# COTTON FIBRE TESTING TRAINING COURSE

## Theoretical Background

presented

by

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# TECHNOLOGICAL IMPORTANCE OF

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## 1. INTRODUCTION

Cotton is an industrial raw material which has to be processed into other products, namely yarns and fabrics. The quality of the final products, and hence their value, depends to a large extent on the basic properties of the fibres from which they are made. From the point of view of producing a high-quality product, the most important fibre properties are:

- Fibre Length,
- Fibre Strength,
- Fibre Maturity,
- Fibre Fineness,
- Micronaire value (specific surface)
- Trash content

It is not just the average values of these parameters which are important. Of equal (sometimes greater) importance is the uniformity, or variability in the values. So far as the textile manufacturer is concerned, changes in these six properties are what determine:

- Spinning potential - the finest yarn which can be spun,
- Spinning efficiency - the cost of spinning a particular type of yarn,
- Yarn strength, regularity, and appearance - the quality of a particular type of yarn,
- Yarn processing efficiency - the cost of making the yarn into a fabric,
- Fabric strength and appearance - the quality of a particular type of fabric,
- Dyeing efficiency and regularity - the cost and quality of particular dyed yarns or fabrics.

Several of the properties are correlated one with another. Thus, a cotton type which has a long staple length also tends to be fine and to have a high strength. A fibre which is weak or is non-uniform in strength will tend to be non-uniform in fineness and maturity, and is likely to develop non-uniformity in length due to fibre breakage during processing.

## 2. LENGTH

Fibre length is probably the most characteristic property of cotton. Each cotton fibre is in fact a single hair cell which has grown out from the surface of the seed. Cotton is the longest hair cell known in nature. During the maturing period, the first thing that happens is that the hollow hair cell grows in length, the final length and diameter depending on the species and variety. The development of length takes between 15 and 20 days. Barbadense type cottons will take longer to lengthen than Hirsutum types and they will be finer. For the finest cottons, the ultimate length may be 3000 times the diameter; for the shortest and coarsest types it may be only 1000 times. Only after the hair has grown almost to its full extent does the body of the cell wall begin to be deposited, day by day in a spiralling pattern, working from the outside hair walls towards the centre. This takes a further 40 to 50 days. Hair lengthening and cell wall deposition will occur faster in a warm climate than in a cooler one.

Fibres which are long and strong will also tend to be more lustrous. Finer and longer fibres can be spun into finer yarns of the highest quality.

 

The spinner uses one or other of the indicators of the average length of the longer fibres - effective length, upper half mean length, 2.5% span length - to set up his spinning machinery. The spacing between drafting rollers has to be carefully chosen so that the maximum control is obtained during drafting without excessive fibre breakage. Poor control in drafting leads to irregular yarns with relatively low strength. Thus, the length uniformity, and especially the short fibre content, is very important in determining spinning efficiency and yarn quality.

During drafting, fibres which are gripped by the front rollers are drawn through the fibre fringe and their trailing ends will tend to straighten the leading ends of those fibres which are still gripped by the back rollers. Short fibres cannot be controlled in the drafting zone; they are often called floating fibres because they spend a relatively large amount of time floating between the two pairs of drafting rolls, not being gripped by either. Since they are not properly drawn forward at the appropriate time, they can tend to bunch together and they can cause disturbances in the smooth flow of drafting which can lead to irregularities in the yarn.

Irregularity in the yarn is undesirable in itself, because of the appearance of the yarn, but it also has the secondary effect of producing weak places in the yarn which will reduce its average strength and will increase the non-uniformity of strength. Irregularity in both mass and strength will impair the processing performance of the yarn during winding, beaming, sizing, and weaving. Thus, an irregular yarn is more expensive to produce, more expensive to convert into fabrics, and has a lower value in the final product.

Short fibres can originate in several ways. Usually the length uniformity of a cotton as it grows on the seed is pretty good, although no doubt some cotton types are more disposed to non-uniformity in length than other types. Most short fibres are generated either during ginning or in textile processing by fibre breakage.

The cotton may be a type which inherently tends to produce short fibres. This could be because it is very strongly attached to the seed - finer cottons on the whole tend to be less strongly attached than coarser ones - or it could be because the cotton is genetically disposed towards low maturity or a high frequency of fibre defects and growth abnormalities.

Alternatively, the growing conditions may have been adverse so that a normally strong cotton has been weakened by insect damage or has a low average maturity.

However, high levels of short fibre content can be produced in perfectly sound fibres by poor ginning practice. For example, over drying in the gin so that the cotton is processed at low moisture content, or excessively high production rates, or excessive amounts of lint cleaning after ginning can all result in large amounts of fibre breakage and the generation of short fibres.

## 3. STRENGTH

The average strength of the fibres determines the strength of the yarns which can be made. The dependence of yarn strength upon fibre strength is not simple. It depends on the count of yarn which is to be made and is affected by the fibre length and fineness.

Length and fineness work together in affecting yarn strength so that a useful parameter to consider is the aspect ratio. Aspect ratio, in general, is the ratio of length to diameter but in this case, we use the standard or intrinsic fineness, Hs, in place of diameter. Standard fineness is the gravimetric fineness, H, divided by the maturity ratio, M.

 

Thus, we can define the aspect ratio as

Aspect Ratio = Length / Standard fineness
= Length x Maturity / Fineness

In general, when coarse yarns are being spun, then fibre strength plays a dominant role in determining yarn strength. The finer the yarn, the more important is the aspect ratio.

Strength, and especially strength uniformity, is also important in the generation of short fibres. Obviously, a strong cotton is better able to withstand a harsh ginning treatment than is a weak fibre, so there will be less fibre breakage.

## 4. MATURITY

Cotton of a variety which is well adapted to its growing area and which has been grown under favourable conditions will have a high average maturity. However even such cottons will contain some immature fibres, for example those which came from bolls at the extreme periphery of the plant which did not have time, or nutrition to mature fully before harvesting. A higher proportion of immature fibres may be caused by bad weather, by inadequate nutrition, or by biological attack from pests or diseases.

Mature fibres are stronger, more lustrous, stiffer, and more lively than immature ones. They will dye to a deeper shade from a standard dyebath. Immature fibres are weak, dull, and limp by comparison. They may also be discoloured and will not dye as deeply.

Immature fibres can cause serious trouble in the spinning operation which can lead to low spinning efficiency (high cost) and low quality in yarns which in turn leads to low efficiency in yarn processing and fabric manufacture, and low quality in fabrics and garments.

