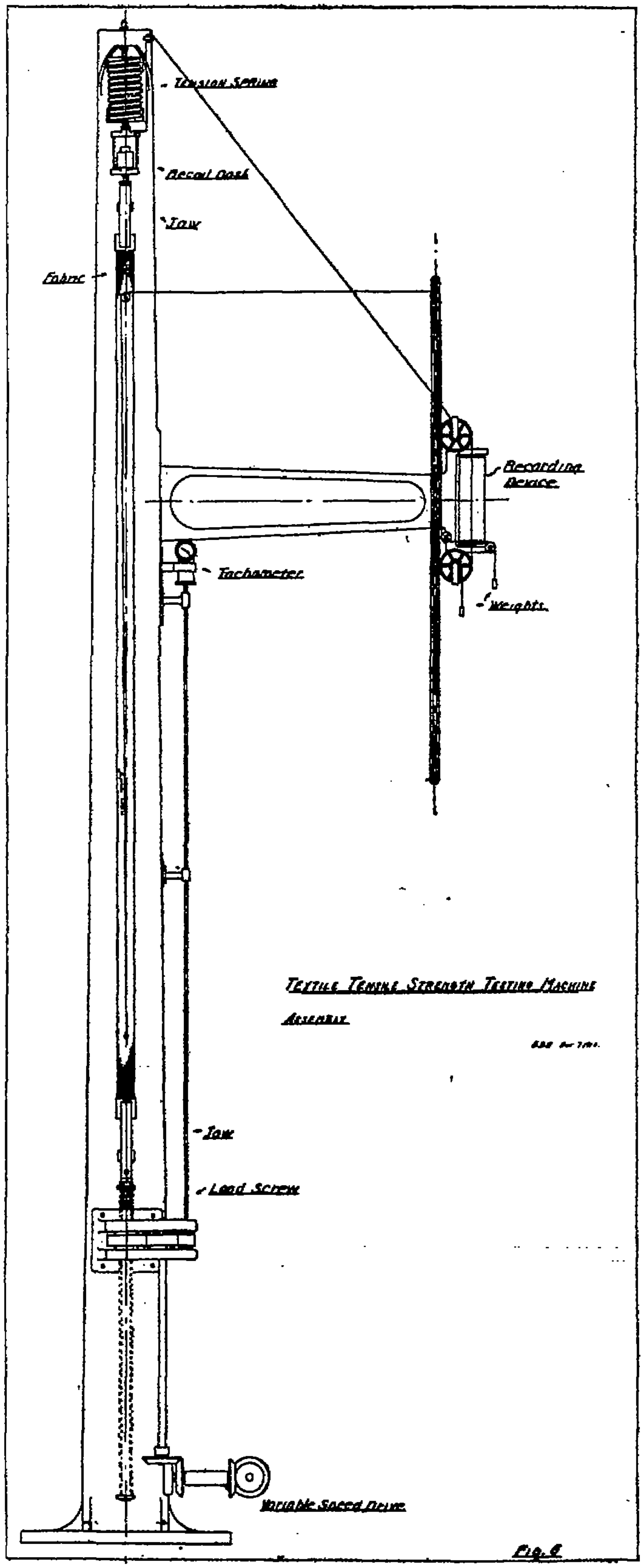



Fig. 6

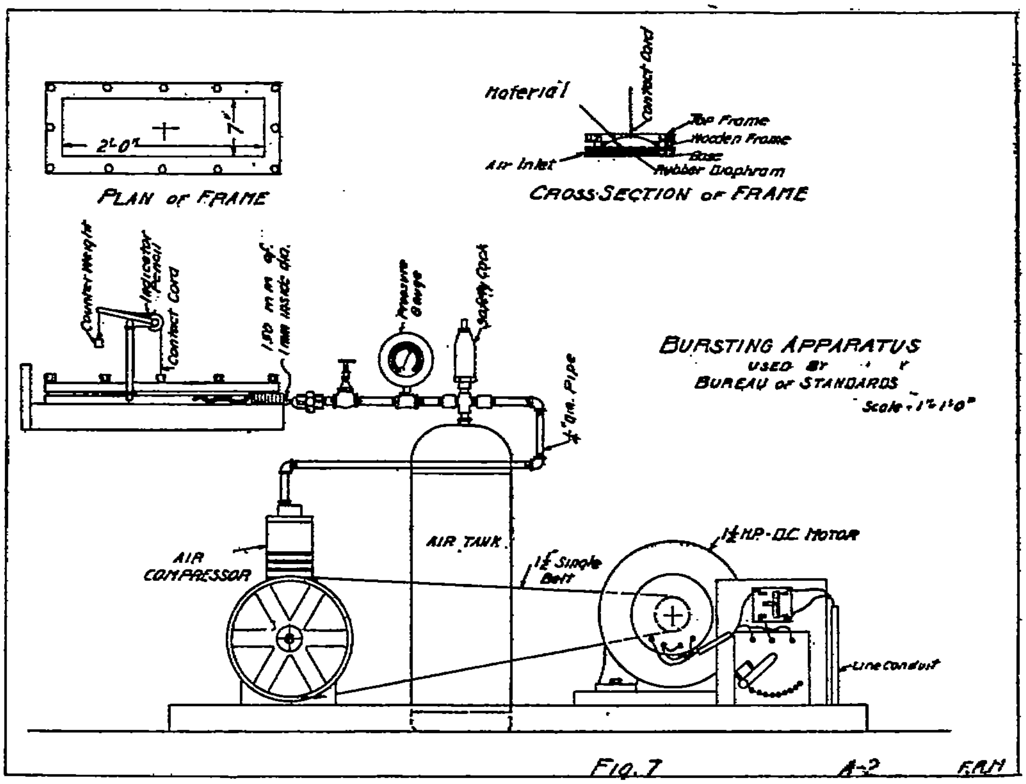
end of the specimen is clamped in the other jaw. The jaws are caused to separate and the maximum resistance recorded.

It is believed that this method as performed does not give information which is of great value, for the fabric detached from the frame turns back from the point of tear, thereby reducing the torsional stresses in the yarn and increasing the area of the tear stress distribution. It is of interest to know the maximum forces necessary to start the tear, but it is of more importance to know the behavior of the material after the tear has started and the behavior of the material under combined conditions of tear and pressure stresses. It is rather difficult to construct such an apparatus, but the behavior may be predicted from several tests of different character.

The rip or tongue test used in this discussion consists in placing the doped frame with the cut tongue directly in the clamps of the testing machine, and the tension necessary to tear the material plotted against the motion of the pulling clamp. It was found impossible to use the inclination balance type of testing machine for this test, as the large inertia effects induced by one thread breaking and throwing the load quickly onto the next gave results of questionable character. A constant increment of stretch machine with a spring recording device, as shown in figure 6, was used. The spring has a very small motion and is connected to an autographic recording device shown at the right. There is a small inertia effect in the recording device which may be considerably reduced by a few slight changes in arrangement and by careful manipulation. It was not thought that the effects were large enough to give results which were exaggerated, excepting the overrun of the recording device after the threads abruptly picked up the load, and this effect is shown by two perpendicular lines which lie actically over one another.

These results, together with the consideration of the results of the other tests described, are thought to be sufficient to predict with a reasonable degree of certainty the performance of the fabric when subjected to tear under flight conditions.

*Resistance to uniformly distributed pressure.*—The material is clamped over a rectangular container and subjected to air pressure. The apparatus is shown diagrammatically in figure 7. The deflection of the center point of the fabric is plotted against the unit pressure under the fabric by means of an ordinary steam-engine indicator. The shape of the deflected surface is determined by measuring the vertical displacement of a series of rods placed at various points over the surface and free to move only in the vertical plane. The rate of flow of air into the chamber under the fabric is very slow and is regulated by passing the air, which is under a pressure of 10 kilograms per square centimeter (140 pounds per square inch), through 110 centimeters (44 inches) of 1-millimeter tubing. A sheet of rubber dam is placed under the fabric to prevent air leakage. Considering these precautions, it is reasonable to assume that there




is a very uniform distribution of pressure under the fabric. As there is practically a zero rate of flow of air into the indicator, it is reasonable to assume that there is no pressure drop in the connecting line. The rate of load application in this apparatus is adjusted by the definition of the pressure and dimensions of the capillary tube in such a manner that the variations in the load application caused by the several fabrics having different stretch ratios produce only a very slight difference in the recorded tensibility properties of the material.

*Bursting tear test.*—The procedure is similar to that followed in the determination of the resistance to uniformly distributed pressure, excepting that slits are cut in the fabric at various parts and the pressure necessary to start the tear is recorded, together with the deflection at the time of the tear.

*Preparation of doped samples.*—The fabrics were stretched and tacked on frames under a tension of 80 grams per centimeter (0.45 pounds per inch) of width, and doped in a room maintained at approximately 65 per cent relative humidity at 21° C. The frames were 30 by 30 centimeters (12 by 12 inches) inside dimensions for the preparation of specimens for the determination of tensibility properties and 18 by 61 centimeters (7.2 by 24.4 inches) for the determination of resistance to pressure.

Films of dope were made by painting the dope on glass plates; the films subsequently were peeled off, and determinations were made of tensibility and resistance to pressure.

*Exposure tests.*—The fabrics, after tacking on frames and doping, were placed on the roof, and determinations were made periodically of their physical properties.

## VALUE OF TESTS.

*Tests made upon undoped and doped fabrics.*—The study of the adaptability of a particular fabric to wing coverings is confined entirely to the study of doped fabrics, as the character of the fabric is materially changed by the application of dope. There are some instances where the dope does not radically change the characteristics, such as the very compact fabrics and the heavier and more dense fabrics. The consideration of the properties of the undoped fabric is limited to the tangible expression of desired properties, which finds its greatest application in conveying to the manufacturer the structure of fabric most suitable for the purpose intended.

*Weight, yarn size, thread count, and tensile strength.*—These determinations, named in the title of this section, have been considered in the past the only requisites necessary to define mechanical fabrics, but the study of airplane fabrics has added to these the defining of the tensibility properties. Apart from the definition of the fabric from the manufacturing view point, these values, when one is familiar with them, convey a mental picture of the fabric and allow one to judge such things as dope absorption, probable crimp, limitations of distribution of load-stretch relations and character of surface, fatigue effects, and change of effective yarn strength after weaving.

*Tensibility properties.*—The determination of tensibility properties indicates more than any other test the performance of the material under flight conditions. It has been observed that the tightness of a wing covering is dependent upon the support which the fabric in its doped condition lends to the dope film. The phenomena of the fabric tightening after the application of the dope may be considered to be caused primarily by the dope constraining the yarns in their crimped condition. An examination of the shape of the load-stretch diagram indicates the manner in which the bond is disturbed when the doped material is stressed. The behavior of the doped fabric is entirely different from the behavior of either the dope or the fabric, and the shape of the tensibility curve determines the degree of permanent distortion which may be expected of any fabric and whether it will become loose or mushy. The tensibility properties, particularly those of elongation and tensile strength, together with the consideration of the number of yarns being stressed, is of value in predicting probable tear resistance.

An analysis of these properties very often indicates the particular phase of the manufacturing processes which should be changed in order to produce a desired result.

*Tear tests.*—The tear test affords practically the only means of determining the relative factor of safety of the wing covering after its continuity has been disrupted. The tear conditions may be classed into two kinds, (1) in which a hole is punctured in the covering which may be large enough for a tear to start in the weakest direction because of the surface tension induced by the pressures of flight; (2) in which a section of the wing covering protruding from the surface is subject to stresses which tend to dislodge it from the body of the cover, such as a tongue exposed in the slip stream. The two kinds of tear tests, the bursting and the rip test, are a measure of the resistance of the material to such stresses. The factors of vibration and tensibility in the case of the rip test are not considered directly, but from the general concepts of vibration and surface tension comparative results may be obtained.

*Bursting tests.*—An observation of a strip of doped fabric being stressed in tension reveals the fact that there is a lateral contraction of the sample which is necessarily accompanied by an increased elongation in the longitudinal or stressed direction. The yarns in a wing covering are under constraint, and it is logical to assume that a constrained sample may give different test results from one which is not. The exact magnitudes of the constraining forces are not known, but from a study of the changes in curvature of a deflected wing it is evident that the constraining forces are not of the same magnitude over the entire surface, even under the conditions of uniformly distributed pressure. It is difficult to integrate the effects of the warp and the filling properties of a fabric from an examination of the load-stretch diagrams of the warp and the filling. The study of curvatures gives an index to the relative effects, but it is still difficult to form an opinion as to the magnitudes of the effects. For these reasons it was thought advisable to subject a doped panel to uniformly distributed pressure and to study the contour of the deflected surface in the hope of arriving at some logical basis for determining the stress distribution in the fabric and of providing a convenient method of obtaining a single figure which might be taken as the relative factor of safety of the material and at the same time might be a measure of the tautness, deflection under pressure, and a test of a stripunder condition of proper constraint.

The bursting test does not give test results which will be comparable with the stresses induced by wing deflections, or rip tear under combined conditions of proper surface tensions and stress to rip; but it is believed that these may be predicted more readily from a consideration of the pressure deflection relations of any particular fabric, and the general concepts of surface tension.

## TEST RESULTS.

*Properties of linen airplane fabric (standard A grade)*—

Weight per square yard, undoped, 4 ounces.

Threads per inch—warp, 94; filling, 97.

Weight per square yard, doped, 5.9 ounces.

Tensile strength, 85 pounds per inch, undoped.

Tensile strength doped, 90 to 120 pounds, depending on the kind of dope.

Resistance to pressure—pressure, 14.7 pounds per square inch; deflection, 0.78 inch.

Tear test, rip, 3.82 pounds average.

Tear test (bursting)—pressure, 2.7 pounds per square inch; deflection, 0.50 inch.

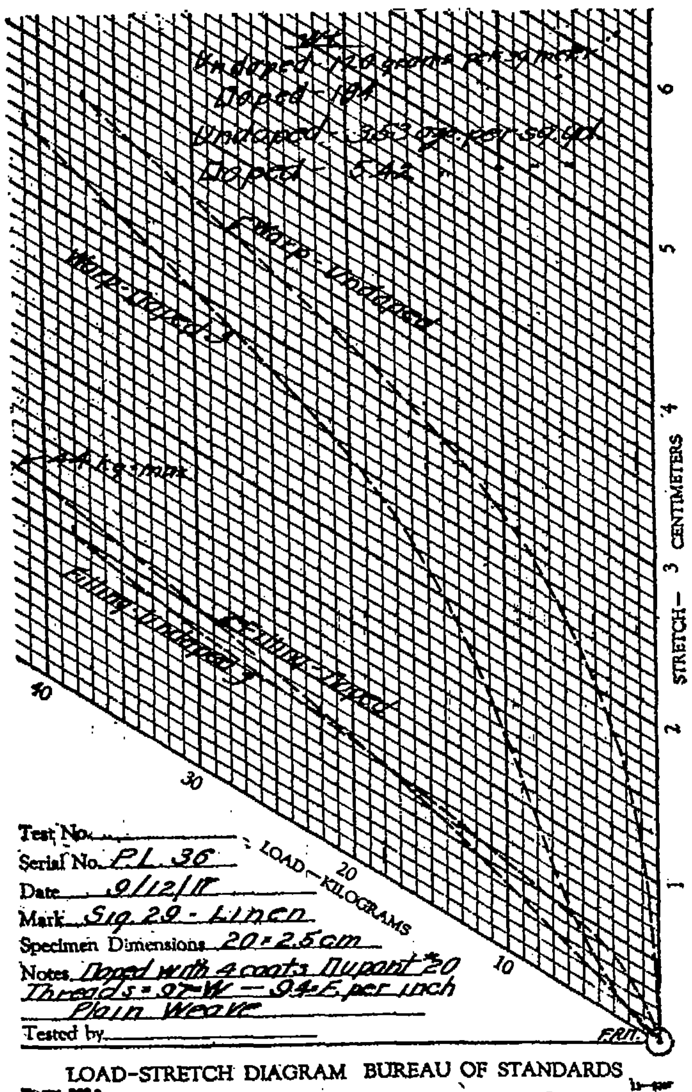
Refer to figures 8, 9, and 12 for tensibility, pressure, and tear tests.

The linen fabric is not uniform in yarn structure, and the tensibility curves vary somewhat, but it is thought that the above results are a fair average. The kind and make of dope used change the properties of the doped fabric; and, so far as is possible, a known fabric is tested with a new group of fabrics.

*The load-stretch diagram of undoped fabrics.*—The load-stretch diagram of the undoped fabric must be influenced by the character of the fiber, the structure of the yarn, and the method of weaving. The diagram may be divided into three parts; (refer to fig. 15) from zero to $(A)$ is almost entirely the crimp of the yarns; from $(A)$ to $(B)$ is the crimp of the yarns dominated by the stretch of the yarn in its crimped condition; from $(B)$ to the breaking load is the stretch of the yarn in its crimped or constrained condition. The curve $(D, O)$ may be taken to be the curve of the same number of yarns, but not interlaced. The line $(E, F)$ may be taken to be the curve of the yarns in their constrained position after the removable crimp $(O, B)$ has been taken out. It will be noted that the line $(E, F)$ has a greater slope than $(D, O)$ and that the warp $(G, H)$ has even more. From this it is seen that as the crimp of the yarns is reduced, the slope of the curve approaches the slope of the yarn curve. It then may be concluded that that part of the curve is very largely influenced by yarn characteristics.

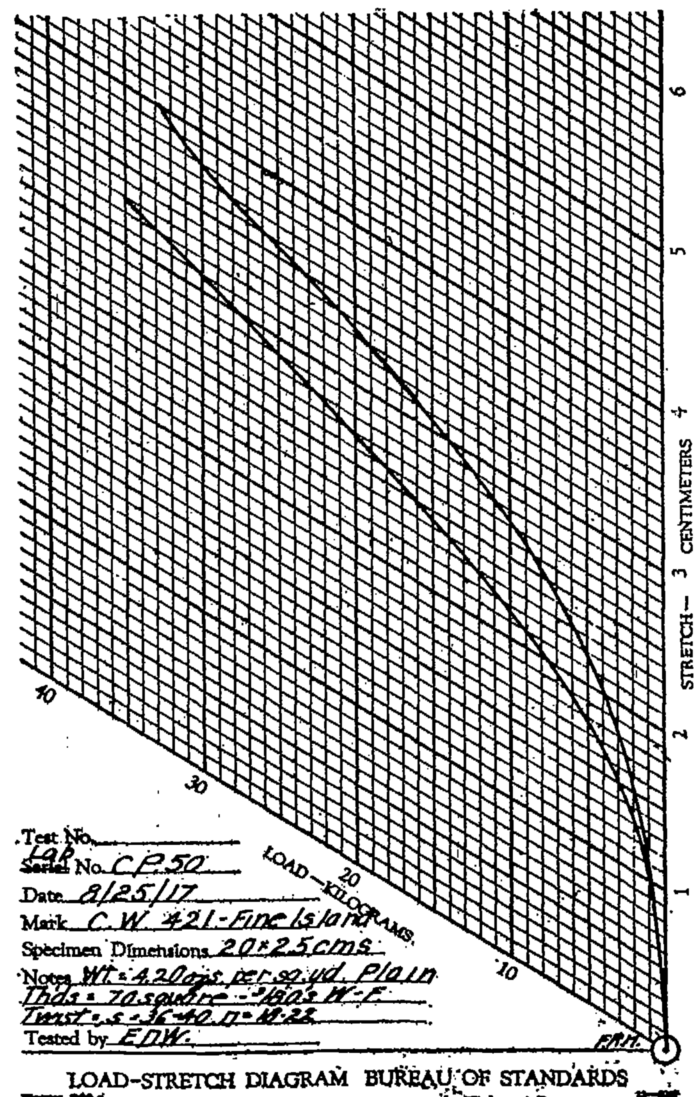
The distances $(O, F)$ and $(O, H)$ may be termed the removable crimp, and the sum of the two is dependent upon the weave structure and thread diameter, and to some extent upon the compressibility of the yarns. The relation between $(O, F)$ and $(O, H)$ is a function of the tensions of weaving. The fabrics shown on figures (15) and (16) are of the same weave structure and of the same yarns, but the weaving tensions are different. The sum of $(OF)$ and $(OH)$ practically equals the sum of $(OF')$ and $(OH')$; but the ratio of $(OF)$ to the total is very different from the ratio of $(OF')$ to the total, or to $(OH)$ and $(OH')$, respectively.

