Management of Quality in Finishing

Part 1: Basic Principles

Introduction

In this session we will look at the value of the Reference State, and the STARFISH system as a whole, from the viewpoint of the Dyer and Finisher. The common view in the industry is that it is the Dyer and Finisher who has the ultimate control over shrinkage and, consequently, if a fabric has a high level of shrinkage, then the finisher is always to blame. The biggest problem that most dyers and finishers have is that they also believe in this fallacy, and they encourage their customers to believe it. Under some special circumstances, it can be true that the finisher is in control but in the modern industry the practical situation is very often exactly the opposite.

Once again, we have to make the clear distinction between the dimensions of the fabric as it is delivered to the customer, on the one hand, and the Reference Dimensions on the other. The potential shrinkage in any fabric is simply the difference between the "as delivered" dimensions and those of the Reference State. Therefore, if the finisher is to be in control of the shrinkage, then he must have full control over either the delivered dimensions, or the Reference Dimensions, or both.

As we have seen in an earlier session, the Reference Dimensions are determined primarily by the key knitting variables and the specific type of wet process that is used. In any given dyeing and finishing plant, there will be only a limited number of wet processing options available, and the choice of which to use for a given product type will be constrained by practical considerations of capacity and economy as well as technical requirements. Thus, the dyer and finisher has very little influence over the effect of wet processing on the Reference Dimensions. The effect will be whatever his particular range of equipment delivers. For all practical purposes, we can assume that the Reference Dimensions are determined by the knitter.

So far as the delivered dimensions are concerned, the finisher is often no better off. This is because these dimensions are usually fixed by the customer's specification in the form of his requirements for the weight, width, and shrinkages. A specific width is generally demanded in order to minimise waste in the garment cutting operation, a definite weight is usually demanded in order to fix the cost, and there is usually a specification for the maximum level of shrinkage that will be accepted.

But if the finisher has essentially no control over the Reference Dimensions, and no flexibility in the dimensions that he may deliver to the customer, then he virtually has no control over the performance of the product that he is delivering. This should be an unacceptable situation for any manufacturer and the only defence that the finisher can have is knowledge. It is only when the finisher truly understands what are his limitations that he can begin to develop the systems and the know-how, which will allow him to gain some control over his operations.

- For every quality that he is asked to process, the finisher must know the Reference Dimensions.
- For every customer specification that he is asked to meet, the finisher must be able to check its validity.
- For every wet processing route that he has available in his factory, the finisher must know what is its effect on the Reference Dimensions.

Without this knowledge, the finisher is powerless and often has to take the blame for poor shrinkage performance, which in fact has been imposed on him by an unreasonable or unattainable specification. With this knowledge, he becomes a full and equal partner in the discussions that are necessary for the setting up of proper targets, and he is free to apply the specialised expertise and equipment, which he has at his disposal for the common benefit.

Bearing in mind the knowledge that the finisher needs to acquire, we will look at what is attainable, and how the finisher can use his facilities to produce the best possible quality from the machinery and raw materials at his disposal.

Check the Customer's Specification

The first duty of the dyer and finisher is to make sure that the performance that he is expected to deliver on a given knitted fabric quality is actually attainable.

Here is a commercial specification for an interlock fabric that was issued by a major retail store to its suppliers some years ago.

- 1/38's cotton count
- Knitted stitch length 3.38 mm, over 1500 needles
- Finished weight 165 gsm
- Finished width 60 cm
- Shrinkages 12% maximum (1 wash and tumble)

The suppliers were having great difficulty in meeting the shrinkage targets whilst delivering the required weight and width. A great deal of time and money was being expended by a number of knitters and finishers trying to adjust the fabric and the finishing by trial and error methods.

Using the STARFISH computer program, it could be established within a few minutes that a fabric with exactly this knitted construction, prepared and dyed in a jet machine, and delivered with exactly 165 gsm and 60 cm, would have average shrinkage values of about 16% in length and 13% in width to a five cycle wash and tumble test. Even allowing for the difference in shrinkage values between a single cycle and a five-cycle test, it was no wonder that the suppliers had difficulty in satisfying the customer.

