Introduction

In order to run an effective Quality Control operation the test methods and procedures that are used to collect the data must be accurate, reproducible and meaningful.

The successful introduction of STARFISH Technology requires that close attention is paid not only to the control of the key production and processing variables but also to the application of appropriate Quality Assurance and quality control procedures within the testing laboratory.

During the collection of the STARFISH Database considerable research effort was expended in developing appropriate testing methods and procedures for the evaluation of cotton knitted fabrics.

When considering the introduction of STARFISH Technology into the mill there are certain key points about testing procedures that should be kept in mind. These are discussed in the following topics.

- Conditioning and Moisture Content
- Yarn Testing
- Fabric Testing
- STARFISH Fabric Test Methods
- Quality Control in the Testing Laboratory

Conditioning and Moisture Content

All Quality Control testing should be carried out under the standard atmospheric conditions of 20 ±2°C and 65 ±2% Relative Humidity. This is because cotton is a hygroscopic fibre, which means that it absorbs moisture from the surrounding atmosphere.

The weight of moisture present in a textile material expressed as a percentage of the oven dry weight is known as the Regain. The Regain of cotton fibres measured in the Standard Atmosphere is about 7%. The weight of moisture in a material expressed as a percentage of the total weight is known as the Moisture Content. At different temperatures and Relative Humidities, different amounts of moisture are absorbed.

The amount of moisture that is absorbed by cotton directly affects measurements of weight, both yarn weight (count) and fabric weight, and shrinkage especially when a tumble dryer is used. Furthermore, the moisture content in the fabric also has an influence on the reproducibility of measurements made for courses, wales and stitch length although at a less significant level.

Properly conditioned testing facilities can be expensive and it is not unusual for knitters and finishers to carry out testing in an unconditioned atmosphere. They should be aware that this will affect the results obtained.

If the local conditions vary significantly from day to day in temperature and relative humidity, then consideration may need to be given to the installation of some form of proper atmospheric control. In any case the location of the room where testing is carried out should be carefully considered to try and eliminate wide and unnecessary fluctuations in atmospheric conditions.

Instruments that measure and record temperature and humidity are not very expensive. Ideally, a record should be kept of the actual temperature and relative humidity at the time of testing so that extreme conditions can be taken into account when evaluating the data. Consideration might also be given to the acquisition of a moisture meter for the laboratory, so that the actual moisture content of a specimen can be measured and the weight corrected to some standard level - e.g. 7%.

Effect on Yarn and Fabric Weight Measurement

It is important to remember the effect of Moisture Content on the measurement of Yarn Count. and Fabric Weight. Cotton is a hygroscopic fibre, which means that it absorbs moisture from the surrounding atmosphere. At different temperatures and Relative Humidities, different amounts of moisture are absorbed.

The amount of moisture that is absorbed by cotton directly affects the measurement of weight, both yarn weight (count) and fabric weight. If a cotton yarn or fabric is not properly conditioned to normal Regain then measurements of yarn count and fabric weight will not be the same as when they are tested at Standard Condition. This can lead to variations in the results obtained from day to day in one laboratory and also between different laboratories. Differences in fabric moisture content can be the main source for disagreement between measurements obtained in the factory and those obtained by customers, and predictions obtained from the STARFISH software.

STARFISH predicts Fabric Properties measured at standard condition. Therefore, if Weight is assessed on fabrics that are not at standard condition the results may not correspond exactly to those predicted by the model. For example, it is not unusual for Weight check measurements to be made on fabric taken shortly after it emerges from the drier (when it is hot and dry) or the finisher calender (when it is warm and moist). Fabric measured at this time will weigh differently than after it has had time to recover moisture from or lose moisture to the atmosphere.

Variation in moisture content can also be the source of apparent knitting losses.

For example,

- Yarns may be pre-conditioned by the spinner before delivery.
- Moisture can be lost from the yarn during storage or while awaiting creeling on the factory floor, especially if the atmospheric conditions are hot and dry.
- Commercial or invoiced weight may not be the same as the actual yarn weight on delivery.
- Knitting machines achieve very high temperatures when operating under production conditions. This can cause moisture to be lost from the yarn during knitting.
- If the grey fabric roll is wrapped immediately on being doffed from the knitting machine, or if the grey fabric store is also hot and dry, then the yarn does not have an opportunity to recover moisture. Grey roll weights may then be lighter than anticipated simply because the moisture content in the yarn is low.

Portable moisture meters can provide an effective method for rapidly evaluating the moisture content in yarn packages and fabric rolls.

Effect on Shrinkage Measurement

The STARFISH Reference Relaxation Procedure specifies that the specimens should be tumble-dried to constant weight since shrinkage continues until the fabric is well below conditioned Regain. In addition, to ensure that there are no damp spots in the load, it is the practice in STARFISH testing to dry to below 2% residual moisture, and then allow the specimens to re-condition before measuring.

More shrinkage will be recorded, especially in the length direction, on a tumble-dried fabric that is not allowed to recondition before measuring than on the same fabric after conditioning. It has been found that length shrinkage recovers by about two percentage points after conditioning from the dry side.

The hysteresis effects of moisture on cotton are well known. At 65% Relative Humidity, cotton's Regain is about 7% when conditioned from the dry side, but almost 9% if wet out and allowed to dry by natural evaporation in a Standard Conditioned Atmosphere.

The later is another way of describing line-drying, and the dependence of shrinkage on the moisture regain may also be one factor in the differences that can be noted between line drying and tumble-drying.

Yarn Testing

Many knitters consider yarn testing to be either unnecessary or too costly to be carried out on a routine basis. Indeed the measurement of such properties as strength, irregularity, imperfections etc. requires very expensive laboratory equipment and large quantities of yarn to obtain meaningful results and few knitting mills are in a position to justify the installation of such equipment.

However, the maintenance of consistent yarn supplies is not only a fundamental prerequisite to the production of dimensionally stable cotton knitgoods but is also essential for maintaining fabric appearance and the efficiency of the knitting operation. Therefore monitoring yarn quality should be given a high priority in the quality control function.

In the first place, much information can be obtained by developing and maintaining an open and honest dialogue with the yarn suppliers. Spinners will almost certainly be equipped with the appropriate instrumentation to measure at least Yarn Count, Yarn Twist, Yarn Friction, yarn strength and Elongation, and yarn irregularity. They should therefore be able to provide test reports on these properties for each yarn delivery made to their customers. Once a good understanding has been established between spinner and knitter, these data are probably all that will be required on a routine basis for the knitter to be aware of the yarn quality that he is receiving.

However, since it would be unwise to rely entirely on data supplied only by the spinner a knitter should also have facilities available for measuring certain of the key yarn properties, e.g. yarn count, friction, and ideally also twist. This is because If the yarn count or twist is incorrect or deliveries are variable then the fabric quality produced will also be variable. In addition, if the yarn friction is too high, or the yarn has been inadequately Waxed during winding then problems will arise during knitting.

For these reasons yarn should be tested immediately after delivery so that out of tolerance deliveries can be quickly identified.

