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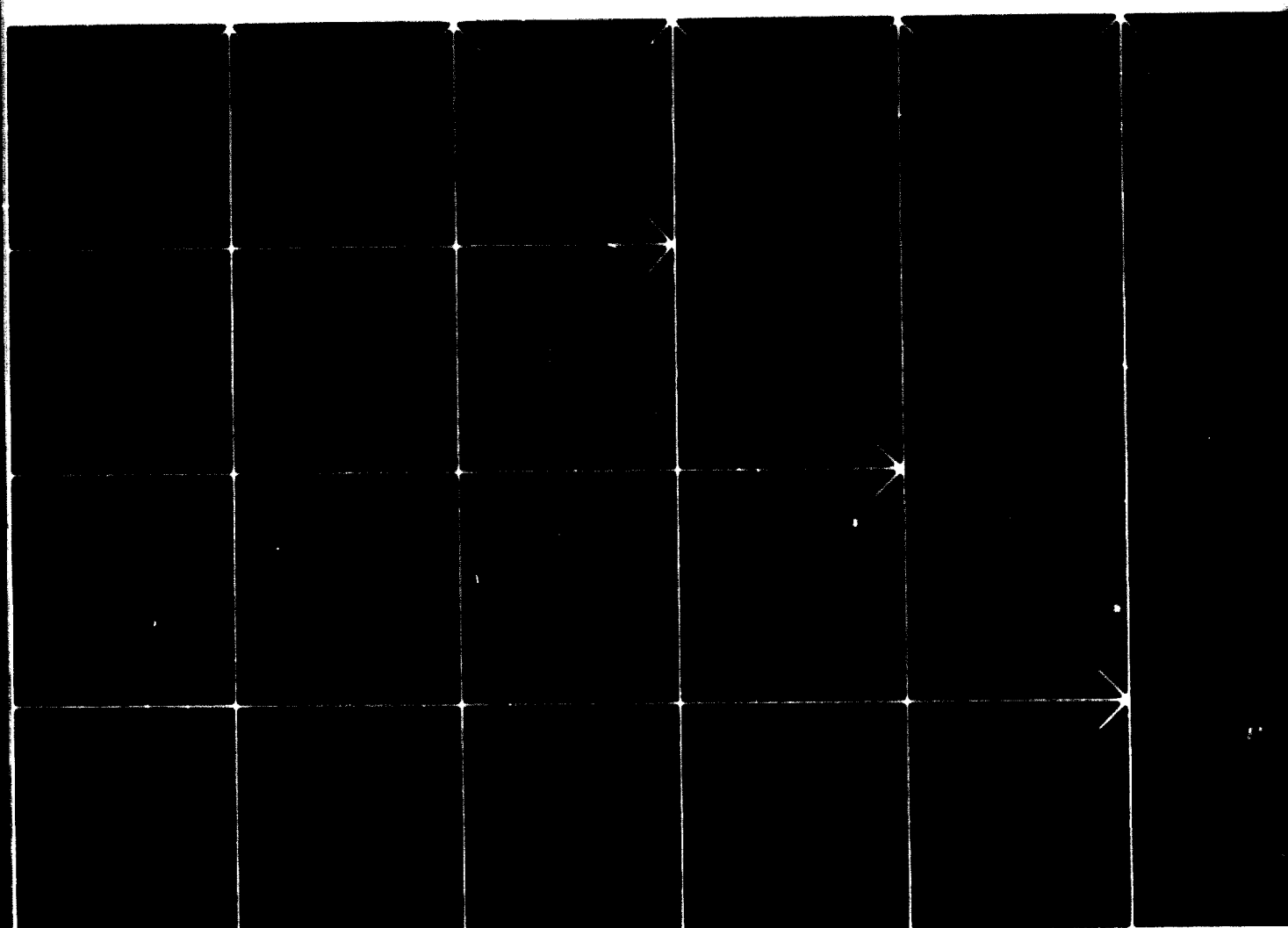
TRAINING FOR INDUSTRY SERIES NO. 3

THE ŁÓDŹ TEXTILE SEMINARS

7. Testing and quality control



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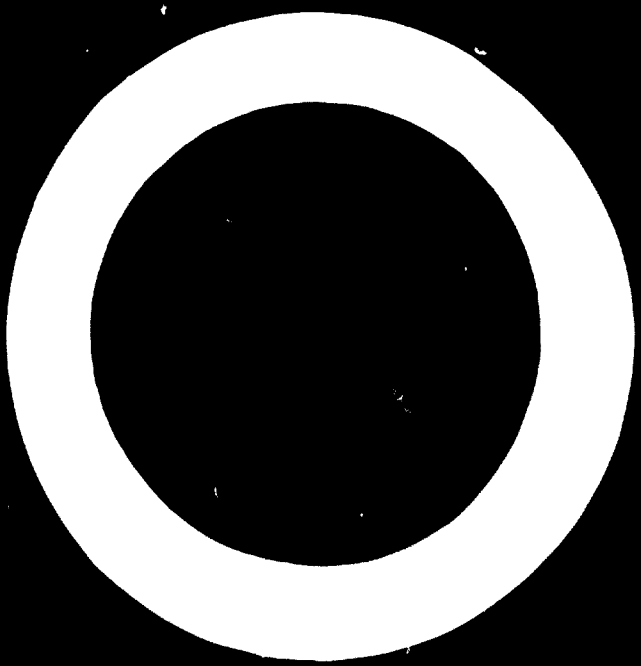

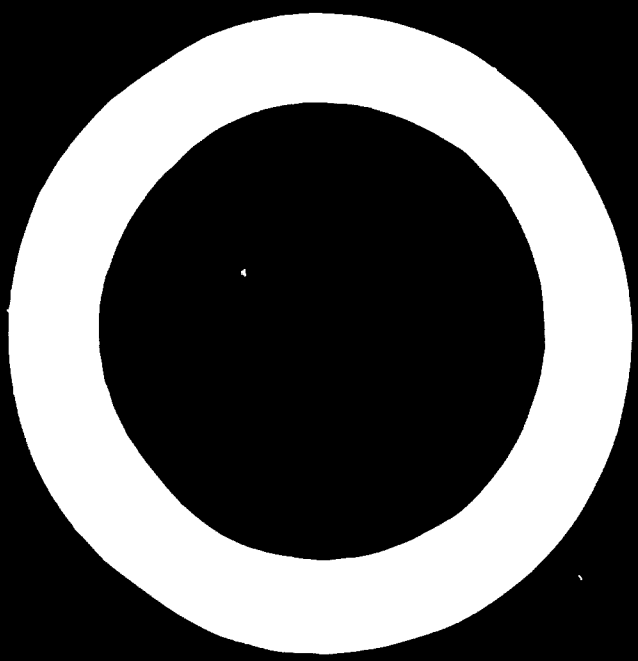

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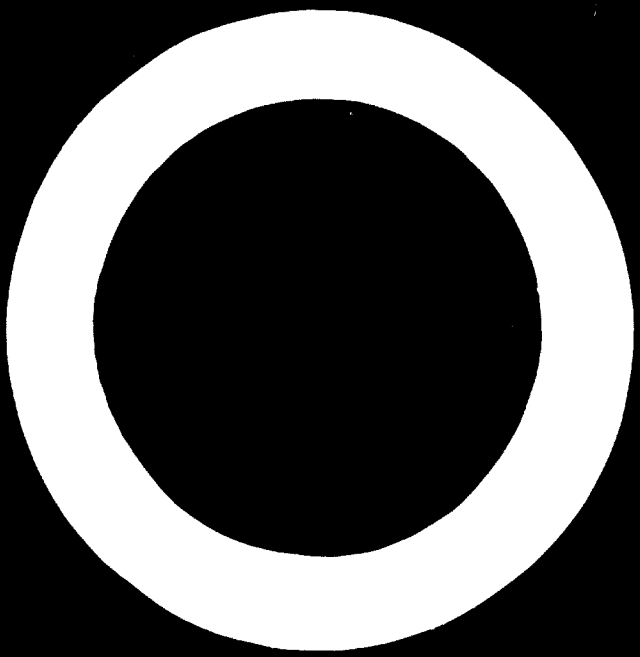

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
VIENNA

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FOREWORD

This publication is the seventh of a series devoted to textile engineering and closely related fields. It is part of the Training for Industry Series published by the United Nations Industrial Development Organization (UNIDO).

Rapid world-wide increases in population and industrialization are reflected in the textile and allied industries. In any ranking of human needs, fibres and textiles for clothing and industrial purposes are second only to foodstuffs. The continuing quantitative and qualitative changes in textile production require the broadest and most complete dissemination of information in this important area.

The purpose of the present series is to make available to the developing countries the most recent scientific and technical information in order to help them to establish textile industries or to improve the effectiveness and economic viability of existing textile industries that are still in the earlier stages of economic development.

At the suggestion of UNIDO, with the support of the authorities of the Polish People's Republic, a post-graduate in-plant training course in textile industries was held in Łódź from May through September 1967. The course was repeated from May through October 1968, and its content was modified and up-dated on the basis of experience and new information. It was repeated again in 1969 and it is planned to continue this programme, up-dating its subject matter and improving its usefulness to the textile industries of the developing countries. It is on these courses that the present series is based.

The courses were organized by the Textile Research Institute in Łódź with the object of training a group of already highly qualified specialists in all branches of industry relating to textiles. Under normal conditions, such training would require work in mills and in research and development over a period of several years.

The courses give the participants an opportunity to become acquainted and to do actual work in conjunction with some of Poland's leading research centres and industrial enterprises, and to discuss with experts problems connected with techniques, technology, economics, organization and research in the field of textiles. In organizing the courses, the Textile Research Institute endeavours to co-ordinate the content of theoretical lectures, technical discussions and practical studies in laboratories and mills, covering all the fundamental problems of textile industries.

The main object of the seminars is to adapt the broad range of problems presented by Polish specialists to the direct needs of the developing countries. Lectures by the research workers of the Institute formed the core of the programme. The lectures do not review or repeat the basic problems usually studied at technical colleges and high schools in the course of normal vocational training; rather, they deal with subjects most often of concern to the management and technical staff of a textile enterprise.

The lectures, as presented in this series, have been grouped in eight parts: textile fibres; spinning; knitting; weaving and associated processes, non-conventional methods of fabric production; textile finishing; testing and quality control; and plant and power engineering.

It is hoped that the experience gained from these courses, as presented in this series, will contribute to the improvement of textile industries everywhere, and particularly in the developing countries.

The views and opinions expressed in this publication are those of the individual authors and do not necessarily reflect the views of the secretariat of UNIDO.

CONTENTS

EXPLANATORY NOTES

References are indicated in parenthesis in the text, by name of author and year of publication. The full references are listed, alphabetically by author, at the end of each article.

References to "tons" indicate metric tons and to "dollars" ($), United States dollars, unless otherwise stated.

The following abbreviations have been used:

cpi means "courses per inch".
Denier (den) is the weight in grams of 9,000 metres of yarn.
gg is "gauge".
kcal is kilocalorie.
Metric count (Nm) is the number of kilometres of yarn per kilogram.
A nanometer (nm) is 10^{-6} mm.
rev/min is revolutions per minute.
Tex is the weight in grams of 1,000 metres of yarn; millitex (mtex) is 0.001 tex.
wpi is "wales per inch".
Worsted count is the number of 560-yard lengths per pound of yarn.

METHODS FOR TESTING FOAM-BACKED FABRICS

by

W. Balcerowski and M. Stasiakowa

Laminated articles (foambacks) are composed of two principal parts; a layer of polyurethane foam and a woven or knitted textile fabric. The first of these must contribute dimensional stability to the laminate and add to its thermal insulation properties stiffness and crease recovery, whereas the second determines its appearance, strength, abrasion resistance, colour fastness and the like.

The quality control of the laminates should include: *(a)* quality of the foam, *(b)* quality of the textile layer, and *(c)* quality of the final product of lamination.

Since methods for the examination of woven and knitted fabrics are universally known, the present report is confined to the examination of foams and laminates.

Examination of the foam

The most characteristic properties of polyurethane foams include thickness, weight per square metre, specific density, linear density of pores, tensile strength, compression recovery, bending rigidity and air permeability. These are discussed individually below.

Thickness

Measurement is done with a gauge of the kind used for normal textiles. The specimen is placed between two discs set horizontally, the upper one usually being suitably weighted. The thickness of the specimen (that is, the distance between the discs) is indicated by means of a feeler with an accuracy as high as 0.01 mm.

The essential factors that affect this test are: the magnitude of the pressing force, the area of the specimen, the time of weighting and the number of specimens. Standard values regarding the mentioned factors are: 5 g/cm^2 of pressing force, 25 cm^2 of tested area and 5 to 10 seconds as time during which the pressure is applied. At least ten specimens should be tested.

Weight and specific density

To determine these properties, a sample at least 50 cm in length and total width is taken. It is trimmed so that its opposite sides are parallel to each other. Length and width of the sample are measured at three places: in the middle of the sample and at both edges, the accuracy required being 1 mm. After the length and width of the sample have been measured, it is weighed on a scale whose accuracy is 0.1 per cent.

The sample is next cut along the diagonal and measured for thickness near the places where the length was measured. The weight per square metre (W/m^2) is calculated as:

$$W/m^2 = \frac{Q}{sl} \ [g/m^2]$$

where Q is the weight in grams

l is the mean length in metres

s is the mean width in metres.

Specific density (D) is calculated as:

$$D = \frac{Q}{slt} \ [kg/m^3]$$

where Q, s, l are as above and

t is the mean thickness in millimetres.

Linear density of pores

The linear density of the pores is indicated by the number of holes at the surface of the specimen per unit length of a straight line crossing it. Ten samples are taken for the test. Five of them are dyed on one face and the other five on the reverse face by means of a 1-per-cent solution of eosin or with India ink. The coloured face is then covered by a magnifying glass with a 1-cm-long mark on it. All the pores crossed by the mark are then counted (figure 1). The magnified area should be illuminated.

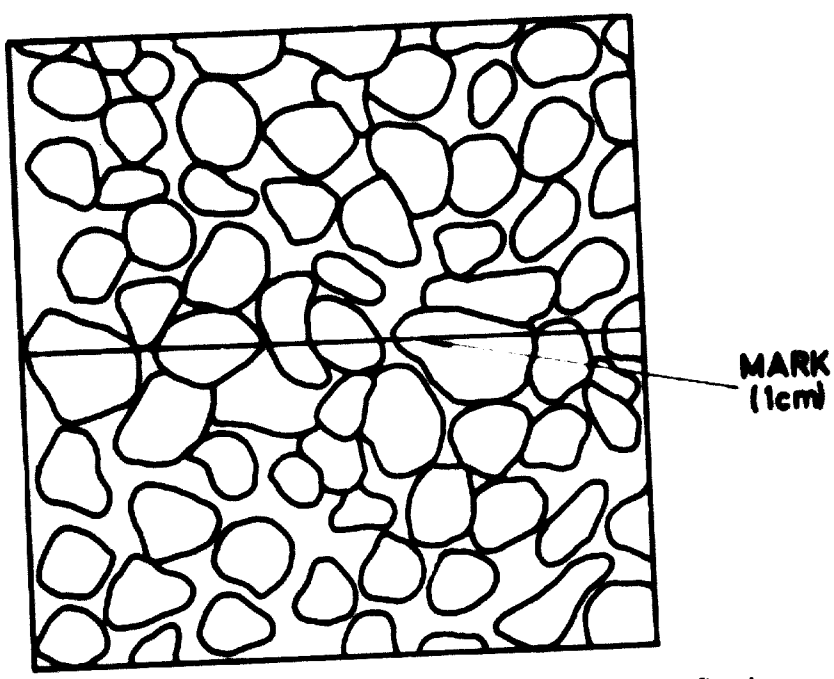

Figure 1. Measurement of the linear density of pores under magnification

A weaver's ordinary magnifying glass (without a mark) can also be used, the pores crossed by the edge of the sight-hole being then counted. The glass must be set so that one end of the edge or mark should be in the space between the pores. The count omits pores that are not crossed by the mark, even if they are tangent to it. However, the last pore, even if partly crossed by the other end of the mark, is counted. Lines along which the counting is done should run at various angles to the axis of the sample. The density is calculated as the number of holes per centimetre.

Tensile strength

This parameter is determined by means of low-range strength-testers equipped with clamps at least 2.5 cm wide. The test is carried out on foam samples, the size and the form of which is shown in figure 2. The form shown there is necessary because, if the sample were cut to a regular rectangular form, it would be seriously narrowed in the course of stretching and breaks close to the clamps would occur. With the suggested shape however, such breaks are completely eliminated and the sample is ruptured in its central rectangular portion.

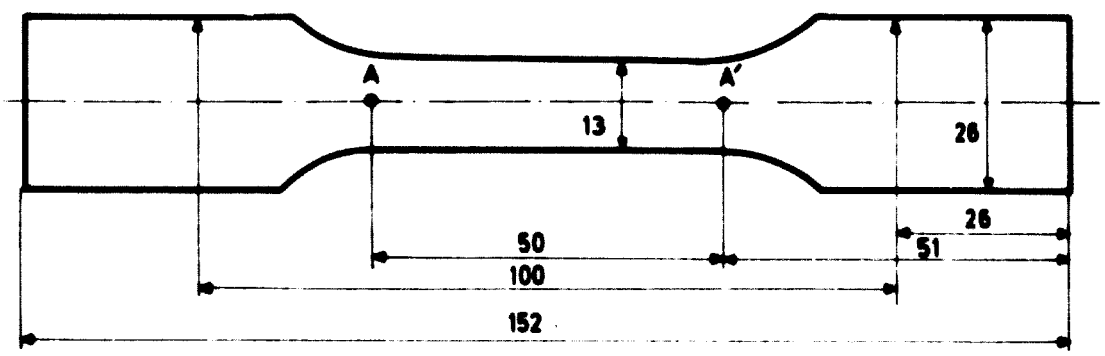

Figure 2. A foam specimen trimmed for tensile-strength testing in a low-range tester

The samples prepared in that way are clamped in the grips of the tester, which are set apart to a distance of 100 mm before extension begins. The time of extension is 30 ± 10 seconds.

One test comprises examination of six samples, three of which are prepared by cutting the test specimens out of the tested foam lengthwise, and the three others crosswise.

The tensile strength is determined by the breaking load (σ_r), calculated as follows:

$$\sigma_r = \frac{P}{1C\,st} \text{ [kg/cm}^2\text{]}$$

where P is the mean breaking load (in grams)

s is the sample width at its rectangular part (in millimetres)

t is the mean thickness of the foam (in millimetres)

The elongation at break of the cut-out specimen comprises the elongation of the rectangular part (AA' in figure 2) and the elongation of the trimmed parts. Since these elongations are not equal, and the elongation of the rectangular part is the only characteristic that must be determined, only that is measured. For this purpose the sample is marked at point A (figure 2). A paper ruler is clamped into the tester,

together with the foam specimen, so that the 0 point of the scale covers A (see figure 3). At the moment of rupture, the position of A is read on the ruler, and the elongation of the upper, trimmed part of the specimen is thus found.

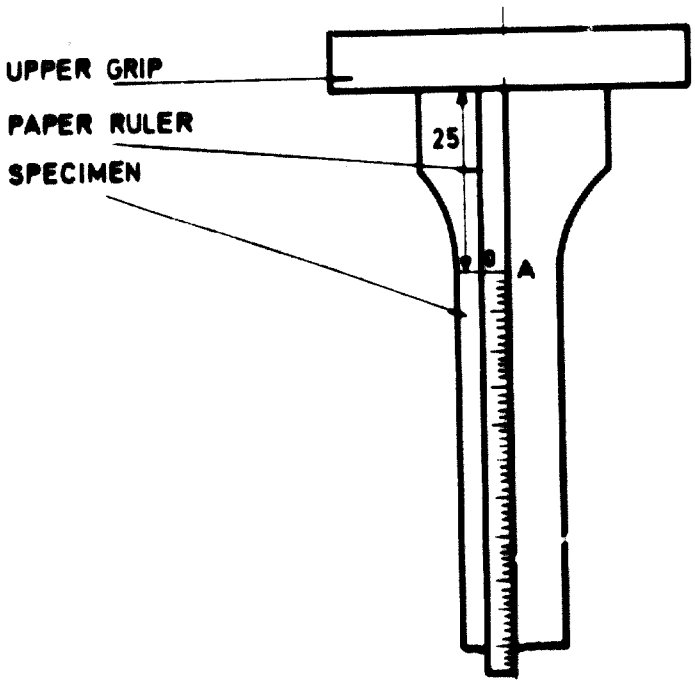

Figure 3. Ruler for measuring the elongation of the trimmed specimen shown in figure 2

The relative elongation (ϵ) of the rectangular part of the sample will be:

$$\epsilon = \frac{\bar{\Delta}_c - 2\bar{\Delta}_k}{l_c} \times 100 \quad [\%]$$

where $\bar{\Delta}_c$ is the mean total elongation (in millimetres)

$\bar{\Delta}_k$ is the mean elongation of the trimmed part (in millimetres)

l_c is the initial length of the rectangular part (sector $AA' = 50$ mm).

Compression recovery

The recovery from the effects of a pressure exerted upon the foam is the evidence of its resilience. It is determined by the formula:

$$r = \frac{t_2}{t_1} \times 100 \quad [\%]$$

where r is the compression recovery (per cent)

t_1 is the thickness of the foam prior to compression

t_2 is the thickness of the foam after compression

under specified conditions and after relaxation.

A special device is used to exert pressure upon the tested foam. It consists of two smooth square plates (144 cm^2) set parallel to each other. One of them is mobile and is connected with a sensitive thickness indicator that measures the distance between the plates with an accuracy as great as 0.01 mm.

Three square samples of 144 cm^2 are taken for the test. They are pressed between the plates of the device to 25 per cent of their original thickness and left in this condition for 72 hours, after which the sample is permitted to recover for 30 minutes. The thickness is measured before and after compression at four places in each sample, with accuracy as high as 0.01 mm.

Bending stiffness

This parameter is demonstrated by the resistance of the sample of a definite unit width against the external bending forces. It is determined by the constant-angle method as follows. The sample, placed on a horizontal surface, is pushed out beyond it until its free end touches another plane, sloping at an angle of 41.5° from the former one (see figure 4). The length of the pushed-out sample allows to calculate its bending stiffness. First, the so-called bending length (c) is calculated as follows:

$$c = \frac{1}{2}L \qquad [\text{cm}]$$

where L is the length of the pushed-out part, in centimetres.

The found value illustrates the ability of the sample to yield to its own weight.

The bending stiffness (B) is found from the formula:

$$B = wc^3 \qquad [\text{g} \times \text{cm}]$$

where w is the weight of the foam (g/cm^2)

c is the bending length, as above.

At a later stage, the so-called "bending-stiffness module" may be determined. It shows the stiffness of the material. (Its thickness is disregarded.)

The module (q) is produced by the formula:

$$q = \frac{12B}{t^3} \qquad [\text{g} \times \text{cm}]$$

where B is as above (bending stiffness — g × cm)

t is the thickness of the sample in centimetres.

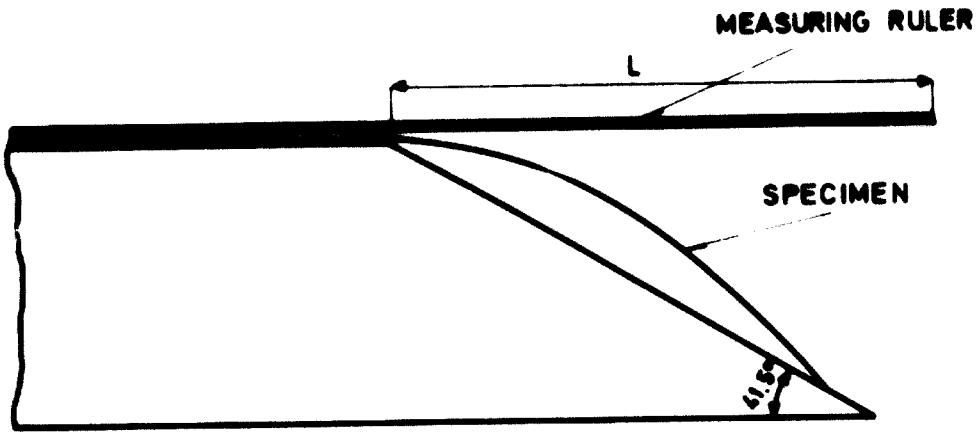

Figure 4. Determination of bending stiffness by the constant-angle method (see text)

The test for bending stiffness is carried out on five samples cut out lengthwise and five other samples cut crosswise from the foam under test. The size of samples is 30 mm × 300 mm. They are examined at both ends and are pushed out at a speed of 1 cm/sec.

Air permeability

The property is determined by the amount of air that passes through the unit area of the material during a unit of time at a definite difference of pressure between the sides of the tested material. The air permeability of polyurethane foam can be measured with vaporimeters or rotameters, which are in common use for the same purpose with other materials. The difference of pressures being applied in this case is equivalent to a 10-mm column of water.

Examination of the laminate

The fourteen parameters to be checked are:
Weight per square metre;
Bond strength;
Tensile strength;
Tearing strength;
Shrinkage after wetting, washing or dry-cleaning;
Resistance to wrinkling;
Resistance to pilling;
Resistance to abrasion;
Thickness;
Bending stiffness;
Air permeability;
Water-vapour permeability;
Water repellency;
Thermal insulation.

Most of these parameters are determined with the conventional methods used with woven fabrics.

The methods that have been worked out especially for foam-backed fabrics concern bond strength and resistance to wrinkling.

Bond strength

This quality is determined by the value of a force acting perpendicularly to the bonding line so as to separate the foam layer from the woven or knitted base fabric.

