A MULTIPLE-STRAND TEST FOR YARNS [1]

By Charles W. Schoffstall and H. A. Hamm

ABSTRACT

The essential features of the multiple-strand test method for determining stress-strain relationships of yarns are as follows: The yarn is wound from its original form of put-up onto a specimen holder under uniform tension in such a way that the strands are placed parallel and do not overlap. The specimen holder containing the yarn is then placed in the jaws of an automatic stress-strain recording tester of the inclination-balance type. The speed of the pulling jaw is recommended to be 12 inches per minute. The distance between jaws is recommended to be 4 inches. The number of strands may be varied but should be calculated to a basis of 100 strands. In cases of various sizes of the same type of yarn further simplification of results on a strength-count basis is recommended.

CONTENTS

I. INTRODUCTION

The need for adequate methods of obtaining the stress-strain relationships of yarns is well recognized in the textile industry. This is especially true for rayon, because variations in the stretch characteristics affect both the appearance and quality of the final product.

[1] A preliminary report on this method was published in the Textile World, Sept. 24, 1927, p. 97, including a comparison with the method outlined tentatively by the rayon subcommittee of D-13 of the American Society for Testing Materials.

The "shiners" which occur at times in the rayon fabric and the puzzling striped effects which are sometimes found in knitted rayon tubing have been attributed to the application of uneven tension to the rayon yarn at some point of the manufacturing process, which distorted the yarn when the load was sufficient to stretch it beyond the elastic limit.

Two general methods have been used for determining the breaking strength of yarns—the single-strand test and the skein test.[2]

The single-strand test consists in stretching a single strand of prescribed length at a prescribed rate of elongation until it breaks. In the skein test a skein, previously wound on a yarn reel, is transferred to the drums of a testing machine and loaded as in the single-strand test. The testing machine in each case records the maximum load applied.

1. SINGLE-STRAND TEST

Several types of apparatus have been devised which will record the stress-strain data on textile yarns and fibers. The Schopper machines in use in this country give the ultimate stretch but do not record the stress-strain relationship. Scott testers for cords and twines have automatic devices for recording stress-strain data, but these machines are not sufficiently sensitive for single yarn or fiber tests. Both of these machines are of the pendulum inclination balance type.

Midgely[3] states that "the pendulum balance is extremely simple in principle and is peculiarly adaptable for the design of simple, accurate, easily calibrated machines which for facility of manipulation are greatly superior to all other types. The sensitiveness of the machine is not a constant quantity, however, and rapidly increases when the angle of inclination of the pendulum to the vertical becomes large, and for this reason the motion of the pendulum should be limited."

Some inherent errors due to inertia effects are present and cause some waviness of the actual curve drawn by the recording device. Shorter and Hall[4] discuss this point and set forth a theory of the motion, with a mathematical analysis indicating that the angular velocity of the pendulum, instead of having a steady value, actually oscillates about this value. This results in "a series of periodic momentary stoppages of the pendulum such as are actually observed."

Several experimental machines have been devised for specific research projects. Barratt[5] subjected cotton fibers to a smooth loading by an electromagnetic apparatus and obtained data on

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[2] The skein test is sometimes termed the hank test, or the lea test.

[3] Midgely, The Machine Commonly Used in the Cotton Industry for the Testing of Materials, J. Text. Inst., T189, **14**, No. 7; July, 1923.

[4] Shorter, S. A., and Hall, W. J., The Dynamical Theory of the Pendulum Yarn-Testing Machine, J. Text. Inst., T501, **14**; 1923.

[5] Barratt, T., Measurements of Breaking Stresses, Extensibilities, and Elasticities of Single Fibers of Cotton, etc., J. Text. Inst., T17, **13**, No. 1; January, 1922.

extension at break and breaking strength. New [6] used a spring balance and applied tension by running water into a pan attached to the yarn. A mechanical recording system was incorporated which recorded the stress-strain curve.

Matthew [7] applied a load through a lever system by water running at a constant rate into a vessel suspended from the end of a lever. An automatic recording system with pen and drum was provided. Shorter and Hall [8] describe a spring-balance type of machine which reduces the effects of inertia and friction to a minimum, so that the stress-strain relationships which hold during rapid changes can be investigated. In this machine all motion-compounding devices are eliminated. "The top end of the yarn is attached to the spring and the bottom end to the stretching mechanism. The pen is attached to the spring and partakes of its vertical motion. The paper is attached to the carriage which, by means of a simple mechanism, is made to move horizontally at a rate equal to that of the vertical motion of the lower end of the yarn * * *".

These machines are typical of those described in the literature. For a further and more detailed study the surveys and discussion of Midgely and Pierce [9] [10] [11] [12] are suggested.

2. SKEIN TEST

The skein test has been used quite extensively in cotton mills and wool mills. The voluminous data [13] compiled by the Draper Co. over a period since 1886 were based on results obtained using this method.

Many changes have been suggested for improving the skein test. In the basic test a skein of 120 yards is first prepared by winding the yarn onto a reel of 1½ yards perimeter to form a skein of 80 strands. The skein is then placed around the drums of a tester, and a pull sufficient to break it is gradually applied; the machine records the maximum force transmitted during the test.

