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No. 393

AN INVESTIGATION OF COTTON FOR PARACHUTE CLOTH

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Bureau of Standards

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Summary

This is a resumé of the work of the Bureau of Standards on a cotton parachute cloth for use as a substitute for silk in the event of an emergency curtailing the supply. Cotton yarn of high strength in proportion to its weight and otherwise specially suitable for parachute cloth was developed. Cloth woven from this yarn in the bureau mill was equal or superior to parachute silk in strength and tear resistance, met the requirements with respect to air permeability, and weighed only a few tenths of an ounce per square yard more than the silk cloth. Practical trials of cotton parachutes carried out by the Navy Department clearly indicate that the cotton parachute closely approaches the silk parachute in performance as to rate of descent, opening time, strength and ability to function when stored in the pack for sixty days. The increase in weight of the equipment resulting from the use of cotton cloth instead of silk is considered to be well within practicable limits. A specification for cotton parachute cloth and the way in which the requirements of the specification have been met are given. Cotton yarns suitable for parachute cloth are now being woven commercially in the United States.

Introduction

The development of a parachute cloth made from materials grown in the United States was undertaken by the Bureau of Standards late in 1924 at the request and with the financial assistance of the National Advisory Committee for Aeronautics. At that time imported silk cloth was generally considered to be the only reliable material for the construction of parachutes. The purpose of the project was to develop a cloth from domestic materials for use as a substitute for silk in the event of an emergency cur-

tailing the supply. This object was attained and the work was concluded in 1930. A review of the investigation and the principal results are given in this report.

Preliminary to the search for substitutes, in cooperation with the Bureau of Aeronautics, Navy Department, and the Silk Association of America, Incorporated, a comparison was made of silk cloth woven in the United States with that imported from abroad. Contrary to the general belief, cloth woven in this country was found to be equal or superior to the imported. This result at once made it safe for the military services to use American silks for parachutes and, since a certain amount of raw silk is always in stock in the silk mills of the country, lengthened the time between a failure of the supply and an urgent need for a substitute. A report of the tests of silk parachute cloth submitted by the Silk Association of America has been issued in mimeographed form. (Reference 1.) No further mention need be made of this part of the work.

The properties of the silk cloth which practical experience in the military services had shown to be satisfactory were taken to be those required of a substitute. A brief discussion of those properties is given in the following pages.

Adequate test methods for permeability to air or porosity, and elastic properties had to be developed in the course of the work. Descriptions of them have been or are about to be published elsewhere. Accordingly, they will be referred to here only briefly.

Silk, such as is required for parachute cloth, is not produced commercially in the United States. Of the possible domestic substitutes, cotton appeared best to answer all requirements. The work was directed largely toward the development of cotton yarns and cloth approaching parachute silk in properties. In order to give cotton elastic properties similar to silk the effect of dopes and other impregnations was studied. Mercerization and other chemical treatments also received attention. A simple scour in alkaline soap solution coupled with extraction with alcohol and ether was found materially to increase the ratio of strength to weight.

Yarns fine enough for a fabric of the strength and weight desired could not be obtained in the United States

when the work was started. It was therefore necessary to spin suitable yarns in the Bureau of Standards cotton mill. This work led finally to yarns of very high strength in proportion to their weight and otherwise specially suitable for cotton parachute cloth. The best yarns produced cloth equalling silk in strength, tear resistance, and air permeability and weighing only a few tenths of an ounce per square yard more than the silk cloth. During the past year or two, yarns of this high quality have been produced commercially in the United States and are now available, thus answering the principal object of the work.

Mill studies conducted in cooperation with the Bureau of Aeronautics, Navy Department, were directed toward finding weaves of high tear resistance as well as high strength. The resulting weaves are proving to be of special interest for fabrics for lighter-than-air craft. A report on this phase of the work is in course of preparation.

Practical trials of cotton parachutes made from cloth produced under this project were carried out at Lakehurst, New Jersey, by the Bureau of Aeronautics, Navy Department. Although the cloth was not equal to that later manufactured in the Bureau of Standards mill, the parachutes functioned in most respects nearly if not quite as well as the silk parachutes. The results of some of these practical trials are given in this report.