It is not uncommon for a customer to demand weight and width and shrinkage values that are mutually incompatible. Often, the customer simply is asking for better shrinkage on an existing quality without allowing any changes in weight and width. If the finisher has access to STARFISH, and has properly calibrated his wet process route (see below), then the specification can be checked and the customer can be informed of what is possible to achieve without having to commit the fabric to the dyeing process.

In any event, the dyer and finisher must always check the customer's specification before accepting any commission or putting any grey goods into work.

Check the Fabric Specification

The finisher is completely in the hands of the fabric supplier for making sure that the grey fabric quality is appropriate to the final performance required, and is actually being delivered consistently according to the nominal specification.

If the finisher is part of a vertical company then he must:

- make sure there are clear specifications for fabric production, which have been established using STARFISH.
- ensure that quality assurance procedures are installed in the knitting plant which guarantee that the grey fabric conforms consistently with the specification,
- agree attainable finishing targets and specifications,
- make sure that he is kept informed of any changes in fabric production conditions which could affect the Reference State.

If he is a commission finisher then he must:

- obtain knitting specifications from suppliers,
- ensure the fabric conforms to the specifications, if necessary, by making measurements,
- agree an attainable finishing specification with the customer.

Calibrate the Wet Process

Although the finisher may have a limited number of wet processing options, and although he can not change the effects of these processes upon the Reference States of the fabrics that he has to dye and finish, nevertheless it is vitally important that he should know exactly what is the average effect of his processes on the Reference State. This is for three main reasons.

Firstly, so that he can calibrate his STARFISH computer program to give predictions which apply directly to his own situation - rather than the average process which is supplied by the model.

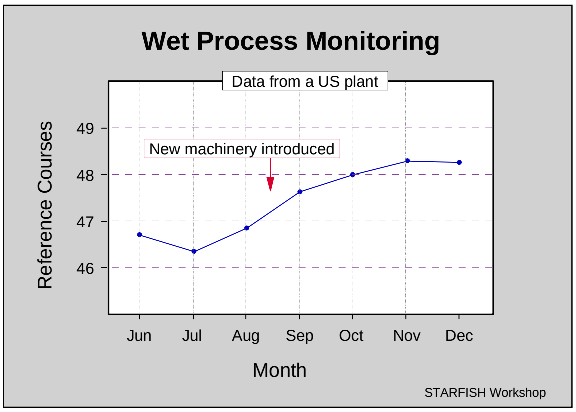
Secondly, so that he can establish "Finishing Factors", and/or "Calibration Ratios" which can then be used to make predictions for fabric types which are not covered explicitly by the STARFISH program.

Thirdly, so that he has a tool which can be used as a powerful aid to process control and quality assurance.

The value of process calibration as a routine quality assurance tool can be illustrated using some results taken from an industrial case study.

A vertical knitting, dyeing, finishing, and garment-making plant had experienced a change in the performance of garments made from a long-running, standard single jersey fabric even though there had been no change in the knitted fabric specification or the delivered weight and width of the finished fabric.

Fortunately, the finishing plant had kept comprehensive quality control records, from which it was possible to calculate the Reference Dimensions for a large series of samples spreading over a period of seven months. Some results are shown in the diagram in the form of monthly averages for the number of Courses / 3 cm in the Reference State.



Clearly something happened in the month of August which affected the Reference Dimensions of this normally standard and consistent fabric quality. In fact, the problem coincided with the installation of new machinery with consequent changes in processing routes.

If this company had been monitoring and plotting the Reference courses and wales on quality control charts, on a routine basis, then the problem would have been spotted almost immediately, so that corrective action could have been taken.

When the finisher can quantify the changes, which are introduced in the Reference State as a result of his own operations, then he can have some control over the performance of the fabric he is producing at the end of his processing line. He can calculate the right CONTROL TARGETS for finishing, in terms of course density and width, to ensure the required stability.

It is in the interests of the finisher that he should know how his processing is likely to affect the Reference State of any fabric, which he will be asked to finish. If he does not know this, how can he agree a sensible specification with his customer?

