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30—VIII.—TENSILE TESTS FOR COTTON YARNS

iii.—THE RATE OF LOADING

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INTRODUCTION AND SUMMARY

The necessity for operating a testing machine at a standard rate is generally recognised. This arises partly from instrumental errors introduced at high speeds, but when these are allowed for (*vide* Paper IV.), there is still a consistent and appreciable increase of apparent strength as the test is speeded up. In comparing the breaking loads of a yarn as measured on different instruments, the results are found to vary very greatly with the time occupied in a break. The Moscrop test, occupying about $\frac{1}{2}$ second in stretching the thread to rupture, has been found to give a result usually between 20 to 30% above that of the standard single-thread test, which occupies about 20 seconds. The ballistic test breaks a specimen in about $\frac{1}{50}$th second, and the breaking load can be calculated, on assumptions which cannot be greatly in error, by dividing the work by one half the extension. The load so calculated was found on 23 different yarns to be on an average 43% above the standard load.

To measure with some precision the variation of breaking load of a yarn when only the speed of testing is altered, a very regular 36s Sakel yarn was tested on several instruments over the range of speed allowed by the mechanism, taking particular care to obtain similar samples and constant testing conditions. The apparent strength was then found to increase with the speed of the test in a definite and regular manner, the rate of change within the range of each instrument agreeing with the greater differences between the results of the several tests. The mean breaking load on the standard single-thread tester varied from 11·7 oz. to 13·0 oz. as the rate of traverse varied from 3 to 30 inches per minute. Taking the mean value when the specimen is broken in 20 seconds as 100, the breaking load given by the Moscrop tester, taking about $\frac{1}{2}$ second, is 129; with a variation in time of break on the autographic instrument from 90 to 0·4 seconds, the value changes from 96 to 121; and the value calculated from the ballistic test, taking $\frac{1}{75}$th second, is 139. Further, one half the specimens broke within $2\frac{1}{2}$ minutes under a load 72% of the standard value, within 92 hours under 58%, or within 18 days under 50%. Taken over all the range of speeds, the mean breaking load of the same yarn varied from 5·6 oz. to 18 oz., due solely to the change in the time occupied in the break, namely from a month to $\frac{1}{50}$th second.

These changes may be generally expressed in a very simple way, namely, that if the time of break is increased tenfold, the breaking load always decreases by the same amount, $\frac{1}{10}$th the value given by the standard deadweight tester. Though the rate of change must become less, both for extremely slow and fast breaks, the relation remains constant over the range of practicable observation.

No change in final extension could be found on the deadweight tester, nor on the autographic instrument when the speed was altered 200-fold. It would seem that a yarn breaks because it is forced beyond a limiting extension, rather than because it is overloaded.

The relation with speed for the breaking load of a yarn is the same as that for hairs, i.e., the ratio between the breaking load of the yarn and of the hairs which compose it remains constant with speed at a value found to be 0·4 in this particular case. Moreover, there seemed no appreciable difference in type of break between ends broken ballistically or slowly. The conclusion thus indicated is that though the uniformity and clinging power of the hairs is only sufficient to make less than half the aggregate strength available, this factor does not alter with speed, and the load at rupture is determined by that of a core of tightly gripped hairs. Data[1] are quoted to show that the same effect in fabrics is of the same order of magnitude and may also be wholly or largely ascribed to the elastic properties of the hairs.[2]

As a matter of testing routine, speed is standardised by the rate of traverse of the loading jaw or by rate of loading. This eliminates mechanical errors but does not wholly eliminate the effect of speed on apparent strength, which is a function of the time occupied in the test. Results given by a strong and a weak specimen on one instrument are not strictly comparable, since the former is broken more slowly. The same specimen would appear a few per cent. stronger on a heavy instrument than on one of just sufficient range, both driven at the standard rate. Fortunately the effect is not rapid enough to demand attention in ordinary routine testing, but as the speed of testing and the resulting breaking load are arbitrary, it is preferable to approximate to the speed with which yarns are broken in practice. The greater rapidity of the ballistic test means a closer approximation to working conditions and also to the upper limit which must exist as an absolute strength characteristic of the material.

The effect should not be lost sight of when interpreting tests for wear, oscillating stress, &c., of which the results are expressed by the number of rubs or jerks survived, for a load less than half the deadweight breaking load will continuously extend the yarn towards rupture without the help of wear.

