Testing Methods

Introduction

In order to run an effective quality control operation, the testing methods used to collect the data must be accurate, reproducible and meaningful. The successful introduction of STARFISH Technology requires not only that close attention is paid to 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 procedures for the evaluation of cotton knitted fabrics. The detailed descriptions of these procedures are provided, in the Reference Section of the STARFISH online Help.

When considering the introduction of STARFISH Technology into the mill there are certain key points about testing methods that should be kept in mind.

Conditioning

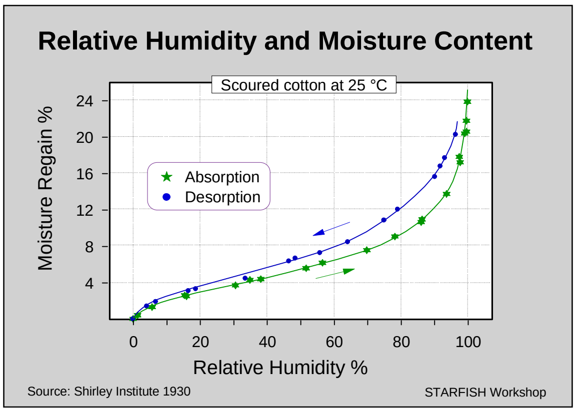
All quality control testing should be carried out under standard atmospheric conditions of 20±2°C and 65±2% relative humidity. This is because cotton is a hygroscopic fibre, which means that it absorbs moisture from the surrounding atmosphere.

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. 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. It is often the reason for dissimilarities between measurements obtained in the factory and those obtained by customers or predictions obtained using STARFISH.

STARFISH predicts fabric dimensions and properties measured at standard condition. Therefore, if fabric weight is assessed on fabrics that are not at standard condition the results may not correspond exactly to those predicted. For example, it is not unusual for fabric weight check measurements to be made on fabric taken directly from the batch at the end of the finishing line - shortly after the fabric has been removed from the drier or finisher calender - when it is still hot and dry. Fabric measured at this time will weigh less than after it has had time to recover moisture from the atmosphere.

The moisture content in the fabric will also have an influence on the reproducibility of measurements made for courses, wales and stitch length although at a less significant level, and in addition, it has an effect on shrinkage measurements especially when tumble-drying is used.



One of the reasons for differences in line dry and tumble dry shrinkage measurements is due to the well-known hysteresis effect of moisture on cotton. i.e. the regain of cotton fibre dried from the wet side (line drying) is higher, approx. 9%, than when it is reconditioned from the dry side (tumble-drying), approx. 7%. If a tumble-dried fabric is not allowed to recondition before measuring, more shrinkage will be measured, especially in the length direction.

Properly conditioned testing facilities are, however, expensive and therefore, 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 in temperature and relative humidity then consideration may need to be given to the installation of some form of proper 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 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 conditions at the time of testing so that extreme conditions (e.g. hot / dry, cool / humid) 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%.

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.

Yarn Count

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, if possible, from different packages. If more than one specimen has to be taken from the same package, care should be taken to ensure that each represents a different pirn or bobbin.

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 his deliveries. For a trusted supplier one sample may be sufficient. The use of Control Charts will assist long term assessment.

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

Yarn Twist

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 multiple) for the yarn can be calculated.

In Imperial Units	Twist Factor (α_e)	=	turns per inch/ $\sqrt{}$ Ne
In Tex Units	Twist Factor (α_{tex})	=	turns per cm * $\sqrt{}$ tex
In Metric Units	Twist Factor (α_m)	=	turns per m / $\sqrt{}$ Nm

To convert

$\alpha_e = \alpha_{tex} / 9.57$

$\alpha_e = \alpha_m / 30.254$

$\alpha_{tex} = \alpha_m / 3.162$

Note: The number of turns per unit length in a yarn can be difficult to determine accurately. A large number of tests are 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 which have improved the reliability and speed of twist testing.

Equipment required: -Yarn Twist Tester.

Yarn Friction

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.

Equipment required: -Yarn Friction tester, cleaning yarn.

Other Yarn Evaluation Tests

For certain critical fabrics the irregularity, evenness, hairiness etc. of the yarn can be very important. Some knitters have found that a pre-production evaluation of the yarn for appearance can in the long run prove beneficial. 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 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. If the dyed tube is dried in a tumble drier, then some idea of the twist liveliness of the yarn can also be obtained by measuring the spirality.

