of the mean in most tops. If n measurements are made on each top, we can then say with a 1 in 20 risk of error that

(1) Tops genuinely differ in mean fibre length if their sample values differ by more than

$$2 \times 56 \times \sqrt{\frac{2}{n}}\,\% = \frac{158}{\sqrt{n}}\,\%$$

(2) A top genuinely differs from a *specified* mean fibre length if its sample value differs from the specified value by more than

$$\frac{2 \times 56}{\sqrt{n}}\,\% = \frac{112}{\sqrt{n}}\,\%$$

For a 1 in 100 risk of error, the factor 2 is replaced by 2·58 and the corresponding figures are (1) $\frac{204}{\sqrt{n}}\%$ and (2) $\frac{144}{\sqrt{n}}\%$ For example, with $n = 1200$, we accept as real, differences of more than 4·6 per cent. with a 1 in 20 risk of error, or 5·9 per cent. with a 1 in 100 risk of error.

In the case of fibre diameter measurement it was possible to decide the number of fibres to be measured from the fact that tops which do not differ in fineness by more than half the average difference between contiguous Bradford qualities are for all practical purposes of the same fineness[8]. This cannot be done with fibre length because there is not such a definite relation between fibre length and quality number. For instance it is possible to obtain warp and weft 64's having mean lengths of 7·5 cm. and 6·0 cm. respectively. In the absence of information on the smallest difference in fibre length which is of practical importance, we suggest that the accuracy obtained with 1,200 measurements is sufficient for most purposes. With four observers, this should take about 3 hours. In many cases it should be sufficient to do half this number in which case the minimum significant difference between samples is 6·5 per cent. and 8·3 per cent. for risks of error of 1 in 20 and 1 in 100.

It is best on general grounds to distribute the measurements over as many cuts as is feasible, and to distribute the cuts as widely as possible throughout the available material. The above analysis indicated that not much was gained with the tops considered by spreading the cuts over the two ends of the ball and it is probably a waste of time to take fewer than about 300 fibres from each cut. But it is conceivable that genuine differences may exist between balls taken from the same batch, and these should be covered as completely as possible. Further work is in progress to ascertain the importance of variation between balls.

Acknowledgments

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REFERENCES.

1 E. Müller. *Zeitsch. des Vereins deut. Ing.* 1894. S997
2 E. Müller. *Leipziger Monats. für Textil Industrie* 1924-39. Hegt 9, pp. 346-347.
3 W. Frenzel. *Leipziger Monatschr.* Jan. 1922 *et seq.*
4 A. Huberty. Report of Tech. Committee of I.W.T.O. 1938.
5 K. Hertel. *Textile Research*

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TRANSACTIONS

8—A NEW DESIGN OF CLOTH WEARING TESTER

By J. G. Martindale, Ph.D., A.Inst.P.

(Wool Industries Research Association)

A new cloth wearing tester has been designed and will be described. Before doing so, a few remarks on the value and limitations of such a tester will be given. Following a description of the tester, some of the uses to which it has been put will be briefly explained.

It is fairly generally recognised that the results of abrasion tests on cloth, cannot always be adequately interpreted since the conditions which govern the wearing of any cloth under service conditions are obviously so complex that it is impossible to imitate them exactly in any one laboratory test. For this reason, the majority of people are very rightly sceptical as to the value of laboratory wear tests. In addition to this, the conditions of wear which operate on different types of cloth and even on various parts of the same garment, the linings, pockets and face of an overcoat for example, are so different that it is unreasonable to expect that a universal type of wear tester could be designed to assess the relative lives of each. Almost every problem of wear has its individual peculiarities and a laboratory test to be of any use should as far as possible take these into account. Any one testing machine can, therefore, only have a limited field of application in so far as the variety of conditions which can be incorporated in one design is limited; in view of this and the uncertainty with which the results are regarded, the designer of a new type of wear testing machine must feel that an apology is needed for adding yet one more to the many types which have already been described.

