DEPARTMENT OF COMMERCE

CIRCULAR

OF THE

BUREAU OF STANDARDS

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No. 41

TESTING AND PROPERTIES OF TEXTILE MATERIALS

[1st Edition]
Issued April 15, 1913

WASHINGTON
GOVERNMENT PRINTING OFFICE
1913

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CONTENTS

1. INTRODUCTION

The textile industry is one of the largest of the manufacturing activities of the United States. Each year large quantities of wool, cotton, silk, jute, and many other fibers are spun into yarns, to be woven into fabric or made into thread, twine, and rope. These products find their way into both the domestic and foreign markets and form the basis for commercial transactions involving a very large amount of money and affecting every

individual consumer. While supply and demand determines in a large way their money value, their true value to the ultimate consumer must depend on the quality of the raw material and care of manufacture. The surest test of quality is, of course, the test of service, but this can not be applied in advance of the many transactions to which textile materials and products are subjected. It therefore becomes desirable to have methods of testing which may be applied easily and which will furnish a reliable means for reaching a harmonious agreement between producer, distributer, and consumer. Experience in the use of any material will indicate the characteristics which that material must have in order to determine its suitability for a certain purpose and the service which it will render. Having determined these characteristics, it becomes a question of developing physical and chemical methods which will indicate and measure them and which will at the same time serve as a guide to the manufacturer to assist in securing them in his product.

The accurate description of the material and quality, supplemented by an indication of the conditions and methods of test by which it is to be determined, forms a specification on which it should be possible for the buyer and seller to reach an agreement. For some materials, like products of iron and steel, cement, and other structural materials, there have, in recent years, been developed through the cooperation of producers, consumers, and engineering societies standard specifications and standard methods of testing. For textile materials no such standardization has been undertaken, and the industry is dependent very largely upon the units and methods of measurement as carried out by certain manufacturers and individuals.

The study of the physical and chemical properties of textile material by means of laboratory tests has been carried on in this country in a more or less desultory fashion for a great many years. Quite recently, however, the development of more systematic and greatly improved methods of testing, with a consequent augmented accumulation of data, has given the results obtained a much more practical significance than in former years.

The present general interest in the necessity for better methods and standardization of tests has resulted in the establishment of testing apparatus in textile institutions, public testing laboratories, stores, and mills.

In England, France, Germany, Austria, Italy, and Japan advanced methods of testing have been utilized with remarkable results.

A large number of samples are submitted to this Bureau for investigation not only from the Government departments but by manufacturers

and dealers. The fact that this work is rapidly increasing is good evidence of the value of the information received.

The Bureau will gladly cooperate with institutions, investigators, manufacturers, and consumers not only in the execution of scientific testing and standardization, but also in furnishing information in its possession concerning methods of testing and the interpretation of results. It will be pleased also to help in the design and construction of special apparatus. It is the object of this circular to outline the scope of work which will be undertaken by the Bureau and the range of fees for all tests performed.

2. GENERAL INFORMATION

Standard Atmosphere.—All weighings and physical determinations will be made upon carefully adjusted calibrated instruments, and performed in an atmosphere containing 65 per cent relative humidity at 70° F temperature.[1]

Classes of Materials.—The tests will comprise the three general forms of textile material: (a) Raw and unspun fibers; (b) yarn, thread, and twine; (c) fabric.

3. RAW AND UNSPUN FIBERS

Nature of Tests.—Whether composed of one or more than one kind of fiber the following information will be furnished: (a) Identification of fiber or fibers; (b) approximate length of fiber; (c) percentage moisture and "regain" under any specified atmospheric condition; (d) the percentage of oil, grease, or foreign matter; (e) "shrinkage," determination of raw wool (scouring and conditioning).

(a) IDENTIFICATION OF FIBER OR FIBERS

This is accomplished by careful inspection and by the use of the microscope and staining mediums. The Bureau has on hand a very complete collection of rare and commercial fibers and, if found necessary, recourse is made to these standards. To determine the percentage fiber composition of a mixture the procedure as outlined in the segregation and chemical methods on page 11 is followed.

