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Development and Transfer of Technology Series

No. 4

MANUAL ON INSTRUMENTATION AND QUALITY CONTROL IN THE TEXTILE INDUSTRY

UNITED NATIONS

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UNITED NATIONS
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Preface

As the textile industry in the developing countries becomes increasingly important, the achievement of standards acceptable to quality-conscious consumers throughout the world takes on greater significance. The aim of this manual is to provide the knowledge necessary to achieve such standards by giving an outline of the measurement and quality control of the mechanical and physical properties of fibres, yarns and fabrics, and to a lesser extent, of their chemical and physico-chemical properties. The various types of equipment required to do this are listed by broad category.

The manual has been prepared by Dr. R. Nield of the Department of Textile Technology at the University of Manchester Institute of Science and Technology, United Kingdom. The views and opinions are those of the consultant and do not necessarily reflect the views of the Secretariat of UNIDO.

Explanatory notes

References to dollars ($) are to United States dollars, unless otherwise stated.

Besides the common abbreviations, symbols and terms, the following have been used in this report:

CRL	constant rate of loading
CRT	constant rate of traverse
CRE	constant rate of extension
V	coefficient of variation
SI	International System of Units

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Introduction

This manual is intended as a guide to the textile properties that are usually tested, the instruments and methods employed, and the suppliers, and the cost, of equipment. Where the reason for a test is not self-evident a brief explanation is given but, as the field is so vast, no attempt is made to describe either the instruments or the methods of test in detail.

It is becoming more important than ever to provide an effective system of controlling the quality of production as the trend in the textile industry towards shorter processing sequences, higher productivity and more automation is accompanied by the removal of many quality safeguards which increases the risk of producing an unacceptable product.

For example, one of the quality problems facing the textile industry is to convert extremely variable raw materials into uniform yarns and fabrics. Traditionally, reliance was placed upon repeatedly blending or doubling the material, particularly in the early stages of production, to even out variations and lessen the effect of any defects present in the raw material. This involved a whole series of machine processes each of which, being itself imperfect, created further variations and, therefore, the need for even more doublings. A very large number of doublings produced satisfactory results even when the machines were not in the best condition. The modern trend, however, is to reduce the number of processes thus achieving cost benefits, which is good provided that quality does not suffer as a consequence.

Considerable success has been achieved in reducing the number of processes owing to three main factors: better machine design and construction; better understanding of textile technology; and better quality control at intermediate stages of production. In the modern cotton spinning mill the number of doublings has been reduced from about 1,728 to 36. However, since there are now so few doublings to even out variations, faulty performance by any machine in the sequence is much more likely to be detectable in the final product, and effective quality control is vital.

Recognition of this has stimulated work on the design and development of all kinds of testing instruments, the use of which has enabled buyers of textile products to specify their quality requirements with greater precision and to verify that their specifications have been met. This, in turn, has made all sectors of the textile industry more quality conscious.

The setting-up and operation of a good quality control department, equipped with precision instruments, staffed by competent people and housed in a controlled atmosphere, are expensive. However, the benefits of a properly managed quality control department more than justify the expense.

The material in this manual is arranged as detailed below.

Chapter I deals with some general aspects of testing textiles, particularly the problems caused by the presence of moisture in the samples. Attention is drawn to the necessity of maintaining control over the atmosphere in the testing laboratory and of carefully specifying the conditions in which the mass and the moisture content of samples are determined. Methods for making such measurements and pre-conditioning samples are described.

In chapters II and III, textile testing and the tensile properties of textiles are discussed.

Chapters IV-VII deal with properties of fibres, yarns and fabrics. The principles of operation of appropriate instruments are given, but no attempt is made to detail the methods of measurement. While attention is focused mainly on mechanical and physical properties, there is also coverage of the chemical and physico-chemical properties.

For ease of reference, the properties are grouped following the natural divisions of the industry (fibres, yarns and fabrics), but first some items of common interest to all laboratories (atmospheric conditions, weight, tensile properties etc.) are considered.

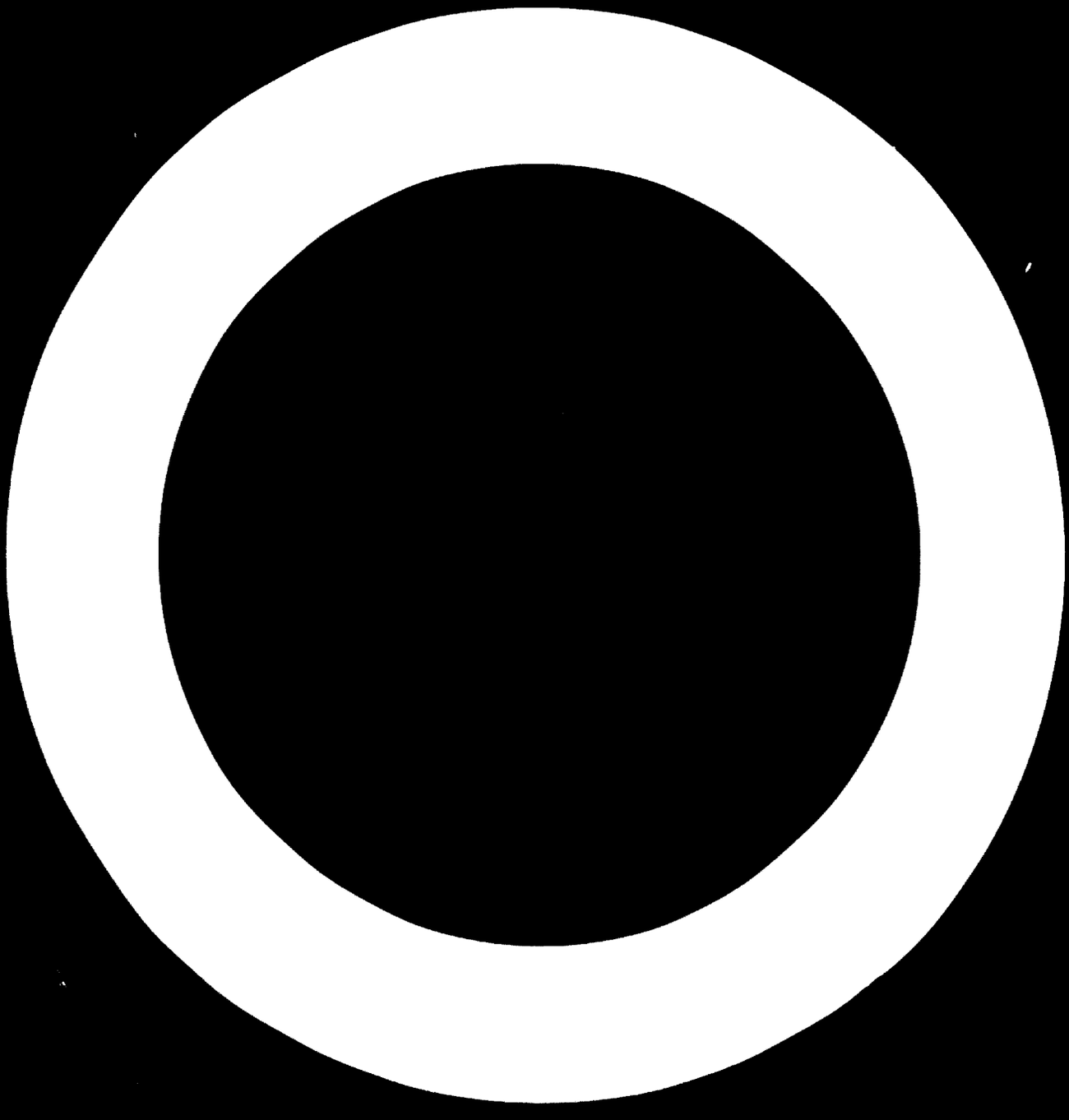
Chapter VIII describes the properties of carpets and textile floor coverings; and chapters IX and X concern the functions of the chemical and physico-chemical laboratories and of the pilot plant.

A tabulation of the instruments required in textile mills and laboratories is provided in annex I. Properties and tests are itemized and appropriate instruments are given together with an indication of the importance attached to each (essential, recommended or useful) and the price range (low, medium or high). A list of suppliers is given in annex II.

A selection of the quantities and units recommended for the measurement of textile properties is given in annex III.

Further information on instruments can be obtained from the suppliers and full details of the methods of procedure and of the precautions that must be taken to produce reliable, reproducible results may be found in handbooks issued by various national and international organizations (annex IV).

Some duplication has been necessary to make each section complete for the benefit of the reader with specialized interests. While care has been taken to make this information as accurate as possible it may not be exhaustive; apologies are tendered in advance for any errors or omissions. It is intended to bring the information up to date in future editions.



I. General aspects of testing

The properties of textiles are dealt with under the appropriate headings of fibres, yarns and fabrics, but some terms of general interest are covered here.

Temperature and relative humidity of the atmosphere

Textile materials are hygroscopic and their properties vary according to moisture content. When a textile material is transferred to a different atmosphere its temperature and moisture content change until they reach equilibrium with that atmosphere. The effective control of temperature and relative humidity is therefore vital in all textile testing laboratories and in most production departments. Frequent checks on the atmospheric conditions are necessary. The internationally agreed standards are as follows:

Standard atmosphere	*Temperature (°C)*	*Relative humidity (%)*
Temperate	20 ± 2	65 ± 2
Tropical	27 ± 2	65 ± 2

Hygrometers measure the wet-and-dry-bulb temperatures from which relative humidity is calculated. Other types of instruments depend upon the response of some substance, e.g. the length of hair, to changes in relative humidity.

The ordinary wet-and-dry-bulb thermometer is inaccurate unless placed in an air stream. Local conditions may be measured by a whirling hygrometer or by a fan-ventilated hygrometer and a continuous record of temperature and relative humidity may be obtained by using a recording thermohygrograph.

A common error is to place the instrument in a safe position, remote from the working area, where, although it is unlikely to be damaged, it may measure conditions that are of little relevance.

Mass of textile materials

Since textile materials are hygroscopic, a specimen consists of dry fibres and water and the amount of water present affects its mass. Fibre being more expensive than water, failure, in any commercial transaction based on weight, to make due allowance for water content can be very expensive. One way around this problem is to dry all samples thoroughly before weighing them. Oven dry mass is determined by one of the following methods:

(a) A sample is placed in a hot-air oven that has a built-in balance and pre-heater, and dried in a forced, hot-air current. Its weight is checked at intervals until it reaches a constant value known as the oven dry mass;

(b) Hot air is blown through a sample placed in a special container;

(c) Small samples may be dried by infra-red radiation;

(d) Samples are dried, in a chemical oven, in glass bottles of known weight;

(e) Small samples are dried in a desiccator with a hygroscopic chemical substance. This is a very slow method, suitable only for research.

Regain or moisture content

Textile materials are rarely used in the dry state so, for commercial purposes, the dry weight is increased by an agreed percentage (official regain) to give the correct invoice mass also referred to as the correct condition weight.

The amount of moisture present in a textile material may be expressed in terms of regain or moisture content.

$$\text{Regain}\,(\%) = \frac{(\text{water present}) \times 100}{(\text{dry weight})}$$

$$\text{Moisture content}\,(\%) = \frac{(\text{water present}) \times 100}{(\text{moist weight})}$$

Four methods commonly used to measure regain are as follows:

(a) Regain or moisture content is determined by weighing a sample before and after drying to constant mass or by using an instrument that responds to the amount of water present;

(b) In the electrical hygrometer, air is drawn over a thermistor pushed into the middle of the sample and then over a pair of wet-and-dry-bulb thermistors. The vapour pressure and relative humidity of the air and hence the regain of the sample are derived from tables;

(c) Moisture content affects the electrical conductivities of textile materials. If the electrical resistance is measured between two electrodes pushed into the sample, the regain may be calculated or read directly from a suitably calibrated scale;

(d) In the electrical capacity method, the dielectric constant of a sample of known mass and shape is measured and the regain deduced.

The official regain varies according to the type of fibre. Some examples are given below.

Fibre	*Official regain (%)*
Acrylic	2.0
Cotton	8.5
Nylon	6.25
Polyester	1.5
Silk	11.0
Viscose	13.0
Carded wool	17.0
Combed wool	18.25

In some cases the values vary with the state of the material and are sometimes increased to take account of any additions such as lubricants. When time does not permit pre-conditioning, the regain on a sample is measured at the time of weighing and an appropriate correction made.

Pre-conditioning of samples

To ensure that the results of weighing and other tests are comparable within a given laboratory and between different laboratories, all specimens are first brought to a standard moisture content by conditioning them for several hours in a standard atmosphere, and are then tested under standard atmospheric conditions. Because of hysteresis over-moist samples are first pre-dried at 10-20 per cent relative humidity and not more than 50°C and then conditioned at 65 ± 2 per cent relative humidity and 20 ± 2°C (or 27 ± 2°C).

Samples drawn from a fully-conditioned area may be tested immediately. However, it is not always feasible to maintain production departments (e.g. the blowing room) at standard atmosphere in view of the enormous quantities of air that are exhausted, nor is it always practicable to wait for samples to condition. In such cases, either the actual air conditions are measured and due allowance made for deviations from standard or the moisture content of the material is measured directly and the appropriate allowances made. Samples may be conditioned by letting them stand in a room in which the temperature and relative humidity are controlled, or by placing them in a conditioning cabinet, which is more rapid.

Weighing instruments

Every mill, textile centre or research laboratory requires an assortment of weighing instruments. In principle, any balances of appropriate capacity and precision may be used. In practice, it is usual to use torsion balances for fibres, chemical-type balances for yarns and fabrics, scales for bobbins and cones, and heavy-duty weighing machines for bales, laps, beams, daily productions and waste. Some balances are calibrated directly in textile units or percentages and some are specifically designed for particular tests. Quadrant balances are widely used. A particular balance may be suitable for several purposes but, for process control, it is important to have instruments available when and where required.

II. Textile testing

The quality of a textile product is difficult to define and even more difficult to quantify since the ultimate test of acceptability is often a personal one. For this reason, perfection and uniformity are not essential, which is fortunate because textile fibres, especially natural ones, are extremely variable and are processed in such huge quantities that some variation in the end product is inevitable and may even be aesthetically desirable. How much variation and what types of defects may be tolerated in any given product depend upon factors related to its use.

Testing, in itself, does nothing to improve quality but the proper use of instrumentation can lead to improved quality and increased productivity, leading in turn to reduced production costs, the penetration of new markets and repeat orders.

One of the major problems in textile testing is to obtain consistent, reproducible laboratory results, which is sufficiently difficult in any one particular laboratory let alone between different laboratories. This problem exists because of the inherent variability of the material tested, differences in the condition of the instruments, atmospheric conditions, techniques of sampling and testing, and differences between operatives. Such variables should be standardized as far as possible; when this is not possible a correction factor should be applied.

In an attempt to reduce variations between laboratories, the National Bureau of Standards, United States of America, has prepared and will supply cotton calibration samples with certified standard values. By testing such samples, a laboratory can compare its results with the average findings of some 400 other laboratories making similar tests and hence work out correction factors for particular operatives and instruments. Testing procedures should be revised periodically to make sure that the aims and objectives are clearly defined and logical, that the work programme is designed to meet those aims and that the methods of testing, recording, summarizing and presenting the results are satisfactory and fully understood by the people who have to carry them out.

Similarly, the International Wool Textile Organisation (IWTO) has set up interwoolabs that periodically check that their results for wool air-flow fineness are in agreement with those of standard top samples

Most textile tests do not demand any great skill on the part of the operative but unless they are carried out conscientiously, with meticulous attention to detail, the results are of little value.

Textile testing is repetitive work and can become extremely monotonous. It is therefore important to devise means, such as rotation of jobs and training in new skills, to maintain the interest and enthusiasm of the operative.

The education and training of control personnel should be continuous, so that they are frequently reminded of the high standards towards which they should strive and are constantly encouraged to stamp out malpractices that tend to arise in the name of expediency.

Sampling

Textile materials are extremely variable and it is usually practicable to test only a very small part. Also, many tests are destructive, so it is seldom possible to examine the same specimen before and after treatment. The only possibility is to test small, often minute, samples and assume that the results will be representative of the whole. Test results can be no more representative than the samples on which they are based, therefore sampling is of prime importance. Various methods of drawing representative samples have been devised, the most appropriate one in any particular case depending upon the circumstances.

Presentation of results

A textile test gives specific information on a particular property, therefore it is essential that the tests be designed to give the required information. Careful planning of a test programme can save time and money while giving more useful data. Testing is of little value unless the results are recorded in such a manner as to reveal the maximum amount of useful information. Great advances in instrumentation and measuring techniques have been made in recent years but specialized knowledge and experience are still often required in order to interpret the results. It is no part of the quality control department's function to usurp the duties of departmental managers. A well-planned process control procedure highlights problems but it is then up to the departmental managers concerned to take corrective action. Good managers use test results to complement their basic expertise, not to replace it. On the other hand, the

test programme should be designed and the results should be presented in such a way as to simplify the decisions required by making the necessary corrective action as obvious as possible. This may be done on a statistical basis using control charts and the like, simple colour codes can sometimes be used with great effect.