It is quite clear that no test can be made to forecast the service life of a fabric in so many hours' wear; fortunately such a statement is never demanded; the usual purpose of a test is one of comparison and the determination of such facts as will warrant an opinion that one fabric will probably outlast another in similar and specified circumstances[1], for instance comparison of the durability of a cloth of new design with an old type cloth which has previously been accepted as serviceable, is often required. In order to arrive at such a conclusion, the test conditions should imitate the required service conditions as far as possible, e.g., the wearing of dress fabrics with emery paper should be avoided because the results obtained would be meaningless.

The tester described below was first designed to carry out tests on the effect of a certain finishing process which was found in practice to be detrimental to the life of a dress fabric. The type of rubbing to which the garments made from this fabric were subjected was then imitated as far as possible on the machine, and the laboratory tests also indicated that the fabric with the special finish was less durable than the material used previously. The machine then played a useful part in wearing patterns from which the reason for this unserviceability was deduced and it also enabled tests to be made on the effects of varying the nature of the finishing process without the need for time-wasting service trials. The final acid test of the usefulness of the finished cloth had to be its service life, but the machine helped greatly in the intermediate stages.

These remarks have been made at some length in order to emphasise that the value of tests made on this machine are to be judged fairly only when the method of use is taken into account. It may be that the machine can be used for a variety of purposes in addition to the one mentioned above, and its adaptation to certain other problems was kept in mind when designing it. It was therefore arranged so that a variety of different test conditions could be used, for example cloth may be rubbed against itself, different cloth, leather or any other material. The cloth may be rubbed flat or it may have a tuck put in it to imitate the wear at the edges of garments, such as cuffs; the rubbing motion can be such that the pattern is rubbed in all directions or it may be rubbed backwards and forwards in one direction only. The way in which it is used depends on the operator who must decide which method appears most applicable and suitable for the problem in hand.

THE MACHINE

The machine is to be seen in Figs. 1 and 2: P is a brass plate supported by three pillars, A, B and C. On the top of each pillar is a ball caster. These allow the plate to glide about easily in the horizontal plane determined by this three-point support. The three bearing surfaces on the plate were machined flat and co-planar in order to correct for slight warping in the plate. The plate is then driven about in this plane by a simple mechanical device consisting of three sets of worms and worm wheels driving three circular discs on vertical shafts. In each of these discs is fixed a stud which engages in a slot in the plate P. The two outside studs work in two slots in the same line, the centre stud works in a slot at right angles to these. As the discs carrying the studs rotate the plate is therefore given a movement which is the resultant of two simple harmonic motions at right angles. The two outer studs make the same number of revolutions per minute, the centre one rather less so that every point on the plate traces out a path known as a Lissajous figure; this figure is shown in Fig. 5, and will be described in a moment or two. The plate has four holes drilled in it at the points H_1, H_2, H_3 and H_4, each hole being fitted with a brass bush perpendicular to the plate. These bushes act as supports and bearings for four special cloth pattern holders which hold a flat disc of cloth in a plane parallel to that of the plate. Before passing on to describe the construction of these holders let us con-