As a final outcome of this study, a specification for parachute cloth that can be made from domestic cotton yarns is offered. The way in which cotton cloth meeting this specification was made in the Bureau of Standards mill is indicated.

Properties of Silk Parachute Cloth

At the beginning of this study and even now there is no adequate theoretical or experimental basis for the limits of tolerance permissible in a specification of the physical properties of parachute cloth. The Army Air Service specification for silk for parachutes was based on the imported cloth which had proved to be satisfactory in service. The essential requirements of this specification were taken to be those required of a substitute. They are listed in Table I. It will be noted that there were no requirements for air permeability nor for elastic properties though

these were no doubt limited by the requirements that the cloth be made of boiled-off silk and of a specified number of threads per inch, warp and filling.

It was considered that the natural resiliency of the silk aided materially in the rapid ejection of the parachute from its pack when released. One of the first steps in the work was to attempt to improve the elastic properties of cotton. Later on the need for high resiliency became somewhat less urgent because mechanical means of ejection were developed.

A report of the work on the properties of parachute cloth which also gives the methods first devised for measuring air permeability and elastic properties has already been published. (Reference 2.) Accordingly, this subject need not be elaborated here.

As this project progressed and as a result of parachute studies carried out by the Army and the Navy Air Services, the specifications for silk parachute cloth were revised from time to time. The properties at present desired in the substitute parachute cloth are given in Table I. The elastic properties of the silk are still considered desirable.

Methods of Test

The methods employed for the determination of weight, breaking strength and stretch are standard procedures used in many laboratories for testing cloth. The "strip" method for breaking strength is used in preference to the "grab" method. (See reference 2 for the details of the method.) The breaking strength is the load in pounds required to break a strip of the cloth one inch wide under prescribed conditions. The amount of stretch when the cloth is loaded to the breaking point or to some intermediate load is expressed as the percentage of the original length of the sample. The weight of the cloth is the weight in ounces per square yard.

Two different methods have been used for the determination of tear resistance. The so-called modified tensibility method used in the earlier experiments is described in the report by McNicholas and Hedrick. (Reference 2.) Because of the preference of the military services, the

strip-tear method was used in later experiments. It is described in U. S. Army Air Service Specification No. 7-8, of May 5, 1923, as follows: "A specimen 3 inches wide and 8 inches long is cut 3 inches down the center, 1½ inches from each edge. One cut end is placed in one jaw of the test machine and the second cut end is placed in the second jaw of the test machine. Resistance to tear is measured by the tension necessary to barely continue the tear started by the separation of the jaws. The pendulum of the test machine shall be free to oscillate during test." All tear resistance values reported here were made by the strip-tear method.

The first method for measuring recovery under flexure devised in connection with this project is described by McNicholas and Hedrick. (Reference 2.) A special instrument for accurately measuring stiffness, recovery from flexure ("resiliency"), and "creasability" of cloth was developed later by Schiefer. It is called the flexometer and is described in a paper which has been prepared for publication by the Bureau of Standards. The energy in ergs required to fold a sample and the energy recoverable on unfolding are measured. The flexometer is particularly suited for evaluating the tendency of parachute cloth to spring out or recover its original form when folded for a period of time, as it is when packed ready for use.

The apparatus for measuring air permeability described by McNicholas and Hedrick (reference 2), has been supplanted by a new and improved apparatus which is described in the Bureau of Standards Journal of Research. (Reference 3.) It is portable, self-contained, and has several advantages over that previously used. The Army Air Corps is now using this apparatus for testing parachutes and U. S. Army Specification No. 16066 for "Special Parachute Fabric" contains an air permeability requirement. Air permeability is reported in cubic feet of air which will flow through the cloth per square foot of area per minute at a pressure difference between the two sides of the cloth of 0.5 inch of water. The air permeability at other pressure differences is sometimes reported. This must be taken into consideration in comparing data.