The average effects of different types of wet-processing can be determined by consulting the STARFISH computer model, and this is perfectly satisfactory for knitters, to help them to establish viable knitting specifications, and for finished fabric buyers, to help them to establish realistic performance specifications. However, the finisher himself often needs to be more precise than this because his wet processing routes are not necessarily average. He needs to know what is the effect of his specific conditions. He needs to *calibrate*.

The STARFISH model prediction equations have been developed from many industrial trials, and represent average values for typical wet processing routes which will give close approximations in most cases to processes actually being used in a given mill. The STARFISH system therefore enables the finisher to select a model processing route which resembles his own, and obtain predictions for proper control targets on his chosen fabric for any combination of, for example, finished weight and shrinkage. However, because of variations in processing practice between dyehouses, these predictions may not correspond exactly with what is found in an individual finishing plant.

If the predictions do not correspond exactly, then either:-

1. the knitting quality is not exactly as specified, or
2. the relaxation procedure being used to measure shrinkage and Reference Dimensions does not correspond exactly to the Reference Relaxation Procedure, or
3. the wet processing route does not have exactly the same characteristics as the average route given in the STARFISH model.

In the latter two cases, it will nevertheless be found that, for a given wet processing route over a series of measurements, the offset between the STARFISH prediction and the actual measurements tends to be a constant. Over a period of time, the values of these constants will become apparent for each of the finisher's wet processing routes.

They represent calibration constants and they allow the finisher to "fine tune" the STARFISH predictions to suit his own situation.

If, over a period of time, the differences are not substantially constant, then either his own relaxation procedures are unreliable or the knitter is not delivering a consistent quality of cloth. In either case, this is something that the finisher needs to know and take action to correct.

Therefore, the finisher should familiarise himself with the STARFISH calibration procedure, carry this out for his main processing routes and product types, and repeat the exercise from time to time to make sure that all is still under control. The influence of changes in processing will thus be identified and established. Any deviation from specification by the knitter will also be detected if regular calibration checks are made.
In addition, the calibration procedure is a valuable quality control tool, enabling him to monitor his processing, and to identify any changes in process conditions that affect fabric stability.

Wet Process Calibration Procedure

Calibration consists essentially in monitoring the Reference Courses and Reference Wales of one or more standard knitted qualities processed through each of the finisher's standard wet processing routes. After a sufficient number of measurements are available for reliable estimates of their mean and standard deviation (or mean range) to be obtained, then these values can be used to:

a) set up quality control charts for the process, to make sure that it is delivering consistent results, or to trace the sources of inconsistencies so that these can be eliminated.

b) find which of the STARFISH average wet processing routes comes closest to predicting the mean values, and then to create a User Defined Process (UDP) which predicts exactly the measured mean values.

It is very important for this procedure to select a fabric which can be relied upon for consistently uniform knitted construction, with yarn count and stitch length under excellent control.

1. Select and sample a series of grey test fabric pieces that will be subjected to the process which is to be calibrated.
2. Make whatever measurements are necessary on the grey fabric to confirm the actual knitted construction. If there is total confidence in the knitter (because of objective measurements carried out in the past) then no measurements may be necessary. If there is less than perfect confidence, then the yarn count and stitch length should be accurately determined.
3. Carry out the normal dyeing and finishing process. Note that the severity of preparation (e.g. scour only, half bleach, full bleach) and the depth of shade (percentage dye in the bath based on the weight of fabric) are a part of the process definition. Different preparations and different depths of shade may yield differences in the Reference Dimensions - especially in the weight.
4. Sample the same pieces after dyeing and finishing and carry out the Reference Relaxation Procedure. Measure the Reference course and wale densities (and the Reference weight per unit area, if required).

It is advisable to repeat this procedure several times with the same or similar quality and wet process to obtain good average values before any attempt is made to utilise the values for process control or for setting up a new UDP on the computer program. Single sets of test data are not sufficiently reliable but a good picture can be built up over a period without excessive workload with a little patience. The Reference course and wale densities, and the Reference weight, should remain more or less constant over a period of time so that they can be continually updated and refined. Data for different preparation intensities and different depths of shade should be considered separately at first and a conscious decision should be made whether certain sets can be combined under the heading of one average process.

