Calculations in Yarns and Fabrics.

By
Fred Bradbury.

Calculations

IN

Yarns and Fabrics.

(Fifth Thousand.)

BY

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PREFACE.

In issuing a new edition of "Calculations in Yarns and Fabrics," I avail myself of the opportunity to thank all those who have written expressing their appreciation of my former treatise on this subject, particularly in reference to my methods of solution, together with the plan of giving exercises with answers at the end of each chapter and also with the chapter dealing with the analysis and reproduction of woven fabrics.

In this issue a somewhat lengthy chapter is added which treats of the cost of producing yarns, which I venture to presume will be much appreciated.

At the suggestion of several students I have added an extra chapter (four in all) on the Science and Practice of the Construction of Woven Fabrics. But, as many people know, these chapters do not by any means represent the full extent of my research, deductions, conclusions and prepared matter on this very interesting and important branch of textile study. Though this section may be interesting and instructive, the higher theoretical stages are valued little and read less by the general mass of readers, for which reason I have added judiciously.

Much new matter has been added to almost every chapter, especially on Linen and Cotton.

The issue of this edition has not been hurried, even though there has been a large number of orders awaiting execution. I trust, however, that the extra care which has been exercised in its preparation will more than compensate for any delay in publication. Finally, my sincerest wish is that, like its predecessor, it will be found helpful to the Student, Spinner, Manufacturer and Merchant alike.

F. B.

BELFAST,

1906.

PREFACE TO FIRST EDITION.

This work embodies both theoretical and practical knowledge and experience gained by the author during several years as manager and designer in the manufacture of worsted, woollen, and mixed goods, and subsequently of eight years' exclusive experience as a lecturer on the preparation of yarns and of their manufacture into woven textures.

As an educationalist I necessarily consider it of paramount importance not only to supply the reader with a collection of the more important systems of counting yarns, costing cloths, &c,, as set forth in the contents, but to demonstrate from *first principles* the why and the wherefore of all methods and formulæ deduced in this treatise, many of which are already applied in practice to the solution of the very numerous arithmetical problems arising out of the preparation and production of woven fabrics of all descriptions. Examples are fully worked out to exemplify every phase of the subject, and from which the formulæ are deduced.

A series of exercises with answers is also appended to each chapter, thus meeting a necessity which has often been felt by the textile students and lecturers. These exercises are, for the most part, arranged in three divisions, A, B, C, representing elementary, intermediate, and advanced stages respectively.

That this treatise will be found most useful in study and practice to the student, instructor, spinner and manufacturer of textile materials is the earnest desire of the author.

F. B.

HALIFAX,
Sept., 1900.

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Errata. Table I., page 26. Length variable; Weight constant.

A few of the Press Opinions on 'Carpet Manufacture.'

(See page 4.)

'Textile Manufacturer.'

" Hitherto there has been no standard book on carpet manufacture and although some works have dealt with it from the designers' standpoint, they have either ignored or barely touched upon the mechanical side. This book therefore meets a long felt want and not only meets it but fills it, for in turning over its three hundred and odd pages we meet with no occasion to criticise adversely .. .. the artistic side has been considered in about seventy pages and the rest of the book is devoted to the manufacture of Brussels, Wilton, Tapestry, Axminster, Chenile, Kidderminster and Scotch carpets. Each type of carpet is taken separately and not only are its various structures illustrated and described but the various mechanical appliances used in its manufacture explained. The description throughout is plain but concise, whilst the illustrations are clear and have been neatly executed "

'Textile Recorder.'

" Although we have occasionally come across books on weaving in which certain sections have been devoted to carpet manufacture, we have never, as far as our knowledge serves us known a book which devotes the whole of its contents to this special subject .. The scheme of the book is decidedly good and very clear .. .. Different makes of carpet are fully described in the work, the special mechanisms employed in their production being clearly illustrated."

'The Scotsman.'

" This valuable technical work is obviously the outcome both of an intimate acquaintance with the mechanical processes by which carpets are made, and of experience in expository teaching in technical schools .... Clear, full and eminently practical, the volume cannot but prove welcome and serviceable to students in this important industry.

'The Publishers' Circular.'

" .. In addition to its practical value for manufacturers it will be useful to students in art schools in towns were textiles are not made. It often happens that admirable designs on paper are useless for expression in cloth simply because the artist has not understood the limits within which he must work to make his design suitable for reproduction."

CALCULATIONS

IN

YARNS AND FABRICS.

CHAPTER I.

Various Systems of Counting Yarns.

To explain in detail all the several systems of numbering or counting yarns is well nigh impossible since their variety is truly legion. Briefly, the terms 'count,' 'lea,' 'run,' 'skeins,' 'cuts,' 'spindle,' etc., literally represent a certain length of yarn for a fixed weight or *vice versa*, but unfortunately, a uniform standard has not yet been adopted. Of the advantage to be gained by the adoption of such a standard there can be but little doubt. The universal system or method which should and will eventually become general remains a problem of the future. A simple standard would be 1000 yards as the unit of length to be called hank, cut, or skein, and the number of such units which weighs 1 lb. avoirdupois (in Great Britain and where British weights and measures are customary) should be taken to represent the count or number of yarn. By this method the counts of the yarn would always show at a glance the number of yards per lb. in thousands of yards, or conversely, the number of yards per lb. would always indicate the counts by the number of thousands mentioned, whilst the figures denoting the hundreds, tens, and digits would give the 1st, 2nd, and 3rd decimal places of one count respectively. Hence, many calculations which have now to be computed on paper would then be performed simply by observation ; *e.g.*,

(a) 20s counts = 20,000 yds. per lb., or conversely, 20,000 yds. per lb. = 20s counts.

(b) $14\frac{3}{4}$s counts = 14,750 yds. per lb., or 14,750 yds. per lb. = 14.75 counts.

Comparatively it is easier to formulate a more uniform method of numbering yarns than it is to establish one, for the difficulties of the problem increase with the study of the subject. The various systems being the growth of ages have woven around them many factors of established interests and customs *e.g.*, Reels and yarn testing apparatus are made to standard sizes and adapted to suit the different denominations. Manufacturers and employees have, after much deliberation, fixed prices to be paid for weaving yarns of specified numbers combined with other factors.

Any radical change from the present system of counting yarns would involve a reconsideration by employers and their departmental managers with the employees and their leaders through each respective country, with a probable dislocation of trade.

Any change which may eventually take place will and can only come gradually, *i.e.* by a process of evolution. The first probable result of such evolution will be *one system* for each respective fibre:—Silk, wool, flax, cotton and jute, or the system as set forth above may be found applicable to all yarns included under Table I.

WORSTED COUNTS.—This system is based upon the hank of 560 yards, and the number of such hanks which weighs 1 lb. equals the counts.

The term 'hank' is but a figure, for the material may either be in the form of weft on spools and bobbins or warp in the ball or on the warp-beam, and not necessarily made into hanks of 560 yards length. Therefore, if the length of a given weight be known it will be obvious that whether the yarn be made into hanks or in any other form it can readily be reduced to the form of 'counts' or lengths of 560 yards which weigh 1 lb.

WOOLLEN COUNTS.—There are several systems of counting woollen yarns, notably the following:—

(1) GALASHIELS, which is based upon the 'cut' of 300 yards in 24 ounces, *i.e.*, the number of cuts of 300 yards which weighs 24 ounces represents the counts, technically and locally termed 'cut.'

NOTE.—300 yards per 24 ozs. is equivalent to 200 yards per lb. (16 ozs.) which number, being more convenient, is frequently adopted in practice, especially when changing from one count to any other.

(2) HAWICK, which is based upon the cut of 300 yards in 26 ounces.

(3) WEST OF ENGLAND, which consists of the hank of 320 yards, and the number of such hanks which weighs 1 lb. equals the counts; this is equivalent to

20 yards per oz., or the number of lengths of yarn of 20 yards each which weighs 1 oz. designates the counts.

(4) YORKSHIRE SKEIN.—This system at first appears somewhat complicated but when modified is really similar in principle to the foregoing. It is based upon the number of skeins of 1,536 yds. each in one 'warten' (6lb.), or when reduced, for convenience, it represents 256 yards per skein per lb. for 1^s count, and this is the basis reckoned in calculations considered in this treatise. By a further reduction of the above terms it will be noted that the number of yards which weighs 1 dram also equals the count, since 256 drams make 1 lb.

(5) HALIFAX RURAL DISTRICT.—In this system the counts are represented by the number of drams which 80 yards weigh, and this method it should be noted is diametric in principle to each of the foregoing systems.

COTTON COUNTS.—The basis of numbering cotton is on the hank of 840 yards prepared on a 54 inch reel as follows:—

1 Revolution of reel 54 inches	$= 1\frac{1}{2}$ yds.	$=$ 1 thread.
80 Revolutions ,, ,,	$= 120$,,	$=$ 1 rap or lea
7 Raps or Leas	$= 840$,,	$=$ 1 hank.

and the number of such hanks which weighs 1 lb. denotes the counts.

This system of counting cotton yarns is generally adopted throughout the English speaking countries.

Cotton yarns if made into bundles are "grossed" to weigh 5 or 10 lbs. each.

FLAX OR LINEN COUNTS.—Flax is a vegetable fibre, the botanical name of which is *Linum usitatissimum;* it is prepared and spun into two chief classes of linen yarn; (1) Long or line yarn. (2) Short or tow yarn.

Long line is prepared by hackling, gill preparing, drawing, roving and spinning.

The process of spinning is generally performed 'wet,' *i.e.* the roving, during this operation and before it enters the nip of the back rollers, passes through a trough filled with hot water, the object being to soften the natural gummy substances attached to the flax fibre and thereby reduce them to their ultimate lengths, viz.:—about $1\frac{1}{2}$ to 2 inches.

The yarn prepared after the foregoing order is technically called "Line."

The basis of reckoning may be summarised as follows:—

The yarn is reeled on to a 'swift' the circumference of which is 90 inches ($2\frac{1}{2}$ yds.); 120 revolutions of such a reel is 300 yds. and this length is called a 'Lea' or cut; the number of such leas which weighs 1 lb. avoirdupois is known as the Count or Lea.

The details of this system of reckoning are fully set forth below:—

Circumference of reel = 90 ins. = $2\frac{1}{2}$ yds. = 1 thread.
120 Revolutions of reel = $(120 \times \frac{5}{2})$ = 300 yds. = 1 lea.
10 Leas or Cuts = 3,000 yds. = 1 English hank.
12 ,, ,, = 3,600 ,, = 1 Irish or Scotch hank.
20 English hanks = 200 cuts = 60,000 yds. = 1 Bundle.
$16\frac{2}{3}$ Irish or Scotch hanks = 60,000 ,, = 1 ,,
3 Bundles = 180,000 yds. = 1 Belgium Pacquet.
6 ,, = 360,000 ,, = 1 French Pacquet.

Linen yarn is usually made into "bunches" for convenience of storage or transit. From $1\frac{1}{2}$ to 12 bundles are sometimes grouped together, though 3, 6 or 12 are most generally selected to form a bunch. The following may be accepted as types.

Up to 20s lea	...	$1\frac{1}{2}$	bundles	per	bunch
20 to 30	...	3	,,	,,	,,
30 to 70	...	6	,,	,,	,,
70 & upwards	...	12	,,	,,	,,

Sometimes linen yarn is 'short reeled,' *i.e.* the swift, as in cotton, has a circumference of 54 inches ($1\frac{1}{2}$ yds.) only, but unlike cotton the reel makes 100 revolutions or threads, which equal 150 yds. for each cut or lea; 12 such cuts form a hank which is consequently equal to one *half* of a *long reeled hank*.

TOW YARN is prepared from the short fibres which have been combed out of the flax material during the preparatory processes of roughing and hackling. The flax tow fibre bears the same relation to line sliver that '*noil*' does to combed top in worsted.

The flax tow fibres are used as self qualities, or blended according to the quality required, then carded prior to passing through a set of preparing and spinning machinery. The spinning process is performed wet, dry or by a damping process according to the fineness, condition or character of yarn required. The counts of dry spun yarn seldom exceed 16s lea.

The basis of numbering is generally the same as for fine linen. In some few cases where very coarse yarns are spun the same method of reckoning is adopted as for *Jute*.

JUTE AND HEAVY FLAXES.

Jute and heavy flaxes are based upon the weight in lbs. per spindle of 14,400 yards, *e.g.* If 14,400 yds. weigh 8, 10 or 12 lbs. the grist of the yarn is called 8, 10 or 12 spindle respectively. The complete method of reckoning is set forth below :—

Circumference of reel $=$ 90 inches $= 2\frac{1}{2}$ yds. $=$ 1 thread.
120 Revolutions of reel $=$ (120 thds. $\times \frac{5}{2}$ yds.) $=$ 300 yds. $=$ 1 lea or cut.
2 cuts or leas $=$ 600 yds. $=$ 1 heer.
6 heers $=$ 3,600 „ $=$ 1 Irish or Scotch hank.
4 hanks (48 cuts) $=$ 14,400 „ $=$ 1 spindle or spangle.

Hemp is reckoned on the same basis as flax and jute according to whether the yarn is very fine or coarse.

Flax, line and tow, jute and hemp yarns are frequently subjected to bleaching and dyeing processes, but the number of the yarn represents its count when it leaves the spinning and reeling room and contains the standard allowance of moisture.—See conditioning chapter X.

SILK COUNTS.—Raw or nett silk is 'thrown' or spun into one of the three following forms :—

Singles, Organzine and Tram.

The threads secreted in the cocoon by the silk worm are so fine that they cannot be used as individual threads; they are therefore first prepared into 'singles' as it is termed by reeling several strands together to form the finest unit thread which it is possible to use in the subsequent manufacture.

'Organzine' is the product of two or more singles which are *hard twisted* before and during the process of folding so as to make a strong thread which will serve for warp purposes.

'Tram' which is generally used for weft is made by *loosely* twisting together two or more singles.

Silk Throwsters generally reel organzine silk into skeins of 20,000 yards and tram silk into skeins of 10,000 yds. each, though this latter is frequently reeled into skeins containing from 2000 to 5000 yards only. Singles are usually made into skeins of from 5000 to 10,000 yards.

(1) The *yards per oz.; e.g.*, 20,000 organzine or Tram Silk means 20,000 yards per oz.

(2) The *Dram System*, in which the hank contains 1,000 yards, and its weight in drams represents the counts; *e.g.*, if one such hank weighs $2\frac{1}{2}$, 3 or 4 drams the counts would be $2\frac{1}{2}$s, 3s, or 4s dram yarn respectively.

(3) The Denier System is based upon the hank of 400 French ells equivalent to 476 metres or 520 yds. and the weight of this hank in deniers represents the counts.

The denier, against which the silk skein was weighed, was originally a small Roman coin (silver) of the value of about 81 centimes.

$$1 \text{ Denier} = \frac{1}{533\frac{1}{3}} \text{ oz.} = 0{\cdot}05315 \text{ grammes.}$$

1 gramme = 15.432 grains and $437\frac{1}{2}$ grains = 1 oz.

Then if 1 hank weighs 20 or 30 deniers, the counts would be 20s or 30s denier respectively.

Spun Silk (or re-manufactured silk) is based upon the hank of 840 yards, and the number of such hanks which weighs 1 lb. represents the counts, whether they be single, two, or more fold thread, the counts or hanks per lb. being written thus:—30/1; 30/2; 30/3 fold spun silk; in each case there are 30 hanks per lb. irrespective of the number of strands which compose each yarn.

In all other yarns the folded counts are expressed thus :—2/30 ; 3/30, which means that the compound threads are made up of two and three threads of 30s yarn, and therefore only contain 15 and 10 hanks per lb. respectively.

AMERICAN COUNTS (Woollen).

Cut, Run and Grain are typical examples of the systems in general use. The last named is opposed in principle of numbering to the two former.

The CUT is based upon the number of 'cuts' of 300 yds. each against a standard weight of 1 lb. avoirdupois, which is virtually the same as for linen.

The RUN is based upon 100 yards as the unit length and 1 oz. as the standard weight, *i.e.*, the number of such units of length (100 yards) which weighs 1 oz. represents the counts.

Thus, 20s Run = 2,000 yards per oz.

In the GRAIN SYSTEM the weight in 'grains' which 20 yards weigh designates the counts.

Thus, if 20 yards weigh 12, 15, or 18 grains, the counts would be 12s, 15s, and 18s grain yarn respectively.

NOTE.—The systems adopted for worsted, cotton, spun and nett silk generally are the same as given for the British Isles.

CONTINENTAL COUNTS.

The CONTINENTAL METHOD FOR WORSTED is based upon 1000 metres per kilogramme, *e.g.*, 2s counts contain 1000×2 metres, 16s counts contain 1000×16.

1 Metre = 1·094 yards.

1 Kilogramme = 2·205 lbs. = 15,432 grains.

Owing to the inconvenience of readily converting Continental into English worsted counts and *vice versa*, by having of necessity to compare metres with yards and kilogrammes with lbs., the following formulæ are deduced, which will be found of much practical advantage.

Example 1.—Find the decimal formula for converting Continental worsted counts into English worsted counts and *vice versa.*

1s French or Continental worsted counts

$$= \frac{1094 \text{ yds. per } 1000 \text{ metres}}{2 \cdot 205 \text{ lbs. per kilogramme}} = 496 \text{ yards per lb.,}$$

and basis of English counts = 560 yards per lb. for 1s counts.

$$\therefore \frac{496}{560} = 0 \cdot 885 \text{ (nearest third decimal place).}$$

Obviously then the English unit count is finer than that of the Continental, since 560 yards of the former weigh 1 lb. to each 496 yards of the latter.

$\therefore$ 0·885 English = 1s Continental counts.

Numerically the English worsted equivalent will always be less than its Continental contemporary thus :—

Then 0·885s English is equal to 1s Continental counts, or 0·885 times Continental counts equals English counts, and English counts divided by 0·885 equals Continental counts.

FORMULA A.

(a) English counts $\div$ 0·885 = Continental counts.

(b) Continental counts $\times$ 0·885 = English counts.

NOTE.—0.9 is a convenient number for mental calculation on the Exchange, and sufficiently accurate for practical work ; *e.g.*, 36s English.

= (36 $\div$ 0·9) = 40s Continental approximately, or $(36 \div \cdot 885) = 40 \cdot 7$s Continental actually.

As an *alternative* plan to the foregoing, the following method may be adopted which in some instances will be found simpler than by using 0·885 either as a multiplier or a divisor.

$$\frac{560 \text{ yards English hank}}{496 \text{ yards Continental hank}} = \frac{1 \cdot 13}{1}$$

FORMULA A[1]

(a) English counts $\times$ 1·13 = Continental.

(b) Continental counts $\div$ 1·13 = English.

Example 2.—36 English $\times$ 1·13 = 40·68 Continental.

The Continental cotton and linen or metric system is based upon 1000 metres per half kilogramme (500 grammes); *e.g.*, 2s Continental cotton or linen contains $2 \times 1000 = 2000$ metres, but the weight is only 500 grammes, whereas the weight of 2s Continental worsted equals 1000 grammes (1 kilogramme).

Example 3.—Find the decimal formula for converting Continental *cotton* counts into English cotton counts and *vice versa*.

1s French or Continental cotton counts

$$= \frac{1094 \text{ yards per } 1000 \text{ metres}}{1 \cdot 1025 \text{ lbs. per } \frac{1}{2} \text{ kilogramme}} = 992 \text{ yds. per lb.,}$$

and basis of English counts = 840 yards per lb. for 1s counts.

$$\therefore \frac{992}{840} = 1 \cdot 18.$$

Then 1s Continental = 1·18s English cotton, or, 1·18 times Continental counts equals English counts, and English counts divided by 1·18 equals Continental counts.

FORMULA B.

(a) English counts ÷ 1·18 = Continental counts.

(b) Continental counts × 1·18 = English counts.

Example 4.—Find the decimal formula for converting lea counts into metric linen counts and *vice versa*.

1s Metric linen counts = 992 yards per lb. for 1s counts as above and the usual lea counts = 300 yards per lb. for 1s counts.

$$\therefore \frac{992}{300} = 3.306 \text{ practically } 3.3,$$

consequently 1s metric linen = 3.3 lea (Irish) or 3.3 times the metric count = the leas count and conversely the lea count divided by 3.3 equals the metric count.

FORMULA C.

(a) Lea count ÷ 3.3 = Metric linen counts.

(b) Metric linen counts × 3.3 = Lea count.

Example 5.—Given 20s metric linen counts, find the equivalent in the lea system.

Then 20 × 3.3 = 66 lea counts.

GERMAN WOOLLEN COUNT is based upon the hank of 2200 Berlin ells and the number of such hanks which weighs $\frac{1}{2}$ kilogramme or 500 grammes = the counts.

1 Berlin ell = $\frac{2}{3}$ metre.

RAW SILK on the Continent and in many other countries except England and U.S.A. is frequently based upon the hank or skein of 500 metres and weighed against the "International Denier" which has given to it an empirical value of 0·05 milligrammes.

1 milligramme = 0·015432 grains.

Example 6.—If 500 metres weigh 30 International deniers the weight of such a skein would be equal to (30 deniers × 0·05 weight of deniers) = 1·5 milligrammes.

LEGAL SILK COUNT (approved Paris 1900) is based upon the skein of 450 metres; the weight of such a length in half decigrammes indicates the counts.

EXAMPLES ON LENGTH AND WEIGHT.

It will now be readily perceived that whenever a definite length of yarn is given together with its weight (or sufficient data to find these two essential factors), the *counts* of yarn in any one of the foregoing denominations can easily be determined; *e.g.*,

Example 1.—Suppose 26,880 yards of yarn weigh 3 lbs., what is the 'count' of yarn in the worsted denomination?

Then $\frac{26880}{3}$ = 8960 yards per lb.

and $\frac{8960 \text{ yards per lb.}}{560 \text{ yards per hank}}$ = 16 hanks per lb.

∴ 16s counts worsted, since the number of hanks which weigh 1 lb. equals the counts.

The whole may be simplified thus:—

FORMULA I.

Total length in yards = total weight in lbs. × yards per lb.

$\therefore \frac{\text{Total length in yards}}{\text{Weight in lbs.} \times \text{yards per hank.}}$ = hanks per lb. = COUNTS.

$= \frac{26880}{3 \times 560}$ = 16 hanks per lb. or 16s COUNTS.

(a) The above in Yorkshire skeins woollen would be $\frac{26880}{3 \times 256}$ = 35 Y. S., or 35s COUNTS.

(b) In the Linen System the above would equal

TABLE I.

LENGTH CONSTANT.		WEIGHT VARIABLE.	
System.	Unit of Length.	Unit of Weight.	Mode of Reckoning.
1. Linen and Hemp	300 yards ...	1 lb.	No. of units of length which equal 1 unit of weight···Counts.
2. Cotton	840 ,, ...	1 lb.	Do. Do.
3. Worsted	560 ,, ...	1 lb.	Do. Do.
4. Woollen Yorkshire skeins	1536 ,, ...	6 lb.	Do. Do.
5. Galashiels ...	300 ,, ...	24 ozs.	Do. Do.
6. Hawick	300 ,, ...	26 ozs.	Do. Do.
7. West of England	320 ,, ...	1 lb.	Do. Do.
8. Raw Silk ...	No. of yards ...	per oz.	Do. Do.
9. Run (American)...	100 ,,	1 oz.	Do. Do.
10. Cut do. ...	300 ,,	1 lb.	Do. Do.
11. Continental Wtd.	1000 metres ...	1 kilog.	Do. Do.
12. do. Linen & Cotton	1000 metres ...	$\frac{1}{2}$ kilog.	Do. Do.
13. German Wool Count ...	2200 Berlin ells	$\frac{1}{2}$ kilog.	Do. Do.
14. Stirling & Alloa ...	cuts yards 48 × 240 (spindle)	24 lbs.	No. of units of length (spindles) which equal 1 unit of weight = counts

N.B.—Yorkshire Skein System may be considered as 256 yards per lb.
Galashiels ,, ,, ,, ,, 200 ,,
These modifications are adopted throughout this work.

TABLE II.

LENGTH CONSTANT. WEIGHT VARIABLE.

System.	Unit of Length.	Unit of Weight.	Mode of Reckoning.
1. Halifax Rural District ...	80 yards ...	drams	Weight in No. of drams of unit length = Counts.
2. Jute, Heavy Flaxes & Hemp	48 (cuts) × 300 (yards) (spindle) ...	lbs.	Do. No. of lbs. Do.
3. Denier System	Raw Silks 476 metres or 520 yards	deniers	Do. No. of deniers Do.
4. Dram System	Raw Silks 1000 yards	drams	Do. No. of drams Do.
5. International Denier ...	500 metres ...	I.D.	Do. No. of I.D. = Counts.
6. Legal Silk Count Appd Paris 1900	456 metres ...	½ Deci-gramme	Do. ,, ½-decigrammes = Counts.
7. Grain (American) ...	20 yards ...	grains	Do. ,, grains = Counts

$\frac{26880}{3 \times 300} = 29{\cdot}86$ or $29\frac{13}{15}$ Lea.

(c) When the counts for the above question are required in the Halifax Rural District denomination, a new method or formula is necessary which will be found applicable to all the systems given in Table II.

Then $\frac{26880}{3} = 8960$ yards per lb.

and $\frac{256 \text{ drams per lb.}}{8960 \text{ yards per lb.}} = \frac{1}{35}$ dram per yard.

∴ The weight of 80 yards $= \frac{1}{35} \times 80 = 2\frac{2}{7}$ drams = counts.

The working may be simplified as follows :—

FORMULA II.

$$\frac{\left.\begin{array}{l}\text{(Weight of given length}\\ \text{in grains, or drams, or}\\ \text{deniers, or lbs.)}\end{array}\right\} \text{(unit of length in yds.)}}{\text{Given length of yarn}} = \text{COUNTS.}$$

$= \frac{3 \times 256 \times 80}{26880} = \frac{16}{7} = 2\frac{2}{7}$ drams per 80 yards or counts.

(d) In the 'Grain' System,

Since 1 lb. avoirdupois = 7000 grains,

Then $\frac{3 \times 7000 \times 20}{26880} = 15\frac{5}{8}$ grains per 20 yards = COUNTS.

(e) In the 'Denier' System,

Since 1 oz. = $533\frac{1}{3}$ deniers,

Then $\frac{3 \times 16 \times 533\frac{1}{3} \times 520}{26880} = 495$ denier silk COUNTS.

(f) In the Aberdeen or Jute System,

$$\frac{\overset{\text{(Spindle)}}{3 \times 48 \times 300}}{26880} = 1{\cdot}6 \text{ lbs. per spindle or } 1{\cdot}6 \text{ counts.}$$

Example 2.—Find the counts of 12 bundles of linen yarn which weigh 24 lbs.

Obviously—

$$\frac{\text{No. of bundles} \times \text{yards per bundle}}{\text{Weight in lbs.} \times \text{yards per lea}} = \text{leas per lb.}$$

$$\therefore \quad \frac{12 \times 60{,}000}{24 \times 300} = 100 \text{ leas per lb.}$$

Example 3.—Given 18s lea yarn, find weight in lbs. and ozs. per bundle and also of a spindle.

Then weight of bundle $= \dfrac{60{,}000 \text{ yds. per bundle}}{18 \times 300 \text{ yds. per lb.}} = 11\frac{1}{9}$ lbs.

and $11\frac{1}{9}$ lbs. $\times$ 16 ozs. per lb. $= 177\frac{7}{9}$ ozs.

Also weight of spindle $= \dfrac{14{,}400 \text{ yds. per spindle}}{18 \times 300 \text{ yds. per lb.}} = 2\frac{2}{3}$ lbs.

and $2\frac{2}{3}$ lbs. $\times$ 16 ozs. $= 42\frac{2}{3}$ ozs.

EQUIVALENT COUNTS IN DIFFERENT DENOMINATIONS.

Owing to the fact that yarns produced from different materials and under separate denominations are frequently twisted together for strength and effective purposes, *e.g.*, silk, wool, etc., and also since yarns made in one district are often consigned for use in other localities where a different system of numbering is adopted, it becomes repeatedly necessary to convert any given 'count' into an equivalent count of some other required denomination.

Example 1.—Given 20s worsted yarn, it is required to find its equivalent counts in Cotton, Yorkshire skeins, Galashiels, Hawick and Linen.

(a) Since 20s worsted = 20 hanks of 560 yards each, per lb.,

Then $20 \times 560 = 11{,}200$ yards per lb.

And since in *cotton* there are 840 yards in one hank.

$$\therefore \frac{11200 \text{ yards per lb.}}{840 \text{ yards per hank}} = 13\tfrac{1}{3} \text{ hanks per lb., cotton.}$$

i.e., $13\frac{1}{3}$ counts of cotton represent the same length and weight as 20s worsted.

The process may be simplified thus:—

FORMULA III.

$$\frac{\text{Given counts} \times \text{yards per hank}}{\text{Yards per hank in required denomination}} = \text{required counts.}$$

(b) In Yorkshire skeins, woollen,

$$\frac{20 \times 560}{256} = 43\tfrac{3}{4} \text{ skeins or counts.}$$

(c) In Galashiels 'cuts,'

$$\frac{20 \times 560}{200} = 56 \text{ 'cuts'—Galashiels.}$$

(d) In Hawick 'cuts.'

$$\frac{20 \times 560 \times 26}{(300 \times 16)} = 60\tfrac{2}{3} \text{ 'cuts'—Hawick.}$$

(e) In Linen 'leas,'

$$\frac{20 \times 560}{300} = 37\tfrac{1}{3} \text{ leas.}$$

If it is required to change the denomination of any count of yarn given in Table II, a different method and formula are necessary; *e.g.*,

Example 2.—Given 20s Yorkshire skeins woollen, find its equivalent in the Halifax Rural District, denier, grain, and jute denominations.

(a) The Halifax Rural District,

Then 20 hanks per lb. × 256 yards per skein = number of yards per lb.

Also 256 equals the number of drams per lb.

And $\frac{256}{20 \times 256} = \frac{1}{20}$ dram. Weight of 1 yard of 20s Yorkshire skeins.

Again, since the weight in drams of 80 yards represents the counts in Halifax Rural District,

$\therefore$ counts $= \frac{1}{20} \times 80 = 4$ drams per 80 yards, or 4s counts.

This may be reduced and simplified thus:—

FORMULA IV.

$$\frac{\text{Lbs., drams, grains, or deniers per lb} \times \text{unit length}}{\text{Yards per lb. of given yarn}} = \text{required counts.}$$

(b) In the 'Denier' System,

$$\frac{\left(\frac{1600 \times 16}{3}\right) \times 520}{20 \times 256} = 30\tfrac{10}{21}$$ deniers per hank of 520 yds. or counts.

(c) In the 'Grain' System,

$$\frac{7000 \times 20}{20 \times 256} = 27\tfrac{11}{32}$$ counts or grains per 20 yds.

(d) In the 'Jute' System,

$$\frac{1 \times 48 \times 300}{20 \times 256} = 2\tfrac{13}{16}$$ counts or lbs. per spindle.

SHORT METHODS FOR FINDING EQUIVALENT COUNTS.

Since worsted and cotton counts are very frequently required to be expressed in terms of each other, and because cotton and linen are similarly related the following abbreviated formulæ will be found most useful in practice.

(a) Cotton and Worsted compared.

$$\frac{\text{Cotton}}{\text{Worsted}} = \frac{840}{560} = \frac{3}{2}$$

Consequently 3 yards of 1^s Cotton is equivalent in weight to 2 yards 1^s Worsted, and since their *counts* are in the *inverse* ratio to their weights—

∴ Worsted count $\times \frac{2}{3}$ = cotton counts.
and cotton „ $\times \frac{3}{2}$ = worsted „

Example 3.—Find the equivalent counts of 10s Cotton in Worsted.

$$\text{Then 10s cotton} = \frac{10 \times 3}{2} \text{ 15s worsted}$$

(b) Cotton and Linen compared.

$$\frac{\text{Cotton}}{\text{Linen}} = \frac{840}{300} = 2{\cdot}8$$

∴ Linen counts $\div$ 2·8 = cotton counts,
and cotton „ $\times$ 2·8 = linen „

Example 4.—Find the equivalent counts in linen of 10s cotton.

Then 10s cotton = 10 $\times$ 2·8 = 28s linen.

Method of changing from jute, heavy flaxes or hemp to fine linen or lea yarn.

The number of cuts per spindle divided by the number of lbs. per spindle is equivalent to the number of cuts or leas per lb.

Example 5.—Assume a heavy flax yarn weighs 4 lbs. per spindle, what number of line yarn is this equal to?

Ans., 1 spindle = 48 cuts,
and since each spindle in the question weighs 4 lbs.,

$$\therefore \frac{48 \text{ cuts}}{4 \text{ lbs.}} = 12 \text{ cuts per lb.}$$

Conversely the number of cuts per lb. divided into the number of cuts per spindle is equivalent to the number of lbs. per spindle, or

(a) $\dfrac{\text{Cuts per spindle}}{\text{Cuts per lb.}} = \text{leas per lb.}$

(b) $\dfrac{\text{Cuts per spindle}}{\text{Leas per lb.}} = \text{lbs. per spindle.}$

EXERCISES.

1. If 11,200 yards of yarn weigh 1 lb., what counts would represent this length and weight in worsted, woollen, Y. S., cotton and linen?

Ans., 20; $43\frac{3}{4}$; $13\frac{1}{3}$; $37\frac{1}{3}$.

2. The weight of a length of 16s worsted yarn is 3 oz., what is its length?

Ans., 1680 yards.

3. Find the respective weights of 3 yards, 20 yards, 75 yards, 560 yards, and 1800 yards (a) of 4s Halifax Rural District, (b) 12s worsted, (c) 18s Y. S. woollen, and (d) 32s linen.

Ans., (a) $\frac{3}{20}$; 1; $3\frac{3}{4}$ drs.; $1\frac{3}{4}$; $5\frac{5}{8}$ ozs.; (b) $3\frac{1}{8}$; $20\frac{5}{6}$; $78\frac{1}{8}$ grs.; $1\frac{1}{3}$; $4\frac{2}{7}$ ozs.; (c) $\frac{1}{6}$; $1\frac{1}{9}$; $4\frac{1}{6}$; $31\frac{1}{9}$; 100 drams; (d) $\frac{2}{25}$; $\frac{8}{15}$; 2; $14\frac{14}{15}$; 48 drams.

4. Convert the following into worsted counts: 18 Skeins woollen (Yorkshire); 100/2 silk; 2/60s cotton; also give the number of yards in 20 lbs. of each of these counts.

Ans., $8\frac{8}{35}$; 150s; 45s; 92,160; 1,680,000; 504,000 yards.

5. If 160 hanks of worsted weigh $9\frac{1}{2}$ lbs., what are the counts?

Ans., $16\frac{16}{19}$.

6. Find the equivalent counts of 2/48s worsted, in

Y. S. woollen, Galashiels, Hawick, and the Grain Systems.

Ans., $52\frac{1}{2}$; $67\frac{1}{5}$; $72\frac{4}{5}$; $10\frac{5}{12}$.

7. If 4800 yards of warp material weigh $\frac{3}{4}$ lb., (a) what are the counts in worsted? (b) what would be the length of this weight of yarn in each of the following materials: 6s Jute, 14s Hawick, 8s Halifax Rural District, and 18s Yorkshire skeins woollen?

Ans., (a) $11\frac{3}{7}$, (b) 1800; 1938; 1920; 3456 yds.

8. The weight of a warp whose total length equals 560,000 yards is 80 lbs. What are the counts in Run, Hawick, linen and cotton?

Ans., $4\frac{3}{8}$; $37\frac{11}{12}$; $23\frac{1}{3}$; $8\frac{1}{3}$.

9. Convert the following into West of England counts: 20s worsted, 36 cut Hawick, 10s Halifax Rural District, and 30s Grain yarn.

Ans., 35; $20\frac{10}{13}$; $6\frac{2}{5}$; $14\frac{7}{12}$.

10. Given 36,000 yards per oz. of organzine (raw silk), what counts in the Denier System would represent this length and weight?

Ans., $7\frac{19}{27}$.

11. What is the difference in principle of counting yarns in the worsted denomination as compared with the American Grain System?

12. Find the equivalent counts (a) in worsted of 18s Continental yarn, (b) in Continental of 16s English (worsted) yarn.

Ans., (a) 15·93, (b) 18·09.

13. How many leas are there in $3\frac{1}{2}$ lbs. of 30s linen, hanks of 2/24 cotton, and 60/2 spun silk?

Ans., 105; 42; 210.

14. What is the difference in designation of two or

more fold cotton, worsted or woollen as compared with spun silk materials?

15. Write out from memory the system of counting Hawick, Aberdeen, Worsted, Cotton, Linen, Run, Grain, Spun Silk, and Y. S. woollen yarns.

16. (a) Find the equivalent counts in cotton and linen of 60/2 spun silk, and (b) the equivalent counts in worsted of 40/2 spun silk.

Ans., (a) 60; 168; (b) 60.

17. (a) Find the number of yards of weft in 1 lb. of 20s cotton; (b) find the equivalent counts in worsted for 20s cotton; and (c) what would be the equivalent counts of 45s worsted?

Ans., 16,800; 30; 30.

18. How many lbs. would there be in 1 gross of hanks of 32s worsted?

Ans., $4\frac{1}{2}$ lbs.

19. If 270 yards of yarn weigh $13\frac{1}{2}$ drams, what counts in worsted would represent this length and weight?

Ans., $9\frac{1}{7}$.

20. Find the weight of 20 hanks in grammes and lbs., also the length in metres and yards of 20s Continental worsted, cotton and linen counts.

Ans.,
1000 grammes; 2·205 lbs. worsted.
500 grammes; 1·1025 lbs. cotton and linen.
1650 grammes; 3·638 lbs. of linen (Irish hank)
20,000 metres; 21,880 yds. linen, cotton and worsted.

21. Find the number of yards per oz. in 2 dram silk.

Ans., 8000.

22. Find the denier count of 10,000 (yards per oz.) organzine silk. *Ans.*, $27\frac{11}{15}$s.

23. What is the equivalent count of 24s English worsted in Continental worsted? *Ans.*, 27·12.

24. 30s Continental cotton and linen counts are given, what counts in English worsted, linen and cotton are equivalent? *Ans.*, 53·1; 99; 35·4.

25. Given 8 leas linen yarn, find the lbs. per spindle. *Ans.*, 6.

26. Find the actual counts linen (a) 4 hanks weighing 3 lbs, (b) 6 cuts weighing 2 oz., (c) 8 bundles of line yarn weighing 17 lbs, but which has lost 15% on the original weight by treatment.

Ans., (a) 16; (b) 48; (c) 80 leas.

27. Find the equivalent counts of 56 line yarn in cotton and of 2/60s cotton in linen.

Ans., 20s cotton; 84 leas linen.

28. Find the weight in lbs. and grammes of 1 French Pacquet of 56s linen yarn.

Ans., $21\frac{3}{7}$ lbs; 9718 grammes.

29. Given 25 lbs. of 20s cotton yarn and 50 spindles of 5 lb. dry spun flax, what number of bundles of linen yarn are equal to these respective lengths?

Ans., 7 and 12.

30. Find the equivalent counts of 16s, 20s and 2/50s cotton in linen.

Ans., 44·8; 56 and 70s lea.

