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STANDARDISATION AND INDEX

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STANDARDISATION

MEASUREMENT OF CLOTH THICKNESS

The importance of being able to measure the thickness of textile fabrics in a reliable manner has become increasingly evident as their application to, and design for service have been developed. It has also been apparent to those called upon to exercise such control that various engineers' instruments such as micrometer screw gauges and dial gauges may give widely different results on the same material. The discrepancies arise very largely from one source—the relative ease of compression of textile materials as compared with those of the mechanical engineer. It is therefore necessary to control carefully the pressure applied to the specimens to be tested for thickness. For this and other reasons arising from their peculiar properties, a standard method of measuring the thickness of textile fabrics is essential.

The present draft is not intended to provide a method applicable to all textile materials for all purposes. There are some constructions whose utility lies in possessing well defined thickness at low pressures. For these and other materials not sufficiently characterised by measurements within the pressure range of 1 to 10 lb. per sq. in., other methods and apparatus must be employed. There is, however, a very large bulk of cloths for which the present draft method is appropriate, including many of the wide range of mechanical and electrical fabrics.

Existing specifications and experience have provided the necessary information for this draft. It is therefore a conservative document. No special development work has been required, to arrive at any particular features, and it is confidently expected that there will be agreement between users of the method. It is important to observe that the method is essentially one for the laboratory. The gauge needs reasonably careful handling and the apparatus requires to be set up on a firm base so that the anvil is horizontal. This at once precludes its use as a portable pocket instrument. For works and other routine control purposes, where it may not be possible to use the apparatus described by this specification, secondary measuring devices will have to be used. These can, of course, be compared against the standard instrument for a given material. It may be that there is room also for a specification which will control the essential features of a thickness gauge for fabrics, which can be held in the hand, but the drafting committee favours the opinion that the adoption of the present proposal will be a sufficient advance for the present.

Explanations of some features of the instrument may be desirable. The choice of a dial gauge, rather than a micrometer screw gauge, is dictated by practical experience and the difficulty of obtaining concordant results with the latter type of instrument. Moreover, the pressure applied, even by ratchet type gauges, is actually high as well as variable; British practice (B.S.S. 870) allows a range of $1\frac{1}{4}$ to $1\frac{3}{4}$ lb., which is equivalent to $25\frac{1}{2}$ to $37\frac{1}{2}$ lb. per sq. in.

The range of pressure 1 to 10 lb. per sq. in. over which it is intended that measurements shall be possible by this instrument, is determined by a variety of considerations. There is a lower limit to the pressure: the weight of the plunger assembly is such that the calculated pressure cannot be brought much below 1 lb. per sq. in. This is therefore a convenient minimum. The upper limit is decided by considerations of safety. The plunger and associated parts will sustain a considerable dead-weight load without appreciable distortion,

but it is essential that the load shall be truly axial and that no shocks be applied. The safe load, allowing for normal care in handling, should be well below the theoretically safe steady load, and it is considered that loading so as to give 10 lb. per sq. in. is a suitable maximum for ordinary purposes. Exceptionally, if special care is exercised, pressures of the order of 25 lb. per sq. in. may be used.

The choice of working pressure is to a large extent arbitrary. There are no over-riding considerations which would necessitate a single exact value for all fabrics for which this method of measurement is appropriate. This is reflected in the variety of pressures required by different extant specifications. Whilst it is considered to be desirable that the same pressure should be used for similar fabrics, the choice of pressure has been left to the material specification.

The task of the drafting committee was considerably lightened by the existence of B.S.S. No. 907 (1940) which deals with dial gauges for linear measurements. For general purposes the type described in Table No. 3 of that specification, having 40 or 50 divisions of 0·001 in. round a dial of $1\frac{3}{4}$ in. to 2 in. diameter is considered suitable; but in exceptional cases the material specification may prescribe the more sensitive type having 100 divisions of 0·0001 in. round the dial.

It will be found that a variety of instrumental details do not appear in this draft. These are left to the discretion of the user and instrument maker. For example, the depth of throat may be less for a user concerned entirely with narrow fabrics. The form of the table surrounding and level with the anvil is a matter of individual convenience. To the instrument maker is left the form of the dead weights and the mode of setting them axially over the plunger: it is only necessary that they shall be readily seated and removed without jarring the gauge.

It is recognised that some care is required in the use of an instrument of this kind. Various proposals have been made to render the operation less subjective, such as the use of auxiliary gradual loading devices and standard lapse periods. It is considered, however, that the procedure laid down in the present draft will be adequate for all except a few materials, and special procedures for these can be prescribed as they arise.

TENTATIVE TEXTILE STANDARD No. 9, 1944

METHOD OF MEASURING CLOTH THICKNESS

Under Loads of 1 to 10 lb. per sq. in.

Part I—The Instrument

General

The instrument shall consist of a dial type gauge mounted vertically on a frame which is provided with an anvil below the foot of the gauge. The instrument shall also be provided with a table for supporting the fabric during thickness measurement. This shall consist of a smooth, plane, horizontal surface, surrounding the anvil and level with it, and of sufficient size to prevent any error in the measurement through bending of the specimen. The table may conveniently constitute part of the base of the frame.

Specification

(1) The gauge shall conform with the provisions of British Standard Specification No. 907—Class 1, except that the main return spring and back lug shall be omitted. It shall be fitted with a revolution counter, and rotatable bezel by means of which the instrument can be adjusted to read zero.

(2) Unless otherwise prescribed by the material specification, the gauge shall have 40 or 50 divisions of 0·001 in. round the dial. (See table No. 3 B.S.S. No. 907).

It is recommended that when a more sensitive type is considered to be necessary, the gauge shall have 100 divisions of 0·0001 in. round the dial. (See table No. 5 B.S.S. No. 907).

(3) The gauge shall be provided with a foot having a hardened, polished, plane, circular face of 0·375 in. ± 0·001 in. diameter rigidly fixed to the plunger.

(4) The plunger shall have fixed axial deadweight loading such that the calculated pressure over the foot shall be 1 lb. per sq. in. when the dial reads zero. This requires a total deadweight of 50·1 g. (0·110 lb.), including the plunger and foot, with a correction for the tension of the backlash spring.

For loadings which will give pressures greater than 1 lb. per sq. in. the loading shall continue to be axial.

This may be attained by any acceptable means, one satisfactory method being the provision of a platform. The platform shall form part of the fixed deadweight loading, and shall be rigidly fixed at the top of the plunger, and shall be provided with means for seating cylindrical weights which will increase the calculated pressure over the foot to a maximum of 10 lb. per sq. in.

(5) The spring which is necessary to prevent backlash in the gauge shall not produce a change of pressure greater than 0·1 lb. per sq. in. (=load difference of 5 g. or 0·011 lb.) for a plunger movement of 0·1 in.

(6) The gauge shall be fitted with a lever for raising and lowering the plunger so that contact with the material to be measured can be effected gently.

(7) The anvil shall be rigidly set in the frame and shall have a hardened, polished, plane, circuler face of 0·375 in. ± ·001 in. diameter.

(8) The surfaces of the foot of the gauge and anvil shall be co-axial and shall be parallel to within 1/5000 in. when tested by a feeler gauge at the edges.

(9) The gauge shall be rigidly fixed to an arm which shall be integral with the base of the frame.

(10) The plunger shall move perpendicularly to the face of the anvil.

(11) The rigidity of the frame shall be such that a load of 1 lb. applied to the dial housing, out of contact with the plunger, does not produce a deflection greater than 0·0001 in. as indicated on the micrometer dial.

Part II—Testing Technique

Procedure

(1) The instrument shall be set on a firm base so that the anvil is horizontal.

(2) The instrument shall be loaded so as to provide the pressure prescribed by the material specification.

(3) The surfaces of the anvil and foot shall be cleaned by placing a clean, smooth sheet of paper between them and withdrawing it, and the gauge shall then be made to read zero by the use of the adjustable bezel.

(4) The fabric shall be conditioned in the standard atmosphere (see B.S.S. No. 1051) in the loose state, for 24 hours, and the thickness measurement made under the same condition, unless contrary instructions are given in the material specification.

(5) The specimen of fabric shall be placed on the anvil in a single layer, flat and without tension. The foot of the gauge shall be lowered gently upon the fabric at a rate of about 2/1000 in. per second, and the reading taken immediately the easily visible movement of the pointer has ceased, unless contrary instructions are given.

Sampling and Numbering of Tests

The number of samples to be tested and the manner of their selection shall be prescribed by the specification. In the absence of other instructions it is recommended that 10 places uniformly and randomly distributed over the specimen, but excluding selvedges, shall be measured on any single specimen of material.

Criteria

The material specification may prescribe the manner in which the results of the tests shall be examined; otherwise the mean value of the results shall be calculated.

THE TESTING OF NARROW FABRICS

Towards the end of 1943 the Textile Institute received a request from the Narrow Fabrics Directorate of the Ministry of Supply for assistance in the preparation of recommendations for a series of standard testing methods, having particular reference to narrow fabrics. The wide range of application of narrow fabrics and the varied nature of their requirements had led to the existence of a great variety and multiplicity of methods of testing, and it was considered that the confusion and misunderstanding occurring in such circumstances could be avoided by the adoption of a system of unified methods of test.

The present proposals represent a step towards standardisation of testing methods for this class of materials. They are tentative recommendations, issued with the primary object of fulfilling practical war-time needs. The adoption of definite standards, for general peace-time purposes must necessarily be postponed until later deliberations of a more comprehensive and representative nature than have been attainable in present circumstances can be undertaken.

The recommendations have been prepared by a number of specialised technical committees appointed to deal with different groups of tests, and the decisions have been achieved largely through the medium of discussion, in the light of existing knowledge and experience. As was to be expected, however, in work of such extended scope, and in the present state of knowledge, investigations of a practical kind were necessary for several of the tests before a satisfactory procedure could be recommended. In the time available the experimental work has been necessarily limited, but it is considered that sufficient has been done to indicate the most suitable methods of test, and to make the range of tests comprehensive. It is left to the compilers of specifications to deal with any exceptional requirements and to prescribe modified or entirely different methods of test where necessary.

The tests are classified under four main types to facilitate reference. Part I comprises the general dimensional and physical properties. The tests have been drafted with special reference to narrow fabrics and certain recommendations are made with regard to details of apparatus and methods of testing which have been proved essential in practice. When the measurement of thickness was considered it seemed desirable to separate the description of the instrument and method of test from the main specification and accordingly Tentative Textile Standard No. 9, 1944, was drafted. The recommendations for machine capacity and rate of traverse in strength testing follow from the work of Technical Committee "A" of the Institute's Standardisation Scheme.[1] Methods of assessing bow and curl are given in order that these properties may be fully defined when necessary.

Part II contains a series of tests intended to provide a measure of the behaviour of elastic fabrics.[2] Methods of testing have been included which are designed to reproduce effects in the material approximating to those of actual conditions of use. This may be especially important in view of the impending greater use of synthetic rubber thread as a constituent of these fabrics. Notes on the issues involved in testing are inserted in the text where necessary.

Part III deals with chemical tests. For many of the tests in this section it has been necessary to include descriptive matter of greater length in order adequately to cover the testing operations, the apparatus and relevant issues. It is left to the material specification to prescribe the appropriate tests to be applied, also the manner of sampling the material, and the values by which the performance of bulk quantities of fabric shall be judged.

Part IV comprises the tests for colour fastness. The material specification should prescribe the appropriate tests to be applied where colour fastness is an important requirement of the fabric.

The majority of the tests, especially those in parts I and II have their texts arranged under one or more of a series of headings:—

Under "General" the nature of the property to be assessed by the test is explained.

"Designation" covers the definition of the property to be measured by the test.

The "Units" by which the property shall be measured are also given where necessary.

Under "Testing Procedure" an outline is given of the practical operations, with attention to the arbitrary features of machines, technique and preparation of specimens.

In addition, it has been considered important to make some reference to other factors involved in the interpretation of the results of testing, and in the formation of representative judgments of fabric in bulk quantities. These can be considered under three headings:—

"Criteria" represents the choice of mean, maximum, minimum or range, etc., for the values given in the material specification; and the method of computing the results of testing for assessing their compliance with the specified values. The choice depends not only on the nature of the test but also on the intended use of the material.

Under the heading of "Performance" the material specification will usually prescribe the results to be shown by a satisfactory material in accordance with the given criteria. In appropriate instances, such as the mean of quantitative results, tolerances or limits should also be prescribed.

"Sampling and number of tests" includes the size of a sample and the manner of its selection from a consignment or other bulk quantity of material, the number of specimens to be tested from the material sample and the manner in which they should be taken. It is, of course, well known that the size and mode of selection of a sample should depend on the size of the bulk, on the variability of the material, on the kind of test and on the information which it is desired to obtain. For some tests it has not been found possible to give any guidance in this matter and it is left to the material specification to supply the necessary information. However, for some well established tests on certain types of materials, recommendations are made regarding the minimum size of a sample, and the number of tests to be carried out on such a sample, for a single determination of the property under test. This has been termed a unit sample. It is left to the specification to prescribe the relationship between the size of a consignment and the number of unit samples which should be tested. It will be noted that the recommended unit sample is of uniform size for certain groups of tests so that economy of material, time and labour is effected by using the same specimens for the various tests.

There is, of course, no question of prescribing a general method of sampling. The unit sample system would be less useful, for instance, in cases where the variation of a particular property may be identifiable, and where a scheme of sampling more closely related to the known causes of variation could be adopted; or in cases where certain characteristics were to be judged by high percentage inspection. The use of the unit sample system would be limited normally to ordinary cotton fabrics and those of similar variability and in the absence of other determining factors, though the scope of its application could be fairly extensive in narrow fabrics.

It is desirable that, when possible, all classes of testing of textile materials in bulk should be applied according to a design or plan broadly conforming to the principles of control outlined above. In the case of narrow fabrics this aspect of testing is of particular significance as variation of properties can be a relatively more serious matter than with most types of wider fabric.

Thanks are due to all who have contributed to the formulation of this series of tests; to the Society of Dyers and Colourists for its work in the preparation of the section on colour fastness; to the technical officers of Government Inspectorates; and particularly to the members of the eight technical sub-committees.

Acknowledgment is also due for the permission of the Textile Rot Proofing Panel of the Ministry of Supply to publish the tests in the chemical section dealing with iron, chromium, copper, zinc, manganese, paranitrophenol, Shirlan and pentachlorphenol. These tests are adapted from unpublished work carried out at the Shirley Institute and will form the subjects of future publications from that Institute.

Comments on the document or any part of it will be welcomed. They should be addressed to the Acting General Secretary, 16, St. Mary's Parsonage, Manchester, 3.

REFERENCES

[1] "Cloth Strength Testing." Series of papers, I to VIII. *J. Text. Inst.*, 1942, **33**, S7-S40 and S53-S62.

[2] G. H. Lunge. "Some Observations on the Measurement of Stretch of Elastic Webbings." *J. Text. Inst.*, 1944, **35**, T7-T16.

TENTATIVE TEXTILE STANDARD No. 10, 1944

STANDARD TESTING METHODS FOR NARROW FABRICS

CONTENTS

Part I

THE GENERAL DIMENSIONAL AND PHYSICAL PROPERTIES OF NARROW FABRICS

1. CONDITION

Definition

The standard atmosphere for the conditioning of fabric samples for testing shall be as defined in British Standard Specification No. 1051, viz.:—

"The conditions of an atmosphere at normal pressure denoted by a relative humidity of 65 per cent. ± 1 per cent. and a temperature of 70° F. ± 2° F."

2. DELIVERY CONDITION OF CONSIGNMENTS

General

The chief object in specifying the condition of fabric in the bulk consignment, when delivered, is that reasonable precautions shall be observed to ensure that no excessive amount of moisture is present in the fabric, as this might result in mildew and other forms of deterioration of the fabric during storage.

Testing Procedure

Samples of fabric taken from rolls selected from the consignment shall be weighed either immediately in the room where the goods are, or if this is inconvenient, they shall be transferred immediately to air-tight containers of known tare, which shall be weighed subsequently before the samples are removed for conditioning.

The samples shall then be conditioned in the standard atmosphere for 24 hours, and again weighed.

The accuracy of the weighing shall be of the order of 0·1 per cent. of the weight of the samples.

Sampling

The samples of fabric for this test shall be taken in such a manner that they are truly representative of the moisture condition of the consignment.

Performance

The material specification shall prescribe the maximum loss in weight as a result of conditioning.

In the absence of other determining considerations it is recommended that the loss in weight shall not exceed:

1 per cent. for materials composed of cotton, flax, acetate rayon, nylon, and other fibres having regains of similar order.

2 per cent. for materials composed of silk, hemp, wool, mohair, jute, viscose and cuprammonium rayons, and other fibres having regains of similar order.

3. CONDITIONING AND PREPARATION OF SAMPLES FOR TESTING (Other than Delivery Condition)

(a) Fabrics (except elastic fabrics)

Specimens of fabric as required for the various tests, shall be prepared from samples which have been allowed to relax and condition in the standard atmosphere for 24 hours, and the tests shall then be carried out under the same condition.

If the specimens are required to be of definite length they shall then be marked to the requisite degree of accuracy with the aid of a steel rule.

In case of dispute and also when the samples lose more than the prescribed weight after conditioning as above, they shall first be dried in an atmosphere having a relative humidity of between 25 per cent. and 45 per cent., and a temperature not exceeding 40° C. (104° F.) and then re-conditioned in the standard atmosphere for 24 hours.

(b) Yarns (except rubber thread)

Packages of yarn (cheeses, hanks, etc.) from which specimens are to be taken for the purpose of any of the tests, shall be conditioned as described for fabrics in Method No. 3(a), unless contrary instructions are given in the specification.

Yarns extracted from fabric for the purpose of cloth analysis, etc., shall be taken from samples which have been conditioned and prepared as described in Method No. 3(a).

Yarns shall be measured after applying only just sufficient tension to remove crimp.

4. TESTING OF FABRIC IN THE WET STATE

It is recommended that wet tests shall be carried out only when the results so obtained are immediately relevant to the use of the material.

The conditions of wetting shall be so defined that reproducible results shall be obtainable.

5. LENGTH

(a) Bulk Inspection

The fabric shall be unrolled and drawn across a smooth, flat measuring table, preferably 5 yards long.

No more tension shall be applied to the fabric than is necessary to make it lie straight and flat.

The above procedure will normally be carried out under ordinary room conditions. In all cases of doubt or dispute the following method shall be employed:—

(b) Testing

The fabric shall be conditioned in the standard atmosphere, in the loose, unrolled state, for 24 hours, and the measurement, as described above, then conducted under the same condition.

Sampling and Number of Tests

A unit sample for either of the above methods shall consist of 5 rolls of fabric, and all shall be measured.

The number of unit samples and the manner of their selection from the consignment shall be prescribed by the specification.

6. WEIGHT PER UNIT LENGTH

Units

The weight per unit length shall be expressed in pounds and decimals of a pound, per gross yards.

(a) Bulk Inspection

The weight shall be taken of fabric which has been measured by Method No. 5(a) or (b), and the weight per gross yards calculated.

Alternatively the following method shall be used:—

(b) Testing

Short lengths of fabric shall be prepared from conditioned samples [see Method No. 3(a)] and these shall then be weighed to a suitable degree of accuracy, and the weight per gross yards calculated.

Sampling and Number of Tests

For the bulk inspection method a unit sample shall consist of 5 rolls of fabric and all shall be measured and weighed.

For testing, a unit sample shall consist of 5 lengths of two yards each; one from each of 5 rolls.

The number of unit samples and the manner of their selection from the consignment shall be prescribed by the specification.

7. WIDTH

Units

The width of the fabric shall be measured in inches and fractions of an inch.

(a) Bulk Inspection

The width shall be measured with a suitably graduated steel rule, and no more tension or pressure shall be applied to the fabric than is necessary to make it lie straight and flat.

The above procedure will normally be carried out under ordinary room conditions. In all cases of doubt or dispute the following method shall be employed:—

(b) Testing

The fabric shall be conditioned in the standard atmosphere, in the loose, unrolled state, for 24 hours, and the width measurements then conducted under the same condition.