The two cases discussed are fabrics woven in the plain weave. It would be expected from the above that these yarns woven into a basket or mat weave would decrease the sum of $(OF)$ and $(OH)$ proportionally to the decrease in the number of interlacings, and this is very largely



Undoped - 120 grams per sq. meter
Doped - 184
Undoped - 3.53 ozs. per sq. yd.
Doped - 5.42
Warp - Undoped
Warp - Doped
Filling - Undoped
Filling - Doped
STRETCH — CENTIMETERS
LOAD—KILOGRAMS
Test No.
Serial No. P.L. 36
Date 9/12/17
Mark Sig. 29 - Linen
Specimen Dimensions 20 × 2.5 cm
Notes Doped with 4 coats Dupont #20
Threads = 97-W — 94-F. per inch
Plain Weave
Tested by
F.R.M.
LOAD-STRETCH DIAGRAM BUREAU OF STANDARDS


Fig. 8



STRETCH — CENTIMETERS
LOAD—KILOGRAMS
Test No.
Lab. No. C.P. 50
Date 8/25/17
Mark C.W. 421 - Fine Island
Specimen Dimensions 20 × 2.5 cms.
Tested by E.D.W.
F.R.M.
LOAD-STRETCH DIAGRAM BUREAU OF STANDARDS


Fig. 19

true. The limitations of adjusting the weaving tensions to change the relation of $(OF)$ to $(OH)$ are considerably reduced, due to the fact that the yarns are not bound and are more free to take up whatever position the internal stresses may demand in their tendency to equality of stresses. As a result, the distances $(OF)$ and $(OH)$ are nearly equal. It is therefore conceivable that the particular weave in question may have less total crimp and still have the crimp of the filling larger than that of the plain fabric. Inasmuch as the tautness is dependent upon the support which the system of yarns having least stretch gives to the dope, the plain fabric having more total crimp may have a greater tautness than the basket fabric.

The effect of changing the diameter of the yarns is of much the same effect as changing the weave structure. For any given weight of fabric an increase of yarn diameter, within fairly large ranges, is accompanied by a tendency of the load-stretch diagrams of the warp and filling to be the same. The lower limit of decrease of yarn diameter is defined by the limits of weaving difficulties. The corollary to this is, for any given yarn diameter, a decrease in the number of yarns is accompanied by a tendency of the load-stretch diagram of the filling to be the same as that of the warp.

The effect of weaving tensions is interesting; and it may be stated generally that an increased warp tension is accompanied by an increased filling crimp, or that a decreased width of cloth at the temples is accompanied by an increased filling crimp.

The control of the load-stretch diagrams by holding the number and diameter of threads constant in one system and varying the other system is not at present subject to a general statement excepting that the factors discussed above are the controlling ones; and it can not be definitely anticipated, with the present knowledge, which will have the dominating influence.

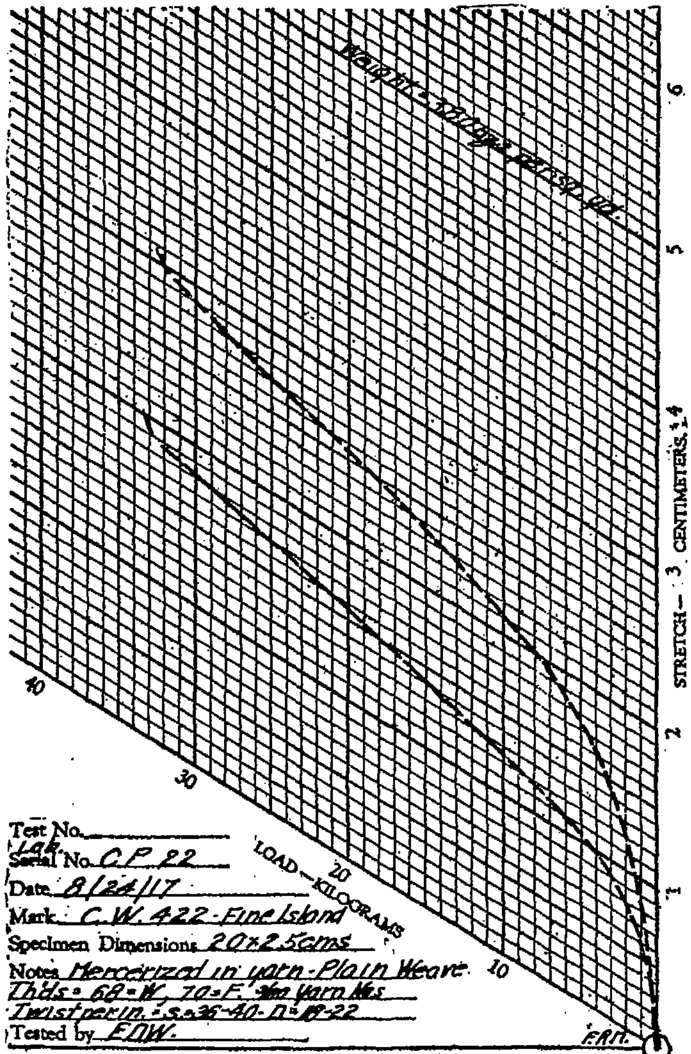
The stiffness of the yarns has a great influence upon the control of the load-stretch relations. The stiffness is taken to be the elongation of the yarn at any particular load. To illustrate, the curves shown in figure (19) are those of a doped unmercerized fabric, and those in figure (20) are those of the same yarns mercerized and woven with the same number of ends and picks. In each case an attempt was made to obtain the minimum crimp in the filling. From an examination of the curves, figure (19), it is concluded that the fabric is of fairly open structure, and it is constructed of 3/80's yarn 68 by 71. The stretch of the mercerized yarn is much less than that of the unmercerized yarn at any load, and hence will not balance in crimp as easily as the unmercerized yarn. The characteristics of the undoped curves are reflected in the curves of the doped fabric.

The curves shown in figure (18) are typical come-back loops. The particular fabric is very compact and has no transition from crimp to yarn characteristics. This is true of all closely woven fabrics and such fabrics when doped always show a breaking away of the dope from the fabric.

The zero load point of the hysteresis loop approaches a line tangent to the load-stretch diagram at the point when the loop leaves the curve. The difference between the area and portion of corresponding loops for the several fabrics is noticeably large, and it is believed that they are a fair index of fatigue failure. Provided the dope remains with the fabric as evidenced by the load-stretch relations, the question of fatigue is relatively unimportant. A break in the doped curve is always accompanied by a decreased amount of recoverable energy and failure in service. For these reasons this phase of the investigation has not been completed.

From the above discussion, it is obvious that the number of variables entering into the equation of the load-stretch diagram are very large, and that the machines used in the manufacture of textiles do not lend themselves to an easy analysis of the magnitude of their influence on the properties of the yarn or fabric. Such a study would be of great value, but it was thought a general knowledge of the factors would be sufficient in view of the exigency of the case. With this in view, many fabrics were constructed of widely different structure, so as to establish end points, in order that the performance of intermediate fabrics might be predicted.

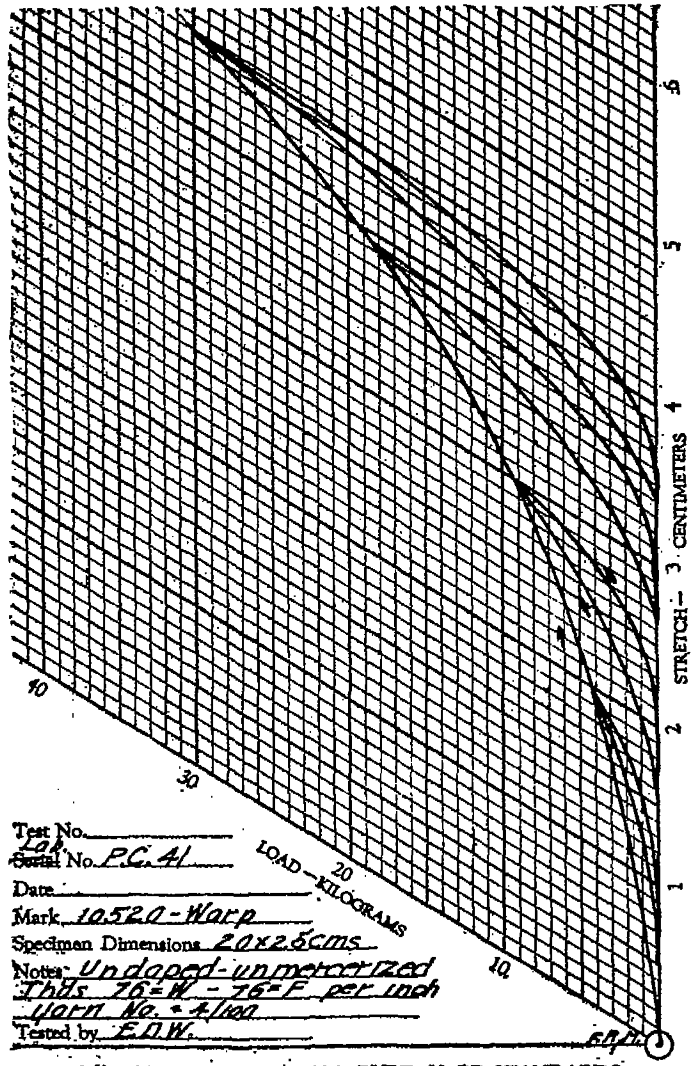
The treating of fabrics by subsequent finishing processes offers many interesting possibilities. The processes to which fabrics are subjected in the finishing operations are less controllable than those of the manufacture of the fabric. It is desirable to have the wings of uniform




Test No.
Lab. Serial No. C.P. 22
Date 8/24/17
Mark C.W. 422-Fine Island
Specimen Dimensions 20×2.5cms
Notes Mercerized in yarn-Plain Weave
Thds. 68=W. 70=F. Yarn Nos.
Twist per in. S.=36-40. F.=18-22
Tested by E.D.W.

LOAD-STRETCH DIAGRAM BUREAU OF STANDARDS
Form 300 a.

Fig. 20




Test No.
Lab. Serial No. P.C. 41
Date
Mark 10520-Warp
Specimen Dimensions 20×2.5cms
Notes Undoped-unmercerized
Thds. 76=W - 76=F per inch
Yarn No. = 4/100
Tested by E.D.W.

LOAD-STRETCH DIAGRAM BUREAU OF STANDARDS
Form 300 a.

Fig. 18

tautness and of uniform safety for any one type of plane. To accomplish this most successfully it is necessary only to control the load-stretch diagram of any particular fabric decided upon. From the consideration of uniformity of product, it appeared desirable to construct a fabric which would be ready for application immediately after weaving. After producing a fabric directly from the loom, the performance of which was as good if not better than the satisfactory linen, it became necessary to give attention to the many other problems of military fabrics.

*Load-stretch diagram of the doped fabrics.*—A doped fabric is a composite material made up of two separate materials interlocked in such a manner that the resultant material does not act like either one of the components or like what may be termed the sum of the two materials.

The load-stretch diagram of the undoped material is characterized by a very large stretch at the low loads, as is shown in figure 15. The load-stretch diagram of a dope film is practically a straight line up to from 1.5 to 3 per cent extension followed by a very rapid increment of stretch per unit of load increased; and the rupture occurs after an extension of 8 to 12 per cent. There appears to be wide variation in the physical properties of the dope film; and, for this reason, it is necessary to test new fabrics against old ones of known value. The effect of weather exposure on a dope film is to reduce its ultimate elongation without a material change in the position of the yield point or the slope of the curve below the yield point. Further exposure (after the ultimate elongation is in that part of the curve, any point of which may be the yield point) has the effect of reducing the elongation at any load below the yield point.

The load-stretch diagrams of doped fabrics may be classed as:

1. Those having the characteristics of the filling-doped curves of figures 8 and 15.
2. Those having the characteristics of the filling-doped curve of figure 16.
3. Those having the characteristics of the warp-doped curves of 8 and 16.
4. Those having the characteristics of the filling-doped curve of figure 17.

From a study of a pressure-deflected doped fabric, it is evident that the system of yarns having the least stretch at any load carries the greater proportionate part of the load. Hence the characteristics of the system having the least stretch are of the greater interest and govern the performance of the material.

The diagrams of figure 8 are those of the standard A linen, and those of figures 15 and 21 are of a 2/60's mercerized yarn 78 by 83. Both of these dope to satisfactory tightness and have the necessary permanency of tightness. Experience has proven them to be satisfactory.

The fabric described in figure 16 does not give the length of service which the cotton of figure 15 will give; it becomes quite loose after continued service.

The fabric of figure 17 is very unsatisfactory, in that it may be permanently dented, and, after a comparatively short time, becomes mushy, and deteriorates very rapidly both in strength and tautness.

The above examples are typical of the performance of fabrics having the general characteristics of these curves, and they will be taken up in detail.

1 (figures 8 and 15). The filling curves are practically straight lines, but it is evident that the yield point of the dope has been exceeded. The penetration of the dope was good, and it had the effect of binding the yarns together and of taking away the effect of the removable crimp to a large extent. This is particularly true of the part of the curve which is under stress during practically all conditions of flight. The filling doped curve would coincide with ($E'O$ if the effect of the removable crimp was entirely eliminated. It has been noted that the strip is not under lateral constraint during test, and that the elongation is exaggerated. The curve is considerably reduced in slope if the elongation is plotted against surface tension as calculated from the bursting test. Under these circumstances the two curves just referred to will coincide.

2 (figure 16). The filling curve of this fabric exhibits a break in its continuity, and, although it is practically parallel to the curve ($E_8$), there is strong evidence that the dope is becoming detached from the fabric. The penetration of the dope was the same as for the previous cotton fabric.

3 (warp-doped curves of 8, 15, and 16). The curves show a radical change of direction of curvature and in the case of 16 the doped curve crosses the undoped-warp curve. It is evident