(b) APPROXIMATE LENGTH OF FIBER

The fibers under consideration are spread upon a velvet background and carefully measured by a fine steel scale and magnifying glass.

[1] Recent experiments and extended work upon this subject by the Bureau of Standards and European testing laboratories indicate that an atmosphere containing 65 per cent relative humidity at a temperature of 20° C (68° F) is probably very near the normal air condition of this country.

(c) PERCENTAGE OF MOISTURE AND REGAIN

Moisture.—All textile fibers in their normal condition contain a certain quantity of moisture. This, however, varies according to the surrounding atmosphere, and in view of this fact it is extremely necessary that some standard conditions of humidity and temperature should be established in this country.

The material under test is exposed to this standard atmospheric condition for a certain period and then dried in a conditioning oven at the proper temperature and length of time for the particular fiber under consideration. From the difference between the air-dry and the bone-dry weights the percentage of moisture present is ascertained by employing the air-dry weight as a basis of calculation.

Regain.—As there is some confusion as to the meaning of this term "regain," an explanation will be made. Bone-dry fibers—that is, fibers having been so dried that all moisture has been expelled except that of their chemical composition—will, if placed in the above-mentioned standard atmosphere, take up a certain quantity of moisture. This increase is known as the "regain" weight, and the basis of calculation is upon the bone-dry weight.

Under the same atmospheric conditions fibers of cotton, wool, silk, linen, jute, hemp, etc., will absorb different percentages of moisture and therefore each have a different "regain."

(d) DETERMINATION OF OIL OR GREASE

The method of procedure is to obtain the weight under standard air conditions, then extract with ether, benzene, alcohol, or other agents, after which the fibers and extracted substance are again exposed to the standard atmosphere.

The percentage of oil or grease is ascertained by calculating from the weight of the oil extract or the difference between the weights of the fiber before and after the extraction. In some cases fibers will absorb more moisture with large quantities of oil present than with small amounts.

(e) DETERMINING "SHRINKAGE"[2] OF RAW WOOL

As applied to raw wool the term "shrinkage" means the percentage of dirt, wool, grease, and foreign matter that is washed out of the wool in the scouring process, and which it is necessary to remove before the wool fiber can be carded.

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[2] In the raw wool trade "shrinkage" refers to loss in weight in scouring and not to change of length.

In determining the skrinkage the following operations are necessary:

1. Weigh the sample under standard atmospheric conditions.
2. Scour at 48° to 55° C (120° to 130° F) temperature in water containing the proper quantity of neutral olive-oil soap.
3. Wash thoroughly with cold water.
4. Throw out the excess water in the scoured wool by the use of the centrifugal machine.
5. Dry in a conditioning oven at 120° C (248° F) to constant weight.
6. Ascertain the quantity of grease remaining in the scoured wool and make the proper correction for it. From the dry weight and the remnant grease corrected the bone-dry shrinkage is thus obtained. If it is desired to know the air-dry shrinkage of the scoured wool, it is given a rough drying, then placed in the standard atmosphere, the grease content corrected, and from the final weight thus obtained the shrinkage is readily calculated.

4. TESTING OF YARN, THREAD, AND TWINE

Nature of Tests.—The important tests to be applied comprise the determination of: (a) Length; (b) tensile strength and elasticity; (c) count or number; (d) twist; (e) percentage of loading, sizing, and coloring material; (f) percentage fiber composition.

(a) LENGTH OF YARN, THREAD, AND TWINE

Measuring.—The length test is made from the skein, cop, bobbin, spool, ball, or other forms.

In order to obtain the correct unit length of a sample for testing, recourse is had to the instrument known as the "yarn reel." This apparatus must necessarily be carefully constructed and is usually made of metal. The arms are formed in such a manner that bending or alteration of any kind is eliminated.

The reeling is performed under standard atmospheric conditions and is carried out by passing the material through a smooth eyelet, and by means of a self-acting guide the strands are laid side by side so that the circumferential length is maintained unaltered throughout the winding. The reel is provided with an arrangement whereby certain tensions can be applied to the yarn being reeled, and there is also a reliable counter and bell indicator to insure the correct number of turns.

