2. Woven fabric construction

2.1 Introduction

The basics of woven cloth construction are explained in this chapter as well as cloth setting rules and formulae. There are also various tables that show full making particulars for different fabrics using the same yarn count for womenswear and menswear woven apparel fabrics. They are all commercially acceptable fabrics and provide accurate guides when developing cloths in other yarn counts.

A very important part of a woven fabric designer's job is that of cloth adjuster and modifier; where existing fabrics are sometimes required to be made in a different weight, weave, yarn (or all three), whilst preserving the firmness of the original cloths. These changes are almost impossible to carry out correctly without a sound understanding of the necessary formulae. This chapter contains several examples of how to use these formulae.

At various stages throughout the weaving and finishing processes, changes in fabric weight and dimension take place. These changes have to be anticipated and allowed for, so that the finished fabric is delivered to the customer at the standard finished width and within the originally quoted weight in grammes per running metre.

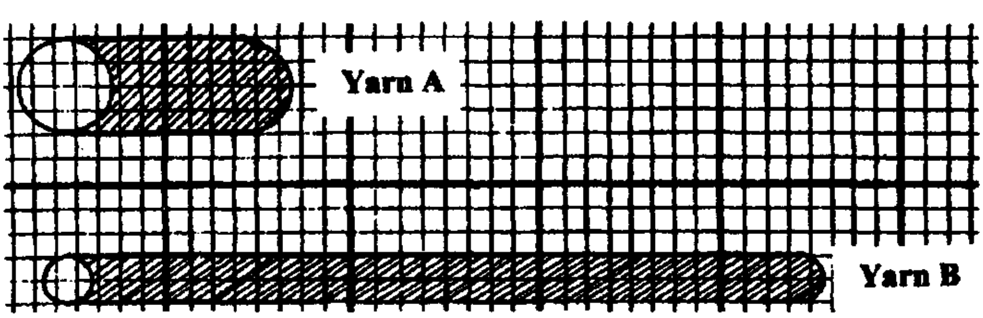
Finished cloth analysis is another important subject dealt with here. Fabrics obtained from customers and elsewhere are often copied for all sorts of reasons and accurate determination of the finished properties of such cloths is essential. These results are then adjusted to give the necessary in-loom making particulars to accurately reproduce the cloths.

The topics in this section address the practical cloth-making responsibilities of the woven fabric designer, rather than the creative and aesthetic ones.

2.2 Relationship between yarn count and thickness

Before considering cloth setting formulae it is important to fully understand the relationship between the count of a yarn and its thickness, see figure 2.1. Assuming it is possible to draw out yarn A to four times its original length, resultant yarn B will be thinner with a reduced radius and both yarns will have the same weight and volume but different yarn counts.

The weight of 20 cms of yarn B will be the same as 5 cms of yarn A, so 5 cms of yarn B will weigh one quarter of 5 cms of yarn A. If yarn A is say 100 Tex, then drawing it out to four times its original length makes resultant yarn B equal to 25 Tex.



2.1 Yarns A and B have the same weight and volume but different yarn counts.

Volumes of yarns A and B are the same, both being equal to the area of cross-section multiplied by length.

$$\pi A^2 \times 1 = \pi B^2 \times 4$$
$$A^2 = B^2 \times 4$$
$$A = B \times 2$$

As A = B × 2, the radius of yarn A is twice the radius of yarn B, therefore yarn A is twice the thickness of yarn B.

In the Direct Tex yarn numbering system, by quartering the yarn count the thickness is halved. The example below shows that 25 Tex is half the thickness of 100 Tex. From this it can be established that the thickness or diameter of a yarn is *directly proportional* to the square root of its count.

$$\text{Diameter of 25 Tex : diameter of 100 Tex} = \sqrt{25} : \sqrt{100} = 5 : 10 = 1 : 2$$

Therefore 25 Tex is half the diameter or thickness of 100 Tex

Having just proved that in the Direct Tex yarn numbering system the thickness or diameter of a yarn is *directly proportional* to the square root of the count, figures 2.2 and 2.3 and the following equations may explain this more clearly in another way.

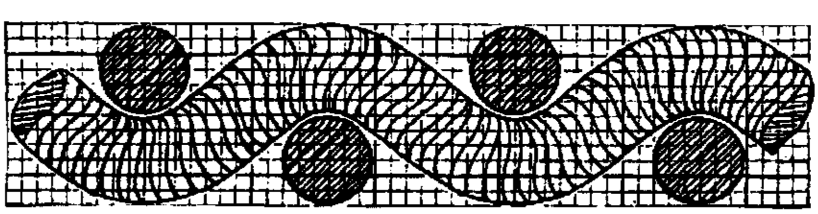
$$\frac{\sqrt{\text{Count B}}}{\sqrt{\text{Count A}}} = \frac{\text{Diameter B}}{\text{Diameter A}}$$

$$\frac{\sqrt{25}}{\sqrt{\text{Count A}}} = \frac{3}{6}$$

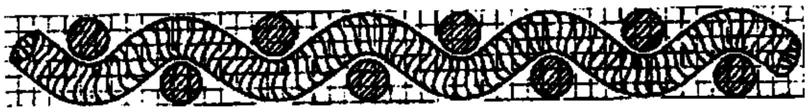
$$\sqrt{\text{Count A}} = (\sqrt{25} \times 6) / 3$$

$$= 10$$

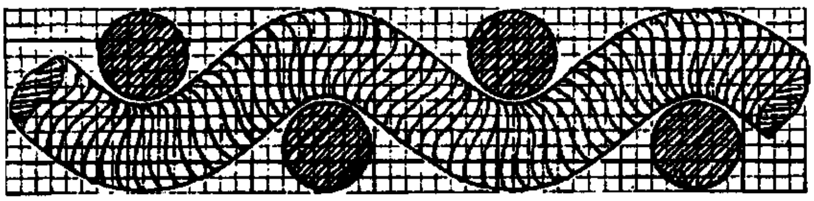
$$\text{Count A} = 100 \text{ Tex}$$



2.2 Yarn A with a relative diameter of six, assume the yarn count is unknown.



2.3 Yarn B with a relative diameter of three, assume the yarn count is 25 Tex.



2.4 Yarn A with a relative diameter of six, assume the yarn count is unknown.

2.5 Yarn B with a relative diameter of three, assume yarn count is 16 sks Yorkshire woollen.

In the Indirect yarn numbering system the yarn thickness or diameter is *inversely proportional* to the square root of the count. Figures 2.4 and 2.5 explain how using Yorkshire skeins woollen yarn counts.

$$\frac{\sqrt{\text{Count B}}}{\sqrt{\text{Count A}}} = \frac{\text{Diameter A}}{\text{Diameter B}}$$

$$\frac{\sqrt{16}}{\sqrt{\text{Count A}}} = \frac{6}{3}$$

$$\sqrt{\text{Count A}} = (\sqrt{16} \times 3) / 6$$

$$= 2$$

Count A = 4 skeins Yorkshire woollen

$$\begin{aligned} \text{Diameter of 16 sks YSW : diameter of 4 sks YSW} &= \sqrt{4} : \sqrt{16} \\ &= 2 : 4 \\ &= 1 : 2 \end{aligned}$$

Therefore 16 sks YSW is half the diameter of 4 sks YSW.

2.3 Relationship between frequency of interlacings and density of fabric

2.6 Cross-section of 24 threads side by side just touching in the space of one inch.

2.7 Plain weave interlacing allows only 12 threads in the space of one inch.

2.8 In 2/2 twill there is sufficient space to allow 16 threads in the space of one inch.

2.9 In 3/3 twill only six interlacings provides space for 18 threads in the space of one inch.

Figures 2.6 to 2.9 inclusive show clearly that if the same thickness of yarn is used in different weaves, for example, plain weave, 2/2 twill and 3/3 twill, the fewer interlacings there are in the weave, the greater the number of threads that can be packed into the same space.

In order to make the examples as simple as possible, Ashenhurst's original theory that one interlacing takes up the same space as one thread has been applied. This theory was subsequently found to be somewhat inaccurate and replaced by the angle of curvature theory which is dealt with in a later section.

2.4 Diameter reciprocal, weave value and percentage reduction below maximum setting

Cloth setting indicates the number of ends and picks per inch (or centimetre), to be inserted during the weaving process. It is influenced by the density and thickness of the yarn used and the firmness of the weave.

A cloth setting formula comprises three parts:

1) **Diameter reciprocal**: The first part of the setting formula determines the maximum number of threads in a particular yarn count that can be laid side by side just touching in the space of one inch.

Attempts to establish a relationship between yarn count and diameter reciprocal were made by Thomas Ashenhurst in the early 1880's when he provided the following formula for worsted yarns:

$$\text{Diameter reciprocal} = 0.9\sqrt{\text{Yarn Count} \times \text{Standard number}}$$

This can be applied to any Indirect yarn numbering system, using the appropriate yarn counts and standard numbers.

2) **Weave value**: After the diameter reciprocal has provided the number of threads in a particular yarn count that can be laid side by side in one inch, an allowance is made for the spaces required for warp and weft interlacings in the particular weave to be used. This value for any given weave can be determined as follows:

Weave value = F/(F+1), where F = average float

e.g. Plain weave = 1/(1+1) = 1/2
2/1 twill = 1.5/(1.5+1) = 1.5/2.5
2/2 twill = 2/(2+1) = 2/3

3) **Percentage reduction below maximum setting**: By using the diameter reciprocal and weave value parts of the formulae, theoretical maximum setting is determined. The figure however is further reduced to give the *actual* number of ends and picks per inch to be inserted during weaving. This percentage figure is based on experience and comparison with other commercially acceptable fabrics.

This final reduction influences firmness, drape, handle, weight and suitability of the fabric for its intended end use.