A very practical and effective use of this technique is to keep a stock of a standard yarn, which is knitted in two bands, either side of a band of the yarn to be evaluated. Differences in depth of shade or spirality between the standard and the test yarn are very easy to see.
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 will of course depend on many factors, not least of which will be the size of the operation and the quality levels demanded by his customers. With the exception of count, twist and friction testing, these other evaluation techniques are mentioned mainly for information.

Fabric Testing

STARFISH test procedures for knitted fabrics have been established for plain jersey, six-thread crosstuck, double crosstuck, single crosstuck, two-thread fleece, interlock, 1x1 and 2x2 rib. These are the fabrics that are covered by the latest version of the STARFISH software. Although they can be used for the evaluation or assessment of other fabric types, these are not included in this discussion. Detailed descriptions of the STARFISH fabric test methods are contained in the Reference Section of the STARFISH online Help

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

1. ***For Routine Production and Process Quality Control***
   - For the knitter to ensure that the control systems for yarn 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 and performance 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.
   - For the customer, to satisfy his quality control requirements.
2. ***For Quality Assurance, Fabric Development and Process Calibration***
   - To check that on-line measuring devices and instrumentation are delivering the correct readings.

- To check that testing procedures are under control and that the technicians are working to a common standard.
- To establish Reference State data and develop the correct Product Specifications when new yarn qualities or yarn suppliers are being assessed, when new fabric qualities are being developed or when new processing equipment has been installed.

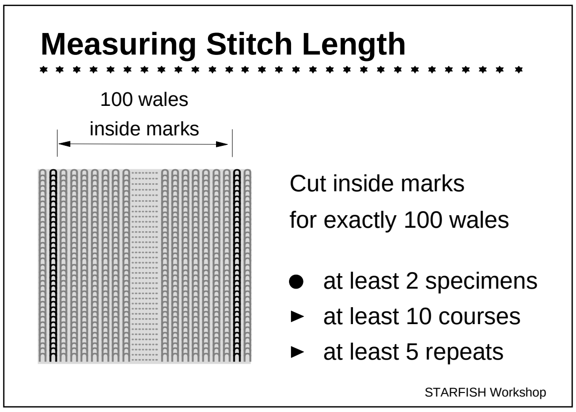
  For these purposes thorough testing and evaluation of the fabric is necessary.

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 courses 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.

Notes:

1. For single jersey and interlock fabrics, 100 visible wales are equivalent to 100 needles. For 1x1 and 2x2 rib fabric, 100 needles is represented by 50 visible wales.

2. In the standard test method, a certain number of yarns (usually nine) are removed and discarded between each test piece however, in many circumstances it may be advisable to measure each consecutive course, e.g.

To check the setting of individual positive feed tapes

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

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-tuck courses can be distinguished. For two-thread fleece fabrics the face yarns and 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 accurate marking and counting of the test length - the 100 wales.

The method of marking the beginning and end of each test length should 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 large 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.

A standard laboratory testing instrument for 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.

Note: If the specimen length required is greater than the test length then these threads can not be used to calculate the yarn count.

Yarn Count (from fabric)

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 which 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

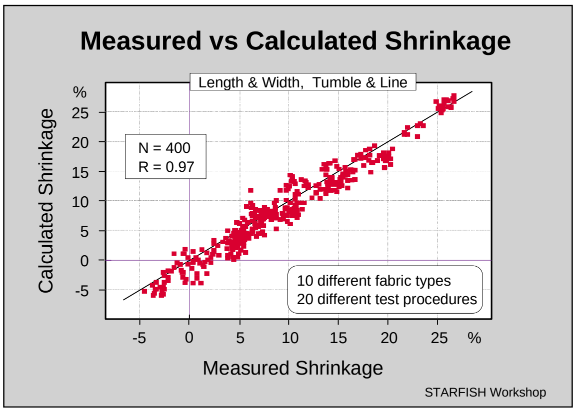
English cotton count (Ne) or Metric count (Nm) can be calculated using the standard formulae.

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 Densities

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. The diagram shows the relationship between average measured shrinkage values compared to shrinkage values calculated from average course and wale counts for 10 different fabric types and 20 different test procedures.