Sampling, and Number of Tests

The material specification shall prescribe whether width measurement is to be carried out on the whole or a portion of the consignment, or on a unit sample, or number of unit samples.

In the absence of other determining considerations it is recommended that a unit sample shall consist of 5 rolls, and 5 measurements shall be made on each roll at randomly selected places.

Criteria

The material specification shall prescribe whether the results shall conform to demands of maximum, minimum or mean width.

Performance

The permissible limits of width shall be specified.

8. THICKNESS

Units

Thickness shall be measured in mils. (Thousandths of an inch.)

Testing Procedure

The fabric specimens for this test shall be conditioned and prepared as described in Method No. 3(a).

Thickness shall be measured by means of a dial micrometer. The construction of the instrument and the technique of the test shall be in accordance with Tentative Textile Standard No. 9.

Sampling and Number of Tests

A unit sample shall consist of 5 lengths of 2 yards each; one from each of 5 rolls, and two measurements shall be made on each specimen.

The number of unit samples and the manner of their selection from the consignment shall be prescribed by the specification.

Criteria

The material specification shall prescribe whether the results shall conform to demands of maximum, minimum or mean thickness.

Pressure

The material specification shall prescribe the pressure under which the measurements are to be made.

Performance

The permissible limits of thickness shall be specified.

9 (a). TENSILE STRENGTH—YARNS (SINGLE THREAD)

Units

Breaking strength shall be specified in pounds and decimals of a pound.

Testing

The following conditions shall be observed:—

An approved testing machine shall be used with a working rate of traverse of 12 in. per minute.

The free length of a specimen at the start of a test shall be 20 in. between the grips of the machine.

The capacity of the machine shall be such that the specified figure for the breaking strength of the yarn under test is not less than 10 per cent. of the capacity of the machine.

All specimens for testing shall be conditioned in the standard atmosphere as described in Method No. 3(b), and the tests carried out under the same condition.

The yarn to be tested shall be taken from the fabric or package (cheese, hank, etc.) in such a manner that the twist in the yarn is not disturbed.

Sampling and Number of Tests

A unit sample shall consist of 5 packages (cheeses or hanks, etc.) and the number of tests from a unit sample shall be:—

50 for single yarns, 10 from each package.
20 for ply yarns, 4 from each package.

The number of unit samples and the manner of their selection from the consignment shall be prescribed by the specification.

Criteria

The specification shall prescribe whether the material shall conform to a mean, maximum, minimum or a range of strength.

9 (b). TENSILE STRENGTH—FABRICS

Units

Breaking strength shall be specified in pounds and decimals of a pound.

Testing

The following conditions shall be observed:—

The testing machine shall be:—

either: Constant rate of loading type, the rate of loading being such that the time taken to reach the specified breaking load shall be 1 minute.

or: Constant rate of traverse type, power driven, and with a uniform traverse speed of 4½ in. per minute.

The specification shall prescribe the type of machine to be used.

The free length of a specimen at the start of a test shall be 7 in. between the grips of the machine.

The capacity of the machine shall be such that the specified figure for the breaking strength of the material under test is not less than 10 per cent. of the capacity of the machine.

The specification shall prescribe whether the material is to be tested whole or whether specimens for testing are to be prepared from part widths. Narrow fabrics will normally be tested whole. When part widths are to be tested the specimens shall be frayed down to a width of 2 in. and the specification shall prescribe the width of fringe required to give satisfactory control of the edge threads in the tests.

All specimens for testing shall be conditioned in the standard atmosphere as described in Method No. 3(a), and the tests carried out under the same condition.

Sampling and Number of Tests

In the absence of other determining considerations a unit sample shall consist of specimens of fabric from 5 rolls, and the number of tests shall be 2 from each roll, giving a total of 10 tests. The number of unit samples and the manner of their selection from the consignment shall be prescribed by the specification.

Criteria

The specification shall prescribe whether the material shall conform to a mean, maximum, minimum or a range of strength.

10. EXTENSION

Units

Extension shall be expressed as a percentage of the length of the material before stretching.

Testing Procedure

Extension shall be measured after stretching the material in a tensile testing machine of the type specified for strength testing of yarns or fabrics.

The material specification shall state the initial and final loads between which the extension is to be measured. Whenever possible it is recommended that these shall be based upon the specified breaking load, or the specified weight per unit length of the material.

Sampling

The number of fabric specimens to be tested and the manner of their selection from the consignment shall be prescribed by the specification.

11. SHRINKAGE

General

Where satisfactory shrinkage performance is an important requirement of the material, the specification shall prescribe a suitable treatment and testing procedure, also sampling instructions and testing criteria.

Units

Shrinkage shall be expressed as a percentage of the length of the material before treatment.

Measurement of Shrinkage

The marking and measurement of the samples before and after the prescribed treatment for a shrinkage test, shall be as described in Method No. 3(a), the samples first having been conditioned in the standard atmosphere for 24 hours unless otherwise specified.

12. FABRIC ANALYSIS—THREAD COUNTING

(a) Warp Ends

The total number of ends in the width of the fabric shall be counted.

(b) Picks, Plaits and Rows of Stitches

Counting shall be on relaxed and conditioned short lengths of fabric prepared as described in Method No. 3(a). The countings must extend over at least a full inch, and to the nearest half thread, plait or row of stitches.

Sampling and Number of Tests

For warp ends, a unit sample shall consist of 5 rolls of fabric, and each shall be counted.

For picks, etc., a unit sample shall consist of specimens of fabric from each of 5 rolls, and two countings shall be made for each roll.

The number of unit samples and the manner of their selection from the consignment shall be prescribed by the specification.

13. FABRIC ANALYSIS—YARN COUNT

General

Because of the difficulty of dissecting many narrow fabrics it is recommended that the count of weft be determined by calculation from other tested cloth particulars as follows:—

The weight of warp in the fabric specimen is calculated from test results of total ends, warp crimp, warp count and specimen length. The weight of weft

is then obtained by difference from the weight of the fabric specimen. The length of weft is calculated from the tested picks per inch and the yarn length per pick. Then the weft count is computed from these calculated values of weight and length of weft.

Preparation of Specimens

Specimens of fabric 2¼ yards long shall be conditioned as described in Method No. 3(a), and the subsequent dissection, measuring and weighing shall be carried out in the standard atmosphere.

(a) Weight per unit length

The weight per unit length of the fabric specimens shall be determined as in Method No. 6(b).

(b) Number of threads

The number of warp threads and picks shall be counted as in Method No. 12.

(c) Measurement of pick length

From each end of each 2¼ yd. specimen ten picks of weft shall be dissected in a continuous length and measured under just sufficient tension to remove the crimp. The mean pick length for all specimens in the sample shall be calculated.

(d) Measurement of warp crimp

In each specimen two cuts shall be made a measured distance apart along the length of the fabric and two warp threads shall be dissected from this length and measured under just sufficient tension to remove the crimp. The warp crimp is the difference between the length of the warp threads and the distance between the cuts, expressed as a percentage of the distance between the cuts.

(e) Warp count

From the remainder of the 2¼ yd. specimens, lengths of two yards are cut off and 10 complete warp ends are dissected from the full length of each 2 yd. specimen. These ends from all the specimens are then weighed together to an accuracy of 0·5 per cent., and the count is calculated after allowing for the mean warp crimp and any finishing treatment.

When the fabric is made from more than one beam or type of yarn the warp tests and calculations shall be repeated for each beam or type of yarn.

(f) Weft count

The weight of weft per gross yards of fabric is obtained by subtracting the weight of warp per gross yards [calculated by the test results of (b), (d) and (e)] from the fabric weight (a).

The length of weft per gross yards of fabric is calculated from the test results of (b) and (c).

The weft count is calculated from the length and corresponding weight so obtained.

Sampling and Number of Tests

A unit sample shall consist of 5 lengths of fabric, one from each of 5 rolls.

The number of unit samples and the manner of their selection from the consignment shall be prescribed by the specification.

14. TWIST IN YARNS

Units

The amount of twist shall be expressed as the number of turns per inch.

Testing Procedure

The yarn to be tested shall be taken from the fabric or package (cheese or hank, etc.) in such a manner that the twist in the yarn is not disturbed.

The yarn shall be inserted in the testing apparatus with an amount of tension only just sufficient to pull it taut between the grips.

The yarn shall then be carefully untwisted and the point of zero twist deter-

mined by inserting a needle in the fibres and passing it from the fixed to the moving grip.

The following table gives recommended lengths of yarn for testing, and also the number of tests to be made from a unit sample:—

Single yarns.	Cotton, Woollen, Staple fibre	1 in. or ½ in.	50 tests.
	Worsted, Mohair, Spun Silk, Hemp, Linen, Jute and similar material	1 in.	50 tests.
	Continuous filament yarns	5 in.	20 tests.
Ply yarns.	All types	10 in.	20 tests.

Sampling and Number of Tests

A unit sample shall consist of specimens from 5 packages of yarn, or from cuttings of fabric taken from 5 rolls. The number of tests on a unit sample shall be as indicated above.

The number of unit samples and the manner of their selection from the consignment shall be prescribed by the specification.

15. DIRECTION OF TWIST

" The direction of twist shall be as defined in British Standard Specification No. 946, viz.:—

Single Yarns

" A yarn has "S" twist if, when it is held in the vertical position, the spirals conform in direction of slope to the central portion of the letter " S ". Similarly the yarn has " Z " twist if the spirals conform in direction of slope to the central portion of the letter " Z ".

Folded Yarns and Cables

" The direction of the twist in successive twisting operations is described by a series of letters " S " and " Z " in which the first letter or group of letters gives the direction of the twist in the single yarns. The letter (or letters) referring to the single yarns, may, if desired, appear in smaller type.

" Twist in folded yarns is designated "S/S" or "Z/Z" when the folding turns are in the same direction as those in the single yarns.

" When folding twist is in the opposite direction to that in the single yarns, the designation is " S/Z " or " Z/S ", and in successive cabling operations, yarns may be shown as " S/Z/S. . . " or " Z/S/Z. . . "

When single yarns of opposite twist are folded, the designations are " SZ/S " or " SZ/Z " according as the doubling twist is in the " S " or the " Z " direction."

16. CURL

General

The material specification shall prescribe whether the specimens shall be specially conditioned as described below, or otherwise pre-treated before their curls are assessed. If the conditions of use are such that unconstrained short lengths may develop or increase their curls by increase or fluctuation of moisture content, it is recommended that the specimens shall be exposed to water vapour or liquid water in such a manner as to effect such increase in the curl. For general purposes and in the absence of special considerations which indicate other procedure, it is recommended that the development method given should be adopted.

Preparation of Specimens

Fabrics wider than 2 in.:—Discs of 2 in. diameter shall be cut from the samples.

Fabrics narrower than 2 in.: Specimens 2 in. long shall be cut from the samples.

Pre-Treatment of Specimens

The specimens shall be conditioned over a saturated solution of sodium sulphate in a closed chamber.* If the air is not removed from the chamber the specimens shall be conditioned for 24 hours. If the air is very largely removed as by the use of a " desiccator " evacuated by water pump, the specimens shall be conditioned for one hour.

*This solution gives approximately 82 per cent. R.H. at room temperature.

Testing Procedure

The specimens shall finally be conditioned in the standard atmosphere for 24 hours, before proceeding to assess their curls.

In order to ensure the removal of transient curl they shall first be made to lie flat on a table; no more than the minimum pressure necessary for this purpose shall be employed and the specimens shall be held flat for 2 to 3 seconds.

The specimens shall then be allowed to curl freely for one minute.

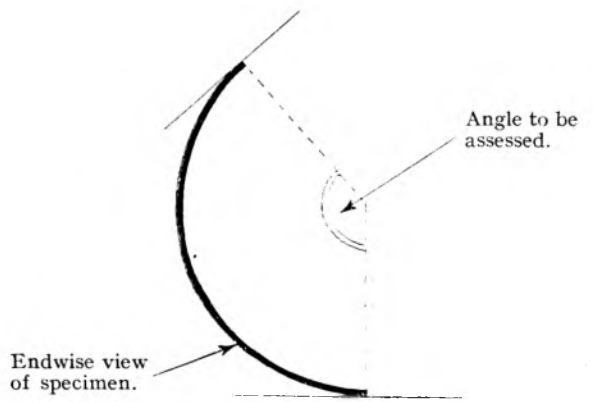


Fig. 1.

The angular rotation of one extremity of the specimen with respect to the other is then assessed by viewing the curled specimen so that it presents the appearance of a cylindrical tube or part of such a tube. This will in general mean that the specimen is viewed along a line at some angle to the warp threads or weft. The assessment is made to the nearest 10 degrees. It has been found that when the curl is less than one whole turn the angle is more readily estimated when the specimen is held at arm's length so that the direction of one extremity is horizontal.

Direction of Curl

If the direction of curl is important it is determined as follows:—

A line is drawn on the concave side of the specimen parallel to the axis of its cylindrical form. The angle between this line and the weft direction is measured, reckoning clockwise from the line.

If it is necessary, and possible, the face and back of the cloth shall be identified and the convexity or concavity of the face noted.

Criteria and Performance

The material specification shall prescribe the desired performance in respect of curl and may include a demand that the direction of any particular curl shall be assessed.

Sampling

The specification shall prescribe the number of tests to be carried out and the manner of their selection from the consignment.

17. BOW

Preparation of Specimens

Samples of fabric exhibiting this characteristic shall be conditioned and prepared as described in Method No. 3(a). The fabric shall then be laid on a smooth surface without any constraint other than the application of such minimum pressure as is necessary to make it lie flat.

Testing Procedure

A steel rule shall be placed on the fabric in such a manner that a chord of appropriate length spans the inside of a bowed portion of the fabric.* The maximum perpendicular distance—d inches—to this chord, from the edge of the fabric shall be measured with a second steel rule. The width of the fabric—w inches—shall also be measured with a steel rule.

*In view of the variability of this characteristic it is recommended that the length of the chord shall be relatively short. Therefore the chord length shall be 10 inches whenever possible, but in cases where the value of d is too small to be measured with reasonable accuracy, alternative chord lengths of 20in., 30in., or 40in. shall be used.

Expression of Results

The bow shall be expressed as the Percentage Length Differential, which is calculated from the formulæ:—

Percentage Length Differential = 8 d w for chord length of 10 in.
2 d w ,, ,, ,, ,, 20 in.
$\frac{8}{3}$ d w ,, ,, ,, ,, 30 in.
$\frac{1}{2}$ d w ,, ,, ,, ,, 40 in.

Criteria and Performance

The material specification shall prescribe the performance of the material in this test, stating whether the specified value for bow relates to a maximum or a mean.

Sampling

The specification shall prescribe whether inspection for bow is to be on the whole or a portion of the consignment and also the number of specimens to be tested.

18. WATER REPELLENCY—FABRICS

General

This is a simple spray test in which the apparatus and practical operations are clearly defined so that reproducible results are assured. The results of testing are assessed after visual examination and comparison with an arbitrary scale of values ranging from maximum to minimum repellency.

Apparatus

The spray device consists of a glass funnel fixed vertically, with a metal nozzle attached to the end of the stem by a short length of rubber tubing. The stem of the funnel is shortened to about $\frac{3}{4}$ in. so that the face of the nozzle is 3 inches below the neck of the funnel.

The face of the nozzle is $1\frac{1}{2}$ in. in diameter, slightly convex, and with 19 holes drilled with a No. 65 drill (0·035 in.). The perforations are equally distributed over the face of the nozzle, the arrangement comprising a central hole surrounded by two concentric rings of holes. The inner circle is of $\frac{1}{2}$ in. diameter and contains 6 holes. The outer circle is of 1 in. diameter and contains 12 holes. The duration of flow for the test quantity of 250 ml. of water poured into the funnel should be 25-30 seconds and the spray should cover an area of 6 in. diameter at a distance of 6 in. from the nozzle.

The fabric test specimens are supported by clamping in a thin double frame of wood or metal—6 in. square inside dimensions. The fabric frame, when in position for a test, rests loosely on a suitable support so that it is at an angle

of 45 degrees to the stem of the funnel and with the centre of the test area 6 in. vertically below the centre of the spray nozzle.

Testing Procedure

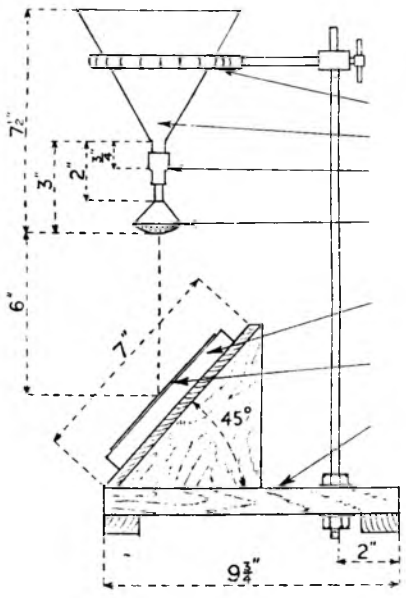
The specimens of fabric for this test (8 in. long) shall be conditioned in the standard atmosphere for 24 hours and the tests carried out immediately afterwards.

The minimum test width of fabric shall be 4 in.

For fabrics narrower than this two or more specimens shall be tested at one time, side by side, to give an effective width of 4 in. or over.

For fabrics wider than 6 in. strips at least 4 in. wide shall be prepared.

To carry out a test the conditioned fabric is mounted in the frame and placed in position below the spray nozzle. Unless contrary instructions are given, the fabric shall normally be placed so that the warp direction is parallel to the flow of water running off the fabric. 250 ml. of water at 70° F. shall then be poured into the funnel, this being done quickly, but steadily, in order that the spraying shall be continuous once it has commenced. Immediately the spray has ceased the fabric frame is removed and tapped smartly six times against a solid object (three taps each on opposite edges of the frame) to remove loosely adhering water from the face of the fabric. During this operation the fabric is held in an almost vertical position but with the test face leaning slightly forward.



Laboratory Ring Support ($3\frac{3}{4}$" inside diameter).

Rubber Covering for Ring Support.

6" Glass Laboratory Funnel

$\frac{3}{8}$" Rubber Tubing.

Spray Nozzle (19 holes Drill No. 65—0·035").

Frame for Clamping Test Specimen of Fabric. (6" sq. inside diameter).

Fabric Specimen to be Tested.

Wooden Support and Stand.

Fig. 2. Apparatus for Water Repellency Test.

Assessment of Results

The performance of the fabric in this test is judged by carefully examining the surface of the test specimen immediately after the test, while still in the clamping frame. The surface of the fabric is viewed by reflected light from both upward and downward directions. The extent of the actual wetting of the surface is noted and also the extent of penetration of the wetting below the surface of the fabric. A comparison is then made with a series of standard spray test ratings and the performance judged thereby. A suitable scale for such a series of standards would be in accordance with the following descriptions:—

100 Surface of fabric remains absolutely dry.
90 Slight random clinging of small droplets to surface.
80 Slight wetting of surface of fabric at points of impingement of the individual spray jets, not exceeding one-third of total surface area.
70 Considerable wetting of surface of fabric, exceeding one-third, but not covering the whole of the test area.
50 The entire surface of the fabric is wetted, but there is little or no penetration to the back.
0 Complete wetting and penetration throughout the test area.

Observation of the effect on the fabric during spraying, and also of the appearance of the globules of water remaining on the surface before subsequent tapping, will provide useful evidence in cases where there is some difficulty in classifying the result between two adjacent ratings in the scale.

Each determination shall be the average of 5 test results.

Criteria

The material specification shall prescribe the appropriate repellency standard for judging this test. In the absence of other determining factors it is recommended that this shall not be below the category of 90 in the above scale.

It is also recommended that wherever possible unproofed samples of the same fabric shall also be subjected to the test, and that the specification shall prescribe the minimum difference of repellency values between the proofed and unproofed fabric.

19. WATER REPELLENCY—YARNS

A small faggot weighing about 10 g. secured with thread at each end, shall be made up from the hanks and placed on the surface of distilled water contained in an open vessel. The water will previously have been heated to a temperature of 140° F. and this temperature shall be maintained throughout the test.