Measuring Yarn Count from package

Yarn Count from package can be measured using the International Standard, ISO 2060. For each sample, at least 10 preferably 20 test skeins should be taken, from different packages.

The number of samples required per yarn delivery or lot will vary depending on the supplier. For a new supplier several samples should be assessed to establish the reliability of deliveries. For a trusted supplier one sample may be sufficient. The use of Control Charts will assist long term assessment.

Basic equipment required:- Wrap reel, electronic balance or automatic yarn counting balance.

Measuring Yarn Twist from Package

The number of turns per unit length in a yarn can be measured using the untwist-retwist method (ASTM D1422). From this measurement and the measurement of Yarn Count the Twist Factor (or twist multiplier) for the yarn can be calculated.

In Imperial Units (alpha$_e$)

Twist Factor = turns per inch / √ English cotton count (Ne)

In Tex Units (alpha$_{tex}$)

Twist Factor = turns per cm * √ tex count (tex)

In Metric Units (alpha$_m$)

Twist Factor = turns per m / √ metric count (Nm)

To convert

α_e	=	α_{tex} / 9.57	α_{tex}	=	α_e * 9.57
α_e	=	α_m / 30.254	α_m	=	α_m * 30.254
α_{tex}	=	α_m / 3.162	α_m	=	α_{tex} * 3.162

Note:

The number of turns per unit length in a yarn can be difficult to determine accurately. A large number of tests is usually required in order to obtain a reliable estimate. If the spinner is dependable then his measurement of yarn twist may be more reliable than that which can be carried out quickly and efficiently in the knitting mill laboratory. However, modern automatic and semi-automatic instruments are available that have improved the reliability and speed of twist testing.

Basic equipment required: Yarn Twist Tester.

Measuring Yarn Friction from Package

Yarns for knitting should be Waxed during winding to ensure that the coefficient of Friction against steel is maintained at the lowest possible level, ideally between 0.10 and 0.15.

Provided that the spinner is applying the correct amount of wax of the appropriate quality during cone winding, or Open-end Rotor Spinning, yarn friction should not cause any problems in knitting.

However, some knitters consider that it is a worthwhile investment to check yarn friction themselves thus avoiding the potential of knitting problems arising later.

Basic equipment required:- Yarn Friction tester, cleaning yarn.

Other Yarn Evaluation Tests

For certain critical fabrics the irregularity, Hairiness etc. of the yarn can be very important. Some knitters have found that a pre-production evaluation of the yarn for appearance can prove beneficial in the long run. This can be done by making blackboard wrappings, which are then viewed and assessed under standard lighting conditions.

Computer simulation assessment systems are now available also. These systems provide a simulation of the appearance of the yarn in fabric form from certain yarn test data. However, the equipment and software is expensive.

Alternatively, the yarn can be evaluated directly in a knitted fabric. Some knitting mills, and indeed some spinning mills, quality check yarn in this way using a small diameter laboratory test knitting machine. This has the added advantage that some idea of the knittability of the yarn can also be obtained. Furthermore, the fabric can be dyed in a laboratory-dyeing machine so that any potential dyeing problems - e.g. Barré and Undyed White Specs - can also be identified.

Laboratory testing equipment is also available for the assessment of lint or Fibre Fly generation in yarns.

The level of sophistication in yarn testing and evaluation that can be justified by any individual knitter depends on many factors, not least of which is the size of the operation and the quality levels demanded by his customers. With the exception of Yarn Count, Yarn Twist and Yarn Friction testing, these other evaluation techniques are mentioned mainly for information.

Fabric Testing

There are at least two main reasons for fabric testing:-

1. For Production and Process Quality Control

   - For the knitter to ensure that the control systems for ensuring consistent Yarn Quality and Stitch Length are working efficiently, and that the correct qualities are being produced.
   - For the finisher to ensure that his processing is under close control and that the finished Fabric Properties are as expected.

Provided that fabric production and processing is under strict control the amount of time and effort spent on Quality Control testing can be kept to a minimum.

2. For Fabric Development and Process Calibration

   - When new fabric qualities are being developed or when new processing equipment has been installed, thorough testing and evaluation of the fabric is necessary to establish the Reference Dimensions and the correct production specifications.

Background information on the key fabric tests is provided in the following topics.

- Measuring Stitch Length
- Measuring Yarn Count
- Measuring Course and Wale Density
- Measuring Fabric Weight
- Measuring the Angle of Spirality
- Measuring Fabric Shrinkage

The actual test methods are included in the topics under STARFISH Fabric Test Methods

Note:

STARFISH test procedures for knitted fabrics have been established for plain jersey, six-thread crosstuck, double crosstuck, single crosstuck, two-thread fleece, interlock, 1x1 rib and 2x2 rib. These are the fabrics that are covered by the latest version of the STARFISH software. The evaluation and assessment of other fabric types using these methods is not addressed specifically in these topics.

Measuring Stitch Length

Stitch Length is the single most important constructional variable in a knitted fabric. Consequently the accurate and reproducible measurement of the average Stitch Length in a knitted fabric is fundamental to the production of fabrics with known dimensions and performance. It is also a pre-requisite for using the STARFISH software effectively.

On the knitting machine the control of Stitch Length is most efficiently and effectively carried out by means of appropriate Course Length measuring instruments. It is important, however, to check that the readings delivered by the instrument are reproducible and that they determine accurately the stitch length that is actually found in the fabric.

To do this a laboratory reference method for measuring Stitch Length in the fabric needs to be established. This can then be used for check-testing the calibration of the course length instrument(s) on a regular basis. The laboratory test will also be necessary for analysing competitor products that have to be emulated.

Briefly, stitch length in the knitted fabric is measured by marking and measuring a length along the wales equivalent to 100 visible wales, i.e. 100 needles. Cutting the fabric along the marked wales, removing at least 10 of the cut pieces of yarn and measuring their length. Stitch Length is calculated by dividing the average of the 10 measured lengths by 100.

Important Notes:

1. *For Single Jersey and Interlock fabrics, 100 visible wales is equivalent to 100 needles. For 1x1 Rib, and 2x2 Rib 100 needles is represented by 50 visible wales therefore the test length for 1x1 or 2x2 rib fabrics may be reduced to 50 visible wales. If 100 visible wales are counted then the length measurements must be divided by 200 in order to calculate the stitch length.*

2. *In the standard test method a certain number of yarns (usually nine) are removed and discarded between each test piece. In many circumstances it is necessary to measure each consecutive course. e.g.*

   To check the setting of individual positive feed tapes

   In this case a sufficient number of courses should be measured to ensure that at least five measurements are taken from each feed tape, per fabric specimen.

   To check the stitch length in more complicated structures.

   In this case the number of courses measured should represent at least five full pattern repeats. The different courses and different yarns should be identified so that any differences between e.g. all knit courses and knit and tuck courses can be distinguished.

   Two-thread fleece fabrics

   In this case the face yarns and the inlay yarns must be treated separately. The same number of measurements is required on both the face courses and the inlay courses.

