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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 450

MERCERIZATION OF COTTON FOR STRENGTH WITH SPECIAL REFERENCE TO AIRCRAFT CLOTH

By J. B. Wilkie
Bureau of Standards

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By J. B. Wilkie

I. INTRODUCTION

The process of mercerization is named after John Mercer who, in 1850, obtained a patent, one claim of which is that cotton fibers and cloth are strengthened by treatment with caustic soda or certain other substances. Another patent granted in 1890 to Arthur Lowe, points out that the luster of cotton textiles is improved by mercerizing them under tension. From the time of Lowe's patent to the present the primary object of commercial mercerization has been either to improve the appearance of yarns and fabrics by increasing their luster or to improve their dyeing qualities. However, there is a growing demand for cloth of the greatest strength for a given weight, especially for use in aviation. Hence the possibility, first pointed out by Mercer, of increasing the strength of yarn and cloth by mercerization is now of greater importance than at any previous time.

The literature indicates that the strength of cotton yarn or cloth can be materially increased by mercerization, but the conditions for obtaining the maximum increase in strength have not been worked out systematically.

A high strength/weight ratio is the main consideration in the use of a cotton cloth for aircraft structural purposes. Accordingly, the object of the present investigation was to determine the conditions for mercerizing cotton yarn to obtain the maximum strength for a given weight. Apparatus for controlling the variables was built and yarns were mercerized with it under systematically varied conditions of tension, time, temperature, and concentration of caustic soda. Attention was given to the relation between the count, twist, and ply of yarns and the increase in strength resulting from mercerization.

The experiments were limited to yarn mercerization because of the better control that appeared to be possi-

ble. However, the results obtained should be applicable to the mercerization of cloth as well as yarn.

This work was undertaken by the Bureau of Standards at the request of and with the financial assistance of the National Advisory Committee for Aeronautics.

II. MATERIALS AND EQUIPMENT

Cotton yarn of count 80 spun from 1-5/16 inch staple length good middling Peeler cotton in the Bureau cotton mill was used for the study of the variables of the mercerization procedure. This yarn was spun with twist multiplier 3* giving about 27 turns per inch, slightly lower twist than is required to produce gray yarn of maximum strength. Yarns of count 80 made from the same cotton in other twists were used in studying the effect of twist. Information concerning certain other yarns used for the experiments is given in the title to Table I.

Commercial caustic soda was purified for these experiments by allowing a 48.5 per cent stock solution to settle, the clear supernatant liquor being used. After this purification, the solution contained 0.001 per cent iron** and 0.5 per cent anhydrous sodium carbonate. This concentrated solution was stored in pyrex glass bottles which were equipped with ascarite tubes to prevent contamination from atmospheric carbon dioxide. It was diluted with carbon dioxide free distilled water for use in the experiments.

The apparatus which was designed for the mercerization of the yarns is shown in Figure 1. It consists of a constant temperature bath in which the containers for the solutions used can be placed and a mechanism for the support of the yarn which provides for the measurement and control of the tension on it. The mechanism is suspended

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*The twist multiplier (M) is a constant relating the number of turns per inch (T) given the yarn in spinning to the yarn count (C) according to the equation $T = M\sqrt{C}$.

**Unpublished work by the author shows that cotton is appreciably degraded, i.e., the alpha cellulose content is decreased, by mercerization at 100°C with caustic soda solution containing only 0.01 per cent of iron but that it is not degraded when the iron concentration is less than this amount.

as a unit by cables which pass over pulleys on the cross-tree at the top of the mast shown in the center of the figure to weights which serve as counterpoises. The mechanism can be lowered to bring the yarn into the solution below it. The mast can be rotated to bring the mechanism over any one of the three containers.

The bath is equipped with motor-driven agitators and is filled with water or, for low temperatures, with alcohol. It is provided with a coil through which either steam or cold brine can be circulated. An auxiliary electric heating unit controlled by a thermostat supplements hand control and permits the temperature to be held constant to within 0.5° for any temperature between about 96°C and -10°C. Three openings in the top of the bath (covered in the photograph) accommodate monel metal containers of 15 liters capacity in which the caustic soda solution and rinse waters are placed.

The frames on which the yarn to be mercerized is wound and the winder are shown in Figure 2. The holes in the corners of the frames slip over studs on the supporting mechanism just above the bath in Figure 1, in which the six frames that are accommodated at one time are shown in place. The ends of the frames are held apart by detachable links (fig. 2) that are removed when the frames are placed on the studs. (Fig. 1.) The lower studs are fixed. The upper studs are attached to a carriage that is free to move vertically on guide rods. The carriage is suspended by a cable from the spring scale which is attached above to a rack that is in turn suspended by a cable passing over pulleys and terminating in the bag of shot (A) in Figure 1. There is too much friction in this mechanism to permit the bag of shot to be used as a constant known load on the yarn. It is simply used as a counterpoise. The load on the yarn is obtained by hand-operated pinion gears which engage the rack. The load on the yarn is indicated by the pointer on the spring scale. Another pointer, attached to the cable from the carriage to the scale, indicates on a ruler any changes in length of the yarn during processing. A propeller directly below the yarn driven by a small motor (B in fig. 1) keeps the liquid in which the yarns are placed thoroughly agitated.*

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*The apparatus is more elaborate than would be necessary if it were designed only for the present work. It can be used for the mercerization of skeins as well as of yarn wound on frames.

The apparatus used in preparing the yarn for mercerization is described in the next section.

PROCEDURE

Pretreatment

All of the yarn used in the experiments was given the pretreatment now to be described. The purpose of the pretreatment was to remove cotton waxes, oils, and in fact, all extraneous materials in order to prevent contamination of the mercerizing solution and to provide a uniform material for mercerization. A commercial pretreatment was not given because foreign materials usually are not completely removed by such treatment. The procedure followed is similar to that recommended by Corey and Gray for the preparation of standard cellulose. (Reference 1.) The gray yarn in the form of 3,000-yard skeins was extracted for 14 hours with ethyl alcohol, then for 14 hours with ethyl ether. Finally, it was boiled for 6 hours with a 1 per cent aqueous solution of caustic soda. The extraction apparatus was constructed from an aluminum pressure cooker and functioned like an ordinary Soxhlet extractor. The yarn was placed in a glass container, contact with metal being avoided. The caustic soda boil was carried out in a monel metal can provided with an agitator. The yarn was kept submerged and was protected from mechanical action by placing it in a cheesecloth net. The alpha cellulose content of the pretreated cotton was 99.7 per cent.