2.5 Ashenhurst's cloth setting formula

Maximum sett = $\mathbf{k}\sqrt{\text{Yards per pound}} \times F/(F+1)$ = ends, picks per inch.

k value for woollens = 0.84
k value for worsteds = 0.90
k value for cottons = 0.95 and F = average float.

Diameter reciprocal (woollens) = $0.84\sqrt{\text{count} \times \text{standard number}}$

Diameter reciprocal (worsteds) = $0.90\sqrt{\text{count} \times \text{standard number}}$

Diameter reciprocal (cottons) = $0.95\sqrt{\text{count} \times \text{standard number}}$

Maximum setting (plain weave) = $k\sqrt{\text{yards/lb}} \times ½$

Maximum setting (2/1 twill) = $k\sqrt{\text{yards/lb}} \times 1.5/2.5$

Maximum setting (2/2 twill) = $k\sqrt{\text{yards/lb}} \times 2/3$

Ashenhurst arrived at a weave value of F/(F+1) by allowing the equivalent of one thread space for each intersection in the weave. This was later proved to be inaccurate on two points:

1) The angle of curvature theory showed geometrically that the space occupied by one intersection in a weave was less than the diameter of one thread – actually 0.732 of a diameter. See section 2.6.

2) In floats longer than two it was likely that threads would bunch together and roll over each other to a certain extent, rather than lie conveniently side by side as Ashenhurst had originally assumed, thereby making more 'space' than that required for exactly one thread.

Later setting theories (such as Law's) take these points into consideration but Ashenhurst's original theory, though on the low side for determining maximum ends and picks per inch, remains reasonably accurate for plain weave, 2/1 twill and 2/2 twill.

Ashenhurst's formula for determining diameter reciprocal used the Indirect yarn numbering system, but adjustments can be made to accommodate Direct yarn numbering systems such as Tex.

Yards per pound of any Tex yarn count can be calculated as follows:

$$\frac{1000 \times 39.37 \times 454}{\text{Tex} \times 36} = \frac{496\,499}{\text{Tex}}$$

For example, diameter reciprocal for worsted yarn in Tex count is:

$$0.9\sqrt{\text{yards/lb}} = 0.9\sqrt{496\,499}\ /\ \text{Tex} = 634\ /\ \sqrt{\text{Tex}}$$

Bearing in mind that Ashenhurst's settings are lower than those of his successors a more accurate value might be: $660\ /\ \sqrt{\text{Tex}}$.

Cloth setting is not an exact science so determination of maximum setting using diameter reciprocal and weave value should only be accepted as an accurate starting point. The *actual* number of ends and picks per inch (or centimetre) to be inserted during weaving is decided after deliberation on what percentage reduction is made to the calculated maximum setting.

The following are examples using the original Ashenhurst setting formula:

Example 1 Calculate setting for a fabric using 20 sks Yorkshire woollen yarn in plain weave, 20% below maximum setting.

$$\text{Sett} = 0.84\sqrt{\text{yards/lb}} \times F/(F+1) \times \text{percentage reduction.}$$
$$= 0.84\sqrt{20 \times 256} \times \tfrac{1}{2} \times 80/100 = 24.04 \text{ ends and } 24.04 \text{ picks per inch.}$$

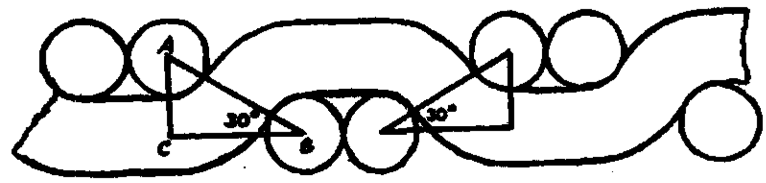
Example 2 Calculate setting for a 2/2 twill fabric, 10% below maximum setting using 2/56 worsted yarn.

$$\text{Sett} = 0.90\sqrt{28 \times 560} \times 2/3 \times 90/100 = 67.6 \text{ ends and } 67.6 \text{ picks per inch.}$$

If ends and picks per centimetre are preferred, calculated ends and picks per inch are simply divided by 2.54.

2.6 Angle of curvature theory

In figure 2.10 the angle between adjacent threads at an intersection is assumed to be 30° in a balanced, square woven cloth.



2.10 The square of the hypotenuse on a right-angled triangle is equivalent to the sum of the squares of the other two sides.

AB = 2 diameters (or 1 diameter plus 2 × ½ diameters) = 2
AC = 2 × ½ diameters = 1
CB is unknown

$$CB = \sqrt{AB^2 - AC^2}$$

$$= \sqrt{2^2 - 1^2}$$

$$= \sqrt{4-1}$$

$$= \sqrt{3}$$

$$= 1.732$$

Therefore, if CB equals one diameter plus one interlacing, then one intersection is equal to 1.732 − 1 = 0.732

After the angle of curvature theory Ashenhurst's new formula for maximum setting became:
DR × F/(F+I) where DR = diameter reciprocal
F = average float in weave
I = intersection = 0.732

Weave value for plain weave = 1/(1+0.732) = 1/1.732
Weave value for 2/1 twill = 1.5/(1.5+0.732) = 1.5/2.232
Weave value for 2/2 twill = 2/(2+0.732) = 2/2.732

Comparing the original Ashenhurst formula with the later one based on the angle of curvature theory for a 2/2 twill fabric with a DR of 63 below:
Old formula = 63 × 2/(2+1) = 63 × 2/3 = 42 ends, picks per inch.
Later formula = 63 × 2/(2+0.732) = 63 × 2/2.732 = 46 ends, picks per inch.

Ashenhurst's original formula (diameter intersection theory) gives firm cloth settings for plain weave, 2/1 twill and 2/2 twill but is not used much when the average float is more than two. Law experimented to increase the maximum setting of square sett cloths and came up with the formula $\sqrt{500 \times \text{yarn count}}$ to find the DR for a yarn. He also added 5% for each float above two.

Below is a comparison between the two theories for an imaginary setting in a 3/3 twill cloth made with 2/18 worsted yarn count:

Ashenhurst for 3/3 twill = $0.9\sqrt{9\times560}\times 3/4$ = 48 ends, picks per inch.
Law for 3/3 twill = $\sqrt{500\times9}\times 3/4\times 1.05$ = 53 ends, picks per inch.

2.7 Law's cloth setting formulae

Maximum sett = $\sqrt{500\times C}\times F/(F+1)$ + 5% for every end in the average float above 2.

This is the setting rule generally used in the Worsted industry.

Maximum sett = $\sqrt{230\times C}\times F/(F+1)$ + 5% for every end in the average float above 2.

This is the setting rule generally used in the Yorkshire woollen industry.

Law's rules for maximum settings in the following weaves:
2/2 hopsack: $DR \times F/(F+1) + 4.5\% = DR \times 2/3 \times 1.045$
3/3 hopsack: $DR \times F/(F+1) + 9.5\% = DR \times 3/4 \times 1.095$
4/4 hopsack: $DR \times F/(F+1) + 19\% = DR \times 4/5 \times 1.190$

Sateens: $DR \times F/(F+1)$ + 5.5% for every end in the average float.

Backed cloths:

2/2 twill 1Face, 1Back warp or weft backed fabric, sateen stitched, reduce face setting by 6.75%.
2/2 twill 1Face, 1Back warp or weft backed fabric, twill or crow stitched, reduce face setting by 13.5%.

Self-stitched double cloths:

2/2 twill 1Face, 1Back double cloth, sateen stitched, reduce face setting by 10%.
Twill or crow stitched, reduce face setting by 20%.
Double sateen stitched, reduce face setting by 20%.
Double twill stitched, reduce face setting by 25%.
Double crow stitched, reduce face setting by 25%.

Non-square cloths:

Sometimes it is desirable to construct a cloth with a steeper twill than the normal 45° of a square sett cloth and this can be simply done by increasing the number of warp ends per inch. However, the difficult part is to determine the *reduced* number of weft picks per inch which will maintain the same degree of firmness in the cloth.

For example, a square sett 2/2 twill cloth which might normally have 64 ends and picks per inch can be made instead with 120 ends per inch in order to give a much steeper twill effect.

The *reduced* number of weft picks per inch is calculated as follows:
If X is the increase in ends per inch above square sett, the *decrease* in picks per inch is $1.8\sqrt{X}$. $1.8\sqrt{120-64} = 1.8\sqrt{56} = 13.5$ *decrease* in picks per inch.

So the setting required to preserve the firmness of the original square sett cloth will be 120 ends and 50 (64–14) picks per inch.

Alternatively, the same square sett 2/2 twill fabric with 64 ends and 64 picks per inch can be adjusted to say, 96 picks per inch to give a flat twill effect. In this case the *reduced* number of ends per inch is calculated as follows:

If X is the increase in picks per inch above square sett, then the *decrease* in ends per inch is $3.6\sqrt{X}$. $3.6\sqrt{96-64} = 3.6\sqrt{32} = 20.36$ *decrease* in ends per inch.

Therefore, the setting required to preserve the firmness of the original square sett cloth is 96 picks and 44 (64–20) ends per inch.

2.8 Different fabric weights, densities and in-loom particulars using woollen yarns

One yarn count can be used to make at least three different, basic cloths:

1) Plain weave
2) 2/1 twill
3) 2/2 twill.

They will be different to each other in weight, density, drape, handle, price and end use. Each of the three cloths can be made in lighter and heavier versions – the lighter ones with fewer ends and picks per centimetre, heavier ones with more ends and picks per centimetre.

In determining cloth setting, care must be taken to ensure that lighter weight versions are not too loosely sett below maximum; otherwise seam slippage might become a problem in garments. At the other end of the scale, cloths which are too firmly sett might be difficult to weave owing to excessive warp end breakages. So before actually using cloth setting formulae it is advisable to consult 'in house' fabric making records kept by all woven cloth manufacturers, in order to find a starting point by comparing weight and firmness of commercially acceptable cloths. As there is no formula to calculate the required total number of warp threads in loom to give a standard finished fabric width of 150 cms, the same 'in house' records will provide guidance.