Cotton Yarns for Parachute Cloth

Effect of dopes.- Cotton yarn that is comparable to silk in weight is much weaker. In order to increase the strength of cotton yarn and to make it more like silk in elastic properties, a study was made of the effect of various dopes applied to cotton yarns. Rubber coatings were tried but they showed little promise. The dopes were solutions of cellulose acetate or nitrate alone and in combination with resins and softeners. Kauri, Canada balsam, and Venice turpentine were the resins, diethyl phthalate and triphenylphosphate the softeners used. The dopes were applied by dipping. In general, doping materially increased the strength of the yarns without affecting the stretch. Softeners increased the pliability of the doped yarns. Resins when used alone made the yarns stiff. In combination with cellulose esters and softeners, however, they gave the strongest impregnations. The increase in strength was offset by an increase in weight. Judging from the behavior of a doped cotton parachute (See section on "Practical Trials of Cotton Parachutes"), no advantage was gained by this treatment.

Mercerization.- A few experiments on mercerization were carried out with the object of increasing the stretch of cotton yarn. Variations in the mercerization procedure, the twist of the yarn, and the pretreatment of the yarn were studied with reference to strength and stretch. This work was by no means exhaustive. In conjunction with the work on pretreatment and spinning of the yarn, described in the following paragraphs, it led to the conclusion that satisfactory results can be obtained with a mercerizing procedure similar to that used in the industry. Some of the experiments indicated the possibility of materially increasing the strength of the yarn by mercerization. A special study of mercerization by the Bureau of Standards and the National Advisory Committee for Aeronautics with a view toward increasing the strength-weight ratio of yarns is now in progress. Some experimental data on the changes in the yarn produced by mercerization both in the laboratory and in commercial plants are given in the discussion of yarn pretreatment.

Pretreatment.- The preparation of the yarns for mercerization led to further experiments on pretreatment. In the usual commercial pretreatment, the yarn is boiled in an alkaline soap solution in a closed vessel under pressure

(kier boiled). This process removes some but not all of the waxes and other foreign materials from the cotton. In order to remove these materials completely and with the hope of obtaining cotton yarns of minimum weight for a given strength, various alkaline soap treatments and extraction of the yarn with solvents were tried. The best results were obtained in the laboratory by extracting the yarns with ethyl ether and denatured alcohol, boiling for six hours in a 1% sodium hydroxide solution containing ½ % olive oil soap and rinsing thoroughly, mercerizing in 35% potassium hydroxide solution for 10 minutes at 0 to 8° C and rinsing thoroughly. The properties of a 160/2 cotton yarn so treated are compared with those of yarn taken from parachute silk in Table II. The cotton yarns may be seen to be comparable to the silk in strength, stretch, and strength-weight ratio.

Having found out how to make cotton yarns comparable to silk, it became necessary to process a sufficient quantity for weaving experimental cotton parachute cloth. The facilities and the cooperation of a commercial plant were obtained. Over 100 different experiments were carried out in this plant. The result was that the laboratory procedure was modified somewhat to make it commercially practical. The best plant experiments increased the strength-weight ratio 58 per cent.

Yarn construction.- In order to make a cloth from cotton having the low weight and high strength of parachute silk, it is necessary to use fine yarn which can be spun only from the longer staple cottons. At the time this study was undertaken such yarn could not be obtained in this country. Most of the preliminary work on doping, mercerizing, and pretreating already described was carried out with cotton yarn spun in England, probably from Egyptian cotton.

The most satisfactory kind of cotton for the purpose, "Sea Island" cotton which formerly grew in the coastal regions of North and South Carolina, Georgia, and Florida was nearly exterminated in 1925 by the ravages of the cotton boll weevil. "Arizona Pima" cotton appeared to be the next best domestic variety and a bale of it was obtained and processed in the bureau's mill. The staple length of this cotton was 1-9/16 inches.

A consideration of the requirements of parachute cloth led to the selection of 160/2 yarn. This ply was chosen in

order to obtain the desired resistance to tear; the high count to give a close, smooth cloth which would not be bulky; the amount of twist in the yarn, both single and ply, to give the greatest strength. That the yarn construction was satisfactory is indicated by the outcome of the study.

The Pima cotton was spun into yarn of this description. The yarn turned out to be rather neppy (that is, containing little knots of tangled fibers), but its strength-weight ratio was 10% higher than that of the British yarns obtained for the preliminary work. One lot of this yarn was then sent to a commercial plant and given the preliminary treatment and mercerization already described. This treatment resulted in an over-all increase in the strength-weight ratio of 34%. This yarn was then woven into fabrics as described in the next section where it is referred to as bureau yarn.

