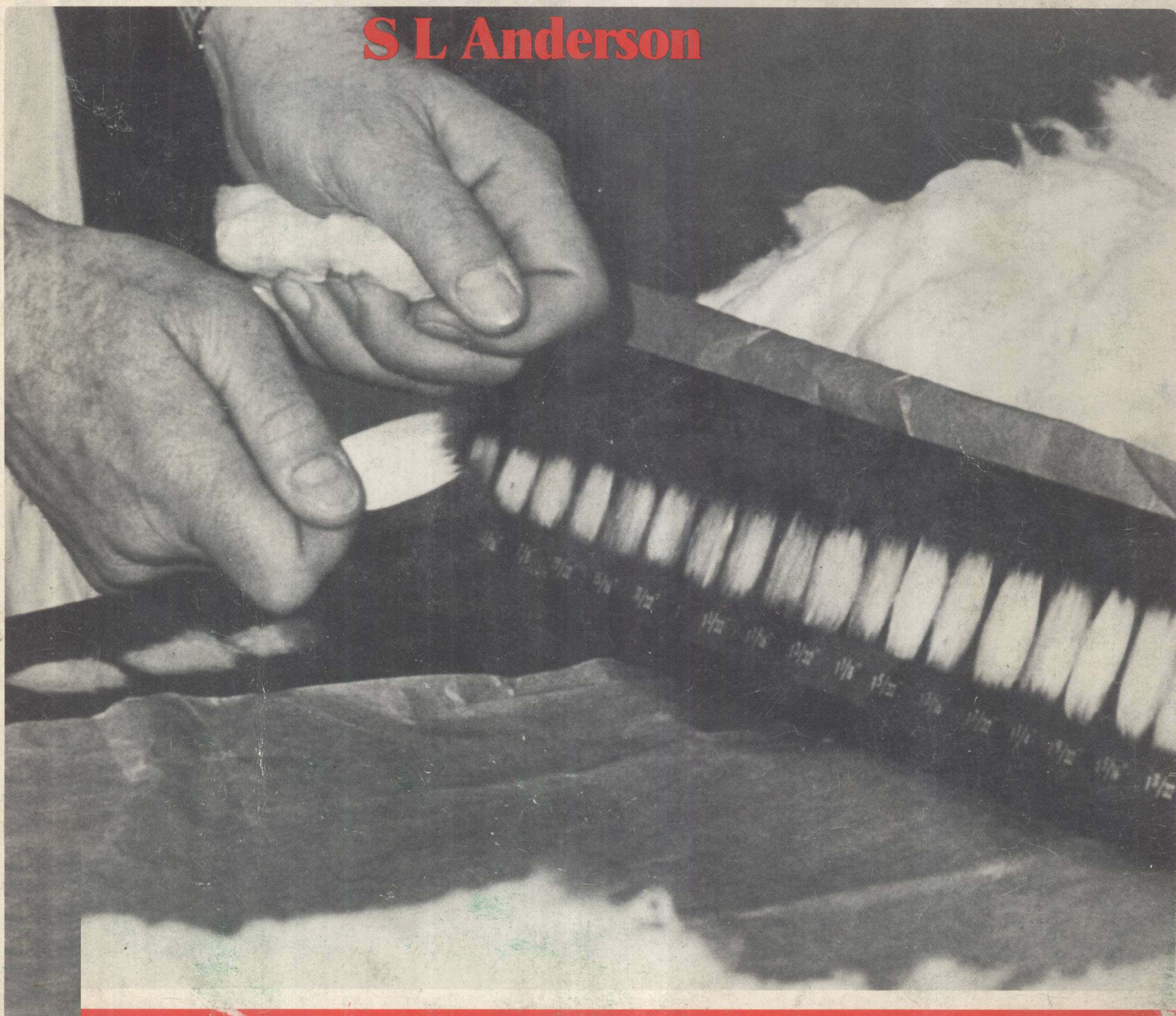
The Textile Institute

Manual of Textile Technology

Quality Control and Assessment Series

Textile Fibres: Testing and Quality Control

S L Anderson



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Textile Fibres: Testing and Quality Control

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Foreword

This third booklet in the Quality Control and Assessment Series deals with physical fibre properties, and I am particularly pleased that Mr. S.L.Anderson, latterly Research Director of WIRA, could be persuaded to write it. His long experience in this field will ensure a sound background to this subject and his intimate knowledge of textile testing in general will ensure that every aspect of physical fibre testing will be referred to in some way.

I would also take this opportunity to pay tribute to the members of my staff in Uster who have transformed the author's text into a booklet of this standard. The Project Team in Manchester should also be mentioned as without a pre-screening of the text and the technical support offered to the author by the staff at Blackfriars Street, the level of technology presented in this booklet would not be possible.

Finally, I would like to mention the importance of the language and the correct textile technological terms and definitions. In this respect, the Textile Institute more than any other authoritative body has been extremely active in promoting standardized textile terminology and offering, through its many publications, a description of the various definitions and abbreviations generally used. I believe this to be one of the most important aspects of any "remote learning" series of monographs.

The next booklet in this Quality Control and Assessment Series is already in preparation. It covers "textile statistics", or, as the author, Mr.G.A.Leaf of the University of Leeds describes his monograph, it explains "the fundamental ideas of the statistics" and is intended "to illustrate the application of the methods with examples drawn from textiles". I am convinced that this invaluable work will become a book of reference for all those concerned with the variability in textile fabrics and made-up goods, and in the yarns and fibres from which they are produced.

I now wish you personal satisfaction, as I have had, in your reading of this third booklet in the "Quality Control and Assessment Series" and would recommend to you all subsequent monographs in this Series.

Uster, July 1983

Locher

Dr.h.c.Hans Locher,
Immediate Past President
of the Textile Institute

Contents

Acknowledgements

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The editor would like to acknowledge the assistance given to him in the preparation of the author's manuscript by Mrs. M.Scotoni who wrote the text, and Miss E.Bossard who prepared the figures and made the layout.