One of the most serious consequences of immaturity is a tendency to form neps - small tangled bunches of fibres which degrade the appearance of yarns and fabrics and interfere with the smooth operation of spinning. Neps of immature fibres will also show up as a quality defect in yarns and fabrics, particularly if these have been dyed. In this case the neps cause white specks to appear on the fabric surface which can ruin the fabric quality if they appear in significant numbers.

Immature fibres are more likely to break during the ginning and spinning operations. This may cause an excessive quantity of short fibres in the raw cotton or the card sliver. Short fibres are very damaging to spinning efficiency and yarn quality because they interfere with fibre control during the drafting operation.

If immaturity is caused by pests or disease, then the cotton may be stained or grey, and there may be stickiness. If a whole boll has been affected, there may be bundles of dead fibres which cling together and are difficult to deal with in spinning.

After dyeing, immature fibres appear to have a paler shade than mature ones for the same amount of dyestuff in the fibre. This is a purely geometrical effect but it can be a cause of poor efficiency in dyeing and a source of barré, (yarns with different depths of colour) in woven and knitted fabrics.

The standard tests for maturity deliver an average value, so they are not particularly sensitive to small concentrations of immature or dead fibres. However, even small concentrations can be damaging to spinning efficiency and yarn and fabric quality. Therefore, it is advisable to be very critical of cotton lots whose average maturity is not fully up to standard.

 

## 5. FINENESS

It is important to differentiate between cottons with a low gravimetric fineness (weight per unit length) and those with a low intrinsic fineness (cross section perimeter). Low gravimetric fineness can be an indicator of low maturity in an intrinsically coarse cotton.

In general terms, provided that a sample has a good average maturity, then a higher quality is indicated by a finer cotton i.e. an intrinsically fine cotton having a small perimeter. Usually, intrinsically finer cottons are longer, stronger, and more uniform than coarser ones. They will make stronger, more uniform yarns and they can be spun at lower twist levels and at higher speeds.

Gravimetric fineness determines the theoretical spinning limit of a given cotton. Depending on the spinning technology being used (e.g. ring spinning or open-end rotor spinning), a certain number of fibres must be present in the cross section of the yarn for efficient spinning and for good yarn quality. For ring spinning, the number of fibres can be less than 80 but for rotor spinning it must be more than 100.

Thus, the finest yarn count that theoretically can be made from a given cotton is directly proportional to the fineness. For example, when spinning with 100 fibres in the yarn cross section, a cotton with a fineness of 100 mtex can be spun into a 10 tex (60 Ne) yarn; a cotton with a fineness of 200 mtex can only be spun to 20 tex (30 Ne).

The practical, or economic spinning limit, for a given spinning set up, will depend on the efficiency of spinning which depends not only on gravimetric fineness but on a combination of fibre properties including length, length uniformity, short fibre content, impurities, surface properties and intrinsic fineness.

Obviously, a very fine fibre is not as strong as a coarse one and it also will have a greater tendency to make neps during ginning and processing. Therefore, it has to be processed more gently. Nevertheless, a better quality of yarn will generally result from an intrinsically fine, mature fibre than from an intrinsically coarse fibre which has the same linear density (due to lower maturity).

## 6. MICRONAIRE

Since micronaire is a function of the product of fineness and maturity, it follows that the same technological considerations apply as for fineness and maturity. For a given variety of cotton, there will be a level of micronaire which corresponds to a fully mature sample. Lower levels of micronaire value will indicate increasing amounts of immature fibres i.e. lower levels of both fineness and maturity. Since individual spinners tend to buy a limited range of cotton types, they learn what is the appropriate range of micronaire values for their cotton types which correspond to a good or adequate level of maturity.

Micronaire is the quickest and most reliable test which can be made on a cotton sample so it is in widespread use by spinners to control the quality of their cotton purchases and to compose even running mixtures of different cotton deliveries.

Provided that the spinner has a fair amount of experience with the particular cotton types, then micronaire is one of his most useful and reliable objective tests. Problems can arise when new varieties are introduced to the mill (which may have a different intrinsic fineness). In this case a separate determination of fineness and/or maturity will be required to establish the true nature of the material but, even so, the spinner will not be sure of the practical performance of the new cotton until he has actually spun large quantities.

 

Thus, micronaire is one of the key blending criteria for a spinner because, for a cotton that he is familiar with, it will be a good indication of the nep forming potential, the processing efficiency, and the dyeing efficiency of the material.

## 7. TRASH CONTENT

Trash content has a large influence on the value of a raw cotton for three reasons.

### 7.1 Waste

The trash content determines the amount of waste which will be made during spinning. Therefore, the value of the cotton is reduced in direct proportion to the amount of trash. The grade of raw cotton, and therefore its selling price, is directly related to the trash content (see tables and charts).

### 7.2 Spinning efficiency

Trash content determines the spinning efficiency i.e. the cost of conversion of the raw cotton into yarn. In this case it is not the absolute quantity of trash which is important but the type of the impurities.

For example, the most damaging form of impurity is seed coat fragments with attached fibres. Such fragments are very difficult to remove in spinning. They can drastically affect the spinning efficiency both in ring spinning and in rotor spinning (see appendices).

The quantity of seed-coat fragments present, in a given lot of cotton, depends mainly on three factors.

a) The genetic constitution of the seed. Some cottons have weak seed coats which are easily broken and some cottons have fibres which are very strongly attached to the seed. In either case there is a tendency for fragments of the seed coat to be pulled away with the fibres during ginning.

b) The growing conditions. Seed coat fragments can arise from immature or aborted seeds which may be small enough to pass through the grids during ginning and are then broken up by the saw blades or by the lint cleaners.

c) Poor maintenance of the gin. Towards the end of the ginning season, gin parts may be worn and settings may not be correct. In such cases seeds can be damaged resulting in the generation of seed coat fragments with attached fibres.

Heavy trash, in large particles, is much easier for the spinner to remove from the cotton than very fine particles. The finest particles are particularly dangerous in open end rotor spinning where they cause a build-up of deposits in the spinning rotors. Spinners usually have a set routine for cleaning out their rotors so a cotton which has a higher level of fine dust and very small trash particles may produce a large quantity of sub-standard yarn before the spinner realises that anything is amiss.

Fragments of seeds can cause stickiness at card rollers and drafting rollers. Much more serious stickiness problems are caused by insect residues, called honeydew which can make a cotton impossible to spin and can shut down the factory.

 

Because of the effect of trash content on the grade and the price of raw cotton, ginners will strive to produce a clean and white material by using very aggressive lint cleaners. Unfortunately, although this removes most of the heavy trash and improves the grade, it also causes trash particles and seed coat fragments to be broken down into small fragments, many of which remain in the ginned lint. In addition, many fibres are broken which causes an increase in the short fibre content (see appendices).