Friction, nonuniform distribution of tension, and variations in the stretch of the individual yarns appreciably influence skein tests, so that the test does not give the average of a large number of single strands. Nevertheless Hall [14] states, "* * * Although the

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[6] New, G. F., The Stress-Strain Curves of Various Yarns, J. Text. Inst., T52, **13**, No. 2; February, 1922.

[7] Matthew, J. A., The Elastic Properties of Yarns, J. Text. Inst., T45, **13**, No. 2; February, 1922.

[8] Shorter, S. A., and Hall, W. J., A New Autographic Testing Machine for Yarns and Fibers, J. Text. Inst., T495; December, 1923.

[9] See footnote 3.

[10] Midgely, E., and Pierce, T. F., Tensile Tests of Cotton—(I) A Survey of Current Tests; (II) The Ballistic Test for Work of Rupture; (III) The Rate of Loading; Shirley Inst. Memoirs, 5; 1926.

[11] Pierce, T. F., Tensile Tests of Cotton—(IV) The Dynamics of Some Testing Instruments; (V) The "Weakest Link" Theorems on the Strength of Long and of Composite Specimens; Shirley Inst. Memoirs, 5; 1926.

[12] Pierce, T. F., The Mechanical Testing of Cotton Materials—(A) The Measurement of the Mechanical Properties of Cotton Materials, J. Text. Inst., T161, **14**; No. 7; July, 1923.

[13] Textile Texts, 4th ed., 1917, Draper Corporation, Hopedale, Mass.

[14] Hall, W. J., An Experiment Examination of the Hank Test and a Comparison with the Single-Thread Tensile Test for Woolen and Worsted Yarns, J. Text. Inst., T223, **16**; 1925.

strength of the single thread can not be deduced from the results of the hank (lea) test, yet the hank test will grade a series of yarns in approximately the same quantitative order as the single-thread test. Since most tests are comparative rather than absolute, the hank test is thus proved to be of considerable value, particularly when it is remembered that generally single-thread testing is unreliable on account of the insignificant amount of material tested, and impractical for general use if enough tests are carried out to give truly representative results * * *."

Hall refers very briefly to a test which has some similarity to the multiple-strand test procedure herein described in that he wound the yarn on a frame and clamped both ends in the machine. No details were given regarding the winding nor were any stress-strain data given. He states, "The hank test gives an appreciable greater value for the breaking load than the multiple single-thread test clamped at both ends, but less than that calculated from the ordinary single-thread test." Lack of details of the procedure precludes any discussion of this conclusion in relation to the test described herein or the results obtained.

A distinct disadvantage of the skein test from many standpoints is the fact that accurate stress-strain data can not be obtained.

3. PROPOSED A. S. T. M. TEST

The rayon subcommittee of D-13 of the American Society for Testing Materials has recommended in their proposed specification [15] for rayon a modification of the skein test for measuring strength and stretch.[16] This is a step in the direction of eliminating the inherent difficulties of the skein test. This method requires the breaking of a segment of a skein prepared as in the skein test. The procedure is as follows:

"The initial distance between jaws shall be 10 cm (4 inches). The skein to be tested shall first be clamped in the upper jaws spread out evenly so that the ends are parallel, forming a ribbon approximately three-eighths to three-fourths inch in width. The rayon shall then be drawn down through the lower jaws and spread out to make a band of equal width, pulled just taut and clamped."

For routine work in which an accuracy no greater than 10 per cent is required the above test is apparently satisfactory. However, for research work in which small differences in the stress-strain curves are to be studied the precision is not sufficient. Much of the inaccuracy is due to the personal equation involved, first, in the way in which the individual strands are placed in the jaws of the tester; and second,

[15] Tentative Specifications for Tolerances and Test Methods for Rayon, serial designation D258-27T; revised, 1927; A. S. T. M.

[16] Edwards, W. F., Value of the Serigraph Test, Textile World, Dec. 23 and 30, 1922; also, Universal Tensile Tests for Yarns, Textile World, p. 2355; Apr. 3, 1926.