EXPERIMENTAL METHODS AND RESULTS

Each testing instrument is designed to work within a particular range of speeds, which is limited by dynamical considerations (*vide* Paper IV.) and by convenience of operation. One machine can be used only over a small portion of the total range of practicable speeds, and the variation of breaking load must be followed through several different tests.

The speeds of the several machines are controlled in different ways, and mutual comparison is facilitated by using the quantity T, "the equivalent time of the break," i.e. the time which would be occupied in loading the specimen to rupture at the rate of loading obtaining just before rupture. The formulæ for the values of T used below are worked out in the following paper. It will be shown at a later stage that the breaking load (F) is most simply expressed as a function of log T, and the curve will be defined by evaluating for the small range covered by each instrument the slope ($dF/d \log T$), and the mean values of F and log T.

The tests were all carried out in a room maintained at 70° F. and 70% R.H. on a very regular 36s Sakel yarn. Wherever possible, comparisons were made by the "cut-skein sample" method (Paper I., p. 78), or on consecutive windings from the same cop.

Standard Single-Thread Deadweight Tester

The instrument used is driven by an oil plunger, thus avoiding the initial jerk and consequent oscillation (*vide* Paper IV.). The pendulum has a very short time of vibration (1·0 sec.), reducing momentum errors to a minimum, and the tester may safely be used over the range which can be obtained from the plunger. The speed is controlled by the fall of the lower jaw, the normal being 12 inches per minute, and tests were made in pairs at speeds from 3 to 30 inches per minute on sets of 50 alternate threads of 20 inches length.

The speed of fall, the time of break (from Equation 10b, Paper IV.), and the corresponding mean values of breaking load and extension for the seven pairs of tests carried out are shown in Table I. The probable error of the difference between any two values of breaking load, considering the samples as independent, is 4·0 grams, and a difference of less than 12 grams is hardly significant. Taken as a whole, the values show a regular and significant increase with speed. Those from pair No. 5, however, are far off the general range and give the only case of a decrease. As the sample is exceptional, the values are ignored in taking the general means. (The deviations of the breaking loads of this pair from the best straight line through the remainder are six times the probable deviation calculated from the other twelve values.)

Between the members of the pairs, the differences have a higher significance and are very consistent. Expressed against log T the mean slope of the six tests is 29·3 $\pm$ 5·1 grams; weighted according to the difference in log T, the mean is 25·7 grams. The slope given by the slowest (1a) and fastest (7b) breaks is 34·2 grams, and the median slope between the pairs is 30·4 grams, perhaps the best value as most independent of the method of expression. The best straight line drawn through the array of points by the method of least squares gives a slope 34·5 grams. (The correlation coefficient between F and log T is 0·84, and the probable variation of the slope is about 3·4 grams.)

There is no correlation between the extension and the speed among the independent samples. (The actual correlation coefficient between e and log T is + 0·067, which is not significant.) The differences within pairs show no regularity either of magnitude or sign, nor are they big enough to be statistically significant, but appear to be purely random variations of testing and sampling.

For the purposes of the general relation, the results on this machine will be expressed by a slope—

$$\frac{-dF}{d \log T} = 30{\cdot}4 \text{ grams from } \log T = 0{\cdot}94 \text{ to } 1{\cdot}91,$$

through the point ($\log T = 1{\cdot}33$, $F = 347$ grams), the extension remaining constant at 6·48 $\pm$ ·03%.

Table I.
Single-Thread Deadweight Tester

Test	Traverse inches per min.	Time T sec.	Breaking Load F gm. $\pm$ 2·8	Extension % $e\%$ $\pm$ 0·06	$-\Delta F$	$\Delta \log T$	Δe	$\dfrac{-\Delta F^*}{\Delta \log T}$
1	3	81·7	334·6	6·64	20·9		−·01	
	12	21·3	355·5	6·65		·584		35·8
2	3	80·0	332·8	6·26	15·1		+·20	
	25	9·8	347·9	6·06		·912		16·6
3	6	40·5	335·7	6·40	14·1		−·08	
	18	13·9	349·8	6·48		·465		30·4
4	6	40·1	331·7	6·46	14·0		−·13	
	18	13·9	345·7	6·59		·460		30·4
5	12	19·1	324·5	5·81	−1·4		−·29	
	21	11·9	323·1	6·10		·206		−6·8
6	12	21·0	349·2	6·61	1·3		+·17	
	24	10·3	350·5	6·44		·309		4·2
7	21	12·2	359·3	6·50	8·6		−·03	
	30	8·7	367·9	6·53		·147		58·5
Grand Mean excluding 5	log T = 1·33		346·7	6·48±·03	12·3	0·480	+·017	29·3±5·1

* $\dfrac{dF}{d \log T}$ is the symbol for the tangent or slope at a point on the curve.