In the meantime developments having an important bearing on this project were taking place in the American cotton industry. Sea Island cotton again became available. Although not a pure strain of the original stock, it is long in staple and suitable for fine yarns. It is grown in the West Indies and on the islands off the coast of the southern states of South America. Some of it comes from American possessions or dependencies and since it can be and is being grown in the United States, it is a domestic product. At least two American spinners of fine yarns became interested in producing yarns as fine as 160's of high strength and such American yarn is now on the market.

After cloth made of the bureau yarn was woven and cotton parachutes made from a number of experimental fabrics were tested, it was possible to write a specification for an American-made cotton yarn suitable for parachutes. Such yarn has, in fact, been purchased in lots of 40 pounds at two different times. The requirements as stated in the invitation for bids, follow: "160/2 dry-twisted, ungassed mercerized yarn made from Sea Island cotton, the single twist to be about that obtained with twist multiplier 3.5 and the ply twist to be about 38 turns per inch. The yarns to be of the best commercial quality and to be uniform in size and strength, the breaking strength to be not less than 200 grams."

Cotton Cloth for Parachutes

The possibility of making a cotton cloth weighing less than 2 ounces per square yard and having the other desired characteristics, appeared to be remote. It is true that cloth of this weight is readily obtainable with commercial cotton yarns. In order to make a cloth weighing not more than 2 ounces with a breaking strength of 40 pounds, yarns of good quality must be used. Such cloth has been an article of commerce for some years. It differs from silk parachute cloth especially in tear resistance and air permeability. The problem thus resolved itself into a search for a means of increasing tear resistance and controlling air permeability without adversely affecting other properties of the cloth. Experimental studies of cloth constructions were undertaken for this purpose.

The preliminary study of weaves with special reference to tear resistance which was made by the Bureau of Standards in cooperation with the Bureau of Aeronautics, has already been mentioned. Cloth was woven from one lot of yarn in 44 different weaves. A summary of the test results for a few of the more interesting cloths reduced to a comparable basis and expressed as a percentage of the result for the plain woven cloth are given in Table III. This table shows that it is quite possible materially to increase tear resistance by proper selection of weaves. Those weaves which permit the yarn greater freedom of motion when tearing stresses are applied to the cloth and thus permit the load to be carried by more yarns, give higher tear resistance. This is well illustrated in basket weaves where two or more yarns are woven together. In such fabrics a greater length of the yarn floats on the surface between the interlacing. If these floats are made too long a cloth with a surface which will catch or snag or otherwise be objectionable, will be produced.

Another method of increasing tear resistance is to use stronger yarns. This fact led to the selection of two-ply yarns. Higher plies do not appear to be at all practicable.

A third method of increasing tear resistance lies in the selection of yarns which, because of their high stretch, will allow a distribution of a tearing stress

over several yarns. The possibilities in this direction are limited when cotton yarns are used.

Subsequent to the development of satisfactory yarns and the preliminary study of tear resistance, a quantity of cloth was woven from the bureau Pima cotton yarns. Some of this cloth was woven from the gray yarns and was then mercerized, boiled out and extracted. Some was woven from yarns which had first been through these treatments. Because of the difficulties incident to the processing of small samples in full-scale equipment, none of the resulting cloths were equal to those produced in the laboratory.

While these cloths were being processed, commercial H H balloon cloth in sufficient quantity for the construction of parachutes was also given the treatments suggested by the laboratory experiments. Tests of parachutes made from this treated cloth are described in the next section.

At this time, good quality commercial yarn of Sea Island cotton became available. After a number of experiments, sufficient yarn was purchased and a series of sample cloths were woven in order to find the optimum construction for a plain woven cloth and for a cloth of high tear resistance. This was a matter of adjusting thread count, ply, twist of yarn and weave. An extensive study of the effect of finishing processes, such as singeing, soaping, shrinking, calendering could not be undertaken, but it was found desirable to wash out the small amount of sizing put in the warp yarns before weaving and to calender the cloth.