31. Find the number of hanks of cotton yarn that would be equal in length to 9 Irish or Scotch hanks and 4 cuts of linen yarn? Give the circumferences of the reels that linen and cotton yarns are usually reeled upon. *Ans.*, 40.

CHAPTER II.

Resultant and Average Counts.

When two or more single threads are folded or twisted together, the resultant thread is usually designated as *twisted* or *folded*; but if these twisted threads are again folded as is the case for harness cords, shoe threads, cords and strands requiring great strength or special effect, they are then said to be 'cabled.'

Resultant Counts.—When two or more threads are twisted or folded together it is necessary then to find the number of hanks per lb. of the combined thread. This process is known as *finding the resultant counts*, *e.g.*, if 2 threads of 20s worsted are twisted together, the number of hanks of the combined thread will equal 20 per every 2 lbs., and consequently, 10 hanks per lb., which latter number represents the 'resultant counts.'

Average Counts.—When two or more yarns of various sizes are used side by side in the same fabric, it is frequently necessary and advantageous to determine the 'average counts,' *i.e.* the count of yarn which will represent the same weight and length for the combined number of the several yarns employed in the given woven fabric, *e.g.*,

Suppose a warp is composed of alternate threads of 20s and 10s worsted respectively; equal lengths of each yarn would be required, so assume that 20 hanks of 20s worsted are used, then also 20 hanks of 10s worsted are wanted; total, 40 hanks. The weight of the former equals 1 lb. while that of the latter equals 2, which gives an average of

$$\frac{40 \text{ hanks}}{3 \text{ lbs.}} = 13\tfrac{1}{3} \text{ hanks per lb.} = \textit{average counts.}$$

NOTE.—When *resultant counts* are required, the threads are supposed to be twisted together, whereas when *average counts* are required, it is assumed that the threads are contiguous in the woven cloth and retain their respective individualities.

RESULTANT COUNTS OF LIKE DENOMINATION.

Example 1.—If one thread of 20s cotton and one thread of 60s cotton are twisted together, what are the resultant counts of the twisted thread?

Supposing there is no variation in the take-up of the length of each yarn during the twisting operation, the same length of each material will be required.

For the purpose of illustration, when 60 hanks of 60s cotton are used, 60 hanks of 20s cotton will also be taken, and when these have been twisted together we shall have only 60 hanks, but 60 of the former count weigh 1 lb., while 60 hanks of the latter weigh 3 lbs. Consequently, the 60 hanks of the twisted thread equal 4 lbs. or

$$\frac{60}{4} = 15 \text{ hanks per lb., or the resultant counts.}$$

The above may be stated thus :—

60 hanks of 60s cotton = 1 lb.
60 hanks of 20s cotton = 3 lbs.
60 hanks of twisted thread = 4 lbs.

$$\therefore \frac{60}{4} = 15 = \text{resultant counts.}$$

The foregoing may be reduced to a simple formula, which will be found applicable for finding the resultant counts of any number of threads of *like* denomination which are twisted together.

N.B.—Threads of various denominations must be reduced to a *like* denomination.

Formula V.

Select the highest count and divide it by itself and each of the given counts; the quotient in each case will then represent the relative weight of each thread in lbs.; then divide the selected count by the sum of these weights, and the answer will equal the Resultant Counts.

Example 2.—Find the resultant counts of 20s, 30s, and 60s worsted thread twisted together.

By formula V.:—

Hanks ÷ counts = relative weight in lbs.

60	÷	60	=	1
60	÷	30	=	2
60	÷	20	=	3

60 hanks of twist = 6 lbs.

$$\therefore \frac{60}{6} = 10 \text{ hanks per lb.} = \text{resultant counts.}$$

Short Method of finding Resultant Counts.

When only two counts are twisted together, a shorter method is adopted in practice, but it cannot be conveniently adopted to the solution of twist yarns of more than two threads.

Formula VI.

Divide the product of the two given counts by their sum.

Example 1.—Given 10s. worsted and 5s worsted, find the resultant counts.

By formula VI.:—

$$\frac{10 \times 5}{10 + 5} = \frac{50}{15} = 3\tfrac{1}{3} \text{ counts.}$$

PROOF.—It will readily be admitted as an axiom that the product of the counts and weight of like materials of equal length are equal; *e.g.* given equal lengths of 10s and 5s worsted, the relative weight of 5s is 10 lbs. when the weight of 10s worsted is 5 lbs. or in inverse proportion to their counts. The total weight of these two counts of given length = (10 + 5) 15 lbs. Let x equal the resultant counts of 10s and 5s worsted. Then since x counts weighing 15 lbs. is of equal length to 5s or 10s weighing 10 lbs. and 5 lbs. respectively, it therefore follows that $(10 + 5)\ x = 5\text{s worsted} \times 10 \text{ lbs.}$, or $10\text{s worsted} \times 5 \text{ lbs.}$

$$\therefore x = \frac{5 \times 10}{(10+5)} = 3\tfrac{1}{3} \text{ counts.}$$

which is the same as given at formula VI.

RESULTANT COUNTS FOR YARNS IN TABLE II.

To find the resultant counts for two or more folded yarns, such as jute, dry spun flaxes, American Grain System and Halifax Rural Count all that is required is to add the weights together for each respective sort and unit length, *e.g.* If 2, 3 and 4 lbs. per spindle of Jute are folded together, the resultant lbs. per spindle is 2 + 3 + 4 = 9. Similarly if 2 and 4 lbs. of dry spun flax are folded the result = 2 + 4 = 6 lbs. per spindle; or if two threads of 6 dram woollen (80 yards) are twisted together, the resultant count equals 6 + 6 = 12 dram (80 yards). And in the case of the American

Grain System if 15 and 20 grain yarn be made into two ply, the resultant number would be equal to $15 + 20 = 35$ grain counts.

RESULTANT COUNTS OF MIXED DENOMINATIONS.

When twist yarns are composed of different materials, or are given in different denominations, it is necessary to first reduce all to any one of the given denominations before any attempt is made to find the resultant counts.

Example 1.—Given a compound twist thread which is made up of one thread 24s black worsted; one thread 16s slate worsted; one thread 32/2 spun silk, red. Find the resultant counts in worsted.

$$\text{Then } 32/2 \text{ spun silk} = \frac{32 \times 840}{560} = 48\text{s worsted.}$$

Then by formula V.:—

$$\begin{array}{lcccc} 48 & \div & 48 & = & 1 \\ 48 & \div & 24 & = & 2 \\ 48 & \div & 16 & = & 3 \\ \hline 48 \text{ hanks} & & & = & 6 \text{ lbs.} \end{array}$$

$$\therefore \ \frac{48}{6} = 8 \text{ hanks per lb.} = \text{resultant counts.}$$

SOLUTION OF UNKNOWN COUNT IN A COMPOUND TWIST THREAD.

Occasionally a spinner or manufacturer has given the counts of his compound twist thread and one or more of the threads which go towards its composition; it then becomes necessary to find the size of the unknown thread which together with the given count makes the required component twist yarn.

Example 1.—Assume a twist thread must be equal to 20s worsted, of which one of the component threads is equal to 60s worsted. What counts worsted must the other thread be equal to?

By the application of formula VI., already proved, we may solve not only the above problem, but also explain an additional formula which is much shorter and of more frequent application.

Let x = the counts of the second thread.

Then by formula VI., $\frac{60x}{60 + x} = 20$s resultant counts.

By multiplying across we obtain

$$60x = 20\,(60 + x)$$

$$60x = 20 \times 60 + 20x.$$

$$60x - 20x = 20 \times 60$$

$$\therefore\ x = \frac{20 \times 60}{60 - 20} = 30\text{s counts of second thread.}$$

It should be observed that the size of the second thread is always equal to the product of the two given counts (first thread and resultant counts) divided by their difference, and this being always the case, the result may be expressed in the following recognised formula :—

FORMULA VII.

Divide the product of the two counts by their difference, thus :—

$$\frac{\text{1st count} \times \text{resultant counts}}{\text{1st count} - \text{resultant counts}} = \text{count of second thread.}$$

Example 3.—A twist thread is composed of 25 Y. S. woollen and a second thread in Galashiels. The combined thread is equal to 16s Galashiels. What is the grist of the second thread?

Then 25 Y. S. $= \frac{25 \times 256}{200} = 32$s counts Galashiels

By formula VII.,

$$\frac{32 \times 16}{32 - 16} = 32 \text{ Galashiels or grist of the 2nd thread.}$$

When more than two threads are used in the composition of a twist thread, and when only one of them is unknown, it is necessary to first reduce all the known threads to one resultant count before attempting to find the unknown count, which may afterwards be accomplished by the aid of formula VII.

Example 4.—A twist thread is equal to 15s worsted counts; it is composed of 1 thread 36s black worsted, a second thread of 40/2 spun silk and a third thread of slate-coloured worsted. Find the counts of the last-named yarn.

Then 40/2 spun silk $= \dfrac{40 \times 840}{560} =$ 60s worsted,

and $\dfrac{60 \times 36}{60 + 36} = \dfrac{45}{2}$ worsted.

Then by formula VII.,

$$\frac{22\frac{1}{2} \times 15}{22\frac{1}{2} - 15} = 45 \text{ worsted.}$$

That is, 45s worsted, 36s worsted and 40/2 spun silk, all twisted together are equal to 15s worsted counts.

Whenever it is required to find the size of any dry spun flax, jute or Halifax rural woollen count to twist with any known size of yarn to produce some other specific count or weight per spindle or other unit of length as in Table II., it is evident that all that is necessary is to subtract the weight of the given single yarn from that of the compound twist thread when the result will equal the required size of the other single yarn thus:—Let it be required to fold 7s jute yarn to make 15 lbs. per spindle.

Then $15 - 7 = 8$ lbs. per spindle.

RESULTANT COUNTS—WHEN LENGTHS VARY.

Fancy twists of such types as spiral, corkscrew, loop or knop yarns, etc., are produced from different lengths of thread, and consequently, the counts do not represent their true relative lengths, but are modified according to the variation in 'take-up' of material.

Example 1.—A spiral twist thread is made from 2/56 Botany and 1/7 Botany—10 inches of the former being required to every 7 inches of the latter thread. What is the resultant counts ?

(a) Then 2/56 Botany equals 28s worsted counts.

(b) And the relative length required of this finer count is $\frac{3}{7}$ more than that of the coarser.

(c) Further, if no variation in length occurred, we should require the same number of hanks of each ; (the term hank being simply used for convenience, since it represents a fixed length). If, for example, we select 28 hanks, the number of hanks in 1 lb. of 2/56 Botany, it is evident we shall require $\frac{3}{7}$ more hanks or length of this count to allow for the extra take-up thus : $28 + (\frac{3}{7} \text{ of } 28) = 40$ hanks (or 28 hanks each 800 yards long).

(d) And weight of 40 hanks of 28s worsted $= 1\frac{3}{7}$ lbs.

(e) Also weight of 28 hanks of 7s worsted $= 4$ lbs.

(f) When these are twisted together the number of hanks will then equal 28 for the above total weight of $(1\frac{3}{7} + 4) = 5\frac{3}{7}$ lbs.

$$\therefore \frac{28}{5\frac{3}{7}} = 5\tfrac{3}{19} \text{ hanks per lb.} = \text{resultant counts.}$$

The foregoing is simplified and expressed in the following formula :—

FORMULA VIII.

(1) Select the highest count or number of hanks per lb. from one of the given counts.

(2) Add the additional length expressed in hanks for take-up in twisting if any. The result equals the relative length of each in hanks.

(3) Divide the relative number of hanks of each by the respective counts. The result equals the relative weights.

(4) Divide the number of hanks per lb. of selected count by the sum of the relative weights—the quotient equals the resultant counts.

Thus in the above example,

Hanks per lb.	+	extra length	=	relative length expressed in hanks	÷	counts	=	rel. weight lbs.
28	+	($\frac{3}{7}$ of 28)	=	40	÷	28	=	$1\frac{3}{7}$
28	+	0	=	28	÷	7	=	4

28 hanks of twist thread weigh $= 5\frac{3}{7}$ lbs.

$$\therefore \frac{28 \times 7}{38} = 5\tfrac{3}{19} \text{ hanks per lb.} = \text{resultant counts.}$$

Example 2.—A knop yarn is made from 1/20s cotton and 36s worsted, 3 inches of worsted are required to every 2 inches of cotton, the latter thread being practically straight. Find the number of hanks per lb. of the twisted thread in worsted.

$$\text{20s cotton} = \frac{20 \times 840}{560} \text{ or } \frac{20 \times 3}{2} = \text{30s worsted.}$$

Also, one half more hanks or length of 36s worsted is required.

By formula VIII. :—

Hanks per lb.	+	extra length	=	relative length expressed in hanks	÷	counts	=	rel. weight lbs.
36	+	($\frac{1}{2}$ of 36)	=	54	÷	36	=	$1\frac{1}{2}$
36	+	0	=	36	÷	30	=	$1\frac{1}{5}$

36 hanks of twist thread weigh ... $2\frac{7}{10}$ lbs.

$\therefore \frac{36}{2\frac{7}{10}} = 13\frac{1}{3}$ hanks per lb. = resultant counts.

Example 3.—A crewel yarn is made from 20s and 16s worsted, 12 inches of the former and 11 inches of the latter are required to produce 10 inches of twist. What number of hanks per lb. does the twist thread contain?

Then of the 20s worsted $\frac{1}{5}$ more length is required than the actual length of the twist yarn.

And of the 16s worsted $\frac{1}{10}$ more length is required than the actual length of the twist yarn.

Then by formula VIII. :—

20	+	($\frac{1}{5}$ of 20)	=	24	÷	20	=	$1\frac{1}{5}$ lbs.
20	+	($\frac{1}{10}$ of 20)	=	22	÷	16	=	$1\frac{3}{8}$ lbs.

20 hanks of twist thread weigh ... $2\frac{23}{40}$ lbs.

$\therefore \frac{20}{2\frac{23}{40}} = 7\frac{3}{4}$ resultant counts.

AVERAGE COUNTS OF LIKE DENOMINATION.

Example 1.—A cloth is woven with two threads of 60s cotton and one thread of 20s cotton. What is the average count?

Since the given counts are in the same denomination, and assuming equal lengths of each thread are required, then, if we select 60 hanks as the unit length (being the highest counts),

There will be two lengths of 60 hanks each of 60s
And there will be one length of 60 hanks of 30s

Further, the weight of (60 × 2) hanks of 60s = 2 lbs.
And the weight of 60 hanks of 20s = 3 lbs.
The total number of hanks = (60 × 2) + 60 = 180.
The weight of these hanks = 2 + 3 = 5 lbs.

$\therefore$ The average number of hanks per lb. $= \frac{180}{5} = 36.$

This process is best expressed in the following formula, which will be found to admit of general application.

FORMULA IX.

(1) Select the highest count (greatest number of hanks per lb.)

(2) Multiply it by the number of threads of each count in one repeat of the pattern.

(3) Divide each product separately by the given counts.

(4) Divide the sum of these quotients *into* the total number of hanks.

The answer equals the average counts.

Example 2.—A woven fabric contains two threads of 2/60s, two of 2/40s, and one of 12s cotton counts. What is the average count?

Then by formula IX.:—

Hanks	×	threads	=	total hanks	÷	counts	=	relative weight
30	×	2	=	60	÷	30	=	2 lbs.
30	×	2	=	60	÷	20	=	3 lbs.
30	×	1	=	30	÷	12	=	$2\frac{1}{2}$ lbs.
				150 hanks weigh				$7\frac{1}{2}$ lbs.

$\therefore \frac{150}{7\frac{1}{2}} = 20$ hanks per lb. = average count.

AVERAGE COUNTS OF MIXED DENOMINATION.

Example 1.—Assume a fabric is woven with two threads of 40s cut Galashiels, one thread of 2/30s cotton, and 2/60s worsted. Find the average count in worsted.

First, resolve each system into one of the given denominations; in this example worsted is demanded.

Then 40s cut Galashiels

$$= \frac{40 \times 200}{560} = \frac{100}{7} = 14\tfrac{2}{7} \text{ worsted.}$$

and 2/30s cotton $= \frac{15 \times 840}{560} = 22\tfrac{1}{2}$ worsted.

Then by formula IX.:—

	Hanks	×	thread	=	hanks	÷	counts	=	rel. weight
Worsted	30	×	1	=	30	÷	30	=	1 lb.
Cotton	30	×	1	=	30	÷	$22\frac{1}{2}$	=	$1\frac{1}{3}$ lbs.
Galashiels	30	×	2	=	60	÷	$14\frac{2}{7}$	=	$4\frac{1}{5}$ lbs.
					120 hanks weigh				$6\frac{8}{15}$ lbs.

$$\therefore \frac{120}{6\frac{8}{15}} = 18{\cdot}36 \text{ average count.}$$

EXERCISES.

A

1. If a thread of 16s and a thread of 40s single cotton be twisted together, what will be the resultant counts?

Ans., $11\frac{3}{7}$.

2. Having 40s cotton yarn and wishing to twist it with another yarn to make it 24s, what number would you employ?

Ans., 60s counts.

3. Give resulting counts of 36s, 40s, and 60s yarn twisted together.

Ans., $14\frac{2}{5}$.

4. (a) What would be the resulting counts of 30s

and 60s worsted twisted together, and (b) of 30s and 20s woollen twisted together?

Ans., (a) 20s; (b) 12s.

5. How many hanks would there be in 1 lb. of 2-ply yarn made by twisting one thread of 24s and one thread of 30s cotton together?

Ans., $13\frac{1}{3}$ cotton.

6. A thread is composed of two threads 30s worsted and one thread of 60/2 silk. Find the resulting counts in worsted.

Ans., $12\frac{6}{7}$ counts.

7. Find the resulting counts of 80s, 60s, 40s, and 20s worsted twisted together.

Ans., $9\frac{3}{5}$ worsted.

8. What would be the resulting counts of 60s spun silk and 30s worsted twisted together? Answer in worsted.

Ans., $22\frac{1}{2}$s.

9. What would be the resulting counts in silk of 30s worsted and 60s spun silk twisted together?

Ans., 15s.

10. Give the resultant counts of a compound thread made by twisting one thread of 21s worsted, one thread of 42s worsted, and one thread of 21s Y.S. woollen. Answer to be in the last named system.

Ans., $12\frac{27}{59}$.

11. What counts should be twisted with 20s cut Galashiels to make it equal to 8s cut Galashiels?

Ans., $13\frac{1}{3}$.

12. A twist yarn which is equal to 8s worsted is composed of 2/60 black worsted, 30/2 spun silk and a

third thread of Y. S. woollen. What is the count of the last named yarn ?

Ans., $31\frac{1}{2}$ skeins.

13. What counts woollen should be twisted with a 60/2 spun silk to make a resultant counts equal to 30 Y. Skeins woollen ?

Ans., $35\frac{35}{89}$ Y. S. woollen.

14. A twist thread is composed of one thread 30s worsted, one of 40s cotton, and a third thread of silk. Find the counts of the silk thread, assuming that the compound thread is equal to 18s worsted.

Ans., 120 spun silk.

15. Find the average counts of a cloth made alternatively with one end of 16s and one end of 32s worsted.

Ans., $21\frac{1}{3}$.

16. A cloth is woven with one pick of 24s mohair and one pick of 16s Y. S. woollen. What is the average counts in woollen ?

Ans., $24\frac{1}{2}$.

17. Given 36s Continental cotton counts, find the resultant counts when twisted with 60/2 spun silk. Answer to be in English cotton counts.

Ans., 24·9.

18. Find the resultant counts of 20s, 32s, and 40s worsted twisted together, also how many leas will there be in a lb. of 50s and 90s line twisted together ?

Ans., $9\frac{7}{17}$; $32\frac{1}{7}$.

B

19. A 3-ply thread is made by twisting the following yarns: one thread $10\frac{1}{2}$ run woollen, one thread 30s worsted, one thread 20s cotton. What would be the

equivalent counts of the compound thread, in (a) a single cotton, (b) a single worsted, and (c) a woollen thread (Run system)?

Ans., (a) $6\frac{2}{3}$s, (b) 10s, (c) $3\frac{1}{2}$s.

20. When a cloth consists of four threads of 80s, two of 40s, and one thread of 16s worsted, what is the average count?

Ans., $43\frac{1}{13}$.

21. What is the average count of two threads of 40s and one thread of 16s worsted?

Ans., $26\frac{2}{3}$.

22. A cloth consists of four threads of 80s, three of 60s and one of 16s. Find the average count.

Ans., $49\frac{3}{13}$.

23. Find the resultant lea counts of a 6 fold 'cabled' linen thread composed as follows:—

50s lea yarn having eighteen turns per inch to the left, *i.e.*, in the opposite direction from which it is spun, afterwards two folded with thirteen turns per inch to the right and finally three of such strands are cabled with ten turns per inch. Shrinkage in length to be ignored.

Ans., $8\frac{1}{3}$ counts.

24. Find the resultant counts in lbs. per spindle of a 3-fold, 3-fold lea cabled harness cord (written thus: 30/9) and also of a 30/12 cabled harness cord made up of 4-ply 3-ply 30s lea.

Ans., 14·4 lbs.; 19·2 lbs.

25. A loop yarn is made up of two threads of 2/32s white cotton and one thread of 24s red worsted, two yards of worsted are used to each yard of cotton.

Find the number of hanks per lb. of the compound thread in worsted.

Ans., 6.

26. A loop yarn has a resultant count of 4s cotton. It is made up of two threads of 2/28s black cotton and a grey thread in worsted. There are two yards of this last thread used to each yard of the cotton, find the counts of the worsted.

Ans., 28s.

27. A fancy loop yarn is composed of two threads of 1/40s white cotton, two threads of 1/40s red cotton, and two threads of 2/100s black cotton. The relative lengths of material used are 8″, 9″, and 4″ respectively. Find the resultant counts. The last thread is straight.

Ans., $6\frac{1}{2}$.

28. A spiral yarn is made by twisting a 2/60s Botany with a 1/8s Botany. If 48 inches of the former are required to each yard of the latter, what is the number of hanks per lb. of the combined thread?

Ans., $5\frac{55}{61}$.

29. A loop yarn is composed of two threads of 24s black mohair, one thread of 2/40s red cotton, and one thread of 8s green cotton. 24, 12 and 10 inches of these respective counts produce 9 inches of twist. Find the resultant counts in cotton.

Ans., 1·86.

CHAPTER III.

Relative Weights and Cost of Twist Yarns.

I. Relative Weights of Component Threads in Twist Yarns—When Lengths are Equal.

Obviously, for all systems given under Table I, when any twist threads are made up of two threads of different thickness, the weight of each count will be different. The counts of yarn as already demonstrated indicate the relative weights of yarn for some fixed length, which weight decreases as the number of counts increase and *vice versa;* hence, the weights of yarns vary in the inverse ratio of their counts, thus:—

Example 1.—If 30s and 15s counts are folded together, what would be the weight of each in a total weight of 60 lbs. of twist?

Then, according to the above reasoning, 30 units of weight of 15s would contain the same length as 15 units of weight of 30s counts; or, for each 30 lbs. of 15s we should require 15 lbs. of 30s. Then, out of a total weight of 45 lbs. there would be 30 lbs. of 15s and 15 lbs. of 30s, and by simple proportion the weight of each count in 60 lbs. of twist may readily be found thus:—

As $45 : 60 :: 30 : x$, where $x =$ the weight of 15s counts.

$$= \frac{60 \times 30}{45} = 40 \text{ lbs. of 15s}$$

$$\therefore 20 \text{ lbs. of 30s}$$

or, $\dfrac{60 \times 15}{45} = 20$ lbs. of 30s.

The same may be expressed in a simple formula for use in practice, thus :—

FORMULA X.

To find the weight of each count, in a given weight of twist yarn,

(a) $\dfrac{\text{Given weight} \times \text{lowest count}}{\text{Sum of the two counts}} = \text{weight of highest count}$

(b) $\dfrac{\text{Given weight} \times \text{highest count}}{\text{Sum of the two counts}} = \text{weight of lowest count}$

When only two counts are given the above formula supplies a ready means of determining the respective weight of each count in a given weight, but when the twist yarn is composed of several threads, some other method of solution is necessary.

By a reference to formula V. (chapter II.) we shall observe that it not only helps us to find the resultant counts but also shows the relative weight of each count, from which we may very easily obtain the respective weights of each in any given weight; thus, in the above example.

By formula V. :—

Hanks	÷	Counts	=	Relative weight in lbs.
30	÷	30	=	1
30	÷	15	=	2

30 hanks of twist weigh 3 lbs.

Then it is very clear that out of every 3 lbs. of a total weight, we have a relative weight of 1 lb. of 30s and 2 lbs. of 15s. Hence, it follows that if we divide the product of the required weight of twist and relative weight of each yarn by the sum of the relative weights of the given yarns, our answer will be the respective weights of each count of yarn required to make a twist of indicated weight.

Thus:— $\frac{60 \times 2}{3} = 40$ lbs. of 15s

and $\frac{60 \times 1}{3} = 20$ lbs. of 30s

or as previously shown.

The whole collected into one formula may be expressed as follows:—

FORMULA XI.

First part, exactly as formula V.

Second part,

$$\frac{\text{Required weight of twist} \times \text{relative weight of respective counts}}{\text{Sum of relative weights}} = \text{weight of respective counts.}$$

Example 2.—120 lbs. of twist are required of 20s, 30s, and 60s cotton, what weight of each count will the compound twist thread contain?

BY FORMULA XI.

1st part, Hanks ÷ Counts = Relative weight in lbs.

60	÷	60	=	1
60	÷	30	=	2
60	÷	20	=	3
60 hanks weigh				6 lbs.

2nd part,

(a) $\frac{120 \times 1}{6} = 20$ lbs. of 60s cotton.

(b) $\frac{120 \times 2}{6} = 40$ lbs. of 30s cotton.

(c) $\frac{120 \times 3}{6} = 60$ lbs. of 20s cotton.

Total weight = 120 lbs.

NOTE.—The relative weight for all systems of counts given under Table II. are in *direct* proportion to their counts.

II. RELATIVE WEIGHT OF COMPONENT THREADS IN TWIST YARNS—WHEN LENGTHS VARY.

To find the respective weight of each count in a given weight of twist such as spiral, curl and all yarns in which the take-up in length of each count varies, involves a slight variation in the first part of the foregoing formula.

Generally if the two fold yarn contains fewer turns per inch than that of the single, the length of the folded material will be greater than the original length of the single; but as the twist in the two ply yarn increases, its length will gradually decrease. The actual amount of variation cannot be reduced to any simple formula. The results for different counts of yarns and twist per inch must be determined by experiment, and then tabulated for future use, *e.g.*,

20s cotton containing 20 turns per inch is afterwards two-folded for experimental purposes, and produces the following results:—

a.	10 turns,	length	of ply	yarn	= 858	yards.
b.	15 ,,	,,	,,	,,	= 838	,,
c.	20 ,,	,,	,,	,,	= 830	,,
d.	25 ,,	,,	,,	,,	= 800	,,

Example 1.—A corkscrew yarn is composed of 10s and 60s Botany, 5 inches of the latter being required to 3 inches of the former. What weight of each will be required to produce 100 lbs. of twist, and what number of hanks of the compound twist will weigh 1 lb.?

By the application of formula VIII., both the resultant counts and the relative weights of the two materials may be obtained.

NOTE.—The length of 60s is greater by $\frac{2}{3}$ than the unit length of 10s worsted.

Then,

Hanks per lb.	+	Extra length	=	Relative length expressed in hanks	÷	Counts	=	Relative weight.
60	+	($\frac{2}{3}$ of 60)	=	100	÷	60	=	$1\frac{2}{3}$ lbs.
60	+	0	=	60	÷	10	=	6 lbs.

60 hanks of twist thread weigh ... ... $7\frac{2}{3}$ lbs.

$$\therefore \frac{60}{7\frac{2}{3}} = 7\frac{19}{23} \text{ hanks per lb.} = \text{resultant counts.}$$

And by the latter part of formula XI., the respective weight of each thread may easily be obtained thus :—

$$\frac{\text{Required weight of twist} \times \text{relative weight of respective counts}}{\text{Sum of relative weights.}}$$

$$\text{(a)} \frac{100 \times 1\frac{2}{3}}{7\frac{2}{3}} = 21\frac{17}{23} \text{ lbs. of 60s.}$$

$$\text{(b)} \frac{100 \times 6}{7\frac{2}{3}} = 78\frac{6}{23} \text{ lbs. of 10s.}$$

Thus it will be self-evident that the combination of formula VIII. with the second part of formula XI. furnishes a ready means of solving all questions of the foregoing description. The whole is expressed in one formula for future use, thus :—

FORMULA XII.

First part, exactly as formula VIII.

Second part—

$$\frac{\text{Required weight of twist} \times \text{relative weight of respective counts}}{\text{Sum of relative weights}} = \text{weight of respective counts.}$$

The same results might be obtained by adding to each count the extra weight to cover the additional length required, to produce the unit length of twist, thus :—

Hanks per lb.	÷	Counts	=	Rel. weight in lbs. when lengths are equal.	+	Extra weight to cover additional length.	
60	÷	60	=	1	+	$\frac{2}{3}$ of lb.	$= 1\frac{2}{3}$ lbs.
60	÷	10	=	6	+	0	$= 6$

60 hanks of twist weigh ... ... $7\frac{2}{3}$ lbs.

This latter method is slightly shorter and may be used in practice, but the former is more exhaustive and consequently more instructive.

Example 2.—An olive coloured loop yarn is composed of two threads of 8s English (32s quality) and one hard twisted thread of 12s worsted; 21 inches of the former are required to 14 inches of the latter. What weight of each will be required to produce 150 lbs. of twist, and what number of hanks per lb. will the compound thread contain ?

NOTE.—The length of the 8s worsted is greater by $\frac{1}{2}$ than the unit length of the 12s.

Then by formula XII.,

Hanks per lb.	+	Extra length	=	Relative length		÷	Counts	=	Relative weight
12	+	0	=	12	hanks	÷	12	=	1 lb.
12	+	($\frac{1}{2}$ of 12)	=	18	,,	÷	8	=	$2\frac{1}{4}$ lbs.
12	+	($\frac{1}{2}$ of 12)	=	18	,,	÷	8	=	$2\frac{1}{4}$ lbs.

12 hanks of twist thread weigh ... ... $5\frac{1}{2}$ lbs.

$$\therefore \frac{12}{5\frac{1}{2}} = 2\tfrac{2}{11} \text{ hanks per lb.} = \text{resultant counts.}$$

and

$$\text{(a)}\ \frac{150 \times 1}{5\frac{1}{2}} = 27\tfrac{3}{11} \text{ of 12s.}$$

$$\text{(b)}\ \frac{150 \times 2\frac{1}{4}}{5\frac{1}{2}} = 61\tfrac{4}{11} \text{ of 8s, first thread.}$$

(c) $\dfrac{150 \times 2\frac{1}{4}}{5\frac{1}{2}} = 61\frac{4}{11}$ of 8s, second thread.

Total 150 lbs. of twist.

COST OF TWIST YARNS—WHEN LENGTHS ARE EQUAL.

Determining the cost of twist yarns is relatively easy if the previous examples and explanations have been carefully perused.

Example 1.—Find the cost per lb. of a twist, composed of 36s Botany at 2/6 per lb. and 18s worsted at 2/- per lb.

Then by the application of formula XI., 1st part.

				Relative weight in lbs.
36	÷	36	=	1
36	÷	18	=	2
36 hanks weigh				3 lbs.

Observe that the weight of 36s is 1 lb. when the weight of 18s is 2 lbs.

Consequently, 1 lb. of the former costs 2/6,

and 2 lbs. of the latter cost 4/-,

giving a total cost of 6/6 for the 3 lb. weight.

Simplified, the above would read thus :—

36 ÷ 36 = 1 lb. at 2/6 = 2s. 6d. cost of 1 lb.

36 ÷ 18 = 2 lbs. at 2/- = 4s. 0d. cost of 2 lbs.

3 lbs. cost 6s. 6d.

$\therefore \dfrac{6s.\ 6d.}{3} = 2/2$ cost per lb.

which, expressed in a formula would be written thus :

FORMULA XIII.

(a) Select the highest count and divide it by itself and each of the given counts; the quotient in each case will then represent the relative weight of each thread in lbs. Then divide the selected count by the sum of these weights and the answer will equal the resultant counts. (b) Multiply the relative weight of each thread by its cost, then divide the total cost by the sum of the relative weights; the answer equals the cost per lb.

Example 2.—A twist thread is made of 19 Y. S. woollen costing 2/4 per lb. and 32s cotton costing 1/2 per lb. What is the price per lb. of the twist?

First convert cotton into woollen counts, or *vice versa.*

$$32\text{s cotton} = \frac{32 \times 840}{256} = 105 \text{ Y. S. woollen.}$$

Then proceed as explained in formula XIII.:—

$105 \div 105 = 1$ lb. at $1/2 =$ 1s. 2d.
$105 \div 19 = 5\frac{10}{19}$ lbs. at $2/4 =$ 12s. 11d.
$6\frac{10}{19}$ lbs. cost 14s. 1d.

$$\therefore \frac{14\text{s. } 1\text{d.}}{6\frac{10}{19}} = 2/2 \text{ (nearly)} = \text{cost per lb.}$$

COST OF TWIST YARNS—WHEN LENGTHS VARY.

These, like the above, can be very readily obtained when the relative weights of each yarn are found, as explained in connection with the 1st part of formula XII or in formula VIII.

Example 1.—A spiral twist is composed of one thread 12s Botany at 2/1 per lb., and one thread of 72s Botany at 2/4 per lb.; 11 inches of the latter are required to 8 inches of the former. Find the cost per lb.

NOTE.—The length required of 72s is greater by $\frac{3}{8}$ than the unit length of 12s Botany.

Then by formula VIII or 1st part of XII.:—

Hanks per lb.	+	Extra length	=	Relative length	÷	Counts	=	Relative weight
72	+	($\frac{3}{8}$ of 72)	=	99	÷	72	=	$1\frac{3}{8}$
72	+	0	=	72	÷	12	=	6
72 hanks weigh		...				...		$7\frac{3}{8}$ lbs

Here we find that the weight of 72s is $1\frac{3}{8}$ lbs., when the weight of 12s is 6 lbs.

Consequently, $1\frac{3}{8}$ lbs. of 72s cost $(2/4 \times 1\frac{3}{8}) = 3/2\frac{1}{2}$
and 6 lbs. of 12s cost $(2/1 \times 6) = 12/6$

Total cost for $7\frac{3}{8}$ lbs. $= 15/8\frac{1}{2}$

$\therefore$ The cost per lb. $= \dfrac{15/8\frac{1}{2}}{7\frac{3}{8}} =$ 2s. $1\frac{1}{2}$d. per lb.

The same result will be more readily achieved by adding the latter part of formula XIII to the formula used above, and for convenience, these will be combined for a new formula, which will be found applicable for problems of this class.

Formula XIV.

(1) Exactly as first part of formula XII.

(2) Multiply the relative weight of each thread by its cost, then divide the total cost by the sum of the relative weights. The answer equals the cost per lb.

Then by formula XIV.—foregoing example =

Hanks per lb.	+	Extra length	=	Rel. length	÷	Cts.	=	Rel. weight	×	Price per lb.	=	Rel. cost.
72	+	($\frac{3}{8}$ of 72)	=	99	÷	72	=	$1\frac{3}{8}$	at	2/4	=	$3/2\frac{1}{2}$
72	+	0	=	72	÷	12	=	6	at	2/1	=	12/6

72 hanks of twist thread weigh $7\frac{3}{8}$ and cost $15/8\frac{1}{2}$

$\therefore \dfrac{15\text{s. } 8\frac{1}{2}\text{d.}}{7\frac{3}{8}} =$ 2s. $1\frac{1}{2}$d. per lb.

Example 2.—A knop yarn is composed of one thread of 2/12s crimson-coloured mohair at 3/- per lb.; one thread of 2/20s black cotton at 1/1 per lb., and one thread of 1/20s black cotton at 1/- per lb. 39 inches of mohair are required to 13 inches of each black cotton thread. Find the number of hanks and cost per lb. and weight of each thread in 180 lbs. of twist.

Then 2/20s cotton $= \frac{10 \times 840}{560} = 15$s worsted counts,

and 20s cotton $= \frac{20 \times 840}{560} = 30$s worsted counts.

Then by formula XIV. :—

Hanks per lb.	+	Extra length	=	Rel. length	÷	Cts.	=	Rel. weight	×	Price per lb.	=	Rel. cost.
30	+	(2 × 30)	=	90	÷	6	=	15	at	3/-	=	45/-
30	+	0	=	30	÷	30	=	1	at	1/-	=	1/-
30	+	0	=	30	÷	15	=	2	at	1/1	=	2/2

30 hanks of twist threads = 18 lbs. and cost = 48/2

$\therefore \frac{30}{18} = 1\frac{2}{3}$ hanks per lb. = resultant counts,

and $\frac{48s.\ 2d.}{18} = 2s.\ 8d.$ per lb.

Then (1) $\frac{180 \times 15}{18} = 150$ lbs. of mohair.

(2) $\frac{180 \times 1}{18} = 10$ lbs. of 1/20s cotton.

(3) $\frac{180 \times 2}{18} = 20$ lbs. of 2/20s cotton.

Example 3.—A knop twist yarn is made of one thread of 2/20s light green mohair at 3/1 per lb., one thread of 2/24s black cotton at 1/2 per lb., and one thread of 1/24s cotton at 1/1 per lb. If 27 inches of mohair and 12 inches of each cotton thread only produce 9 inches of twist, find the number of hanks and cost per lb., and weight of each kind of thread in a total weight of 160 lbs. of twist.

$$\text{Then } 2/24\text{s cotton} = \frac{12 \times 840}{560} = 18\text{s worsted,}$$

$$\text{and } 1/24\text{s cotton} = \frac{12 \times 840}{560} = 36\text{s worsted.}$$

NOTE.—The length of mohair is twice greater, and that the cotton is $\frac{1}{3}$ greater than the unit length of twist thread.

By formula XIV.:—

Hanks per lb.	+ Extra length	= Rel. length	÷ Cts.	= Rel. weight	× Price per lb.	= Cost.
36	$+(2 \times 36)$	$= 108$	$\div 10$	$= 10\frac{4}{5}$	$\times$ 3/1	$= 33/3\frac{1}{2}$
36	$+(\frac{1}{3} \times 36)$	$= 48$	$\div 36$	$= 1\frac{1}{3}$	$\times$ 1/1	$= 1/5\frac{1}{4}$
36	$+(\frac{1}{3} \times 36)$	$= 48$	$\div 18$	$= 2\frac{2}{3}$	$\times$ 1/2	$= 3/1\frac{1}{4}$
36 hanks of twist weigh				$14\frac{4}{5}$	and cost	$= 37/10$

(a) $\frac{36}{14\frac{4}{5}} = 2\frac{16}{37}$ hanks per lb. = resultant counts

(b) $\frac{37\text{s. } 10\text{d.}}{14\frac{4}{5}} = 2\text{s. } 6\frac{1}{2}\text{d.}$ per lb. cost of twist thread.