The yarn will be considered satisfactory if the faggot remains floating on the surface of the water for a period of 2 hours.

In case of doubt or dispute the yarn shall be conditioned before testing, as described in Method No. 3(b).

Part II

THE SPECIAL CHARACTERISTICS OF ELASTIC NARROW FABRICS

FOREWORD

In general, tests for the dimensional and physical properties of narrow fabrics, in Part I, shall also be applied as required, but the preparation of the samples for testing shall be as described in Method No. 20, with the single exception of the test for delivery condition which remains as in Method No. 2.

20. CONDITIONING AND PREPARATION OF SAMPLES FOR TESTING (Other than Delivery Condition)

General

Fabrics containing rubber threads continue to retract in length for a considerable time after manufacture, and it is therefore essential to ensure that samples for testing purposes shall be so treated as to bring about satisfactory relaxation before measurement.

Standard Atmosphere

This is defined in the first paragraph of Part I.

(a) **Fabrics.** (**All tests except Determination of Weight per Unit Length**)

Specimens of fabric as required for the various tests shall be prepared from samples which have been allowed to relax for not less than 4 days after taking

from the loom, or from the last finishing process or other source of substantial tension.

The samples shall then be warmed at a temperature of 90° F. for one hour, and shall then be " massaged " by stretching them twelve times to the point of greater resistance.

This treatment shall be followed by conditioning of the freely relaxed samples in the standard atmosphere for one hour.

If the specimens are required to be of definite length they shall then be marked to the requisite degree of accuracy with the aid of a steel rule, and for stretch measurements, a gauge distance shall be suitably marked.

(b) Fabrics (Determination of Weight per Unit Length).

The specimens of fabric shall be prepared as described above, but the time of final conditioning in the standard atmosphere shall be 24 hours.

(c) Rubber Thread

For tests involving measurement of the length of extracted rubber threads, e.g. determination of the unstretched length of the rubber threads in relation to the length in the fabric, or determination of count, the threads shall be withdrawn from 5 in. lengths of fabric prepared from samples which have been treated as described above in Method No. 20(a).

The extracted rubber threads shall be warmed at a temperature of 90° F. for a further period of one hour, and then again conditioned in the standard atmosphere for one hour.

21. RUBBER THREAD CONTENT OF ELASTIC FABRICS

Designation

The rubber thread content of elastic fabrics shall be specified as the total weight of rubber thread in a certain length of the finished fabric which has been relaxed and conditioned as described in Method No. 20(a).

Units

The rubber thread content shall be expressed in pounds and decimals of a pound per gross yards of fabrics.

Testing Procedure

Fabric specimens 5 in. long shall be prepared from samples which have been treated as described in Method No. 20(a).

From each specimen the same number of rubber threads shall be taken and the textile covering removed.

The rubber threads shall then be weighed to within an accuracy of 1 per cent., and from this weight and the knowledge of the total number of rubber threads in the whole width of the fabric the estimated mean weight of rubber per 144 yards shall be calculated.

Sampling and Number of Tests

In the absence of other determining considerations, it is recommended that a unit sample shall consist of one specimen from each of 3 rolls of fabric, and that a total of 36 threads shall be extracted, 12 threads from each roll.

The number of unit samples and the manner of their selection from the consignment shall be prescribed by the specification.

Performance

The material specification shall prescribe the permissible limits of rubber thread content of the fabric by this test.

22. STRETCH CHARACTERISTICS OF ELASTIC FABRICS

General Remarks

The performance of elastic fabrics can be considered under a number of headings, of which the following are the most important from the practical point of view of testing, and the satisfactory service of the material.

The performance when the material is immediately stretched for periods not exceeding about 2 minutes. The material should show an adequate limit of useful extension, and should develop an appropriate tension at this limit and at intermediate stretches both in extension and retraction.

The behaviour when the material is stretched within the limit of useful extension for periods of the order of 18 hours. Here it is a question of the imperfection of the elasticity or flow; a feature more to be expected in material containing synthetic rubber. The material should show a minimum decay of tension when stretched for such a period.

The performance after periods of frequent stretching and relaxing within the limit of useful extension. In such conditions resistance to fatigue is important; otherwise there may be serious loss of stretch characteristics, or even breakdown of the fabric due to actual failure of some or all of the rubber threads. Fabrics containing synthetic rubber are again more likely to be affected, and after such treatment it is essential that the elastic properties should be retained to a useful degree.

The performance after much longer periods of time, of the order of 6 months and upwards. Here it is a question of loss of the desired properties because of chemical changes in the rubber or other elastic constituent of the fabric. The material should show a minimum loss of elasticity when it is stored under certain defined atmospheric conditions.

The following tests in this section are based upon this classification.

23. IMMEDIATE ELASTIC PROPERTIES

General

The following quantities are measured in this test: The stretch ratios S_1, S_2, S_3, etc., developed in the material when it is subjected to loads W_1, W_2, W_3, etc.

The material specification shall prescribe the loads to be applied, but the following recommendations are made:—

(1) The specification shall state the load required to stretch the material to its limit of useful extension or near thereto.

(2) In addition the specification shall prescribe, when considered necessary, certain loads intended to produce intermediate stretch ratios related to the use of the material, by either load-extension or unload-retraction, or both.

(3) The stretch ratio at zero load on completion of a test shall be measured.

Designations

The *stretch ratio* is the ratio of the stretched length of the material to its original unstretched length.

The *Limit of Useful Extension*[2] is the same as the loom stretch or the stretch produced by the tension under which the fabric was woven, and it is the point at which considerably greater resistance is felt when the fabric is stretched between the hands. The method of determining its value is explained in the appendix to this test.

Units

Loads shall be measured in pounds weight and decimals of a pound weight. The stretch ratio shall be expressed decimally.

Testing Procedure

Specimens of fabric for this test shall be prepared as described in Method No. 20(a). For measurements of stretch during the test a distance of 5 inches shall be suitably marked in the middle of each specimen, and the length of the specimens shall be such that when mounted in the testing apparatus there shall be a distance of 3 inches between each end of the marked length and the fixing points.

Loading and unloading shall be performed steadily, each weight being applied or removed gradually.

The load changes shall be effected successively at two minute intervals and the stretch measurements taken at the end of each interval.

Fabrics up to 2 in. wide shall be tested whole-width.

For fabrics wider than this the specimens shall be frayed down to a specified number of rubber ends occupying approximately 2 in.

Sampling and Number of Tests

In the absence of other determining considerations it is recommended that a unit sample shall consist of 3 rolls of fabric and that one specimen from each roll shall be tested.

The number of unit samples and the manner of their selection from the consignment shall be prescribed by the specification.

Criteria

The material specification shall prescribe whether mean values shall be computed or whether all the results shall comply with the performance demanded for the material or whether any other system of compliance of the results with the demands shall be followed.

Performance

The material specification shall prescribe the permissible limits of the stretch ratios which are to be measured by this test.

APPENDIX

Determination of the Limit of Useful Extension

(1) Plot the characteristic curves of the fabric for load-extension and unload-retraction, on any convenient scale.

(2) Draw the tangent to the unload curve from the origin.

(3) Drop a perpendicular from any convenient point P1 on this tangent, to the load axis at A, and mark off on it a height AB equal to 1/5th of the height AP1.

(4) Draw a straight line through OB, and then draw a second tangent to the unload curve parallel to OB.

(5) Read off the extension at the point of contact P2 of the second tangent. This is the limit of useful extension. The load required to produce it is read from the load curve.

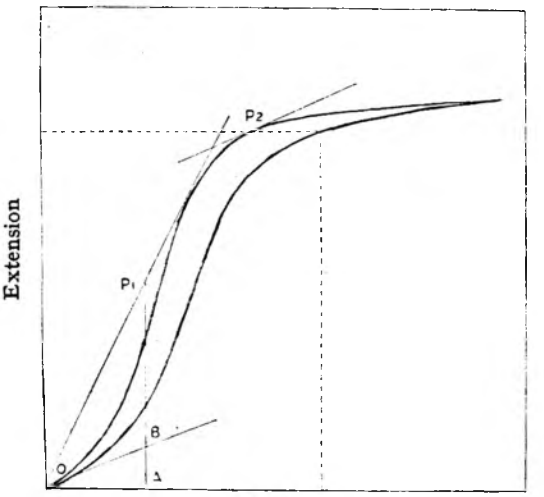


Fig. 3.

24. DECAY OF TENSION AT CONSTANT STRETCH-RATIO

General

The decay of tension in this test is the fall of tension after a certain lapse of time during which a specimen of fabric has been maintained at a constant stretch-ratio. It is measured by the tension-ratio.

The material specification shall prescribe the stretch to be applied.

In the absence of other determining considerations it is recommended that the stretch-ratio for this test shall be the value given by the point of contact of the tangent from the origin to the unload curve.

Designation

The tension-ratio is the ratio of the tension in the specimen at the end of the test, to the tension in the specimen at the start of the test.

Units

The tension-ratio shall be expressed decimally.

Preparation of Test Specimens

All samples of fabric for this test shall be treated as described in Method No. 20(a).

The material may be tested in the form of either bands or single strips. (see Note 1.)

Band specimens are formed from strips of fabric of suitable length by securing their ends together.

An appropriate gauge distance for stretch measurements shall be marked on all test specimens.

In the absence of contrary instructions it is recommended that band specimens shall be prepared from 12½ in. strips of fabric, by stitching the ends of each specimen together with a flat overlap of ½ in., using three rows of hand-sewn stitches. The loop so formed shall be laid flat with the overlap at one end, and marked with a gauge distance of 5 inches.

Specimens for testing in single strip form shall be 7 in. long unless otherwise prescribed and the gauge distance of 5 inches shall be marked centrally on each specimen.

Fabrics up to 2 in. wide shall be tested whole width.

For fabrics wider than 2 in., and in the absence of other deciding factors, it is recommended that the specimens shall be frayed down to a specified number of rubber ends occupying approximately 2 in.

Apparatus

The apparatus shall comprise suitable means for maintaining the test specimens at any specified stretch-ratio, and for measuring the tension in the stretched specimens. The diagram illustrates a typical form of apparatus which has given satisfactory results in practical tests.

Band specimens are stretched by two brass bars of not greater than ¼ in. diameter. The upper bar, b1, is rigidly held by a brass boss, B1, on a ½ in. mild steel rod R. The lower bar, b2, is held by a brass shackle, S, having a lower aperture through which passes another brass bar of ¼ in. diameter, b3, held by an adjustable boss, B2, on the rod R. The sides of the aperture have insulating cheeks of suitable material. The boss B2 is provided with a terminal, T, so that connection can be made to a 2-volt accumulator. Another wire has one end held in contact with the shackle by being bound under one of the knurled nuts which secure the bar b4 in the shackle. This wire is connected to the accumulator via a 2·5V flash lamp bulb and switch. With this arrangement it is possible to see whether the bar b3 is in contact with the bar b4. It is necessary to keep the brass surfaces clean, otherwise the visual warning device may fail to operate. A hook, H, below the bottom plate of the shackle allows tension to be applied to the specimen by a hanger and deadweights and by a 1 kg. spring balance reading to 0·01 kg. When the tension so applied is just in excess of the tension in the specimen, the latter extends slightly and so breaks the contact between the bars. When stretched specimens are to be stored over-

night for the duration of the test, they can be removed by detaching the rod R assembly after removal of the hanger weights and spring balance. Further specimens can then be tested simultaneously by the use of additional rods and fittings. Strip specimens are tested by the use of suitable non-slip grips which slide on the bars b1 and b2.

Testing Procedure

When inserting test specimens in the apparatus single strips are fixed so that the gauge marks are clear of the grips; and band specimens are set so that the stitched overlap lies over one of the end supports. The tests shall be carried out under standard atmospheric conditions as described in Part I. Each specimen is brought to the required stretch-ratio, using the gauge marks for measurement, and the apparatus is then clamped in that position. The initial tension in the specimen is measured at the end of 2 minutes after applying the stretch. The specimen is then maintained in the stretched state for a period of 18 hours (see Note 2), after which the tension is again measured. The gauge distance is measured on the relaxed sample after a specified lapse of time, for comparison with the original length before the test.

NOTE 1.—It has been shown that there is no practical difference for the purposes of this test, in the results given by the two types of specimen.

NOTE 2.—Tension decay continues for a considerable time, if not indefinitely. In the absence of other decisive considerations it is recommended that 18 hours shall be specified for the duration of this test. This gives characteristic results and is also closely related to the conditions of use of many elastic materials.

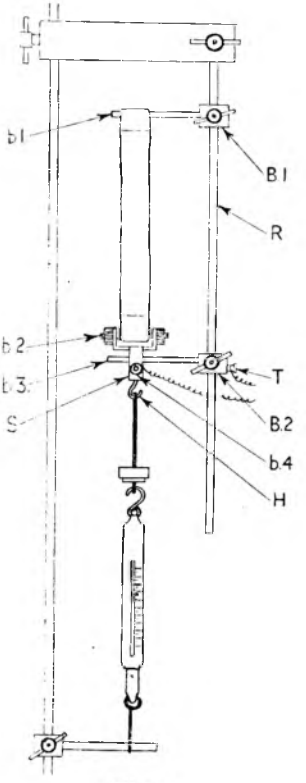


Fig. 4.

Sampling and Number of Tests

In the absence of other determining considerations it is recommended that a unit sample shall consist of three rolls and that one specimen from each roll shall be tested. The number of unit samples and the manner of their selection from the consignment shall be prescribed by the specification.

Criteria

The material specification shall prescribe whether mean values shall be computed or whether all the results shall comply with the performance demanded for the material, or whether any other system of compliance of the results with the demands shall be followed.

Performance

The material specification shall prescribe the permissible limits of the tension ratio of the material.

25. FATIGUE OF ELASTIC FABRICS

General

Specimens of fabric are subjected to repeated stretching, after which the effects on the properties of the material are examined.

Testing Procedure

Specimens of fabric for this test shall be prepared as described in Method No. 20(a).

The specimens shall first be mounted so that they are at zero tension, but not slack, and shall then be repeatedly stretched by suitable mechanical means

to the limit of useful extension, at a rate of 60 to 100 oscillations per minute, for a specified number of oscillations.

The specimens shall then be subjected to one or more of the following tests:

(1) Measurement of the length (over a previously marked portion), at zero tension, for comparison with the length before the fatigue treatment.

(2) Test for immediate elastic properties.

(3) Test for decay of tension.

The material specification shall prescribe the number of oscillations to be applied in this test, and shall prescribe the appropriate tests to be applied after the treatment.

Sampling and Number of Tests

In the absence of other determining considerations it is recommended that a unit sample shall consist of 3 rolls, and that a sufficient number of specimens shall be subjected to the fatigue treatment to enable each of the subsequent tests to be applied to one specimen from each of the 3 rolls. The number of unit samples and the manner of their selection from the consignment shall be prescribed by the specification.

Criteria

The material specification shall prescribe whether mean values are to be computed or whether all the results shall comply with the performance demanded for the material, or whether any other system of compliance of the results with the demands shall be followed.

Performance

The material specification shall prescribe the performance of the fabric in this test.

26. AGEING TEST

General

Specimens of fabric are aged by a prescribed heating treatment in air, and are afterwards submitted to various tests to determine any deterioration in their properties.

Ageing Treatment

The fabric specimens for this test shall be prepared as described in Method No. 20(a).

The specimens shall then be heated in an electrically heated dark oven at a temperature of 70° C. ± 1° for 240 hours.

The total volume of the specimens shall not exceed 5 per cent. of the air space of the oven. The air shall circulate freely on both sides of the specimens; this may be achieved by a forced circulation of the air around suspended specimens, or by mounting the specimens on a cage which can be revolved in the oven. The oven shall be ventilated by devices dependent upon natural convection or by the deliberate introduction of a slow stream of fresh air equivalent to a complete change of air about three times per hour.

After removal from the oven the specimens shall be allowed to relax freely and condition for 24 hours in the standard atmosphere.

Testing of Aged Specimens

The material specification shall prescribe the tests to be carried out after the above treatment. One or more of the following tests may be prescribed:— (1) Test for Immediate Elastic Properties. (2) Test for Tension Decay. (3) Fatigue Test. In addition, or alternatively, the following tensile test may be prescribed:—

The specimens shall be stretched in a tensile testing machine to the point of rupture of the textile warp threads. Such rupture shall take place in about one minute. The breaking load shall be observed and any breakage of the elastic threads at this point shall also be noted.

Sampling and Number of Tests

In the absence of other determining considerations it is recommended that a unit sample shall consist of 3 rolls and that sufficient specimens shall be aged to enable each of the subsequent tests to be applied to one specimen from each of the 3 rolls. The number of unit samples and the manner of their selection from the consignment shall be prescribed by the specification.

Criteria

The material specification shall prescribe whether mean values shall be computed or whether all the results shall comply with the performance demanded for the material, or whether any other system of compliance of the results with the demands shall be followed.

Performance

Test of Immediate Elastic Properties and *Test for Tension Decay at Constant Stretch-Ratio.* The performance shall be demanded in the form already described for those tests; the numerical values of the permissible limits will, however, require to be appropriately adjusted for the aged material.

Tensile Test. The material specification shall prescribe the permissible breaking load for the textile threads, and may demand that none of the elastic threads shall have broken under this load.

27. APPLICATION OF ADDITIONAL TESTS TO ELASTIC FABRICS

Any or all of the Chemical Tests and Colour Fastness Tests in Parts Three and Four of these proposals may be required by the material specification for an elastic fabric.

After such tests have been carried out, one or more of the following tests may be prescribed:—

Test for Immediate Elastic Properties.
Test for Tension Decay.
Fatigue Test.
Tensile Strength Test.

Part III

CHEMICAL TESTS

28. *p*H VALUE OF AQUEOUS EXTRACT, ACIDITY AND ALKALINITY

Preparation of Extract

10 g. of the sample, cut into pieces $\frac{1}{2}$ in. square or less if practicable, shall be boiled in 200 ml. of distilled water for $\frac{1}{2}$ hour. After decanting the extract, the fabric residue shall be twice re-extracted, each time with 100 ml. of distilled water for 15 minutes at the boil. The combined extracts shall be filtered, if necessary, and after cooling, made up to 400 ml. with boiled out distilled water.

Testing for *p*H Value

The *p*H value of the aqueous extract shall be determined by a standard method, either electrometrically, or by the use of appropriate indicators.

The material specification shall prescribe the appropriate *p*H range. Alternatively, in certain cases, the specification may prescribe a maximum permissible amount of acidity, calculated as sulphuric acid, or of alkalinity, calculated as sodium carbonate, determined by titration to a stated *p*H value. In such cases, titration may be either electrometric, to the stated *p*H value, or by the use of suitable or specified indicators.

Blank Test on the Water

This must be carried out under identical conditions and the necessary corrections applied.

29. TOTAL WATER-SOLUBLE MATTER

An aliquot portion of filtered extract prepared as described in Method No. 28, shall be evaporated to dryness on a steam bath. The residue shall then be dried to constant weight in an oven at a temperature of 105°-110° C., and its percentage weight in relation to the conditioned weight of the fabric calculated.

30. WATER-SOLUBLE CHLORIDES

Method No. 1

10 ml. of extract prepared as described in Method No. 28, shall be transferred to a suitable vessel and a few drops of 2N-nitric acid are added.

A similar vessel containing a saturated solution of silver chloride in water to which a few drops of 2N-nitric acid and a few ml. of N-ammonium nitrate have been added, is connected to the first vessel by means of a suitable bridge. (See appendix.)

A stout silver wire electrode is placed in each vessel, and the cell so formed is connected in series with a tapping key and a galvanometer. N-100 silver nitrate is run into the extract solution, closing the circuit momentarily by means of the key, after each addition. The end point is indicated by a reversal of the galvanometer deflection.