$\dfrac{\Delta F}{\Delta \log T}$ is the symbol for the slope between two points separated by an appreciable distance.

Moscrop Tester

The breaking load can be measured at much greater speeds on the Moscrop tester, to the limit of speed imposed by the errors discussed in Paper IV. The speed is controlled by the number of complete cycles per minute, eight being normal. The equivalent time of break is given by Equation 27, Paper IV., in terms of velocity of the loading jaw ($\dot{x}$), which in the present work, with breaks occurring at the middle of the 32 oz. record, is 1·306 p, whence $T = 0{\cdot}217\ F/p$.

The correction for the fling of the pointer is also evaluated as 0·00406 p^2 oz., and is thus allowed for in Table II., where results of tests from 3·6 to 25 cycles per minute are given. The first seven tests were carried out in one day in immediate succession, 75 specimens on each of six cops at each speed, this being the nearest approach to alternate thread sampling for this machine.

The dynamical analysis and tests given in Paper IV. show that the speeds 25 and 22·5 cycles per minute are too high, and the corresponding low results are due to injury from the jerks of the recording slide. At the speed 18·1, the frequency curve of the breaks (Fig. 3, Paper IV.) shows that this error is beginning to affect the results, and though they are not seriously wrong from the standpoint of routine testing, the mean for this speed is best omitted in evaluating the fine effect under discussion.

Within the limits of sound testing speed, the results of Table II. show an increase with speed but also considerable sampling differences. To obtain a general mean most free from instrumental and sampling errors, the sum of the differences was found between 1—3 and 6—7, and the ratio of the total change in F to the total change in log T gives a slope $-dF/d \log T = 24.2$ from $\log T = \bar{1}.97$ to $\bar{1}.39$ through the point ($\log T = \bar{1}.66$, $F = 447$ grams).

Table II.

Moscrop Single Thread Tester

p Cycles per minute	Time T sec.	Breaking Load* oz. ± ·05	Correction $0.00406\,p^2$	Breaking Load, Grams, corrected	$\dfrac{-\Delta F}{\Delta \log T}$
(1) 3·6	0·94	15·68	0·05	443	(1) − (3)
(2) 6·0	0·57	15·90	0·15	447	10/0·542 = 18·5
(3) 13·0	0·27	16·67	0·69	453	
(4) 22·5	0·13	15·73	2·06	388	
(5) 18·1	0·19	17·25	1·33	451	(6) − (7)
(6) 14·2	0·24	16·75	0·81	452	12/0·368 = 32·6
(7) 6·0	0·56	15·67	0·15	440	
(8) 3·5	0·98	15·86	0·05	448	
(9) 25·0	0·12	16·36	2·54	392	

* Each figure is the mean of 450 single tests.

Shorter and Hall Autographic Load-Extension Instrument

The autographic instrument is reliable over a wide range of speeds if the time of vibration of the spring be kept small in comparison with the time of break. It was therefore used to obtain a direct comparison between the breaking loads at deadweight and Moscrop speeds on alternate threads and a measure of the change of final extension for a large difference in log T.

Tests were carried out on two sets of 48 alternate threads 64·5 cm. long. For the slow speed, the carriage was traversed by connecting it to the oil plunger of the deadweight tester adjusted to a fall of 3 inches per minute, each test occupying on the average 90 seconds. The other set was tested by traversing the carriage by hand at the highest speed consistent with steady movement, the break occupying about 0·4 second. An initial tension of 10 grams was applied to make the extension measurements more exactly comparable.

Table III.