(c) $\frac{160 \times 10\frac{4}{5}}{14\frac{4}{5}} = 117$ lbs. weight of 2/20s mohair.

(d) $\frac{160 \times 1\frac{1}{3}}{14\frac{4}{5}} = 14{\cdot}4$ lbs. weight of 1/24s cotton.

(e) $\frac{160 \times 2\frac{2}{3}}{14\frac{4}{5}} = 28{\cdot}8$ lbs. weight of 2/24s cotton.

$160{\cdot}2$ lbs., total.

EXERCISES.

A

1. What will be the resultant counts in worsted of 80s cotton and 36s worsted, and what quantity will be required of each to produce 100 lbs. of twist?

Ans., $27\frac{9}{13}$; $23\frac{1}{13}$; $76\frac{12}{13}$.

2. 50s and 70s cotton yarn are twisted together, what is the resultant twist and how much of each would be required to produce 120 lbs. of folded yarn ?

Ans., $29\frac{1}{6}$; 70; 50.

3. What will be the resultant counts of two threads twisted together as follows, viz :—80s single cotton with 30s single worsted, and what quantity of each will be required to produce 100 lbs. of yarn—answer in cotton.

Ans., 16s; 20; 80.

4. Required the weight of 2/48s and 40s cotton in 100 lbs. of twist.

Ans., $62\frac{1}{2}$; $37\frac{1}{2}$.

5. Required the weight of 24s worsted to twist with 100 lbs. of 40s worsted.

Ans., $166\frac{2}{3}$.

6. 30s and 36s worsted and 40/2s silk are twisted together. Find the relative weights of each in 150 lbs., and the resultant counts.

Ans., $64\frac{2}{7}$; $53\frac{4}{7}$; $32\frac{1}{7}$; $12\frac{6}{7}$.

7. A twist thread is composed of 60s and 40s worsted and 30s cotton of respective values 32, 24 and 16 pence per lb. Find the resultant counts in worsted and cost per lb.

Ans., $15\frac{15}{23}$; $1/11\frac{7}{23}$.

8. If 36s cotton containing 20 turns per inch when two-folded, produces 860, 852 and 830 yards per hank as compared with 840 in the single, the respective turns per inch in the two ply yarn being 15, 21 and 30, find the number of hanks per lb. of the cotton ply.

Ans., $18\frac{3}{7}$; $18\frac{9}{35}$; $17\frac{3}{4}$.

9. Find the cost per lb. of two yarns twisted together composed of 36s at 3/6 and 14s at 2/6.

Ans., 2/9$\frac{9}{25}$.

10. A twist thread is composed of 60/2 spun silk at 12/- and 20s skeins woollen at 2/8 per lb. Find the cost per lb.

Ans., 3/6$\frac{1}{3}$.

11. Find the resultant counts of 40s and 16s cut Hawick, and the proportion of each in 100 lbs.

Ans., 11$\frac{3}{7}$; 28$\frac{4}{7}$; 71$\frac{3}{7}$.

12. A woollen twist yarn is made of 4s run and 12s Yorkshire Skeins, find the resultant counts and proportion of weight of each in 200 lbs. Answer in Y. S.

Ans., 8$\frac{1}{9}$; 64$\frac{32}{37}$; 135$\frac{5}{37}$.

13. An 8-dram yarn (80 yds.) is twisted with 24s cut Gala. Find the relative weight of each sort in 60 lbs of twist.

Ans., 39$\frac{3}{23}$; 20$\frac{20}{23}$.

B

14. A compound twist thread contains one thread of 2/80s worsted at 3/-, one of 60/2 spun silk at 16/-, and one thread of 2/60s worsted at 2/10 per lb. Find the counts, price per lb., and quantities of each in 100 lbs. of twist.

Ans., 14$\frac{2}{5}$; 5/-; 36; 16; 48.

15. 18s and 32s Continental worsted, at 7 and 7·5 francs per kilogramme, are twisted together. Find the resultant counts, Continental, price per kilogramme in francs, also counts in English worsted, and price per lb. of compound thread.

Ans., 11·52; 7·18; 10$\frac{1}{5}$; 2/7 nearly.

16. 16s West of England and 70/2 spun silk are

twisted together. Give size of compound thread and cost per lb. when the former costs 2/6 and the latter 15/- per lb. Answer in West of England.

Ans., $14\frac{7}{10}$; 3/6.

17. What are the counts and price of one thread of 2/84s worsted at 3/6 per lb., one thread 28 skeins woollen costing 2/6 per lb. Allow 5% for take-up in worsted.

Ans., $9\frac{9}{13}$; 2/9.

18. A compound twist thread is made of 60s, 48s, and 40s worsted costing respectively 3/6, 3/4 and 2/8 per lb. Find resultant counts and proportionate weight of each in a total weight of 300 lbs., and price per lb. of compound thread.

Ans., 16s; 80; 100; 120; $3/1\frac{1}{3}$.

29. A compound cotton thread is made of 3/30s, 2/36s and 3/24s. Find resultant counts and proportion of each in 240 lbs.

Ans., $3\frac{1}{2}$; 85·6; 47·5; 106·9.

C

20. A spiral worsted twist is composed of 2/60s at 3/- and 1/8s at 2/8 per lb. 12 inches of the former are required to 8 inches of the latter. What are the number of hanks and price per lb. of the compound thread?

Ans., $5\frac{5}{7}$; $2/9\frac{1}{7}$.

21. A special twist thread is made up of one thread of 18s and one thread of 24s. The former costs 2/4 and the latter 2/5 per lb. 13 inches of the single yarns produce 12 inches of twist. Find the cost and hanks per lb.

Ans., $2/4\frac{1}{2}$, $9\frac{1}{2}$.

22. A fancy loop yarn is composed of 1/60s slate worsted at 2/10; 2/60s slate worsted at 3/-; 2/60s light green cotton at 2/-; 2/60s yellow cotton at 2/- per lb.; 18 inches of 1/60s and 9 inches of each cotton thread are required to every 6 inches of 2/60s worsted and compound twist thread. Find the resultant counts in worsted and pride per lb.

Ans., $6\frac{2}{3}$; $2/4\frac{2}{3}$.

23. A five-grain yarn costs 3/- which is twisted with a four-dram organzine silk at 32/-. 10 inches of the former are required to every 9 inches of the latter. Supply the counts in the Grain system and proportion of each in 60 lbs. of twist and cost per lb.

Ans., $7\frac{3}{4}$; 43; 17; 11/2.

24. If 12 lbs. per spindle Jute twist yarn is composed of 7 lb. per spindle and a second thread, find the size of the latter and the relative proportions of each in 100 lbs. of twist.

Ans., 5; $58\frac{1}{3}$; $41\frac{2}{3}$.

25. A twist yarn is composed of dry spun flax 2 lbs. per spindle at 1/6 per spindle, 50s lea or line yarn at 5/- per bundle and 18s cotton at 10d. per lb. Find (1) resultant counts in lbs. per spindle and (2) cost per spindle; (3) resultant counts in Linen system; (4) cost per lb. and (5) per bundle.

Ans., 3·912; 3s. $6\frac{3}{4}$d.; 12·26s lea; 10·95d.; 14s. 11d.

26. What is the cost per lb. of a spiral twist yarn composed of 20s linen at 10/- per bundle and 12s cotton at 9d. per lb.; 9 inchs of linen are required to 10 inches of cotton.

Ans., 10·8d.

CHAPTER IV.

Weight and Cost of Producing Yarns and Blending of Textile Fibres.

I. Respective Weights and Cost of Mixed Yarns.

Yarns used in the manufacture of woven fabrics are frequently made up from wools of different qualities, values, and proportions. There are also many produced by the mixture of wool and silk, cotton and wool, etc., including Angolas and other semi-woollen yarns.

In the production of flax yarns it is occasionally found necessary to blend the different flax fibres as in wool and cotton. This process affords the opportunity of producing a yarn of uniform quality and to meet a given price. The poor and indifferent fibres blended with the strong and more uniform are thereby capable of being spun into suitable yarn, which might otherwise only be accomplished with great difficulty.

Blends are more frequently made in tows than for line yarns.

The object here is to show how to determine the values of given mixtures and also how to produce a mixture of various materials at a fixed value.

Average Price per lb. of Mixtures of Given Quantities and Value.

The method employed in solving problems of this kind is governed by the law of averages, which is so simple that no explanation of the formula is necessary.

Formula XV.

Multiply the given quantities of each sort by its price per lb., and divide the sum of the quantities by the total cost. The result equals the price per lb. of the mixture.

Example 1.—A mixture of wool is made of 75 lbs. of black at 2/- per lb.; 15 lbs. of yellow at 2/2 per lb., and 10 lbs. of lavender at 2/3 per lb. Find the average cost per lb.

By formula XV.:—

75 lbs.	×	2/-	=	150s. 0d.
15 lbs.	×	2/2	=	32s. 6d.
10 lbs.	×	2/3	=	22s. 6d.
100 lbs. cost			...	205s. 0d.

$$\therefore \frac{205}{100} = 2s.\ 0\tfrac{3}{5}d. \text{ per lb.}$$

Example 2.—A mixture yarn is composed of 30 lbs. of wool at 1/6 per lb.; 20 lbs. of cotton at 6d. per lb.; 30 lbs. of shoddy at 2d. per lb.; and 20 lbs. of waste at $1\frac{1}{2}$d. per lb. Find the cost per lb. of the mixture.

Then by formula XV.:—

30 lbs. of wool	at	1/6	=	45s. 0d.
20 lbs. of cotton	at	6	=	10s. 0d.
30 lbs. of shoddy	at	2	=	5s. 0d.
20 lbs. of waste	at	$1\frac{1}{2}$	=	2s. 6d.
100 lbs. of mixture cost				62s. 6d.

$$\therefore \frac{62s.\ 6d.}{100} = 7\tfrac{1}{2}d. \text{ per lb. of mixture.}$$

Example 3.—Assume a mixture of dressed line is made up as follows: 500 lbs. of Irish flax at $9\frac{1}{2}$d. per lb.; 250 lbs. of Dutch at 9d. per lb.; and 250 lbs. of Riga at 6d. per lb. Find the average cost per lb.

Then 500 lbs. at	10d.	=	5000 pence.
250 lbs. at	9d.	=	2250 ,,
250 lbs. at	6d.	=	1500 ,,
1000 lbs. cost			8750 pence.

$\therefore$ Mixture costs $\frac{8750}{1000} = 8{\cdot}75$d. per lb.

Any mixes for line yarn are usually made on the Spreader Machine and the proportion of each sort is largely governed by the number of divisions in the Spread board, *e.g.* If there are eight divisions the proportions might be in eighths thus:—$\frac{1}{8}$, $\frac{2}{8}$, $\frac{3}{8}$, and $\frac{2}{8}$ or $\frac{1}{8}$, $\frac{3}{8}$ and $\frac{4}{8}$, etc.

Some spinners introduce a doubling or mixing gill box between the spreader and the first drawing frame, which affords a greater field for blending purposes, as the finishing gill boxes do for worsted.

Tow mixes, like blends for woollen yarn, are made by arranging the respective sorts in layers upon the store room floor in proportions which circumstances may require, until the whole of the blend has been formed into a large square or rectangular pile, *e.g.*, If $\frac{1}{3}$ of Irish (Brown), $\frac{1}{3}$ of Flemish (Blue), and $\frac{1}{3}$ of Courtrai (Light Brown), are required to form a blend, a pile of these different flaxes of equal layers would be formed. When required for use the material would be taken off the sides from top to bottom so as to assist in mixing the different fibres, which process is principally and more thoroughly performed on the carding machine preparatory to the drawing and spinning of tow yarns, and the condensing and spinning of woollen yarns.

NOTE.—The additional cost per lb. of manipulating the above materials into yarn would, of course, have to be added to the average cost.

PROPORTION OF MIXTURE YARNS TO COST A GIVEN PRICE, AND PROPORTIONS OF EACH SORT IN A REQUIRED WEIGHT OF MIXTURE.

When two sorts of given value are mixed together to yield a fixed price the relative proportion of each material is always the same, but if three, four, or more sorts are required, the proportions may vary and still the cost of the mixture remain the same.

The solution of problems of this class will be best understood by working out the following examples upon the system most generally adopted for all mixtures, irrespective of kind.

Example 4.—A mixture is required to be made of wool which costs 1/4 per lb., and of cotton at 6d. per lb. The mixture is to cost 1/- per lb., what is the relative proportion of each sort, and what quantity of each will be wanted to produce a mixture of 100 lbs. ?

Let x = number of lbs. at 16d.

Let y = number of lbs. at 6d.

Then $16x + 6y$ = total cost of mixture in pence.

Also $12(x + y)$ = ,, ,, ,, ,, ,,

$\therefore 16x + 6y = 12(x + y) = 12x + 12y$,

and $16x - 12x = 12y - 6y$.

$\therefore 4x = 6y$.

Consequently if $4x$ weights are equal to $6y$ weights, the x weight is heavier than the y weight in the proportion of 6 to 4.

These weight ratios are always found to be in inverse proportion to the difference in the price of each sort, with the average cost of the mixture, thus :—

$$12\text{d.}\ \left[\begin{matrix}16\text{d. difference } 4\\ 6\text{d.}\quad\ \ ,,\qquad\ \ 6\end{matrix}\right.\ \therefore\ \begin{matrix}\text{Relative}\\ \text{Weights}\end{matrix}\ \text{are}\ \begin{matrix}6\\ 4\end{matrix}$$

The foregoing may be expressed in formula as used in practice, to save time.

FORMULA XVI.

Arrange the values of the different sorts so that one value shall be over the other, then place the average cost to the left of these values and connect a greater and a lesser value than the required average cost together with a bracket. Place the difference in price between the greater value and the average price opposite the lesser, and the difference in price between the lesser value and the average price opposite the greater. The results thus obtained represent the relative weight of each sort. Then the proportions of each in a required weight may be found by simple proportion, or thus :—

$$\frac{\text{Total weight} \times \text{relative weight}}{\text{Sum of relative weights}} = \text{weight of respective sorts.}$$

The above example worked out by formula XVI. would appear thus ;—

$$12 \left| \begin{matrix}16\\ 6\end{matrix}\right] = \begin{matrix}6 \text{ units of weight at } 1/4\\ 4 \text{ units of weight at 6d.}\end{matrix}$$

and respective weight of each =

$$\frac{100 \times 6}{(6 + 4)} = 60 \text{ lbs. at } 1/4$$

$$\frac{100 \times 4}{(6 + 4)} = 40 \text{ lbs. at 6d.}$$

PROOF.—6 lbs. at 1/4 = 96
4 lbs. at 6d. = 24
10 lbs. cost 120

$\therefore \quad \frac{120}{10} = 1/-$ per lb., as required.

All examples of more than two sorts are simply an extension of this elementary principle of mixing materials of any kind to produce a given price.

Example 5.—A mixture contains wool at 1/8 per lb., waste at 2d., and cotton at 5d. per lb. What are the relative weights and proportions of each required to produce 120 lbs. of mixture at 8d. per lb.?

First, consider the question as a compound of two questions similar to the previously worked-out example.

A As a mixture to cost 8d., materials costing 1/8 and 2d.
B As a mixture to cost 8d., materials costing 1/8 and 5d.

A 8	20	6 units of weight (lbs.) at 1/8 =	10/-
	2	12 units of weight (lbs.) at 2d. =	2/-
		18 units of weight	cost 12/- at 8d. pr. lb.

B 20	20	3 units of weight (lbs.) at 1/8 =	5/-
	5	12 units of weight (lbs.) at 5d. =	5/-
		15 units of weight	cost 10/- at 8d. pr. lb.

Consequently, it is evident that if A and B be mixed in equal proportions, or in any multiple of A or B, the resultant mixture will still cost 8d. per lb. The proportion of weight of each sort may then be found by simple rule-of-three as above. There is scarcely any limit to the variety of mixtures obtainable even at a fixed price and with the same elements of cost.

Example 5 (above) worked out by formula XVI.:—

= 8	20	6 + 3 =	9 units of weight of wool	Relative Weights.
	2	12	= 12 units of weight of waste	
	5	12	= 12 units of weight of cotton	

and $\frac{120 \times 9}{33} = 32\frac{8}{11}$ lbs. of wool.

$$\frac{120 \times 12}{33} = 43\tfrac{7}{11} \text{ lbs. of waste.}$$

$$\text{Ditto} \qquad = 43\tfrac{7}{11} \text{ lbs. of cotton.}$$

$$\overline{120} \text{ lbs., total weight.}$$

Example 6.—It is required to mix four materials together so as to produce 160 lbs. of mixture at 7d. per lb., viz. :—Wool at 1/6; cotton at 9d.; mungo at 2d., and waste at $1\frac{1}{2}$d. Find the relative weights of each so as to produce the mixture at the required price, together with the proportion of each in the total weight.

$$7 \left| \begin{array}{l} 18 \\ 9 \\ 2 \\ 1\frac{1}{2} \end{array} \right. \quad \begin{array}{rl} 5 & \text{units of weight of wool} \\ 5\frac{1}{2} & \text{units of weight of cotton} \\ 11 & \text{units of weight of mungo} \\ 2 & \text{units of weight of waste} \\ \hline 23\frac{1}{2} & \text{sum of relative weights.} \end{array}$$

$$\text{Wool } \frac{160 \times 5}{23\frac{1}{2}} = 34\tfrac{2}{47} \text{ lbs.}$$

$$\text{Cotton } \frac{160 \times 5\frac{1}{2}}{23\frac{1}{2}} = 37\tfrac{21}{47} \text{ lbs.}$$

$$\text{Mungo } \frac{160 \times 11}{23\frac{1}{2}} = 74\tfrac{42}{47} \text{ lbs.}$$

$$\text{Waste } \frac{160 \times 2}{23\frac{1}{2}} = 13\tfrac{29}{47} \text{ lbs.}$$

$$\overline{160} \text{ lbs., total weight.}$$

The foregoing mixture may be produced at the same cost and in different proportions as follows :—

$$7 \left| \begin{array}{l} 18 \\ 9 \\ 2 \\ 1\frac{1}{2} \end{array} \right. \quad \begin{array}{rl} 5\frac{1}{2} & \text{units of weight of wool} \\ 5 & \text{units of weight of cotton} \\ 2 & \text{units of weight of mungo} \\ 11 & \text{units of weight of waste} \\ \hline 23\frac{1}{2} & \end{array}$$

and $\dfrac{160 \times 5\frac{1}{2}}{23\frac{1}{2}} = 37\frac{21}{47}$ lbs. of wool.

$\dfrac{160 \times 5}{23\frac{1}{2}} = 34\frac{2}{47}$ lbs. of cotton.

$\dfrac{160 \times 2}{23\frac{1}{2}} = 13\frac{29}{47}$ lbs. of mungo.

$\dfrac{160 \times 11}{23\frac{1}{2}} = 74\frac{42}{47}$ lbs. of waste.

160 lbs., total weight.

A further illustration of the varieties of mixture producible at the same price and cost of elements is indicated below, the details of which may be worked out by the spinner or manufacturer.

$$7 \left| \begin{array}{l} 18 \\ 9 \\ 2 \\ 1\frac{1}{2} \end{array} \right. \quad \text{or} \quad 7 \left| \begin{array}{l} 18 \\ 9 \\ 2 \\ 1\frac{1}{2} \end{array} \right.$$

Conversion of Price in Francs per Kilogramme into Pence per lb.

Continental manufacturers largely purchase British spun yarns, and frequently Continental yarns of certain types are bought by the English manufacturer, so that the price per lb. in pence has often to be converted into cost per kilogramme in francs and *vice versa*.. In consideration of these facts the following short method of converting price in francs per kilogramme into pence per lb. will be found useful.

Factors—

1 kilogramme = 15432 grains or 2·205 lbs.

25·2 francs = 1 sovereign.

$\therefore$ 1 franc $\dfrac{240}{25{\cdot}2} = 9{\cdot}502$ pence.

∴ The cost in price per lb. when 1 kilogramme costs 1 franc equals $\frac{9 \cdot 502}{2 \cdot 205} = 4 \cdot 31$d. or $4\frac{1}{3}$d.

Then it is evident that if the price per kilogramme be 2 francs, the price per lb. will be $2 \times 4 \cdot 31 = 8 \cdot 62$ pence, from which reasoning the following formula is deduced.

FORMULA C.

Multiply the price per kilogramme in francs by 4·31 or $4\frac{1}{3}$, *e.g.*, The price per kilogramme of a twist yarn is 8·5 francs. Find the price per lb.

$8 \cdot 5 \times 4 \cdot 31 = 36 \cdot 635$ pence, or

$8 \cdot 5 \times 4\frac{1}{3} = 3/0\frac{3}{4}$.

II. COST OF YARN PRODUCTION.

The correct or even approximate cost of producing any kind of yarn can only be determined by carefully noting and recording all the data associated with the manipulation of the raw material into yarn as set forth in the following pages under their respective heads and divisions.

It should however be noted that no two firms would arrive at exactly the same result for the same quality and count of yarn, the difference being chiefly due to local conditions and type and value of machinery which may materially affect the turn off.

Consequently the following, though based on actual facts and practice can only be taken as suggestive and representative.

A. COST OF PRODUCING WORSTED YARNS.

The cost of producing Worsted Yarns depends upon the cost of the raw materials, the yield of clean wool, the amount paid for carriage, sorting (if any), scouring and drying, preparing or burring when necessary, carding, combing, drawing, spinning and twisting, and wages paid to miscellaneous workpeople whose labour cannot be located to any particular process. Allowance must also be made for the amount of waste, including shrinkage, the cost of plant and depreciation, power consumed, engineers' and firemen's wages compared with the actual turn off for any given period—say one week—and for some specific quality and number of yarn. While there is not available space here to deal with every phase and detail, I have no doubt but the following particulars, problems and solutions will be found useful to many.

The yield of clean wool from the natural or greasy state varies from 33 to 70%, the yield being usually less in the fine sorts such as merinoes or botanys. Scoured or half washed wool will yield from 70 to 80%.

The average cost of sorting English and domestic wools is about $\frac{1}{4}$d., while merinoes vary from $\frac{1}{16}$ to $\frac{1}{8}$ of a penny.

The cost of washing greasy wool generally adds about $\frac{1}{2}$d. to the cost of the clean wool, and $\frac{1}{4}$d. per lb. if the wool has been previously scoured.

Example 1.—If 1920 lbs. of Sydney greasy wool cost 9d. per lb. in the grease, and if the loss in scouring be 40% on the greasy weight, and the cost of carriage be $\frac{1}{6}$d. per lb. on the greasy weight, and $\frac{1}{2}$d. per lb. be added to the cost of the clean wool for wages, machinery and materials used, find the average cost per lb. of the clean wool,

Then 1920 lbs. of greasy less 40% loss in washing, etc. :—

$$= \frac{1920}{1} \times \frac{60}{100} = 1152 \text{ lbs. of clean wool.}$$

		s.	d.
Then 1920 lbs. greasy wool @ 9d. per lb.	=	1440	0
1920 ,, carriage @ $\frac{1}{6}$d. ,,	=	26	8
Total Cost	=	1466	8

And $\dfrac{\overset{\text{s.}}{1466}\ \overset{\text{d.}}{8}}{1152}$ lbs. of clean wool $= 1/3\frac{1}{4}$ per lb.

$1/3\frac{1}{4} + \frac{1}{2}$d. for cost of washing, etc. $= 1/3\frac{3}{4}$ per lb.

Example 2.—A "lot" of wool costs 10d. per lb. If the lot is classed into two sorts, and yields 65% of the lower quality, leaving 35% of the higher quality, which latter is estimated to be worth 2d. more per lb. than the former. What is the value of each sort?

Let. $x =$ the price per lb. of the lower quality.
Then $x + 2 =$,, ,, better ,,

$\therefore 65\,x + 35\,(x + 2) = 10 \times 100$ pence.
$= 65\,x + 35\,x + 70 = 10 \times 100$d.
$= 100\,x = 1000 - 70 = 930.$

$\therefore x = \frac{930}{100} = 9{\cdot}3$ pence, the price per lb. of the lower.

And $(9{\cdot}3 + 2) = 11{\cdot}3$,, ,, ,, better.

Proof 65 lbs. at	$9{\cdot}3 =$	$604{\cdot}5$ pence
35 lbs. at	$11{\cdot}3 =$	$395{\cdot}5$,,
100 lbs. cost		1000 pence

$\therefore$ Price per lb. $= \frac{1000}{100} = 10$ pence.

NOTE.—If it should be required to make two, three, or more sorts, which are necessarily of different values, but when the average cost price is known, a moment's reflection will demonstrate that the product of the average cost price and the total weight is equal to the sum of the products of the respective proportionate weights and prices.

Example 3.—What would be the price of each sort if the average cost price of a 'lot' of clean wool be 1/- per lb., and respective weights are 30, 24, 20, 16 and 10 lbs. per cent., and if their values are respectively estimated at 1, 2, 2 and 3 pence per lb. above the lowest price?

Let x = the price of the lowest grade in pence.
Then $x + 1$ = " " second " "
also $(x + 2)$; $(x + 2)$ and $x + 3$ = the price of the third, fourth and fifth grades respectively.

$$\therefore\ 30x + 24(x + 1) + 20(x + 2) + 16(x + 2) + 10(x + 3) = 12 \times 100.$$

$$= 30x + (24x + 24) + (20x + 40) + (16x + 32) + (10x + 30) = 1200.$$

$$= 30x + 24x + 20x + 16x + 10x + 126 = 1200.$$

$$= 100x = (1200 - 126) = 1074.$$

$$\therefore\ x = \frac{1074}{100} = 10{\cdot}74\text{d. per lb.}$$

the price of the lowest.

Consequently the respective prices are:—10·74; 11·74; 12·74; 12·74 and 13·74 pence per lb.

Cost of Preparing or Carding.

When the wool has been thoroughly dried it is then usually prepared for the combing by passing the material through a series of about six gill boxes called 'preparers'; the turn off per week of 50 hours is about 3000 to 4000 lbs. or 60 to 80 lbs. per hour, for each set of machines. The amount of waste during this process is small; the operation adds from $\frac{1}{4}$d. to $\frac{3}{8}$d. per lb. to the cost. If the fibre is too short for the gilling process it is prepared for the combing by a process of carding which usually adds from $\frac{1}{2}$d. to 1d.

per lb. Consequently it is generally better to prepare the wool, if the length of fibre will permit, on the gill boxes in preference to the carding, since it is more economical both as regards cost of production and subsequent taring in combing.

Cost of Combed Top.

The greasy or scoured wool is frequently bought by a topmaker or spinner and after being sorted it is sent to a commission wool comber, who washes, dries, prepares, combs the fibres and forms the wool into tops in which form, together with the noil and waste it is returned to the top maker or spinner.

In some cases the spinner puts the material through these respective processes on his own machinery, but whatever may be the merits or demerits of either system it is necessary to determine the cost of the combed top. This involves adding to the raw material, the cost of washing, drying and preparing or carding, and also the amount paid for combing which is always reckoned on the combed top and which amount varies from $1\frac{1}{4}$d. to 2d. for long wools; $1\frac{3}{4}$d. to $2\frac{1}{4}$d. cross breds, and from about $2\frac{1}{4}$d. to $3\frac{1}{4}$d. per lb. for merinoes from the greasy wool to the finished top according to how it tares. From the sum total deduct the amount received for the noil and waste and divide the total cost by the net weight or yield per cent. of the combed top, *e.g.*,

Example 4.—Calculate the cost of combed top when the yield per cent. is 44 of top and 11 of noil. Charge $\frac{3}{4}$d. per lb. for sorting, washing, etc., 1d. for carding, and $1\frac{1}{2}$d. for combing; estimate the value of the noil at 1/3 per lb. Raw wool costing 11d. per lb.

			s.	d.
Answer.—100 lbs.	@ 11d.... ...	=	91	8
55 ,,	washing @ $\frac{3}{4}$d. ...	=	3	$5\frac{1}{4}$
55 ,,	carding @ 1d. ...	=	4	7
44 ,,	combed top @ $1\frac{1}{2}$d.	=	5	6
			105	$2\frac{1}{4}$
Less 11 ,,	of noil @ 1/3 ...		13	9
			91	$5\frac{1}{4}$

$\therefore$ Cost per lb. of combed top $= \dfrac{91 \cdot\cdot 5\frac{1}{4}}{44} = 2/1$ nearly.

Example 5.—10,000 lbs. of greasy merino wool is delivered by the spinner to wool comber. Calculate the cost per lb. of the combed top if the yield is 56% and tares 6 to 1. If the raw wool costs 8d., the value of the noils is 13d., and 3d. per lb. is charged by the commission comber on the finished top to cover all his expenses for washing, preparing and combing.

Alternative method:—

Then combed top $= \frac{6}{7}$ of 56% yield of clean wool $= \dfrac{56 \times 6}{7} = 48\%$

And noil $= \frac{1}{7}$,, ,, ,, $= \dfrac{56 \times 1}{7} = 8\%$

Also (Price per lb. of raw wool) + (Yield % of top × cost per lb.) − (Yield % of noil × cost per lb.) ÷ Yield % of combed top.

$$= (8) + \left(\frac{48 \times 3}{100}\right) - \left(\frac{8 \times 13}{100}\right) \div \frac{48}{100} = \text{Cost per lb. of combed top.}$$

$$= \left(\frac{800 + 144 - 104}{100} \div \frac{48}{100}\right) = \frac{840 \times 100}{100 \times 48} = 17\tfrac{1}{2}\text{d.}$$

Cost of Drawing, Spinning and Twisting.

The costs at this stage like every other depend upon the turn off in lbs. divided into the total cost of wages and expenses, etc., incurred during the same period of time.

The following data which has been taken from actual practice, but which in many cases can only be approximate, owing to constantly changing factors, will nevertheless serve as a guide to demonstrate some of the methods and principles adopted for determining costs and on the same basis students may make observations and keep records,

(1.) 1 set of botany drawing 10 operations, producing 5 dram roving turned off 460 to 470 lbs. per day and subsequently spun to 24's worsted counts.

(2.) 1 set of drawing, 7 operations, producing 7 dram roving turned off 500 lbs. per day.

(3.) 1 set of drawing, 9 operations, producing 10 dram roving from Cashmere top weighing 386 drams per 40 yards turned off about 510 lbs. per day.

(4.) 1 set of botany drawing, 9 operations, produced 400 lbs. per pay of 2 dram roving and kept 10 frames with 180 spindles each spinning 60s botany with 14 to 15 turns per inch.

(5.) 1 set of long wool drawing, 7 operations, producing 5·8 dram roving from top weighing 450 drams per 40 yds. produced about 430 lbs. per day.

NOTE.—The actual waste made in drawing is from 2 to 3%.

, (6.) 14 spinning frames each containing 144 spindles and spinning 60's botany from 2 dram roving, required 1 set of drawing with 9 to 10 operations. Every two spindles in the spinning frame required 1 spindle in the twisting which is a safe rule to follow.

NOTE.—The weight of worsted roving is always given for 40 yds. length and since the weight of this length for 1s counts worsted is equal to 18·3 drams (obtained thus $\frac{40}{560} \times \frac{256}{1} = 18{\cdot}3$ drams), this number is invariably used as a 'gauge point' for determining the counts, attenuation or 'draft' and weight of roving required when any two of these factors are known.

The amount of draft is always determined by the length of staple, consequently the weight to which the roving must be made will depend upon the length of fibre and counts of yarn required. It is usual to draft under the length of staple.

Example 6.—The gauge point for 40 yds. of roving is 18·3 drams. Find the amount of draft if 40 yds. of roving weigh 10 drams, when it is required to spin to 10s.

Then $\frac{18 \cdot 3}{\text{10s counts}} = 1 \cdot 83$ drs, = the weight of 40 yds. of 10s,

and $\frac{10}{1 \cdot 83} = 5 \cdot 4$ amount of draft required to draw the 10 drs. to 1 83,

or weight of roving × counts ÷ gauge point = draft

$$\frac{10 \times 10}{18 \cdot 3 \text{ (gauge point)}} = 5 \cdot 4 \text{ draft.}$$

Example 7.—If 40 yds. of roving weigh 7·3 drs., find the counts when a draft of 8 is given,

Then $\frac{7 \cdot 3}{8}$ drs. = The weight of 40 yds. when a draft of 8 has been given

and $\frac{18 \cdot 3}{\frac{7 \cdot 3}{8}}$ = 20s counts, or the number of times lighter than the gauge point for 1s counts when a draft of 8 has been given,

or $\frac{\text{Gauge point} \times \text{draft}}{\text{weight of roving}} = \text{counts} = \frac{18 \cdot 3 \times 8}{7 \cdot 3} = 20\text{s}.$

Example 8.—Find the weight of 40 yds. of roving when a frame is spinning 40s worsted with a draft of 4.

Then $\frac{40}{4}$ = 10s counts of the roving before being drawn out,

and $\frac{18 \cdot 3}{10} = 1 \cdot 83$ drs. The weight of 40 yds. of 10s worsteds,

or $\frac{\text{Gauge point} \times \text{draft}}{\text{counts}} = \text{weight of roving} = \frac{4 \times 18 \cdot 3}{40} = 1 \cdot 83$ drams

When the turn off per day for any given number and speed of spindles and turns per inch is known, this length for the specified number of turns can be and frequently is used as a 'gauge point' for determining *pro rata* the product of any other yarn where the turns are specified and the speed and number of spindles are known.

Example 9.—A spinning frame having 144 spindles which revolve at an average of 1983 per minute, produced 5·1 gross of hanks per day of 24s mohair or alpaca containing 10 turns per inch. Find (a) the weight in lbs. per day; (b) the gross of hanks and weight if the yarn receives 12 turns per inch of 32s mohair counts.

(a) $\frac{5{\cdot}1 \text{ gross of hanks} \times 144 \text{ hanks per gross}}{24 \text{ hanks per lb. of mohair.}} = 30{\cdot}6$ lbs. per day.

(b) NOTE.—Since the length of the yarn delivered by the front spinning rollers varies in the inverse proportion to the number of turns per inch, other factors remaining constant.

$\therefore$ As 12 turns : 10 turns : : 5·1 gross : 4·25 gross of hanks,

and $\frac{4{\cdot}25 \times 144}{32} = 18\frac{1}{8}$ lbs. per day.

Example 10.—Find the cost per lb. in producing 2/48s worsted yarn when one set of botany drawing produces $2\frac{1}{2}$ dram roving (40 yds.) and supplies 10 frames of 200 spindles each and producing 2,500 lbs. nett per week, when the following wages and costs are known :—

		£	s.	d.
8 Drawing hands, average each 14/- ...	=	5	12	0
1 Overlooker, spinning and twisting ...	=	1	10	0
1 ,, drawing	=	1	10	0
10 Hands for spinning, average cost 8/-	=	4	0	0
8 ,, twisting ,, 14/-	=	5	12	0
5 ,, winding ,, 14/-	=	3	10	0
3 ,, warping ,, 14/-	=	2	2	0
6 ,, doffing, jobbing, etc. ,, 8/6	=	2	10	0

	£	s.	d.
Rent and taxes ... ... =	6	0	0
Depreciation on machinery and bobbins =	2	14	0
Cost for oil, bobbins, tapes, laces, belting, etc. ... ... =	2	0	0
Engines or motors, power consumed, wages for firemen, engineers or electricians, etc., light and heat, interest on capital, expenditure and bank charges =	10	0	0
	£47	0	0
Plus 18% for waste and sinkage from combed top to folded yarn = 47 × 18% =	8·46		
	£55·46		

$$\therefore \text{ Cost per lb.} = \frac{55 \cdot 46}{2500} \times 20 \times 12 = 5 \cdot 32 \text{ pence.}$$

The following tabulated results of costs of production from combed top to spun yarn will also be found useful for comparison with any costs subsequently worked out by the students and for purposes of calculations. 60/1 Botany, 6d. per lb.; 48/1, 4¾d.; 40/1, 4d.; 36/1, 3½d. to 3¾d.; 24/1, 2½d.; and 18/1, 2d. per lb.

For twisting two-fold yarns add ½d. to 1d. per lb.

B. Cost of Flax Yarns.

Line Yarn.—*First*, find the average cost involved in producing dressed line from the scutched bale of flax. The flax spinner usually receives his supply in this form at the mill; *second*, determine the cost of production from the *dressed* line to the *spun* and reeled yarn.

The solution of the foregoing for any average lea involves a knowledge of the yield per cwt. of sorted or unsorted flax, the proportions and present value of each sort of tow made, the amount of waste, and subsequently of the relative number of machines required to precede or succeed each other, such as spreader, preparing, roving, spinning and reeling frames and their productive capacity, together with expenses incurred at every operation including the wages paid and cost of plant, power, light, heat, and miscellaneous operatives' wages whose work cannot be located to the cost of any specific process of production.

Several processes may be grouped into lots and prices determined which may be used for purposes of calculation in estimating subsequent total costs.

General Particulars.—The average yield per cwt. of sorted Courtrai flax is about 60/65 lbs. for fine counts, 65/80 for medium counts and 80/90 for low counts. The remainder being tow and waste the latter of which only totals $\frac{3}{4}$ to 1 lb. per cwt.

1 Rougher can hackle on an average about 2 cwt. per day; 1 Hackling Machine with 24 tools turns off about 50 cwt. per week and 1 Sorter dresses an average of 75 lbs. per day of machine hackled flax.

The following are the average prices paid for Roughing:—Irish 1/8 and foreign flax 1/10 per cwt.; 4 machine boys 7/- to 9/- average 8/- per week each, sorting 4/4 for an average of 75 lbs. per day.

The approximate cost of dressed line for spinning to an average of 60s lea is as follows:—

Roughing 1/10 per cwt.—scutched weight; Machinery 2/2, sorting 4/6 and general expenses of datal employers including office staff and management is about 1/6; total 10/- per cwt.

NOTE.—The average cost of dressed line is usually expressed at so much per bundle. The method of determining the cost per bundle of any given sort of dressed or undressed line will be best understood by considering the following problems.

Example 1.—Assume that the current market value of tows is as follows :—Roughers 30/-, machine 1 and 2, 35/-, machine 3 and 4, 40/- and sorters' tow 45/- per cwt. respectively. Find the average price per lb. if the following proportions are made per cwt. Roughing 3 lbs., machines 1 and 2, 12 lbs., machines 3 and 4, 24 lbs. and sorting 3 lbs. Find the average price per lb.

Then 3	units of	weight	at 30/-	per cwt.	= 90	0
And 12	,,	,,	at 35/-	,,	= 420	0
,, 24	,,	,,	at 40/-	,,	= 960	0
,, 3	,,	,,	at 45/-	,,	= 135	0
42	,,	,,	Cost		1605	0

$$\therefore \text{ Price per lb.} = \frac{1605 \times 12}{42 \times 112} = 4{\cdot}09 \text{ pence.}$$

It will be readily perceived that out of each and every bale of flax several sorts and spinning properties may be and in fact usually are made.

For purposes of subsequent costing it is usual to reduce these to one common count or lea.

Example 2.—Find the average sort when the following weights and sorts of dressed line are made—8 lbs. of 40s ; 10 lbs. of 49s ; 26 lbs. of 62s and 30 lbs. of 68s lea.