3. *A common cause of variation in the measurement of stitch length is in the marking and counting of the test length - the 100 wales.*

   The method of marking the beginning and end of each test length must be precisely defined so that all testing technicians are marking and counting in exactly the same way. Different methods for marking and counting wales can lead to quite significant inaccuracies in the determination of stitch length in a fabric.

   As a simple example; If the actual length measured represents only 99 wales, or if it represents 101 wales but the nominal value of 100 is used for the calculation of the stitch length then the *calculation for stitch length will not be accurate. On any one occasion the discrepancy may only be equivalent to 1%, but if two technicians are consistently measuring or counting 99 or 101 wales then the difference between them will be 2%. This represents a very large potential error in the measurement of stitch length.*

4. *A standard laboratory instrument for measuring stitch length is the Shirley Crimp Tester. Instruments other than the crimp tester may require that the length of the test specimen is greater than the length to be measured to allow for mounting of the specimen in clamps. If this is the case, use the same marking and counting procedure to establish the correct test length but then, instead of cutting down the inside of the marked wale, cut down a wale outside of the marks. Measure the test length as defined by the inside of the marked wales. Make sure that the marked wales are continuously and distinctly marked.*
5. If the specimen length required is greater than the test length then these threads cannot be used to calculate the Yarn Count.

Measuring Yarn Count

The control of Yarn Quality is essential for the knitter, for the production of fabrics with known dimensions and performance and to obtain the best results from the STARFISH software.

For a given Yarn Type, the most important yarn property is the average Yarn Count. The count of yarn used to produce a particular fabric quality has a fundamental influence on the Properties of the finished fabric. Thus it is essential that the yarn count is known and is maintained consistently.

From the practical point of view this should be achieved through consultation with the spinner and through appropriate control procedures in the knitting mill to check that incoming yarn deliveries are delivered according to specification. These measurements should be carried out on yarn cones sampled from each delivery before knitting.

Sometimes, however, it is necessary to measure the Yarn Count actually found in the knitted fabric. When this is the case, the measurement of yarn count can be carried out in conjunction with the test for Stitch Length.

At least 50 (preferably 100) threads are removed from the section of the sample that has been prepared for measuring stitch length, and weighed. These can include the lengths of yarn on which length measurements have been made provided that the specimen length is the same as the test length.

The total length of the sample is calculated using the average length obtained from the measured lengths multiplied by the total number of threads in the sample. The yarn count (tex) is obtained by calculation.

Tex = 1000 W/L

Where W = weight in grams; L = total length in metres.

English cotton count (Ne) or Metric Count (Nm) can be calculated using the standard formulae

English Cotton Count (Ne) = 590.54 / tex; Metric Count (Nm) = 1000 / tex.

Note:

If the Fabric Type is Two-thread fleece then the same number of threads should be removed and weighed for both the face and the inlay yarn.

The STARFISH method for measuring the count of yarn taken from the fabric is summarised and annotated in the following topic.

- Yarn Count Test Method

Measuring Course and Wale Density

In a mill operating using STARFISH principles the key process control measurements are Course Density and Wale Density.

The accurate measurement of Course and Wale Densities is vital for the successful employment of STARFISH Technology. It is essential for production staff monitoring fabric quality through the production line, and it is vital for quality control staff.

If reliable averages for Reference Course and Wale densities can be established for each production quality, and accurate course and wale densities are measured on the delivered fabric, then routine shrinkage testing can be virtually eliminated with the consequent savings in fabric and time.

Therefore, it is worth devoting a considerable effort to thoroughly training all personnel responsible for counting and reporting course and wale densities so that they are all counting and reporting stitch density measurements in the same way, reliably and reproducibly.

Establish a Common Method

The single most important task is to establish a common method for counting courses (or Cells) and wales and for estimating part loops or cells at the edge of the counting area. Everybody in the factory who is required to count courses or cells and wales must do so in exactly the same way.

Measurements of courses and wales should be estimated to at least the nearest half loop. For medium to coarse fabrics estimates to the nearest quarter loop provide improved accuracy.

Measurements of cells should be estimated to (at least) the nearest quarter cell since each cell can represent 4 or 6 actual courses.

The following is a simple illustration of why this is important.

If the average number of stitches in a given fabric quality is 60 per 3 cm and estimates are made to the nearest whole stitch, the potential difference in the results obtained by different persons will be 1 stitch or 1.7%. If estimates are made to the nearest half course the potential difference is only 0.8%.

On the other hand, if the average number of stitches per 3 cm is only 30, then an estimate to the nearest whole stitch would give a potential difference between persons of 3.3%. To reduce this to below 1%, measurements must be estimated to the nearest quarter stitch.

Accuracy of Counting Glasses

It is perhaps worth mentioning that the accuracy of Piece Glasses or travelling microscopes that are used in the factory should also be checked. Several instances have been reported where the measuring area of counting glasses in use in the factory have been found to vary significantly, one from the other.

It is also important to standardise the measuring area, especially in countries that have converted from using English units (inches) to Metric units (centimetres). An inch glass and a 3 cm glass may look very similar but the measurements obtained will be quite different. (1 inch = 2.54 cm).

Most reputable suppliers of stitch counting instruments should be prepared to guarantee accuracy or offer a calibration service.

For most knitted fabrics stitch densities can be determined with adequate accuracy by counting over lengths of 3 cm. With coarse yarns, 10 cm may be preferable. Measuring over test length of less than 3 cm is not recommended.

Direction of Testing

The STARFISH rule is that courses are counted along a wale, while wales are counted along a line that is perpendicular to the wale line. The course and wale densities are thus determined in directions that are at right angles to each other, even though the lines of courses and wales may not appear to be so.

This rule was established to ensure that the measurement of course and wale densities is compatible with the measurement of shrinkage so that calculations of length and width shrinkage based on changes in the values of course and wale densities are valid.

Wale Density

Wale densities are recorded as "visible wales", that is those that are visible on the test face of the fabric. In a 1x1 Rib or 2x2 Rib construction, for example, there will be an equal number of wales on the reverse side of the fabric that will not be counted. The total wale density, taking both sides of the fabric into account, is termed the "true wales".

Course Density

Course densities are usually recorded as "true" courses. For Interlock, Rib and Plain Jersey constructions the "true courses" are equivalent to the "visible courses."

For Two thread Fleece fabrics, as defined in STARFISH, there is an inlay course for each face course. Therefore, the total or "true" number of courses in the construction is exactly double the Visible Courses. In this case the visible courses are recorded.

In Crosstuck constructions the total or "true" number of courses in the fabric may be significantly different from those that are actually visible.

Use of the Structural Knitted Cell (SKC)

In crosstuck fabrics it is extremely difficult to count the total or "true" number of courses per unit length. This is because the combination of tuck and knit loops causes some of the courses to "disappear" into the body of the fabric. For most practical purposes it is therefore more usual to count the number of Structural Knitted Cells (SKC) in the fabric.

A Structural Knitted Cell is the repeating pattern of stitches that are required to produce a particular fabric construction. The Cell or pattern may extend over several wales and courses. In crosstuck fabrics this repeating pattern creates a diamond-like pattern in the fabric, which is usually quite distinct and relatively easy to count.