1. Introduction and Scope

1.1 General

Quality has been defined as 'fitness for purpose' and hence quality-control systems, in the context of textile staple fibres, as systems for ensuring that fibres obtained for the ultimate manufacture of a given finished textile product will prove suitable for such a purpose and provide saleable articles, possibly to a specification.

This, then, is the ultimate objective, but quality-control systems may be applied at several stages during manufacture so that quality-control systems for staple fibres include the subsidiary objective of ensuring satisfactory processing on particular machinery lines obtainable in a mill, at acceptable costs and production rates.

Quality-control systems for fibres should not be considered solely to consist of one or more laboratory instruments with associated statistical procedures, but should be regarded as providing all means for realizing the above objectives. These means will include elements of the following.

1) Standard methods and machines for sampling fibres from the bulk at any stage for the purpose of assessment or testing for quality-control purposes.

2) Rapid methods and instruments for testing for the required properties, including the associated data-processing and expression of results in standard form.

3) Agreed procedures for (a) calibrating test instruments and (b) ensuring continued reproducibility and accuracy, by means of round tests, and thus ensuring that systematic differences in test results between different parties (e.g., buyer and seller) are minimized.

4) Standard or reference methods, which may not necessarily be sufficiently rapid for mill use but are accepted as 'courts of appeal', particularly in the case of man-made fibres, although the tests may be performed infrequently.

5) Additional diagnostic methods, which, though not applied to each batch of throughput, may be used, for instance, to investigate the reason for some difficulties that may have occurred during the processing of a particular batch of fibres and were not predicted by the routine quality-control procedure.

6) Visual inspections of fibres by technical staff and regular exchanges of information on the 'quality-circle' concept.

7) Preventive-maintenance schedules for processing machinery.

Although details of preventive-maintenance schedules will not be included in this manual, it is appropriate to mention them in the context of the different philosophies of quality-control systems that have evolved between man-made fibres and natural fibres. Provided that the machinery of extrusion, etc, is working correctly and ingredients are correct, the quality of the staple fibres will not vary, and hence fibre manufacturers' quality-control systems tend to be machine-orientated and the objective tests recommended for users to be of the reference type mentioned earlier, i.e., direct measurement of the basic properties. This is in contrast to the natural fibres, where the effects of growing conditions, weather, and animal health may cause unpredictable variations in the fibre properties, requiring much more quality control down the production line, for which the basic reference methods are too slow. Hence the rapid indirect tests have been developed mostly for the natural-fibre industries. Quality control is to fulfil a practical purpose, and knowledge of the principles behind any method or instrument may not be considered essential for its application. However, some understanding of the principles of operation of test methods or instruments is a great advantage, to give quality-control staff a 'feel' for the limitations of a particular method and its reproducibility. This is particularly important for the indirect methods, such as air-flow, which sense a property (surface area) one stage removed from the property (fineness) that is being estimated. It is one of the aims of this manual to give sufficient understanding of the principles of working of the instruments described to enable quality-control staff to obtain this perspective.

Textile fibres range in length from a few millimetres to about one metre and in thickness from about 10 to 100 μm. Similarly fibre costs range from comparatively expensive fine Australian wools and speciality man-made fibres to much less expensive waste fibres, processed on the condenser systems. Quality-control methods for the expensive fibres thus tend to be more elaborate and to utilize sophisticated test instruments, which their use for cheaper fibres would not justify.

1.2 Relative Importance of Different Staple-fibre Properties for Quality Control

There are vast ranges of different fibre types and many different properties, and it is not possible to generalize about the relative importance of all these. This is particularly so for the natural fibres, where two or more properties may be associated.

Thus, over the whole range of cottons, fibre length tends to decrease as fibre linear density increases, i.e., fine cottons tend to be longer. For wool, the reverse is true, and fibre length tends to increase as linear density (or fibre diameter) increases. Furthermore, the maturity and linear density of cottons tend to be associated.

There are a few principles, however, that give some general guidance.

1) The lower limit of irregularity of drafted products, V%, measured by the coefficient of variation of linear density of short lengths, whatever the state of drawing machinery, is given by:

$$V\% = 100\ (h/H)^{1/2},$$

where h is the average fibre linear density and H the average sliver or yarn linear density.

Thus, other factors remaining constant, irregularity will tend to increase as fibre linear density increases. Since yarn irregularity tends to influence the end-breakage rate in spinning, this also will tend to increase (other things being equal) as coarser fibres are substituted.

2) Fibre flexibility is proportional to a negative power of fibre diameter or thickness. The handle, softness, and pliability of fabrics are all dependent on the bending properties of the fibres, so good fabric handle will require fibres of small diameter (or linear density).

3) Since nep production depends on fibres being flexible enough to be bent round adjacent fibres, it would be expected that the nep content in carding would increase as the fibre diameter or fibre linear density decreased.

A vast amount of work on the effect of changing the various cotton-fibre properties has been published, and this is exhaustively reviewed by Hunter[1]. Seshan et al.[2] reported that fibre length, tenacity, fineness, and maturity together account for about 82% of the variation in the count-strength product (a measure of yarn tenacity) of open-end-spun yarns. Preysch[3] found over many different cottons the following contributions to yarn tenacity.

Fibre length (span length and uniformity ratio)	39%
Micronaire value (fineness and maturity)	18%
Fibre tenacity	20%
Unknown factors	23%

For combing wools, the paramount importance of fibre diameter is well recognized. Fig. 1.2A shows a plot of the U.K. price of wool tops against the mean fibre diameter. Second in importance to fibre diameter is the fibre-length distribution of wool.