Cloth setting is more than just calculating the number of warp ends and weft picks per centimetre to be inserted during weaving using a particular yarn count and weave structure. Desired weight in grammes per linear metre has to be considered, as well as the aforementioned total number of warp ends to produce a cloth of 150 cms finished width. Pieces that finish under the standard width will cause problems for the garment maker and might well be rejected. Finished widths that are two or three centimetres over 150 cms will probably be acceptable to the customer, but the cloth manufacturer will be giving cloth away as costings are calculated for 150 cms finished width.

The following series of tables (2.1 to 2.7 inclusive) are given as accurate guides to 'in-loom' making particulars. As well as recommended warp and weft details, they show resultant weights in grammes per linear metre and total number of threads required to produce fabrics at standard finished width. They also show percentage width shrinkage from 'in-loom' width, as well as finished length yield from a standard 70 metre warp length. The cloth setting formula shows how loom ends and picks per centimetre are calculated and then rounded up or down to give the appropriate metric reed and picks per 10 cms to be inserted in loom.

The data provided in the tables is from commercially acceptable fabrics and serves as an accurate guide for developing other pure new wool woven fabrics.

Table 2.1 shows full 'in-loom' making particulars for three different menswear jacketing cloths made from the same single lambswool yarn in 2/2 twill weave. They are different in weight, firmness, drape, handle and price.

From the same calculated maximum number of ends and picks per centimetre in loom, Cloth 1 is reduced by 45%, Cloth 2 by 35% and Cloth 3 by 25%. Each is then rounded up or down to give the appropriate metric reed required and number of picks per 10 cms to be inserted during weaving. Note that as percentage reduction below maximum becomes less, settings are firmer and width shrinkages decrease.

As previously stated no formula exists with which to calculate the total number of ends required in the warp to give 150 cms standard finished width of cloth. Experience of and comparison with existing commercially acceptable fabrics is essential.

Cloths 4, 5, 6 and 7 in table 2.2 are made from the same single Shetland yarn. Two of the cloths are made in plain weave, the other two in 2/2 twill.

The cloths in plain weave are sett firmer (see column 14 showing percentage reduction below maximum setting) and are suitable for womenswear lightweight jackets and skirts. The fabrics in 2/2 twill are sett looser and wider in loom and make excellent jacketings for both womenswear and menswear.

Two-ply versions of the above Shetland yarn, one in plain weave the other in 2/2 twill are featured in table 2.3. Plain weave Cloth 8 is sett 25% below maximum but there is no technical reason why a reduction of 20% or 30% cannot be used as it is entirely a question of personal preference and experience. Heavier Cloth 9 in 2/2 twill is sett wider in loom to allow greater width shrinkage in finishing and ensure the desirable fuller handle in a womenswear coating.

Table 2.4 features four traditional Donegal cloths suitable for both womenswear and menswear garments. Cloths 10 and 11 are made from the same Donegal yarn in plain weave and 2/2 twill respectively. Both are ideally suitable for jacketings in the characteristic homespun look.

Cloths 12 and 13 are also in plain weave and 2/2 twill respectively, but this time made from a typical Donegal yarn twice the thickness of the one used in Cloths 10 and 11. Notice how percentage reduction below maximum setting in both plain weave fabrics is fairly similar, as is also the case with the twills.

Two Cheviot wool cloths are featured in table 2.5, one of which, Cloth 15, is made in 2/2 twill from a single Cheviot yarn of 7 nm count warp and weft. It is sett 45% below maximum and gives a finished cloth weight of 385 grammes per linear metre 150 cms finished width. This is an ideal jacketing cloth for both men and women.

Plain weave Cloth 14 is made with a two-ply version of the same Cheviot yarn, sett firmly in loom (only 10% below maximum) to give a substantial coating fabric for womenswear.

Two lightweight worsted cloths are shown in table 2.6, one in plain weave the other 2/2 twill and both made with the same 2/48 nm worsted yarn. Plain weave Cloth 16 is firmly sett 5% below maximum whilst 2/2 twill Cloth 17 is sett looser at 15% below. These firmer settings give the sleek, smooth yet firm handle associated with worsted fabrics and both fabrics are suitable for lightweight menswear jacketings.

Table 2.1 'In-loom' making particulars for different menswear jacketings made from the same single lambswool yarn

Cloth No.	Weight grm/lm	Metric reed	Picks/ 10 cms	Weave	Warp yarn (nm)	Weft yarn (nm)	Total ends	Loom width (cms)	Std. fin. width (cms)	Width shkge %	Std. wp. length (metres)	Std. fin. length (metres)	Sett below max.
1	310	47/2	95	2/2 twill	11.5	11.5	1756	186.8	150	19.7	70	63.6	45%
2	345	51/2	110	2/2 twill	11.5	11.5	1888	185.1	150	18.9	70	63.5	35%
3	375	30/4	125	2/2 twill	11.5	11.5	2100	175.0	150	14.3	70	63.5	25%

To calculate in loom $k\sqrt{\text{yards/lb}} \times F/(F+1) \times \%$ below maximum $\times 1/2.54$ = ends, picks per cm.

Cloth 1 $0.84\sqrt{11.5\times 496} \times 2/3 \times 55/100 \times 1/2.54 = 9.16$ ends, picks/cm = 47/2 reed (94ends/10cm), 95 picks/10cm.

Cloth 2 $0.84\sqrt{11.5\times 496} \times 2/3 \times 65/100 \times 1/2.54 = 10.82$ ends, picks/cm = 51/2 reed (102ends/10cm), 110 picks/10cm.

Cloth 3 $0.84\sqrt{11.5\times 496} \times 2/3 \times 75/100 \times 1/2.54 = 12.49$ ends, picks/cm = 30/4 reed (120ends/10cm), 125 picks/10cm.

Table 2.2 'In-loom' making particulars for different fabrics made from the same single Shetland yarn.

Cloth No.	Weight grm/lm	Metric reed	Picks/ 10 cms	Weave	Warp yarn (nm)	Weft yarn (nm)	Total ends	Loom width (cms)	Std. fin. width (cms)	Width shkge %	Std. wp. length (metres)	Std. fin. length (metres)	Sett below max.
4	300	40/2	85	PC	8.5	8.5	1380	172.5	150	13.0	70	63.9	25%
5	325	45/2	85	PC	8.5	8.5	1552	172.4	150	13.0	70	63.9	15%
6	340	40/2	90	2/2 twill	8.5	8.5	1476	184.5	150	18.7	70	63.5	40%
7	370	45/2	95	2/2 twill	8.5	8.5	1644	182.7	150	17.9	70	63.5	35%

To calculate in loom $k \sqrt{\text{yards/lb}} \times F/(F+1) \times \%$ below maximum $\times 1/2.54$ = ends, picks per cm.

Cloth 4 $0.84 \sqrt{8.5 \times 496} \times 1/2 \times 75/100 \times 1/2.54 = 8.05$ ends, picks/cm = 40/2 (80ends/10cms), 85 picks/10cm.

Cloth 5 $0.84 \sqrt{8.5 \times 496} \times 1/2 \times 85/100 \times 1/2.54 = 9.13$ ends, picks/cm = 45/2 reed (90ends/10cms), 85 picks/10cm.

Cloth 6 $0.84 \sqrt{8.5 \times 496} \times 2/3 \times 60/100 \times 1/2.54 = 8.59$ ends, picks/cm = 40/2 reed (80ends/10cms), 90 picks/10cm.

Cloth 7 $0.84 \sqrt{8.5 \times 496} \times 2/3 \times 65/100 \times 1/2.54 = 9.30$ ends, picks/cm = 45/2 reed (90ends/10cms), 95 picks/10cm.

Table 2.3 'In-loom' making particulars for two different fabrics using the same two-ply Shetland yarn

Cloth No.	Weight grm/lm	Metric reed	Picks/ 10 cms	Weave	Warp yarn (nm)	Weft yarn (nm)	Total ends	Loom width (cms)	Std. fin. width (cms)	Width shkge %	Std. wp. length (metres)	Std. fin. length (metres)	Sett below max.
8	385	28/2	55	PC	2/8.5	2/8.5	932	166.4	150	9.8	70	64.4	25%
9	475	26/2	60	2/2 twill	2/8.5	2/8.5	1052	202.3	150	25.8	70	66.4	45%

To calculate in loom $k\sqrt{\text{yards/lb}} \times F/(F+1) \times \%$ below maximum $\times 1/2.54 =$ ends, picks per cm.

Cloth 8 $0.84\sqrt{4.25 \times 496} \times 1/2 \times 75/100 \times 1/2.54 = 5.69$ ends, picks/cm = 28/2 reed (56ends/10cm), 55 picks/10cm.

Cloth 9 $0.84\sqrt{4.25 \times 496} \times 2/3 \times 55/100 \times 1/2.54 = 5.57$ ends, picks/cm = 26/2 reed (52ends/10cm), 60 picks/10cm.

Table 2.4 'In-loom' making particulars for traditional Donegal cloths.

Cloth No.	Weight grm/lm	Metric reed	Picks/ 10 cms	Weave	Warp yarn (nm)	Weft yarn (nm)	Total ends	Loom width (cms)	Std. fin. width (cms)	Width shkge %	Std. wp. length (metres)	Std. fin. length (metres)	Sett below max.
10	330	38/2	80	PC	8.0	8.0	1368	180.0	150	16.7	70	63.9	25%
11	365	38/2	85	2/2 twill	8.0	8.0	1400	184.2	150	18.6	70	63.3	40%
12	435	26/2	50	PC	4.0	4.0	912	175.4	150	14.5	70	63.9	30%
13	500	28/2	55	2/2 twill	4.0	4.0	1032	184.3	150	18.6	70	64.4	45%

To calculate in loom $k \sqrt{\text{yards/lb}} \times F/(F+1) \times$ % below maximum $\times 1/2.54$ = ends, picks per cm.