Appendix

A suitable bridge for use in the above test consists of a U tube of $\frac{1}{4}$ in. glass tubing with legs about 2 ins. long. A solution of 3 per cent. agar in N-ammonium nitrate is allowed to set in the bend of the tube. Then the legs of the tube are filled with a solution of N-ammonium nitrate. The ends of the tube are plugged with rolls of filter paper.

Alternatively the following method may be employed:—

Method No. 2

10 ml. of extract prepared as described in Method No. 28 shall be transferred to a 150 ml. beaker, diluted to 60 ml. with distilled water, and 1 ml. of 5 per cent. nitric acid added. Stir thoroughly and filter through a Whatman No. 42 paper into a 100 ml. Nessler tube, washing twice with distilled water. Make up to 100 ml. with distilled water and add 1 ml. of 0·1 per cent. aqueous solution of silver nitrate. Stir thoroughly and compare the turbidity with a series of standards prepared at the same time under similar conditions.

31. WATER-SOLUBLE SULPHATES

400 ml. of extract shall be prepared from 10 g. of the material as described in Method No. 28. The solution is filtered, and 3 ml. of concentrated hydrochloric acid are added. The solution is then brought to the boil and 10 ml. of a boiling 2 per cent. solution of barium chloride is added, drop by drop. The boiling shall be continued until the precipitate coagulates. Allow the mixture to cool overnight and weigh the barium sulphate in the usual manner.

32. WATER-SOLUBLE PHOSPHATES

General

This is estimated as ammonium di-hydrogen phosphate volumetrically by titration with uranium acetate solution.

Method

200 ml. of extract prepared as described in Method No. 28 shall be titrated with standard uranium acetate solution which is made up by dissolving 15 g. of uranium acetate in 500 ml. of water to which are added 17 ml. of glacial acetic acid.

1 ml. of uranium acetate solution $\equiv$ 0·007 g. $(NH_4)H_2PO_4$

This is standardised against di-ammonium phosphate (A.R. quality) as follows:—

The uranium acetate solution is titrated into the extract solution until the end point is almost reached (pre-determined by a rough titration), then the solution is just raised to the boil and the titration completed. A 5 per cent. potassium ferro-cyanide solution is used as external indicator, the first brownish colouration being the end point.

33. EXTRACTION WITH OTHER SOLVENTS

General

The determination of matter extractable by the various organic solvents shall be carried out by the following standard method:—

Method

5 g. of the material shall be extracted for four hours in a Soxhlet extractor. The solution is then filtered, if necessary, and evaporated, and the residue dried to constant weight at a temperature of 105-110° C.

The method shall be applicable to any of the following solvents: ether, methylene chloride, alcohol, benzene-methyl alcohol mixture.

34. SOLUBLE CHROMIUM

Foreword

In those cases where proofing of fabrics against attack by micro-organisms is carried out by impregnation with chromium and iron salt solutions, followed by development with potassium chromate, the active proofing principle on the fibre is hexavalent chromium. The latter is estimated by the method described below for soluble chromium-hexavalent.

Extraction Procedure

A quantity of the material is well shredded. A portion (2·5 g.) is then weighed out into a 100 ml. conical flask, 50 ml. of extracting liquor are added (*p*H 7·8 borax/boric acid, for wool; *p*H 9·2 M20-borax for cotton and flax). The conical flask is weighed and the total weight noted. The contents of the flask are then maintained at 40° C. for 30 minutes with occasional shaking, then cooled, and any loss in weight by evaporation replaced by distilled water. The textile material is then removed by filtering through a Whatman No. 44 filter paper, and the chromium content of the solution determined.

(a) Soluble Chromium—Hexavalent

10 ml. of the filtrate are treated with 1 ml. of diphenylcarbazide reagent (an 0·2 per cent. solution in a mixture of glacial acetic acid—1 part, and rectified spirit—9 parts) followed by 2 ml. of 2N-sulphuric acid. The solution is made up to 50 ml. in a graduated flask. A standard chromium solution containing 0·00001 g. of Cr^{vi} per ml. (0·0283 g. of $K_2Cr_2O_7$ per litre) is prepared, and a set of colorimetric standards obtained by taking, respectively, 1, 2 and 3 ml. of this solution and treating after dilution with 1 ml. of the diphenylcarbazide reagent and 2 ml. of 2N-sulphuric acid. The volumes are then made up to 50 ml. in graduated flasks. After 15 minutes the solution prepared from the fabric and the nearest of the three standards are matched in a suitable colorimeter, using a depth of 30 mm. for the standard and varying the depth of the sample until the fields match. If the depth of the sample is less than 25 mm. or more than 35 mm. an adjustment must be made in the volume of the filtered extract taken. The volume of the extract in ml. to be taken in the final matching will be 10 × depth of sample/depth of standard. Assuming that a 2 ml. chromium standard has been employed to match the colour generated from 10 ml. of the cloth extract solution, the result in p.p.m. of Cr^{vi} on the air-dry weight of the fabric is calculated as follows:—

$$Cr^{vi}\ \text{p.p.m.} = 0{\cdot}00002 \times \frac{\text{depth of standard}}{\text{depth of sample}} \times \frac{50}{10} \times \frac{10^6}{2{\cdot}5}$$

(b) Total Soluble Chromium

A volume of the filtrate equal to that finally taken in the previous determination is treated with 0·5 ml. of water saturated with bromine and then with 2N-sodium hydroxide until the colour has discharged and two drops have been added in excess. After 1 minute, 1 ml. of an 0·7 per cent. solution of phenol, 1 ml. of the diphenylcarbazide reagent, and 2 ml. of 2N-sulphuric acid are added. The volume is then made up to 50 ml. with distilled water. After 15 minutes, the colour is matched against the standards as already described.

35. IRON, CHROMIUM, COPPER—PRELIMINARY SEPARATION METHODS

General

The methods for the analysis of fabrics containing iron, chromium and/or copper depend upon the number of metals in the material and the quantities in which they are present. The separation of the constituents to be determined usually presents more difficulty than their estimation and it has therefore been deemed advisable to give the procedure in some detail. The following methods of analysis will cover the majority of cases, but instances may arise of difficulty in the dissolution of metals after the preliminary ashing or of difficulties introduced by the presence of silica (e.g. from china clay in sizing) or of metals other than those listed. It is desirable, therefore, that all analyses should be carried out by, or under the direction of an experienced analyst.

(a) Copper content large; iron and chromium absent

The material (5 g.) is dried at 110° C., weighed, transferred to a 55 mm. silica or porcelain crucible and ashed in a muffle furnace at incipient red heat (450° C.). The ash is dissolved by heating with 2N-sulphuric acid, the solution transferred to a conical flask, filtering if necessary, and the copper determined by Method No. 38(a).

(b) Copper content small; iron and chromium absent

The sampled material (1 or 2 g.) is dried at 110° C., weighed and ashed in a silica or porcelain crucible at incipient red heat. The ash is digested with aqua regia, the solution evaporated to dryness, the residue moistened with a few drops of 0·2N-hydrochloric acid, and evaporated again. It is then dissolved in 0·2N-hydrochloric acid, filtered if necessary, and made up to 100 ml. Copper is then determined by Method No. 38(b).

(c) Iron present; copper and chromium absent

The sampled material (1 or 2 g.) is dried at 110° C., weighed and ashed in a silica or porcelain crucible at dull red heat. The ash is digested with 5 ml. of concentrated hydrochloric acid until the ferric oxide has dissolved completely, and the solution evaporated to dryness. The residue is dissolved in N-hydrochloric acid and transferred to a 250 ml. conical flask, filtering if necessary. If the iron content is large it is determined by Method No. 36(a). If the iron content is small, the filtrate is made up to 100 ml. in a graduated flask and the iron determined by Method No. 36(b).

(d) Chromium present; iron and copper absent

The sampled material (1 or 2 g.) is dried at 110° C., weighed and ashed in a silica or porcelain crucible at dull red heat. The ash is digested with concentrated nitric acid (5 ml.) and A.R. potassium chlorate (0·3 g.), the crucible being covered with a watch-glass during the process. After the chromic oxide has dissolved, the contents of the crucible are evaporated to dryness, treated with 5 ml. of 2N-sulphuric acid and evaporated to dryness again. The residue is then treated with 2N-sulphuric acid and transferred to a 250 ml. conical flask, filtering if necessary. If the chromium content is large it is determined by Method No. 37(a). If the chromium content is small, the solution is made up to 100 or 250 ml. and analysed by Method No. 37(b).

(e) Iron and chromium present; copper absent

The sampled material (1 or 2 g.) is dried at 110° C., weighed and ashed in a muffle furnace at dull red heat in a 55 mm. silica or porcelain crucible. Concentrated nitric acid (5 ml.) and potassium chlorate A.R. (0·3 g.) are added and the crucible is heated on a boiling water bath until a clear solution or one containing only a white residue of silica is obtained. After evaporation to dryness the residue is dissolved in dilute sulphuric acid (5 ml.) and the solution again evaporated to dryness. The residue is then dissolved in dilute sulphuric acid and transferred to a 250 ml. conical flask, filtering to remove silica if necessary. The filtrate is brought to the boil and sufficient 2N-sodium hydroxide is added to precipitate the iron as ferric hydroxide and afford an excess of approximately 10 ml. The flask is then closed with a pear bulb stopper and the solution boiled for one minute before filtering through a No. 541 Whatman filter paper. The filtrate containing the chromium as sodium chromate, is acidified with sulphuric acid and analysed by Method No. 37(a) or (b), according to the quantity present. If Method (b) is used the acidified solution is cooled and made up to 250 ml. in a graduated flask.

The ferric hydroxide precipitate is dissolved in hot N-hydrochloric acid and the solution cooled. If the amount of iron is large it is estimated by Method No. 36(a). If the iron content is small the solution is made up to 250 ml. and Method No. 36(b) employed.

(f) Copper and chromium present; iron absent

The sampled material (1 to 5 g. according to the anticipated copper and chromium contents) is dried at 110° C., weighed and ashed in a muffle furnace at incipient red heat in a silica or porcelain crucible. Concentrated nitric acid (5 ml.) and A.R. potassium chlorate (0·3 g.) are added and the crucible is covered with a watch-glass and heated on a boiling water bath until solution is complete except for any silica which may be present. The solution is evaporated to dryness, 1 ml. of concentrated hydrochloric acid is added, and the solution again evaporated to dryness. The residue is then treated with 0·2N-hydrochloric acid and the solution transferred to a 60 ml. beaker, filtering through a No. 44 Whatman filter paper if necessary. The copper is then precipitated with hydrogen sulphide in the cold and, after heating on the water bath, the gas is passed into the solution again to ensure complete precipitation: the supply is then disconnected leaving the glass tube in the beaker. The copper sulphide is filtered off through a No. 44 paper and well washed with distilled water saturated with hydrogen sulphide. Traces of copper sulphide adhering to the beaker and tube are dissolved in 2 ml. of aqua regia and the beaker is heated on the water bath until effervescence ceases. The solution is then transferred to the crucible in which the filter paper containing the copper sulphide has been ashed. The beaker and tube are washed with 1 ml. portions of aqua regia, which are transferred to the crucible, the combined solution being evaporated to dryness. If the amount of copper is large the residue is dissolved in 2N-sulphuric acid, the solution transferred to a 250 ml. conical flask, filtering if necessary, and the copper is determined by Method No. 38(a). If the quantity of copper sulphide is only small the residue is taken up in 0·2N-hydrochloric acid and the solution is transferred to a 100 ml. or 250 ml. graduated flask, filtering if necessary through a No. 44 Whatman paper. The copper is then determined by Method No. 38(b).

The filtrate from the copper sulphide, containing the chromium is boiled in a conical flask closed with a pear bulb stopper until free from hydrogen sulphide. The solution is then cooled and treated successively with 100 volume hydrogen peroxide (3 ml.) and an excess of 2N-sodium hydroxide. It is then heated on a water bath until effervescence has subsided, 5 ml. of a 5 per cent. solution of nickel sulphate are added and the solution is boiled for 5 minutes, cooled and acidified with concentrated sulphuric acid (10 ml.). Chromium is then determined by Method No. 37(a).

If the quantity of chromium is small, the solution which has been boiled to remove hydrogen sulphide is cooled, acidified with 2N-sulphuric acid and made up to 250 ml. in a graduated flask. The chromium is then determined by Method No. 37(b).

(g) Iron and copper present; chromium absent

The sampled material (1 or 2 g.) is dried at 110° C., weighed and ashed in a muffle furnace at incipient red heat in a silica or porcelain crucible. The ash is dissolved in aqua regia, and when effervescence has ceased, the watch-glass cover is removed and the solution evaporated to dryness. The residue is dissolved in 0·2N-hydrochloric acid and the solution transferred to a 60 ml. beaker filtering if necessary. Copper is then precipitated and separated as described in Method No. 35(f).

The filtrate from the copper sulphide is boiled until free from hydrogen sulphide, the mouth of the 250 ml. conical flask being closed with a pear bulb stopper. The solution is made approximately N in hydrochloric acid and the iron determined by Method No. 36(a) if it is present in quantity. If only traces are present, the solution is cooled and made up to 100 ml. or 250 ml. in a graduated flask. The iron is then determined by Method No. 36(b).

(h) Iron copper and chromium all present

The sampled material (1 or 2 g. according to the anticipated content of metallic oxides) is dried at 110° C., weighed and ashed in a muffle furnace at incipient red heat. The ash is dissolved by warming with a mixture of concentrated nitric acid (5 ml.) and A.R. potassium chlorate (0·3 g.) and the solution evaporated to dryness. The residue is treated with concentrated hydrochloric acid (1 ml.) and the solution evaporated to dryness again. The residue is dissolved in 0·2N-hydrochloric acid and, after filtering off any silica that may be present, copper is separated and determined as described in Method No. 35(f).

The filtrate from the copper sulphide, contained in a conical flask closed with a pear bulb stopper, is boiled until free from hydrogen sulphide. 100-volume hydrogen peroxide (3 ml.) and an excess of 2N-sodium hydroxide are added and the flask is heated on a water bath until effervescence has subsided. The precipitated ferric hydroxide is filtered off, washed with boiling distilled water, and redissolved in hot N-hydrochloric acid. If the iron content is large, this solution is analysed by Method No. 36(a). If the iron content is small, the solution is cooled and made up to 250 ml. in a graduated flask before analysis by Method No. 36(b).

The filtrate containing the chromium as sodium chromate is acidified with 2N-sulphuric acid and, if the content is small, it is made up to 250 ml. in a graduated flask and determined by Method No. 37(b). If the chromium content is large, the solution is treated with a 5 per cent. solution of nickel sulphate (5 ml.), boiled for 5 minutes, cooled, acidified with concentrated sulphuric acid (10 ml.) and the chromium determined by Method No. 37(a).

36. IRON

(a) Macro-method

The solution of iron in N-hydrochloric acid is passed through a silver reductor* and collected in a 600 ml. conical flask. The reductor is washed with 150 ml. of N-hydrochloric acid and the combined filtrate and washings titrated with 0·2N-ceric sulphate using 0·5 ml. of 0·02M-orthophenanthroline-ferrous sulphate as indicator.

The indicator is prepared by dissolving 0·3 g. of *o*-phenanthroline and 0·14 g. of ferrous sulphate in 250 ml. of water.

A blank titration is made on 150 ml. of the N-hydrochloric acid after passing through the reductor and any necessary corrections applied.

1 ml. of 0·02N-ceric sulphate $\equiv$ 0·001597 g. Fe_2O_3
$\equiv$ 0·001117 g. Fe

*Walden, Hammett and Edmonds. *J. Amer. Chem. Soc.*, 1934, **56**, 350.

(b) Micro-method

An aliquot part of the iron solution is diluted to 45 ml. with distilled water in a 50 ml. measuring flask, treated with 3 drops of thioglycollic acid, and the solution mixed thoroughly. Ammonium hydroxide (2 ml.) is then added and the volume adjusted to 50 ml. A suitable depth of shade for colorimetric comparison is given by a solution containing 0·0001 g. of iron in 50 ml. The amount of the test solution to be used for the final matching should therefore be determined by preliminary comparisons with a solution prepared in this way. The comparison is made in a suitable colorimeter with the standard at a depth of 30 mm.

37. CHROMIUM

(a) Macro-method

The sodium dichromate solution is titrated with 0·1N-ferrous ammonium sulphate using phenylanthranilic acid as indicator.

1 ml. of 0·1N-ferrous ammonium sulphate $\equiv$ 0·002534 g. Cr_2O_3
$\equiv$ 0·001733 g. Cr

The indicator is prepared by dissolving 1·065 g. of phenylanthranilic acid in hot water containing 0·53 g. of A.R. sodium carbonate, and diluting to 1,000 ml.

(b) Micro-method

A suitable aliquot part of the dilute chromium solution is transferred to a 50 ml. graduated flask, diluted to 40 ml. and treated with 1 ml. of saturated bromine water. 2N-sodium hydroxide is then added drop by drop, until the yellow colour disappears and there are two drops in excess. After 1 minute 1 ml. of 0·68 per cent. phenol, 1 ml. of 0·2 per cent. diphenylcarbazide (in a mixture of acetic acid 10 per cent. and rectified spirits 90 per cent.) and 2 ml. of 2N-sulphuric acid are added in this order. The volume is adjusted to 50 ml. and after mixing thoroughly, the solution is matched against standards prepared from a chromium solution containing 0·00001 g. of chromium per ml. A depth of shade suitable for matching in the colorimeter is obtained with 2 ml. of standard chromium solution treated in the above manner and diluted to 50 ml. If possible, the volume of the test solution used should be adjusted by preliminary trials to give a depth of shade close to the standard. Should this be impossible a 1 ml. standard must be employed.

38. COPPER

(a) Macro-method*

Potassium iodide (2 to 3 g.) is added to the solution of copper in 2N-sulphuric acid. After 5 minutes it is diluted with distilled water and the liberated iodine titrated with 0·1N-sodium thiosulphate until the colour has almost disappeared. A few drops of a freshly prepared solution of soluble starch are then added and the titration continued until the solution is nearly, but not quite colourless. Ammonium thiocyanate (2 g.) is then dissolved in the solution and the titration continued until the blue colour disappears completely.

1 ml. of 0·1N-sodium thiosulphate $\equiv$ 0·006357 g. of copper.

If only a small amount of yarn or fabric is available or the copper content is low, 0·01N-sodium thiosulphate may be used instead. If this is done it is preferable to add the ammonium thiocyanate at the beginning of the titration.

(b) Micro-Method

A suitable aliquot part of the dilute copper solution is transferred to a 50 ml. measuring flask and treated successively with 10 ml., of a 4 per cent. solution of sodium pyrophosphate, 5 ml. of a freshly prepared 1 per cent. solution of gum arabic, 1 ml. of a 0·2 per cent. solution of sodium diethyldithiocarbamate and 1 ml. of 0·880 ammonia before making up to volume. The colour of the solution is matched against standards prepared similarly from a copper solution

*Foote and Vance. *J. Amer. Chem. Soc.*, 1935, **57**, 445.

containing 0·00001 g. of copper per ml. in a suitable colorimeter, a 10 ml. copper standard at a depth of 30 mm. giving a suitable average colour density.

39. MANGANESE

(a) Manganese in presence of copper; no other metals being present in appreciable amount. (Materials intended for rubber proofing).

The sampled material (10 g.) is dried at 110° C., weighed, transferred to a large crucible or silica dish and ashed at incipient red heat in a muffle furnace. The ash is dissolved in aqua regia, the solution evaporated to dryness and transferred to a small beaker with 0·2N-hydrochloric acid. Hydrogen sulphide is then passed into the solution first in the cold and again after boiling and the precipitate filtered off using a No. 44 Whatman filter paper. After washing with distilled water saturated with hydrogen sulphide, the paper is dried, ashed in a porcelain crucible and treated with a small quantity of aqua regia which has been previously used to wash the beaker and the tube used in the precipitation. After evaporation to dryness the residue is taken up in 0·2N-hydrochloric acid and the solution transferred to a graduated flask (50 ml. or 100 ml. according to the anticipated copper content) and the copper determined by Method No. 38(b).