An important factor is the regularity in the speed of the reeling, and great care is taken when making this test.

(b) TENSILE STRENGTH AND ELASTICITY OF YARN, THREAD, AND TWINE

Tensile strength and elasticity can be determined upon single strands, or if desired, in the form of a skein which has been wound upon a 54-inch reel. The latter is known as the lea test.

The instrument employed in this test registers the stress to within 1 gram, is of the dead-weight type, the pendulum and recording arm rests upon knife edges, and a uniform stress is applied either by motor or water pressure. To determine the elasticity of a single strand the machine is equipped with an arm which registers this determination. The instrument is carefully calibrated and any necessary correction is made when a test is performed. The speed of the lower jaw or clamp holding the yarn descends at a uniform rate of 9 inches per minute.

All yarns under test should be 7 inches in length between the jaws or clamps of the testing machine and all tests must be performed under standard atmospheric conditions. If a special analysis is desired, any reasonable length of yarn can be tested under almost any atmospheric condition.

Unless otherwise requested the results of analysis will be reported as the average of 20 tests for the single strand determination, and the average of 5 tests for the lea method.

(c) COUNT OR NUMBER OF YARN, THREAD, AND TWINE

The "count," i. e., the ratio of length to weight of a yarn (or of weight to length) is a fundamental basis for textile calculation. See p. 12, sec. (e).

In testing for counts, four different results can be obtained by employing the several methods now in use.

1. Determination of the weight of sample in condition as received.

2. Determination of the weight after sample has been exposed to a specified standard atmosphere.

3. Determination of the weight after all moisture is driven out (i. e., "bone-dry" weight).

4. Determination of the "regain" weight.

In the first instance it will be readily understood that tests made for counts upon yarn as received will give a result which varies in accordance with the condition of the sample submitted. If the sample is in a very dry state, the resultant counts are greater (yarn will be finer), or if submitted in a damp state the counts are smaller (yarn is coarser), and will not represent the bulk from which it is drawn, having varied in weight during transit according to the existing atmospheric conditions.

The large amount of computation and the confusion now existing with reference to calculating the results might be minimized if a standard atmosphere as outlined in No. 2 should be agreed upon. In this method all lengths and weights would be made in such an atmosphere.

The basis of calculation in No. 3 is upon the "bone-dry" weight condition of sample. In this instance the sample should first be exposed to the standard air conditions and the proper length taken.

In the case of No. 4 the same procedure must be followed as in No. 3, and, in addition, the percentage "regain" must be added to the dry weight. This method is employed by the Bureau of Standards, and the desired regain is applied according to the specifications submitted. The regain of the various forms of textile material under atmospheric conditions, as mention on page 6, is now being determined. It is hoped that in the near future standard regains will be definitely adopted in this country as they are in Europe.

The length of skeins used in all determinations and the temperature employed for methods No. 3 and No. 4 are as follows:

Fiber	Length (yards)	Temperature
Silk	120	140° C (284° F)
Cotton	120	110° C (230° F)
Wool	140	120° C (248° F)
Linen	150	110° C (230° F)
Jute	150	120° C (248° F)

(d) TWIST OF YARN, THREAD, AND TWINE

The twist in yarn, thread, or twine is necessary not only for strength but for a variety of uses to which it is afterwards employed.

In all determinations 20 tests are made for the number of turns per inch and the average of these will be reported unless otherwise requested. For single strands, roving, individual strands in plys or folds, the length of each specimen under test will vary from 1 inch upward, in accordance with the length of staple. In the case of ply, or folded material, each test will be made upon a 10-inch specimen, thus giving a result representing 200 separate inches of yarn.

To determine the twist present, an instrument especially designed for that purpose is used. It consists of a bar graduated in inches, which carries upon it a sliding horizontal spindle that can be secured at any point. This holds one end of the specimen rigidly and the other end is securely held in

a jaw which can be revolved by the operator. To the latter is attached an automatic counter which registers the revolutions. Under these conditions the specimen is held firmly in the process of untwisting and the number of revolutions of the revolving spindle required to arrange the fibers parallel to each other is ascertained.