Cloth 10 $0.84 \sqrt{8.0 \times 496} \times 1/2 \times 75/100 \times 1/2.54 = 7.81$ ends, picks/cm = 38/2 reed (76ends/10cm), 80 picks/10cm.

Cloth 11 $0.84 \sqrt{8.0 \times 496} \times 2/3 \times 60/100 \times 1/2.54 = 8.33$ ends, picks/cm = 38/2 reed (76ends/10cm), 85 picks/10cm.

Cloth 12 $0.84 \sqrt{4.0 \times 496} \times 1/2 \times 70/100 \times 1/2.54 = 5.16$ ends, picks/cm = 26/2 reed (52ends/10cm), 50 picks/10cm.

Cloth 13 $0.84 \sqrt{4.0 \times 496} \times 2/3 \times 55/100 \times 1/2.54 = 5.40$ ends, picks/cm = 28/2 reed (56ends/10cm), 55 picks/10cm.

Table 2.5 'In-loom' making particulars for two Cheviot cloths, one with a single yarn and the other with a two-ply version of the same yarn

Cloth No.	Weight grm/lm	Metric reed	Picks/ 10 cms	Weave	Warp yarn (nm)	Weft yarn (nm)	Total ends	Loom width (cms)	Std. fin. width (cms)	Width shkge %	Std. wp. length (metres)	Std. fin. length (metres)	Sett below max.
14	650	32/2	65	PC	2/7.0	2/7.0	1104	172.5	150	13.0	70	62.5	10%
15	385	36/2	75	2/2 twill	7.0	7.0	1336	185.5	150	19.1	70	64.4	45%

To calculate in loom $k\sqrt{\text{yards/lb}} \times F/(F+1) \times \%$ below maximum $\times 1/2.54 =$ ends, picks per cm.

Cloth 14 $0.84\sqrt{3.5\times 496} \times 1/2 \times 90/100 \times 1/2.54 = 6.20$ ends, picks/cm = 32/2 reed (64ends/10cm), 65 picks/10cm.

Cloth 15 $0.84\sqrt{7.0\times 496} \times 2/3 \times 55/100 \times 1/2.54 = 7.14$ ends, picks/cm = 36/2 reed (72ends/10cm), 75 picks/10cm.

Table 2.6 'In-loom' making particulars for two lightweight worsted cloths

Cloth No.	Weight grm/lm	Metric reed	Picks/ 10 cms	Weave	Warp yarn (nm)	Weft yarn (nm)	Total ends	Loom width (cms)	Std. fin. width (cms)	Width shkge %	Std. wp. length (metres)	Std. fin. length (metres)	Sett below max.
16	235	94/2	165	PC	2/48	2/48	3068	163.2	150	8.1	70	63.0	5%
17	295	57/4	210	2/2 twill	2/48	2/48	3800	166.7	150	10.0	70	63.5	15%

To calculate in loom $k\sqrt{\text{yards/lb}} \times F/(F+1) \times \%$ below maximum $\times 1/2.54 =$ ends, picks per cm.

Cloth 16 $0.90\sqrt{24\times496} \times 1/2 \times 95/100 \times 1/2.54 = 18.36$ ends, picks/cm = 94/2 reed (188ends/10cm), 165 picks/10cm.

Cloth 17 $0.90\sqrt{24\times496} \times 2/3 \times 85/100 \times 1/2.54 = 21.90$ ends, picks/cm = 57/4 reed (228ends/10cm), 210 picks/10cm.

Table 2.7 gives making particulars for four novelty tweed jacketings and coatings for womenswear. They are all sett between 40 to 45% below maximum and wide in loom to encourage fairly high width shrinkage in finishing to give the full and soft handle desired.

Jacketing Cloth 18 is constructed with two threads of 8.5 nm Shetland yarn and one thread of 4 nm bouclé yarn warp and weft, using an 8-end weave. In order to calculate the ends and picks per centimetre required in loom, an average yarn count has to be calculated as follows:

8.5 units of 8.5 nm	=	1.00	× 2	=	2.00
8.5 units of 4 nm	=	2.12	× 1	=	2.12
8.5 units of X	=	?	× 3	=	4.12

average yarn count (warp and weft) = (8.5 × 3) / 4.12 = 6.19 nm.

The other jacketing Cloth 19 in 2/2 twill has a ground section of 8.5 nm Shetland yarn, with a single line overcheck of 4 nm bouclé yarn replacing every twentieth thread warp and weft. Average yarn count is calculated as previously:

8.5 units of 8.5 nm	=	1.00	× 19	=	19.00
8.5 units of 4 nm	=	2.12	× 1	=	2.12
8.5 units of Y	=	?	× 20	=	21.12

average yarn count (warp and weft) = (8.5 × 20) / 21.12 = 8.05 nm.

Coating Cloth 20 is constructed with two threads of two-ply Shetland yarn equivalent to 4.25 nm and one thread of 2 nm large bouclé yarn warp and weft in 2/2 twill weave. Average yarn count is calculated below:

4.25 units of 4.25 nm	=	1.00	× 2	=	2.00
4.25 units of 2 nm	=	2.12	× 1	=	2.12
4.25 units of Z	=	?	× 3	=	4.12

average yarn count (warp and weft) = (4.25 × 3) / 4.12 = 3.09 nm.

Finally, coating Cloth 21 is warped with three threads of two-ply Shetland yarn equivalent to 4.25 nm and one thread of 2 nm large bouclé yarn. The weft this time is not the same as the warp but instead solid two-ply Shetland yarn as used in part of the warp, so an average count has to be calculated for the warp only. This time the weave is 3/3 twill.

4.25 units of 4.25 nm	=	1.00	× 3	=	3.00
4.25 units of 2 nm	=	2.12	× 1	=	2.12
4.25 units of X	=	?	× 4	=	5.12

average yarn count (warp) = (4.25 × 4) / 5.12 = 3.32 nm.
yarn count (weft) = 4.25 nm.

Table 2.7 'In-loom' making particulars for four novelty tweed jacketings and coatings for womenswear.

Cloth No.	Weight grm/lm	Metric reed	Picks/ 10 cms	Weave	Warp yarn (nm)	Weft yarn (nm)	Total ends	Loom width (cms)	Std. fin. width (cms)	Width shkge %	Std. wp. length (metres)	Std. fin. length (metres)	Sett below max.
18	375	34/2	70	Crepe	6.19	6.19	1216	178.8	150	16.1	70	63.5	45%
19	340	40/2	85	2/2 twill	8.05	8.05	1476	184.5	150	18.7	70	63.5	40%
20	525	23/2	50	2/2 twill	3.09	3.09	820	178.3	150	15.9	70	64.5	45%
21	560	28/2	60	3/3 twill	3.32	4.25	1050	187.5	150	20.0	70	64.5	45%

To calculate in loom $k\sqrt{\sqrt{\text{yards/lb}}} \times F/(F+1) \times \%$ below maximum $\times 1/2.54$ = ends, picks per cm

Cloth 18 $0.84\sqrt{6.19 \times 496} \times 2/3 \times 55/100 \times 1/2.54 = 6.72$ ends, picks/cm = 34/2 reed (68ends/10cm), 70 picks/10cm.

Cloth 19 $0.84\sqrt{8.05 \times 496} \times 2/3 \times 60/100 \times 1/2.54 = 8.36$ ends, picks/cm = 40/2 reed (80ends/10cm), 85 picks/10cm.

Cloth 20 $0.84\sqrt{3.09 \times 496} \times 2/3 \times 55/100 \times 1/2.54 = 4.75$ ends, picks/cm = 23/2 reed (46ends/10cm), 50 picks/10cm.

Cloth 21 (wp) $0.84\sqrt{3.32 \times 496} \times 3/4 \times 1.05 \times 55/100 \times 1/2.54 = 5.81$ ends/cm = 28/2 reed (56ends/10cm).

(wft) $0.84\sqrt{4.25 \times 496} \times 3/4 \times 1.05 \times 55/100 \times 1/2.54 = 6.58$ picks/cm = 60 picks/10cm.

When a cloth is made for the first time it is usually in the form of a trial length or sample piece. Changes in weight, width and length, which will occur at various stages of manufacture, should be diligently recorded. If the finished trial is satisfactory as to intended weight, firmness and handle but is under or over the standard finished width of 150 cms, warp ends can be added or subtracted from the total number of threads in the original trial. The fabric would then be costed in the full knowledge that all future lengths and pieces would finish at the standard width of 150 cms.

2.9 Suggested in-loom making particulars for menswear worsted fabrics

Table 2.8 shows full making particulars for four menswear worsted suiting cloths in plain weave. They range in yarn count from finest of 2/80 nm to coarsest of 2/56 nm.

The loom settings are calculated as follows:

$$\text{Ends, picks per cm} = k\sqrt{\text{yards/lb}} \times F/(F+1) \times \%\ \text{below maximum} \times 1/2.54$$

Results are rounded off for appropriate metric reed numbers and picks per 10 cms in loom. Subsequent pages show how the four different fabric settings are calculated.

As there is no formula with which to calculate the total number of warp ends required to give 150 cms standard finished width of cloth, comparisons have to be made with existing commercially acceptable cloths. Percentage reductions below maximum setting are also decided after comparison with existing cloths and by experience.

Plain weave setting calculations:

Cloth A   2/80 nm warp and weft,

$$0.9\sqrt{40 \times 496} \times 1/2 \times 98/100 \times 1/2.54 = 24.46 \text{ ends, picks/cm.}$$

Use 64/4 metric reed (256 ends/10cms), 255 picks/10cms.

Cloth B   2/72 nm warp and weft,

$$0.9\sqrt{36 \times 496} \times 1/2 \times 98/100 \times 1/2.54 = 23.20 \text{ ends, picks/cm.}$$

Use 60/4 metric reed (240 ends/10cms), 240 picks/10cms.