To carry out the test a rectangular strip of the laminate is prepared by separating its two layers at one end for about 70 mm. The free ends are then clamped in a strength tester. The tester to be used must be of a low range of loads and must be equipped with a drawing device and broad clamping grips. The specimens are torn apart with a simultaneous registration of the strain-stress curve of the tearing force.

The resulting diagram is divided into five equal sections along the path of separation, minimum and maximum load of separation in each section being noted (see figure 5).

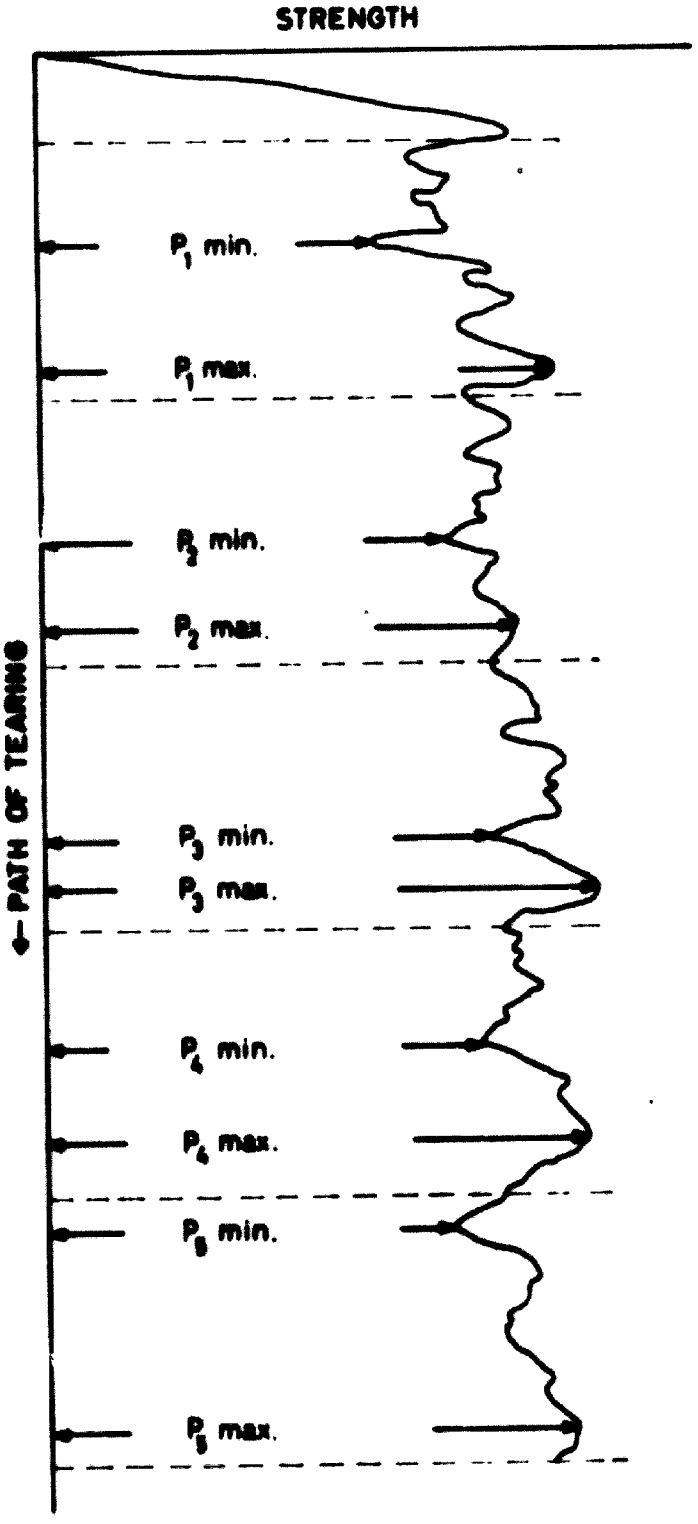

Figure 5. Diagram of bond-strength testing

The following test conditions must be observed: number of tested specimens, four (two cut out lengthwise and two crosswise); specimen size, 50 × 200 mm; extension rate, 100 mm/sec.; length of the path of separation, 100 mm.

Bond strength is calculated as the mean of the minimum loads noted for all tested specimens. In addition, the irregularity of bond lamination may be determined.

The bond-strength test can be carried out on dry (conditioned) samples or on ones that have been dry-cleaned (in benzine or perchlorine ethylene) or washed. Washed or dry-cleaned samples can be tested either wet or after drying.

Resistance to wrinkling

Wrinkle resistance is tested with the device shown in figure 6. A rectangular sample of the laminate is fixed on discs (1) and (2) so that it forms the outer surface of a cylinder. The lower disc (1) is immobilized on rod (3). The upper disc (2) is mobile on the rod along a helical line so that after it is lowered, it makes a turn of 180°, thus rolling up the sample. The diameter of the rolled-up sample is 100 mm. The initial distance between the discs is 145 mm. As the upper disc moves downward regular rhomboid wrinkles appear on the sample. After the upper disc has been lowered, it is weighted with a load of 6 kg for 45 minutes. Resistance to wrinkling is assessed by comparison with a set of five standard photographs, the sample being first allowed to relax for 15 minutes. Assessment is repeated after three hours of relaxation.

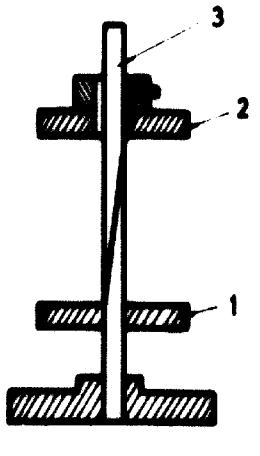

Figure 6. Device for testing resistance to wrinkling (see text)

METHODS FOR TESTING NON-WOVEN FABRICS

by

W. Balcerowski and M. Stasiakowa

The most essential features of non-woven textiles, which affect their technological and wearing properties very greatly, are 22 in number. They include:

Linear dimensions;
Thickness;
Weight per running metre and per square metre;
Specific density;
Irregularity of weight;
Tensile strength;
Bond strength;
Resistance to tearing at seams;
Tearing strength;
Resistance to abrasion;
Shrinkage after wetting, washing, ironing and dry-cleaning;
Resistance to wrinkling;
Bending stiffness;
Compactness;
Recovery from compression;
Absorption of water;
Hygroscopicity;
Capillarity;
Air permeability;
Thermal conductivity.

Recently, in many countries, including Poland, large-scale studies have been made to develop adequate methods for the determination of the above-mentioned properties. As far as possible, the methods were adjusted to those already used with woven materials or felts. However, in some cases this was hardly possible because of the characteristic features of non-woven fabrics as well as because of their special end-uses. For these reasons, completely new parameters had to be taken for assessments, as, for example, irregularities of weight and bond strength and unsuitability for dry-cleaning. The same difficulties applied to the laboratory equipment which not always complied with the specific requirements of non-woven fabrics. Thus, for example, strength testers may have clamps similar to those used for woven goods, but their range of loads should be greatly reduced, more or less to that for yarns.

As noted, most of the above-listed parameters are tested with conventional methods used for woven goods or felts. Since these methods are well known, only those especially adapted for non-woven fabrics are dealt with here. They concern the examination of thickness, specific weight, irregularity of weight, compactness, compression recovery, bond strength and air permeability.

Thickness

Bonded non-woven textiles such as Termonina (Poland) and the Mali-type fabrics (East Germany) are tested for thickness with the gauges discussed elsewhere in this publication.[1] The pressure to be applied here should be 2 g/cm^2.

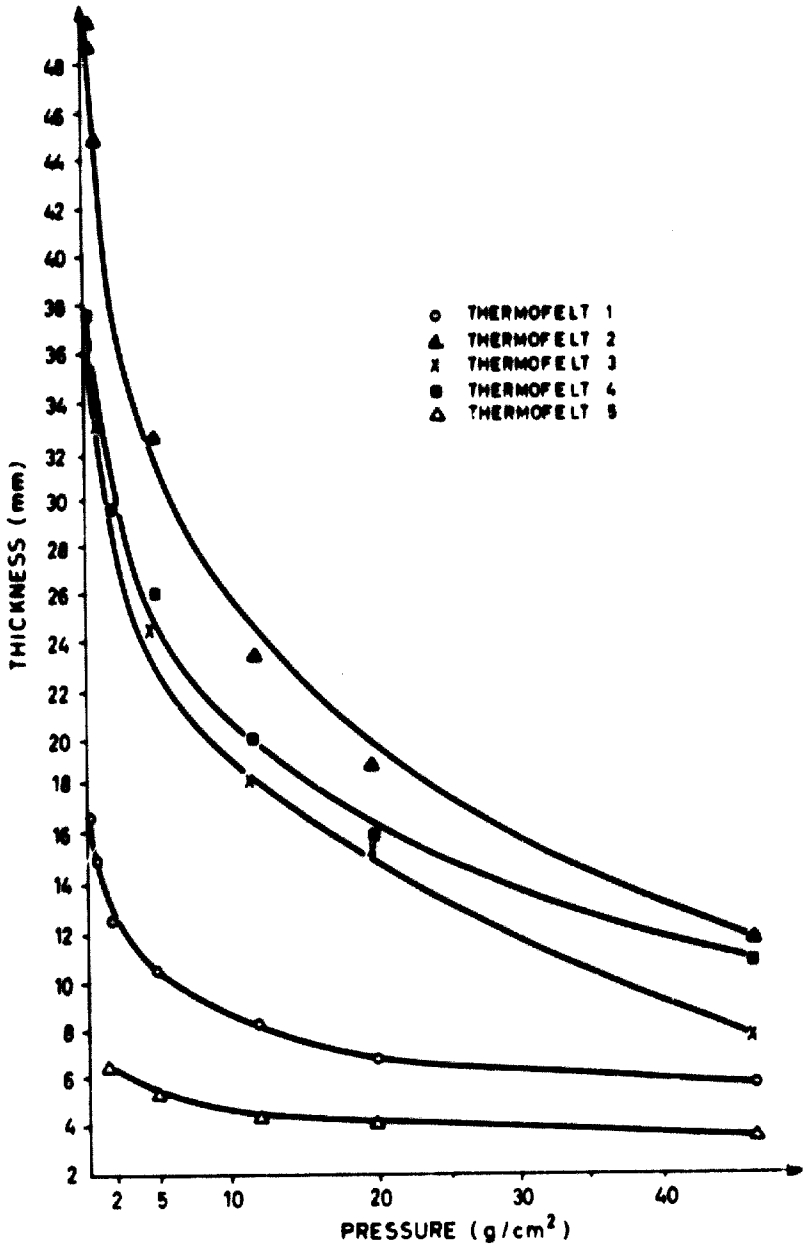

Figure 1. Thickness of thermofelts, plotted against pressure

[1] W. Balcerowski and M. Stasiakowa "Methods for Testing Foam-Backed Fabrics" pp. 1 – 8, this volume.

There may be some difficulty in testing bulky materials such as thermofelts or some needled-and-shrunk non-woven goods. Such products have very loose structures, and the minimum pressure of 2 g/cm^2 that can be applied by usual measuring devices is too great, causing excessive contraction. Figure 1 illustrates, diagrammatically, the alterations of thickness of several thermofelts, plotted against the load value.

When this is taken into account, the thickness is measured with a load of only 0.5 g/cm^2. Since instruments with such a load are not available, the test is carried out in a special way. The rectangular specimen of a non-woven fabric of 36-cm^2 area is placed between two plates. The upper one should be of the same size as the specimen, exerting a pressure of 0.5 g/cm^2 upon it. The distance between plates is measured at the four sides of the specimen, the mean value being taken for the thickness of the specimen. The time of the application of load should be 10 seconds, and ten samples should be tested

Specific weight

The specific weight is particularly important in the evaluation of thermofelts and needled-and-shrunk non-woven goods. This parameter should be determined by tests on small samples, since there is a great irregularity in their weight. The samples should be circular, with an area of 25 cm^2. It is advisable to use special patterns to cut out the samples. Before the samples are cut out, their thickness should be measured at a suitably small load.

The specific density (γ) is calculated as:

$$\gamma = \frac{10\,W}{Ft} \qquad [\text{g/cm}^3]$$

where W is the weight of sample in grams

F is the area of sample in square centimetres

t is the thickness of sample in millimetres.

The mean value of twenty test results on samples cut from various places in the tested fabric is taken as the final index.

Irregularity of weight

Since non-woven fabrics may be very irregular with regard to weight, the determination of such irregularity is important for the assessment and control of processes as, for example, the uneven spread of the latex in bonded fabrics. Irregularity of weight also affects adversely the wearing properties and aesthetics of non-woven materials, since these qualities differ widely in thick and thin places.

As with yarns, the irregularity of weight of non-woven materials is a function of the length of specimens used for the test. It is obvious that the irregularity of small sample weights is most essential as far as technological and wearing properties are concerned.

The method that was developed at the Textile Research Institute requires samples of 25-cm^2 area. Two series of samples, each series comprising 40 specimens, are tested.

The specimens must be taken from various places in a piece of tested material at least 3 m long. The individual weights of each series are then for calculation of the coefficient of weight variation (V), as follows:

$$V = \frac{\sigma}{G} \times 100 = \frac{\sqrt{\frac{\sum_{1}^{n} (G_i - \bar{G})^2}{n-1}}}{\bar{G}} \times 100 \ [\%]$$

where

G_i = individual weight of a specimen

$\bar{G}$ = mean weight of specimens

σ = standard deviation

n = number of specimens (40).

The final index is the average of the two series of tests.

It is important that the samples should really represent the "within" irregularity of the tested length. This may be checked by means of the F (Fisher's) test. If that test must be made, standard deviations of both series must be compared. Let σ_1 be the lower value of the two deviations and σ_2 the higher one. If the following inequality holds good:

$$\frac{\sigma_2^2}{\sigma_1^2} \leqslant 1.7$$

the results of the F test can be considered as positive, that is, both series are representative, and differences between them are negligible from the statistical point of view. If it does not, then a third series of specimens should be taken, and the average of the three tests considered as the final index.

Compactness

Compactness may be defined as the decrease in thickness of a material that results from forces acting perpendicularly to its surface.

The compactness (S) can be shown by the formula:

$$S = \frac{g_p}{g_0} \times 100 \quad [\%]$$

where g_0 is the thickness as usually determined at a low pressure

g_p is the thickness measured at specified higher pressure (p).

Compactness is an important property for thermofelts and needled-and-shrunk non-woven fabrics, manufactured for such end-uses as medical and upholstery paddings, footwear linings, washers and gaskets.

As the definition of compactness given above indicates, this quality depends upon the magnitude of the pressure on the material. Furthermore, compactness is also dependent upon the duration of the pressure.

Figures 2 and 3 demonstrate how the compactness of certain thermofelts depends upon these two factors. The method being applied at the Textile Research

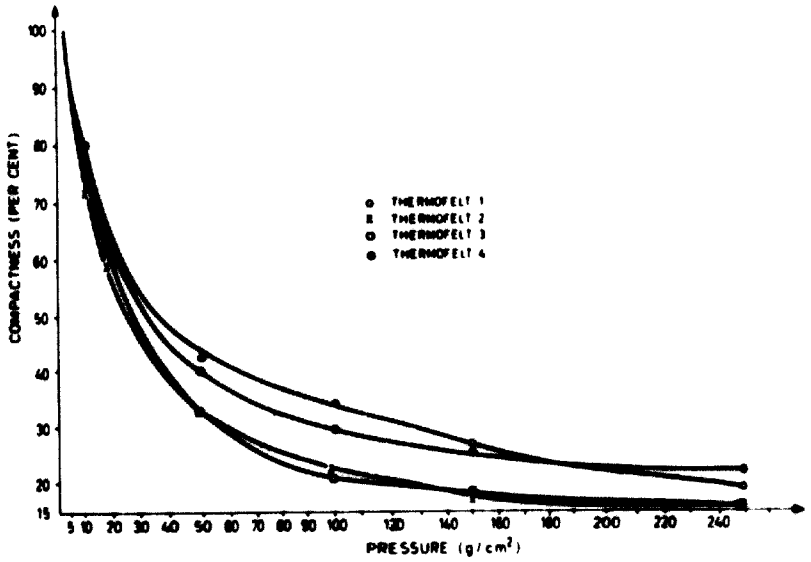

Figure 2. Relation of compactness of thermofelts to the amount of pressure on them

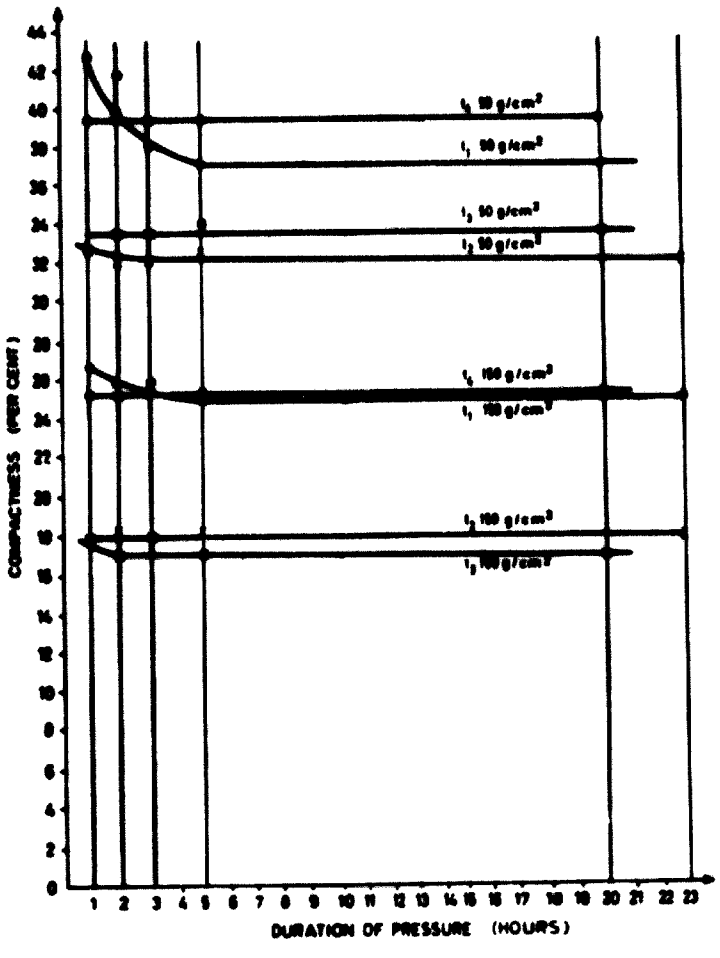

Figure 3. Relation of compactness of thermofelts to the duration of pressure on them

Institute requires the use of pressure of 100 g/cm^2, with a duration of one hour. These values have been assumed as corresponding to the conditions that prevail in the actual use of upholstery, the magnitude of pressure and its duration being also taken into account. Ten samples are tested. Thickness is measured as described above.

Recovery from compression

This property concerns the behaviour of the material after pressure upon it has ceased. Similarly to compactness, this property plays a primary role in thermofelts and needled-and-shrunk non-woven fabrics.

The recovery (R) may be determined by various means, the best one being expressed with the following formula:

$$R = \frac{g_{p,t_1,t_2}}{g_0} \times 100 \quad [\%]$$

where g_0 is the thickness of the material

g_{p,t_1,t_2} is the thickness of the material as measured after it has been subjected to pressure p for the duration of time t_1 and after the relaxation time t_2.

The indices p, t_1 and t_2 have been introduced into the formula in order to stress that recovery depends upon pressure as well as upon its duration and upon its relaxation.

Figure 4 demonstrates changes in the recovery from pressure effects, plotted against the time of recovery from various pressures and their durations.

The method used at the Institute specifies a pressure of 100 g/cm^2 for a duration of 5 hours. Recovery is determined for two times of relaxation; namely, after 5 hours and after 20 hours. The first of these refers to immediate recovery, the other to the delayed one.

The remaining parameters of the test are identical with those for the determination of thickness and compactness.

Air permeability

The air permeability of non-woven fabrics is determined by methods applied to other textile materials, instruments with vaporimeters and rotameters being used. It is customary to assume the difference between pressures on both sides of the tested non-woven fabric as equal to a 10-mm column of water. For non-woven fabrics of a very great permeability, the difference should be equivalent to only a 5-mm column of water.

When bulky non-woven fabrics are tested, the clamping head of the measuring device can develop pressure on the test specimen with the result that the test results may be biased. To eliminate this difficulty, a special clamping head has been designed at the Textile Research Institute (figure 5). With this attachment, the tested sample is not subject to deformation where air penetration occurs.

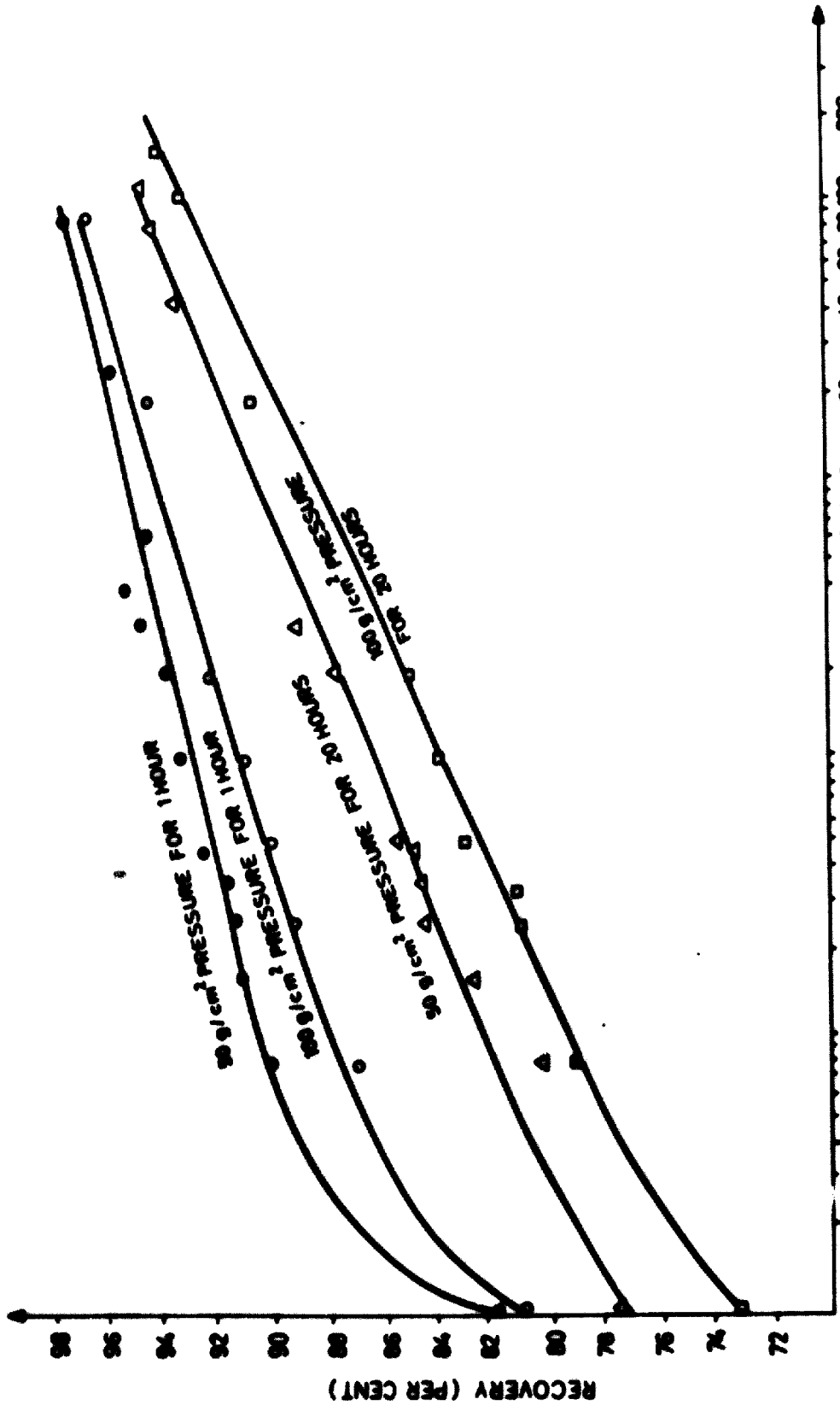

Figure 4. Recovery of thermoplastic from the effects of pressure in relation to relaxation time

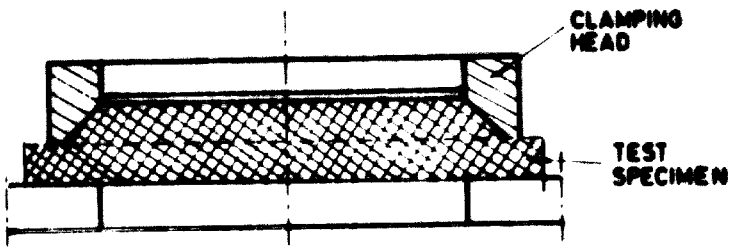

Figure 5. Clamping on a specimen of non-woven fabric for air-permeability testing

METHODS FOR TESTING THE PHYSIOLOGICAL PROPERTIES OF CLOTHING

by

K. Robakowski

The methods for the examination of physiological properties of clothing result from the necessity to design and manufacture garments for everyday use and for special purposes and of increasingly improved quality.

It is a commonplace to say that clothes should keep the human body comfortable, protecting it against sudden changes in ambient conditions, such as temperature, relative humidity and movement of air. Man thus tends to wear clothes that safeguard the thermal balance of his body under definite climatic conditions and at a definite level of physical effort.

The maintenance of human life depends upon the proper amount of heat being produced in the body; this, in turn, depends upon the climatic and physical effort. The body of an adult yields 75 to 800 kcal/hour of heat (Bradtke and Liese, 1958; Mecheels, 1962). This internal heat, together with the heat admitted from outside, is partially used for the physiological needs and work, the balance being carried away into the surrounding atmosphere by such dry means as conduction, convection and radiation or by wet means, such as evaporation of water by the skin and lungs. Heat balance is a basic condition for life itself.