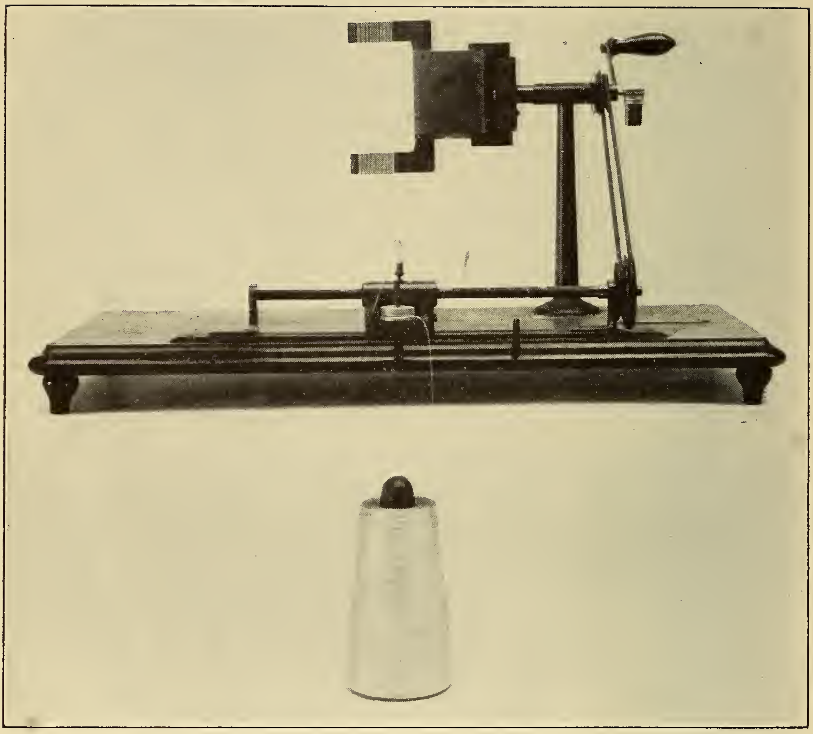

FIGURE 1.—*General view of apparatus for winding the yarn on the specimen holder (multiple-strand method)*

A card winder for evenness tests is adapted. The yarn is led through the tensioning device. A clamp to which is attached the specimen holder takes the place of the usual card. A revolution counter is attached.

in the inequality of the tension of the individual strands as they are fastened between the jaws of the tester. The proposal of Prof. G. B. Haven[17] to fasten the specimen at each end with a gummed label or sticker, so that the yarns will not slip during handling, is an improvement in this respect.

II. APPARATUS AND TESTING PROCEDURE

The apparatus and testing procedure used in the multiple-strand test are described below.

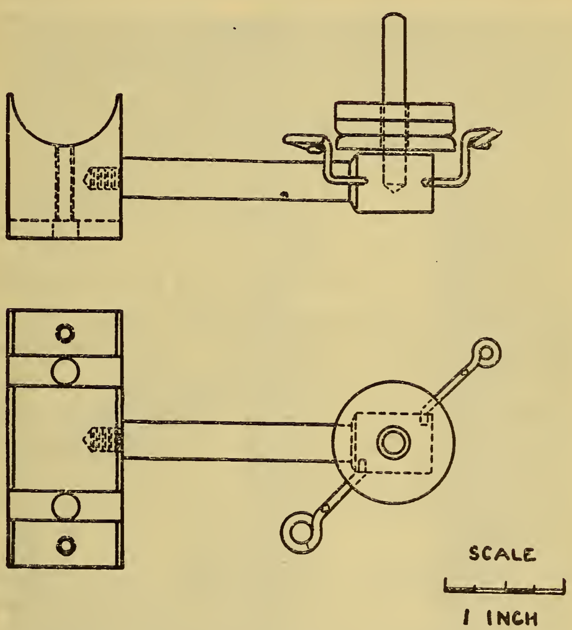

Figure 2.—*Tension device used in winding the specimen in the multiple-strand method*

The disks are aluminum about 3.5 g each. The remainder is brass (or any suitable metal).

1. APPARATUS

(*a*) Yarn Winder.—The winder is an adaptation of a card winder used for inspection of yarn evenness. (Fig. 1.) It is equipped with a tension device attached to the usual driving-screw carrier mechanism, and a ratchet counter for indicating the number of strands.

(*b*) Tension Device.—The tension device (fig. 2) consists essentially of three highly polished aluminum disks arranged so that they are free to revolve and a holder with eyelets for guiding the yarn

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[17] Massachusetts Institute of Technology.

through the disk arrangement. Each disk weighs approximately 3.5 g.

(*c*) Specimen Holder.—This consists of two arms and a clamp for holding them (figs. 1 and 3). The arms are clamped in proper position by using as guides several small pins which project from the clamp and fit into holes in the arms. The wing nut and bolt are used to secure the arms in position during the winding operation.

(*d*) Breaking-Strength Machine.—The machine used for breaking the specimens is an automatic recording Scott power tester of the inclination-balance type with capacities of 0 to 55 pounds and 0 to 110 pounds, the total load being indicated on a scale which is graduated in ½-pound steps. Stretch may be read from the curve to an accuracy of 0.02 inch.

2. TESTING PROCEDURE

(*a*) Winding Operation.—The first operation consists in winding the yarns under a uniform tension on the specimen holder. This is accomplished by placing the spool, cop, or pirn of the yarn to be tested under the winder. The yarn is then brought up between the two lower tension disks, through the winder guide, and fastened by means of a gummed sticker to one of the cross arms of the specimen holder. The required number of strands are then put on by turning the winder crank at the rate of approximately 100 revolutions per minute. This operation lays the yarn strands on the holder under uniform tension, equally spaced and at right angles to the arms. The last strand is also fastened by a gummed sticker. The set-up is shown in Figure 1.

(*b*) Testing Operation.—The specimen holder is then transferred to the jaws of the testing machine. After the jaws are tightened (see fig. 3) the wing nut is unscrewed and the holder for the arms is removed (see fig. 4). The specimen is then broken in the usual manner.