Mercerization

The pretreated yarn to be mercerized was conditioned by exposure for at least 24 hours in an atmosphere of 65 per cent relative humidity, having a temperature of 70°F. One hundred turns, about 56 yards, were then wound upon each frame with the winder shown at A in Figure 2, a very small but uniform tension being applied during winding. The frames were next placed in position on the apparatus that has been described. After the first frame was placed on the apparatus, the movable carriage was locked in position. The connecting links of the frame were next removed. The remaining five frames were placed in position in like manner, each having its connecting links removed. The carriage was then unlocked and the desired tension was applied to the yarn. This tension was

maintained during mercerization, or changed as desired, by the hand-operated rack and pinion. The mechanism was then lowered to immerse the yarn in the caustic soda solution. After the caustic treatment was completed, the yarn was shifted over into another container filled with distilled water at a temperature of 0°C or, if mercerization was carried out at room temperature or higher, 20°C. This rinse was followed by three 5-minute rinses with tap water. Any caustic remaining in the yarn was then neutralized by placing the yarn for 10 minutes in a 1 per cent solution of acetic acid at room temperature. The yarn was then given three 5-minute rinses with tap water followed by a final 5-minute rinse with distilled water, all at room temperature. The mercerized yarn was then removed from the final rinse by elevating the mechanism. The tension was reduced to about 0.2 pound per 100 ends and the yarn was allowed to dry in a current of air from an electric fan.

When the yarn was dry, it was shifted from the metal frames to cardboard holders, care being taken not to disarrange it. Yarn to be used for the breaking strength test was obtained as shown at 1 in Figure 3. Gummed paper was pasted over the yarn to hold it to the cardboard. The yarn was then cut across at each end where it looped back, giving two sheets of strands. Yarn to be reeled and weighed for the determination of count was obtained as shown at 2 in Figure 3.

B. Testing

All tests were made after conditioning the yarn by exposure for at least 24 hours in an atmosphere of 65 per cent relative humidity having a temperature of 70°F.

The count of the yarn, i.e., the number of 840 yard lengths in a pound, was obtained by calculation from the weight of a 45 yard length.

The breaking strength of the yarn was found as follows: The one hundred strands taken from one side of the frame as described above were inserted simultaneously (multiple strand method) in the jaws of a pendulum type tester. The capacity of the machine was 110 pounds except for testing the 10's yarn, when a machine of 300 pounds capacity was used. The distance between the jaws was 4 inches and the rate of separation was 12 inches per minute. The elongation of the yarn at break was recorded

by the machine. Six breaks were made for each mercerization and the results averaged.

Pretreatment or mercerization affects not only the strength but also the count of a yarn. Since the strength of a yarn is very nearly proportional to the reciprocal of the count for small changes in count, the strength of each yarn was multiplied by the ratio of its actual count to the nominal count of the gray yarn (given in the first column of Table I). The nominal strength thus obtained, that is, the (approximate) strength the yarn would have had if its count were the nominal count of the gray yarn, is a useful figure for comparison of the results of the treatments. It is the figure reported in this paper.

RESULTS

Pretreatment

Scouring, kier-boiling, bleaching or other wet treatments that may precede the mercerization of cotton yarn remove noncellulosic materials and decrease the weight. At the same time the yarn may shrink or stretch. The very thorough pretreatment given the yarns used in this study resulted in changes in the nominal strength of from -11 per cent to 100 per cent of that of the gray yarn depending upon the size, twist, ply and character of the yarn. In general, the low-twist yarns showed the greater increase in strength. Data for a variety of yarns are given in Table I.

The pretreatment also resulted in an increase in the diameter of the yarn, a fact of significance for aeronautical uses, for example, in cotton parachute cloth, where the air permeability of the cloth must be controlled. The diameters of some of the yarns before and after pretreatment and mercerization are given In Table II.

Tension

In order to determine the relation between the tension applied during mercerization and the strength of the resulting yarns, experiments were run in which the tension was varied and the other conditions were those reported to give the maximum swelling and optimum commercial result. (Reference 2.) The caustic soda concentration was 23 per

cent, the mercerization temperature was 20°C, and the time of immersion in the caustic five minutes. Three tensions were applied: 0.2 pound per 100 ends, which was the tension just necessary to eliminate the slack in the yarn, 1.1 pounds per 100 ends, and 2.8 pounds per 100 ends. In some experiments, the tension was applied to the yarn just before it was placed in the caustic soda bath and was not removed until after the final rinse. In others, different tensions were used during immersion in the caustic and in the rinses.

The results are given in Table III. The strength of the pretreated yarn was not improved by mercerization. It was, in fact, decreased where the tension was only 0.2 pound. Later experiments were carried out under the conditions subsequently found to be more favorable to an increase in strength with yarns differing in size and construction. The results, which are given in Table I, indicate that in general a tension greater than enough to eliminate slack is required for an increase in nominal strength over that of the pretreated yarn. Further, they show that, provided sufficient tension is applied, a considerable variation in the tension does not materially affect the results.

The last two experiments in Table III show the effect of applying tension to the yarn in the rinse instead of during immersion in the caustic. They indicate that tension should be applied in the caustic bath.

The amount of contraction of the yarn in the caustic solution was observed. It was dependent upon the tension applied during mercerization. All of the yarns studied except those having relatively high twist contracted between 10 and 16 per cent when only 0.2 pound tension was applied to the yarn in the caustic solution. With the greater tensions tried, they contracted not over 3 per cent and some of them stretched 1 or 2 per cent. The yarns which contracted in the caustic all elongated somewhat during the rinsing.