The basic and most effective control of the thermal balance by man is the choice of an adequate number of layers of clothing; self-regulating garment has not yet been invented. Certain institutions are attempting to work out the assortment of clothing that will best answer the needs of the wearer without impeding his freedom of movement, while being as light as possible. In laboratories of many countries the physiological properties of woven and knit goods, blankets and ready-to-wear clothes are studied in detail to find the correct answers to such questions as: Will synthetic fibres replace the natural fibres in the textile industry? How do climatic conditions such as temperature, moisture and movement of air, affect the physiological properties of textiles? What is the effect of their structure and finish upon physiological properties of textile materials?

Heat loss through clothing

Thermal conduction occurs in all forms of matter. It consists of an exchange of energy due to a direct contact of particles, the energy being transferred by means of waves, diffusion of atoms, molecules or free electrons.

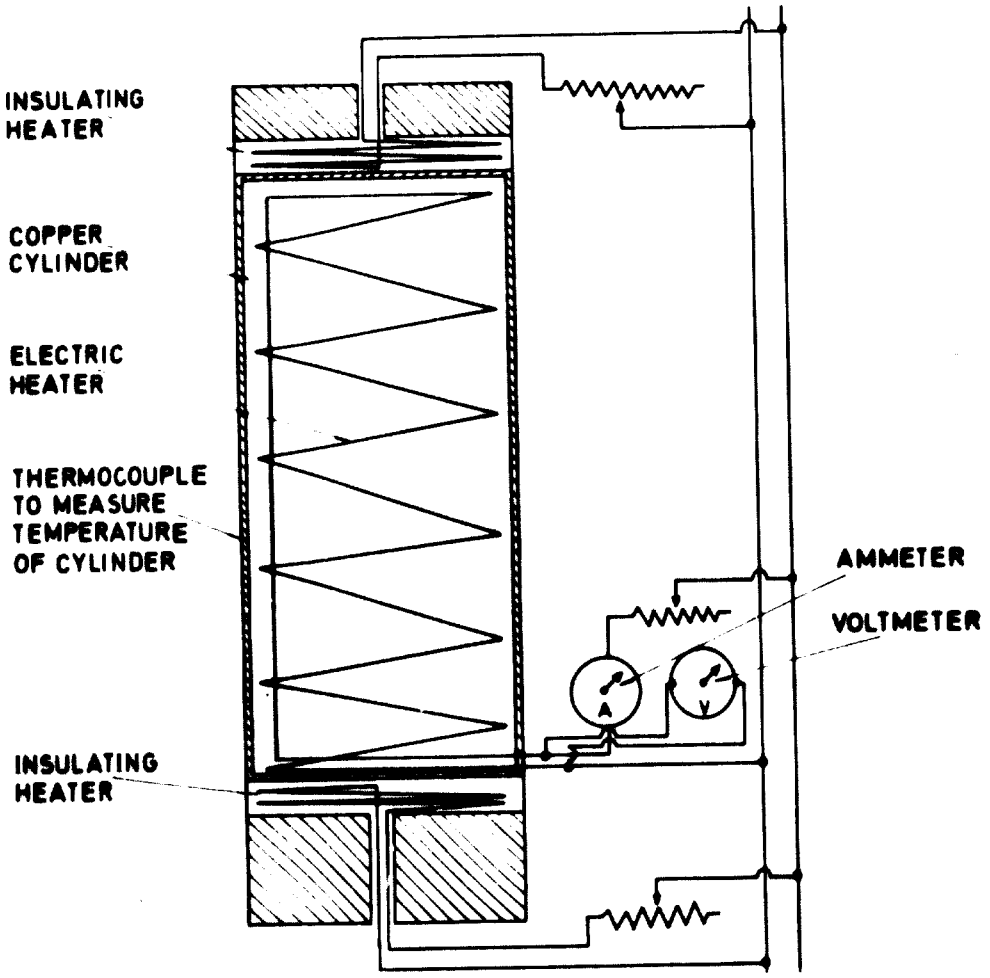

Figure 1. Schematic drawing of a device for determining, by the cylinder method, heat loss through fabrics

Thermal convection occurs only in liquids and gases. In this process the energy is transferred by movement of particles of a fluid substance. This phenomenon occurs together with thermal conductivity. The clothing that protects a person usually consists of fibres and of air, so that a method for the assessment of heat loss *via* clothing must account for both of these phenomena.

The exchange of heat taking place between a human body and the ambient air actually has two aspects: thermal conduction and thermal convection. Their combined action is referred to as the thermal transmittance. Examination and determination of the coefficient of thermal transmittance is usually done by the plate or cylinder method. The latter is shown schematically in figure 1. The fabric sample to be tested is wrapped around a copper cylinder 20 cm long that contains an electric heater coil. At an established thermal condition of the system, the heat produced by the coil will tend to penetrate from the outside surface of the cylinder wall outward through the tested material. Measuring the amount of that heat Q, temperature t_1 of the cylinder wall, temperature t_2 of the ambient air, and knowing the length l and the diameter d of the copper cylinder, and with V as the voltage and I as the currents, the thermal transmittance coefficient can be calculated with the following formula:

$$a = \frac{Q}{F(t_1 - t_2)} = \frac{0.86 \times VI}{\pi dl(t_1 - t_2)} \qquad [\text{kcal/m}^2 \cdot \text{hour} \cdot ^\circ\text{C}]$$

If the wall is composed of several layers, the value of the equivalent thermal transmittance coefficient for all the layers will be determined simultaneously.

The examination of the thermal transmittance coefficient for textiles at a determined rate of the exchange of heat requires the use of special thermohygrostats with great stability of temperature, relative humidity and air circulation.

Heat loss due to radiation through clothing can also be measured. Thermal radiation consists in the conveyance of energy in form of electromagnetic waves of 0.8 to 40 μ length. Textile products are porous materials within which incessant radiation and absorption of energy occurs. Fibres can be considered as athermic substances that cannot be penetrated by heat, and consequently it can be assumed that the radiation and absorption of the energy carried away from the human body to the ambient atmosphere takes place at the surface of the clothing.

Assuming that the differences in temperature between clothing surfaces and the surrounding objects (except in some special cases) are not great, we can consider the phenomena of conduction and convection of heat as the basic ones to be taken into account in tests of the thermal insulation properties of garments.

Methods for testing the conveyance of perspiration by textiles

The following data may give an idea about the importance of the evaporation of perspiration by the skin in maintaining the general balance of heat in the human body.

A person normally loses about 1 litre of water per day through the skin. If he works hard physically he can, for a short time, lose 3 or 4 litres of perspiration per hour (Leach, 1957). Considering that 590 kcal are needed to evaporate 1 litre of water, it should be noted that the evaporation of perspiration requires the loss of more than a half of the simultaneously produced body heat.

Excess body heat can be eliminated by perspiration only if a sufficient amount of it is produced and if it can be evaporated.

The perspiration that is given off by a human body in a quantity dependent upon physical effort and climatic conditions is transferred to the surrounding atmosphere in forms of water-vapour (through pores in woven, knitted, or otherwise made fabrics), liquid (also through pores in textile products) or of particles adsorbed or absorbed by the fibres.

Determination of hygroscopicity

The hygroscopicity, or capacity for water absorption, of fibres is determined as the increase in weight of a conditioned specimen, placed for a specified time in an atmosphere at 100 per cent relative humidity taken as a per cent ratio to the dry weight of the same specimen.

Determination of water-vapour permeability

It is important to know the degree to which a textile material is permeable by water-vapour passing through its pores, since this is done by diffusion through the air trapped in the pores of the fabric. Such penetration occurs in all conditions of work and climate.

The permeability of textiles by water-vapour is defined by the amount (grams) of water-vapour passing through the unit area of the tested material in a unit of time at strictly controlled conditions of temperature, relative humidity and air movement.

Determination of capillarity

If an intense perspiration occurs, it may not be possible to evaporate all of the perspiration given off by the skin. Any excess should be carried away by capillary surface tension outside of the clothing, to be evaporated there. This property of textiles depends on the characteristics of its fibres, fabric structure and finishing processes.

The capillarity of a textile product is defined by the height to which suitably coloured water rises through the capillaries of a tested specimen hanging vertically, with its end immersed in the water, for a specified time.

Determination of water absorption

The method should aim at the determination of an index that will show how the tested material absorbs heavy perspiration[1] or rain-water when all microcapillaries and macrocapillaries are filled.

The absorption is determined as a per cent increase of weight of a conditioned specimen immersed for a specified time in distilled water as compared to the weight of the specimen before its immersion.

Determination of the rate of drying

The rate at which water is evaporated from the microcapillaries and macrocapillaries of an apparel fabric is another important characteristic feature of clothing.

The rate of drying is defined by the per cent loss of water per hour from a conditioned specimen that has absorbed water according to a standard specification and was then suspended for a specified time in a room at 20°C ± 0.5°C, 65 ± 2 per cent relative humidity with air moving only by convection, the loss of water being compared to the amount formerly absorbed. The details of the procedure are given in special standard specifications and instructions.

Plethysmographic assessment of physiological properties of clothing

The methods briefly outlined above are applied in textile laboratories as means for the assessment of the quality of clothing. However, there are still serious difficulties in finding ways for the complex assessment of products, the individual properties of which yield different measurement results.

For example, it is difficult to tell which is preferable, a product with an excellent index of thermal insulation but that is hardly permeable by perspiration, or one with the opposite properties; namely, poor thermal insulation but excellent moisture permeability.

In such cases, so-called plethysmographic tests may be very useful. They are carried out in the laboratories of some medical research centres (Boguszewska, 1963). The tests consist of the recording of dermovascular responses of human skin to physical effort and climatic conditions when the skin is protected by the clothing being tested. Such tests permit assessment of the physical control of thermal conditions by clothing. This, in turn, may be considered as an over-all assessment of the physiological properties of the garments.

[1] Human perspiration is an acid or alkaline solution, of which 97.5 to 99.5 per cent is water the remainder being composed of salt, urea, lactic acid and glucose.

The more important results of physiological tests on clothing

Numerous studies have revealed that the thermal insulative properties of clothing are not determined by the type of raw material used but by the air contained within the fibres, yarns and fabrics from which it is made. Any fibres can be used to manufacture a fabric of any kind with a specified index of thermal insulation. The thickness of the fabric is in this case of the first importance. High wind velocity reduces the insulative properties of clothing, but the effects of the relative humidity of air are quite negligible in this respect. As the temperature of the surrounding air is lowered, the heat loss of the body through the clothing to the ambient atmosphere increases.

Since there are various factors that limit the thickness of the produced fabrics, the required thermal properties are attained by a system of layers. The advantage of this system is that, according to changes in climatic conditions and physical effort, which may be very considerable even in the course of a day, the thermal insulation of clothing can be controlled simply by changing the number of layers.

Studies now being conducted in many research centres mostly tend to define an optimum structure and fibre composition of certain apparel goods, particularly of work clothing and of garments designed for special purposes. From the physiological point of view, such clothing has a stable place in the layer system of garment design, since it is not affected by fashion.

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QUALITY CONTROL OF FIBRES, YARNS AND TEXTILE END-PRODUCTS

by

H. Górski

Standardization of quality control methods

The increase in the number of kinds of textile products, the use of various raw materials and finishes, and increasing international exchange of goods make it necessary to standardize quality control methods, not only on the national level but also on an international scale. In this field, the activities of the International Organization for Standardization (ISO), in Geneva, are becoming increasingly important. The standardizing activities of the ISO relative to control methods are concentrated mainly upon the methods for testing fibres and textile end-products. However, the procedure of the ISO for establishing standards and issuing recommendations is very prolonged, so each country must establish its own standards pending final determination by the ISO. The tentative standards of the ISO, along the lines of which individual countries work out their own standards, are also very helpful.

Although the established standards, tentative standards and recommendations of the ISO do not fully satisfy the demand, they make possible the determination of the most important quality indices for raw materials and end-products, which greatly facilitates international commerce.

In addition to the ISO, there are other international organizations that are concerned with standards, but their scope is limited either by the object of standardization (for example, the Bureau International pour la Standardisation de la Rayonne et des Fibres Synthétiques (BISFA) in Basel for fibres) or by the territory covered (for example, the countries that are members of the Council for Mutual Economic Aid (COMECON). The ISO is universally recognized as the leading setter of standards, and all standards established outside this organization follow its principles.

In Poland standardization is controlled by the Polish Committee for Standardization, under which the Light Industries Subcommittee for Standardization is responsible for the problems of the textile and the leather industries. The activities of this are supplemented by those of the Branch Standardization Centres for cotton, flax, wool etc., which prepare the tentative standards required by particular industries. This efficient organization of standardization and the high qualifications of the staff of standards engineers ensures that the demand for standardization of quality control methods is very nearly met.

Whenever governmental standards have not yet been established for new quality control methods, perhaps because they are still insufficiently accurate or have had only limited use, it is permissible to refer to the provisional instructions issued by the Textile Research Institute or other research institutions in this field.

The extent to which the ISO is engaged in standardization of quality requirements relative to fibres, yarns and textile end-products is rather limited, especially as regards textile end-products. The quality requirements for these goods is determined, in a high degree, by the requirements of the consumer in a particular country, by the kind of raw material used and by the production and finishing methods used. These factors limit the applicability of objective standards to the countries of origin. The limitation has caused a tendency to modify Polish Standard Specifications by making them more generally applicable. In most countries such standards specify only the minimum requirements relative to definite assortment groups. A good illustration is provided here by the American Standard Performance Requirements for Textile Fabrics (ASPRTF), which state the basic wearing indices of products and the lowest acceptable values.

In Poland, in addition to the governmental standards there are also Branch Standards and Technical Specifications. The most detailed of these are the technical ones, which are worked out in a textile mill and approved of by the appropriate Branch authorities. They include technical and wearing data and refer only to a clearly defined product assortment. The Branch Standards, which are now less used than formerly, fall between a Polish Standard Specification and a Technical Specification, both in respect to detail and to range of application.

Classification of fibres

Of the natural fibres, Poland produces only flax, hemp and small quantities of wool. The entire demand for cotton, jute, hard bast fibres and most of the demand for wool is met by imports. The demand for all of the basic chemical fibres is met by domestic production. The following man-made fibres are produced: viscose, polyamide and polyester (staple and filament) and staple polyacrylonitrile. The technical and quality requirements in relation to the Polish bast, wool and man-made fibres have been standardized.

Cotton is classified in Poland according to the practice prevailing in the country of the supplier. Thus, Egyptian cotton is classified as it is in the United Arab Republic, American cotton as it is in the United States and Soviet cotton as it is in the Soviet Union. It is of interest that the classification of cotton in the Soviet Union does not rely upon manual or visual evaluation of the fibre quality but is exclusively based on the results of standard laboratory tests.

Depending on the maturity and strength of the fibres, and according to the content of impurities, Soviet cotton is sorted into seven qualities (0–6). The Soviet cotton of the first six qualities (0–5) is divided according to fibre-lengths, as determined by laboratory tests. It should be noted that the Soviet classification of cotton disregards the fibre colour, which is an essential element in the American classification.

In Poland, wool is classified according to a standard system that includes division into qualities by assessing the average fineness against the coefficient of fineness variation and into classes according to fibre length. The division into classes permits

sorting wool for definite spinning systems (woollen system or French or English worsted systems). With regard to fibre uniformity, wool is classified as homogeneous or heterogeneous. Both groups are broken down into subgroups of fine, medium-fine and medium-coarse fibres, and each subgroup is classified according to the average fineness according to the Bradford system.

Flax fibres are classified according to a standard system by either of two methods, one for long fibres, the other for short ones. With respect to their technological value, the long and short fibres are divided into qualities marked with maximum counts of yarn attainable from them.

The quality of long fibres is determined by the average fineness of the hackled flax, by the minimum permissible yield of hackled flax, by the rate of waste in the hackling process and by the amount of impurities (shives, dry peduncles and the like). Moreover, according to the percentage share of the fibres designated for warp in hackled flax, the long fibres are classified into three groups as weft, intermediate and warp. If the yield of a lot of hackled flax is lower than indicated for a given standard count, the lot is assigned to the next lower quality. However, when the yield is higher, the quality rating is not changed.

The quality of short fibres is established on the basis of the following parameters: strength, card-sliver delivery, impurities in card sliver and in fibre, and average content of loose foreign matter in the fibre. The standard count is determined manually and visually, but is checked in the laboratory against the numerical values of the factors listed above, on the basis of which a general index of quality is calculated.

Hemp fibres are classified in much the same way. Imported bast fibres are usually classified manually and visually against reference quality samples.

Polish man-made staple fibres are classified according to uniform principles. These fibres are sorted into two quality classes according to the permissible values of the following indices: deviation of average fibre length from nominal length, deviation of average fineness from nominal fineness, breaking strength, variation coefficient of tensile strength, elongation, loop strength, crimp, and the number of cohering fibres. These indices form the basis for determining fibre quality. Wherever the index values indicate different qualities, the over-all quality is assumed as that of the lowest index. Manually and visually examinable properties such as degree of colour dulling and degree of opening must be uniformly distributed throughout the fibre bulk. The chemical agents applied should, after a prescribed time, make the fibres anti-electrostatic. The fibres should be spinnable under normal processing conditions.

Classification of yarn

The quality of cotton and cotton-like yarns spun together with man-made fibres is rated according to the tentative standard for the class of the yarn and its grade of purity. The class of yarn is determined by the permissible values of breaking length, variation coefficient of tensile strength, variation coefficient of fineness and number of defects. The tentative standard provides for four classes and two grades of purity. The first class requires first grade of purity, and the second and third classes must be of the first and second grades of purity; the fourth class has purity below the second grade. The grade of purity is determined visually by comparing the yarn, wound on a

plate, with a reference yarn sample. In addition, there is a division into warp, weft, and knitting yarns.

Wool and wool-like yarns are classified on the basis of general or particular requirements. The general requirements cover those properties of yarn that are found by manual and visual examination of all the packages. The following faults are noted: irregularity of shape and inferior density of the packages, incorrect blend contents, uneven shade, oilings and soilings, irregularities of yarn fineness, nonuniformity of mixing and the like.

The particular requirements concern spinning defects, such as slubs, and the permissible values of the following indices: variation coefficient of fineness, deviation from nominal twist, variation coefficient of twist, tensile strength, and variation coefficient of tensile strength. Wool-like yarns are classified according to four grades of quality, and the quality of the yarn is finally decided by the lowest grade index. No faults listed under the general requirements can appear in yarn of the first quality.

Yarns of bast fibres are classified by standards that determine the technical conditions for first quality. These specify, for a given fineness and type of yarn: strength, twist, the variation coefficients of strength and fineness, and the permissible number of faults. The yarns are classified according to separate standards that specify permissible deviations from the above indices for each particular quality.

Synthetic continuous filament yarns are classified in much the same way. The differences, if any, refer to the special characteristics of the particular material. The yarns are divided into three quality classes with regard to the magnitudes of the following indices: deviation of fineness, deviation of twist, variation coefficients of fineness and twist, dry tensile strength, wet tensile strength (for viscose yarns), breaking elongation, sulphur content (for viscose yarns), content of additives, monomer content (for synthetic filament yarns), wet shrinkage (for viscose yarns) and spinning faults (slubs, neps, broken elementary fibres, kinks and the like). Furthermore, the yarn should conform to the general requirements, which specify the conditions relative to the package shape, colour uniformity of yarn, yarn soiling and the like.

Classification of final textile products

The quality grades of linen, cotton, silk, and woollen fabrics and garments are determined by the requirements of the Polish Standards. Knitted fabrics and knitted garments, hosiery, foam-backs, and other consumer products are classified according to the Branch Standards or appropriate instructions for their classification. These standards are not applicable to the quality evaluation of products for special use. These are classified according to Polish Standards Specifications, Branch Standards, or instructions issued jointly by the manufacturer and the buyer.

The Polish quality classification system for textile products is based upon three considerations: *(a)* The magnitude of technical deviations and end-use indices of quality, *(b)* the number of defects discovered over a definite length of fabric, and *(c)* the conformity of the appearance and finish of the fabric to those of the reference sample.

These factors determine the quality to be assigned to a fabric. Whenever the indices indicate different grades of quality, the fabric is classified by the lowest

index. The classification includes the following wearing and technological parameters: width, length, weight, density, tensile strength, shrinkage, colour-fastness and all other indices that are essential for the end-use of the fabric. The technical and wearing indices of first quality must conform to the values stipulated by the Polish Standard Specifications or Technical Specifications.

Cotton fabrics are classified according to four quality grades. Deviations from the technical and wearing quality indices are independent of the end-use of a fabric.

The permissible number of defects is dependent on the length and width of a fabric but is independent of its end-use. The admissible magnitudes of defects depend on the type of the fabric (fabrics of combed, carded and waste-containing yarns). The determination of the quality of a fabric is done manually and visually by comparing it visually with its reference sample. Special attention should be paid to dispersed defects, including seedcoat fragments, neppiness, incorrect colour repeat, incorrect printing, unevenness of shade and improper finish.

Wool fabrics are classified into four quality grades. Deviations from the technical and wearing indices of quality are independent of the end-uses of the fabrics. The permissible number of defects depends on the length of the fabric, its wool content, its type (not considered here are woollen-type and cotton-woollen fabrics that contain no more than 20 per cent wool fibres) and weave (plain weave and others), and is independent of the end-use of the fabrics. The permissible magnitudes of the defects are independent of the fabrics and of their end-uses. Reference samples are not used for the classification of woollen fabrics.

Silk and rayon fabrics are classified according to four grades of quality. Deviations from the technical and wearing indices of quality are independent of the end-use, but they do depend on the type of the fabric (fabrics of regenerated cellulosic or synthetic fibres or of natural silk). The permissible number of defects depends on the length and width of the fabric and its type (fabrics made entirely of regenerated cellulosic fibres or of blends with major contents of them, fabrics made entirely or partially of synthetic fibres or of natural silk). Here, also, the permissible number of defects is independent of the end-uses of the fabrics. Similarly, the permissible magnitude of the defects is independent of either the end-use or the type of the fabric. The classification of silk fabrics is performed by reference to quality samples.

Linen fabrics are classified according to three quality grades. Deviations from the technical and wearing indices of quality are independent of the end-uses of these fabrics. The permissible number of defects depends on the width and length of the fabric and on its type (fabrics of worsted, woollen and waste yarns). The permissible magnitudes of defects depend on the end-uses of the fabrics. Reference samples are not used to classify linen fabrics.

In Poland's domestic retail trade, no rebates are granted to purchasers for fabric defects. However, such rebates are granted in the export trade and, in some cases, for the domestic clothing industry.

Quality classification of garments

In the Polish clothing industry, garments are classified according to the following indices: *(a)* conformity of the product to general requirements, *(b)* the magnitudes of deviations from correct products size, and *(c)* the number of permissible tailoring errors and fabric defects.

These factors determine the quality grade that is assigned to a product; when a product is found to contain greater numbers of defects and errors than is permissible by the lowest standard, it is designated as unclassified.

Apparel fabrics and the clothing accessories are subject to laboratory testing and quality classification according to binding standards. Garments are classified according to three grades of quality. The allowable number of tailoring errors and fabric defects, the conformity of a garment with the general requirements, and the correctness of its size depend on the end-use of the product. In the case of garments, the allowable number of faults depends also on the composition of the fabric (wool, wool-like, and so on) and on the particular end-uses of the garments. Reference samples are not used for quality classification of garments. Fabric samples are used only for trade contract purposes.

Organization of quality control

Quality control of fibres is based upon standards specifying testing methods and quality requirements and upon the provisions of the contracts concluded between supplier and buyer.

In Poland, imported fibres are examined manually and visually by the importing authority (Polcargo Exports and Cargo Surveyors) for conformity with contract terms. With cotton, the Cotton Arbitration Chamber performs laboratory tests for conformity of given fibre features to the specific technical requirements. Cotton supplied from the Soviet Union is accepted only upon the basis of laboratory test findings. Wool, after manual and visual evaluation by Polcargo, is tested technically for yield of top. This index is then used as a basis for the settling accounts between buyer and supplier. Laboratory tests for the yield of wool top and its quality are performed by the Wool Federation. Imported bast and man-made fibres are controlled in much the same way.

The quality of man-made fibres produced domestically is ascertained by the buyers on the basis of the manufacturers' certificates and the appropriate quality standards. If a claim is filed, the required quality tests are performed by the Textile Research Institute or other research institutions in the field.

Quality control of yarns and final products is performed against standards for quality grades and against objective standards or technical specifications, including the required values for the technical and wearing indices. Quality control is performed by the technical control sections of the producers on the basis of the valid standards. The certificates issued by the producers are verified by the buyers by means of spot checking. When claims or disputes arise, quality tests for the technical and wearing indices are performed by the Textile Research Institute.

Trade marks and quality marks

Recent developments in the processing techniques of the textile industries have created favourable conditions for expansion of goods assortments. With increasing exchange of goods, which are often of complex structure and are made from heterogeneous materials, the problem arises, on the one hand, how to protect the consumer from goods of poor quality and, on the other hand, how to inform him of

the wearing values of textile goods in general. These circumstances have induced producers to place on their goods trade marks that attest quality. By the use of such marks on his products the manufacturer informs the consumer that the processing of products is under constant control and that the products themselves are made so as to meet their respective wearing requirements. Apart from quality marks there are marks attesting to conformity with standards established by local standards organizations. A manufacturer must obtain a licence to use his mark from the appropriate standards organization which defines the conditions of its use. The quality mark, by virtue of its trade-mark character, becomes in a sense an element of advertising. Recently, the ISO has been evincing interest in the quality marks used by different countries and in determining at their degrees of conformity with international standards.