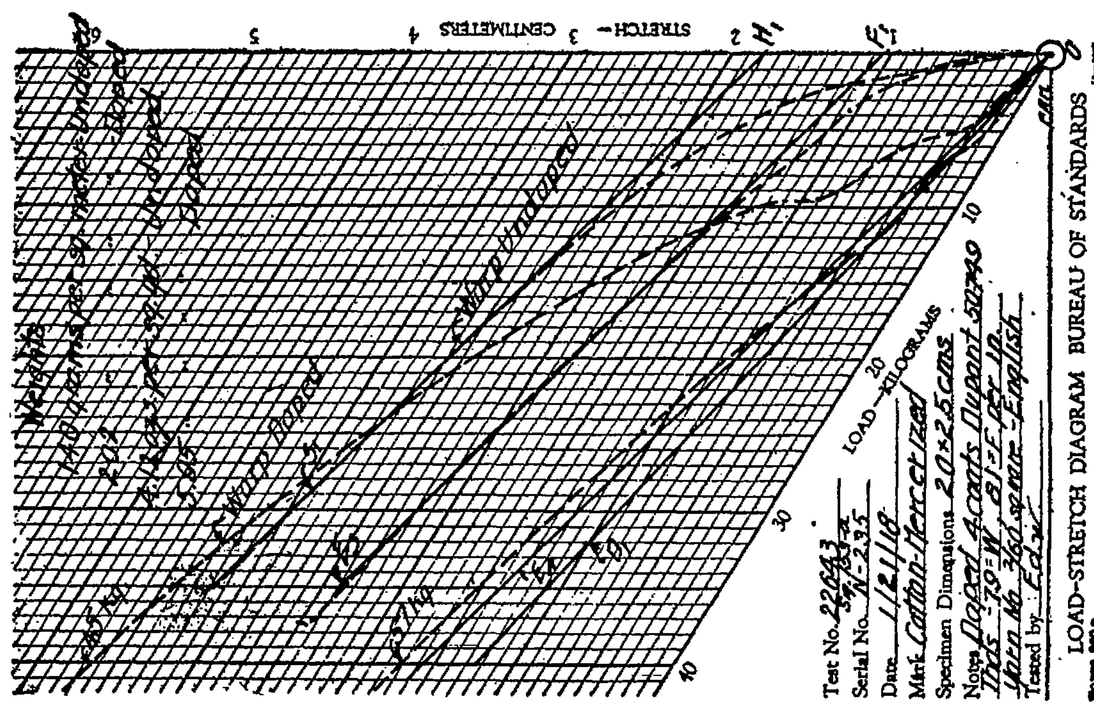

STRETCH — CENTIMETERS
LOAD—KILOGRAMS
LOAD-STRETCH DIAGRAM BUREAU OF STANDARDS

Fig. 16

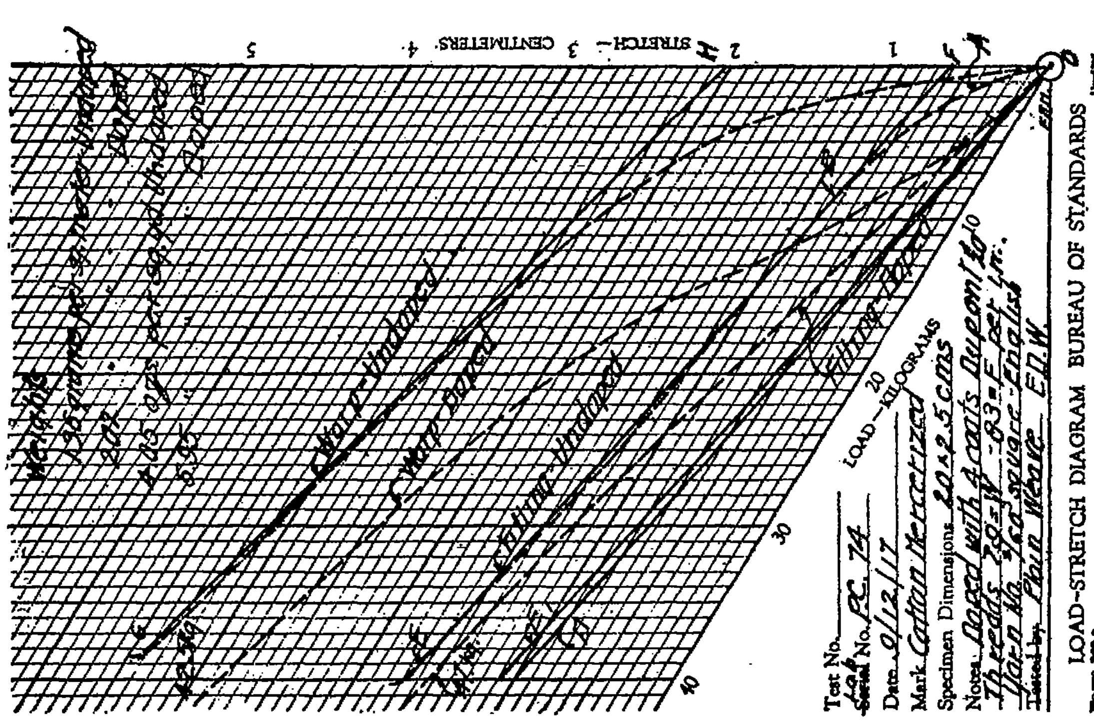

STRETCH — CENTIMETERS
LOAD—KILOGRAMS
LOAD-STRETCH DIAGRAM BUREAU OF STANDARDS

Fig. 15

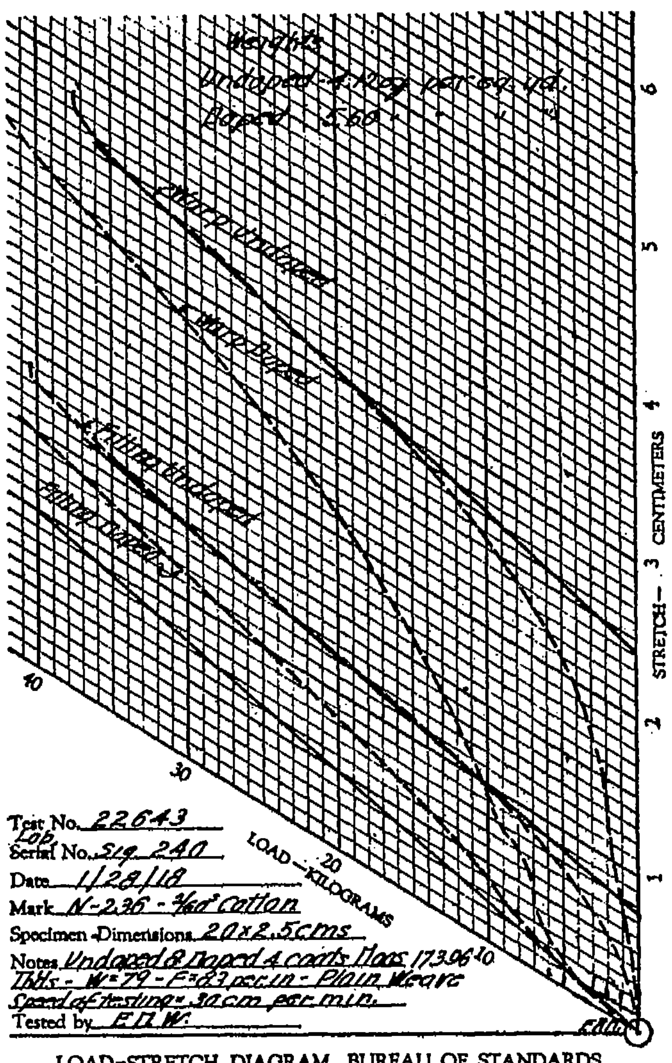

Weights
Doped 5.60
Warp Undoped
Warp Doped
Filling Undoped
Filling Doped 3
STRETCH — CENTIMETERS
LOAD—KILOGRAMS
Test No. 22643
Serial No. Sig. 240
Date 1/28/18
Mark N-236 - 4oz Cotton
Specimen Dimensions 20x2.5cms
Notes Undoped & Doped 4 coats
Thds - W=79 - F=83 per in - Plain Weave
Speed of testing = 30cm per min.
Tested by E.D.W.
LOAD-STRETCH DIAGRAM BUREAU OF STANDARDS
Form 360 a

Fig. 21

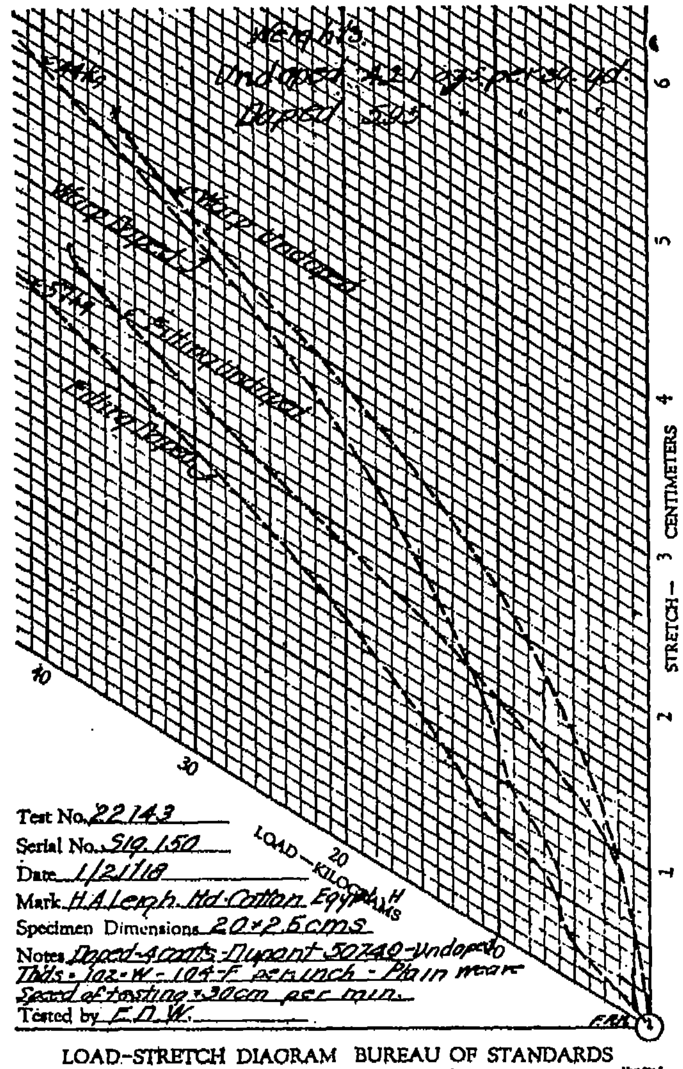

Weights
Warp Undoped
Warp Doped 3
Filling Undoped
Filling Doped 3
STRETCH — CENTIMETERS
LOAD—KILOGRAMS
Test No. 22143
Serial No. Sig. 150
Date 1/21/18
Mark H.A.Leigh. Md-Cotton
Specimen Dimensions 20x2.5cms
Notes Doped-4 coats-Dupont-Undoped
Thds = 102-W-104-F per inch - Plain weave
Speed of testing = 30cm per min.
Tested by E.D.W.
LOAD-STRETCH DIAGRAM BUREAU OF STANDARDS
Form 360 a

Fig. 17

that the dope has become entirely detached from the yarns and no longer binds the fabric together. Under such conditions the fabric is as easily and permanently deflected as the undoped material, and the dope will soon crack or dust off, exposing the raw fabric to the weather.

4 (figure 17). The undoped filling curve practically coincides with the undoped filling curve of figure 16. The filling doped curve shows a very marked break in the curve which may be interpreted as the fabric separating itself from the dope. This fabric will become mushy long before that of figure 16. In this particular case the dope penetration was not good and the dope film is merely a surface coating, and becomes easily separated from the fabric, whereas the penetration of the fabric figure 16 was very good.

From this discussion of typical weathering and service tests, it is evident that the life of the covering is very largely a function of the shape of the load-stretch diagram, and to some extent of the penetration of the dope. This assumes that the light protection is the same in all cases. It may now be assumed that the characteristics of the filling of figures 8 or 15 are the correct limitations to be placed in judging the performance of a fabric in so far as its life and tautness is concerned. It is comparatively easy to design a cotton fabric which will dope to satisfactory tightness and weather well, provided one is not interested in any other property of the material.

*Bursting resistance to uniformly distributed pressure.*—It has already been pointed out that this test gives a load-stretch diagram more nearly correct than the tensile method, and it permits a more complete study of the functions of the warp and filling. From measurements it is found that the greatest stress in the fabric is in a zone extending from about 12 centimeters from one short side of the frame to a like distance from the other end. If the filling is put on parallel to the short axis of the frame, it carries practically all of the load, and the stress in the warp is very slight.

The supposedly balanced fabrics placed on the bias and caused to be burst do not develop the looked-for high bursting pressures. It is probable that they are not really balanced, and that it is difficult to place them on frames and still preserve the condition of balanced stretch. From this it may be concluded that a biased balanced fabric can not be used to its full advantage in practice.

From the study of the fabric under pressure, it would appear that a fabric placed on with the warp parallel to the short axis of the wing or the long axis of the panel would, if it had the balance of the yarn in the filling, most efficiently satisfy the stresses in a wing covering. It is assumed that the filling stretch is very low as compared with the warp, and it is therefore under much greater stress. Under these conditions the warp strength may be only enough to provide satisfactory tongue tear resistance. The tear resistance (tongue test) of the warp is in a square fabric such as the standard A cotton 50 per cent greater than that of the filling; and under conditions of flight it is probable that it is nearly 75 per cent greater. A fabric having the balance of the yarn in the filling could not be laced according to the method using lacing cords through the fabric alone, but it is thought that the use of a corded reinforcing tape would satisfy the stresses at the lacing points. The results of bursting tests on such fabrics are appended.

The curves of pressure deflection shown in figure 9 show the relation between the pressure and deflection of the undoped fabric, the dope film, and the doped fabric. An examination of these curves with particular reference to the break in the curvature of the dope film curve indicates that the yield point is exceeded at a point very close to the breaking load of the doped fabric. This substantiates the previous contention that this lateral constraint modifies the characteristics of the strip test. From this it is evident that the value of the strip test is only to obtain an index to the performance of a fabric and should only be thought of in connection with the probable change due to lateral constraint such as is produced in the bursting apparatus.

The magnitude of the lateral constraint varies with the properties of the fabric, and, as will be pointed out under the consideration of tear, the effect may be to reverse completely the opinion based on the strip test.

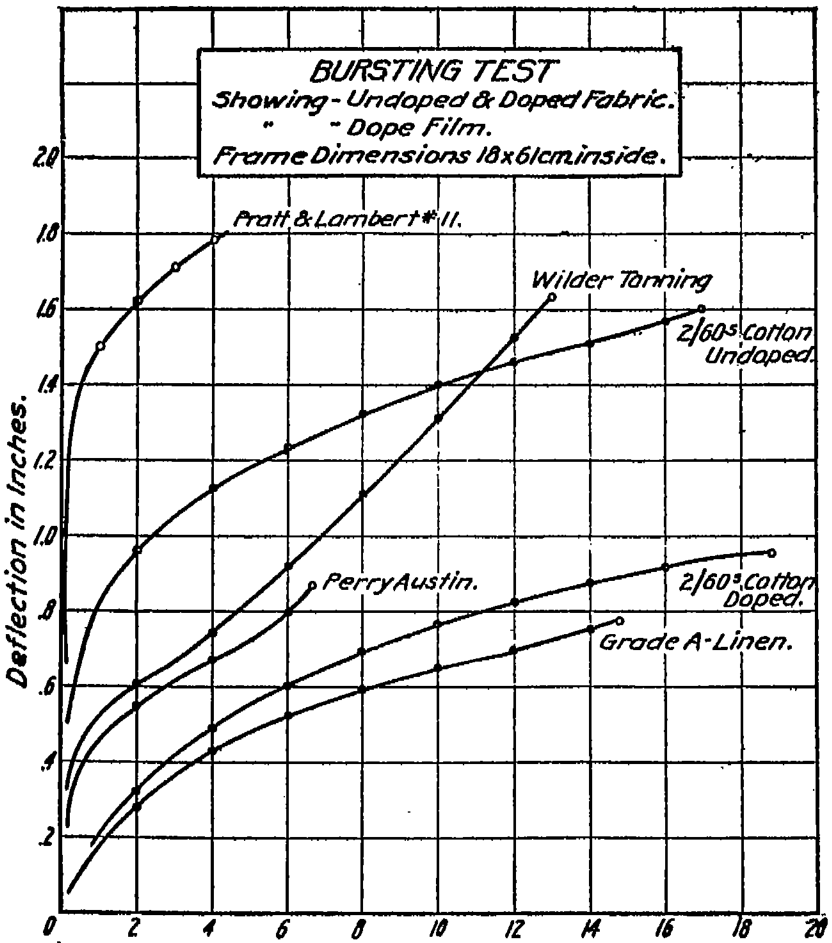

BURSTING TEST
Showing - Undoped & Doped Fabric.
" - Dope Film.
Frame Dimensions 18x61cm.inside.
Pratt & Lambert # 11.
Wilder Tanning
2/60s Cotton Undoped.
Perry Austin.
2/60s Cotton Doped.
Grade A-Linen.
Deflection in Inches.
Pressure - Lbs.per sq.in.

Fig. 9

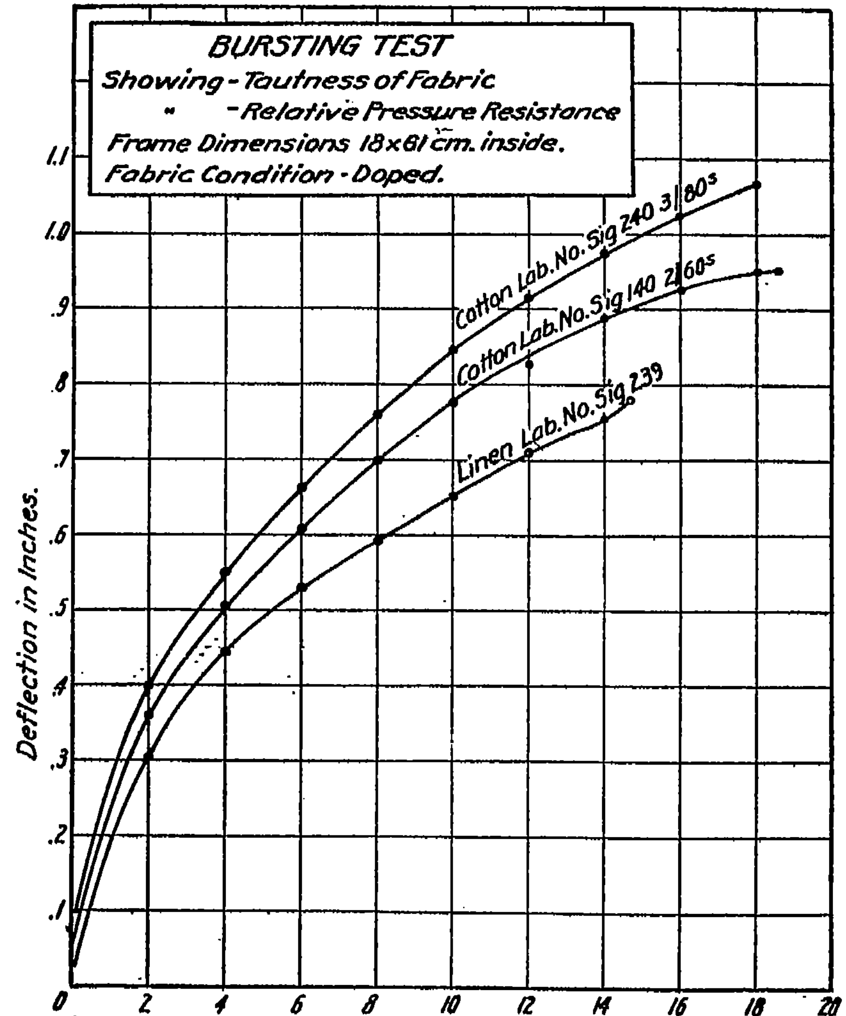

BURSTING TEST
Showing - Tautness of Fabric
" - Relative Pressure Resistance
Frame Dimensions 18x61 cm. inside.
Fabric Condition - Doped.
Cotton Lab. No. Sig 240 3/80s
Cotton Lab. No. Sig 140 2/60s
Linen Lab. No. Sig 239
Deflection in Inches.
Pressure - Lbs. per sq. in.

Fig. 22

The pressure-deflection relations of the 2/60 or linen fabric, figure 22, may be taken as the maximum allowable amount to be consistant with the maximum life of the dope and permanency of tautness.

## TEAR RESISTANCE.

The tear resistance constitutes one of the most important determinations in the study of the adaptability of a fabric of an airplane wing. The tear resistance of an undoped fabric differs so radically from that of the doped fabric that this phase will be discussed only in so far as it is interesting to know why the difference exists.

It has been observed that the yarns in an undoped fabric when torn slip a considerable amount, depending upon the weave structure, assuming any one yarn and thread count. The slippage is then a function of what may be termed slaziness. The amount of slippage in a doped fabric is so small as compared with the slippage of yarns in the undoped material that it may be considered negligible. The yarns may be considered as being held more or less rigidly in their relative positions.

The tear resistance of a doped material may be considered as the integration of the stresses in the direction of the plane of the fabric within the zone of tear. The distance to which the stresses exist either side of the point of tear is a function of the elongation of the material, and the magnitude of the stresses is dependent upon the effective strength of the individual yarns.

To illustrate more clearly the factors influencing the tear resistance the following fabrics are considered.

| Sample mark. | Thread count. | | Yarn number. | | Weight per square yard (un doped). |
|---|---|---|---|---|---|
| | W. | F. | W. | F. | |
| Linen A | 96 | 94 | ........ | ........ | 3.5 |
| Cotton A | 80 | 80 | 2/60 | 2/60 | 4.2 |
| 265 P | 88 | 92 | 1/60 | 2/60 | 3.9 |
| 265 B | 88 | 92 | 1/60 | 2/60 | 3.7 |
| 8774 | 78 | 81 | 2/60 | 2/60 | 4.2 |

*Tension tests.*

| Sample. | Tensile strength (pounds per inch), doped. | | Stretch (per cent), ultimate, doped. | | Threads per inch. | | Yarn strength—tensile+threads. | |
|---|---|---|---|---|---|---|---|---|
| | W. | F. | W. | F. | W. | F. | W. | F. |
| Linen A | 94 | 108 | 18 | 8 | 96 | 94 | 0.98 | 1.15 |
| Cotton A | 93 | 103 | 16 | 10 | 80 | 80 | 1.16 | 1.29 |
| 265 P | 52 | 128 | 15 | 10 | 88 | 92 | ........ | 1.39 |
| 265 B | 57 | 134 | 13 | 7 | 88 | 92 | ........ | 1.46 |
| 8774 | 90 | 101 | 19 | 12 | 78 | 81 | ........ | 1.25 |

*Tear tests.*

| Sample. | Rip tear (pounds). | | Rip tear, single (pounds). | | Single by 2. | Wound test (pounds). | |
|---|---|---|---|---|---|---|---|
| | W. | F. | W. | F. | | W. | F. |
| Linen A | 6.45 | 3.83 | ........ | 3.56 | 7.12 | 78 | 97 |
| Cotton A | 5.06 | 3.82 | ........ | 2.84 | 5.68 | 70 | 99 |
| 265 P | ........ | 4.41 | ........ | 2.82 | 5.64 | 43 | 95 |
| 265 B | ........ | 3.52 | ........ | ........ | ........ | 51 | 115 |
| 8774 | 3.36 | 2.67 | ........ | ........ | ........ | ........ | ........ |

The wound tests were made according to the following:

1. Sample, 4 by 6 inches.
2. Distance between jaws, 3 inches.
3. Jaw width, 3 inches.
4. Slit, 1 inch.
5. Movement of pulling clamp, 12 inches per minute.