The question of the regularity with which twist can be put into yarns, thread, or twine is a very important one, and on this depends to a large extent the uniformity in tensile strength. If requested, the Bureau will furnish the individual tests when reporting results.

(e) DETERMINATION OF LOADING, SIZING, AND COLORING MATTER OF YARN, THREAD, AND TWINE

The practice of adding to the weight of silk and, to a less extent, cotton and other fibers in the dyeing and finishing operations has become so common that it is frequently desirable to ascertain the amount of true fiber present and the amount and kind of weighting.

Black-dyed silks have been weighted to the extent of 400 per cent or more and cotton as high as 25 per cent, consequently the knowledge of the extent of this adulteration in many cases is very important.

The sample to be tested is weighed in the standard atmosphere and then the necessary treatment for the elimination of the adulteration is performed. The sample is weighed again under standard atmospheric conditions and from the difference between these two weights the percentage of loss is computed.

(f) PERCENTAGE FIBER COMPOSITION

Segregation Method.—The specimen under test is exposed to the standard atmosphere and then weighed. Each yarn is now carefully untwisted; the different fibers are placed in separate piles in the standard atmosphere the proper length of time and then weighed. The work during this test is checked or verified by the use of the microscope.

Chemical Method.—The sample is first weighed in the standard atmosphere and then the proper chemical procedure is followed according to the constituent fibers present

5. FABRICS

Nature of tests.—The following are the determinations of fabric analysis: (a) Weight; (b) tensile strength and elongation; (c) percentage fiber composition; (*d*) thread count; (e) yarn number or size; (f) folding endurance; (g) action of light on colors.

(a) WEIGHT

Unless otherwise specified, weighings shall be made in standard atmosphere and the result reported in either of the following dimensions:

1. Grams per square meter.
2. Ounces per square or linear yard.

The samples submitted for this test should be, if possible, 2 yards in length and containing both selvages.

(b) TENSILE STRENGTH AND ELONGATION OF FABRICS

The test pieces are prepared by cutting samples 12 inches long by 1¼ inches wide and then pulling out threads from either side of the narrow section until the standard width of 1 inch is reached. Five specimens each from both warp and filling directions are cut from various parts of the fabric within the selvage and the average result of these tests are reported separately for warp and filling.

This test is performed under standard air conditions, the length and width of test piece between the jaws or clamps of testing machine is 7 inches and the lower jaw or clamp descends at the rate of 9 inches per minute.

The machine employed in this test is of the same type as that used for the tensile strength of yarns, except that it has a capacity up to 2000 pounds breaking stress and is motor driven.

(c) PERCENTAGE FIBER COMPOSITION OF FABRICS

If only one fiber is present, it is ascertained as outlined under identification of raw or unspun fibers (p. 5).

When composed of more than one fiber, the following is an explanation of procedure:

1. Weight of the fabric under standard air conditions.
2. A strip about 4 inches wide is cut from selvage to selvage and weighed as a whole, then the warp threads and filling threads are weighed separately. The percentage of warp threads and filling threads is calculated from these results.

Segregation Method.—Each warp and filling thread or yarn is now segregated. Each yarn is carefully untwisted, the different fibers present are placed in separate piles in the standard atmosphere and weighed. If any difficulty is experienced in identifying a fiber a chemical test combined with a microscopical examination is made.

Chemical Method.—For the ordinary determination, a test specimen about 4 square inches, containing the ascertained proportion of warp and

filling yarns, is weighed in standard atmosphere, then treated with the proper chemical or chemicals. The latter is neutralized and washed with distilled water and then dried, weighed, etc., in accordance with the correct procedure. In this way one constituent is eliminated at a time and the percentages are obtained by simple calculation.

For complicated fabrics a long series of tests is necessary, and this could only be outlined in a general way, because each fabric must be analyzed according to its fiber composition.