The quality marks and the marks attesting conformity with standards are affixed durably on products in form of graphic, literal, or digital symbols. The general conditions (more or less similar in different countries) of licensing the mark are as follows:

(a) The mark is protected by law.

(b) The mark is licensed, on application, to individual manufacturers or to manufacturers' associations.

(c) The organization that licenses the mark performs tests and evaluations of the products, analyses their processing conditions and the ability of manufacturer to maintain the quality level.

(d) Simultaneously with licensing the use of the quality mark, the conditions of its use are defined; for example, the quality requirements, validity of the licence and conditions of quality control. These conditions are binding on the manufacturer.

(e) The organization that licenses the use of the mark reserves the right of inspection into its use and may withdraw the licence upon finding irregularities.

In addition to the general principles there are many special regulations that relate to definite types and varieties of products, with particular regard to technical requirements.

The rules that govern the licensing and use of the mark differ somewhat from one country to another. As a rule, the graphic forms of the marks are similar for different products. Only a few countries use different graphic forms for different products, for example, the Federal Republic of Germany.

Some organizations that license quality marks have introduced supplementation of the mark with additional information on the product. This additional information specifies the type or composition of the raw material, the essential features of the structure of the product, the values of such essential quality indices as colour-fastness, and care conditions such as indications and contra-indications relative to washing and ironing. This form of more general marking of goods, especially of textiles, is already widely used in a number of countries, among them France and Sweden.

The International Wool Secretariat in London has introduced a special woolmark to distinguish the quality of products made of natural wool. This mark has been registered in more than 90 countries. It provides a guarantee that the products marked with it have the required quality, no matter what their country or origin.

Two classes of the quality mark are in use in Poland: the international class quality mark, and the Polish highest class quality mark. Each of the classes is ascribed to a product according to its quality level. The general methods of grading products in the respective classes of the quality mark are as given below.

The international class quality mark may be awarded to a product of very high quality not inferior to the quality represented by similar foreign-made high-quality products. Another condition is that the product should conform to the requirements of the international standards.

The Polish highest class quality mark may be awarded to a product that represents a very high quality in Poland, that is, not inferior to similar international products of good quality.

No quality mark can be licensed for a product that does not conform to the Polish Standard Specifications or Branch Standards.

THE APPLICATION OF STATISTICAL QUALITY-CONTROL METHODS IN TEXTILE MILLS

by

J. Głowacki

A characteristic feature of textile processes in all the branches and divisions of the industry is that they are usually continuous and of a mass character. The raw materials, semi-finished products and final products are processed and transferred, in the course of the technical processes, not individually but as a whole mass or a continuous flow.

A spinning machine is usually designed as a set of operating units. A single machine such as a draw-box or a gill box is fed with several, sometimes tens or even hundreds, of parallel slivers processed at the same time. The raw material and semi-finished and final products all have specific variations in their properties, of a random or periodic character. These irregularities result from the varying characteristics of such factors as the raw material (fibres), the operation of the machine, the work of operatives or the ambient conditions. The ideal condition for almost all the processes and properties of any fibres, semi-finished and final products would not be their absolutely steady and unchangeable character, but incidental and random variations within definite intervals.

The limits of these intervals depend upon the magnitude of natural variation and the characteristics of a given process. In turn, such a variation of the process and of its products depends upon the way it is controlled. An entirely complete control of textile processes and products is hardly possible unless visual examination for classification purposes is made. Usually, however, only a random check is performed. In this case only a part (and usually a very small part) of a given lot is taken for examination. This part or sample is selected to represent, as nearly as possible, the property that is to be determined. A mathematically justified random check represents a statistical control. Methods for statistical quality control (SQC) are applied broadly at present in many industries, among them the textile industry. These methods were successfully introduced for textiles in 1924 in the United States of America and in 1929 to 1932 in Germany. At present the SQC methods are almost universally used, always with great success, in the textile industries of Eastern Germany, the Federal Republic of Germany, France, the United Kingdom, the United States and other developed countries.

One of the most important textile applications of SQC methods is inter-operational control. Thanks to this system, the management of the mill gets easily understandable reports that provide reliable information on the process. This

information constitutes a statistically justifiable basis for adjustments of the machines and thus contributes to the stabilization of the process; that is, to the achievement of a balanced interrelation of all the factors involved. The prompt and timely receipt of such information is thus ensured, and the fact that these data are quickly available helps to maintain the quality of the produced goods at a desired level. The practical application of the SQC methods does not require the employment of additional personnel with special qualifications other than accuracy of work and some basic knowledge of textile measurements and mathematics. Moreover, if the great easiness and simplicity of the procedure are considered, its advantages for the mill are evident.

In establishing the SQC system it must be recognized that its primary purpose is the timely detection of the sources of any defects that may occur in course of production. The control has served its purpose when the specific information concerning location of defects and the reasons for them have been passed on to those who supervise production and are responsible for making the necessary adjustments. Consequently the SQC system alone cannot be considered as a panacea for any and all production troubles if the signals provided by it are not properly understood and followed up.

Preparation and organization of the SQC system and proper use of its signals requires that the persons responsible for control, as well as those in charge of production, be acquainted with the principles of the statistics that it provides and with the interpretation of data provided by them. Of course, detailed knowledge of the theory of mathematical statistics and of probability is not indispensable here; a practical familiarity with the six following elements will suffice:

(a) Basic definitions on statistics;

(b) Calculation of statistical parameters;

(c) Some statistical tests such as t, F and χ^2;

(d) Principles regarding design of control charts and their introduction and application;

(e) Familiarity with the use of statistical tables and nomographs;

(f) Thorough knowledge of special SQC methods.

The present paper is confined to a brief review of the principal applications of SQC methods in a specific section of a textile operation; that is, a spinning mill.

The use of SQC methods in a spinning mill

SQC methods can have wide application in the following sections and control zones of a spinning mill:

Control of the raw material	Zone of receipt
Control of the spinning plan	
Control of the irregularity of semi-finished products and yarns	Zone of technology
Control of cleanliness of semi-finished spinning products (card-web, combed sliver)	
Control of ends-down (roving, yarn)	
Control of yarn faults	Zone of sales
Final control of yarn quality	

The inter-operational control in a spinning mill should be carried out according to a detailed programme. Since each spinning plant has its own specific requirements with regard to raw materials, technology and organization, only some general problems are dealt with here. They are illustrated by examples that refer to a particular material or process. These examples can be widened and generalized. The selection of SQC methods that are in use in specific production stages and control zones may be very large, according to need. In each case both graphic recording of results and statistical tests should be represented. The statistical tests are needed in the following three areas:

(a) In the zone of receipt, to check the compliance of the delivery with the contract;

(b) In the zone of technology, to check the settings and conformity with the required course of the process;

(c) In the zone of sales, to check the conformity of the lot ready for sale with the requirements of the buyer.

Control of the raw material

The incoming lots of fibres are subjected to examination so as to determine whether they conform to prescribed standards or regulations.

At present the control is made either by a visual examination by experts, who evaluate the material without use of any instruments, or by laboratory tests, with the use of special measuring devices that determine the tested parameters.

Usually the first method applies to all lots of natural fibres (cotton, wool, flax), laboratory tests being made only for those lots or parameters that aroused some doubts at the visual check, or because of their specific features, or because of technological requirements etc. Man-made fibres are usually examined by laboratory methods.

The measurement data of a tested parameter are usually presented as its mean (arithmetical) value $\bar{X}$, its standard deviation from the mean s and its coefficient of variation

$$V = \frac{s}{\bar{X}} \times 100 \quad [\%].$$

In each case the base of an assessment is the mean $\bar{X}$. In addition, with reference to some of the properties, the coefficient of variations V (considered to be an independent index) is also taken as an element of the assessment. Thus far, wool fineness is assessed by the determination of the mean diameter of the fibre microns, but at the same time the coefficient of variation is compared with the limits set by the standard specifications.

The laboratory tests of fibres should be readily applicable in the SQC system of raw materials,[1] with a statistical interpretation and graphic recording of test results. The interpretation primarily concerns the determination of confidence limits, the use of t and F tests and a graphic recording of measurements.

[1] Including yarn and fabrics in the receipt and sales zones.

Determination of confidence limits

The unknown real mean value μ of a tested lot is assessed from the formula:

$$\bar{X} - t\frac{s}{\sqrt{n}} \leqslant \mu \leqslant \bar{X} + t\frac{s}{\sqrt{n}}$$

which indicates the confidence limits of the mean value (t –stands for factor "t" of the Student's distribution table, found for the degree of freedom $r = n - 1$ and for the definite probability, s average deviation determined for n measurement results).

The unknown real value of standard deviation σ for a lot is determined by the inequalities, as follows:

For small samples

$$s\frac{1}{\sqrt{F_1}} \leqslant \sigma \leqslant s\sqrt{F_2}$$

For large samples

$$s - \lambda\frac{s}{\sqrt{2n}} \leqslant \sigma \leqslant s + \lambda\frac{s}{\sqrt{2n}}$$

These inequalities set confidence limits of the standard deviation. The symbols used there have the following meaning:

s – average deviation for n measurements

F – a variable factor found for the definite probability in the F distribution table (F_1 for the degree of freedom $r_1 = n - 1$ and $r_2 = \infty$, whereas F_2 for $r_1 = \infty$ and $r_2 = n - 1$)

λ – a variable factor, which for the probability of 95 per cent is equal to 1.96.

The t and F tests

These tests can apply to the following cases: *(a)* When deliveries of materials are checked by examination of samples for their compliance with the specified requirements, and *(b)* when various lots must be mutually compared on the basis of the examination of their samples.

Diagrams of test results

Various types of control charts and of diagrams may be used. Each property, such as fibre length, strength or fineness, may be recorded on a separate chart.

Practical reasons require that the charts combine the records of several tested properties (see figure 12). In any case, control charts at this stage have a different character from those at the zone of technology (for example, at the control of spinning plants), where they provide information for the regulation of production processes.

Control of the spinning plan

Control here consists of a repeated examination of n element samples. The sample in this case is a set length of the tested material, the fineness of which is expressed with a figure that represents its weight or count.

Test results are plotted on a specially prepared control graph. This chart facilitates the use of test results by the management of the mill, giving a clear picture of known confidence limits of the course of the process. Thus, proper conclusions may be drawn, and statistically justified decisions can be made as to corrections of machine settings or other technological adjustments.

Presentation test results at the control of the spinning plan may be done on charts of several kinds.

Single-line control chart

(a) The X chart is used to obtain a diagrammatic recording of test results concerning single-element samples ($n = 1$). Charts of this kind may have various applications, as in a cotton-spinning mill to check the weight of laps from scutchers (figure 1), in flax or hemp spinning for checking the weight and length of slivers delivered into cans by cards (figure 2), or in a worsted mill to control the fineness of a combed sliver (figure 3) of a roving or yarn.

(b) XX chart (of primary values) registers data of all n sample elements. Such charts are used for the control of count of a roving in woollen and cotton-waste spinning mills (figure 4).

(c) $X\tilde{X}$ chart (primary values - medians of samples) on which data are plotted of tests of all n sample elements with a simultaneous marking of the median of every sample, control lines of the chart being calculated for medians. Such a method of recording makes possible the use of a simple gauge to control the range R for each sample (figure 5).

Charts of this type are very effective in the standing control of the spinning plan, since two parameters of the sample can be checked at a time, namely, the centre of a group (that is, the median $\tilde{X}$) and the value of the range R. That is why the $X\tilde{X}$ chart is readily used in the current control of the spinning plan in mills of all textile branches. We can see it used not only for the control of sliver weights in the drawing section of the mill (figure 6), but also to check the roving (figure 7) and yarn (figure 8).

Two-line control charts

As a running control of the spinning plan, only the most simple two-line $\tilde{X}$–R (median-range) chart is used. It has two parallel tracks on which medians and ranges of data are plotted. The application of such a chart in the running control of the spinning plan is rather limited, since there the digital values of primary parameters must also be registered. In worsted mills this chart is used for the control of the weight and regularity of tops (figure 9).

Control charts with a standing scale of per cent deviations

Frequent changes of the scale on a control chart when small lots of material are processed may be avoided by using charts with a standing scale of per cent deviations (both ways) from the required count (figure 10). Test data are marked on the chart by means of a special gauge (figure 11) provided with a count scale. There is a separate gauge for each nominal count of the product.

This method of recording is recommended for worsted spinning mills, especially when there is a frequent change of the nominal count in production on a given machine. Since the per cent tolerance of the count applies to a wide range of counts,

it is sufficient, whenever the count being spun is changed to replace the gauge by a new one, the scale of the track on the control chart and its control lines remaining the same. This facilitates plotting, on the same track, of data regarding frequently changed yarn lots produced on the same machine, since the scale and control lines of the chart are unchanged. An analysis of test results over longer periods is also made with charts of this type.

Laboratory tests of yarn[2]

The quality control of yarn is carried out by the mill laboratory according to regulations set by standard specifications. The quality of yarn is referred to such yarn characteristics as count, tensile strength, elongation at break, twist, number of faults per unit length and number of filaments in cross-section (only for filament yarns). Test results are presented as the values of mean $\bar{X}$; standard deviation s; and coefficient of variations V [%].

Test results are subjected to statistical interpretation and are plotted on charts, as noted above in the discussion of raw-material control. In this respect the procedure is usually confined to the determination of confidence limits and to the use of the t and F tests.

The measured values that constitute the basic data are marked on a graph. Figure 12 shows an example of a multi-line chart for yarns spun from staple fibres. The number of lines is determined by the number of tested properties (indices). Each track is marked with tolerance lines, as prescribed by requirements for top quality. The second and third qualities are not marked with lines, but they may be shown with coloured dashes at the left margin of the chart.

Such a recording facilitates the observation of yarn quality in all of the lots in production. Conclusions drawn from a divergence between the received values and those required by standard specifications must be based upon analysis of confidence limits or on t- and F-test results.

The SQC methods in a weaving shed

The SQC methods are less applicable in a weaving shed than in a spinning plant. Nevertheless, in the latter case there are several problems that might be dealt with by the use of statistical control methods. A few such applications are the following:

Control chart for a graphic presentation of test results on the incoming lots of yarn (figure 12);

Control chart for a graphic presentation of faults found in grey goods (figure 13) (zone of technology);

Multi-line control chart to plot laboratory test results of the weaving process (technology and sales zone, similar to figure 12);

Control chart for a graphic presentation of the qualitative classification of yarn packages from the winding machine (zone of technology);

Multi-moment observations for an analysis of reasons for stoppages of looms and breaks of yarn during weaving (zone of technology);

[2] This applies to spinning (zone of sales) and weaving (zone of receipt).

Multi-moment observations for the determination of a difference in break rates between two deliveries of yarn being woven on the same loom;

Multi-moment observations for an analysis of reasons for spindle stoppages and yarn breaks on winding machines (zone of technology);

Multi-moment observations for analysis of the efficiency work time of operatives and of machines;

Statistical tests, particularly in the zones of receipt and of sales.

Inter-operational control in a weaving shed should be based upon a detailed programme.

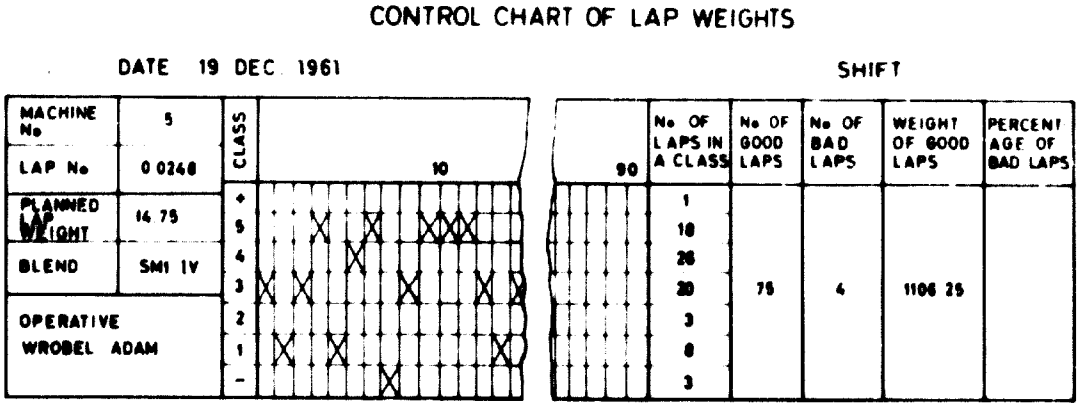

Figure 1. Lap weight control chart (cotton spinning)

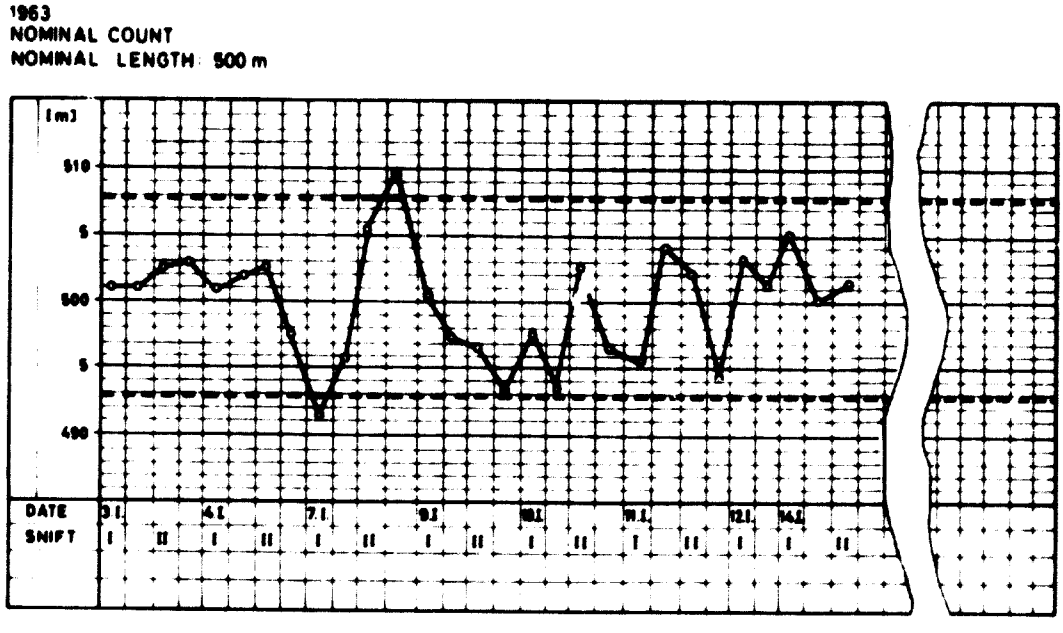

Figure 2. Control chart for length of a card sliver in a can

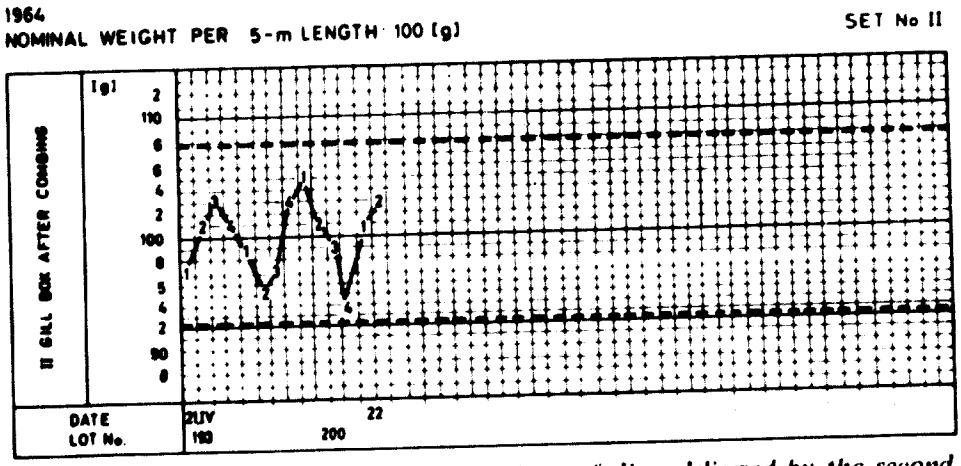

Figure 3. Control chart for weight of 5-m sections of sliver delivered by the second gill box after combing (wool combing)

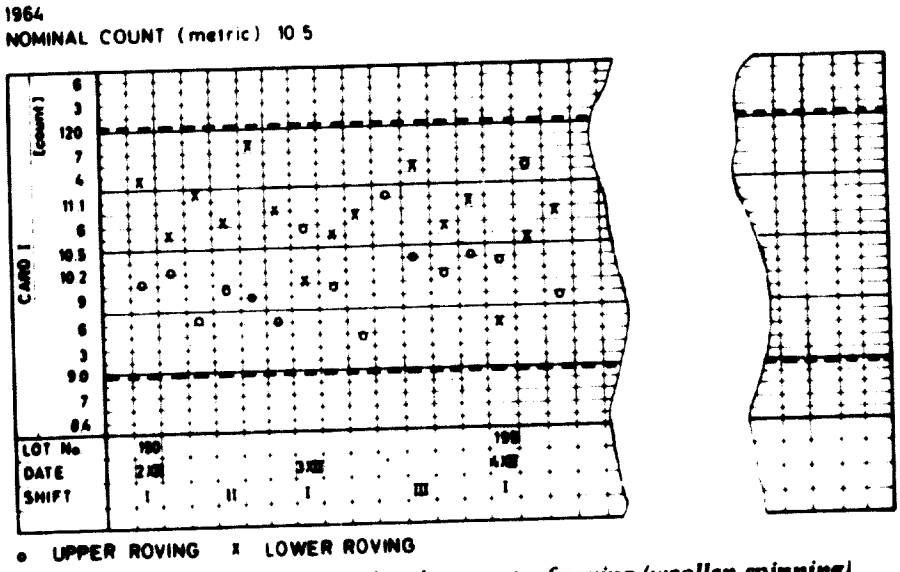

Figure 4. Control chart for the count of roving (woollen spinning)

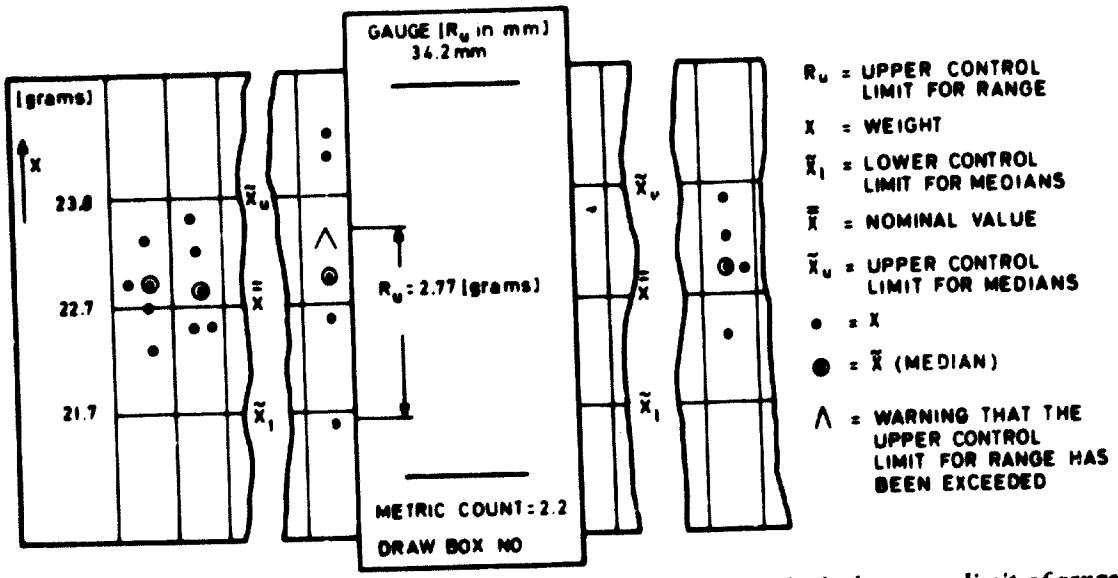

Figure 5. Control of range of sample with the use of a gauge on which the upper limit of range is marked R_u

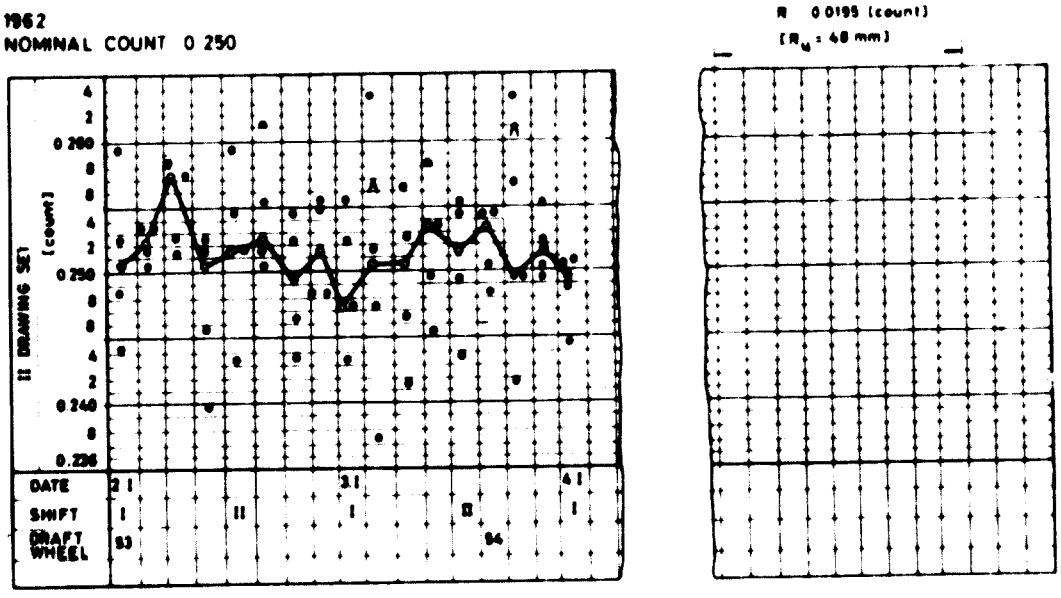

Figure 6. Control chart for the count of sliver as delivered by finisher draw boxes (cotton spinning)