Cloth C   2/64 nm warp and weft,

$$0.9\sqrt{32 \times 496} \times 1/2 \times 97/100 \times 1/2.54 = 21.65 \text{ ends, picks/cm.}$$

Use 56/4 metric reed (224 ends/10cms), 225 picks/10cms.

Cloth D   2/56 nm warp and weft,

$$0.9\sqrt{28 \times 496} \times 1/2 \times 96/100 \times 1/2.54 = 20.04 \text{ ends, picks/cm.}$$

Use 52.5/4 metric reed (210 ends/10cms), 210 picks/10cms.

Table 2.8 'In-loom' making particulars for four menswear worsted suiting cloths in plain weave.

Cloth No.	Weight grm/lm	Metric reed	Picks/ 10 cms	Weave	Warp yarn (nm)	Weft yarn (nm)	Total ends	Loom width (cms)	Std. fin. width (cms)	Width shkge %	Std. wp. length (metres)	Std. fin. length (metres)	Sett below max.
A	215	64/4	255	PC	2/80	2/80	4224	165	150	9.0	70	64.4	2%
B	225	60/4	240	PC	2/72	2/72	3960	165	150	9.0	70	64.4	2%
C	235	56/4	225	PC	2/64	2/64	3720	166	150	9.6	70	64.4	3%
D	255	52.5/4	210	PC	2/56	2/56	3488	166	150	9.6	70	64.4	4%

Finished fabric weights in grammes per linear metre which appear in table 2.8 are calculated as follows:

$$\text{Warp weight (grammes)} = \frac{\text{Total ends} \times 100 \times 100 \times 98}{\text{nm} \times 95 \times 97 \times 100}$$

$$\text{Weft weight (grammes)} = \frac{\text{Picks/10 cms} \times 10 \times \text{width (cms)} \times 100 \times 98}{\text{nm} \times 100 \times 97 \times 100}$$

Warp weight + weft weight = weight in grammes/linear metre 150 cms finished width.

Assumed length take-up in weaving = 5%
Assumed length loss in finishing = 3%
Assumed weight loss in finishing = 2%

Plain weave calculations of grammes/linear metre (150cms wide):

Cloth A 2/80 nm, 25.6 ends/cm, 25.5 picks/cm, 165cms loom width,

warp: $\frac{25.6 \times 165 \times 100 \times 100 \times 98}{40 \times 95 \times 97 \times 100}$ = 112.30 gms.

weft: $\frac{25.5 \times 165 \times 100 \times 98}{40 \times 97 \times 100}$ = 106.27 gms.

Total = 218.57 (215 gms/lm)

Cloth B 2/72 nm, 24.0 ends/cm, 24.0 picks/cm, 165cms loom width,

warp: $\frac{24.0 \times 165 \times 100 \times 100 \times 98}{36 \times 95 \times 97 \times 100}$ = 116.98 gms.

weft: $\frac{24.0 \times 165 \times 100 \times 98}{36 \times 97 \times 100}$ = 111.13 gms.

Total = 228.11 (225 gms/lm)

Cloth C 2/64 nm, 22.4 ends/cm, 22.5 picks/cm, 166cms loom width,

warp: $\frac{22.4 \times 166 \times 100 \times 100 \times 98}{32 \times 95 \times 97 \times 100}$ = 123.58 gms.

weft: $\frac{22.5 \times 166 \times 100 \times 98}{32 \times 97 \times 100}$ = 117.92 gms.

Total = 241.50 (235 gms/lm)

Cloth D 2/56 nm, 21.0 ends/cm, 21.0 picks/cm, 166cms loom width,

warp: $\dfrac{21.0 \times 166 \times 100 \times 100 \times 98}{28 \times 95 \times 97 \times 100} = 132.40$ gms.

weft: $\dfrac{21.0 \times 166 \times 100 \times 98}{28 \times 97 \times 100} = \underline{125.78 \text{ gms}}$.

Total = 258.18 (<u>255 gms/lm</u>)

Table 2.9 provides similar information to that in table 2.8 but this time for four worsted suiting fabrics in 2/2 twill. The appropriate calculations for cloth setting and grammes per linear metre are as follows:

2/2 twill setting calculations:

Cloth E 2/80 nm warp and weft,

$0.9\sqrt{40 \times 496} \times 2/3 \times 97/100 \times 1/2.54 = 32.27$ ends, picks/cm.

<u>Use 82/4 metric reed (328 ends/10cms), 330 picks/10cms.</u>

Cloth F 2/72 nm warp and weft,

$0.9\sqrt{36 \times 496} \times 2/3 \times 97/100 \times 1/2.54 = 30.62$ ends, picks/cm.

<u>Use 77/4 metric reed (308 ends/10cms), 310 picks/10cms</u>.

Cloth G 2/64 nm warp and weft,

$0.9\sqrt{32 \times 496} \times 2/3 \times 95/100 \times 1/2.54 = 28.27$ ends, picks/cm.

<u>Use 72/4 metric reed (288 ends/10cms), 290 picks/10cms.</u>

Cloth H 2/56 nm warp and weft,

$0.9\sqrt{28 \times 496} \times 2/3 \times 94/100 \times 1/2.54 = 26.16$ ends, picks/cm.

<u>Use 67/4 metric reed (268 ends/10cms), 270 picks/10cms.</u>

Table 2.9 'In-loom' making particulars for another four menswear worsted suiting cloths but this time in 2/2 twill

Cloth No.	**Weight grm/lm**	**Metric reed**	**Picks/ 10 cms**	**Weave**	**Warp yarn (nm)**	**Weft yarn (nm)**	**Total ends**	**Loom width (cms)**	**Std. fin. width (cms)**	**Width shkge %**	**Std. wp. length (metres)**	**Std. fin. length (metres)**	**Sett below max.**
E	290	82/4	330	2/2 twill	2/80	2/80	5644	172	150	12.8	70	64.4	3%
F	300	77/4	310	2/2 twill	2/72	2/72	5296	172	150	12.8	70	64.4	3%
G	320	72/4	290	2/2 twill	2/64	2/64	4952	172	150	12.8	70	64.4	5%
H	335	67/4	270	2/2 twill	2/56	2/56	4608	172	150	12.8	70	64.4	6%

2/2 twill calculations of grammes/linear metre (150cms wide):

Cloth E 2/80 nm, 32.8 ends/cm, 33.0 picks/cm, 172cms loom width,

warp: $$\frac{32.8 \times 172 \times 100 \times 100 \times 98}{40 \times 95 \times 97 \times 100} = 149.99 \text{ gms.}$$

weft: $$\frac{33.0 \times 172 \times 100 \times 98}{40 \times 97 \times 100} = \underline{143.36 \text{ gms}}.$$

Total = 293.35 (<u>290 gms/lm</u>)

Cloth F 2/72 nm, 30.8 ends/cm, 31.0 picks/cm, 172cms loom width,

warp: $$\frac{30.8 \times 172 \times 100 \times 100 \times 98}{36 \times 95 \times 97 \times 100} = 156.50 \text{ gms.}$$

weft: $$\frac{31.0 \times 172 \times 100 \times 98}{36 \times 97 \times 100} = \underline{149.64 \text{ gms.}}$$

Total = 306.14 (<u>300 gms/lm</u>)

Cloth G 2/64 nm, 28.8 ends/cm, 29.0 picks/cm, 172cms loom width,

warp: $$\frac{28.8 \times 172 \times 100 \times 100 \times 98}{32 \times 95 \times 97 \times 100} = 164.63 \text{ gms.}$$

weft: $$\frac{29.0 \times 172 \times 100 \times 98}{32 \times 97 \times 100} = \underline{157.48 \text{ gms.}}$$

Total = 322.11 (<u>320 gms/lm</u>)

Cloth H 2/56 nm, 26.8 ends/cm, 27.0 picks/cm, 172cms loom width,

warp: $$\frac{26.8 \times 172 \times 100 \times 100 \times 98}{28 \times 95 \times 96 \times 100} = 176.90 \text{ gms.}$$

weft: $$\frac{27.0 \times 172 \times 100 \times 98}{28 \times 97 \times 100} = \underline{167.57 \text{ gms.}}$$

Total = 344.47 (<u>335 gms/lm</u>)

2.10 Changing cloth weights and settings

Consider two ways to increase the weight of any woven fabric.

1) By using thicker yarn, because yarn count reflects weight a direct change of yarn count used in a cloth implies a direct change of weight.

For example, a fabric is made with 20 nm yarn count warp and weft and weighs 300 grammes per linear metre. The same fabric made with 10 nm yarn (double the thickness of 20 nm yarn) will weigh 600 grammes per linear metre – 20 to 10 inversely. This sounds sensible but of course is completely impractical.

The cloth weight has changed proportionally but no allowance has been made for the increased diameter of 10 nm yarn count. If the original cloth is of acceptable firmness, this heavier one will be much too firm and impossible to weave.

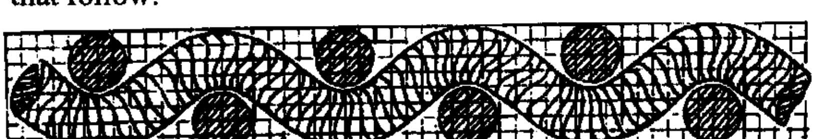
2) By increasing the number of ends and picks per centimetre, the desired change of weight might be achieved.

It can be assumed that 32 ends and picks per centimetre in the same yarn count will give double the weight of 16 ends and picks per centimetre. However, if no allowance is made for the increased number of ends and picks, doubling the number is as impractical as doubling the yarn thickness in order to double the weight of a cloth.