(d) METHOD OF COUNTING THREADS

An instrument called a "thread counter" is generally employed to ascertain the threads per centimeter or per inch. The "counter" carries a pointer which may be moved along a horizontal bar by means of a turn screw. Directly above the pointer and moving with it is a low-power magnifying eyepiece, with which each thread can be distinctly seen and readily counted. Under the pointer and resting upon the fabric under observation is a stationary piece of flat steel which is graduated to read to ¼-inch divisions and to 0.5 centimeter divisions.

It is, therefore, a comparatively simple matter to count the threads of most fabrics. If the number can not be determined by this instrument, a higher power microscope is employed, or the threads in a measured distance are pulled out by hand and counted.

The results of analysis, unless otherwise specified, will be reported as the number of threads per inch or per centimeter. If so desired, the number of warp ends across the full width of fabric will be determined.

(e) DETERMINATION OF THE COUNT OR NUMBER OF YARN IN FABRIC

The yarn "count" or "number" designates the length of such yarn in a unit weight of the yarn.

The systems of "count" differ with the kind of yarn or the units of weight and measure used. In this circular the more common English counts are employed.

The knowledge of the count of yarn is necessary to spinners, cloth manufacturers, and to large consumers of yarn and fabric. It is obvious that spinners and cloth manufacturers must know the count of the yarn they are to manufacture, and the large consumer should give this information to the spinner in the form of a specification.

To illustrate the method of procedure in the case of a cotton fabric, the following example is given:

If the count is desired in the warp direction only, 60 yarns each 24 inches long (=40 yards) from three different parts of the cloth are taken, aggregating 120 yards. If both the warp and filling are tested, shorter lengths are employed. Three tests are made for warp threads and six tests for filling threads, the latter being more irregular than the former.

The method of determining the count in this case is the same as given in the procedure for yarn, thread, and twine (p. 8).

(f) FOLDING ENDURANCE

Material such as silk, book cloth, and window-shade cloth, when in actual use, are subjected to folding to a greater or less extent. This test is indicative of the use to which they can be put. Especially in silks and book cloths that have been heavily sized and weighted this test is an important one, as the cracking or splitting after short usage would in some cases be serious.

The folding test is made upon a machine specially constructed for this purpose and gives the number of alternate complete folds which a specimen will endure before it breaks under a given constant tension.

This determination is made in standard atmosphere[3] upon a test strip 15 millimeters ($\frac{19}{32}$ inch) wide by 95 millimeters ($3\frac{3}{4}$ inches) long, and the number of double folds, i. e., folded flat upon itself, then opened and folded at the same point flat upon itself in the reverse direction. A constant tension of 1000 grams (35 ounces avoirdupois) is applied during the folding operation and the double folds are made at a rate of 200 per minute.

(g) ACTION OF LIGHT ON COLORS

The permanency of the coloring material of certain fabrics when exposed to the action of sunlight is a matter of considerable importance.

Test strips of cloth are fastened to a board, one half of each strip being covered, the other half is exposed to direct sunlight for 25, 50, and 75 hours, respectively.

Degree of Light Effect.—The result of tests of light action will be reported as follows: (1) None; (2) slight (lighter or darker); (3) medium (lighter or darker); (4) decided (lighter or darker).

[3] See note 1, p. 5.

Form of Report.—Results will be reported in the following form:

25 hours exposure	50 hours exposure	75 hours exposure
None	Medium	Decided

It will be readily understood this test is good for comparative purposes only, as actual number of hours of sunlight can not readily be determined during a test.

6. GENERAL INSTRUCTIONS REGARDING APPLICATIONS FOR TESTS

(a) *Application for Test.*—All articles submitted for test should be accompanied by a written request. This request should enumerate the material or materials, giving an identification mark, and should state explicitly the nature of the testing desired. When the test is one regularly provided for in the appended schedule, the fee may be computed in advance, and should be sent with the request for the test at the time the material is shipped. When an article or material is sent simply for test without definite instructions the Bureau will, when practicable, decide upon the nature of the test without correspondence.