For Single Crosstuck and Double Crosstuck fabrics, as defined in STARFISH, the SKC repeats over four courses and two wales. For Six-Thread Crosstuck fabric, as defined in STARFISH, the SKC repeats over six courses and two wales.

Each Structural Knitted Cell contains all of the courses required to produce the particular crosstuck construction, whether or not they can actually be seen and counted. Therefore the total or "true" number of courses can be calculated by multiplying the number of Cells by the number of feeders required to produce each pattern repeat. Conversely the number of Cells can be calculated by dividing the "true" courses by the number of feeders per repeat. STARFISH makes these calculations automatically depending on the chosen units.

Structural cells should be counted to at least the nearest quarter cell.

Measuring Fabric Weight

Area Weight is probably the most frequently tested property of any fabric. A great deal of emphasis is placed on the measurement of fabric weight, both by the customer and the manufacturer, because it is a direct representation of the cost of the fabric.

Consequently, when fabric weight measurements vary by more than a few grams they are used as justification for making adjustments to the knitting specifications or to the width or overfeed settings on the finishing equipment, in order to try and correct the situation.

It is surprising therefore that so little attention is actually paid to obtaining reliable and reproducible measurements of fabric area weight.

Effect of Moisture Content

The importance of proper conditioning and the effect of atmospheric conditions on the measurement of fabric weight are discussed in the topic Conditioning and Moisture Content.

Effect of Sample Cutter

A frequent cause of variation in fabric weight measurements is due directly to one of the most common methods of cutting fabric area weight samples - the circular cutter.

Knitted fabrics are generally fairly extensible and the act of cutting the sample can distort, stretch and spread the sample under test. This means that the cut specimen is actually not the 100 square centimetres that it is supposed to be. This can lead to errors in the estimation of fabric weight by as much as 3-4 %.

The problem is most apparent on thick, or easily extended fabrics and with fabrics that have been subjected to a tumble-drying relaxation procedure but can be found on other types of fabric as well.

For accurate determination of fabric weight it is important that:

- the test specimen is allowed to relax for a period (> 1 hour) after cutting, and
- the size and shape of the test specimen, after it has been relaxed, is checked to establish that the correct specimen area is being measured.

For example, if a cutter of nominal area 100 sq. cm is used, the diameter of the specimen should be 11.28 cm. A circle of this diameter, drawn on graph paper and stuck to a rigid material such as card, can act as a template for checking the shape and size of the specimens before weighing. If a discrepancy is found then the measured weight can be corrected by measuring as accurately as possible the major and minor axes of the specimen. If these are (a) cm and (b) cm respectively, the area of the specimen is given by:-

Area sq. cm = $(\pi * a * b) / 4$

The performance of the fabric cutter depends on the sharpness of the blades. Blades are cheap and should be replaced frequently. Attention should also be paid to the condition of the cutting board. A board which is heavily scoured or indented can affect the efficiency of cutting and trap the cut yarn ends causing yarn (and therefore weight) to be lost from the specimen.

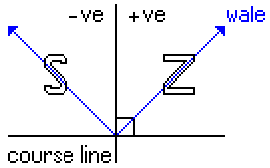
The STARFISH method for measuring Fabric Weight is summarised and annotated in the following topic.

- Fabric Weight Test Method

Measuring the Angle of Spirality

Spirality in a circular knitted fabric is the name given to the visual effect produced when the lines of wales and courses are not perpendicular to each other.

Spirality is defined as the angle made between the wales and a line drawn perpendicular to the courses. Positive spirality, or "Z" spirality indicates that the wale line is displaced to the right, or clockwise. It is caused by the use of "Z" twist yarns. Negative, "S" spirality has the wales displaced to the left or anti-clockwise and results from the use of "S" twist yarns.



Measurement is carried out simply by marking the wale line with a pen and laying a protractor on the flat, horizontal fabric so that the base line of the protractor follows the line of courses, and the centre covers the marked line. The angle subtended by the marked line and the perpendicular to the line of courses can then be noted.

Fabric spirality can cause significant problems in garments. The problem is most easily seen in garments manufactured with side seams. Spirality in the fabric causes the garment to twist, Displacing the Seam from the side of the garment. If the amount by which the seam is displaced during laundering is excessive consumer complaints will be received by retailers.

Although at the present time the STARFISH software does not predict directly the angle of spirality, it is an important physical property that may need to be evaluated - especially when new yarn suppliers are being considered. It is therefore important that a precise method and procedure is established in the mill. Spirality measurements have been made on the vast majority of the STARFISH Database fabrics. It is anticipated that predictions for this important fabric property will be included in future versions of the software.

The STARFISH Test method for Spirality is summarised in the following topic.

- Spirality Test Method

A Test Method for evaluating Seam displacement is summarised in the following topic

- Seam Displacement Test Method

Measuring Fabric Shrinkage

If a mill is operating using STARFISH principles, then routine quality control testing for Shrinkage can be reduced to a minimum. This is because, when the knitted fabric has been produced correctly, the finishing process has been properly calibrated, and the Reference Dimensions have been established, then Shrinkage in the delivered fabric can be calculated from the routine quality control measurements of courses and wales just as reliably as it can be measured.

However, when a shrinkage test is required to be carried out, it is important that the procedures adopted are strictly defined and controlled in order to eliminate (minimise) variation in the shrinkage results obtained.

For the standard STARFISH Reference method, five replicate specimens each with a minimum area of 70 x 70 cm and a measuring area of 50 x 50 cm are prepared from each fabric under evaluation. For each specimen three estimates for length shrinkage and three estimates for width shrinkage are made. Length and width results are therefore the average of fifteen measurements in each direction.

Even using this very rigorous method it is not possible to measure shrinkage more accurately than ±1 percentage point. For difficult fabrics such as Rib, Interlock, Crosstuck etc. the reproducibility of average shrinkage measurements will be not better than ± 2 percentage points.

Routine Shrinkage Measurement

For routine quality control purposes, measuring Reference State Shrinkage is too expensive, both in terms of the amount of fabric and the length of time required to carry it out. An abbreviated procedure (e.g. two cycles) will usually provide adequate information on product performance for the manufacturer and his customer.

It should be remembered however, that sample size, measuring technique and the number of replications tested all have an influence on the accuracy of the results obtained and therefore their reliability and reproducibility. These need to be taken into account when abbreviated shrinkage testing procedures are utilised.

Laundering and Drying Conditions

The laundering and drying conditions employed are very important. For example if line drying is used instead of tumble-drying, then the conditions of the washing cycle, time, temperature, duration of cycle etc. can all have an influence on the results obtained.

If tumble-drying is used then, although the details of the washing procedure are less important, proper control of the tumble-drying conditions is essential. It is also important to ensure that specimens that have been tumble-dried are allowed to properly recondition before measuring.

Similarly the number of washing and drying cycles that are carried out will affect the level of shrinkage that is developed. Generally length shrinkage increases with the number of laundering cycles, but width shrinkage may reduce with the number of cycles.

It is therefore necessary to carefully establish how the results of the routine quality control test for shrinkage relate to shrinkage measurements obtained using the Reference Relaxation Procedure, so that shrinkage values predicted by STARFISH can be evaluated in an appropriate manner.