## 7.3 YARN QUALITY

Trash influences the yarn quality. Because the spinning efficiency is impaired, the yarn quality suffers. The yarn may appear dirty and it may have poor regularity. A cotton which is difficult to clean, because of the nature of the trash, will have to be processed aggressively by the spinner which may cause the generation of excessive neps and short fibres. Both of these have an adverse effect on spinning efficiency and yarn quality.

 

# THE MEANING AND MEASUREMENT OF

# COTTON FIBRE PROPERTIES

## 1. INTRODUCTION

Length, Strength, Fineness and Maturity are four of the most important fibre properties of raw cotton. They have a strong influence on the spinning potential of the cotton, the efficiency of the spinning operation, the quality of the yarn which can be produced, and the efficiency of the subsequent dyeing and finishing processes. In this paper we will look at the various definitions of length, strength, fineness, maturity, and micronaire and some of their interrelationships in terms of fibre structure and fibre geometry. We will also consider the methods of measurement of these parameters and the reliability as well as the interpretation of the test data.

## 2. LENGTH

### 2.1 Definitions

There is no single measurement which adequately describes the length of a sample of cotton. This is because, even for the same variety of cotton, differences in growing conditions or ginning treatments will result in raw cottons with different proportions of short fibre and different average lengths even though the nominal staple length may be the same or similar. In the days before rapid instrumental measurements were available, the "staple length" was agreed to be that length which was most common. In practice, this meant that different customs arose in different areas so that, for example the classers staple for an American cotton was not assessed on quite the same basis as the Classers length for Egyptian types. Thus, the staple length is determined subjectively, according to established practice and can hardly be defined except by reference to cotton standards which are maintained by different cotton producers in order to preserve continuity.

Since the advent of objective instrumental measurements, various length parameters have been defined on the basis of the length distribution - especially the cumulative length distribution, or staple diagram. Thus, length is defined in terms of one or more of a series of statistical parameters such as:

- Mean length
- Effective length
- Upper half mean length
- 2.5% Span length
- 50% Span length

As well as measures of length, we have measures of length uniformity:

- Coefficient of variation
- Uniformity Ratio
- Uniformity Index

More specific measures of length uniformity are concerned with the proportion of short fibres:

- Short fibre content
- Floating fibre index

Mean length and coefficient of variation have the normal statistical interpretations.

Effective length was originally developed in the UK as a practical length parameter for spinners which is a measure of the average length of the majority of the longer fibres. It is derived from a special, repetitive construction on the staple diagram. Its statistical definition is the upper quartile of the fibre length distribution curtailed below a value equal to one half of the effective length.

Upper half mean length is similar to the effective length but is determined (and described) more simply. It is the upper quartile of the length distribution curtailed below 1/4 inch.

2.5% Span length and 50% Span length are both derived from the fibre distribution which is produced by the Fibrograph instrument. They represent the span of the fibres at the 2.5% and the 50% point on this distribution, respectively.

The Uniformity Ratio is the ratio of mean to upper half mean length. The Uniformity Index is the ratio of the 50% to the 2.5% Span length.

Short fibre content is the percentage of fibres in the distribution which are less than a certain length - usually 12mm or half an inch.

Floating fibre index is a measure of short fibre content which takes the mean length into account. This allows that, for practical purposes, a short fibre in a long staple cotton is longer than a short fibre in a short staple cotton. Various definitions have been developed, among which are the following.

V = 100 . (staple length / mean length - 1)

V = 100 . (upper half mean / mean length - 1)

V = 100 . (2.5% Span length / mean length - 1)

## 2.2 Measurement

### Classers Length

This is a subjective appraisal as described above. It is being replaced by instrumental measurements and will not be further detailed.

### Comb Sorter Devices

These were the first semi-instrumented measurements. Essentially, mechanical devices are used to assist the operator to prepare a staple diagram i.e. to lay all of the fibres in a sample side by side on a velvet pad in descending length order. The staple diagram is obtained by tracing around the outline of the distribution. The method is slow and unreliable so it is being replaced by the more rapid, automated instruments. Its importance lies in the fact that it is the only method for producing a true staple diagram, from which all basic parameters are derived. It therefore stands as the theoretical reference method for basic research studies. Furthermore, it is the only method (with the possible exception of the Almeter) which allows the short fibre content to be derived.

 

### Almeter AL 101

The Almeter is a semi-automatic method for producing a staple distribution. It was originally developed for wool fibres, for which it is well suited. With cotton, specimen preparation is substantially more difficult so the results are probably not quite so reliable. Nevertheless, it is about as reliable as hand methods and is very much quicker. A random fibre fringe is produced and straightened by repeatedly drawing the specimen through combs - somewhat like the hand comb sorter device. The fringe is then scanned by an optical device to produce the staple diagram. The data is collected by a computer which can then print out the diagram together with the appropriate statistics.

### Fibrograph

The Fibrograph is the most rapid and the most successful automated length measurement device, whether as a free-standing instrument or incorporated into a High Volume Instrument (HVI) system. It takes a length-biased sample by pinching a specimen from the sample. The specimen is combed and straightened by brushes and then is scanned by an optical device. Scanning begins at the clamp and proceeds down the length of the fibre beard. The amount of light passing through the beard is expressed in relation to that at the clamp, which is taken as 100%, and a length frequency distribution is generated by a computer with appropriate software which allows for the fact that the sample is length-biased. The computer also makes the appropriate manipulations of the distribution to deliver span lengths or upper half mean length etc. The whole frequency distribution (Fibrogram) can be printed. The Fibrogram is not the same as the staple diagram but is a derivative of it. It essentially shows the distribution of fibre lengths that would project on one side of a pair of drafting rollers. Thus, if two pairs of drafting rollers are set at a distance corresponding to the 2.5% Span length apart, then it can be assumed that about 2.5% of the fibres would be gripped by both sets of rollers at the same time.

## 3. Strength

### 3.1 Definitions

Breaking Load is the force required to break a fibre or fibre bundle.

Breaking extension, or elongation, is the extension of the fibre or fibre bundle at the moment that it breaks.

Strength, or Specific strength, or Tenacity is the breaking load per unit of cross section or per unit of fineness. In the case of fibres or fibre bundles, strength is usually expressed in units of grams per tex.

### 3.2 Structural Origins of Fibre Strength

The cotton fibre is composed of highly crystalline micro fibrils which themselves are probably extremely strong - values in the region of 130 g/tex can be deduced from theoretical studies. The strength of the single fibre depends on the way that these microfibrils are arranged in a helical pattern and the way that the direction of the fibrillar helix reverses from time to time along the length of the fibre. The spiralling arrangement of the fibrils gives rise to convolutions, or twisting of the fibre. The periodic reversals in the direction of the fibrillar helix cause the convolutions also to reverse their direction.