Management of textile testing

It is a waste of money to install expensive instruments in a laboratory where the atmospheric conditions cannot be maintained at internationally accepted standard levels. Not only does failure to condition and test samples under standard atmospheric conditions often invalidate the results, but the instruments themselves may become damaged. Similarly, valuable instruments should not be placed in the hands of inadequately trained operatives. Operatives should be thoroughly trained and testing procedures clearly laid down in accordance with internationally accepted practices and these procedures should be rigorously followed.

Realistic quality standards should be laid down by management. It is futile to demand standards that past experience has shown cannot be attained with the materials and machinery available.

Regular servicing on a planned maintenance basis is as important for instruments as for any other type of machinery. Routine testing can often be substantially reduced if the machines are serviced and re-set at planned, regular intervals, and tested to ensure that they are producing standard or higher quality before they are put back into production. Frequent calibration of instruments is required. Before an instrument is purchased, its role should be clearly defined and a test programme mapped out for its use.

Quality and process control

The term quality control is commonly used to mean the assessment of the quality of a finished product, which is necessary to ensure that goods supplied match the buyer's specifications. This involves testing a representative sample and deciding, on the basis of that sample, whether the whole is acceptable or not. It is in this sense that the term will be used in this manual.

If anything is wrong at this final stage, there is little the supplier can do apart from down-grading the product and reducing its price. The manufacturer, therefore, needs more detailed information and he needs it during processing. First, he needs frequent monitoring of the material in progress to ensure that all is well. Secondly, if something does go wrong, not only does he need to know as soon as possible, but also he needs a breakdown of the information into a form that will enable him to discover the source of the fault and take remedial action. This second process is often referred to, in the mill, as quality control but it will be referred to as process control in this manual.

A quality control laboratory may be required to deal with both quality control and process control and sometimes the same instruments may be used for both purposes; the differences lie in the testing procedures and in the presentation and analysis of the results.

The production of textiles involves a long series of processes: fibre production, yarn manufacturing, grey cloth manufacturing and fabric finishing. Each stage is often carried out in a separate factory. Even in integrated mills, processes tend to be managed quite independently so quality control is, therefore, applied at the end of each stage to ensure that goods supplied or received conform to the required specifications.

In view of the long sequence of operations, it is most important that each individual process should be kept under proper control so as to minimize the amount of substandard material produced. Process control is the routine monitoring of intermediate processes in such a way that off-standard machines or techniques can be pin-pointed and corrective action taken as soon as possible to minimize off-standard production. Because of the variability of the material tested and of the practical limitations on the amount of testing that can be carried out, some variations in the results must be expected. The question arises whether any recorded deviation from a required value is due to faulty processing or merely a reflection of the inherent variations. Statistical methods can be used to assess the significance of any differences.

The aim of the quality control department should be to do the minimum amount of routine testing consistent with discovering off-standard work. In a well-controlled mill producing standard lines, machine changes should be very infrequent. Once a real deviation from standard is discovered by the quality control department, it should be reported to, and corrective action taken by, the production department. A record should be kept of why the change was considered necessary, what action was taken and the result of that action, which again involves the quality control department. There should be a further check, say one or two days later, to make sure that conditions have not reverted to what they were before it was decided to make the change. To obtain realistic results from the testing programme, all the production should be represented, which means that, even it testing is actually done only during the day shift, sampling should extend over the production of all shifts.

The vast amount of information that accumulates over a period of time can be used as a background against which specific results may be judged. The information may be used to produce quality-control charts.

With the time factor in mind, it is not always necessary or wise to choose the most expensive and sophisticated instruments. For process control purposes in particular, a simple robust instrument that can be used frequently, on the spot, by an operative is often more effective than a sophisticated precision instrument that requires careful handling by a highly-trained technician who may not always be available when required. Lack of absolute precision can be offset by a greater frequency of testing.

On-line quality control

Most textile process control procedures consist of making occasional spot checks on certain properties. Deviations are only discovered after the event so that substandard material is bound to slip through, the amount depending upon the frequency of testing and the speed with which corrective action is taken. Ideally, the whole of the production should be monitored and the response to any observed deviations should be immediate and automatic.

Continuous, on-line quality control is available in some areas. The initial cost is high and the equipment tends to be rather complex but these disadvantages may be more than offset by savings in other respects.

When on-line quality control is installed, operatives come very quickly to rely upon it and therefore the maintenance of such equipment is of great importance.

Frequency of testing

The frequency of testing and the number of readings to be taken are not matters for arbitrary decision. The number of instruments of each kind that are required depends upon the number of tests to be carried out which, in turn, depends to some extent on the size of the mill, but, more especially, on the number of different qualities of textiles produced and the frequency with which they are changed. It also depends upon the degree or precision and the confidence level required. The number of tests required can be obtained from tables or calculated from the formula:

$$n = \frac{t^2 V^2}{E^2}$$

where V is the coefficient of variation of the sample tested
E is the desired precision (allowable random sampling error)
t is the probability factor corresponding to the confidence level required
n is the number of tests

For example, if V equals 2.0 per cent and it is decided that the random sampling error should not exceed 1 per cent of the mean value, then at the 95 per cent confidence level and t equals approximately 2, the number of tests should be

$$n \approx \frac{2^2 \times 2^2}{1^2} = 16$$

(The exact values for the 95 per cent confidence level, as found from tables, are n equals 16 and t equals 2.12, in which case the precision would be 1.062 per cent. If n is less than 10 and V is large, corrections may be necessary.)

Thus, if a mill has 8 machines, two samples should be drawn from each machine; but if it has 16 machines, then only one sample per machine is needed to give an equally reliable answer provided that the variation is the same in both cases.

The required number of instruments of a given type may be calculated from the number of tests required and from the time necessary to make the test, but other factors are involved, such as the location(s) of the instruments, which may necessitate duplication of the equipment.

III. Tensile properties of textiles

The strongest fibres do not necessarily make the strongest yarns or the strongest yarns make the strongest fabrics because other factors related to yarn and fabric structures play important roles; the tested performance of a yarn in a fabric is quite different from when it is tested alone. A textile material may break because it is overloaded or because it is over-extended.

Tensile strength and elongation

Tensile strength is the resistance of a material to elongation under a load applied in one direction. The load applied during processing may theoretically be constant as in beaming or it may be continually varied as in spinning, but either way there will always be some variation. Also, as with the other physical characteristics, the tensile strength of the material varies from point to point. Obviously, a breakage is most likely to occur when the maximum load is applied to the weakest point. However, the loads applied and the local strength characteristics vary independently of each other so that the maximum loads coincide only rarely with the weakest points. Because of this, and for economic reasons, it is usual when processing yarns to tolerate some end-breaks and the processing conditions are selected so as to contain the number of end-breaks within acceptable limits.

The ultimate tensile strength, or *breaking load*, of a fabric specimen is the force required to stretch it to its breaking point, and the *breaking extension* is the elongation of the specimen at that point. From the results of testing a number of similar specimens of a fabric on a tensile strength machine, one can calculate the mean value and coefficient of variation *(V)* of both the breaking load and breaking extension of the fabric. However, there are different testing methods, and the values obtained for these parameters depend on the method employed.

Under load, textile materials stretch in rather complicated ways, so that the measured value of breaking load or ultimate tensile strength depends not only on the actual load applied but also on the way in which it is applied. Thus, in order to achieve meaningful and comparable results for tensile tests, the load must be applied in a standardized way. One way is to increase the load at a constant rate irrespective of how the specimen stretches and to record the value the load or the elongation has reached when the specimen breaks. The method is known as the *constant rate of loading* (CRL) method.

In practice, textile materials are seldom subjected to uniformly increasing loads. What often happens is that they are stretched until they break. Admittedly, stretching the material induces internal tension, which builds up until failure occurs, but essentially the specimen breaks because it has been stretched beyond its limit rather than because of the magnitude of the load applied.

Another way of testing the tensile properties of a specimen is to elongate it at a constant rate, for example by fixing one end of the specimen and withdrawing the other at a constant rate. This is known as testing at *constant rate of extension* (CRE). Some instruments of this general type have constant rate of traverse of one end of the specimen, but some small movement of the other end is required to actuate the mechanism that indicates the value of the load applied. Thus they correspond only approximately to CRE and are known as *constant rate of traverse* (CRT) machines.

Different results are obtained according to whether the method of testing is CRL, CRE or CRT. Other factors that affect the results are the length of the specimen, the time taken to break it and its previous history. When presenting results full details of these factors should be given.

Impact resistance

Often textile materials break owing to shock loads. The resistance to such loads may be determined by using an impact tester in which one end of the specimen is fixed while the other end is subjected to a shock load along its length, which may be applied by a pendulum. The energy lost by the pendulum before it comes to rest is calculated and equals the energy needed to break the specimen. This is known as the work of rupture.

Other tensile properties

Some of the more modern textile testing machines can be adapted to measure such tensile properties as:

(a) Creep, or the slow extension of a specimen kept at constant load;

(b) Relaxation, or the slow loss of tension in a specimen kept at constant elongation;

(c) Elastic recovery, or the degree to which the specimen recovers after loading or elongation to less than its breaking point;

(d) The effect of load cycling, or constantly varying the load applied between chosen limits;

(e) The effect of extension cycling, or constantly varying the elongation between chosen limits.

Machines with different capacities are required according to the type of material (fibres, yarns or fabrics) to be tested. The principles are the same: the differences are in scale.

IV. Fibres

Fibres are the basic raw materials of the textile industry. Usually they are converted first into yarn and then into fabric. Fibres fall into two main categories: naturally occurring and man-made. The natural fibres may be of animal (wool, hair etc.), vegetable (cotton, linen etc.) or mineral (asbestos etc.) origin. The man-made fibres are classified as natural polymers (viscose rayon, acetate etc.), synthetic polymers (polyester, polypropylene, acrylic etc.) and others (carbon, glass, metal etc.). Apart from silk, the natural fibres occur in relatively short lengths. Man-made fibres, on the other hand, are initially produced as continuous filaments; they may be used as such, singly or in groups, to produce monofilament or multifilament yarns, or they may be cut to a staple length (40 mm for cotton and 120 mm for wool), usually to simulate one of the natural fibres.

Each type of fibre may be used individually or in blends. It is now a common practice to blend natural with man-made fibres so as to achieve an optimum combination of physical properties and price.

Identification

Individual types

In specifying any yarns or fabric, one of the most important factors is the raw material used. It is therefore very important to be able to identify fibres and analyse blends quantitatively.

A sample of unknown fibres can be classified as a single type or as a blend by simple microscopical examination. Sometimes this may also be sufficient to identify the fibres, or at least to isolate them into broad groupings.

A light microscope is adequate for natural fibres and slides may be prepared as whole mounts, cross-sections or surface casts. Reversing convolutions and a lumen in the side view indicate cotton; surface scales characterize animal fibres; cross-markings are typical of bast fibres, and smooth profiles indicate man-made fibres.

However, since crimping, bulking, texturing, finishing and other chemical processes affect the shape of man-made fibres, such fibres are best examined under a polarizing microscope.

Most textile fibres are birefringent, that is, the refractive index along the fibre differs from that across it. When such a fibre is examined between crossed polars under a polarizing microscope, interference bands are usually seen and may be used to identify the fibres. A quartz-sensitive tint plate (first-order red plate) placed in the lens system gives more colours and is particularly useful for fibres with low birefringence.

The various animal fibres are distinguishable by their different scale patterns. If the scale pattern is not easily seen, as is often the case when the fibres are dyed a dark shade, a cast of the fibre surface is made and examined.

Cross-sections are informative with natural fibres, but less so with man-made fibres whose cross-sectional shape may be varied in manufacture and may be further distorted by such treatments as texturing.

Cross-sections are cut by the plate method or by using a microtome. Larger samples may be produced by using a grinding technique.

Hot-stage microscopy is particularly useful for synthetic polymer fibres. Fibres are heated under the microscope and observations are made of the temperature at which melting takes place.

Behaviour on heating

Fibres respond in different ways when heated: some melt, some decompose without melting, some burn, some do not. Fibres may be broadly grouped by their reaction to different ways of heating. They should be studied in the following ways:

(a) By bringing fibres slowly up to a flame and observing whether they shrink or melt;

(b) By observing whether fibres melt or char when heated to a certain temperature, e.g. 337°C, as indicated by the melting of a particular type of crystal;

(c) By observing whether the fibres burn when placed in a flame and whether any characteristic smell or vapour is produced.

Other tests

Having broadly classified the fibres, e.g. as animal fibres or thermoplastic polymers, additional classification is made by:

(a) Testing for the presence of certain elements such as chlorine and nitrogen;

(b) Observing any reaction to staining;
(c) Measuring fibre density;
(d) Treating with a series of solvents either at room temperature or the boiling point until one is found in which the fibres dissolve;
(e) Checking extensibility;
(f) A drying twist test;
(g) A refractive index test for glass fibres;
(h) X-ray diffraction;
(i) Electron microscopy;
(j) Infra-red spectroscopy;
(k) Differential thermal analysis;
(l) Thermographimetric analysis;
(m) Microscopical examination of fibre ash;
(n) Studying the microscopical appearance, in profile and cross-section and, if necessary, making surface casts.

Procedures *(h)* and *(m)* are highly sophisticated.

A very difficult identification problem exists where materials have been treated with fibre-modifying finishes and dyestuffs.

Bicomponent fibres may be identified by cross-sectioning and staining.

Analysis of fibre blends

Many textile materials contain more than one type of fibre. Mixed yarns of different fibres may be sorted manually after visual or microscopical examination and then further analysed as individual fibre types.

Mixed fibres cannot readily be separated by hand, especially if the fibre types are similar. In such cases, the presence of more than one fibre type is established by microscopical examination. A selective stain is often helpful.

Further differentiation is best done by solubility tests using various reagents in a planned sequence. When one component dissolves, tests are continued on the residue until every component has been identified.

Infra-red spectroscopy

Synthetic fibres are readily identified using infra-red spectroscopy, a technique that is particularly useful for very small samples. The above techniques are well covered in *Identification of Textile Materials*[1] which also includes tables giving appropriate schemes of analysis and recommended sequences in which the various tests should be applied. The seventh edition also includes a comprehensive set of photomicrographs of various textile fibres.

[1] Textile Institute, Manchester, 1975.

Fibre finishes

Before embarking on any chemical analysis or staining test it is necessary to remove dyestuffs and finishes. Care should be taken in the choice of reagent to avoid excessively harsh treatment that may damage the fibres. In this connection tests are required to identify resin and silicone treatments.

Fibre properties

The physical properties of yarns and fabrics depend upon many factors including the fibre properties. An analysis of fibre properties, coupled with experience, can give a broad idea of what the results are likely to be when the fibres are spun into yarn. However, because of the many properties to take into account, and the fact that their interactions are still imperfectly understood, it is not yet possible to predict with any great degree of accuracy the effect on the yarn of varying one or two of the fibre properties. Nevertheless, to ensure uniformity of the quality of the raw materials purchased, and for many other reasons, it is desirable to be able to measure fibre properties.

Fibres may be classified by visual assessment. Grade of cotton, for example, is based upon the visual assessment of colour, impurity content and quality of ginning (removal of cotton fibres from the seed) in comparison with standard samples. More scientific methods are discussed below.

Length characteristics

Fibre-length data are a guide to spinning limits. Changes in fibre length, for example, indicate the efficiency of short fibre removal in combing or the extent of fibre damage in carding. Effective length is a guide to machine settings.

Because of the great variability in the length of natural fibres, even among those grown on the same animal or plant, several properties are required to adequately describe fibre length. The properties chosen depend on the method of testing employed. Different length fibres may require different instruments.

Short staple fibres

A hand-prepared sample is measured for staple length. This method is used by classers for commercial purposes. Individual fibres may be soaked in paraffin oil to control their movement, gently straightened and measured.

By means of a *comb sorter* (manually operated or semi-automatic) fibres are withdrawn in order of

length and arranged on a pad in the form of a frequency diagram from which the following properties are obtained:

Effective length (approxi nates to staple length)
Distribution of fibre lengths (frequency diagram)
Dispersion (variability in fibre length)
Percentage of short fibres

Alternatively, a *sledge sorter* can be used that withdraws fibres from a small sliver and deposits them on a velvet pad in order of increasing length. Mean length, standard deviation etc. are calculated and a fibre diagram prepared. Manual and automatic sledge sorters are available.

A fibre diagram may be based upon the frequency of occurrence of fibres in different length groups, i.e. a frequency distribution, or upon the weight of the fibres in each length group, i.e. a weight distribution. The two diagrams are somewhat similar except that the weight diagram is biased in favour of the longer fibres, which are heavier. The comb sorter gives a frequency distribution and the sledge sorter a weight distribution.

The *photoelectric stapler* scans a prepared sample by a traversing photoelectric cell that measures changes in the intensity of reflected light along the tuft. It gives "photoelectric staple", which approximates effective length.