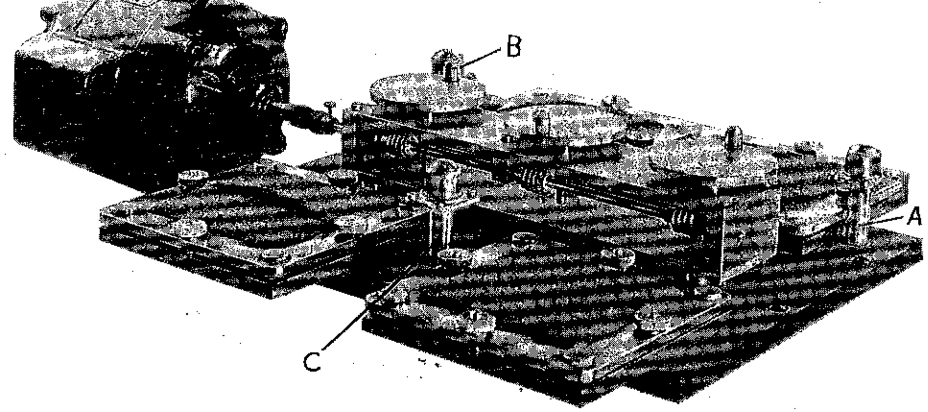


Fig. 1

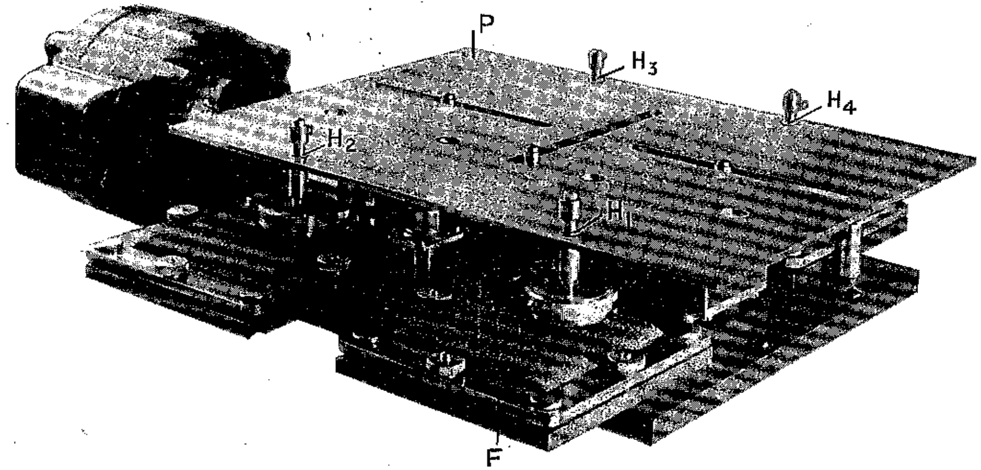


Fig. 2

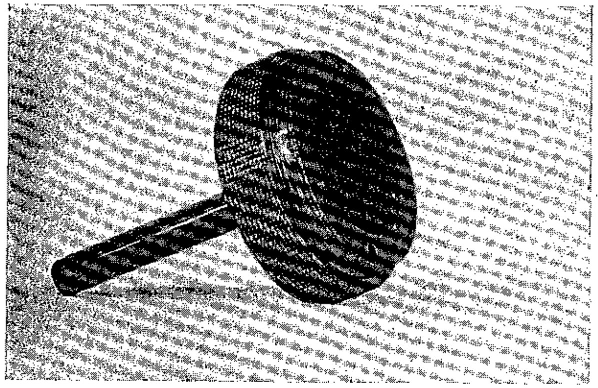


Fig. 4

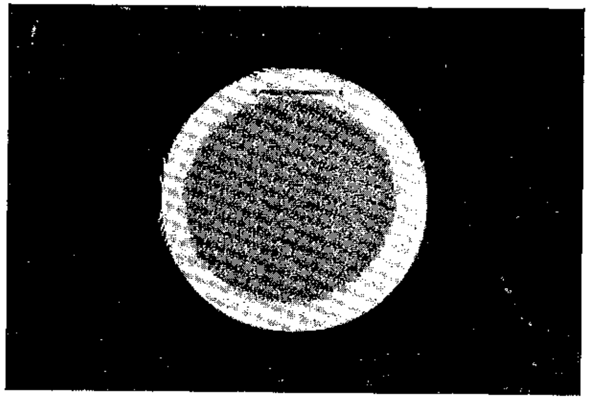
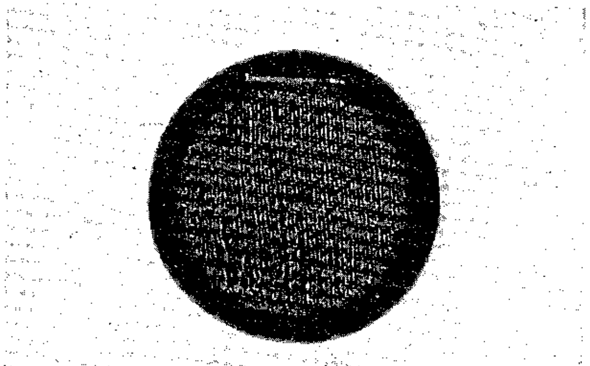


Fig. 6



pattern holders are able to slide vertically in the bushes, but they must partake of the horizontal movement of the plate. They each rest upon one of four small tables whose surfaces are also flat and parallel to the plane in which the plate glides; the cloth patterns in the holders are, therefore, each rubbed on one of these surfaces, the path of each being the Lissajous figure referred to.