The following results were obtained from pressure tests on a doped frame:

| Sample mark. | Burst test. | | | | Burst tear, 2-inch slit. | | | | Burst tear, 1-inch cross slit. | | Yarn strength, S. T.+ threads. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | P. | D. | S. T. | E. | P. | D. | S. T. | E. | P. | D. | |
| Linen A | 16.2 | 1.02 | 104 | 5.5 | 2.5 | 0.48 | 33 | 1.8 | 4.4 | 0.51 | 1.00 |
| Cotton A | 18.8 | 1.13 | 113 | 6.8 | 3.2 | .64 | 31 | 2.2 | 5.5 | .54 | 1.41 |
| 265 P | 24.6 | 1.81 | 128 | 9.1 | 3.2 | .67 | 30 | 2.4 | 6.2 | .73 | 1.39 |
| 265 B | 22.4 | 1.12 | 134 | 6.7 | 2.4 | .53 | 29 | 1.5 | 5.9 | .52 | 1.46 |

P. = Pressure, pounds per square inch.

D. = Deflection of center point in inches.

S. T. = Calculated surface tension.

E. = Elongation of material in per cent.

Burst tear = 1-inch cross slit (±). Cross slits were cut at various parts of the fabric.

Fabric 265 P is woven in the plain weave—mercerized filling; unmercerized warp.

Fabric 265 B is woven 2 by 2 in the warp and 1 by 1 in the filling—mercerized filling; unmercerized warp.

Fabric cotton A is a plain weave of mercerized yarn.

Fabric 8774 is a plain weave of unmercerized yarn.

The general characteristics of the fabrics for the purpose of this discussion are:

The effective yarn strength varies somewhat and the character of the yarns is different. The fabric 8774 exhibits radical reversals of curvature in the load-stretch diagrams, indicating that the dope has a great tendency to become separated from the fabric. The fabric 265 B, when torn across the filling, shows considerably more yarn slippage or rather more yarn distortion than the other fabrics. The tear resistance across the filling will be considered largely.

The results noted in foregoing tables were obtained from tension tests and rip-tear tests:

A comparison of the tensile strength and stretch surface tension and the value of (E) is interesting and substantiates the statement that the strip test is subject to lateral contraction, which influences the magnitude of the results.

The rip test proper was made according to the test outlined, in which the material was torn when subjected to the lateral constraint of the fabric doped on a panel.

The single rip test was performed on unconstrained material and having only one point on the line of tear. It is observed that ;wice he single unconstrained test is greater than the double constrained test. This shows clearly the effect noted earlier that a fabric detached from a frame turns back from the point of tear and increases the apparent tear resistance. Considering the fact that a wing fabric is constrained laterally, it is evident that tear tests should be made on the panel.

The values of rip tear were taken from the autographic records shown in figures 10 to 14, inclusive. The variations of tension are plotted against time. They show maximum tensions necessary to start the tear and minimum tensions at which the tear stops. The values of average maximum tear are of importance and are listed in the tables. However, it is necessary to know how the material behaves after the tear starts, and the graphs are sufficient to indicate this. The linen has a slightly higher average tear, a much lower minimum tear and a lower average tear than the grade "A" cotton. A comparison between the irregularity of the tear curves for cotton and the stretch is of interest. The warp and filling tear of grade "A" cotton illustrates graphically the effect of stretch or tear resistance. The number of threads and strength of the yarns are the same, and the increased stretch of the warp materially increased the tear resistance as well as the irregularity.

The tables may be more easily visualized by referring to the figures 30 and 31, which may be considered as graphic tables. Figure 30 refers to rip tear alone.

From an examination of the curve 1–F, which represents the rip or tongue tear test, and the curve 2–F, which represents the yarn strength, it is observed that with the exception of fabric

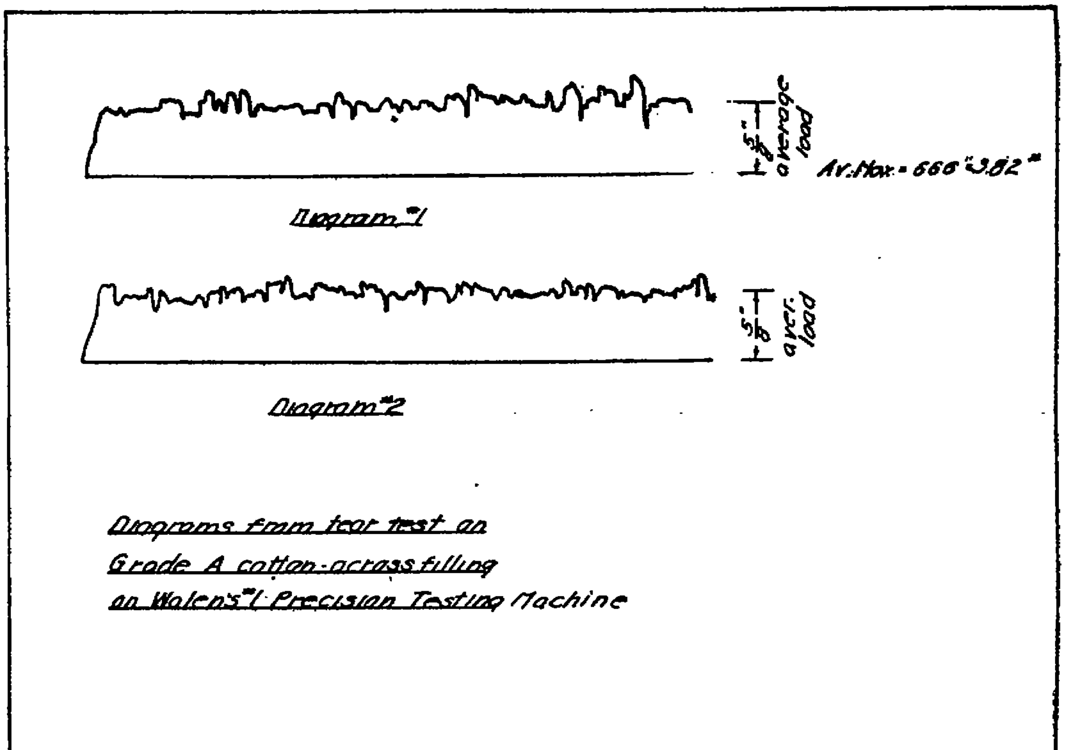

average load
Av. Max = .666" = 3.82"
Diagram #1
aver. load
Diagram #2
Diagrams from tear test on
Grade A cotton-across filling
on Wolen's #1 Precision Testing Machine

Fig. 10

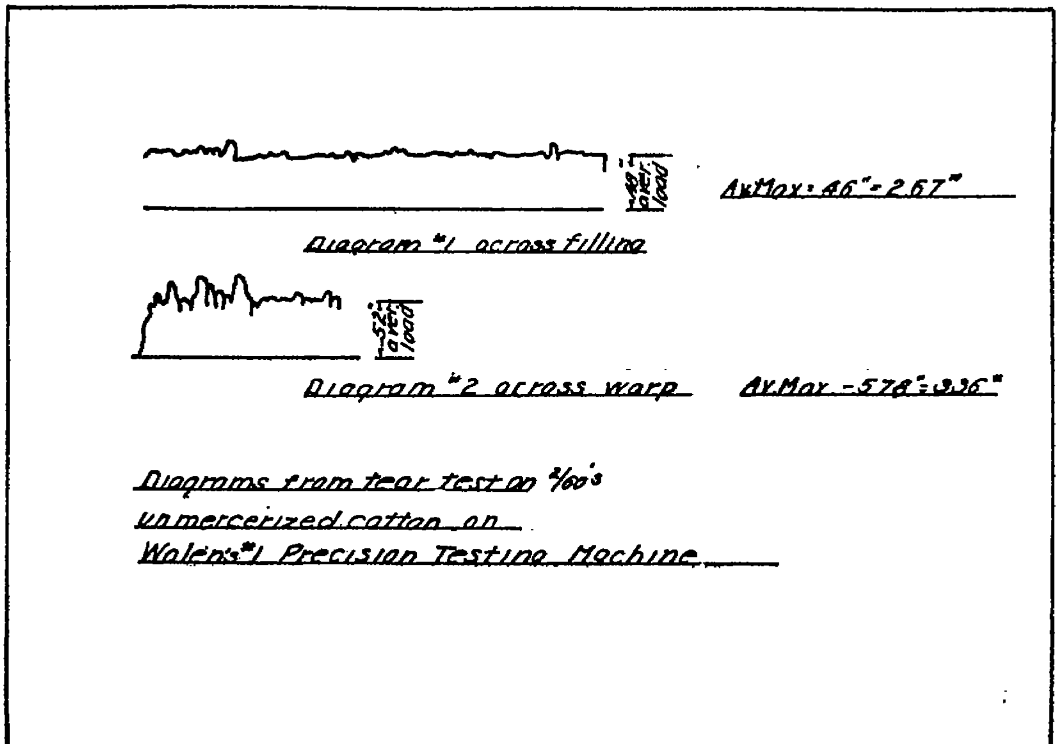

aver. load
Av. Max = .46" = 2.67"
Diagram #1 across filling
aver. load
Diagram #2 across warp
Av. Max = .578" = 3.36"
Diagrams from tear test on 2/60's
unmercerized cotton on
Wolen's #1 Precision Testing Machine

Fig. 11

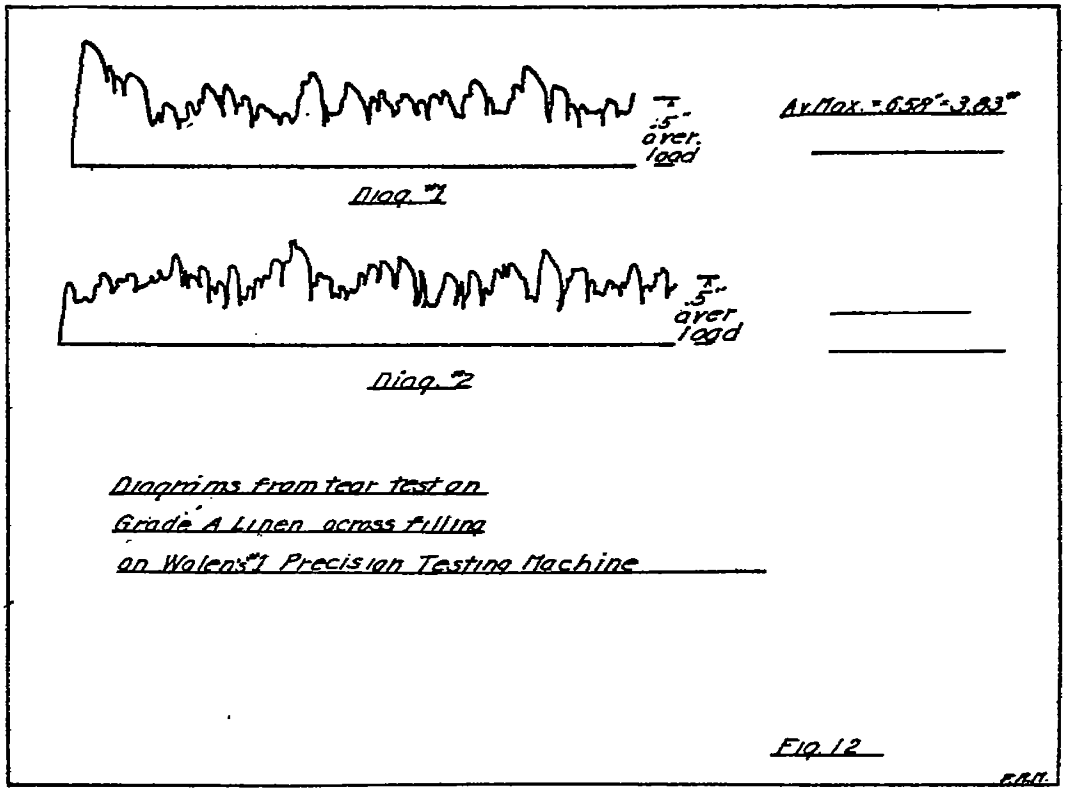

.5" aver. load
Av. Max. = 6.58" = 3.83"
Diag. #1
.5" aver. load
Diag. #2
Diagrams from tear test on
Grade A Linen across filling
on Walen's #1 Precision Testing Machine
F.R.M.

Fig. 12

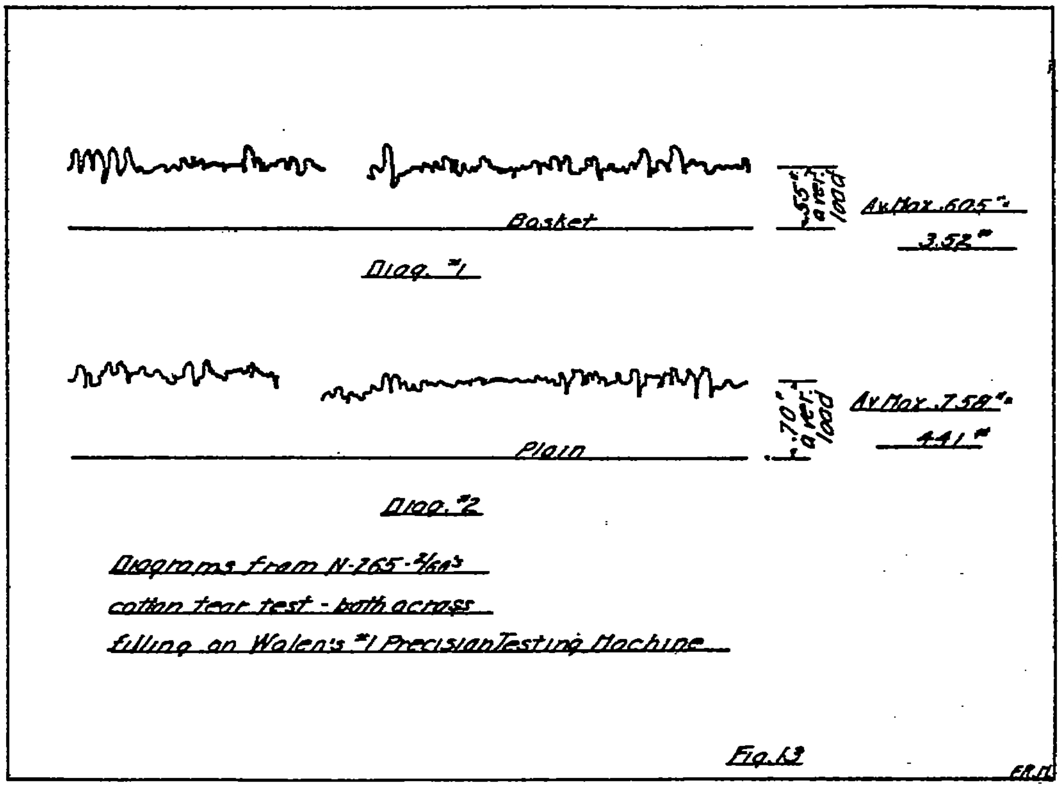

Basket
.55" aver. load
Av. Max. .605" = 3.52"
Diag. #1
Plain
.70" aver. load
Av. Max. .758" = 4.41"
Diag. #2
Diagrams from N-265-3/4oz
cotton tear test - both across
filling on Walen's #1 Precision Testing Machine
F.R.M.

Fig. 13

8774 the effective single yarn strength dominates the tear resistance, and that the elongation or stretch (3–F) has considerable influence. The fabric 265 B has yarn slippage to a greater degree than the others, which would tend with the greater effective strength to increase materially the tear resistance. This is not the case, as the tear resistance is lower and is made lower by reason of comparatively little stretch.