In another method, the sample fringe is traversed by a light source and the amount of transmitted light measured electronically. It gives useful parameters such as mean length; upper-half mean length, which approximates to staple length; a fibrogram; span lengths (2.5, 50 and 66.6 per cent); and uniformity ratio.

Long staple fibres

Single fibres are withdrawn and measured. This may be done manually, using tweezers and a scale, or semi-automatically using a length measuring machine.

By use of a comb sorter, the fibres are sorted into groups according to length, and weighed. A fibre diagram, based upon this weight distribution, is plotted and the various statistics calculated.

In the *clamped tuft method*, a sample of sliver is held in a clamp and loose fibres are combed away from each side to form two projecting combed fringes. These fringes are cut off and weighed, as is the tuft remaining in the clamp. Mean fibre length is calculated as:

$$\frac{\text{(Length of clamp)} \times \text{(weight of combed fringes)}}{\text{(weight of tuft in clamp)}}$$

Fineness

Fibre fineness affects processing behaviour and the number of fibres present in the cross-section of a yarn of given weight per unit length. It therefore affects the spinning limit, i.e. the finest yarn that can be spun, since, other things being equal, a minimum number of fibres are necessary in cross-section for satisfactory spinning. Fibres, especially natural fibres, vary in cross-section along their lengths and from fibre to fibre. Diameter, cross-section and linear density are properties used to indicate fibre fineness. Some tests for fineness are influenced by maturity.

Fibre diameter

Fibres of basically circular cross-section can be measured by mounting very short lengths in a suitable fluid and using a projection microscope. The mean fibre diameter and variation is thus obtained. This method may also be used for estimating the proportion of medullated fibres in animal fibres.

A *microtome* is used to cut fibre sections for examination under the microscope.

Weight per unit length

Groups of fibres are taken from different parts of a sorter diagram, measured for length, weighed (whole) and counted to determine the fibre weight per unit length. Alternatively, sections of a given length (e.g. 10 mm) are cut from the fibres, weighed and counted.

Linear density

A fibre is clamped at one end, led over a knife-edge, tensioned by a weight and induced to vibrate at its natural fundamental frequency from which its mass per unit length can be calculated. This method is used only for research purposes.

Maturity of cotton

Cotton fibres are tubular, with a wall thickness that increases with maturity. Immaturity favours the creation of neps and affects the shade after dyeing. After being left to swell in a caustic soda solution, fibres are classified as normal or dead by examination under the microscope. This gives the immaturity count. A visual assessment of immaturity may be obtained by differential dyeing. Fibres are boiled in a bath containing two dyes, only one of which has an affinity with the cellulose in the secondary wall.

Under polarized light, cotton fibres assume different colours according to their degree of maturity.

Air-flow fineness

The resistance to air-flow through a sample of fibres of fixed mass and volume is taken as an indication of fibre fineness. The result for cotton fibres is generally called the micronaire value and is also influenced by fibre maturity. This influence can be allowed for by testing a specimen for micronaire value before and after swelling in a caustic soda solution.

Fineness and maturity can be measured separately using electronic means.

Tensile properties

Individual fibres may be tested at CRL, CRE or CRT. It is possible to produce a load-extension curve, but this is delicate work and requires great care in mounting the specimens.

A less correct, but quicker and more robust, method is to break fibres in groups or bundles which are then weighed and the Pressley Index (breaking load in lb ÷ bundle weight in mg) calculated. The test length, which is critical as it has a considerable effect on the result obtained, may be zero or 0.125 in. (3.2 mm).

A special fibre-bundle tester is required for synthetic staple fibre in which a high degree of fibre is associated with relatively high extensibility. The instrument features a slow, controlled rate of extension and a comb and friction device to remove fibre crimp.

Neps

Neps are small entanglements of fibres that, in the case of cotton, usually comprise dead or immature fibre. Neps, burrs and trash are found in natural fibres; fused fibres and various other defects occur in man-made fibres. Neps may be present in the raw material or may be created as a result of faulty processing. Some processes, e.g. combing, are designed to remove neps. Neps affect fabric appearance, particularly after dyeing.

Neppiness is defined as the number of neps present in a given quantity of material. Different techniques of nep counting are necessary depending upon the state of the material to be tested, e.g. lap, sliver or yam.

In the case of raw fibres, a sample of known weight is spread, by hand, as evenly as possible over the surface of a velvet pad and the number of neps counted.

In carding, samples of web are collected on boards and the number of neps per board counted. Alternatively, the board may be covered by a template containing a number of holes, or cells, of known area. The number of cells containing one or more neps is noted and the mean number of neps per cell calculated from a formula based on the Poisson distribution. This method may also be used for comber and draw-frame webs.

Nep counts on slivers and rovings may be made using the same method as for raw fibre, or by hand-drawing. Small tufts are withdrawn successively from the end of the sliver or roving, the number of neps in each draw is noted and the process is continued until a specified number of neps has been accumulated, whereupon the withdrawn fibres are weighed.

The *nep comparator* is an instrument that applies a high draft to two or more individual slivers or rovings thus forming webs over an illuminated inspection plate of known width. Neps and impurities, which are clearly visible, are then counted. This instrument provides the means of comparing two or more slivers directly, allowance being made for any differences in tex.

A visual assessment of neps in yarn may be made by winding samples on inspection boards or drums. Templates with holes may be used to cover the samples and the number of neps per cell obtained. Neps in yarn may also be counted electronically by running the yarn through a detector capable of recognizing increases in thickness and of differentiating between very short thick places (neps) and longer ones (slubs). Such a test may be conveniently run concurrently with a test of yarn regularity.

Nepping potential

It is often useful to have an indication of the amount of nep that is likely to be developed during processing. Some idea is given by the micronaire test since nepping potential is related to maturity. A more direct measure is given by treating a small, hand-prepared sample, in an instrument that is basically a miniature card, for about four minutes and then displaying it on a velvet pad. Thus the nepping potential of different samples may be compared or a given sample may be judged relative to a set of standards.

Trash (or lint) content of cotton or waste

The material, after being opened virtually to individual fibres by a taker-in, is fed into an air-stream that carries the fibres forward while permitting impurities to fall away. Dust is exhausted with the air.

Trash content percentage is calculated for cotton, and lint content percentage for waste.

V. Yarns

A yarn is an assembly of fibres and/or filaments usually bound together by twist.

The basic specification of a yarn must include at least the material, the count and the twist.

Count

Yarn count may be expressed directly as mass per unit length (e.g. denier or tex) or indirectly as length per unit mass (e.g. British or metric count). Many counting systems are in use but the recommendation of the International System of Units is tex, i.e. the weight in grams of 1 kilometre of yarn. Measured yarn count depends upon the moisture content, so samples should be tested after either conditioning in a standard atmosphere or being oven-dried and the standard regain allowance added. Oven-drying is more reliable and accurate. When analysing specimens, allowance should be made for changes in weight due to sizing, scouring etc.

Average count (tex) is usually determined by reeling off, under specified tension, and weighing 100-metre lengths of yarn from several bobbins. This also gives an indication of variation in count between bobbins.

Note that yarn from tightly-wound packages should be reeled off into skein form and allowed to relax before starting the test.

For smaller samples, consecutive 100-millimetre lengths are cut off and weighed. This gives an indication of the variation in count on a single bobbin.

Yarns taken from fabric are tested similarly, but allowance is made for crimp. Special templates are used for taking yarn samples from very small fabric samples.

Diameter

The projected diameter of a yarn is a measure of the covering power (the extent to which the area of cloth is covered by one set of threads) of the yarn when in the fabric. It is measured by throwing a shadow (silhouette) of the yarn on to a graduated glass scale.

Twist

Twist causes frictional trappings between the fibres and hence imparts strength to the yarn. Twist uniformity is important as it affects the reflection of light from the surface of the yarn or fabric. The direction of twist is important in both single and ply yarns.

Twist is defined as the number of turns per unit length of yarn. The twist factor relates twist to the linear density and is a measure of twist hardness. It is given by the formula:

$$\text{Twist factor} = \text{twist} \times \sqrt{\text{linear density}}$$

Twist influences yarn strength. During spinning, twist tends to run into thin places. Although twist is not usually free to redistribute itself over long lengths, handling the specimen can disturb twist and twist distribution locally. Tension can also disturb twist. Twist can be lost from the ends of the specimen, therefore, specimens should be taken from points well away from the ends of the yarn and tested under constant tension with minimum handling. It is relatively simple to measure twist in filament yarns and doubling twist in ply yarns, but it is more difficult to measure accurately twist in spun yarns, especially in open-end yarns where fibres in the core have different twist to those on the surface of the yarn.

Twist contraction or extension is the change in length of a yarn due to twisting and is expressed as a percentage of the untwisted length.

There are several methods of measuring twist in yarns. In the *untwist method*, the specimen is untwisted by fixing one end and rotating the other until all the twist is removed. This gives no measure of twist contraction.

In the *take-up twist method*, one clamp of the tester is free to move under tension so that the specimen is allowed to extend as it is untwisted. The twist removed and the change in length (take-up) are measured.

In the *straightened fibre method*, a short specimen is untwisted between clamps until the fibres are straight. A variant is the *continuous straightened fibre method*, in which a short specimen is untwisted as in the straightened fibre method. The twist is then put back, the yarn moved forward a distance equal to the length of the specimen and the test repeated. In this way consecutive specimens are tested.

In the *untwist and retwist method* a pre-tensioned specimen is untwisted so that it extends. Opposing twist is inserted until the specimen

returns to its original length. The total number of turns is then halved.

The *twist to break method* involves twisting a small specimen, held at a fixed length, until it breaks. Then a similar specimen is twisted in the opposite direction until it breaks. Half the difference represents the original twist in the specimens.

In the *optical method*, the yarn diameter is measured under the microscope, and the angle between the fibres and the yarn axis (twist angle) is measured at the same point, when:

$$\text{Twist} = \frac{\text{(tangent of the twist angle)}}{\text{(yarn diameter)}}$$

A particular twist tester may be used in a variety of ways.

Twist liveliness (snarling)

Twist in yarn tends to be unstable so that when the yarn is released from constraint, e.g. by unwinding from a package, it tends to snarl or twist around itself which causes difficulties in processing. This tendency is defined as twist liveliness and is measured in terms of the number of turns of twist that form when a measured length of yarn is formed into a loop, suspended under slight tension, and allowed to twist upon itself.

Evenness

The pursuit of uniformity in mass per unit length is one of the main preoccupations of the yarn producer. The spinner is required to convert extremely variable fibres into yarn that has similar dimensions, millimetre to millimetre, and characteristics from bobbin to bobbin, irrespective of which machines are used in its preparation and which day, or year even, it is produced. Different sampling and measuring techniques are used according to the type of variation to be studied.

Information on count variation is usually obtained while measuring the average count. By using systematic sampling and appropriate analysis techniques, any machines producing off-standard results may be isolated. Despite the increasing use of sophisticated instruments, visual assessment is still important since appearance is often the only test the consumer applies. Yarns are wound on boards or drums and examined under standard lighting conditions and may be compared with one another or with standard samples. Parallel-sided boards and cylindrical drums give a general impression of the likely appearance of the yarn in the fabric. Tapered boards or drums help to discover periodic variations.

Samples may be wound manually or automatically, singly or in batches. Other characteristics, such as hairiness and neppiness, may be assessed at the same time.

Cutting and weighing

The basic method of measuring evenness is by cutting and weighing successive lengths of the strand. It is usual to measure 1-metre lengths of lap, 5-metre lengths of sliver, 15-metre lengths of roving and 100-metre lengths of yarn. Shorter lengths, e.g. 10-millimetre lengths of yarn, may be used for research purposes or to check other methods.

Electronic evenness testing

Random and short-term variations may be measured electronically. The yarn, sliver, or roving is run through the sensing head of an *electronic evenness tester* that is equipped with an integrator and graphical recorder, automatically producing a measure of the general irregularity of the yarn in terms of mean deviation *(U)* or coefficient of variation *(V)* together with a graph that gives a visual image. Different testing speeds and ratios of chart speed to yarn speed permit the study of medium-term and longer variations.

Periodicities may often be detected by examining the regularity chart. Alternatively, a wavelength analyser or spectograph linked to the electronic evenness tester produces a chart or spectrogram that clearly indicates the presence of periodic variations together with their wavelengths and amplitudes.

Thick or thin places that occur only occasionally and at random may be serious faults, but they have a negligible effect on yarn-regularity measurements and none on the spectrogram. They may, however, be detected and counted by an *imperfection indicator* linked to the electronic evenness tester. The instrument may be programmed to stop so that individual faults may be examined.

Neps and impurities, which are in effect very short, thick places, are counted separately by the same instrument. Optional attachments perform the relevant computations and print-out the results.

Hairiness

Fabric appearance is affected by the hairiness (or roughness) of staple yarns, which is assessed by counting the number of fibre ends per metre that project beyond a pre-selected distance.

Tensile properties

During processing spinning, beaming, sizing, winding, and weaving or knitting yarn is put under

tension. Thus, in addition to giving satisfactory performance in the fabric, the yarn used must be capable of withstanding the stresses and strains applied during processing or the processing conditions must be adjusted to bring the effects of processing within the capacity of the yarn processed.

The tensile properties of yarn depend, to some degree, upon those of the constituent fibres, but other factors are involved.

Yarns may be tested singly, in groups, or in skeins. The single thread test is more precise and more informative but hank testing is still used for comparative purposes on the grounds that it is simple, quick and sufficiently sensitive to detect fairly substantial changes in yarn strength.

Tests may be conducted at constant rate of loading, constant rate of extension or constant rate of traverse. Breaking load, *V* of breaking load, elongation at break and *V* of elongation at break are determined.

From the point of view of efficient processing, the most important factor is the frequency of occurrence of places in the yarn weak enough to cause an end-break during processing. This variable is virtually impossible to quantify and therefore, in practice, it is usual to measure other relatively simpler variables, namely: mean breaking load; *V* of breaking load; tenacity (breaking length); mean breaking extension; and *V* of breaking extension.

Other things being equal, the coarser the yarn the stronger it is. Tenacity is a concept used to facilitate comparison of the tensile strengths of yarns of different count by imagining them reduced to a common basis (unit tex). A similar concept is breaking length or Reisskilometer (Rkm) which may be regarded as the length of suspended yarn (in km) that would break under its own weight. In practice the figure is achieved by dividing the mean breaking load in grams by the mean count in tex. Tenacity in g/tex as well as breaking length (Rkm) in km equals 5.36 times the Pressley Index.

Interpretation of the results is of great importance. The *V* of breaking load is a measure of the frequency of occurrence of very weak (and very strong) places with respect to the mean value and, when considered in conjunction with the mean, it gives an idea of the proportion of places that are weak enough to cause an end-break, thus enabling the experienced textile technologist to predict the likely performance of the material. A slightly lower mean breaking load might be preferred if coupled with a lower *V* of breaking load.

The *V* of breaking extension, considered in conjunction with the mean value, gives an indication of the frequency of occurrence of sections of yarn that break at exceptionally low extension.

The preparation of yarns for weaving or knitting involves high-speed winding from one package to another. This is done at tensions well below the mean breaking load of the yarn so that end-breaks occur only rarely. To obtain a reliable figure for the end-breakage rate under these conditions, therefore, it is necessary to test a very long length of yarn. A study of the winding process itself indicates the total of end-breakages from all causes. The number of breaks caused by weak places can be found by using a *constant tension winding tester*, an instrument that applies uniform tension to a running yarn. To obtain quick results, the tensions used for testing are higher than those used in practice, which has its disadvantages. Sometimes, particularly with filament yarns, it is useful to measure the stress and strain in running threads when they are extended to a certain degree.

Resistance to shock loads (work of rupture) is measured on an *impact tester*.

Creep (the slow extension of a specimen under a constant load), relaxation (the slow loss of tension in a specimen kept at constant elongation), elastic recovery and the effects of repeated load or extension cycling (fatigue) between chosen limits are measured for particular purposes.

The above techniques are also applied to doubled and cabled yarns. Different machines are required in particular cases according to the level of strength etc. The principles are the same; the differences are in scale.

Tensile strength may be reduced if there is a knot in the yarn or if the yarn is bent to a small radius of curvature. The methods of test used are basically the same as for normal yarns. For the knot test, a single knot is tied in each specimen. For the bending test, the specimen comprises two interlinked loops of yarn. The results may be compared with those from ordinary single thread tests.

Flexural rigidity (stiffness) of yarn

The stiffness of a yarn affects the way it lies in the fabric, which is particularly important in the case of sewing threads. Flexural rigidity may be measured by forming the yarn into a ring, suspending it under its own weight and measuring the distance it extends.

Friction

The tension of yarn in processing is mainly dependent on the friction as it passes around yarn guides or machinery parts. Abnormal or irregular tension can cause such problems as too hard packages, overstretched yarns, high breakage rates, and irregular fabric dimensions in knitting or puckered seams in making-up; it can also induce wear on the yarn guides themselves.

