The
Graphic Yarn
Calculator.

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PREFACE.

The object in writing this book is to provide manufacturers and spinners, as well as textile workers and students in general, with a concise statement and proofs of the various rules and principles involved in the calculation of yarn quantities, and with a ready reckoner for single and twist numbering. A unique feature in the work is the diagram of yarn numbers, which, although constructed six years ago by the author, has been delayed in publication through pressure of other work. By the aid of this diagram it is possible to find the mutual equivalents of yarn numbers in all the chief systems of numbering by mere inspection; while the assimilation of twisted numbers, no matter how complex, may be effected by measurement on the diagram without any calculation whatever. As some may not approve of making measurements with dividers, the calculated numbers or decimal equivalents from which the diagram was plotted are collected in tables at pages 19 and 20, and their use is exemplified on pages 21 and 22.

Great care has been taken in the preparation of this work, yet it is not improbable that mistakes may have been made. I shall be greatly indebted to readers who point out any defects which they notice.

THOMAS OLIVER.

Galashires,
18th November, 1905.
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THE GRAPHIC YARN CALCULATOR.

I. YARN NUMBERING.

It is necessary for purposes of practical utility that yarns should be numbered. That the numbering should be on one uniform basis for all materials and countries is highly desirable, and, undoubtedly, if the textile industries were making a fresh start at the present day this would be effected. But the textile industries sprung up in widely separated districts at different periods; the result is that the methods of numbering yarns are very varied. Many of these systems were designed to facilitate the calculations for the cloths which formed the staple trade of their respective districts in the incipient stages. As an example, let us consider the origin of the Scotch cut of 300 yards. It was customary to sley the warp two threads in a split of the reed, and, then as now, the length of the warp was reckoned in ells, and the number of threads in groups of 40, called porters. The reel was designed so that one revolution would produce two threads, or one splitful, of warp, one ell in length, i.e., it was made 90 inches in circumference; then 120 turns of this reel was made up into one cut. So one cut produced six porters of warp, one ell in length; this yielded a material saving in the labour of calculation. In many cases these conditions, favourable to easy calculation, have long since passed away, owing to the constant changes in the fashion of cloths. The arbitrary standards have now nothing to commend them but settled custom.

International conferences have met at different periods to attempt the unification of yarn numbering. The latest of these met at Paris in 1900. At the Paris conference it was proposed to make the hank one kilometre in length, and the kilogram the standard of weight. It is probable that in a few years this system may become the legal standard throughout the world; but legal enactments will not eradicate local custom. Therefore, for many years, we may count upon having the same variations to deal with as formerly.
The division of labour and speedy transport existing at the present
day bring a manufacturer and his employees into touch with yarns
spun in distant districts and countries. It is of importance that they
should be able to change these yarn numbers into the equivalents in
the system in which they are accustomed to think.

All the systems of numbering yarns may be grouped under one
or other of two categories, viz., “inverse” or “direct.” In the
inverse systems, the number of units of length (hank, out, &c.) which
weigh one unit of weight (lb., oz., &c.) is the yarn number, i.e., the
length is variable while the weight is constant, or the number of the
yarn is inversely proportional to the weight of unit length. In the
direct systems, on the other hand, the number of units of weight
which one length unit weighs is the yarn number, i.e., the length is
constant while the weight is variable, or the number of the yarn is
directly proportional to the weight of unit length. In England, the
yarn number is usually designated “the counts,” while in the Scotch
woollen trade the equivalent term is “the grist.”

**INVERSE SYSTEMS.**

<table>
<thead>
<tr>
<th>Name</th>
<th>Length Unit.</th>
<th>Name.</th>
<th>No of Yds.</th>
<th>Weight Unit</th>
<th>Standard Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>COTTON</td>
<td>bank</td>
<td></td>
<td>840</td>
<td>1 lb.</td>
<td>840</td>
</tr>
<tr>
<td>SILK (spin)</td>
<td></td>
<td>840</td>
<td></td>
<td>810</td>
<td></td>
</tr>
<tr>
<td>Do. (orgazine)</td>
<td></td>
<td>1000</td>
<td>1 oz.</td>
<td>16,000</td>
<td></td>
</tr>
<tr>
<td>LINEN</td>
<td>lea</td>
<td>300</td>
<td>1 lb.</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>WORSTED</td>
<td>hank</td>
<td>560</td>
<td></td>
<td>560</td>
<td></td>
</tr>
<tr>
<td>WOOLEN</td>
<td>skein</td>
<td>1520</td>
<td>1 Wartlen  (6 lbs)</td>
<td>256</td>
<td></td>
</tr>
<tr>
<td>West of England</td>
<td>snap</td>
<td>20</td>
<td>1 oz.</td>
<td>320</td>
<td></td>
</tr>
<tr>
<td>Dowabury (old)</td>
<td>yard</td>
<td>1</td>
<td></td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Galashiels</td>
<td>cut</td>
<td>300</td>
<td>24 oz.</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>Hawick</td>
<td></td>
<td>300</td>
<td>20 oz.</td>
<td>184</td>
<td></td>
</tr>
<tr>
<td>Hillfoot</td>
<td>spindle</td>
<td>11,520</td>
<td>24 lb.</td>
<td>490</td>
<td></td>
</tr>
<tr>
<td>American Run</td>
<td>run</td>
<td>100</td>
<td>1 oz.</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>Do. Cut</td>
<td></td>
<td>800</td>
<td>1 lb.</td>
<td>800</td>
<td></td>
</tr>
<tr>
<td>Metric (Intern.1)</td>
<td></td>
<td>1 kilon</td>
<td>kilogr.</td>
<td>436</td>
<td></td>
</tr>
<tr>
<td>Do. (Cotton)</td>
<td></td>
<td></td>
<td></td>
<td>952</td>
<td></td>
</tr>
<tr>
<td>“Inverse” Decimal</td>
<td>bank</td>
<td>1000</td>
<td>1 lb.</td>
<td>1000</td>
<td></td>
</tr>
</tbody>
</table>

The standard number is the number of yards of No. 1s yarn which
weigh 1 lb., and is convenient in the conversion of a yarn number
in one system to its equivalent in another.
Organzine counts are often denoted by yards per oz., e.g., 20s is written 20,000s, i.e., 20,000 yards per oz.

Nottingham lace is counted in the same way as spun silk. Silk for the hosiery trade is always numbered as twice its equivalent in spun silk count.

It will be seen from the table that the numbering of cotton, spun or waste silk, linen and worsted yarns in Britain and America is uniform for each material, in fact, the use of the British cotton and linen systems is practically universal.

In woollen yarns great diversity of numbering exists. Most of the systems are, however, confined to isolated mills spinning their own yarns, hence only a few of the better known are enumerated. In recent years the Yorkshire skein system has gained ground greatly in England, while the Galashiels cut system has made corresponding steps into favour with Scotch woollen manufacturers commencing business. The Yorkshire skein was originally 1520 yards, but for convenience in testing, the number of one-yard threads which weigh one dram was taken as indicating "the counts." This makes the skein = 1536 yards in practice, and accordingly 256 has been entered in the "Standard No." column.

In the Hillfoots system, the spindle consists of 48 cuts of 240 yards each, while the weight standard is one wool stone, or 24 lbs. This system is used in the Ochil Hillfoot district (Tillicoultry, Alva, Alloa, &c.), and also at Kilmarnock. The Hawick system is used by only four mills in Hawick who spin their own yarns; the remainder, being weaving firms, use the Galashiels unit of 24 oz. in preference to the awkward 26 oz. unit.

The "direct" systems are very obscure and little used, except those relating to raw and thrown silk and jute.

**DIRECT SYSTEMS**

<table>
<thead>
<tr>
<th>Name</th>
<th>Length Unit</th>
<th>Weight Unit</th>
<th>Standard No. or N.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thrown Silk (tram)</td>
<td>hank 1000</td>
<td>1 dram</td>
<td>256,000</td>
</tr>
<tr>
<td>Raw Silk (Denier) (Italian)</td>
<td>&quot; 450 m.</td>
<td>0.05 gram</td>
<td>4,465,000</td>
</tr>
<tr>
<td>&quot; (American &quot; grain &quot; (Lyons)</td>
<td>&quot; 476 m.</td>
<td>0.0331</td>
<td>4,447,000</td>
</tr>
<tr>
<td>West of England</td>
<td>snap 320</td>
<td>1 grain</td>
<td>140,000</td>
</tr>
<tr>
<td>Cumberland (old)</td>
<td>bunch 3860</td>
<td>1 oz.</td>
<td>5,190</td>
</tr>
<tr>
<td>Sowerby Bridge, Halifax district</td>
<td>cut 80</td>
<td>1 oz.</td>
<td>53,760</td>
</tr>
<tr>
<td>Selkirk &quot; drap &quot;</td>
<td>800</td>
<td>1 dram</td>
<td>29,480</td>
</tr>
<tr>
<td>Aberdeen woollen, Dundee jute</td>
<td>spindles 14,400</td>
<td>1 lb</td>
<td>76,800</td>
</tr>
<tr>
<td>&quot; Direct &quot; decimal</td>
<td>hank 1000</td>
<td>1 lb.</td>
<td>14,400</td>
</tr>
</tbody>
</table>
The "dram" system is used chiefly for tram silk, but also to some extent for organzine. The "Denier" system is universally used for raw or reeled silk, also for thrown silk (organzine) occasionally.

The Italian "Denier" system has been legalized in France on the recommendation of the 1900 Congress, when it was found that the 500 metre system, invented by the Congress in 1866 had received no attention from silk manufacturers.

The "grain" system is used by a few hosiery mills in U.S.A., while the "drap" system has only one exponent in Selkirk.

The Scotch spindle consists of 48 cuts of 300 yards each, i.e., 14,400 yards.

The "direct" West of England system expresses the count by the weight of a snap in ozs. and drams, e.g., 4 oz. 6 dr. yarn.

The "direct" decimal is a hypothetical system, and is the basis of the yarn diagram annexed.