(1) The Cloth Pattern Holder

This is shown in section in Fig. 3, and consists of three metal parts, A, B and C. A is a ring into which the cloth disc, D, $1\frac{1}{2}$ in. in diameter, fits exactly; B is a kind of circular plunger which is put in on top of the cloth, and C is screwed down over the outside of A. It then squeezes the plunger against the rim of A, so gripping the cloth, and as the plunger protrudes slightly below the rim of A, the cloth is tensioned. It has been found that to obtain a satisfactory tension this operation must be done whilst pressing the

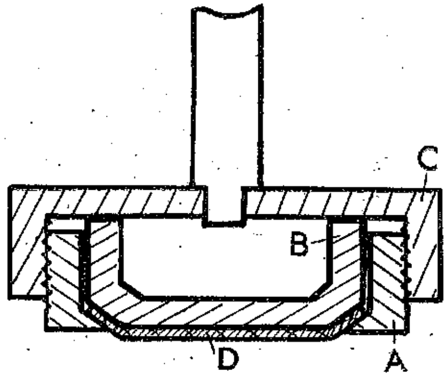


Fig. 3

holder down against a flat surface. To facilitate this two small holes have been drilled in the bottom face of A diametrically opposite to one another. Two metal studs which engage in these holes are fixed in the bench so that A is gripped whilst C is being screwed up and the cloth surface pressed against the flat surface of the bench. It will be noted that the part C is fitted with a rod which passes through the bush in the brass plate.

Fig. 4 shows a photograph of the loaded holder.

With this device the patterns may be removed at any stage of wear testing and weighed or their thickness may be measured. They can easily be put back into the holders for further rubbing exactly the same portion of cloth being exposed.

(2) The Abrading Tables

There are four of these just as there are four holders. They are square, of cast iron and machined flat. The surface against which the $1\frac{1}{2}$ in. disc is to be rubbed is usually cloth, in which case a pattern 5 in. square is laid on a table and a heavy weight with a flat smooth surface is placed on it. Opposite edges of the cloth are then pulled apart gently to remove any creases. The weight holds the pattern firmly whilst a square brass frame, the table, as in Figs. 1 and 2; it is prevented from slipping and working loose by a series of serrations on the lower side of the brass framework.

If any other type of abrading medium is used, e.g. emery cloth, it can be placed on the table in place of the cloth.

It may be noted that no mention has been made of the tension in the cloth patterns either on the abrading tables or in the pattern holders. This is not to say that the matter has been overlooked. It would be possible to measure the tensions in the samples, but only by having additional apparatus. In practice, however, it was found that when each unit was set up in the manner described, the rate of wear was the same on each (see the results which follow). Consequently it was decided that any differences in tension which do arise are not big enough to have any effect on the results obtained.

(3) The Method of Rubbing

When all the patterns are in position and the holders are fixed in the brass plate, the surfaces of the 1½ in. discs of cloth in the holders are parallel to and in contact with the material on the abrading tables, see Fig. 1.

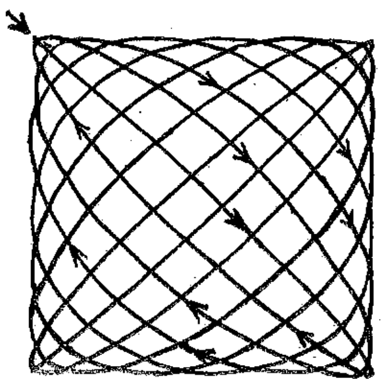


Fig. 5

When the machine is running, the discs are rubbed over the surface on the abrading table, following the path shown in the diagram of Fig. 5.