		Fast Loading T = 0·4 seconds.		Slow Loading T = 90 seconds.
Breaking load		418 ± 2·8	... ...	332 ± 2·4 grams.
Standard deviation	σ	28 = 6·7%	... ...	30 = 9·0%
Extension %		6·637 ± 0·043	... ...	6·645 ± 0·056
	σ	0·446 = 6·7%	... ...	0·556 = 8·4%
Load/extension		61·6 ± 0·3	... ...	48·4 ± 0·3 gms. for 1% extension.
	σ	3·0 = 4·9%	... ...	3·2 = 6·5%

$$\frac{-\Delta F}{\Delta \log T} = \frac{86}{2{\cdot}35} = 36{\cdot}6$$

The breaking load at the lower speed is in the same range as those obtained on the single thread tester, but at the high speed it is 29 grams lower than the Moscrop result. While the latter may have been obtained on a stronger sample of yarn, it is nevertheless in accordance with other Moscrop tests made on the Sakel yarn, and the difference is probably or largely instrumental error.

In the extension measurements, the difference of 0·008% of the length is quite insignificant, and in view of the great difference in speed, may be taken as evidence that the final extension is independent of the speed of testing and is the determining factor of rupture. The extension found on the deadweight tester is not significantly different from that found on the autographic tester.

The shape of the load-extension curve allows a measure of the work of rupture, most conveniently obtained by the "work factor" (Paper II.). The initial tension of 10 grams takes out much of the very unresisting extension which produces the curve at the beginning of load-extension diagrams of yarn, without doing appreciable work, thus raising the work factor to little below 0·5. The figure cannot be measured with the same degree of accuracy as the final load and extension, and little error is introduced by taking the work of rupture as one half the product of breaking load and extension.

Ballistic Tester

Much quicker breaks can be made on the ballistic tester than on any machine depending on a static principle of measurement, but the result is in energy units. Assuming that the extension remains constant at 6·64%, the value given by the autographic tester, and that the work factor is 0·5, the breaking load—

$$F = \frac{100\,w}{3{\cdot}32} = 30{\cdot}1\ w \text{ grams.}$$

where w is the work of rupture in gram.cm. per cm. Possibly about 5% of the work of rupture is due to work done after the maximum load is attained (Paper II.), but the work factor may also be about 5% less than 0·5, the two errors affecting the calculation in opposite ways. The equivalent time of break for the ballistic test is calculated from Equation 37, Paper IV. As the rate of extension decreases during the break, this is not exactly comparable with the time taken in a test at constant rate of loading, and the resulting value of log T is rather an upper limit of approximation to the best value for the general relation.

Ballistic tests were done on cut-skein samples, the alternate threads of which were tested on the standard tester at the speed 3 inches per minute, with the results—

Ballistic Test—10 specimens of 30 threads, 16 inches long. Mean reading, 379 units, $w = 16{\cdot}41 \pm 0{\cdot}10$ grams.

$T = 0{\cdot}01$ sec. $F = 494$ grams.

Single Thread—283 specimens, 15·8 inches long.

$T = 76$ sec. $F = 353{\cdot}8 \pm 1{\cdot}1$ grams.

$$-\frac{\Delta F}{\Delta \log T} = 140/3{\cdot}68 = 38{\cdot}0 \text{ grams.}$$

Within the range of the ballistic tester, the speed may be varied in two ways, by breaking similar specimens with different heights of fall or by breaking different numbers of threads with the same fall.

Table IV.

Similar Specimens Broken by Bob Released from Varying Height. 54 Specimens of 30 Threads, 24 in. long, tested at each height

Release Machine Units	Reading Units	T seconds	w grams	F grams
500	192	·034	15·5	467
700	385	·024	15·8	477
900	592	·019	15·5	467
1100	780	·017	16·1	485

Table V.

Varying Number of Threads—Constant Height of Fall, 1,100 units. 20 Specimens of each size, 67·4 cm. long.

No. of threads	80	60	40	20	10
Reading—1st 10	173 ± 9·7	409 ± 7·8	624 ± 8·8	862 ± 2·3	975 ± 1·3
" 2nd 10	187 ± 4·2	403 ± 6·5	638 ± 2·8	862 ± 2·3	977 ± 1·8
w grams	15·72	15·82	16·03	16·28	16·95
F grams	474	476	483	490	511
T sec.	·038	·026	·021	·018	·016

The figures show a definite trend upwards with speed, but the change is too small to be estimated accurately. For instance, the apparently large difference between the results on 10 and 80 threads is produced by nine units in the reading for the former test. The highest accuracy cannot be obtained when comparisons are made between different settings of the machine, as in Table IV., or when only a small fraction of the energy of the bob is absorbed. The most accurate difference is probably that between 80 and 40 threads in Table V., which gives a slope $-\Delta F/\Delta \log T = 34{\cdot}6$. The line of least squares drawn through the nine points in these tables fixes the slope as $-dF/d \log T = 62$, from $\log T = \bar{2}{\cdot}58$ to $\bar{2}{\cdot}20$ through the point ($\log T = \bar{2}{\cdot}35$, $F = 481$), but the quantitative accuracy of the slope is low.