The filtrate and washings from the precipitation of copper sulphide are evaporated to dryness, moistened with concentrated sulphuric acid and a few drops of concentrated nitric acid, and heated cautiously over a flame until fuming is observed. The residue is diluted with distilled water and transferred, filtering if necessary, into a conical flask (100 ml.), the volume being adjusted to about 30 ml. Concentrated sulphuric acid (8 ml.) and potassium periodate (0·3 g.) are then added and the solution is boiled for about 1 minute and then heated for 15 minutes on a steam bath. After cooling, the solution is made up to a definite volume according to its colour and compared in a colorimeter with a suitable standard prepared by oxidation of a standard solution of manganese under similar conditions.

To prepare a standard solution of manganese, potassium permanganate (0·2877 g.) equivalent to 0·1 g. manganese, is dissolved in 300 ml. of water, the solution being acidified with 2N-sulphuric acid (2 ml.) and treated with sulphur dioxide until decolourised completely. The excess of sulphur dioxide is then removed by boiling and the solution cooled and diluted to 1 litre. This solution is finally diluted tenfold, so that the final manganese content is 0·00001 g. per ml.

(b) Manganese in presence of iron, chromium, copper

Method No. 35(h) is followed up to the end of the removal of copper by means of hydrogen sulphide, with the exception that 5 g. of the material should be employed. The filtrate from the copper sulphide contained in a conical flask is boiled until free from hydrogen sulphide, neutralised with sodium carbonate, acidified faintly with hydrochloric acid, after which an excess of finely divided barium carbonate is added and the mixture shaken for 2 hours. The iron and chromium are absorbed completely in the carbonate and removed by filtration. The filtrate and washings are then evaporated to dryness, heated with concentrated sulphuric acid and a little nitric acid to remove chlorides and analysed for manganese as in Method No. 39(a).

40. ZINC

Extraction procedure

10 g. of the material, cut into small pieces and thoroughly sampled, are digested for 30 minutes with 130 ml. of water and 20 ml. of N-hydrochloric acid in a 250 ml. conical flask immersed in an actively boiling water bath. The extract is filtered by suction through a No. 1 Whatman filter paper and the material well pressed and washed with four portions of 20 ml. of boiling distilled water. The filtrate and washings are cooled and made up to 250 ml.

Method

100 ml. of the solution are transferred to a 500 ml. conical flask and treated with 2N-ammonium hydroxide solution until just alkaline to methyl red. 10 ml. of 2N-ammonium chloride solution, 25 ml. of N-sodium acetate solution and 6 ml. of N-acetic acid are added and the solution diluted to 190 ml. with distilled water after heating to 70° C. 9 ml. of 2 per cent. oxine in N-acetic acid are added and the solution brought to the boil. The flask, loosely stoppered, is then placed on a steam bath for 30 minutes. The solution is then filtered through a No. 41 or No. 541 Whatman filter paper, the flask washed out with hot water and the precipitate washed a further three times on the filter. The precipitate on the filter and any residue adhering to the sides of the flask are dissolved in 100 ml. of boiling 2N-hydrochloric acid and the solution collected in a 250 ml. long necked flask. After cooling, 1 ml. of methyl red indicator (0·005 per cent. M.R. in 80 per cent. alcohol) is added, and 0·1 N-potassium bromate-bromide solution (2·784 g. potassium bromate and 12 g. potassium bromide per litre) is run in from a burette until the colour of the solution is sulphur yellow. A further 1 ml. of indicator is then added and the process continued until a 1 ml. portion of the indicator is decolourised immediately. This second stage of the titration should not take up more than a few ml. of the potassium bromate-bromide solution. The burette is then adjusted to a convenient mark and the reading noted. The solution is allowed to stand for 2 minutes to ensure complete bromination of the oxine and the excess bromine is then determined by adding 5 ml. of 20 per cent. potassium iodide solution and titrating the liberated iodine with 0·1 N-sodium thiosulphate solution, using a 1 per cent. solution of soluble starch as indicator. The back titration should not exceed 2 ml.

1 ml. of 0·1 N-potassium bromate-bromide solution $\equiv$ 0·0008166 g. zinc.

If the titration with 0·1 N-potassium bromate-bromide solution exceeds 35 ml. the estimation must be repeated using 50 ml. of extract solution instead of 100 ml. This is necessary only when the zinc content is greater than 0·72 per cent.

41. LEAD

Incinerate 10 g. of shredded material in a porcelain crucible at low temperature to avoid loss of lead by fusion into the glaze of the crucible or by volatilisation, until all carbonaceous matter is destroyed. Cool and transfer to a 100 ml. beaker. Wash the crucible with small successive quantities of dilute nitric acid (1 volume nitric acid to 2 volumes distilled water) to remove any adherent ash. Make up the solution to approximately 50 ml. with dilute nitric acid and boil for half an hour. Filter through a No. 40 Whatman filter paper into a 600 ml. beaker and wash the beaker and filter paper with hot distilled water. Add 5 ml. of concentrated sulphuric acid (A.R.) to the filtrate and evaporate the solution until sulphuric acid is freely evolved.

Cool, add cautiously about 150 ml. of distilled water and boil the solution for five minutes. Allow to stand overnight at laboratory temperature.

Filter the precipitate through a No. 42 Whatman filter paper and wash several times with 2 per cent. sulphuric acid solution. Boil the paper and precipitate with 20-30 g. of ammonium acetate dissolved in 50 ml. of distilled water in a tall 250 ml. beaker for about half an hour. Filter through a No. 40 Whatman filter paper into a tall 250 ml. beaker and wash the filter paper thoroughly with hot distilled water.

Pass hydrogen sulphide into the filtrate for 10 minutes, stand the beaker on a water bath to coagulate the precipitate of lead sulphide and re-saturate with hydrogen sulphide. Cool and filter through a No. 42 Whatman filter paper and wash with hydrogen sulphide water. Dissolve the precipitate in hot dilute nitric acid and wash the filter paper with hot distilled water. Collect the solution and washings in a 600 ml. beaker and add 5 ml. of concentrated sulphuric

acid (A.R.). Evaporate to fuming, dilute boil and allow to stand overnight as before.

Filter the precipitate on to a G.4 sintered glass crucible (previously washed with hot ammonium acetate solution then hot distilled water, dried at 130° C. and weighed). Wash thoroughly with 2 per cent. sulphuric acid and then finally with methylated spirit. Dry at 130° C. to constant weight.

Extract the contents of the crucible thoroughly with hot ammonium acetate solution and finally wash with hot distilled water. Dry at 130° C. and re-weigh.

Calculate the amount of lead sulphate (the difference between the weight of the crucible before and after extraction with ammonium solution) to percentage metallic lead on the sample.

42. PARANITROPHENOL

Extraction procedure—Solution "A"

A sample, roughly 10 g. of the material to be analysed is cut up into ¼ in. squares. These are mixed well and 2·66 g. (equivalent to 2·50 g. dry cloth) are placed in a glass stoppered 100 ml. conical flask, 50 ml. of N-10 sodium hydroxide are added and the whole weighed.

A glass pear bulb is then substituted temporarily for the stopper and the alkali is just brought to the boil in order to wet out the cotton thoroughly. After cooling, the glass stopper is replaced, the weight adjusted to the original, and the flask is shaken at intervals over about an hour to complete dissolution of the paranitrophenol.

Solution "B"

A stock reference solution is prepared by dissolving 0·375 g. of paranitrophenol in water containing 1·35 ml. of 2N-sodium hydroxide and making up to 100 ml. This is diluted 100 fold as required to give the reference solution for use in the analysis.

Method

20 ml. portions of solutions A and B are placed in 25 ml. graduated flasks, neutralised to disappearance of the yellow colour with 2N-acetic acid, and an additional 2 ml. of the acetic acid added to each. The volumes are then made up to 25 ml. and 1 g. of zinc dust is added to each flask, after which they are shaken at intervals over an hour, releasing liberated hydrogen when necessary. The contents are then filtered (Whatman No. 1 paper) and aliquot portions of 1, 2 and 4 ml. are pipetted into 100 ml. boiling tubes, followed by 2·5 ml. of a 1 per cent. solution of sodium orthocresate, water to bring the volume to 45 ml. and then 5 ml. of 2N-acetic acid in the order given. The contents are stirred very thoroughly with a glass rod, and the tubes closed with pear bulbs, are kept overnight to attain full development of the indophenol blue colour.

The reference solutions and as many of the test solutions as come within their ranges are finally compared in a suitable colorimeter.

The technique described covers a paranitrophenol content of the cloth ranging from 0·02 to 0·3 per cent.

43. SHIRLAN

5 g. of the material to be analysed shall be cut up into small pieces, well mixed, and portions of 0·5, 0·25, and 0·125 g. are weighed into 3 in. × ¾ in. specimen tubes.

Eleven lots of 0·5 g. of similar material (i.e. grey or bleached but free from Shirlan) are then weighed similarly to provide references.

5 ml. of 4 per cent. borax saturated with cyclohexanol are added to the material to be analysed; and 5 ml. of solutions of Shirlan in 4 per cent. borax saturated with cyclohexanol, the quantity of Shirlan being varied to give a suitable range, to each of the references. All of the tubes are then stirred intermittently with a glass rod for about an hour. After this 1 ml. from each of the tubes is transferred to a 4 in. × 1 in. specimen tube; 0·5 ml. of a suspension

of 2:6 dibromquinone chlorimide in 4 per cent. borax saturated with cyclohexanol is added to each, and they are mixed thoroughly. A disc of bleached cloth (diameter less than 1 in.) is then placed in each of the tubes and they are agitated at intervals over about an hour. The discs are then removed, washed gently in a dilute solution of borax, transferred to a white tile and covered with a glass plate. The Shirlan content is estimated by comparing the depth of colour of the disc from the sample that is being analysed with those of the discs from the reference.

With 0·5 g. of material, 5 ml. borax solution, 1 ml. of extract and 0·5 ml. of the dibromquinone chlorimide suspension, the procedure is sensitive to within 10 per cent. for Shirlan contents up to 0·05 per cent. Larger contents of Shirlan may be dealt with by taking a smaller quantity of the sample for analysis and/or by using more than 5 ml. of the borax solution for extraction.

For most purposes the range of solutions of Shirlan used to treat the controls is as follows:—0·005, 0·0045, 0·004, 0·0035, 0·003, 0·0025, 0·002, 0·0015, 0·001, 0·0005, 0·0002 per cent.

These correspond to Shirlan contents of cloth ranging from 0·05 per cent. down to 0·002 per cent.

In order to obtain satisfactory results it is necessary to reduce the particle size of the D.Q.C. by grinding with a little of the borax-cyclohexanol solution.

44. PENTACHLORPHENOL

General

It has been found that pentachlorphenol can be removed completely from cotton by means of a solution of borax, and that in order to avoid so far as possible, interference with the colour of the copper derivative, it is essential that the pentachlorphenol should be distilled in steam prior to analysis. The accuracy of the two methods is reasonable (± 5 per cent.) and they have been applied satisfactorily to the analysis of a number of undyed and variously dyed cotton yarns and fabrics, and to paper proofed with pentachlorphenol.

Preliminary separation

The yarn or fabric (5 g.) previously cut into small pieces, is placed in a 300 ml. round-bottomed short-necked flask and treated with 100 ml. of a saturated solution of borax, using a filter pump to ensure thorough wetting of the material. The flask is then placed in a steam bath and the contents are maintained at about 50° C. for 15 minutes, with frequent shaking, after which the residual cotton is collected in a Buchner funnel, and washed repeatedly with a dilute solution of borax. The extract and washings are transferred quantitatively to a 500 ml. long-necked flask fitted with a spray trap and a vertical double-surfaced condenser, acidified with hydrochloric acid, diluted to about 300 ml. and distilled until 200 mls. have passed over, the distillate being collected in a separating funnel.

Method

The distillate is shaken with three successive portions (total 30 ml.) of chloroform, using the first to dissolve any adhering solid from the condenser. The combined extracts are shaken thoroughly with 50 ml. of distilled water and 2 ml. of a 3 per cent. solution of copper sulphate ($CuSO_4.5H_2O$) in a 40 per cent. aqueous solution of pyridine. The chloroform layer is run off into a 50 ml. measuring flask and the blue aqueous layer shaken with further small amounts of chloroform. The combined extracts are made up to 50 ml. and compared in a suitable colorimeter with an appropriate standard prepared similarly from a 0·2 per cent. solution of pure pentachlorphenol in chloroform.

45. EXTENDED SOLUBILITY TEST

General

This test is intended to be applied to materials proofed with organic antiseptic such as paranitrophenol, Shirlan, pentachlorphenol, etc.

Testing

A 10 gm. sample of the material is cut into pieces approximately half an inch square, which are then placed in a glass tube about 6 in. long and 1 in. in diameter.

This tube (T) is fitted to the continuous syphon apparatus shown in the accompanying sketch.

The Winchester bottle (A) is filled with 2 l. of distilled water (*p*H 6·7 to 7·3) and syphoning is started by blowing down the air inlet tube at C. The screw clip is adjusted so that 20 drops of water per minute pass from the apparatus.

The 2 litres will thus require 48 hours to run through the material.

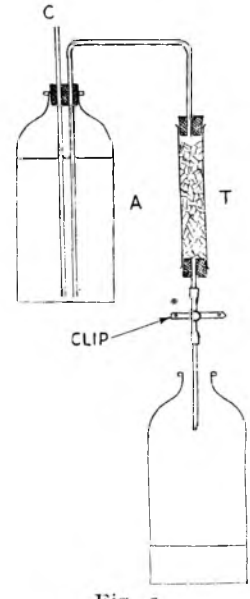


Fig. 5

Performance

The amount of organic antiseptic which is removed during the test is determined by estimating the concentration on the material before and after extraction with distilled water. The quantity of antiseptic removed must not be so great as seriously to interfere with the proofing on the material, which before and after extraction, must be subjected to test No. 46(a).

46. PERFORMANCE TESTS FOR PROOFINGS AGAINST ATTACK BY MICRO-ORGANISMS.

Foreword

Conformity with a chemical specification does not necessarily mean that the material is proofed against attack by micro-organisms. It is therefore recommended that the chemical estimations be supplemented by a simple qualitative mycological test.

The first of the following tests is intended for application to materials which, under service conditions, are unlikely to come into prolonged contact with soil.

In some instances, however (e.g. sand bags and the valances of tents), the material is liable to attack by both airborne and soil micro-organisms. It is recommended, therefore, that in those cases where the fabrics will, under service conditions, come into prolonged and intimate contact with soil, a microbiological test, in which the effectiveness of the proof against both these forms of attack can be judged, should be prescribed by the specification.

These tests shall be carried out on both leached and unleached material. In the case of organic antiseptics, the leached material is that which has undergone the extended solubility test, whilst in the case of inorganic proofing agents leached material is that which has undergone some form of weathering or accelerated weathering test.

(a) Test for the Effectiveness of a Proof against Air-borne Microbiological attack

At least two samples (approximately 2 × 2 inches each) of the proofed fabric, together with two samples of untreated fabric, are placed in Petri dishes, and each sprayed with 5 ml. of an aqueous suspension of cellulose-decomposing fungal spores taken from a mixed culture which should contain the following species: Penicillia, Aspergilli (e.g. Aspergillus fumigatus, and Aspergillus glaucus), Cladosporium herbarum, Rhizopus nigricans, Memnoniella echinala, Chætomium globosum and Metarrhizium anisoplia.

The inoculated samples in the Petri dishes are placed above water in a desiccator, the tap of which is left open, and the desiccator is then stored at 25°-30° C.

If, after 21 days' incubation, the untreated material is covered with fungi, whilst the treated material is completely unaffected, the proof can be considered satisfactory.

(b) Test for the Effectiveness of a Proof against both Air-borne Microbiological attack and Soil Bacterial attack

A thin aqueous sludge of a mixture of 2 parts unsterilised soil and one part horse dung is prepared, and the surfaces of Berkfeld filter candles (preferably at least 6 × 2 inches) are impregnated by immersing the candles in the sludge and drawing the liquor through the candles by means of a suction pump. A thin film of inoculum rich in both air-borne micro-organisms and soil bacteria is thereby obtained. Strips of the proofed material are wound round the filter candles which are then fixed in glass jackets and incubated at 25° C. and 92-95 per cent. R.H. for 21 days. Control samples of untreated fabric are tested in a similar manner. After 21 days, the treated sample must be free from fungoid growth. The samples are carefully unwound, washed in running cold water, air-dried, and conditioned in the standard atmosphere for 24 hours. They are then tested for tensile strength. The untreated control samples shall have lost at least 90 per cent. of their initial tensile strength. The loss in tensile strength of the proofed samples not be more than 10 per cent. of its initial value.

NOTES.—This test has the following advantages over a soil burial test:—

It gives more reproducible results.

It more nearly reproduces service conditions in that the outer surface of the fabric is exposed to the air, whilst the inner surface is in close contact with a rich inoculum of soil bacteria.

Unlike the soil burial test, it enables visual results of microbiological attack to be observed.

47. PERFORMANCE TESTS FOR FLAME-PROOFING AND SMOULDER-PROOFING

Apparatus

It is strongly recommended that the apparatus for these tests shall conform in its essential features to the following description:—

(1) The platform for the test specimens shall consist of a frame of wood or metal on which are mounted a series of nichrome wires 28 s.w.g. at 1 in. centres, to form a grid for supporting the fabric throughout its length. The frame is graduated in inches along its front edge to facilitate reading of results, the graduations proceeding from the third wire (from the bottom), which is marked zero. The frame shall have an internal width of 6½ ins., and shall be sufficiently long to accommodate 21 wires in all.

(2) The baseboard on which the specimen platform is suitably mounted, shall be provided with sides and back of ample height, but no front or top. The whole is finished in matt black.

(3) The igniting cup shall be of iron, steel or copper, about $\frac{1}{32}$ in. thick, and shall be $\frac{11}{16}$ in. external diameter and $\frac{9}{32}$ in. high. The cup shall be mounted on cork or other material of low thermal conductivity.

The sketch illustrates the above features, and shows the specimen platform hinged to the base and supported at an angle of 45° by a movable arm. It can thus be lowered for easier attachment and removal of the test specimens, and can also be adjusted to other angles of slope if required, by the provision of suitable additional supports, as the smaller one shown in the sketch.

The ignition cup is shown mounted on cork on the head of a screwing arrangement so that its height can be adjusted.

Testing Procedure

Specimens of fabric 24 in. long shall be prepared and conditioned as described on page 2.

Fabric up to 6 in. wide shall be tested whole width.

For fabric wider than this, 6 in. strips shall be prepared.

The test pieces are fixed centrally on the specimen platform and secured at top and bottom by means of drawing pins or other suitable means.

Only one specimen of fabric shall be tested at a time irrespective of width.

In the absence of specific instructions to the contrary it is recommended that all tests shall be carried out with the fabric platform at an angle of 45°, and with the ignition cup placed at a vertical distance of 1 in. below the centre of the third (zero) wire.

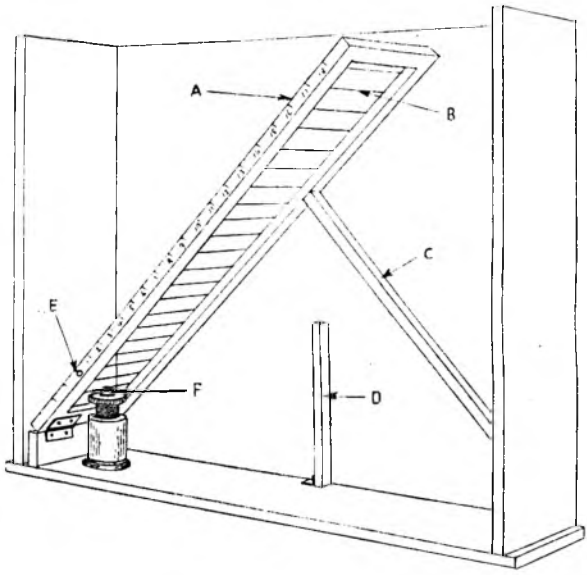


Fig. 6. Flame-proof and Smoulder-proof Apparatus

A—Specimen platform supported at an angle of 45°. B—Nichrome wires 28 s.w.g. at 1" centres. C—Movable support. D—Extra support if special angle of slope is required. E—Zero mark. F—Ignition cup on screw head.