The practical result of the contraction was the effect on the elongation of the mercerized yarn. The elongation at break of yarns mercerized under conditions permitting them to contract was equal to or several per cent higher than that of the gray or pretreated yarn whose elongation varied from 4 to 7 per cent (rarely 10 per cent). The elongation of the yarn mercerized under a tension of 1.1 pounds or more was usually from 2 to 5 per cent.

3. Time

A series of experiments were performed in which the time of immersion in the caustic was varied from 30 seconds to one hour. A tension of 1.1 pounds per 100 ends and a 23 per cent solution of caustic soda were used in these experiments. The nominal strength of the resulting yarn remained practically unchanged as also did the elongation at the break. This indicates that for periods over 30 seconds the time of immersion under the specified conditions does not affect the strength of the yarn.

4. Temperature

The 80's yarn, twist multiplier 3, was mercerized under different conditions of temperature and concentration of caustic, the time of mercerization being 5 minutes and the load 1.1 pounds per 100 ends. The results are given in Table IV. The nominal strength of the yarn mercerized at 0 and -10°C was somewhat higher than that of the pretreated yarn (nominal strength 25 pounds per 100 ends). Temperature appears to have little effect in the range 10° to 96°C.

5. Concentration of Caustic

Table IV also gives the results of mercerization experiments covering a range of concentrations of caustic from 5 per cent to 48 per cent. There is no clear evidence that the nominal strength is materially influenced by variations in the concentration within this range. It was not possible to run an experiment with a 5 per cent solution of caustic at -10° C because of the separation of a crystalline hydrate.

6. Twist

The results of the experiments already described led to the selection of the following conditions for a study of relation of yarn twist to mercerization for strength: tension 1.1 pounds per 100 ends for 80's, time 5 minutes, temperature -10°C, caustic concentration 10 per cent. A series of 80's yarns spun from the same cotton with twist multipliers ranging from 2 to 6.7 was mercerized under these conditions. Yarns of other counts, some of them in several twists, were mercerized under the same conditions except that the tension applied to the stronger yarns was greater. The results are given in Table I. Some of them

are presented graphically in Figures 4 and 5. The pretreatment of the gray yarn increased the strength of the yarns of twist multipliers up to 3.0 much more than that of the higher twist multipliers. In some cases it actually weakened the yarns having higher twists. Mercerization under a tension of only 0.2 pound per 100 ends usually increased the strength of low-twist yarns over that of the pretreated. In some cases it decreased the strength of the higher twist yarns. In every instance when a greater tension was applied, mercerization resulted in yarn having greater nominal strength than either the gray yarn or the pretreated yarn. The maximum increase over the strength of the gray yarns was in excess of 150 per cent for the low-twist, low-count yarns and 80 per cent for the low-twist 80's.

Two-ply 160's and two-ply 80's yarn were mercerized with results similar to those obtained with singles of the equivalent count.

8. Double Mercerization

From the results given above it appeared that a tension greater than 0.2 pound per 100 ends applied while the yarn is in the caustic solution is essential for the maximum increase in strength. The elongation at break of yarn so mercerized is very low, usually about 2.5 per cent and practically never exceeding 5 per cent. Yarn with too little stretch is undesirable for many purposes.

Some experiments were carried out in which the yarn mercerized under conditions giving the greatest increase in strength was mercerized again with less tension. The second mercerization differed from the first in that about 15 minutes were required for complete contraction of the yarn in the caustic, whereas the contraction in yarn being mercerized for the first time was complete within two or three minutes. This double mercerization resulted in yarns having the maximum strength obtainable in a single mercerization and also any desired elongation up to about 10 per cent, depending upon the amount of tension used in the second mercerization. Results of double mercerization experiments are given in Table I.

It appeared that yarn having the maximum strength but greater elongation might be obtained by other procedures than double mercerization. Thus the yarn could be mercerized under tension in the usual way and the tension then

decreased before the yarn is removed from the caustic in order to allow it to contract. Several such procedures were tried. Although it was possible to increase the elongation in this way, the strength was not always equal to that obtained by the double mercerization procedure.

DISCUSSION OF RESULTS

The pretreatment given the yarn for these experiments was more thorough than the usual commercial pretreatments, mercerization was carried out with an extremely large volume of fresh, clean caustic solution, and the rinses were very thorough. Consequently, the increases in strength obtained are for what may be considered ideal rather than practical commercial conditions. However, they can be used as a measure of the efficiency of commercial processing.

The pretreatment itself resulted in a very considerable increase in the nominal strength of all yarns of low or medium twist. Whether this pretreatment is essential for the increase obtained by combined pretreatment and mercerization was not determined.

Because of their greater diameter, the pretreated yarns may be of more value for some uses than the mercerized yarns even though the latter are stronger.

The strength of a thoroughly pretreated yarn can be still further increased by suitable mercerization. Unless the twist of the yarn is low, tension of the order of 1 or 2 pounds per 100 ends during mercerization is necessary to obtain this increase and even in the case of the low-twist yarns, the increase is greater when tension sufficient to prevent the yarn contracting more than 2 or 3 per cent in the caustic bath is used. The time of mercerization, temperature, and concentration of caustic need not be carefully controlled, though somewhat greater strength results when the caustic concentration is low, say 10 per cent, and the temperature is kept at 0° C or even lower.

The results clearly indicate that the twist in the yarn must be low if the maximum increase in nominal strength is to result from mercerization, and if yarns of maximum nominal strength are to be obtained. This effect of twist is so great that on 80's yarn of twist multiplier 2.2 having a strength of only 17 pounds per 100 ends is

stronger after pretreatment and mercerization than a similar yarn of twist multiplier 3.0 having an initial strength of 21 pounds per 100 ends. Similarly for plied yarns, where the singles and ply twist are low the increase in strength resulting from mercerization is greater than when the twists are higher. In the case of 80's two-ply yarns differing only in twist, the strength of the yarn having low singles and ply twist was doubled as a result of pretreatment and mercerization.