When the yarn is numbered according to a given system, it is often necessary to find its equivalent in some other system. This conversion is effected for inverse systems by the following formula:

\[ c \times \frac{N}{n} = c' ; \quad N' = \frac{L}{p}, \quad n' = \frac{L'}{p'} \]

where:
- \( c \) is the yarn No. and \( N \) the standard No. in the 1st system.
- \( c' \) is the yarn No. and \( n' \) the standard No. in the 2nd system.

**Proof**—If \( c \cdot n = a \cdot n = \text{yards per lb.} \), which is a constant quantity quite irrespective of how the yarn is numbered.

*E.g.*, 18s worsted = \( 18 \times 560 \), or 10,080 yds. per lb.; but this also = \( 50\frac{2}{3} \times 200 \) yds. per lb. = 50\frac{2}{3} cut Galashiels.

The conversion from one "direct" system to another is not often necessary, because it so happens that two of these systems are seldom in use in the same district; but the following formula is applicable when required. The symbols have the same meaning as in the "inverse" formula, but a suffix is added for distinction:

\[ c_1 \times \frac{n_1}{N_1} = c_2 \]

**Proof**—If \( c_1 = n_1 = \text{yards per lb.} \).

It is more frequently necessary, however, to change a yarn number in an "inverse" system to its equivalent in a "direct" system and vice versa. To effect these conversions the following formulae may be used:

\[ \frac{1}{c_1} \times \frac{N_1}{n_1} = c_2 \text{ or } \frac{1}{C} \times \frac{N_2}{N} = c_3 \]

\[ \frac{L}{p} \text{ or } \frac{L'}{p'} \]

\[ \frac{1}{c_1} \times \frac{N_1}{n_1} = 4.96 \]

\[ \frac{1}{C} \times \frac{N_2}{N} = 840 \]
Proof—\( N C = N_1 \div C_1 \) = yds. per lb.

In mill work, where the number of systems in use are necessarily few, short rules are deduced from these general formulæ by cancelling common factors from the numerator and denominator.

From what has been said, it is evident that yarn numbers are either inversely or directly proportional to weights of unit lengths, or, expressed in the language of the mathematician, the yarn number is a function of the weight of unit length, and conversely. For our purpose the converse proposition is of most consequence.

Therefore \( w = \frac{h}{x} \) for inverse systems.

\[ w = \frac{h}{x} \text{ for direct systems.} \]

Where \( x = \) yarn number.
\( w = \) weight of unit length or of some standard length.
\( h = \) a constant for the system in question.

Since yarn numbers and weights are so related, their relation may be represented graphically on squared paper. Plotting values of \( w \) as ordinates or vertical lines, and values of \( x \) as abscissæ or horizontal lines and joining points, gives a curve or graph for each system. Each of these curves for the "inverse" systems is readily recognised as a rectangular hyperbola, while the "direct" system graph is in each case a straight line through the origin or zero point.

In the diagram annexed, \( w \) is taken as the weight of 1000 yards of each yarn in decimals of a lb.

**Fig. 1.** Illustrates the use of the diagram in the conversion from one system to another.

Two "inverse" graphs, \( B \) and \( C \), and one "direct" graph, \( A \), are shown.

The weight of 1000 yards of any given yarn is a constant quantity, no matter on what system it may be numbered. Suppose it is repre-
sented on the diagram by length O S. Projecting on curves A, B, and C gives the points P, Q, and R, and projecting again on O X gives I, M, and N. But O S = P L = Q M = R N represents the weight of 1000 yards, therefore

O L represents the number of the yarn on system A.
O M represents the number of the yarn on system B.
O N represents the number of the yarn on system C.

II. TWIST NUMBERING.

For various purposes it is necessary to double or twist threads together, producing what is called in England a "folded" yarn and in Scotland a "ply" yarn. It is also necessary in such cases to ascertain what single thread is equivalent in size to the twist, so as to facilitate calculations relative to weight and setting.

INVERSE SYSTEMS.

When the threads twisted together are of the same number this is an easy matter. Dividing the single number by the number of folds gives the twist yarn number for all materials except silk and Nottingham lace, e.g., 2-fold 48s worsted (usually written 2/48s) would be equal to 48 ÷ 2, or 24s; similarly, 3/24s = 8s. In silk and lace yarns the number of hanks which weigh 1 lb. is the yarn number quite irrespective of whether the yarn is single or twisted, e.g., 2-fold 70s silk (usually written 70/2) = 70 hanks per lb.; 2/6000 organzine = 6000 yards per oz.; 3/60 lace = 60 hanks per lb.; and 3/50 silk (hosiery) = 25 hanks per lb. When the yarns twisted are of unequal sizes the problem is less easy, but the following method is applicable when the yarns are all numbered in the same system (when the numbers are in different systems they must be converted into the same system by the methods of page 4). Consider a three-fold twist made from single numbers A, B, C.

Then one unit of length of yarn number A = 1/A unit of weight.
one unit of length of yarn number B = 1/B unit of weight.
one unit of length of yarn number C = 1/C unit of weight.

:. one unit of length of twist number weighs \( \frac{1}{A} + \frac{1}{B} + \frac{1}{C} \)
\[ 1 \div \left( \frac{1}{A} + \frac{1}{B} + \frac{1}{C} \right) \text{ length units of twist weigh one unit of weight;} \]

or \[ A \div \left( 1 + \frac{A}{B} + \frac{A}{C} \right) = \text{twist number (according to definition).} \]

This may be illustrated to the non-mathematical reader by the following example:—What single number will be equivalent to a twist made of 1/60s, 1/48s, and 1/40s?

- 60 hanks of 60s = 1 lb. \[ \frac{1}{60} \]
- 60 hanks of 48s = \[ \frac{1}{48} \] lb. \[ \frac{1}{48} \]
- 60 hanks of 40s = \[ \frac{1}{40} \] lb. \[ \frac{1}{40} \]

\[ \text{60 hanks of twist} = 3\frac{4}{5} \text{ lb.} \]

\[ \text{16 hanks of twist} = 1 \text{ lb., or} \ 60 \div 3\frac{4}{5} = 16. \]

From the same example it will be evident that the quantities of each yarn in a given weight of twist may be found by simple proportion. In 3\frac{4}{5} lbs. of twist there are 1 lb. of 60s, 1\frac{4}{5} lbs. of 48s, 1\frac{1}{5} lbs. of 40s, so that in e.g., 300 lbs. of twist there would be (a) \[ 300 \times 1 \div 3\frac{4}{5} = 80 \text{ lbs. of 60s;} \]
(b) \[ 300 \times 1\frac{4}{5} \div 3\frac{4}{5} = 100 \text{ lbs. of 48s;} \]
(c) \[ 300 \times 1\frac{1}{5} \div 3\frac{4}{5} = 120 \text{ lbs. of 40s.} \]

Also the price of a twist may be calculated by using the above data. If the prices of the above single yarns are:

- 60s at 4s; 48s at 3s 4d; 40s at 3s:

<table>
<thead>
<tr>
<th>Yarns</th>
<th>Price per lb.</th>
</tr>
</thead>
<tbody>
<tr>
<td>60s</td>
<td>4s</td>
</tr>
<tr>
<td>48s</td>
<td>3s 4d</td>
</tr>
<tr>
<td>40s</td>
<td>3s</td>
</tr>
</tbody>
</table>

\[ 1\frac{4}{5} \text{ lb. of twist} = 12s 8d \]

\[ \text{1 lb. of twist costs} \ 12s 8d \div 3\frac{4}{5} = 3s 4\frac{1}{2} d. \]

From these results we may summarise the following general formulae:

\[ \text{Twist number} = A \div \left( 1 + \frac{A}{B} + \frac{A}{C} \right). \]

\[ \text{Price of twist} = \frac{X + \frac{A}{B} \times + \frac{A}{C} \times}{\left( 1 + \frac{A}{B} + \frac{A}{C} \right)} \times \left( 1 + \frac{A}{B} + \frac{A}{C} \right) \]

\[ W_1 = \frac{W}{1 + \frac{A}{B} + \frac{A}{C}} \]

\[ W_2 = \frac{W}{B} \div \left( 1 + \frac{A}{B} + \frac{A}{C} \right) \]

\[ W_3 = \frac{W}{A} \div \left( 1 + \frac{A}{B} + \frac{A}{C} \right) \]
Where \( w_1 \) lbs. of yarn No. \( A \) at price \( x \),
\( w_2 \) lbs. of yarn No. \( B \) at price \( y \),
\( w_3 \) lbs. of yarn No. \( C \) at price \( z \),
are twisted together to make \( w \) lbs. of twist.

When the twist is only two-fold, these general formula may be
simplified considerably, thus:—

1. \( A \div (1 + \frac{A}{B}) \) or \( A \div (A + B) = \text{Twist number.} \)
2. \( (X + \frac{A}{B}Y) \div (1 + \frac{A}{B}) \) or \( (A \times X + B \times Y) \div (A + B) = \text{Price of twist.} \)
3. \( W \div (1 + \frac{A}{B}) \) or \( W \div (A + B) = w_1 \).
4. \( W \times \frac{A}{B} \div (1 + \frac{A}{B}) \) or \( W \times A \div (A + B) = w_2 \).

From (3) and (4) we may deduce

5. \( w_1 = w_2 \times \frac{B}{A} \); and (6) \( w_2 = w_1 \times \frac{A}{B} \).

Where \( w_1 \) lbs. of yarn number \( A \) at price \( x \),
\( w_2 \) lbs. of yarn number \( B \) at price \( y \),
are twisted together to make \( w \) lbs. of twist.