What is important for our discussion is the crucial role which is played by the presence of the reversals and the convolutions, their frequency, and, especially, the uniformity of their distribution along the fibre length. In brief, and grossly simplified, the tensile strength of a normal

 

fibre (i.e. a fibre of normal maturity and without gross defects) is governed firstly by the uniformity of spacing of the reversals and secondly by the cross-sectional uniformity of the fibrillar packing.

This is because the initial effect of a tensile load is to untwist the convolutions which causes stress concentrations to occur adjacent to the reversal zones - on either side of a reversal zone, the convolutions are untwisting in opposite directions so the reversal zone is the centre of rotation. If the length of the fibre segments between each reversal zone is roughly the same, then stress concentrations are shared more or less equally between all reversal zones. However, if some segments between reversal zones are relatively short, then all of the twist will be removed from such segments before other, longer segments have been fully de-twisted. Stress will begin to concentrate close to the reversal zone, on the untwisted side, causing the fibre first to split along the fibrillar helix, and then to fracture.

How quickly the fibre will fail beside such reversal zones, and at what stress, will depend on the underlying uniformity of the fibrillar packing at the places near the reversals and hence how well the rapidly concentrating stresses can be distributed over the cross section and back through the length of the fibre segment. The uniformity of fibrillar packing across the fibre cross section is influenced by the way that the fibre collapses when it first emerges from the boll and dries out in the field, so that some areas of the fibre structure are more uniform - i.e. stronger - than others.

This general tensile fracture mechanism (together with specific weak places in the fibres caused by growth irregularities) is probably the source of the well-known effect of the tensile test gauge length upon fibre strength. The longer the test length, the more likely it contains either a weak place or a region of unbalanced twist, where stress can concentrate.

An important consequence of this fracture mechanism is that the breaking extension is governed by the number of convolutions in the shorter fibre segments. Under low loads, extension of the fibre is almost entirely the result of deconvolution - the greater the number of convolutions, the greater the extension. Deconvolution ceases either when the fibre breaks or when all of the segments having one twist direction are fully untwisted.

If the convolutions are removed, for example by mercerising under tension, then the extension at break is drastically reduced although the strength is generally significantly increased. The increase in strength is probably partly because there is no longer such a strong concentration of stress adjacent to particular reversal zones, due to the untwisting of convolutions, but also because of the improved distribution of fibrillar packing across the fibre cross section. The pronounced drop in both fibre strength and extensibility which is caused by chemical cross-linking (for example in easy-care processes) is probably partly due to an increase in the torsional stiffness of the fibre, which makes it more difficult to untwist the convolutions, and partly due to irregularities in the fibrillar packing being "frozen" into the structure so that stresses are concentrated into a smaller length of the fibre.

When cotton fibres are evaluated for their strength in the marketing system, they are not measured as individual fibres but as bundles. Bundle testing exaggerates the effects described above - since there is a greater likelihood of finding "weak" places - but also adds its own complications. These are to do with differences in the orientation of the different fibres within a bundle (some fibres may not be straight) and also different levels of crimp in the fibres. In addition, of course, there are differences in the actual strength and extensibility of different fibres in the bundle which means that the weaker or less extensible fibres break first, throwing the load onto the remainder. The smaller the differences in orientation and crimp which are present between different individual fibres in a bundle, then the higher will be the bundle strength. Likewise, the smaller the differences in strength and extensibility between different fibres (i.e. the greater the uniformity among fibres) the better will be the bundle strength.

 

## 3.3 Measurement

### Single Fibre Tests

Strength may be measured on single fibres and there are instruments for this purpose. However, in order to have a good average value, the number of fibres which must be tested is of the order of 1000. This makes single fibre measurement so slow and expensive that it is never done except in the most basic research studies.

### Bundle Testing

### 1. Pressley

In practice, virtually all fibre strength testing is done on bundles. Since each bundle may contain up to 2000 fibres, the result of a single test is already a good average. However, because of the difficulties of preparing uniform and reproducible bundles, it is necessary to test a number of bundles to have a reproducible average for a given cotton. In fact, about ten bundles should be tested but usually only two to four are measured.

The original bundle tester was the Pressley device which tested bundles with a test length of zero - i.e. the clamps were close up to one another. Later, after the effect of test length was discovered, it was found that tests made with a specimen length of 1/8 inch, or 3.2 mm gave results which were better correlated to yarn strength than the zero-gauge test. In fact, the zero-gauge test is eliminating the effect of the weak places and the convolutions, so it measures differences in the fibrillar orientation and packing uniformity. Tests at 3.2 mm allow the effect of reversals and convolutions to be felt, since the frequency of reversals in most cottons is about 2 to 3 per mm.

The Pressley device is essentially a loaded beam with the test bundle in clamps at one end of the beam. On the other side of the beam fulcrum is a rolling weight on an incline. As the weight rolls down the incline, a greater and greater load is applied across the clamps until the bundle breaks. The weight is arrested at this point and the load can be read off on a scale. The broken fibres are collected from the clamps and weighed. Since their length is known - from the width of the clamps - the tex value for the bundle can easily be calculated. The breaking load is divided by the tex to obtain the strength of the bundle.

Later models of the Pressley tester allow a spacing of 3.2 mm between the clamps.

### 2 Stelometer

The Stelometer is also a loaded beam device but its mechanical design is more sophisticated than the Pressley to avoid the large inertial effect of the rolling weight. A test length of 3.2 mm is standard and provision is made to register the breaking extension as well as the breaking load. The bundle preparation and clamping arrangements are almost identical to those of the Pressley tester so it is subject to the same difficulties and uncertainties. Bundle tex is also measured in the same way.

### 3 H.V.I

The HVI bundle tester is radically different from the two other bundle testers. The critical differences are the sample preparation and the estimation of the specimen mass. The bundle which is tested is the same one which is used for measuring length. This means it is not a flat parallel bundle but a tapered beard. The point at which the bundle is tested, is selected automatically by the instrument by reference to the length scan, in order to have a more or less consistent mass at the break point. The mass of the specimen is not determined directly but is

 

estimated from the length scan data, with a correction made for the micronaire. The reason for this correction has to do with the fact that the method of estimating specimen mass via light absorption (Spinlab) or air flow (Motion Control) is biased according to the micronaire value of the cotton.

The HVI method is much quicker than the other two methods, and is slightly more reproducible. However, its precision is open to question with certain cottons because of the empirical nature of the mass estimation. The other serious consequence of this empirical mass determination is that the device must be constantly calibrated to make sure that the mass determination is kept within proper bounds.