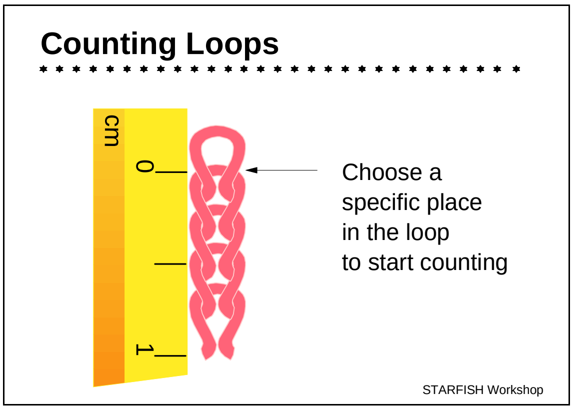
Therefore, it is worth devoting a considerable effort to thoroughly training all personnel responsible for counting and reporting course and wale densities so that they are all counting and reporting stitch density measurements in the same way, reliably and reproducibly.

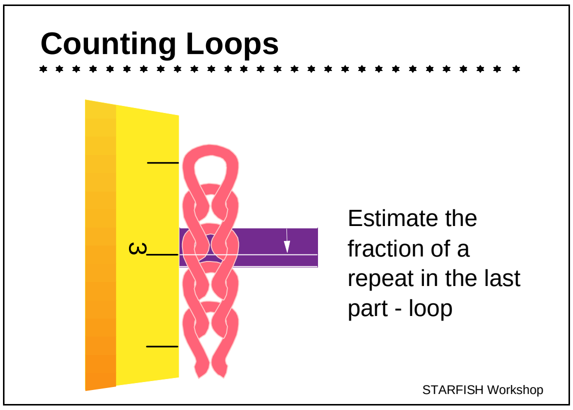
Establish a Common Method

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.





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

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).

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 lengths 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 which 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 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

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 and double crosstuck, as defined in STARFISH, the SKC is produced by four courses and two wales. For six-thread crosstuck fabric the SKC repeats over six courses and two wales.

Each SKC contains all of the courses required to produce the particular crosstuck construction whether or not they can actually be seen. Therefore the "true" number of courses can be calculated by multiplying the number of cells by the number of feeders per 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.

Fabric Weight

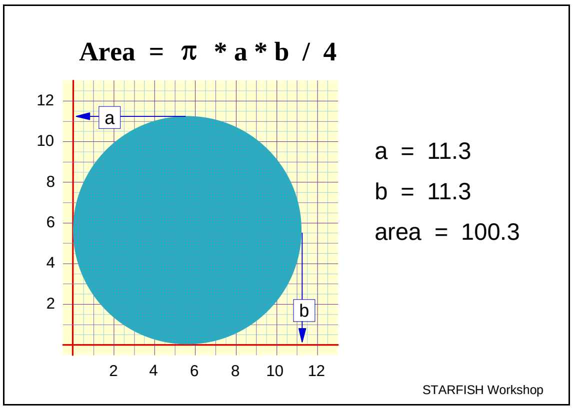
Area weight is probably the most frequently tested property of any fabric. Both the customer and the manufacturer place a great deal of emphasis on the measurement of weight because it is a direct representation of the cost of the fabric. Consequently, when fabric weight measurements vary by more than 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.

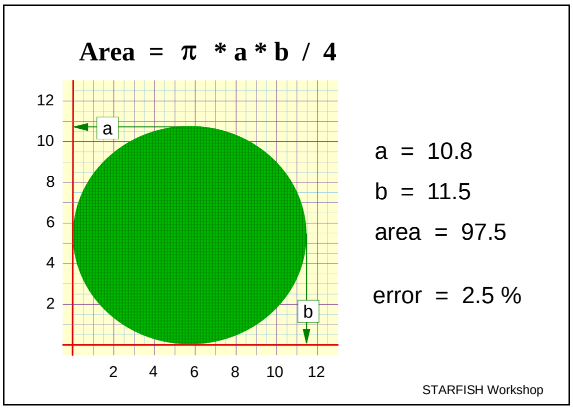
It is surprising therefore that so little attention is actually paid to obtaining reliable and reproducible measurements of fabric area weight.

The importance of proper conditioning and the effect of atmospheric conditions to the measurement of fabric weight measurements have already been discussed. However, another perhaps less familiar 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.

Effect of Sample 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 cm 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 cm² is used, the diameter of the specimen should be approx. 11.3 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.