3. DISCUSSION OF APPARATUS AND METHOD

Several changes were made in the winding apparatus, the most important of which was the addition of a tension device attached to the part holding the eyelet. It was found, by trial, that two polished aluminum disks, rotating on a third, each weighing approximately 3.5 g, produced satisfactory tension for the several types of yarn under consideration; that is, this appeared to the eye to be the minimum weight which would lay the yarn on the rod straight and unkinked. This device is similar to those sometimes used in yarn-winding machines. The tension was found to be 8 g for a 150-denier rayon yarn moving at 80 feet per minute through the disk tension device. These disks and the upright on which they are placed must be kept

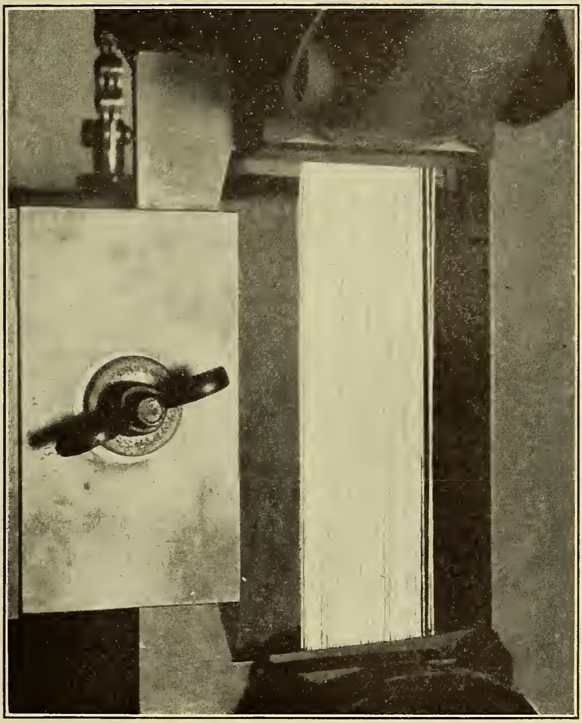

FIGURE 3.—*Specimen holder inserted in the jaws of the machine with clamp still attached*

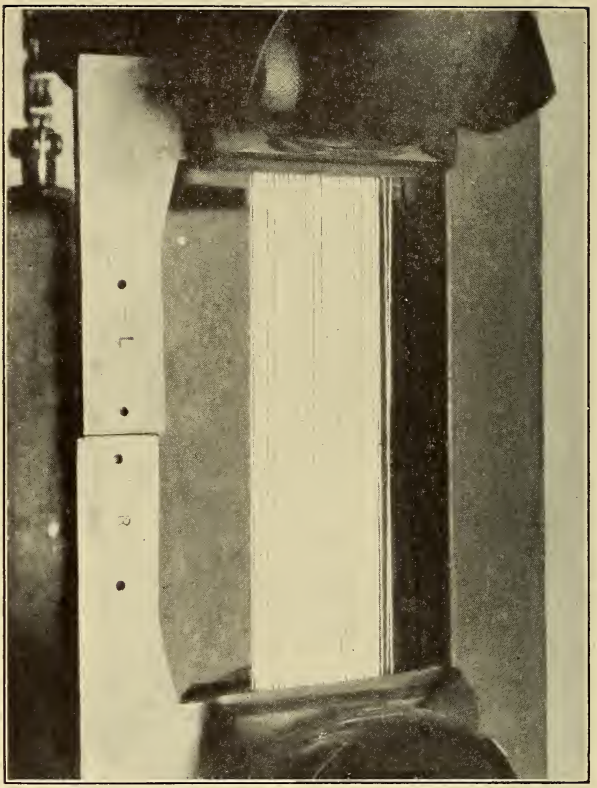

Figure 4.—*Specimen holder in the jaws of the machine with clamp removed*

smooth and polished. This is especially important for silk or rayon, because roughened places may cut or break the filaments.

The testing procedure for the multiple-strand test has three major advantages over previous attempts to supplant or improve the skein test. These are (1) minimum handling of the yarn (2) uniform tension on the strands of the test specimen, and (3) no overlapping of the strands.

III. TEST RESULTS

1. INFLUENCE OF THE NUMBER OF STRANDS

From each of four different types of rayon (obtained in February, 1927), specimens wound to contain 20, 40, 60, 80, and 100 strands [18]