These results may be verified arithmetically by the following example.
What single number is a twist made of 28s and 21s? Also find the
price per lb. if the 28s yarn cost 2s 6d and the 21s cost 2s per lb., and
the quantities of each constituent in 245 lbs. of twist.

\[ 28 \times 21 \div (28 + 21) = 12s. \]

Verification—28 \times 21 hanks of 28s weigh 21 lbs., at 2s 6d = 52s 6d.
28 \times 21 hanks of 21s weigh 28 lbs., at 2s = 56s 0d.

\[ 28 \times 21 \text{ hanks of twist weigh } (28 + 21) \text{ lbs.} = 108s 6d. \]
\[ \therefore 1 \text{ lb. of twist contains } (28 \times 21) \div (28 + 21) \text{ hanks,} \]
\[ \text{i.e., 12 hanks per lb.,} \]

while 1 lb. of twist costs 108s 6d \div (28 + 21) = 2s 2\frac{1}{4}d.

It is evident from the above proof that in 49 lbs. of twist there are
21 lbs. of 28s and 28 lbs. of 21s; hence in 245 lbs. of twist there are
105 lbs. of 28s and 140 lbs. of 21s, by simple proportion.

In making twist yarns it is frequently necessary to ascertain what
yarn twisted with one or more given yarns will make a twist equal to
a required number. 

This may be determined mathematically thus:—where \( T = \text{twist number} \), \( A, B, \text{and } C = \text{given numbers} \), \( D = \text{the required number} \).
Then by definition and page 6, \[ \frac{1}{T} = \frac{1}{A} + \frac{1}{B} + \frac{1}{C} + \frac{1}{D} \]

\[ \therefore \frac{1}{D} = \frac{1}{T} - \left( \frac{1}{A} + \frac{1}{B} + \frac{1}{C} \right) \]

or \[ \frac{A}{D} = \frac{A}{T} - (1 + \frac{A}{B} + \frac{A}{C}) \]

\[ \therefore D = A \div \left\{ \frac{A}{T} - (1 + \frac{A}{B} + \frac{A}{C}) \right\} \]

**Arithmetical Verification.**—What worsted yarn, twisted with 1/50 worsted, 1/75 worsted, and 80/1 silk, will produce a four-fold thread = 15s worsted?

80s silk = 120s worsted. 120 hanks of 15s = 8 lbs.

\[
\begin{align*}
120 \text{ hanks of } 120s &= 1 \text{ lb.} \\
130 \text{ hanks of } 75s &= 16 \text{ lbs.} \\
120 \text{ hanks of } 50s &= 24 \text{ lbs.}
\end{align*}
\]

\[ \therefore 120 \text{ hanks of reqd. thd.} = 3 \text{ lbs.} \]

\[ \therefore \text{required thread must have 40 hanks per lb., i.e., No. 40s.} \]

Again, when the twist is only required two-fold, the foregoing process may be simplified thus:

\[ \frac{1}{D} = \frac{1}{T} - \frac{1}{A} \]

\[ \therefore D = \frac{A}{T} \div (A - T) \]

**Example.**—What woollen yarn twisted with 15s worsted will make a twist = 18 cut Galashiel?

(1) 15 worsted = 42 cut. (2) \(42 \times 18 \div (42 - 18) = 31\frac{1}{2} \) cut.

**Verification.**— \(42 \times 18 \text{ cuts of 18 cut} \text{ weigh} 42 \text{ spinner's lbs.} \)

\[ 42 \times 18 \text{ cuts of 42 cut weigh} 18 \text{ spinner's lbs.} \]

\[ 42 \times 18 \text{ of reqd. thd. weigh} 42 - 18 \text{ spinner's lbs.} \]

\[ \therefore 42 \times 18 \div (42 - 18) \text{ cuts of reqd. thd. weigh} 1 \text{ spinner's lb.} \]

Hitherto we have been considering for simplicity a hypothetical case, viz., that no contraction takes place in twisting. This is only approximately fulfilled in slack twists, while in hard twists the contraction may be as much as 10 per cent. Then there are fancy twists (knops, loops, curls, &c.), designed to give a special effect in the cloth. These have an abnormal amount of “take-up” impressed on them by the twisting frame.
The author has found, from the results of a long series of experiments, that the normal take-up in twisting two yarns of the same size may be expressed in the form:

\[ y + a = c(x - b)^2 \]

Where \( y \) is the take-up, \( x \) is the number of turns per inch of twist, and \( a, b, \) and \( c \) are constants for any one yarn, depending upon the size of the yarn and the material of which it is composed. These constants can only be determined by experiment and not by abstract reasoning. For example, experiments on a good Scotch Saxony yarn, 56 cut 2-ply, gave the following:

**Percentage contraction** = \((\text{turns} - 3)^2 \div 30 - .5\)

Another set on 2/10s Sea Island cotton gave:

**Percentage contraction** = \((\text{turns} - 3)^2 \div 25 - 1\)

The method of treatment is shown in the following examples:

1. Calculate the count of a twist made from 56s and 42s, with \( \frac{1}{16} \) take-up.

56 hanks of 56s = 1 lb.
56 hanks of 42s = \(1\frac{1}{3}\) lb.

56 hanks of singles produce \(52\frac{1}{2}\) hanks of twist.

\(52\frac{1}{2}\) hanks of twist = 22 lb.

\[ \therefore 16 : 15 = 56 : 52\frac{1}{2} \]

\[ \therefore 22\frac{1}{2} \text{ hanks per lb., or No. 22} \frac{1}{2} \text{s.} \]

2. A twist is made thus: 1 of 12s worsted - at 2s per lb.
   1 of 30s cotton - at 1s per lb.
   1 of 24 cut Galsheiels at 1s 6d per lb.

Find the grist and cost of the above and weight of each yarn in 40 lbs. of twist, if 112 ins. worsted, 68 ins. woollen, 63 ins. cotton produce 60 ins. twist. Twisting, 2d per lb.

12s worsted = 33 6 cut, 30s cotton = 126 cut. (See page 4.)

The relative lengths given in inches will obviously be also true for cuts or any other units.

\[ \therefore 63 : 126 = \frac{1}{3} \text{ lb. at 1s} \quad = \quad 6d \]
\[ 112 : 33\frac{1}{2} = \frac{3\frac{1}{2}}{2} \text{ lb. at 2s} \quad = \quad 80d \]
\[ 68 : 24 = 2\frac{2}{3} \text{ lb. at 1s 6d} \quad = \quad 51d \]

\[ \frac{60 \text{ of twist}}{6\frac{2}{3} \text{ lb.}} = 137d \]

\[ \therefore 60 \div \frac{6\frac{2}{3}}{9} = 9 \text{ cut.} \]
also \( 137 \div \frac{6}{3} = 20 \frac{1}{2} d \), plus twisting = \( 1 s 10 \frac{1}{2} d \)

\[
\begin{align*}
6 \frac{2}{3} : & \quad 1 \frac{1}{2} = 40 : 3 \text{ lb. of cotton.} \\
6 \frac{2}{5} : & \quad 3 \frac{1}{2} = 40 : 20 \text{ lb. of worsted.} \\
6 \frac{2}{8} : & \quad 2 \frac{1}{2} = 40 : 17 \text{ lb. of woollen.}
\end{align*}
\]

The general solution of the problem is as follows:—If \( n_1 \) units of
No. \( a \), \( n_2 \) units of No. \( b \), \( n_3 \) units of No. \( c \), and so on, produce \( n \) units
of twist No \( t \); then

\[
\frac{n_1}{a} + \frac{n_2}{b} + \frac{n_3}{c} = \frac{n}{t}
\]

from definition of numbering.

\[
\therefore \quad t = n \div \left( \frac{n_1}{a} + \frac{n_2}{b} + \frac{n_3}{c} \right)
\]

We have now considered at some length the arithmetical operations
relative to twisted threads, and it is obvious that these are tedious,
especially when dealing with complex twists. But again, the diagram
comes to our help, and we are enabled to solve, with sufficient accuracy
for all practical purposes, the most complicated twist problems without
any calculation whatever. The method consists of measuring the
ordinates of each yarn number on the diagram with a pair of dividers
and adding these together mechanically: the sum will be the ordinate
of the twist number.

Since the weight of 1000 yards of any given yarn does not vary
with its numbering, it is represented on the diagram by a definite
horizontal line. Adding the heights, corresponding to different yarns,
must give the weight of 1000 yards of the yarn formed by twisting
these together.

As illustrations: (1) Take 28s and 21s worsted; add the ordi-
inate of 28s to that of 21s, the sum will be the ordi-
ante of 12s, which is thus the twist
number.

(2) Again consider a more com-
p lex example:—
2/48 worsted,
60/2 silk, 40
skein. B E is
the ordinate of
2/48s or 24s wor-
sted, transfer this height to the top of $CF$, the ordinate of 40 skein, then $FE_1 = BE$. Similarly, transfer $DG$, the ordinate of 60 silk, to $E_1G_1$, then $CG_1$ is the ordinate of the twist number, or represents the weight of 1000 yards to the scale of the diagram, and projecting down from $H$, $K$, and $J$ the points where the horizontal line $G_1J$ cuts the curves, gives the reading 20·3, 9·3, and 6·2 at the points $H_1$, $K_1$, and $J_1$ respectively, therefore the twist may be numbered 20·3 skein, 9·3 worsted, or 6·2 silk as convenient.

(3) Consider a case where the yarns take up unequally in twisting, e.g., 2/20s cotton with 36s worsted, allowing 3 ins. worsted to 2 ins. cotton. In Fig. 3, $BC$ is the ordinate of 36s worsted; increase it in the ratio of 2 to 3 (a) by eye estimation; or, better, (b) by bisecting $BC$ with the dividers and making $CD = \frac{1}{2} BC$; or (c) read off height of $BC = 4·96$, half of $4·96 = 2·48$, and $4·96 + 2·48 = 7·44$; add this measurement to $EF$, then $ED_1$ is the twist ordinate where $FD_1 = BD$; then $G_1$ or $H_1$ gives 9·2 worsted or 6·1 cotton respectively as the twist number.