The solution of this and similar problems is made on the basis of the law of averages, viz. :—Divide the sum of the products of each lea and sort by the total weight of the sorts, *e.g.*

8 lbs. of 40s	...	=	320 leas.
12 ,, 49s	...	=	588 ,,
26 ,, 62s	...	=	1612 ,,
30 ,, 68s	...	=	2040 ,,
76 lbs.			4560 leas.

$\therefore \frac{4560}{76}$ = Average of 60s lea per lb.

NOTE.—The lea numbers usually ascend in fives, the above sorts are made for demonstration purposes only.

The tow results are determined in the same way as for average line, careful observations must however be made so as to certify that the sum of the respective weights of line, tow and waste are always equal to the original cwt. of scutched flax.

Example 3.—Find the cost per lb. of dressed line when the following particulars are known:—1 cwt. of scutched flax costing 78/9 per cwt., yield of dressed line 76 lbs., tow 34 lbs. the average value of which is $4\frac{1}{2}$d. per lb.; allow 1/10 per cwt. for roughing, 2/2 per cwt. for machine hackling, 4/6 per cwt. for sorting and 1/6 per cwt. general expenses. Amount of waste 2 lbs.

The solution of this and similar problems is as follows:—

		s.	d.
Cost of 1 cwt. of scutched flax	...	78	9
,, ,, roughing ...	...	1	10
,, ,, machine hackling	...	2	2
,, ,, sorting or dressing	...	4	6
Miscellaneous expenses per cwt.	...	1	6
Total cost of production...	=	88	9
Less value of 34 lbs. of tow at $4\frac{1}{2}$d.	...	12	9
Nett total cost of 76 lbs. of dressed line	=	76	0

$\therefore$ Cost per lb. $= \dfrac{76/-}{76 \text{ lbs.}} = 1/-$ for the average lea of 60.

This or any other similarly obtained result may be used as a standard for purposes of comparison, thus, *e.g.*, if it be required to know the average cost for any other lea count, the approximate result may be obtained *pro rata* or by making careful observations in practice the average cost per lea may be approximately determined, which for purposes of illustration may be $\frac{1}{8}$d. per lb. per lea; then by adding or deducting this amount for each lea number above or below the standard of 60s the average cost may be obtained for any other count or lea.

Example 4.—Assume that the cost per lb. of 60s average lea dressed line is 1/- and that the average cost per lea is approximately $\frac{1}{8}$d. per lb., find the price of 44s average lea dressed line.

Then difference between 60s and 44s = 16s lea, and 12d. − (16 × $\frac{1}{8}$d.) = 10d. cost of 44s lea.

Example 5.—Assume 1 bale (2 cwts.) of scutched Courtrai flax costs £80 per ton and yields 480, 660 and 60 lbs. of 100s, 110s and 120s dressed line and produces 55 lbs, of roughers' tow, 260 lbs. of machine 1 and 2, 515 lbs. of machine 3 and 4 and 120 lbs. of sorters' tow; "ends" 60 lbs. and waste 30 lbs. If total dressing costs 8/6 per cwt. and general expenses are 1/6 per lb., the average value of the tows is 5½d. per lb. and of the ends 7½d. per lb.; find (1) the yield per cwt. of dressed line, (2) tow; (3) ends; (4) waste; (5) the average sort of line; (6) the cost per lb. and (7) per bundle.

	lbs.
Tow Roughing ..	55
,, Machine 1 and 2	260
,, ,, 3 and 4	515
,, Sorting ..	120
	950 lbs. of Tow
Ends	60 ,,
Waste	30 ,,

	£	s.	d.
Cost of scutched flax =	80	0	0
Dressing per cwt. 8/6 =	8	10	0
General Expenses per cwt. 1/6 =	1	10	0
Total Cost..	90	0	0
950 lbs. of Tow at 5½d. =	21	15	5
Ends at 7½d. =	1	17	6
Less	23	12	11
Nett cost of line =	66	7	1

Line — 100s ..	480
,, 110s ..	660
,, 120s ..	60
	1200

(1) Yield per cwt. of line

$$= \frac{1200 \times 112}{2240} = 60 \text{ lbs.}$$

(2) Amount of tow per cwt.

$$= \frac{950 \times 112}{2240} = 47{\cdot}5 \text{ lbs.}$$

(3) Ends per cwt.

$$= \frac{60 \times 112}{2240} = 3 \text{ lbs.}$$

(4 Waste per cwt.

$$= \frac{30 \times 112}{2240} = 1{\cdot}5 \text{ lbs.}$$

(5) Average lea sort =

100s × 480 lbs.	=	48000 leas
110s × 660 ,,	=	72600 ,,
120s × 60 ,,	=	7200 ,,
1200 lbs.	=	127800 leas

$$= \frac{127800}{1200} = 106{\cdot}5$$

(6) Cost per lb. of dressed line

$$= \frac{66 \quad 7 \quad 1}{1200} = 13{\cdot}28\text{d.}$$

(7) Cost per bundle of D.L.

$$= \frac{13{\cdot}28 \times 200}{106{\cdot}5} = 24{\cdot}94\text{d.}$$

Cost per Bundle from Dressed Line to Yarn.

To the cost per lb. or bundle must be added the cost of spreading, preparing, roving, spinning and reeling, etc., *e.g.*

Assume the market price of 105s lea is 4/3 per bundle, less the usual 11%; dressed line cost 25 pence, then the amount left to cover preparing spinning and profit may be found as follows :—

4/3 less 11% = 45·39 pence per bundle.
∴ 45·39 − 25 = 20·39 „ „

Some idea of the total cost of preparing, spinning, and reeling per bundle may be formed by the following particulars of turn off and sectional costs. These will serve as bases to demonstrate the principle of solution and as examples of the variety of problems which arise in costs and production.

One spreader with two boards will turn off from 300 to 350 lbs. of Courtrai and 450 to 500 lbs. of Belgium and similar flaxes per day, and keep an average of 3 systems of preparing supplied with material ; 3 systems of drawing will turn off about 2000 lbs. per week of rove weighing an average of 200 yds. per oz. or 1620 lbs. per week of rove, weighing an average of 250 yds. per oz. and supply rove for 1800 to 2000 spindles, which will turn off 825/880 bundles per week respectively, or an average of 16 cuts per spindle per day for the 60s lea count. The average wage list per system of preparing is about 50/- to 52/6 and per spinning room of 3000 spindles about £22 and the proportion for reeling about £10.

The proportionate cost of spreading, preparing, spinning and reeling per bundle for an average of 60s lea warp is as follows :—

a. Preparing	$2\frac{1}{4}$ to	$2\frac{1}{2}$	per bundle.
b. Spinning	$3\frac{1}{4}$ to	$3\frac{3}{4}$	„
c. Reeling	$1\frac{3}{4}$ to	$1\frac{3}{4}$	„

d. Sundries, engineers, managers, etc. ..	2 to $2\frac{1}{4}$	per bundle
e. Capital expenditure, interest, and depreciation	$3\frac{3}{4}$ to 4	,,
	$12\frac{1}{2}$ to $14\frac{1}{4}$	,,
f. Sinkage, etc. 18% ..	$2\frac{1}{4}$ to $2\frac{1}{2}$	,,
Total	$14\frac{3}{4}$ to $16\frac{3}{4}$	pence per bundle.

For most lea sorts from 18 to 20% must be added to the required number of bundles of spun yarn, as demonstrated in the following :—

Example 1.—Required the weight of dressed line to to spin 500 bundles of 50s lea yarn when the loss is estimated at 20% on the reeled thread.

Then 200 cuts per bundle plus 20 cuts per 100 =

$200 + (2 \times 20) = 240$ cuts of dressed line for each bundle,

and 240 cuts ÷ 50s lea = 4·8 lbs. per bundle.

∴ Amt. of dressed line reqd. = $500 \times 4{\cdot}8$ lbs. = 2400 lbs.

The whole may be simplified and stated thus:—

$$\frac{500 \times (200 + 20 \times 2)}{50} = 2400 \text{ lbs.}$$

Example 2.—Assuming that the dressed line cost 11d. per lb. and the average cost of production to the reeled yarn is 1/3 per bundle on the nett weight, and if 1220 lbs. of dressed line are required to produce 250 bundles of 50s lea warp yarn, find the total cost per lb. omitting commission and profits; allow for 200 lbs. waste which realise 4d. per lb.

	s.	d.
1220 lbs of dressed line at 11d. per lb. =	1118	4
250 bundles of 50s lea at 1/3 per bundle =	312	6
Total =	1430	10

Less 200 lbs. waste at 4d. per lb. = 66 8

Total nett cost ... ... = 1364 2

Then $\frac{250 \text{ bundles} \times 200 \text{ cuts per bundle}}{50 \text{ cuts per lb.}} = 1000$ lbs.

and $\frac{1364 \quad 2}{1000} = 1/4\,\frac{37}{100}$ per lb.

If the price per bundle were required, then the solution would simply be—

$$\frac{1364 \quad 2}{250} = 5/5\,\tfrac{12}{25} \text{ per bundle.}$$

Example 3.—If 14 cuts per spindle are produced per day (10 hours) on 3 frames each containing 200 spindles revolving at the rate of 5000 revolutions per minute and producing 70s lea warp with 14 turns per inch, what weight is produced per week?

Then $\frac{14 \text{ cuts per spindle} \times 600 \text{ spindles}}{70 \text{ cuts per lb.}} = 120$ lbs. per day.

And $120 \times 5\frac{1}{2} = 660$ lbs. per week.

Example 4.—If the spindles of a flax spinning frame producing 65s lea yarn with 13·9 turns per inch, revolve at the rate of 5000 turns per minute and if the turn off per spindle be 15 cuts per day of 10 hours, what is the actual loss per cent. in running of the spindles from all causes?

Then calculation length of yarn spun

$$= \frac{5000 \times 60 \times 10}{13{\cdot}9 \times 36 \times 300} = 20 \text{ cuts}$$

and 20 cuts − 15 = 5 cuts, loss on 20.

or As 20 : 100 :: 5 : x or loss per cent.

$$\therefore \quad x = \frac{100 \times 5}{20} = 25\%.$$

Example 5.—Assume 10 systems of drawing, turn off 6500 lbs. per week of rove weighing 200 yds. per oz. What is the wage cost per bundle of preparing for an estimated average lea of 60s line to be spun from double rove, when the total wage list for the rooms amounts to £20 6s. 3d.?

$$\text{Then } \frac{6500 \text{ lbs.} \times (300 \text{ yds.} \times 60 \text{ leas})}{60{,}000 \text{ yds. per bundle.}} = 1950 \text{ bundles.}$$

$$\text{And } \frac{£20 \ 6\text{s.} \ 3\text{d.}}{1950} = 2\tfrac{1}{2}\text{d. per bundle.}$$

Example 6.—If the average turn off per spindle per day, for an average lea of 60s is 16 cuts., what is the cost of spinning per bundle in a room which contains 3000 spindles, assuming the total wage list amounts to £20 per week?

$$\text{Then } \frac{3000 \text{ spindles} \times 16 \text{ cuts}}{200 \text{ cuts per bundle}} = 240 \text{ bundles per day.}$$

$$\text{And } 240 \times 5\tfrac{1}{2} = 1320 \text{ bundles per week.}$$

$$\therefore \text{ Cost per bundle} = \frac{20 \times 20 \times 12}{1320} = 3{\cdot}64 \text{ pence.}$$

Weight and Draft of Rove.

The weight of flax rove is usually designated in yards per ounce or drams per 100 yards. The solution of any problem involving the weight of rove, draft and lea number, may be readily ascertained as below.

Example 7.—Required the draft for 24s lea yarn when the rove weighs 50 yards per ounce.

Then yds. per lb. of yarn required = yds. per lb. of rove × draft.

= yds. per lea × leas per lb. = weight of rove in ozs. × ozs. per lb. × draft.

$= 300 \times 24 = 50 \times 16 \times \text{draft.}$

$$\therefore \text{ Draft} = \frac{300 \times 24}{50 \times 16} = 9.$$

The constant factors, yards per lea and ozs. per lb. may be reduced to one common factor or gauge point thus, $300 \div 16 = 18{\cdot}75$, which equals the number of yards per oz. for 1s lea.

$$\text{Then } \frac{\text{Gauge point} \times \text{lea number}}{\text{Weight of rove in ozs.}} = \text{Draft.}$$

$$= \frac{18{\cdot}75}{50} \times 24 = 9.$$

Example 8.—The weight of 100 yds. of rove is 32 drams, find the amount of draft requisite to produce 16s lea yarn.

Then yds. per lb. of yarn = yds. per lb. of rove × draft.

$$= \text{yds. per lea} \times \text{leas per lb.} = \left(\frac{\text{yds. of rove}}{\text{weight in drams}} \times \frac{\text{drams per lb.}}{1}\right) \text{draft}$$

$$\therefore \text{Draft} = \frac{\text{yds. per lea} \times \text{leas per lb.} \times \text{weight of rove in drams.}}{\text{Length of rove} \times \text{drams in one lb.}}$$

$$= \text{Draft} = \frac{300 \times 16 \times 32}{100 \times 256} = 6.$$

The constant factors, yards per lea, standard length of 100 yds. and drams per lb., reduced to their lowest equivalent may be used as a gauge point, thus:— $\frac{100 \times 256}{300} = 85{\cdot}3$ from which the following formula may be deduced:—

$$\frac{\text{Lea No. reqd.} \times \text{weight of rove in drams}}{\text{Gauge point}} = \text{draft.}$$

$$\therefore \text{Draft} = \frac{16 \times 32}{85{\cdot}3} = 6 \text{ as above.}$$

EXERCISES.

A

1. A mixture is made in the ratio of 3 to 2 of respective values of 1/4 and 2d. Find the relative cost of mixture. *Ans.*, $10\frac{2}{5}$.

2. Find the proportionate quantities required of two materials, 1 at 1/4 and the other at 2d., the combination to cost $10\frac{2}{5}$d.

Ans., 3 and 2.

3. Wool costing 1/8 and 1/4, cotton at 10d. and 6d., is mixed to sell at 1/2. Give one blend that will solve this question.

Ans., 4, 8, 6, 2.

4. Find the cost per lb. if the following tows are blended:—125 lbs. Roughers tow at $3\frac{1}{2}$d. per lb., 250 of machine tow (Nos. 1 and 2) at 4d. and 125 of re-scutched tow at 3d. per lb.

Ans., $3\frac{5}{8}$d.

5. If a good tow yarn be required by blending equal quantities of the following:—Courtrai at 5d., Irish at $4\frac{1}{2}$d., Dutch 4d., Pernau at $4\frac{1}{8}$d., find the average cost per lb. in a total lot of 4 cwt.

Ans., $4\frac{13}{32}$d. or 4·4d.

6. Given 8 cwts. of dressed line, find the number of bundles of 75s lea that would be produced if the loss of fibre on the finished yarn equals 20%?

Ans., 280 bundles.

7. Assume it is required to spin 250 bundles of 50s lea yarn and that the amount of loss in fibre on the spun thread is 18%, find the total weight of dressed line required.

Ans., 1180 lbs.

8. A 50s lea warp yarn contains 13 turns per inch: if spindles making 5000 revolutions per minute turn off 15·6 cuts per spindle per day, find the number of bundles per week for 40 frames, 200 spindles each.

Ans., 3432 bundles.

9. If a spindle revolves at 4800 per minute and puts 13 turns per inch into the yarn and assuming the turn off per spindle is 15·5 cuts per day of 10 hrs., what is the actual loss per cent. for stoppages of all kinds? *Ans.*, 24·4.

10. If 1 spindle produces 16 cuts per day, how many bundles will 12000 spindles produce per week ($5\frac{1}{2}$ days). *Ans.*, 5280.

11. (a) What yards per ounce rove would spin 25s tow on spinning draft of 7·5? (b) Find the spinning draft for double rove, 160 and 180 yards per ounce to make 40s lea.

Ans., (a) $62\frac{1}{2}$ ozs. (b) $9\frac{3}{8}$ and $8\frac{1}{3}$.

B

12. It is required to produce 200 lbs. of mixture to cost $6\frac{1}{2}$d. per lb. Noils cost 1/3; cotton, shoddy, and sweepings, $7\frac{1}{2}$d., 3d. and 1d. per lb. respectively. What relative weights of each will be required? Find three ratios of relative weights which will satisfy this question and prove your answers.

13. Assume 720 lbs. of greasy Botany wool cost 7d. per lb. in the grease and the yield of clean wool is 56%. If the cost of scouring be estimated at $\frac{1}{2}$d. per lb. on the clean wool and the carriage at $\frac{1}{2}$d. per lb. on the greasy weight, what is the average cost per lb? Assume further if the wool is sorted into two lots and the value of the better quality yielding 40% is estimated to be 2d. per lb. more than that of the lower quality, what would be the average cost and price of each, charging an extra $\frac{1}{4}$d. lb. on the greasy weight for sorting?

Ans., 13·8 unsorted; 14·3 sorted; 13·5d. and 15·5d.

14. If clean wool cost an average of 1/10 per lb. depreciation and cost of plant 1½d. per lb., waste and shrinkage 1d., wages and miscellaneous expenses 1½d., preparing 1d., combing 1½d., drawing 2d., spinning 1d., and twisting ½d.; add 2½d. per lb. profit, find the selling price of 2/36 worsted.

Ans., 2/11.

15. Assume the average cuts per spindle per day be 16·5 for 40s lea warp yarn, 12 turns per inch; find the number of bundles for 8000 spindles per week for a 55 warp yarn with 13·1 turns per inch.

Ans., 561·7 bundles.

16. Given 3 dram roving, what draft would be required to spin 40s worsted?

Ans., 6·56.

17. What weight of roving will be required to spin a 36s worsted yarn with a draft of 6·3?

Ans., 3·2.

18. Given a 3 dram roving and a draft of 7, find the counts of worsted yarn that would be spun.

Ans., 42·7.

C

19. Calculate the cost of combed top; clean wool costing 1/- per lb., noil worth 1/3 per lb., combing 3d. per lb.; result 44% top to 11% noil.

Ans., 2/2½.

20. Find the cost per lb. of combed top. Given 6500 lbs. of raw wool costing 9d., yielding 48% of clean wool costing ½d. per lb. washing (on the raw wool), tares 7 to 1, noils worth 14d. and 3d. per lb. for preparing and combing.

Ans., 1/10½.

21. If 5·1 gross of hanks per day are produced on 144 spindles which make 1983 revolutions per minute, and put 10 turns per inch into the thread, (a) what quantity of hanks would be produced if the spindles revolve at 2400 per minute? (b) What weight would be made if the yarn is spun to 16s worsted and contains 8 turns per inch?

Ans., (a) 6·03 gross of hanks; (b) 67·8 lbs.

22. If 6000 lbs. of 2/40s worsted are produced in one week from two sets of Botany drawing and a suitable complement of spinning and twisting machinery, and if wages cost $1\frac{1}{2}$d. per lb., shrinkage and waste 1d., twisting $\frac{3}{4}$d., capital expenditure, interest, depreciation, power, light, heat, engines, etc., £40, find the cost of production per lb.

Ans., 4·85d.

CHAPTER V.

Weight and Cost of Warp and Weft in hank, ball or otherwise.

Warps and weft prepared by the spinner for the manufacturer are usually delivered on bobbins, cheeses, the warp beam or in the ball for warp and on spool, tube, cop or hank for weft; but, in whatever form it may be despatched and received, there are necessarily a few calculations involved.

Example 1.—Assume a manufacturer orders 4 warps, 6-cut of 2/56s Botany, each 450 yards long, and containing 5760 ends. What is the calculation weight?

4 warps × 450 × 5760 ends = total length in yds., and 560 yards per hank × 28 hanks per lb. = the number of yards of 2/56s Botany per lb.

$$\therefore \frac{\text{Total length of warp in yds.}}{\text{Yds. per lb. of given counts}} = \text{weight of warps.}$$

$$\text{Thus, } \frac{4 \times 450 \times 5760}{560 \times 28} = 661\tfrac{1}{4} \text{ lbs.}$$

No additional formula is necessary since formula I. may be made to apply, thus:—

Let x = the weight of the 4 warps in lbs., then by formula I.,

$$\frac{\text{Total length in yards}}{\text{Weight in lbs.} \times \text{yards in hank}} = \text{counts.}$$

Substitute x for weight in lbs., thus;—

$$\frac{4 \times 450 \times 5760}{x \times 560} = 28$$

$$\therefore x = \frac{4 \times 450 \times 5760}{28 \times 560} = 661\tfrac{1}{4} \text{ lbs.}$$

Example 2.—If each warp in example 1 actually weighed 10 lbs. less than the calculation weight, find the actual counts, assuming the length and number of ends agree with order.

Then calculation weight of one warp $= \frac{661\frac{1}{4}}{4} = 165\frac{1}{4}$

and actual weight of each $= 165\frac{1}{4} - 10 = 155\frac{1}{4}$ lbs.

Then, since counts of yarn are in inverse ratio of their weights (see chapter 2, page 40), and $165\frac{1}{4}$ lbs. represent the weight of 2/56s Botany,

$\therefore 155\frac{1}{4} : 165\frac{1}{4} :: 28 : x$ where x equals the counts of the lighter weight.

$$\therefore x = \frac{28 \times 165\frac{1}{4}}{155\frac{1}{4}} = 29{\cdot}8, \text{ or about } 2/60\text{s.}$$

Example 3.—Assume 100 gross of 2/32s cotton in hank is ordered, what is the calculation weight and total cost at 1/6 per lb. ?

Then 1 gross = 144 hanks. And 100×144 equals total number of hanks. Also the number of hanks of 2/32s in 1 lb. = 16.

$$\therefore \frac{100 \times 144}{16} = 900 \text{ lbs. calculation weight.}$$

$$\text{And total cost} = \frac{900 \times 3}{2 \times 20} = £67\ 10\text{s.}$$

Example 4.—A bundle which contains 1 gross of hanks of twofold worsted yarn weighs 12 lbs., what are the counts ?

$$\text{Then, } \frac{144 \text{ hanks}}{12 \text{ lbs.}} = 12 \text{ hanks per lb.}$$

And, since the yarn is twofold, the counts are consequently equal to 2/24s worsted.

BOILED, BLEACHED, SIZED AND DYED YARNS.

Flax and cotton yarns are frequently subjected to bleaching, sizing, and dyeing processes, all of which influence the weight of the yarn, but the yarn number represents its count for the spun thread of standard condition.

The amount of loss on flax yarns is chiefly due to the decomposition of foreign matter, such as gum, woody substances, and dirt. The following table gives approximately the loss for the respective processes :—

(1) Scoured	Loss 2 to 6	per cent.
(2) Boiled, once	„ 10 to 15	„
(3) „ twice	„ ·15 to 20	„
(4) $\frac{1}{4}$ Bleached (creamed) ...	„ 6 to 10	„
(5) $\frac{1}{2}$ „ (high creamed)	„ 10 to 12	„
(6) $\frac{3}{4}$ „	„ 15 to 20	„
(7) Fully Bleached ...	„ 20 to $22\frac{1}{2}$	„

BOILED YARN is chiefly used in the finer linens including damasks and table covers because it is cleaner and relatively stronger than the natural grey or green yarn ; it admits of closer setting, the manufacture of a better cloth and is easier to bleach.

The increase in weight, due to size or dressing, added for the purpose of strengthening the warp, varies from 8 to 10%, but if sized for 'weighting' only, the increase may be anything from 25% upwards.

Example 5.—A parcel of dry spun yarn weighs 450 lbs. after bleaching, the loss in weight being 20% on the spun yarn ; what number of spindles of 3 lb. yarn is there ?

$$\text{Then original weight} = \frac{450 \times 100}{80} = \frac{2250}{4} = 562\tfrac{1}{2}$$

$$\therefore \frac{562\frac{1}{2}}{3} = 187\tfrac{1}{2} \text{ spindles.}$$

Example 6.—Assume a half bleached cotton yarn loses 10% on the natural weight. If 54 yards weigh 1 dram, what is the count of the spun cotton thread?

$$\text{Then} \frac{1 \text{ dram} \times 100}{90} = \frac{10}{9} \text{ original weight in drams.}$$

$$\text{And } \frac{54 \text{ yds.}}{\frac{10}{9} \text{ drams}} = \frac{54 \times 9}{10} = \text{yards per dram.}$$

$$\text{Also } \frac{54 \times 9}{10} \times \frac{256 \text{ drams in 1 lb.}}{840 \text{ yds. per hank}} = 14{\cdot}8 \text{ hanks per lb.}$$

The whole may be simplified and stated as a fraction, thus:—

$$\frac{54 \times 90}{1 \times 100} \times \frac{256}{840} = 14{\cdot}8 \text{ hanks per lb.}$$

Example 7.—A flax or cotton warp weighing 80 lbs. is increased 5% during the process of sizing, what is the actual weight of the sized warp?

Since the increase is 5 lbs. on every 100, the weight of 80 lbs. of warp will be *pro rata* thus:—

$$\frac{80}{1} \times \frac{(100 + 5)}{100} = \frac{80 \times 105}{100} = 84 \text{ lbs.}$$

Example 8.—If a sized warp weighs 130 lbs. and contains $7\frac{1}{2}$% of size what was the original weight?

Since each original 100 lbs. was increased to $107\frac{1}{2}$ lbs., the weight of the warp will be *pro rata* thus:—

As $107\frac{1}{2} : 100 :: 130 : x$.

Where x = the original weight of warp

$$= \frac{130 \times 200}{215} = 120\tfrac{40}{43} \text{ lbs.}$$

YARN CONTRACT PROBLEMS.

Example 9.—A manufacturer places a contract for the delivery of 20,000 lbs. of worsted yarn in warp or weft within 6 months from date of contract. During the first 3 months he gives particulars for and receives 50 warps, each 2800 ends and 350 yards long of 2/56s; 30 warps, each 1700 ends and 320 yards long of 2/40s; 350 gross of 1/28s, 1500 lbs. of 1/36s, 500 lbs. of 1/18s; and 12 skeps of 1/20s with an average nett weight of 75 lbs. What weight has still to be delivered to complete the original contract?

By formula I.,

(1) Weight of warps of 2/56s $= \frac{50 \text{ warps} \times 2800 \text{ ends} \times 350 \text{ yds.}}{560 \text{ (yds. per hank)} \times 28 \text{ (counts)}} = 3125$ lbs.

(2) Weight of warps of 2/40s $= \frac{30 \times 1700 \times 320}{560 \times 20} = 1457\frac{1}{7}$ lbs

(3) $\frac{350 \text{ gross} \times 144 \text{ (hanks per gross)}}{28 \text{ (hanks per lb.)}} = 1800$ lbs.

		$6382\frac{1}{7}$ lbs.
of	1/36s	1500 lbs.
of	1/18s	500 lbs.
of	1/20s (in 12 skeps = 75 × 12)..	900 lbs.
		$9282\frac{1}{7}$ lbs.

∴ 20,000 lbs., amount of contract.

$9,282\frac{1}{7}$ lbs., delivered at end of 3 months.

$10,717\frac{6}{7}$ lbs., quantity awaiting particulars to complete contract.

Example 10.—A manufacturer makes a contract with a spinner for the delivery within six months of 13,500 lbs. of yarn prepared from 70s Botany top, to be delivered at the following prices:—1/16s and all counts below, at 2/1; 1/17s to 1/24s, at 2/1½d.; 1/25s to 1/36s, at 2/2 per lb.; 2/36s to 2/24s, at 2/3; 2/40s to

2/48s, at 2/3½ per lb. If during the specified time he received the complete delivery of the above weight to the following particulars, find the weight of each sort delivered and the total amount to be paid by the manufacturer; also his gain or loss as compared with purchases made at the current prices as given below:—

30 warps 5760 ends 450 yds. of 2/48s current price		2/4
25 ,, 3400 ,, 350 ,, 2/36s	,,	2/3½
10 skeps of 1/30s weft, nett weight 800 lbs.	,,	2/3
300 gross of 2/30s in hanks	,,	2/4
9 skeps of 1/16s weft, nett weight 750 lbs.	,,	2/0½
332¾ lbs. in hank of 2/24s	,,	2/3

By formula I.,

$$\frac{\text{Total length in yards}}{\text{Yards per hank} \times \text{weight in lbs.}} = \text{counts.}$$

$$\therefore \frac{\text{Total length}}{\text{Yards per hank} \times \text{counts}} = \text{weight in lbs.}$$

		£	s.	d.
(1) Of 2/48s warp	$\frac{30 \times 5760 \times 450}{560 \times 24} = 5785\frac{5}{7}$ lbs. at 2/3½ =	662	19	0
	Gain on contract price at ½d., £12 1 0¾			
(2) Of 2/36s warp	$\frac{25 \times 3400 \times 350}{560 \times 18} = 2951\frac{1}{2}$ lbs. at 2/3 =	332	0	10½
	Gain on contract price at ½d., £6 2 11½			
(3) Of 1/30s weft	Nett weight = 800 lbs. at 2/2 =	86	13	4
	Gain on contract price at 1d., £3 6 8			
(4) Of 2/30s in hank	$\frac{\text{No. of gross} \times \text{hanks per gross}}{\text{Hanks per lb.}} = \text{weight.}$			
	$\therefore \frac{300 \times 144}{15} =$ 2880 lbs. at 2/3 =	324	0	0
	Gain on contract price at 1d., £12 0 0			
(5) Of 1/16s weft	Nett weight = 750 lbs. at 2/1 =	78	2	6
	Loss on contract price at ½d., £1 11 3			

(6) Of 2/24s in hank	Nett weight	$= 332\frac{3}{4}$ lbs. at 2/3			= 37	8	$8\frac{1}{4}$
	Total weight	= 13,500 lbs.					
	Total cost ..	..			.. £1521	4	$4\frac{3}{4}$
Total gain on contract price		.. £33	10	$8\frac{1}{4}$			
Loss ..	..	.. £1	11	3			
Nett gain	..	.. £31	19	$5\frac{1}{4}$			

WARPERS' PROBLEMS.

Example 11.—If 4 warpers' beams must contain 400 ends each of 50s lea warp laid 10,500 yards, find the suitable length on each bobbin and the total number of bundles required, also the actual number of bundles on the 4 beams.

The length of linen yarn on each warping bobbin is usually some multiple of a hank or half hank according to the counts of the yarn and size of bobbin, the primary object being to avoid making too many knots in the warping process.

The number of hanks which a 5 × 4 bobbin will hold is approximately as follows:—

14s, 1 hank; 20s, $1\frac{1}{2}$ hanks; 25s, 2 hanks; 35s, 3 hanks; 50s, 4 hanks; 65s, 5 hanks, and so on *pro rata* to the counts to the nearest hank or half hank.

1. Then in the foregoing example the combined length of the 4 warps = 10,500 × 4 = 42,000 yds.

$$\text{And } \frac{42{,}000 \text{ yds. of warp}}{3600 - 50 \text{ yds. per hank}} = 12 \text{ hanks approximately.}$$

This would be called by the warping master a 12 "hank run" or "sett" meaning that each warp thread for each of the 400 bobbins in the creel or bank would be approximately 12 hanks long; but since one bobbin will not hold 12 hanks of 50s lea it is necessary to tell the winder how many hanks she must wind on to each bobbin.

In this case since a 50s lea warp will hold about 4 hanks.

2. Then the number of bundles

$$= \frac{\text{No of bobbins in creel or bank} \times \text{hanks per run.}}{\text{Hanks per bundle.}}$$

$$= \frac{400 \times 3 \times 4}{16\frac{2}{3}} = 288 \text{ bundles.}$$

3. And No. of bundles on 4 beams

$$= \frac{400 \times 4 \times 10{,}500}{60{,}000} = 280 \text{ bundles.}$$

Thus leaving (288-280) 8 bundles for waste and portion remaining on bobbins.

Testing Yarns for Counts.

It is frequently necessary to test the yarn for counts, and this may be accomplished in several ways, notably by weighing a few yards of yarn against some standard weight as is explained below, or by measuring a whole hank and weighing it against the standard weights, which represent fractional parts of a lb.

The explanations given herewith are confined to worsted, but the same principle of reasoning applies to any other system.

In 1 lb. avoirdupois there are 7000 grains. Also, in 1 hank of worsted there are 560 yards.

Then $\frac{7000 \text{ grains}}{560 \text{ (yds. in hank)}} = 12 \cdot 5$ grains the weight of 1 yard of 1s worsted.

Therefore, if 1 yard of yarn weighs $12\frac{1}{2}$ grains, the counts are 1s.; or, if 2, 3, or 4 yards weigh $12\frac{1}{2}$ grains, the counts are 2s, 3s, or 4s respectively; or the number of yards of yarn which weighs $12\frac{1}{2}$ grains equals the counts in worsted.

In the worsted trade a small weight (lettered Y) is made to weigh exactly $12\frac{1}{2}$ grains, against which, a number of yards of yarn as near the number of counts as can be approximately estimated are reeled and weighed; hence, if 20 yds. are equal in weight to the yarn weight, the counts are therefore 20s. If 20s yarn is invoiced, and only 19 yards are sufficient to balance the Y weight, it is evident that the counts are too heavy, being 19s instead of 20s. When the manufacturer wishes to determine the counts of yarn in a given cloth from which he can obtain only a few inches of yarn at the most, he must then weigh this quantity as exactly as possible in grains—say, to the hundredth part of a grain.

Example 1.—Supposing 9 threads were obtainable, each 4 inches long (1 yard), and these weigh 1 grain, then the counts of this yarn would be $12\frac{1}{2}$s, because $12\frac{1}{2}$ yards would be required to weigh $12\frac{1}{2}$ grains.

Example 2.—If 60 inches of worsted yarn weigh 1·2 grains, what are the counts?

The number of yards required to weigh $12\frac{1}{2}$ grains can readily be obtained by simple proportion, and these equal the counts, thus:—

$$\text{As } 1{\cdot}2 : 12{\cdot}5 :: \frac{60}{36} \text{ yards} : x \text{ yards.}$$

$$= \frac{60 \times 12{\cdot}5}{36 \times 1{\cdot}2} = 17\tfrac{13}{36} \text{ counts.}$$

where x = the counts in worsted.

$$\text{Similarly } \frac{7000 \text{ grains per lb.}}{840 \text{ yds. per hank of cotton}} = 8\tfrac{1}{3} \text{ grains for 1 yd. of 1s cotton.}$$

And consequently the number of yards of cotton which weighs $8\frac{1}{3}$ grains = the counts.

$$\text{Also for linen yarns } \frac{7000 \text{ grains per lb.}}{300 \text{ yds. per lea.}} = 23\tfrac{1}{3}.$$

$\therefore$ The number of yards which weighs $23\frac{1}{3}$ grains
= No. of leas or counts.

The three foregoing examples together with the following which have been similarly deduced are tabulated for future and ready reference.

1.	Worsted	The No. of yds. which weighs	$12\frac{1}{2}$ or	$12{\cdot}5$	grains	=	counts.
2.	Cotton	,, ,,	$8\frac{1}{3}$,,	$8{\cdot}\dot{3}$	,,	=	,,
3.	Linen	,, ,,	$23\frac{1}{3}$,,	$23{\cdot}\dot{3}$	,,	=	,,
4.	Woollen (Y.S.)	,, ,,	$27\frac{11}{32}$,,	$27{\cdot}34$	,,	=	,,
5.	,, (Galashiels)	,, ,,	35		,,	=	,,
6.	,, (W. of England)	,, ,,	$21\frac{7}{8}$,,	$21{\cdot}875$	,,	=	,,
7.	,, American Run	,, ,,	$4\frac{3}{8}$,,	$4{\cdot}375$	,,	=	,,
8.	,, ,, Cut	,, ,,	$23\frac{1}{3}$,,	$23{\cdot}\dot{3}$	,,	=	,,

9. Continental Worsted. The number of
   (a) Metres which weigh 1 gramme or 15·432 grains = Metric counts.
   (b) Yards ,, 14·1 ,, = ,,
10. Continental Cotton or Linen. The number of
   (a) Metres which weigh $\frac{1}{2}$ gramme or 7·716 grains = Metric counts.
   (b) Yards ,, 7·05 ,, = ,,
11. Jute, tows, etc. Length in yards, divided into twice its weight in grains = lbs. per spindle approximately or the weight of 3 cuts in ounces = lbs. per spindle.

When it is possible for the spinner or manufacturer to reel a sufficient length of yarn as will represent one hank, or to extract a complete hank or lea from the bundle, the counts of the materials may be determined with greater accuracy.

Then, since the number of hanks which weigh 1 lb. avoirdupois represents the counts, it is evident that the weight of 1 hank of 10s is $\frac{1}{10}$ of 1 lb.; of 16s, it is $\frac{1}{16}$ of 1 lb.; of 20s, $\frac{1}{20}$ of 1 lb.; of 28s, $\frac{1}{28}$ of 1 lb.; and similarly with other counts. Consequently, for greater convenience and despatch, small brass weights are made $\frac{1}{16}$, $\frac{1}{17}$, $\frac{1}{18}$, etc., parts of a lb., each weight being numbered 16, 17, 18, etc., according to the fractional part of 1 lb. that it weighs.

Against these weights the hank is compared for weight, and so, if the hank is equal in weight to the 12, 16, 20, 24, or 28 number, the counts of the material coincide with the weight number.

There is a simple invention called a hank quadrant, which is sometimes used for the above purpose. Without discussing its merits or demerits, suffice it to say, that it consists chiefly of a quadrant ($\frac{1}{4}$ circle) graduated and numbered to represent different parts of 1 lb., say from $\frac{1}{16}$ to $\frac{1}{100}$. A simple lever which contains a pointer at one end and a scale pan at the other is delicately adjusted so that if a hank is placed on the scale pan the number on the quadrant which the pointer is immediately over represents the fractional part of 1 lb. which the hank weighs, and therefore, the counts.

Testing Cotton Counts—Modified Length of Hank.

The reel for testing cotton is $1\frac{1}{2}$ yds. in circumference, the same as the swift used for reeling cotton. Instead however of reeling from 7 cops and making the usual 80 revolutions which would then equal one complete hank (as is the case in the worsted trade) it is customary to reel from 4 cops and make the same number of revolutions, viz.: 80, which produces $(120 \times 4) = 480$ yards or 4 leas.

In cotton there are 7 leas of 80 yards each in 1 hank.

The weight of the 4 leas in grains divided into 4000 grains equals the counts of the yarn.

Note.—Since there are 7000 grains in 1 lb. and that if 1 hank (7 leas) weighs 70 grains, it follows that if this weight be divided into the number of grains in 1 lb. the quotient will represent the number of hanks in 1 lb.

Thus $\frac{7000 \text{ grains in } 1 \text{ lb.}}{70 \text{ grs.} \times \text{weight of } 1 \text{ hank}} = 100$ hanks per lb.

It will also be evident that 4 leas represent $\frac{4}{7}$ of 1 hank and 4000 grains are equal to $\frac{4}{7}$ of 1 lb., therefore, if 7 leas weigh 70 grains, 4 leas will weigh 40 grains, and if this weight be divided into 4000 grains, the result will be the same, thus :—

$$\frac{4000 \text{ grs., grains in } \frac{4}{7} \text{ of } 1 \text{ lb.}}{40 \text{ grs., weight of } 4 \text{ leas.}} = 100 \text{ hanks per lb.}$$

from which the usual formula is deduced, viz :—

Formula for testing cotton counts—

$$\frac{4000 \text{ grains}}{\text{Weight in grains of } 4 \text{ leas}} = \text{cotton counts.}$$

In a similar way it can be shown that if only 1, 2 or 3 cops are available the weight in grains of 1, 2 or 3 leas divided into 1000, 2000 or 3000 grains respectively will equal the cotton counts, *e.g.*

Example 1.—Assume 1 lea of cotton weft weighs $12\frac{1}{2}$ grs., what are the counts ?