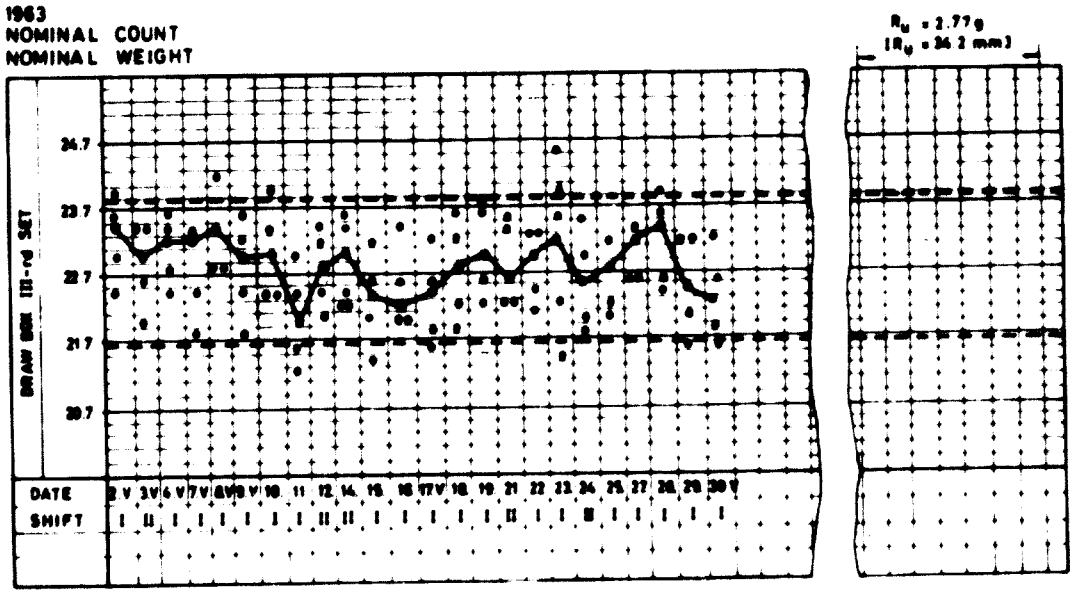

Figure 7. Control chart for weight of 50-m sections of roving (flax spinning)

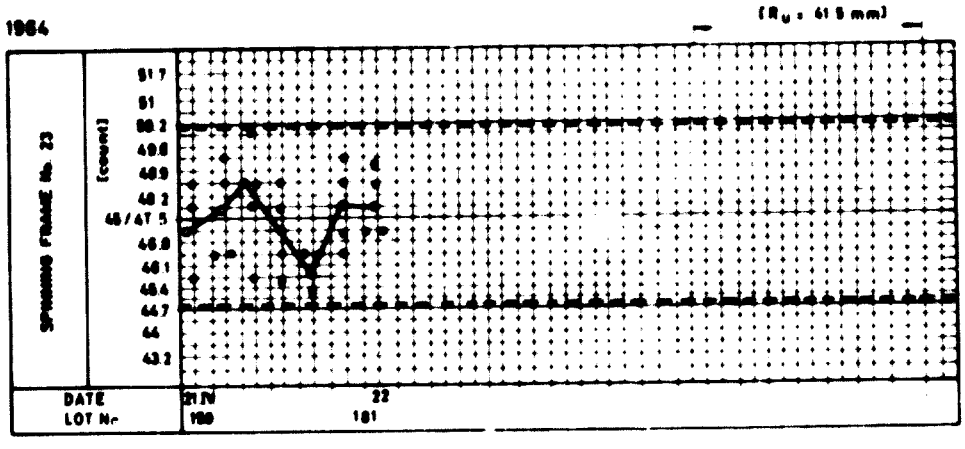

Figure 8. Control chart for yarn count (worsted spinning)

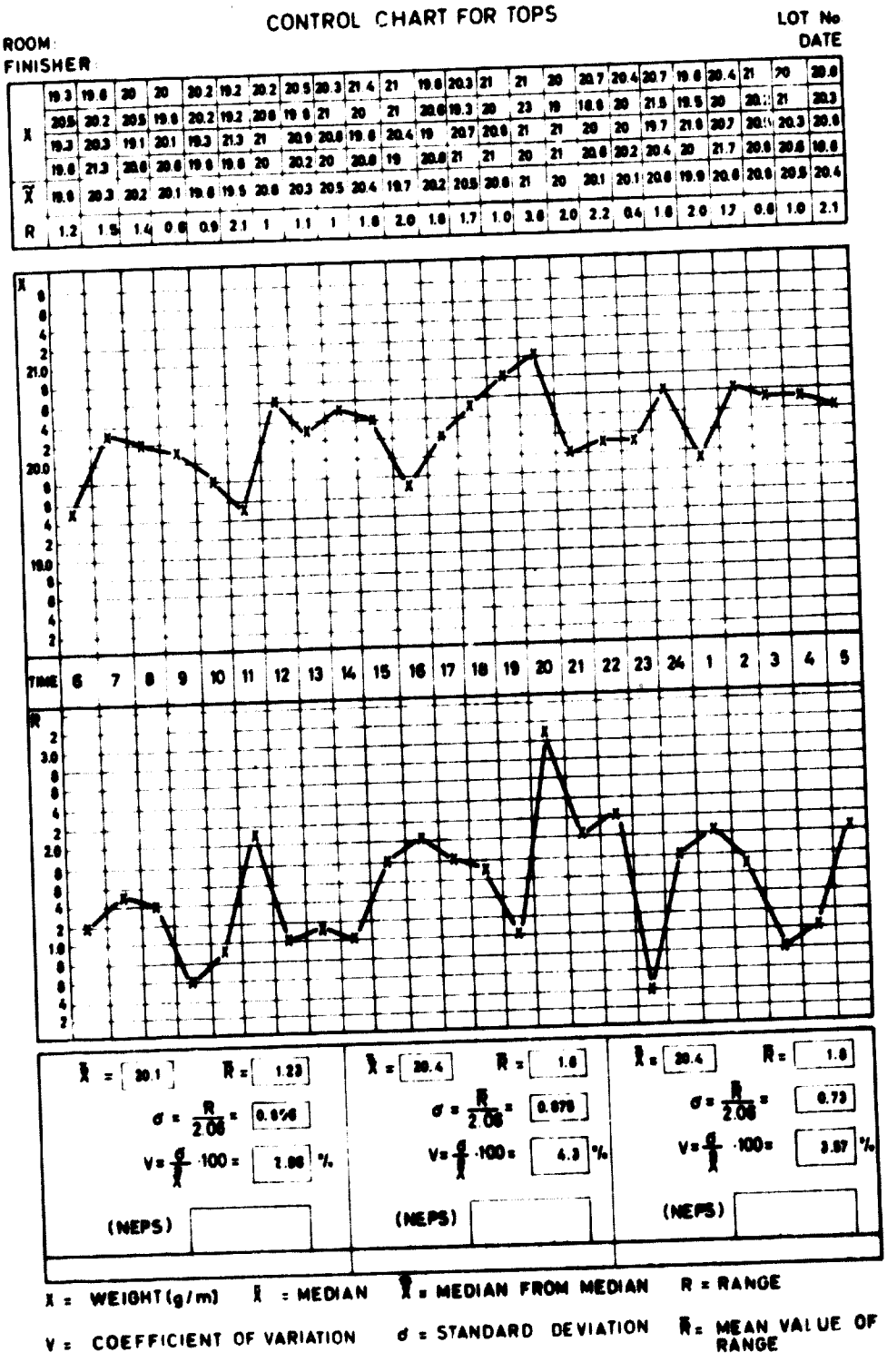

Figure 9. Control chart for tops (worsted spinning)

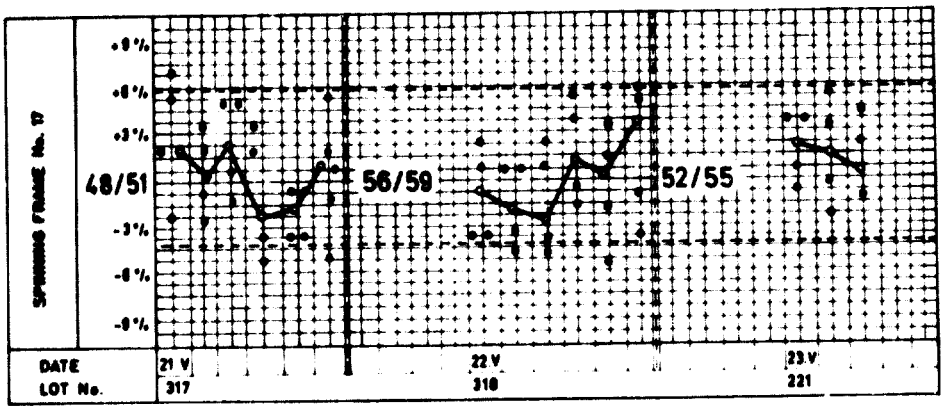

Figure 10. Yarn count control with a standing scale of percentage deviations. Test data are plotted on the track with the use of a special gauge (see figure 11). This method is recommended for small lots

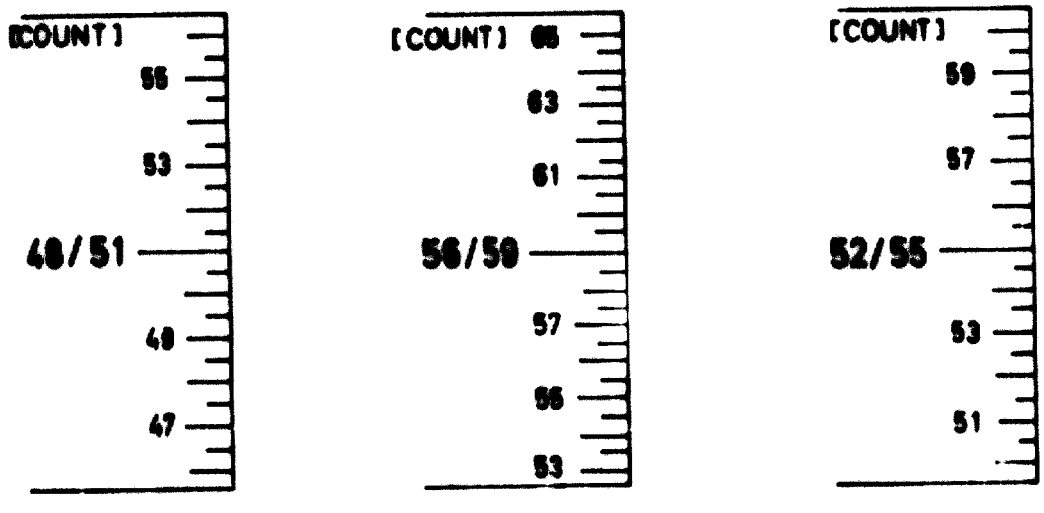

Figure 11. Exchangeable gauges for use with yarn count control chart shown in figure 10

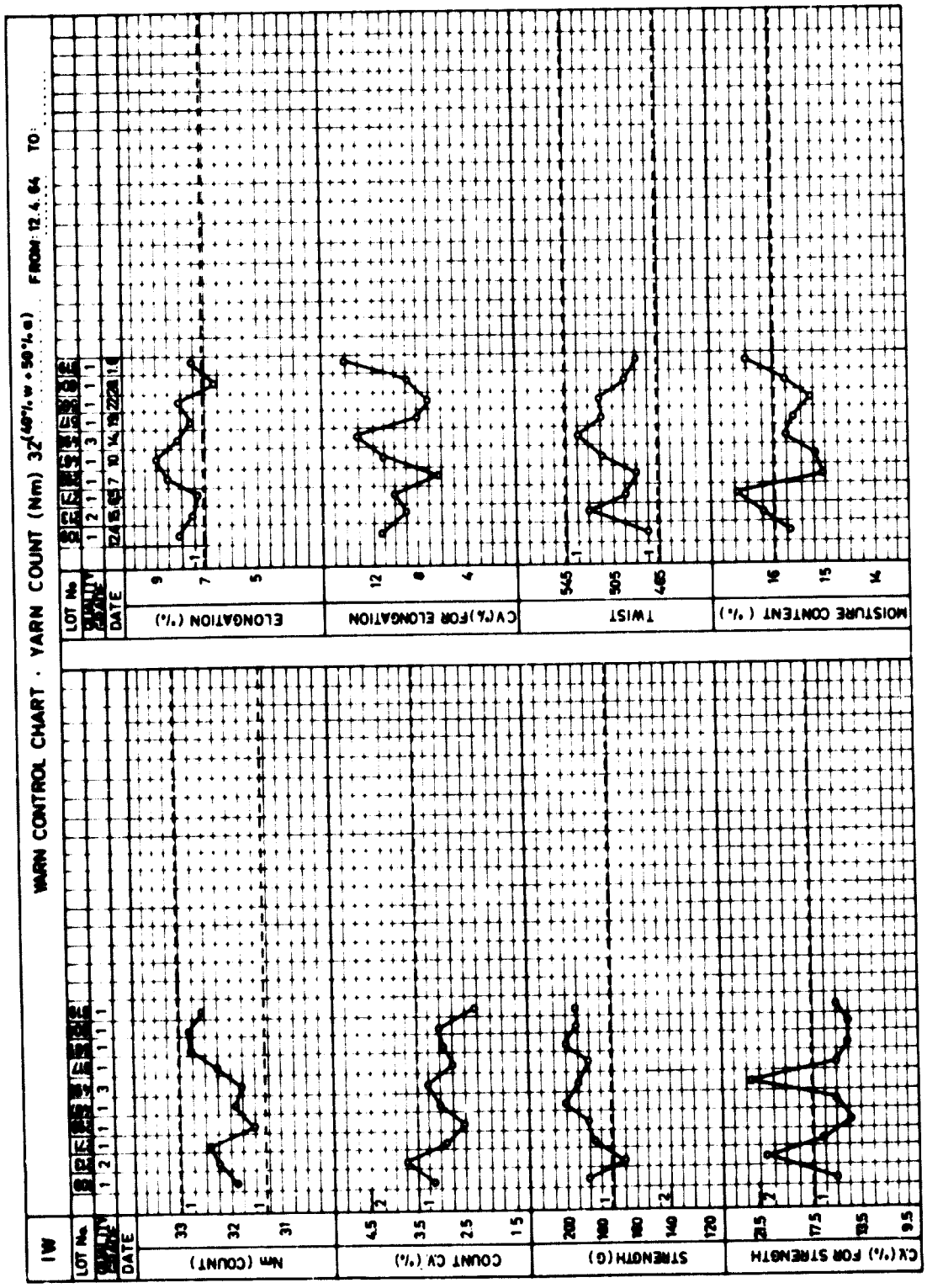

Figure 12. Yarn control chart

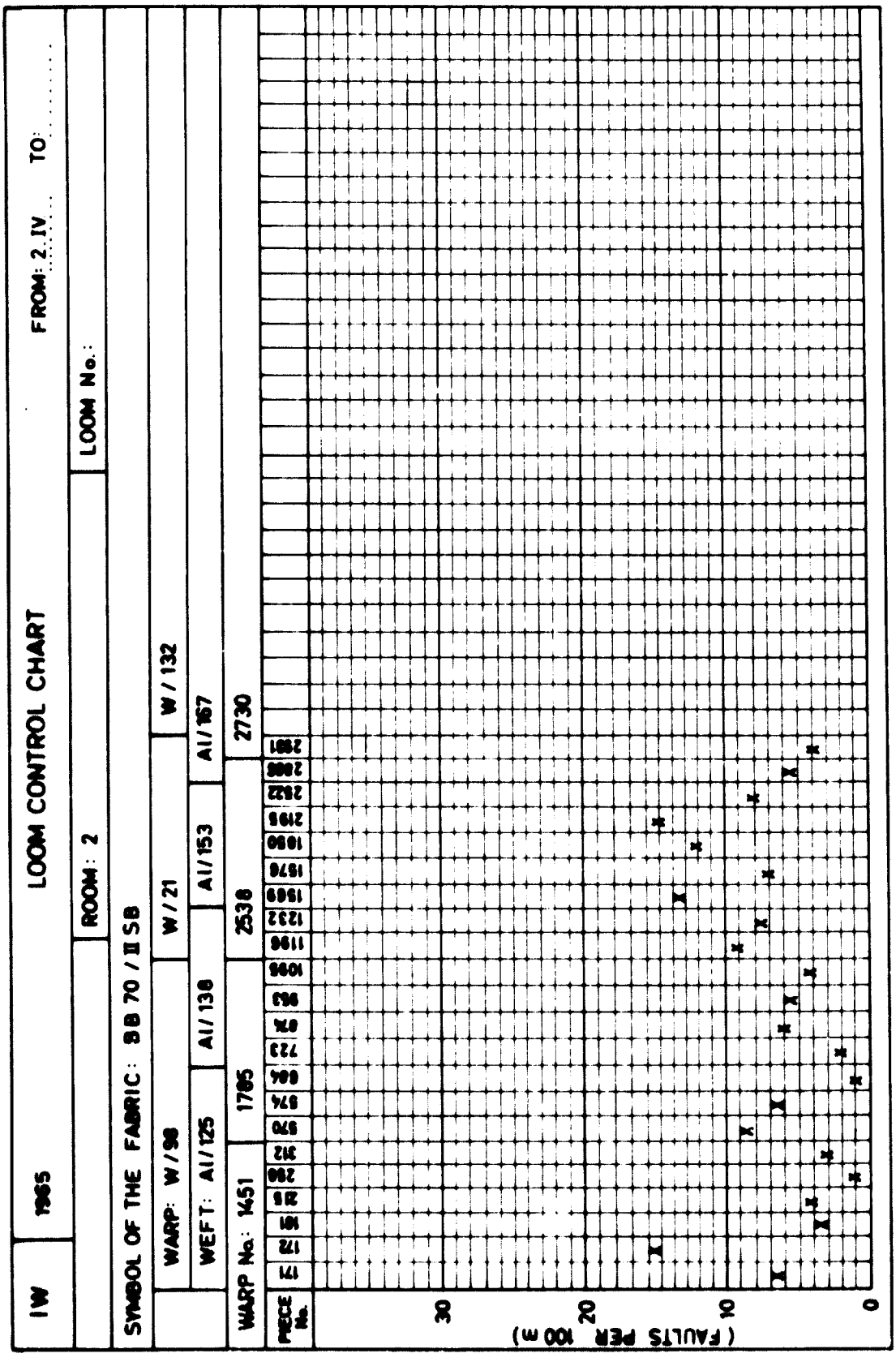

Figure 13. Loom control chart for graphic presentation of faults found in grey goods

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TESTING METHODS FOR WOVEN FABRICS: SELECTED PROBLEMS

by

M. Stasiakowa and W. Balcerowski

Resilience

During use, woven fabrics are subjected to numerous strains of a value much below that which would cause rupture. These strains can, however, by prolonged fatigue, bring about a gradual deformation of the fabric or even make it useless.

Textiles, like many other materials, can recover from deformation after the stress that caused it has been removed. This property is referred to as resilience or elasticity.

If a fabric sample is stretched and the stress is then relieved, the sample will tend to recover its original form. The portion of this elongation that disappears almost at once is called the "immediate elongation". It appears and disappears at a speed equal to the speed with which acoustic waves are transmitted by the material of the sample. This speed, for cotton thread, amounts to about 1,500 m/sec, and for linen thread to about 2,000 m/sec.

The immediate elongation is caused by the strain or deformation of fibres resulting from the displacement of atoms, molecules or polymer chains, without any breaks of interatomic or intermolecular bonds.

Part of the total elongation disappears less rapidly and is therefore referred to as the "delayed elongation". This portion of the elongation is caused by a strain on the fibres that straightens or shifts polymer chains. In many cases, partial recovery from this strain takes only a few seconds or minutes after the stress has been removed, but in most cases it takes several hours. However, many hours or even days must pass before recovery from strain is really complete.

Treatment with heat or with water or some other liquids can accelerate recovery from delayed elongation. The gradual recovery from elongation in terms of time is called "relaxation from strain" and may be expressed approximately by the following equation:

$$\epsilon_{(t)} = \epsilon_{\infty}(1 - e^{-t/T})$$

where t is the time of relaxation;

$\epsilon_{(t)}$ is the delayed recovery after time t;

ϵ_{∞} is the constant factor, equivalent to the whole value of delayed elongation;

τ is the constant time factor determining the speed of recovery, depending on the properties of the material, temperature, ambient conditions and the like.

The portion of the elongation that remains in the sample, no matter how long a time for recovery is allowed, is described as the "lasting" or "plastic" elongation. This elongation is caused primarily by a shift of the fibres within the yarn or of the threads within the fabric, but also by the elongation of fibres by an irreversible displacement of polymer chains in relation to each other. The plastic elongation depends not only on the amount of stress but also on the length of time during which it operates.

The total elongation (Δl_c) is therefore:

$$\Delta l_c = \Delta l_i + \Delta l_d + \Delta l_p$$

where Δl_i is the immediate elongation

Δl_d is the delayed elongation

Δl_p is the plastic elongation.

Methods for testing the resilience of woven fabrics or of other materials are of two principal kinds: *(a)* the single strain-recovery cycle and *(b)* multiple-cycle fatigue.

Single-cycle methods permit the characterization of the tested materials only for the early stages of their use. Fatigue methods should yield more complete information about the performance of the materials, but there is the difficulty that high-frequency fatigue cycles, which must be used, can produce results that are not applicable to textiles, the nature of the use of which does not expose them to such frequent stresses. For this reason, consumer fabrics, such as for apparel or upholstery, are tested by the single-cycle method. This method is very useful, since most of the plastic elongation occurs during the initial stages of the multiple-cycle fatigue test. For this reason, only single-cycle testing methods are considered here.

The single-cycle methods can be divided into the two following groups:

(a) Testing on relaxometers; that is, with devices in which the stress is applied and removed relatively quickly (in a second or less), but in which the time during which the material remains under stress and the time of relaxation are long (several hours);

(b) Examination with strength-testers, the stress being slowly increased and decreased (tens of seconds), while the time during which the material is under stress is short, or nearly nil, relaxation time being short also. This group of methods comprises tests with a few, several, or tens of straining cycles. Actually, this second group is practically multi-cycle fatigue examination, but even with tens of cycles the tested samples do not show changes caused by fatigue.

Resilience is best tested with strength testers that operate with a regular increase of elongation per unit of time. These testers are provided with recording devices and with special controls that permit change and automatic adjustment of the parameters of measurement. Examples are the Instron (United Kingdom) and Zwick (Federal Republic of Germany) testers.

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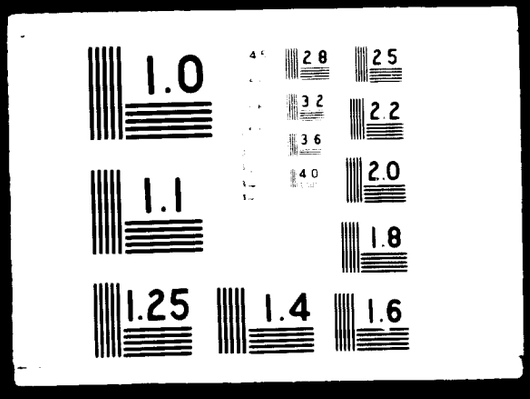

Graphs made by the instrument while the sample is being tested show elongation during the strain and the components of the recovery from it when the stress is removed.

There are two types of graphs: *(a)* those that plot stress against the strain curve and *(b)* those that plot strain or stress against time.

Figure 1 shows the first type of graph. The strain increases with the rise in stress (sector $0A$), and then the stress diminishes (sector AB) until it disappears completely, leaving time for relaxation (BC), starting again in the next cycle (CD).

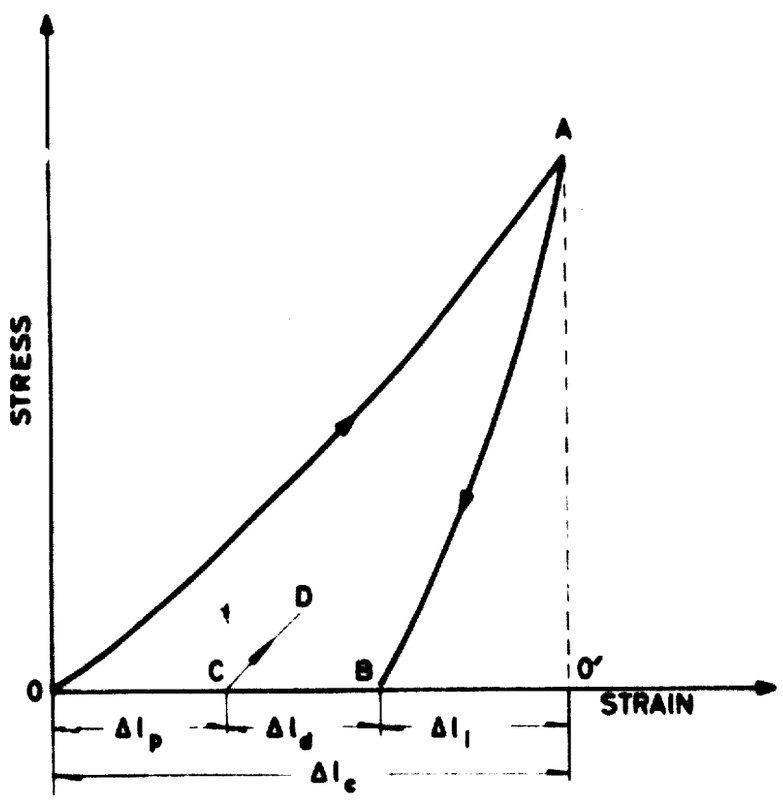

Figure 1. *Graph made by a fabric strength tester, plotting stress against the strain curve*

In this graph Δl_c represents the complete elongation, Δl_i the immediate elongation, Δl_d the delayed elongation, and Δl_p the plastic elongation. Actually, Δl_i is the sum of the immediate elongation and a part of the delayed one, disappearing when the stress is removed. The value of Δl_d is less than the true value of the delayed elongation by that part of it which was incorporated into Δl_i and also by the part of the elongation that would have disappeared had the time for relaxation been longer. Finally, Δl_p surpasses the true value of the plastic elongation by the part of it that would have disappeared had the relaxation not been interrupted by the new stress. A graph of this kind is recorded by the strength tester.