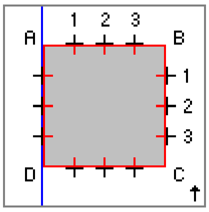
Sample Preparation

Regardless of the number and size of shrinkage specimens used, sample preparation and measuring technique should be standardised.

Fabric specimens for shrinkage testing should be single layers, not tubular fabric, and should always be square in shape; long, narrow specimens may give anomalous results.

The preparation, marking and measuring of specimens for shrinkage evaluation should be carried out according to the procedures described in ISO 3759. The use of a template is recommended.

The specimen should be marked in a square of the appropriate size, with three equidistant measuring marks on each side, so that three measurements can be made in each direction.



template on cut specimen
showing alignment with wale line and
measuring marks on the specimen

One side of the template should be aligned with a wale line, so that the length shrinkage measurements are always made along the line of wales, while width measurements are made at right angles to the line of wales.

The specimen should be marked with indelible ink, and the distances between the marks should be recorded before and after carrying out the test procedure. It is not safe to assume that the distance between the marks is the same as the size of the template.

The generally accepted convention is that shrinkage is recorded as negative, and extension is positive. Where possible, the original marked distances in the fabric should be 50 cm, but if the fabric is too narrow, or insufficient material is available, then 25 cm squares can be used.

Specimen Size and Number

The number of replications tested and the size of the test specimens will have an influence on the reliability of the results obtained. In a study of the variability of results for different test methods and specimen sizes, the following were obtained:-

Specimen Size cm	No of Cycles	Drying Method	Standard Deviations Length	Width
50 x 50	1	Tumble-dried	0.67	0.93
50 x 50	5	Tumble-dried	0.66	1.05
25 x 25	1	Tumble-dried	0.86	1.28
25 x 25	5	Tumble-dried	0.78	1.46

In order to obtain an equivalent level of reproducibility when carrying out Reference State testing, ideally at least six of the 25 x 25 cm specimens should be taken, compared with five of the 50 x 50 cm.

For commercial quality control testing at least two and preferably three specimens should be tested.

Conditioning and Moisture Content

The STARFISH Reference Relaxation Procedure specifies that the specimens should be tumble-dried to constant weight since shrinkage continues until the fabric is well below conditioned Regain. In addition, to ensure that there are no damp spots in the load, it is the practice in STARFISH testing to dry to below 2% residual moisture, and then allow the specimens to re-condition before measuring.

More shrinkage will be recorded, especially in the length direction, on a tumble-dried fabric that is not allowed to recondition before measuring than on the same fabric after conditioning. It has been found that length shrinkage recovers by about two percentage points after conditioning from the dry side.

The hysteresis effects of moisture on cotton are well known. At 65% Relative Humidity, cotton's Regain is about 7% when conditioned from the dry side, but almost 9% if wet out and allowed to dry by natural evaporation in a Standard Conditioned Atmosphere.

The later is another way of describing line-drying, and the dependence of shrinkage on the moisture regain may also be one factor in the differences that can be noted between line drying and tumble-drying.

The STARFISH Test Method for measuring Shrinkage is summarised and annotated in the following topic.

- Shrinkage Test Method

STARFISH Fabric Test Methods

STARFISH test procedures for knitted fabrics have been established for plain jersey, six-thread crosstuck, double crosstuck, single crosstuck, two-thread fleece, interlock, 1x1 rib and 2x2 rib. These are the fabrics that are covered by the current version of the STARFISH software.

Although these methods can be used for the evaluation or assessment of other fabric types, these are not discussed.

The Test Methods described in the following topics are provided for information purposes only in order to provide background information for users of the STARFISH software on how the underlying data were collected.

When the STARFISH Research Project began many of the National and International Standards that were available at the time were either found to be inadequate for the particular task that we had set ourselves or had not been developed specifically for the evaluation of cotton knitgoods.

It was therefore necessary to expend a considerable research effort on developing reliable and reproducible methods that would enable the key dimensional properties if the fabric to be discovered. Where possible published standard methods were used to provide the basis for the test method development program.

Since 1978 new or revised International Standard Methods have been developed and agreed. The STARFISH Test Methods are not intended to be taken as replacements for these published International or National Standards.

Copies of published International Standard Methods can be obtained from ISO.

Copies of published European Standard Methods can be obtained from CEN.

Copies of published National Standard Methods can be obtained from the relevant National Standards Associations, e.g. from BSI in the UK; from ASTM and ANSI in the USA; from DIN in Germany etc.

Stitch Length Test Method

The STARFISH method for measuring stitch length is summarised as follows. It should be read in conjunction with the topic Measuring Stitch Length

Apparatus

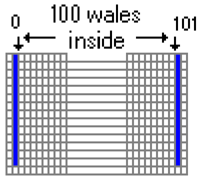
- Crimp Tester
- Counting Glass, fine marking pen, scissors.
- Means for providing the standard atmosphere for testing textiles as specified in BS 1051 and ISO 139; 65 ±2% RH at 20 ±2°C.

Test Samples

Test samples should be sufficiently large to enable 100 stitches to be cut from a series of courses in at least two different positions on the sample, avoiding edges and centre creases.

Test Procedure

1. Condition the test sample in the standard atmosphere for testing textiles until it has reached equilibrium.
2. Lay the sample on a flat horizontal surface, removing wrinkles without stretching.
3. Cut out a specimen that is a convenient size for manipulation - usually about 15 to 20 cm square.
4. Fray down the top or last knitted edge of the specimen until yarns can be removed easily without snagging.
5. Mark down a wale. Count 100 visible wales and mark down a second wale so that exactly 100 wales are inside the two marks. Carefully make two cuts exactly alongside the two marked wales on the inside of the marks.



mark wale 0, count 100 wales and mark wale 101

total wales inside the marks = 100

make cuts alongside the marked wales inside the marks

6. Remove a length of yarn from the cut portion, taking care not to lose any twist, and insert it into the jaws of the crimp tester so that the correct amount of yarn is gripped in the jaws. Measure the length to the nearest 1 mm using the appropriate tension.

Tension:

yarns greater than 100 tex	=	150 mN
yarns of 30 to 100 tex	=	100 mN
yarns less than 30 tex	=	50 mN

7. Remove the following nine lengths of yarn (unless consecutive courses have to be measured). If the test length has been cut to exactly 100 wales then these yarns together with the yarns that are measured may be saved and weighed to provide information for the calculation of yarn count otherwise they should be discarded.
8. Repeat steps 6 and 7, four more times.
9. Repeat steps 3 to 7 on another part of the sample to give a total of 10 length measurements.

Calculation of Results

In order to check that the correct number of wales has been counted in both areas of the sample, compare the length results obtained from the first specimen with those obtained from the second using the Student's t. The two sets of measurements should not be significantly different at the 99% level.

If a significant difference is found, repeat the test on two new specimens and recount the number of wales between the cuts or marks. Use all four specimens to calculate the final result.