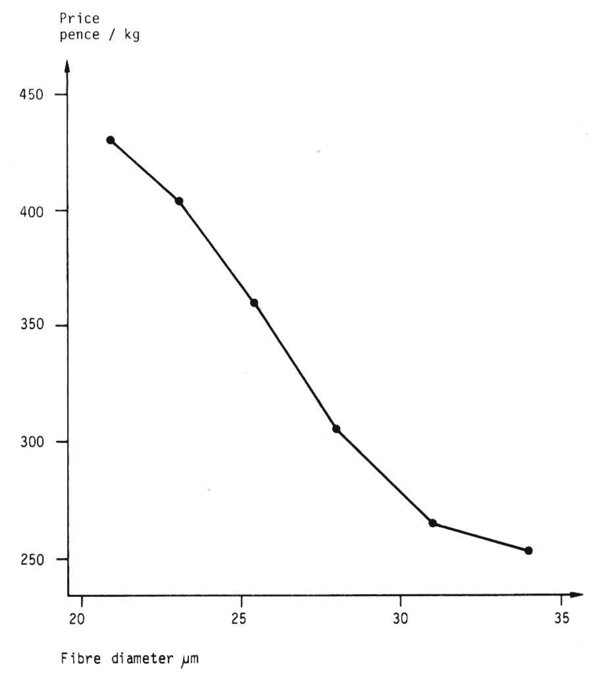

Fig. 1.2A Quoted price of U;K; tops plotted against average fibre diameter

The amount of short fibre (the percentage below 15 mm in length is an accepted measure) correlates with short thickness faults in yarn, and coefficient of variation of length with long faults (Grignet and Delfosse[4]). Unlike cotton, the fibre-bundle test for tenacity has not been applied much to wool, but it has been studied for 306 hosiery yarns by Hunter[5], who gives the following expression relating yarn breaking strength to fibre bundle tenacity (B), twist (T), mean fibre length (L), yarn linear density (H), and fibre diameter (D):

breaking strength varies as: $H^{1.3}B^{1.1}L^{0.2}T^{0.2}D^{-1}$.

Fibre crimp may be of importance for man-made fibres since, in the short-staple field, crimp has been shown to affect the cohesion required to produce a card web with sufficient strength for further processing. For jute, it has been stated that the factors of importance in decreasing order are: fineness, bark, energy, and colour.

The quality of fibres is bound up very much with the marketing and sales function in industry. Lancaster and Waxman[6] give some important information on industrial attitudes to fibre quality in their work on industrial buyer behaviour in relation to the purchasing of synthetic fibres for use in the U.K. textile industry. This work included a postal ballot carried out among a number of firms in the apparel, industrial-textiles, upholstery, carpets, and fillings fields. The questions were designed to assess the relative importance attached by buyers of fibre to the following eight factors: suitability (i.e., suitability for processing on a particular machinery line), price, quality, availability, delivery, service, previous experience of fibre, and lastly miscellaneous factors. The histogram in Fig. 1.2B shows the results of the over-all ranking. It can be seen from this that 'quality' and its associated factor 'suitability' together score over 50% of the total.

The main conclusions of this work were as follows. Suitability and quality were the overriding factors in any purchase of synthetic fibres, and it was significant that the larger the firm the greater was the importance attached to these factors. In seeking supplier, reliable quality and reputation were the

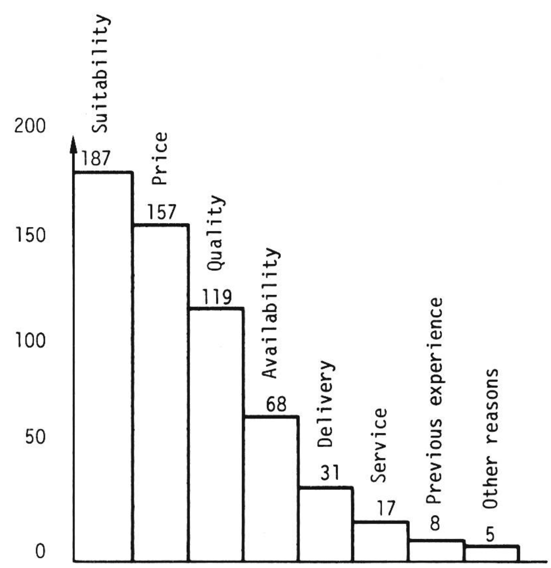

Fig. 1.2B The relative importance of various factors to any purchase of synthetic fibres (from Lancaster and Waxman)

most salient features. It could also be suggested that the smaller the firm, the greater was the importance attached to reputation. Consistently poor quality was the foremost factor likely to prompt a search for an alternative supplier, and the larger firms rated this aspect higher than the smaller firms.

1.3 Man-made Fibres: Quality Control of Staple Fibre - General

As was explained earlier, quality-control systems for man-made fibres are intrinsically different from those for the natural fibres, since, by controlling the machinery of staple-fibre production and the

Table 1.3A Example of Quality-control Information Supplied by Man-made-fibre Manufacturers (by courtesy of Montedison UK Ltd)

- Acrylic Fibre (Bright (L)) of Standard Production

Linear density (dtex)	Tow Total Linear Density (ktex)	Staple Length (mm)		Top				Notes
		from	to	T (inch)	C (mm)	CP (mm)	P (mm)	
1.7	-	25	80		-	-	-	HB = blend of heat-set fibre/heat-shrinkable fibre (22 ± 1%)
2.2	-	25	80	-	-	-	-	
2.8/RA	-	25	150	6	-	110		NP = anti-pilling
3.3	53-70	25	150	6	110	-	110	RA = heat-shrinkable fibre (22 ± 1%)
3.3/CA	-	25	150	-	-	-	-	
3.3/HB	-	-	-	6	-	110	-	RT = heat-shrinkable fibre (28 ± 1%)
3.3/HB-NP	-	-	-	6	-	110	-	
3.3/NP	53-70	25	150	6	-	110	-	CA = high-crimp fibre
4.4	70	25	150	6	-	-	-	CF = crimp-set fibre (for woven carpets, except Wildmann)
4.4/RA	-	25	150	6	110	110	-	
5.6	67	25	150	6	110	-	110	Top T = from Seydel or Tematex
5.6/CA	-	25	150	-	-	-	-	Top C = from Converter
5.6/HB	-	-	-	6	-	110	-	Top CP = Combed from Converter
8.9	53	25	150	-	-	-	-	Top P = Combed from card
8.9/HB	-	-	-	6	-	-	-	
8.9/CA	-	25	150	-	-	-	-	
8.9/CF	-	25	150	-	-	-	-	
13.5/RT	-	25	150	-	-	-	-	
17	55	25	150	-	-	-	-	
17/CF	-	25	150	-	-	-	-	
17/CA	-	25	150	-	-	-	-	