The fabric 8774 is of interest in that it is apparently contradictory of the above-noted tendencies. It was noted that the load-stretch diagram exhibited a radical change of curvature, which indicates a great tendency for the dope to become separated from the yarn. This condition is exaggerated in the tear test due to torsion of the yarns, and the effective strength approaches the strength of undoped fabric yarns. The increase of strength due to doping is much greater in the case of unmercerized yarns than in the case of mercerized yarns, which further exaggerate the value of the effective strength as found by dividing the tensile strength doped by the number of threads. The dotted line of curve 2–F indicates the effective strength

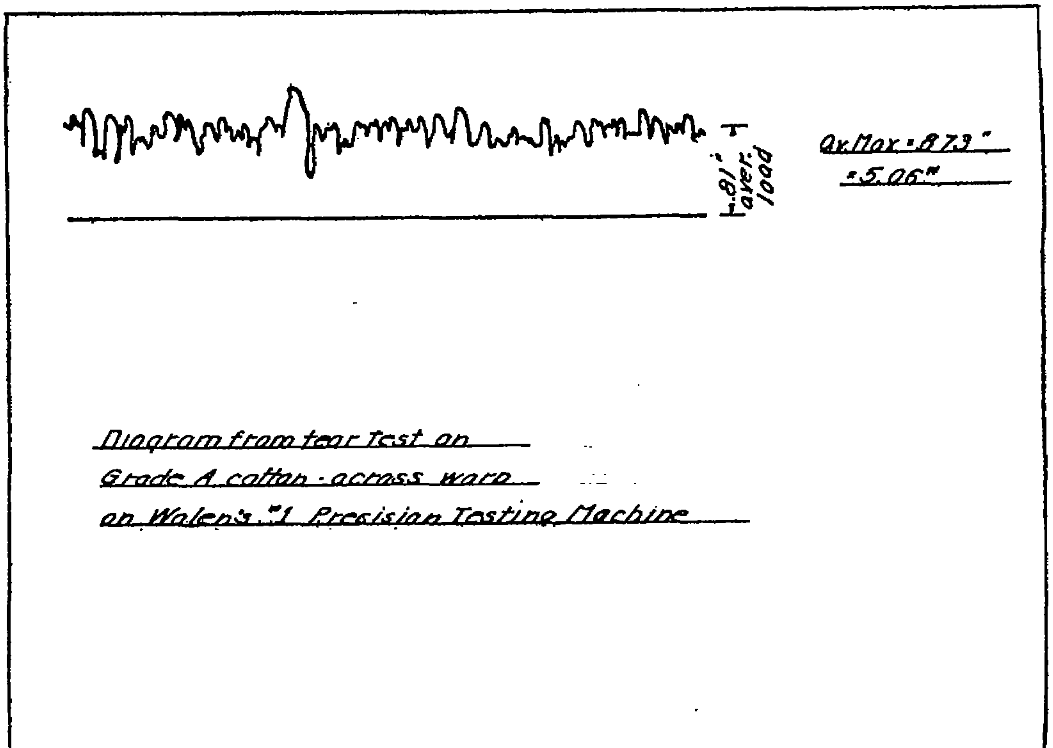
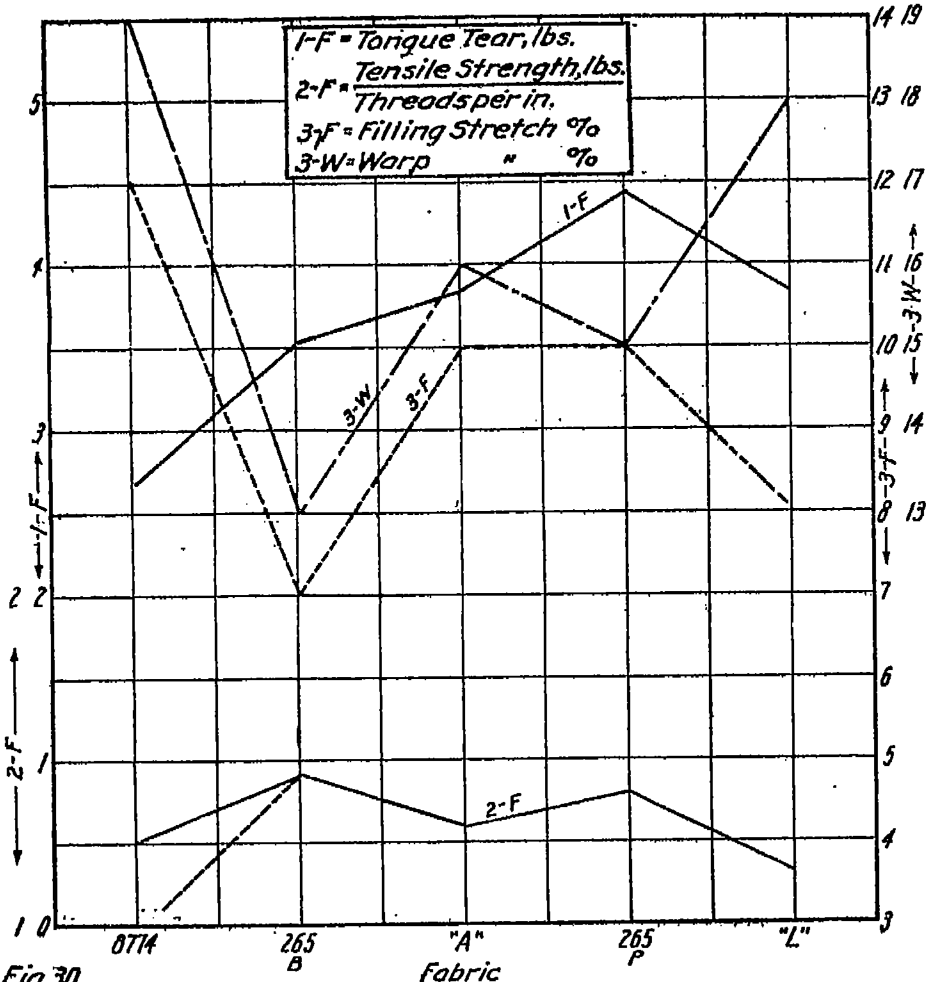
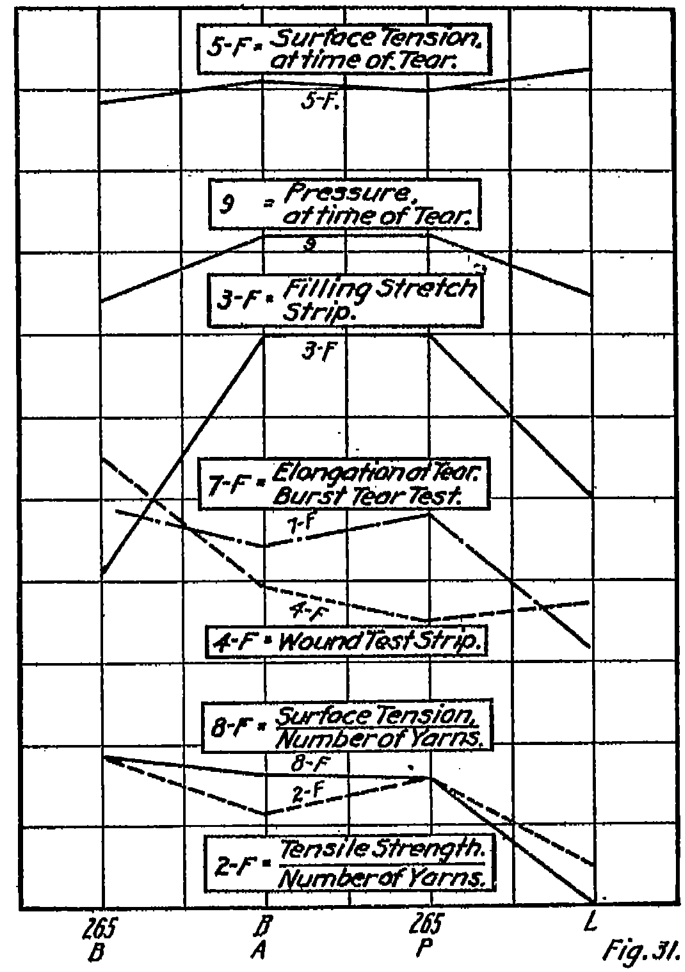



Fig 14

of the undoped yarns. The curve ought to be more steep. From this consideration, it is seen that the noted tendencies are true.

The curves on figure 31 are plotted from values obtained from burst test. The curve 5–F is the surface tension at the time of tear and corresponds to the tensile wound test, the results of which are plotted in curve 4–F. The results are radically different, due to difference in lateral constraint. The elongation in the burst tear at the time of tear is shown by curve 7–F. The elongation at the burst is parallel to this curve. It will be observed that the relative amount of stretch is reversed in the two methods of test, and that the curves of effective tensile yarn strength (2–F), stretch (3–F), and wound test (4–F) are fairly consistent in themselves. The effective surface tension yarn strength (8–F), elongation (7–F), and surface tension at time of tear (5–F) are consistent. The differences between the groups are therefore due to lateral constraint. It is observed that the wound test without lateral constraint may lead to conclusions which are not correct.


1-F = Tongue Tear, lbs.
2-F = Tensile Strength, lbs. / Threads per in.
3-F = Filling Stretch %
3-W = Warp " %
1-F
2-F
3-W
3-F
8714
265 B
"A"
265 P
"L"
Fabric
Fig. 30


5-F = Surface Tension, at time of Tear.
9 = Pressure, at time of Tear.
3-F = Filling Stretch Strip.
7-F = Elongation at Tear. Burst Tear Test.
4-F = Wound Test Strip.
8-F = Surface Tension, Number of Yarns.
2-F = Tensile Strength. Number of Yarns.
265 B
B A
265 P
L
Fig. 31.

The curve 9, figure 31, is a more nearly true index to wound tear resistance, for the factor of safety in an airplane wing covering is the relative pressure which the material is capable of withstanding before tear starts from a wound. The value of surface tension as determined by a tension wound test is apt to be misleading and can not be used to calculate pressures.

The elongation influences tear, and from the considerations of the above discussion and burst tests it is possible to predict change in performance due to wing deflections.

From the fact noted that the elongation may be considerably reduced in the burst test, it is logical to assume that the interpretation of the load-stretch diagram may be misleading, and therefore, in judging performance, it is best to consider the pressure deflection curves rather than the load-stretch diagrams.

It was noted that the elongation influenced the tear resistance, in that a decreased elongation caused a decrease in tear resistance. It is assumed from this that an increased amount of lateral constraint perpendicular to line of tear will reduce the tear resistance. The surface tension, or lateral constraint, is less in the cotton "A" than in the linen for any given pressure, as far as tear is concerned. From this it may be concluded that, although the rip tear tests show the same values for "A" cotton and "A" linen, the factor of safety is greater for the cotton than for the linen.

The consideration of bursting pressures lead to the same conclusion.

*Tabulation of tests.*—The following groups of fabrics have been tested to give enough information from a consideration of the foregoing to allow one to draw his own conclusions as regards the suitability of any fabrics of the group.

The values of yarn number were given by the manufacturer. The values of weight and thread count are actual determinations made in the laboratory, and it is possible that in some cases the three values will not check.

## DISCUSSION OF GROUP A.

The fabrics of group "A" are miscellaneous fabrics which have been considered. Service tests were made on several of these and the results may be summarized.

The fabric No. 7 of 2/40 unmercerized yarn gave satisfactory service on many planes. The same material of mercerized yarn, fabric 17, gave very good service. The dope absorption was excessive.

The fabric (50) of 3/80's yarn gave fair service on training planes, but became mushy in spots and loose after continued use. The same material made of mercerized yarn, fabric (22), gave excellent service. The dope penetration was excessive, which reduced the tear resistance materially.

The fabric (51) of 2/50 and 3/80's yarn gave questionable service.

The fabric (26) of 2/60's mercerized yarn gave excellent service and the dope penetration was not greater than was considered consistent with good service. More extensive tests on this material are given elsewhere in the report under "A" cotton.

It was concluded that this fabric had the most advantageous combination of desirable qualities, and that it was the best fabric for use immediately after weaving.

*Group A.*

| Sample. | Weight (ounce per square yard). | Thread count. | | Yarn number. | | Tensile strength. | | Elongation. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 20 | | 70 | |
| | | W. | F. | W. | F. | W. | F. | W. | F. | W. | F. |
| 25 | 5.3 | 88 | 87 | 2/70 | 2/70 | 70.5 | 79.0 | 17.5 | 6.0 | 24.5 | 11.0 |
| 7 | 4.2 | 55 | 59 | 2/40 | 2/40 | 72.6 | 81.5 | 10.5 | 10.25 | 15.5 | 14.5 |
| 51 | 4.2 | 68 | 71 | 2/50 | 3/80 | 79.0 | 79.0 | 14.5 | 8.5 | 20.5 | 18.5 |
| 50 | 4.2 | 70 | 70 | 3/80 | 3/80 | 72.6 | 77.0 | 13.5 | 10.5 | 20.0 | 16.0 |
| 22 | 3.8 | 68 | 70 | 3/80 | 3/80 | 72.6 | 72.6 | 10.5 | 6.0 | 15.0 | *9.5 |
| 27 | 5.0 | 76 | 75 | 4/100 | 4/100 | 75.0 | 83.5 | 14.5 | 9.5 | 21.0 | 15.0 |
| 26 | 4.2 | 79 | 84 | 2/60 | 2/60 | 88.0 | 90.0 | 10.0 | 5.0 | 14.5 | *8.0 |
| 17 | 4.2 | 56 | 56 | 2/40 | 2/40 | 77.0 | 83.5 | 9.5 | 5.0 | 13.0 | *7.0 |
| 15 | 5.4 | 85 | 88 | 2/50 | 2/50 | 79.0 | 110.0 | 17.0 | 7.0 | 24.5 | 11.0 |
| 59 | ........ | 80 | 65 | 3/80 | 2/50 | 70.5 | 66.0 | 16.5 | 5.5 | 23.5 | 10.0 |
| 52 | 4.5 | 93 | 86 | 2/60 | 2/60 | 79.0 | 81.5 | 11.5 | 6.5 | 18.0 | 11.0 |
| 36 | 5.0 | 77 | 76 | 2/45 | 2/47 | 77.0 | 75.0 | 13.5 | 9.0 | 20.0 | 13.5 |
| 16 | 4.2 | 71 | 69 | 3/80 | 3/80 | 72.6 | 77.0 | 13.0 | 10.5 | 19.0 | 16.0 |
| 14 | 5.3 | 88 | 87 | 2/70 | 2/70 | 72.6 | 75.0 | 18.5 | 7.0 | 25.5 | 11.5 |
| 13 | 4.5 | 76 | 78 | 2/50 | 3/80 | 83.5 | 81.5 | 24.5 | 6.5 | 28.0 | 11.0 |
| 11 | 5.4 | 67 | 71 | 2/40 | 3/60 | 88.0 | 97.0 | 23.0 | 6.5 | 28.0 | 10.5 |
| 10 | 5.2 | 67 | 71 | 2/40 | 2/40 | 97.0 | 101.0 | 19.0 | 6.5 | 25.5 | 10.0 |
| 9 | 4.6 | 81 | 45 | 2/50 | 2/50 | 67.0 | 88.0 | 21.5 | 6.5 | 28.5 | 10.0 |
| 6 | 4.2 | 69 | 68 | 2/50 | 2/50 | 70.5 | 81.5 | 13.0 | 7.5 | 18.5 | 12.0 |
| 40 | ........ | 101 | 95 | 3/100 | 3/100 | 88.0 | 90.0 | 14.0 | 7.0 | 22.0 | 11.0 |
| 38 | ........ | 74 | 76 | 4/100 | 4/100 | 72.6 | 86.0 | 18.0 | 7.0 | 25.0 | 11.0 |
| 37 | ........ | 76 | 75 | 4/100 | 4/100 | 77.0 | 88.5 | 14.5 | 9.5 | 21.0 | 15.0 |
| 12 | 4.2 | 68 | 71 | 2/50 | 3/80 | 77.0 | 77.0 | 15.0 | 8.5 | 20.5 | 13.0 |

* Mercerized.

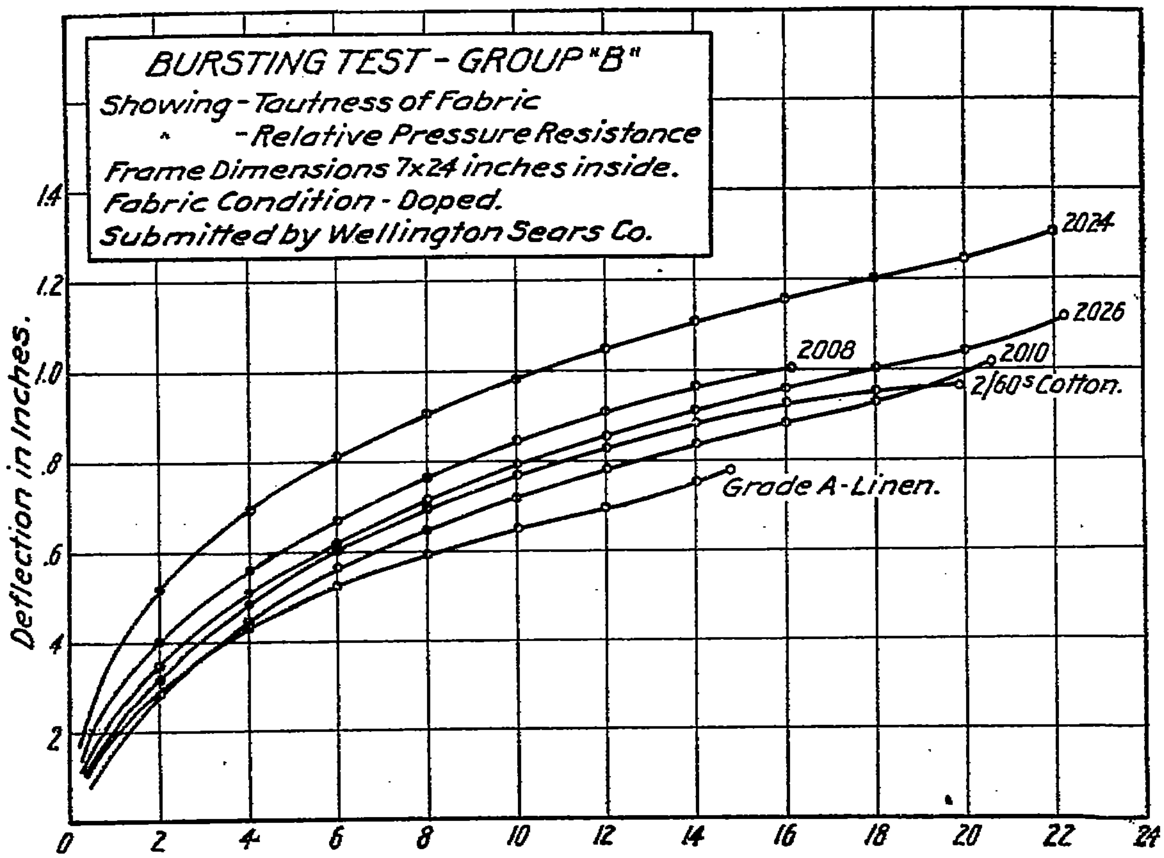



Fig. 23

## DISCUSSION OF GROUP B.

The fabrics of group B were all made of 3/80's mercerized and bleached yarns, excepting those referred to as A and B cotton. The grade A cotton is the standard 2/60's mercerized cotton fabric, and the B is the 3/80's mercerized cotton fabric.

The experiments were based on the general knowledge that a 3/80's mercerized and bleached thread yarn is the strongest per unit of weight, and it was thought advisable to conduct a few experiments on fabrics made up of these yarns. The values listed under the heading "unit strength" were found by dividing the tensile strength of the warp and filling respectively by the weight per square yard. This value appeared to be the best common basis to be used in de-

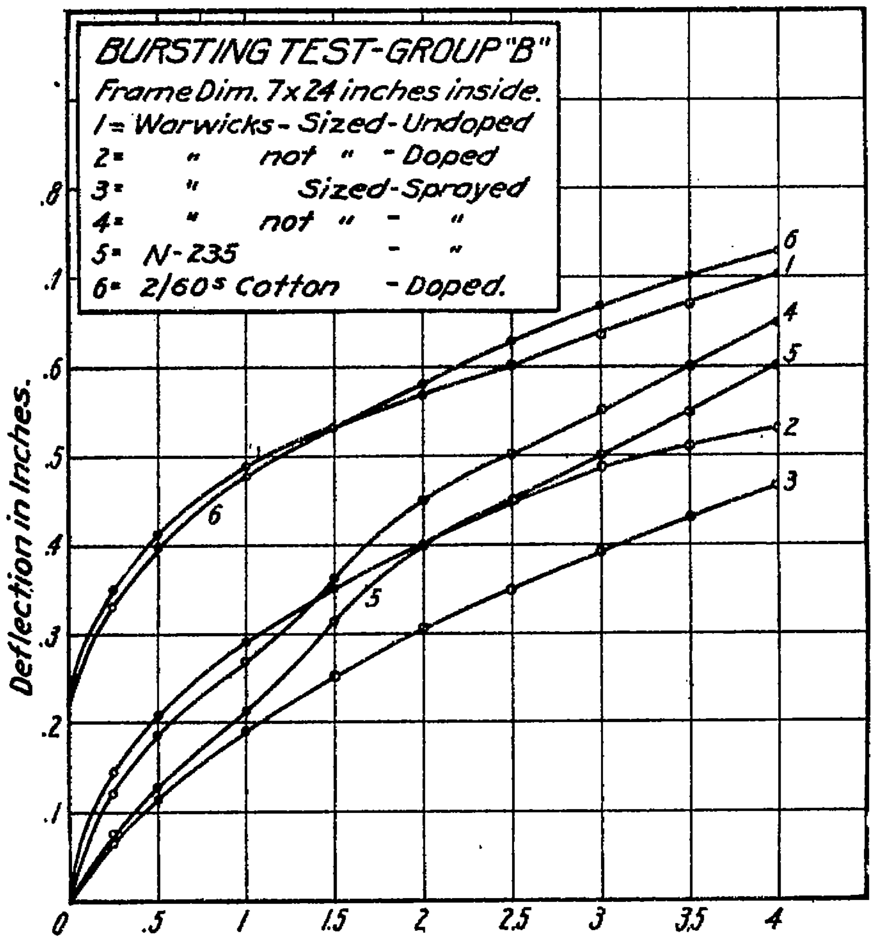



Fig. 26.

termining the relative values of the strengths of fabrics of different weights. It will be noted that the unit strength is greater than that obtained from the experimental 3/80's fabric and that it is somewhat less than the unit strength of the experimental 2/60's fabric. From this it was concluded that although the yarn strength is greater per unit of weight the fabrics are not stronger. Assuming a plain weave fabric of fairly close structure such as 2011, it is evident that the strongest yarn will not produce the strongest fabric. The tensile strength is a measure of the vertical components of stresses parallel to the line of stress. For the same stress in the yarn, the measured component is reduced in proportion to the manner in which the yarn is interlaced as compared to the straight yarn. The interlacing of the yarn serves to impart to the fibers an additional bond, and hence has the tendency to increase the yarn strength.