Results of tests of several of the most promising experimental fabrics are given in Table IV. For purposes of comparison, the requirements of silk cloth for parachutes are also given. It will be seen that each of the requirements for the silk can be equaled or exceeded in cotton cloth, but that to equal all of them in the same cotton cloth requires a very careful adjustment of constructions. In fact, it has not been possible to reduce the weight of the cotton cloth to that of the silk and still meet the requirements. Cotton cloth weighing only a few tenths of an ounce more than the silk and otherwise equal to it, has been made.

The strength and tear resistance required coupled with a low weight were obtained through the use of the 2-ply 160's Sea Island cotton yarn. The tear resistance was fur-

thur increased by using any one of several weaves instead of the plain weave. However, this led to a cloth much too high in air permeability. In fact, the air permeability of the plain woven cloth is inclined to be high. This can be overcome in part by the use of dry, twisted, ungassed, that is, fuzzy yarns, and in part by decreasing the ply twist of the yarn. The decrease in twist, however, may not be carried too far for the strength is also decreased. The cloth can readily be closed up by using single yarns but the tear resistance is then lowered.

It was found that the air permeability can be decreased by calendering the cloth. In order to determine the permanency of the effect of calendering, samples of the calendered cloth were wet with water and manipulated and stretched by hand, dried, and again tested. The air permeability is increased by this treatment but not to that of the original uncalendered cloth. Similar tests of a piece of regular parachute silk showed that it also is affected somewhat by wetting and manipulation. These experiments suggest that the cotton parachute cloth should be calendered sufficiently to bring the air permeability well below the upper limit of the specification.

Practical Trials of Cotton Parachutes

In order to determine the relative merits of the proposed finishing processes, treated cloth was submitted to the Navy Department for manufacture into parachutes and for service tests. At the same time, several types of commercial cotton cloth were made up into parachutes and tested. The tests were carried out at the Naval Air Station, Lakehurst, New Jersey, by the Bureau of Aeronautics, and the results reported under reference No. NA/4 F43 of July 29, 1930. The cloths are listed and their properties given in Table V. The results of the tests of the parachutes are given in Tables VI, VII, and VIII.

With the exception of the K K cloth and the doped cloth No. 41, all of the cotton parachutes performed well in comparison with standard silk parachutes. The doped cloth made the poorest showing. Doping appears to be not only unnecessary but undesirable. The parachute made of K K cloth, which had low breaking strength, showed remarkable resistance to destruction. The high air permea-

bility of the K K cloth resulted in a more rapid descent of the parachute and slower opening time. For this reason, the K K cloth is not satisfactory for parachute construction. However, the results obtained suggest the desirability of studying the design of parachutes to be made of more porous cloth.

The effect of storage on the functioning of cotton and of silk parachutes which have been packed and stored for sixty days, is indicated in Table VIII. It will be noted that there is little difference between the cotton and the silk parachutes.

The data obtained from these tests clearly indicate that the cotton parachute closely approaches the silk parachute in performance as to rate of descent, opening time, strength, and ability to function when stored in the packed condition for sixty days. The increase in weight of the equipment resulting from the use of cotton cloth instead of silk is considered to be well within practicable limits. The cloth woven since these tests were carried out is superior to that from which the cotton parachutes were made, particularly with reference to air permeability and tear resistance and should therefore have a wide margin of safety.

As cotton parachutes have been in use for some time by commercial aviators on account of their lower cost, the results obtained from this investigation will be reassuring to them, while the military services, which use silk exclusively, are assured of a domestic source of supply in case of emergency.

Specification for Cotton Parachute Cloth

The following requirements are suggested for a specification for cotton parachute cloth that can be made from domestic commercial yarn: weight 2 ounces per square yard; breaking strength, strip method, 40 pounds both warp and filling; tear resistance, strip method, 4 pounds both warp and filling; air permeability 80-140 cubic feet per minute per square foot at a pressure difference of 0.5 inch water. Further, this cloth should be free from sizing or finishing materials. Its properties should not be adversely affected by wetting and drying, or aging under ordinary storage conditions.

It will be noted that the kind of cotton, the size, ply, and twist of the yarn, and the thread count of the cloth are not specified. It is believed that the manufacturer should not be hampered by nonessential requirements of this kind.