In fact, the need for constant calibration is not that different from the Pressley and Stelometer instruments. Because of the large operator effects with these two instruments, it is also necessary to run many calibration samples on them also.

## 4. MATURITY

### 4.1 Definitions

Maturity is defined as the relative degree of fibre wall development, or the relative wall thickness. It is essentially the proportion of the total potentially available volume within the fibre which has actually been filled by cellulose during the growing phase. The limit of fibre wall development is set by the genetic constitution of the particular cotton variety but the extent to which that limit is realised in a given fibre or fibre population is determined by the growing conditions.

A cotton fibre is a single cell which grows out from the surface of the seed. This process begins at about the time of flowering and the individual hair cells continue to lengthen for about 20 days. It is only after the cell has almost reached its full length that the cell wall begins to be deposited, in daily growth layers, working from the outside inwards. Deposition of the cell wall continues for about 35 to 50 days depending on the variety and the environmental conditions.

Flowers and fruits appear on the plant in succession so that seeds and fibres are at all stages of development throughout the season. The rate of development is also different at different positions on the plant and in different areas of the field. Thus, at harvest time there will be a relatively wide distribution of maturities present in the crop and there will always be a proportion of fibres which have not properly matured.

There are two ways to express the relative development of the fibre wall. Both of them depend on a knowledge of the fibre perimeter i.e. the perimeter of the fibre cross section. The circle which has the same perimeter as the fibre perimeter is called the equivalent circle.

a) Maturity is the ratio of the cross-sectional area of the fibre wall to the area of the equivalent circle, or

b) Maturity is the ratio of the fibre wall thickness to the radius of the equivalent circle.

Definition (a) is usually called the "degree of thickening" and is denoted by the Greek letter theta, θ. It also has been known as the "shape factor" or "form factor", or "circularity". However, these latter terms are often applied to the reciprocal of θ so they are best avoided in discussing maturity. If the area of fibre cross section is denoted by A, and the perimeter is P, then

$$\theta = 4\pi A / P^2 \qquad [1]$$

 

Definition (b) is called the "relative wall thickness" and is usually denoted by RWT or 2e / D which is twice the wall thickness, e, divided by the diameter of the equivalent circle, D.

The relationship between the degree of thickening and the relative wall thickness will be examined later.

### 4.2. Measurement

The fundamental definition of maturity as degree of cell wall development means that the only way to measure it properly is by preparing a large number (at least 500) of representative transverse fibre sections and photographing them or drawing around their projected images. From the photographs or drawings, direct measurements of the perimeter and the cross-sectional area of the fibres can be made to establish θ, or of perimeter and wall thickness to establish 2e / D. The method is extremely slow and is prone to errors so that for everyday purposes, the method is impracticable - even when use is made of computerised image analysis software to speed up the analytical part of the measurement. Therefore, more rapid methods of estimating maturity had to be developed.

Many practical procedures for estimating maturity have been developed over the years and some of the more useful of these are described in "The Origin and Assessment of Cotton Fibre Maturity" by E. Lord & S. A. Heap. Many of these methods yield estimates which are biased to some degree i.e. the maturity estimate is influenced by the intrinsic fineness of the specimen. The only practical method which is probably free of such bias, and which has actually been calibrated against careful measurements of either degree of thickening, θ, or relative wall thickness, 2e / D, is the classification of swollen fibres, according to the British method.

**Classification of Swollen Fibres.**

When cotton fibres are swollen in 18% by weight sodium hydroxide solution, the shape adopted by a given fibre depends on its degree of thickening. Large numbers of such swollen fibres can be observed relatively quickly and classified according to their visual appearance.

In the British system of classification (BS 3085), three levels of distinction are made as follows.

**Normal fibres**: appear as more or less solid rods, substantially without convolutions, and show no continuous lumen.

**Dead fibres**: have a continuous lumen and an apparent wall thickness of one fifth or less of the maximum ribbon width. They will often show frequent convolutions but may also appear as flat unconvoluted ribbons.

**Thin-walled fibres**: are those which are not classed as either Normal or Dead.

Detailed research in the 1930's and 1940's showed that the category of Normal fibres corresponds to a degree of thickening, θ, greater than about one half whereas, Dead fibres had a θ of less than about one quarter. Furthermore, it was found that the relationship between the average degree of thickening and the percentages of Normal and Dead fibres was given by the following equation.

$$\theta = 0.577 [(N-D) / 200 + 0.70] \quad [2]$$

 

For practical convenience, the term between the square brackets was designated the "maturity ratio", M.

$$M = [(N-D) / 200 + 0.70] \quad [3]$$

The maturity ratio is thus directly proportional to the degree of thickening provided that the distribution of the parameter θ for the specimen under test is typical of normal cottons. Occasionally an abnormal distribution is encountered which may cause M to be an inadequate representation of the average degree of thickening. Such cases are thought to be rare but this supposition has not actually been proved.

In the American system of classification (ASTM D1442), the swollen fibres are separated into only two groups.

**Mature fibres**: have a ratio of apparent wall thickness to ribbon width that is greater than one quarter.

**Immature fibres**: are the remainder.

The result is quoted as "percent mature fibres", Pm.

The American system of classification is more simple and rapid but it is less sensitive than the British method, and is not directly proportional to the degree of thickening. Nevertheless, it has been found that there is a fairly good statistical relationship between the results of the two tests so that the one can be estimated from the other by use of the following empirically determined equations.

$$M = 1.76 - \sqrt{(2.44 - 0.0212\ Pm)} \quad [4]$$

and

$$Pm = (M - 0.2)(1.565 - 0.471\ M) \quad [5]$$

More recently, it has been found that Pm is related to the relative wall thickness by an equation of the following form.

$$\log Pm = 2.19 + 0.88 \log (2e / D) \quad [6]$$

## 5. FINENESS

### 5.1 Definitions

Fineness can also be defined in two different ways, by relation to either the fibre geometry or to the linear density (weight per unit length).

Definitions which relate to the fibre geometry, such as the fibre perimeter or the diameter of the equivalent circle, are called biological fineness or intrinsic fineness.

Definitions which relate to the linear density are called gravimetric fineness. Linear density is nowadays expressed in units of millitex (milligrams per kilometre) although formerly units of micrograms per inch were used in some countries (especially the USA). The old British unit of grams x $10^{-8}$ per centimetre are numerically equal to millitex. Gravimetric fineness is usually denoted by the symbol H (hair weight).