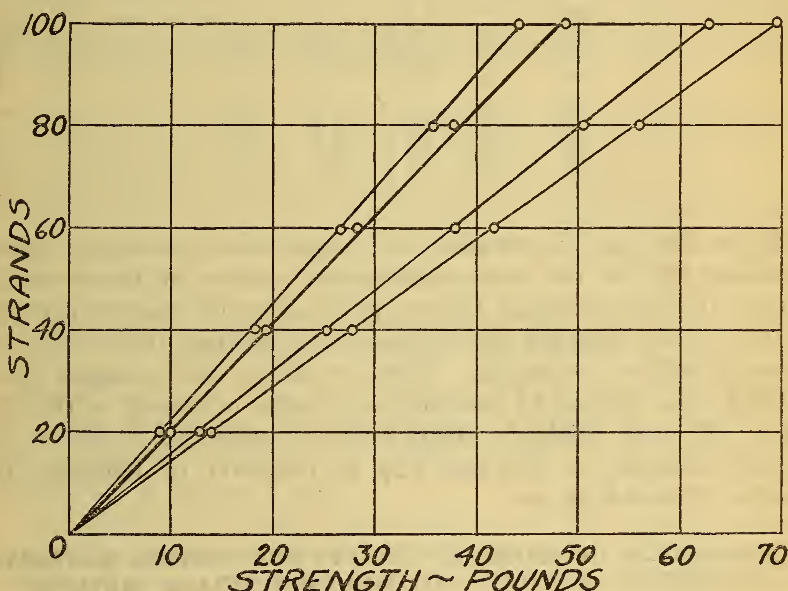

Figure 5.—*The effect of number of strands in the specimen on the strength using the multiple-strand method*

Four types of rayon yarns were used in this test. Note the excellent straight-line relationship indicating a direct proportionality between number of strands and strength with this method.

were tested. The results calculated on a basis of 100 strands are given in Table 1.

The results are given in graphical form in Figure 5. It will be noted that the total breaking load is closely proportional to the number of strands and that comparable results in per cent of stretch are obtained regardless of the number of strands used in the specimen. The agreement of the results when computed to a basis of 100 strands is especially good.

[18] "Strand" is used in this paper to mean a part of the specimen extending from one arm of the specimen holder to the other and should not be confused with the words "filament" or "ply."

TABLE 1.—*Influence of the number of strands on the breaking strength*

[All results calculated on 100-strand basis]

Sample	Number of strands	Stretch at—						Breaking strength
		10 pounds	20 pounds	30 pounds	40 pounds	50 pounds	60 pounds	
		Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Pounds*
V-1	100	0.42	1.4	1.8	7.7	11.4	15.1	69.8
	80	.46	1.4	1.9	7.7	11.6	15.1	70.0
	60	.53	1.4	2.0	7.9	11.8	15.8	69.7
	40	.46	1.2	1.8	7.7	11.4	15.3	69.6
	20	.46	.93	1.9	7.6	11.2	14.5	70.0
N-2	100	.70	1.2	2.3	6.1	8.9	12.0	62.3
	80	.46	1.2	2.1	6.2	8.7	12.0	63.1
	60	.53	1.2	1.9	6.0	8.9	12.4	63.3
	40	.46	1.2	1.9	6.0	8.9	11.9	63.3
	20	.77	1.2	2.5	6.5	8.8	11.6	63.3
C-3	100	.70	1.2	3.6	7.5			48.8
	80	.60	1.2	3.0	7.5			47.1
	60	.77	1.3	3.0	7.5			47.2
	40	.60	1.2	2.6	7.5			48.3
	20	.53	1.1	3.4	7.3			50.0
A-4	100	.56	1.5	12.5	23.0			44.1
	80	.53	1.5	11.5	22.8			44.8
	60	.46	1.7	10.8	21.7			44.7
	40	.46	1.6	11.4	21.7			45.8
	20	.46	.9	13.1	22.9			45.0

This makes possible the adoption of a procedure which will largely eliminate two of the most troublesome sources of discrepancies, namely (1) inaccuracies at different points along the range of capacity of the machine and (2) lack of sensitivity resulting from using machines of different capacities. These variations can be largely eliminated by this method by choosing the number of strands so that the break will occur within a small carefully calibrated range on the testing machine. A trial test may be necessary to determine the number of strands to use.

2. COMPARISON OF AMERICAN SOCIETY FOR TESTING MATERIALS (PROPOSED) METHOD AND MULTIPLE-STRAND METHOD

A series of tests were made on four different types of rayon using the proposed method of the rayon subcommittee of the A. S. T. M. A specimen of rayon yarn from a particular cone was tested according to the multiple-strand method; the next length was tested using the A. S. T. M. method and so on. Since the A. S. T. M. method proposes a speed of pulling jaw of 6 inches per minute and most of the work on the multiple-strand method was done at 12 inches per minute, both these speeds were included for comparison. An analysis of the results is given in Table 2.

TABLE 2.—*Comparison of results on rayon using the proposed A. S. T. M. and the multiple-strand methods*

[All results are on a 100-strand basis]

Test method	Number of tests	Number of strands per test	Speed of pulling jaw	Maximum deviation strength	Maximum deviation stretch	Maximum deviation in load at 0.1 inch stretch
				Pounds	*Per cent*	*Pounds*
A. S. T. M.	40	80	6	3.3	0.09	3.0
M. S.	40	80	6	.6	.06	1.5
A. S. T. M.	40	100	6	2.1	.10	3.5
Do	100	100	12	2.3	.09	4.0
M. S.	100	80	12	.3	.06	1.6
A. S. T. M.	180			2.5	.09	3.7
M. S.	140			.4	.06	1.6

NOTE.—The mean deviation of the strength results obtained by the A. S. T. M. method using 12-inch speed of pulling jaws was 0.6 pound (strength ranged from 43 to 59 pounds in 100 tests using 100-strand specimens) as compared with a mean deviation of 0.1 pound for the multiple-strand test (strength ranged from 37 to 47 pounds in 100 tests using 80-strand specimens).