The diagram will also aid in the solution of costs, e.g., if in the last instance the cotton cost 1s and the worsted cost 2s 6d per lb., read off the heights $BD$ and $EF$ on the diagram, viz., 7·44 and 11·90;

Then $7·44$ lbs. at 2s 6d = 18 60s.
11·90 lbs. at 1s = 11·90s.

\[
\begin{align*}
19·34 \text{ lbs. twist} & = 30·50s \\
\therefore 30·50 \div 19·34 & = 1s 6·9d.
\end{align*}
\]

Similarly, the quantities in (say) 200 lbs. of twist may be determined by simple proportion:

\[
\begin{align*}
19·34 : 7·44 : 200 & : 76·9 \text{ lbs. of 36s worsted.} \\
19·34 : 11·90 : 200 & : 123·1 \text{ lbs. of 2/20s cotton.}
\end{align*}
\]

All problems in proportion should be solved by the slide rule, with the use of which every textile student should be familiar.

The diagram can be used to solve the problem of page 9, i.e., to
find a thread which with given threads will form a required twist. For example: What skein yarn with 2/60 worsted and 40/2 silk will make a twist = 8s worsted?

The ordinates are 8s worsted, A D; 30s worsted, B E; 40s silk, C F. Make G H = B E, and H I = C F. Project from I horizontally until the projector cuts the skein curve at J, then J I, the foot of the perpendicular from J, reads 29.2, i.e., the required yarn must be 29.2 skeins.

Obviously the above operation consists of subtracting the ordinates of 2/60 worsted and 40/2 silk from that of 8's worsted, and the remainder must be the ordinate of the yarn required.

A frequent source of error in the making of yarns is "spinning heavy," i.e., the yarn is made thicker than is specified. Since the spinning operative is paid by weight produced of a given number, and the output of his machine depends largely upon length, it is natural that he should spin the yarn as near as possible to the thicker limit of permissible error. If the error is not greater than 2 or 3 per cent., the following investigation is practically true. If one yarn is spun "heavy," how much smaller must the other yarn in a 2-ply twist be made so that the twist number is unaltered?

\[
\frac{1}{T} = \frac{1}{A} + \frac{1}{B}
\]

\[
\frac{dT}{T^2} = \frac{dA}{A^2} + \frac{dB}{B^2} \quad \text{differentiating and changing sign.}
\]

If the twist number is to be constant then \(dT\) must = 0,

\[
\therefore \frac{dA}{A^2} + \frac{dB}{B^2} = 0
\]

i.e.,

\[
dB = -\frac{B^2}{A^2} \cdot dA, \text{ or } -\left(\frac{B}{A}\right)^2 \cdot dA
\]

Examples

\[
\begin{align*}
N &= 36; N' = 48; A = 1; \text{ i.e., } z = 1 \frac{21}{31} \ldots = 1 \frac{51}{67} \\
A &= \frac{A(N+N')N^2}{A(N+N')N^2}
\end{align*}
\]

\[
\text{hence } N' = 48 + 1 \frac{51}{67}
\]
Example.—If a 2-ply twist is made from Nos. 36 and 48, and it is found that the 36s is really 35s what change should be made on the 48s to keep the twist number unchanged?

\[ dA = -1, \quad A = 36, \quad B = 48, \quad \text{and} \quad \frac{48}{36} = \frac{4}{3} = \frac{B}{A} \]

\[ : \quad dB = - \left( \frac{4}{3} \right)^2 ( -1 ) = 1\frac{1}{3}, \text{or} 1.8 \text{ nearly.} \]

The 48s should be 49.8s.

This result is more of theoretical interest than of practical value, as it is unlikely that a manufacturer would have yarns in stock of the same quality and so nearly equal in thickness.

**DIRECT SYSTEMS.**

In these the number of a twist is — the sum of its constituent numbers.

If \( w_1 \) lbs. of yarn No. \( A \) at price \( x \),

\( w_2 \) lbs. of yarn No. \( B \) at price \( y \),

\( w_3 \) lbs. of yarn No. \( C \) at price \( z \) make \( w \) lbs. of twist;

Then twist number = \( A + B + C \)

Price of twist = \( (A \times x + B \times y + C \times z) \div (A + B + C) \)

\[ W_1 = W A \div (A + B + C) \]

\[ W_2 = W B \div (A + B + C) \]

\[ W_3 = W C \div (A + B + C) \]

**AVERAGES.**

It is sometimes convenient to find the “average” count in a warp or cloth composed of different sizes of yarn. What is meant by this expression is not the arithmetical average of the numbers themselves in “inverse” systems, but of the respective weights of each in the proportion of threads in which they occur. [In “direct” systems this average count is the arithmetical average.] If \( n_1 \) length units of No. \( a \), \( n_2 \) of No. \( b \), \( n_3 \) of No. \( c \), and so on, occur in a warp or cloth or bundle of yarn, where the length unit is a thread or pick in the warp or cloth, and a hank, end, &c., in the bundle,

Then the weight of \( (n_1 + n_2 + n_3) \) length units = \( \frac{n_1}{a} + \frac{n_2}{b} + \frac{n_3}{c} \)

\[ : \quad (n_1 + n_2 + n_3) \div \left( \frac{n_1}{a} + \frac{n_2}{b} + \frac{n_3}{c} \right) \quad \text{length units to one weight unit} \]

= the “average” count.
It is usually convenient to multiply both numerator and denominator by a or some other number to keep clear of fractions. The average number or grist is therefore that yarn number which with the same sett would produce a cloth of the same weight as the actual cloth.

*Arithmetical verifications.—Examples:—*

(1) What yarn will make a "square" cloth (80 ends and picks) of the same weight as the following: warp, 90 ends of 2/30 worsted; weft, 70 picks of 30 cut?

\[
\begin{align*}
2/30 \text{ worsted} &= 42 \text{ cut.} \\
90 \text{ cuts of } 42 \text{ cut} &= 2\frac{1}{4} \text{ spinner's lbs.} \\
70 \text{ cuts of } 30 \text{ cut} &= 2\frac{1}{3} \text{ spinner's lbs.} \\
\hline \\
160 \text{ cuts of both} &= 4\frac{10}{11} \text{ spinner's lbs}
\end{align*}
\]

\[160 \div 4\frac{10}{11} = 35\frac{2}{11} \text{ cut average.}\]

(2) Find the average count in a warp: 100 porters of 20s, 30 of 15s, 20 of 10s. As it is merely a question of proportion we can substitute hanks for porters.

\[
\begin{align*}
100 \text{ hanks of } 20s &= 5 \text{ lbs.} \\
30 \text{ hanks of } 15s &= 2 \text{ lbs.} \\
20 \text{ hanks of } 10s &= 2 \text{ lbs.} \\
\hline \\
150 \text{ hanks of all} &= 9 \text{ lbs.}
\end{align*}
\]

\[150 \div 9 = 16\frac{2}{3} \text{ hanks per lb., or } 16\frac{2}{3} \text{ average.}\]

(3) Calculate the average worsted count in a warp: 2 of 2/60 worsted, 1 of 30/2 silk, one of 2/30 cotton.

\[
2/60 \text{ worsted} = 30s, 30/2 \text{ silk} = 45s \text{ worsted, } 2/30 \text{ cotton} = 22\frac{1}{2} \text{ worsted.}
\]

\[
(1 + 2 + 1) \div \left( \frac{1}{45} + \frac{2}{30} + \frac{1}{22\frac{1}{2}} \right) = 30
\]

or \[
(1 + 2 + 1) 45 \div \left( 1 + 2 \times \frac{45}{30} + \frac{45}{22\frac{1}{2}} \right) = \frac{180}{6} = 30
\]

otherwise 60 hanks of 30s = 2 lbs.

\[
\begin{align*}
30 \text{ hanks of } 45s &= \frac{2}{3} \text{ lbs.} \\
30 \text{ hanks of } 22\frac{1}{2}s &= \frac{1}{3} \text{ lbs.}
\end{align*}
\]

\[120 \text{ hanks of all} = 4 \text{ lbs.}
\]

\[30 \text{ hanks per lb., or } 30 \text{s average.}\]

The "average" may be more easily obtained by the aid of the diagram of yarn numbers.
Treating example (3) as if it were a twist, 2 of $2/60s = 15s$. Then the weights of 15s worsted, 30s silk, and 15s cotton may be added mechanically on the diagram as in Fig. 2, this will give an ordinate — that of 7·5s worsted. The yarns are not twisted together, but placed side by side, therefore it is necessary to multiply by the number of threads, i.e., $7·5 \times 4 = 30s$ average.

Another "average" which is more of theoretical than practical interest is the mean weight value of all the counts possible between certain limits. Geometrically, this is equal to the abscissa of the mean ordinate of the graph on the diagram. The mean ordinate is found by dividing the area enclosed by the curve, the base line and the two limiting ordinates into strips, and taking the arithmetical average of the mid-ordinates of each strip. That is the weight of 1000 yards of the "average" count number used in this sense. Analytically, this problem may be solved by the integral calculus for "inverse" numbering.

The equation for the curve is $y = \frac{k}{x}$ The area of the small shaded strip $= y \, dx = k \, \frac{dx}{x}$ Summing these between the limits $x_1$ and $x_2$

we have $k \int_{x_1}^{x_2} \frac{dx}{x} = k \left[ \log_e x_2 - \log_e x_1 \right]$ or $k \cdot \log_e \frac{x_2}{x_1}$ as an expression for the area.

\[ \frac{k}{x_2 - x_1} \log_e \frac{x_2}{x_1} \] is the mean ordinate, or $\bar{y}$, but $\bar{y} = \frac{k}{\bar{x}}$ or $\bar{x}$

where $\bar{x}$ is the required count corresponding to the mean ordinate.

\[ \bar{x} = k \div \frac{k}{x_2 - x_1} \log_e \frac{x_2}{x_1} \]

\[ = (x_2 - x_1) \div \log_e \frac{x_2}{x_1} \text{ or } (x_2 - x_1) \div (\log_e x_2 - \log_e x_1) \]

i.e., the arithmetical difference divided by the Napierian logarithmic difference.

\[ \text{(*) in many cases it is equivalent to the same relationship when } x_2 - x_1 \text{ should be divided by } \]
Example. — Find the yarn number which possesses the mean weight per unit length of all numbers between the limits of 10s and 40s.