- Acrylic Fibre (Semi-matt (So)) of Standard Production

Linear density (dtex)	Tow Total Linear Density (ktex)	Staple Length (mm)		Top				Notes
		from	to	T (inch)	C (mm)	CP (mm)	P (mm)	
2.2	-	25	80	-	-	-	-	HB = blend of heat-set fibre/heat-shrinkable fibre (22 ± 1%)
2.2/HB	-	-	-	6	-	-	-	
2.8/RA	-	25	150	6	-	110	-	NP = anti-pilling
2.8/RB	-	-	-	-	-	110	-	RB = heat-shrinkable fibre (14 ± 1%)
3.3	53-70	25	150	6	110	110	110	
3.3/HB	-	-	-	6	-	110	110	RA = heat-shrinkable fibre (22 ± 1%)
3.3/PR	70	-	-	-	-	-	-	RT = heat-shrinkable fibre (28 ±1%)
3.3/HB-CT	-	-	-	6	-	-	-	
3.3/NP	53-70	25	150	6	-	110	-	RS = heat-shrinkable fibre (35 ±1%)
3.3/HB-NP	-	-	-	6	-	110	-	
3.3/RS	-	-	-	6	-	-	-	PR = fibre for stretch-break
4.4	70	25	150	6	-	110	110	SA = high stretchability
4.4/RA	-	25	150	6	110	110	-	
4.4/SA	70	-	-	-	-	-	-	CT = fibre for production of fine yarn
5.6	67	25	150	6	110	-	110	
5.6/HB	-	-	-	6		110		CF = crimp-set fibre (for woven carpets, except Wildmann)
8.9	-	25	150	-	-	-	-	Top T = from Seydel or Tematex
8.9/CF	-	25	150	-	-	-	-	
8.9/HB	-	-	-	6	-	-	-	Top C = from Converter
13.5/RT	-	25	150	-	-	-	-	Top CP = combed from Converter
17	-	25	150	-	-	-	-	Top P = combed from card
17/CF	-	25	150	-	-	-	-	

properties of the monomer, etc., the physical properties can be more or less guaranteed over long runs and will only fall short of those required by specification when some undetected fault in machinery or material happens. Man-made-fibre producers provide, and are expected to provide, much detailed information on their staple fibres for customers.

An example of such information is shown in Table 1.3A. This information may be considered the second link in a quality-control system for man-made fibres, the first being the planned-maintenance system used by the fibre manufacturer. The third link occurs when a user complains that a particular consignment of staple fibre is not up to specification, possibly because some difficulty in processing has been experienced. The practice is then for the producer's technical staff to examine the staple fibre complained of and possibly visit the user and establish by inspection or test if the staple fibre is up to specification. If there is then disagreement, the user can formally challenge the supplier, and tests on which the qualities under dispute can be measured have been formally laid down by man-made-fibre manufacturers or their associations (e.g., BISFA).

The tests that will be described are mostly of the reference type and apply to square-cut, bias-cut, or stretch-broken fibres, which are defined as follows.

Square-cut: Staple fibres obtained by cutting into bundles of constant length and specified by a single nominal length.
Bias-cut: Staple fibres cut so as to deliberately introduce several lengths. They are specified by two finite nominal lengths corresponding to the limits of the cut lengths.
Stretch-broken: Staple fibres obtained by stretch-breaking to a range of lengths up to a defined upper limit.

Fibre-type particulars of the physical properties of staple fibres, supplied by fibre manufacturers to their customers, include the following: linear densities; fibre lengths; shape of cross-section; breaking force; force-extension curves; tenacity; extension at break; material density; viscoelastic and recovery properties; crimp; lustre; electrical resistance; dielectric constant; specific heat; softening temperature.

BISFA rules on linear density of staple fibres
When tested by approved BISFA methods, it is laid down that the difference between the nominal linear density of a consignment and the average result as found by test should not exceed 10% of the nominal linear density.

1.4 Definitions and Abbreviations

Population or bulk

The aggregate of fibres that it is desired to characterize in one or more particulars.

Laboratory sample

A sample of fibres abstracted from the population or bulk and intended to be representative of the population or bulk.

Test specimen

The group of fibres, single fibre, or part of fibre that is tested at one time.

Critical difference

The observed difference between two test results which should be considered significant at a stated probability.

ISO

International Organization for Standardization.

BISFA

The International Bureau for the Standardization of Man-made Fibres.

IIC

International Institute for Cotton.

IWTO

International Wool Textile Organization.

ITF

Institut Textile de France

CSIRO

Commonwealth Scientific & Industrial Research Organization (Australia)

ASTM

Prefix to a standard published by the American Society for Testing and Materials.

BS

Prefix to a British Standard.

DIN

Prefix to a German Standard.

NF

Prefix to a French Standard.