The second type of graph is shown by figure 2 *(a)* and *(b)*. Sector $0A$ represents the increasing stress, AA' the situation when the material remains under stress, $A'B$ when the stress is removed and BC the relaxation of the material.

Graphs of this kind are recorded by modern relaxometers during a typical test, when the strain is of the character shown in figure 2*(a)*. Sometimes such graphs are recorded by strength testers. Typical tests would be recorded as shown in figure 2*(b)*.

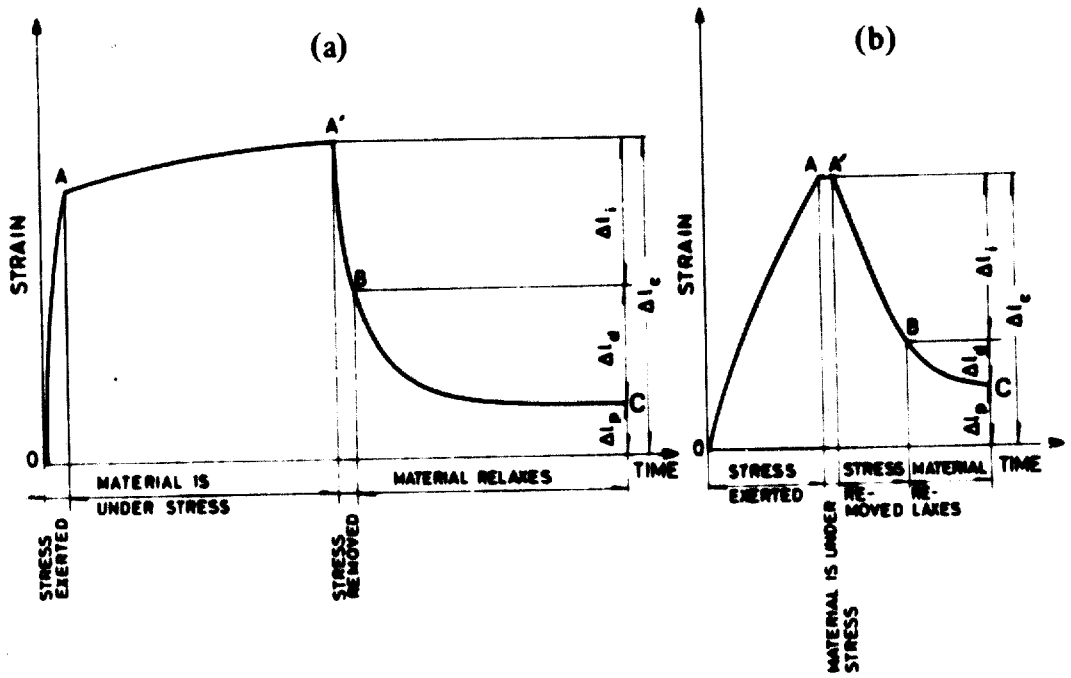

Figure 2. Graphs made by a fabric strength tester, plotting strain against time. The difference between (a) and (b) results from the differences of time for particular stages of the test (see text)

Differences between *(a)* and *(b)* in figure 2 result from the differences of time for particular stages of the test. The values Δl_i, Δl_d and Δl_p in figure 2*(a)* and *(b)* refer to the same elongations as described previously. Evidently, *(a)* represents results that resemble much more closely the natural values of the immediate, delayed, and plastic elongations than do those shown in *(b)*. It is for this reason that relaxometers yield more reliable test results than do strength testers.

The factors that affect most test results are the four following: the degree of stress, the time taken to impose and continue the stress, the time of removal of the stress and relaxation time, and the types of stress that are applied for testing of various types of fabrics.

The degree of stress can be selected practically at will in all the testing methods. However, taking into account the conditions that prevail in normal use, it should not be too great (it usually amounts to 5 ± 30 per cent of the breaking force, or a few kilograms per centimetre of the sample width).

The time during which the stress is exerted and time of relaxation can be selected within a great range if relaxometers are used, whereas with strength testers the time-limits are narrower.

There are various methods of exerting stress; namely, *(a)* constant load, *(b)* constant stress, *(c)* constant ratio of actual stress to its breaking value, *(d)* constant strain, and *(e)* constant ratio of actual strain to its value at the breaking point.

If an appropriate method has been adopted, the test results will be more or less comparable. The method selected must be related to the natural conditions to which the tested material will be exposed in normal use. This is not easy, since these conditions may vary to some extent. If fabrics having the same end-use are to be compared, the most comparable results will be obtained with stress performed as described in *(a)*, *(d)* or *(e)* above. With fabrics that may be intended for different end-uses, the types of stress described in *(b)* or *(c)* are recommended. In any case, the

proper choice of method requires full information about the end-use of the material under test.

It should be mentioned that the type of stress to be exerted affects the conditions of straining to some extent. For instance, figure 2*(a)* shows the strain resulting from stresses exerted according to types *(a)*, *(b)* and *(c)* on a relaxometer. If stresses of types *(d)* or *(e)* are exerted, the resulting strain changes will be as shown in figure 3.

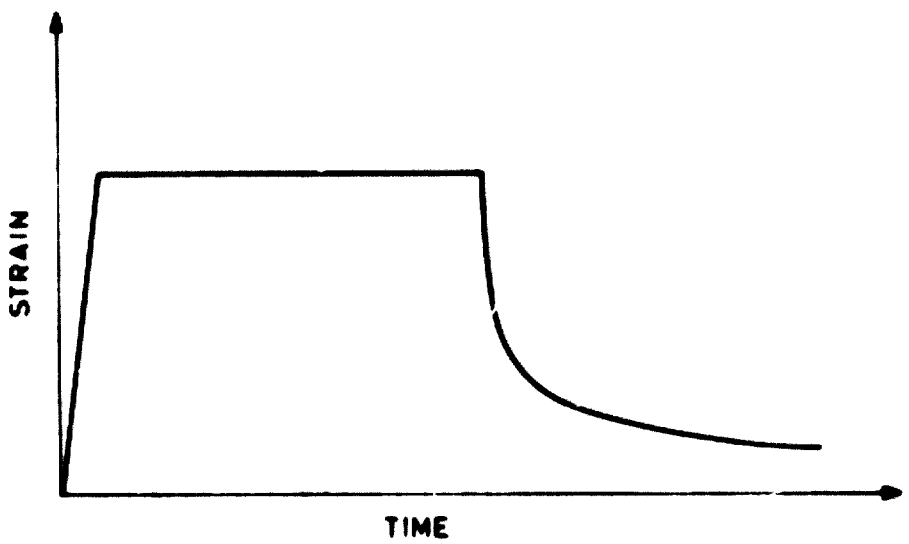

Figure 3. Graph made by a relaxometer when the fabric sample is under constant strain or with a constant ratio of actual strain to its value at the breaking point

If figure 2*(b)* and figure 3 are compared, it becomes evident that stress types *(a)*, *(b)* and *(c)* are more vigorous than types *(d)* and *(e)* if the load is the same.

In examining resilience, the following indices are determined: apparent relative immediate elongation (ϵ_i), delayed elongation (ϵ_d) and plastic elongation (ϵ_p). The following formula is used:

$$\epsilon_{i(d,p)} = \frac{\Delta l_{i(d,p)}}{l_o} \times 100 \quad [\%]$$

where $\Delta l_{i(d,p)}$ are the direct values of elongations, as defined previously

l_o is the original length of the sample.

Proportion (percentage) of differential elongations (U)—immediate, delayed and plastic—in the total elongation:

U_{ϵ_i}, U_{ϵ_d}, U_{ϵ_p} according to the formula

$$U_{\epsilon_{i(d,p)}} = \frac{\Delta l_{i(d,p)}}{\Delta l_c} \times 100 \quad [\%].$$

Of course, the following relation holds good:

$$U_{\epsilon_i} + U_{\epsilon_d} + U_{\epsilon_p} = 100.$$

Indices are based on the area of resilience of the sample. A graph recorded such as that shown in figure 1 permits determination of the area of strain and the area of resilience. The former (L_s) is defined by the area $0A0\,0$, and the latter (L_r), by $BA0'B$.

Resilience can be determined by the area of resilience of the sample or by the ratio of the area of resilience to the area of strain. In addition to the characteristics mentioned above, there may be others, but they are of minor importance and have only limited application.

Methods for testing the resilience of some textiles have been worked out in the Textile Research Institute. Upholstery fabrics are tested by a single-cycle method on a strength tester.

The test sample is 30 × 200 mm in size. The load to perform the stress is 15 kg, the time of applying it is 15 minutes, and the time for relaxation is 5 minutes. Elongation ϵ_p must be determined after 5 minutes.

For highly resilient textiles, a 20-cycle test on a strength tester is carried out. The load is near the limit of extensibility.

Elongation $\epsilon_i + \epsilon_d$ is determined within 2 minutes after the stress is removed at the end of the twentieth cycle, whereas ϵ_p is determined after 4 hours of relaxation.

Knitted fabrics are tested with relaxometers. Test samples are 50 mm × 100 mm in size. The strain is applied near the limit of extensibility of the knitwork. The times of stretching and relaxation amount to 1 hour each. Elongation $\epsilon_i + \epsilon_d$ is determined after a 5-minute relaxation, whereas ϵ_p is determined after 1 hour of relaxation.

The slippage of threads in fabrics

The slippage of threads in a fabric occurs, for example, when, in making up or in use, the threads of one system shift in relation to the other. This produces a strip of clearance that spoils aesthetics of the fabric and lowers its quality. The slippage of threads in a fabric can be tested by various laboratory methods. The three following are the most widely used: the thread-cutting methods, the comb method and the seam-slippage method.

The thread-cutting method

This method is used in the Netherlands and Switzerland. Strips of 6 cm × 15 cm size are cut out of the fabric. Threads at both long edges of the strips are pulled out until a test sample of 5 cm width is obtained. Out of the centre of the sample 2 transverse threads, selected at a distance of exactly 1 cm from each other, are removed. A "track" across the sample of 1 cm width is thus obtained. Next, outside this track, some further transverse threads are pulled out, further uncovering the threads that run along the sample. Every second one thread is cut through near the track, but at one side of the track the cut fibres are of even numbers, whereas at the other side they are of odd ones (see figure 4). Samples prepared in that way are now placed in clamps of a strength tester and stretched. The load required to pull the cut ends out of the track is considered as one half of the force of resistance against slippage (every second thread being cut through). The doubled value of that load is the measure of slippage.

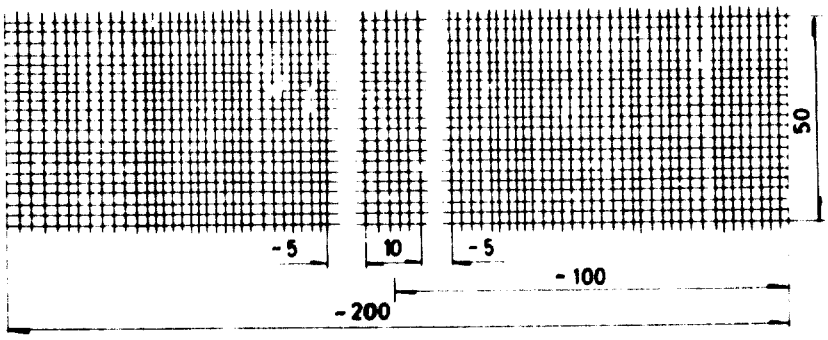

Figure 4. The thread-cutting method for testing the slippage of threads in a fabric sample (see text)

The test is carried out on strength testers for yarn, the clamps being adjusted for samples 50 mm wide, with the ranges of load being 0 to 1 kg, 0 to 10 kg, and 0 to 25 kg, on strength testers for fabrics with a load range from 0 to 50 kg. At least 10 tests must be made, with the lower jaw moving down at the speed of 100 mm/min.

The comb method

The test samples are strips 6 cm X 20 cm in size, cut out of the fabrics and trimmed by pulling out the edge threads to the size of 5 cm X 20 cm. Next, threads going across the strip at 12 cm from its end are removed so that a 1-cm clearance is obtained. Leaving 10 transverse threads intact, more threads are removed so that a total clearance 3 cm wide is obtained (see figure 5). The sample prepared in this way is now clamped in the upper jaw of the strength tester so that the end with the clearance is down. An initial load of 200 g is attached to the lower end of the sample. The lower jaw of the tester is provided with a comb, the teeth of which are now pushed between the threads of 1 cm clearance of the sample, above the 10 transverse threads that were left intact. The comb used here has 27 tempered steel teeth of 1 mm diameter and 20 mm length, spaced evenly across the comb at 2 mm distance between their tips, which are slightly rounded.

The load needed to shift down the 10 transverse threads is read on the graph and is considered to be the measure of slippage.

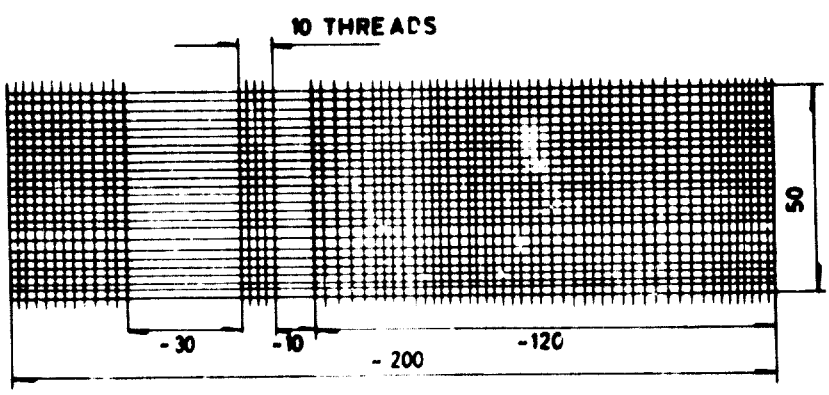

Figure 5. The comb method for testing slippage of threads in a fabric sample (see text)

The seam-slippage method

This method is widely used in the United States. It is based on the stress applied to a sample containing a seam and strained by a strength tester. The sample has the form of a strip, the width of which is greater than that of the clamping jaws.

The recorded stress-strain curve is compared with the graph obtained in a similar way for a seamless sample. A typical picture of slippage in the seam is shown by figure 6. Curve *A* refers to a sample with the seam, and curve *B* to a seamless sample. The difference between elongations shown by curve *A* and *B* must be ascribed to the slippage of threads in the seam.

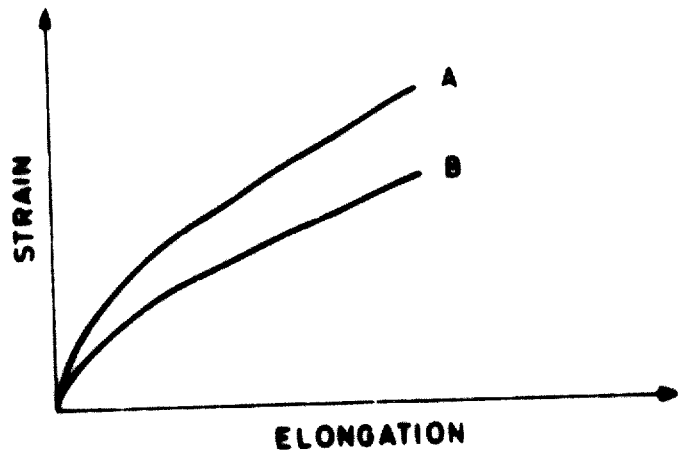

Figure 6. The seam-slippage method for testing slippage of thread in a fabric sample (see text)

The graphs allow the following data to be read out: the amount of stress required to obtain a definite displacement of threads, and the magnitude of slippage at a definite stress.

In the former case, it is usual to determine the load that causes the threads to slip 4 mm, whereas in the latter the slippage caused by a load of 7.5 kg is measured. Tests are carried out on strength testers with a low range of load (0 to 10 kg or 0 to 20 kg) and suitably sensitive recording devices.

Regulations in Poland at this time prescribe the thread-cutting test for fabrics made of wool or of flax, whereas silk and rayon fabrics must be tested by the comb method. Arrangements are being made to change these requirements to permit use of the seam-slippage method for fabrics of any type.

Assessment of the fixation of fibres forming a textile product

Some textiles tend to shed some of their fibres during use because individual fibres become detached from the surface of the fabric. The fibres that fall out may adhere to other parts of clothing where, because of colour contrast, they can affect aesthetics of the garment adversely.

This phenomenon is strictly connected with fibre properties, yarn structure and the construction of the final product, as well as with finishing processes.

Loose fibres are shed mostly by pile fabrics or by those with raised surfaces and open structures. Fabrics containing acrylic fibres are particularly prone to shedding.

Methods for investigating how securely some groups of fibres are bound by the fabric have been known and applied for many years. The usual procedure consists in clamping a row of protruding fibre bundles in the jaws of a strength tester to determine the load necessary to pull them out. The load per bundle is considered to be the measure of the fixation of the surface fibres. However, such a procedure applies only to textiles in which there are regular rows of fibre bundles that can be distinguished easily. Some examples are plush fabrics, pile carpeting and imitation furs.

However, there is a large group of fabrics whose piles are formed by evenly distributed individual fibres and not by tufts of fibres; examples are raised-surface fabrics and shawl fabrics of the mohair type. When fabrics of this kind are made from synthetic fibres and have a loose structure, the surface fibres shed readily, thus lowering considerably the quality of the fabric.

To test such products a special instrument and methods for its use have been developed by the Textile Research Institute. The principle of operation of this instrument is shown schematically in figure 7. It is used as follows: A test sample (1), 200 mm × 300 mm in size, is placed on the lower head (2), which has the form of a truncated pyramid with a square base. It is fastened to a carriage (3), which has a reciprocal stroke and is operated manually. The upper head (4) is provided with a wedge bar (5) wrapped in smooth rubber (6).

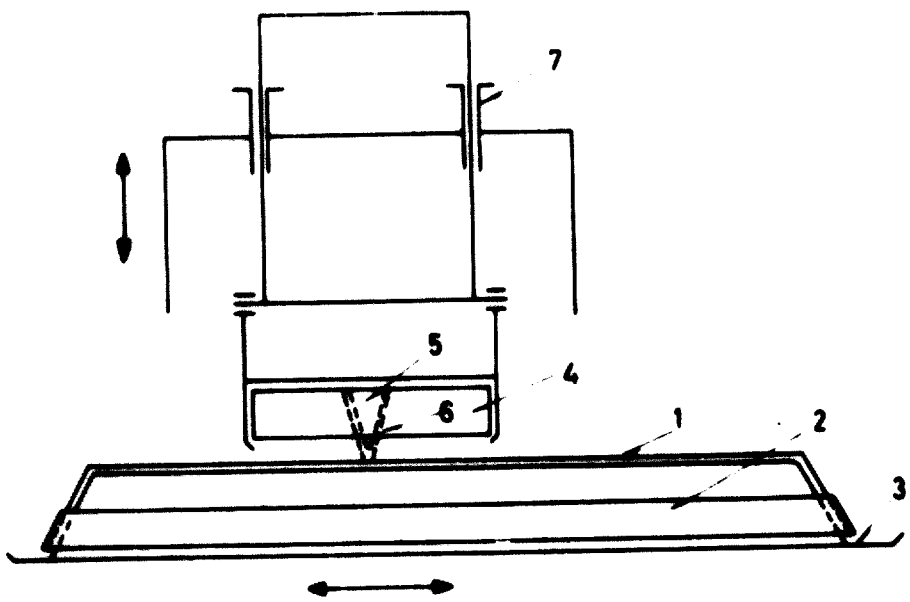

Figure 7. Schematic diagram of the operation of an instrument, developed at the Textile Research Institute in Łódź, for testing the resistance to shedding of surface fibres (see text)

The upper head is raised by guiding rods (7) at one stroke of the carriage and drops automatically when the carriage reverses its direction. When the head drops, its friction surface makes contact with the sample and presses it by its weight (500 g). Consequently, the friction is always exerted at one direction of the stroke, and surface fibres are pulled out of the sample without being knotted or tangled.

The test procedure is as follows: After the sample has been secured in place, the instrument is set into operation for five reciprocal strokes of the carriage. The fibres that have stuck to the friction bar are removed, and the instrument is restarted for another five strokes, and so until 200 cycles have been completed. The fibres

collected from the friction bar are conditioned for standard state and weighed. The resistance to shedding of the surface fibres (T) is calculated with the formula:

$$T = \frac{\overline{M}}{F} \times 10^4 \qquad [g/m^2]$$

where $\overline{M}$ is the mean mass of fibres collected

F is the sample area (cm^2).

Laboratory tests performed with this device have permitted the establishment of the approximate grades of fibre security on the surface of textile fabrics shown in table 1.

TABLE 1. APPROXIMATE GRADES OF SURFACE FIBRE FIXATION

Mass of collected fibres (g/m^2)	*Definition*
0 – 1.40	No fibres are shed
1.41 – 5.60	Some fibres are shed
Over 5.60	Fibre shedding is considerable

It should be noted that the permissible degree of shedding depends on the type of the tested product.

METHODS FOR EXAMINING TEXTURED YARNS

by

A. Różycki

Yarns that may be designated as "textured" differ from one another in several of their properties, although there is one feature that they all share; namely, increased volume or bulkiness as compared with the yarns from which they were derived.

There are many different criteria for the classification of textured yarns. Relatively simple ones are their division on the basis of their relative length when straightened and their ability to recover their initial form after the applied stress has been removed. In any case, the basic factors in the analysis of all properties and in an assessment of the quality of textured yarns are the initial stress and the straightening load. Various values of the initial stress are given by different sources, the corresponding elongation at the breaking-point for the same yarn being as follows:

Elongation (per cent)	*Stress (g/tex)*
500	0.003
120	0.020
60	0.100
30	0.500
25	1.000

While these stresses are important, other values should also be considered. For example, as shown in figures 1 and 2, the assumed initial bases of all tests of elongation, crimp and bulkiness affect their results. Figure 1 presents load extension curves for several yarns, plotted with no initial stress; figure 2 shows similar curves plotted with an initial stress of 200 mg. The patterns are markedly different.

The differences among the testing methods that are being applied all over the world and the disparity of details even when the same basic testing principle is assumed make it difficult to use fully the literature on this subject, and a comparative study of it is hardly possible. From all existing methods it is necessary to select those that are most representative and most widely used.

The length to which a yarn specimen has been extended due to the initial stress of 0.002 grams per denier (g/den) or 0.018 grams per tex (g/tex) (often rounded to 0.02 g/tex) may be assumed as the basic length under normal stress. That figure has been accepted as basic, since it was obtained from studies on the strains to which a

yarn is subject in a knit fabric. Later in this report, the stress of 1 g/tex is assumed as sufficient to straighten a yarn without extending its component fibres. In any case, differences in lengths due to straightening loads of between 0.75 g/tex and 2 g/tex are of no practical consequence.

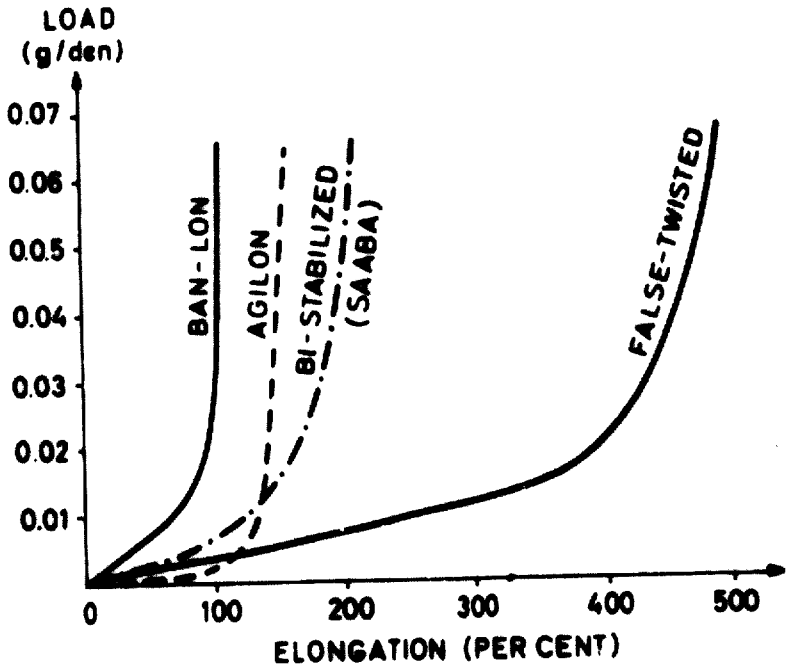

Figure 1. Load-extension curves for yarns (no initial stress)

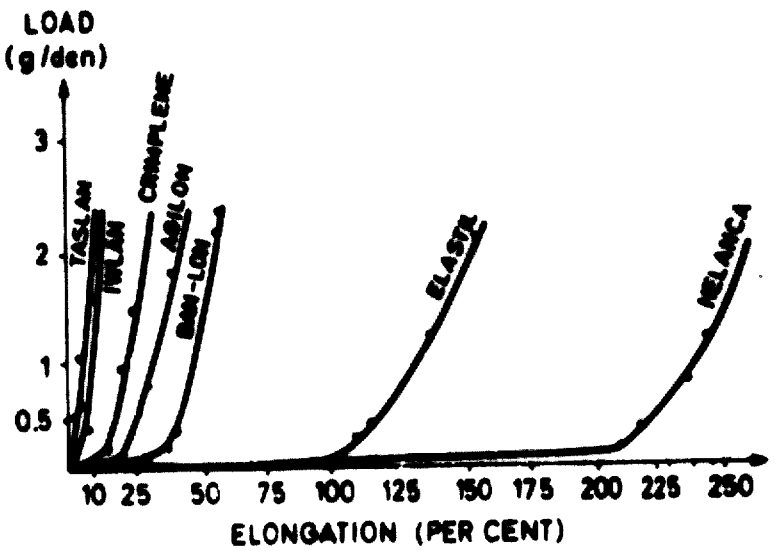

Figure 2. Load-extension curves for yarns (initial stress of 200 mg)

If these two reference factors are assumed, all textured yarns can be divided into three principal groups:

(a) Elastic yarn of a great elongation (over 150 per cent), such as Helanca or other yarns of polyamide, polyester, polypropylene or similar material, which are textured with the false-twist technique;

(b) Elastic yarn of moderate elongation (within the 50 to 150 per cent range), such as bi-stabilized yarn (Astralon);

(c) Yarn principally of extensibility similar to conventional types, whether spun of filament or staple fibres, such as air-textured and high-bulk yarns.