The *yarn friction tester* measures the coefficient of friction of a yarn as it runs around a test object. If a standard yarn is used then the frictional properties of different test objects, such as yarn guides or machinery parts, can be studied and the effect of

shape or surface-finish measured. In this way, the best yarn guide or component surface-finish can be selected for the yarn being processed. A standard test object can be used when measuring variations between samples of yarn. The frictional properties of yarn depend upon the fibre used and the yarn structure and also upon dressings and finishes (size, lubricant, wax etc.) applied to the yarns or fibres.

Abrasion resistance

Surface abrasion reduces yarn strength. Resistance to abrasion is measured either as the number of rubs needed to break a yarn at a given initial tension or as the ratio of the residual to the initial strength of the yarn after a number of rubs.

Sometimes yarns are abraded intentionally, e.g. to give continuous filament yarns a certain hairiness.

Crimp of yarn in fabric

Accurate measurement of yarn length is essential in calculating crimp (take-up, regain, shrinkage etc.) in woven fabrics, in measuring course and loop-length in knitted fabrics, and in determining the count of short lengths of yarn. Shade bars or stripes in yarn-dyed fabrics can be caused by variations in crimp, so crimp measurements help to distinguish between faulty weaving and faulty yarn dyeing. Threads, removed from a specimen of fabric cut to a given length, are straightened under a given tension and measured. The formula is as follows:

$$\text{Crimp}\,(\%) = \frac{(\text{straightened length}) - (\text{length in fabric}) \times 100}{(\text{length in fabric})}$$

VI. Filament yarns

Continuous filament yarns comprise one or more filaments running the whole length of the yarn. The filaments are extruded together and wound directly on to a package. This produces a flat yarn that feels uncomfortable when made up into garments. Filament yarns are therefore frequently textured, i.e. given permanent crimp to increase their bulk and stretch properties and generally to improve their suitability for apparel.

Many instruments designed for staple yarns can also be used to test filament yarns, but there are additional aspects that require attention.

Testing of filament yarns

The monitoring of the filament of tex is usually confined to the fibre producer. The number of filaments in cross-section coupled with a measurement of yarn tex is a sufficient indication to the user. Filaments may be counted manually or electronically. The elastic properties of textured yarns, which depend upon such processing conditions as tensions, temperatures and twisting speeds, affect the rate of yarn up-take and cause barring in fabrics so a high level of process control is essential. The crimp rigidity test is used to estimate the bulking potential or crimp strength of multi-filament bulk and stretch yarns. A weighted skein of yarn is suspended, totally immersed in water. After a given time the original length is measured. The load is then reduced and, after a further interval, the reduction in length is measured. The formula is as follows:

$$\text{Crimp rigidity (\%)} = \frac{\text{(reduction in length)}}{\text{(original length)}} \times 100$$

Relaxation and shrinkage occur in yarns owing to wet and hot treatments during processing. Yarns often partially recover, in time, from deformations caused by tensions during processing. When a textured yarn is knitted or woven there is some fabric collapse, the amount depending not only on the retractive power of the yarn, as measured by the crimp rigidity test, but also on its ability to fill the spaces between the loops or the warp and weft threads. Space-filling ability is largely determined by the bulk and compressibility of the yarn. The bulking potential of a yarn is assessed by a test that simulates wet processing conditions. First, a small hank of yarn is tensioned to remove crimp, cut to a given length and allowed to contract within the confines of a tube. Then, the tube is submerged in gently boiling water which causes further relaxation and develops the full bulking potential of the yarn.

Static electricity

Static electricity is produced when dissimilar substances rub together. Most textile fibres are good conductors of electricity (except when very dry) so that the electricity leaks away without causing any problems. However, some man-made fibres, notably polyesters, polyamides and acrylics, are good electrical insulators and therefore accumulate static charges. This creates difficulties in processing where fibres with like charges repel one another. It also causes problems in use; oppositely-charged garments stick together, charged garments crackle and sometimes spark when taken off while static charges not only attract dirt, thus causing rapid soiling, but also cause the particles of dirt to become so strongly attached to the fibre surface that laundering becomes very difficult.

The magnitude and variation of electrostatic charges may be measured on rapidly-moving threads and the electrical resistance of fibres, yarns and fabrics may be tested. The *static electricity tester* measures the conductivity of the fibres, which is a fundamental factor in the generation of static electricity; it indicates the potential gradient and the amount of static electricity generated. The *electrostatic meter* measures the intensity of the electrostatic charge.

The electrostatic charges picked up by filament yarns may be controlled, to some extent, by the application of antistatic dressings.

VII. Fabrics

Fabric properties

Appearance

Often appearance and handling qualities are the only criteria the consumer applies to assess fabric quality. Therefore one of the most important facets of quality control in textiles is cloth inspection. The entire production of grey cloth is passed over an inspection table and examined for uniformity of surface and defects such as thick and thin places in the yarn, moiré effect, knots, tight picks, cockling etc. A certain degree of mending (the combing out of slubs, untying of knots and removal of projecting threads) may be done at the same time. Oil marks and major flaws may be marked for further attention at a later stage, for instance, after finishing when the cloth is again inspected.

Dimensions

The width is measured by a scale and the piece length by a length-meter or tape-measure during cloth inspection, care being taken to avoid stretching the sample. The thickness of a compressible material, such as a textile fabric, is taken as the distance between two plates that are separated by the fabric under a predetermined pressure.

Fabric structure (analysis)

It is possible to achieve a great variety of effects in fabrics by interlacing the threads in different ways. Information regarding the weave or the knit is obtained by dissecting the fabric and ascertaining the method of interlacement of the yarns. The number of ends or picks per unit length may be found by *(a)* dissecting a specimen of known length; *(b)* counting the number of threads visible within the aperture of a counting glass; *(c)* using a *traversing thread counter; (d)* finding the number of interference bands produced when a parallel-line grating is placed on the fabric; or *(e)* studying the interference pattern obtained when a taper-line grating is placed on the fabric. In a knitted fabric the number of wales and courses per unit length are counted.

The cover factor of a woven fabric is a number that indicates the extent to which the area of a cloth is covered by one set of threads (warp or weft). In a knitted fabric it is a number that indicates the extent to which the area of a knitted fabric is covered by the yarn. Fabrics are sometimes sold by weight. The mass per unit length or the mass per unit area is determined by cutting and weighing rectangular or circular specimens after conditioning.

The mass of warp or weft threads per unit area is found by dissecting a specimen into warp and weft threads and weighing them separately.

In knitted fabrics the length of yarn contained in a given number of stitches is removed and measured to determine the loop length, which is a measure of the rate at which yarn is used.

Tensile strength and elongation

Strips of fabric are tested at constant rate of loading, constant rate of extension or constant rate of traverse (see chapter IV). If the grips do not extend the full width of the specimen the test is known as the grab test. Load extension curves may be produced.

Bursting strength and distension

For knitted fabrics and fabrics subjected in use to biaxial stressing, bursting strength is a better criterion than tensile strength.

A circular specimen is clamped over an elastic diaphragm, which is caused to expand until the specimen bursts (across the threads having the lesser breaking extension). Bursting strength is the maximum fluid pressure necessary, and bursting distension is the linear displacement of the centre of the specimen immediately prior to rupture.

Bagginess results from the biaxial distension of a fabric, as in the bursting test, within its bursting distension. Tendency to bagging or pouching is studied by repeated distension within the bursting distension.

Resistance to tearing of woven fabrics

Fabrics may be torn by gradually applied, or by shock, loads. A cut is made in the specimen parallel to the warp (for tears across the weft) or weft (for tears across the warp) and the two wings so formed are pulled apart in a *tensile strength tester* for a slow tear,

or in a *ballistic tester* for shock loads. Sometimes it is preferred to make two parallel cuts and tear along the two sides of the tongue so formed.

In a slow tear, since the load applied fluctuates as each successive thread breaks, an autographic trace is useful. In the ballistic test, allowance is necessary for the work done in stretching the specimen before it tears and this is usually estimated by tearing through specimens of different lengths.

Stretch and recovery

Fabrics may be stretched and garments pulled out of shape when in service. The extent to which a textile article is capable of returning to its original size and shape is obviously very important. A specimen of standard dimensions is stretched to either a specified load or a specified extension below the breaking point, which extension is then measured. The load is then gradually removed and the residual extension measured; extension percentage and residual extension percentage are then calculated.

Rigidity and drape

Flexural rigidity (bending length) is estimated from an overhanging specimen and relates to the length of overhang that corresponds to a specified angular deflection of the tip below the horizontal.

Drape, the extent to which a fabric deforms when allowed to hang under its own weight, may be measured by the deformation under gravity of an initially horizontal annular fabric specimen.

Crease resistance

The resistance of a fabric to creasing or its ability to recover from being creased is very important, particularly in clothing, but difficult to qualify. To make a visual assessment, a rectangular specimen is pushed by a rod into a cylinder and compressed by a piston. After a prescribed time the specimen is removed, mounted on a board, rolled flat and then hung for some hours in a vertical position, after which its appearance is assessed relative to standards that have been photographed.

The crease recovery angle, i.e. the angle formed between the two parts of a specimen previously folded under prescribed conditions of load and humidity, is measured at certain times after removal of the load.

Air permeability

Air permeability is important in filters, water-repellant fabrics etc. as well as in clothing. The rate of air-flow through a specimen of given area is measured at a specified pressure drop across the thickness of the fabric.

Waterproofness

Several aspects of waterproofness, from impermeability to wettability, are important for different fabrics and applications; they are assessed in various ways, some of which are very simple such as those given below.

Absorption by static immersion. A specimen is immersed in water for a given time and the increase in mass is then measured.

Wettability. This is the time taken for a drop of water to soak into the fabric. Good wettability, i.e. quick penetration of water, is important in some textile processes. A small specimen is placed on the surface of the water and the sinking time, i.e. the time that elapses before it sinks is measured.

Wetting time. A strip of fabric is withdrawn at a specified speed from a tank of water and the time taken for the angle between the surface of the water and the specimen to fall to 90° is measured.

Spray resistance. Specimens are sprayed with water and then compared visually with photographed standards to measure spray resistance.

Absorption and penetration. The upper surface of a specimen is exposed to a simulated rain shower while, in some tests, the under surface is rubbed. Absorption, the increase in mass of the fabric, and penetration, the quantity of water that passes through in a given time, are then measured. In the hydrostatic head test a specimen is subjected to steadily increasing pressure of water until penetration occurs.

Dimensional changes due to wetting, washing, dry or steam pressing etc.

Fabrics may shrink or extend in washing, pressing etc. A specimen is subjected to the appropriate treatment under carefully controlled conditions, and any changes in dimensions are measured.

Thermal resistance

Heat may be transmitted through a fabric by conduction through the fibres and entrapped air or by radiation through air spaces. A material of known thermal resistance is used as a standard, the temperature changes across it and the specimen are measured, and the thermal resistance of the specimen calculated.

Abrasion resistance

Abrasion resistance gives an indication of wearing properties. A textile specimen is rubbed against an abradant surface. Evaluation is in terms of the loss in

mass after a given number of rubs or the number of rubs required to cause partial breakdown of the specimen. The degree of wear is sometimes plotted against time. Any loss in strength may be found by a bursting test.

Abrasion is a complex subject. Testing may be restricted to plain abrasion, in which a flat surface is rubbed, or the specimen may be folded and the fold abraded. In flex abrasion the specimen is continually bent or flexed while it is being rubbed. Rubbing may be done with a circular or reciprocating motion.

Pilling tendency

Pills are small balls of fibre that form on the surface of the fabric. Pilling is due to surface abrasion that rolls and entangles projecting fibre ends and can ultimately work fibres out of the fabric. Pilling tendency can be studied by using ordinary *abrasion testers* with a suitable choice of abradant and pressure, or by using special instruments in which small specimens are treated in rapidly rotating drums lined with abradant.

Tendency to snagging

Fabrics containing filament yarns are liable to snag in use. In order to establish the extent to which this might occur, a spiked ball is caused to bounce on a specimen so that the spikes catch in the threads and cause snagging. The degree of snagging is rated relative to standards that have been photographed.

Electrical properties

Instruments are available to measure the electrical resistance of a fabric, the magnitude of any electrostatic charge that it may have, and the tendency of the fabric to generate such a charge.

Seam slippage

Seams are sewn under standard conditions across specimens and then seam slippage is measured under load. This estimates the likelihood of thread slippage occurring at a seam.

VIII. Carpets

Carpet properties

Carpets and textile floor coverings are subjected to different usages than other fabrics and it is important that they should not stretch or shrink much in service. The following properties, therefore, are particularly relevent to them.

Dimensional stability

The dimensional stability of floor coverings may be affected by mechanical action, such as walking, changes in humidity or wetting.

An indication of the stretch that might occur when the floor covering is walked on is obtained by applying cyclic loading to a specimen using a constant rate of extension machine. To assess the effect of walking on the appearance of the fabric, a cylindrical drum containing a mechanical tetrapod, is lined with a specimen of carpet and rotated causing the tetrapod to walk over the carpet. The appearance of the specimen is then compared with either the original or with a control sample.

Resistance to changes in humidity is assessed by measuring the dimensional changes that occur when a specimen is allowed to condition for specific periods at controlled relative humidities.

To assess the changes that occur by wetting, a specimen is dried at 60°C, soaked and redried; the changes are then measured.

Loss of pile

Abrasion resistance is estimated by the loss in weight of the pile after rubbing for a given time or by the amount of rubbing needed to expose the backing.

Compressibility and recovery

Compressibility is the deformation of the pile under both static and dynamic loading conditions; recovery is measured after specified times.

Flammability

To estimate flammability, a heated steel nut is placed on the surface of the carpet, then the times of flaming and of after-glow or smouldering, and the radius of the effects of ignition, are measured. The test is carried out in a special chamber. Several other methods may be used, e.g. radiant panel and vertical strip tests. Laws have been enacted in some countries requiring certain standards in these tests, particularly for carpets to be used in public places.

IX. Chemical laboratories

Chemical laboratory facilities comprise two parts: the analytical chemical laboratory and the physico-chemical laboratory.

The analytical chemical laboratory

The analytical chemical laboratory has a number of important functions. One is to monitor the quantity and quality of incoming raw materials which is, in most cases, done by conventional inorganic and organic chemical analysis techniques. Another function is the analysis of textile materials, chemicals, dyestuffs, auxiliaries and allied materials. Textile materials usually contain non-fibrous substances that may occur naturally or be added deliberately to assist in the manufacture or processing of fibres or to influence the properties of the end-product. It is often necessary to remove such non-fibrous matter prior to embarking on chemical analyses of the textile material. Tests to detect the presence of non-fibrous matter are required, for instance, to ensure that a specimen is suitable for chemical analysis or to check on the efficiency of a process such as scouring. Sometimes it is necessary to determine the quantity of non-fibrous matter present, for instance, to ensure conformity with some specification.

The analytical chemical laboratory is also required to assist in day-to-day process control and in product development by assessing the effects of chemical treatments and evaluating finished fabrics. This laboratory need not be air-conditioned and need only be equipped with the usual chemical glassware etc. However, in many cases tests can be expedited by the use of specialized instruments such as a projection-microscope, a colorimeter or a spectrophotometer.

The following analyses, determinations, processes and tests are usually carried out in the analytical chemical laboratory:

Analyses

- Chemicals used in textile processing, e.g. acids, alkalies, oxidizing and reducing agents such as hydrogen peroxide, sodium hypochlorite and sodium hydrosulphite
- Fibre blends (quantitative)
- Medical dressing and gauze tissue
- Optical brighteners
- Printing pastes
- Soap, total fatty matter, reacted fats, free fats, total alkalinity, insoluble matter and water content
- Sodium silicate
- Surface-active agents: anionic, cationic and non-ionic
- Textile auxiliaries, e.g. wetting, levelling and starching agents and detergents
- Textile fibres (qualitative and quantitative)
- Water hardness: total solids, dissolved solids, total alkalinity, chlorides and sulphates

Determinations

- Alkali solubility of flax
- Ash alkalinity
- Ash content
- Barium activity number (degree of mercerization)
- Conductivity of aqueous extracts from textile fibres
- Content of water-soluble matter
- Copper number
- Desizing efficiency of enzymes (rate of removal of starch)
- Estimation of the strength of dyestuffs (vat: naphthols, fast bases)
- Felting properties of wool
- Fluidity of cellulose
- Free and total formaldehyde content in resins and resin-treated fabric
- Methylene-blue number
- Na_2O/SiO_2 ratio in bleaching baths
- Oil and fat content in wool
- pH value of extracts
- Resin finish content
- Saponification value of oils
- Size content in yarns
- Solubility number of wool
- Starch content
- Wax content

Processes

- Degumming of silk

Tests

- Detection of: chromium, copper, iron, magnesium, titanium etc.
- hydrocellulose and oxycellulose in degraded cotton
- residual silicate in peroxide-treated fabrics
- sugars in cotton (Honeydew test)
- traces of acids and alkalies in bleached fabrics

Dry distillation
Flame
Identification of dyestuff class
Solubility
Stain

The physico-chemical laboratory

The role of the physico-chemical laboratory is closely linked with the fact that textile materials are subjected during processing, and later during use, to attack by a great variety of agents that tend to cause degradation of the fibres. For example, excessive heat causes some fibres to soften or melt and others to decompose. Some fibres burn in air more readily than others. Sunlight and, to a lesser extent, artificial light cause deterioration. Bleaches, detergents, scouring agents, dyes and other chemicals are used in finishing and fabrics are commonly exposed to acid and alkali solutions in washing and organic solvents in dry cleaning. Natural fibres, particularly wool, are often eaten by insects. Textiles are also attacked by bacteria and other micro-organisms, and may be affected by mildew.