The elements of fiber crushing and radial slippage enter into the consideration of stresses at the interlacings. From these considerations, it is observed that a yarn weaker than the maximum strength may give the stronger fabric, for in such a case it is possible to utilize abvantageously the forces expended at the points of interlacings. The yarns of these fabrics have little stretch, and it is observed that this has the effect of inducing stresses at the bending of the yarns at the interlacings. This is evidenced from a consideration of the unit strength of the plain weave fabrics of low and high thread count, and in the basket weave fabrics.

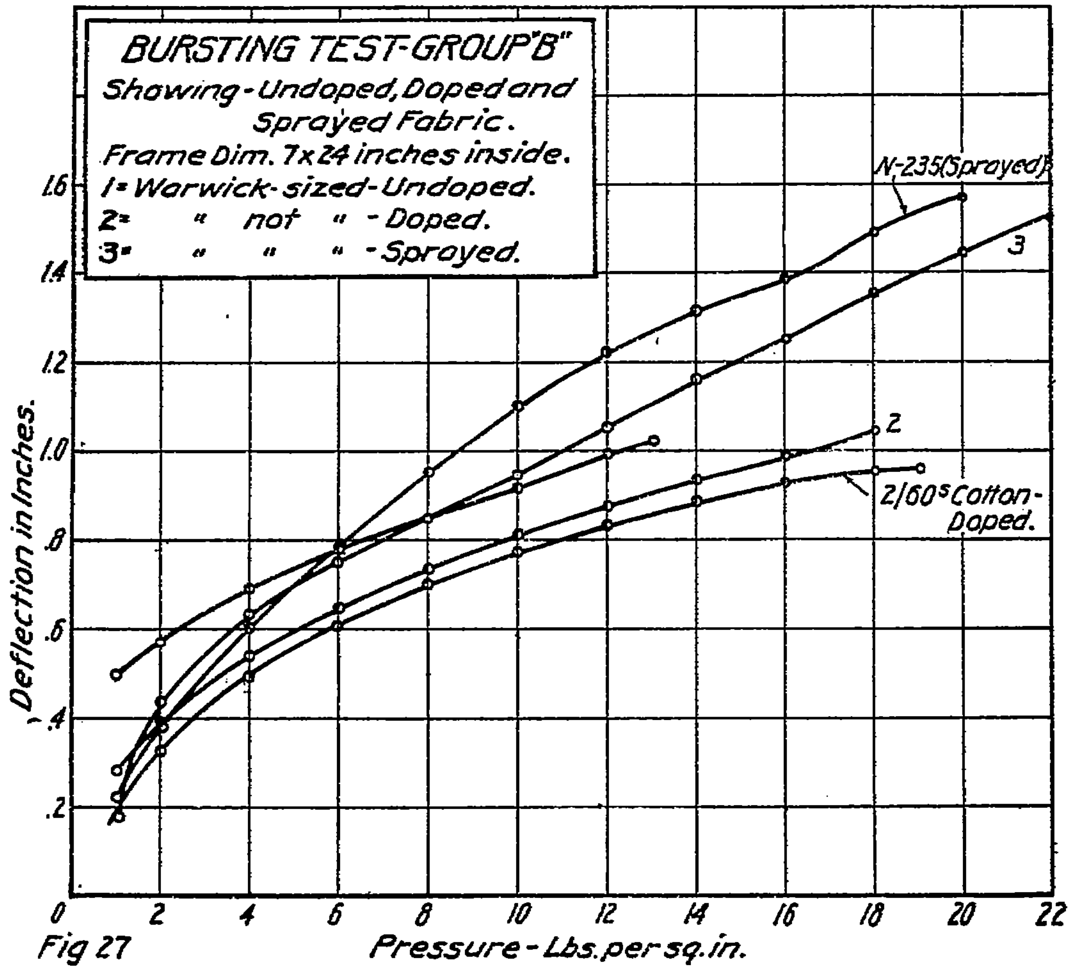



Fig 27

The bursting pressures and pressure deflection curves of these fabrics indicate that they would make very desirable airplane fabrics. The tear resistance is considerably reduced by excessive dope penetration into the yarns and into the interstices of the fabric. The bleaching of the yarns make them more absorbent, and it is thought that it allows excessvie dope penetration to the detriment of the tear resistance. These fabrics may be treated to prevent dope penetration, but it is believed that fabrics of equal strength can be made of 2/60's or other more easily produced yarns.

These yarns would find their principal application in a fabric of gray or mercerized warp and a filling of the mercerized and bleached filling, with considerably more picks than ends.

GROUP B.—*Stretch relations undoped.*

| | Warp. | | | Filling. | | |
|---|---|---|---|---|---|---|
| At pounds | 10 | 20 | 65 | 10 | 20 | 65 |
| 2008 | 4.0 | 5.1 | 8.2 | 3.3 | 3.8 | 6.4 |
| *2008S* [1] | *3.3* | *4.3* | *6.7* | *3.3* | *4.2* | *7.2* |
| 2009 | 5.0 | 6.0 | 9.2 | 2.7 | 3.8 | 6.4 |
| *2009S* [1] | *3.0* | *3.8* | *6.0* | *4.4* | *5.3* | *8.2* |
| 2010 | 7.2 | 8.9 | 12.0 | 3.0 | 3.0 | 5.0 |
| *2010S* | *6.4* | *7.4* | *10.3* | *3.2* | *4.2* | *6.5* |
| 2011 | 10.5 | 13.3 | 17.8 | 2.4 | 3.2 | 5.9 |
| *2011S* | *11.0* | *13.7* | *18.0* | *2.7* | *3.6* | *6.5* |
| 16005 | 8.75 | 10.75 | 14.5 | 5.5 | 6.5 | 9.75 |
| 16004 | 8.1 | 10.0 | 15.0 | 4.0 | 6.0 | 8.0 |

[1] Filling stretch greater than warp.

2008 to 2010S are 2/2 twills.
2011 and 2011S are plain weave.
S=Warp sized.

GROUP B.—*Tensile undoped.*

| Sample marks. | Weight per square yard (ounces), undoped. | Threads per inch. | | Tensile strength (pounds). | | Unit strength, tensile divided by weight. | | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | | W. | F. | W. | F. | W. | F. | |
| 2008 | 3.4 | 66 | 64 | 77 | 81 | 22.6 | 23.8 | 2 by 2 twill. |
| *2008S* | *3.6* | *66* | *62* | *79* | *78* | *21.9* | *21.7* | Do. |
| 2009 | 3.6 | 68 | 67 | 79 | 82 | 21.9 | 21.8 | Do. |
| *2009S* | *3.55* | *68* | *62* | *85* | *72* | *23.9* | *20.3* | Do. |
| 2010 | 4.35 | 80 | 79 | 88 | 94 | 20.2 | 21.6 | Do. |
| *2010S* | *4.4* | *80* | *79* | *90* | *97* | *20.4* | *22.0* | Do. |
| 2011 | 3.7 | 68 | 67 | 77 | 84 | 20.8 | 22.7 | Plain. |
| *2011S* | *3.8* | *68* | *66* | *77* | *76* | *20.3* | *20.0* | Do. |
| A cotton spec | 4.5 | 80 | 80 | 80 | 80 | 17.8 | 17.8 | Do. |
| *B cotton spec* | *4.0* | *68* | *68* | *73* | *73* | *18.4* | *18.4* | Do. |
| A experimental | 4.2 | 79 | 84 | 90 | 110 | 21.4 | 26.2 | Do. |
| *B experimental* | *3.8* | *68* | *70* | *75* | *75* | *19.7* | *19.7* | Do. |
| | 4.8 | 72 | 72 | 84 | 80 | 17.5 | 16.6 | 16 harness-broken twill. |

GROUP B.—*Tensile undoped.*

| Sample mark. | Weight per square yard, (ounces), undoped. | Threads per inch. | | Tensile strength (pounds). | | Unit strength, tensile divided by weight. | | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | | W. | F. | W. | F. | W. | F. | |
| 1986 | 5.0 | 76 | 76 | 84 | 86 | 16.8 | 17.2 | Plain. |
| *1* | *5.6* | | | *128* | *123* | *22.8* | *22.0* | 5 by 5 basket. |
| 2 | 5.7 | | | 132 | 121 | 22.8 | 21.2 | 6 by 6 basket. |
| *2026* | | *76* | *74* | | | | | Plain weave, gray yarn. |
| 2026S | | 76 | 74 | | | | | Do. |
| 2024 | | 72 | 70 | | | | | Do. |

S=Sized warp.

GROUP B.—*Bursting tests doped.*

| Number. | Bursting test. | | Tearing test. | | Weight (ounces). | | Thread count. | | Weave. |
|---|---|---|---|---|---|---|---|---|---|
| | P. | D. | P. | D. | Undoped. | Doped. | W. | F. | |
| 2008 | 16.1 | 1 | 2.7 | 0.34 | 3.6 | 6.2 | 66 | 63 | Twill. |
| *2008S* | *16.4* | *1.08* | *2.0* | *.3* | *3.65* | *6.2* | *67* | *63* | *Do.* |
| 2009 | 17.6 | 1.03 | 3.8 | .45 | 3.7 | 5.8 | 68 | 66 | Do. |
| *2009S* | *18.5* | *1.27* | *2.1* | *.27* | *3.6* | *5.9* | *68* | *63* | *Do.* |
| 2010 | 21.9 | 1.15 | 2.8 | .32 | 4.4 | 6.3 | 78 | 80 | Do. |
| *2010S* | *20.4* | *1.1* | *1.9* | *.38* | *4.4* | *6.4* | *80* | *80* | *Do.* |
| 2011 | 17.8 | 1.03 | 2.2 | .35 | 3.8 | 6.5 | 66 | 65 | Plain. |
| *2011S* | *18.1* | *.93* | *3.2* | *.43* | *3.8* | *6.5* | *68* | *66* | *Do.* |
| 2026 | 22.2 | 1.1 | 4.1 | .47 | 4.2 | 6.4 | 76 | 75 | Do. |
| *2026S* | *24.8* | *1.11* | *3.3* | *.57* | *4.2* | *6.5* | *76* | *78* | *Do.* |
| 2024 | 23.0 | 1.3 | 2.6 | .48 | 4.4 | 6.9 | 74 | 73 | Do. |
| *Grade A cotton* | *18.6* | *.94* | *3.2* | *.52* | *4.0* | *5.6* | *79* | *84* | *Do.* |
| Linen | 14.7 | .78 | 2 | .14 | 3.5 | 5.4 | 94 | 97 | Do. |

P=pressure in pounds per square inch.
D=deflection in inches of center point of fabric.

## DISCUSSION OF GROUP C.

The fabrics of group (C) were constructed to meet an urgent demand for fabrics of twice the strength and twice the tear resistance of the standard A cotton fabrics. There was no limit placed on the weight, and it was necessary to use immediately available yarns. As a result, the fabrics may appear to be illogical, but the group is interesting.

Many of these fabrics, as seen from the structure, are very closely woven, and the dope penetration was not good, and those fabrics failed to tighten. The degree of tightness is rather misleading, for the regular "ping" test does not give the desired noise in the case of the heavy fabrics, but actual tautness measurements showed that many of these fabrics were very satisfactory. There is an element of stiffness in the heavy and thick fabrics which gives a better tautness than would be expected from a consideration of load-stretch diagrams This factor has no appreciable influence on the thinner fabrics.

Of the group the fabric 3092, N-12, P-5, G-29, A-3000, A-3001, G-23, and similar ones were very satisfactory. It will be observed that the tear test used is a radical modification of the wound test. The samples were cut 4 inches wide by 6 inches long, and clamped in the testing machine with 3 inches between the jaws. A ½-inch slit was cut perpendicular to the line of pull midway between the clamps. Five coats of acetate dope were used in all cases.

The demand for this class of fabric stopped as suddenly as it had arisen, and the group was not completed.

*Test results of group (C).*

| Sample mark. | Weight, doped. | Tensile, undoped. | | Strength, doped. | | Tear test, bursting. | | Tear test, wound.[1] | | Bursting test. | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | W. | F. | W. | F. | P. | D. | W. | F. | P. | D. |
| A-2/60 | 7.0 | 80 | 80 | | | 3.15 | | 80 | 95 | 22.07 | 1.247 |
| P-1 | | 111 | 166 | | | | | | | | |
| P-2 | | 112 | 105 | | | | | | | | |
| P-3 | 12.1 | 141 | 153 | 193 | 257 | | | 138 | 195 | | |
| P-4 | 12.6 | 132 | 114 | 249 | 144 | | | 144 | 183 | | |
| P-5 | 13.6 | 139 | 181 | 252 | 141 | | | 141 | 221 | | |
| P-6 | 12.6 | 150 | 169 | 255 | 148 | 6.0 | 0.66 | 148 | 237 | 22.8 | 1.56 |
| P-7 | | 135 | 143 | 225 | 143 | 6.9 | .78 | 142 | 191 | | |
| P-8 | | 133 | 139 | | | | | | | | |
| P-9 | | 151 | 151 | 176 | 242 | 9.1 | 1.10 | 140 | 187 | | |
| P-10 | | 133 | 130 | 153 | 204 | | | 136 | 191 | | |
| A8760 | | 168 | 188 | | | | | | | | |
| N-11 | 8.5 | | | 172 | 160 | | | 129 | 135 | | |
| N-12 | 11.2 | | | 152 | 249 | | | 141 | 178 | | |
| N-13 | 12.8 | 159 | 178 | 193 | 226 | | | 152 | 168 | | |
| G-22 | | 120 | 124 | 171 | 204 | 7.0 | .90 | 143 | 191 | | |
| G-23 | | 132 | 194 | 162 | 271 | | | 143 | 266 | | |
| G-24 | | 134 | 153 | 170 | 202 | 8.0 | 1.00 | 146 | 187 | | |
| G-25 | | 112 | 117 | | | | | | | | |
| G-26 | | 105 | 203 | | | 9.6 | 1.02 | | | | |
| G-27 | | 118 | 189 | 145 | 272 | | | 134 | 233 | | |
| G-28 | | 113 | 151 | | | 7.0 | .70 | | | | |
| G-29 | | 139 | 139 | 175 | 172 | 7.7 | .99 | 149 | 149 | | |
| G-30 | | 153 | 207 | 175 | 220 | 12.7 | 1.10 | 173 | 227 | 36.4 | 1.82 |
| GA-2953-6 | | 120 | 181 | 171 | 204 | | | | | | |
| Gx2 | | 107 | 128 | 271 | 143 | 5.2 | .68 | | | | |
| G-40 | | 143 | 173 | 202 | 146 | 6.8 | .68 | | | | |
| G-41 | | 53 | 71 | | | 4.8 | .75 | | | | |
| G-42 | | 106 | 122 | | | 6.0 | .82 | | | | |
| G-45 | | 176 | 142 | | | 5.9 | .69 | | | | |
| G-Mx | | 168 | 182 | | | | | | | | |
| G-M1175 | | 102 | 109 | | | | | | | | |
| G-M1176 | | 101 | 124 | | | | | | | | |
| G-M1177 | | 76 | 77 | | | | | | | | |
| P-8760 | | 168 | 188 | | | | | | | | |
| AH1 | | 129 | 137 | | | | | | | | |
| AH2 | | 106 | 146 | | | | | | | | |
| AH3 | | 119 | 137 | | | | | | | | |
| AH4 | | 90 | 134 | | | | | | | | |
| AH5 | | 118 | 129 | | | | | | | | |
| A2953x | | 110 | 109 | | | | | | | | |

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*Structure of fabrics group (C).*

| Sample mark. | Weight per square yard. | Thread warp. | Count filling. | Yarn number. | | Weave. |
|---|---|---|---|---|---|---|
| | | | | W. | F. | |
| | *Ounces.* | | | | | |
| P-1 | 9.8 | 86 | 80 | | | |
| P-2 | 6.9 | 108 | 84 | | | |
| P-3 | 9.2 | 166 | 83 | 2/60 | 2/60/2 | T 2 x 2. |
| P-4 | 9.3 | 168 | 84 | 2/60 | 2/60/2 | BT. |
| P-5 | 8.8 | 168 | 88 | 2/60 | 2/60/2 | B 4 x 4. |
| P-6 | 8.8 | 168 | 84 | 2/60 | 2/60/2 | B 2 x 4. |
| P-7 | 8.3 | 168 | 78 | 2/60 | 2/60/2 | BT. |
| P-8 | 8.3 | 168 | 78 | 2/60 | 2/60/2 | T 2 x 2. |
| P-9 | 8.2 | 168 | 82 | 2/60 | 2/60/2 | BT 2 x 2. |
| P-10 | 8.1 | 168 | 78 | 2/60 | 2/60/2 | T 2 x 2. |
| A-8760 | 8.6 | 76 | 76 | 2/60 | 2/60/2 | BT. |
| N-11 | 6.2 | | | 2/60 | 2/60 | |
| N-12 | 7.4 | | | 2/60 | 2/60/2 | |
| N-13 | 8.6 | 160 | 164 | 2/60 | 2/60 | |
| G-22 | 7.8 | 72 | 88 | 50/3 | 30/3 | Double fabric, plain weave. |
| G-23 | 9.3 | 76 | 72 | 50/3 | 30/3 | ML. |
| G-24 | 7.8 | 72 | 88 | 50/3 | 50/3 | Double fabric, 3/1+1/3. |
| G-25 | 6.6 | 116 | 120 | 2/60 | 2/60 | BT. |
| G-26 | 9.1 | 71 | 98 | 60/3 | 40/3 | Double fabric. |
| G-27 | 9.5 | 72 | 102 | 60/3 | 50/3 | Double fabric, 1/3+3/1. |
| G-28 | 8.3 | 72 | 102 | 60/3 | 60/3 | Double fabric, plain weave. |
| G-29 | 9.2 | 72 | 72 | 60/3 | 60/3 | Do. |
| G-30 | 11.0 | 52 | 88 | 30/3 | 30/3 | ML. |
| A-29553-6 | 8.7 | 72 | 74 | 50/3 | 50/3 | B 2 x 2. |
| G x-2 | 6.3 | 120 | 120 | 2/60 | 2/60 | ML 4 x 4. |
| G x-40 | 9.2 | 164 | 86 | 2/60 | 2/60/2 | T 2 x 2. |
| G x-41 | 5.0 | 45 | 66 | 2/30 | 2/30 | P 1/1. |
| G x-42 | 6.4 | 120 | 116 | 2/60 | 2/60 | ML. |
| G x-45 | 8.8 | 162 | 176 | 2/60 | 2/60/2 | BT 2 x 2. |
| MX | 4.0 | 64 | 68 | 40/2 | 2/60/2 | ML. |
| M-1175 | 5.4 | 96 | 96 | 40/2 | 2/60/2 | ML. |
| M-1176 | 7.2 | 128 | 144 | 3/80 | 3/80 | B 3 x 3. |
| M-1177 | 4.2 | 94 | 96 | 2/60 | 2/60 | P. |
| A-8760 | 8.6 | 76 | 69 | | | P. |
| A-H1 | 7.5 | 72 | 76 | 50/3 | 50/3 | |
| A-H2 | 7.4 | 72 | 76 | 50/3 | 50/3 | |
| A-H3 | 7.3 | 72 | 76 | 50/3 | 50/3 | |
| A-H4 | 7.0 | 72 | 76 | 50/3 | 50/3 | |
| A-H5 | 7.4 | 72 | 76 | 50/3 | 50/3 | |
| A-2953x | 9.6 | 64 | 64 | 50/3 | 50/3 | |

T=Twill.
B=Basket.
BT=Broken Twill.
ML=Mock Leno.