Once the process is well characterised, then the computer program can be customised with a named UDP, and quality control charts can be set up according to the normal rules of statistical process control. Routine measurements can then be made, at a reduced level, on a regular basis and plotted on the QC chart. If they change significantly, or show a tendency to drift, then this is a good sign that something in the whole fabric - finishing - testing system is changing and should be investigated.

The wet process calibration procedure needs to be done carefully and needs to be updated regularly. It consumes significant resources and should therefore provide commensurate benefits. This it certainly does. When a wet process is accurately calibrated, then the average Reference Dimensions can be calculated, using the STARFISH program, before any given fabric is ever put into work.

Once the average Reference Dimensions are accurately known then the finisher can:

a) Check the demands and the specifications of his customers with complete confidence. If a specification is unreasonable, then the customer can be advised and, more importantly, can be offered an alternative specification, which is attainable.

b) Check that the specification for a given grey cloth that he is supposed to process is in fact the correct one for delivering the required final performance after finishing.

c) Assuming that both the grey cloth and the customer's specification are reasonable, he can immediately determine the proper finishing control targets, in terms of width and course density, for any given knitted quality so that, provided he can actually achieve these targets, he can guarantee to deliver the required combination of weight and shrinkage.

d) Save a lot of time and effort on quality control. After all, if the knitted fabric is correct, and if the finished targets of width and course density have actually been achieved, then the weight and shrinkage must also be correct. Therefore, it is not necessary for the finisher to routinely monitor weight and shrinkage on the finished fabrics - only width and courses. These two are the quickest and easiest measurements that can be made and, moreover, they need to be made on a routine basis anyway in order to control the final production. Measurements of shrinkage are not only expensive, they are also very unreliable. In other words, so far as ensuring that targets of weight and shrinkage are being met, the whole of the effort of the quality control department should be directed towards calibrating and monitoring the process rather than performing mindless and largely ineffective routine tests on samples of fabric which have probably already been delivered before the QC test data have been reported.

Many practical dyers and finishers are very nervous about abandoning shrinkage testing, but our experience is that, provided the Reference Dimensions are accurately known, then calculated weight and shrinkage values are actually at least as reliable as directly measured values. An example is given in the following case study.

Case Study: Simulation of QC data

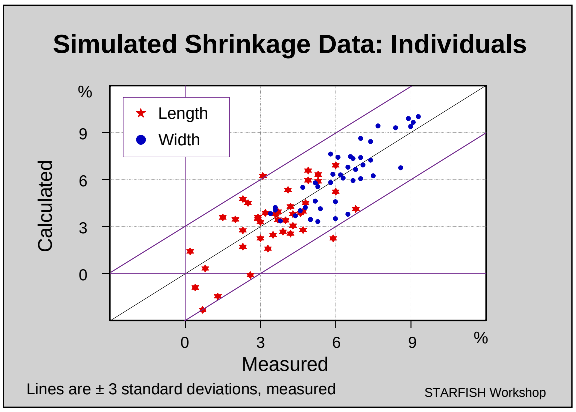
Computer printouts were obtained from a large manufacturer of body-width single jersey fabric for T-shirts. The data comprised course density, weight, width and shrinkage values measured on about 800 samples of the as-delivered fabrics, taken over a period of several months, and classified according to the machine size. For the simulation exercise, data for sizes 16, 17, 18, 19, 20 and 21 were utilised. The data from size 20 were used to "calibrate" the process, and to simulate the QC data, as follows.

1. Reference courses and wales were estimated for all of the size 20 samples, using the measured as delivered courses and width, the number of machine needles, and the length and width shrinkages. These values were averaged to provide the calibration values for course and wale densities.
2. The average process weight loss was calculated from the as delivered weight, courses and wales, together with the known grey yarn count and stitch length (delivered wales were calculated from delivered width and machine needles).
3. The calibration values were used to calculate as delivered weight and shrinkages for all of the samples using only the measured as delivered course density and width.

The results of the simulation are given in the following table, averaged within machine sizes, and in the diagram for individual monthly periods.