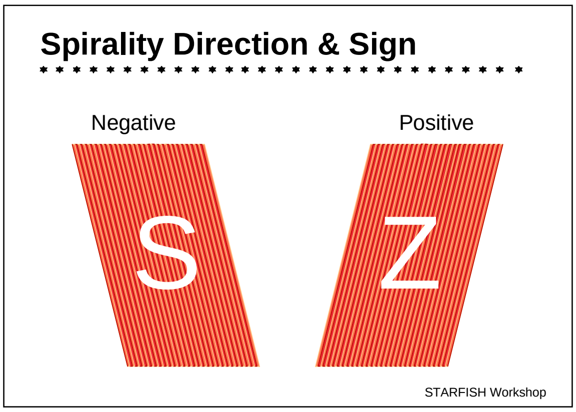
If a discrepancy is found then the measured weight can be corrected by measuring as accurately as possible the major and minor axes of the specimen. If these are (a) cm and (b) cm respectively, the area of the specimen is given by:-

Area cm² $=$ $\pi * a * b / 4$

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.

Spirality

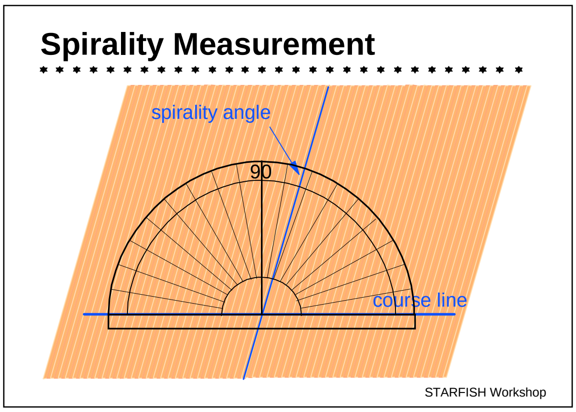
Spirality in a circular knitted fabric is the name given to the visual effect produced when the lines of wales and courses are not perpendicular to each other.



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 or "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 retailers will receive consumer complaints.

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.

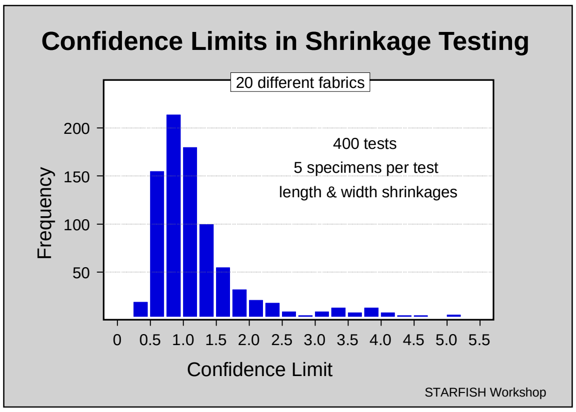
Spirality measurements have been made on the vast majority of the STARFISH Database fabrics. It is anticipated that predictions for this important fabric property will be included in future versions of the software.

Shrinkage

If a mill is operating using STARFISH principles, routine quality control testing for shrinkage can be reduced to a minimum, provided that the knitted fabric has been produced correctly, and that the finishing process has been properly calibrated and the reference dimensions established. This is because 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 for measuring shrinkage 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 of 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 no better than ±2 percentage points.

Routine Shrinkage Measurement

For routine product quality control purposes measuring shrinkage to the reference state is too expensive, both in terms of fabric and time required to carry it out, and an abbreviated procedure (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 variability of the results obtained and therefore their reliability and reproducibility. These need to be taken into account when abbreviated shrinkage testing procedures are utilised.

The laundering and drying conditions employed are also very important. For example, if line drying is used instead of tumble drying 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. Less shrinkage is developed after line drying than tumble drying but tumble drying is more reproducible.

Similarly, the number of washing and drying cycles which are carried out will affect the level of shrinkage which 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.

Reference Relaxation Procedure

The STARFISH Reference Relaxation Procedure is defined as follows

1. Wash in automatic domestic washing machine at 60°C.
   (Domestic detergent, no added softener).
2. Tumble dry to constant weight.
3. Wet out in washing machine (rinse only cycle).
4. Tumble dry to constant weight.
5. Repeat steps 3 and 4, three more times.
6. Condition to normal regain.