In order to determine the resistance of textile materials to such exposure, chemical tests may be carried out on specimens before and after exposure. Alternatively, physical tests may be carried out before and after treatment. Various kinds of apparatus are available to simulate and accelerate the treatments and to control the conditions of exposure. Such apparatus are housed in the physico-chemical laboratory.

Flammability

The properties usually measured to assess the burning hazard of apparel fabrics are the ease of ignition, the rate of spread of flame and the amount of heat produced. All three measures are necessary for a full assessment.

Samples of fabric are ignited from a standard source and the extent and time of burning recorded. Specimens do not always give reliable results since they do not burn in the same way as whole garments particularly in the case of some thermoplastic fabrics. Therefore, specimens should be made in shapes and sizes similar to the garments they represent. The standard conditions for testing vary according to the end use and country of origin.

A standard heat source is required. The flame may be applied to the edge or the surface of the fabric as appropriate. The tests must be carried out in a draught-free room or enclosure.

In the case of carpets, mattresses and bedding fabrics, smouldering and the emission of smoke and toxic fumes are also studied.

In tests for flame-proofing, a flame is applied to the specimen for a specified period (say 12 seconds) and then withdrawn. The time during which flaming continues and the length of the char are measured.

Colour fastness

Apart from degradation of the physical and chemical properties of the fibres themselves, there is also the effect of exposure on colour to take into account. Any change in colour that results from a particular treatment is assessed by a visual comparison of the treated specimen with the original material. A colour-fastness rating is given by comparing the observed difference with the standard Grey Scale for Assessing Change in Colour. (There is a special scale for light-fastness.) Loss of colour by one fabric may cause staining of other fabrics in contact with it. Colour-fastness with respect to staining is determined by attaching an undyed cloth to the specimen. There is also a Grey Scale for Assessing Staining.

Colour-fastness of dyestuffs is assessed similarly. Treatments before or after dyeing may affect the results. In order to facilitate testing, specimens of yarn may be knitted into fabric, and fibre specimens may be sewn between two undyed cloths, prior to treatment.

X. Pilot plant

Testing of raw materials

The testing of raw materials by skilled technologists enables them to estimate the performance of material during processing and the properties of the finished products. But even if this testing is done very carefully by expert technologists, it is a far less satisfactory method than actually processing a sample through to yarn or fabric and then testing the product. The processing of sample lots on ordinary mill machinery requires a great deal of organization and interrupts the flow of production so a pilot plant is used wherever possible. Ideally a pilot plant for spinning comprises:

A short blowing-room line with four cleaning points, by-pass valves and provision for recycling the material so as to give, in effect, six or even seven cleaning points, arranged for both lap and chute delivery
One card equipped for both lap and chute feed, with auto-leveller
One draw frame with auto-leveller
One short-length speed frame
One short-length ring frame
One short-length open-end spinner
One lap-former
One comber

The machinery should be housed in a fully air-conditioned room and a well-equipped fibre and yarn testing laboratory attached.

For weaving and knitting also, full-sized machines should be provided and housed in separate, air-conditioned rooms. Miniature spinning plants as well as small sample looms and knitting machines are available but these are a poor substitute for a proper pilot plant.

In the area of bleaching, dyeing and finishing, however, the machinery is so large and costly and production rates are so high that an efficient small-scale pilot plant is of vital importance. This is in addition to an analytical chemical laboratory, a physico-chemical laboratory, a fabric laboratory and, of course, effective process control. The pilot plant should be continuously in use for monitoring quality and performance on a semi-commercial basis, evaluating the performance of new materials and suppliers, evaluating new colour combinations, designs and finishes, and so on. Further details are given in annex I, table 3.

Annex I

INSTRUMENTS, EQUIPMENT AND SUPPLIERS

This annex details the various items that are usually studied in the different sections of the industry, together with the instruments required and the suppliers of such instruments. The suppliers are given a code number according to country and these codes are cross-referenced to annex II. Whenever possible, simple inexpensive but effective instruments are included in addition to modern sophisticated automatic expensive ones. Distinction is made between process control and measurement of product quality. The importance of each feature or instrument in the mill or textile centre is graded as follows:

xxx = Essential
xx = Recommended
x = Useful, if funds permit
R = Used mainly for research

The price is indicated as:

L = Low (below $2,000)
M = Medium ($2,000-$5,000)
H = High (over $5,000)

The list is not exhaustive, it includes those instruments and suppliers known to the author at the time of going to press. It is intended to bring this information up to date from time to time.

Information is given under the following headings:

Table 1. Instruments for process control in mills

General
Spinning mill
Texturing mill
Weaving mill (including winding, beaming and sizing)
Knitting mill
Bleaching, dyeing and finishing mill

Table 2. Instruments for textile-testing laboratories (mill or textile centre)

Fibre laboratory
Filament laboratory
Fibre identification laboratory
Yarn laboratory
Filament yarn/textured yarn laboratory
Fabric laboratory
Knitted fabric laboratory
Dyeing and finishing laboratory
Carpet laboratory
Analytical chemical laboratory

Table 3. Pilot plant

Table 4. On-line quality control equipment

Process control laboratories are usually small laboratories located within the mill, readily accessible to the production personnel and equipped with relatively simple instruments that give quick results.

A textile centre may be the central laboratory for a group of mills or an independent laboratory serving the needs of a local or national industry. Such laboratories usually include both simple and more sophisticated instruments and often a pilot plant to enable processing trials to be made. Their activities usually include some development work and, frequently, fundamental research work.

TABLE 1. INSTRUMENTS FOR PROCESS CONTROL IN MILLS

The codes of the suppliers are cross-referenced to annex II

Property or test	*Importance*	*Instrument or method*	*Price range*	*Supplier*
General				
Temperature and relative humidity	xxx	Wet-and-dry-bulb thermometers	L	72, 82
		Sling hygrometer	L	72, 82
		Ventilated hygrometer	L	9, 72
		Recording thermohygrograph	L	9, 72, 78, 82, 85, 93
		Dew point meter	L	72, 78, 93
		Electrical hygrometer	L	32, 89, 96, 97
Regain or moisture content	xxx	Drying oven with balance	M	9, 34, 35, 37, 41, 44, 69, 79, 82, 105, 112, 122
		Rapid drying unit	M	82
		Electronic moisture meter	M	24, 29, 104, 107, 109, 116
		Portable moisture meter	L	7, 9, 12, 24, 34, 41, 45, 50, 82, 85, 93, 97, 119, 136
		Pocket psychrometer	L	7, 9, 34, 45, 65, 93
Pre-conditioning of samples	xxx	Conditioning cabinet	M	9, 34, 35, 41, 50, 97
Weight	xxx	Textile balances (various)	L	4, 9, 11, 26, 29, 32, 34, 35, 37, 40, 42, 50, 62, 73, 79, 82, 94, 100, 142

Property or test	*Importance*	*Instrument or method*	*Price range*	*Supplier*
General (continued)				
Production rates etc.	xxx	Length counters	L	6, 9, 44, 54, 81, 98
	xxx	Weighing-machines	M	44, 68
Temperature	xxx	Thermometers	L	44, 45, 74
Speed of rotating parts	xxx	Tachometers	L	6, 9, 18, 34, 35, 44, 54, 76, 80, 81, 98, 111
	x	Electronic tachometer		20, 29, 44, 52, 66, 94
	x	Stroboscope	L	9, 16, 29, 34, 44, 50, 82
	xxx	Stop-watch	L	
Yarn speed	xxx	Yarn speed meter	L	9, 34, 44, 54, 81, 95, 97, 114
Yarn tension	xx	Portable tension meter	L	19, 30, 33, 54, 57, 59, 65, 82, 97, 108
		Electronic tension meter	H	29, 59, 102, 106, 108, 113, 141
		Tension weights		
Roller eccentricity	xxx	Eccentricity tester	L	94, 108
Roller vibration	xxx	Roller vibration tester	L	94
Spindle vibration	xx	Spindle vibration tester	L	34
Spindle position	xxx	Spindle centring device	L	44, 57
Roller pressure	x	Roller pressure gauge	L	18, 34
Hardness of packages	x	Hardness tester	L	18, 34, 44, 50, 63, 82, 108, 133
Settings	xxx	Setting gauges	L	
Microscopical examination	xxx	Microscope	L	9, 29, 32, 44, 50, 57, 87, 97
		Polarizing microscope	M	
		Electron microscope	H	16, 25, 39
		Scanning electron microscope	H	16, 25, 62, 71
Visual assessment	xx	Optical instruments	L	17, 25, 56, 87
Special lighting	xx	Laboratory lamps	L	16, 25, 29, 62
Air speed	xx	Anemometer	L	44
Spinning mill				
Fibre identification and fibre properties	See *Fibre, Filament* and *Fibre identification laboratories*, table 2, especially items marked as important in the mill			
Weight of bale	xxx	Weighing-machine (platform)	M	See *General*, above
Daily waste production	xxx	Weighing-machine (platform)	M	See *General*, above
Regain or moisture content	xxx	See *General*, above		
Length of lap	xxx	Tape-measure or floor markings	L	
Weight of lap	xxx	Lap scales (may be built-in to scutcher)	L	See *General* (balances), above
Moisture correction of lap weight	xxx	Moisture compensating balance	L	94
Waste from each element	xxx	Balance	L	See *General*, above
Lap regularity		Lap regularity tester	M	30, 50
Weight metre by metre	xxx	Template and balance	L	
Transverse uniformity	xxx	Illuminated inspection plate	L	30, 50
Continuous measurement	xx	Electronic evenness tester	H	65
Fibre breakage	x	Comb or sledge sorter	L	See *Fibre laboratory*, table 2
	x	Photoelectric stapler	M	See *Fibre laboratory*, table 2
Cleaning power	xxx	Trash analyser	H	See *Fibre laboratory*, table 2
Card waste	xxx	Balance	L	See *General*, above
Flat strip	xxx	Balance	L	See *General*, above
Card wire condition	xxx	Card wire inspector	L	40, 75
Neps in web	xxx	Nep counting templates	L	94
Count of sliver or roving	xxx	Measuring wheel and balance	L	3, 9, 32, 34, 35, 37, 50, 63, 79, 82
Fibre cohesion	x	Cohesion tester	M	108
Irregularity of sliver or roving	xxx	Mechanical evenness tester	M	34, 65
		Electronic evennesss tester	H	34, 65
Periodic variations	xxx	Electronic wavelength analyser	H	34, 65
Comber waste extraction	xxx	Percentage balance	L	See *General*, above
Fractionating efficiency	xx	Fibre sorter	L/M	See *Fibre laboratory*, table 2
Neps in sliver or roving	xx	Nep meter	L	15, 34, 63
Twist in roving	xxx	Tachometer	L	See *General*, above
Count of yarn	xxx	Measuring reel (and balance)	L	See *Yarn laboratory*, table 2

TABLE 1 *(continued)*

Property or test	*Importance*	*Instrument or method*	*Price range*	*Supplier*
Spinning mill (continued)				
Irregularity of yarns	xxx	Electronic evenness tester	H	34, 65
Appearance of yarn	xxx	Inspection boards	L	3, 15, 32, 34, 35, 37, 50, 79, 82
		Inspection drums	L	
Twist in yarns	xxx	Tachometer	L	See *General*, above
		Pocket twist tester	L	18, 94
		Twist tester	L	5, 9, 18, 32, 34, 35, 37, 50, 79, 82
Yarn tension	xx	Portable tension meter	L	See *General*, above
		Electronic tension meter	H	See *General*, above
Spindle speed	xxx	Tachometer	L	See *General*, above
End breakage rate	xxx	Stop-watch	L	
Package size and shape	xxx	Template	L	
Package density	x	Hardness tester	L	See *General*, above
Weight of:				
Doff	xxx	Weighing-machine	M	See *General*, above
Bundle of hanks	xxx	Balance	L	See *General*, above
Bale of hank bundles	xxx	Balance	L	See *General*, above
Cone	xxx	Balance	L	See *General*, above
Bale of cones	xxx	Weighing-machine	M	See *General*, above
Texturing mill				
False twister speed	xxx	Electronic tachometer	L	77
Yarn tension	xxx	Electronic tension meter	H	77
Heater temperature	xxx	Pyrometer	L	44
Weaving mill (including winding, beaming and sizing)				
Fibre identification	x	See *Fibre identification laboratory*, table 2		
Fibre properties	x	See *Fibre* and *Filament laboratories*, table 2		
Yarn properties	xx	See *Yarn laboratory*, table 2		
Weight of bale of cones	xxx	Weighing-machine	M	See *General*, above
Weight of cone	xxx	Balance	L	See *General*, above
Pirn diameter	xxx	Callipers or gauges	L	
Pirn hardness	xx	Hardness tester	L	See *General*, above
Settings of slub catchers	xxx	Setting gauges	L	See *General*, above
Faults in yarn Clearing efficiency	xxx	Electronic fault detector	H	40, 65
End breaks in beaming	xx	Stop-watch	L	
End breaks in sizing	xx	Stop-watch	L	
Temperature of size	xxx	Thermometer	L	See *General*, above
Viscosity of size	xxx	Viscosimeter	L	9
		Portable viscosimeter	L	9
Concentration of size	xxx	Refractometer	L	9
Analysis of size	xxx	Hydrometer (chemical laboratory)	L	
Take-up of size	xxx	Weighing-machine for beams	M	See *General*, above
Yarn speed	xxx	Yarn speed meter	L	See *General*, above
Yarn stretch (during sizing)	xxx	Yarn speed meter	L	See *General*, above
		Length counters	L	See *General*, above
		Shrinkage tester	H	35
Moisture in sized beam	xxx	Portable moisture meter	L	See *General*, above
		Pocket psychrometer	L	
Yarn abrasion resistance	xx	Yarn abrasion tester	L	34
Width of fabric in loom	xxx	Scale	L	
		Picks to produce given length	L	
Threads per unit length	xxx	Counting glass	L	
		Line gratings	L	9, 94
Reed spacing	xxx	Reed gratings	L	9, 94

Property or test	*Importance*	*Instrument or method*	*Price range*	*Supplier*
Weaving mill (including winding, beaming and sizing) (continued)				
Mass per unit area	xxx	Template and balance	L	
Warp contraction in weaving	xxx	Length counter	L	See *General*, above
Warp tension	xxx	Warp tension meter	L	18, 34, 97
Weft tension	xxx	Weft unwinding tension meter	L	18, 34, 94, 97, 108
Shuttle acceleration	x	Accelerometer	M	1
Cloth appearance in loom Pattern Spacing of warp threads Thick and thin places in yarn Knots Moiré effect	xxx	Observation		
Cloth appearance (weaving faults, oil marks, barriness etc.)	xxx	Inspection table	L	
Cloth pattern	xxx	Dissection	L	
Threads per unit length	xxx	Counting glass Line gratings Thread counter	L	94
Width of cloth	xxx	Scale	L	
Length of piece	xxx	Tape measure	L	
		Measuring reel	L	18
Weight of bale of cloth	xxx	Weighing-machine	M	See *General*, above
Knitting mill				
Yarn speed	xxx	Yarn speed meter	L	See *General*, above
		Yarn speed monitor	H	99
Yarn length/loop	xxx	Stitch length tester	L	6, 34, 43, 97
Yarn tension	xxx	Tension meter	H	See *General*, above
Yarn tension across cloth	x	Cloth tension meter	H	138
Yarn consumption per feeder	xxx	Course length tester	L	9, 18, 46, 94, 97, 123, 134
		Portable course length tester	L	6
Faults in fabric	x	Electronic scanner	H	105, 135
Broken filaments (warping)	xx	Broken filament detector	M	115
Stitch density	xx	Stitch density meter	L	4, 44
Run-in	xx	Run-in tester	L	88, 94
Shrinkage	xx	Shrinkage gauge	L	140, 142
Courses in moving fabric	xx	Automatic course counter	M	94, 125
Bleaching, dyeing and finishing mill				
Fibre properties	x	See *Fibre laboratory*, table 2		
Fibre identification	x	See *Fibre identification laboratory*, table 2		
Yarn properties	x	See *Yarn laboratory*, table 2		
Basic fabric properties	xxx	See *Weaving mill*, above		
Appearance of grey cloth	xxx	Inspection table	L	
Appearance after singeing and scouring	xxx	Inspection table	L	
Presence of starches after desizing and washing	xxx	Potassium iodide test[a]	L	
Presence of wax after scouring	xxx	Methane blue test[a]	L	
Water absorbancy after scouring	xxx	Sinking-time test (stop-watch)	L	
Alkali content of bleach bath	xxx	[a]	L	
Degree of whiteness (after bleaching and washing)	xxx	Reflectometer	M	4, 9, 41, 120
Permanence of whiteness (after exposure)	xxx	Reflectometer	M	4, 9, 41, 120
Effect of optical brighteners	xxx	Reflectometer	M	4, 9, 41, 120
Ash content (after scouring)	xxx	Muffle furnace	M	9, 60

TABLE 1 *(continued)*

Property or test	*Importance*	*Instrument or method*	*Price range*	*Supplier*
Bleaching, dyeing and finishing mill (continued)				
Degree of mercerization	xxx	Microscope	L	See *General*, above
Concentration of hydrogen ions in dyeing liquor	xxx	pH indicators	L	9, 14, 90, 144
		pH meter	M	9, 45
Up-take of dye	xxx	Balance	L	See *General*, above
Colour intensity (after dyeing or printing)	xxx	Colorimeter	H	2, 9, 49, 55, 118
Accuracy of printed design	xxx	Observation		
Resin content (after finishing)	xxx	*a*		
Free formaldehyde content (after finishing)	xxx	*a*		
Finish content	x	*a*		
Finish type	x	*a*		

[a] These properties are determined, or the tests performed, in a chemical laboratory.