The first two of these groups are the most important. They are very popular and are available in many varieties. In practice, there are unlimited possibilities of conferring on them various properties by the application of different texturing techniques and by suitable weaving, knitting and finishing. These manifold characteristics imply the use of specific, sensitive and differentiated methods for the examination of properties of these yarns. The methods apply to the control of the manufacturing processes and to the appropriateness of the end-use of the tested material.

The five following characteristics of textured yarns (that is, those with greater elongation than conventional yarns) are usually determined: degree of crimp (sometimes referred to as maximum elongation), crimp contraction, crimp retention, residual shrinkage and elastic pull. Crimp rigidity, apparent diameter, and bulkiness are determined less often.

More recently developed, but considered to be very important and therefore in increasing use, are two characteristics that are shown by the load-extension curve; these are the elasticity modulus and the crimp modulus.

A separate group of characteristics is based on visual examination of yarn specimens. It is carried out with shrunken yarn strands or with samples of fabrics that have been knitted under standard conditions.

The examination begins with a check of the crimp development. The yarn under examination is wound evenly on tubes and is then subjected first to the action of a given stress such as tension, hot or boiling water, steam, moist air or dry air, and then allowed to relax so as to permit it to recover its strainless position under standard atmospheric conditions.

This brief description of crimp testing makes clear the reasons for the divergences among test findings in different places. Nevertheless, these differences are sufficiently small to permit, in some large-scale textile enterprises or even in certain countries, the standardization of various testing methods. If this were done, test results would be reproducible and, to a great extent, comparable.

Since space does not permit consideration of its many details, only the general principles of the method are considered here. The terminology used is as follows: "strainless" means no initial load, "slightly stressed" means an initial load of 0.02 g/tex and "straightened" means an initial load of 1.0 g/tex. Heat treatment is referred to with indication of neither temperature nor duration of treatment. "A short time" means a few minutes, and "a longer time" means several hours. When there is no reference to time, it is assumed to be short.

Degree of crimp

The degree of crimp indicates the percentage of increase in length of a yarn from a strainless to a straightened condition. After crimp development has been checked, the lengths L_1 (strainless) and L_2 (straightened) of the specimen are measured.

The degree of crimp is given as:

$$\frac{L_2 - L_1}{L_1} \times 100 \quad [\%].$$

Crimp contraction

Crimp contraction refers to the shrinkage of yarn after it has been washed and dried. As with the degree of crimp, the crimp development must first be checked, after which the yarn is dipped into hot water for a short time and while still wet, measured for straightened length L_3. The specimen is then dried in a hot-air dryer and left there for a long time in the strainless condition. The dry specimen is finally conditioned and measured without strain for length L_4. The crimp contraction is calculated as:

$$\frac{L_3 - L_4}{L_3} \times 100 \quad [\%].$$

Crimp retentiveness

Crimp retentiveness is actually the most important of the characteristics that determine the quality of textured yarn. It may be defined, roughly, as that part of the degree of crimp that has survived the finishing processes, mechanical strains and cleaning or washing operations in the course of wear. Each of these stresses can bring about yarn shrinkage as well as a partial loss of crimp, that is, straightening of the yarn.

After a check of crimp development, the yarn specimen is steamed and then conditioned in standard air conditions. The free specimen is now measured for length L_5, dipped into warm water and measured again while wet and slightly stressed to determine the length L_6. The yarn is finally dried for a longer time with warm air conditioned for a longer time and then measured, free of strain, for length L_7.

The crimp retentiveness is now calculated as:

$$\frac{L_6 - L_7}{L_6 - L_5} \times 100 \quad [\%].$$

Residual shrinkage

Contrary to the case with crimp retentiveness, the residual shrinkage indicates t the technician how the yarn length may be changed by steaming, boiling and simil finishing operations. Simultaneously, taking into account the overlapping of effec of both the factors, that is, the latent shrinkage of raw yarn (polyamide or polyeste as well as the shrinkage caused by hot extension at texturing, the determination the residual shrinkage is also an element in the direct control of the texturi process. A low value for this parameter is very desirable.

Residual shrinkage is found by the determination of length L_8 of t straightened yarn, without checking of the crimp development. Samples a afterwards boiled for half an hour in an aqueous soap solution and then rinsed, dri and conditioned. Finally they are stretched with use of a strength tester, the rate

extension being 10 cm/min, until they are straightened and the length L_9 is achieved. The amount of residual shrinkage is calculated from the formula:

$$\frac{L_8 - L_9}{L_8} \times 100 \quad [\%].$$

Elastic pull

Elastic pull is particularly important, since it is this characteristic that enables textiles, and especially knit goods, to retain their shape.

Test specimens are prepared without checking the crimp development, just as in the determination of residual shrinkage. They are dipped in warm water and measured when loaded to a straightened position to determine length L_{10}. After they have been dried in the strainless condition by hot air, they are measured again while slightly stressed to find length L_{11}. The elastic pull will be:

$$\left(1 - \frac{L_{10}}{L_{11}}\right) \times 100 \quad [\%].$$

Crimp rigidity in tepid water

The crimp rigidity of a textured yarn in tepid water may be defined as the crimp development that has not been arrested. The specimen is straightened up in tepid water and measured to find length L_{12} and then measured again in the strainless condition, while still in water, for length L_{13}.

The calculation is as follows:

$$\frac{L_{13} - L_{12}}{L_{12}} \times 100 \quad [\%].$$

The resulting index is of particular significance in knitting.

Apparent diameter of yarn

The apparent diameter of yarn is determined with use of a projection method after the yarn has been checked for crimp development.

Bulkiness

After the yarn has been checked for crimp development, its bulkiness is determined in a calibrated slot, the specimen being under a standard pressure and stress. Bulkiness is indicated by the ratio of the volume of yarn in the slot to the volume of the material. It may also be defined as the specific volume of yarn (cubic centimetres per gram), the yarn being wound at a standard tension onto a bobbin of known volume, for example, 10 cm^3.

Elasticity modulus and crimp modulus

The elasticity modulus is determined on the load-extension diagram, in the same manner as with conventional yarns, whereas the modulus of crimp must be determined in a special way. It is defined by the initial slope of the load-extension curve when the yarn elongation is 100 per cent (see figure 3). The higher the crimp modulus, the more stable is the handle of the product.

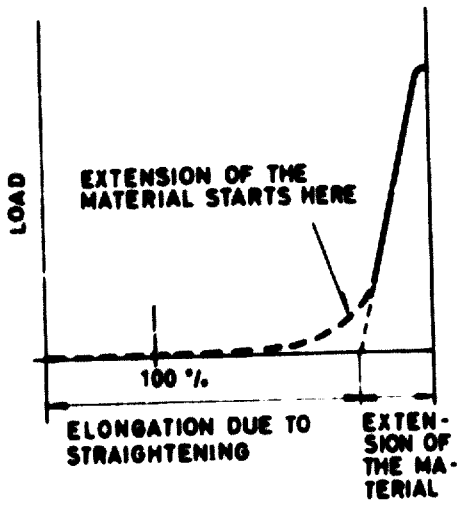

Figure 3. Determination of the elasticity modulus

This survey of methods for the quality control of textured elastic yarns cannot and does not include all methods presently in use; they are, for the most part, those applied by the Heberlein Company in Switzerland (the so-called Helanca Test) or by companies licensed by them, and by the British Hosiery and Allied Trade Research Association (HATRA).

However, because of recent developments in textured yarns and in their increased use, some new elements have appeared. On the other hand, some of the older methods, which were often very complicated, are being simplified by use of new techniques that yield the same results more quickly and easily (for example, the modified Helanca Test).

The examination of high-bulk yarns is hardly more difficult than that of textured yarns. The parameter that receives most attention is bulkiness, the determination of which is done as described above.

METHODS FOR EXAMINING THE IRREGULARITY OF SPINNING PRODUCTS

by

A. Różycki

Survey of methods and selection of the most suitable one

Many problems are associated with the assessment of irregularities in spinning products, and the selection of the most suitable method for detecting them is of basic importance. Moreover, many conventionally accepted ideas on this subject now need revision because of the increasing use of various fibre blends.

A determination of the real irregularity of spinning semi-products and yarns produced from blends is much more complicated than is the case with homogeneous materials, because the differences in the characteristics of various components that are not evenly blended may be recorded as irregularities of fineness. It is to be noted that none of the methods thus far developed and in use in the industry can be recognized as free from that error. Consequently, the selection of a procedure whose accuracy complies best with the actual requirements is of cardinal importance.

Consequently, consideration is given below to several aspects of the application of specific test methods used with both homogeneous and blended materials.

As far as irregularity of fineness is concerned, the determination of which is the broadest division of textile measurements. the five following tests can be considered as basic:

(a) Visual examination,

(b) Gravimetric test,

(c) Evaluation with the use of photo-electric devices,

(d) Evaluation with the use of mechanical devices, and

(e) Evaluation with the use of electronic capacitance devices.

There are also many other methods such as measurement by means of radiation (with beta rays), measurement with use of electric resistance of yarn and with ultrasonic waves. However, these methods have had little practical value until recently and are little used.

Discussion

The three following considerations largely determine the suitability of testing methods:

(a) The tested specimen should not be deformed by the strain exercised by the

measuring elements. Ideally, repeated measurements of the same yarn specimen would be possible.

(b) The test should record not only variations of the diameter of the yarn but should also detect alterations in its cross-section or, more precisely, variations of the total sum of cross-section areas of fibres in a cross-section of the tested product.

(c) The graph that represents these variations should be strictly proportional to the variation of the cross-section area.

The second method, the gravimetric test, while completely objective, only partially satisfies the first consideration. Although this test does not deform the tested samples, it cannot be repeated on the same section of yarn, which has been cut into smaller pieces and thus no longer exists as an entity. This defect in the method is offset, to some extent, by the fact that the weights of the cut sections can be totalled, whenever desired, for mathematical interpretation of the measurements. The second consideration is not satisfied either, since the gravimetric method cannot reveal irregularities along the length of a tested section of yarn; it is assumed that the sample has an identical cross-section, equal to its mean cross-section area, throughout its length. The test is most accurate with short test specimens; error increases with increase in the length of the specimen tested. The gravimetric test is thus not very accurate, and it is also laborious to perform. In some circumstances, however, it may be used to obtain approximations.

The mechanical micrometric test does not satisfy the consideration of accuracy, and it has the further limitation that its results depend on the compactness and resilience of the fibres in the tested yarn samples.

The photo-electric method does not satisfy the consideration of reproducibility and, furthermore, test results obtained with it are highly dependent upon differences in the optical properties of the tested materials.

The method based on electrical capacitance fulfils all of the conditions considered to be general, provided that the moisture content of the tested specimen is evenly distributed in it. However, this provision holds true for all the methods: for the gravimetric procedure because moisture effects weight, in the micro-mechanical method because it alters compactness and resilience, and in the photo-electric method because colour and bulkiness are changed by moisture.

When the applicability for testing of blended fibres is considered, it should be noted that the micro-mechanical and electro-capacitance methods are the most suitable. The latter one seems to show rather smaller differences between particular readings for specific materials. However, it should not be overlooked that the micro-mechanical test has the disadvantages that have been discussed.

Examination of irregularity of semi-finished products and yarn with curves of variation

It is possible to control the spinning process in a mill by examination of the so-called variation curves, which can be relatively quickly prepared on the basis of irregularity tests made with an evenness tester of the electrical capacitance type equipped with an integrator.

Of course, all characteristics of yarn irregularity cannot be expressed by a single figure. Although there may be no doubt that a specified yarn sample is very irregular,

the reasons for such irregularity may not be known. On the other hand, it may happen that a yarn with low irregularity index will yield a fabric of quality inferior to that of another yarn of a similar type that is more irregular. Such practical observations have since long given rise to attempts to make possible a more detailed study of the irregularity of semi-finished spinning products and yarns. The following methods of assessment are presently known: *(a)* auto-correlating function, *(b)* wave spectrum and *(c)* variation-length curves. There is evidence that all three of these methods are connected mathematically. However, their applicability is very different.

The auto-correlating function is determined in a very complicated way. Moreover, its interpretation is very difficult, and it is therefore hardly applicable to the evaluation of yarn quality.

The wave spectrum can now be quickly and accurately determined by means of the Uster spectrograph.[1] The spectrum that it produces gives a precise picture of any draft waves and of periodic changes of fineness in the course of two or three final operations. Once the spectrogram is known, it is possible to make predictions about the final product. Unfortunately, a spectrum yields no figures that illustrate the magnitude of any irregularity that may be detected. Furthermore, the method is hardly suitable for comparative studies, for instance, of two spinning plans.

The variation curve method links the irregularity of mass, as measured with the Uster device, and the deviation of count of 100-metre yarn lengths. A disadvantage of this method is the fact that the plotting of the curve is a very laborious task. For certain studies, however, the curve is very useful and replaces or complements the information supplied by the spectrogram. The curve gives numerical values that refer to the variations of count as a function of length of the test specimen, and a joint picture of the entire production is produced. With the use of variation curves of the yarn it is easy to compare different spinning plans.

These aspects permit the use of the variation curve as a function of length, not only in research but also in routine mill operation for the assessment of yarn quality and for the control of production.

Obviously, a plotting of the variation curve cannot be based on the gravimetric method since it is very time consuming. This work can be done much more quickly with the use of a device equipped with an integrator that measures electrical capacitance.

In precise studies, the values of the direct variance are used, since they may be summed up geometrically. An approximate curve is more often used in mill practice, illustrating relations between length and the coefficient of variation $V\%$ (or mean deviation irregularity $U\%$) instead of variance, because such a procedure is simpler, and a direct reading of the integrator may be used. Two types of variation curves are shown in figure 1.

The curve $CB(L)$ is more often used. It is a variation curve plotted for yarn or sliver sections of varying length L when the number of variants of L tends towards ∞ (that is, when the total length of the tested specimen tends towards ∞).

The construction of this curve can be theoretically represented as follows: The specimen is cut into equal sections of length L, each of them being weighed for the calculation of the coefficient of variation $CB(L)$. The procedure is repeated several times, and each time the length L is altered. This construction is shown schematically by figure 1(a).

[1] Produced in Switzerland by Zellweger Uster.

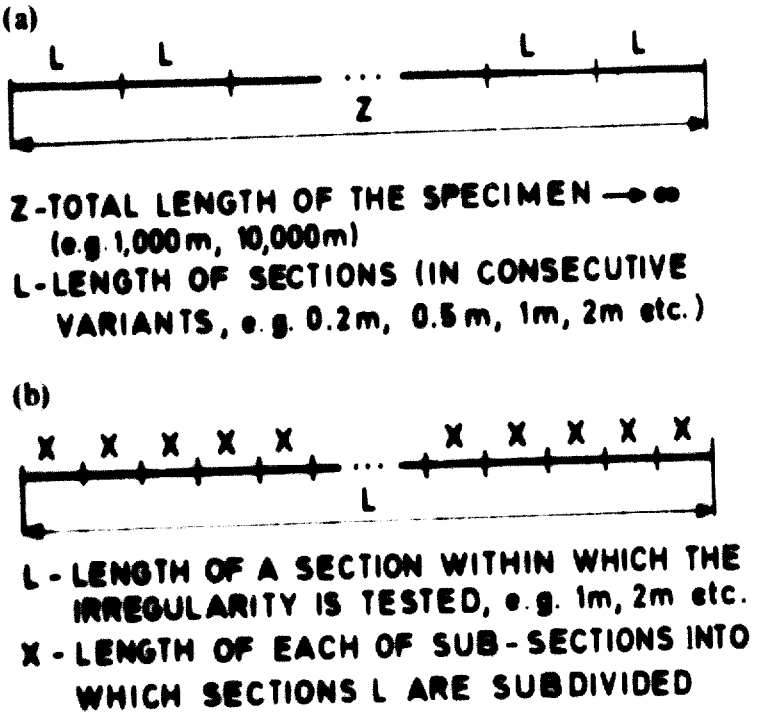

Figure 1. Principles of construction of variation curves

This curve is internationally known under the symbol $CB(L)$,[2] where C stands for coefficient of variation, B for the differences between the tested sections and L for the function of length. This curve is the one most generally used, and is shown in figure 2. When the length of sections approaches zero, then $CB(L)$ or $UB(L)$ tends towards a boundary value, called the over-all irregularity, which is very close to the irregularity shown by the Uster device when set for the "normal test". That boundary is represented with the line CB (0), that is, irregularity of sections with a length $L \to 0$, whereas the length of the tested sample tends towards ∞.

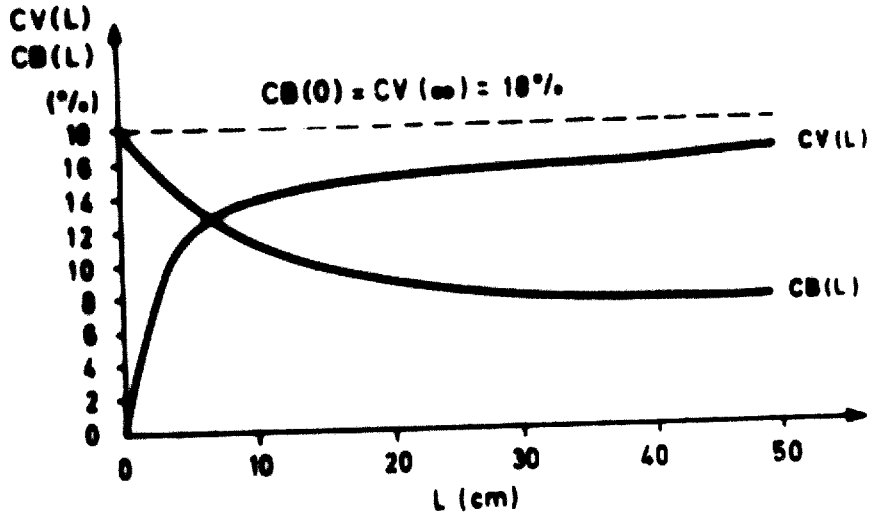

Figure 2. Variation-length curves

[2] To be precise, $CB(L)$ refers to V_B^2 (L), the curve being of a slightly different shape but of the same character.

As the length L increases, the irregularity index at first diminishes slowly, finally to approach zero, when L has greatly increased. It is well known to every spinner that the variation of yarn count decreases as the length of the specimen being weighed increases.

Detection of errors and of their place by means of spectrograms

When an analysis of periodic irregularities is made to find the source of a defect, a diagram drawn by the spectrograph is of great assistance to the spinner. It permits location of the defect, no matter at which stage of the process it occurs. Furthermore, it can, indirectly, point out the reason for it.

It should be noted that the spectrogram can be made in just a few minutes and at the same time it can determine other parameters of yarn such as irregularity, number of faults and diagram of variations of fineness. The same data would take several days of hard work to obtain if means other than the spectrogram (variation curve as a function of length, correlograms) were used.

The spectrogram is drawn on a special chart. The abscissa of the diagram has divisions that correspond to wave-lengths of alterations of fineness, the divisions being from 1 cm to 20 m. To shorten the diagram, the scale is made logarithmic. The ordinates refer to amplitudes of the waves. They are arranged in a system according to the periods of their occurrence, presented as a mean with regard to the total length being tested, so that, with a certain approximation, an average change of fineness at a definite periodicity is obtained. Alterations of fineness are segregated in the course of the test in 30 channels, and after the test, when a button is pressed, the device issues recorded data in form of a diagram, that is, a spectrogram. A typical example is shown in figure 3, representing the result of a test of cotton yarn.

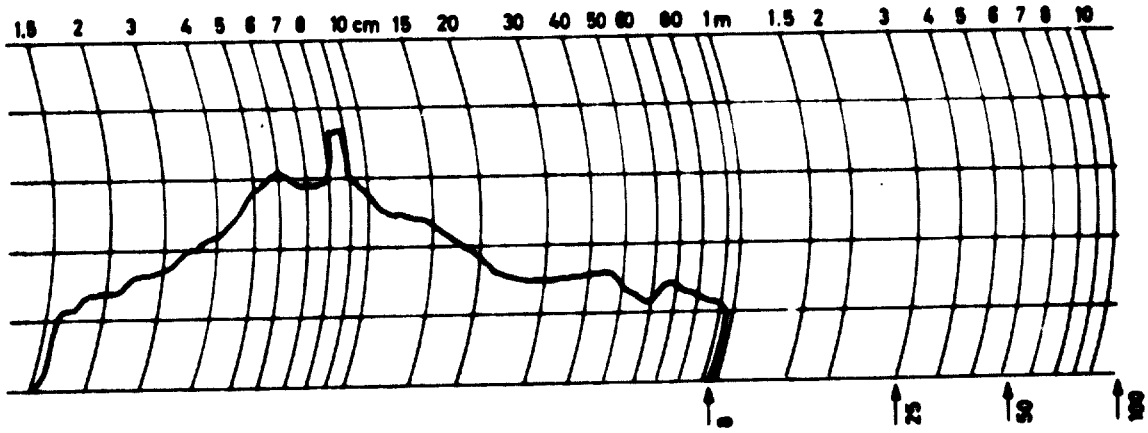

Figure 3. Typical spectogram test of a cotton yarn

The interpretation of such a diagram with regard to the detected defects can be performed with a rather simple procedure.

At the outset, it must be taken into account that faulty operations of spinning machines, resulting in irregularity of their product, can be divided into two groups of faults:

(a) Purely mechanical faults such as those resulting from bent rolls, notched gears, eccentric rollers, and the like,

(b) Faults attributable to an unsatisfactory control of fibres in the draft zone (creeping fibres), causing the so-called drafting waves.

It is important to distinguish between these two groups. A spectrograph makes this distinction possible, since mechanical faults usually bring about alterations of the cross-section, the intervals between thick places being of very much the same length. The spectrogram will reveal it with one (sometimes two) distinct wave peaks ("chimneys"), whereas draft zones form flatter bulgings ("hills"). In practice, several different kinds of pictures of defects are presented by the spectrogram, resulting from combinations of both of these types. Thus, for example, the spectrogram shown in figure 3 shows at the summit of a draft wave an additional thrust (chimney) at a wave length of about 9 cm.

THE ASSESSMENT OF YARN QUALITY

by

A. Różycki

As regards the classifying indices for the assessment of the kinds and qualities of yarns, it can be said that, generally throughout the world, the following are used: the range of tolerance of the yarn (skein count) and its variation coefficient, tensile strength of yarn and the coefficient of variation of the breaking strength, the maximal twist and/or the range of its tolerance, especially for blended yarns, the yarn appearance and, only rarely, the variation coefficient of twist and elongation at break. Some others are also found.

The number of so-called hidden faults is also treated as a quality criterion, but this is often determined under quite differentiated and rather individual contract conditions.

On the other hand, one of the indices, which is applied more and more in international practice, is unevenness as determined by the Uster apparatus.[1] When this index is introduced, other indices have sometimes been omitted, since it is considered to be superior. There is thus a possibility of decreasing the number of classifying indices (according to the above list there are at least seven), and from the point of view of the statistical requirements of quality control, there are too many.

The tolerances of the yarn skein count and its variation

Tolerances

An examination of the standards relating to the tolerances of the yarn count allows the statement to be made that the question of deviations of the count is considered one of the most important conditions of the delivery of yarn in every country and is even incorporated into several international branch trade agreements. There are even regulations for deviations from the standard count when suitable assessment rules do not state exactly several other important yarn quality indices. This is quite understandable, in the light of the consequences of variations of the count of the yarns used from the one planned, as in weaving mills or in knitting mills. With a given previously planned construction of the fabric, too low a count makes the use of a greater amount of yarn necessary for the production of the same meterage of woven or knitted fabric, and too high a skein count, with an unchanged

[1] Produced by Zellweger Uster in Switzerland.

number of picks or ends in the fabric, will cause too slight filling of the product and a lowering of its value.

In spinning, this matter has two aspects. On the one hand, in the light of the regulations cited above, there are serious financial consequences when the tolerance limits are exceeded, especially in the direction of a coarser count. On the other hand, the finer the count must be, the more costly it may become, even within the permissible deviations, as regards the output of the machines and the price of the raw material.

The theoretical values of these tolerances result from the regulability of the spinning frame and the accuracy of yarn count determination. For each kind of yarn and the ranges of the counts, there can be quite different values. As an orientation, the following information on average values can be given (for the coarser counts they are a little higher):

(a) For carded and combed cotton yarn, ± 3 per cent;

(b) For worsted yarn, from ± 2 to ± 4 per cent;

(c) For woollen yarn, from ± 3 to ± 10 per cent;

(d) For linen yarn, from ± 3 to ± 7 per cent;

(e) For continuous-filament rayon yarn, from ± 3 to ± 5 per cent;

(f) For continuous filament polyamide and polyester yarn, from ± 3 to ± 6 per cent.