1.5 Standard Atmosphere for Quality-control Tests

The test values obtained for many of the quality-control methods to be described are dependent on the temperature and relative humidity at which the specimens are conditioned and tested. This is particularly true of hygroscopic fibres, such as wool. It will thus be assumed that one of the ISO standard atmospheres for testing (e.g. 65 ± 2% r.h. 20 ± 2°C) is in use as specified in many of the test methods and contracts. Sometimes, if this is not possible, corrections may be made to the values obtained. Unless otherwise stated, and to avoid repetition, it will therefore be implicitly assumed that the test as described is carried out and the laboratory sample conditioned in a standard atmosphere for testing.

1.6 Confidence Limits of Test Results

For any quality-control test, the mean value obtained will have a standard error associated with it. The standard error indicates the extent to which the mean obtained, say, from testing n specimens, may differ from the bulk or consignment mean. Thus, if the same operator, using the same test equipment, carried out a number of such tests by taking further samples from the bulk, the standard deviation calculated from the series of means obtained would be an estimate of the standard error.

The value of standard error x t (an agreed factor) gives the maximum likely deviation of a single mean obtained from that of the bulk and is called the confidence limit (or confidence limits, since they are both positive and negative). Since the standard error is given by (standard deviation) x $n^{-1/2}$, the number, n, of specimens it is necessary to test to obtain any desired confidence limits may be calculated. Table 1.6A gives values of confidence limits for the 95% probability level for values of the coefficient of variation (the standard deviation expressed as a percentage of the mean) covering the range of interest for quality-control tests on staple fibres.

Example A test for fibre-bundle strength is known to have a coefficient of variation of around 8% for the mean value. How many specimens must be tested to give 95% confidence limits of ± 3%? From Table 1.6A, interpolating between 5% and 10% coefficient of variation for 3% confidence limits gives a value of 30 for the number of specimens required to be tested.

Table 1.6A Number of specimens to be tested to obtain stated confidence limits

Coefficient of Variation %	95% Confidence Limits as Percentage of Mean					
	2	3	5	10	20	30
2	8	5	3	2	1	1
5	24	11	4	1	1	1
10	96	43	15	4	1	1
15	220	96	35	9	2	1
20	384	171	61	15	4	3
25	600	266	96	24	6	3
30	864	384	138	35	9	4
35	1176	523	188	47	12	5
40	1537	683	246	61	15	7
45	1945	864	311	78	19	10
50	2401	1067	384	96	24	11
55	2906	1291	464	116	29	13
60	3458	1537	553	138	35	15
65	4059	1803	649	162	41	18
70	4706	2091	752	188	47	21
75	5402	2401	864	216	54	24
80	6147	2732	983	246	61	27
85	6939	3084	1110	278	69	31
90	7779	3458	1245	311	78	35
95	8670	3853	1386	347	87	39

2. Sampling Staple Fibres in Bulk for Quality-control Tests

2.1 Introduction

A quality-control system has for its objective that a piece of information, such as a set of test results, should be produced to characterize the property of a defined bulk. The bulk may consist, for example, of a number of bales of cotton or wool, the total production of combed sliver for a 6-hours production in a mill, or a consignment of man-made staple fibres consisting of 50 containers.

For all except determinations of commercial weight, testing 100% of the bulk is not possible, and the scale of the problem may be gauged from the fact that the material for a typical four-specimen fineness test may consist of a total of 10 g of fibre, whereas a typical bulk from which it is taken is 10 000 kg, so that only one-millionth of the bulk will actually be tested in this case.

Methods have been laid down to optimize the procedure of abstracting samples from the bulk and providing the laboratory sample from which one or more specimens are tested. These, as will be seen later, depend on the type of fibre and the type of package forming the bulk, but the following two principles are universally agreed to be vital in achieving the objective.

1) The samples taken from the bulk should be spread as widely as possible throughout the available bulk.

2) The method of abstracting the sample should have a negligible possibility of affecting the property to be tested. If there is any doubt about this, a subsidiary experiment should be made to prove it.

In general, it cannot be assumed that a bulk is homogeneous, so that procedures are required to take samples from different places according to a rational system. These samples may be combined to provide a single laboratory sample from which the specimens are taken, or they may be tested separately. In general, the sampling scheme must be more elaborate, the earlier in the production line it occurs, since, when taken at later stages, e.g.,from combed sliver, appreciable mixing and homogenization have taken place. No single sampling scheme can be laid down that will serve in all circumstances, and the methods to be described are examples of those specified by several international and national organizations. All these methods are designed to give a numerical sample.

2.2 Man-made Staple Fibres: Bulk-sampling

The BISFA rules, widely used for the bulk-sampling of man-made fibres, apply to the determination of properties other than commercial mass, notably fibre length and linear density. For material in the form of bales, a maximum of ten bales chosen at random are opened and a hand sample is taken from four places in the bale, two from the outside, two from the inside. The four samples are then combined in the following way with those taken from the other bales. From each of the samples obtained, a tuft of about 100 mg is taken. Each of the four tufts from the same bale is divided into four parts, each of about 25 mg. Each of the sixteen samples obtained in this way from the first bale is combined with corresponding samples obtained from the other bales. In this way, sixteen samples are obtained, each of which is representative of the consignment. A final single sample, representative of the whole consignment, is obtained by repeated doubling and halving as follows.

The first tuft is laid together with the second tuft and parallelized by repeated drawing and doubling. The drawing must be done gently so as to avoid fibre breakage. The tuft obtained by mixing tufts 1 and 2 is finally split into two equal tufts, one of which is discarded. In the same way, tuft 3 is combined and mixed with tuft 4, 5 with 6, 7 with 8, etc., one half of the resulting tuft being discarded each time. The two tufts resulting from 1, 2, 3, and 4 are then combined and so on, as shown in Fig. 2.2A. This mixing of pairs, halving, and discarding, is continued until the final sample is produced. It is essential always to split the tufts widthwise and not to pull out the fibres by their ends.