Then $\frac{1000}{12\frac{1}{2}} = \frac{1000 \times 2}{1 \times 25} = 80$s cotton.

Example 2.—The weight of 2 leas of cotton is 50 grains, find the counts.

Then $\frac{2000}{50} = 40$s cotton.

EXERCISES.

A

1. If 25 yards of yarn weigh 15 grains, what are the counts in worsted, cotton, linen and American cut yarn ? *Ans.*, $20\frac{5}{6}$; $13\frac{8}{9}$; $38\frac{8}{9}$; $38\frac{8}{9}$.

2. A 10 lb. bundle of 2/36s worsted is ordered, but when grossed and weighed it is found to weigh only $9\frac{1}{4}$

lbs. What are the actual counts of yarn, assuming that there are no hanks missing from the bundle?

Ans., 2/39.

3. Find the cost of 5 gross of hanks of 40s worsted, at 2/6 per lb. *Ans.*, 45/-

4. A hank of cotton measuring 820 yards indicates on the quadrant $\frac{1}{18}$ part of 1 lb. What are the actual counts? *Ans.*, $17\frac{4}{7}$.

5. 20 yards of woollen yarn weigh 28 grains. What are the cuts, Galashiels?

Ans., 25.

6. 120 gross of 2/60s cotton cost 1/10 per lb. Find the total weight and cost.

Ans., 576; £52 16s. 0d.

7. 8 warps, each 420 yards long of 2/36s Botany, and containing 6960 ends, cost 2/9 per lb. What is the calculation weight and total cost?

Ans., 2320; £319.

8. If 1 of the warps in question 7 only weighs 280 lbs., and if the counts of yarn and ends agree with order, what is the length?

Ans., $405\frac{1}{2}$.

9. 80 yards of woollen yarn are reeled, and weigh $7\frac{1}{2}$ drams. What are the counts, Y. S?

Ans., $10\frac{2}{3}$.

10. $7\frac{1}{2}$ yards of a 3-fold tow carpet weft weigh 25 grains. What are the lea counts and lbs. per spindle?

Ans., 7s lea or $6\frac{6}{7}$ spindles.

11. Find the weight in grains of 1 lea of 40s, 2 leas of 60s, 3 leas of 75s and 4 leas of 90s cotton weft.

Ans., 25; 33·3; 40; 44·4.

12. If 2 leas of cotton weigh 71·3 grains and 4 leas weigh 32 grains, what are the counts?

Ans., 28; 125.

13. How many bundles of yarn would be required for a warp 1200 yds. long with 1600 ends?

Ans., 32.

B

14. What is the weight in grains of 1 yard of 1s cut Hawick; 1s Run (American); 1s linen, and 1s West of England?

Ans., 37·9; 4·375; 23·3; 21·875.

15. If 30 yards of jute weigh 2 drams. What is the number of lbs. per spindle?

Ans., $3\frac{3}{4}$.

16. A merchant places an order for 15,000 lbs. of yarn, and supplies particulars for a 1000, 500, and 150 gross of 40s, 30s and 2/24s respectively, and 30 warps 2/24s worsted, containiug 1200 ends and 280 yards long. What weight of the original order remains to be executed?

Ans., 5700.

17. A spinner has in stock 1200 warping bobbins of 2/32s worsted, the average length on each bobbin being 8960 yards. How many warps, each containing 2000 ends, and 360 yards long, can be made, and what remains over?

Ans., 14; 75.

18. A three months' contract is made between a spinner and manufacturer for the delivery of 15,000 lbs. weight of worsted warp and weft, at the following rates:—

All counts up to 1/24s, at 2/6; 1/25s to 1/36s, at 2/7; 2/24s to 2/36s, at 2/8. All counts above 2/36s and up

H

to 2/48s, at 2/9 per lb. All above 2/48s to be 2/10 per lb.

During the first two months of contract, the following warps and wefts are delivered when current prices are as detailed below:—

15 warps, 3400 ends, 300 yards of 2/24s ..	current rate,	2/9
12 warps, 4500 ends, 240 yards of 2/48s ..	,,	$2/10\frac{1}{2}$
25 skeps of 1/12s weft of total weight 2050 lbs.	,,	$2/7\frac{1}{2}$
50 gross in hanks of 2/36s	,,	2/9
10 skeps of 1/30s weft of total weight 850 lbs.	,,	$2/7\frac{1}{2}$
10 warps, 5760 ends, 450 yards of 2/44s ..	,,	2/8
130 gross of hanks of 2/24s	,,	2/7

What weight yet remains to be delivered, and what is the manufacturer's gain or loss on the goods already received by him?

Ans., $4795\frac{1}{3}$; £16 9s. 11d. gain, nett.

19. There are in stock 160 bobbins of 30s cotton, with an average weight of 8 ounces of yarn. Allowing 5 per cent. for material left on the bobbins and for waste, what length of warp can be made with 3600 ends?

Ans., 532.

20. Assume the capacity of the creel or 'bank' for a 10 yards warping mill is 100 and that a warp is required to be made with 1680 ends and 450 yards long. Find (1) the most suitable number of bobbins to put in the warper's creel, *i.e.* the highest number divisible into 1680 which the creel will hold; (2) the number of revolutions of the mill to produce the required length of warp; (3) the number of single journeys and also the number of rounds or "bouts" necessary to produce the requisite number of threads.

Ans., 84 bobbins; 45 rev; 20 single; 10 "bouts."

21. Find the lbs. per spindle of the following :—

(a) 6 yds. of dry spun flax weighing 15 grains ;

(b) 3 cuts of jute yarns weighing 6 ozs.

(c) 1 cut of hemp weighing $1\frac{1}{3}$ ozs.

Ans., $5\frac{1}{7}$; 6 ; 4.

22. If 16 yds. of a boiled boiled flax yarn weigh 6 grains and the loss in weight due to boiling is 6% what is the size or lea of the spun yarn ?

Ans., 58·5.

23. A 600 lb. lot of fully bleached 16s lea spun flax yarn has lost $22\frac{1}{2}$% on the spun thread. Find the number of bundles, cuts and yards.

Ans., 61 bundles ; 187 cuts ; 29 yds.

24. (a) A 40s twist cotton warp with 2000 ends and 150 yds. is increased 5% by sizing ; what is its actual weight ?

(b) A cotton warp, 1800 ends, 770 yds. long weighs 45 lbs. and is estimated to contain 6% of size. What is the twist or count of the spun warp ?

Ans., (a) $9\frac{3}{8}$ lbs. ; (b) 38·86 counts.

25. If a warp beam contains 600 ends laid 7200 yds. and weighs 365 lbs., allowing 65 lbs. for the empty warp beam, find the leas per lb. linen and the hanks per lb. cotton.

Ans., 48 ; $17\frac{1}{7}$.

26. If a set of 4 warping beams each contain 464 ends, 10600 yds. long ; what quantity in bundles, of linen yarn would be required and about how many yards should be wound on to each cheese or bobbin of 45s lea ?

Ans., 327·89 bundles ; 3 hanks per bobbin.

NOTE.—The manufacturer would order about 334 bundles thus allowing about $2\frac{1}{2}\%$ for waste.

27. If the total weight of each beam in the previous question is 420 lbs. and the weight of each empty warp beam is 60 lbs., what is the lea of the yarn? Also if 10% size is added what would be the weight of each cut laid 100 yds. on the weaver's beam?

Ans., 45.54; 15.

28. If a winder with 20 ends makes 12/- per week at 8d. per 100 hanks of linen, how many winders would be required to keep three warpers going who make 15/- per week, being paid 6d. per 1000 yds. of a 350 end bank allowing 100 yards per hank for waste?

Ans., 5.

CHAPTER VI.

"SETT SYSTEMS,"

OR

VARIOUS SYSTEMS OF COUNTING REEDS AND HEALDS.

The proximity of the warp threads to each other in the process of weaving, and subsequently in the woven structure, is represented by the relative number of mails in the healds, or splits in the reed distributed over some fixed unit of space, including the number of warp threads which are passed through each split in the reed.

This fineness, or distance apart of the warp threads, is technically termed the "SETT."

The number of threads, mails, or splits and unit of measurement, which may indicate the Sett is optional, and this fact accounts for the introduction of so many different methods of counting reeds and healds.

Obviously, the simplest basis which is conceivable for a 'Sett System' that ought to be generally adopted, is to indicate the Sett by the number of threads per inch, at least in all countries where the British measurements are used, and for the Continent the number of threads per centimetre appears the most feasible. But individual enterprise and locality of industry have long since established their respective systems, so that to-day there are a considerable number in use. It is, consequently, advisable for those interested in the manufacture of woven structures to acquaint themselves with the principles which underlie the system in use in their own locality, and also a few of those most generally adopted. For this reason, a few typical examples of Sett Systems have been collected and herein described and tabulated for use and convenient future reference.

At this juncture, it should be pointed out that the technical terms frequently employed in connection with Setts of reeds and healds, such as Beer, Portie, Porty, Porter, and Groups of Splits, are all arbitrary in name and value, each of which is made to represent a group of warp threads, which, being spread over any fixed number of inches, is made to represent the Sett.

The Bradford System of designating *Setts* is based upon the 'BEER' of 40 ends each, in a standard width of 36 inches, or of 20 splits, with 2 threads in each split in the standard width of 36 inches. An explanation of this system in detail will form the key to understanding the several systems herein enumerated.

The arbitrary term 'Beer' represents the *unit* number of threads grouped together. The standard width of 36 inches represents the *unit of measurement* across the width of the reed. Consequently, if 40 threads be distributed over a distance of 36 inches, the Sett Bradford would be 1s; if 80 threads, then 2s Sett; and 120 threads, then 3s Sett Bradford.

Example 1.—If in a reed of 30 inches width there are 3000 threads, the Sett would then

$$= \frac{3000 \times 36}{30} = 3600 \text{ ends in 36 inches,}$$

$$\text{and } \frac{3600}{40} = 90 \text{ Beers of 40 ends each in 36 inches,}$$

$\therefore$ 90s Sett Bradford.

Example 2.—A cloth is woven in 72s Sett Bradford. To how many ends per inch is this equivalent?

Since each Sett is equivaleut to 1 Beer, then 72s Sett = 72 Beers, and each Beer contains 40 threads when the standard width is 36 inches.

$\therefore$ The number of threads per inch $= \frac{72 \times 40}{36} = 80.$

A very important point should here be emphasised with respect to reeds or sleys, *e.g.*, a 50, 54, 60 or 80 sley Bradford Sett would indicate that these reeds would respectively contain $50 \times 20 = 1000$; $54 \times 20 = 1080$: $60 \times 20 = 1200$; $80 \times 20 = 1600$ splits in a standard width of 36 inches. Hence, these reeds when sleyed 2 threads through each split would produce a fabric in the above Setts respectively. But very frequently any of these reeds may be woven with 3, 4, or more threads through each split, and then the Sett is greater in the ratio as 3 is to 2; 4 is to 2, etc., and similarly with other systems, thus *e.g.*, a 50/3 sley, *i.e.*, 3 in a dent or split, instead of 2, would equal

$$\frac{50 \times 3}{2} = 75\text{s Sett Bradford}$$

or 60/4 sley Bradford $= \frac{60 \times 4}{2} =$ 120s Sett Bradford.

The *Leeds System* is based upon the number of Porties of 38 ends each, in 9 inches, so that 1s Sett or Portie Leeds contains 38 threads distributed over a unit distance of 9 inches, and 10s Portie Sett would represent 380 threads distributed over the 9 inches, or an average of $\frac{380}{9} = 42\frac{2}{9}$ threads per inch over any width of cloth in the reed.

The *Huddersfield present System*, which is the most rational, is based upon the number of dents or splits per inch in the reed multiplied by the number of threads passed through each split; then, 15s reed 4s implies that the cloth is woven in a reed which has 15 splits per inch, and that 4 threads are passed through each split, which is consequently equal to 60 ends per inch.

The *U.S.A. System* is also based upon this method.

In the *Dewsbury System*, the Beer has a value of 38 ends, and the standard width is 90 inches; the system is therefore based upon the number of Beers of 38 ends each, in 90 inches, or 19 splits 2 ends in a split in 90 inches.

THE PRINCIPAL TOWNS IN LANCASHIRE.

The *Bolton System* is based upon the Beer of 40 ends each, in a unit distance of $24\frac{1}{4}$ inches, or 20 splits 2 ends in a split in the standard width of $24\frac{1}{4}$ inches.

At *Blackburn*, the Beer has a value also of 40 ends, but the standard width is 45 inches, or 20 splits 2 ends in a split distributed over 45 inches for 1s Sett.

In *Manchester*, the method adopted is based upon the number of splits of 2 threads each in 36 inches, thus:

$$900 \text{ Manchester} = \frac{900 \times 2}{36} = 50 \text{ threads per inch.}$$

At *Stockport*, the system is based upon the number of splits (2 ends to a split) in a distance of 2 inches, which is equivalent to the number of threads per inch, *e.g.*, 60s Stockport equals 60 ends per inch or 60 splits in 2 inches, 2 ends in a split.

THE SCOTCH SYSTEMS.

The *Glasgow Cotton System* is based upon the number of splits, 2 ends in a split, in 37 inches; thus a cloth woven 60 threads per inch is equal to

$$\frac{60 \times 37}{2} = 1110 \text{ Sett Glasgow, usually written, thus } 11^{10}$$

The *Scotch Tweed* is based upon the number of Porters of 40 ends each in 37 inches, or of 20 splits each, 2 ends in a split in the unit distance of 37 inches.

LINEN, *Belfast and North of Ireland.*

The "Scale" or System most generally adopted is based upon the number of dents or splits, 2 ends in a split, in a standard width of 40 inches, *e.g.*, 8^{00}; 10^{00}; 12^{00} and 13^{00} indicate that in a reed width of 40 inches there are 800, 1000, 1200, and 1300 splits respectively. Usually these would be sleyed 2 ends through each split, but for the finer sorts there may be 3, 4 or more threads through each dent in which case the sett would increase *pro rata.*

Example.—A fabric is woven in 10^{00} reed 3 threads in a split, find the usual sett.

$$\frac{1000 \times 3}{2} = 15^{00} \text{ sett.}$$

NOTE.—36, 37 (Glasgow), 38, and 41 inch scales are also used, but the 40 inch basis may be said to be virtually the *linen* scale, because of its most general adoption.

DAMASKS, Linen.—There are several systems in use. (1) The old method of counting the number of Beers of 40 ends each in the full width of the warp; (2) the number of Beers of 40 ends each in a standard width of 30 inches; (3) in some few cases the Scotch system of reckoning the number of Porters of 40 ends each in the Scotch ell of 37 inches; (4) The more rational system of ends per inch multiplied by the reed width which is being gradually adopted.

The *Silk System* of representing the Sett is based upon the number of splits in the full width of the warp, and the Sett multiplied by the number of threads through each split indicates the total number of ends in the whole warp, thus, warp 21 inches wide, 5 threads in each dent, 2100 Sett $= 2100 \times 5 = 10{,}500$ ends.

Since in every system it is frequently necessary to obtain the Sett after having first decided upon the threads per inch which the cloth must contain, or to reduce any given Sett to threads per inch, a few examples are here worked out and reduced to simple formulæ for use in practice.

Example 1.—If a cloth must contain 80 threads per inch, what Sett is equivalent to this in Bradford, Leeds, Dewsbury, Manchester, Blackburn, Scotch Tweed, and in Linen 40 in. scale and Damask No. of Beers on 30 in. scale ?

(a) Bradford, 40 threads = 1 Beer,

and $\dfrac{80}{40} = 2$ Beers in 1 inch.

Since the standard number of Beers = 36.

Then $2 \times 36 = 72$ Beers in 36 inches = 72s Sett.

(b) Leeds, 38 threads = 1 Portie,

and $\dfrac{80}{38} = 2\frac{2}{19}$ Porties in 1 inch.

Since the standard width = 9 inches.

Then $2\frac{2}{19} \times 9 = 18\frac{18}{19}$ Porties in 9 inches $= 18\frac{18}{19}$s Sett.

(c) Dewsbury, 38 threads = 1 Beer.

Standard width = 90 inches.

$\therefore \dfrac{80}{38} \times \dfrac{90}{1} = 190$s Sett (nearly).

(d) Blackburn,

$$\frac{80}{40} \times \frac{45}{1} = 90 \text{ Beers in } 45 \text{ inches} = 90\text{s Sett.}$$

(e) Manchester,

$$\frac{80 \times 36}{2} = 1440 \text{ Splits in } 36 \text{ inches} = 1440\text{s Sett.}$$

(f) Scotch Tweed,

$$\frac{80 \times 37}{40} = 74 \text{ Porters in } 37 \text{ inches} = 74\text{s Sett.}$$

(g) Linen 40 in. Scale,

$$\frac{80 \times 40}{2} = 16^{00} \text{ Sett.}$$

(h) Damask—30 in. Scale,

$$\frac{80 \times 30}{40} = 60 \text{ Beers.}$$

The foregoing is best expressed in the following formulæ, which will be found of general application.

Formula XVII. applies to the method of finding the Sett in any required denomination when ends per inch are known, and is as follows:—

$$\frac{\text{Ends per inch} \times \text{standard width in inches}}{\text{Number of threads in Beer, Portie or Split}} = \text{Sett.}$$

If it is required to find the ends per inch, when the Sett is given, then the above formula simply requires to be modified as follows:—

FORMULA XVIII.

$$\frac{\text{Sett} \times \text{No. of threads in Beer, Portie or Split}}{\text{Standard number of inches.}} = \text{Ends per inch.}$$

Example 2.—

18^{50} Sett Glasgow and Linen 40 inch Scale.

12s reed 4s Huddersfield.

Find ends per inch.

(a) Glasgow, $\frac{1850 \times 2}{37} = 100$ ends per inch.

(b) Linen, $\frac{1850 \times 2}{40} = 92\frac{1}{2}$ ends.

(c) Huddersfield, $\frac{12 \times 4}{1} = 48$ ends per inch.

If it is required to change from any given system to another for any purpose whatever, it is only necessary to refer to formula XVII. and XVIII., and apply these to the solving of such problems as above. Since formula XVIII. gives the ends per inch for any given Sett, and formula XVII. supplies the Sett for any known ends per inch, it is only required to multiply formula XVIII. by formula XVII., omitting the ends per inch in formula XVII., thus:—

FORMULA XIX.

applies to the method of changing from any given Sett in any given system to an equivalent Sett in any other system.

$$\frac{\text{Given Sett} \times \text{No. of threads in Beer}}{\text{Standard width in inches}} \times \frac{\text{Standard width in inches}}{\text{Threads in Beer of Sett}} = \text{Required Sett.}$$

Example 3.—Given 1260 Sett Manchester, find its equivalent Sett in Bradford and Belfast.

Then by formula XIX.,

(a) $\frac{1260 \times 2}{36} \times \frac{36}{40} = 63$ Sett Bradford.

PROOF.—1260 splits, 2 in a split $= 2520$ threads in 36 inches. $2520 \div 36 = 70$ threads per inch. And, $70 \div 40 = 1\frac{3}{4}$ Beers per inch.

$\therefore \quad 1\frac{3}{4} \times 36 = 63$ Beers of 40 ends each in 36 ins.

(b) $\dfrac{1260 \times 40}{36} = 14^{00}$ Belfast.

For future and easy reference, all the foregoing details are tabulated and concisely arranged in Table III.

VARIOUS OTHER EXAMPLES.

Example 4.—If a warp containing 2000 ends has to be sleyed 2 ends in a split over a width of 36 inches, what would be the Sett in Scotch Tweed, Huddersfield and Blackburn?

By formula XVII.,

Scotch Tweed $= \dfrac{2000}{36} \times \dfrac{37}{40} = 51\tfrac{7}{18}$s Sett.

Huddersfield $= \dfrac{2000}{36} \times \dfrac{1}{2} = 27\tfrac{7}{9}$s reed 2s Sett.

Blackburn $= \dfrac{2000}{36} \times \dfrac{45}{40} = 62\tfrac{1}{2}$s Sett.

Example 5.—If a warp contains 100 Beers in a width of 60 inches; what is the Sett Bradford?

By formula XVII.,

$\left(\dfrac{100 \times 40}{60}\right) \times \dfrac{36}{40} = 60$s Sett Bradford.

Example 6.—Given a warp 72 Beers to be woven 54/3 Bradford, what is the reed width?

Then $54/3 = \dfrac{54 \times 3}{2} = 81$s Sett Bradford.

and $72 \times 40 =$ total number of threads in warp.

Also $\dfrac{81 \times 40}{36} =$ ends per inch of warp.

$\therefore \quad \dfrac{72 \times 40}{1} \times \dfrac{36}{81 \times 40} = 32$ inches in width.

TABLE III.

VARIOUS SYSTEMS OF COUNTING REEDS AND HEALDS.

		Locality and System.	Standard width in Inches.	No. of threads in 1 Beer, Portie, Porter, etc.	No. of splits in 1 Beer, etc., reckoning 2 ends in each split.	Given ends per inch to find sett, multiply by	Given sett to find ends per inch, multiply by	Given ends per inch to find sett.	Given sett to find ends per inch.
						Ordinary	method,	Short	method.
YORKSHIRE.	1	Bradford ...	36″	40	20	$\frac{36}{40}$	$\frac{40}{36}$	deduct $\frac{1}{10}$	add $\frac{1}{9}$
	2	Leeds ...	9″	38	19	$\frac{9}{38}$	$\frac{38}{9}$		
	3	Hudd'fd. & U.S.A.	1″	Splits	per inch	× ends	in split		
	4	Dewsbury ...	90″	38	19	$\frac{90}{38}$	$\frac{38}{90}$		

								Formula	
LANCASHIRE.	5	Bolton ...	$24\frac{1}{4}''$	40	20	$\frac{24\frac{1}{4}}{40}$	$\frac{40}{24\frac{1}{4}}$		
								add	deduct
	6	Blackburn ...	45″	40	20	$\frac{45}{40}$	$\frac{40}{45}$	$\frac{1}{8}$	$\frac{1}{9}$
	7	Manchester ...	36″	2	No. of Splits in unit width.	$\frac{36}{2}$	$\frac{2}{36}$	× by 18	÷ by 18
	8	Stockport ...	2″	2	1 =	Threads	per	inch.	
SCOTCH.	9	Glasgow ...	37″	2	No. of splits in unit width.	$\frac{37}{2}$	$\frac{2}{37}$		
	10	Tweed ...	37″	40	20	$\frac{37}{40}$	$\frac{40}{37}$		
BELFAST AND NORTH OF IRELAND.	11	Linen, Plain, etc...	40″	2	No. of splits in unit width.	$\frac{40}{2}$	$\frac{2}{40}$	× 20	÷ 20
	12	,, Damask ...	30″	40	20	$\frac{30}{40}$	$\frac{40}{30}$	$\frac{1}{4}$	$\frac{1}{3}$
	13	,, ,, ...	37″	2	20	$\frac{37}{40}$	$\frac{40}{37}$		
	14	,, ,, ...	Ends	per inch	× reed	width.			
	15	Silk	Width of Fabric.	No. of Ends through each split.	No. of splits in total width of piece.	$\frac{\text{Ends per in. x width in inches.}}{\text{No. of ends in each split.}}$	$\frac{\text{Sett x Ends in each split.}}{\text{Width in inches.}}$		

VARIETIES IN FINENESS OR CRAMMED STRIPES.

Example 7.—It is required to make a crammed stripe in a 66 sley Bradford woven,

60 ends of 2/80s cotton, 2 in a split, plain weave.
60 ends of 40/2 spun silk, 5 in a split, sateen weave.
Reed width 29 inches.

Find the number of threads of each sort, the total number of ends in the whole warp, and also the average Sett Bradford.

Then, $\frac{60}{2} = 30$ splits of 2/80s cotton.

and $\frac{60}{5} = 12$ splits of 40/2s spun silk.

Therefore $30 + 12 = 42$ splits in 1 repeat of pattern.

Also, 66 Bradford $= \frac{66}{2} \times \frac{40}{36} = \frac{110}{3}$ splits per inch.

Further, $\frac{110}{3} \times 29$ inches $= \frac{3190}{3}$ splits in total width of reed.

Then (1), $\frac{3190}{3} \times \frac{30}{42} \times \frac{2}{1} = 1520$ ends of cotton.

Also (2), $\frac{3190}{3} \times \frac{12}{42} \times \frac{5}{1} = 1520$ ends of silk.

$\therefore$ (3), $1520 + 1520 = 3040$, total threads in warp.

(4), Then by formula XVII., *page* 123.

$\frac{3040}{29} \times \frac{36}{40} = 94$ average Sett Bradford.

NOTE.—In order to save expense it would be advisable to commence and finish with 60 ends of cotton. This would save one pattern of silk without increasing the total number of ends and would not in any way alter the effect of the cloth.

Calculation of the Mails on each Shaft and Per Inch for Straight and Specially Drafted Patterns.

When the warp threads are drawn through the healds in arithmetical order and similarly repeated, then the calculation is simple, thus—

Example 1.—A 4-end twill pattern has to be woven with 60 threads per inch, what number of mails per inch upon each heald shaft is required? Then, since 4 heald shafts are necessary to weave the 4 shaft twill design, the number of mails per inch upon each heald shaft would necessarily be

$$\frac{60 \text{ (ends per inch)}}{4 \text{ (heald shafts)}} = 15 \text{ mails per inch per shaft.}$$

The total number of mails on each heddle would therefore be the product of the mails per inch and the width of the warp required to be woven.

Example 2.—If for the same Sett a six shaft design was required to be produced, then 6 healds would be necessary, and consequently

$$\frac{60}{6} = 10 \text{ mails per inch per shaft.}$$

Supposing the warp threads have to be drawn through the mails of the healds in any special order for any purpose whatever, then if the number of warp threads drawn through the mails of each heald shaft are not exactly the same in each repeat of the draft, the number of mails per inch upon each heald shaft in the aggregate will bear the same relation to the number of warp threads upon each respective shaft, as is shown in the heald drafting plan, Fig. 1, where the horizontal lines represent the heald shafts; the vertical lines, the warp threads, and the crosses (×) show the order in which they are drawn through the mails of the healds. The total number of threads in each repeat of the draft plan is 18, and the number of mails upon each shaft in one repeat of the draft is respectively 3, 7, 6, and 2, as shown by the figures at the right hand side of the draft.

If now it be assumed that the cloth with which this draft is employed has to contain 90 threads per inch, what number of mails per inch must each shaft contain to suit the above draft.

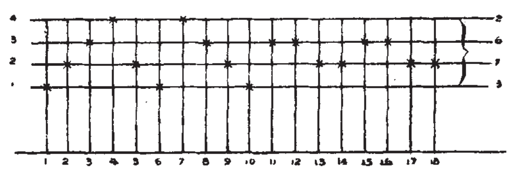


FIG. 1.

Then, since there are 90 threads per inch, and one repeat of the draft contains 18 threads.

$$\therefore \frac{90 \text{ threads}}{18 \text{ threads}} = 5 \text{ repeats of the drafts in 1 inch.}$$

Then the number of repeats of the draft, multiplied by the number of threads upon each shaft in one repeat of the draft, represents respectively the number of mails per inch required upon each shaft, thus:—

1st shaft	...	$5 \times 3 = 15$
2nd shaft	...	$5 \times 7 = 35$
3rd shaft	...	$5 \times 6 = 30$
4th shaft	...	$5 \times 2 = 10$
	Total mails per inch	$= 90$

The foregoing reduced to its simplest form reads thus:—

FORMULA XX.

$$\frac{\text{Ends per inch of cloth} \times \text{ends on each shaft in 1 repeat of draft}}{\text{Number of ends in one repeat of the draft}} = \text{mails per inch on shaft.}$$

Example 3.—If the draft given at Fig. 1 were employed in a 66 Sett Bradford, what number of mails per inch should each shaft then contain?

Ends per inch by formula XVII. $= \frac{66 \times 40}{36} = \frac{220}{3}$

By formula XX.,

$$\text{1st shaft } \frac{220}{3} \times \frac{3}{18} = 12\tfrac{2}{9}$$

$$\text{2nd shaft } \frac{220}{3} \times \frac{7}{18} = 28\tfrac{14}{27}$$

$$\text{3rd shaft } \frac{220}{3} \times \frac{6}{18} = 24\tfrac{4}{9}$$

$$\text{4th shaft } \frac{220}{3} \times \frac{2}{18} = 8\tfrac{4}{27}$$

$$\text{Total mails per inch} = 73\tfrac{1}{3}$$

SPECIALLY KNITTED (SPACED) HEDDLES.

For striped and drafted patterns including crammed stripes where the pattern is set finer in some parts than in others it is better to knit the healds to suit the design. The advantage of this is to reduce any friction upon the warp caused by the mail cords being drawn more to one side than the other.

When this plan is adopted the finest sett on one or more heddles of the same fineness is taken as the pitch at which the knitting machine is made to knit the healds. All the remaining heddles are then knitted to this same rate according to their relative fineness and spaced as indicated by the requisite drafted pattern. Without entering into the details of the construction of the heald knitting machine, suffice it to say that it is usually constructed to automatically knit or miss, at will, any cord or number of cords in succession on each shaft. It is usual to base the *rate* of knitting on 4 shafts for the finest count of heald in the sett.

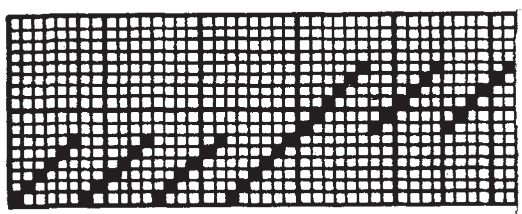


Fig. 2.

Example 4.—Given the spaced draft at Fig. 2, find the rate and order of knitting for 72 ends per inch. Then the fineness of the sett in each successive group of threads on the front six and back six heddles must be equal to 72 threads per inch to coincide with the reed and fineness of fabric required.

The rate of knitting on 4 heddles will therefore be in direct ratio of 6 to 4, thus :—

As 6 heddles : 4 heddles : : 72 sett : 48 sett or knitting rate on 4 shafts.

The healds would then require to be knitted as follows :—

Heddles 1 to 6 knit 4 and miss 3.

" 7 to 12 " 3 " 4.

Example 5.—Given draft as at Fig. 3 for a cloth containing 48 threads per inch. Find the knitting rate and the order of knitting so as to properly space the mails on each shaft.

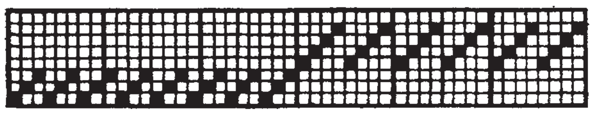


Fig. 3.

Then since the heddles must contain 48 mails per inch *pro rata* for the first 3 and the back 4 heddles :—

Rate for heddles 1, 2 and 3 = $\frac{48 \times 4}{3} = 64$,

and ,, ,, 4, 5, 6 and 7 = $\frac{48 \times 4}{4} = 48$.

Also for heddles 1, 2 and 3, knit 8 miss 8—Rate 64,
and ,, ,, 4, 5, 6 and 7, ,, 6 ,, 6— ,, 48.

Without multiplying examples, the principle is the same for all spaced and drafted patterns required to be knitted to pattern.

EXERCISES.

A and B.

1. A cloth has to be woven in 90s Sett Bradford 4 threads through each split; how many splits per inch must the reed contain?

Ans., 25.

2. A cotton fabric is woven 3 threads in a dent, 42 inches wide, and contains 2520 ends. What is the Sett Blackburn, and how many dents per inch does the reed contain?

Ans., 20 splits; $67\frac{1}{2}$ Sett.

3. A reed contains 1320 splits in 33 inches. (a) What is the Sett Bradford, 2 in a split; (b) Linen system 40″ scale?

Ans., 72; 16^{00}.

4. A worsted warp which contains 2346 threads has to be woven in a 64/2 Sett Bradford. What width should it be in the reed?

Ans., 33 inches.

5. Reduce 80 Sett Bradford to Blackburn, Scotch Tweed, and Stockport Systems.

Ans., 100; $82\frac{2}{9}$; $88\frac{8}{9}$, respectively.

6. A warp contains 2102 ends and must be woven in a 55/2 Sett Blackburn, what is the width in the reed and the splits per inch?

Ans., 43; $24\frac{4}{9}$.

7. A woollen warp. 1520 ends, has to be woven 72 inches wide, what is the Sett Leeds?

Ans., 5.

8. Find the equivalent of 24/3 Scotch Tweed in Dewsbury, Leeds, and Huddersfield, 2 in a split.

Ans., 92; 9·2; $19\frac{1}{2}$s reed 2s.

9. A woollen warp contains 76 Porties Dewsbury. It has to be sleyed in a 95 Sett Dewsbury. What is the reed width?

Ans., 72 inches.

10. Reduce 20^{50} Glasgow to Manchester, Bolton, Stockport, and Belfast 40″ scale.

Ans., 1994; 67; 111; 2216, respectively.

11. Given 120 threads per inch, find the Sett Bradford, Huddersfield (4 in a dent), Dewsbury, and Scotch Tweed.

Ans., 108; 30/4; 284; 111.

12. If a 40 Porter Sett, Scotch tweed or linen damask, 37″ scale, contains 1644 threads, what is the width in the reed?

Ans., 38 inches.

13. A woollen warp contains 5760 threads. It is required to be set 72 inches wide in the reed. What is the Sett Leeds, Bradford, and Huddersfield, 4 in a split?

Ans., $18\frac{18}{19}$; 72; 20/4.

14. A pattern has to be drafted on to five heald shafts. The number of ends upon each shaft in one repeat of the draft is respectively, 6, 7, 8, 9, 5. What number of mails per inch are required, if the pattern has to be 90s Sett Bradford and 20^{00} Belfast?

Ans., $17\frac{1}{7}$; 20; $22\frac{6}{7}$; $25\frac{5}{7}$; $14\frac{2}{7}$.

15. A warp contains 2275 threads, and is required to be woven in 64 Sett Bradford, what is the width in the reed?

Ans., 32 inches.

16. If a warp is set 66 inches in the reed and woven 88 Sett Bradford, what is the total number of ends in the warp?

Ans., 6453.

17. If the draft specified in question 14 had to be woven in 100 Sett Blackburn, how many mails per inch would each shaft require?

Ans., $15\frac{15}{63}$: $17\frac{49}{63}$; $20\frac{20}{63}$; $22\frac{54}{63}$; $12\frac{44}{63}$.

18. A linen warp containing 3300 ends is required to be woven in 20^{00}, 40 inch scale find the reed width; also find the No. of splits in 37″ scale if a warp with 2660 ends is woven 41 inches in the reed.

Ans., 33″; 12^{00}.

19. Assume a 3 end drill is woven 3 in a dent, in a 12^{00} reed, 40 inch scale, find (a) the ends per inch; (b) the total number of ends and (c) the sett for the usual scale. *Ans.*, 90; 3600; 18^{00}.

20. Find the number of mails per inch for draft supplied at Figs. 2 and 3, with 72 and 48 ends per inch respectively.

Ans., $6\frac{6}{7}$ and $5\frac{1}{7}$; 8 and 6.

21. Given 60 beer damask on 30 inches find its equivalent in the plain linen scale on 40 inches and the No. of Porters, Scotch, on 37″ scale.

Ans., 16^{00}; 74.

22. Given 15^{00} sett on 40″ and 37″ scales respectively allow 5% for shrinkage in each case and find the ends per inch in cloth.

Ans., 78·5; 85·3.

C

23. If a striped cloth is made in a 60/2 sley Bradford, having 40 ends, 2 in a dent (plain weave), 80 ends 4 in a dent (broken sateen), reed width $28\frac{1}{2}$ inches, state what number of ends would be required, and what would be the Sett of the healds.

Ans., 2850; 90.

24. A figured pattern, of which one repeat occupies 5 inches, is made as follows:—The first inch contains 5 ends in each dent, the remaining 4 inches have only 2 threads through each dent, the width of the fabric in the reed is 30 inches, and the total number of ends is 2400. Find (1) the average Sett of the healds, (2) the sley, (3) the Sett of the finer portion of the stripe, and (4) the coarser portion, all in the Bradford system.

Ans., 72; $55\frac{5}{13}$; $138\frac{6}{13}$; $55\frac{5}{13}$, respectively.

25. A cotton cloth is made in which the warp contains 3328 ends, it is set 40 inches wide in the reed, and dented as given below. Find the average number of splits per inch of the reed.

30 ends, 2 in a split
20 ends, 1 in a split
12 ends, 2 in a split
Miss one split.
12 ends, 2 in a split — Repeat 58 times.
Miss one split.
12 ends, 2 in a split
20 ends, 1 in a split
30 ends, 2 in a split

Ans., $59\frac{1}{4}$.

CHAPTER VII.

Quantities and Weight of Warp and Weft in Plain and Fancy Fabrics.

To the spinner and manufacturer, calculations under this heading are among the most useful and necessary. The method of solution will be best demonstrated by a consideration of the following examples :—

Example 1.—Find the weight of a warp 75 yards long, made from 2/36s Botany and woven 18s reed 4s in a 66 inch reed.

Then, the total length in yards divided by the number of yards per lb. represents the total weight in lbs., which is simply a modification of formula I., thus :—

Formula XXI.—Weight of Warp.

$$\frac{\text{The No. of threads per inch} \times \text{inches wide} \times \text{length of warp}}{\text{Yards per lb.}} = \text{weight in lbs.}$$

$$= \frac{72 \times 66 \times 75}{(18 \times 560) \text{ yds. per lb.}} = 35\tfrac{5}{14} \text{ lbs.}$$

Example 2.—Find the weight of weft required to weave a piece 63 yards long, 64 inches wide in the reed, made from 70 yards of warp and containing 84 picks per inch of 1/16s worsted ; add 5% to the actual weight of weft put into the cloth to cover the waste in weaving.

Then, the number of picks per inch × number of inches wide equals the number of yards of weft in 1 yard of cloth. And this number of yards × the length of cloth in yards equals the total number of yards actually put into the cloth. Thus,

$$\frac{\text{Picks per inch} \times \text{width in reed} \times \text{length of piece out of loom}}{\text{Yards per lb. of weft}} = \text{actual weight of weft in cloth.}$$

To the above must be added the allowance made for waste in weaving, but a better method is to treat the waste as part of the original problem, and state it thus:—

FORMULA XXII.

$$\frac{\text{Pks. per inch} \times \text{reed width} \times \text{piece length grey} \times (100 + \%\ \text{for waste})}{\text{Yards per lb. of weft} \times 100} = \text{weight of weft to be purchased.}$$

Then by Formula XXII.,

$$\frac{84 \times 64 \times 63 \times 105}{16 \times 560 \times 100} = 39 \cdot 7 \text{ lbs.}$$

Very frequently the length of the warp is taken instead of the piece length, the difference in length being considered sufficient to cover the extra cost for waste of weft during weaving, and preferable to adding a certain percentage to the actual weight of the weft put into the piece.