The average perimeter of a given cotton variety is genetically determined and its value will show only relatively small variations, for a given variety of cotton, no matter what the local growing

 

conditions. The very finest of Sea Island cottons may have average perimeters as low as 40 micrometres whereas the coarsest Asiatic types may average around 75 micrometres. However, within a given sample there will be quite a range of perimeters so that the coarsest fibres in a Sea Island cotton sample may be larger than the finest fibres in an Asiatic type.

Obviously, for a range of cotton types, the average gravimetric fineness will be very closely dependent on the average perimeter and the average maturity but this relationship is not simple because of variations in the average shape of the cross section and of the overall specific volume. The finest Sea Island cottons can have an average gravimetric fineness in the region of 100 mtex; the coarsest Asiatic types may have values over 400 mtex. As with the intrinsic fineness, there is a large variation over individual fibres within a sample from single cotton variety.

### 5.2 Measurement

Direct measurement of the intrinsic fineness or fibre perimeter has to be done on large numbers of photographs or drawings of clean cross-sections and, just as with the direct determination of maturity, it is very difficult, tedious, and subject to errors. Therefore, it is very seldom done in practice. It is much more common to measure the gravimetric fineness or linear density or fibre mass per unit length. The measurement is usually made on bundles of fibres obtained from a comb sorter or staple diagram test.

There are many different ways of obtaining linear density from fibre bundles but the two main methods are:

a) weighing a known number of fibre segments of known length which have been cut from the centres of fibre bundles taken from different length classes of the comb sorter.

b) weighing bundles containing a known number of whole fibres taken from a series of given length classes.

In each case the very short length classes are rejected before samples are taken, and the number of fibres in each bundle is counted before weighing. The total length of the fibres is known from the number of fibres in each length group so the gravimetric fineness is simply obtained from the mass of the fibres divided by the total length.

Method (b) will usually give results somewhat lower than method (a) because cotton fibres taper towards the tip (the end remote from the seed) so that the linear density is higher at the centre than at the tip end.

### 5.3 Standard Fineness

The standard fineness, Hs, is defined as the average linear density which would have been measured if the sample had an average value of maturity ratio equal to unity.

$$Hs = H / M \qquad [7]$$

Variations in the Standard Fineness are independent of maturity and reflect corresponding variations in average fibre perimeter. Thus, Hs is a measure of the intrinsic or biological fineness.

 

## 6. MICRONAIRE

### 6.1 Definition

Micronaire is derived from the rate of flow of air which will be measured when a specimen of a given mass is confined within a chamber of given volume and subjected to a given pressure drop across the specimen. The mass, volume, and pressure drop are those provided in any of the available micronaire test instruments.

The micronaire unit is an arbitrary one, having limited physical meaning of itself. Originally, the unit was thought to be one of fineness in micrograms per inch. However, the micronaire scale had been set up by regression calibration of an airflow instrument against a series of cottons of a single species, i.e. cottons having very similar intrinsic fineness. Later experience showed that the micronaire value is in fact a measure of specific surface area which is a function of the product of fineness and maturity.

### 6.2 Measurement

Measurement of the micronaire value is straightforward and needs no special comment. However, it is useful to consider the basic theory of air permeability of fibre samples as this has a direct bearing on the use of the IIC-Shirley Fineness and Maturity Tester (FMT).

This theoretical background has been described in detail by Lord but his textbook is now out of print. The following is a summary.

According to Lord, the basic law of flow by a fluid through a porous medium is summarised by the following equation.

$$Q = K \cdot AP / L$$

where Q is the rate of flow
A is the cross-sectional area of the specimen
L is the length of the specimen
P is the pressure difference

Poiseuille's law for laminar flow through a smooth circular tube is taken to be a particular case which takes the form

$$Q = 0.125 R^2 A P / \mu L$$

where R is the tube radius
μ is the viscosity of the fluid

This has been extended to non-circular channels, giving

$$Q = 1 / Ko \cdot M^2 A P / \mu L \qquad [8]$$

where M is the ratio between the cross-sectional area normal to the flow and the total perimeter presented to the flow.

The factor Ko is said to vary between 2 and 3 for a wide range of shapes of section.

For a bed of particles, the assumption has been made that this is equivalent to a group of parallel and similar channels whose total internal surface and total internal volume are respectively equal to the particle surfaces and pore volume.

 

Assuming that the particles are held in a container of length L and section area A, and that

So is the specific particle surface, i.e. surface area per unit volume of material

E is the porosity, i.e. the proportion of space not occupied by the material

then $M = \frac{\text{volume of fluid in the channels}}{\text{surface area presented to fluid}}$

i.e. $M = \frac{E}{So\,(1-E)}$

Furthermore, since the total cross-sectional area of the channels is A.E, it follows that equation [8] may be transformed into

$$Q = 1 / Ko \,.\, A\,P / So^2 \mu L \,.\, E^3 / (1-E)^2 \qquad [9]$$

A correction to equation [9] is required to take account of the tortuosity of the channels. If Le is the equivalent average increased path length, then this leads to

$$Q = 1 / K \,.\, A\,P / So^2 \mu L \,.\, E^3 / (1-E)^2 \qquad [10]$$

where $K = Ko\,(Le / L)^2$

For various systems, Ko has been found to vary between 2 and 3, and K between 4 and 5 but in practice the value of the correction factors K or Ko has to be determined experimentally for a given system.

For plugs of fibres in a micronaire type apparatus, Lord found that K depends on the type of fibre and on the porosity (density of packing of the specimen).

After experimenting with a range of fibre types, Lord deduced the following modification to equation [10]

$$Q = 0.903 \,.\, A\,P / So^2 \mu L \,.\, E^5 / (1-E)^{\alpha} \qquad [11]$$

Where α is a factor which depends on the fibre type. For cotton it is about 1.4.

Equation [11] may thus be regarded as the practical expression of the laws governing air flow in an instrument of the micronaire type. Note that it is very sensitive to variations in E, the porosity, which depends on the dimensions of the chamber. Thus, it is necessary to calibrate a given apparatus very carefully.

In the case of a specific micronaire instrument, used for a single type of fibre, the mass of the sample, the dimensional parameters, and the viscosity of the fluid are held constant so that the rate of flow through the plug will be inversely proportional to the square of the specific surface, So. Therefore,

$$Q = I / So^2 \qquad [12]$$

where I is the instrument calibration constant

 

For cotton, the relationship between specific surface, fineness and maturity is of the following form.

$$So = S / V \quad [13]$$

and $$S = 3.79 / \sqrt{(MH)} \quad [14]$$

where H is the linear density
M is the maturity ratio
S is the surface area per gram
V is the specific volume of fibre and enclosed lumen

The specific volume of cotton probably varies somewhat with variety and growing conditions but a good average value is about 0.75 which leads us to

$$So^2 = 25.5 / MH \quad [15]$$

Therefore, the rate of flow of air through a plug of cotton should be directly proportional to the product of fineness and maturity. In practice, the micronaire instrument is calibrated according to the arbitrary micronaire scale. The relationship which Lord found between micronaire value and MH was the following.

$$MH = 3.86 X^2 + 18.16 X + 13.0 \quad [16]$$

where X is the micronaire value.