TABLE 2. INSTRUMENTS FOR TEXTILE-TESTING LABORATORIES
(Mill or textile centre)
The codes of the suppliers are cross-referenced to annex II

Property or test	*Instrument or method*	*Importance*		*Price range*	*Supplier*
		Mill	*Centre*		
Fibre laboratory					
Grade (cotton)	Set of standard samples	x	x	L	National Bureau of Standards and CATGO (annex IV)
Moisture content	See *General*, table 1	xxx	xxx		
Pre-conditioning	Conditioned laboratory	xxx	xxx	H	
	Conditioning cabinet	xxx	xxx	M	See *General*, table 1
Sampling	By hand or fibre sampler	xxx	xxx	L	34, 62, 63, 108
Fibre length–short staple:					
Staple length	By hand	xxx			
Individual fibre measurement	Photoelectric stapler (1)	x	xx	H	3, 9, 62, 63
	By hand		R		
Frequency diagrams	Comb sorter	x	xxx	L	9, 32, 40, 50, 65, 94
	Sledge sorter		R	L	50
Fibre length–long staple:					
Individual fibre measurement	By hand	x	xx		
	Semi-automatically	x	xx	M	100
Clamped tuft	Clamp		R	L	94
Fibre diagram	Comb sorter	x	xx	L	94
Staple length	Photoelectric stapler (2)	x	xx	H	3, 63, 100
Colour	Colorimeter		xx	M	62
Fineness:					
Cross-section	Microtome		xx	L	4, 97
Diameter	Fibre section kit		xxx	L	9, 94
	Projection microscope		xxx		See *General*, table 1
Weight/cm:					
Whole fibre	Torsion balance		R	L	See *General*, table 1
Cut fibre	Cutter				See *General*, table 1
Micronaire value	Portable air-flow tester		xx	L	4, 100
	Air-flow tester	xxx	xxx	L	4, 9, 40, 50, 62, 94, 97
Fibre diameter (wool)	Air-flow tester (wool)	xxx	xxx	M	34, 62, 100
	Sonic fineness tester		R	M	9

Property or test	*Instrument or method*	*Importance*		*Price range*	*Supplier*
		Mill	*Centre*		
Fibre laboratory (continued)					
Maturity (cotton):					
Immaturity count	Microscope		xx		See *General*, table 1
Differential dyeing	Visual assessment		xx		
Polarized light	Polarizing microscope		xx	M	See *General*, table 1
Maturity index	Air-flow tester	xxx	xxx	L	See Micronaire value, above
Fineness/maturity	Fineness/maturity tester		R	H	94, 97
Tensile properties:					
Single fibre	Single fibre tensile tester		R	H	16, 21, 32, 34, 78, 97
Fibre bundle	Fibre bundle tensile tester	xxx	xxx	M	9, 40, 50, 62
	Autographic fibre bundle tester		R	M	34, 62
Nep count (cotton)	Balance (and display pads)		xx	L	See *General*, table 1
Nepping potential	Air-flow tester	xxx	xxx	L	See Micronaire value, above
	Miniature card		xx	L	34, 63, 108
Trash (or lint) content	Trash analyser	xxx	xxx	H	9, 34, 88
Felting property (wool)	Felting test set	xx	xx	L	11
Filament laboratory					
Tex	Vibroscope		R	M	32
Cross-section	Cross-section kit		xxx	L	94
Evenness	False twist apparatus	xx		L	34
Tensile properties	Vibration type tester		R	H	32, 34, 108
Elastic properties	Elastometer		R	M	32, 34, 44, 103
Flexibility	Cantilever micro-balance		R	M	See *General*, table 1
Bending fatigue	Bending fatigue tester		R	M	34
Crimp	Crimp tester		xx	L	41, 94
Crimp rigidity	Crimp rigidity tester		xxx	L	44, 94
Curliness Endurance of crimp	Curliness tester		R	L	34
Electrical resistance	Electrical resistance tester		R	H	108
Electrostatic charge	Electrostatic voltameter		R	M	108
Fibre identification laboratory					
Profile, cross-section and surface	Microscope	xxx	xxx	L	See *General*, table 1
	Polarizing microscope (man-made fibres)		xx	M	See *General*, table 1
	Microtome		R	L	44, 94
	Mounting, sectioning and casting kit		xx	L	94
	Electron microscope		R	H	See *General*, table 1
	Scanning electron microscope		R	H	See *General*, table 1
Reaction to heating	Bunsen burner	xx	xxx	L	
Response to fixed temperature	Hot stage microscope and crystals		R		See *General*, table 1
Presence of chlorine and nitrogen	[a]	xx	xx		
Reaction to staining	Fibre staining kit	xx	xx	L	94
Solubility	Various reagents[a]	xx	xx	L	
Drying twist			x		
Infra-red absorption	Infra-red spectrometer		R	H	
Change of weight with temperature	Thermo-balance		R	H	53
Change of state with temperature	Thermal analyser		R	H	53
Fibre ash analysis	Microscope	xx	xx		See *General*, table 1
Analysis of blends	Microscope and staining kit	xxx	xxx		See *General*, table 1
Dissolution of components	Dissolution of components[a]		xxx		
Infra-red spectrophotometry	Infra-red spectrometer		R	H	90

TABLE 2 *(continued)*

Property or test	*Instrument or method*	*Importance*		*Price range*	*Supplier*
		Mill	*Centre*		
Yarn laboratory					
Yarn count:					
Normal	Measuring reel (and balance)	xxx	xxx	L	3, 9, 11, 29, 32, 34, 35, 36, 38, 41, 44, 50, 79, 82, 94
Small samples	Scale and balance		xxx	L	79
Samples from fabric	Template and balance		xxx	L	79
Diameter	Projection microscope		R	L	See *General*, table 1
Twist	Twist tester:	xxx	xxx		
	Manual			L	4, 41, 44, 79, 82, 94, 108, 130, 142
	Motorized			L	
	Semi-automatic			L	
	Automatic			L	
	Continuous			L	
Twist in ply yarns	Twist tester or yarn undoubler	xxx	xxx	L	See Twist, above
Twist liveliness	Snarling tester	xxx		L	40
Evenness:					
Count variation	Measuring reel (and balance)	xxx	xxx	L	See Yarn count, above
Cutting and weighing	Template		R	L	
General irregularity	Electronic evenness tester	xxx	xxx	H	34, 65
Periodic variations	Electronic wave length analyser	xxx	xxx	H	34, 65
Thick or thin places	Imperfection indicator	xxx	xxx	H	34, 65
Appearance	Inspection boards (parallel or tapered)	xx	xxx	L	3, 32, 34, 35, 37, 44, 50, 79, 82
	Inspection drum (cylindrical or conical)	xx	xxx	L	
	Inspection winder	xx	xxx	L	
	Viewing cabinet	xx	xxx	L	
Hairiness	Inspection boards or drums	xxx		L	See Appearance, above
	Hairness tester		xx	M	94
Abrasion resistance	Yarn abrasion tester	xx	xx	L	41
Neppiness	Inspection boards or drums	xxx		L	See Appearance, above
Knot content	Inspection boards	xxx		L	See Appearance, above
Trash content	Inspection boards	xxx	xxx	L	See Appearance, above
	Imperfection indicator	xxx	xxx	H	See Thick or thin places, above
Single thread tensile properties:[b]					
At constant rate of loading	CRL tester:				
	Manual	xxx	xxx		29, 34, 63, 65, 68, 130
	Motorized				
	Automatic				
At constant rate of extension	CRE tester:				
	Manual	xxx	xxx		9, 11, 16, 29, 33, 41, 44, 68, 82, 108, 121, 130
	Automatic				
At constant rate of traverse	CRT tester:				
	Manual	xxx	xxx		3, 29, 34, 35, 37, 40, 44, 50, 68, 79, 130
	Motorized				
	Semi-automatic				
Load cycling	CRE tester		R	H	See single thread tensile properties (CRE), above
Extension cycling					
Elastic recovery					
Relaxation					
Creep					
Multiple thread strength	Multi-thread tester		R	M	3
Skein strength	Skein tester:				
	Manual	x		L	32, 79
	Motorized	xx	xxx	M	41, 79, 82
Impact strength	Ballistic tester	x	xx	L	40, 79
Work of rupture					
End breakage prediction	Constant tension winder		R	H	16, 35, 41, 59, 94
Stress/strain in running thread			R	M	29
Flexibility	Yarn rigidity tester		R	L	94

Property or test	*Instrument or method*	*Importance*		*Price range*	*Supplier*
		Mill	*Centre*		
Yarn laboratory (continued)					
Compactability	Compactability tester		R	L	94
Friction	Kinetic friction tester		R	L	16, 32, 41, 50, 59, 94, 100, 108, 123, 142
Abrasion resistance	Linear friction tester		R	L	100
Filament yarn/textured yarn laboratory					
Number of filaments present	Electronic filament counter	xx	xx	M	9, 94
End breaks at constant tension	Constant tension winder	x	x	H	16, 35, 41, 59, 94
Stiffness	Weighted ring test		xxx	L	9, 94
Unevenness of filaments Variation in tex	False twist tester		R	L	34, 127
Evenness	Electronic evenness tester	xxx	xxx	H	34, 65
Elastic properties	Strainometer		R		16, 32, 34, 44, 59, 108
Bulking potential	Tube tester	xx	xxx	L	9, 94
Relaxation	Crimp rigidity tester			L	9, 94
Shrinkage	Contraction tester			L	16, 29, 33, 34, 44, 59
Twist liveliness Residual twist	Snarling tester		xx	L	40
Degree of entanglement (enlacement yarns)	Entanglement tester		R		59
Electrical resistance	Electrical resistance tester		R		108
Electrostatic charge	Electrostatic voltameter		R		108
Tendency to generate static	Static testing device		R		59, 101, 108, 129
Fabric laboratory					
Weight of bale of cloth	Weighing-machine	xxx		M	See *General*, table 1
Cloth appearance	Inspection table	xxx		L	
Cloth width	Scale	xxx		L	
Length of piece	Tape measure or measuring wheel	xxx		L	18
Cloth structure	Dissection or counting				
Threads/unit length	Counting glass	xxx	xxx	L	17, 94
	Line gratings	xxx		L	
	Thread counter		xxx	L	
Mass per unit length Mass per unit area Mass of warp (or weft) per unit area	Scale and balance Template and balance Template and balance (dissection)	xxx	xxx	L	
Count of yarn from cloth	Direct count balance	x	xxx	L	See *General*, table 1
Crimp of yarn in cloth	Scale		xxx	L	
Yarn length in cloth	Scale		xxx	L	
Twist in yarn	Twist tester		xxx	L	See *Yarn laboratory*, above
Cloth thickness	Thickness tester		R	L	9, 41, 54, 94, 117
Compressibility	Thickness tester		R	L	9, 55, 94
Streakiness	Fabric streak analyser	xx	xxx	M	101
Tensile properties Delaminating strength Peeling strength Tearing strength–impact	Tensile tester for fabrics	x	xxx	H	3, 4, 9, 11, 33, 37, 41, 50, 79, 82, 108, 121, 130
Impact strength Tearing strength–impact Work of rupture	Ballistic tester	x	xxx	M	34, 41, 79
Slippage of seams	Seam-slippage tester	x	xx	L	82
Sewability	Sewability tester	x	xx	L	83
Bursting strength and distension	Bursting tester	x	xxx	M	9, 21, 32, 37, 41, 50, 51, 82, 130
Bagginess or pouching	Portable bursting tester	x	xxx	M	79, 103, 111, 121, 142

TABLE 2 *(continued)*

Property or test	*Instrument or method*	*Importance*		*Price range*	*Supplier*
		Mill	*Centre*		
Fabric laboratory (continued)					
Resistance to abrasion (plane, edge, flex)	Abrasion tester	x	xxx	L	4, 9, 34, 37, 41, 50, 79, 82, 83, 100, 103, 137, 139, 142
	Abrasion accelerator		xxx	L	9, 101, 108
Resistance to snagging	Snagging tester		xxx	M	94, 108
Resistance to fluffing	Fluffing tester		xxx	L	9, 94
Resistance to pilling	Pilling tester		xxx	L	22, 35, 41, 82, 101, 108, 142
	Portable pilling tester		x	L	6
Fatigue characteristics	Vibration-type fatigue tester		R	M	34
Stiffness Bending length Flexural rigidity	Cantilever tester	x	xx	L	4, 94
	Heart-loop tester	xx	xx	L	34, 94
	Cyclic bending tester		x	L	9, 94
Softness	Softness tester		x	L	41
Crease recovery	Crease recovery tester	x	xxx	L	9, 34, 41, 50, 94
Wrinkle recovery	Wrinkle recovery tester	x		L	41, 108, 114
Drape	Drape-meter	x	xxx	L	4, 82
Air permeability	Air-permeability tester	x	xxx	M	9, 35, 41, 94, 100, 117, 140
Pore size	Pore-size apparatus		xx	L	94
Electrostatic charge	Electrostatic voltameter		R	H	34, 108
Electrical resistance	Electrical-resistance tester		R	H	108
Tendency to generate electrostatic charge	Static testing device		R	H	108
Waterproofness:					
Absorption:					
Static immersion	Stop-watch (and balance)	xxx	xxx	L	See *General*, table 1
Soaking time	Stop-watch	xxx	xxx	L	
Sinking time	Stop-watch	xxx	xxx	L	
Wetting time	Stop-watch	xxx	xxx	L	
Spray resistance	Spray tester	xx	xxx	L	13, 41, 100, 108
Absorption and penetration	Shower-and-friction tester	xx	xxx	M	79, 107, 126
Penetration resistance	Hydrostatic-head tester	xx	xxx	M	35, 41, 94, 132
Shrinkage	Shrinkage tester	xx	xxx	L	20, 34, 41, 136
Resistance to mildew	Soil-burial equipment		xxx	L	34
Resistance to rotting	Rotting testing equipment		xxx	L	34
Resistance to staining	Staining tester		xxx	L	34
Resistance to soiling	Soiling tester		xxx	L	9, 94, 108
Thermal conductivity Insulation	Hot-plate tester		xxx	L	34, 41
Flammability	Flammability tester	xx	xxx	L	41, 47, 108, 110, 142
Flameproofness	Flame-resistance apparatus		xxx	L	41, 47, 108, 110, 128, 142
Degree of lustre	Glossmeter	x	xxx	L	4, 41, 120
Degree of whiteness Colour intensity Optical brightness	Reflectometer	xxx	xxx	M	4, 9, 41, 44, 120
	Portable reflectometer	xx	xx	M	41
Presence of optical brighteners	Ultraviolet lamp	xx	xxx	L	See *General*, table 1
Colour matching	Colour-difference meter	xx	xx	H	2, 41, 44, 56, 120
Colour fastness Change of colour Staining	Grey scales	xxx	xxx	L	British Standards Institution (annex IV)
Knitted fabric laboratory					
Courses per unit length	Counting glass	xxx	xxx	L	9, 94
Wales per unit length	Line gratings	xxx	xxx	L	9, 94
Stitch density	Maillimeter			L	4