Some reasons for the increase in strength resulting from pretreatment and mercerization may be suggested. It is generally recognized that gray yarns having low twist are weak because of fiber slippage and yarns having high twist are weak because of torsional stresses on the individual fibers. An intermediate twist permits less slippage, yet does not introduce undue torsional stresses and therefore results in yarn of maximum strength. This is illustrated by the curve for the untreated yarn in Figure 4.

Some of the factors which probably contribute to the increased strength of the pretreated and mercerized yarns are increased friction between the fibers, increased strength of the fibers, and better distribution of the load among them.

It is recognized that a better distribution of the load among the fibers may take place during pretreatment and especially during mercerization when the fibers are in a plastic condition, but the extent to which this contributes to the increase in strength is not evident.

The removal during pretreatment of material which lubricates the movement of fiber on fiber or which does not contribute as much to the strength of the fiber as the same weight of cotton cellulose, would increase the friction between fibers and increase the ratio of their strength to their weight. The data in Tables I and II clearly show that the count and diameter of the pretreated yarns of lower twists are greater than the count and diameter of the corresponding gray yarn; that is, the weight per unit length is less and the diameter more. The pretreated yarns feel harsher than the gray, indicating an increase in coefficient of friction of the fibers and an examination of the broken ends of the yarns shows that there is less fiber slippage when they are broken than when the gray yarns are broken. These facts indicate that increased friction between the fibers is probably the predominant reason for the increased strength of pretreated yarns.

The low-twist yarns mercerized under a tension of 0.2 pound have both smaller diameter and lower count than the corresponding pretreated yarns. (Tables I and II.) This means that the fibers are in closer contact and the area of contact between them has increased. The broken ends of these yarns indicate the absence of fiber slippage. Just as the increase in strength of low-twist gray yarns with twist is attributable to decreased fiber slippage, the increased strength of these yarns may be attributed to decreased fiber slippage. The yarns having higher twist did not change much in diameter and count when mercerized under 0.2-pound tension. It is not surprising to note that their strength after mercerization differs but little from that before, since no fiber slippage is observed in either case.

When the yarns were mercerized under the higher tensions they decreased but slightly more in diameter than when mercerized under 0.2-pound tension and changed but little more in count. No evidence of fiber slippage was found by examining the broken ends. However, the strength was in general greater than that of the yarns mercerized under the 0.2-pound tension. The increase would appear to be attributable to an actual increase in fiber strength. The study of how mercerization would increase the strength of the cotton hair is beyond the scope of this paper.

VI. CONCLUSION

The general conclusion to be drawn from this work is that the strongest mercerized yarn of a given count from a given quality of cotton is obtained under the following conditions:

1. Use of low-twist yarn obtained with twist multipliers from 2.2 to 3.

2. Thorough pretreatment of the yarn to remove all extraneous materials.

3. Mercerization at a temperature of 0° C, or lower.

4. Use of sufficient tension during mercerization to prevent the yarn from contracting more than 3 per cent.

5. Use of caustic solution having a concentration of 10 per cent, or higher.

6. The time of mercerization to be 5 minutes.

The resulting yarn should be from 40 to 100 per cent stronger than the original yarn of the same weight.

Bureau of Standards,
Washington, D. C., December 29, 1932.

REFERENCES

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2. Skinkle, J. H.: Present Practice in Warp Mercerization. Textile World 75, 1929, pp. 2377-2378-2427.

TABLE I

Results for the mercerization of yarns of different counts and twists. Caustic soda concentration 10 per cent, temperature -10°C, time 5 minutes, tension as indicated. The 10's and 20's yarn were made from 1 inch, the 35's from 1-1/16 inch, and the other yarns from 1-5/16 staple length Peeler cotton, unless otherwise indicated.

			Actual count						Nominal strength in pounds per 100 ends						Increase in strength over that of gray yarn in per cent				
Nominal count	Twist multiplier	Ply twist in turns per inch	Gray	Pre-treated	Mercerized Load during mercerization in pounds per 100 ends 0.2	1.1	other	Double mercerization	Gray	Pre-treated	Mercerized Load during mercerization in pounds per 100 ends 0.2	1.1	other	Double mercerization	Pre-treated	Mercerized Load during mercerization in pounds per 100 ends 0.2	1.1	other	Double mercerization
90	2.6		84	94	87	94			18	22	21	25			22	17	39		
80	2.0		78	87	80	84			16	21	27	30			31	69	88		
80	2.2		80	83	81	85		77	17	24	27	31		29	41	59	82		71
80	2.5		77	78	89	79			20	28	21	31			30	5	55		
80	3.0		78	85	73	86			21	25	23	30			19	10	43		
80	3.5		74	78	72	78			22	25	23	27			14	5	23		
80	5.0		76	79	75	82			20	22	20	23			10	0	15		
80	6.7		70	82	81	79			13	15	16	16			15	23	23		
160 2-ply[a]			79	83	76	80			22	28	33	33		32	18	50	50		45
60	2.8		58	61	53		59[c]		32	35	33		40[c]		9	3		25[c]	
60[b]	3.7		61	67	56		62[c]		37	45	34		42[c]		21	-8		14[c]	
40	2.4		41	43	39	44	45[e]	41	46	57	65	68	74[e]	69	34	41	48	61[e]	47
40	4.0		40	42	40	42	42[d]		48	52	54	57	54[d]		8	12	19	12[d]	
40	4.2		42	41	38		46[d]		58	63	47		63[d]		9	-19		9[d]	
80 2-ply	2.5	10	38	42	38	43		38	39	59	68	81		75	51	72	108		92
80 2-ply	2.8	18	40	46	40	44			53	63	70	78			19	32	43		
80 2-ply	2.9	30	36	38	38	38	41[e]		59	63	68	70	78[e]		7	12	19	29[e]	
80 2-ply	3.5	10	37	41	37	39	42[e]		52	63	68	75	77[e]		31	27	44	48[e]	
80 2-ply	5.0	25	39	41	37	42	43[e]		56	57	63	67	71[e]		2	12	20	27[e]	
80 2-ply	6.4	40	40	41	39		43[e]		44	50	50		59[e]		14	14		34[e]	
35	2.5		35	35	32		38[f]	32	23	43	54		58[f]	54	87	135		152[f]	135
35	3.3		32	37	32		36[f]		39	57	53		61[f]		46	36		56[f]	
35	4.5		34	35	33		37[f]		46	48	49		54[f]		4	7		17[f]	
20[d]	2.5		20	22	19	21[e]	19[g]	21	38	76	97	103[e]	105[g]	111	100	155	171[e]	176[g]	192
20	3.5		20	20	19		23[e]		78	94	102		118[e]		20	31		49[e]	
20	4.7		20	20	19		21[e]		88	78	88		89[e]		-11	0		1[e]	
10	2.5		9.7	10.0	8.5	10.3[i]	9.5[i]	10	114	184	240	245[h]	245[i]	242	61	135	114[h]	115[i]	112
10	4.1		9.7	10.5	9.2		10.2[h]		163	170	172		188[h]		4	5		15	
10	5.1		9.7	10.8	10.1		11.0		174	155	165		180[h]		-11	-5		3[h]	