Example 3.—A piece is woven from 65 yards of warp, 2/48s Botany, 54 Sett Bradford, 64 inch reed, 56 picks per inch, 1/24s Botany. Find the weight of warp and weft required. The length of warp to be taken to cover the waste of weft in weaving.

The weight of warp equals, by formula XXI.,

$$\frac{54 \times 40}{36} \times \frac{64 \times 65}{24 \times 560} = 18\tfrac{4}{7} \text{ lbs.}$$

And the weight of weft, substituting picks for ends per inch of the same formula, equals

$$\frac{56 \times 64 \times 65}{24 \times 560} = 17\tfrac{1}{3} \text{ lbs.}$$

Quantitative Calculations for Linen Warp and Weft.

Example 4.—Given a 40's lea warp and weft woven in 12^{00} reed, 40 inch scale, 40 inch reed width, laid 85 yards with 12 shots of weft to 37 inch glass, producing 75 yards of cloth. Find the quantities in bundles and weight of warp and weft. Add 5% for loss of weight in warp and weft.

Warp.—(1) The number of bundles

$$= \frac{\text{Total ends in warp} \times \text{length in yds.}}{\text{Yards per bundle}} + \%\text{ for waste, etc.}$$

$$= \frac{1200 \times 2 \times 85}{60{,}000} \times \frac{105}{100} = 3\cdot57 \text{ bundles or 3 bdles, 9 hanks, 6 cuts.}$$

(2) The weight of warp

$$= \frac{\text{Sett} \times \text{reed width}}{\text{Scale of reed}} \times \frac{\text{Length of warp in yds.}}{\text{Yds. per lb. of yarn}} + \%\text{ of waste, etc}$$

$$= \frac{2 \times 1200 \times 40}{40} \times \frac{85}{300 \times 40} \times \frac{105}{100} = 17 \text{ lbs. } 13\tfrac{3}{5} \text{ ozs.}$$

$$\text{or } \frac{3\cdot57 \text{ bundles} \times 200}{40} = 17\cdot85 \text{ lbs.}$$

Before attempting to determine the quantity or weight of weft required for any given web, it is first necessary to understand the method of counting the shots or picks of weft put into the fabric. In the linen trade the mode of reckoning is frequently based upon the number of shots under a 37″ glass, The unit distance covered by this measure or glass is $\frac{37}{200}$ part of one inch (0·185)″, consequently the number of shots of weft under a 37″ glass multiplied by 200 gives the number of shots in 37″ of linen fabric. And since 37 inches are frequently measured to each yard of cloth it therefore represents the number of picks per yard 37″ measure which if multiplied by the length of the web gives the total number of shots in the web and this number multiplied by the reed width in inches and divided by 36 (inches in 1 yd.) equals the total length in yards of the weft in the complete web. Consequently if this length be divided by the number of yards per bundle or lb., the quotient equals the length in bundles or weight in lbs. respectively of the weft in the whole web, to which must be added the amount allowed for waste.

NOTE.—This measurement, which is empirical, corresponds to the gauge measure used for counting reeds on the 37 inch scale. The number of splits covered by this gauge multiplied by 200 represents the number of splits in 37 inches and conversely the sett or number of splits on 37″ divided by 200 gives the number of splits under a 37 inch glass, *e.g.*, if the sett is 12^{00} on 37 inch, then $1200 \div 200 = 6$ splits under 37 inch glass or 6 splits $\times$ 200 = 1200 sett on 37 inches.

It is probable that the method detailed above for counting the shots of weft has been derived from this system of testing reeds.

The foregoing may be simplified and expressed as follows:—

Formula for finding the quantity of weft in a web of 37″ measure for 37″ glass.

$$\text{a.} = \frac{\text{Shots per glass} \times 200 \times \text{length of web} \times \text{reed width}}{\text{Yards per bundle} \times 36'' \text{ per yard}} = \text{bundles}$$

$$\text{Plus waste} = \text{bundles} \times \frac{100 + \%\ \text{waste.}}{100}$$

$$\text{b.} = \frac{\text{Shots per glass} \times 200 \times \text{reed width} \times \text{length}}{\text{Yards per lb.} \times 36'' \text{ per yard}} = \text{weight in lbs.}$$

or $\dfrac{\text{Number of bundles} \times \text{cuts per bundle}}{\text{Cuts per lb.}} = \text{weight in lbs.}$

NOTE.—If the cloth is measured 36″ to the yard then the formula would read.

$a^1 \dfrac{\text{Shots per glass} \times 200 \times \text{reed width} \times \text{length}}{37 \times \text{yards per bundle}} = \text{No of bundles.}$

Plus waste = bundles $\times \dfrac{100 + \%}{100}$

$b^1 \dfrac{\text{Shots per glass} \times 200 \times \text{reed width} \times \text{length}}{37 \times \text{yards per lb.}} = \text{weight in lbs.}$

Then applying the foregoing formula the quantity and weight of weft would be :—

(1) $\dfrac{12 \times 200 \times 75 \times 40}{60{,}000 \times 36} = 3\tfrac{1}{3}$ bundles.

Plus waste $= \dfrac{10}{3} \times \dfrac{105}{100} = 3\tfrac{1}{2}$ bundles.

(2) $\therefore$ Weight in lbs. $= \dfrac{7}{2} \times \dfrac{200}{40} = 17\tfrac{1}{2}$ lbs. including waste.

or $\dfrac{12 \times 200 \times 40 \times 75 \times 105}{300 \times 40 \times 36 \times 100} = 17\tfrac{1}{2}$ lbs.

RELATIVE QUANTITIES AND WEIGHT OF WARP AND WEFT IN FANCY WOVEN FABRICS.

In the production of fancy woven fabrics, in which there are several colours or different sorts of warp and weft introduced, it is essential to ascertain the weight of each sort of warp and weft, and in the case of the warp the respective number of ends of each colour and sorts, so that the several warps can be ordered and made to the required number of ends.

The method of determining these factors will be best understood by a consideration of the following examples.

Example 1.—A 2/36 worsted warp containing 2880 ends is 70 yards long, and warped to pattern as follows :—

$$\left.\begin{array}{l}\text{2 threads dark brown}\\ \text{2 threads dark blue}\end{array}\right\}\ \text{16 threads.}$$
$$\left.\begin{array}{l}\text{2 threads dark brown}\\ \text{2 threads slate}\end{array}\right\}\ \text{8 threads.}$$

24 threads in each repeat of the pattern.

Then it is evident that

$$\frac{\text{Total number of ends in warp}}{\text{Threads in 1 repeat of pattern}} = \text{No. of repeats of pattern in warp,}$$

and, number of repeats $\times$ ends in each repeat of any colour $=$ number of ends of given colour.

FORMULA XXIII.

$$\frac{\text{Total No. of threads in warp} \times \text{threads in each repeat of any colour}}{\text{Total number of threads in one repeat of pattern}}$$
$$= \text{the number of threads of colour in warp.}$$

Then, since there are

12 threads of dark brown in each repeat of pattern
and 8 ,, dark blue ,, ,, ,,
and 4 ,, slate ,, ,, ,,

(1) Dark brown $= \dfrac{2880 \times 12}{24} = 1440$ ends.

(2) Dark blue $= \dfrac{2880 \times 8}{24} = 960$ ends.

(3) Slate $= \dfrac{2880 \times 4}{24} = 480$ ends.

The weight of each sort may be found by the ordinary method thus :—

(1) Dark brown $= \dfrac{1440 \times 70}{560 \times 18} = 10$ lbs.

(2) Dark blue $= \dfrac{960 \times 70}{560 \times 18} = 6\frac{2}{3}$ lbs.

(3) Slate $= \dfrac{480 \times 70}{560 \times 18} = 3\frac{1}{3}$ lbs.

Example 2.—

A fancy worsted is warped and woven

$$\left.\begin{array}{l}\text{3 threads dark steel}\\ \text{1 thread light steel}\\ \text{1 thread dark steel}\\ \text{3 threads light steel}\end{array}\right\}\ \text{40 threads.}$$

$$\left.\begin{array}{l}\text{2 threads dark steel}\\ \text{1 thread light steel}\\ \text{1 thread dark steel}\\ \text{1 thread light steel}\\ \text{1 thread dark steel}\\ \text{2 threads light steel}\end{array}\right\}\ \text{48 threads.}$$

88 threads in each repeat of the pattern.

If the Sett is 19s reed 4s and 64″ wide, 70 yards of warp of 30s Y. S. woollen, find the number of ends of warp and weight of each colour of warp and weft. The length of warp to be taken to cover the waste of weft when calculating the weight of weft, 72 picks per inch of 30 skeins woollen.

In each repeat of the pattern it will be noted that there are 44 threads each of the dark and light steel.

Then 19s reed 4s = 76 threads.

and 76×64 = total number of threads in warp.

$\therefore$ By formula XXIII.,

$$\frac{76 \times 64 \times 44}{88} = 2432 \text{ threads of dark steel.}$$

do. = 2432 ,, light ,,

Then weight of dark steel =

$$\frac{2432 \times 70}{30 \times 256} = 22\tfrac{1}{6} \text{ lbs.}$$

and weight of light steel $= 22\frac{1}{6}$ lbs.

Total $= 44\frac{1}{3}$ lbs. of warp.

Weight of dark colour of weft.

$$= \frac{72 \times 64 \times 70 \times 44}{30 \times 256 \times 88} = 21 \text{ lbs.}$$

and weight of light colour of weft $= \underline{21 \text{ lbs.}}$

Total $= 42$ lbs. of weft.

Example 3.—A vesting fabric is made to the following particulars:—

Face warp 2/48s black worsted.
Back ,, 2/48s black cotton.
,, ,, 2/48s light green worsted.
,, ,, 24/2 spun silk, red.

The red silk and light green worsted are used in place of the cotton threads at the back of the cloth, and brought to the face for spotting effects where required.

Face weft 2/44 black worsted.
Back ,, 2/48 black cotton.
Reed width 62 inches, length of warp 70 yards.

Length of cloth grey 66 yards, add 5% for waste of weft in weaving. Find the weight of each sort of warp and weft, and the number of threads of each colour of back warp. The texture is warped and woven one end and pick of warp and weft respectively. The order of the backing warp is as follows:—

1 thread of black cotton
2 threads of red silk
7 threads of black cotton
3 threads of light green worsted
2 threads of red silk
3 threads of light green worsted
6 threads of black cotton

24 threads in each repeat of backing warp.

SUMMARY—

14 threads of black cotton
4 threads of red silk
6 threads of light green worsted

24 threads.

Then, since the warp and weft threads are end and end and pick and pick respectively, and since there are 112 ends and 96 picks per inch respectively, the number of ends and picks of face and back are 56 and 48 respectively.

(1) Then the number of ends of face

$$= 56 \times 62 = 3472$$

(2) The weight of face warp

$$= \frac{56 \times 62 \times 70}{24 \times 560} = 18\tfrac{1}{12} \text{ lbs.}$$

In this example it is better to find the number of patterns or repeats in the full width of the warp, then to multiply the complete number of repeats by the number of ends in each repeat of the pattern, and add the number of ends of each respective colour in the last fraction of a repeat. If the pattern is very large, it is sometimes possible to arrange the beginning and ending of the warping plan so as to save a relative number of the more expensive threads without in any way deteriorating the effect of the cloth.

$$\frac{3472}{24} = 144 \text{ repeats plus 16 threads.}$$

(3) The number of ends of black cotton,

$$= 144 \times 14 + 8 = \quad 2024$$

(4) Of red silk,

$$= 144 \times 4 + 4 = \quad 580$$

(5) Of light green worsted,

$= 144 \times 6 + 4 = \qquad 868$

Total number of backing threads $= 3472$

(6) Weight of 2/48s black backing cotton

$$= \frac{2024 \times 70}{24 \times 840} = 7 \text{ lbs.}$$

(7) Of 24/2 spun silk, red—(back)

$$= \frac{580 \times 70}{24 \times 840} = 2 \text{ lbs.}$$

(8) Of 2/48s light green worsted (back)

$$= \frac{868 \times 70}{24 \times 560} = 4\tfrac{1}{2} \text{ lbs.}$$

(9) Weight of face weft

$$= \frac{48 \times 62 \times 66}{24 \times 560} \times \frac{105}{100} = 15\tfrac{1}{3} \text{ lbs.}$$

(10) Weight of back weft

$$= \frac{48 \times 62 \times 66}{24 \times 840} \times \frac{105}{100} = 10\tfrac{1}{4} \text{ lbs.}$$

Example 4.—Given the order as below for a striped pattern, 40s linen warp, show how the warp must be put on 4 warping beams so that the pattern will be in regular order on the dressing machine and weaver's beam. Also give the number of threads and weight of each colour of warp when the length is 360 yards and to be woven in a 12^{00} reed.

(1) The following table, reading down each column, is summarised as follows :—

Warper's beam 1 and 2; 3 ends white, 4 ends red, 1 white.

" " 3 and 4; 1 white 1 blk. 1 white 1 red 1 blue 1 red 1 white 1 blk.

NOTE.—The warp beams must always be arranged in the same order as the draft so as to correspond with it.

PATTERN.	WARP BEAM NUMBER.			
	2	4	3	1 Linen draft
	1	2	3	4 Straight ,,
6 ends white	2	2	1	1
2 ,, black			1	1
4 ,, white	1	1	1	1
6 ,, red	2	2	1	1
2 ,, blue			1	1
6 ,, red	2	2	1	1
4 ,, white .. {			1	1
	1	1		
2 ,, black			1	1
32 threads in repeat =	8 +	8 +	8 +	8

(2) No. of threads of each colour of warp =

(a) White, $\dfrac{2400 \text{ ends in warp} \times (14 \text{ ends of white in 1 repeat})}{32 \text{ ends of white warp in 1 repeat}} = 1050$

(b) Black, $\dfrac{2400 \times (4 \text{ ends in 1 repeat})}{32} = 300$

(c) Red. $\dfrac{2400 \times (12 \text{ ends in 1 repeat})}{32} = 900$

(d) Blue, $\dfrac{2400 \times (2 \text{ ends in 1 repeat})}{32} = 150$

2400

(3) (a) Weight of white warp $= \dfrac{1050 \times 360}{40 \times 300} = 31{\cdot}5$ lbs.

(b) ,, black ,, $= \dfrac{300 \times 360}{40 \times 300} = 9$,,

(c) ,, red ,, $= \dfrac{900 \times 360}{40 \times 300} = 27$,,

(d) Weight of blue warp $= \dfrac{150 \times 360}{40 \times 300} = 4{\cdot}5$ lbs.

Total weight of warp $= 72$ lbs.

When the colour scheme is of large repeat it will be found more convenient and expeditious to write out the warping and weaving plan something after the following order, since the summary of threads of each colour may be much easier obtained than by the ordinary and previous arrangements.

Example 5.—A Tartan is made from 2/24s worsted warp and weft 12s reed 4s and 44 picks per inch. Width in reed is 32 inches exclusive of edges. The length of warp to cover the waste of weft in weaving. The order of warping and wefting is as given below. Find the number of ends of each colour of warp and the weight of each colour of warp and weft.

Shade.	Threads of each colour in one repeat.	
Black,	8, 4, 16, 4, 4, 4, 4, 16, 4, 16, 4, 4, 8	= 96
Light green,	16. 16, 16, 16	= 64
Navy blue,	4 4, 16, 4, 4. 16, 4, 16	= 68
	Total number of threads in each repeat	= 228

Then,

(1) The total number of threads in warp exclusive of edges $= 32 \times 48 = 1536$.

(2) The number of repeats of pattern in full width of piece $= \dfrac{1536}{228} = 6$ repeats of pattern $+ 168$ ends.

And to find the number of threads of each colour in the remaining portion of pattern, the designer should then mark off the portion of repeat of pattern (168 threads and afterwards total up the number of threads of each colour in this portion of repeat of pattern. These threads can then be added to their respective colours of warp as below :—

(3) Then the No. of ends of black $= 6$ repeats of pattern $+ 72$ ends
$= (96 \times 6) + 72 =$ 648

(4) ,, ,, light green $= 7$ repeats of pattern
$= 64 \times 7 =$ 448

(5) ,, ,, navy blue $= 6$ repeats of pattern $+ 32$ ends
$= (68 \times 6) + 32 =$ 440

Total number of ends in warp $= 1536$

In patterns of large repeat it is frequently advisable to commence the colour scheme so that each side of the piece will be as much alike as possible. In this example, the pattern has purposely been started with 8 threads of black and finished with the same number and colour of threads, in addition to which, it should be noted that the other colours on the opposite sides of the cloth also balance each other.

Then the weight of the respective colours of warp and weft are :—

(6) Black warp $= \dfrac{648 \times 70}{560 \times 12} = 6\frac{3}{4}$ lbs.

(7) Light green warp $= \dfrac{448 \times 70}{560 \times 12} = 4\frac{2}{3}$ lbs.

(8) Navy blue warp $= \dfrac{440 \times 70}{560 \times 12} = 4\frac{7}{12}$ lbs.

The weight of each colour of weft may be found separately as before, or the total weight can be first obtained and then the proportions of weight determined by the ratio of picks of each colour to the total number of picks in each repeat, thus :—

(9) The total weight of weft including lists $(32 + 1)$ 33 inches

$$= \frac{44 \times 33 \times 70}{560 \times 20} = 9 \text{ lbs.}$$

(10) Weight of black weft $= \dfrac{9 \times 96}{228} = 3 \cdot 8$ lbs.

(11) ,, light green ,, $= \dfrac{9 \times 64}{228} = 2 \cdot 5$ lbs.

(12) ,, navy blue ,, $= \dfrac{9 \times 68}{228} = 2 \cdot 7$ lbs.

Total 9 lbs.

EXERCISES.

A

1. A dyed woollen cloth is made from 2/32 Y. S. warp 16 reed 3s, 70 inches wide, 15 skeins woollen weft, 44 picks per inch; length of warp, 80 yards; piece out of loom, 72 yards; allow 5% for waste of weft in weaving. Find the weight of warp and weft.

Ans., $65\frac{5}{8}$; $60\frac{5}{8}$.

2. A Union Coating is made from 70 yards of warp of 2/30s cotton, 72 Sett Bradford; 68 inches reed width; 88 picks per inch of 1/36s Botany weft; length of piece out of loom, 68 yards. Required the weight of warp and weft. Add 5% to cover waste of weft.

Ans., $30\frac{2}{9}$, $21\frac{1}{5}$.

3. A cotton cloth is made from 80 yards of warp of 2/80s cotton, 40 inches wide in the reed; 75 Sett Blackburn; 15 picks per $\frac{1}{4}$ inch of 1/40s cotton. What weight of warp and weft is required exclusive of any sizing substance. 5% to be added to the weight of weft to cover waste; length of piece 75 yards.

Ans., [illegible]$\frac{7}{20}$; $5\frac{5}{8}$.

4. There are in stock 13 lbs. of 20 skeins woollen. What number of ends of warp will this weight make if the warp has to be 65 yards long? *Ans.*, 1024.

5. Given 540 hanks of 20s worsted, it is required to weave this lot up with a warp 64 inches wide, and the cloth is to contain 75 picks per inch. What length of piece will this number of hanks produce, exclusive of any loss of waste in weaving.

Ans., 63.

6. Given 50 lbs. of 40s twist cotton. A warp is required to contain 2080 ends. What will be the length of the warp after allowing 5% for waste in working up.

Ans., $767\frac{4}{13}$.

7. 120 hanks of worsted have to be woven into a cloth 40 yards long. The width in the reed is 32 inches. What number of picks per inch will the cloth contain ?

Ans., $52\frac{1}{2}$.

8. The length of a warp is 70 yards; length of piece 60 yds.; reed width 63 inches; 64 ends 2/48s worsted; 64 picks per inch of 20s worsted. Find the weight of warp and weft; add 5% to weight of weft for waste in weaving.

Ans., 21 ; $22\frac{17}{25}$.

B

9. A Scotch Tweed double cloth is produced from 34 cut warp, and 33 cut weft (Gala.). The cloth is woven with 84 ends and picks per inch, 68 inches reed width. The length of warp is 80 yards, and that of the piece 70 yards. Add 5% for waste of weft in weaving. Find the respective number of ends of warp and weight of each colour of warp and weft when the warping and weaving scheme of colouring is as given herewith.

8	threads	dark brown	for 72 threads.
2	,,	white	
2	,,	brown and white	
4	,,	dark brown	for 24 threads.
4	,,	white	
4	,,	brown and white twist	
4	,,	dark brown	
4	,,	white	
2	,,	brown and white twist	
2	,,	red and white twist	
4	,,	dark brown	60 threads.
4	,,	white	
4	,,	brown and white twist	

Ans., 5712; 67·2; 63·6.

10. A worsted costume cloth is made from 2/36s warp and weft. It contains 44 ends of warp and 40 picks per inch. Length of warp 70 yards; width in reed 64 inches; length of piece 63 yards; warped and woven as follows:—

2	threads	black
1	thread	white
1	,,	black
2	threads	white
1	thread	black
1	,,	white

Find the weight of each colour of warp and weft, and the ends of each colour of warp.

Ans., $9\frac{7}{9}$ lbs. of each warp; 8 lbs. of each weft; 1408 ends each.

11. A heavy fancy worsted is composed of 2/28 worsted warp and weft. It contains 92 ends and 84 picks per inch; reed width 66 inches. Length of warp 75 yards, which length is to be also taken to cover the waste of weft in weaving. Find the number of ends of each colour of warp, and weight, together with the

respective weights of warps and wefts, when the warp and weft plan is as follows :—

16	threads	dark	smoke	for 128 threads.
16	,,	light	,,	
12	,,	dark	,,	for 96 threads.
12	,,	light	,,	

Ans., 6072 ; 58 ; 53.

12. What counts of cotton weft will be required in the production of the following cloth ? Weight of piece (70 yards) including 100% of sizing material, is $16\frac{1}{2}$ lbs. Warp 1/34s cotton ; 75 yards of warp ; 48 ends per inch ; 38 inches wide, and 40 picks of weft per inch.

Ans., $36\frac{3}{5}$.

13. A warp is required to be made of two threads of 2/60s worsted to one thread of 2/40s worsted. Length of warp 300 yards, weight of material 50 lbs. What number of ends and what weight of each sort will be required ?

Ans., 1600 ; 800 ; $28\frac{4}{7}$; $21\frac{3}{7}$.

14. Find the amount of linen and cotton in bundles and lbs. respectively in a web of checked glass cloth 24″ wide, 90 yards long (36″) made in 10^{00} reed on 40″ scale—12 shots to 37″ glass of 35s lea weft. Allow 10% for shrinkage in length and 5% shrinkage in width. The cotton is 2/24s.

Warp pattern 40 threads of linen, 2 threads of cotton.
Weft ,, 50 ,, ,, 2 ,, ,,

Ans., 4·36 bundles ; 1·15 lbs.

15. Given a union cloth of which the warp is 200 yards long producing 176 yds. of cloth (37″ per yd.) 36 inches wide, 40 inch reed space. Warp 60s cotton

made in 600 reed 40″ scale and woven 4 shots to 37″ glass. Find the lea of the weft, when the weight of warp and weft are equal.

Ans., 108·9.

16. Find the number of bundles of weft that would be required to make 12 pieces with 18 shots of weft on 37″ glass. Width of warp in reed 39″; length of each web per 37″ yard equals 70 yards.

Ans., 54 bundles; 120 cuts.

17. A union is made from 32s cotton warp laid 100 yards and in a 12^{00} reed, 40″ scale 30 inches in the reed 13 shots on 37″ glass of 50s lea yarn. Find the total weight of the warp and weft, if 90 yds. of 36″ cloth is produced.

Ans., 6 lbs. 11 ozs.; 12 lbs. 10 ozs.

18. Find the quantity of yarn in bundles required to make 4 webs of 12/14 (12^{00} reed × 14 shots) warp laid 80 yards. Reed width 40 inches, 40″ scale and 37″ glass, length of 37″ web is 72 yards. Add $2\frac{1}{2}\%$ to warp and 5% to weft to cover waste in preparation and weaving.

Ans., 7·2.

19. Given 12^{00} reed, 37″ scale, how many warp threads should be laid over 40″ reed and how many bundles of lea yarn would be required to produce 90 yards of warp?

Ans., 2595; 3·8925.

C

20. A vicuna cloth is composed of 2/48s worsted warp for face and back. Face weft 1/24s worsted, back weft 20 skeins woollen, woven 2 ends and picks of face to 1 end and pick of back. 16s reed 6s; 75 inches reed width; finished 56 inches; 96 picks per

inch; face warp 66 yards; back warp 73 yards; 63 yards out of loom; allow 5% for waste of weft in weaving. Find weight of each warp and weft.

Ans., $23\frac{4}{7}$; $23\frac{5}{8}$; $13\frac{1}{28}$; 31.

21. A cotton tapestry is made of 1 thread 3/2/30 cotton, and 1 thread 2/100 cotton; 30s reed 2s; 60 inches reed width; length of thick warp 70 yards, of fine warp 90 yards; length of piece 65 yards.

Weft 1 pick	2/30s	cotton		72 picks per inch.
1 ,,	1/4s	,,	soft twist dark green	
1 ,,	1/4s	,,	,, light ,,	

Add 5% for waste of weft in weaving. Supply the weight and number of ends of each sort of warp, and weight of each kind of weft.

Ans., 30; $3\frac{6}{7}$; 1800; $7\frac{4}{5}$; $29\frac{1}{4}$.

22. A warp is required to weigh 35 lbs. and contain 1800 ends. There must be 2 threads of 2/48s cotton to 1 thread of 2/24s worsted. What weight of each sort will be required, and what will be the length of the warp? *Ans.*, 14; 21; 235·2.

23. A double cloth is composed of 2 ends and picks of face to 1 end and pick of back. It is made from 2/28s worsted, and 16 skeins woollen; length of warp 70 yards; reed width 64 inches; 72 ends and 68 picks per inch; length of piece out of loom, 63 yards. The warping and wefting plan is as follows:—

4 threads black 4 threads slate	24 threads	Face.
2 threads black 2 threads slate	24 threads	
2 threads black 2 threads slate	12 threads	Back.
1 thread black 1 thread slate	12 threads	

Find the number of ends of each colour of warp, and weight of each sort and shade of warp and weft. Add 5% to weight of weft for waste in weaving.

Ans., 3072; $27\frac{3}{7}$; $24\frac{1}{2}$; 1536; $26\frac{1}{4}$; $23\frac{2}{5}$.

24. The weight of a warp is 49 lbs.; it must contain 60 ends of worsted for face, and 30 ends of cotton for back; width in reed 63 inches; length of face warp to be 120 yards, and that of back warp 108 yards. The relative weight of the former to the latter is as 4 to 3. Find the counts of each warp.

Ans., 29; $11\frac{4}{7}$.

NOTE.—In all questions warped and woven to pattern, the answers are only given for the TOTAL number of ends and weights of warp and weft, which totals, the SUM of the respective proportions should equal.

CHAPTER VIII.

THE WEIGHT AND COST OF WOVEN FABRICS.

In the production of woven textures, the actual cost must as far as possible be determined in order that the manufacturer may know at what price his production can be sold so as to leave a working profit.

In the buying and selling of fabrics, the quality, width, price and weight per yard are usually specified. To arrive at the actual cost and weight per yard, a consideration of the following particulars is involved.

(1) The weight and cost of warp
(2) The weight and cost of weft.
(3) The preparatory cost of sleying, dressing, twisting, or looming and final sleying.
(4) The relative cost of wear and tear of gears or harness and reeds.
(5) The cost of weaving, including winding of the weft when necessary.
(6) The cost of burling and mending, if any.
(7) The proportionate cost, on each piece, of master, designer, manager, overlookers, perchers, and various other assistants.
(8) Interest and depreciation of capital expended on loom, mill, boilers, engines and accessories.
(9) The waste of warp and weft in the preparation and weaving.
(10) The loss of weight in scouring and finishing.
(11) The shrinkage in width and length.
(12) The cost of dyeing and finishing.

(13) The 'over'-measure to customers.

(14) The percentage in commission to salesmen, agents, and travelling expenses.

The operation of finding the weight and cost of warp and weft is in reality a simple process to the student and manufacturer who has studied the previous chapters; the methods explained and adopted in relation thereto admit of general application. But the mode of appropriating the incidental or departmental costings to each piece or yard of cloth produced, varies essentially with the kind of material made, and incidentally in method and detail with the locality and manufacturer.

Generally, the incidental expenses connected with the production of woven structures are carefully noted upon a 5 or 6-cut warp for worsted, and about a 10-cut warp for dress or cotton goods. The average cost per piece is then struck for 1 cut, which is usually found to be about twice the amount of the actual price paid for weaving. It will thus be seen that three times the cost of weaving covers the cost of production, and to this must be added the cost of dyeing and finishing, and an allowance for commission to agents and salesmen. In the latter case 5% is added to the actual cost for plain and dyed goods, but for fancies, about 7½% is considered necessary.

A few of the varying factors may here be pointed out to illustrate some of the difficulties which appear at every attempt to formulate a scheme that will admit of general application in every detail. The payment to the weaver, though generally reckoned at some fixed price per number of picks in a ¼, ½, or 1 inch for some definite and standard length of warp, also varies with the kind and width of loom, *e.g.*, whether plain, drop box, circular box, odd or even pick, and the number of colours of weft. Further, the warp threads may be drawn through a set of gears containing 4, 8, 16 or more heald shafts, which, as they increase in number, increase the difficulty in production, especially with harness mountings. The Setts may also vary in fineness, while some warps weave much better than others, and thus the latter retard the output for the same datal expenses. Again, the length of the warp is sometimes very short (1 cut) which also adds to the relative cost in making a piece. All things considered, it will be best to find some approximate multiple of the weaving wage which will cover the incidental expenses in the cost of making some standard cloth, and afterwards add or deduct any extraordinary expenses or savings on any special type of cloth. If a customer has a large order to place at a lower price than the manufacturer's quotation, it is advisable then for the latter to enter most thoroughly into the details of all incidental expenses so as to ascertain whether it be possible to effect a reduction in any of the miscellaneous items specified in the costing book.

The following progressive examples will clearly demonstrate the principles and method of finding the weight and cost of fabrics :—

Example 1.—Find the average cost per cut in weaving a 5-cut warp, 350 yards long, and containing 5280 ends, 18 picks per $\frac{1}{4}$ inch, at 7d. per $\frac{1}{4}$ pick for weaving 70 yards of warp, the departmental expenses being as given herewith :—

	Incidental and datal expenses.	Total cost for full warp.	Proportionate cost per cut.
1.	Cost of sleying and dressing, at 5d. per 1000 ends for sleying and starting, and 2/1 per cut of 70 yards for running warp on to beam	12s. 6d.	2s. 6d.
2.	Cost of twisting in at $5\frac{1}{2}$d. per 1000 ends	2s. 6d.	6d.
3.	Wear and tear of gears and reed	6s. 3d.	1s. 3d.
4.	Proportionate cost of salaries and wages paid to masters, designers, overlookers, perchers, pattern-man, weft-man, and other datal helpers		5s. 0d.
5.	Burling and mending		5s. 6d.
6.	Loom, interest and depreciation of capital, buildings, engines and boilers		5s. 0d.
7.	Cost of weaving 18 picks at 7d.		10s. 6d.
	Average cost per cut		£1 10s. 3d.

Or, approximately, three times the weaving wages, leaving about twice the weaving wage for incidental expenses.

Example 2.—Find the cost per yard of a finished worsted coating, 58 yards long, 56 inches finished, made as follows:—Warp 70 yards, 2/36s Botany at 2/6 per lb., 20s reed 4s, 66″ reed width; weft 19 picks per $\frac{1}{4}$ inch, 1/18s Botany at 2/5 per lb.; 63 yards of cloth out of loom. Cost of weaving 7d. per $\frac{1}{4}$ pick; departmental expenses twice the cost of weaving; allow 5% for commission; length of warp to cover the cost of waste of weft in weaving. Dyeing and finishing, Indigo blue 39/-. Allow the usual 37 inches per yard, and 1 yard over-measure.

It will generally be found best to arrange the various factors as when finding the weight of warp and weft, and then multiply each statement by its respective price, in shillings by preference.

Thus for warp by formula XXI. and price per lb.

$$\frac{\text{Ends per inch} \times \text{inches wide} \times \text{length of warp}}{\text{Yards per lb.}} \times \text{price per lb.} = \text{cost of warp.}$$

And for weft, by formula XXII. and price per lb.

$$\frac{\text{Picks in inch} \times \text{ins. wide} \times \text{lgh. of piece} \times 100 + \%\text{ for waste}}{\text{Yards per lb.} \times 100} \times \begin{array}{c}\text{price}\\ \text{per lb.}\end{array}$$
$$= \text{cost of weft.}$$

In this example the length of the warp is taken to cover the waste of weft in weaving.

Then cost of warp

$$(1) \quad = \frac{80 \times 66 \times 70 \times 5}{18 \times 560 \times 2} = \quad 91\text{s. } 8\text{d.}$$

The cost of weft

$$(2) \quad = \frac{76 \times 66 \times 70 \times 29}{18 \times 560 \times 12} = \quad 84\text{s. } 2\text{d.}$$

Cost of weaving

(3)	= 19 picks at 7d.	=	11s. 1d.
Incidental expenses—twice weaving			
(4)	=		22s. 2d.
(5)	Dyeing and finishing		39s. 0d.
			248s. 1d.
(6)	5% for commisssion, etc. = 248 × 5% = 12·40	=	12s. 5d.
	Total cost		260s. 6d.

(7) Then 58 yards less $\frac{1}{37}$ or converted into yards of 37 inches $= \frac{58 \times 36}{37} = 56\frac{16}{37}$ yards and $56\frac{16}{37}$ yards $-$ 1 yard over-measure $= 55\frac{16}{37}$ yards for which payment is received.

$$\therefore \text{ Cost} = \frac{260\text{s. } 6\text{d.}}{55\frac{16}{37}} = 4\text{s. } 7\tfrac{1}{2}\text{d. per yard.}$$

NOTE.—It saves time to measure the pieces 37 inches to the yard.

Example 3.—Find the weight and cost per yard of a fabric which is made from 2/48s Botany at 3/- per lb., woven in a 90 Sett Bradford, 66 inches reed width, 70 yards of warp, 63 yards of cloth out of loom, 56 yards (37″) finished; weft 1/26s Botany, 120 picks per inch at 2/10 per lb., add 5% to weight of weft for waste in weaving. Cost of weaving, 7d. per $\frac{1}{4}$ pick. Incidental expenses twice the cost of weaving. Dyeing black and finishing 23/-. Add 5% to total cost for allowances, commission, etc. Allow 1 yard over-measure. Loss of weight in scouring and finishing is neutralised by increased weight of the dyewares.

NOTE.—In the solution of such questions as above, it is better to keep both weights and costs separate so that the weight and cost per yard can be more readily obtained, thus:—

Weight and cost of warp.

By formula XXI. Weight in lbs. Cost in shillings.

(1) $\frac{90 \times 40}{36} \times \frac{66 \times 70}{24 \times 560} = 34\frac{3}{8} \times 3/- = 103 \quad 1\frac{1}{2}$

(2) Weight and cost of weft,

By formula XXII.

$$\left.\begin{array}{ll} \frac{120 \times 66 \times 63}{26 \times 560} & = 34\frac{1}{4} \\ \text{Plus waste in weft.} & \\ 34\frac{1}{4} \times 5\% & = 1\frac{3}{4} \end{array}\right\} \times 2/10 = 102 \quad 0$$

(3) Cost of weaving 30 picks per $\frac{1}{4}$, at 7d. =	17	6
(4) Incidental expenses, twice the weaving wage =	35	0
(5) Dyeing and Finishing =	23	0
Actual cost	280	$7\frac{1}{2}$

(6) Add 5% for allowances, commission, etc. = 280s. $7\frac{1}{2}$d. × 5% =	14	0
Total cost	294	$7\frac{1}{2}$

And 56—1 yard for over-measure = 55 yards.

$$\therefore \frac{294\text{s. } 7\frac{1}{2}\text{d.}}{55} = 5/4\tfrac{1}{4} \text{ price per yard.}$$

Calculated weight of warp = $34\frac{3}{8}$ lbs.

" " weft = $34\frac{1}{4}$ lbs.

$68\frac{5}{8}$ lbs.

$$\therefore \text{Weight per yard (37'') of cloth} = \frac{68\frac{5}{8} \times 16}{56} = \overset{\text{ozs.}}{19/20}$$

Costing of Dress Goods.

In the manufacture of dress goods and linings, the prices paid for weaving vary from 2d. to $5\frac{1}{2}$d. per $\frac{1}{4}$ pick, for a unit length of warp of 70 yards, these prices being for plain and box looms whose reed space varies from 36 to 76 inches.

The woven fabrics are delivered to the merchant both in the grey and finished as circumstances may demand. For pieces delivered in the grey, the incidental expenses generally average from $1\frac{1}{4}$ to $1\frac{1}{2}$ times the cost of weaving for all cloths woven on the 'square' or approximately so, and containing not less than 15 picks per $\frac{1}{4}$ inch. When the pieces are delivered in the finished state, the incidental expenses vary from $1\frac{1}{4}$ to $1\frac{3}{4}$ times the weaving wage, to which must be added the cost of dyeing and finishing, or finishing only.

In finding the cost of production of dress fabrics, as in most other types of cloth, extraordinary circumstances arise for consideration, and any attempt to supply the multitudinous details for the great variety and types of cloth requires an amount of space which, in such a treatise as this, is out of proportion to the value of the information detailed, more especially so, since the prices and other items of cost are constantly varying factors. In this chapter, it is my purpose only to explain the fundamental principles which form the basis of costing cloths manufactured ready for sale.

A very good method is to first determine the average cost per loom per week of all the datal and miscellaneous expenses. Then divide the cost of each loom thus obtained by the number of pieces which can be produced in any given quality in any given loom per week, which would, of course, furnish the manufacturer with the cost per piece.

Some idea of the varying cost per piece of dress textures may be gleaned by a comparison of the following types selected indiscriminately from actual practice, irrespective of width in reed and other details, and delivered to the merchant grey.

(1) A piece containing 6 picks per ¼, cost 1/7 for weaving, and 2/7 for all other expenses, including dressing 6d.

(2) A 5-shaft satin, containing 14 picks per ¼ inch, cost 2/3 weaving, and 2/11 for all other expenses.

(3) Another, with 17 picks per ¼, cost 4/6 weaving and 7/2 for other expenses.

(4) A vicuna, with 7 picks per ¼, cost 1/8 for weaving and 2/11 for general expenses.

(5) For a cotton warp with 56 ends and 14 picks, 4/- was paid to the weaver, whilst the extras only amounted to 4/3.

(6) A grey cotton warp, with demi-filling and 13 picks per ¼, cost 5/- for weaving and 7/- for other expenses.

All the foregoing were woven in tappet looms, whilst the two following examples were produced in Jacquard harness looms :—

(1) A coloured warp and weft, 9 picks, cost 1/9 weaving and 4/2 in other expenses.

(2) A silk warp, 60 ends per inch, and worsted weft, 17 picks, cost 2/10 in weaving and 6/3 for incidental expenses.