The yarn number \( = \frac{x_2 - x_1}{\log_e \frac{x_2}{x_1}} \)
\[ = \frac{40 - 10}{\log_e \frac{40}{10}} = 30 \div \log_e 4 \]
\[ = 21.6 \]

The logarithms to the base \( e \), or 2.718..., of the whole numbers from 1 to 10 are given in the following table:

<table>
<thead>
<tr>
<th>No.</th>
<th>Log(_e)</th>
<th>No.</th>
<th>Log(_e)</th>
<th>No.</th>
<th>Log(_e)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1.386</td>
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<td>1.609</td>
<td>9</td>
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</tr>
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<td>6</td>
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<td>10</td>
<td>2.303</td>
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<td>1.099</td>
<td>7</td>
<td>1.216</td>
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<td></td>
</tr>
</tbody>
</table>

These numbers should be plotted on squared paper, taking the Nos. for abscissae and Log. for ordinates; the curve drawn through the points will enable us to interpolate for any values intermediate between the above whole numbers.

The question is often raised: — If suitable length and weight units could be arranged, whether should the “inverse” or “direct” numbering be followed? This question cannot be answered in a word. A spinner who delivers his yarn in hank or cop would find a “direct” system best, because if he has to make a twist yarn composed of two or more yarns of equal size, the sum of the single numbers is equal to the twist number: 20s and 30s singles would make a 50s twist; on the other hand, with an “inverse” system the twist number could only be arrived at by adding the reciprocals of the single numbers and inverting—a longer operation. But when the spinner has to deliver his yarns made up into warps, or is a cloth manufacturer as well as a spinner, especially in the fancy trade, he will find that the “direct” systems do not lend themselves to short cuts in warp and weft calculations. Short cuts are obtained by eliminating constant factors, which occur both in the numerator and denominator. Perhaps it is due to this fact that the “inverse” method has found most favour. It is probable that more than 90 per cent. of the whole yarn in the world,
irrespective of material, is numbered inversely. The following explanation of the adaptability of the two methods is sometimes given. In spinning wool, cotton, flax, and waste silk, the thread becomes finer as it passes through the successive processes of condensing, drawing, &c., and, therefore, an inverse system shows the variation better with high numbers for fine yarns; while as the process goes on the yarn number increases. On the other hand, silk yarns become thicker with preparation. The silk-worm spins an extremely attenuated filament—1000 miles weighing often less than 1 lb. A number of these filaments are doubled and twisted by the reeling process to form commercial "raw silk." The product is still too fine for weaving, and passes through further doubling and twisting operations until it is formed into "thrown" silk. A "direct" system of numbering shows the progress of the formation of the thread by an ascending series of numbers. This plausible advantage, however, is perhaps more imaginary than real, and the explanation takes no account of the fact that jute and hemp belong to the first class but are for the most part numbered on a direct system.
### TABLE OF WEIGHTS OF 1000 YARDS OF YARN IN HUNDREDTHS OF A POUND.

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<tr>
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<th></th>
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The foregoing tables show the "direct" decimal equivalents of numbers in the various "inverse" systems. These equivalents are the numbers plotted as ordinates against the yarn numbers as abscissae in the diagram annexed.

The decimal equivalent = 100,000 ÷ yards per lb. The Metric cotton equivalents are not shown in the tables since they are half those of the corresponding International Metric units, and are thus easily calculated.

For the sake of uniformity in the tables, the equivalents of the woollen systems have been tabulated to two places of decimals. In practice one decimal place would be sufficiently accurate, since woollen yarns vary so much in weight and bulk throughout their lengths that even experienced men find difficulty in estimating differences of 5 % to 10 % by the eye.

The mutual conversion of yarn numbers in different systems A and B is effected by finding the "equivalent" of the number in A and seeking out what yarn number is opposite the same equivalent in column B.

*e.g.* "equivalent" of 32s cotton = 3.72 = "equivalent" of 48s worsted.

"equivalent" of 11 skein = 35.51 = "equivalent" of 14 cwt Gala (approx.)

"equivalent" of 32s metric = 6.30 = "equivalent" of 18s cotton (approx.)

"equivalent" of 12s worsted = 14.88 = "equivalent" of 42 ÷ 10, or 4.2 run.

Intermediate values may be interpolated thus:

"Equivalent" of 16s cotton = 7.44

"of 44 lea (linen) = 7.57

"of 46 " = 7.25

\[ \text{difference} = 13 \text{ for } x \text{ diff. in leas.} \]

\[ \text{difference} = 32 \text{ for } 2 \text{ diff. in leas.} \]

\[ \therefore 32 : 2 = 13 : x \text{ or } 8.} \]

i.e., 44.8 lea = 16s cotton.

The interpolation can be done mentally with a little practice.

The American "run" system, on account of its high standard number expresses many yarns in fractions; the equivalents of such may be found thus:—"Equivalent" of 1.5 run = 41.7, since that of 15 run is 4.17 from the tables. Again, 60s worsted has an "equiv.
alent" = 2.98. This is too low a number for the Galashiels column; but 2.98 × 2, or 5.96, is the "equivalent" of 84 cut Gala.

\[ \therefore 84 \times 2, \text{ or } 168 \text{ cut } = 60 \text{s worsted}. \]

To grist or size a twist composed of any number of folds.—The sum of the decimal equivalents of the singles = the decimal equivalent of the twist.

**Examples:**

1. **7\(\frac{1}{2}\)/*40 worsted with 22 cut Gala.**
   
   Equivalent of \(7\frac{1}{2}\) worsted = 23.81
   
   " of 40 worsted = 4.46
   
   " of 22 cut = 22.72
   
   " of 9.8 cut = 50.99
   
   \[ \therefore \text{twist} = 9.8 \text{ cut or } 3.5 \text{ worsted}. \]

2. **30 skein, 48s worsted, 50s spun silk form a twist.**
   
   Equivalent of 30 skein = 13.02
   
   " of 48s worsted = 3.72
   
   " of 50s silk = 2.38
   
   " of 20.5 skein = 19.12
   
   \[ \therefore \text{twist} = 20.5 \text{ skein or } 9.3 \text{ worsted}. \]

3. **What woollen yarn with 32s worsted and 18s cotton will make a twist = 15 skein?**
   
   Equivalent of 15 skein = 26.04
   
   " of 32 worsted = 5.58
   
   " of 18 cotton = 6.61
   
   \[ \begin{aligned} &\text{of } 28.2 \text{ skein } = 13.85 \\ \therefore \ \text{required yarn} = 28.2 \text{ skein.} \end{aligned} \]

4. **What is the average run number in a warp:**—Two of 3 run, one of 12s worsted, one of 30s spun silk?

   Equivalent of two threads of 3 run = 20.83 × 2 = 41.66
   
   " of 12 worsted = 14.88
   
   " of 30 silk = 3.97
   
   \[ 4 \ 60 \ 51 \]
   
   " of 4.1 run (approx.) = 15.13
   
   \[ \therefore \text{average} = 4.1 \text{ run.} \]
III. WARP AND WEFT.

Warp is the longitudinal series of threads in a piece of cloth. Obviously, the length of yarn in a warp will be equal to the length of one thread or the length of the warp multiplied by the number of threads, regard being paid to an appropriate unit of length. The total number of threads or ends in a warp may also be specified (1) as ends per inch × inches in width; (2) as beers, porties, or porters, the beer or porty in England consisting of 38 or 40 ends, while the porter in Scotland has 40 ends. Again, the warp length is usually specified in yards, but in some parts of Yorkshire the string of 10 feet is used, and in Scotland the ell of 45 inches is the common unit. The length of yarn is expressed as hanks in the cotton, silk, and worsted trades, and as slips and spindles in the Scotch woollen trade, since the yard is not a convenient unit. The length and the weight of yarn in the warp must equal the length and weight of yarn in hank or on bobbin to make up the warp. Therefore the general warp equations are:

\[ E \times L = Y \times H \quad (1) \]
\[ = N \times C \times W \quad (2) \]

Where \( N \) = standard number, \( C \) = count, \( W \) = weight in lbs, \( E \) = total number of ends, \( L \) = length in yards, \( Y \) = yards per hank, slip, or other length unit, \( H \) = number of hanks, slips, &c.

Any one of these quantities may be found if the others are given. Beginners should work at first from the equation direct, cancelling out factors common to both sides of equation, as in the following examples.

(1) How many yards of a 3500 end warp will 225 hanks of worsted make?

\[ 3500 \times L = 560 \times 225 \]
\[ \therefore L = 36 \text{ yards.} \]

(2) What length of warp, 60 ends, 32 ins. wide, can be made from 18 lb. of 2/24s cotton? \( (\text{Here } e = 60 \times 32.) \)

\[ \therefore 60 \times 32 \times L = 840 \times 12 \times 18 \]
\[ \therefore L = 94\frac{1}{2} \text{ yards.} \]

(3) What is the weight of a 30 skein warp, 48 ends, 64 ins. wide, 60 yds. long?

\[ 48 \times 64 \times 60 = 256 \times 30 \times W \]
\[ \therefore W = 24 \text{ lb.} \]
(4) What run count of yarn will be required for a 28 lb. warp, 50 yds. long, 64 ins. wide, 35 ends?

\[ 35 \times 64 \times 50 = 1600 \times c \times 28 \]

\[ \therefore c = \frac{21}{4} \text{ run.} \]

Weft is the series of threads intersecting the warp transversely in cloth. The number of inches of weft yarn in an inch of cloth = the length in inches of a "pick" or "shot" (as a weft thread is technically called in England or in Scotland respectively) multiplied by the number of picks per inch. This is usually taken as the width in inches × picks, but the number of inches of weft in an inch of cloth = the number of yards of weft in a yard of cloth. Therefore the yards of weft in a piece = width in inches × picks per inch × length of piece in yards, or \( I \times P \times L \). As in the case of warp, this quantity must = yards per hank × number of hanks or = standard × count × lb. weight of weft. Therefore the general weft equations are:

\[ I \times P \times L = Y \times H \quad (3) \]

\[ = N \times C \times W \quad (4) \]

Any of these quantities may be found if the others are given.