Rupture Under a Constant Load

Numerous observations of breaking load under steadily increasing tension cannot be carried out conveniently at rates much lower than that at which one break takes 90 seconds on the deadweight tester. The decrease of breaking load for very much slower breaks can, however, be followed by the simple device of hanging weights from a set of threads which are left undisturbed till rupture, even though that may not occur for a month.

Sets of 250, 200, 175, and 150 grams were hung from threads of the 36s Sakel yarn in a humidified box (Paper I.) which maintained the conditions of 66% R.H. and 70° F. night and day, and the time was noted when each thread was found broken. Of 70 specimens loaded with 250 grams the first broke in 1 minute, the last in 23 hours; of 38 loaded with 175 grams, the first broke in 46 hours and 13 were still unbroken after 800 hours.

The apparently irregular and divergent range of duration of the individual threads does not appear at first sight to lead to any simple relation between rate of break and breaking load. The scatter, however, is purely a question of the method of expressing the time factor; for example, if this were expressed by the mean rate of extension, the later breaks would be crowded together instead of being widely scattered. The results can be made comparable with those of the standard test, independently of the method of expressing the time, by a simple assumption, namely, that if a set of threads be tested under a slowly increasing tension or alternatively under a constant load which they can sustain for some time, the threads will break in approximately the same order. This need not hold strictly for each thread, but rather for frequency groups; in particular, the threads which would break at the middle of the range will be the same in each case. Thus in the results given in Table VI. half the threads have broken when the increasing tension attains 350 grams in the slow standard test, half have broken in 150 minutes under a constant load of 250 grams. Then, on the above assumption, if the breaking load of a thread be 350 grams when T is 80 seconds, it is 250 grams for a duration of 150 minutes under constant load.

There is this difference between the two methods, that in the first the average load during the whole time is half the breaking load, in the second the full breaking load. This does not affect the mutual comparison of results obtained by the latter method, but comparison with the former method is improved if the time of survival be doubled to give the value of T.

The transformation of the time distribution to strength distribution was made by using the strength frequency curve at the slowest speed on the single thread tester, at which 100 specimens had been tested before winding the yarn for the hanging weight test, and 283 specimens were tested after. The latter were used in a comparison with the ballistic test, giving close sampling between the extreme limits of speed.

For uniformity of expression, all the breaking loads (F in Table VI.) are given as those of the median threads by assuming that the loads for the different quartiles bear the same ratio to each other as in the slow standard test; for example, if the weakest thread breaks at 280 grams in the latter test and in one minute under 250 grams, then the median thread breaking at 350 grams will break in one minute under

$$\frac{350}{280} \times 250 = 312 \text{ grams.}$$

The plot of the results in Fig. 1 shows that the overlapping of the figures for the several loads is so consistent that this proportionality is justified.

Table VI.

Standard Tester No. of Tests 383			250 grams 70		200 grams 18		175 grams 38		150 grams 19	
Up to	% Broken		Time mins.	F	Time hrs.	F	Time hrs.	F	Time hrs.	F
280 gms.	2	1st break ...	1	312	4	250	46	218	120	187
330 ,,	25	1st quartile	33	265	36	212	200	186	800	159
350 ,,	50	Median ...	150	250	92	200	428	175	?	150
370 ,,	75	3rd quartile	350	236	202	189	800	166		
410 ,,	98	Last break	1400	213	610	171	?	149		

Within this very extended range there is still no definite sign of curvature and the best straight line through the points given by the medians and quartiles, weighted in proportion to the square root of the number of observations, is given by the slope $-dF/d \log T = 31{\cdot}2$ grams from $\log T = 3{\cdot}60$ to $6{\cdot}49$ through the point ($\log T = 5{\cdot}15$, $F = 220$).

A further test on 59 specimens under 250 grams was made on an independent sample, the results of which are shown by the dotted line in Fig. 1. It agrees with the first test as nearly as should be expected, allowing for sampling differences.

Beyond extending the relation to much greater durations, this constant load test gives a direct criterion for the method of expressing the time factor. The threads of a sample vary in such a way as to give an approximately normal or symmetrical distribution to most measurable characters.