It will be noted that the use of the proposed A. S. T. M. method leads to greater deviations both in strength and stretch than the multiple-strand method. The average deviations in the strength results of the multiple-strand method seems to be within the sensitivity of the machine (½ pound); the stretch variations are about three times the possible experimental error caused by the machine.

3. INFLUENCE OF THE VARIABLES OF THE MULTIPLE-STRAND METHOD ON STRENGTH RESULTS

Several series of tests were conducted to ascertain the effect of (*a*) speed of pulling jaw and (*b*) various distances between jaws. The results are tabulated in Tables 3 and 4 and are illustrated graphically in Figures 6 and 7.

The results of the tests using different speeds of the pulling jaw showed the expected increase in strength as the speed increased. The chief interest in these results lies in the 6 and 12 inch speeds. There has been some discussion as to whether or not a 6-inch speed should be used for stress-strain testing. As noted previously, the proposed A. S. T. M. method for rayon specifies 6 inches. However, the most common speed used in textile testing with this type of machine is 12 inches per minute.[19] Probably for this reason the gearing of the machine is such that it operates best at about 12 inches per minute, although other speeds may be obtained by changes in the pulleys or by placing a rheostat in the power line. Judging from the results obtained in this study, there seems to be little justification for the change to 6 inches, and in the interest of standardization in laboratories testing all types of yarns and fabrics the 12-inch speed is to be preferred.

[19] Federal Specification Board specification No. 345a; A. S. T. M. test methods Nos. D39-27, D180-27, D203-25, D122-27, D179-27.

TABLE 3.—*Breaking strength of yarns broken at different distance between jaws* [1]

Sample No.	Kind	Breaking strength at distance between jaws				
		1 inch	2 inch	3 inch	4 inch	6 inch
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1	Rayon	60	60	58	58	56
2	Rayon	56	56	56	54	52
3	Rayon	45	44	43	43	41
4	Rayon	37	36	35	35	34
5	Rayon	39	38	37	37	36
6	Rayon	37	36	36	35	34
7	Rayon	46	45	44	44	43
8	Rayon	39	39	39	38	--------
9	Rayon	40	40	40	39	40
10	Worsted	20	18	16	15	14
11	Cotton	41	40	37	35	34
12	Silk	60	58	54	52	50
13	Mercerized cotton	64	59	57	55	53

[1] Multiple-strand method; speed of machine 12 inches per minute; 80-strand specimens.

TABLE 4.—*Breaking strength of yarns broken at different speeds of pulling jaw* [1]

Sample No.	Kind	Breaking strength at speeds per minute				
		1 inch	2 inch	6 inch	12 inch	20 inch
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1	Rayon	124	131	141	149	152
2	Rayon	111	121	135	139	144
3	Rayon	90	94	101	105	110
4	Rayon	75	80	85	85	90
5	Rayon	85	91	102	110	115
6	Rayon	74	81	91	94	96
7	Rayon	90	95	103	109	112
8	Rayon	76	81	88	93	96
9	Rayon	73	83	92	95	98
10	Worsted	30	35	36	38	42
11	Cotton	81	80	85	86	90
12	Silk	118	125	132	147	151
13	Mercerized cotton	138	138	139	142	145

[1] Multiple-strand method; distance between jaws was 4 inches; 200-strand specimens were used; capacity of machine was 300 pounds.

Considering the curves (fig. 7) for different distances between jaws, it is clear that the percentage stretch and the breaking strength decrease as the distance between jaws increases, probably due to the increase in the time of break, which is equivalent to decreasing the rate of elongation. A pulling speed of 12 inches per minute on a 6-inch specimen represents a rate of elongation of 2 inches per inch of specimen per minute (assuming that the pendulum jaw is stationary). The same speed on a 1-inch specimen represents a rate of elongation of 12 inches per inch per minute, or six times as great.