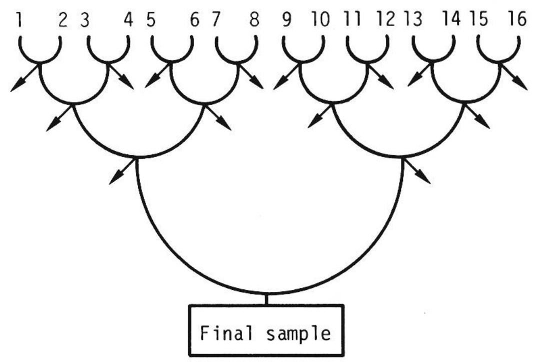

Fig. 2.2A Preparation of representative sample from consignment (BISFA)

In the USA, methods of sampling bulk staple man-made fibres for testing physical properties differ in some respects from the BISFA rules, the main differences being as follows. For consignments of 1-3 bales, sample all bales; for 4-24 bales, sample 4 bales; for 25-50 bales, sample 5 bales; and for more than 50 bales in the consignment, sample 10% of the bales, with a maximum of 8. In addition, separate sampling of inner and outer layers is eliminated, and the final combining procedure to obtain a laboratory sample from the sub-samples is eliminated for testing fibre properties **not** dependent on the as-received moisture content.

2.3 Wool: Bulk-sampling

For sampling raw or scoured wool in bulk for the purpose of quality-control tests of the physical properties of fibres, there are several procedures in use, mostly based on the principles set out below. These require the use of containers, bins, etc., and the core-boring tools described elsewhere and are facilitated by the use of conveyor belts. The first is conveniently carried out just before bulk is being transported or fed to a production line.

A decision having been made on the number of zones to be sampled and the amount to be taken from each, if W is the weight of the bulk, W/n is calculated. The bulk is then divided into this number of units, one bale package, etc., taken at random from each zone is identified and marked, and sub-samples are abstracted. If in the form of bales, the sub-samples may be taken by core-boring. IWTO specifies that the number of zones should be at least 100.

2.4 Cotton: Bulk-sampling

The number of samples taken is decided by the general principles already discussed so as to be representative. Individual bales are sampled by taking 100 g from each side of the bale and combined into one. The number of bales sampled in this way is ten or 10% of the lot, whichever is greater. For cotton products at later stages of production, three or four sub-samples are specified.

2.5 Bast fibres: Bulk-sampling (BS 2545: 1965)

Method A This method applies to bales or other bulks of bast fibres, such as flax and hemp, in the raw state and to a bulk of dressed line in bunches.

A number of bunches (preferably not fewer than 20) are selected at random from various parts of the bale or bulk, and a strick of fibre is removed from each one. Each strick is divided lengthwise by gripping the centre and pulling transversely to the length of the fibres to separate the two portions. One portion is discarded and the identity of the root and tip of the retained portion is preserved. The retained portion is halved again and again until the amount of fibre retained is sufficiently small. A composite sample is made up for test purposes by combining the retained fibre from each strick and placing root ends together and tip ends together.

Method B This method applies to bales or bulks of jute or kenaf in the raw state.

A number of heads of jute (preferably not fewer than 50) are selected at random and a reed is removed from each head. Each of these reeds is then cut into root end, middle, and tip end, the sections being kept separate and the corresponding cut lengths from all reeds bundled toghether. Each of the three composite bundles is teased out by hackling on pins or other means to remove cross-linked and tangled fibres.

2.6 Machines and Tools for Extracting Samples from the Bulk

Whenever possible, sampling from bulk is done manually by first opening the bale or package, but this may be a costly procedure. Machines have been developed for extracting wool from bales for quality-control testing.

The core test (ASTM D1060-80 and other methods) is made by using a power drill driving a rotating tube with a cutting edge. Tube diameters range from 1 to 5 cm and lengths from 25 to 100 cm.

The core-boring tool has been found suitable for determinations of wool fineness but not accepted for determining fibre length or strength owing to the chances of cutting the fibres that may become part of the specimen. Advantages of core-boring are that opening the bale is avoided and samples may be extracted from the inner parts of the bale.

The CSIRO Grab-sampling Machine was developed in Australia to extract undamaged samples of wool fibres from any position inside the bale (Tollis* and Rottenbury). The bale is positioned underneath the frame of the machine. A hydraulic ram provides the force for penetrating the bale and another ram does likewise for taking the sample. Prior to sampling, a hot-melt adhesive is applied to the pack and an incision is made at an angle to the weave; both processes reduce the possibility of pack contamination of the wool. The main ram pushes the 'grab jaws' into the side of the bale, through the incisions, to a predetermined depth. The secondary ram then opens one jaw of the grab, the other jaw being in a fixed position. A sample of size 100-550 g can be taken, depending on the length of the main-ram travel of the grab in the 'open' position, in what might be called the feed mode. The grab jaws then close, and the sample is withdrawn from the bale. Since the grab sample is not damaged, it provides samples for any quality-control test.

2.7 Sampling Efficiency from Bulk

When one is sampling fibres from bulk lots consisting of bales, bins, or packages of staple fibre or balls, packages, crates, bobbins, etc., of intermediate products, the objective is to arrive at a final laboratory sample and hence specimens for test that are representative.

The scheme of sampling is aimed at minimizing the standard error of the estimate of property to be determined.

There will be normally two main components of variability of fibre property in the bulk to be sampled, and these are often unknown and can only be estimated from previous experience of similar bulks being sampled. These components can be represented as follows:

Let σ_z be the standard deviation due to bales, bins, packages, etc., which we shall refer to collectively as 'zones', so that σz is the between-zones standard deviation.

Let σ_r be the average standard deviation within zones. Let n be the number of zones and N the total number of specimens to be tested. The average number of specimens to be tested from each zone is N/n. The standard error of the mean value of the property to be tested for quality-control purposes will be given by:

$$SE = (\sigma r^2/N + \sigma z^2/n)^{1/2}$$

It can be seen from this that, unless σz is known to be very small compared with σr, the way to reduce the standard error is by increasing the number of zones at the expense of the number of specimens to be taken from each zone.