**Examples:**

(1) What length of piece, 36 ins. wide, 64 picks, will 112 hanks of worsted weft?

\[ 36 \times 64 \times L = 560 \times 112 \]

\[ \therefore L = 27\frac{3}{5} \text{ yards.} \]

(2) What skein count will give 42 lb. of weft in a piece, 56 yds. by 64 ins., with 30 picks?

\[ 30 \times 64 \times 56 = 256 \times c \times 42 \]

\[ \therefore c = 10 \text{ skein.} \]

(3) Find the weight of 12s cotton weft in a piece, 120 yds. × 36 ins., with 12 picks per \( \frac{1}{4} \) in., allowing 40 yds. per hank for waste. [In this case \( N \) may be taken = 800.]

\[ 48 \times 36 \times 120 = 800 \times 12 \times w \]

\[ \therefore w = 21.6 \text{ lb.} \]

From equations (1), (2), (3), and (4) it is easy to obtain the following formulae by simple transposition:

**From Equation (2):**

\[ \text{WARP.} \]

\[ \frac{E \times L}{N \times C} = W \]

**From (1),**

\[ \frac{E \times L}{Y} = H \]
\[
\begin{align*}
(b) \quad & \frac{E \times L}{N \times W} = C \\
(c) \quad & \frac{N \times C \times W}{E} = L \\
(d) \quad & \frac{N \times C \times W}{L} = E \\
\text{From (a)} \quad & \frac{I \times P \times L}{N \times C} = W \\
\text{From (b)} \quad & \frac{I \times P \times L}{N \times W} = C \\
\text{From (c)} \quad & \frac{N \times C \times W}{I \times P} = L \\
\text{From (d)} \quad & \frac{N \times C \times W}{I \times L} = P \\
(e) \quad & \frac{N \times C \times W}{P \times L} = I \\
\end{align*}
\]

Beginners should, however, work at first direct from the equations, in preference to learning the above formulæ without understanding them.

In the above discussion we have been considering only the "inverse" numbering in warp and weft calculation. The number of yards of yarn in \( \text{W lb. of No. C in a "direct" system of numbering (whose standard is } N_1 = W \times N_1 \div C \).

Therefore the warp equation is \( E \times L = W \times N_1 \div C \)

or \( E \times L \times C = W \times N_1 \)

and the weft equation is \( I \times P \times L \times C = W \times N_1 \)

Summary of formulæ for "direct" systems:

\[
\begin{align*}
\text{WARP.} \\
(a) \quad & \frac{E \times L \times C}{N_1} = W \\
(b) \quad & \frac{W \times N_1}{E \times L} = C \\
(c) \quad & \frac{W \times N_1}{E \times C} = L \\
\text{WEFT.} \\
(a) \quad & \frac{I \times P \times L \times C}{N_1} = W \\
(b) \quad & \frac{W \times N_1}{I \times P \times L} = C \\
(c) \quad & \frac{W \times N_1}{I \times P \times C} = L \\
\end{align*}
\]
(d) \[ \frac{W \times N_1}{L \times C} = E \]

(\text{c}) \[ \frac{W \times N_1}{P \times L \times C} = I \]

Examples:

(1) Find the weight of 16 "dрап" yarn for a web, 50 yds. \times 72 ins., 36 ends and picks.

\[ \frac{72 \times 36 \times 50 \times 16}{76,800} = 27 \text{ lb. of warp or weft.} \]

\[ : \text{ : 54 lb. yarn.} \]

(2) Calculate the weight of yarn for a hessian, 14 porters of 9 lb. warp, 14 shots of 8 lb. weft, piece 108 yds. \times 48 ins.

14 porters = 14 \times 40 ends.

\[ \frac{14 \times 40 \times 108 \times 9}{14,400} = 37.8 \text{ lb. warp.} \]

\[ \frac{48 \times 14 \times 108 \times 8}{14,400} = 40.3 \text{ lb. weft.} \]

Notes.—(1.) The length of a pick is a little greater than the web width, since the pick is placed by the shuttle at an angle with the fell of the cloth. This discrepancy, which may amount to half-an-inch, is covered in practice by an allowance on broad goods of two inches, ostensibly for lists or selvedges. (2.) No account of waste has been taken in the above formulae; this must be added. It is usual to allow 5 \% on the net weight; but no general rule can be laid down, as waste varies with the material, conditions of manufacture, and care of the workers. The student is advised by some authorities to make this allowance in the warp and weft formulae, by introducing the factor \( \frac{105}{100} \) into formula 4 (a) for example. Experience with beginners has shown that this procedure is a frequent source of error owing to the greater mass of figures entailed in the calculation. A much surer method is to find the net weight, then divide by 20, and the quotient will be the waste which should be added. This simple operation is suited for mental calculation, which every student should practise. The beginner in textile calculation should make it a point from the outset to reduce all calculations to their simplest form, working with as few figures as possible. (3.) It is usual to calculate the weft on the warp length minus "thrum," as the picks mentioned in the web specification are measured on the line of the temple while the cloth is in the loom. The length of cloth produced while under tension is not more than one
or two per cent. shorter than the warp. As students may meet with problems in which the “grey” length or length out of loom is stated, it may be mentioned that they are intended to calculate the weft on this length in such cases. This is, however, very artificial; a weaver wishes to know the picks wanted in the loom not out of loom. Otherwise he would have great trouble in fulfilling requirements, as the cloth shrinkage would require to be estimated for every piece. (4.) In “square” cloths it is usual to assume that the weft weighs the same as the warp, although the actual woven length of cloth is shorter than the warp length, this difference is counterbalanced by the fact that the warp is subjected to greater tension in the loom than the weft is subjected to by the drag of the shuttle.

The diagram of yarn numbers can also be used to some extent in warp and weft calculation, if the threads are counted in hundreds and dividing the length by 10.

Example.—Calculate the weight of a 60 yd. warp, 2650 ends, 17 skein.

The weight of 1000 yds. of 17 skein taken from the diagram = 23 lb.

\[
\text{weight of warp} = \frac{26.5 \times 6 \times 23}{1000} = 36.6 \text{ lbs.}
\]

But as a rule it is no gain except in complex warp calculations.

c. g., 1400 ends of 7½/42 crossbred, twisted with 13 sk. woollen, 60 yards.

\[
\begin{align*}
1000 \text{ yards of } 7\frac{1}{2} \text{ worsted} & = 238 \text{ lbs. } \{ \\
42 & = 0.42 \} = 28 \\
13 \text{ skein} & = 300 \\
\end{align*}
\]

\[
\begin{align*}
14 \times 6 \times 28 & = 225 \text{ lbs. of worsted. } \\
14 \times 6 \times 3 & = 252 \text{ lbs. of woollen. }
\end{align*}
\]

IV. SHORT CUTS IN TEXTILE CALCULATION.

In any one factory, the routine calculations are usually of a restricted nature. Therefore the general formulae can be shortened by cancelling out common factors from the numerator and denominator, thus yielding simpler formulae which are, however, only applicable to
the particular system of numbering peculiar to the factory or district in question.

In changing from one system of yarn numbering to another, it is convenient to find the "conversion factor."

<table>
<thead>
<tr>
<th>TABLE OF CONVERSION FACTORS FOR INVERSE SYSTEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton and silk</td>
</tr>
<tr>
<td>------------------</td>
</tr>
<tr>
<td>Metric</td>
</tr>
<tr>
<td>Italian</td>
</tr>
<tr>
<td>Huddersfield</td>
</tr>
<tr>
<td>Hawick</td>
</tr>
<tr>
<td>Galashiels</td>
</tr>
<tr>
<td>W. of E.</td>
</tr>
<tr>
<td>Shelin</td>
</tr>
<tr>
<td>Worsted</td>
</tr>
<tr>
<td>Linen</td>
</tr>
<tr>
<td>Cotton</td>
</tr>
</tbody>
</table>

*Use of "Conversion" Factors.—Yarn No. in a system of right hand column \times factor = equivalent in a system named at the top of the table.*

*Examples.—To change a worsted "count" into a West of England "count," multiply by \(\frac{15}{16}\), and into a Galashiels grist, multiply by \(\frac{3}{4}\).*
SCOTCH TWEED YARN CALCULATIONS.

2 1/2 yds. = 1 thread (from 10 qr. reel)
120 thds. = 1 cut.
12 cuts = 1 slip.
4 slips = 1 spindle or millfil.

72 ÷ Galashiels grist = weight of 1 spindle in lbs.
78 ÷ Hawick = " 

Because 1 spindle of 1 cut weighs 72 lbs. and 78 lbs. respectively.

If the weight of s slips of g grist (Galashiels) be w lbs.,

then (1) \( w \times \frac{g}{18} = s \)
(2) \( s \times 18 \div g = w \)
(3) \( s \times 18 \div w = g \)

Because 1 slip of 1 cut yarn weighs 18 lbs.

Substitute 19 1/2 for 18 with Hawick grists, because 1 slip of 1 cut
Hawick weighs 19 1/2 lbs. For the same reason,

Galashiels grist \( \times \frac{4}{5} \) = slips per stone of 24 lbs.
Hawick grist \( \times \frac{16}{15} \) = slips per stone of 24 lbs.

384 ÷ grist (Galashiels) = weight in drams of 1 cut, i.e., “drag” No.
416 ÷ , (Hawick) = " 

384 and 416 are the number of drams in the Galashiels and Hawick
spinner’s lb. respectively.

SCOTCH WARPS.