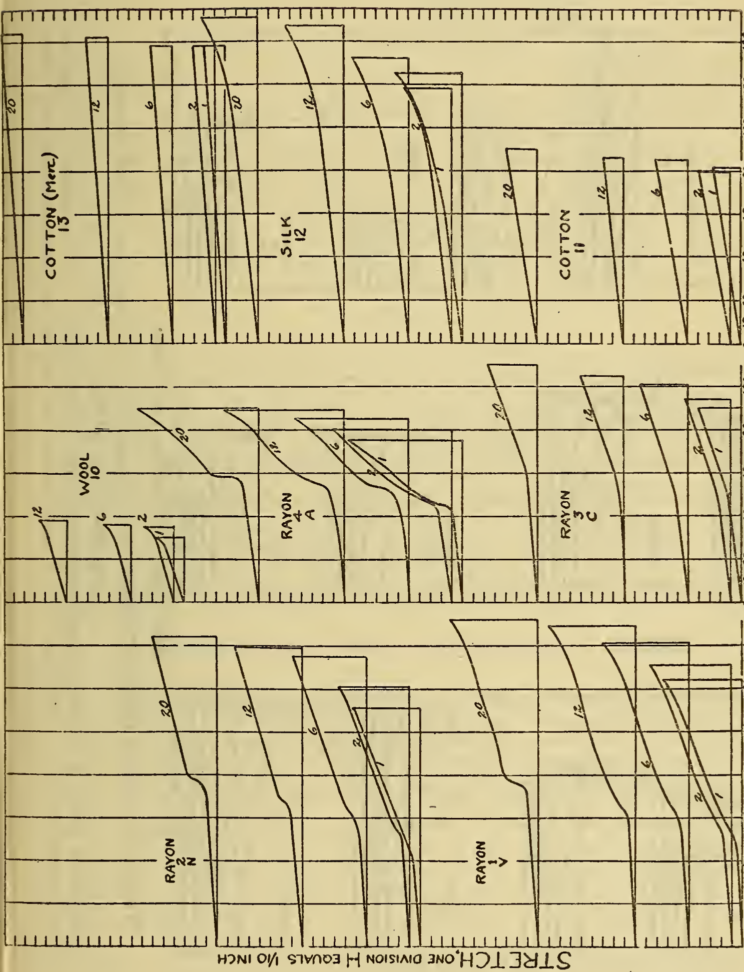

FIGURE 6.—*The influence of speed of pulling jaw on the strength and stretch using the multiple-strand method*

Although the groups of curves are typical for different types of yarns, they are not comparable with each other because of differences in size. The Figures 1, 2, 6, 12, and 20 on the curves indicate the speed of the pulling jaw. The zero-stretch or base line is drawn for each curve.

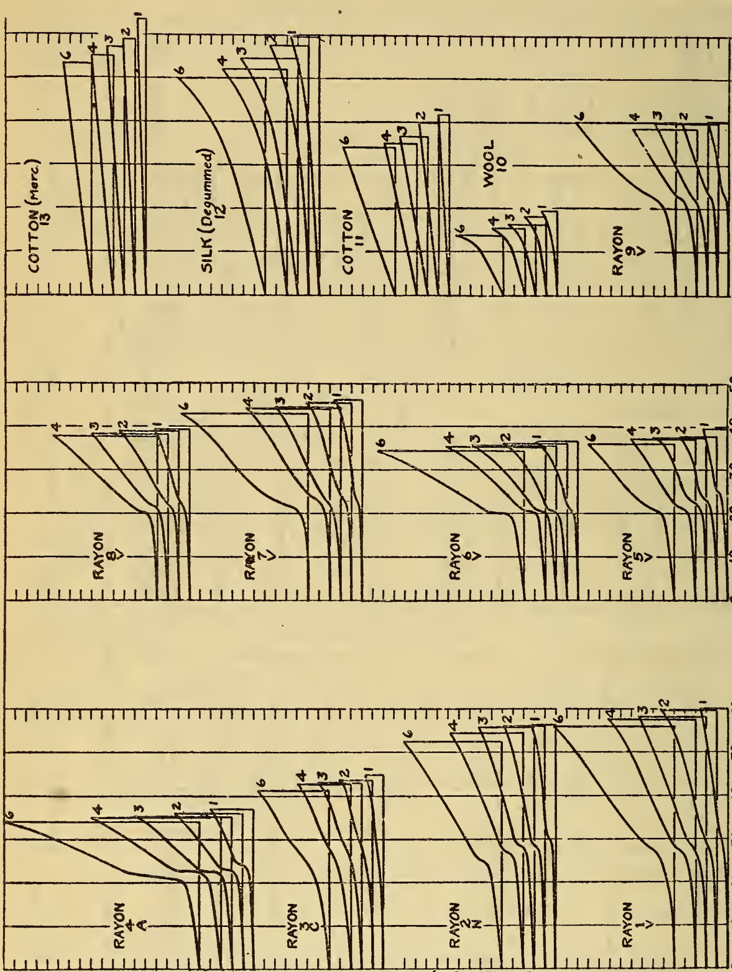

FIGURE 7.—*The influence of distance between jaws on the strength and stretch using the multiple-strand method*

Although the groups of curves are typical for different types of yarns they are not comparable with each other because of differences in size. The Figures 1, 2, 3, 4, and 6 on the curves indicate the distance between jaws. The zero-stretch base line is drawn for each curve.

TABLE 5.—*Comparison of results obtained with different test conditions*

[Calculated to 100-strand basis]

No.	Conditions	
	2 inches between jaws, 12 inches per minute, 80-strand specimen	4 inches between jaws, 20 inches per minute, 200-strand specimen
1	75	76
2	70	72
3	55	55
4	45	45
5	47. 5	57. 5
6	45	48
7	56. 3	56
8	48. 7	48
9	50	49
10	22. 5	21
11	50	45
12	72. 3	75. 5
13	72. 7	72. 5

NOTE.—Sample No. 5 was noticeably variable in its structure.

A check on the method covering the proportionality of the number of strands and the pulling speed is shown in Table 5, in which the strength results obtained at 12 inches per minute, with 2 inches between jaws for 80 strands, is compared with the results shown in the last column of Table 4. Both sets of results are calculated to a 100-strand basis. The 20 inches per minute on a 4-inch specimen are roughly equal to 12 inches per minute on a 2-inch specimen.