If time and cost allow, it is therefore best to take one or two sub-samples from the largest possible number of zones to provide the amount from which the specimens will ultimately be taken.

* Tollis and Rottenbury, REF.7

3. Laboratory Sampling to Select Specimens for Test

3.1 Introduction

When the bulk-sampling procedure has been carried out to provide a smaller but representative amount, further sampling procedures that have been devised are used to ensure that the specimens selected for test are unbiassed and are representative of the laboratory sample. These four methods, which will now be described, are also used when for some reason only a small sample is provided, e.g., when it is received through the post or taken from a ball of sliver in current production.

3.2 Apparatus

The apparatus required for all methods is as follows:

1. velvet-covered boards about 1 cm thick x 35 cm x 35 cm;
2. similar velvet-covered boards 12 cm x 25 cm;
3. glass or transparent plastics plates about 3 mm thick x 15 cm x 25 cm;
4. similar glass or perspex plates about 12 cm x 15 cm;
5. surgical forceps with pointed ends suitable for gripping single fibres;
6. a piece of net or a net bag containing 400 meshes, each about 10 mm square.

3.3 Zoning Method for Loose Staple Fibre

The whole available bulk is spread out on the floor or on a large table, and about 40 handfuls are taken. Each handful is taken from a different region, about equally spaced throughout the bulk. One of the handfuls is then divided carefully into two, and half is rejected. The retained half is again divided into two, and half rejected. This procedure is continued until about 20 fibres are left: only a little experience is necessary to decide from the size of the tuft when this number of fibres remains. Random selection during this process is obtained by rejecting the half remaining in the left and right hands alternately. At each stage, care should be taken to avoid fibre breakage, for example, a single lock should be divided into two locks lengthwise. Each of the handfuls is reduced in this way, the groups of fibres selected from each being stored separately on a large velvet-covered board and covered with glass plates. The groups of 20 or so fibres are then transferred separately as required to a small velvet-covered board and are all tested.

If the material is a large amount contained in a bin from which it will be removed in containers, it is best to carry out the sampling while it is being moved. From each container (or every second or third) a handful is taken as it is being filled; if the number of handfuls thus taken is rather more than required, it may be reduced afterwards by discarding, say, every third handful taken. The handfuls are then reduced to about 20 fibres each, as described.

3.4 Random-draw Method for Slivers

The sliver to be sampled is held firmly in the right hand near to a free end and gripped at a distance of about 30 cm by the left hand. It is then gently parted by separating both hands, and the shorter piece is discarded. The remaining piece is placed along the centres of two velvet boards, placed edge to edge with the parted end near the front of the first board as shown in Fig. 3.4A.

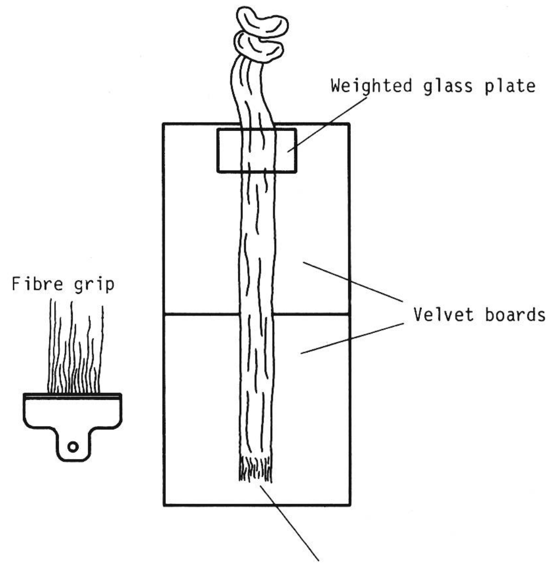

Fig. 3.4A Random-draw sampling

A weighted plate is first placed on the sliver near the back edge of the second board to prevent the sliver from moving. The grip is then used to remove and discard a 2-mm fringe of fibres. The procedure is repeated, successive 2-mm fringes of fibres being removed and discarded for a distance about equal to that of the longest fibre in the sliver. The sliver end has now been 'normalized', and any succeeding draw of fibre ends will be a representative sample. A draw chosen at random from, say, the next five taken, is taken as the test specimen.

The sampling device of the Almeter (Fibroliner) described in 4.8.3 is an efficient method of carrying out this method of sampling by automatic means.

3.5 Cut-square Method for Sampling Slivers and Yarns

A length of about 60 cm of sliver is spread out widthways at one end and laid on a velvet-covered board so as to give a uniform layer of fibres as thin as possible, as shown in Fig. 3.5A.

The sliver is covered with the rectangular glass plate of 25 cm x 15 cm, the long side being placed slightly obliquely to the orientation axis of the fibres and a fringe a few centimetres long being left protruding at the edge. The weight of the glass plate should be sufficient to ensure a firm adherence of the fibres to the velvet.

The fringe is then cut by scissors a few millimetres from the edge of the glass plate. With tweezers, all the fibres that project beyond the edge of the glass plate are extracted one by one or in small tufts and discarded. Great care should be taken to avoid any displacement of the fibres covered by the glass.

The plate is then moved back about 2 mm, and the protruding fibres are removed one by one. This is

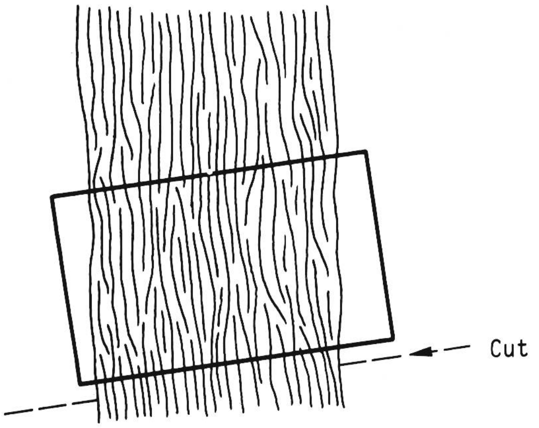

Fig. 3.5A Cut-square sampling

repeated twice. The plate is moved back a third time to expose fibre ends to provide the specimen. If there are obviously too many fibres exposed, every alternate fibre or every third fibre is selected for test to reduce the number and still maintain a representative sample. If more are required, the plate may be moved back a fourth time to provide further specimens.