a - Staple length and kind of cotton not known.
b - Pima cotton.
c - Load during mercerization 1.5 lb. per 100 ends.
d - " " " 2.25 " " " "
e - " " " 4.5 " " " "
f - " " " 2.6 " " " "
g - Load during mercerization 0.2 lb., during rinse 4.5 lb. per 100 ends.
h - " " " 9.0 " per 100 ends.
i - " " " 0.2 " , during rinse 9.0 lb. per 100 ends.

TABLE II

Effect of pretreatment and mercerization on diameter of yarn mercerized with a 10 per cent solution of caustic soda, temperature -10° C, time 5 minutes.

Nominal count*	Twist multiplier of yarn	Diameter in millimeters			
		Gray	Pre-treated	Mercerized Load during mercerization in pounds 0.2	1.1
80	2.0	0.134	0.135	0.100	0.094
80	2.2	.129	.124	.102	.086
80	2.5	.136	.134	.116	.110
80	3.0	.124	.132	.098	.091
80	3.5	.113	.121	.110	.093
80	5.0	.100	.105	.099	.092
80	6.7	.106	.112	.093	.102
40	2.4	.157	.163	.132	.130
40	4.0	.164	-	.151	.132
35	2.5	.200	.170	.143	.142
35	4.5	.148	.148	.146	.131
10	2.5	.435	.364	.343	.271
10	4.1	.318	.318	.309	.269

*For actual count and nominal strength, see Table I.

TABLE III

Effect of tension on the strength and elongation of 80's yarn (twist multiplier 3) mercerized with a 23 per cent solution of caustic soda for 5 minutes at 20°C. Data for the gray and pretreated yarn are given for comparison.

(Loads given are per 100 ends of yarn)	Actual count	Nominal strength	Increase in strength over that of gray yarn in per cent	Elongation at break in %	Maximum contraction in mercerization bath in per cent*	Contraction at end of final rinse in per cent*
Gray yarn	78	21	-	6	-	-
Pretreated yarn	85	25	19	5	-	-
0.2 pound in mercerization and rinses	73	21	0	10	15	11
1.1 pounds in mercerization and rinses	83	25	19	2	0	-2
2.8 pounds in mercerization and rinses	83	25	19	1	-	-
0.2 pound in caustic and 1.1 pounds in rinses	80	23	10	4	10	5
0.2 pound in caustic and 2.8 pounds in rinses	79	22	5	2	12	4

*Based on length of yarn before entering caustic solution.

TABLE IV

Relation between temperature and concentration of caustic solution and the nominal strength of 80's yarn (twist multiplier 3) when it was mercerized for 5 minutes under a load of 1.1 pounds per 100 ends.

The values given are the nominal strength in pounds per 100 ends.

Temperature in °C	Concentration of NaOH in per cent						
	5	6	10	15	23	36	48
96	25		26	26		25	
95					24		
75					23		
50	26		25	26	25	24	
30					25		
20		25	25	26	25	26	26
10					27		26
0		26			28	26	
-10			30	29	28		