*Stretch of fabrics group (C).*

| Sample mark. | Stretch, per cent undoped. | | | | | | Stretch, per cent doped. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20 | | 70 | | 100 | | 20 | | 70 | | 100 | |
| | W. | F. | W. | F. | W. | F. | W. | F. | W. | F. | W. | F. |
| 98A | 8.0 | 7.0 | 11.0 | 10.5 | 14.0 | 12.0 | | | | | | |
| 98B | 6.5 | 6.0 | 12.0 | 9.0 | 15.0 | 10.0 | 8.0 | 2.0 | 13.0 | 6.0 | 16.0 | 8.0 |
| 97A | 9.0 | 8.0 | 13.0 | 12.0 | 15.0 | 14.0 | | | | | | |
| 97B | 8.0 | 7.0 | 11.0 | 10.0 | 13.0 | 12.0 | | | | | | |
| 96A | 8.0 | 7.0 | 13.0 | 11.5 | 15.5 | 14.0 | | | | | | |
| 96B | 7.0 | 4.0 | 12.0 | 11.0 | 14.0 | 13.0 | 3.0 | 1.5 | 1.1 | 7.0 | 9.0 | 14.0 |
| A-3000 | | | | | | | 2.5 | 2.0 | 8.0 | 6.0 | 10.0 | 8.8 |
| A-3001 | | | | | | | 3.0 | 3.0 | 7.0 | 8.5 | 9.1 | 11.0 |
| 95A | 9.0 | 1.8 | 13.0 | 15.0 | 15.0 | 18.0 | 5.0 | 2.0 | 13.0 | 8.0 | 16.0 | 10.0 |
| 95B | 7.0 | 6.0 | 11.0 | 9.0 | | 18.0 | 3.0 | 2.0 | 13.5 | 14.0 | 11.0 | 11.5 |
| 1 | 26.0 | 8.5 | 35.0 | 6.0 | 38.0 | 8.0 | | | | | | |
| 2 | 21.0 | 5.0 | 30.0 | 8.0 | 33.0 | 11.0 | | | | | | |
| 3 | 11.0 | 4.0 | 16.0 | 7.0 | 18.0 | 8.0 | | | | | | |
| 4 | 20.0 | 4.0 | 23.0 | 7.0 | 37.0 | 8.0 | | | | | | |
| 5 | 17.0 | 2.0 | 22.0 | 4.0 | 25.0 | 4.5 | | | | | | |
| 6 | 7.0 | 1.0 | 26.0 | 2.5 | 20.0 | 3.5 | | | | | | |
| 7 | 9.0 | 2.0 | 15.0 | 4.0 | 22.0 | 5.5 | | | | | | |
| 8 | 9.0 | 2.0 | 14.0 | 4.0 | 17.0 | 6.0 | | | | | | |
| 9 | 9.0 | 3.0 | 15.0 | 5.5 | 17.0 | 7.0 | | | | | | |
| 10 | 10.0 | 4.0 | 14.0 | 6.0 | 16.5 | 7.0 | | | | | | |
| 8760 | 9.0 | 3.5 | 15.0 | 6.0 | 17.0 | 7.0 | | | | | | |
| A-2951 | 7.0 | 4.0 | 10.0 | 6.0 | 12.0 | 8.0 | | | | | | |
| A | 11.0 | 3.0 | 17.0 | 4.5 | 14.0 | 6.0 | | | | | | |
| B | 16.0 | 2.5 | 28.0 | 5.0 | 33.0 | 7.0 | | | | | | |
| 22 | 6.0 | 4.0 | 9.0 | 6.0 | 11.0 | 8.0 | | | | | | |
| 23 | 4.5 | 11.0 | 7.0 | 15.0 | 7.0 | 18.0 | | | | | | |
| 24 | 11.0 | 8.0 | 18.0 | 11.0 | 21.0 | 18.0 | | | | | | |
| 25 | 6.5 | 4.0 | 10.0 | 7.0 | 13.0 | 9.0 | | | | | | |
| 26 | 17.0 | 7.0 | 26.0 | 10.0 | 31.5 | 12.0 | | | | | | |
| 27 | 11.0 | 4.0 | 15.0 | 6.0 | 19.0 | 7.0 | | | | | | |
| 28 | 8.0 | 4.0 | 1.7 | 6.0 | 14.0 | 7.0 | | | | | | |
| 29 | 6.5 | 7.0 | 10.0 | 11.0 | 12.0 | | | | | | | |
| 30 | 9.0 | 6.0 | 12.0 | 8.0 | 15.5 | 9.0 | | | | | | |
| 40 | 11.5 | 2.5 | 16.0 | 8.0 | 19.0 | 9.0 | | | | | | |
| 42 | 6.5 | 6.0 | 9.5 | 8.0 | 11.0 | 9.5 | | | | | | |

*Stretch of fabrics* (C)—Continued.

| Sample mark. | Stretch, per cent undoped. | | | | | | Stretch, per cent doped. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20 | | 70 | | 100 | | 20 | | 70 | | 100 | |
| | W. | F. | W. | F. | W. | F. | W. | F. | W. | F. | W. | F. |
| 45 | 9.5 | 10.0 | 15.0 | 14.5 | 18.0 | 17.0 | — | — | — | — | — | — |
| MX | 9.0 | 7.0 | 11.0 | 8.5 | 15.0 | 10.0 | — | — | — | — | — | — |
| M-1176 | 10.0 | 2.0 | 17.0 | 4.0 | 17.5 | 5.0 | — | — | — | — | — | — |
| M-1177 | 15.0 | 5.0 | 20.0 | 7.5 | — | — | — | — | — | — | — | — |
| A-2953 | 11.0 | 4.5 | 15.0 | 7.0 | 19.0 | 9.0 | — | — | — | — | — | — |
| VI-2x | 14.0 | 10.0 | 21.0 | 15.0 | 25.0 | 18.0 | — | — | — | — | — | — |
| M-1175 | 6.0 | 4.0 | 9.5 | 6.0 | 11.5 | 7.5 | — | — | — | — | — | — |
| ML | 8.0 | 4.5 | 12.0 | 7.0 | 14.5 | 8.0 | — | — | — | — | — | — |
| AH-1 | 6.0 | 6.0 | 9.0 | 9.5 | 13.0 | 12.0 | — | — | — | — | — | — |
| AH-2 | 7.0 | 4.0 | 14.0 | 8.0 | 16.0 | 10.0 | — | — | — | — | — | — |
| AH-3 | 10.0 | 5.0 | 14.0 | 7.0 | 17.0 | 10.0 | — | — | — | — | — | — |
| A-44 | 4.0 | 6.0 | 7.0 | 10.0 | — | 12.0 | — | — | — | — | — | — |
| A-2953x | 3.0 | 6.0 | 6.0 | 10.0 | 9.6 | 13.0 | — | — | — | — | — | — |
| W. B | 10.0 | 2.0 | 13.0 | 3.5 | 14.7 | 4.0 | — | — | — | — | — | — |

## DISCUSSION OF GROUP D.

The fabrics of group D are made of mercerized yarn of a number in the vicinity of 2/25's; and the grade of cotton is a long staple. These fabrics have no immediate value, but it was thought advisable to study the possibilities of utilizing the spinning capacities of the mills

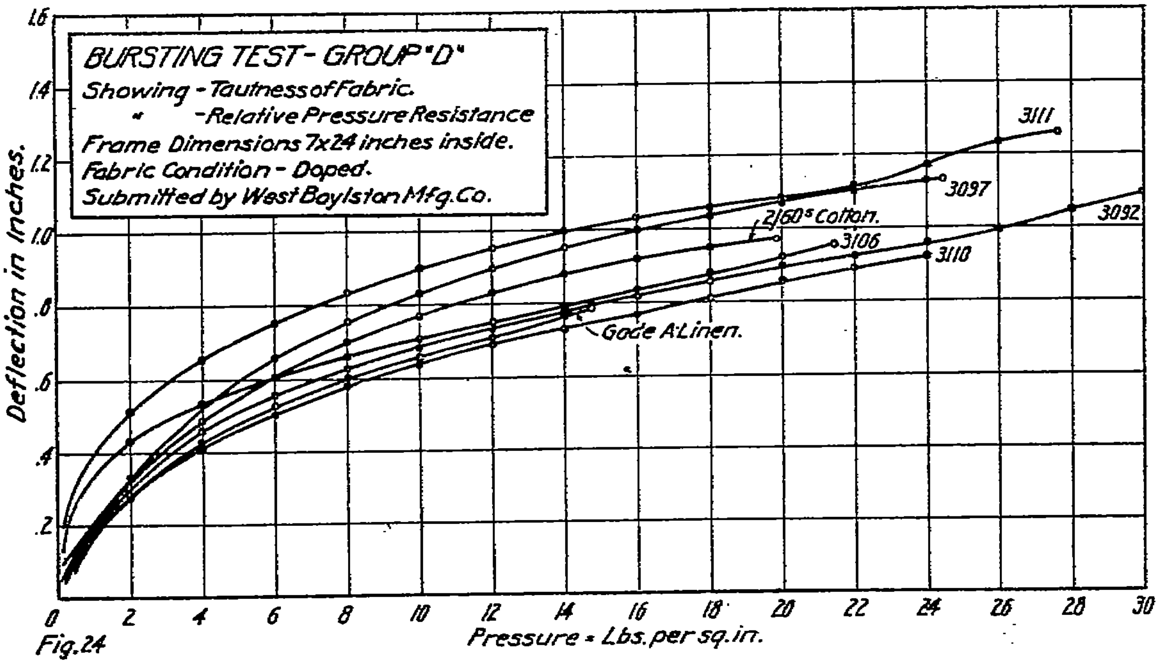


Fig. 24

which were hung up to make the lower counts of yarn from long-staple cottons. The structure is much too open in the case of the lighter weights, and allows an excessive dope penetration; and their structure is too open to allow the closing of the interstices by finishing processes such as calendering or beetling, although the finishing would help much.

Experiments were made to determine the feasibility of spraying a surface coating of dope on such fabrics. The spraying apparatus was not all that could be desired, but the results were satisfactory within the limits of the values desired. It was observed that in many cases the dope film shrank to such an extent as to break the frame upon which the fabrics were doped. The bursting tear tests on this material indicate a higher bursting pressure when spray doped than when brush doped, and the higher pressures are accompanied by an increased deflection. The film of dope does not bind the yarns in their crimped condition, and hence allows a higher deflection, which will account for the higher bursting pressures. A brush doping of very viscous dope covers the fabric well, but is extremely hard to apply.

The very open structure fabrics when doped by a brush become set in a distorted position and present a surface which may be termed baggy. From this it is assumed that brush doping is not the proper method for open fabrics, and that, if the demands are great enough, the open fabrics may be satisfactorily doped by means other than brush doping.

Of this group, it is thought that the fabric 3092 is the best of the lighter ones, and that 3106 is the best of the heavier fabrics. An examination of pressure deflection curves for this group will show that there are peculiarities which are not common to the other groups. For instance the pressure deflection curve of 3106 shows a very rapid increase of deflection at the

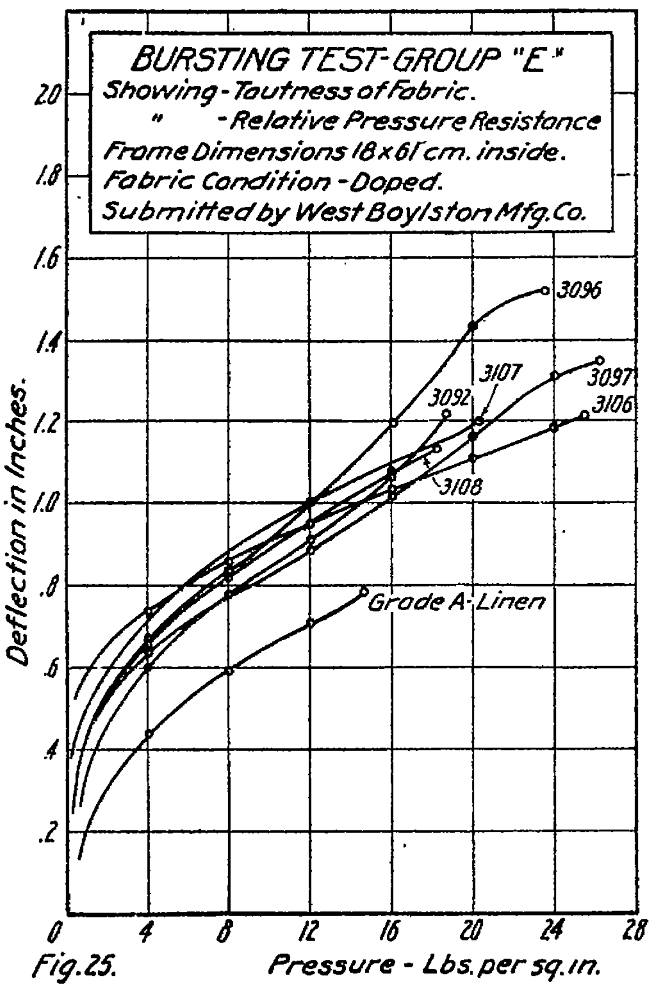


Fig. 25.

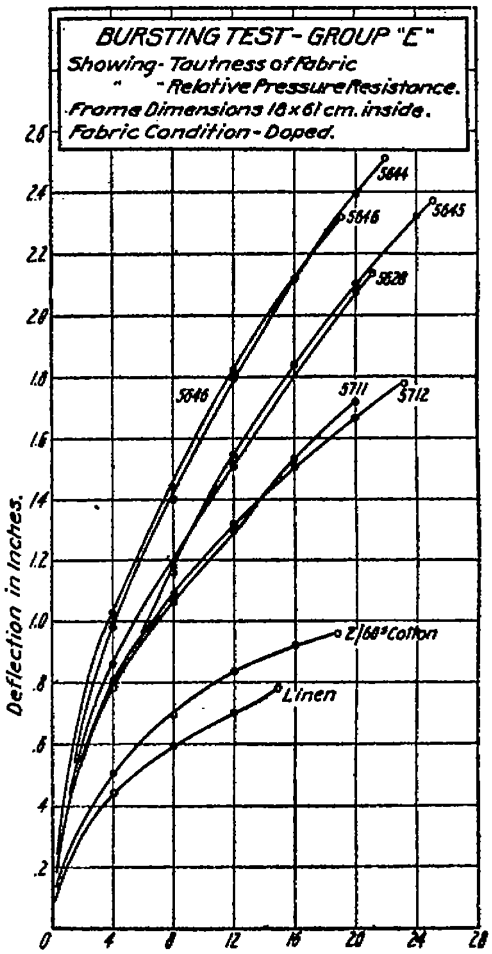


Fig. 26.

lower pressures, and that the upper part of the curve is normal. This is probably due to the manner in which the dope has adhered to the fabric. The union between the dope film and fabric of a heavy fabric is quite different from that in the lighter and thinner fabrics. The difference lies in the fact that the second and third coats of dope do not penetrate as thoroughly as they do in the thinner fabrics, and hence the yarns are not bound as well. This condition may be overcome to a large extent by change of weave structure, such as a mock leno, which allows the dope to permeate to the other side of the fabric. The heavy fabrics of the group are fairly dense even in the basket weave, and a four by four mock leno would open the structure but very slightly. Fabrics of this nature may be corrected more advantageously by leaving out quite a few warp ends and if necessary the fabric may be calendered.