The only practical way to make such an alteration is to combine a change of yarn count with a change of setting, in order to keep the firmness of the adjusted cloth similar to the original one. Finer yarns (higher yarn count numbers in the Indirect system) must be accompanied by an increased number of ends and picks per centimetre. Thicker yarns (lower yarn count numbers in the Indirect system) require fewer ends and picks per centimetre.

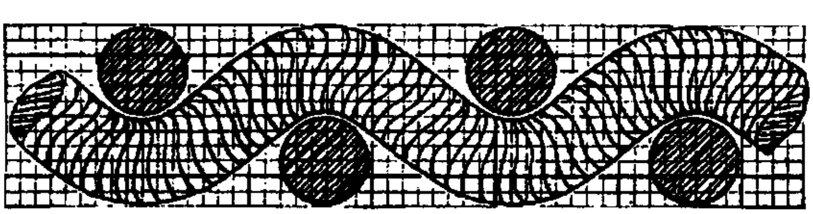
In the Indirect yarn numbering system, yarn diameters are in *inverse* proportion to the square root of the counts and cloth settings are in *direct* proportion to the square root of the counts.

This is best illustrated in plain weave cross-sections figures 2.11a, 2.11b and 2.11c where weave and firmness are identical. Each weave intersection occupies the same space as the diameter of one thread (pre-angle of curvature theory) in order to simplify the calculations that follow.



2.11a Yarn diameter takes up 4 squares on point paper.

2.11b Yarn diameter takes up 3 squares on point paper.



2.11c Yarn diameter takes up 6 squares on point paper.

Assuming the yarn in figure 2.11a above is 9 skeins Yorkshire woollen count and picks per inch are 20.5; it is easy to determine yarn count and ends, picks per inch for the cloth in figure 2.11c, by using the following formula:

$$\frac{\sqrt{\text{Count A}}}{\sqrt{\text{Count C}}} = \frac{\text{Diameter C}}{\text{Diameter A}}$$

(yarn diameters are in *inverse* proportion to the square root of the counts)

By cross-multiplication:

$$\sqrt{\text{Count C (?)}} \times \text{Diameter C (6)} = \sqrt{\text{Count A (9)}} \times \text{Diameter A (4)}$$

$$\sqrt{\text{Count C (?)}} = (\sqrt{9} \times 4) / 6 = 2, \quad \text{therefore count C} = 4 \text{ sks Yorkshire}$$

$$\frac{\sqrt{\text{Count A}}}{\sqrt{\text{Count C}}} = \frac{\text{Ends A}}{\text{Ends C}}$$

(cloth setting is in *direct* proportion to the square root of the count)

By cross-multiplication:

$$\text{Ends C (?)} \times \sqrt{\text{Count A (9)}} = \text{Ends A (20.5)} \times \sqrt{\text{Count C (4)}}$$

$$\text{Therefore ends C} = (20.5 \times \sqrt{4}) / \sqrt{9} = 13.67 \text{ ends, picks per inch}$$

Cloth in figure 2.11a with an assumed count of 9 sks Yorkshire and 20.5 ends/picks per inch,
Cloth in figure 2.11c with a calculated count of 4 sks Yorkshire and 13.67 ends/picks per inch.

In order to check that the above calculated yarn count and setting for cloth in figure 2.11c are correct, simply calculate the settings for both cloths using Law's formula allowing 10% reduction below maximum setting for both of them as follows:

$$A = \sqrt{230 \times 9} \times ½ \times 90/100 = 20.5 \text{ ends, picks per inch}$$
$$C = \sqrt{230 \times 4} \times ½ \times 90/100 = 13.65 \text{ ends, picks per inch}$$

Similarly yarn count and ends per inch for cloth B in the same firmness as cloth A are calculated as follows:

$$\frac{\sqrt{\text{Count A}}}{\sqrt{\text{Count B}}} = \frac{\text{Diameter B}}{\text{Diameter A}}$$

(yarn diameters in *inverse* proportion to the square root of the counts)

By cross-multiplication:

$$\sqrt{\text{Count B (?)}} \times \text{Diameter B (3)} = \sqrt{\text{Count A (9)}} \times \text{Diameter A (4)}$$
$$\sqrt{\text{Count B (?)}} = (\sqrt{9} \times 4) / 3 = 4, \quad \text{therefore count B} = 16 \text{ sks Yorkshire}$$

$$\frac{\sqrt{\text{Count A}}}{\sqrt{\text{Count B}}} = \frac{\text{Ends A}}{\text{Ends B}}$$ (cloth setting is in *direct* proportion to the square root of the count)

By cross-multiplication:

$$\text{Ends B (?)} \times \sqrt{\text{Count A (9)}} = \text{Ends A (20.5)} \times \sqrt{\text{Count B (16)}}$$

$$\text{So ends B} = (20.5 \times \sqrt{16}) / \sqrt{9} = 27.3 \text{ ends, picks per inch}$$

Cloth in figure 2.11a with an assumed count of 9 sks Yorkshire and 20.5 ends/picks per inch, Cloth in figure 2.11b with a calculated count of 16 sks Yorkshire and 27.3 ends/picks per inch.

As before in order to check that the above calculated yarn count and setting for cloth in figure 2.11b are correct, calculate both settings using Law's formula and allow 10% reduction below maximum setting for each as follows:

$$A = \sqrt{230 \times 9} \times ½ \times 90/100 = 20.5 \text{ ends, picks/inch.}$$

$$B = \sqrt{230 \times 16} \times ½ \times 90/100 = 27.3 \text{ ends, picks/inch.}$$

2.11 Similar cloths formulae

This section focuses on one of the most important functions of the woven fabric designer, namely that of cloth modifier and adjuster. Earlier sections showed how setting formulae are used in the construction of new cloths, whereas the examples in this section deal with adjustments and alterations to existing cloths.

To make a slight alteration to the weight of a fabric an end and pick or two might be added to make it a little heavier. Conversely the odd end and pick or two might be taken out to make it a little lighter in weight. This is quite acceptable but the former adjustment will make the cloth *firmer* than the original whilst the latter adjustment will make it *looser* than the original. Ideally therefore any alteration to cloth setting should be such that the adjusted cloth retains the same firmness as the original one.

Woven fabrics are described as being of similar firmness if they have the same percentage reduction below maximum setting. In the following examples, which are calculated according to Law, each is reduced by 10% below maximum setting regardless of the weave used, thereby making each of similar firmness.

$$\sqrt{500 \times C} \times F/(F+1) \times 90/100 = \text{ends, picks/inch, 10\% below maximum setting,}$$

2/56 worsted, 2/2 twill, 10% below maximum = 71 ends, picks/inch,
2/32 worsted, 2/2 twill, 10% below maximum = 54 ends, picks/inch,
2/48 worsted, plain weave, 10% below maximum setting = 49 ends, picks/inch.

The diameter of a yarn and the number of threads per inch (or centimetre) must be increased or decreased in proportion, to ensure identical firmness in the adjusted cloth. The following formulae do just that.

Formula for use with yarn counts in the Indirect yarn numbering system:

$$\frac{W1}{W2} : \frac{\sqrt{C2}}{\sqrt{C1}} : \frac{E2}{E1}$$

W1 = weight of original or known cloth,
C1 = yarn count of the original or known cloth (Indirect system),
E1 = ends, picks/inch of the original or known cloth,
W2 = weight of the adjusted cloth,
C2 = yarn count of the adjusted cloth (Indirect system),
E2 = ends, picks/inch of the adjusted cloth.

Formula for use with yarn counts in the Direct yarn numbering system:

$$\frac{W1}{W2} : \frac{\sqrt{C1}}{\sqrt{C2}} : \frac{E2}{E1}$$

W1 = weight of original or known cloth,
C1 = yarn count of the original or known cloth (Direct system),
E1 = ends, picks/inch of the original or known cloth,
W2 = weight of adjusted cloth,
C2 = yarn count of the adjusted cloth (Direct system),
E2 = ends, picks/inch of the adjusted cloth.

The examples that follow show how the formulae work by cross-multiplication.

Change setting and yarn count but in the same weave:

Example 1

An existing cloth has been made with 72 ends, picks/inch in 2/48 worsted yarn. If this yarn should become unavailable how many ends and picks per inch of alternative yarn count 2/56 worsted would be required to make another cloth of similar firmness in the same weave?

Cloth 1 72 ends, picks/inch, 2/48 worsted yarn,
Cloth 2 ? ends, picks/inch, 2/56 worsted yarn.

$$\frac{W1}{W2} : \frac{\sqrt{C2}}{\sqrt{C1}} : \frac{E2}{E1}$$

By cross-multiplication we get the following equation:

$$E2 \times \sqrt{C1} = E1 \times \sqrt{C2}$$

$$\text{so } E2 \times \sqrt{24} = 72 \times \sqrt{28}$$
$$E2 = (72 \times \sqrt{28}) / \sqrt{24}$$
$$= (72 \times 5.29) / 4.90$$
$$= 77.73 \text{ or } 78 \text{ ends, picks/inch.}$$

Example 2

In a cloth trial the designer might wish to put solid wefts of different yarn counts across a common warp. The picks per inch of each must be adjusted so that all wefts will make cloths of similar firmness. This is how to calculate the different picks/inch.

Weft 1	8.5 nm (20 picks/inch assumed),
2	9.0 nm,
3	10.0 nm,
4	7.5 nm.

$$\frac{\sqrt{C2}}{\sqrt{C1}} : \frac{P2}{P1} \qquad P2 \times \sqrt{C1} = P1 \times \sqrt{C2}$$

$$P2 = (20 \times \sqrt{9}\,) / \sqrt{8.5}$$
$$= (20 \times 3) / 2.91$$
$$= 20.6 \text{ picks/inch.}$$

$$\frac{\sqrt{C3}}{\sqrt{C1}} : \frac{P3}{P1} \qquad P3 \times \sqrt{C1} = P1 \times \sqrt{C3}$$

$$P3 = (20 \times \sqrt{10}\,) / \sqrt{8.5}$$
$$= (20 \times 3.16) / 2.91$$
$$= 21.7 \text{ picks/inch.}$$

$$\frac{\sqrt{C4}}{\sqrt{C1}} : \frac{P4}{P1} \qquad P4 \times \sqrt{C1} = P1 \times \sqrt{C4}$$

$$P4 = (20 \times \sqrt{7.5}\,) / \sqrt{8.5}$$
$$= (20 \times 2.74) / 2.91$$
$$= 18.8 \text{ picks/inch.}$$

If picks/inch had not been adjusted then wefts 2 and 3 (both finer than weft 1) would have been *looser* than weft 1, and weft 4 (thicker than weft 1) would have been *firmer* than weft 1.