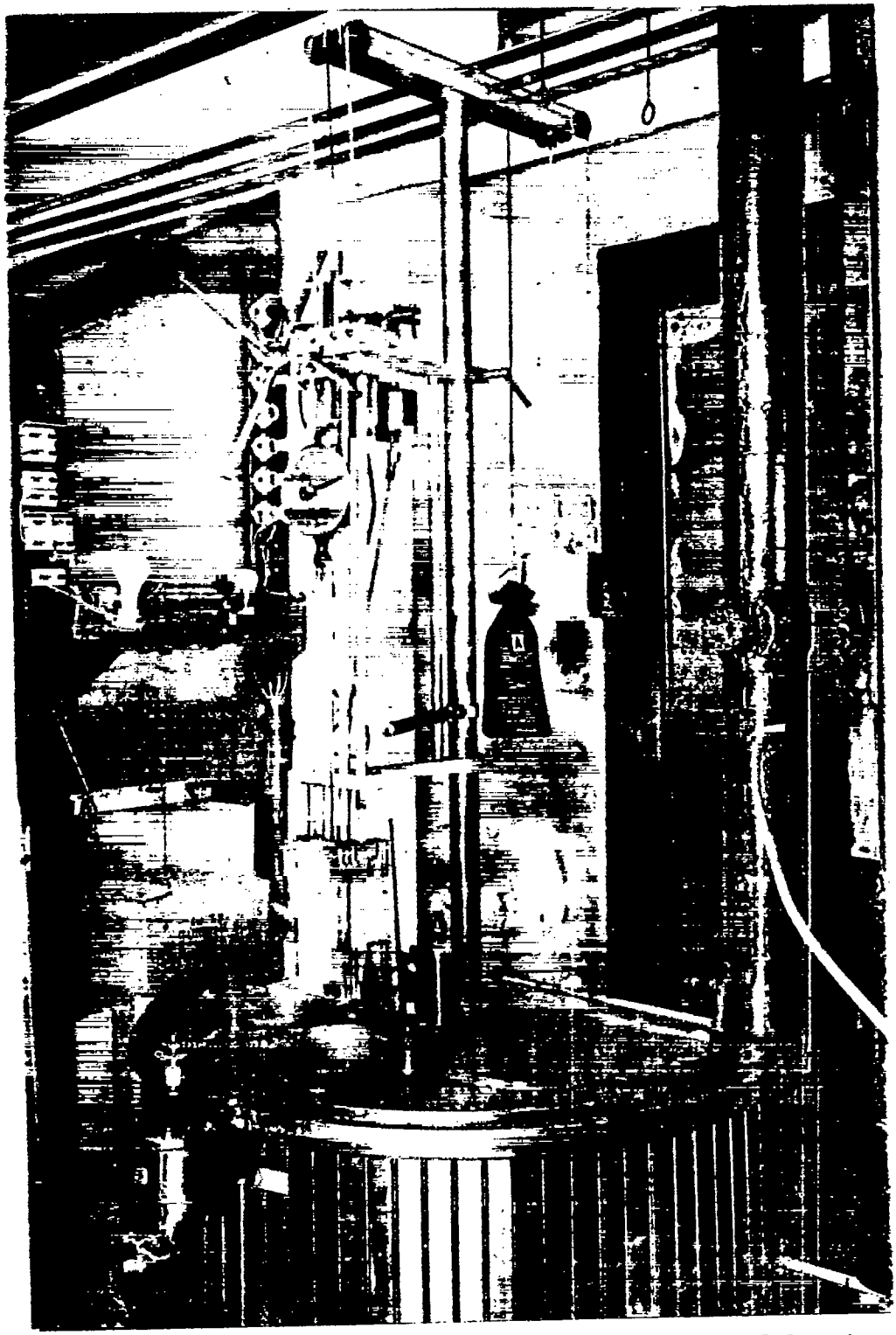

Figure 1.-Machine for mercerization of yarns in the laboratory.