(b) *Special Tests.*—The Bureau will gladly cooperate with scientific investigators, manufacturers of apparatus, and others who need higher precision than is provided in the regular tests, as far as the regular work of the Bureau will permit. Kinds of tests not at present provided for may be undertaken if the work is important and the facilities and time are available. Approved tests not provided for in the regular schedules will be considered special, and a special fee will be charged for them. The test should be arranged for by correspondence before shipment of the material. The application should state fully the need for the test, and the precision required. The special fee charged will depend chiefly upon the time consumed and the amount of alteration required in the regular testing apparatus. An estimate of the fee will be given when possible.

(c) *Identification Marks.*—All packages should be plainly marked with the shipper's name and address and a list of the contents. Each separate piece or sample of material should be provided with an identification mark or number. The identification mark should also be given in the application for the test.

(d) *Shipping Directions.*—Apparatus or test specimens should be securely packed in cases or packages which will not be broken in transportation and which may be used in returning them to the owner. The shipment in both directions is at the applicant's expense and risk. The tops of boxes should be put on with screws, as the jar due to nailing and the subsequent opening is liable to cause damage. The tops of the shipping boxes should have the return or forwarding address on the underside. Transportation charges are payable by the party requesting the test. The charges for shipment to the Bureau must be prepaid, and, unless otherwise arranged, articles will be returned "charges collect."

(e) *Address.*—Material submitted for test, as well as all correspondence, should be addressed simply "Bureau of Standards, Washington, D. C."

(f) *Remittances.*—Fees in accordance with the appended schedules should be sent when the material or apparatus is shipped, or promptly upon receipt of bill. Certificates are not given, nor is material returned, until the fees due thereon have been received. Remittances may be made by money order or by check drawn to the order of the "Bureau of Standards."

7. FEES

The following schedules of fees for testing textile materials have been established:

Schedule 200.—Raw and Unspun Fibers

	Fee.
(*a*) Identification of fiber (if composed of one fiber only)	$1.00
(*b*) Identification of a mixture of fibers	1.00–2.00
(*c*) Quantitative determination of a mixture	1.00–3.00
(*d*) Determination of the approximate length (if composed of one fiber only)	1.00
(*e*) Determination of the approximate length (if composed of two or more fibers)	1.00–3.00
(*f*) Quantitative determination of moisture	1.50
(*g*) Determination of the percentage of oil or grease	1.00
(*h*) "Shrinkage" determination of raw wool (scouring and conditioning)	2.50–5.00

Schedule 201.—Yarn, Thread, and Twine

(*a*) Measuring of skeins, cops, bobbins, spools, or balls (average of 2 tests), one sample	1.00
(*b*) Tensile strength determination (average of 10 tests), one sample	.50
(*c*) Elasticity determination (average of 10 tests), one sample	.50
(*d*) Determination of the yarn count or number (average of 5 tests), one sample	1.00
(*e*) Twist determination of single-ply yarn (average of 20 tests), one sample	.50
(*f*) Twist determinations of two or more ply yarns (average of 20 tests), one sample	.50–1.50
(*g*) Percentage fiber composition (same as for raw and unspun fibers)	1.00–3.00
(*h*) Determination of moisture (same procedure as for raw and unspun fibers)	1.50

Schedule 202.—Fabric

	Fee.
(*a*) Weight (calculated for any dimension), one sample	$0. 50
(*b*) Tensile strength (average of 5 tests upon warp and filling, respectively), one sample	1. 00
(*c*) Elasticity determination (average of 5 tests upon warp and filling, respectively), one sample	1. 00
(*d*) Percentage fiber composition (average of 2 complete tests, i. e., warp, filling, and whole fabric), one sample	1. 00–3. 00
(*e*) Count of threads per inch and per centimeter (average of 10 tests both in the warp and filling directions), one sample	. 50
(*f*) Determination of the yarn count or number (average of 5 tests), one sample	1. 00–2. 00
(*g*) Folding determination (average of 3 tests for warp and filling, respectively), one sample	. 50–1. 50
(*h*) Determination of the loading, sizing, and coloring materials (average of 2 tests), one sample	1. 00–2. 00
(*i*) Action of light on colors (average of 2 tests), one sample	. 50–1. 50

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Approved:

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