Changing sett, yarn count and weight in the same weave:

Example 1

An acceptable cloth is made with 24 threads/cm warp and weft in 2/48 nm yarn and weighs 370 grammes/linear metre. If 2/40 nm yarn is used in place of 2/48 nm what would be the threads/cm for a fabric of similar firmness in the same weave? Also what would be the weight of the new cloth?

Cloth 1	2/48 nm,	24 threads/cm,	2/2 twill,	370 grammes/linear metre,
Cloth 2	2/40 nm,	?	2/2 twill,	?

$$\frac{W1}{W2} : \frac{\sqrt{C2}}{\sqrt{C1}} : \frac{E2}{E1}$$

By cross-multiplication:

$$E2 \times \sqrt{C1} = E1 \times \sqrt{C2}$$
$$E2 \times \sqrt{24} = 24 \times \sqrt{20}$$
$$E2 = (24 \times \sqrt{20}) / \sqrt{24}$$
$$= (24 \times 4.47) / 4.9$$
$$= 21.89 \text{ ends, picks/cm.}$$

Further cross-multiplication:

$$W2 \times \sqrt{C2} = W1 \times \sqrt{C1}$$
$$W2 \times \sqrt{20} = 370 \times \sqrt{24}$$
$$W2 = (370 \times \sqrt{24}) / \sqrt{20}$$
$$= (370 \times 4.9) / 4.47$$
$$= 405 \text{ grammes/linear metre.}$$

Example 2

An acceptable plain weave fabric has 19.5 threads/cm of 2/48 nm warp and weft in loom and weighs 280 grammes/linear metre. What would be the new yarn count and setting to make a cloth of similar firmness to weigh 300 grammes/linear metre?

Cloth 1	2/48 nm,	19.5 threads/cm,	plain weave,	280 grammes/linear metre,
Cloth 2	?	?	plain weave,	300 grammes/linear metre.

$$\frac{W1}{W2} : \frac{\sqrt{C2}}{\sqrt{C1}} : \frac{E2}{E1}$$

By cross-multiplication:

$$\sqrt{C2} \times W2 = \sqrt{C1} \times W1$$
$$\sqrt{C2} = (\sqrt{C1} \times W1) / W2$$
$$= (\sqrt{24} \times 280) / 300$$
$$= (4.9 \times 280) / 300$$
$$= 4.57$$
$$C2 = 20.9 \text{ or } 2/42 \text{ nm.}$$

Further cross-multiplication:

$$W2 \times E2 = W1 \times E1$$
$$E2 = (W1 \times E1) / W2$$
$$= (280 \times 19.5) / 300$$
$$= 18.2 \text{ threads /cm.}$$

Example 3

A cloth is made with 60 ends and picks per inch in loom of 2/48 worsted yarn in 2/2 twill. What would be the loom particulars for another cloth of similar firmness but made 25% heavier?

Cloth 1	2/48 worsted,	60 ends,picks/inch,	2/2 twill,	weight 1,
Cloth 2	?	?	2/2 twill,	weight 1.25

$$\frac{W1}{W2} : \frac{\sqrt{C2}}{\sqrt{C1}} : \frac{E2}{E1}$$

Cross-multiply:

$$\sqrt{C2} \times W2 = \sqrt{C1} \times W1$$
$$\sqrt{C2} = (\sqrt{C1} \times W1) / W2$$
$$= (\sqrt{24} \times 1.00) / 1.25$$
$$= (4.9 \times 1.00) / 1.25$$
$$= 3.92$$
$$C2 = 15.36 = 2/32 \text{ worsted.}$$

Further cross-multiplication:

$$E2 \times W2 = E1 \times W1$$
$$E2 = (E1 \times W1) / W2$$
$$= (60 \times 1.00) / 1.25$$
$$= 48 \text{ ends, picks.}$$

Changing sett, yarn count weight and weave:

Changes dealt with up till now have applied to weight, setting and yarn count. Each formula has been used to cross-multiply and form different equations depending on the unknown factors.

All previous examples and those that follow can be looked on as everyday technical questions the woven fabric designer has to address. Time must be spent on studying the formulae otherwise potential designers and woven fabric makers might face problems when they first join a woven fabric manufacturing company.

The following examples now include changes of weave as well so another factor has to be added to the equations. Setting ratios or weave values for the more common weaves are listed below:

Plain weave	= 0.50	also $0.50^2 = 0.250$
2/1 twill	= 0.60	$0.60^2 = 0.360$
2/2 twill	= 0.67	$0.67^2 = 0.449$
3/3 twill	= 0.79	$0.79^2 = 0.624$

Example 1

A 2/2 twill fabric is made with 72 ends and picks/inch of 2/48 worsted yarn and weighs 340 grammes/linear metre, supply details for a cloth of similar firmness in 3/3 twill to weigh 395 grammes/linear metre.

Cloth 1	340 grammes,	72 ends/picks,	2/48 worsted,	2/2 twill,
Cloth 2	395 grammes,	?	?	3/3 twill.

$$\frac{W1}{W2} : \frac{\sqrt{C2}}{\sqrt{C1}} : \frac{E2}{E1}$$

$$W1 \times E1 \times (\text{setting ratio } 2)^2 = W2 \times E2 \times (\text{setting ratio } 1)^2$$
$$W1 \times E1 \times (0.79)^2 = W2 \times E2 \times (0.67)^2$$
$$340 \times 72 \times 0.624 = 395 \times E2 \times 0.449$$

$$E2 = \frac{340 \times 72 \times 0.624}{395 \times 0.449} = 86.13 = 86 \text{ ends, picks/inch.}$$

$$W1 \times \sqrt{C1} \times \text{setting ratio 2} = W2 \times \sqrt{C2} \times \text{setting ratio 1}$$
$$W1 \times \sqrt{C1} \times 0.79 = W2 \times \sqrt{C2} \times 0.67$$

$$\sqrt{C2} = \frac{W1 \times \sqrt{C1} \times 0.79}{W2 \times 0.67} = \frac{340 \times \sqrt{24} \times 0.79}{395 \times 0.67}$$

$= 4.97$, therefore $C2 = 24.7 = 2/49$ worsted.

2.12 How to calculate warp and weft weights for piece and sample length production

There are three different basic formulae depending on which yarn numbering system is used:

1) Direct Tex yarn numbering system,
2) Indirect metric yarn numbering system,
3) Indirect (yards/lb) yarn numbering systems – worsted, cotton, etc.

1) Direct Tex system:

$$\text{Warp} = \frac{\text{Total ends} \times \text{length (metres)} \times \text{Tex} \times \text{waste}}{1000 \times 1000} = \text{kgs}$$

$$\text{Weft} = \frac{\text{Picks/cm} \times \text{length (metres)} \times \text{width (cms)} \times \text{Tex} \times \text{waste}}{1000 \times 1000} = \text{kgs}$$

Example 1

Calculate warp and weft weights for a piece 64 metres long using 280 Tex warp and weft. There are 1190 warp ends and 5.9 picks per centimetre, and the loom width is 199.7 cms. Allow 2.5% waste.

$$\text{Warp} = \frac{1190 \times 64 \times 280 \times 1.025}{1000 \times 1000} = 21.86 \text{ kgs}$$

$$\text{Weft} = \frac{5.9 \times 64 \times 199.7 \times 280 \times 1.025}{1000 \times 1000} = 21.64 \text{ kgs}$$

2) Indirect metric yarn numbering system:

$$\text{Warp} = \frac{\text{Total ends} \times \text{length (metres)} \times \text{waste}}{\text{nm} \times 1000} = \text{kgs}$$

$$\text{Weft} = \frac{\text{Picks/cm} \times \text{length (metres)} \times \text{width (cms)} \times \text{waste}}{\text{nm} \times 1000} = \text{kgs}$$

Example 2

Calculate weights of warp and weft required for two pieces each 70 metres long with a total number of 1348 warp ends, 186.3 cms wide in loom and 7.5 picks/cm. Warp and weft yarn count is 7 nm and 2% has to be allowed for waste.

$$\text{Warp} = \frac{1348 \times 140 \times 1.02}{7 \times 1000} = 27.5 \text{ kgs}$$

$$\text{Weft} = \frac{7.5 \times 140 \times 186.3 \times 1.02}{7 \times 1000} = 28.5 \text{ kgs}$$

3) Indirect (yards/lb) yarn numbering system:

$$\text{Warp} = \frac{\text{Total ends} \times \text{length (yards)} \times \text{waste}}{\text{count} \times \text{standard number}} = \text{lbs}$$

$$\text{Weft} = \frac{\text{Picks/inch} \times \text{length (yards)} \times \text{width (inches)} \times \text{waste}}{\text{count} \times \text{standard number}} = \text{lbs}$$

Example 3

Calculate warp and weft weights in 15 sks Yorkshire woollen, for a 75 yard piece with a total number of 1328 ends. Width in loom is 76.5 inches and there are 18.5 picks/inch. Allow 3% waste in warp only.

$$\text{Warp} = \frac{1328 \times 75 \times 1.03}{15 \times 256} = 26.71 \text{ lbs}$$

$$\text{Weft} = \frac{18.5 \times 75 \times 76.5}{15 \times 256} = 27.64 \text{ lbs}$$

2.13 Influences on both weight and dimensional changes in woven fabrics

The standard finished width of a piece of woollen or worsted woven apparel fabric is 150 cms within selvedges. The finished length can be anything between 60 and 75 metres depending on the standard piece warp length which can vary from one fabric manufacturer to another.