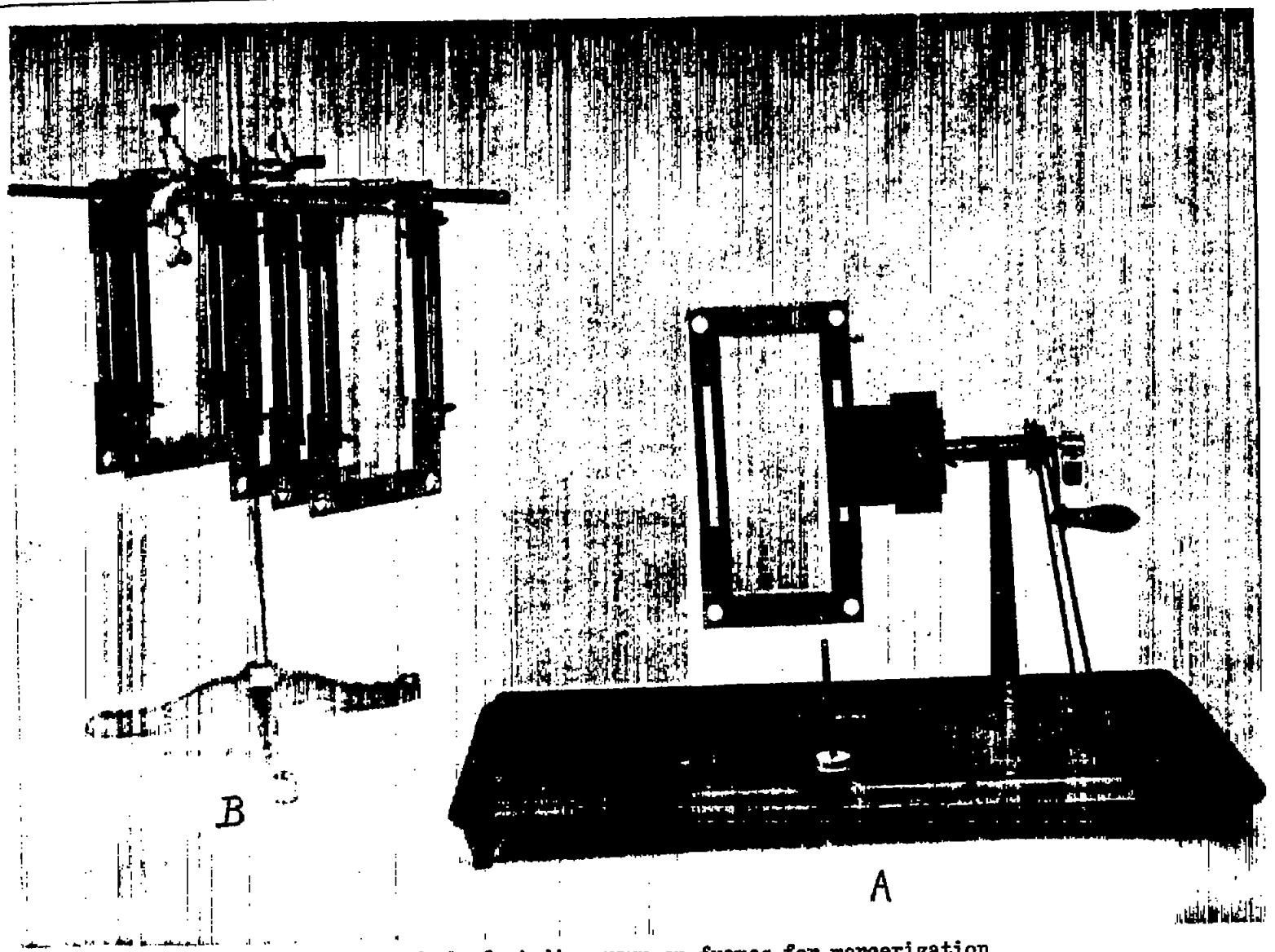

Figure 2.-Method of winding yarn on frames for mercerization

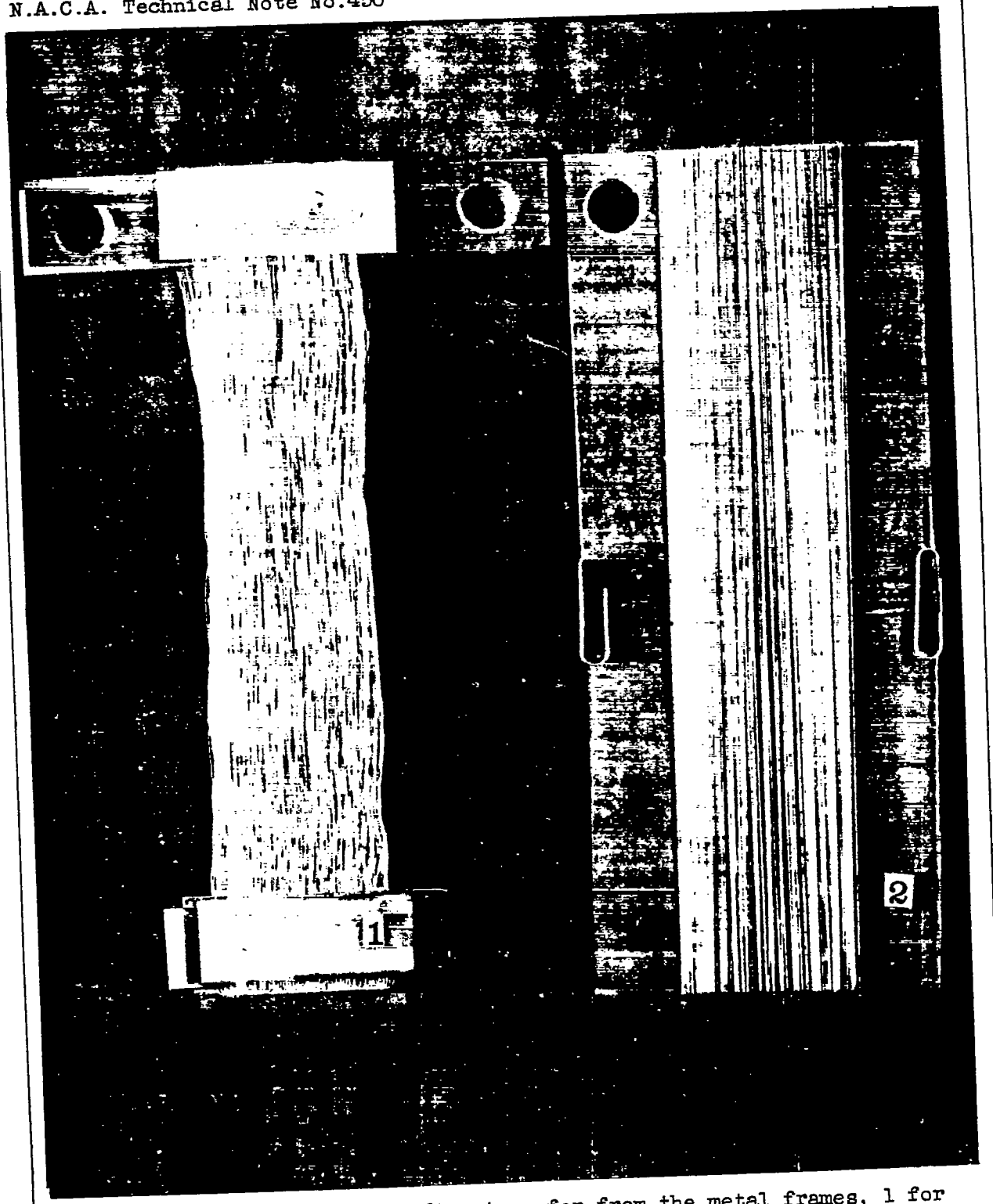

Figure 3.-Mercerized yarn after transfer from the metal frames, 1 for strength tests, 2 for determination of count.