At one stage the path followed is a circle, but this gradually changes and progressively alters through a series of narrowing ellipses until the motion is in a straight line along the diagonal of the figure. As the motion continues, it develops again through the same series of ellipses (which are, however, now described in the opposite direction) until the circular motion is again produced. This cycle of operations is repeated for as long as desired.

This type of motion has the advantage that the pattern under examination is rubbed in all directions, not merely warp way or weft way; the motion is continually altering so that the fibres of the cloth are flexed in all directions, and are not merely being stroked in one direction.

The mechanical drive is such that by loosening one gear wheel only, the centre worm wheel, this type of motion can be replaced by a linear motion

Estimation of Degree of Wear

This may be done either by visual inspection, say rubbing until holes appear, or until some evidence of breakdown occurs, and the time taken for this to occur used as a measure of durability, or the patterns may be taken out at intervals of, say one hour, conditioned and weighed to determine their rate of loss of weight. The second is the more objective method and is to be preferred. Alternatively, the thickness of the patterns may be measured periodically during rubbing.

As the machine takes four samples, an average value for any particular material may be obtained. It has been found that in order to get the same results on all four patterns, it is essential that the four tables should be flat and that their surfaces should be absolutely parallel to one another and to the plane in which the driving plate moves: in addition the driving plate should be perfectly flat or at least those areas of its surface which are in contact with the three points of support should be flat and co-planar. The weights of the four pattern holders which press the cloth disc against the rubbing medium must be equal. In the tests carried out so far we have found no need to use heavier pressure than is provided by the weight of these holders—about ½ lb. However, their weight can readily be increased by fixing additional weights to the tops of the shafts which project through the brass plate.

Uses of the Machine

1. It may be used for testing the fastness of dyes to rubbing. For this purpose the dyed cloth is put on the table and rubbed with a piece of standard white calico in the circular holder. A well-defined circle of colour is then transferred to the white disc. (See Fig. 6).

2. A second use is to test fabrics for that annoying fault known as "pilling" or "balling-up" which occurs on knitted fabrics, e.g. gloves or sweaters. In this case, the tables and holders are each loaded with the same kind of material and the degree of the fault may be estimated by visual means or by weighing the small balls of fibres which accumulate between the two fabrics.

3. Another use is the one already mentioned where fabric from a garment, say a pair of trousers, has been found to wear into holes rapidly at points where cloth rubs against cloth. A cloth-against-cloth type of wear is easily given on the tester and the rate of wear measured by loss in weight by the method already described.

4. If a tuck is put in the cloth pattern which lies on the table, it will stand up like the cuff of a coat-sleeve and when the pattern holders loaded with cloth run over this tuck, which they will do easily, the edge of the tuck becomes frayed. This arrangement may be seen in Fig. 2.

As was said at the beginning, none of these results must be interpreted in an absolute fashion: the value of the above type of tests lies in the comparison of various types of samples.

As an illustration of the performance of the machine the following results show the uniformity of treatment on the four units and the effects of a certain

Cloth A rubbed against Cloth A on each of the four units. Loss in weight in milligrams in successive hours.

Unit	1	2	3	4
Loss in—				
1st hour ...	9	7	7	9
2nd hour ...	6	7	7	7
3rd hour ...	7	7	7	6
4th hour ...	4	5	4	3
5th hour ...	2	2	3	3
6th hour ...	3	3	3	2
7th hour ...	1	1	2	1
8th hour ...	2	2	2	2
9th hour ...	1	1	1	2
Total ...	35	35	36	35

Cloth B_1 (special finish) against cloth B_1 on units 1 and 2.
Cloth B_2 (unfinished) against cloth B_2 on units 3 and 4.