Calculate the Mean stitch length in mm and the Accuracy from the 10 length measurements and report the result correct to 2 decimal places.

Yarn Count Test Method

The STARFISH method for measuring the Yarn Count taken from a fabric is summarised as follows. It should be read in conjunction with the topic Measuring Yarn Count

Apparatus

- Crimp Tester
- Counting Glass fine marking pen, scissors.
- Means for providing the standard atmosphere for testing textiles as specified in BS 1051 and ISO 139; 65 ±2% RH at 20 ±2°C.

Test samples

Test samples should be sufficiently large to enable 100 stitches to be cut from a series of courses in at least two different positions on the sample, avoiding edges and centre creases.

Test Procedure

1. Follow the procedure for measuring Stitch Length with the following modifications.

2a If the specimen length is the same as the test length - Crimp Tester.

Save all of the removed threads until at least 50 have been accumulated. These can include the lengths of yarn on which length measurements have been made.

Collect at least two such specimens from each of the samples that has been prepared for the measurement of stitch length.

2b If the specimen length is greater than the test length

After the stitch length has been determined, make a careful cut alongside each of the marked wales on the inside of the marks so that the test length is exactly equal to 100 wales, and remove at least 50 threads.

Collect at least two sets of threads from each of the samples that have been prepared for the measurement of stitch length.

3. Weigh the separate bundles of threads and calculate the total length of yarn.

Calculation of Results

The total length of the sample is calculated using the average length obtained from the measured lengths multiplied by the total number of threads in the sample.

The count of the yarn in tex units is obtained by calculation.

tex = 1000 W / L

where

W = weight in grams, L = total length in metres

Calculate the mean tex of the specimens and report the results correct to 1 decimal place.

English cotton count (Ne) or Metric count (Nm) can be calculated using the standard formulae.

Cotton count (Ne) = 590.54 / tex

Metric count (Nm) = 1000 / tex

Note:

If the fabric type is Two thread Fleece then the same number of threads should be removed and weighed for both the face yarn and the inlay yarn.

Course and Wale Density Test Method

The STARFISH method for counting courses and wales is summarised as follows. It should be read in conjunction with the topic Measuring Course and Wale Density

Apparatus

- Counting Glass with a viewing field of at least 3 cm, or a travelling microscope.
- Counting needle
- Means for providing the standard atmosphere for testing textiles as specified in BS 1051 and ISO 139; 65 ±2% RH at 20 ±2°C.

Test Samples

Test samples should be sufficiently large to enable Courses and Wales to be counted at 10 different places over a distance of at least 3 cm, spaced to give a good representation of the sample, avoiding edges and centre creases.

Test procedure

1. Condition the sample in the standard atmosphere for testing textiles until it has reached equilibrium.
2. Lay the sample on a flat horizontal surface removing wrinkles without stretching.
3. Position the edge of the counting glass so that it is either parallel to or perpendicular to the line of wales and count the number of courses and wales in the field of view to the nearest half course or half wale.

   Courses are counted along a wale, wales are counted perpendicular to the wale line.
4. Repeat steps 3 and 4 at nine different places on the sample to give a total of 10 determinations for courses and 10 determinations for wales.

Calculation of Results

Calculate the Mean and the Accuracy for courses and wales from the 10 measurements.

Adjust the mean to the required reporting base, e.g. per 1 cm, per 3 cm, per inch and report the result correct to three significant digits.

Note:

For most knitted fabrics, stitch densities can be determined with adequate accuracy by counting over lengths of 3 cm. With coarse yarns 5 or 10 cm may be preferable. Measuring over test lengths less than 3 cm is not recommended.

Fabric Weight Test Method

The STARFISH method for measuring fabric area weight is summarised as follows. It should be read in conjunction with the topic Measuring Fabric Weight

Apparatus

- Circular cutter of nominal area 100 square centimetres, or equivalent
- Electronic balance
- Means for providing the standard atmosphere for testing textiles as specified in BS 1051 and ISO 139; 65 ±2% RH at 20 ±2°C.

Test Samples

Test samples should be large enough to enable 5 specimens of 100 sq. cm to be taken, spaced to give a good representation of the sample, avoiding edges and centre creases.

Test Procedure

1. Condition the sample in the standard atmosphere for testing textiles until it has reached equilibrium.
2. Using the circular cutter of area 100 sq. cm cut 5 test specimens
3. Leave the specimens to relax for 1 hour
4. Measure the area of each specimen and record the measurements.
5. Weigh each specimen to an accuracy of 0.0001g and record the weights

Calculation of Results

The weight per unit area of each specimen is calculated using the formula

Area Weight g / m^2 = 10,000 * W / A

where

W is the weight of the specimen in grams

A is the area of the specimen in square centimetres

Calculate the Mean of the five specimens and the Accuracy and report the result correct to 1 decimal place.

Spirality Test Method

The STARFISH method for measuring Spirality is summarised as follows. It should be read in conjunction with the topic Measuring the Angle of Spirality

Apparatus

- Large Protractor
- Ruler
- Fine marking pen
- Means for providing the standard atmosphere for testing textiles as specified in BS 1051 and ISO 139; 65 ±2% RH at 20 ±2°C.

Test Samples

Test samples should be sufficiently large to enable 25 measurements to be taken, spaced to give a good representation of the sample, avoiding edges and centre creases.

Test Procedure

1. Condition the sample in the standard atmosphere for testing textiles until it has reached equilibrium.
2. Lay the sample on a flat horizontal surface removing wrinkles without stretching.
3. Using the fine marking pen, carefully mark along a wale line and mark along a course line. If the course line is difficult to determine by eye, unravel a few courses until the exact line is established.
4. Place the base line of the protractor along the course line, ensuring that the marked wale line intersects with the bottom of the 90° line on the protractor.
5. Record the angle between the 90° line and the wale line together with the direction of spiral.
6. Repeat steps 3 and 4 at 24 different places on the sample to give a total of 25 determinations.

Calculation of Results

Calculate the Mean and Accuracy for the 25 readings, and report the results correct to 1 decimal place. The positive or negative direction should always be included in the calculation.

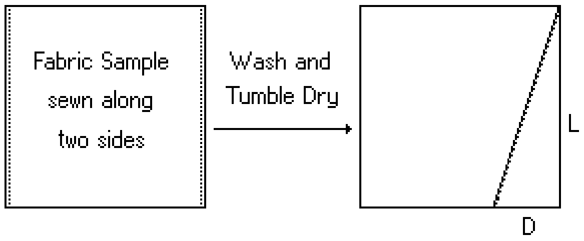
Notes:

The accurate determination of Spirality is difficult and requires a large number of measurements to be made in order to derive a reliable average. For this reason, the test is both time consuming and expensive to carry out.

To determine the Reference Spirality of fabrics there is no alternative, but for practical evaluation of garment twisting the Seam Displacement Test Method may be more useful.

Seam Displacement Test Method

A practical test for Seam Displacement can be carried out by taking a rectangular sample of fabric, whose length is double its width, and sewing it into a bag - a kind of simulated garment.



The bag is then given the standard wash and tumble-dry (shrinkage test) laundering. The amount of Seam Displacement can then be measured fairly easily.