Changes in length, width and weight take place at different stages of manufacture before the finished piece of cloth is ready for dispatch to the customer. This must be at the standard finished width and at the previously quoted weight in grammes per linear metre.

The weight and dimensional changes that occur in a piece of woven fabric during manufacture might be recorded as follows:

Warp length --------------- 70 metres
Woven length ------------- 67 metres
Finished length ------------ 64 metres
In-loom reed width ------- 188 cms
Ex-loom piece width------ 178 cms

Finished piece width-------150 cms
Ex-loom piece weight------26.0 kgs
Finished piece weight------24.7 kgs.

The difference between warp length and woven length is due to wastage in starting up in loom and take-up in warp thread interlacings during the weaving process.

Variation between woven length and finished length is due to length contraction taking place during scouring and milling operations. This difference has to be monitored closely because excessive length shrinkage in finishing simply means less cloth to sell in a piece.

Ex-loom width is narrower than in-loom width because weft interlacings relax after being held out to loom width by the reed during weaving. Finally, finished piece weight is less than ex-loom piece weight due to oil and fibre loss in scouring and milling processes.

As pieces have to be 150 cms width within selvedges after wet and dry finishing processes are completed, careful consideration has to be given to the following direct influences. Only then can decisions be made as to what width in loom will give 150 cms finished cloth width.

1) Raw materials used – a pure new wool weft yarn will encourage greater weft shrinkage during wet finishing than say a polyester/wool or synthetic yarn.

2) Soft or hard spun yarn – naturally a soft spun yarn will contract more in wet finishing than a hard spun one.

3) Weave structure – a weave with long floats and few interlacings will encourage greater width shrinkage than one with short floats and more frequent interlacings.

4) Density of ends and picks – the denser and firmer the fabric the less width shrinkage there is likely to be.

5) Finishing routine – generally speaking the more scouring and milling a fabric receives, the more width and length shrinkage.

It is therefore obvious that in constructing any new woven fabric all the aforementioned weight and dimensional changes must be anticipated and taken into consideration. Cloth making particulars have to be carefully calculated and assessed so that after length, width and weight changes take place, finished pieces will be delivered to the garment maker in the standard finished width of 150 cms. They should also be within say + or – 4% of the previously quoted weight in grammes per linear metre.

Accurate records of weight and dimensional changes are normally kept for every piece produced and should be studied and used as accurate guides when developing new fabrics.

2.14 Finished cloth analysis

The following information is required to reproduce an unknown fabric:

1) Fabric weight in grammes per linear metre.

Trim, measure and weigh the finished fabric sample and calculate as below:

$$\frac{\text{Weight of sample (grammes)} \times 100 \times 150}{\text{Dimensions of sample}} = \text{grammes/linear metre}$$

2) Finished warp ends per centimetre (or inch).

Using a piece glass, carefully count the number of ends in one inch.

3) Finished weft picks per centimetre (or inch).

In a like manner count the number of weft picks in one inch.

4) Weave analysis.

Put down on point paper each warp and weft thread interlacing in one repeat of the weave. Determine draft and peg plan required to reproduce the weave.

5) Percentage warp shrinkage.

Take a few warp ends from the pre-measured fabric sample and measure the stretched length of each one in turn against a ruler. Take the average stretched length and calculate as follows:

$$\frac{\text{Stretched length minus unstretched length} \times 100}{\text{Stretched length}} = \text{percentage warp shrinkage}$$

6) Percentage weft shrinkage.

Take a few weft picks from the pre-measured fabric sample and calculate as previously:

$$\frac{\text{Stretched length minus unstretched length} \times 100}{\text{Stretched length}} = \text{percentage weft shrinkage}$$

7) Warp yarn count (clean).

Weigh the warp ends previously taken from the fabric sample having first determined the total unstretched length of yarn and calculate thus:

$$\frac{\text{Total inches of yarn} \times 454 \times 1}{36 \times \text{weight (grammes)} \times 256} = \text{clean yarn count (Yorkshire woollen)}$$

8) Weft yarn count (clean),

Weigh the weft picks taken from the sample and calculate as before:

$$\frac{\text{Total inches of yarn} \times 454 \times 1}{36 \times \text{weight (grammes)} \times 256} = \text{clean yarn count (Yorkshire woollen)}$$

The above finished state particulars then have to be modified in order to provide the necessary ‘in-loom’ particulars and dimensions to accurately reproduce the original fabric.

2.15 How to calculate in-loom particulars from finished state

1) 'In-loom' warp ends per centimetre (or inch) are calculated by *reducing* the finished number of ends by the weft shrinkage.

Example: A finished fabric has 20 warp ends per centimetre and weft shrinkage is known to be 11%. What would be the number of warp ends per centimetre in loom?

In-loom ends per cm $= (20 \times 89) / 100 = 17.8$

2) 'In-loom' picks per centimetre (or inch) are calculated by *reducing* the finished number of weft picks by the warp shrinkage.

Example: A finished fabric has 16 weft picks per centimetre and warp shrinkage is known to be 5%. Calculate the number of weft picks per centimetre in loom.

In-loom picks per cm $= (16 \times 95) / 100 = 15.2$

3) 'In-loom' width of warp is calculated by *increasing* the finished width by the weft shrinkage.

Example: Standard finished width of a piece is 150 cms and the width shrinkage is 12.5%. Calculate the width in loom to give 150 cms finished width of cloth.

Width in loom $= (150 \times 100) / 87.5 = 171.4$ cms

4) To calculate the woven length required to give 1 metre of finished cloth *increase* the finished length by the length shrinkage.

Example: If length shrinkage is 6% what will be the woven length?

Woven length $= (1 \times 100) / 94) = 1.064$ metres to yield 1 metre finished cloth.

5) To calculate the greasy warp yarn count from clean count, use length shrinkage and oil loss as follows:

Example: Clean warp count 21 sks Yorkshire woollen
Length shrinkage 5%
Oil loss in finishing 8%

Greasy warp count $= (21 \times 100 \times 92) / (95 \times 100) = 20.3$ sks Yorkshire

6) To calculate the greasy weft yarn count from clean, width shrinkage and oil loss in finishing are used as in the previous example:

Example: Clean weft count 22 sks Yorkshire woollen
Width shrinkage 10%
Oil loss in finishing 8%

Greasy weft count $= (22 \times 100 \times 92) / (90 \times 100) = 22.5$

Warp and weft yarn counts are influenced by yarn contraction during weaving, accompanied by further yarn contraction and weight loss in finishing. Warp or weft contraction makes the yarn count thicker but loss in finishing makes it thinner, so one offsets the other to a certain extent.

2.16 How to determine finished fabric weight in grammes per linear metre at standard finished width

Method A: This is done in four stages as follows:

1) Calculate the greasy weight (kilos) of warp yarn required for a piece of cloth, excluding waste.
2) Calculate the greasy weight (kilos) of weft yarn required to weave the piece, excluding waste.
3) Add the two weights together and reduce by the anticipated weight loss in finishing.
4) Multiply the resultant clean weight (kilos) total by 1000 and divide by the known or estimated finished length of the piece in metres. This will give the weight in grammes of 1 metre of finished cloth, 150 cms wide.

Information required to make the calculation:
Warp length of piece,
Woven length of piece,
Finished length of piece,
Total number of ends in warp,
Width of warp in loom,
Picks per centimetre in loom,
Warp yarn count (nm),
Weft yarn count (nm).

$$\text{Greasy warp weight (kilos)} = \frac{\text{Total ends} \times \text{warp length (metres)}}{\text{nm} \times 1000}$$

$$\text{Greasy weft weight (kilos)} = \frac{\text{Picks/cm} \times 100 \times \text{woven lgth (m)} \times \text{loom width (cms)}}{100 \times \text{nm} \times 1000}$$

Method B:

The information required for this alternative method is as follows:

Percentage reduction warp to woven length (W%),
Percentage reduction woven to finished length (F%),
Percentage weight loss in finishing (L%),
Total number of ends in warp,
Width of warp in loom (cms),
Picks per centimetre in loom,
Warp yarn count (nm),
Weft yarn count (nm).

(W%, F% and L% values can be supplied by production control or estimated)

$$\text{Wt of warp (gms) for 1m fin. cloth} = \frac{\text{Total ends} \times 100 \times 100 \times (100\text{-L})}{\text{nm} \times (100\text{-W}) \times (100\text{-F}) \times 100}$$

$$\text{Wt of weft (gms) for 1m fin. cloth} = \frac{\text{picks/cm} \times 100 \times \text{loom width (cms)} \times 100 \times (100\text{-L})}{100 \times \text{nm} \times (100\text{-F}) \times 100}$$

Add warp and weft weights together to give the weight in grammes of 1 metre of finished cloth, 150 cms wide.

This chapter has explained how various cloth setting formulae are applied in the construction of woven fabrics. It has shown, with the help of tables, how different types and weights of cloths can in some instances be manufactured with the same yarn. The tables contain manufacturing details of commercially acceptable fabrics made in pure new wool and can therefore be used as guides in the construction of others.

Woven fabrics can be created inspirationally or by copying, and the way to accurately determine the 'finished' details of a cloth has been comprehensively dealt with. The equally important task of converting this information into 'in-loom' manufacturing data has also been explained.

The sometimes neglected subject of cloth modification and adjustment has been a sizeable part of this section. For example, the woven fabric designer in the course of his work might need to remake an existing cloth in another weight, yarn count or weave, whilst retaining the firmness of the original cloth. The formulae required to do this successfully must be studied carefully in the examples.