QC Data Simulation: Averaged Within Sizes

	Length Shrinkage %		Width Shrinkage %		Weight gsm	
Size	Meas.	Sim.	Meas.	Sim.	Meas.	Sim.
16	3.5	3.9	5.1	3.9	144	144
17	4.4	4.4	4.6	3.9	144	143
18	2.2	1.1	8.5	9.5	144	142
19	3.0	3.5	6.8	6.6	142	141
20*	**3.0**	**2.5**	**6.9**	**7.4**	**142**	**141**
21	5.1	4.5	5.8	5.9	141	140



It should be noted that the average standard deviation for the shrinkage testing was about one percentage point. Therefore, we should expect that the average simulated shrinkage values in the table should be within about one percentage point of the measured values, and the individuals in the diagram should be mostly within about two to three percentage points, if the simulation is to be judged successful. It can be seen that this was actually the case.

This set of calculations is simulating the situation where the dyer and finisher is maintaining a process calibration by making detailed measurements on only one size. Product performance for all sizes is checked only by measuring the course density and the width - i.e. the finishing control targets that have to be monitored in any case.

Note that this was not a true calibration, because the Reference course and wale densities had not actually been measured. They were only estimated from the measured courses, width and shrinkage values averaged over all of the data from size 20. Therefore, this is a pretty stringent test for the hypothesis that simulated QC data are as good as those, which are actually measured.

Calibration Procedures for Fabrics not covered by STARFISH

Finishing Factors

Finishing factors are used when the finisher does not have access to the STARFISH computer program, or when the fabric or yarn type is quite different from anything given in the STARFISH computer model. The principle used is that, for a given quality of fabric and a given wet process, there will be a more or less constant ratio between the Reference courses and wales in the grey fabric and those in the finished fabric. The procedure works best when the fabric type is a long running one, with regular repeat orders, but can also be applied on a one-off basis to any individual quality. Finishing factors established with one quality of fabric can be used to make predictions of finishing control targets for slightly different qualities of the same basic yarn and fabric type, and finished through the same wet processing sequence.

As with any STARFISH procedure, it is very important that the basic grey fabric can be relied upon for consistently uniform knitted construction, with yarn count and stitch length under excellent control.

1. Select and sample a series of grey test fabric pieces that will be subjected to the process which is to be calibrated.
2. Carry out the Reference Relaxation Procedure on each sample.
3. Measure course and wale densities. Let the averages of these be Cg and Wg stitches per cm respectively.
4. Sample the same pieces after preparation and dyeing and carry out the Reference Relaxation Procedure.
5. Measure course and wale densities (Cf, Wf).
6. Calculate Finishing Factors, which represent the ratios of finished fabric Reference Dimensions to the corresponding grey fabric Reference Dimensions, as follows:-

Courses Finishing Factor:	FFc	=	Cf / Cg
Wales Finishing Factor:	FFw	=	Wf / Wg
Width Finishing Factor:	FFwid	=	Wg / Wf

The width factor is simply the reciprocal of the factor determining wales.

Use the Finishing Factors to calculate the correct finishing targets of course density and width in the fabric as delivered to the customer, as illustrated below.

If the quality is one that is processed regularly, then it is advisable to repeat this procedure several times with the same or similar quality and wet process to obtain good average values. Single sets of test data are not sufficiently reliable. The Finishing Factors should remain more or less constant over a period of time so that they can be continually updated and refined. If they change significantly, or show a tendency to drift, then this is a good sign that something in the whole fabric - finishing - testing system is changing and should be investigated.

Example

For a 20 gauge interlock fabric, knitted on 1500 needles with 1/38's cotton count at a stitch length 0.340 cm, a calibration trial yields the following results.

Reference State	Grey	Winch Dyed	Finishing Factor
Courses / 3cm	49.5	45.9	0.927
Wales / 3cm	44.0	42.9	0.975
Tubular width (cm)	51.1	52.5	1.026

From these figures, how can we calculate the correct finished dimensions for a new fabric quality knitted on the same machine from 1/36's yarn to a stitch length of 0.350 cm if the shrinkage must not be greater than 10% in either direction?