Cloth	B_1		B_2	
Unit	1	2	3	4
Loss in—				
0– 2 hours ...	21	25	24	23
2– 4 hours ...	39	38	6	6
4– 6 hours ...	24	21	2	1
6– 8 hours ...	22	12	1	2
8–10 hours ...	32	21	0	1
Total ...	138	117	33	33
Mean ...	128		33	

Fig. 7 shows a photograph of some material worn into a hole; the threadbare appearance of the pattern and a few threads remaining intact may be seen. These results show the use of the machine in making comparative tests of cloth B_1 against cloth B_2, the latter having previously been regarded as satisfactory. B_1 is clearly unsatisfactory.

Another example of the use of the machine in comparing the wearing properties of four cloths is given in Fig. 8. These wool serges of approximately the same weight per unit area were each tested by rubbing together two faces of the same material. At intervals the circular patterns in the cloth holder were removed and weighed. The graphs show the rate of loss of weight at all stages; there was an original rather rapid loss corresponding to the removal of the nap then, when the cloth was threadbare, in three cases out of the four, the weight remained fairly constant for a time. Finally the cloth failed, the pattern lost weight rapidly and in a very short time holes appeared. When the first hole appeared the test was

until the moment of complete rupture the cloths rapidly became thinner and on holding them up to the light the structure became more and more easily discernible. The material worn away was not removed as fibres but as a fine dust which was on examination found to be powdered wool.

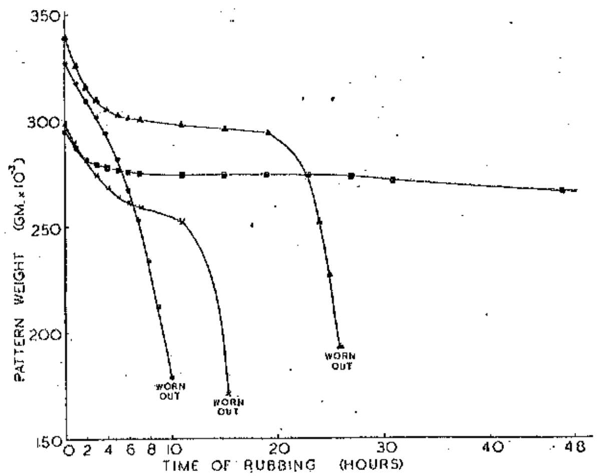


Fig. 8

Mention has also been made of the use of the machine for testing the fastness of dyes to rubbing and of the tendency of knitted fabrics to shed fibres. In the latter case the fibres often nep and form small pellets on the surface of the fabric. These are removed at intervals and they may be weighed.

With this machine the pressure between the cloth patterns is fairly small, the only pressure usually used being the weight of the pattern holders themselves (½ lb. each) although additional weight can be applied if necessary. The rate of wear of cloths under these gentlest conditions is probably much less than on the majority of existing abrasion testing machines as it seems to have been regarded as necessary to provide a fierce wearing action in order to get tests done quickly. Quite apart from whether this is advisable because actual service wear is not a fierce grinding action and so is not reproduced by such extreme treatment it is the author's opinion that the slower rate of wear and the conveniences provided for removing and replacing the test pattern are an advantage as they allow the progressive deterioration of the cloth to be studied; Fig. 8 is an example of this, if necessary air permeability tests could be made on the pattern at any intermediate stage. Furthermore the practice of using the time needed for the appearance of holes in a cloth as an index of durability is not necessarily a sufficient criterion of its wearing properties particularly where wool fabrics are concerned. Such a cloth may have lost its smartness and character and so have come to the end of its useful life, long before it is in holes. The gentle friction provided by this machine allows easy control over the early stages of wear when the surface is damaged which is not the case with machines

The author would like to acknowledge the services of Mr. S. Dilworth who made this machine in the W.I.R.A. workshops as well as earlier versions on which experimental work was done; also the valuable help of Mr. F. Hewitt, who did much of the experimental work leading to the development of the final machine; and the work of Miss E. E. Coulson, who has done most of the experimental tests carried out. His thanks are also due to the Director of Research, Mr. B. H. Wilsdon, for his continuous interest in this work and much helpful criticism and to the Council of the Wool Industries Research Association for permission to publish this description.

The machine is now being made by Messrs. Goodbrand & Co., Ltd., of Manchester and Stalybridge.