As a guide to the manufacturer, the following resumé of the way in which the requirements of the specification have been met is given. 160's two-ply, dry-twisted, ungassed, mercerized yarn made from Sea Island cotton was used. The single twist was about that obtained with twist multiplier 3.5; that is, 44 turns per inch and the ply twist was about 38 turns per inch. Such yarn when well made, has an average breaking strength of 200 grams or better (single strand method). The same yarn was used for warp and filling. The warp beam was sized with a 2% solution of a commercial modified starch. The cloth was woven 38 inches wide in the loom with 100 warp and 100 filling threads per inch. It was treated with boiling water for 15 minutes without tension, tentered to a width of 36 inches, dried, and calendered rather lightly. The thread count of the finished cloth was 110 warp and 106 filling. The air permeability of the cloth from the loom was 280 and this changed to 135 when the cloth was wet out, dried, and calendered. The strength and tear resistance of the finished cloth exceeded the requirements of the specification given above. The weight was 2.1 ounces per square yard and the air permeability was within the prescribed limits.

Bureau of Standards,
Washington, D. C.,
June 17, 1931.

References

1. Bureau of Standards: Silk Parachute Fabrics Submitted by the Silk Association of America. Nov. 16, 1928.

2. McNicholas, H. J., and Hedrick, A. F.: The Structure and Properties of Parachute Cloths. N.A.C.A. Technical Note No. 335, March, 1930.

3. Schiefer, H. F., and Best, Alfred S.: A Portable Instrument for Measuring Air Permeability of Fabrics. Bureau of Standards Journal of Research, Vol. 6, Jan., 1931, pp. 51-58. (Research Paper No. 261.)

TABLE I

Requirements of U. S. Army Air Service

Specification No. 7-8, May 5, 1923

Silk for Parachutes and the Properties at Present

Desired in the Substitute Parachute Cloth

	Silk U.S. Army Spec. May 5, 1923	Substitute desired 1931
Weight		
Ounces per square yard	1.5	2.0
Tolerance	±0.1	any minus
Breaking strength		
Strip method, lb.		
Warp	40	40
Tolerance	-5	any plus
Filling	50	40
Tolerance	-5	any plus
Air permeability		
Cu.ft./min./sq.ft. at 0.5 in. water pressure		80 to 140 inc.
Tear resistance		
Strip method, lb.		
Warp	4	4
Tolerance	-1	any plus
Filling	6	4
Tolerance	-1	any plus
Threads per inch		
Warp	90	-
Tolerance	+50	
Filling	90	-
Tolerance	+50	

TABLE II

Comparison of Treated Cotton Yarn

with Parachute Silk Yarn

Yarn	Breaking strength grams	Stretch %	Weight per yard grams	Strength divided by weight
Cotton 160/2 35 turns per inch single 25 turns reverse doubling	198	9.0	0.0070	28500
Parachute silk "A"				
Warp	53	9.1	0.0034	15500
Filling	245	10.6	0.0084	29220
Parachute silk "B"				
Warp	238	10.5	0.0093	25600
Filling	163	9.9	0.0068	24200

TABLE III

Relation between Weave, Strength, and Tear Resistance

Test results have been reduced to a comparable basis and expressed as the percentage of the results obtained with plain woven cloth from the same yarns. Only a few of the more promising constructions are given. Later studies led to the selection of a combination of the plain and basket weave.

Weave	Strength/weight per cent	Tear resistance, warp per cent	Tear resistance, filling per cent
Combination of zigzag and $\frac{2}{1}$ broken twill	98	152	139
Combination of 4 ends plain weave and 8 ends of $\frac{1}{3}$ pointed twill	99	141	128
4 harness sateen weaving 1-3-2-4	95	174	150
Combination of 8 ends of $\frac{1}{3}$ 45° twill and 4 ends of 1-2-4-3 sateen	94	159	139
Granite weave derived from $\frac{2}{2}$ twilled basket and $\frac{1}{5}$ twill weaving $\frac{1\ 1\ 2\ 1}{1\ 1\ 2\ 3}$	93	144	144
$\frac{2}{1}$ 45° twill	90	133	122
Mock leno	83	207	161
$\frac{2}{2}$ basket, 4 picks	82	185	194

TABLE IV

Results of tests of several of the more promising cloths made from cotton yarns. Requirements of silk parachute cloth are given for comparison.