Example 4.—A plain *glacie* dress fabric is made as follows: 53 yards warp 2/100s cotton at 2/-, 50s Sett Bradford, 1/24s mohair weft at 3/2, 15 picks per $\frac{1}{4}$ inch, 31″ reed width, $30\frac{1}{4}$ inches grey, to finish 27 inches: 48 yards of cloth out of loom, to finish 50 yards. Find the weight of warp and weft, and cost of cloth grey when weaving costs $2\frac{1}{4}$d. per pick; add $1\frac{1}{2}$ times the cost of weaving to cover expenses, and 5% for waste of weft in weaving: add 5% commission for travelling expenses, freightage, etc.

(1) Weight and cost of warp,

$$= \frac{50 \times 40 \times 31 \times 53}{36 \times 50 \times 840} = 2\tfrac{1}{6} \text{ lbs. at } 2/\text{-} = 4\text{s. } 4\text{d.}$$

(2) Weight and cost of weft,

$$\frac{60 \times 31 \times 48 \times 105}{24 \times 560 \times 100} = 7 \text{ lbs. at } 3/2 = 22\text{s. } 2\text{d.}$$

(3) Paid for weaving, 15 picks at $2\frac{1}{4}$d.	=	2s. $9\frac{3}{4}$d.
(4) Incidental Expenses, 2s. $9\frac{3}{4}$d. $\times$ $1\frac{1}{2}$	=	4s. $2\frac{1}{2}$d.
Cost		£1 13s. $6\frac{1}{4}$d.
(5) Commission, freightage, etc., £1 13s. $6\frac{1}{4}$d. $\times$ 5 per cent.	=	1s. 8d.
Total cost		£1 15s. $2\frac{1}{4}$d.

Various Systems of Payment for Weaving Woollens.

In the woollen trade, as in other types of cloth, the basis of payment for weaving has its methods and variations. In some localities the amount paid is reckoned at so much per stone on the calculation weight of the piece—warp and weft, which amount may vary from 6d. to 10d. per stone, according to width of loom and thickness of warp and weft. In other districts the weaver is paid at the rate of 1d. per yard, warp length, based on 36 picks per inch with an increase or decrease in almost the same ratio according as the number of picks are more or less, some account being taken of the very thick weft which necessarily entails more shuttling relatively. Another method is to pay a fixed price per string, which is a variable factor from 9 to 10½ feet, usually 10 feet; 4d. per string, 40 picks per inch, is a fair average price for broad plain goods, which is equal to 1d. per string per every 10 picks; other conditions being equal, the price varies in direct proportion to the number of picks put into the cloth. Whatever be the system adopted, they all eventually amount to a similar result, and further, in each case the incidental expenses add from 1½ to twice the price paid for weaving to the actual cost of the woven structure.

Example 5.—A dressed face fabric is composed of 2/36s cotton at 1/2 per lb., 15s reed 2s and 71 inches wide in the reed, length of warp 21 strings, 34 picks per inch of 10s pure woollen weft at 2/3 per lb.; cost of weaving, 3½d. per string; cost of other items in production, 9/3; dyeing and finishing, 35/-; 68 yards (36 inches) of cloth out of loom, and 66 yards finished (37 inches per yard). Add 5% to weight of weft for waste in weaving, and 5% of total cost for commission, etc. Allow 10 per cent. for loss in scouring, raising, cutting and finishing. Find weight and cost per yard; allow 1 yard over-measure; 1 string equals 10 feet.

(1) Weight and cost of warp.

$$\frac{30 \times 71 \times 21 \times 10}{18 \times 840 \times 3} = *9\tfrac{5}{8}\text{lbs. at } 1/2 \quad = 11\text{s. } 6\text{d.}$$

(2) Weight and cost of weft,

$$\left.\begin{array}{l} \dfrac{36 \times 71 \times 68}{10 \times 256} = *67\tfrac{7}{8} \\ \text{Waste of weft } 67\tfrac{7}{8} \times 5\% = 3\tfrac{2}{5} \end{array}\right\} \begin{array}{l} 71\tfrac{1}{4}\text{ lbs.} \\ \text{at } 2/3 \end{array} = 160\text{s. } 3\tfrac{3}{4}\text{d.}$$

(3) Cost of weaving 21 strings at $3\frac{1}{2}$d.	= 6s. $1\frac{1}{2}$d.
(4) General expenses	= 9s. 3d.
(5) Cost of dyeing and finishing	= 35s. 0d.
Actual cost	222s. $2\frac{1}{4}$d.
Commission etc. £222 at 5%	= 11s. $1\frac{1}{2}$d.
Total cost	233s. $3\frac{3}{4}$d.
*Calculation weight of warp and weft	= $77\frac{3}{4}$ lbs.
Loss in scouring and finishing, $77\frac{3}{4} \times 10\%$	= $7\frac{3}{4}$ lbs.
∴ Actual finished weight ...	= 70 lbs.

$$\text{Then weight per yard} = \frac{70 \times 16}{66} = 17 \text{ ozs.}$$

And $66 - 1 = 65$ yards for which payment is received.

$$\therefore \frac{233\text{s. } 3\tfrac{3}{4}\text{d.}}{65} = 3/7 \text{ per yard.}$$

Payment for Weaving Tapestries.

In the manufacture of tapestries, the payment for weaving necessarily varies very much on account of the enormous variety of woven structures produced. The following indicates the basis in its general outline for a six-quarter tapestry (52 inches finished); for 2 shuttles, 36 picks per inch, 6d. per yard is paid, with $\frac{1}{2}$d. per yard more or less, for every 6 picks, within reasonable limits, above or below the standard of 36 picks, together with a very long list of extras for number of warp beams, shuttles, length of warp, tender warp, etc., all of which vary very considerably. The general expenses for each structure must be treated separately since the cost of designing, cards, cutting, etc., are sometimes enormous, but are, of course, relatively great or moderate according to the number of pieces required of each design.

The price for finishing is usually reckoned at so much per yard since the length of the pieces are so different. Pieces which contain silk usually require a dry finish and cost about $1\frac{3}{8}$d. per yard, whilst worsted tapestries, which require a wet finish to enable them to 'set' properly, cost about $1\frac{1}{2}$d. per yard.

Example 6.—A tapestry fabric of compound structure is made as follows :—Warp, 21s reeds 7s ; 55 inches reed width ; 52 inches finished cloth, 68 yards out of loom (36 inches), and 64 yards finished (37 inches).

Warped :—

(a)	2	threads of	dark green	2/56s Botany	80 yards	at	2/10	per lb.
(b)	1	,,	light	,, ,,	,, 96	,,	2/10	,,
(a)	2	,,	dark	,, ,,	,, 80	,,	2/10	,,
(b)	1	,,	light	,, ,,	,, 96	,,	2/10	,,
(c)	1	,,	light	,, 2/48s cotton	96	,,	1/2	,,

7 threads in 1 repeat of pattern.

Weft :—48 picks per inch.

Woven { 2 picks of 2/48s light green cotton at 1/2 per lb.
{ 1 ,, 2s ,, ,, ,, 10d. ,,

3 picks in one repeat of pattern.

Add 5 per cent. to weight of weft to cover waste in weaving ; cost 7d. per yard on grey length ; cost of finishing $1\frac{1}{2}$d. per yard on finished length ; general expenses, including Jacquard cards 1/6 per yard on finished length ; allow $7\frac{1}{2}$ per cent. on total cost for commission to agents, travelling expenses, etc.; loss in scouring and finishing, 10 per cent. Find weight of each sort of warp and weft, and weight and cost per yard of the tapestry, 37 inches per yard, and 1 yard over-measure.

Then, since there are 7 threads in each repeat of the warp pattern, and the number of threads of each sort in each repeat are 4 of dark green, 2 of light green (both Botany), and 1 of light green (cotton), the total number of ends of each sort in the whole warp are $\frac{4}{7}$, $\frac{2}{7}$, and $\frac{1}{7}$ respectively; and in the weft, $\frac{2}{3}$ of (2/48s) fine cotton and $\frac{1}{3}$ of (2s) thick cotton. If now the question be stated as heretofore and multiplied by the proportion of each respective sort, the total cost will readily be found, thus:—

(1) Weight and cost of dark green Botany,

$$= \frac{21 \times 7 \times 55 \times 80 \times 4}{28 \times 560 \times 7} = 23\tfrac{4}{7} \text{ lbs.} \times 2/10 = 66\text{s. } 9\tfrac{1}{2}\text{d.}$$

(2) Weight and cost of light green Botany,

$$= \frac{21 \times 7 \times 55 \times 96 \times 2}{28 \times 560 \times 7} = 14\tfrac{1}{7} \text{ lbs.} \times 2/10 = 40\text{s. } 1\text{d.}$$

(3) Weight and cost of light green cotton

$$= \frac{21 \times 7 \times 55 \times 80 \times 1}{24 \times 840 \times 7} = 4\tfrac{7}{12} \times 1/2 = 5\text{s. } 4\text{d.}$$

(4) Weight and cost of weft of 2/48s cotton,

$$\left.\begin{array}{l} \dfrac{48 \times 55 \times 68 \times 2}{24 \times 840 \times 3} = 5\tfrac{59}{63} \\ \text{Add 5\% for waste} \\ \quad = 5\tfrac{59}{63} \times 5\% = \tfrac{3}{10} \end{array}\right\} \begin{array}{l} \text{lbs.} \\ 6\tfrac{1}{4} \text{ at } 1/2 \quad = 7\text{s. } 3\tfrac{1}{2}\text{d.} \end{array}$$

(5) Of 2s cotton,

$$\left.\begin{array}{l} \dfrac{48 \times 55 \times 68}{2 \times 840} \times \tfrac{1}{3} = 35\tfrac{13}{21} \\ \text{Add 5\% for waste} \\ \quad = 35\tfrac{13}{21} \times 5\% = 1\tfrac{4}{5} \end{array}\right\} \begin{array}{l} \text{lbs.} \\ 37\tfrac{3}{7} \text{ at } 10\text{d.} = 31\text{s. } 2\tfrac{1}{4}\text{d.} \end{array}$$

(6) Cost of weaving = 68 yards at 7d.	=	39s. 8d.
(7) Cost of finishing = 64 yards at $1\frac{1}{2}$d.	=	8s. 0d.
(8) General expenses, 64 yards at 1/6	=	96s. 0d.
Actual cost	=	294s. $4\frac{1}{4}$d.
Cost of commission, etc., $7\frac{1}{2}$%	=	22s. $0\frac{3}{4}$d.
Total cost		316s. 5d.

Weight out of loom	=	$83\frac{6}{7}$lbs.
Loss in scouring 10%	=	$8\frac{1}{3}$lbs.
Actual weight of piece finished	=	$75\frac{11}{21}$lbs.

$$\text{And weight per yard} = \frac{75\frac{1}{2} \times 16}{64} = 18\tfrac{7}{8} \text{ ozs.}$$

And 64 yards less 1 yard over-measure = 63 yards

$$\therefore \frac{316\text{s. } 5\text{d.}}{63 \text{ yds.}} = 5\text{s. } 0\tfrac{1}{4}\text{d. per yard.}$$

Costing Cotton Cloths.

In the cotton manufacturing district of Lancashire a uniform list of prices to be paid for weaving is fixed, together with additions and deductions for every conceivable change in width of reed, length of warp, ends and picks per inch, twist of warp and counts of weft, weave or pattern whether plain or coloured of every possible variety. To the above must be added the incidental factory expenses which are from $\frac{1}{2}$ to the whole of the cost for weaving. In addition there are local systems which for general purposes can be ignored. The standard price is made for a plain loom 45″ reed space producing cloth 39 to 41 inches wide; ends per inch 60 and picks per quarter inch 15 plus $1\frac{1}{2}$% for contraction; length of piece 100 yards (36″) twist of warp 28s or finer, counts of weft from 31s to 100s; amount paid to weaver 2d. per $\frac{1}{4}$ pick or 2/6 for the web.

A varying amount per cent. is added or deducted for each inch, more or lesss of the warp in the reed, *e.g.*, $1\frac{1}{2}\%$ is added per inch up to and including 51 inches, 2% from 51 to 56, $2\frac{1}{2}\%$ from 56 to 64 and 3% from 64 to 72 inches. The deductions are $1\frac{1}{4}\%$ from 45 to and including 37 inches; 1% from 37 to 24 inches and below. The complete list is very lengthy and may be obtained from either the cotton employers' or operatives' association.

Example 7.—Ascertain the cost per yard of a grey cotton cloth which measures 100 yds. (36") over the counter. Warp 30s twist, 108 yards at 10d. per lb., sett 60 ends per inch, 40" wide in the reed and woven with 15 picks per $\frac{1}{4}$ inch of 32s cotton in cops at 9d. per lb. Price to be paid for weaving 2d. per $\frac{1}{4}$ pick, add $\frac{3}{4}$ cost of weaving to cover general expenses. Add $2\frac{1}{2}\%$ to cost of warp and 4% to cost of weft for waste.

(1) Cost of warp

$$= \frac{\text{Ends per inch} \times \text{width in reed} \times \text{length of warp} \times \text{cost per lb.}}{\text{No. of yards of warp twist per lb.}}$$

$$= \frac{60 \times 39 \times 108 \times 10}{30 \times 840} = 100{\cdot}3 \text{ pence}$$

$$\text{plus waste per cent.} = 100{\cdot}3 \times 2\tfrac{1}{2} = 2{\cdot}5 \quad ,,$$

(2) Cost of weft

$$= \frac{\text{Picks per inch} \times \text{width in reed} \times \text{length of cloth} \times \text{cost per lb.}}{\text{No. of yds. per lb. of weft}}$$

$$= \frac{60 \times 40 \times 100 \times 9}{32 \times 840} = 80{\cdot}3 \quad ,,$$

$$\text{plus waste per cent.} = 80{\cdot}3 \times 4 = 3{\cdot}2 \quad ,,$$

(3) Cost of weaving 15 picks per $\frac{1}{4}$" at 2d. $= 30$,,

(4) General Expenses $\frac{3}{4}$ of weaving $= 30 \times \frac{3}{4} = 22{\cdot}5$,,

Total cost of cloth in pence $= 238{\cdot}8$,,

$$\therefore \quad \text{Cost per yard} = \frac{238{\cdot}8}{100} = 2{\cdot}388 \text{ pence.}$$

Example 8.—Find the cost of a cotton cloth woven with 56 threads of 40s twist warp (a) 1/1 per lb., 32·3″ wide, 48 picks per inch of 32s cotton weft at 10d. per lb. Weaving 2d. per $\frac{1}{4}$ pick per 100 yds. of warp. Expenses half weaver's wage, finishing 1/8, finished length of piece 90 yds. Add 5°/₀ for waste of weft; shrinkage 5°/₀ in width and 6°/₀ from taper's length to loom state.

$$\text{Reed width } \frac{32{\cdot}3 \times 100}{95} = 34''$$

			pence.
(1)	Cost of warp $= \dfrac{56 \times 34 \times 100 \times 13}{40 \times 840}$	=	$73\frac{1}{2}$
	Length of piece = 100 − 6 = 94 yds.		
(2)	Cost of weft $= \dfrac{48 \times 34 \times 94 \times 105 \times 10}{32 \times 840 \times 100}$	=	60
(3)	,, weaving = 12 picks per $\frac{1}{4}$ inch at 2d.	=	24
(4)	Expenses half weaving	=	12
(5)	Finishing	=	20
	Total cost of piece	=	$189\frac{1}{2}$

$$\therefore \text{ Cost per yd. } = \frac{189}{90} = 2{\cdot}1 \text{ pence.}$$

Example 9.—Find the total cost and cost per yard of the following fancy striped cotton fabric:—Warp 330 yards producing 300 yards of cloth, woven 33 inches wide in the reed and containing 66 ends and 64 picks per inch respectively; the pattern is warped

40 threads	slate,	4 threads	white	mercerised.	
16 ,,	,,	12 ,,	,,	,,	
16 ,,	,,	4 ,,	,,	,,	
40 ,,	,,	4 ,,	,,	,,	

Add 32 threads of 2/40s bleached cotton for selvedge at 1/2 per lb.; cost of 2/40s mercerised cotton 2/6; slate coloured warp 36s twist at 1/2; slate weft 32s in hank at 10d.; dyeing warp at $3\frac{1}{2}$d. and weft at $2\frac{1}{2}$d.; bleaching selvedge at $\frac{3}{4}$d., sizing coloured warp at $\frac{3}{8}$d. per lb.; winding 36s twist warp at 1d. per 32 hanks, 2/40s mercerised warp and 32s weft at 1d. per 20 hanks; warping 8d. per 1000 hanks; beaming 2d. per 100 yards and looming 6d. per 1000 ends; weaving 3d. per $\frac{1}{4}$ pick per 100 yds. of cloth; general expenses for machinery, datal wages etc. in preparation and weaving the same as cost of weaving. Add 5% for waste of warp and weft.

In the solution of the foregoing it is better to find the warp and weft independently of the allowance for waste and cost so as to facilitate the tabulation of cost of dyeing, bleaching, mercerising, winding, etc.

1. Weight and cost of warps :—

NOTE.—The number of threads of each sort in one repeat of the pattern equals 112 of slate and 24 of mercerised white, total 136 exclusive of edges.

(a) Slate warp.

$$= \frac{66 \times 33 \times 330}{36 \times 840} \times \frac{112}{136} = 19{\cdot}57\text{lbs.}$$
plus waste $= 19{\cdot}57 \times 5\% = 1$

$\left.\right\}$ 20·57 at 1/2 = 24 s. 0 d.

(b) Mercerised warp.

$$= \frac{66 \times 33 \times 330}{20 \times 840} \times \frac{24}{136} = 7{\cdot}55$$
plus waste $= 7{\cdot}55 \times 5\% = 0{\cdot}37$

$\left.\right\}$ 7·92 at 2/6 = 19 $9\frac{1}{2}$

(c) Selvedge.

$$= \frac{32 \times 330}{20 \times 840} = \quad {\cdot}63 \text{ at } 1/2 \quad = \quad 9$$

2. Weight and cost of weft.

$$= \frac{64 \times 33 \times 300}{32 \times 840} = 23{\cdot}57 \quad \left.\begin{matrix} \\ \\ \end{matrix}\right\} \begin{matrix} 24{\cdot}74 \\ \text{at 10d.} \end{matrix} = 20 \;\; 7\tfrac{1}{2}$$

plus waste $= 23{\cdot}57 \times 5\% = 1{\cdot}17$

3. Dyeing slate warp	19·57lbs. at $3\frac{1}{2}$d.	=	5	$8\frac{1}{2}$
4. Dyeing weft	23·57lbs. at $2\frac{1}{2}$d.	=	4	11
5. Bleaching selvedge	·63lbs. at $\frac{3}{4}$d.	=	0	$0\frac{1}{2}$
6. Sizing slate warp	19·57lbs. at $\frac{3}{8}$d.	=	0	7

7. Winding 36s twist warp at 1d. per 32 hanks

$$= \frac{19{\cdot}57\text{lbs.} \times 36 \text{ hanks}}{32 \text{ hanks}} \text{ at 1d.} \qquad = 1 \;\; 10$$

8. Winding 2/40s white warp at 1d. per 20 hanks

$$= \frac{7{\cdot}55\text{lbs.} \times 20 \text{ hanks per lb.}}{20 \text{ hanks}} \text{ at 1d.} \qquad = 0 \;\; 7\tfrac{1}{2}$$

9. Ditto weft.

$$= \frac{23{\cdot}57 \times 20}{32} \text{ at 1d.} \qquad = 1 \;\; 3$$

10. Warping at 8d. per 1000 hanks.

$$\text{Slate warp} = \frac{19{\cdot}57\text{lbs.} \times 36 \times 8}{1000} \qquad = 0 \;\; 5\tfrac{1}{2}$$

11. White warp $= \dfrac{7{\cdot}55\text{lbs.} \times 20 \times 8}{1000}$ $= 0 \;\; 1\frac{1}{4}$

12. Beaming per 330 yards at 2d. per 100 $= 0 \;\; 6\frac{3}{4}$

13. Looming (66×33) at 6d. per 1000 $= 1 \;\; 1$

14. Weaving 3 cuts of 100 yds. each at 3d. per $\frac{1}{4}$ pick

$$= 3 \times 3 \times 16 \qquad = 12 \;\; 0$$

15. Miscellaneous expenses $= 12 \;\; 0$

Total cost = £5 6 4

$$\therefore \text{ Cost per yard} = \frac{£5 \;\; 6 \;\; 4}{300} = 4\tfrac{1}{4}\text{d.}$$

Costing Linen Fabrics.

The cost of weaving linen fabrics, like all other woven textures varies according to the many factors which enter into their construction, *e.g.*, width and length of web; set of warp and shots of weft; the kind of loom in which the fabric is woven, whether tappet, dobby, jacquard, single shot or check; the condition of the yarn whether grey, boiled, partly or fully bleached; the severer the treatment, the higher the payment; if the fabric be a union, *i.e.*, a cotton warp and linen weft, then it will require less trouble in weaving, and the payment will be accordingly. The system of payment for weaving, differs somewhat from worsted, woollen or cotton goods, where the price is frequently fixed at so much per quarter, half or whole pick for some fixed length of warp, width and type of loom, and where any alteration in the number of picks or length of warp involves a change in price pro rata.

In linen weaving most manufacturers pay a fixed price per web for a given standard fabric, which has been determined by carefully noting the time that it has taken to weave each specific fabric.

As an alternative method the amount which should be paid for weaving each given make of fabric may be pre-determined by *calculation* on the basis of the average running in picks per minute for any and all classes of looms which the factory contains. Such average running may be obtained by taking the total production of webs (for each week) multiplied by their respective shots of weft and dividing the product by the total number of looms in the factory; each week's running is then added together and the average is struck for 6 or 12 months.

The average running time thus obtained allows not only for the stoppages of the particular loom on which a given fabric is being woven but it gives the average for all the looms in the factory which may be out of order or without warps; such a plan ensures the costing being slightly on the right side; of course in the event of a large order being in the balance, the actual *average* running of the looms intended to weave the prospective order might be greater than the average for the whole factory in which case the cost would be proportionately less and which might therefore be the deciding factor in accepting or otherwise of the order.

The manufacturer also makes periodical tests to determine the proportionate cost per day of all datal hands, plant, power etc. for each type of loom of given width and capacity. From these he can readily approximate the incidental or factory expenses on any given make of fabric when he knows the time required to weave it.

e.g. If the cost per day of all datal and mill expenses works out at 2/- and a piece has taken $1\frac{1}{2}$ days to weave after allowing for stoppages of all kinds, the incidental expenses on such a fabric would be $1\frac{1}{2}$ times 2/- = 3/-. The amount to be paid for the actual weaving would also be determined according to the time taken to produce the given fabric. The price thus arrived at becomes the fixed sum for all subsequent webs of corresponding make and length of warp.

Example 10.—Assume that the average running of 1000 looms of all widths as follows is 75 picks per minute, due allowance having been made for all stoppages; there are 300 looms with 43″ reed space, 200 with 52″, 150 with 56″, 150 with 72″, 100 with 76″, and 100 with 84″. If datal expenses including cost of machinery, plant, interest, depreciation etc. amount to the sum total of £504 3s. 4d. per week, find the average cost per loom per day for the average reed space, also the cost per day for each loom of given reed width pro rata.

1. Then average number of inches reed space per loom =

43″ ×	300 looms	=	12900″	
52 ×	200 ,,	=	10400	
56 ×	150 ,,	=	8400	
72 ×	150 ,,	=	10800	
76 ×	100 ,,	=	7600	
84 ×	100 ,,	=	8400	
	1000 looms	=	58500″	or 58·5″ per loom.

2. Average cost per loom per week $= \dfrac{£504\ 3\ 4}{1000} = 10/1$

$$\text{,,} \qquad \text{,,} \qquad \text{,,} \quad \text{day} = \frac{10/1}{5\frac{1}{2}} = 1/10$$

3. Then

							d.		
	As	58·5	: 43	: :	1/10	:	16·17	say	1/4
and	,,	58·5	: 52	: :	1/10	:	19·5	,,	1/7½
and	,,	58·5	: 56	: :	1/10	:	21·05	,,	1/9
and	,,	58·5	: 72	: :	1/10	:	27·08	,,	2/3
and	,,	58·5	: 76	: :	1/10	:	28·58	,,	2/4½
and	,,	58·5	: 84	: :	1/10	:	31·58	,,	2/7½

Example 11.—Given the cost per day at 2/3 for 72″ reed space, find the total incidental expenses for weaving a web laid 54 yards of warp, and containing 12 shots of weft, and producing 50 yards of 37″ cloth.

Then shots in web = Shots in glass × 200 × length of web.

$$\text{and } \frac{\text{Total number of shots in web}}{\text{Total number of picks per day}} = \begin{array}{c}\text{Time in days required}\\ \text{to weave the web.}\end{array}$$

$$= \frac{12 \times 200 \times 50}{75 \times 60 \times 10} = 2\tfrac{2}{3} \text{ days.}$$

$$\therefore\ 2/3 \times 2\tfrac{2}{3} = 6/\text{- per web.}$$

The cost of *weaving* the above fabric would be about 5/-, the preparing of warp and weft 3/-, and the cards 1/-, which gives a total approximate cost of 3 times the weaver's wage.

To the actual amount paid to the weaver, together with the incidental weaving expenses, must be added the expenses of preparing, which include winding, warping and dressing, and of boiling at $\frac{5}{8}$d. per lb., less 10%; bleaching, $1\frac{1}{8}$d. per lb., less 15%; and dyeing, from 3d. to $3\frac{1}{2}$d. per lb., less 15%. The cost of preparing is usually about half the incidental weaving expenses; the cost of pattern cards should average about 1/- per web made from 50 yards of warp, and for a quantity of not less than 100 webs. It may appear singular, but a careful analysis reveals that the *total* factory expenses, including weavers' wages, on each web, in the majority of cases, is 3 times the amount paid to the weaver.

Allowance must also be made for waste in preparing and weaving, which is usually about $2\frac{1}{2}$% for warps and 5% for weft added to the actual cloth weight.

The following types of various linen structures selected from actual practice will serve to verify some of the previous statements, as well as to illustrate the approximate cost of production.

(1) A plain boiled linen fabric woven in 16^{00} reed on 40″ scale and 40″ reed, contains 18 picks per 37 inch glass, 65s

lea warp laid 90 yards, and weft 100s lea. The price paid for weaving same would be about 5/-, and total factory expenses 11/3, which includes boiling, warping, dressing, and proportionate cost of all datal hands, together with that of machinery, plant, power, etc., which it will be noticed is about $2\frac{1}{4}$ times the amount paid for actual weaving.

(2) A grey or unboiled similar make of fabric would cost about 2d. per web less for weaving, and about 1/8 less for boiling, from the general factory expenses, which in this case is about twice the amount paid for weaving. A union made to the same particulars would admit of a still further reduction of about 2d. per web for weaving for 100 yards length of warp as compared with 90 yards above.

(3) A coarse grey linen 10/12, *i.e.* 10^{00} reed and 12 shots, 100 yards laid, 40″ reed, would cost about 2/6 weaving (about 25s warp and 40s weft).

(4) A union damask woven 56 ends of 18s cotton and 38 picks per inch of 25s tow, 53 yards of warp and 49 yards of 37″ cloth, 70 inch reed and 68 inch cloth, cost of weaving 1/11, general expenses 2/3, winding, warping and dressing 1/5, pattern 1/-. Total factory expenses = 1/11 + 2/3 + 1/5 + 1/- = 6/7 = $3\frac{1}{3}$ times weaving wages.

(5) A double damask laid 50 yards yielding 44 yards of 37″ cloth and 46 yds. bleached made from 40s lea warp in 37 Porter reed, 36″ scale, set 76″ in the reed, 74″ loom state and 70″ bleached, woven with 20 shots of 50s boiled line weft; cost of weaving 6/6, incidentals 6/9, preparing 3/7, pattern 1/6 = Total factory expenses or nearly 3 times weavers' wages and $3\frac{1}{3}$d. per shot for weaving.

(6) A low quality damask, 45 ends per inch, 8 shots on 37″ glass, reed width 52″, loom state of cloth 50″ laid 50 yds. warp, 45 yds. (37″) out of loom. (Shrunk in width 2″ more when bleached, but run out in length nearly 2 yards.) Cost of weaving 2/- plus all factory incidentals 3/11. Therefore the weaving averages 3d. per shot.

(7) A medium quality damask, 70 ends, 16 shots, 58″ reed space, 56″ cloth 50 yards laid. Cost of actual weaving 5/8, total factory expenses 16/6 or 3 times weaving = $4\frac{1}{4}$d. per shot.

(8) A fine quality, double damask, 90 ends per inch, 30 shots $78\frac{1}{2}''$ reed, $76''$ cloth out of loom; costs 18/- weaving 50 yards laid and total factory expenses including weavers' wages 47/8 which equals $2\frac{2}{3}$ times the weavers' wages, also $7\frac{1}{5}$ pence per shot for weaving.

(9) A $25'' \times 25''$ napkin laid the usual length of 100 yds. costs 4/10 per web plus 8/10 for all other factory expenses including preparing and pattern the total of which is 13/8 or nearly 3 times the amount paid for weaving.

Example 12.—Given 90 yards of grey cloth of $37''$ measure made from 100 yds. of 60s line warp at 6/3 per bundle less 11% woven in 13^{00} reed, $40''$ scale and $40''$ reed width with 15 shots under $37''$ glass, 60s lea weft costing 5/6 per bundle less 11%. Add $2\frac{1}{2}\%$ for waste in warp and weft and allow 13/6 for weaving and factory expenses. Find the total cost and weight of web.

(1) Cost per bundle of warp = 6/3 less 11% $= (75 - 8\frac{1}{4}) = 66\frac{3}{4}$d.

(2) ,, ,, weft = 5/6 ,, 11% $= (66 - 7{\cdot}26) = 58{\cdot}74$.

(3) Cost of warp $= \dfrac{1300 \times 2 \times 100}{60000} \times \dfrac{205}{200} \times \dfrac{66\frac{3}{4}}{12} =$ £1 4 9

4) ,, weft $= \dfrac{15 \times 200 \times 90}{60000} \times \dfrac{40}{36} \times \dfrac{205}{200} \times \dfrac{58{\cdot}74}{12} =$ £1 5 0

(5) Total weaving and factory expenses = 0 13 6

Total cost of web = £3 3 3

(6) Weight of web = weight of warp + weight of weft.

(a) Warp $= \dfrac{1300 \times 2 \times 100}{60 \times 300} = 14{\cdot}\dot{4}\dot{4}$ lbs.

(b) Weft $= \dfrac{15 \times 200 \times 90 \times 40}{60 \times 300 \times 36} = 16{\cdot}\dot{6}\dot{6}$ lbs.

Total weight of web $= 31{\cdot}\dot{1}$ lbs.

Example 13.—Find the cost per $37''$ yard of brown linen woven in a 10^{00} reed, $40''$ scale, $40''$ reed width, 78 yards of warp, producing 72 yards ($37''$) of cloth, 40s lea warp and weft, costing 5/6 and 5/3 per bundle net respectively, 10 shots of weft, 37″ glass. Add for total factory expenses $1\frac{1}{8}$d. per yard and $2\frac{1}{2}\%$ for waste of warp and weft.

$$\text{Cost of warp} = \frac{1000 \times 2 \times 78 \times 205 \times 11}{60000 \times 200 \times 2} = 14\ 8$$

$$\text{,, weft} = \frac{10 \times 200 \times 72 \times 40 \times 205 \times 21}{60000 \times 36 \times 200 \times 4} = 14\ 4$$

$$\text{Total cost of web} = 29\ 0$$

$$\text{Then } \frac{29/-}{72 \text{ yds.}} = 4\tfrac{5}{6} \text{ pence.}$$

$$\text{And } 4\tfrac{5}{6} + 1\tfrac{1}{8} = \frac{116 + 27}{24} = 5\tfrac{23}{24} \text{ pence per yd.}$$

Example 14.—Find the cost per dozen huckaback towels 24 inches wide by 39 inches in length plus 3 inches of fringe at each end. Width of warp in reed 26″, 56 ends per inch of 15s cotton at 1/2 per lb., bleaching 1d. per lb.; 24 double picks per inch of 16s lea dry spun flax weft at 1/4 per lb., bleaching $1\frac{1}{8}$d. per lb., one inch border of 6s Turkey red cotton (double weft) at 1/4 per lb.; length of warp 120 yds. producing $112\frac{1}{2}$ yds. of towelling including fringe. Total cost of weaving 7/- per web. Add 5% for waste of weft in weaving.

(1) Cost of warp and bleaching

$$= \frac{\text{Ends per inch} \times \text{reed width} \times \text{length of warp}}{\text{Yards per lb.}} = \text{wt. in lbs.}$$

$$= \frac{56 \times 26 \times 120}{18 \times 840} = 13\tfrac{13}{15} \text{ lbs. at } 1/2 \qquad = 16\ \ 2$$

$$\text{and bleaching} \qquad 13\tfrac{13}{15} \text{ lbs. at 1d.} \qquad = 1\ \ 2$$

(2) Cost of flax weft and bleaching

$$\frac{\begin{matrix}\text{Picks}\\\text{per in.}\end{matrix} \times \begin{matrix}\text{reed}\\\text{width}\end{matrix} \times \begin{matrix}\text{length}\\\text{of web}\end{matrix} \times \left(\begin{matrix}100+\\\text{waste}\%\end{matrix}\right) \times \begin{matrix}\text{ins. of given}\\\text{weft in towel}\end{matrix}}{\begin{matrix}\text{Yards per lb. of given weft} \times 100 \times\\\text{(No. of ins. of towel + fringe.)}\end{matrix}} = \text{wt. in lbs.}$$

$= \frac{(24 \times 2) \times 26}{16 \times 300} \times \frac{225}{2} \times \frac{105}{100} \times \frac{37}{45} = 25\frac{1}{4}$ lbs. at 1/4 = 33 8

Bleaching $= 25\frac{1}{4}$,, at $1\frac{1}{8}$ = 2 $4\frac{1}{2}$

(3) Cost of Turkey red weft

$= \frac{(24 \times 2) \times 26 \times 225 \times 105 \times 2}{6 \times 840 \times 2 \times 100 \times 45} = 1\frac{3}{10}$,, at 1/4 = 1 9

Total cost for weaving = 7 0

Total cost of web $112\frac{1}{2}$ yds. long = 62 $1\frac{1}{2}$

practically 62 0

(4) No. of towels of 45″ length in web

$= \frac{225}{2} \times \frac{36}{45} = 90$ towels

$\therefore$ Cost of 1 doz. towels $= \frac{\text{Total cost of web}}{\text{Total No. of towels}} \times 1 \text{ doz.} = \frac{62 \times 12}{90} = 8/3$

EXERCISES.

A

1. A cloth is made with 126 ends per inch of 2/48s worsted at 2/8 per lb.; weft, 2 picks of 2/48s worsted to 1 pick of 20 skeins woollen at 1/6 per lb.; 96 picks per inch; reed width 35 inches, 75 yards of warp; $64\frac{1}{2}$ yards of cloth. Allow 5% for waste of weft in weaving. Find the total cost of the material.

Ans., £5 17s. $10\frac{1}{2}$d.

2. Find the total cost of the material in a cloth made as follows:—Warp 72 ends per inch of 2/60s cotton; weft 80 picks per inch 36s worsted; reed width 64 inches; length of warp 54 yards; length of piece 48 yards; cost of cotton 2/4 per lb., and of worsted 3/4 per lb. Add 5% to weight of weft to cover waste in weaving.

Ans., £3 5s. $8\frac{1}{2}$d.

3. Find the cost of material in a piece of worsted coating cloth made as follows:—Warp 2/36 at 3/-

per lb.; weft 18s at 2/10; 76 ends and 80 picks per inch; 66 inches wide in the sley; 52 yards long made from 60 yards of warp, allowing $7\frac{1}{2}$ per cent. for actual waste of weft in weaving.

Ans., £8 12s. $6\frac{1}{2}$d.

4. Find the cost of weft in a cloth 50 yards long woven in a reed 34 inches wide with 18 picks per $\frac{1}{4}$ inch; 1/20s cotton at 9d. per lb. Add 5 per cent. for waste of weft.

Ans., 5s. 9d.

5. Find the cost of material for a cloth made from 2/48s worsted warp 64 ends per inch; 18s worsted weft, 64 picks per inch; warp 3/2 per lb.; weft 2/11 per lb.; length of warp 70 yards; length of piece 63 yards. Allow 5 per cent. for waste of weft in weaving; width in reed 66 inches.

Ans., £7 10s. 6d.

6. What is the total cost of a cotton cloth constructed thus:—Warp 80 yards of 80s twist at 1/11 per lb. on the warp beam, 100 ends per inch, 48 inches wide; weft 20 picks per $\frac{1}{4}$ inch of 100s twist at 2/- per lb. ready for weaving; length of piece 76 yards; weaving 5/-; mill expenses $1\frac{1}{2}$ times the weaving cost; commissions, travelling expenses, etc., 5 per cent. Allow 5 per cent. for waste of weft in weaving.

Ans., £1 12s. $3\frac{1}{2}$d.

B

7. Calculate the cost per yard of a dress fabric made as follows:—Warp 72 ends per inch 2/80s super cotton at 2/8 per lb.; 84 picks per inch of 36s worsted at 3/- per lb.; piece $29\frac{1}{2}$ inches in the reed; 48 yards long from 54 yards warp. Add 5 per cent.

to weight of weft for waste in weaving; cost of weaving $2\frac{1}{2}$d. per $\frac{1}{4}$ pick; incidental expenses $1\frac{3}{4}$ times the weaving; add 5 per cent. for commission, etc. Finished length of cloth 45 yards (37 inches) 44 yards to be charged. Cost of finishing 3/6.

Ans., $12\frac{1}{3}$d.

8. Required the weight and cost per yard of a worsted cloth made as follows:—Warp 2/40s at 2/9 per lb.; weft 2/48s at 2/10 per lb.; 64 ends and 72 picks per inch; 63-inch reed width; length of warp 65 yards, length of piece 60 yards, finished length 55 yards (37 inches); cost of weaving 7d. per $\frac{1}{4}$ pick; incidental expenses twice the weaver's wage; dyeing, burling and finishing 24/-; length of warp to be taken to cover waste of weft in weaving; add 5 per cent. to total cost for commissions, etc. Allow 1 yard over measure; weight of dyed cloth equals calculation weight.

Ans., $12\frac{3}{4}$; 3s. $6\frac{1}{2}$d.

9. Find the cost per yard of a fabric constructed as follows:—Warp 90s Sett Bradford, consisting of 1 end of 2/60s worsted at 2/9 per lb. to 1 end 2/40s cotton at 1/6 per lb.; reed width 54 inches; length of warp 56 yards; length of piece 52 yards, finished length 47 yards (37 inches); weft 1/32s English at 2/- per lb., 60 picks per inch; cotton 1/40s at 1/4 per lb., 40 picks per inch; cost of weaving 8d. per $\frac{1}{4}$ pick; incidental expenses twice the weaving; length of warp to cover waste of weft; burling and finishing 10/-; add 5 per cent. for commission, etc. Allow 1 yard over-measure.

Ans., 2s. $9\frac{1}{4}$d.