The amount of Seam Displacement is expressed as a percentage of the seam length.

If D is the displacement, and L is the length, then:-

%SD = 100 * D / L

The Percentage Seam Displacement can be related to Spirality, by means of the following facts.

The displacement angle must be the difference between the after-wash spirality, A, and the before-wash spirality, B.

and

D / L is equal to the tangent of the displacement angle.

Therefore, %SD = 100 * D / L = 100 * tan(A - B)

If the Reference Spirality, for a given Fabric Quality, is established by calibration trials, then it is a simple matter to work out what will be the Percentage Seam Displacement for any proposed spirality which can be delivered in the finished fabric. The actual displacement for a given garment style is obtained by multiplying by the effective garment length.

Reference Relaxation Procedure Test Method

The key to producing fabrics with appropriate shrinkage performance lies in the ability to predict the dimensions of a fabric when all of the potential shrinkage has been removed, that is when it is in its Reference State of Relaxation.

Apparatus

- Automatic domestic washing machine or equivalent.
- Domestic tumble dryer or equivalent.
- Domestic automatic washing powder.
- Scales.
- Means for providing the standard atmosphere for testing textiles as specified in BS 1051 and ISO 139; 65±2% RH at 20°±2°C.

Test Specimens

Specimens for relaxation should be between 45 cm and 70 cm square and of single thickness. Tubular specimens should not be used; edges and crease marks should be avoided.

Sufficient specimens of appropriate dimensions should be prepared from the sample to allow for those tests required to be made on Reference State fabric to be carried out according to the appropriate methods. Five specimens 70 x 70 cm are usually sufficient.

Laundering

Wash Cycle

It is important that the first cycle of the relaxation procedure is a full-length hot wash with detergent to ensure thorough wetting of the specimens and the removal of loose dirt, waxes and grease.

For domestic automatic washing machines this is achieved by using the 60°C wash cycle.

Rinse Cycle

Subsequent cycles are designed to ensure thorough re-wetting of the specimens before drying and this can be achieved conveniently by using the rinse only cycle.

Sample Load

It is important to maintain a standard load weight in the washing machine and not to overload the machine. Domestic automatic washing machine manufacturers normally specify a recommended load for absorbent materials; these recommendations should be followed. Choose a standard load that is within the recommended maximum.

Detergent

A normal domestic automatic washing powder or liquid can be used in the first full washing cycle. Use the quantity recommended by the manufacturer. Do not use a detergent that contains softener or fabric conditioner.

Drying

To achieve the STARFISH Reference State with reliability and consistency it is essential that the test specimens are thoroughly dried, i.e. contain only a minimum amount of residual moisture (<2%), on leaving the tumble dryer. Cotton knitgoods continue to shrink as residual moisture levels fall below normal Regain. Therefore, fabrics that have not been thoroughly dried may not have developed their maximum shrinkage potential and achieved their fully relaxed dimensions. The dryer must not be overloaded. Choose a standard load that is well within the recommended maximum. Ideally it would be the same as that for the washing machine.

To ensure that the minimum moisture level is achieved, it is necessary to determine the length of time required to bring the load to a constant dry weight prior to testing.

Drying Time

1. Weigh a Standard Conditioned load of specimens of the same or similar construction to the sample load being tested, and carry out a standard 60°C hot wash with long spin.
2. On completion, transfer the load to the tumble dryer. Make sure the exhaust filter is clean. Tumble-dry at the hottest temperature setting for a nominal period of time, e.g. 60 minutes.
3. Remove the load and weigh it.
4. Return the load to the tumble dryer and continue tumbling at the highest temperature for a further 10 minutes.
5. Remove the load and weigh it.
6. Repeat steps 4 and 5 until the weight of the washed and tumble-dried load remains the same.
7. Drying time is the length of time taken to reach the stable weight plus 10 minutes cool down period, i.e. continue tumbling for 10 minutes with the heat turned off.

Test Procedure

1. Prepare the specimens as described under "Test Samples"
2. Weigh the test specimens and, where necessary, make up the load to the standard weight with make-weights of similar construction and finish to the specimens being tested. Clean the exhaust filter of the tumble dryer.

3. Place in the washing machine, add the recommended amount of detergent to the dispenser and set the machine to wash at 60°C with long spin (e.g. final spin at 800 rpm for 4 minutes).
4. On completion of the wash cycle, transfer the load to the tumble dryer and tumble-dry at the highest temperature setting until dry.
5. On completion of the first tumble-dry cycle return the load to the washing machine and, using the rinse-only cycle (including the long final spin), thoroughly re-wet the load. On completion return the load to the tumble dryer and tumble-dry for the same length of time as before.
6. Repeat step 5 three more times.
7. After completion of the full 5 cycles, condition the test specimens in the standard atmosphere until they have reached equilibrium.
8. The test specimens are now defined as being in the STARFISH Reference State.

Measurement of the **Reference Dimensions**, yarn count, stitch length, courses, wales and weight are carried out on samples after they have been subjected to the **Reference Relaxation Procedure**.

Note:

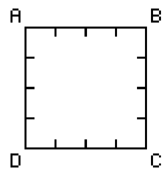
The required drying time can also be determined by fitting a temperature sensor in the exhaust duct of the dryer. So long as the load is wet the exhaust temperature remains relatively low. When the specimens are nearly dry the temperature rises. When the temperature has been at its maximum level for at least 10 minutes the load is dry.

Shrinkage Test Method

The STARFISH Reference shrinkage method is summarised as follows. It should be read in conjunction with the topic Measuring Fabric Shrinkage.

Apparatus

- Means for providing the specified washing and drying conditions.
- Two Perspex templates; a) 25 x 25 cm and b) 50 x 50 cm, both having equidistantly located measuring marks on all sides.



The markings on AD are opposite to those on BC (width measurement) and the markings on AB are opposite to those on DC (length measurement).

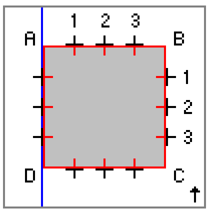
- ruler and indelible marker.
- Means for providing the standard atmosphere for testing textiles as specified in BS 1051 and ISO 139; 65±2% RH at 20°±2°C.

Test Samples

Samples should be sufficiently large to enable 5 test specimens of single thickness to be prepared of 70 x 70 cm, or six test specimens of 45 x 45 cm. They should be spaced to give a good representation of the sample avoiding edges and crease marks.

Specimen Preparation

1. Condition the test sample in the standard atmosphere for testing textiles until it has reached equilibrium.
2. Lay the sample on a flat horizontal surface, removing wrinkles without stretching.
3. Prepare the test specimens from the sample, spaced to give a good representation, avoiding edges and crease marks. Each specimen should be a minimum of 20 cm larger in each direction than the size of the template. e.g. if the 25 x 25 cm template is used the specimen size should be 45 x 45 cm. If the 50 x 50 cm template is used the specimen should be 70 x 70 cm. Prepare six specimens if the smaller template is used and 5 specimens if the larger template is used. The larger template should always be used where sample size permits.