Cloth designation	Weight oz. per sq.yd.	Strength lb./in.		Air permeability cu.ft./min. per sq.ft. at 0.5 in. water pressure	Tear resistance strip method lb.		Threads per inch	
		W	F		W	F	W	F.
34B	2.2	50	45	65	5	4	122	104
40A	2.3	48	47	276	12	11	120	120
40B	2.5	50	50	114	13	10	132	120
43Z	1.8	37	37	184	6	5	98	93
44Z	2.0	40	45	136	6	4	106	104
Army Spec. No. 16066 1/7/30 silk	1.5	40	40	80-140	4	4		
Navy Spec. No. 2759 12/1/30 silk plain weave	1.55	45	45		3	4		

TABLE V

Cotton cloth used in parachutes tested at the Naval Air Station, Lakehurst, and reported under NA 4/F43, July 29, 1930.

Identification No.	Weight oz./sq.yd.	Thread count		Tensile strength		Tear resistance		Air permeability*
		W	F	W	F	W	F	
34 Alcohol extracted, desized, kier-boiled and mercerized	2.2	143	150	51	47	1.6	1.6	42
36 Same as 34 but not mercerized	2.2	136	151	49	39	1.5	1.5	73
37 Commercial alcohol extracted, desized and kier-boiled	2.3	155	172	52	47	2.0	1.6	35
38 Commercial alcohol extracted, desized and kier-boiled	2.0	143	160	43	38	1.5	1.4	77
41 Same as 34 but also doped	2.7	143	146	62	40	1.5	1.6	39
KK Commercial not treated	1.3	130	130	23	21	-	-	220

*Air permeability is expressed in cubic feet per minute per square foot of fabric at 0.5 inch water pressure.

TABLE VI

Results of dropping tests of cotton and standard silk parachutes with 200-pound load, made from an airplane travelling 100 miles per hour at an altitude of 1000 feet.

Cloth designation	Time of release to full open seconds	Time of release to ground seconds
34	2	59
34	1 4/5	43
34	2	41
36	2	42
36	2 1/5	34
37	2 1/5	47
37	2 3/4	39
38	2 1/5	44
38	2 3/4	46
41	3 1/5	41
41	2 1/5	47
41	2 2/5	49
KK	4 2/5	39
KK	3	33
KK	4 2/5	33
Standard silk	2 2/5*	47*

*Average of 10 drops.

TABLE VII

Results of dropping tests of cotton and standard silk parachutes with varying loads, made from a kite balloon, at an altitude of 1000 feet. The trip was 330 feet below the basket. Time of release to trip was 4 4/5 seconds.

Cloth designation	Load lb.	Time of release to full open seconds	Time of release to ground seconds	Remarks
34	200	6 3/5	28	
"	250	6 2/5	24	
"	300	6	20	
"	350	5 2/5	25	
"	400	5 4/5	30	
"	450	6	25	Destruction complete
36	200	6 1/5	28	
"	250	5 1/5	23	
"	300	6	21	
"	350	7	13	
"	400	6	20	
"	450	6	21	
"	500	6 1/5	14	Destruction complete
37	200	6 3/5	26	
"	250	7 1/5	18	
"	300	6	23	
"	350	5 3/5	22	
"	400	6	24	
"	450	5 4/5	20	
"	500	6 2/5	12	Destruction complete
38	200	6 1/5	29	
"	250	7	8	Premature release
"	300	6	18	
"	350	5 4/5	24	
"	400	6 1/5	23	
"	450	6 1/5	23	
"	500	6 2/5	10	Destruction complete
41	200	6 1/5	34	
41	250	6	20	
"	300	6 2/5	31	Destruction complete

TABLE VIII

Results of dropping tests of cotton and standard silk parachutes which had been packed and stored for sixty days. The parachutes were dropped from a kite balloon at an altitude of 1000 feet. The load was 200 pounds. They were tripped 120 feet below the basket. Time of release to trip 2 4/5 seconds.

Cloth designation	Time of release to full open seconds	Time of release to ground seconds
34	4	44
36	4 1/5	33
37	4 2/5	39
38	4	49
41	4	49
KK	4 3/5	40
Standard silk	4	32