First, we carry out the 5-cycle Reference Relaxation Procedure on several samples of the new grey fabric, and obtain these values for the Reference Sate

48.2 courses / 3 cm
42.7 wales / 3cm

By applying our finishing factors for winch-dyed interlock, we can calculate Reference State dimensions for the finished goods: -

48.2 * 0.927 = 44.7 courses / 3 cm
42.7 * 0.975 = 41.6 wales / 3 cm

We now have to calculate finishing control targets for the specified residual shrinkages. If the maximum allowed shrinkage is 10%, then the average shrinkage should be not more than 8%. Therefore, the finished dimensions would be those which correspond to: -

44.7 * 0.92 = 41.1 courses / 3 cm
41.6 * 0.92 = 38.3 wales / 3 cm

This simple proportioning procedure can only be applied to rather similar fabrics. In the present example, it could not be applied, for instance, to a 28 gauge interlock knitted from 1/60's yarn, because it assumes linear relationships which do not actually exist. The true relationships are much more complicated, which is why we have had to develop the STARFISH computer program. Finishing factors, on their own, work well enough with closely-related fabric structures because the proportioning errors are small.

Calibration Ratios

Calibration ratios can be used when the exact fabric and/or yarn type to be processed, and/or the wet process to be used are not available on the STARFISH computer program, but a similar yarn or fabric type is. The principle used is that, for a given fabric type and wet process, there will be a more or less constant ratio between the Reference courses and wales measured after finishing and those predicted by STARFISH for a similar fabric type which is made from a different yarn type, or finished through a different wet process. Calibration Ratios are an alternative to User Defined Processes.

Example

A manufacturer of fleece fabrics has calibrated his processing for plain single jersey fabrics but three-thread fleece is not available in STARFISH. However, he does have

Reference State data for one of the three-thread fleece fabrics. How can he use this knowledge to calculate finishing control targets for a new three-thread fleece quality?

Here the comparisons we are concerned with are not between grey and finished Reference States, but between the STARFISH-predicted Reference State and that which the finisher himself measures on the finished product.

The first step is to make STARFISH predictions for the three-thread fabric as though it were plain single jersey. The yarn count to use for the predictions is the sum of the ground and tie yarns, and the stitch length is the average of the ground and tie yarns.

If the STARFISH predictions are Cs and Ws, then:

Courses Calibration Ratio:	CRc	=	Cf / Cs
Wales Calibration Ratio:	CRw	=	Wf / Ws

Following are some data taken from an actual case study

	Measured (3-thread)	**Starfish (PSJ)**	**Calibration Ratio**
Reference C/cm	14.9	14.3	1.04
Reference W/cm	10.0	10.4	0.96

How should he finish another three-thread fleece fabric through the same route, if STARFISH predictions for the corresponding plain single jersey fabric are 15.0 courses per cm and 72.0 cm tubular width?

By applying his own Calibration Ratios to the new STARFISH predictions, he concludes that his course density target is 15.6 per cm and the finished tubular width should be 75.0 cm.

C/cm	=	15.0 * 1.04	=	15.6
Width	=	72.0 / 0.96	=	75.0

Note that the predictions of fabric weight per unit area made by the STARFISH plain single jersey model based on these calibrations will need to be corrected to find the weight of the corresponding three-thread fleece fabric. This is because of the additional weight provided by the inlay (backing) yarn. Also, remember that the process weight loss will be different for three-thread fleece. Allowance may have to be made for this effect (see next section).

To make the correction

1. Calculate the weight of each course of Ground yarn.

   G = ground yarn tex * ground course length * 0.01 mg

2. Calculate the weight of each course of Tie yarn.

   T = tie yarn tex * tie course length * 0.01 mg

3. Calculate the weight of each course of Inlay yarn

   I = inlay yarn tex * inlay course length * 0.01 mg.

4. Calculate the Weight Correction Factor as

   WCF = (G + T + I) / (G + T)

5. Multiply the plain single jersey weight prediction by the Weight Correction Factor.
6. Multiply the resulting three-thread fleece weight by the courses Calibration Ratio.