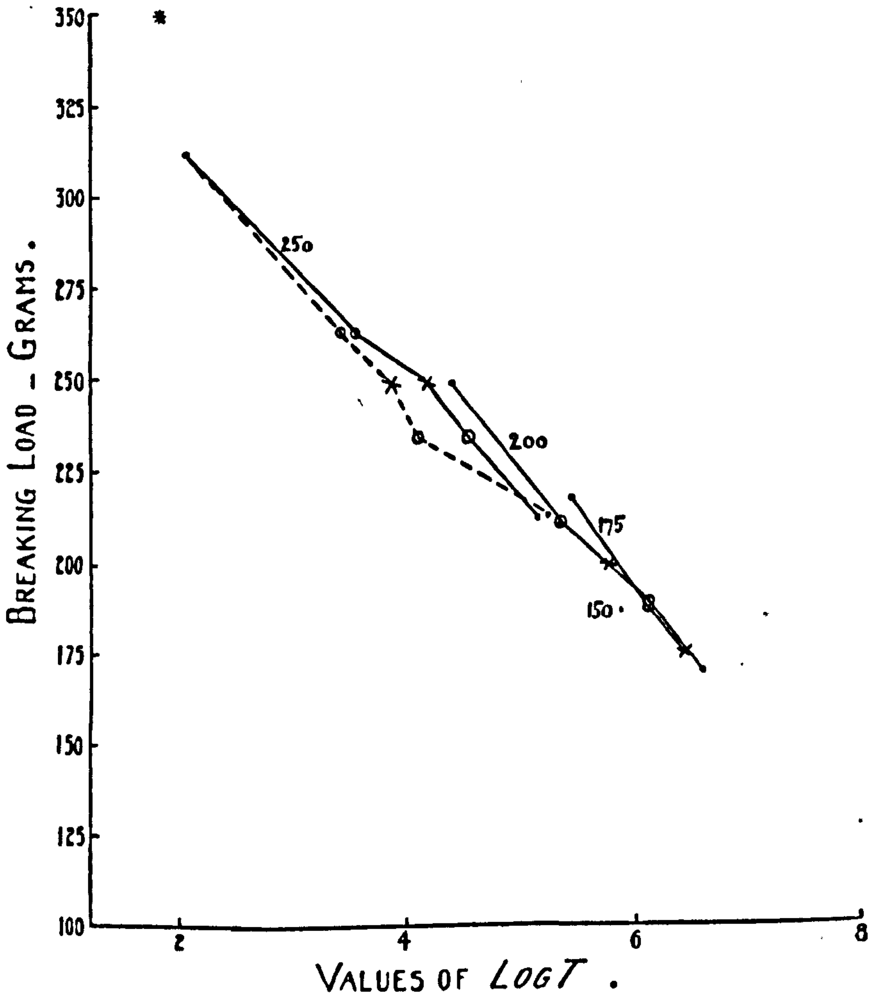

Fig. 1

Thus for breaking load, the mean, median, and most frequent values are nearly identical, the quartile deviation and maximum deviation nearly the same on either side of the median. When the load is kept constant and the strength is measured by the time of survival, the latter should be expressed by a function of which the mean value will also be approximately the median, at the middle of a symmetrical distribution.

There are several plausible methods of expression, the time T, $1/T$ which is proportional to the mean rate of extension and roughly to the rate of loading, and log T. The last has no *à priori* justification, but was found to give the simplest relation for the change of breaking load.

Table VII.
Values at Quartiles of T, $1/T$, and log T.

	Standard Test		Under 250 grams Load					
	F grams	Difference	T sec.	Difference	$1/T \times 10^5$	Difference	Log T	Difference
1st break ...	280		60		1667		1·78	
		50		1380		1616		1·52
1st quartile ...	330		1,980		51		3·30	
		20		7020		40		0·65
Median ...	350		9,000		11		3·95	
		20		12,000		6		0·37
3rd quartile	370		21,000		5		4·32	
		40		63,000		4		0·60
Last break ...	410		84,000		1		4·92	

From Table VII. it is plain that T and $1/T$ cannot be treated as quantities expressing strength, of which the mean value would represent a sample, but that log T might be used in such a way without very great error, though there is still a distinct skewness. The advantage of log T is also made clear by an examination of the results of the second test on 59 specimens, of which the mean value of the time T differs from the median by $+ 1{\cdot}62$ times half the difference between the 1st and 3rd quartiles. For $1/T$ the ratio is $- 2{\cdot}64$, but for the function log T it is only $- 0{\cdot}22$. These ratios are roughly proportional to the skewness of the frequency distributions.