4. RESULTS OF TESTS ON DIFFERENT KINDS OF YARN

In order to demonstrate the universal character of this test method for all types of textile yarns, a number of tests were made on various kinds of yarns. The distance between jaws was 4 inches; the number of strands was varied so that the results fell within the range of 30 to 70 pounds on the 110-pound capacity machine. Table 6 summarizes the results reduced to a basis of 100 strands by simple calculations. Some further simplification of the results may be desirable from the standpoint of any particular class of yarn. In the column headed "strength-count factor," a suggested unit basis for rayon and silk is indicated which is obtained by dividing the strength per 100 strands by the size, respeetively. The remaining data in this column are not comparable because calculations are made on a different basis. The results have little significance in themselves, because the samples were chosen more or less at random and only for the purpose of showing the application of the method to all types of yarns. The strength results are averages of 10 breaks.

TABLE 6.—*Breaking strength and stretch (multiple-strand method) of various kinds of yarns*

Sample No.	Kind	Description	Count[1]	Count system	Number of strands	Breaking strength	Breaking strength 100-strand	Strength-count factor	Stretch at breaking
						Pounds			*Per cent*
1	Rayon		159	Denier	100	69.8	69.8	0.44	20.9
2	do		154	do	100	62.8	62.8	.41	14.0
3	do		135	do	100	48.9	48.9	.36	11.4
4	do		156	do	100	44.1	44.1	.28	29.5
5	do		153	do	100	51.3	51.3	.36	15.1
6	do		150	do	100	43.4	43.4	.29	23.2
8	do		149	do	100	43.4	45.4	.30	22.1
10	Wool	Fr. worsted	52.6	Worsted	160	30.3	19.0	.36	3.7
11	Cotton	Unbleached	34	Cotton	100	44.3	44.3	1.3	7.1
12	Silk	Degum	135	Denier	40	40.0	100.0	.74	11.1
13	Cotton	Mercerized	69/2	Cotton	60	44.3	73.3	1.1	4.3
14	do	do	15	do	40	51.8	129.5	8.6	7.1

[1] Denier (legal) system, the size is the weight of a 450 m skein in deniers (0.05 g); cotton system, the size is the number of 840-yard hanks in 1 pound (avoirdupois); worsted system, the size is the number of 660-yard hanks in 1 pound (avoirdupois).

IV. SUMMARY

1. ESSENTIAL FEATURES OF METHOD

The essential features of the multiple-strand test method for determining stress-strain relationships of yarns are as follows: The yarn is wound from its original form of put-up onto a specimen holder under uniform tension in such a way that the strands are placed parallel and do not overlap. The specimen holder containing the yarn is then placed in the jaws of an automatic stress-strain recording tester of the inclination-balance type. The speed of the pulling jaw is recommended to be 12 inches per minute. The distance between jaws is recommended to be 4 inches. The number of strands may be varied but should be calculated to a basis of 100 strands. In case of various sizes of the same type of yarn a further simplification of results on a strength-count basis is recommended.

2. ADVANTAGES OF THE METHOD

The advantages of the multiple-strand test method may be summarized as follows:

(*a*) The apparatus required is simple. It utilizes two machines which are generally available in most laboratories and plants, namely, an inclination-balance tester and an evenness tester. The changes necessary on the evenness counter are the addition of the tension device and ratchet counter. The only other device needed is a specimen holder which may be made easily. The procedure is easy to carry out, requiring only the care and technique of the usual laboratory operator.

(*b*) The average deviation of the strength results obtained, especially on rayon, are within the recording accuracy of the machine. The stretch deviations are about three times the possible experimental error caused by the machine. These are in both cases better than the proposed A. S. T. M. method for rayon, which is the nearest comparable method.

(*c*) The handling of the specimen has been reduced to a minimum. The necessary handling is mechanical and not personal.

(*d*) Each strand of the specimen is under uniform tension, and there is no overlapping of the strands.

(*e*) A smaller amount of the sample is wasted than in the skein test or the proposed A. S. T. M. test for rayon.

(*f*) Probably the chief advantage is based on the results which show that the breaking strength is directly proportional to the number of strands of the specimen. This permits the selection of the number of strands for any particular sample which will bring the result within a small range on the testing machine. (A trial test may be necessary to select this.) This procedure will avoid two of the most troublesome sources of variation in results, namely, inaccuracies at different portions along the range of the machine and differences in sensitivity of machines of different capacities.

(*g*) The results may be readily converted either to a unit basis of 100 strands or to a strength-count basis.

V. ACKNOWLEDGMENT

Acknowledgment is made to A. M. Tenney, chairman of the rayon subcommittee of the A. S. T. M.; Dr. E. E. Chandler, consulting physicist of the Department of Agriculture; and David C. Scott, for helpful suggestions in connection with the development of this project. Acknowledgment is also made to W. T. Schreiber and R. E. Stevens, of the bureau staff, for help in obtaining the data and to a number of rayon manufacturers for samples.

WASHINGTON, December 19, 1928.