Yarns are sampled in the same way except that the length of yarn to be squared is first untwisted.

3.6 Mesh Sampling of Loose Staple (Man-made Fibres)

A mass of at least 25 g of fibre is taken, this being sufficient to form under the specified mesh net a fibre pad of thickness at least equal to the nominal fibre length but not greater than 60 mm. From each mesh of the net, one fibre, an end of which is visible within the area of the mesh, is extracted by forceps, but a fibre that protrudes by more than 10 mm should not be selected. The mesh is searched systematically and fibres are removed, one from each mesh, and either measured for the required property or stored on a velvet board. Any fibre too difficult to extract is abandoned, and the operator should pass at once to the next mesh. If the required number of fibres is not obtained with one fibre from each mesh, the search is repeated until the number required are obtained.

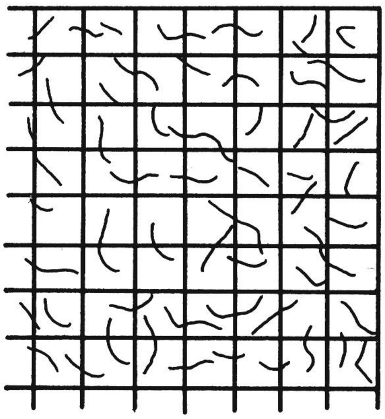

Fig. 3.6A Mesh sampling (man-made fibres)

4. Quality-control Tests for Fibre Length

4.1 Fibre-length Distributions

The basic method of expressing a fibre-length distribution for quality-control purposes is by a graph, diagram, or table on which the 'amount' of fibre is shown against a length unit, and generated manually or instrumentally by attached transducers and data processors. The two general properties used to represent the amount of fibre are: (i) the number of fibres in each length group and (ii) the mass of fibre in each length group (perhaps estimated indirectly by some related property, such as electrical capacitance or optical density).

Although the development of methods and instruments for measuring fibre length has taken different courses in the short- and long-staple fields, notably for cotton and wool, the general principles of the distributions are the same and will be considered together as far as possible to preserve the unity of the subject and avoid repetition. They will be explained in relation to Table 4.1A, which is a synthesized distribution of 100 fibres, and the corresponding figures 4.1A-4.1H.

Table 4.1A Basic Fibre-length Distributions

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Group	Numerical		Length-biassed			Tuft Curve (%)	
Centre	Distribution		%Number x Group		Length Exceeding	Numerical	Length-biassed
(mm)	%Number	%Exceeding	Centre	%	%		
2.5	1	100	2.5	0.07	100	100	100
7.5	2	99	15	0.41	99.95	87.21	89.20
12.5	4	97	50	1.37	99.54	74.55	78.40
17.5	8	93	140	3.83	98.17	62.15	67.66
22.5	11	85	247.5	6.76	94.34	50.26	57.05
27.5	14	74	385	10.52	87.58	39.39	46.87
32.5	13	60	422.5	11.54	77.06	29.92	37.41
37.5	9	47	337.5	9.22	65.52	22.25	29.09
42.5	8	38	340	9.29	56.30	16.24	22.01
47.5	6	30	285	7.79	47.01	11.38	15.93
52.5	6	24	315	8.61	39.22	7.54	10.85
57.5	7	18	402.5	11.00	30.61	4.48	6.62
62.5	5	11	312.5	8.54	19.61	2.17	3.31
67.5	6	6	405	11.07	11.07	0.77	1.20
Total	100			100			
Mean (mm)	36.6			43.8			
σ	16.3			15.6			
CV%	44.3			35.7			

With the word 'specimen' retained to refer to the fibres that are actually measured to provide the data or signals, there are two types of specimen that arise naturally from textile products and are convenient for length measurement.

The first is the numerical specimen, in which the relative numbers of fibres in each length group are the same, within the usual statistical sampling limits, as in the bulk from which the specimen is taken. This type of specimen arises naturally, for example, by selecting all the ends of fibres lying within a narrow strip of sliver as illustrated in Fig. 4.1A. Such a specimen is illustrated in Fig. 4.1B with the left fibre ends aligned on a vertical axis. If all the fibres in this numerical sample are measured for length and classified in 5-mm groups, as in columns 1 and 2 of Table 4.1A, the basic fibre-length distribution illustrated as a histogram in Fig. 4.1C is obtained. It is a numerical distribution, since the frequencies are based on numbers of fibres (transformed to percentages of a total).

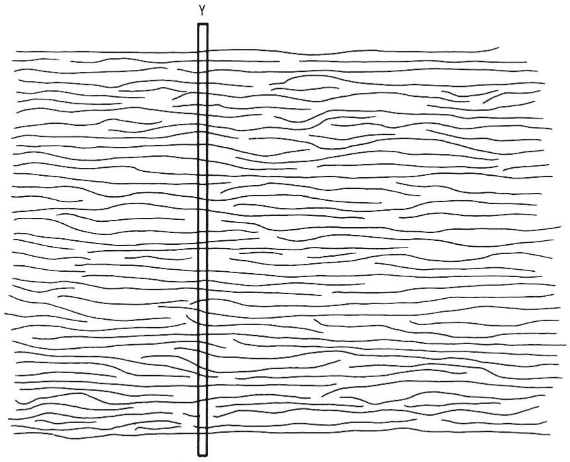

Fig. 4.1A Fibre ends in sliver giving numerical sample