If \( p \) porters of warp, \( e \) ells in length, require \( s \) slips (nett),

Then (1) \( p \times e \div 72 = s \)
(2) \( s \times 72 \div p = e \)
(3) \( s \times 72 \div e = p \)

Because 1 porter, 1 ell in length = \( \frac{1}{72} \) slip.

If the yarn is \( g \) grist Galashiels, and the weight \( w \) lbs. (nett),

Then (4) \( p \times e \div 4g = w \)
(5) \( p \times e \div 4w = g \)
(6) \( 4g \times w \div p = e \)
(7) \( 4g \times w \div e = p \)

Because 1 porter of 1 cut yarn, 1 ell in length = \( \frac{1}{4} \) lb.

48 ells is a standard length of warp with Scotch manufacturers,
especially in making estimates of cost. In such cases (1) and (4)
become obviously:—
1 \(\text{Porters} \times \frac{3}{5} = \text{slips (nett)}\).

4 \(\text{Porters} \times 12 \div \text{grist} = \text{lbs. (nett)}\).

**Examples:**

Find \((a)\) the weight of yarn for a warp, 68 porters, 54 ells, 24 cut (allowing 5 \(\%\) waste); \((b)\) the grist to make a 27 lb. warp, 45 ells, 72 porters; \((c)\) the length of stock piece that can be made from an odd lot containing 60 lbs. of 14 cut, 52 porters, weft as warp.

\[(a)\] \(68 \times 54 \div (24 \times 4) = 38\frac{1}{2} \text{ lbs.} \div 1.9 \text{ lbs. (waste)} = 40.2 \text{ lbs.}\)

\[(b)\] \(72 \times 45 \div (27 \times 4) = 30 \text{ cut.}\)

\[(c)\] \(60 - 3 \text{ lbs. waste} = 57 \text{ lbs. nett, i.e., 28}\frac{1}{2} \text{ lbs. warp.}\)

\[4 \times 14 \times 28\frac{1}{2} \div 52 = 30.7, \text{i.e., 31 ells practically.}\]

Use the same rules for Hawick grists and add 1 lb. in 12 of the answer for nett weight, or 1 lb. in 8 for weight with 4 \(\%\) allowance.

For Scotch worsteds, since 1 porter of 1s worsted warp, 1 ell long \(= \frac{5}{6}\) or \(\frac{1}{11}\) lb. pract.

\[(8)\] \(P \times E \div 110 = W \text{ with 2 \(\%\) allowance.}\)

\[(9)\] \(P \times E \div 11W = C\)

\[(10)\] \(110 \times W \div P = E\)

\[(11)\] \(110 \times W \div E = P\)

where \(C\) = worsted count.

**Examples:**

Find \((a)\) the weight of yarn for a 2/18 crossbred warp, 66 porters, 45 ells; \((b)\) the count to make a 28 lb. warp, 77 porters, 48 ells.

\[(a)\] \(66 \times 45 \div (11 \times 9) = 30 \text{ lbs.}\)

\[(b)\] \(77 \times 48 \div (28 \times 11) = 12s \text{ worsted.}\)

**YORKSHIRE WARPS.**

For Yorkshire warps, where the ends are expressed in porties of 40, and the length in strings of 10 feet each.

\[(4)\] \(\text{Porties} \times \text{strings} \div (\text{worsted No.} \times 4) = \text{lbs. of warp}\)

with 5 \(\%\) allowance for waste.

Because

\[
\frac{\text{Porties} \times 40 \times \text{strings} \times \frac{1^0}{9}}{560 \times \text{worsted No.}} \quad \text{or} \quad \frac{\text{Porties} \times \text{strings}}{4.2 \times \text{worsted No.}} = \text{lbs. nett.}
\]
Similarly

\( (5) \text{Porters} \times \text{strings} \div (\text{skein No.} \times 1.92) = \text{lbs. nett.} \)

or \(1\frac{1}{2}\) may be substituted for 1.92 if \(4\%\) waste is to be allowed.

The above formulae would be modified thus for districts using the 38-thread party.

\(4 (a) \text{Porties} \times \text{strings} \div (\text{worsted No.} \times 4\frac{1}{4}) = \text{lbs. of warp with 4\% allowance.} \)

\(5 (a) \text{Porters} \times \text{strings} \div (\text{skein No.} \times 2) = \text{lbs. of warp with 7\% allowance.} \)

**CLOTHS.**

(1) Finished weight in ozs. per single width yard \(\times k = \text{weight of yard in lbs. for a piece} \) yards in length finished.

When \(L = 30, 35, 40, 45, 50, 55, 60.\)

\(k = 4\frac{1}{8}, 5\frac{1}{2}, 6\frac{1}{4}, 7, 7\frac{3}{4}, 8\frac{1}{4}, 9\frac{1}{2}.\)

This is approximately true for cloth which lose \(\frac{1}{8}\) of their weight in scouring, &c., and allowing \(3\%\) to \(4\%\) waste.

Proof for 40 yds. :—Ozs. per yd. \(\times 40 \times 2 \times 4 \div 16\), or ozs. \(\times 6 = \text{greasy weight of piece in lbs.} \)

Using \(6\frac{1}{4}\) instead of 6 gives \(4\%\) allowance for waste.

(2) \(\text{Porters} \times 7 = \text{Gala grist = ozs. per yard (finished cloth).} \)

also \(2 (a) \text{Porters} \times 7 = \text{ozs. = grist.} \)

\(2 (b) \text{Grist} \times \text{ozs.} \div 7 = \text{porters.} \)

These hold for cloths which lose \(\frac{1}{8}\) of their weight in scouring, &c.; assuming that 1 ell of warp produces 1 yard finished cloth, and weft = warp.

Proof :— Porters \(\times 1 \div \text{Grist} \times 4 \times 2 \times \frac{7}{8} \times 16 = \text{ozs. per yd. finished,} \)

which reduces by cancelling to formula (2).

When, as is usual with Scotch woollens, the loss in scouring is \(\frac{1}{8}\), \(6\frac{2}{3}\) should be substituted for 7. For Hawick grists, \(7\frac{1}{4}\) should be used.

(These useful rules were first stated by the late Mr Robert Johnstone.)

(3) \(\text{Porters} \times 2\frac{1}{2} = \text{worsted No. = oz. per yard (finished cloth).} \)

also \(3 (a) \text{Porters} \times 2\frac{1}{2} = \text{oz. per yd. = worsted No.} \)

\(3 (b) \text{Worsted No.} \times \text{oz. per yd.} \div 2\frac{1}{2} = \text{porters.} \)
These hold for Scotch worsted square cloths which lose \( \frac{1}{16} \), or 6 \%/ in scouring, and with \( \frac{1}{7} \) shrinkage, i.e., \( \frac{5}{6} \) yds. warp = 1 yd. finished cloth (an average condition).

**Proof:**

Porties \( \times \frac{40 \times \frac{7}{6} \times 2 \times \frac{5}{16} \times 16 = \text{ozs. per yd.}}{560 \times \text{worsted No.}} \) (finished), which reduces by cancelling to formula (3).

\( (4) \) Porties \( \times 5 = \text{skein No.} = \text{ozs. per yard (finished)}. \)

also \( \frac{1}{5} \) Porties \( \times 5 = \text{ozs.} = \text{skein No.} \)

\( 4 (b) \) Skein No. \( \times \text{ozs.} \div 5 = \text{porties}. \)

These are true for "square" cloths in which the loss of weight in scouring, &c., just balances the increase of weight due to shrinkage from warp length to finished length. The porties have 40 ends.

**Proof:**

Porties \( \times \frac{40 \times \frac{y}{256} \times 2 \times f \times 16 = \text{ozs. per yard}}{\text{skeins (finished)}} \)

Where \( y \) yards of warp produce 1 yard finished cloth, and 1 lb. greasy yields \( f \) lbs. clean. Then if \( y = \frac{1}{f} \), the above expression reduces to formula (4). For 38 thread porties, \( 4\frac{1}{2} \) should be substituted for 5. The above condition that shrinkage should balance loss in scouring is seldom true in the Yorkshire trade. The average Yorkshire woollen cloth shrinks \( \frac{1}{5} \) and loses \( \frac{1}{6} \) of its weight in scouring. For such the multiplier is \( 4\frac{1}{2} \) with 40 thread porties, and \( 4\frac{1}{2} \) with 38 thread porties.

**Examples:**

- Find \( (a) \) the weight of yarn for a 48 yd. piece in 12 oz. cloth; \( (b) \) the finished weight of a 24 cut Cheviot, 66 porters; \( (c) \) the porters to make a 22 oz. cloth in 20 cut yarn; \( (d) \) the finished weight of a 2/30 Botany worsted, 156 porters; \( (e) \) the porters to make an 18 oz. cloth in 2/18 worsted; \( (f) \) the finished weight of a 30 skein cloth, 84 porties of 40 ends; \( (g) \) the porties of 38 ends to make a 23 oz. cloth in 12 skein yarn.

\( (a) \) Interpolating between 45 and 50 yds. in Rule (1), we find

\[ \kappa = 7\frac{1}{3} \text{ for 48 yds}. \]

\[ . \times 12 \times 7\frac{1}{3} = 90 \text{ lbs. of yarn}. \]

\( (b) \) \[ 66 \times \frac{6\frac{3}{5}}{24} = 18\frac{1}{5} \text{ oz. per yd. (Yarn losing \frac{1}{5} in scouring.)} \]

\( (c) \) \[ 20 \times 22 \div 6\frac{3}{5} = 66 \text{ porters.} \]

\( (d) \) \[ 156 \times \frac{2\frac{1}{2}}{15} = 26 \text{ oz. per yd.} \]

\( (e) \) \[ 9 \times 18 \div 2\frac{1}{2} = 65 \text{ porters.} \]

\( (f) \) \[ 84 \times 5 \div 30 = 14 \text{ oz. per yd.} \]

\( (g) \) \[ 12 \times 23 \div 4\frac{3}{4} = 58 \text{ porties.} \]
MISCELLANEOUS EXAMPLES.