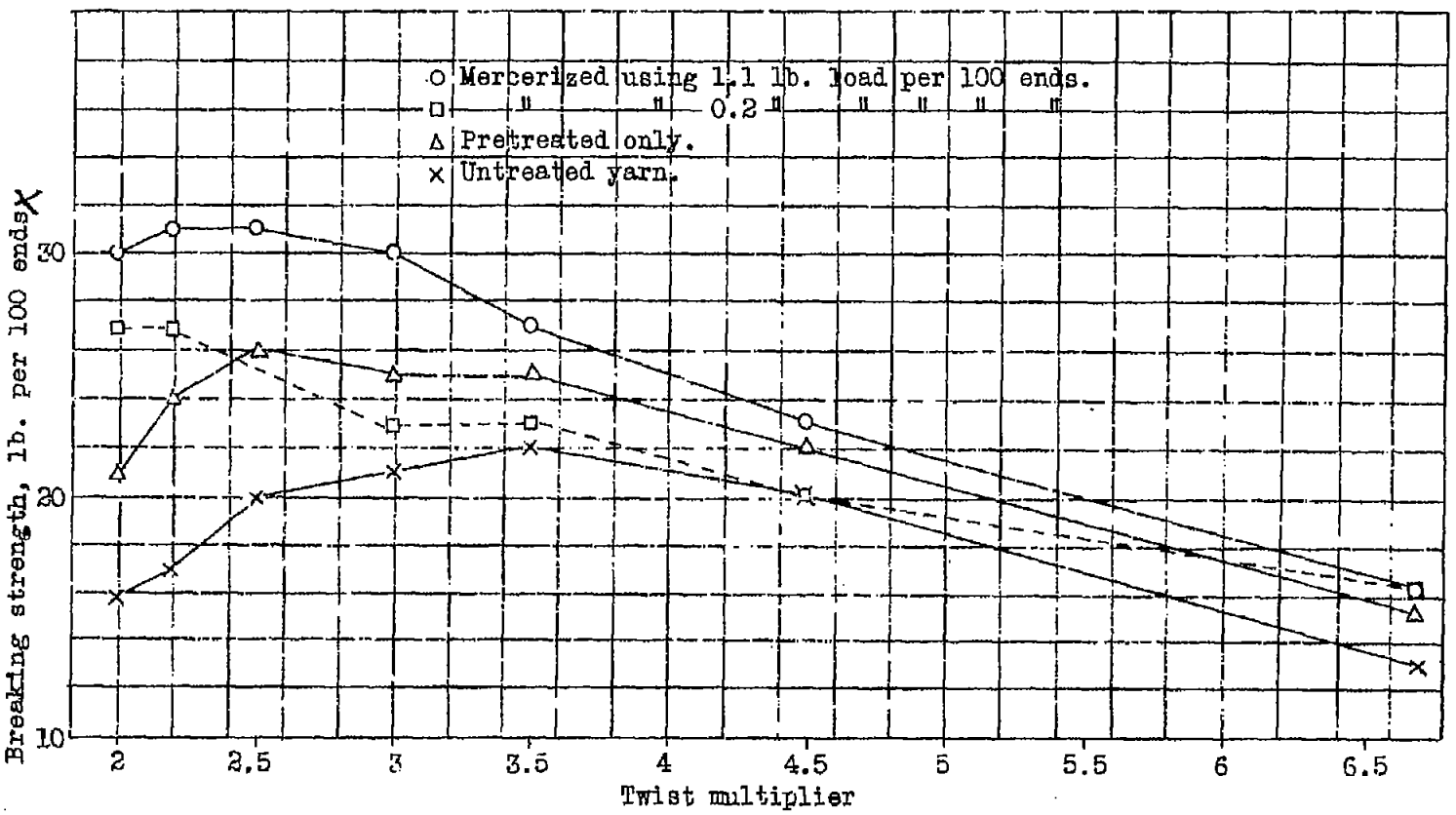

Figure 4.- Relation between breaking strength and twist 80's cotton yarn.

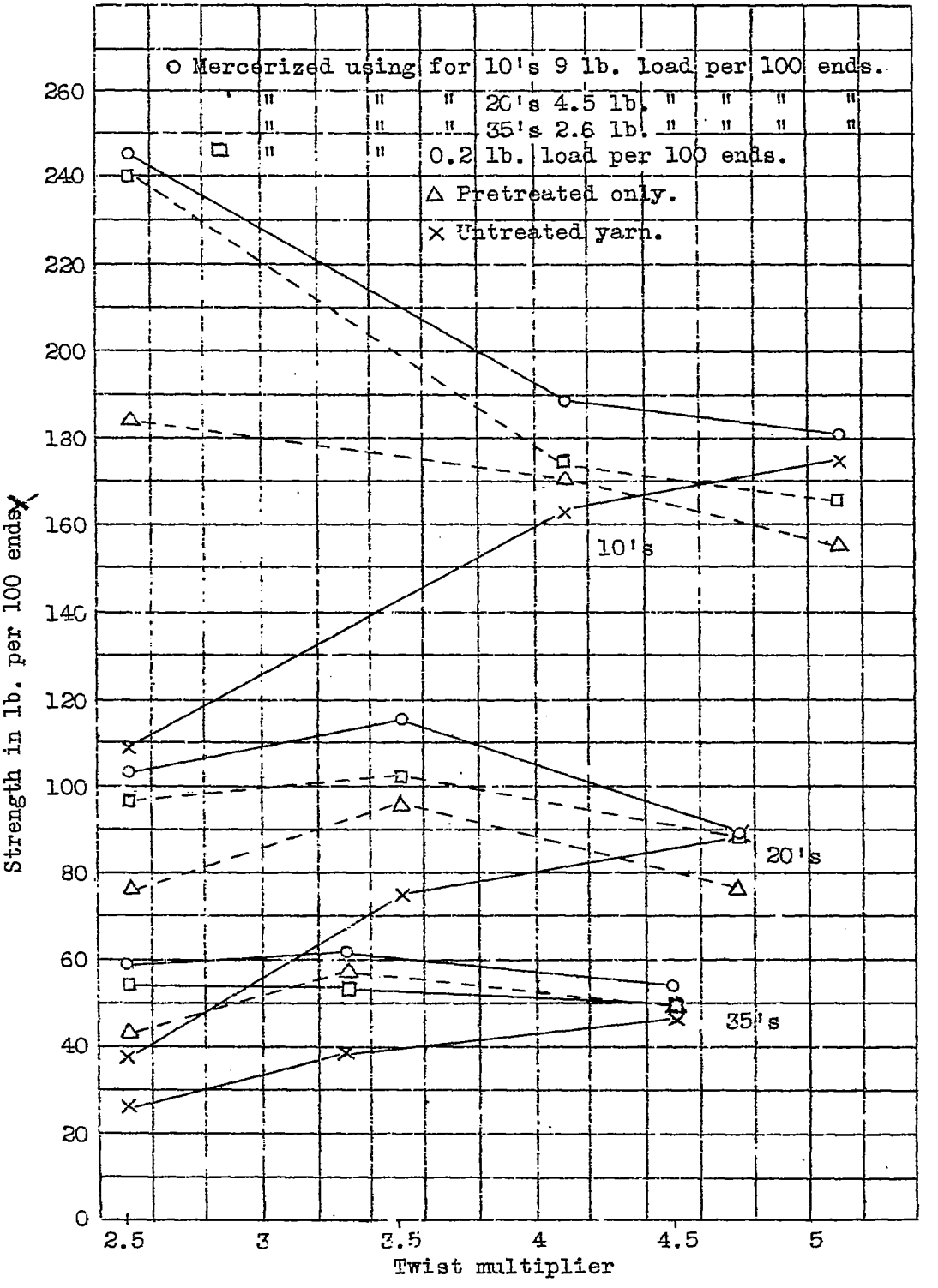

Figure 5.- Relation between breaking strength and twist, 10's, 20's, and 35's cotton yarn.