Property or test	*Instrument or method*	*Importance*		*Price range*	*Supplier*
		Mill	*Centre*		
Knitted fabric laboratory (continued)					
Yarn length/loop	Stitch length tester	xxx	xxx	L	6, 34, 97
Yarn consumption	Course-length tester	xxx	xxx	L	9, 18, 46, 94, 97, 123
	Portable course-length tester	xx		L	6
Static extensibility	Static-extension tester	x	xxx	L	108
Elastic properties	Elastometer	x	xxx	M	32, 34, 103
Bagginess or pouching Bursting strength Distension	Bursting tester	x	xxx	M	See *Fabric laboratory*, above
Barriness	Barriness scale	x	x	L	9, 94
Stitch damage	Stitch-damage tester	x	x	L	82
Shrinkage	Knit-shrinkage tester	x	x	L	34, 41, 89
Dyeing and finishing laboratory[c, d]					
Physical properties ot tabrics	See *Bleaching, dyeing and finishing mill*, table 1				
Inspection	Ultraviolet lamp	xx	xxx	L	See *General*, table 1
Colour fastness to:					
Daylight	Fading tester	xx	xxx	M	9, 21, 25, 101
Artificial light (carbon arc) weathering	Weathering tester	xx	xxx	M	25, 41
Spotting with water, acid or alkali	Pipette	xx	xxx		
Water Sea water Chlorinated water	Plate tester Perspirometer Staining tester	xx	xxx	M	9, 25, 101
Washing Acid and alkali treatments Bleaches (chlorine and peroxide)	Wash wheel Launderometer	xx	xxx	M	22, 25, 47, 101
Dry cleaning	Dry-cleaning tester		xx	M	41, 101
Sublimation	Hand iron	xx	xxx	L	
Ironing	Ironing tester	x	xxx	M	8, 25, 92
Scorching	Scorch tester	xx	xxx	L	9, 25, 92, 101, 142
Dry pressing	Dry-plate press	xx	xxx	L	70
Steam pressing	Steam press	xx	xxx	L	41
Milling (alkaline or acid)	Wash wheel	xx	xxx	M	22
Felting	[a]	xx	xxx		
Rubbing	Rubbing tester	xx	xxx	L	9, 94
	Crockmeter	xx	xxx	L	9, 50, 101
Scrubbing	Scrubbing tester	xx	xxx	L	41
Mercerizing	Mercerizing machine[a]	xx	xxx	L	41
Boiling in soda	Boiling autoclave	xx	xxx	L	41, 142
Burnt gas fumes	Gas-fastness tester[a]	x	xxx	L	
Carbonizing	Drying-and-baking oven	xx	xxx	M	60, 92
Oil content	Residual-oil extractor Soxhlet-oil extractor	xx	xxx	L	44, 94, 100
Chlorination	[a]	x	xxx		
Metal in dyebath	[a]	x	xxx		
Organic solvents	[a]	x	xxx		
Cross-dyeing (wool)	[a]	xx	xxx		
Steaming (acetate)	[a]	x	xxx		
Sublimation (acetate)	[a]	x	xxx		
Degumming (silk)	[a]	x	xxx		
Carpet laboratory					
Count of yarn and tuft length	Yarn-count apparatus	x	xxx	L	9, 94, 117
	Tuft-length block	x		L	9, 94
Thickness	Thickness gauge for carpets	x	xxx	L	9, 34, 94, 100, 108
	Portable thickness gauge	xx		L	34, 100

TABLE 2 *(continued)*

Property or test	*Instrument or method*	*Importance*		*Price range*	*Supplier*
		Mill	*Centre*		
Carpet laboratory (continued)					
Compressibility of pile	Static-loading tester	x	xxx	L	34, 100
	Dynamic-loading tester	x	xxx	L	34, 94, 100
Tuft retention	Tuft-withdrawal tensometer	x	xxx	L	34, 94, 100, 117
Abrasion resistance Pile loss	Carpet abrasion tester	x	xxx	L	9, 41, 100, 117
Flammability	Carpet flammability tester	x	xxx	L	100
Flameproofness	Carpet flame-resistance apparatus	x	xxx	L	142
Dimensional stability to:					
Cyclic loading	Tensile tester	x	xxx	H	See *Fabric laboratory*, above
Walking	Treading machine	x	xxx	M	34, 94
Changes in humidity	Conditioning cabinet	x	xxx	M	See *General*, table 1
Heat and wetting	Drying oven	x	xxx	M	See *General*, table 1
Appearance	Visual inspection	xxx	xxx		
Retention	Treading machine	x	xxx	M	94
Electrostatic properties	Static voltameter, hand-probe and electrodes		xxx	L	34, 108
Analytical chemical laboratory[e,f]					
Identification and investigation of fibres and materials	Projection microscope Chemical tests	x	xxx	M	See *General*, table 1 See *Fibre identification laboratory*, above
Concentration of dye solution	Colorimeter	x	xxx	H	101
Total formaldehyde in resins	Colorimeter		xxx	H	101
Total formaldehyde in resin-treated fabrics	Spectrometer		xxx	H	90

[a] These properties are determined, or the tests performed, in a chemical laboratory.

[b] The laboratory must be able to carry out this test but has a choice of instrument and technique.

[c] The effect of chemical treatments on fabric properties during dyeing and finishing is measured by simulating the conditions and using the tests given under *Yarn*, *Fabric* and *Knitted fabric laboratories*.

[d] The following instruments are used to simulate or accelerate the wear textile materials receive.

[e] The instruments in this section of the table can be used instead of ordinary chemical analysis.

[f] Besides the instruments already mentioned under this heading, the equipment listed below is required. The prices for this equipment are in the low category.

Balances
Centrifuge for separating suspended solids and colloids
Drying oven
Fume cupboard
Hot-plate
Incubator
Kjeldahl's apparatus
Magnetic stirrer with hot plate
Mechanical stirrer for solutions
Melting point apparatus
Paper chromatography equipment
Rapid oil extractor for wool
Refrigerator
Sewing machine
Shaker for shaking solutions at different speeds and displacements
Surface softness tester
Thermostat to maintain the bath temperature
Thin-layer chromatography equipment
Viscosimeter for printing pastes
Water-bath
Water distillation apparatus

In addition, the following expendable equipment is required:

Asbestos sheets
Beakers
Bottles with ground-glass stoppers
Bunsen burners, tripods, gauzes
Burettes
Calibrated flasks
Capillary tubes
Combustion crucibles
Condensers
Cork borers
Desiccators with covers and porcelain inserts
Evaporating dishes with spouts
Filtering flasks
Filter funnels
Flasks
Funnels
Graduated cylinders
Graduated pipettes
Pestles and mortars
Petri dishes
Scissors
Scoops, tweezers, spatulas etc.
Stands for test-tubes, pipettes etc.
Tongs for test-tubes, flasks, crucibles etc.

TABLE 3. PILOT PLANT[a]

Machines	*Price range*	*Supplier*
Spinning		
Miniature spinning plant	M	88
Laboratory spinning unit	M	27, 35
Laboratory open-end spinner	H	28, 58
Various spinning machines	H	Spinning machine makers
Laboratory knitting machine (for bulked yarns)	M	19, 23, 44
Weaving[b]		
Various looms	H	Loom makers
Knitting		
Flat-bed knitting machines	L	Knitting machine makers
Circular knitting machines	M	Knitting machine makers
Warp knitting machines	H	Knitting machine makers
Bleaching, dyeing and finishing		
Laboratory winch with automatic temperature control	H	9, 44, 64
Laboratory mercerizer	H	34
Laboratory jigger	H	9, 34, 44, 64
Laboratory high-temperature pressure dyer (for piece dyeing)	H	44, 84, 92
Laboratory jet-dyer	M	92
Laboratory drying, curing and setting machine	H	44
Laboratory steamer	H	44, 45, 64
Laboratory hand-dyeing machine with automatic temperature control	L	44, 84
Laboratory open-width washing machine	L	84, 143
Laboratory printing machine	M	34, 64
Two-bowl laboratory padding mangle with electrically heated trough	H	44, 143
Laboratory calendering machine equipped with electrically-heated cylinders	H	44
Laboratory stirrer for pastes	L	9, 48, 143
Laboratory water extractor	M	9, 143
Laboratory jet-drier	H	9, 44, 64
Tumble drier	L	9, 92
Coating device	M	64
Felting tester	L	64
Thermoliser	H	44, 64
Dispersion test unit	M	92
Printworks viscosimeter	L	9, 94
Screen sample printer	M	44, 64
Roller sample printer	M	44, 64
Heat-transfer press	L	
Carpet steamer	M	64

[a]Obviously, the pilot plant should simulate, as closely as possible, processing machinery and techniques.

[b]It is normally too expensive to include beaming etc.

TABLE 4. ON-LINE QUALITY CONTROL EQUIPMENT

Equipment	*Price range*	*Supplier*
Moisture content of bales, cartons, cones etc.	H	116
Regularity of webs	H	26
Sliver count (tex)	H	65
Sliver regularity at the card, drawframe, gillbox, drawbox etc. (auto-levellers)	H	65
Slubbing count (condenser card)	H	97
Moisture in sizing	M	136
Tension in sizing	M	29, 77

TABLE 4 *(continued)*

Equipment	*Price range*	*Supplier*
End-breaks in sizing	H	124
Titration of bleaching liquor	M	31
Electropsychrometer and variator	H	10, 136
Denier control	H	65, 127
Speed of false twist units	H	77
Tension in running yarns	H	2, 77
Yarn-break detectors	M	61, 74, 97, 127
Slub detectors (warp knitting)	M	97
Thin places in yarns	M	61
Yarn clearers	L	3, 61, 65, 97
Classification of faults in yarns	H	61, 65
Stretch or shrinkage in processing	M	20, 29
Dyeing programmer	H	80
Temperature and pressure control	M	5

Annex II

INSTRUMENT SUPPLIERS

The names and addresses of instrument suppliers are listed alphabetically by country. Each supplier is given a code number that is used for reference purposes in the tables in annex 1.

Belgium

1. Barco Textile Department NV
   Passionistenlaan 75
   B-8500 Kortrijk
2. Jencks & Cie SPRL
   152, rue Hôtel des Monnaies
   B-1060 Brussels
3. Texcontrol SA
   97, Boulevard Maurice Lemonnier
   B-1000 Brussels

France

4. Adamel Lhomargy SA
   Division d'instruments
   B.P. 38
   15, avenue Jean Jaurès
   F-94201 Ivry-sur-Seine
5. Groux SA
   90 bis, rue Pasteur
   F-59110 La Madeleine (Lille)
6. Jaeger
   Division industrie
   B.P. 73
   129, rue Eduard Vaillant
   F-92303 Levallois-Perret
7. Société d'appareils de Precision
   87, rue Racine
   F-69100 Villeurbanne, Rhône
8. Société d'études d'automatisation de régulation et d'appareils de mesures (SETAREM)
   101-103, rue de Sèze
   F-69451 Lyon
9. Stutz & Compagnie
   47-51, rue Wastin
   F-59120 Loos-les-Lille
10. Télémécanique
    33, avenue de Chatou
    F-92503 Rueil-Malmaison

German Democratic Republic

11. VEB Thüringer Industriewerk Ravenstein
    Schicklerstrasse 7
    DDR-102 Berlin

Germany, Federal Republic of

12. Acker-Präzision
    Postfach 126
    D-6900 Heidelberg
13. Erhardt-Leimer KG
    Postfach 291
    Leitershoferstrasse 80
    D-8900 Augsburg 1
14. E. Merck AG
    Postfach 4119
    Frankfurterstrasse 250
    D-6100 Darmstadt 2
15. Ernst Toenniessen KG
    Balanstrasse 368
    D-8000 Munich 90

16. Erwin Sick Optik-Elektronic
Postfach 310
An der Allee 7-9
D-7808 Waldkirch

17. Greiner & Company
Niedersachsendamm 71
D-2800 Bremen 61

18. Hans Schmidt & Company KG
Schichstrasse 16
D-8264 Waldkraiburg

19. Harry Lucas Maschinenfabrik
Gaderlanderstrasse 24-26
D-2350 Neumünster

20. Industrie-Elektronik Stuttgart (IES)
Postfach 1106
D-7050 Waiblingen

21. Karl Frank GmbH
Postfach 263
D-6940 Weinheim-Birkenau

22. Karl Kolb GmbH & Company KG
Postfach 100
Im Steingrund 3
D-6079 Buchschlag

23. LIBA Maschinenfabrik GmbH
Postfach 108
D-8674 Naila-Bavaria

24. Mahlo KG
D-8424 Saal/Donau

25. Original Hanau Quarzlampen GmbH
Hohensonnestrasse
D-6450 Hanau/Main

26. Dr. Ing. Rudolf Hell GmbH
Postfach 6229
Grenzstrasse 1-5
D-2300 Kiel 14

27. SKF Kugellagerfabriken GmbH
Postfach 500640
Löwentorstrasse 68
D-7000 Stuttgart 50

28. Süssen Spindelfabrik
Schurr, Stahlecker und Grill GmbH
Postfach 60
Dammstrasse 1
D-7334 Süssen

29. Textechno Stein
Regentenstrasse 37-39
D-4050 Mönchengladbach

30. Trützschler & Company
Postfach 165
D-4050 Mönchengladbach-Odenkirchen 3

31. Wolfgang Degussa
Postfach 602
D-6450 Hanau/Main

32. Zweigl KG
Fabrik für Textilprüfmaschinen und -geräte
Postfach 100
Bismarckstrasse 95
D-7410 Reutlingen

33. Zwick Prüfmaschinen and Company KF
D-7900 Ulm-Einsingen

Hungary

34. Metrimpex
Hungarian Trading Company for Instruments
P.O. Box 202
Nador utca 21
H-1391 Budapest 62

Italy

35. Branca Idealair S.a.s.
Via Milano 7
I-21020 Mercallo dei Sassi (Varese)

36. Caipo de Bolli Giuseppe
Frazione Violetto
I-13060 Campore di Vallemosso (Vercelli)

37. Calderara-Bossi Ingg. S.p.A.
Via Mauro Macchi 54
I-20124 Milan

38. Gama di F. Gava & L. Manicardi
Viale Caduti sul Lavoro 170
I-41100 Modena

Japan

39. Hitachi Electronics Ltd
32 Miyuki-cho
Kodaira-shi
Tokyo 187

40. Keisokki Kogyo Company Ltd
3 Sugigama-cho
Higashi-ku
Osaka

41. Sanso Company Ltd
31-6, 1-chome Hamamatsu-cho
Minato-ku
Tokyo 105

42. Shimadzu Seisakusto Ltd
14-5 Uchikanda 1-chome
Chiyoda-ku
Tokyo 101

43. Shikishima Spinning Company Ltd
35, 3-chome
Bingoma-shi
Higashi-ku
Osaka

44. Tekmatex Marubeni
GPO box 595
4-2 Ohtemachi, 1-chome
Chiyoda-ku
Tokyo 100-91

Spain

45. Renigal SA
Caspe 139
Barcelona 13

Sweden

46. Roséns Trikäindustri AB
P.O. Box 54
Villag 39-41
S-52301 Ulricehamn

Switzerland

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Hardstrasse 50
CH-4127 Birsfelden

48. Chemiecolor Ltd
Seestrasse 42
CH-8802 Zurich-Kilchberg

49. Datacolor AG
Brandbachstrasse 10
CH-8305 Dietlikon

50. Hans Baer AG
Zweierstrasse 35
CH-8004 Zurich

51. Hepatex AG International Trading
CH-9630 Wattwil

52. Jaquet AG
Thannerstrasse 15
CH-4009 Basel

53. Mettler Instruments AG
CH-8806 Zurich-Greifensee

54. N. Zivy und Cie SA
Mühlemattstrasse 7
CH-4104 Basel-Oberwill

55. Pretema AG
Division of Colour Measurement
CH-8903 Zurich-Birmensdorf

56. Projectina Ltd
Optical Precision Instruments
P.O. Box 115
CH-9435 Heerbrugg

57. Renate und Ernst Schweitzer-Blätler (RES)
Rohanhalderstrasse 49
CH-8713 Uerilon

58. Rieter AG
Klosterstrasse 20
CH-8406 Winterthur-Töss

59. Rothschild Measuring and Controlling Instruments for Industry and Research
Traubenstrasse 3
CH-8002 Zurich

60. Salvis AG
Haupstrasse 49
CH-6015 Lucerne-Reussbühl

61. Siegfried Peyer AG
Im Roos
CH-8832 Wollerau

62. Spinlab (Special Instruments Laboratory) AG
P.O. Box 180
Rautistrasse 58
CH-8048 Zurich

63. Textest AG
Weinbergstrasse 93
CH-8802 Zurich-Kilchberg

64. Werner Mathis AG
Textilmaschinen-Laborapparate
CH-8155 Zurich-Niederhasli

65. Zellweger AG
Sonnenbergstrasse 10
CH-8610 Zurich-Uster

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66. Abbey Electronics and Automation Ltd
Delamare Road
Cheshunt, Hertfordshire EN8 9SW

67. AEI Scientific Apparatus Ltd
Barton Dock Road
Urmston, Greater Manchester M31 2LD

68. Avery-Denison Ltd
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Romford, Essex RM1 1HA

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Britannia Walk
London N1 7ND

73. C. I. Electronics Ltd
Brunel Road
Churchfields
Salisbury, Wiltshire

74. Crabtree Instruments Ltd
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Colne, Lancashire BB8 8AY

75. Dronsfield Brothers Ltd
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Oldham, Lancashire OL8 1E2

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78. Foster Cambridge Ltd
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Vernon Building
23 Westbourne Street
High Wycombe, Buckinghamshire