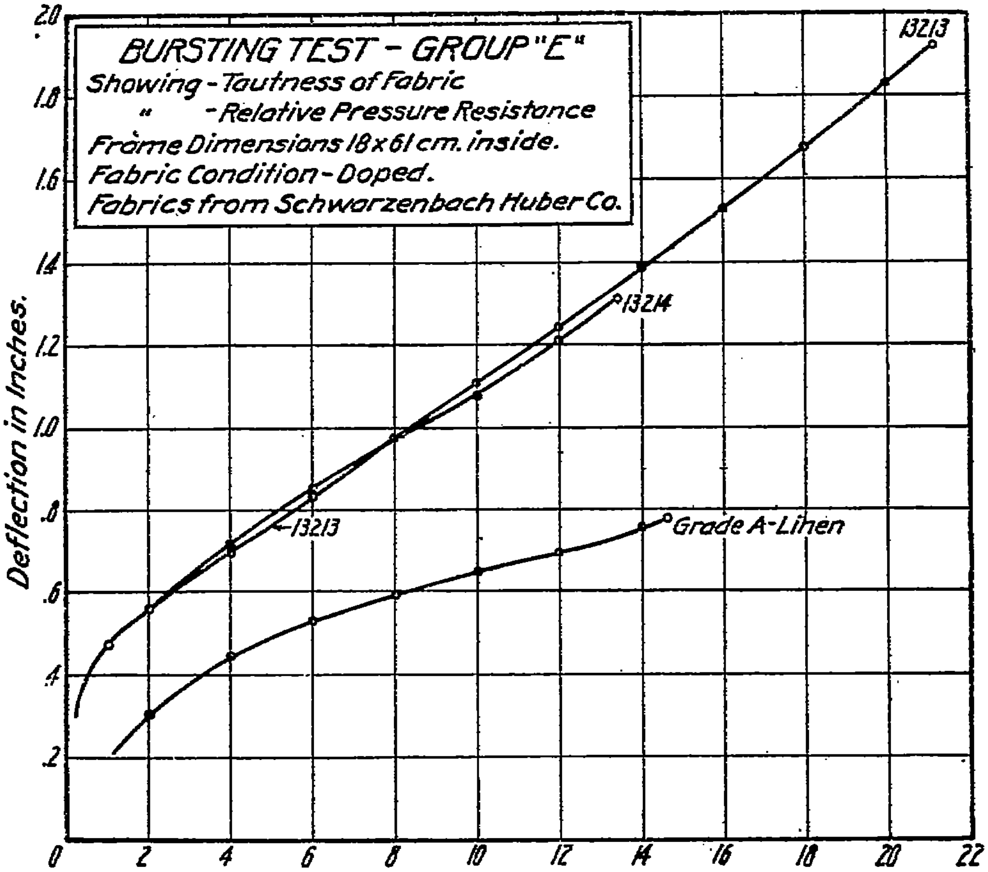


Fig. 29

GROUP D.

| Mark. | Weight per square yard. Undoped. | Weight per square yard. Doped. | Thread count. W. | Thread count. F. | Bursting test. P. | Bursting test. D. | Bursting tear. P. | Bursting tear. D. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|
| 3106 | 4.2 | 6.8 | 18 | 54 | 21.4 | 0.96 | 4.8 | 0.43 | Brush doped 4 watts acetate dope. |
| 3092 | 4.2 | 7.2 | 72 | 74 | 34.6 | 1.22 | 7.2 | .57 | |
| 3096 | 4.0 | 6.4 | 29 | 49 | 16.3 | 1.20 | 5.4 | .86 | |
| 3097 | 4.2 | 6.6 | 32 | 54 | 22.5 | 1.03 | 7.6 | .97 | |
| 3098 | 4.0 | 7.0 | 24 | 46 | 19.2 | .93 | 2.8 | .34 | |
| 3109 | 6.0 | 7.9 | 44 | 62 | 28.1 | 1.30 | 5.7 | .68 | |
| 3110 | 6.0 | 8.2 | 50 | 46 | 27.0 | .96 | 4.8 | .66 | |
| 3111 | 6.0 | 8.4 | 54 | 70 | 27.6 | 1.25 | 7.1 | .92 | |
| 3112 | 6.0 | 7.7 | 60 | 62 | 24.6 | 1.18 | 4.3 | .81 | |
| 3100 | 4.0 | 5.7 | 30 | 40 | 22.2 | 1.46 | 4.0 | .78 | |
| 3101 | 4.0 | 5.7 | 38 | 48 | 20.6 | 1.37 | 3.8 | .76 | |
| 3102 | 4.0 | 7.1 | 44 | 46 | 19.8 | 2.63 | 2.6 | .64 | |
| 3107 | 4.0 | 7.8 | 44 | 44 | 20.6 | 1.20 | 3.0 | .51 | |
| 3108 | 4.2 | 6.2 | 44 | 44 | 18.4 | 1.13 | 3.9 | .82 | |
| A cotton | 4.0 | 5.6 | 79 | 84 | 18.6 | .94 | 3.2 | .52 | |
| A linen | 3.5 | 5.4 | 94 | 97 | 14.7 | .78 | 2.4 | .47 | |
| 3096 | 4.0 | 7.4 | 29 | 49 | 17.4 | 1.30 | 7.0 | .90 | |
| 3097 | 4.2 | 7.6 | 32 | 54 | 24.4 | 1.18 | 9.6 | 1.00 | Spray doped acetate dope. |
| A cotton | 4.2 | 5.4 | 79 | 84 | 22.8 | 1.60 | 5.1 | .71 | |

## DISCUSSION OF GROUP E.

The fabrics of group E were made of silk fibers, both schappe and the natural length fibers. The silk fiber is extremely interesting, and, contrary to the general idea, it is very inelastic. Up to about one-fourth to one-half of the full load the load-stretch relations of the silk fiber follow a straight-line ratio, and the silk is fairly elastic up to this region of yield. Beyond this region the permanent set is very large. The strength per unit of weight is much greater than for the other fibers, but because of the yield region the effective working strength is comparatively low. It is very possible that this condition is good, considering that under extreme conditions of loading the silk fabric would stretch a large amount and materially decrease the tension in the fabric and preserve the desired factor of safety. An examination of the pressure deflection curves will give a better impression of the actual performance in this respect. The wing would have to be covered anew after such a condition of loading. The yield region is hidden in the schappe fabrics, but is shown by a gradual change of curvature of the load-stretch diagram.

The silk fabrics doped up very well and had all the outward appearances of successful fabrics. It was observed that they became loose when exposed to humid conditions, and that they deteriorated very rapidly on exposure to weather, probably due to the development of an internal rot. The schappe fabrics did not have as great a tendency to become loose on exposure to humid conditions. It was found that if the silk fabrics were tentered to exceed the yield point they did not exhibit the large stretches per unit load increase, and that they did not loosen materially on exposure to humid conditions. The manufacture of schappe has probably caused the yield point of the fibres to be exceeded, and is a possible explanation of its performance. The reason why the exceeding of the yield point would give better performance under humid conditions is not clear. The prevention of rot by chemical impregnation is entirely feasible, and it is believed that a further systematic study of silk fabrics would lead to the conclusion that they are entirely possible. Very satisfactory fabrics were constructed of selected tussah, and fabrics constructed to weigh about 4.3 ounces per square yard of schappe yarns 2/100's metric were very promising.

GROUP E.

| Sample. | Weight, ounces. | | Tensile strength. | | | | Tear test. | | Burst test. | | Elongation, per cent, undoped. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Undoped. | | Doped. | | | | | | 20 pounds. | | 70 pounds. | |
| | Undoped. | Doped. | W. | F. | W. | F. | P. | D. | P. | D. | W. | F. | W. | F. |
| 13212 | | | | | | | 5 | 0.69 | 21.2 | 1.92 | 5.0 | | 4.5 | |
| 13214 | | | | | | | | | 13.1 | 1.31 | | | | |
| 5675-80829 | 4.4 | 5.1 | 99 | 128 | 92 | 98 | | | | | 4.0 | 1.5 | 10.5 | 6.0 |
| 5674-80928 | 3.6 | 5.1 | 89 | 102 | 83 | 103 | | | | | 3.0 | 1.0 | 14.0 | 4.5 |
| 5673-80830 | 3.6 | 5.2 | 81 | 90 | 72 | 108 | | | | | 3.0 | 1.3 | 15.5 | 5.0 |
| 5712 | 3.4 | 5.2 | 74 | 102 | 85 | 93 | 3.5 | .79 | 23.6 | 1.78 | 5.7 | 1.0 | 18.5 | 7.5 |
| 5711 | 3.1 | 4.1 | 81 | 80 | 56 | 70 | 2.7 | .75 | 20 | 1.71 | 4.5 | 1.8 | | 12 |
| 5628 | | | | | | | 5.6 | 1.06 | 21.6 | 2.13 | | | | |
| 5644 | | | | | | | 2.7 | .91 | 19.2 | 2.32 | | | | |
| 5645 | | | | | | | 5.6 | .98 | 25.4 | 2.37 | | | | |
| 5646 | | | | | | | 5.6 | 1.17 | 23 | 2.51 | | | | |

## DISCUSSION OF GROUP F.

Group F compares the properties of several fabrics purposed for use as airplane wing coverings. From an examination of the tables it is evident that the 2/60's and 3/80's fabric are to be compared with linen. The "H" fabrics are capable of withstanding higher pressures, but the deflection is large and the dope adhesion at increased loads is poor; and it is considered that they will not give satisfactory service.

The curves, figure 22, show the pressure-deflection relations for the grade "A" linen, grade "A" cotton, and the grade "B" cotton.

## GROUP F.

### UNDOPED FABRIC.

[English unit.]

| Laboratory No. | Sample mark. | Weight (ounces per square yard). | Tensile strength (pounds per inch). | | Threads per inch. | | Remarks. |
|---|---|---|---|---|---|---|---|
| | | | Warp. | Filling. | Warp. | Filling. | |
| P. L. 36 | Standard "A" | 3.5 | 83 | 85 | 94 | 97 | Linen. |
| P. C. 74 | Experimental 2/60 | 4.0 | 86 | 89 | 79 | 84 | American cotton. |
| C. P. 22 | Experimental 3/80 | 3.8 | 74 | 74 | 68 | 71 | Do. |
| Sig. 153 | Standard "A" | 3.6 | 80 | 74 | 97 | 97 | Linen. |
| Sig. 153a | Signal Corps delivery 2/60 | 4.1 | 78 | 82 | 79 | 81 | American cotton. |
| Sig. 150 | "H" single yarn | 4.2 | 85 | 78 | 102 | 104 | English cotton (Leight). |
| Sig. 151 | do | 3.7 | 74 | 69 | 107 | 102 | English cotton (Fountain). |
| Sig. 152 | do | 4.3 | 87 | 78 | 109 | 102 | English cotton (Wilding). |
| Sig. 241 | S. C. delivery 3/80 | 4.0 | 73 | 82 | 68 | 70 | American cotton, mercerized yarn. |
| Sig. 240 | S. C. delivery, 2/60 cotton, N 236 | 4.1 | 82 | 88 | 79 | 84 | Do. |

### DOPED FABRIC.

[English unit.]

| Laboratory No. | Sample mark. | Weight (ounces per square yard). | Tensile strength (pounds per inch). | | Remarks. |
|---|---|---|---|---|---|
| | | | Warp. | Filling. | |
| P. L. 36 | Standard "A" | 5.4 | 92 | 99 | Linen, 4 coats Dupont No. 20. |
| P. C. 74 | Experimental 2/60's | 6.0 | 94 | 105 | Cotton, American, 4 coats Dupont No. 20. |
| Sig. 153 | Standard "A" | 5.3 | 94 | 121 | Linen, 4 coats Dupont No. 50749. |
| Sig. 153a | Signal Corps delivery 2/60's | 6.0 | 101 | 128 | Cotton, American, 4 coats Dupont No. 50749. |
| Sig. 150 | "H" single yarn | 6.0 | 99 | 128 | Cotton, English (Leigh), 4 coats Dupont No. 50749. |
| Sig. 151 | do | 5.1 | 105 | 103 | Cotton, English (Fountain, 116 H), 4 coats Dupont No 50749. |
| Sig. 152 | do | 6.2 | 104 | 107 | Cotton, English (Wilding), 4 coats Dupont No. 50749. |
| Sig. 241 | Cotton 3/80, N 239 | 5.8 | 84 | 101 | Cotton, 4 coats Maas 1739C dope. |
| Sig. 240 | Cotton 2/60, N 236 | 5.6 | 93 | 112 | Do. |
| Sig. 239 | Linen "A" | 5.1 | 84 | 82 | Linen, 4 coats Maas 1739C dope. |

### BURSTING PRESSURE.

[Per unit of weight. Doped fabric.]

| Laboratory No. | Sample mark. | Pressure per square inch per ounce of weight. | Weight (ounces). |
|---|---|---|---|
| Sig. 240 | 2/60 cotton, N 236 | 3.3 | 5.6 |
| Sig. 241 | 3/80 cotton, N 239 | 3.1 | 6.8 |
| Sig. 239 | Linen, "A" grade | 2.9 | 5.1 |

### BURSTING TESTS.

| Laboratory No. | Sample mark. | Pressure (pounds per square inch). | Deflection (inches). | Remarks. |
|---|---|---|---|---|
| Sig. 240 | Signal Corps delivery 2/60, N 236 | 18.6 | 0.94 | 4 coats Maas 1739C dope. |
| Sig. 241 | Signal Corps delivery 3/80, N 239 | 18.0 | 1.06 | Do. |
| Sig. 239 | Standard "A" | 14.7 | .78 | Do. |

### TEARING RESISTANCE.

[Pressure method.]

| Laboratory No. | Sample mark. | Pressure (pounds per square inch). | Deflection (inches). | Remarks. |
|---|---|---|---|---|
| Sig. 153a | N 235 cotton, American, 2/60 | 8.6 | 0.85 | 1 centimeter cut parallel to warp; tear across filling. |
| Sig. 153a | do | 8.2 | .52 | 5 centimeters cut parallel to warp; tear across filling. |
| Sig. 153 | Standard "A" linen, English | 4.8 | .63 | 1 centimeter cut parallel to warp; tear across filling. |
| Sig. 153 | do | 2.5 | .48 | 5 centimeters cut parallel to warp; tear across filling. |
| Sig. 153a | N 235 cotton, American, 2/60 | 8.2 | .82 | 2 centimeters cut 45° to warp; tear across filling. |
| Sig. 153 | Standard "A" linen, English | 6.4 | .62 | Do. |
| Sig. 241 | N 239 cotton, American, 3/80 | 5.5 | .65 | 1 centimeter cut parallel to warp; tear across filling. |
| Sig. 241 | N 239 cotton | 3.8 | .35 | 5 centimeters cut parallel to warp; tear across filling; English cotton (Wilding Bros.). |
| Sig. 152 | "H" single yarn | 7.1 | .64 | 1 centimeter cut parallel to warp; tear across filling; English cotton (Fountain 116H). |
| Sig. 151 | do | 7.4 | 1.28 | 1 centimeter cut parallel to warp; tear across filling. |

All fabric put on under tension of 0.45 pounds per inch or 80 grams per centimeter and doped with 4 coats Maas 1739C nitrate dope.

## DISCUSSION OF GROUP G.

Fabrics of group (G) were designed from a consideration of the distribution of stress as derived from the bursting test. These are more or less extreme in their construction, but it is believed that they are subject to satisfactory development, as will be noted from a consideration of the bursting pressures and the weights. The yarns are all unmercerized; and, as a result, the filling stretch is greater than is desired, and much more of the load is carried by the warp yarns than would be if the filling yarns were mercerized. The warp yarns gave way first near the short edge of the frame where the curvature in the direction of the warp is a finite value. The filling gave way immediately after the warp, and in many cases it was extremely difficult to determine which actually did give way first.

The fabric 110C, because of the availability of mercerized 2/60 yarn, was made up in the plain and 2 x 2 filling with 1 x 1 warp. These results are given at the end of the table.

It is not intended that these fabrics are the ultimate ones to be desired, but it is of interest to note that there is a great possibility of developing fabrics which have the balance of the weight in the direction of the greater stresses.

GROUP G.

| Mark. | Weight (square yard), G. | Thread count. | | Yarn number. | | Bursting pressure. | | Yarn broken first. |
|---|---|---|---|---|---|---|---|---|
| | | W. | F. | W. | F. | P. | D. | |
| 110A | 3.76 | 88 | 70 | 1/58 | 2/40 | 24.8 | 0.89 | Warp. |
| 110B | 3.54 | 88 | 80 | 1/58 | 2/50 | 26.8 | 1.60 | Do. |
| 110C | 3.38 | 88 | 90 | 1/58 | 2/60 | 23.8 | 1.60 | Do. |
| 111A | 4.56 | 80 | 80 | 1/40 | 2/40 | 29.6 | 1.82 | Do. |
| 111B | 4.27 | 80 | 90 | 1/40 | 2/50 | 22.8 | 1.90 | Do. |
| 111C | 4.07 | 80 | 100 | 1/40 | 2/60 | 16.0 | 1.36 | Do. |
| 112 | 2.90 | 70 | 90 | 1/80 | 2/60 | 16.3 | 1.30 | Do. |
| 265P | 3.90 | 88 | 92 | 1/60 | 2/60 | 24.6 | 1.31 | Filling.[1] |
| 265B | 3.70 | 88 | 92 | 1/60 | 2/60 | 22.4 | 1.12 | Do.[1] |

[1] Mercerized.

The filling yarns of 265P and 265B are mercerized, and more comprehensive tear tests are given under the discussion of tear.

## DEPARTMENT OF AGRICULTURE TESTS ON COTTON FIBRE FOR AIRPLANE FABRICS.

GROUP H.

| | Weave. | Weight (ounces per square yard). | Thread count. | | Tensile strength (pounds). | | Yarn sizing. | | | Yarn breakage. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | W. | F. | W. | F. | 80's. | 3/80's, gray. | 3/80's, mercerized. | 80's. | 3/80's, gray. | 3/80's, mercerized. |
| Fancy pima Arizona Egyptian. | Plain | 3.9 | 68 | 70 | 81 | 86.5 | 79.3 | 25.24 | 25.27 | 28.2 | 142.4 | 138.1 |
| Sakel S. K. L. | do | 3.91 | 68 | 70 | 88 | 91.5 | 75.0 | 25.81 | 25.98 | 30.6 | 158.1 | 163.5 |
| Sakel F. V. S. | do | 4.00 | 68 | 70 | 83.5 | 87.5 | 75.4 | 26.14 | 26.32 | 28.3 | 144.7 | 148.0 |
| Sea Island | do | 4.01 | 68 | 70 | 78.5 | 88 | 75.7 | 25.62 | 25.52 | 27.8 | 146.2 | 140.9 |

| | Weave. | Weight (ounces per square yard). | Thread count. | | Tensile strength (pounds). | | Yarn sizing. | | | Yarn breakage. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | W. | F. | W. | F. | 60's. | 2/60's, gray. | 2/60's, mercerized. | 60's. | 2/60's, gray. | 2/60's, mercerized. |
| Fancy pima Arizona Egyptian. | Plain | 4.23 | 80 | 80 | 88 | 88.5 | 56.8 | 28.92 | 28.79 | 47.9 | 118.5 | 128.3 |
| Sakel S. K. L. | do | 4.15 | 80 | 80 | 98 | 98.5 | 55.4 | 28.93 | 29.04 | 49.5 | 131.1 | 141.6 |
| Sakel F. V. S. | do | 4.22 | 80 | 80 | 91.5 | 98.5 | 55.9 | 28.70 | 28.81 | 46.2 | 124.8 | 136.7 |
| Sea Island | do | 4.00 | 80 | 80 | 86.5 | 92 | 56.2 | 28.62 | 28.32 | 49.0 | 118.5 | 125.1 |
| West India | do | 3.80 | 82 | 82 | 93 | 94 | | | | | | |

SUMMARY.

The cotton 2/60's fabric made of mercerized yarn is equal to or better than the standard linen. It has the best combination of desirable properties which may be obtained for use directly from the loom, with the possible exception of the heavy filling fabrics.

The possibilities of finishing fabrics open up many interesting possibilities. The factors influencing the variable, and the control of the variables, should be thoroughly studied to insure uniformity of output.

The burst test gives values which are more nearly correct than tensile tests, by introducing the element of lateral constraint. The value obtained from the burst test serves as a basis for calculation of probable performance of wing fabrics with reference to pressure, wing deflection, and rib spacings.

The tear tests on undoped fabrics are of little value in the study of airplane wing coverings

The rip tear test made on a doped panel gives more nearly correct results than those made on a detached piece of doped fabric. The results may be reversed and are always exaggerated in the case of the loose fabric.

Any tear test on a doped fabric is a function of the effective yarn strength, the number stressed in tear, and the load-stretch relations of the material.

The pressure of rupture, either in the case of the wound test or bursting test, is a more correct indication of relative factors of safety than the results of a tensile test.

At the present time it is not possible to arrange the variables of manufacture in an equation so as to calculate mathematically the performance of a hypothetical fabric.

The field for further research is very wide.