The Relation Between Breaking Load and Time

If the breaking load be expressed against the time from the beginning of loading to rupture, the curve is very concave to the abscissa, if against rate of loading it is very convex. It was found that the change could be expressed most simply against the logarithm of the time and the data obtained for a general relation between F and log T are collected in Table VIII. and shown graphically in Fig. 2.

Table VIII.
Collected Data on Relation between F and log T

Method	Range of log T	Mean Point F gm.	Mean Point log T	Slope $- dF/d \log T$
(1) Hanging weight ...	6·49 – 3·60 ...	220	5·15 ...	31·2
(2) Standard tester ...	1·91 – 0·94 ...	347	1·33 ...	30·4
(3) Autographic tester ...	1·95 – $\bar{1}$·60 ...	332	1·95 ...	—
		418	$\bar{1}$·60 ...	36·6
(4) Moscrop tester... ...	$\bar{1}$·97 – $\bar{1}$·39 ...	447	$\bar{1}$·66 ...	24·2
(5) Ballistic tester ...	$\bar{2}$·58 – $\bar{2}$·20 ...	481	$\bar{2}$·35 ...	62
(6) Standard to Ballistic ...	1·88 – $\bar{2}$·20 ...	354	1·88 ...	—
		494	$\bar{2}$·20 ...	38·0
			Mean ...	37·1

Total Range of log T, 6·5 – $\bar{2}$·2, of F, 177 – 494 grms.

To a first approximation these results give a simple linear relation. The best straight line (judged) through the whole range is shown in Fig. 2 and it has a slope $- dF/d \log T = 37{\cdot}4 = 0{\cdot}10F_1$, where F_1 is the breaking load for a time of 10 seconds. From this line the absolute values deviate no more than might be expected from sampling differences. To the mean slope the local slopes approximate according to the accuracy of determination. That given by the standard tester differs only by the manner of finding the general mean from the individual tests. The slopes obtained by methods 4 and 5 have little quantitative significance, and the individual values of which they are the mean include values very close to 37.