4. Place the template centrally on a specimen so that the edge of the template follows a wale line.
5. Define the test area by carefully drawing round the template and marking the position of the measuring marks. Avoid stretching the fabric. Remove the template and clearly define the measuring marks on each side of the square ABCD.
6. Place an arrow in one corner of the specimen to indicate the direction of the fabric and also to provide a reference point.
7. Measure and record the distance between the 3 pairs of measuring marks for width and the three pairs for length. Make a note of the order of measuring (by reference to the arrow) to ensure that the same pairs of marks can be identified for measurement after laundering.
8. Repeat steps 4 to 7 for the remaining 4 or 5 specimens in turn.

Test Procedure

1. Prepare the specimens as described in "Sample Preparation".
2. Subject the specimens to the specified washing and drying procedure.
3. After completion of the specified washing and drying procedure, lay the specimens on a flat horizontal surface, removing wrinkles without stretching.
4. Condition the specimens in the standard atmosphere for testing textiles until they have reached equilibrium.
5. Re-measure and record the distances between the three pairs of measuring marks for width and the three pairs fro length.

Calculation of Results

The change in Length or Width is expressed as a percentage of the length or width of the sample before relaxation.

LS% = 100 * (IL - RL) / IL

WS% = 100 * (IW - RW) / IW

where

IL is the Initial Length; IW is the Initial Width

RL is the Relaxed Length; RW is the Relaxed Width

For each of the length measurements, calculate the change in length caused by laundering and express it as a percentage of the original length. Calculate the average of the three to two decimal places.

For each of the three width measurements, calculate the change in width caused by laundering and express it as a percentage of the original width. Calculate the average of the three to two decimal places.

Calculate the Mean and Standard Deviation of the percentage changes in length and width by averaging over the five or six specimens. Indicate an extension by using the prefix Ext.

Report the results correct to one decimal place and state the specified washing and drying procedure.

Quality Control in the Testing Laboratory

Testing is expensive, therefore it is essential that any testing that is carried out is relevant, appropriate and reliable and will provide an adequate means for controlling production. This will only be true if the same attitude to quality control is applied in the testing laboratory as to the production operations.

There are standard statistical techniques for deciding on the appropriate number of measurements that should be carried out in order to deliver the required level of accuracy and reliability in yarn and fabric testing. Typically, these involve calculations of the Standard Deviation, Coefficient of Variation, Confidence Limits and Accuracy etc.

The actual levels of statistical confidence in test data that an individual company demands will depend on its own particular requirements. However, there is no excuse for not knowing what are the confidence levels for test data.

In most manufacturing operations, a fabric with a Shrinkage test result of 5% would generally be considered superior to one with a shrinkage result of 8%. However, if the confidence interval of the shrinkage test is ±2 percentage points, then there is actually no difference in the two results. Most industrial test laboratories will have confidence intervals for their testing of at least this level.

- Accuracy of Test Measurements
- Sampling for Testing
- Checking the Test Data
- Related Topics
- Testing
- Conditioning and Moisture Content
- The Quality Control Function
- Quality Charts

Accuracy of Test Measurements

For the acquisition of the STARFISH Database the following guide-lines were typical:-

Test	Typical CV %	Accuracy Limit %	Minimum Value of n
Course Density	1.6 - 2.0	2.0	6
Wale Density	1.6 - 2.0	2.0	6
Stitch Length	0.5	0.5	6
Weight (g/m¨)	2.0	3.0	4

Taking the measurement of weight as an example, this parameter shows a Coefficient of Variation of 2%. Therefore, in order to have a testing Accuracy of 3.0%, at least 4 replicate specimens must be tested. On the average, results will be accurate to within 3% of the true value 95% of the time, i.e. 19 times out of 20.

In fact, in the STARFISH laboratory, ten measurements are carried out for course and wale density and stitch length determinations, and for weight the average of 5 measurements was obtained.

It is also important to check periodically that all of the testing procedures are being carried out in like manner by all the testing technicians and that they are all on average obtaining the same results.

This can be achieved by introducing into the testing laboratory a standard fabric (or fabrics) at random intervals. The results obtained on this fabric by each technician can then be compared over time in order to monitor reproducibility and drift in the results. This system can be especially useful when a new member of staff joins the team to ensure that the results are compatible with those obtained by existing staff. It is however important to try to ensure that this is done "in the blind" so that the technicians do not know what the results are expected to be.

Sampling for Testing

For all testing procedures it is important that sampling is carried out in a random manner. This may seem self-evident, but can easily be forgotten.

For example, in the knitting mill, if several specimens of a given fabric quality are taken from production, make sure they are from different machines, unless the output from a particular machine is to be studied.

The ends of finished pieces are often not representative of the batch. Ideally, samples should be taken from the middle of a roll.

When counting courses or wales, move to various places in the fabric specimen, so that different sets of wales or courses are counted each time.

Checking the Test Data

Even in the best-regulated laboratories, errors can be made. Many of these can be detected using standard statistical procedures, e.g. Confidence Limits and Accuracy to indicate rogue data, and the increasing use of computer data storage and analysis makes it very easy to do this.

Similarly the use of Control Charts can make errors or discrepancies in results very visible to the testing technicians and requires little more than a calculator for computing Mean and Standard Deviation, and a graph pad.

There is, however, another way of detecting errors and deviations in the data. This relies on the fact that most of the properties that have been measured are inter-dependent.

Fabric Weight

For example, Fabric Weight per unit area, is given by the length of yarn in that area, multiplied by the yarn linear density. This is simply a function of the Yarn Count (tex) the Stitch Length (sl in cm) and the number of stitches (courses and wales per cm) in the area of fabric.

Fabric weight (g/m^2) = (c * w * tex * sl) * 0.1

Courses and wales are expressed as "true", not "visible" measurements. For example, if a 1x1 Rib or Interlock structure is being examined, the visible wale count must be doubled before the fabric weight can be calculated.

For Crosstuck constructions the "true courses" must be measured or calculated from the number of Structural Knitted Cells multiplied by the structural repeat (number of feeders).

For Two-thread Fleece fabrics the weight of the inlay yarn and of the face yarn must be calculated separately and the results added together.

The calculated value for fabric weight can be compared with the measured value. If the discrepancy is negligible, no action is indicated, but if it exceeds a certain level, say 5%, then a close study of the data must be undertaken to explain the inconsistency.

Shrinkage and Course and Wale Density

If Course Densities and Wale Densities are measured both before and after the shrinkage test, there is another means for checking the self consistency of the data, because:-

CdA / CdB = 100 / (100 - LS)

WdA / WdB = 100 / (100 - WS)

where

CdA is the Course Density and WdA is the Wale Density After the shrinkage test,

CdB is the Course Density and WdB is the Wale Density Before the shrinkage test,

LS is the Length Shrinkage and WS is the Width Shrinkage

These equations can be used to check discrepancies, for example between measured and calculated final stitch density values. Variations exceeding say 5% would then be investigated.

On a long-term basis, these figures can be used to check laboratory performance. If the variations are consistently above or below unity, there may be a problem in the testing procedures.