## 7. IIC-Shirley Fineness & Maturity Tester (FMT)

During the 1950's and 60's several workers had shown that if an airflow instrument was adapted to provide two readings on a specimen, at different levels of compression (i.e. at two different specimen volumes) then the difference in the two airflow readings could be related to the average maturity of the specimen. Several commercial test instruments were developed to exploit this finding, the best known of which was the Arealometer.

During the 1960's this type of research was pursued further by the International Institute for Cotton in collaboration with the Shirley Institute with the twin objectives of:

a) discovering which test conditions would give the best test accuracy consistent with ease of operation, and

b) finding a test procedure which could yield unbiassed estimates of both fineness and maturity.

The result of this research was the eventual development of the FMT instrument.

It was found that better accuracy could be obtained by measuring the pressure drop at constant flow, rather than flow at constant pressure drop (as in the micronaire instrument). In the FMT, the specimen mass is 4.0 g and the pressure drop is measured at two levels of specimen compression. The specimen density for the first pressure measurement is about 0.2 g/ml and the airflow is 4.0 litres/min. These conditions are similar to those of a micronaire test so the reading for pressure drop, PL, at low specimen density is highly correlated with the micronaire value.

 

In fact, the following relationship was found.

$$MEQ = 0.6 + 850 / (PL + 40) \quad [17]$$

where MEQ is the micronaire equivalent, as estimated by the FMT.

For the second pressure reading, PH, the sample density is increased to about 0.4 g/ml and the constant airflow rate is 1.0 l/min

In order to develop the relationship between PL, PH and the fineness and maturity, it was necessary to test a large number (100) of cotton samples having a very wide range of intrinsic fineness and maturity. These samples had all been measured for fineness and maturity by the classical methods, namely cut-and-weigh for fineness and the British method for classification of swollen fibres for maturity.

The following equations were developed.

$$FIN = 60000 / PL\ (PH / PL)^{1.75} \quad [18]$$

$$MAT = 0.247\ PL^{0.125}\ (PL / PH)^2 \quad [19]$$

where FIN is the estimate for gravimetric fineness, H, and MAT is the estimate for maturity ratio, M. In the original prototype instrument, the correlation coefficients between the estimated airflow values and the directly measured values were r = 0.934 for maturity ratio and r = 0.994 for linear density. The corresponding coefficients of variation for the differences between estimated and directly measured values were 3.8% and 3.5% respectively.

It is important to remember that the FMT is calibrated against the cut and weigh linear density and the maturity ratio. It therefore cannot be expected to deliver such good estimates of linear density measured by the whole fibre method, or maturity as percent mature fibres. An estimate for the percentage of mature fibres is delivered by the FMT instrument but this is derived from the estimate of maturity ratio by using the relationship given in equation [5].

Later, it was found by Heap that Lord's relationship between the product MH and micronaire, given by equation [16] was also a good fit for data from the FMT but that slightly different coefficients gave a fit for the relationship between MAT.FIN and MEQ.

$$MAT.FIN = 2.07\ MEQ^2 + 32.09\ MEQ - 12.68 \quad [20]$$

This equation is a very useful one as it can be used as a quality control tool in laboratories using the FMT. For every determination of MAT, FIN, and MEQ, equation [20] should be applied to estimate the product MAT.FIN. This estimate is then compared with the product of the actual measured values. If the measured and calculated products differ by more than about 5%, then there has been some error in the test technique, such as inaccurate weighing of the specimen or setting of the flow rates.

More recently, workers at the university of Ghent have investigated the relationships between microscopical measurements of relative wall thickness, 2e / D, percent mature fibres, and the PL, PH readings of the FMT. They have proposed equations of the following form.

$$100\ 2e / D = 54.5 + 0.012\ PL - 0.094\ PH \quad [21]$$

and $$Pm = 112.375\ PL^{1.21} / PH^{1.36} \quad [22]$$

and $$\log (Pm) = 2.18871 + 0.876873 \log (2e / D) \quad [23]$$

 

## 8. FIBRE GEOMETRY

Knowledge of average linear density, H or FIN and average maturity ratio, M or MAT allows the calculation of most of the other geometrical parameters. The following relationships summarise the average geometry of the cotton fibre. The specific volume of the cell wall material, at 20°C and 65% relative humidity, is taken as 0.66 (density = 1.515).

| | |
|---|---|
| Standard Fineness | $Hs = H/M$ |
| Area of wall section | $A = 0.66\ H$ (square micron) |
| Perimeter | $P = 3.8 \sqrt{Hs}$ (micron) |
| Degree of thickening | $\theta = 0.58\ M$ |
| | $= 4 \pi A / P^2$ |
| Surface area per gram | $S = 3.8 / \sqrt{MH}$ (square metre) |
| Wall thickness | $W = 0.60 \sqrt{Hs} [1 - \sqrt{(1 - \theta)}]$ (micron)<br>$= 0.60 \sqrt{Hs} [1 - \sqrt{(1 - 0.58M)}]$ |
| Diameter of equivalent circle | $D^2 = 1.456\ H / M$ |
| Diameter of equivalent lumen | $d^2 = 1.456\ H / M - 0.838\ H$ |
| Relative wall thickness | $2e / D = (D - d)/D$ |

# REPRODUCIBILITY OF TEST DATA

# FROM AIRFLOW TESTING INSTRUMENTS

## 1. INTRODUCTION

There are two particular problems with airflow testing instruments. The first is that their results can be significantly affected by operator technique, especially in the preparation and weighing of specimens. The second is that they are not absolute measuring devices but are indirect estimates for some fundamental fibre property. This means that they are dependent on calibration cotton standards to check their performance.

In order to get consistent and reliable results it is necessary to: -

a) ensure that laboratory operatives are well trained so that their preparation and testing procedures are standardised and so that all operatives are following identical, correct procedures.

b) carry out a thorough initial calibration of the test instrument before allowing it to be used for routine testing work.

c) maintain good supplies of uniform calibration cotton standards and use these to check the performance of both operatives and instrument on a regular basis.

d) participate in interlaboratory round tests to ensure that the laboratory obtains similar results to other laboratories around the world.

## 2. SOURCES OF VARIATION

The main three sources of variation are the samples, the operatives, and the instrument.