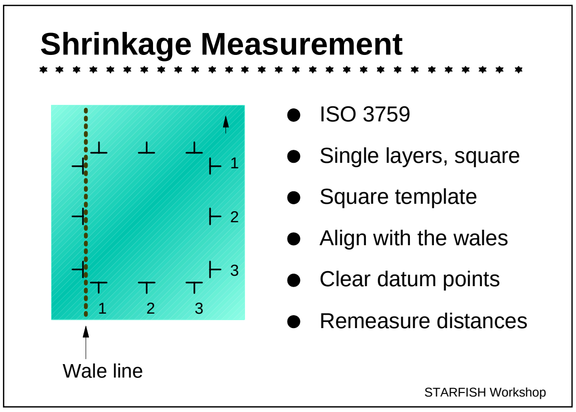
Measurement of the Reference Dimensions, tex, stitch length, courses, wales and weight are carried out on samples after they have been subjected to the Reference Relaxation Procedure.

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 equidistantly spaced measuring marks on each side, so that three measurements can be made in each direction.

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, we obtained the following: -

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

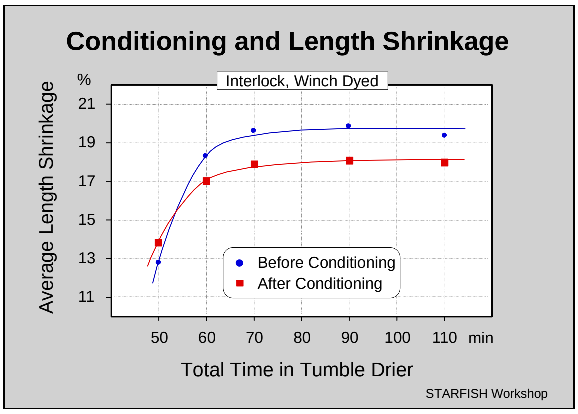
In order to obtain an equivalent level of reproducibility when carrying out Reference State testing, ideally at least six of the 25 x 25 cm specimens should be taken, compared with five of the 50 x 50 cm.

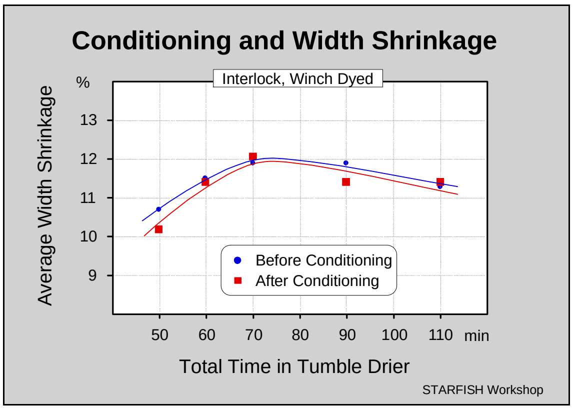
For commercial quality control testing at least two and preferably three specimens should be tested.

Conditioning and Moisture

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.

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. In trials we have found that length shrinkage recovers by 1-2% 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 pre-conditioned dry, but almost 9% if wet out and allowed to dry in a standard conditioned atmosphere.

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

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 to be superior to one with a shrinkage test 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 Measurement

For the acquisition of the STARFISH database however we typically used the following guidelines: -

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/m²)	2.0	3.0	4

Accuracy is calculated as follows: -

$$A = t * CV / \sqrt{(n)}$$

where t is the student's t statistic.

Taking the measurement of weight as an example, this parameter shows a coefficient of variation of 2%. Therefore, 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 determinations were made for stitch density and stitch length, 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 carried out by using a standard fabric (or fabrics) which is introduced at random intervals into the testing lab. The results obtained on this fabric by each technician can then be compared both one with the other 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 he/she is producing results that 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 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 has to be studied.

The ends of finished pieces are often not representative of the batch. Ideally samples should be taken from the middle of the 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 Data; Internal Consistency

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 targets 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

Fabric weight per unit area, for example, is the same as the weight of the yarn in that area. This is simply a function of the yarn count, the stitch length and the number of stitches in the area of fabric.

Fabric Weight (g / m²) = courses / cm * wales / cm * tex * s.l. * 0.1

where

1. Stitch Length (s.l) is expressed in cm.
2. Courses and wales are expressed as "true", not "visible" measurements.

For example, if a 1x1 or 2x2 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.

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 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)

and

WdA / WdB = 100 / (100 - WS)

where

1. CdA is the Course Density and WdA the Wale Density After the shrinkage test.
2. CdB is the Course Density and WdB the Wale Density Before the shrinkage test
3. 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.