For each test 0·3 ml. of absolute alcohol shall be poured into the cup from a suitable pipette or burette. The cup is then immediately placed in position and the alcohol ignited by means of a small (bead) gas or oil jet, or by other suitable small source of heat, which is removed as soon as the alcohol is ignited.

During testing, draughts are excluded, if necessary, by a glass shield placed in front of the apparatus.

The greatest possible accuracy in assessing the results shall be ensured by carrying out the tests in reasonably subdued light, although a dark room is not essential if the apparatus has a good black finish.

An interval of 2½ minutes shall be allowed to elapse between each test.

Before testing, 0·3 ml. of absolute alcohol shall be burnt in the ignition cup and an interval of 2½ minutes allowed afterwards, before commencing the first test.

Definitions

A material is *flame-proof* when it does not continue to flame after the source of heat is withdrawn.

A material is *smoulder-proof* when it does not continue to smoulder after the flame has died out.

Performance

Flame-proof. The material specification shall prescribe the maximum permissible time (if any) for continuance of flame, after the source of heat has been removed; and may also prescribe permissible limits (if any) for the extent of scorching or charring.

Smoulder-proof. The material specification shall prescribe the maximum permissible time (if any) for continuance of glow after the disappearance of the flame.

Part IV

COLOUR FASTNESS TESTS

48. FASTNESS TO LIGHT

The method described in British Standard Specification No. 1006, 1942, shall be used.

NOTE.—It is considered essential that the appropriate Standard or Standards should be exposed with each test.

49. FASTNESS TO WASHING

The tests and machine recommended in the report of the Fastness Committee of the Society of Dyers and Colourists, 1934, page 35, shall be used, with the following modifications:—

(1) The materials under test shall be sewn to a piece of white unmercerised cotton limbric or cambric, 4 × 4 in. (10 × 10 cm.) so as to cover the whole area.

(2) The volume of the test liquor shall be 250 ml. in all cases.

(3) The dyed Standards prescribed in the above report (page 36) have not proved adequate, and cannot now be recommended.

The tests shall be carried out against a portion of the "Sealed Sample."

NOTE.—It must be recognised that many materials coming within the category of narrow fabrics are not washed in practice. It is therefore recommended that the above washing tests be included only in those specifications where washing fastness is an important property of the material.

50. FASTNESS TO BLEEDING AND MARKING OFF

The general method is as follows:—

A test piece about 2 in. (5 cm.) long, covered on one side with a piece of white unmercerised cotton fabric, and on the other side with a white woollen fabric of the same dimensions, shall be placed on the bottom of a flat glass or porcelain dish about 4 ins. (10 cm.) in diameter, with the white cotton fabric uppermost.

The dish shall then be flooded with test liquor without disturbing the assembled materials. After allowing to soak at room temperature for 15 minutes, the materials shall be covered with a smooth glass plate weighing approximately 50 g. Light and even pressure shall be applied on the plate with three fingers, and the excess liquor poured off.

The materials shall then be treated at the temperature and for the time prescribed below, after which they shall be removed from the dish and allowed to dry at room temperature without separation.

When dry, the test piece shall be examined for loss in depth and change in shade, and the white materials for staining.

This general method shall be used with the corresponding modifications when testing for fastness to the following agencies:—

1. Cold Water (Rain)

The test liquor shall be distilled water at 20°-25° C. The duration of treatment shall be 24 hours.

2. Water at Body Temperature

The test liquor shall be distilled water at 37° C. The duration of treatment shall be 4 hours.

3. Perspiration

The test liquors shall be those prescribed in the report of the Fastness Committee of the Society of Dyers and Colourists, 1934, page 27, and the tests shall

be carried out with both the acid and the alkaline perspiration liquors. The temperature of treatment shall be 37° C. and the duration of treatment shall be 4 hours.

NOTE.—All bleeding and marking off tests shall also be carried out against a portion of the "Sealed Sample."

51. FASTNESS TO DECONTAMINATION

The test piece shall be kept immersed in 50 times its own weight of boiling distilled water for 3 hours, and after drying, it shall be examined for loss in depth and change in shade.

NOTE.—The test shall also be carried out against a portion of the "Sealed Sample."

52. FASTNESS TO RUBBING

A test piece about 5 in. (13 cm.) long shall be secured without tension to a flat smooth wooden surface, and strongly rubbed 10 times to and fro over a distance of 4 in. (10 cm.) with a white cotton cambric wrapped round the forefinger.

1. Dry Test

The white cotton cambric shall be used dry.

2. Wet Test

The white cotton cambric shall be wetted, and then squeezed so as to contain approximately its own weight of water.

NOTE.—All rubbing tests shall also be carried out against a portion of the "Sealed Sample."

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STANDARDISATION

CLOTH STRENGTH TESTING—IX

EXAMPLES OF INERTIA ERROR IN TEST RESULTS FROM PENDULUM BALANCE TENSILE TESTING MACHINES

By A. W. Bayes

INTRODUCTION

This paper describes further work on one of the errors in cloth strength testing. The waviness of load-extension curves drawn by pendulum balance strength testing machines is well-known. Shorter & Hall[1] and Peirce[2] have suggested that the errors associated with this waviness do not attain serious proportions in practice, but their work was confined to single-thread and lea testers. Cloth testing machines of the pendulum balance type have usually much heavier pendulum systems and a faster rate of traverse, and the test specimens are usually much shorter. Paper IV by Martindale & Woods in this series[3] extends the analysis made by Shorter & Hall and shows that serious errors due to the inertia error of the pendulum system are to be expected under certain conditions, namely, with normal Goodbrand machines with 18 inches per minute rate of traverse, testing linen or cotton in 7 inch specimens. The largest errors occur with the weakest specimens and errors are quoted ranging from 30 to 49 per cent. for linen specimens and from 15 to 20 per cent. for cotton specimens. These are estimates from theory of the maximum possible inertia errors and the authors point out that the average errors in practice may be smaller due to non-observance of Hooke's law and to positive and negative errors cancelling.

The reports of various researches explain that testing machine conditions were chosen in which the pendulum jerks had died away before the break, but in others it is obvious that conditions liable to serious inertia errors had been used. In routine testing, machines are used for a wide range of fabrics and some tests are done in which the specimens break after only one or two jerks of the pendulum. The inertia error may, therefore, be important in practice and the present paper presents some evidence of this.

Peirce, Turner, Matthews & Barr have discussed the effect of specimen dimensions on the tested strength of yarns and fabrics. It has been shown by "the weakest link" theory[1] that long specimens must tend to be weaker than short ones and that the strength per unit width is likely to fall as the width of specimen is increased, but it has been suggested[5] that very narrow fabric specimens may be less strong comparatively, and[6] that in some circumstances, if a wide enough range of widths of test specimen could be used, with continuously increasing width, the strength might be expected to increase, decrease, increase and again decrease. Little experimental evidence was put forward in support of these last two suggestions. The weakening of very narrow specimens could occur only once in a series of various widths and the alternate increasing and decreasing is said to require a wide range of widths. No one seems to have suggested that large increases and decreases in strength, occurring between quite small changes in width, could be due to the dimensions of the test specimens.

The jerky movement of the pendulum can be observed easily enough without an autographic recorder. The indicating pointer can be seen to hesitate, and the number of jerks before the break can be counted. On autographic traces the jerks appear with great regularity. It has been shown that these jerks correspond with the theoretical inertia error waves. The object of the present paper is to examine breaking load data for evidence of variations in accordance with the spacing and violence of the jerks. It is assumed that variations in strength per unit width, occurring more or less regularly, at about the spacing, and of about the same magnitude, as would be predicted from Martindale & Woods's formulæ, are, in fact, due to those inertia errors which they analysed. It would be possible to change the spacing of the jerks or waves by altering the traverse speed, or the extensibility of the material tested, or the characteristics of the pendulum, and so to demonstrate whether or not the jerks followed the theory. Alternatively, a variety of materials and testing conditions could be used. The second alternative covers the various machines and materials of practical interest, and is, therefore, to be preferred for the present purpose.

Theory has shown that at a particular jaw speed a pendulum should follow a regularly repeating cycle of acceleration and deceleration. Experiments with weights[7] have shown that the cycles occur, and are associated with inertia errors in the recorded load. Textile specimens introduce variations by changes in extensibility, which affect the head jaw speed, and changes in strength which affect the point in the pendulum cycle at which the specimens break. When the specimens break within the second or third cycle normal variations in extensibility and strength are not likely to mask the inertia effect, but as the number of cycles increases variations in extensibility may mask the effect completely and variations in strength may complicate the analysis. In such series the effect may show up as a cyclic variation in apparent variability of the strength rather than in cyclic variations in mean strength.

Two sets of published data have been found suitable for the present study. The paper then proceeds to experiments designed specially to test the inertia error. Estimates of the period and magnitude of the inertia error were made from the testing machine particulars and the data were subjected to statistical analysis. In all the experiments the normal variability of the material makes it difficult to obtain obvious proof of the error and some of the experiments and analysis may appear somewhat inconclusive, but it is believed that, taken together, they form a considerable body of evidence in support of the conclusions of the theoretical analysis.

The practical question to be answered is: given a particular fabric and set of testing conditions, what error is being introduced by the machine. To answer this three experimental methods may be employed:

(*a*) The starting position of the pendulum may be advanced a small amount at a time from zero and the mean strengths and the standard deviation for each starting point compared,

(*b*) the strength of the specimen may be varied in small increments, e.g. by varying the width of the specimen; then the variation in mean strength per thread, or per unit of width, should show the extent of the inertia error.

(*c*) The specimen width and length may be varied simultaneously.

One difficulty with the second method on normally extensible material is that specimens of any width have practically the same extension at break so that the testing machine behaves differently as the specimen width is changed, and the experimental points are not in fact traversing that error wave in which the normal break occurs. This difficulty may be overcome to some extent by varying the specimen length, between the jaws, and the width together, as in method (*c*), but as the load-extension curve is not usually straight the speci-

men lengths should be adjusted accordingly. This makes the experiment more complicated and rather less objective.

No doubt the experiments could be simplified by using more regular material such as filament rayon or wire, but the error is most obvious on the less extensible linen and cotton fabrics and, anyway, the aim is to demonstrate the practical importance of the error in normal testing.

Examination of some Data published by Matthew, on Linen Fabric

Matthew[8] has described an extensive series of tests on specially woven linen fabrics in which changes in the number of threads per inch in warp and

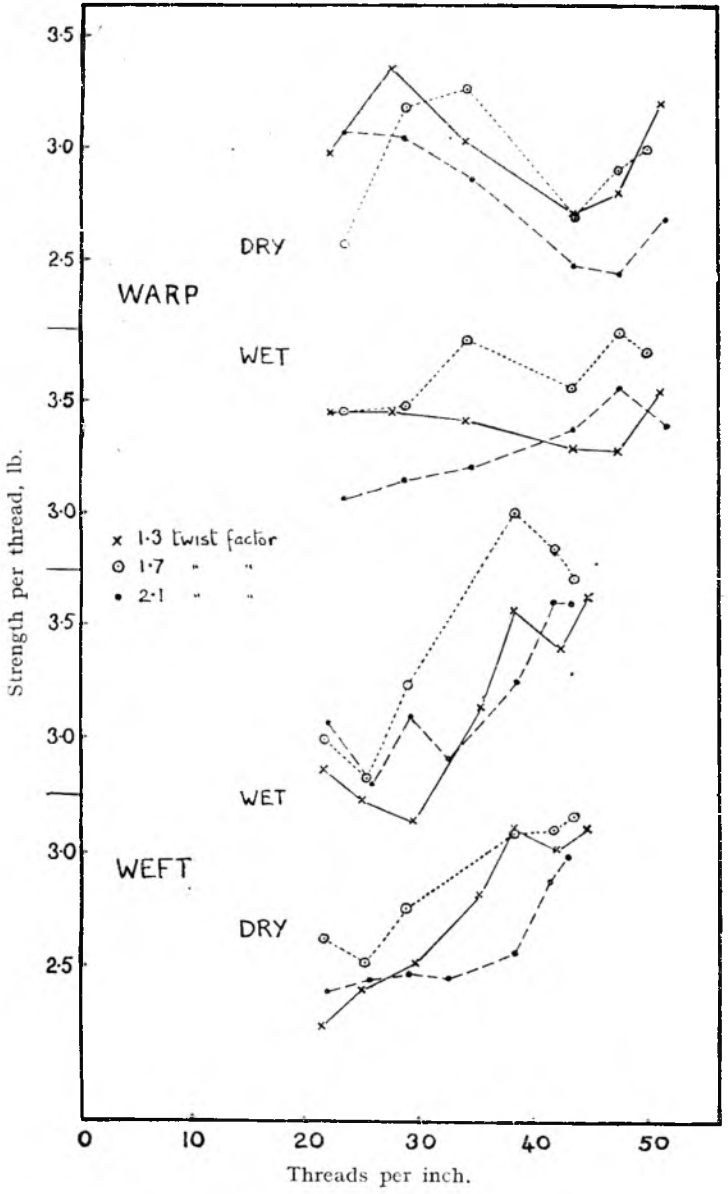

Fig. 1. Variation of strength per thread with the number of threads tested. Linen fabric tested dry and wet (Matthews's data).

weft were made and the effects of these changes were investigated by tensile and other tests. The tensile tests were made on a pendulum balance machine and the author noticed, in one series, an unexpected undulation in the graph when the strength per thread was plotted against the number of threads tested. In his own words: "..... as the number of warp threads is increased the cloth strength per single end increases to a maximum and is followed by a decrease to a minimum, when the strength again increases. The possibility of the effect being due to chance, or errors due to cloth variation, or sampling, appears to be definitely discounted in view of the close similarity in the results from three independent sets of fabrics. So far as the writer is aware there is no previous record of this effect. It is evidently an outstanding feature of the results and therefore it may be presumed that it could be used as a conclusive check on any proposed theories as to the interpretation of the meaning of tensile test results in terms of cloth structure and yarn strength." The data which gave rise to these remarks were obtained on the lines of method (*c*) so it may be worth while to consider whether the wave noticed by Matthew was due to some curious interaction of cloth structure and yarn strength as he suggests, or to the inertia error of the pendulum system in the testing machine. The testing machine used for these experiments was a Goodbrand horizontal model, 1,000 lb. capacity, with a nominal machine rate of load of 1,100 pounds per inch. The jaw speed was reported as 20 inches per min. The jaws were set 7 inches apart. The specimens ranged in strength from about 100 to 360 lb. From Martindale & Woods's analysis large inertia errors are to be expected under such circumstances. The test material consisted of three series of specially woven and laundered samples of plain linen cloth, made from 2½ lb. dry spun line, in which the warp ends per inch were varied while the picks were kept approximately constant, and then the picks were varied while the warp ends were kept constant. The changes in thread spacing produced changes in crimp, which in turn produced proportional changes in extension at break. The three series differed in yarn twist factor. All specimens were frayed down to two inches wide. Twelve strips were tested from each sample after conditioning at 75% R.H. and a further twelve were tested after soaking in cold water for 30 minutes. The author has reported mean strengths for dry strips and the percentage increase resulting from wetting, and has plotted the breaking strength per thread for the dry tests against the threads per inch for each twist factor, in his Fig. 8. Of the four sets of graphs plotted therein we are interested in the warp tests with the weft threads per inch kept constant and the weft tests with the warp threads kept constant. The dry warp test graph reproduced at the top of Fig. 1 shows a distinct wave form in all three twist factors, but the dry weft test graph shows a more or less steady rise in strength as the threads per inch are increased. But when the wet strengths are calculated and plotted similarly, the shapes of the graphs are altered; the wet weft now showing what may be part of a wave and the wet warp an upward trend in two of the lines.

The range of strengths from the highest twelve test mean to the lowest for each graph is as follows:

Twist factor of yarn	Range of strength per thread, lb.	
	Warp, dry specimen	Weft, wet specimen
1·3	0·64	1·00
1·7	0·69	1·18
2·1	0·62	0·81
Average range ...	0·65	1·00
Average strength ...	2·93	3·25
Average range % ...	22·2	30·8

Table II of paper IV[3] of this series gives figures for the maximum possible inertia error for linen fabric tested on a machine similar to that used by Matthew, and quotes an error of 35 per cent. at a breaking load of 200 lb., so the maximum possible inertia error is large enough to account for the whole of the range of strength found in these experiments.

An explanation has still to be given for the curious effect of wetting on the shape of the graphs. Matthew pointed out that the effect of wetting was very irregular; increases in strength were recorded ranging from 2·8 to 45·9 per cent. Now the overthrow occurring at the break depends on the value of the breaking load and on the speed of the head jaw, and the speed of the head jaw depends upon the extensibility of the test specimen. It should, therefore, be possible to break specimens at any point in the overthrow cycle by modifying either the strength or the extensibility of the test specimen, but when they are altered together, the effects may cancel, wholly or in part. When the effects oppose one another the wave length of the inertia error cycle will increase and, in a short range of conditions as employed in the present tests, approximately straight line graphs of varying slope will be produced. But when the effects support one another, clearly defined waves are to be expected. It follows from this that a change in the relationship between strength and extension for a particular sample, such as occurs in wetting, may change the graph from a straight line to a wave, and vice versa. If this is the true explanation, the variation in the extent of the strength change, apparently due to wetting, is really due to changes in the inertia error.

Examination of some Data published by Richardson, Bailey and Conrad, on Fibre Bundle Tests

The simplest extension of the foregoing experiment with weights,[7] is to one employing specimens of negligible length, or of negligible extension. Such very short specimens are used in the Chandler bundle test for cotton hair strength, and a similar technique has been proposed for flat bundles of staple fibre.[9] In both a bundle of fibres of necessarily varying size is broken in special jaws fitted on an ordinary lea tester. The jaws are practically touching, so the headjaw moves almost at the same speed as the pulling jaw, and the varying size of bundle produces breaking loads of varying amount, which, when reduced to strength per fibre unit, should show an inertia error wave similar to that found with weights.

The Chandler bundle test is described in detail in one of the American Society for Testing Materials Standards on Textile Materials.[10] This specification states "a pendulum type testing machine having a capacity of 150 lb. shall be used. The pulling clamp shall have a speed of $12 \pm \frac{1}{2}$ in./min. . . . Breaking loads shall be tabulated from 50 to 100 lb." The details of the test were investigated at length by Richardson, Bailey and Conrad.[11] They tabulated the bundle strengths of six different cottons measured on about thirty bundles of varying size. Their figures are analysed below in a manner which shows that large systematic overthrow errors are present. Though their machine was of greater capacity than that specified, similar, though possibly smaller, errors are to be expected with the specified capacity.

The technique employed by these workers was as follows: The bundles of fibres were prepared by combing in a standardised manner and each bundle was tightly wrapped with cotton thread in special apparatus. The wrapping proceeded from each end simultaneously towards the middle till the threads touched, then outwards to the ends again. The length of thread used in wrapping was measured and from this length and the thread diameter the "corrected circumference" of the bundles was calculated. The authors give a photograph of their "yarn skein tester adapted for attachment of the special jaws," which appears to be a normal Scott, vertical model, motor driven, pendulum balance, lea tester with the usual ratchet quadrant and pawls on the pendulum lever. The special clamps for gripping the specimen were carried

on extension pieces which appeared to fit directly on the top and bottom hooks of the machine. Apparently the machine capacity was 300 lb. and the jaw speed was 12 inches per minute, although these details are not given specifically.

The paper includes a correlation chart, constructed from a large number of bundle tests, which shows that the density of the bundles decreased as the bundle circumference increased. A regression line is shown on the chart joining the following limits:

Density, gm./c.c.	...	1·61	...	1·31
Circumference, ins.	...	0·095	...	0·170

Having made this point the authors pass on to study the variation of strength with bundle circumference and do not use the regression line further. Whether or not this was the best course for their subsequent analysis our present purpose is better served by applying their regression equation and reducing their breaking loads to breaking stress, in pounds per square inch, at constant bundle density. The data has been re-arranged accordingly by calculating the cross sectional areas from the circumferences, taking the densities from the regression equation, and correcting the breaking stress at the estimated density to breaking stress at a density of 1·55 gm./c.c. (the value quoted by other workers for the density of cotton cellulose).