Example:

16g 30” 1500 Needles Fleece Machine

Ground = Yarn 20 tex; SL 3.95 mm
Tie = Yarn 20 tex; SL 4.14 mm
Inlay = Yarn 62.4 tex; SL 1.6 mm

G = 20 * 1500 * 0.395 * 0.01 = 118.5 mg

T = 20 * 1500 * 0.414 * 0.01 = 124.2 mg

I = 62.4 * 1500 * 0.16 * 0.01 = 149.8 mg

G + T + I = 392.5

G + T = 242.7

WCF = 392.5 / 242.7 = 1.617

Predicted plain single jersey weight = 206 gsm
Predicted three-thread fleece weight = 206 * 1.617 * 1.04 = 346.4

Process Weight Loss

Cotton fabrics lose weight during scouring and bleaching but they gain weight during dyeing and finishing. The net result is usually a loss in weight, called process weight loss. Actual measured values for Process Loss can be used to Calibrate a STARFISH model when one of the standard Depth of Shade options is not sufficiently accurate.

Many dyers and finishers will weigh the incoming grey rolls and the outgoing finished rolls to establish overall average net weight losses. Others will measure the piece lengths and calculate roll weights from the fabric weight per unit area, measured on cut samples. These are simple and practical measures to use for cost control purposes but for various reasons they do not give an accurate measure of process losses. They are not suitable for use in calibrating STARFISH.

Note that comparisons of changes in weight per unit area from grey to finished fabric are especially unreliable in this respect.

It is the nature of process losses that they are not constant, from time to time, from wet process to wet process, and from fabric quality to fabric quality. This means they must be handled statistically, by classifying fabrics and processes into groups and by taking more or less frequent measurements over a period of time.

Handled in this way, a relatively accurate picture can be built up for use either to reveal the true extent of unavoidable fabric weight changes (to exert pressure on avoidable losses) or to calibrate the STARFISH software.

Calculating Process Weight Loss

The method depends on the basic formula for the calculation of fabric weight, from yarn count, stitch length, and stitch density.

$$Wt = tex * SL * C * W * F$$

Where Wt = fabric weight per unit area, tex is the Yarn Count, SL is the average Stitch Length, C is the true Course Density, W is the Wale Density and F is a scaling factor, depending on the measurement units.

The formula applies equally to grey and dyed and finished fabrics, provided that the tex and stitch length of the dyed and finished fabric is used for the calculation of finished fabric weight.

In the grey fabric, we should have an accurate knowledge of the yarn count and the stitch length, because these are the knitting specification. But we do not know the stitch densities because these are not process control parameters. In the dyed and finished fabric, we should have an accurate knowledge of the course and wale densities, because these are the Finishing Control Targets, and we can easily determine the weight per unit area. But we do not know the tex and stitch length.

Using these two sets of information, we can estimate process losses by comparing the weight per loop in the grey and finished materials.

In the grey fabric, the weight per loop is given by

LpWt (g) = grey yarn tex * knitted stitch length * F

In the finished fabric, the weight per loop is given by

LpWt (f) = Weight / (C * W)

And the percentage process loss is then given by

Net Weight Change % = 100 * (LpWt (g) - LpWt (f)) / LpWt (g)

All of the necessary data should be available in the QC records of a well-run operation. It is only necessary to organise the system of logging and manipulating the data to facilitate calculations of process losses as a routine part of the process control / quality assurance system.

Calculating Process Weight Loss: An Example

The following data are taken from an actual industrial case study on Plain Jersey fabric, dyed to three different colours in deep shades.

Grey fabric	**Nominal**	**Measured**
Yarn Count, Ne	30	29.8
Stitch length, cm	0.282	0.2819

Finished Fabric	**Yellow**	**Navy**	**Red**	**Average**
Courses, cm	19.0	19.77	18.6	19.13
Wales, cm	15.0	15.0	14.9	14.97
Weight, gsm	153.5	160.5	154.3	156.1

Calculations

1.	Grey yarn tex	=	590.5 / 29.8	=	19.82
2.	Scaling factor			=	0.1
3.	Loop Wt grey	=	19.82 * 0.2819 * 0.1	=	0.5587
4.	Loop Wt finished	=	156.1 / (19.13 * 14.97)	=	0.5451
5.	Net Loss %	=	100 (0.5587 - 0.5451) / 0.5587	=	2.43

It should be emphasised that the result is quite sensitive to the accuracy of individual measurements. At least ten independent determinations are required for a reliable average.