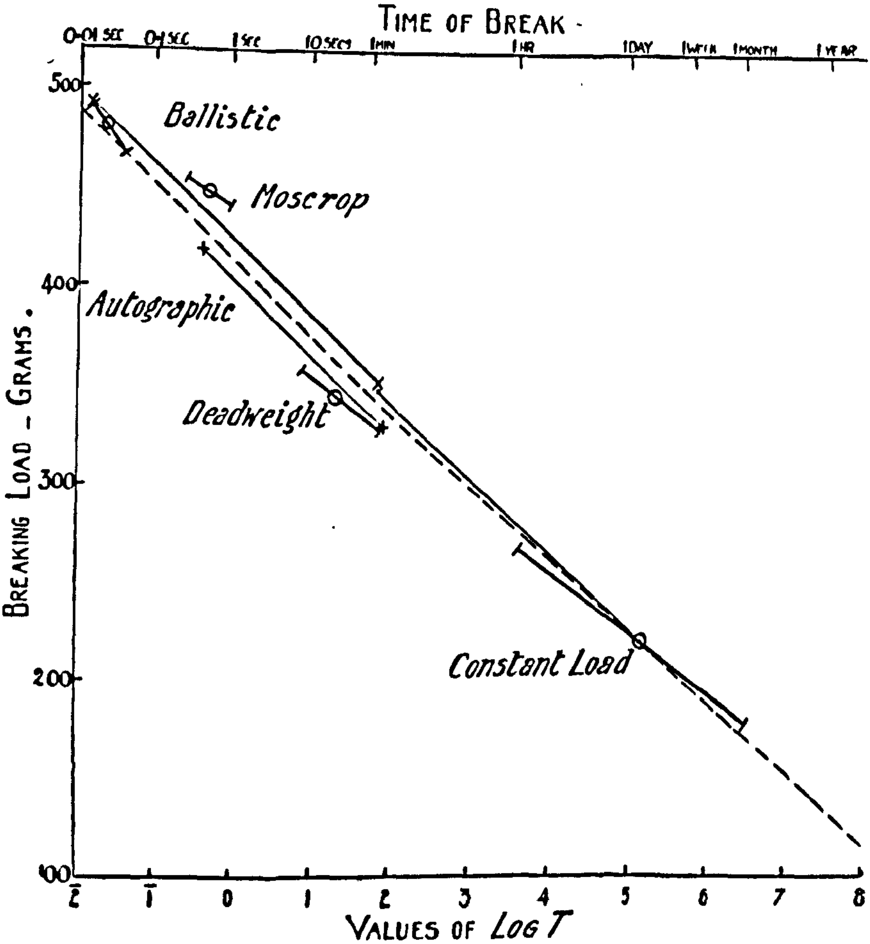

FIG. 2

In another paper[2] this logarithmic expression is related to other effects of elastic imperfection, and it is shown that limiting values must be reached at either end of the curve, but these do not seem to be approached within the limits of time covered by the present experiments. The slope from Method 1 is determined with considerable accuracy, and it may be really lower than the general slope. The fact that only one thread broke under a load of 150 grams in a month seems to point to a flattening out of the curve.

The logarithmic expression, however, covers the practicable range of experimentation with all the accuracy justified by the data or demanded for purposes of interpolation, &c., if not for theories on the physical cause.

The time effect has also been studied on the breaking load of single hairs of a Sakel cotton very similar to that which composes this yarn. It is surely significant that the identical formula $-dF/d \log T = 0{\cdot}1F_1$ applies equally to the hairs and the yarn, in other words, that the ratio of yarn to hair breaking load remains constant, independent of the speed of testing.

The following measurements were made on the yarn and constituent hairs—

Yarn weight = $1{\cdot}72 \times 10^{-4}$ gram per cm.
Hair weight = $1{\cdot}39 \times 10^{-6}$ gram per cm.
$\therefore$ Average number of hairs per section = $123{\cdot}4$.
Hair breaking load = $5{\cdot}97$ gm. at a rate of loading $0{\cdot}5$ gm. per sec., i.e. $\log T = 1{\cdot}077$.
$\therefore$ Aggregate breaking load of hairs = 737 gm.
Yarn breaking load ($\log T = 1{\cdot}077$) = 373 gm. = $0{\cdot}402 \times$ aggregate breaking load of hairs.

To interpret this ratio in terms of the properties of the hairs and yarn is a very complex question. It must be less than unity; first, because the hairs are oblique to the length of the yarn, so that the aggregate tension on the hairs is greater than that on the yarn ; second, because the tensions and tensile properties of the hairs are not uniform (*vide* Paper V). These features of structure are not affected to any great extent by the rate of loading, and the effect of this will depend on the relative importance of fibre slip and rupture in determining the breaking load. It is possible that loosening of the least tightly held fibres proceeds during extension, throwing the load more and more on to the strongly gripped core till it ruptures. Examination of breaks under the microscope shows that rather more than half the hairs are snapped and no appreciable difference in type of break could be noticed between ends ruptured in the ballistic and hanging weight tests.

Comparisons have been made at the Manchester Chamber of Commerce Testing House[1] on the strength of fabrics as given by machines working at various speeds, and these also show a general increase of breaking load as the speed is increased. The most thorough is a test on cotton duck, alternate warp specimens being broken on an Avery and a Goodbrand machine. The first two sets, each with 500 tests on each machine, were carried out at the usual rates on specimens 2 in. wide. the times of break being 85 and 8 seconds respectively. For the third set, with 100 tests on each machine, the specimens were 1 in. wide and the rates adjusted to make the times of break equal, about 12 seconds. The results are given in Table IX.

Table IX.

	1st Set	2nd Set	3rd Set
Avery	426·5	386·7	252·1 lbs.
Goodbrand	454·3	398·9	237·5 ,,
Difference	−27·8	−12·2	+14·6 ,,

To make the relation between breaking load and time of break the same as for hairs and yarns, the difference in the first two sets due to speed should be about 40 lbs. Taking into consideration the difference shown by the machines working at the same rate, it appears to be of this order. Further, the extensibility did not differ appreciably in these tests.

REFERENCES

[1] Fabrics Co-ordinating Research Committee. First Report. London, 1925, p. 36.
[2] Mann and Peirce. Shirley Inst. Mem., 1926, **5**, 7–18; J. Text. Inst., 1926, **17**, T82—T93.

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