Assuming that any particular recorded breaking load contains an inertia error of an amount which is unknown, but which is constant for that breaking load, the differences in mean breaking stress between the six samples may be disregarded. The first step in the analysis was, therefore, to express all the breaking stresses as stresses relative to the sample mean. Then the data were collected in groups of similar recorded breaking load, in five pound increments, from $74\frac{1}{2}$ up to $159\frac{1}{2}$ lb. Outside this range the data were too scanty for convenient analysis.*

Table I gives the arrays obtained in each group. There are 17 groups covering 189 test results. The arrays in Table I show a general curvilinear trend and a variation in array means along the trend, and we wish to test whether the variation of the array means about the trend is statistically significant.

A third order regression line, fitted to the weighted array means by the method of least squares, had the following formula:

$$Y = -1{\cdot}07160 - 0{\cdot}032104X + 0{\cdot}054645X^2 - 0{\cdot}0064727X^3$$

where Y was the relative breaking stress measured from an origin of 100 and X was the central value of the breaking load group measured in 5 lb. units from an origin of 117 lb. The variance was then analysed into three parts, namely, the variance due to the regression line, the variance between array means and the corresponding regression line values, and the within array variance. The results are given in Table II.

The ratio of the mean square of the deviations of the array means to the residual mean square is 3·73, which is considerably greater than the 1 per cent. point given in the ratio tables for the Z test, so there is statistical confirmation of the reality of the wavy or zigzag variation in bundle strength shown in Table I.

The shape of the general trend is probably due to the use of the original authors' straight regression line for bundle density and circumference. The third order regression line fitted to the array means of Table I curves from 77 lb. to 107 lb. breaking load and then is practically parallel to the breaking load axis up to the limit of the data. Of the bundle densities calculated for

* One low breaking load in lot 4, two low values in lot 6 and twelve high values out of lot 1 were thus left out of the analysis. The effect of this is to make the relative lot means differ from 100 and so to introduce a small between lot mean variance. This has been disregarded in the statistical analysis so the residual mean square in Table II is slightly enlarged.

Table I

Recorded Breaking Load and Relative Breaking Stress of Chandler Bundle Specimens

Data from Richardson, Bailey and Conrad[11].

Relative breaking stress	Breaking loads in pounds. (Central values)																	
	77	82	87	92	97	102	107	112	117	122	127	132	137	142	147	152	157	Total
87									1									1
8									–									–
9							1		–									1
90							–		–									–
1						1	–		–									1
2						–	–		–									–
3						–	1		–	1	2							4
4			2			1	–		–	–	–			1				4
5		1	–	1		1	3		1	–	1	2		–	2			12
6		–	1	–		–	1		1	–	2	–		1	–			6
7		1	1	2		1	3	2	1	2	1	3		–	2	2		21
8		–	1	–		2	2	–	–	2	1	1		–	–	–		9
9		1	2	1		1	1	1	1	2	2	–	1	2	2	1	1	19
100		2	1	–	1	1	1	1	–	1	1	2	4	1	1	1	2	23
1		3	1	1	1	2	–	–	–	2	1	–	–		1	–		12
2		6	2	–	1	2	2	–	1		–	–	1		–	–		15
3	1	4	1	–	2	3		2	3		–	3	2		1	–		22
4	–	1	–	3	2	–		1			–	–	–			1		8
5	1	–	1	–	1	1					–	2	1					7
6	1	–	–	–	1	1					–							3
7	–	2	–	1	3	1					–							7
8	1	–	1	1	1						–							4
9	–	1			1						–							2
110	3	1									1							5
1	1																	1
2	–																	–
3	1																	1
4	–																	–
5	–																	–
6	–																	–
7	1																	1
Total ...	10	23	14	10	14	21	15	7	9	10	12	13	9	5	9	5	3	189

Analysis of Variance of Relative Breaking Stress, units (1 per cent.)[2]

Source	Sum of squares	Degrees of freedom	Mean square
General trend (3rd order regression)	890·075	3	296·69
Deviation of array means from general trend...	691·360	13	47·64
Residual within arrays	2194·803	172	12·76
Total	3776·238	188	—

bundles breaking below 100 lb. half were higher than 1·55 gm./c.c., but it is unlikely that the method of wrapping employed compressed the smaller bundles beyond the normal density of cotton cellulose. The regression line gives a density of 1·55 and over for bundle circumferences of 0·111 in. and below. Evidently the correction is unreliable for this range.*

* A.S.T.M. Designation, D414—40T Tentative Methods of Testing Cotton Fibres. Table I. "Tensile Strength for Bundles of Various Circumferences and of Different Observed Breaking Loads," commences at an actual circumference of 0·115 in.

There appear to be four waves between 77 and 157 lb., so if they are due to inertia error the pendulum will have jerked at load intervals of approximately 20 lb. This is the order of interval to be expected on this type and capacity of machine.*

Inertia error is at least a possible explanation of the variation in breaking stress and, as the average variation appears to amount to about 6 per cent. on the weaker bundles, it seems advisable to modify the test procedure, for instance by a reduction in jaw speed, so that inertia errors are less likely to arise.

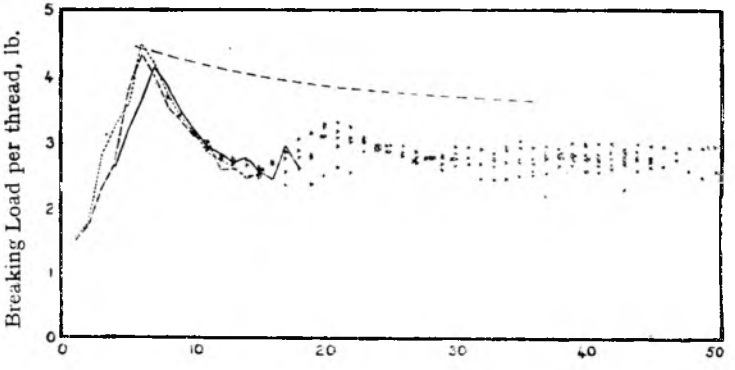

Fig. 2. Variation in strength per thread in tests on strips of cloth of varying width.

The Effect on the Apparent Strength per Thread of Small Changes in Width in Short Specimens of Cotton Cloth

A simple method of investigating the inertia error wave is to break a long strip of cloth repeatedly, a short length at a time, removing one or two threads from the remainder of the strip after each test. The results, when expressed as strength per thread, would normally be expected to remain constant, or to show a simple trend, but if a pendulum inertia error is present a wave form is to be expected. Weft way strips with all the threads coming from one cop should give the most regular results, but this direction restricts the length of strip available for testing to the width of the cloth.

In an experiment on these lines weft way strips from a plain woven cotton filter cloth were used. The weft was 32s/3 combed Uppers quality. Tests were made on a Scott machine, 400 lb. capacity, $\frac{1}{2}$ inch between the jaws, 10·4 inches per minute rate of traverse. A load extension chart was drawn for each break and the retaining pawls were in action. Fifteen tests were obtained from each strip. Several strips were tested varying in initial number of threads from 50 down to 15. Fig. 2 reproduces the values obtained for strength per

* From the text it appears that the machine capacity is 300 lb., and the jaw speed 12 inches per min. From the photograph the testing machine appears to have been made by H. L. Scott. If we may assume that it complied with the A.S.T.M. specification for pendulum type testers, the pendulum deflection at full load was 45°, and the pitch radius of the chain drum in the pendulum head was 11 inches minimum, from which the machine rate of load, μ^0, is 340 lb./inch. Then by measurement of the photograph, using an assumed distance between the lea test hooks of 27 inches to fix the scale, the radius of the centre of oscillation of the pendulum is about 18 inches, from which the natural period of oscillation of the pendulum works out at about 1·4 seconds.

The experiments with weights in paper VIII indicated that the period of the error wave approaches one-quarter of the natural period of the pendulum. In the present experiment the head jaw moves at practically the same speed as the pulling jaw, namely 12 in. per minute. The period of the error wave would be expected to be 0·34 secs., in which time the head jaw would move 0·068 inch and the pointer would move through 23·1 lb.

thread plotted against the number of threads in the strip. The results for the three narrowest strips are joined by lines and show a pronounced crest at 6 and 7 threads, but the results of wider strips are more variable and, although there appears to be a second crest at about 20 threads, the third crest is lost in the variability of the material. This test material was chosen for its regularity, so more difficulty is to be expected with more usual, and irregular, cotton fabrics.

The mean strength per thread for the wider specimens is 2·75 lb. The trough at 15 threads averages 7·2 per cent. below this mean, and the crest at 20 threads appears to be rising to about 18 per cent. above the mean.

The maximum inertia error has been calculated for 6, 22 and 36 threads from Martindale and Woods's formula (paper IV, S31)[3] taking 11·3 per cent. for the extension at break of the fabric, $\mu_0 = 454$ lb./in., $T = 1{\cdot}40$ secs., $v = 10{\cdot}4$ in./min. and assuming $s = s_0$ for these small deflections of the pendulum. The calculation values are:—

Threads broken	6	22	36
Maximum possible inertia error, per cent. ...	61·8	39·2	32·0
Maximum expected strength per thread, lb....	4·45	3·83	3·63

A curve has been drawn through these calculated values on Fig. 2. It agrees with the experimental value for 6 threads, but it is much too high for the wider strips.

The load extension charts for strips wider than 15 threads showed an obvious wave at about 38 lb. and the charts for strips wider than 28 threads showed a second wave at about 80 lb. These loads correspond with the first and second troughs in Fig. 2. Some of the curves for the strongest specimens showed a third wave also, but not sufficiently clearly for its position to be measured.

A similar experiment on a horizontal Goodbrand machine with the jaws set $6\frac{3}{4}$ in. apart gave indications of two waves, but there was considerable variation in the data, and it was clear that a different experimental method was required which would give results more suitable for statistical analysis.

The Effect of Changes in the Number of Loops in the Lea Test for Yarn Strength

As in cloth testing it is a simple matter to vary the specimen width a few threads at a time, so in the lea test, although it is customary to break a lea of yarn wrapped in a skein of 80 loops, it is a simple matter to vary the number of loops and so to discover whether the strength per loop remains reasonably constant or whether machine errors introduce inconsistencies. Accordingly a test was carried out on a Goodbrand lea tester as follows:—

The yarn was a commercial 80s/3 super combed and gassed Giza quality with 18 turns per inch in doubling.

The machine details were:—
Capacity, 130 lb.
v = Speed of pulling hook 12 inches/min.
μ_0 = Machine rate of load, 109 lb./inch.
T, Natural period of pendulum, 1·025 secs.

The machine was motor driven through reduction gearing. Multiple retaining pawls held the pendulum in position after the break. Readings of the pointer position were taken to the nearest half pound after the pendulum was held firmly by the pawls. There were five pawls and twelve ratchet teeth for 10 lb. load, so the smallest load change shown by the mechanism was one-sixth of a pound. The pawls appeared to move smoothly. The machine was calibrated by dead weights in small increments before the test and a correction was applied to the lowest readings.

Twenty-four pirns of the yarn from one skip were thoroughly conditioned and then tested repeatedly. Eight pirns were put in the wrap reel together and skeins were made varying in number of loops from 3 to 48 in steps of three loops. The numbers were distributed at random down the pirn. In testing this series it became clear that the steps were too large, so subsequently the test

was repeated on the same pirns at the same controlled humidity and by the same observer taking skeins of 1 and 2, 4 and 5, 7 and 8 loops, etc., up to 23, again at random, down the pirn so obtaining strengths for all loops, from 1 to 24, in steps of one loop. Fig. 3 shows the mean strength per loop for each number of loops. The diagram shows an obvious wave repeating on three loops. The troughs coincide with the first portion of the test so they may be due to some change in testing conditions between the two testing periods instead of to the presumed inertia error. However, the machine pointer hesitated at about 5, 10 and 15 lb. during the tests, which corresponds to the troughs found, and, besides the variation in means, there is a similar cyclic variation in irregularity which is unlikely to have arisen through any

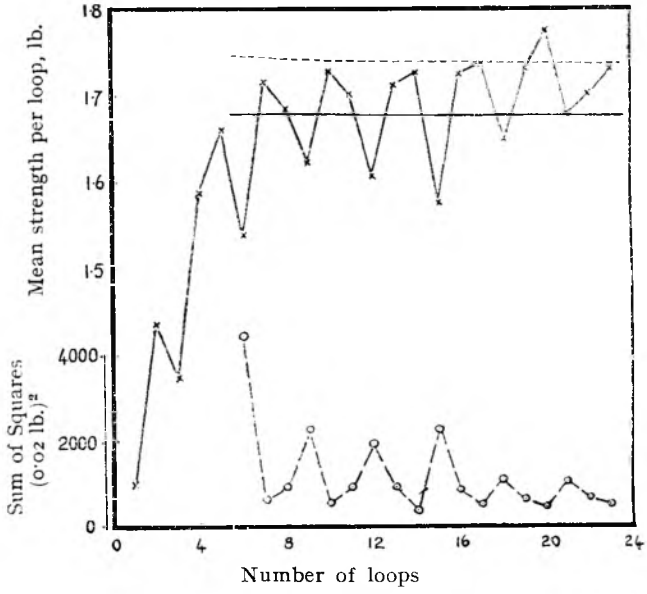

Fig. 3. Variation of strength per loop with the number of loops in the lea test.

unobserved changes in humidity or other testing conditions. It must be concluded, therefore, that the waves are due to some cyclic error in the test, presumably the pendulum inertia error, and not to any change in testing conditions.

The statistical significance of the variation in mean strength per loop was tested for the data of strength per loop from 6 loops to 23 loops, inclusive. 18 loop groups in all for all 24 pirns. The variance was analysed into three sections; between pirns, between loop groups, and residual.

Analysis of variance, lea test data, units (0·02 lb.)².

Source	Sum of squares	Degrees of freedom	Mean square
Between loop groups ...	3,997	17	235
Between pirns	2,421	23	105
Residual	18,823	391	48
Total	25,241	431	—

The ratio of the between loop group mean square to the residual is above the 1 per cent. point and the ratio of the between pirn mean square to the residual is between the 1 per cent. and 5 per cent. points, so both sources of variance add significantly to the total and we conclude that the wave is statistically significant.

A further statistical examination was made of the variance within loop groups. The within loop group sum of squares was calculated for each loop group separately and the results are shown plotted on the lower half of Fig. 3. The sum of squares is much higher for six loops than for the others, and there is a cyclic variation repeating on three loops; a high sum of squares coinciding with a low mean strength per loop. The statistical significance of these variations was tested by the L_1 test, using Nayer's tables, by which the ratio of the geometric and the arithmetic means of a series of variances is compared with the ratio for the normal distribution for corresponding degrees of freedom. Various comparisons give the following results:—

	N	k	L_1	P
All variances	24	18	0·820	P<·01
All except the variance for 6 loops	24	17	0·859	P<·01
All six crests	24	6	0·886	P about ·01
Five crests excluding the variance for 6 loops ...	24	5	0·947	P>·05
All troughs	24	12	0·959	P>·05

Evidently, even when the high variance for six loops is omitted, the variation in variance is statistically significant. There is also a real variation between the crest values, though its statistical significance is due to the high value for six loops.

It may be argued that as the number of loops is increased the breaking load variance should fall, although, because the loops are formed from a continuous length of yarn and are not gripped at the hooks, a simple proportional relationship is not to be expected. There is a trend towards lower variances with higher numbers of loops, both with the figures for crests and for troughs, but the change is small compared with the cyclic variation and is not statistically significant so, though the reality of the trend might be proved by more extensive tests, there is no justification for weighting the present data in the analysis of variance.

It is doubtful if either crest or trough values of the variance may be taken as true measures of the yarn variability as the inertia error is likely to cause abnormally regular breaks at one point, and abnormally irregular breaks at another. There is, therefore, this further objection to high speeds of traverse on pendulum type machines, that the standard deviation of the results is biased.

The experimental wave has been compared with the theoretical maximum possible inertia error as for the previous example, taking the effective extension at break of the yarn, from separate measurements, as 3·0 per cent.* and the mean strength per loop as 1·68 lb.

Loops broken	6	13	20
Calculated mean breaking load, lb.	10·1	21·8	30·6
Maximum possible inertia error, per cent. ...	3·9	3·6	3·5
Maximum expected strength, per loop lb. ...	1·745	1·741	1·738

The curve of the theoretical maximum strength per loop is shown in Fig. 3, and comes rather above the mean values, but the experimental wave extends well below the mean also, so that in the neighbourhood of 20 loops, for instance, the range of strength is about $5\frac{1}{2}$ per cent. and, for smaller numbers, the range approaches twice the calculated value. This may be because the formula of Martindale and Woods gives the overthrow only, and not the low values due to accelerating the pendulum.

This experiment investigates the lea test at the low end of the dial only, and inertia error waves are demonstrated only for specimens of a quarter of a lea and less. Further, the material is unusually regular and inextensible. It

*Note.—The effective extension is the extension measured on the latter part of the load extension curve. The load extension chart for this yarn showed the usual rapid initial extension followed by a straight line relationship between load and extension up to the break. The slope of the straight portion was equivalent to 3·0 per cent. extension from zero to breaking load. It has been assumed in the present calculations that the effect of the early, rapid extension is negligible.

is quite likely, therefore, that smaller inertia errors are to be expected in normal testing practice, but, on the other hand, the error waves are shown to persist through at least seven cycles, so there are evidently some circumstances in which the effect is not damped by the test specimen and in which the whole extent of the calculated error may be found in practice.

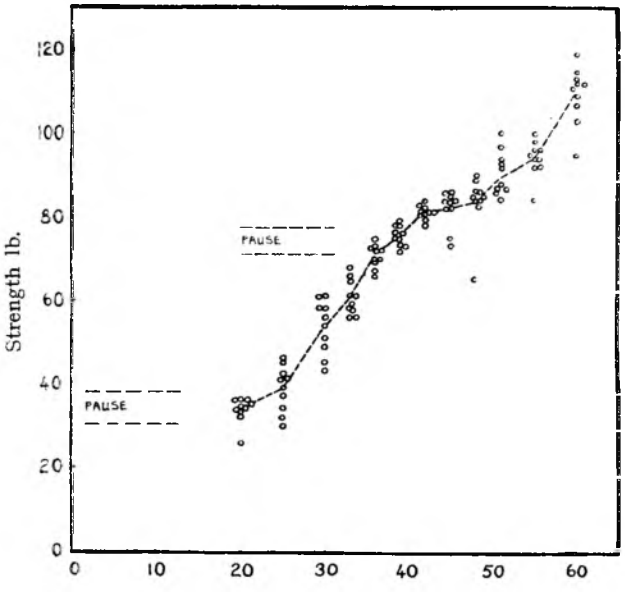

Fig. 4. Strength of weft way strips of Florentine drill with the width and length varied simultaneously.

The Effect of Simultaneous Variation in Specimen Width and Length of Cloth Strips

As explained in the introduction, the testing conditions round about the break of a particular size and type of specimen can be traversed by simultaneous adjustment of both specimen width and length. This has been done with weft way strips of a Florentine drill tested on a horizontal Goodbrand machine.

The weft was 22s/2 American cotton 55 picks per inch.

The machine details were:—

Capacity 700 lb.
v speed of pulling jaw 18 inches/min.
μ_0 machine rate of load 638 lb./inch.
T, natural period of pendulum 1·25 secs.

The machine was motor driven through reduction gearing. Multiple retaining pawls held the pendulum in position after the break. The machine pointer pushed before it a light wire pointer pivoted loosely on the main pointer pivot. The position of the wire pointer after the break was read. The machine pointer usually fell back a pound or two after the break as the pawls engaged in the ratchet quadrant. The wire was not seen to jerk forward when the specimens broke.