Coefficient of variation of yarn skein count

The coefficient of variation of the yarn skein count is among those yarn indices that have been greatly improved in the last ten years. This is partly because of the tendency to produce finer products in which variations in thickness are very evident and also because of the tendency to use single yarns whenever possible, so as to eliminate the plying process, which increases unevenness in the thickness of the single yarns.

Table 1 shows the maximum percentage values of the coefficient of variation of the yarn skein count that characterize the present stage in the evolution of international standards.

Average breaking strength of yarn and its variation

Apart from the skein count, the basic index of yarn quality is its breaking strength. This index is so important that, when speaking of the yarn strength, the tensile strength is intended, although the bending strength, for example, is also tested. The two indices mentioned (the yarn skein count and the breaking strength) are combined in the tenacity index (g/tex) which is the basic yarn quality index and is usually considered first.

Important as the mean strength is, its variation is equally significant. Both the average value and the variation in the strength limit the outputs of many machines, especially the modern ones, that is, high-speed and automatic ones. For example, the automation of weaving mills is not possible unless a suitably high strength of the yarn (especially of the warp threads) and a suitably low variation of the strength are guaranteed. These two values should be considered as one, because the greater the variation, the higher the average strength required, so that the permissible level of the

TABLE 1. MAXIMUM VALUES (PER CENT) OF THE COEFFICIENT OF VARIATION IN THE DISCUSSED INTERNATIONAL STANDARDS FOR SOME TEXTILE FIBRES

Quality class	*Cotton (combed and carded)*	*Worsted system yarns*	*Bast fibres (except jute)*	*Jute*	*Woollen system yarns*	*Filament yarns*
Very regular	below 2.0	below 2.0	below 2.5	below 3.5	below 2.5	below 0.5
Regular	2.0—2.5	2.0—2.5	2.5—3.5	3.5—5.0	2.5—4.0	0.5—1.0
Medium regular	2.5—3.5	2.5—3.0	3.5—4.5	5.0—6.5	4.0—5.5	1.0—1.5
Irregular	3.5—4.5	3.0—3.5	4.5—5.5	6.5—8.0	5.5—7.0	1.5—2.0
Very irregular	above 4.5	above 3.5	above 5.5	above 8.0	above 7.0	above 2.0

number of breaks is not exceeded. Conversely, the lower the variation, the lower the average strength can be.

Both the strength value and the coefficient of strength variation are very dependent upon the raw material used. This dependency is shown in table 2, in which it can be seen that the quality classes for American warp, which are determined by breaking-strength values, cover each other; that is, they are not convertible. Also, this inconvertibility covers the very wide variety of kinds of raw material included under the common name "American cotton". This is not seen in the case of Egyptian cotton warp yarn, in which the range is very much narrower and there is a certain interval between the classes, making allowance for the determination error.

Generally, in commerce, a limit value of the coefficient of variation of 15 per cent is taken for the carded cotton yarn. For combed (single) yarn, this value is higher (approximately 18 per cent).

Yarn faults

The definition of yarn faults covers practically all irregularities of appearance, dimensions, composition, construction and the like, and suitable standards have been established for them. However, in the quality assessment of some kinds of yarn, such as those made from silk or cotton, a division is commonly made, in Poland and elsewhere, into so-called "appearance" and "faults".

By appearance is meant very small defects that appear quite often, depending upon the characteristics of the raw material and the run of the technological process (neps, trash, fuzz and the like). Faults include a longer thickening (places not sufficiently drafted), interlooped fly, faulty piecings, knots, twisting faults, soiling and the like which occur very much less often and are more difficult to discern; because of this they are called "hidden faults".

This problem has become especially acute in the last few years in connexion with the automation of the winding and weaving processes, as a result of which the opportunities for the operators to remove the faults have decreased. The automatic removal of defects raises the fundamental question of how the control elements of the cleaners should be adjusted or, in other words, where the limits of a fault should be set. Another reason was the increasing use of synthetic fibres which give on the whole a very much clearer and smoother surface quality to the products, which magnifies the faults. And finally, the process for removal of these faults in the finished products is far more difficult and gives worse results. The tendency to eliminate this arduous and time-consuming operation should not be overlooked in this connexion.

International co-ordination of the ideas and resolutions in the sphere of the definition of faults for cotton yarn was undertaken by Zellweger Uster, which had already carried out similar work with positive results in the determination of standard irregularity values of thickness and yarn strength indices. This was done for worsted yarns by the Fédération Lainière Internationale (FLI) and other groups.

In establishing these standards, the principle was adopted that visible irregularity of construction in the product is a fault rather than an appearance defect. Because of the fact that the degree of perceptibility of a fault of a given size depends upon the weave of the fabric, its colour, yarn thickness and so on, in these standards the faults were divided into grades.

TABLE 2. ORIENTATION VALUES OF THE BREAKING LENGTH AND THE COEFFICIENT OF VARIATION FOR COTTON YARN

		Tenacity (g/tex)			*Coefficient of variation*			
No.	*Raw material*	*Very good*	*Good*	*Medium*	*Very good (below)*	*Good*	*Medium*	*Poor (above)*
1	American cotton warp	12.5—15.5	11.0—13.5	9.5—12.0	9	9—14	14—19	19
2	Egyptian cotton warp	16.5—18.0	14.5—16.0	12.5—14.0	9	9—14	14—19	19
3	Plied, combed cotton yarn				6.5	6.5—10	10—15	15

Tolerances of yarn twist and its variation

The importance of the twist for the strength, wearing and aesthetic properties of yarns and the fabrics made from them is very great and very well recognized. At least as important is the economic significance of this index for spinning mills and twisting departments, since twist strongly affects the output of these departments.

In practice, the twist cannot be uniform, since this would require fulfilment of the three following conditions: *(a)* identical yarn cross-section, *(b)* identical mechanical properties (resistance when twisted, elasticity etc.) of the fibres in each cross-section of the yarn and *(c)* the twisting and delivery of yarn, with no time-change.

Furthermore, there are differences between the real twist and the one assumed because of the shortening of the yarn as a result of twisting. Also, the twist before and after winding can differ because of stresses during winding that cause changes in the reference length.

None of the three above conditions can be met: the first because of the natural and unavoidable unevenness of the fibre thickness of the yarn, the second because of the unavoidable heterogeneity of the material and the structure of the yarn, and the third because of the slippage of the belts and the operating principle of the delivery mechanism.

In practice, the real twist cannot be equal to the nominal one because of the limited sensitivity of the regulability of the spinning frames or twisting machines, resulting from the comparatively small number of teeth of the twist wheel.

Inspection of the permissible values of the average twist deviations for the wide scale of raw materials and systems of spinning that are valid in several countries will show that the main part is played here by an orientation deviation in the range of ± 7.5 per cent for single yarns made from staple fibres and 5 per cent for plied yarns. With continuous-filament yarns for the most representative groups, with a twist approximately 300 turns per metre, such a value would be ± 10 per cent.

However, in conclusion it can be said that, in the last few years, a tendency connected with the improvement of machines and methods of control to sharpen the twist tolerance, which was practically stable over several decades, can be observed.

Yarn appearance

Several factors connected with the characteristics of the raw material, such as the nature of the technological process, the condition of the machines and the conscientiousness of the operators influence the appearance of the yarn. As regards the appearance of cotton yarn, the following properties of the raw material are significant: the fineness of the fibres, the shape of their cross-section, their length and moisture content, and the amount and kind of impurities in it.

Only a few of the factors that affect the surface appearance of yarns, such as the occurrence of neps, can be registered by instruments at this time. Many others, such as variations in nap and the presence of small amounts of vegetable impurities, cannot be detected accurately and unequivocally by existing devices.

In the case of cotton yarn with large amounts of impurities lying near together, even the measurement of the number of neps often becomes inaccurate, since the counters, because of their mechanical inertia, have insufficient time to react to every

impulse. The subjective method for the estimation of the appearance of the yarn wound on a plate with a contrast colour, which has been used for hundreds of years, is changing its character. This versatile method, which once served to determine the number of faults, irregularity of the thickness of the yarn and its appearance, is now coming to be limited only to the determination of yarn appearance; the determination of the indices of the number of faults of dimensional variation and irregularity of thickness has been taken over by instruments that do it much more quickly and accurately. (Previously the yarn had to be wound on the plates in such a way as to make it possible to count the faults in order to refer them to the given length or weight of yarn.) The next step is to try to visualize the appearance of the fabric that will be made from this yarn. The yarn should be wound on the plates in a manner that would make this possible also.

In accordance with the above, many industrial countries, while recognizing that quality assessment according to the appearance of the yarn is still indispensable, have established regulations or standards concerning this method in such a way as to maximize the objectivity of this estimation, despite its basically subjective nature.

Such regulations exist for many kinds of yarns and, the more costly the given yarn, the more precise these regulations are. The highest level of precision of procedure was achieved in the establishment of the accepted regulations for the assessment of silk yarn on the international level. These regulations are also suitable for continuous-filament yarns.

TESTING DYED AND FINISHED MATERIALS

by

H. Cichowski and J. Gajda

The quality of any textile fabric must meet standard requirements, and suitable test methods should be used to ensure that they do so. Such methods, most of which are standardized, permit checking the correctness of processing performance and determination of the extent to which the intended wearing properties of the products have been achieved. The testing of materials is of significant importance for both producer and consumer.

The full testing of a textile article should include the evaluation of fabric construction (yarn number, number of ends, density and the like), mechanical properties (tensile strength, tearing strength, abrasion resistance), and determination of dye fastness and the quality of the finish. It is with the two latter aspects of testing, namely, dye fastness and finishing quality control, that the present article is concerned.

Determination of dye fastness

Tests of dye fastness may be divided into those that concern only the producer, from the point of view of protecting the dye against the changes in shade during such processes as kiering, bleaching, decating, felting and the heat-setting of fabrics made from synthetic fibres and those of consumer significance, such as fastness to light, washing, perspiration and rubbing. By "fastness of dyeing" is understood the extent of changes in shade of the fabric itself and the staining of a white material in contact with the tested fabric, dyed to any depth. The changes in shade and staining are determined by comparison against an International Organization for Standardization (ISO) scale ranging from 1 to 5, where grade 5 represents the highest fastness and grade 1 the lowest. In the determination of light fastness, fading is compared against grades of fastness ranging from 1 to 8, where grade 8 represents the highest light fastness and grade 1 the lowest one.

Somewhat different is assessment of the fastness of a dye, which is determined by the same test methods as the fastness of a dyed fabric. In this case the test is carried out on fabric dyed to a specific intensity that corresponds to a standard depth. More details on determination of dyeing fastness, as well as on the Grey Scale for Assessing Staining and Grey Scales for Assessing Change in Colour can be found in the ISO Recommendation R 105. Methods for determining fastness have been

standardized internationally, and these standards form the basis for uniform agreements between the producers and consumers of dyes and textile fabrics.

Determination of dye fastness may be carried out on any fibre in any form (loose stock, yarn, woven or knitted fabric). The end-product is subjected to tests involving the wearing properties. Each test is carried out on a separate specimen. Assessment is performed by comparing the alteration in the tested specimen against an untreated sample and by determination of the fastness according to the standard grey scales.

Determination of light-fastness of colours

The method of testing colour light-fastness is included in the ISO Recommendation cited above. The test consists in the exposure of a fabric specimen to daylight in a cabinet under a glass sheet, facing south in the Northern Hemisphere and north in the Southern Hemisphere, at an angle of 45°, together with standard blue-dyed samples of fastness to light numbered from 1 to 8. Light-fastness is expressed on the eight-grade scale. Part of the surface of each sample and of each standard are covered with an opaque sheet leaving the remaining part exposed continuously until sufficient fading has occurred to permit comparison to be made with the standards. After the first perceptible change in colour has been observed, a further part of the specimen is covered and exposed until the contrast between the exposed and covered portions of the specimen is equivalent to grade 4 on the Grey Scale for Assessing Change in Colour. At this stage, still another portion of the specimen and of the standards are covered, and exposure continues until the contrast between the continuously illuminated and completely shielded portions is equal to grade 3 on the Grey Scale, or a standard has previously faded to grade 4 before the same contrast is reached for the tested sample. The colour changes of the sample and standards are then compared and the light fastness of the sample is assessed. After treatment has been completed, the change in colour of the specimen and the staining of the undyed materials are compared with the untreated sample and the two Grey Scales, respectively.

The results obtained consist of three different values: one that characterizes the change in colour; the second, the degree of staining of the undyed material composed of the same fibres as the dyed sample; and the third, the degree of staining of the fabric composed of other fibres, since this is also of interest to the consumer.

Recently, five proposals for ISO Recommendations for washing tests, to be carried out under different conditions, have been made.

Determination of colour fastness

Fastness to perspiration

The samples to be tested are prepared in the same manner as for washing fastness. The test consists in the treatment of the specimen with a solution of histidine monohydrochloride, which simulates human perspiration. Since this test method has not been included in the ISO Recommendation, other methods are in use in various countries. In Poland, for example, the artificial perspiration solution contains 5 g/litre of disodium hydrogen orthophosphate and 5 g/litre of sodium

chloride instead of histidine hydrochloride. For the first treatment the pH value of the solution is in the alkaline range, for the second treatment the pH is adjusted to the acid side.

After treatment with these solutions, the specimen is dried without rinsing at a temperature not above 60°C. Assessment of the change in colour and staining is performed in the same manner as with the washing test.

The test methods now in use in Poland will soon be altered according to the ISO Recommendation.

Fastness to dry and wet rubbing

The dry test consists in rubbing a bleached white cotton fabric over the surface of the sample tested by means of a Crockmeter apparatus,[1] which ensures a constant pressure between the surfaces being rubbed. After the treatment, the white cotton fabric is removed from the mandrel of the apparatus, and its staining is compared against the Grey Scale for Assessing Staining.

Testing by exposure to daylight is rather time consuming and can be done, as a rule, only during the summer months. For this reason the use of that method is restricted to cases in which the duration of testing is not of primary importance.

Colour fastness to artificial light is often tested by means of a filtered carbon-arc lamp such as the Atlas Fadeometer (United States). The duration of the test with such devices is about 60 hours. However, the results obtained may differ from those obtained with exposure to daylight, so any published results should be accompanied by information concerning the type of testing apparatus used. Low-pressure enclosed carbon arcs should not be used to test light fastness, since their emission spectrum differs considerably from that of daylight and may yield completely anomalous results.

Filtered light from the Xenotest (Federal Republic of Germany) high-pressure xenon lamp is also used, and recently a method of colour-fastness testing with a xenon lamp has been under consideration by the ISO and is expected to be recommended by it.

Fastness to washing

There are three washing tests that cover different washing conditions, namely, hand washing at temperature of 40°C, and two mechanical washing tests at 60°C and 95°C, respectively. An appropriate washing test is selected according to the purpose for which the material is intended.

The specimen to be tested is placed between two pieces of undyed fabric, the three pieces being stitched together. One of the undyed fabrics that enclose the tested specimen should be of the same fibres as the specimen, and the other of different fibres; for example, when a cotton fabric is being tested, the second piece should be of wool. The composite specimen is treated in a soap solution of controlled concentration and composition at an appropriate temperature for 30 minutes and then rinsed in cold running tap-water and dried at a temperature no higher than 60°C.

For the hand washing test at 40°C, a solution containing 5 g/litre of soap is used, the specimen being held in the solution by a glass rod with a flattened end. For the

[1] Developed in the United States by the American Association of Textile Chemists and Colorists (AATCC).

mechanical washing tests at 60°C and 95°C, an aqueous solution containing 5 g of soap and 2 g of sodium carbonate per litre is used. The composite sample is placed, together with the soap solution, in a glass or metal vessel that has a hermetic seal. The sealed vessels are mounted in a washing wheel rotating at 40 rev/min and immersed in a water-bath at a controlled temperature. The wet rubbing test is carried out in a similar manner, with the white cotton fabric being wetted to about 100 per cent saturation. The degree of staining is assessed after the cotton fabric has been dried. The rubbing test is carried out separately in the warp and weft directions and the lower value represents the final result.

Determination of resistance to sublimation during heat treatment

The test involves treatment of the composite specimen in an apparatus such as the Sublimotest[2] at a predetermined temperature for a fixed time (between 15 and 30 seconds). The testing conditions are given in detail in the ISO Recommendation and in the compulsory Polish Standard. In this case, also, the change in colour and staining are assessed with the two Grey Scales. The test permits evaluation of the suitability of dyes and the determination of whether some finishing processes may be carried out on dyed fabrics composed of synthetic fibres.

The colour fastness tests discussed above are only the most important ones to which dyed fabrics are subjected. There are many others covering different properties that are important in wearing and production, which are included in both the Polish and international standards.

Testing finished materials

Space does not permit detailed discussion of all of the testing methods for all kinds of finishing. However, such detailed information is accessible in the relevant standards and instructions, on the international level as well as those established in individual countries. It is quite important to consider the principles of test methods for finished fabrics and the manner in which the results are interpreted. For these reasons, the most important finishes, namely, the crease-resistant, waterproofing, flame-proofing and moth-proofing finishes are considered here at some length.

Crease-resistant finish

To assess the effectiveness of a resinous crease-resistant finish, a series of mechanical and chemical tests must be performed. The following properties are determined: crease recovery, dry and wet tensile strengths and elongations, abrasion resistance, tearing strength, resin add-on, loss of resin in laundering and evolution of formaldehyde.

Since the mechanical testing methods are discussed elsewhere in this publication,[3] only the principles of chemical and biological testing methods are discussed here.

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[2] Developed in Poland at the Textile Research Institute.

[3] See M. Stasiakowa and W. Balcerowski "Testing Methods for Woven Fabrics: Selected Problems", pp. 45–54, this volume.

Resin add-on

The most satisfactory test for the amount of resin present in the treated fabric is based on its removal by acid hydrolysis. The alternative method based on nitrogen estimation is not regarded as satisfactory since the ratio of resin to nitrogen may vary over quite a wide range.

Among the various treatments that have been suggested for the removal of urea-formaldehyde and melamine-formaldehyde are hydrolysis by:

(a) 0.1*N* HCl at 60°C for 60 minutes;

(b) 5 g/litre oxalic acid and 2 g/litre $(NH_4)_2SO_4$ at 70°C for 15 minutes;

(c) 1.5 per cent of 85 per cent H_3PO_4 and 5 per cent urea at 90°C for 30 minutes.

The following hydrolysis conditions have been developed at the Textile Research Institute:

For urea-formaldehyde resins:

Hydrolysis by 1 per cent HCl at 65°C for 2 hours;

For melamine-formaldehyde resins:

Hydrolysis by 1 per cent HCl at about 100°C for 45 minutes (boiling water bath);

For reactants:

Hydrolysis by 1 per cent HCl at 65°C for 60 minutes.

Loss of resin in laundering

For this purpose, the resin content of the finished fabric is determined in the fabric sample before and after laundering. In Poland, a solution containing 5 g/litre of soap or a detergent is used at 50°C for 30 minutes. The percentage loss of resin caused by laundering is calculated from the difference in the quantity of resin in the sample before and after laundering.

Evolution of formaldehyde

It is well known that resin-finished fabrics release formaldehyde in storage. This evolution is caused by hydrolysis of the resin in fabric owing to the action of heat and moisture. The amount of formaldehyde evolved depends mainly on the extent of curing the resin on the fabric during the finishing process. For a quantitative determination of the formaldehyde evolved, the method of accelerated storage is very often used. A sample of the fabric to be tested is placed in a hermetically sealed jar together with an open weighing vessel containing a measured volume of distilled water. The jar is stored for 18 hours in a thermostatically controlled box at 55°C. After this storage period, the formaldehyde content in water is determined by a calorimetric method with chromatropic acid (1,8-dihydroxy-naphthalene disulphonic acid-3,6).

A correctly finished fabric will have the following characteristics:

(a) The crease angle is increased and should be at least 110° in both the warp and weft direction.

(b) The tensile strength of cotton fabrics is decreased considerably (from 10 per cent to more than 40 per cent, depending on the type of resin and catalyst used and the curing conditions).

(c) The dry and wet tensile strengths of regenerated cellulosic fabrics usually increase by about 10 per cent and 40 per cent respectively, but elongation at break is reduced.

(d) Tearing strength is decreased, particularly in cotton fabrics.

(e) Abrasion resistance is usually decreased, but this decrease can be limited considerably by adding suitable softeners to the impregnation bath.

(f) The resin add-on should be from 3 to 6 per cent for cotton, and from 6 to 12 per cent for regenerated cellulosics, depending on the types of fabric and resin used. The loss of resin in laundering is from 30 to 35 per cent for fabrics that are not rinsed after curing and should not exceed 10 per cent after first domestic laundering.

(g) The amount of formaldehyde evolved in accelerated storage should not be over 0.2 per cent, according to the recommendation of the Textile Research Institute.

Waterproof finishes

The evaluation of waterproof finishes depends mainly on mechanical testing of the fabric protection against the action of water and rain. As with finishes of other kinds, quality control is assessed on the basis of wearing properties. There are three basic test methods which are described below.

The Spray Test (AATCC Method 22–52)

The Spray Test consists essentially in permitting a spray of water to fall onto the fabric tested under controlled conditions and comparing the effect with a standard chart. This chart measures the resistance of the fabric to surface wetting but takes no account of penetration.

The Hydrostatic Head Test (AATCC Method 1952–18)

This test method measures the resistance of the fabric to the penetration of water under uniformly increasing pressure. It is a measure of the combined effects of the waterproofing agent used and of the construction or porosity of the fabric. It is particularly suitable for testing the resistance of heavier fabrics. The method is, however, only of limited suitability for predicting the resistance of garments to rain.

The Bundesman Test

With the Bundesman apparatus an attempt has been made to reproduce to some extent the actual conditions likely to be encountered when a garment is worn in heavy rain. The apparatus produces a heavy rainlike shower of controlled intensity, dropping simultaneously onto four samples of the fabric being tested, while the under surface of each specimen is rubbed, thus simulating the body movements of a person wearing a garment during a heavy rainshower. Two measurements are made. The amount of water that actually passes through the fabric is collected and measured, the fabric is weighed before and after the test, and the amount of water clinging to the exposed portion of the fabric is ascertained. The use of this single test gives numerical values for both the resistance to penetration and the resistance to surface wetting.

Flame-proofed fabrics

The flame test is the basic method. Its results provide the following data: *(a)* flame time in seconds, *(b)* afterglow time in seconds, and *(c)* char area or char length, in square centimetres or in centimetres, respectively. Flammability testing is based on subjecting the sample, in strips, to the action of an igniting flame in a special cabinet (British Standard 2963 : 1958, Polish Standard PN60–P–04638).

The presently used methods of flammability testing were originally developed for fabrics composed of flammable natural fibres. Some modifications of these methods are now being made to adapt them for the testing of synthetic thermoplastic fibres and flame-resistant fibres.

According to the British Standard 3120 : 1959, the following requirements should be fulfilled by the flame-proofed fabric: flame time, not more than 8 seconds after removal of the flame; extent of afterglow, not spread beyond the area of material damaged by flaming; and char length, not above an average of 9 cm.

For the horizontal flame test, the Polish requirements are as follows: flame time, up to 2 seconds; afterglow time, up to 50 seconds; char area, up to 100 cm^2 and, for flame-resistant fibres 0 seconds, 0 seconds, and 20 cm^2, respectively.

Moth-proofed fabrics

The evaluation of the moth-proof finishes is based on biological testing. A controlled number of moth larvae are placed on the sample to be tested and, after a fixed time, the following factors are ascertained: *(a)* visible evidence of damage, *(b)* loss of weight (in milligrams) of the test piece, and *(c)* the number of larvae remaining alive.

The finish is assumed to be perfect if there is no visible damage and the loss of weight is no more than 6 per cent. In addition to the biological test methods, chemical methods are also used that yield a quantitative determination of moth-proofing agents on finished fabrics.

As can be seen from the examples mentioned above, the testing of finished fabrics is a very time-consuming activity. Recently, however, some progress has been observed in this field. The basic trends include a wider application of chromatography, colorimetry and spectrography. It may be expected that, in the near future, chemical testing of textile finishes will be enriched by a wider application of radiation techniques, including the use of tracer atom methods.

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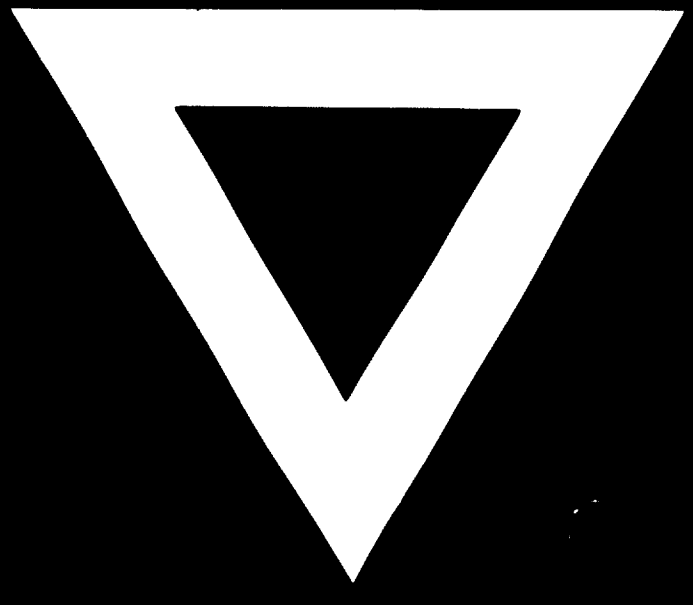

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