Work the following examples by (1) ordinary calculation; (2) use of conversion factors; (3) table of decimal equivalents; (4) the diagram of yarn numbers.

1. Change (a) 50s cotton to worsted No.; (b) 12,000 organzine to spun silk No.; (c) 40s cotton to linen leas; (d) 24s worsted to skein No.; (e) 18 cnt Gala to Hawick grist; (f) 32s worsted to American runs.

(a) \[50 \times 840 \div 560 = 75\text{ s worsted.}\]
(b) \[12,000 \times 16 \div 840 = 228\frac{4}{5}\text{ s spun.}\]
(c) \[40 \times 840 \div 300 = 112\text{ lea.}\]
(d) \[24 \times 560 \div 256 = 52\frac{1}{2}\text{ skein.}\]
(e) \[18 \times 200 \div 184\frac{3}{5} = 19\frac{1}{2}\text{ cut.}\]
(f) \[32 \times 560 \div 1600 = 11\frac{1}{2}\text{ run.}\]

2. Change (a) 10 “drap” to American “grain”; (b) 4 oz. 8 dram West of England to Sowerby Bridge.

(a) \[10 \times 140,000 \div 76,800 = 18\frac{9}{10}\text{ grain.}\]
(b) \[4\frac{1}{2} \times 20,480 \div 5120 = 18\text{ dram.}\]

3. Change (a) 10s or 10,000 organzine to tram; (b) 8 dram Halifax to skeins; (c) 24 “drap” to Gala grist; (d) 6 lb. jute to linen lea No.

(a) \[256,000 \div (16,000 \times 10) = 1\frac{6}{10}\text{ tram.}\]
(b) \[20,480 \div (256 \times 8) = 10\text{ skein.}\]
(c) \[76,800 \div (200 \times 24) = 16\text{ cut.}\]
(d) \[14,400 \div (300 \times 6) = 8\text{ lea.}\]

4. Change 60s worsted, 15 skein, 2/40 cotton, 20,000 organzine, 100/2 silk, 12 spindle Hillfoots into Gala grists and American runs. Give the weights of 42,000 yards of each.

5. If 168,000 yards of a yarn weigh 24 lbs., calculate its numbers in all the systems mentioned in the tables.

6. Find the counts if (a) 25 turns from 10 qr. reel weigh 4 oz.; (b) 1 yard woollen weighs 3\frac{1}{2} grains; (c) 140 yds. worsted weigh 4 drams. (20 cut; 10 cut; 16.)

7. How many yards of 12 skein weigh 1 oz.? (192.)

8. Calculate slips in 42 lbs. of 24 cut and weight of 1 gross of 2/16 worsted. (56, 18.)

9. How many lbs. of 2/18 worsted will fill 180 bobbins with 3 hanks each? (60.)
10. Find the following twist numbers (a) 20 worsted || 40 cut ;
(b) 2/30 worsted || 30 sk. ; (c) 42 cut || 50/2 silk.

11. Find yarns to twist with (a) 2/32 worsted to make 15 sk. ;
(b) 2/35 worsted to make 21 cut ; (c) 30 worsted and 36 cut to make 14 cut.

12. How many lbs. of 30 sk. are required to twist with 30 lbs. of
40 cut || 18 worsted twist ?

13. Calculate No. and price per lb. of twist and the weight of each
constituent in the given weight of twist.

(a) 190 lbs. twist : 40 worsted at 3s 6d, 30 worsted at 3s, 28 cut
at 2s.
(b) 81 lbs. twist : 1/60 worsted at 4s, 2/60 silk at 15s, 1/45
worsted at 3s.
(c) 25 lbs. twist : 24/2 silk at 12s, 2/48 worsted at 3s.
(d) 215 lbs. twist : 2800 organzine at 16s, 2/30 worsted at 3s,
28 cut at 3s 6d.
(e) 70 lbs. twist : 2/40 worsted at 3s, 42 cut at 2s 6d.
(f) Same as (e), but with \(\frac{1}{10}\) take-up.
(g) A thread of 20s is now added to (f) with a further \(\frac{1}{10}\) take-up.
(h) 1200 lbs. twist : 12/40 worsted at 1s 9d, 25 sk. at 1s 6d,
10 \(\%\) take-up on worsted.
(i) 180 lbs. twist : 2/15 worsted at 1s 10d, 30 cotton at 1s.
     Allow 4 ins. worsted to 3 ins. cotton. Twisting, 1d per lb.
(j) 50 lbs. knop twist : 2/20 mohair at 3s, 24 cotton at 1s 1\(\frac{1}{2}\)d.
     5 yds. mohair to 2 yds. cotton.
(k) 170 lbs. twist : 6000 organzine at 20s, 30 cut at 2s. 2 in.
silk to 1 in. woollen.

14. A twist can be made either with 40 cut and a worsted thread
or with 30 cut and a worsted thread of half the size. Find the twist
and worsted numbers.

15. A worsted and silk knop twist can be made either with 45s
worsted and a 2-fold silk thread (3 in. silk to 2 in. worsted), or with
40s worsted and one of the silk singles (2 in. silk to 1 in. worsted).
Find the twist and silk numbers.

16. If yarn numbers 60, 42, 30, 24, 20, 17 are in stock, show all
the ways in which a twist = 12s can be made. Calculate the cost of
each single and of each twist, if the cost of single in pence per lb. =
21 + yarn No. \(\div\) 4. Allow 1d for twisting.
17. Calculate grist and contraction per slip in twisting 56\(\frac{1}{2}\)6 cut, 18 turns, if percentage contraction = \(\frac{\text{turns} - 3}{30} \div 0.5\).

18. Calculate count and contraction per hank in twisting 2/6 cotton, 8 turns, if percentage contraction = \(\frac{\text{turns} - 3}{9} \div 1.4\).

19. Find the average worsted count in a warp: 2 of 2/40 worsted, 1 of 20 cotton.

20. What yarn number would make a cloth of the same weight and sett as one arranged: 3 of 2/36s, 1 of 2/44s?

21. Find the average count: 120 porters of 30s, 40 of 15s, 20 of 12s.

22. Find the average grist if 4 cops taken from one skip weigh respectively 15, 15\(\frac{1}{2}\), 14\(\frac{2}{3}\), 15\(\frac{3}{4}\) drams per cut. If the same weights per hank had been found for a worsted lot, calculate the worsted number.

23. Find weight of 45 yd. warp, 70 porties of 2/18s worsted, 4 % waste.

24. What grist would make a 36 lb. warp, 72 porters, 48 ells?

25. What length can be wefted from 40 lbs. of 18 sk., 38 picks, 64 in. wide, 5 % waste?

26. How many 50 yd. pieces can be wefted from 210 lbs of 20s worsted, 64 picks, 70 in. wide, 10 lbs. waste?

27. Calculate weights of warp and weft for web: 52 porters of 2/28 cut, 30 picks of 12 cut, 90 ells \(\times 72\) ins.

28. Find weight of 24 cut to woof (50 yds. \(\times 72\) ins.), 33 picks, 3 % waste.

29. A 24-oz. 56-in. worsted has 105 ends and picks finished, shrinkage \(\frac{1}{4}\). What is the count?

30. Calculate the "thread" and "weight" percentages of cotton in a "square" costume cloth. Warp, 27 cut; weft, 16 of 24 cut, 3 of 3/24 mercerised. Find the percentages if the woollen yarns had the same skein numbers.

31. What is the smallest twist number which can be made from two singles, one of which is numbered on a "direct" system (constant \(k_1\)), the other has the same number in an "inverse" system (constant \(k_2\))? Find the single number.

\[
\begin{align*}
w &= \text{weight of unit length of twist}, \\
\kappa_1 &= \text{weight equivalent of unit "direct" number}, \\
\kappa_2 &= \text{weight equivalent of unit "inverse" number}, \\
x &= \text{single yarn number}.
\end{align*}
\]
Then \( w = k_1 x + \frac{k_2}{x} \)

\[
\frac{dw}{dx} = k_1 - \frac{k_2}{x^2}
\]

by differentiation.

But \( \frac{dw}{dx} = 0 \) when \( w \) has a minimum value.

\[
\therefore k_1 - \frac{k_2}{x^2} = 0 \quad \text{or} \quad x, \text{ the single yarn number } = \sqrt{\frac{k_2}{k_1}}
\]

The minimum value of \( w \) is therefore \( k_1 \sqrt{\frac{k_2}{k_1}} + k_2 \sqrt{\frac{k_1}{k_2}} \)

\[
\therefore w \text{ or the "direct" number of the twist } = 2 \sqrt{k_1 k_2}
\]

\[
\therefore \text{ the twist number expressed on the "inverse" system } = \frac{k_2}{2 \sqrt{k_1 k_2}} \text{ or } \frac{1}{2} \sqrt{\frac{k_2}{k_1}}
\]

In particular, solve the following:—(a) Galashiels and Drap (9·8 and 19·6 cut); (b) West of England "direct" and "inverse" (2 and 4 snap); (c) Skein and Sowerby Bridge (4·47 and 8·95 sk.); (d) Aberdeen and Hillfoots (2·74 and 5·48 sp. Hillfoots); (e) organzine and dram silk (2000 and 4000 organzine).

(a) \( k_1 \) for the "dram" system = 1 dram.

\[
k_2 \text{ for the Galashiels system } = 384 \text{ dram.}
\]

\[
\therefore \text{ minimum twist } = 2 \sqrt{k_1 k_2} = 2 \sqrt{384} = 39·2 \text{ dram yarn.}
\]

\[
= \frac{1}{2} \sqrt{\frac{k_2}{k_1}} = \frac{1}{2} \sqrt{384} = 9·8 \text{ cut.}
\]

single number = \( \sqrt{\frac{k_2}{k_1}} = \sqrt{384} = 19·6 \text{ dram and 19·6 cut.} \)

\( k_1 \) and \( k_2 \) may also be expressed in decimal equivalents taken from the tables pp. 19 and 20.