The cloth was first cut into cop widths and then test specimens were prepared from five of them. From each cop width strips were cut twice the length of the specimens and frayed down to the number of threads required. This provided two tests from every strip and a complete series of tests from each cop. Preliminary tests had shown where the pointer hesitated so the specimens were arranged to give more results at this place. Load-extension diagrams had also shown the customary rapid initial extension, followed by a straight line relationship. From a typical curve, from which E = 0·00625

inches/lb., specimen lengths were calculated which would give extensions approximately proportional to the breaking load for each strip width. The strip dimensions tested were:—

Number of picks ...	20	25	30	33	36	39	42	45	48	51	55	60
Distance between jaws, inches ...	3·7	4·3	4·9	5·2	5·6	5·9	6·3	6·6	7·0	7·3	7·8	8·4

Fig. 4 shows the individual results of the test with the breaking loads plotted against the specimen width and length. The results obviously follow a wavy line similar to that found on load-extension curves and demonstrate that it is possible to traverse such a line with actual breaking load results.

The movement of the pointer was watched closely during the tests. It was an easy matter to note, approximately, the part of the scale at which the pointer slowed down. The apparent pauses occurred at 30 to 38 lb. and at 71 to 77 lb. The latter does not quite agree with the experimental curve so it seems that the specimen length adjustment had not been quite accurate, but this does not spoil the validity of the experiment.

The data, reduced to strength per thread, have been analysed statistically by the analysis of variance and the L_1 test, which prove that the wave is statistically significant and that the data are significantly more regular for the high strength per thread means (36, 39 and 42 pick strips) than for the low strength per thread means.

Analysis of Variance. Florentine weft data, units (1 lb.)².

Source	Sum of squares	Degrees of freedom	Mean square
Between strip widths ...	1·551	11	0·1410
Between repeats	·552	9	0·0613
Residual	1·253	99	0·0127
Total	3·355	119	—

$L_1 = 0·675$.

(from Nayer's table for k = 12 and N = 10, $L_1 = 0·789$ lies on the 1% level of significance).

Much the larger part of the variation in variance appears to be associated with the variation in means, but there is a trend also, in which the variance falls as the strip width increases, as would be expected from statistical theory.

Martindale and Woods's formula has been used, as before in this paper, to estimate the maximum possible inertia error. Taking the grand mean strength per pick, of 1·796 lb., an effective extension of 8·3 per cent. and a strip 36 picks wide, 5·6 in. between the jaws, the maximum strength per pick works out at 2·014 lb. This is slightly more than the experimental result, but the succeeding minimum strength, at 55 picks, is 4·8 per cent. below the mean, and the range from crest to trough in the mean values is greater than the calculated inertia error.

A second test was made on specimens from the same piece of cloth, but using wider strips and a different load-extension gradient (E = 0·00408 inches/lb.) which, it was thought, would make the results fit the observed pauses more closely. One set of samples was prepared from each of ten cops. The strip dimensions tested were:—

Number of picks ...	51	55	60	63	66	69	72	75	78	81	85	90
Distance between jaws, inches ...	4·8	5·1	5·4	5·6	5·8	6·0	6·2	6·4	6·6	6·8	7·1	7·4

The mean strengths per thread in the first experiment appeared to follow a saw-tooth wave like that obtained in the earlier experiment with weights,

and the means for the narrower strips in the second experiment similarly followed a straight line down to a minimum, but the means for the three widest strips did not show the expected rise. The analysis of variance showed that the significance of the between strip widths variance was just below the 5 per cent level, and the value of L_1 was not significantly different from unity. Omission of the three widest strips from the analysis brought the ratio of the between strip width variance up to the 1 per cent. level, but the results remain much less spectacular than the first experiment and the value of L_1 was still not significantly different from unity. It seems likely that the chief reason for this different result is an unsuitable choice of specimen lengths. This view is supported by the results of further tests in which specimens of the same width as those which gave the highest and lowest results in the second experiment were tested at other specimen lengths. Specimens 51 picks wide and 4·8 inches between the jaws, gave the maximum strength in the second experiment, but in further tests, at jaw spacings of 2·9, 3·6, 4·2 and 4·4 inches, maximum strength was reached at about 3·6 inches. Similarly 69 pick strips 6·0 inches between the jaws gave the minimum strength in the second experiment, but with this strip width further tests at jaw spacings of 5·1, 5·7, 6·3 and 6·9 inches, indicated that the lowest strength was to be expected at the original spacing of 6·0 inches between the jaws. It seems likely, therefore, that a steeper gradient, more nearly equal to that used in the first experiment, would have given a more obvious wave.

Analysis of Variance. Florentine weft, 2nd experiment, strength per thread, units (1 lb.)²

Source	Sum of squares	Degrees of freedom	Mean square
Between strip width ...	0·1635	11	0·01305
Between cops	0·3015	9	0·03339
Residual	0·6687	99	0·00675
Total ...	1·1337	119	—

Analysis of Variance. Florentine weft 2nd experiment, excluding widest strips.

Source	Sum of squares	Degrees of freedom	Mean square
Between strip width ...	0·1300	8	0·01625
Between cops	0·1777	9	0·01974
Residual	0·3991	72	0·00554
Total ...	0·7068	89	—

It would be expected from general considerations that a maximum inertia error could be obtained at a particular point only by a nice adjustment of the variables, and so this method of simultaneous variation of width and length can be effective only when the extension characteristics of the test material are well known.

The Effect on the Apparent Strength of Cloth Strips of Varying the Starting Position of the Pendulum

In the earlier experiments with weights it was shown that the inertia error wave could be traversed by advancing the starting position of the pendulum. The experiment now to be described applies the same idea to tests with fabric strips. The advantage of this method of investigation is that the strip dimensions are constant throughout the test, which eliminates one source of variation in the group variances, so showing up more clearly the effect of inertia error on variance.

A comparison of parallel routine tests from two laboratories had shown considerable discrepancies both in means and in standard deviations and, as calculations showed that considerable inertia errors were to be expected in both sets of results, a special investigation was undertaken on one machine. The particulars were:—

Testing machine: Scott 400 lb. capacity, 10·4 inches/minute rate of traverse, machine rato of load, μ_0, 454 lb./min., natural period of the pendulum, T, 1·40 secs.

Fabric: Weft strips 1 in. wide, 4 in. between the jaws. Three shaft drill. Five cop widths of cloth were taken from the same cutting and from each cop width five strips were cut the full width of the cloth and frayed down to 50 picks wide. Then, after thorough conditioning, each strip was tested eight times along its length, each time with the pendulum starting from a different place. The starting point for successive tests was chosen at random for each test. The results were analysed statistically for each cop width separately and then, as the between-strip variance was significantly greater than the residual for each cop the results were regrouped into five classes in which the strip means were more nearly equal. The data in these classes were analysed again separately for each class as before.

Analysis of Variance. Drill weft, units (½ lb.)²

	Degrees of freedom	Mean square					
		Cop E	F	G	H	I	All cops
Between pendulum settings	7	38·05 **	21·48	33·07 **	20·80 **	15·71	25·82 **
Between strips	4	43·15 **	210·05 ***	274·16 ***	180·00 ***	200·24 ***	181·52 ***
Residual	28	14·93	19·29	11·92	8·44	12·81	13·48
		Class V	W	X	Y	Z	All classes
Between pendulum settings	7	19·17 ***	52·06 *	12·61	24·68 *	31·68 **	28·04 ***
Between strips	4	42·46 ***	27·48	7·44	16·56	10·03	20·79 **
Residual	28	5·32	22·86	6·98	11·25	11·08	11·50

Significance from ratio tables by Mahalanobis

* barely on the 5 per cent. point of significance

** between the 5 per cent. and 1 per cent. points

*** on the 1 per cent. point and over.

The analysis shows that the rearrangement of the strips improves the comparison, eliminating much of the between strip variation and improving the significance of the between-pendulum-settings variance, but even without rearrangement the between-pendulum-settings variance is significantly different from the residual.

The variance was tested for homogeneity by the L_1 test for which the variance for each pendulum setting in each class of five strips was calculated separately and then these were combined for all five classes, yielding eight variances based on twenty-five tests each. The value of L_1 was 0·8487 which, for $k=8$ and $N=25$ lies between the 0·05 and 0·01 levels of significance.

Figure 5 shows the mean values of strength for each pendulum setting in each class, together with the sum of squares for all classes. Classes V, W and X and the variance show an obvious wave, but Y and Z do not. The graph of the mean of all classes is similarly wavy. It is not clear why classes Y and Z have failed to show a wave. The mean curve ranges from a maximum of

71·82 lb. at 6 lb. starting point to 69·46 lb. at 12 lb. starting point; a range of 3·3 per cent. whereas the calculated value of the maximum possible inertia error for the conditions of this test is 15·3 per cent. The range for the largest wave, Class W, is 7·2 per cent., or about half of the calculated value, but the graph of the variances shows that the results are very variable when the mean strength curve reaches both its minimum and its maximum, so it would be unwise to suppose that the error in individual results is never larger than the mean variation found in this experiment, or in Class W. It seems more likely that the full calculated error has occurred in many of the tests, but that the variability of the material has made the waves overlap, so lowering the crest, and raising the trough, and increasing the variability.

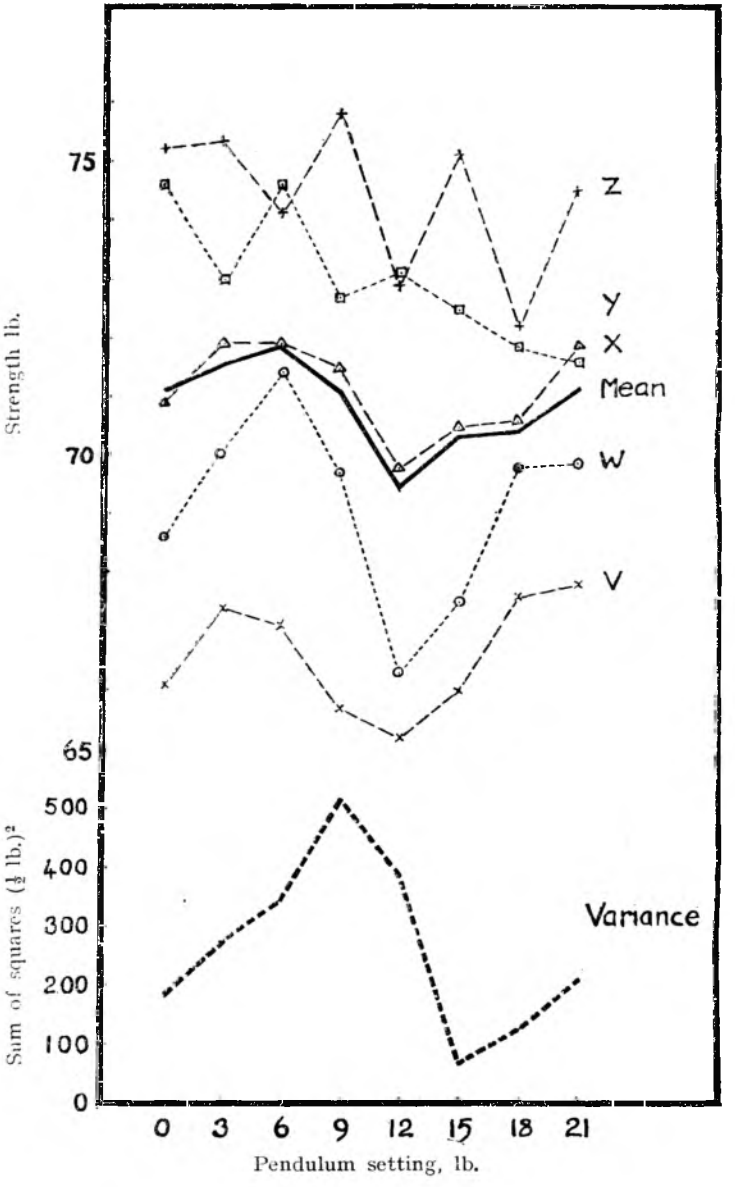

Fig. 5. Variation in the apparent strength of weft way strips of 3 shaft drill as the starting position of the pendulum is altered.

GENERAL DISCUSSION

Two examples from the literature and four special experiments have been employed to demonstrate the practical importance of the inertia error in pendulum type-testing machines. Routine load-extension charts on a wide variety of fabrics show that waves invariably occur at normal jaw speeds. In general, the first wave along a trace is shorter than the remainder, and the more extensible the test piece the shorter the waves tend to be. Repeats of the wave can commonly be followed through five cycles, and even up to seven, but there are some indications that waves of the correct period, but which fail to die away, may be caused by friction in the head jaw. Such waves can be demonstrated by deflecting the test specimen round guide pulleys arranged between the machine jaws. Then, as the specimen extends under load, the pulleys slowly rotate, but the friction in their journals may be sufficient to make their action jerky, and so to keep the pendulum moving jerkily throughout its traverse. A similar friction effect may be present in the head jaw slides of horizontal machines when they are inadequately lubricated, and, again, quite small burrs on the teeth of the ratchet quadrant are capable of modifying the pendulum movement and regenerating the inertia wave.

Matthew's data appear to cover the second and beginning of the third wave; Richardson, Bailey and Conrad's data appear to trace from the fifth to the tenth wave. In the present tests waves extending to seven repeats were found in the lea test and up to five in a test on cloth. Presumably, the more nearly perfect the elasticity of the material, the more clearly will the waves persist, but when many waves are present small differences in strength or in extensibility between samples will mask the effect of the waves on the average breaking load.

The significant variations in variance, found in addition to the variations in average strength, show that even in these special experiments the variations in average strength do not measure the whole of the calculated inertia error. It does not seem possible to find out how much of the breaking load indicated for a particular strip is inertia error. Real variations in strength merge with variations in the error to produce a general variability which cannot normally be split up. However, the variations in average and variance appear to be broadly in accordance with the theoretical calculations. The crests of the later waves do not always rise to the expected level, but on the other hand the data show negative inertia errors occurring immediately after a pause when the pendulum is being accelerated, and the calculations do not provide for this, so that, in the absence of more precise information, the formula proposed by Martindale and Woods (paper IV S31) can be used to estimate the probable maximum inertia error occurring in individual test results.

The current A.S.T.M. standard for textile testing machines[7] requires that the specimen shall break when the angle which the pendulum makes with the vertical is between 9 and 45°. In practice the pendulum is deflected to 45° at the maximum reading of the machine and the lower limit for specimen breaks is marked at one-fifth of this. Similarly the U.S. Government[8] has fixed a limit at one-tenth of the machine capacity. It seems likely that these limits have been fixed from practical experience of the unreliability of results obtained at small pendulum deflections. Martindale and Woods' formula could be used to estimate more precisely the lower limits of the dial reading which should be employed for particular specimen characteristics. The higher the jaw speed used, the higher the limit of readings should be. It seems impracticable to have speed changes from cloth to cloth on this type of testing machine. Some Goodbrand machines are already provided with gear boxes giving a speed of $4\frac{1}{2}$ inches per minute. Much lower speeds than this appear to be indicated by the formula for linen and cotton if the inertia error is to be kept down to $\frac{1}{2}$ per cent., but these make the test very slow. Bearing in mind the other possibilities of error and the probable effect of averaging, it may be advisable to standardise Goodbrand machines at $4\frac{1}{2}$ inches per minute rate of

traverse and to prescribe minimum breaking loads for particular types of fibre or particular cloth extensibilities. These minima could be calculated, but it might be sufficient to take them as a multiple of the observed wave length, e.g. ten times the load at the first pause. It would be necessary to increase the width of specimen for weak fabrics to bring their breaking loads up to the calculated minimum. This is already done to some extent; fabrics being tested in widths of 2 in., 4 in. and 6⅛ in. Comparisons between different fabrics would be complicated by the variations in strip width, but complications from one source or another seem to be inevitable.

The present tests do not provide an exhaustive examination of the behaviour even of cotton fabrics. They have had to be confined, indeed, to somewhat unusual testing conditions in order to obtain measurable errors and the results must be used with caution. It may be that inertia errors do not account for any large part of the differences experienced between laboratories in tests of warp way strips of heavy drills and ducks, but it is usual to test weft way strips under the same conditions and these, being commonly weaker and less extensible, are more likely to give appreciable inertia errors. The wide variety of fabrics makes it likely that tests are frequently attempted on unsuitable capacities of machines and the use by some British firms of American specifications, built on the vertical Scott machine, introduces strip dimensions smaller than are advisable for the usual Goodbrand machine. Further, as the industrial uses of fabric extend, tests are likely to be made on pendulum type machines designed for other materials. When the testing facilities are not ideal there is a temptation to argue, for instance, that the lower portion of the scale of a heavy capacity machine is sufficiently accurate for routine testing because there appears to be no reason why a small deflection in a pendulum balance device should not be measured accurately. But the difficulty is not with the pendulum regarded as a static weighing device. Luckily the presence of serious errors can be judged easily from the motion of the pointer.

It is to be expected that a particular cloth will give fairly consistent results in repeat tests on one machine, but it does not follow that equivalent results should be expected on a different machine, or that consistent differences will be found between cloths. A specified strength will normally be fixed from experience with a particular set of conditions, but these conditions may give rise to an appreciable overthrow error and the specified figure will then include this error. In the meetings of the Physical Testing Committee of the Institute Standardisation Scheme it has been pointed out that although the strength of a fabric is commonly specified as so many pounds, the figure is to be understood to apply solely to the machine and speed specified, and therefore to include all the errors associated with that machine and speed. It by no means follows that the same strength is to be expected at a different speed, at a different machine capacity, or machine rate of loading, or on a machine differing in the method of applying the load, for example, with a spring loaded machine.

The relative importance of different sources must vary with the conditions. No doubt in some machines the chief errors are due to inadequate maintenance and in others to poor technique. The inertia error is one of many difficulties in fabric testing.

CONCLUSIONS

(1) Experiments on cotton specimens confirm the reality of cyclic errors corresponding to the inertia errors examined in earlier papers. These affect the mean strength and the standard deviation.

(2) The error cycles or waves persist through several repeats, but the variability of the material makes them difficult to isolate.

(3) The errors are large for relatively weak and inextensible specimens. The jaw speeds in common use on pendulum type machines are too fast. Theory indicates that if the maximum possible inertia error is to be reduced to ½ per cent., the jaw speed should be reduced for linen and cotton to less

than one twentieth of its present value. This would make testing impracticably slow. As interest is centred chiefly on the average of a set of tests and the inertia error probably varies within such a set, it may be permissible to provide for a higher maximum possible inertia error, of say 2 per cent., and to employ schedules of minimum breaking loads for different types and dimensions of specimen. It is suggested that the speed of $4\frac{1}{2}$ inches per minute now used on Goodbrand machines in some quarters should be regarded as a maximum for cotton and linen fabrics.

(4) It does not appear to be practicable to apply a correction for the inertia error except, perhaps, to the results of the Chandler bundle test in which the extensibility of the specimen is likely to be so small that the error is independent of the test specimen.

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TENTATIVE TEXTILE STANDARD No. 7, 1942

Specification for a Bundesmann Type Water Repellency Testing Machine

Tentative Textile Standard No. 7, 1942—"Specification for a Bundesmann Type Water Repellency Testing Machine," published in the *Journal* of the Textile Institute, 1942, **33**, S50-S52, has been before the members of the Institute for the required period of ten months. It is proposed, unless any objections are received, to submit this tentative standard to the British Standards Institution for acceptance as a British Standard (Textile). Comments should reach the Acting General Secretary not later than 31st December.

The Method of Test for a Bundesmann Type Water Repellency Testing Machine will form the subject of Tentative Textile Standard No. 8. This will be published at a later date.

TENTATIVE TEXTILE STANDARD No. 1a, 1942

Standard Method for Determining Resistance to Shrinkage of Wool Fabrics

This tentative standard was published in the *Journal* of the Textile Institute, 1942, **33**, S41-S48. In the light of further development work the recommendations are now being revised. The technical committee which is dealing with this work will also give consideration to any comments on the published tentative standard which are received not later than 31st December.