81. IVO Counters Ltd
303 Morland Road
Croydon, London CR0 6HF

82. James H. Heal and Company Ltd
Richmond Works
Lake View
Halifax, Yorkshire HX3 6EP

83. John Godrich
Ludford Mill
Ludlow, Shropshire

84. John Jeffreys Ltd
Elm Works, Mere Lane
Rochdale OL11 3TE

85. Moisture Control and Measurement Ltd (MCM)
Thorp Arch Trading Estate
Wetherby, Yorkshire LS23 7BJ

86. Molecular Controls Ltd
30 Park Cross Street
Leeds, Yorkshire LS1 2QH

87. M. S. Optics
P.O. Box 8
Princes Risborough
Aylesbury, Buckinghamshire HP17 9LL

88. Platt Saco Lowell Ltd
P.O. Box 55
Accrington, Lancashire BB5 ORN

89. Precision Processes (Textiles) Ltd
Dylan Laboratories
Ambergate, Derby, Derbyshire DE5 2EY

90. Pye Unicam Ltd
York Street
Cambridge, Cambridgeshire CB1 2PX

91. Reynolds and Branson
Lakeside Laboratories
Rawdon, Leeds, Yorkshire LS19 7YA

92. Roaches Engineering Ltd
Upper Hulme, Near Leek
Staffordshire ST13 8TY

93. Shaw Moisture Meters
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Westgate
Bradford 1, Yorkshire

94. Shirley Developments Ltd (ESSDIEL)
P.O. Box 6
856 Wilmslow Road
Didsbury, Manchester, Lancashire M20 8SA

95. Smith Industrial Division
Kelvin House
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Wembley, Middlesex

96. Telemechanics Ltd
Department 151 376
Pembroke House
Frimley Road
Camberley, Surrey

97. Thorn Automation Ltd
Beech Avenue
New Basford, Nottinghamshire NG7 7JJ

98. Trumeter Company Ltd
Milltown Street
Radcliffe, Manchester, Lancashire

99. Vernon H. Cooper Ltd
Glaisdal Drive West
Bilborough, Nottingham NG8 4GH

100. WIRA
Headingley Lane
Leeds, West Yorkshire LS6 1BW

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101. Atlas Electric Devices Company
4114 North Ravenswood Avenue
Chicago, Illinois 60613

102. Barber-Colman Company
Textile Machinery Division
P.O. Box 1177
Gastonia, North Carolina 28052

103. B. F. Perkins and Sons, Inc.
P.O. Box 366
Chicopee Street
Chicopee, Massachusetts 01021

104. Boonton Electronics Corporation
Route 287 and Smith Road
Parsippany, New Jersey 07054

105. Brabender Corporation
Division of Maake, Inc.
P.O. Box 128
240 Saddle River Road
Saddle Brook, New Jersey 07662

106. Compensating Tension Controls, Inc.
476-T Thomas Boulevard
Orange, New Jersey 07050

107. Crompton and Knowles Corporation
Preparatory and Finishing Machinery Division
P.O. Box 249
Mauldin, South Carolina 29662

108. Custom Scientific Instruments, Inc.
P.O. Box A
13 Wing Drive
Whippany, New Jersey 07981

109. Delmhorst Instrument Company
117 Cedar Street
Boonton, New Jersey 07005

110. Diano Corporation
P.O. Box 346
75 Forbes Boulevard
Mansfield, Massachusetts 02048

111. Electromatic Equipment Company
560 Albemarle Road
Cedarhurst, New York 11516

112. Emerson Apparatus Company
200 Tremont Street
Melrose, Massachusetts 02176

113. Enterprise, Machine and Development Corporation
100 Fernwood Avenue
New Castle, Delaware 19720

114. Fabric Research Laboratories
Division of Albany International Corporation
1000 Providence Highway
Dedham, Massachusetts 02026

115. Fabrionics Corporation
117 Urban Avenue
Westbury, New York

116. Forté Engineering Division
Kingsbury Technology, Inc.
15 Strathmore Road
Natick, Massachusetts 01760

117. Frazier Precision Instrument Company, Inc.
210 Oakmont Avenue
Gaithersburg, Maryland 20760

118. Gardner Laboratory, Inc.
P.O. Box 5728
5521 Landy Lane
Bethesda, Maryland 20014

119. Hart Moisture Meters, Inc.
398-400 Bayview Avenue
Amityville, New York 11701

120. Hunter Associates Laboratory, Inc.
9529 Lee Highway
Fairfax, Virginia 22030

121. Instron Corporation
2500 Washington Street
Canton, Massachusetts 02021

122. Laboratory Equipment Company, Inc.
Leco Corporation
3000 Lakeview Avenue
St. Joseph, Michigan 49085

123. Lawson-Hemphill, Inc.
96 Hadwin Street
Central Falls, Rhode Island 02863

124. Lindly and Company, Inc.
248 Herricks Road
Mineola, New York 11501

125. Matrix Controls Company, Inc.
P.O. Box 459-R
189 South Bridge Street
Somerville, New Jersey 08876

126. Mico Instrument Company
80 Trowbridge Street
Cambridge, Massachusetts 02138

127. Micro-Sensors, Inc. (MSI)
New Englander Industrial Park
Route 126
Holliston, Massachusetts 01746

128. MKM Machine Tool Company, Inc.
P.O. Box 309
State Road 31-E
Jeffersonville, Indiana 47130

129. Pasco Scientific
1933 Republic Avenue
San Leandro, California 95477

130. Precision Scientific Company
(GCA Corporation)
3737 West Cortland Street
Chicago, Illinois 60647

131. Research, Inc.
P.O. Box 24064
Minneapolis, Minnesota 55424

132. Richmond Machine Company
Richmond and Wensley Streets
Philadelphia, Pennsylvania 19134

133. Shore Instrument and Manufacturing Company, Inc.
90-35T Van Wyck Expressway
Jamaica, New York 11435

134. Singer Company
Knitting Division
393 Seventh Avenue
New York, New York 10001

135. Stop-Motion Devices Corporation
155 Ames Court
Plainview, New York 11803

136. Strandberg Engineering Laboratories, Inc.
Industrial Electronics Division
1001 South Elm Street
Greensboro, North Carolina 27406

137. Teledyne Taber
455 Bryant Street
North Tonawanda, New York 14120

138. Tensitron, Inc.
288-290 Harvard Depot Road
Harvard, Massachusetts 01451

139. Testing Machines, Inc.
398-400 Bayview Avenue
Amityville, New York 11701

140. Thwing-Albert Instrument Company
10960 Dutton Road
Philadelphia, Pennsylvania 19154

141. Uniwave, Inc.
75 Marine Street
Farmingdale, New York 11735

142. U.S. Testing Company, Inc.
1415 Park Avenue
Hoboken, New Jersey 07030

143. Venango Engineering Company, Inc.
(Textile machinery)
8311 Torresdale Avenue
Philadelphia, Pennsylvania 19136

West Berlin

144. Dr. Gerhard Kloz Chem Laboratorium
Postfach 210
Weichselstrasse 59
1000 West Berlin 44

Annex III

QUANTITIES AND UNITS RECOMMENDED FOR TEXTILE MEASUREMENTS

A. Dimensioned quantities

Quantity	*Unit*	
	Name or definition	*Symbol*
Expressed in SI-compatible units		
Acceleration	Metre per second per second	m/s^2
Area	Square metre	m^2
Areal density (mass per unit area)	Gram per square metre	g/m^2
Bending length	Centimetre	cm
Bending modulus	Newton per square centimetre	N/cm^2
Breaking load	Newton, millinewton	N, mN
Bursting pressure	Kilonewton per square metre	kN/m^2
Compactability	Cubic centimetre per gram	cm^3/g
Cover factor		
Woven fabrics	Hundred threads per centimetre times square root of tex	$(\text{thread/cm})\sqrt{\text{tex}} \cdot 10^{-2}$
Knitted fabrics	Square root of tex divided by stitch length in millimetres	$\sqrt{\text{tex}}/\text{mm}$
Crease recovery	Millimetre	mm
Crease recovery angle	Degree ($\pi/180$ radian)	$°(1° = (\pi/180)\ \text{rad})$
Diameter (fibre)	Micrometre	μm
Electrostatic potential ("charge")	Volt, Kilovolt, millivolt	V, kV, mV
Flexural rigidity	Milligram-centimetre	mg-cm
Fluidity	Reciprocal of viscosity in poises (1 poise equals 0.1 pascal-second)	P^{-1} $(1P = 0.1\ Pa \cdot s)$
Hairiness	Number of hairs per metre	hair/m
Hydrogen ion concentration	The negative of the logarithm of the concentration in moles per litre	pH
Initial Young's modulus	Newton per tex	N/tex
Length	Metre, kilometre, centimetre, millimetre	m, km, cm, mm
Linear density	Tex (milligram per metre)	tex (1 tex = 1 mg/m)
Mass	Kilogram, gram, milligram	kg, g, mg
Pilling tendency	Pills formed per second	pill/s
Rigidity "G"	10^9 newtons per square metre	$10^9\ N/m^2$
Rotational speed	Revolution per minute	r/min, rpm
Specific work of rupture	Millinewton per tex	mN/tex
Stitch length	Millimetre	mm
Strength of single fibre	Millinewton	mN
Surface or yarn speed	Metre per minute	m/min
Tearing strength	Newton	N
Temperature	Kelvin or degree Celsius	K, °C
Tenacity	Millinewton per tex	mN/tex
Tension in yarn	Newton, millinewton	N, mN
Time	Second, minute, hour	s, min, h
Thermal conductivity	Milliwatt per metre and per kelvin	$mW\ m^{-1}K^{-1}$
Thermal resistance	Tog	tog $(1\ \text{tog} = 0.1\ K\ m^2/W)$
Threads in cloth		
General	Number of threads per centimetre along length or width	thread/cm
Woven fabrics	Number of picks per centimetre along length	pick/cm
	Number of ends per centimetre along width	end/cm
Knitted fabrics	Number of courses per centimetre along length	course/cm
	Number of wales per centimetre along width	wale/cm
Torsional rigidity	10^{-12} newtons per square metre	$10^{-12}\ N/m^2$
Twist	Turn per metre	turn/m
Twist factor	Hundred turns per metre times square root of tex	$(\text{turn/m})\sqrt{\text{tex}} \cdot 10^{-2}$
Volume	Litre	l
Warp threads in loom	Number of ends per centimetre	end/cm

A. Dimensioned quantities *(continued)*

Quantity	*Unit*	
	Name or definition	*Symbol*
Other		
Air permeability	Cubic centimetre per second, per square centimetre, and per centimetre water pressure	$cm^3 sec^{-1} cm^{-2} (cm\ H_2O)^{-1}$
Change in colour	Grey Scale (colour) number	–
Degree of staining	Grey Scale (staining) number	–
Hardness	Degree Shore	° Shore
Micronaire value (fineness or maturity)	A measure of resistance to air flow through a fibre sample	–
Pressley Index (strength of fibre bundle)	Pound-force per milligram	lbf/mg

B. Dimensionless quantities

Quantity	*Definition*
Ratios expressed as percentages	*Ratio of:*
Coefficient of variation (V)	Standard deviation of a group of measurements to the mean
Compressibility	Change in pile depth to initial depth
Crimp	Difference between yarn length and cloth length to cloth length
Crimp rigidity	Reduction in length to original length
Efficiency	Actual performance to theoretically attainable performance
Elongation	Increase in length to initial length
Mean deviation (U)	Mean of absolute deviations from the mean of a group of measurements to the mean
Moisture content	Weight of moisture in sample to total weight
Regain	Weight of moisture in sample to oven-dry weight
Relative humidity	Pressure of water vapour in atmosphere to saturation pressure of water vapour at same temperature
Shrinkage	Decrease in length (or width) to initial length (or width)
Other	
Abrasion resistance	Cycles to failure
Coefficient of friction (sliding)	Ratio of frictional force to the normal force on a sliding body

Annex IV

ORGANIZATIONS AND COMPANIES THAT ISSUE TEXTILE STANDARDS

International

Bureau internationale pour la standardisation de la rayonne et des fibres synthetiques (BISFA)
Lautengartenstrasse 12
CH-4010 Basel,
Switzerland

Canvas Products Association International
600 Endicott Buildings
St. Paul, Minnesota 55101
United States of America

Council of the European Economic Community
200 rue de la Loi
B-1040 Brussels
Belgium

International Standards Organization (ISO)
1 rue de Varembé
1211 Geneva 20
Switzerland

International Wool Textile Organisation (IWTO)
Hastlegate
Bradford, Yorkshire BDI IDE
United Kingdom

Pan American Standards Commission
c/o Argentine Standards Institute (IRAM)
Chile 1192
Buenos Aires
Argentina

Zellweger Ltd.
(Uster Standards)
CH-8610 Uster
Switzerland

National

Eighty-seven countries have national organizations that issue textile standards, sometimes as part of a general series. Many of these are members of the ISO and issue equivalent national standards. Some of the most widely used are:

American Society for Testing and Materials (ASTM)
1916 Race Street
Philadelphia, Pennsylvania 19103
United States of America

Association française de normalisation (AFNOR)
Tour Europe
Cedex 7
92080 Paris-La Défense
France

British Standards Institution (BSI)
Textile Division
10 Blackfriars Street
Manchester M3 5DR
United Kingdom

Deutscher Normenausschuss (DNA)
Burggrafenstrasse 4-7
1000 West Berlin 30

Ministry of Trade
Cotton Arbitration and Testing General Organization (CATGO)
Alexandria
Egypt

National Bureau of Standards
Washington, D.C.
United States of America

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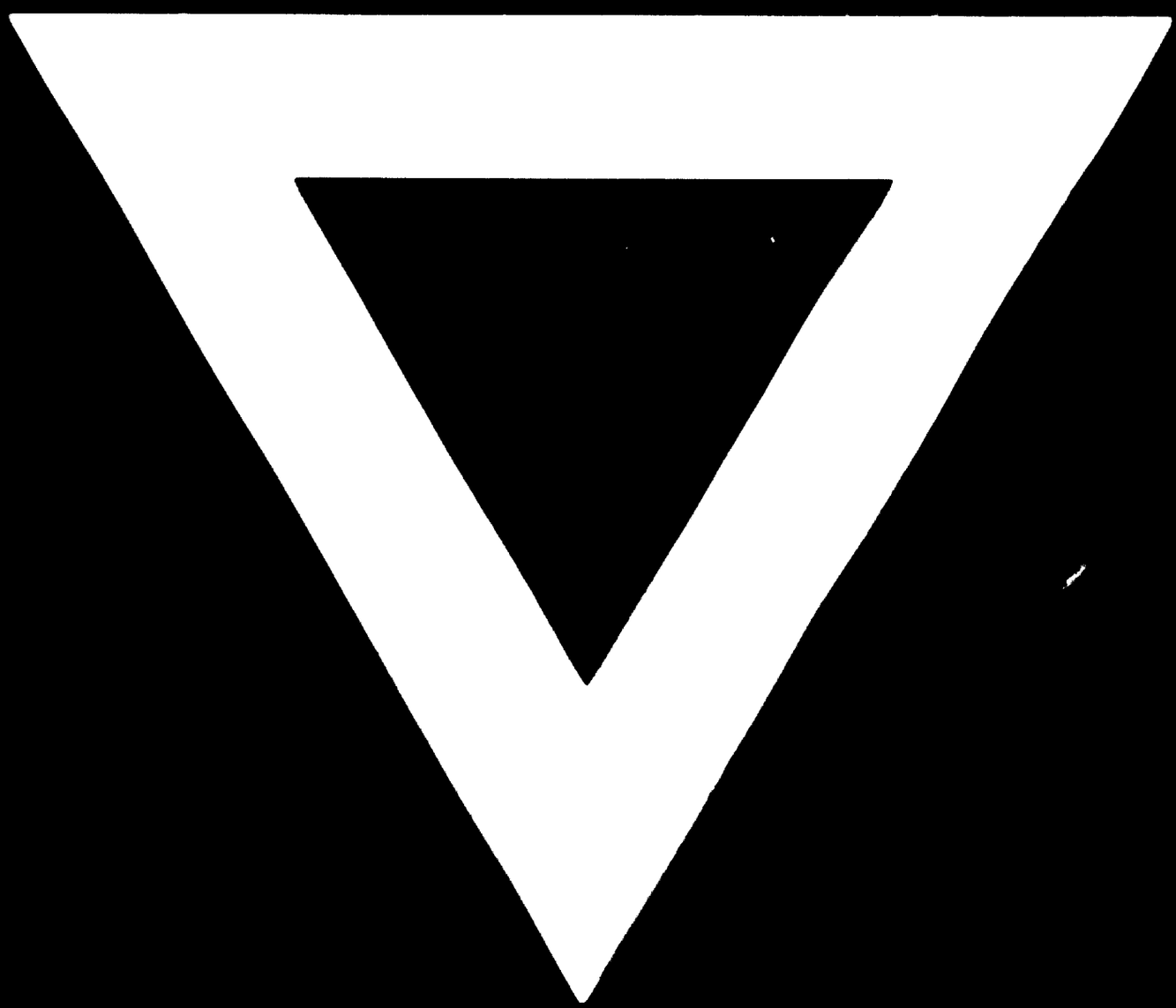

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