### 2.1 Sample Variation

In order to contain variation in the test results from the raw cotton samples one must ensure that sub-samples are taken from several places in the bale, mix the sub-samples well, make sure that the final specimens are truly representative of the sub-samples, and take sufficient specimens to ensure good confidence limits for the mean result of the specimens.

The number of specimens to take depends on the standard deviation to be expected between replicates and the confidence limit which is required. This number can be obtained from standard statistical texts and will not be described in detail. It is deduced from the following expression.

$$\text{Confidence Interval} = t\sigma / \sqrt{N}$$

where $t$ is the Students t statistic
$\sigma$ is the standard deviation
$N$ is the number of replications

However, it is as well to note that, in general, at least five specimens are needed for a good precision whereas there is very seldom time in a busy testing lab to use more than two or three. It is to be recommended, therefore that some form of quality control or acceptance procedure be developed within the laboratory routine which looks at the level of agreement between

 

replicate specimens and makes a decision to select further specimens for testing if the agreement is not good enough.

### 2.2 Operative Variation

Variation due to the operative is caused by use of incorrect or variable procedures, inadequate attention to detail, and inaccurate weighing. Operatives must be thoroughly trained in the correct procedures and especially in the proper use of balances. Often the proper procedures are not well defined in the manuals which are provided by instrument manufacturers. In this case (or indeed in any case) it is recommended that;

1. Firstly, the laboratory manager, or chief technician, should visit a competent laboratory which is very experienced in using the instrument. He should receive training there and spend time actually operating the instrument. If possible, he should obtain a copy of the standard method of test used by that laboratory and study the way that they carry out calibrations.

2. Secondly, he should carry out preliminary training of his own laboratory staff according to what he has learned.

3. Thirdly, he should write out a standard procedure for use with the instrument in his own laboratory, taking note of any lessons learned during the preliminary training phase.

4. Fourthly, the practical method and the written test procedure should be reviewed after some experience has been gained by the operatives in testing a range of samples specially selected for this training phase. These samples should be available in sufficiently large quantity to carry out the entire training programme. They should not be standard calibration cottons. Special attention should be paid to standardising procedures exactly and making sure that each stage is written down fully, exactly and unambiguously so that it is capable of only one interpretation.

5. Fifthly, each operative should be issued with a copy of the standard procedure so that it can be referred to at any time.

6. Finally, a further series of tests should be carried out in which each operator tests the same samples several times in a blind test, to ensure that all operators are achieving the same results (according to a selected statistical test criterion).

If consistent results are not being obtained between operators, then an investigation should be launched to try to discover the source of the discrepancies and to take corrective action whether this is by additional training or by further refinement of the standard procedure.

### 2.3 Instrument Variation

Variation between airflow instruments is due to the fact that the result of an airflow test is extremely sensitive to the exact dimensions of the test chamber. Within the normal manufacturing tolerances (i.e. at reasonable cost) for these instruments, it is not possible to build every machine exactly the same. There is also a small effect due to the local gravitation constant and to atmospheric temperature and pressure. This means that, ideally, every instrument should be thoroughly calibrated in the place where it is to be used.

In principle this is done by comparing the results actually recorded by the instrument for a range of calibration cottons compared to the average values which have been specified as the "true" values for those cottons. The calibration cottons used are the International Calibration Cotton Standards (ICCS) which are supplied by the USDA. These calibration standards are supplied

 

with the specified micronaire values but the corresponding values for FIN and MAT (or PL and PH) must be obtained from the manufacturers of the FMT.

Calibration should not be attempted until the operative who is to carry out the test has been thoroughly trained and is capable of delivering consistent and reproducible results.

At least ten tests should be carried out on each calibration cotton because it is important to establish the standard deviation of the calibration data for each individual cotton standard. This is so that, in subsequent calibration checks, it can be seen whether an individual determination on a calibration cotton is significantly different from the standard value. Too often not enough attention is paid to the normal variation within calibration standards so that unnecessary adjustments are made to the instrument in an attempt to reduce variation but which only have the effect of changing the test level.

In each case, a graph of measured versus standard values is constructed. This graph may be used to derive corrected values for the parameter in question.

Further measurements on the calibration cottons should be made at regular intervals and a control chart should be set up for each standard, with warning lines at one standard deviation and action lines at two standard deviations. Separate charts can be constructed for different operators. The mean and standard deviation for each cotton should be updated after each new determination, provided that the instrument does not appear to have drifted. Over a period of time, a very clear picture will emerge of the performance of the instrument, the reliability of the calibration standards, and the performance of individual operators.

Since the regular purchase of ICCS cottons can be expensive, many laboratories maintain their own calibration cotton standards, once they are sure that the instrument is operating satisfactorily and the operators are well trained. It is important to ensure that such "in-house" standards are available in an adequate supply and that they are well mixed so that results are uniform over a long time period. Accurate determinations of their mean values and standard deviations are of course very important before they can be used as standards. Cottons with a high standard deviation should not be selected as calibration standards.

## 3. INTERLABORATORY AGREEMENT

Many laboratories have no great interest in ensuring that their results are similar to those obtained in other laboratories. This is often the case, for example in a spinning mill where the main problem is to control their own production without the need for outside comparisons. However, even such organisations may have to buy cotton according to specifications and therefore need to be able to check their data against those of, say, a merchant.

In cases where two laboratories are testing the same materials, it is important to take account of the normal variations to evaluate the resulting test data. An excellent explanation of this aspect of acceptance or arbitration testing was given by Sasser at the 1990 International Cotton Conference in Bremen where reference was made to apparent discrepancies in test data found between a buyer and a seller of raw cotton. This paper will repay careful study (see appendices).

In addition, it is strongly recommended that a laboratory should participate in the two main series of international interlaboratory round tests, namely the Bremer Rundtest and the USDA International Calibration Cotton Check Test. Such participation is invaluable in obtaining a good oversight of testing performance and variability for the most important cotton fibre testing methods in a wide range of laboratories, and it provides a good indication of how well one's own laboratory compares with others (see appendices).

 

If the laboratory is able to participate in research and development, or standardisation work, and is also able to send a delegate to attend the International Cotton Test Conference every two years in Bremen, then a senior representative should apply for membership of the ITMF International Committee on Cotton Testing.

This committee meets every two years, at the same time as the International Cotton Conference. It discusses the standardisation of cotton testing methods and carries out research work to establish the reliability of particular instruments and procedures. At present, the committee has five working groups, namely Maturity, Honeydew, Length, Dust & Trash, and HVI testing. The committee comprises delegates from the most important cotton testing and research laboratories in the world.

 