10. Find the cost per yard of a cotton cloth, grey, made as follows:—80 yards of warp of 30s twist at 8d. per lb. in cop; 64 ends per inch; 42 inch reed; length of cloth 75 yards; weft, 15 picks per $\frac{1}{4}$ inch; 24s on cop at 6d. per lb. winding warp and weft 1d. per lb.; weaving 2d. per $\frac{1}{4}$ pick; $1\frac{1}{4}$ times weaving to cover warping, sizing, twisting, and other mill expenses; add 5 per cent. to weight of weft for waste in weaving; and 5 per cent. commission on total cost.

Ans., 3.

11. What is the weight and cost per yard of the following cloth:—Warp 80s Sett Bradford; 2/32s worsted at 2/10; 66-inch reed; 75 yards warp; 67 yards grey; 61 yards finished (37 inches); weft 26 picks per $\frac{1}{4}$ inch; 20s worsted at 2/9 per lb.; cost of dressing, twisting and weaving on commission 1/6 per quarter pick; length of warp to cover waste of weft in weaving; dyeing and finishing 24/-; burling and mending 5/-; add $7\frac{1}{2}$ per cent. of the total cost to cover owner's expenses; allow for 1 yard over-measure.

Ans., $23\frac{3}{4}$; 5s. $11\frac{3}{4}$d.

12. A linen cloth is woven in 17^{00} reed 40″ wide on 40″ scale and 19 shots on 37″ glass with 80s lea warp boiled, costing 5/6 and 85s weft boiled at 4/9 per bundle respectively, warp laid 100 yds. web 90 yds. of 37″ measure, total factory expenses 13/6 and charges for boiling 4/-. Find the total cost per web and per yard, loom state, after adding $2\frac{1}{2}$% to warp and 5% to weft for waste.

Ans., £4 1s. 0d.; $10\frac{4}{5}$d.

13. A "mixture" dress linen is woven in 10^{00} reed, 40″ scale, 34″ reed width and 6 shots on 37″ glass; the

warp is 30s lea dyed and the weft is 2/25s lea (composed of one thread white and one thread pink). The warp costs 6/9 per bundle nett including dyeing and the twist thread 15/- per bundle nett ; the warp is laid 100 yds. and the length of the web is 90 yds. of 37″ measure. If the total factory expenses amount to 6/- find the cost of the fabric in the loom state and the cost per yard. Add $2\frac{1}{2}\%$ to warp and $5^{\circ}/_{\circ}$ to weft for waste.

Ans., £2 12s. 3d. ; 7d.

C

14. A Scotch tweed is made with 30 ends and picks per inch ; warp and weft 14-cut Gala. at 2/6 per lb. ; 66 inches reed width required to produce 54 inches finished (37 inches) ; 80 yards produce 72 yards grey and 63 finished (37″). Cost of weaving 10/- ; incidental expenses £1 ; add $7\frac{1}{2}$ per cent. to weight for waste of weft in weaving ; 12/6 for knotting, scouring and finishing ; add 5 per cent. to total cost to cover travelling expenses and commission. Loss in scouring and finishing 15 per cent. Find the weight and cost per yard ; allow 1 yard over-measure.

Ans., $23\frac{1}{4}$; 5s. 5d.

15. A figured silk texture is made with 108 yards of warp of 3 dram silk ; 200 ends per inch at 35/- per lb. when ready for weaving ; weft in 3 shades 252 picks per inch of 4 dram silk costing 32/- per lb. when ready for weaving. Length of piece 100 yards ; cost of weaving cloth 4d. per yard. Design cut and laced on 1000 cards at $\frac{1}{2}$d. each ; cloth repairing and finishing 20/-. General expenses 10 per cent. on total cost ; reed width 25 inches, including 1 inch for edges of 120

ends 30/2 spun silk at 10/- per lb. 99 yards to be charged for. Find the cost per yard.

Ans., 6s. $11\frac{3}{4}$d.

16. What is the cost of 1 dozen tapestry table covers, particulars as follows :—

32 by 34 inches, width in reed 33 inches. Warps—

$\begin{cases} \text{600 ends 2/60s cotton, Indigo blue at 3/- per lb.} \\ \text{4864 ends in two shades at 1/4 per lb. of 2/40s cotton.} \end{cases}$

Weft 60 picks per inch in two shades of 6s cotton at 1/1 per lb.

Cost of weaving per dozen 1/3 ; incidental expenses 20 per cent. more than weaving ; add 5 per cent. for waste in both warp and weft ; allow 5 per cent. for take-up of 2/40s, and 10 per cent. for take-up of 2/60s cotton.

Ans., 13s. 7d.

17. A fancy worsted coating double cloth is constructed to the following particulars :—

Face Warp 72 threads per inch 2/44s Botany at 2/10 per lb.
Back ,, 36 threads per inch 2/24s Botany at 2/9 per lb.

Reed width 63 inches ; length of warp 70 yards, which length is to cover the cost of waste in weaving ; finished length of piece 56 yards (37 inches) ; weft and picks as warp : price per $\frac{1}{4}$ pick for weaving 1/- ; mill and general expenses twice the cost of weaving ; mending, 5/- ; cloth finishing 12/- ; allow $7\frac{1}{2}$ per cent. on total cost for commission, travelling expenses, etc., and the usual 1 yard over-measure. Find the cost per yard.

Ans., 7s. $3\frac{1}{2}$d.

18. Find the weight and cost per yard of a mantle fabric made to the following particulars :—

Warp 2/48s worsted at 3/- per lb., 63 Sett Bradford.
Weft :—

For 4 picks $\begin{cases} \text{1 pick 30/2 spun silk (figuring) at 14/- per lb.} \\ \text{1 pick 24s worsted (ground) at 2/- per lb.} \end{cases}$
1 pick 10s skeins woollen (backing) at 1/6 per lb.
168 picks to the inch.

Width in reed 32 inches, 60 yards of warp gives 53 out of loom, and 50 yards finished (37 inches); allow 8 per cent. for waste of weft; cost of weaving 6½d. per yard grey length; general expenses £2; 900 Jacquard cards at ½d.; finishing 10/6; allow 7½ per cent. of total cost to cover commission, etc., and 1 yard over-measure. *Ans.*, 14½; 5s. 10¾d.

19. A decorative reversible double cloth is composed of the following materials :—

Warp $\begin{cases} \text{1 thread 2/36 cotton, cream} \\ \text{1 thread 2/36 cotton, deep brown} \end{cases}$ at 1/6 per lb.
Sett 180 threads per inch 55 inch reed.

80 yards of warp produce 70 yards out of loom and 66 yards (37 inches) finished.

Weft $\begin{cases} \text{1 pick 1375 yards per ozs. tram silk at 33/- per lb.} \\ \text{1 pick 2/36s cotton at 1/6 per lb.} \end{cases}$
74 picks per inch.

Cost of weaving 9d. per yard on grey length; cost of finishing 1⅜d. per yard on finished length; general expenses and commission 1/3 per yard; 800 Jacquard cards at ½d. each; add 5 per cent. to cost of weft for waste; weight of finished cloth 4 per cent. less than calculation weight. What is the weight and cost per yard of finished cloth, 65 yards only to be charged for? *Ans.*, 16; 7s. 7d.

20. What is the weight and cost per yard of a Union Woollen dressed face cloth made as particulars given herewith? Warp, 24 strings 2/24s cotton at

1/2 per lb.; 72 inches reed width; 27 ends per inch; weft, 8 Y.S. woollen at 2/4 per lb.; 35 picks per inch. Cost of weaving 3½d. per string; dyeing and finishing 36/-; 78 yards of cloth grey (36 inches), 76 yards (37 inches) finished; allow 9/6 for general expenses and 5 per cent. of total cost for travelling expenses, etc.; deduct 10% nett loss after dyeing, scouring, cropping and finishing and 1 yard over-measure; add 5% to weight of weft to cover waste in weaving. *Ans.*, 21; 4s. 3¼d.

21. How many bundles of linen yarn would be required to make 20,000 yards of cloth, 37 inch measure, 34 inches in width, counting 42 ends and 54 picks per inch, made from 35s and 45s tow, adding 2½% to yarns for waste; allow for contraction in width $\frac{1}{18}$; length of warp to be taken at 22,000 yards? What amount of wages would be paid for making same at 10d. per 100 hanks for warp winding; 3d. per 1000 yards of 357 ends per bank for warping; 3d. per cut of 100 yards laid for beaming; drawing and sleying 22 warps at 5d. per 1000 ends; weft winding 1/10 per 100 hanks; weaving 1/11 per web of 100 yards laid?

Ans., Warp 536·7; Weft 663·7; £39 9s. 0d.

22. Assume a damask fabric is woven in 16^{00} reed, 40″ scale, 15 shots on 37″ glass, 80″ reed width, warp laid 55 yards, yielding 48 yards of 37″ cloth. The warp is 45s lea boiled, the weft 50s lea boiled, and cost 7/6 and 5/6 per bundle respectively; the loss in weight due to boiling is 8%; add 2½% to weight of warp and 5% to weight of weft to cover waste. Amount paid for weaving 6/6; other factory expenses to be reckoned at twice the wages paid for weaving;

total charges for boiling 5/6. Find the cost per 37″ yard and of the complete web.

Ans., 2/1¼; £5 1s. 0d.

23. Required the cost per dozen union damask table covers, also the weight of cotton warp and the number of bundles of flax weft that would have to be ordered to weave 100 cuts of warp laid 56 yards per cut, producing 51 yards of 37″ cloth, loom state and 51½ yards finished. Width of warp in reed 70″, 68″ cloth and 66″ finished; made from 20s cotton warp costing 1/- per lb., and bleaching same 1d. per lb.; 25s tow weft at 6/- per bundle and bleaching 1⅛d. per lb.; woven 60 ends and 40 picks per inch; add 5% to weft to cover waste; charge for weaving 2/3; other factory expenses 6/9 per web; allow 68 inches to each cover.

Ans., 1400 lbs.; $256\frac{1}{40}$ bundles; 17/9½ per doz.

CHAPTER IX.

CALCULATIONS INVOLVED IN THE ANALYSIS AND REPRODUCTION OF WOVEN FABRICS.

The ANALYSIS OF A CLOTH consists in determining :—

The nature of the material of which the fabric is composed.
The weight per yard.
The counts of warp and weft.
The ends and picks per inch or other unit.
The design.
The quantities of each colour, if more than one shade be used.
The kind of finish the cloth received.
Other treatment which the yarn or fabric may have received.

In this chapter I propose to consider and exemplify the various calculations arising from the study and practice of the analysis and reproduction of woven textures of similar weight and fineness as any sample supplied.

The principles and problems involved will be best demonstrated by a careful consideration of the following typical examples worked out in detail.

A. TO FIND THE WEIGHT PER YARD.

Weigh one square inch or as many square inches of sample supplied as is convenient. In order to attain very great accuracy it is found desirable in practice to use a grain balance. Then by simple proportion the weight per yard for any required width of cloth may readily be obtained in grains, ounces, or otherwise —ounces by preference.

Example 1.—A piece of worsted coating, 2 inches square, weighs 20 grains; what would be the weight per yard of a cloth which is to be 56 inches wide when finished, and contain 37 inches per yard?

Then since $2'' \times 2'' = 4$ square inches.

And 1 yard of cloth $37 \times 56 = 2072$ square inches.

$$\text{Also } \frac{\text{Weight of given cloth in grains}}{\text{No. of square inches in sample weighed}} = \text{Weight of 1 sq. inch in grains.}$$

$$= \frac{20}{4} = 5 \text{ grains per square inch.}$$

$\therefore$ Weight per yard in grains = No. of sq. ins. in 1 yd. of cloth $\times$ weight per square in. of given cloth.

$$= 2072 \times 5 \quad = 10{,}360 \text{ grains.}$$

The weight of most woven fabrics is usually expressed in ozs. per yard, and since there are 7000 grains in 1 lb. avoirdupois.

$$\text{Then weight per yard in ozs.} = \frac{\text{Weight per yard in grains}}{\text{No. of grains in 1 lb.}} \times \text{ozs. in 1 lb.}$$

$$= \frac{10360 \times 16}{7000} = 23{\cdot}68 \text{ ozs.}$$

The above detailed solution admits of the following simplification, which I think will be evident without any further explanation.

FORMULA XXIV.

$$\frac{\text{Wt. in grs. of sample} \times \text{No. sq. ins. in 1 yd. cloth} \times \text{ozs. per lb.}}{\text{No. sq. ins. of sample wghd.} \times \text{No. grs. in lb.}} = \text{The weight per yard in ozs.}$$

The foregoing explains the principles which underlie the work to be done, and should be thoroughly understood by each student, but I have formulated a much shorter method for use in practice. It consists in reducing to one uniform number or *gauge point* all the constant factors.

A *gauge point* is a standard number which is a simple equivalent to all the constant factors in any set of problems, fractions, or equations. In the above example the constant factors are 1 yard, fixed width, ozs. per lb., and grains in 1 lb. avoirdupois.

Then for all cloths 37 inches $\times$ 56 inches, the gauge point

$$= \frac{\text{Inches per yard} \times \text{width in inches} \times \text{ozs. per yard.}}{\text{Grains in 1 lb. avoirdupois.}}$$

$$= \frac{37 \times 56 \times 16}{7000} = 4{\cdot}736 \text{ or } 4\tfrac{3}{4} \text{ for all practical purposes.}$$

NOTE.—If 1 square inch of sample actually weighed 1 grain, then 4·736 ozs. or $4\frac{3}{4}$ ozs, would represent its weight per yard for 37″ by 56″ wide. Consequently, if 1 square inch weighed 2, 3, or 4 grains. its weight per yard would be $4{\cdot}736 \times 2$; $4{\cdot}736 \times 3$; and $4{\cdot}736 \times 4$ ozs. per yard respectively.

Then the whole expressed as a formula stands thus:—

FORMULA XXV.

Gauge point for any given length and width $\times$ weight in grains of 1 square inch of cloth. = weight per yard in ozs.

and applies to finding the weight per yard of any given cloth of similar length and width as is represented by 'Gauge Point.'

The utility of the formula is at once apparent when applied to the solution of example 1, where 4 square inches weighed 20 grains.

Then 1 square inch weighs $\frac{20}{4} = 5$ grains, and by formula XXV., $4{\cdot}736 \times 5 = 23{\cdot}68$ ozs. per yard, as previously obtained.

Example 2.—Given a small pattern of cloth 3×2 inches which weighs 24 grains, find the weight per yard, 56 inches finished and 37 inches per yard.

Then $\frac{24 \text{ grains}}{6} = 4$ grains, in 1 sq. inch of cloth.

And by formula XXV.

$4{\cdot}736 \times 4 = 18{\cdot}944$ ounces per yard.

In pattern analysis, it is very often advisable to obtain the weight per yard for 56 inches × 36 inches since it is much easier to obtain the counts of warp and weft from the weights thus acquired.

Then the gauge point or formula for 56 inches × 36 inches

$$= \frac{56 \times 36 \times 16}{7000} = 4{\cdot}6.$$

TABLE IV.

	Width.		Inches per yard.		Gauge point.		
1.	56	×	37	=	4·736	or	$4\frac{3}{4}$
2.	56	×	36	=	4·6	or	$4\frac{3}{5}$
3.	57	×	37	=	4·82	or	$4\frac{4}{5}$
4.	57	×	36	=	4·69	or	$4\frac{7}{10}$
5.	55	×	37	=	4·65	or	$4\frac{13}{20}$
6.	55	×	36	=	4·525	or	$4\frac{1}{2}$
7.	54	×	36	=	4·4	or	$4\frac{4}{9}$
8.	52	×	36	=	4·27	or	$4\frac{7}{25}$
9.	48	×	36	=	3·95	or	$3\frac{19}{20}$
10.	42	×	36	=	3·456	or	$3\frac{3}{7}$
11.	38	×	37	=	3·21	or	$3\frac{1}{5}$
12.	38	×	36	=	3·126	or	$3\frac{1}{8}$
13.	36	×	37	=	3·04	or	3
14.	36	×	36	=	2·96	or	3
15.	29	×	37	=	2·45	or	$2\frac{9}{20}$
16.	29	×	36	=	2·38	or	$2\frac{2}{5}$
17.	28	×	37	=	2·368	or	$2\frac{2}{5}$
18.	28	×	36	=	2·3	or	$2\frac{3}{10}$
19.	24	×	36	=	1·97	or	2

By a similar process the standard number for any other customary width and length may be procured. The gauge point for a few of the most typical widths is supplied at Table IV.

As a result of experiment and contemplation upon this subject I have been able to deduce the following short method which should prove of much practical advantage.

The weight in grains of a small sample of cloth whose area is equivalent to any of the foregoing gauge points in square inches is equal to the weight in ozs. per yard for the standard width which the gauge point represents *e.g.* (1) Consider item No. 7, where the gauge point is 4·4 square inches. Then if 4·4 square inches weighs 22 grains, the weight per yard (36″) 54 inches wide = 22 ounces.

Proof:—If 4·4 square inches of cloth weighs 22 grains the weight of 1 sq. inch $= \frac{22}{4 \cdot 4} = 5$ grains and by previous demonstration (Formula XXV.) the weight in grains multiplied by the gauge point equals the ounces per yard $= 5 \times 4 \cdot 4 = 22$ ozs.

(2) If 3 square inches, the gauge points for items 12 and 13, weigh 9 grains, the weight per square yard of fabric would be 9 ozs.

Then all the manufacturer or analyst has to do is to get a 'die' made to stamp out an area of cloth in accordance with the gauge point for the width of fabric which he is accustomed to make or has usually to quote for.

B. Determination of the Warp and Weft.

Before ascertaining the counts of warp and weft it will be as well to note the following guiding factors which assist in distinguishing warp from weft in the cloth.

1. If the sample of cloth submitted for analysis contains a selvedge, the warp direction is at once obvious.
2. If one set of threads be two-fold and the other single, the two-fold represent the warp.
3. The direction of the twist in the warp threads is usually from right to left.
4. If one set of threads be harder twisted than the other, the hard twisted threads represent the warp.
5. If the cloth has a dressed face finish, the direction of the nap indicates the warp.
6. When the yarns are of unequal thicknesses, the finer and better quality *usually* represents the warp.
7. If one set of threads be cotton and the other woollen or worsted, the cotton threads usually indicate the warp.
8. If one set of threads has been sized and the other has not, the former represents the warp.

The counts of warp and weft may be obtained in several ways, *e.g.*

I. BY COMPARISON. This method, though somewhat crude, is yet simple aud ready, and therefore frequently resorted to in practice for low and medium counts of yarns, which, when compared in a practiced hand and with an experienced eye yields fairly accurate results, for which reason I have given it a place in this work.

It consists in extracting a few threads from the cloth, which are crossed and folded over a few threads of some known count, the two ends of each respective group of threads being taken and held between the fingers—the group of the unknown in one hand, and the known in the other. The two groups are then simultaneously twisted so as to compare their relative counts.

By the simple act of twisting, we necessarily make a comparison of the areas and solidities of the threads, and since areas and solidities of threads are represented by the equivalent term "counts of yarns," it follows that when the number of threads of some known count is of equal thickness to some other number of known or unknown counts, these numbers bear a simple and direct proportion to each other. During comparison, threads are added or taken from one or other of the sets and again twisted as above and compared until the two sets appear to make a similar thickness of thread.

Example 1.—6 threads of 2/30s worsted are found by twisting and comparison to equal 8 threads of some unknown count, what are the counts of the latter ?

Then since the counts of yarn vary in the same ratio as the number of threads of yarn, which are compared, they may be found by proportion, thus :—

As $6 : 8 :: 15 : x =$ 20s counts or 2/40s worsted.

i.e., 8 threads twisted together of 2/40s are equal in thickness to 6 threads of 2/30s worsted twisted together.

II. By Weighing Small Quantities of Warp or Weft.

Obtain as many inches of yarn (warp or weft) by taking as many threads from the cloth as is possible and weigh exactly, say to the 100th part of a grain. Then since the number of yards of *worsted* which weigh 12·5 grains equals the counts, and supposing we have obtained 9 threads each 4 inches long (1 yard) and these are found to weigh 1 grain, the counts of this yarn would be 12·5s, because it would require $12\frac{1}{2}$ yards to weigh 12·5 grains.

Example 2.—If 12 threads each 3 inches long are found to weigh ·87 grains, find the counts in worsted.

$\therefore$ As ·87 : 12·5 : : 1 : $14\frac{32}{87}$s counts.

Example 3.—If 72 inches of cotton yarn weigh ·4 grains, what are the counts?

Then, since the number of yards of *cotton* which weighs $8\frac{1}{3}$ grains equals the counts,

$\therefore$ As ·4 : $8\frac{1}{3}$: : 2 : $41\frac{2}{3}$s counts.

When adopting this method it is necessary to consider the loss in weight during scouring and finishing, together with the amount of take-up in length of warp and weft in the process of manufacture. In some instances, particularly in fancy worsteds which are woven on the square, the loss of weight in scouring and finishing is neutralised by the shrinkage in length of warp and weft as far as ascertaining the counts of yarn is concerned; consequently, the results obtained by the above method would coincide with the actual counts of the material used in the construction of the cloth. No law can, however, be laid down which admits of general application.

III. BY WEIGHING A SMALL SAMPLE OF CLOTH.

Weigh a small piece of cloth, as a rule 1 square inch, then count the threads and picks per inch, and if they are equal in thickness add them together to find the total length of yarn weighed. After allowing for loss in scouring and finishing together with shrinkage in length and width, find by simple proportion the number of yards which weigh 12·5 grains. This number will represent the required counts in worsted.

Example 4.—Assume that 1 square inch of worsted material weighs 3 grains and contains 60 ends and picks per inch, the warp and weft being of equal thickness, the loss in weight by scouring and finishing is neutralised by the contraction in length of warp and weft. Find the counts of warp and weft.

Then total length of yarn weighed = 60 in. of warp.
and 60 in. of weft.
= 120 in. of yarn.

$$\therefore \text{ As } 3 : 12{\cdot}5 :: \tfrac{120}{36} \text{ yds.} : x$$

$$= \frac{120 \times 12{\cdot}5}{36 \times 3} = 13\tfrac{8}{9} \text{ counts worsted,}$$

or approximately 14s = 2/28s worsted.

Example 5.—A small sample of dyed single worsted cloth weighs $2\frac{1}{2}$ grains per square inch. It contains 96 ends and 76 picks per inch, the relative weight of warp and weft is as 2 to 3 respectively. The loss in weight after dyeing, scouring, and finishing, is estimated at 5 per cent. The shrinkage in the length of the warp is $\frac{1}{5}$, and of weft $\frac{1}{20}$; find the counts of warp and weft used in the construction of the fabric.

1. The weight of 1 square inch, plus loss in scouring and finishing $= \frac{5}{2} \times \frac{100}{95} = \frac{50}{19}$ grains.

(2) And the weight of warp $= \frac{50}{19}$ grs. $\times \frac{2}{5}$ pts. $= \frac{20}{19}$ grs.

(3) Also the weight of weft $= \frac{50}{19}$ grs. $\times \frac{3}{5}$ pts. $= \frac{30}{19}$ grs.

(4) The length of warp before shrinkage = 96 threads per inch × 5 parts originally ÷ 4 parts finished.

$$=\frac{96 \times 5}{4} = 120 \text{ inches.}$$

$\therefore$ 120 inches of warp weigh $\frac{20}{19}$ grs.

(5) The length of weft before shrinkage $= \frac{76 \times 20}{19} = 80''$

$\therefore$ 80 inches of weft weigh $\frac{30}{19}$ grs.

(6) Then cts. of w'p $= \frac{120}{36} \times \frac{25}{2} \times \frac{19}{20} = 39\frac{7}{12}$ or 2/80s wtd.

(7) And cts. of weft $= \frac{80}{36} \times \frac{25}{2} \times \frac{19}{30} = 17\frac{2}{3}$ or 2/36s wtd.

Example 6.—A cotton fabric, 1 × 3 inches, weighs 6 grains. It contains 80 threads and 72 picks per inch, the relative weight of warp and weft in the same area of cloth is as 3 to 2 respectively. The take-up in length and width is 5 per cent. The weight of size which it contains is estimated at 120 per cent. Find the counts of warp and weft.

(1) Weight of 1 sq. in. of cloth including size $= \frac{6 \text{ grains}}{1'' \times 3''} = 2$ grs.

(2) ,, ,, ,, ,, without ,, $= \frac{2 \times 100}{220} = \frac{10}{11}$ grs.

(3) ,, warp in 1 sq. in. of cloth unsized $= \frac{10}{11} \times \frac{3 \text{ pts.}}{5} = \frac{6}{11}$ grs.

(4) ,, weft ,, ,, ,, ,, $= \frac{10}{11} \times \frac{2 \text{ pts.}}{5} = \frac{4}{11}$ grs.

(5) Length of warp before shrinkage, in yds. $= \frac{80'' \times 100}{36 \times 95} = \frac{400}{171}$ yds.

(6) ,, ,, weft ,, ,, ,, $= \frac{72 \times 100}{36 \times 95} = \frac{40}{19}$ yds.

(7) Therefore counts of warp = as $\frac{6}{11}$ grs. : $\frac{25}{3}$ grs. : : $\frac{400}{171}$ yds. : x cts.

$$= \frac{400 \times 25 \times 11}{171 \times 3 \times 6} = 36\text{s cotton.}$$

(8) The counts of weft $= \text{as} \frac{4}{11} \text{grs.} : \frac{25}{3} \text{grs.} :: \frac{40}{19} \text{yds.} : x \text{ cts.}$

$$= \frac{40 \times 25 \times 11}{19 \times 3 \times 4} = 48\text{s cotton.}$$

IV. Alternative Method to No. III.

The loss in weight due to boiling decreases the weight of the yarn and produces an *apparently* higher count, while the contraction or shrinkage in length increases its relative weight and contributes to make an *apparently* lower count; consequently if the difference in these two factors be obtained the result can be added to or deducted from the ascertained weight of yarn sample tested and from which the counts of the yarn may be found as already demonstrated.

As an alternative the counts may be first ascertained for the finished weight or condition in which the material is tested, then to the weight of counts must be added the excess of loss in scouring, boiling, bleaching, or other treatment, over contraction in length or width. The width of the material in the loom can then be separately determined by the estimated or known shrinkage as set forth in the following pages.

Example 7.—If one square inch of linen fabric weighs 2 grains, the ends and shots per inch finished are 45, assume 8% has been lost in weight by treatment and the contraction is 4% for length and width, find the lea counts assuming warp and weft to be equal.

Then according to reasoning in method IV. The loss % through treatment − contraction % = the equivalent nett loss in weight for original length of thread, thus :—

8% loss − 4% contraction = 4% nett equivalent loss.

Therefore the original weight for original natural length of spun yarn before treatment

= Weight in grains of sample weighed + loss % added

$= \frac{2 \times 100}{96} = \frac{25}{12}$ grains.

And since the number of yards of lea yarn which weigh $23\frac{1}{3}$ grains equals the counts

$$\therefore \text{ As } \frac{25}{12} : \frac{70}{3} :: \frac{45 + 45}{36} : x.$$

Where x = the required lea count

$$= \frac{90}{36} \times \frac{70}{3} \times \frac{12}{25} = 28\text{s linen.}$$

or by the alternative plan as in method IV.

$$\text{As } 2 : \frac{70}{3} :: \frac{45 + 45}{36} : x$$

$= \frac{90}{36} \times \frac{70}{3} \times \frac{1}{2} = \frac{175}{6}$ lea counts of yarns in sample state.

$\therefore$ Since the nett loss % = 4 as above, the original lea counts would be $\frac{175}{6} \times \frac{96}{100} = 28$.

Example 8.—A sample of a plain boiled linen fabric contains 85 threads per inch which weigh 0·7 grains and 96 picks per inch with an aggregate weight of 0·6 grs. If the contraction in width is 6% and that of the length 4% ascertain the counts of the spun thread after allowing 10% for boiling.

Then by method IV.

(1) Warp 10% − 4% = 6% nett loss in weight.
(2) Weft 10% − 6% = 4% ,, ,,

$$\therefore \text{ Counts of linen warp } = \frac{85}{36} \times \frac{70}{3} \times \frac{94}{0·7 \times 100} = 74\text{s.}$$

And counts of linen weft $= \frac{96}{36} \times \frac{70}{3} \times \frac{96}{0 \cdot 6 \times 100} = 99 \cdot 5$s.

The cloth would be made with 75s lea warp and 100s weft.

Example 9.—A double damask in the finished state contains 90 ends and 140 picks per inch respectively. One square inch weighs 2·1 grains. Assuming that it has lost 15% in bleaching, contracted 10% from reed to finished state and 4% in length and that the relative weight of warp to weft in one square inch is as 1 to 2, find the counts of warp and weft.

Then finished weight of warp $= \frac{2 \cdot 1}{3} = 0 \cdot 7$ grs.

And ,, ,, weft $= \frac{2 \cdot 1}{3} \times 2 = 1 \cdot 4$ grs.

Also nett loss in weight of warp $= 15\% - 4\% = 11\%$

And ,, ,, ,, weft $= 15\% - 10\% = 5\%$

$\therefore$ Counts of warp $= \frac{90}{36} \times \frac{70}{3} \times \frac{95}{0 \cdot 7 \times 100} = 79\frac{1}{6}$s

And ,, ,, weft $= \frac{140}{36} \times \frac{70}{3} \times \frac{89}{1 \cdot 4 \times 100} = 57 \cdot 6$s

The actual warp and weft would be 80s and 55s or 60s lea respectively since the lea counts, up to 100 generally run in 5s.

C. Determination of Sett and Picks in Loom.

First ascertain the number of ends and picks in one inch of the finished cloth, then the product of the finished width in inches and the number of ends per inch must equal the total number of ends in the whole warp. Now, if this total be divided by the number of inches of warp in the reed, the result will consequently equal the ends per inch of the warp in the loom.

The width of the warp in the reed will depend upon the class of goods to be made, the required width of the finished piece and the structure of the design.

In ordinary worsted textures the shrinkage of the cloth from the loom to the finished state, varies from 8% to 12%, in milled fabrics the shrinkage is often from 25% to 30%, whilst in cotton materials the take-up in length of warp and width of piece is often less than 5%.

In linen cloths the contraction in width is difficult to express in terms per cent. which admit of application to all widths since the relative shrinkage for narrow fabrics is greater than for wider textures, *e.g.* A warp 40″ in the reed yields 38″ loom state and 36″ finished; a similar texture 80″ reed produces 77″ loom state and 74 to 75″ finished. Also if the fabric when bleached is shrunk in width from the grey condition it generally pulls out in length somewhat through the process. For purposes of calculation the shrinkage may be generally reckoned as varying from 5 to 10% according to width and special treatment.

In *questions* for *exercises* it is necessary to assume the foregoing or other amounts of shrinkage, and in *practice* to treat each cloth which requires reproduction upon its separate merits, but the principles of solution for both theory and practice are coincident.

It is also important to remember the following observations, which, I presume, will be readily understood:—

1. The total length of grey warp in yards required to produce 1 yard of finished cloth equals

Ends per inch finished × finished width × grey length of warp in yards required to produce 1 yard of finished cloth.

2. The total length of grey weft in yards required to produce 1 yard of finished cloth equals

Picks per inch finished × width of warp in reed.

$$\text{or } \frac{\text{Picks per inch finished} \times \text{finished width} \times 100}{100 - \text{shrinkage of width per cent.}}$$

If shrinkage is expressed as a fraction, then substitute the fraction for percentage.

Example 1.—Assume a finished fabric, 56″ wide, contains 90 ends and picks per inch. If the contraction in length and width is estimated at 10%. Find the grey length in yards of warp and weft to produce one yard of the above finished cloth.

(1) Then No. of yds. of wp. in 1 yd. of finished cloth $= 90 \times 56$

Plus 10% for contraction $= \dfrac{90 \times 56 \times 100}{90} = 5600$ yds. grey.

(2) And the No. of yds. of wft. in 1 yd. of finished cloth $= 90 \times 56$

Plus 10% for contraction $= \dfrac{90 \times 56 \times 100}{90} = 5600$ yds. grey.

Example 2.—A sample of cloth is found to contain 80 picks and ends per inch. If the shrinkage be estimated at 10%, find the width of the warp in the reed and the number of ends and picks with which it must be woven (assume 56 inches finished).

(a) Total No. of ends in the warp $= 80 \times 56 = 4480$.

And 80 ends finished $= \dfrac{80 \times 90}{100} = 72$ ends grey.

(b) $\dfrac{4480}{72} = 62\frac{2}{9}$ inches in reed.

Example 3.—A small sample of finished cloth contains 64 ends and picks per inch. If shrinkage be estimated at 9%, find the reed width and the number of ends and picks with which it should be woven. (55 inches finished.)

(a) Total No. of ends in warp $= 64 \times 55 = 3520$.

And 64 ends finished $= \frac{64 \times 91}{100} = 58{\cdot}24$ ends per inch grey.

(b) $\frac{3520}{58{\cdot}24} = 60{\cdot}4$ inches in reed.

Example 4.—A finished fancy worsted coating weighs 13 ozs. per yard (57 inches $\times$ 37 inches); it contains 81 ends and 71 picks per inch finished; it loses 10 per cent. weight in scouring and finishing; an average of 70 yards of warp produces 63 yards of cloth out of loom (36 inches), and $55\frac{1}{2}$ yards when finished (37 inches); the width in reed required to produce 57 inches finished is 64 inches. If the warp and weft in 1 square inch or other convenient area are of equal weight, find the counts of warp and weft, and ends and picks per inch required to produce this texture.

(1) Total weight of cloth finished $= \frac{55\frac{1}{2} \times 13}{16} = 45$ lbs.

(2) " " out of loom $= \frac{45 \times 100}{90} = 50$ lbs.

(3) The weight of warp and weft each equal 25 lbs.

(4) The number of ends per inch in loom

$$= \frac{\text{Ends per inch finished} \times \text{finished width}}{\text{Width of cloth in loom}} = \frac{81 \times 57}{64} = 72$$

(5) The number of picks per inch when it leaves the loom

$$= \frac{\text{Picks per inch finished} \times \text{finished length}}{\text{Length of cloth when it leaves the loom.}}$$

$55\frac{1}{2}$ yds., 37″ finished $= \frac{55\frac{1}{2} \times 37''}{36''} = 57$ yds. 36″ finished.

$$\therefore \quad \frac{71 \times 57}{63} = 64 \text{ picks per inch in loom.}$$

(6) Counts of warp—by formula I.

$$= \frac{72 \times 64 \times 70}{25 \times 560} = 23\text{s counts}$$

(7) Counts of weft—by formula I.

$$= \frac{64 \times 64 \times 63}{25 \times 560} = 18\tfrac{1}{2}\text{s count worsted.}$$

Example 5.—A fancy woollen fabric weighs $3\frac{1}{2}$ grains per square inch. It contains 40 ends and 36 picks per inch finished. The weight of warp and weft in the same area is equal. Allow for loss in scouring and finishing 15%; for shrinkage from warp length to grey length $\frac{1}{10}$, from grey length to finished length $\frac{1}{10}$, and for shrinkage in width $\frac{1}{7}$. Find weight per yard finished (56 × 37 inches), ends and picks per inch in loom, and counts of warp and weft.

(1) Weight per yd (by formula XXV) $56 \times 37'' = 4{\cdot}736 \times 3\frac{1}{2} = 16\frac{3}{5}$ ozs.

(2) ,, ,, ,, $56 \times 36'' = 4{\cdot}6 \times 3\frac{1}{2} = 16\frac{1}{10}$ ozs.

The latter is the necessary factor for finding the counts.

(3) Weight per yard plus loss in scouring and finishing =

$$\frac{16{\cdot}1 \times 100 \text{ parts}}{85 \text{ parts}} = 19 \text{ ozs.}$$ = The original weight of warp and weft required to produce 1 yd. of cloth finished $56 \times 36''$

(4) Weight of warp and weft is equal,

$\therefore \frac{19}{2} = 9\frac{1}{2}$ozs = original weight of warp req'd to produce 1 yd. cloth.

Also $9\frac{1}{2}$ozs. = ,, ,, weft ,, ,, ,, ,,

(5) The ends per inch in loom =

$$\frac{40 \text{ ends finished} \times 6 \text{ parts}}{7 \text{ ,,}} = 34\tfrac{2}{7} \text{ per inch.}$$

(6) The picks per inch in loom =

$$\frac{36 \text{ picks finished} \times 9 \text{ parts finished}}{10 \text{ ,, ,,}} = 32\tfrac{2}{5} \text{ per inch.}$$

(7) The reed width $= \frac{56 \text{ in. finished} \times 7 \text{ parts grey}}{6 \text{ parts finished}} = 65\frac{1}{3}$ ins.

(8) The counts of warp (by formula I.) $= \left(\frac{40 \times 56 \times 5 \text{ parts}}{4 \text{ ,,}}\right) \times \left(\frac{2 \times 16}{19 \times 256}\right) = 18\frac{8}{19}$ Y.S. counts.

(9) The counts of weft (by formula I.) $= \left(\frac{36 \times 56 \times 7 \text{ parts}}{6 \;\;,,}\right) \times \left(\frac{2 \times 16}{19 \times 256}\right) = 15\frac{9}{16}$ Y.S. Counts.

Example 6.—A trousering cloth 28″ finished including list weighs 5 grains per square inch. The relative weight of the face and back cloth is as 10 to 9 (obtained by detaching a portion of the back cloth from the face cloth). The weight of face warp and weft in 1 square inch of cloth is relatively the same, and the relative weight of the face warp to back weft is as 8 to 9. The cloth contains 60 ends and picks per inch of face, and 30 ends and picks of back finished. Assuming that 33 inches reed width is necessary to produce 28 inches finished, and that 68 yards of warp produce 63 yards grey (36″), and 57 yards (36″) finished, find the weight per yard for for 28″ × 37″, also the ends and picks per inch in loom, and the counts of warp and weft of face and back respectively.

(1) The weight per yd. (28″ × 37″), table IV., = $2{\cdot}368 \times 5 = 11{\cdot}84$ ozs.

(2) The weight per yard (28″ × 36″), table IV., = $2{\cdot}3 \times 5 = 11{\cdot}5$ ozs.

(3) Total weight of piece plus loss in scouring and finishing $= \frac{11\frac{1}{2} \times 57 \times 100}{16 \times 90} = 45\frac{1}{2}$ lbs.

(4) Weight of face cloth, $\frac{10}{19}$ parts of total warp $= \frac{45\frac{1}{2} \times 10}{19} = 24$ lbs.

(5) Weight of back cloth, $\frac{9}{19}$ parts of total warp $= \frac{45\frac{1}{2} \times 9}{19} = 21\frac{1}{2}$ lbs.

(6) Weight of face warp $= \frac{1}{2}$ face cloth $=$ 12 lbs.

(7) Weight of face weft $= \frac{1}{2}$ face cloth $=$ 12 lbs.

(8) Weight of back warp $= \frac{8}{17}$ back cloth.

$$= \frac{21\frac{1}{2} \times 8}{17} = 10\cdot1 \text{ lbs.}$$

(9) Weight of back weft $= \frac{9}{17}$ back cloth

$$= \frac{21\frac{1}{2} \times 9}{17} = 11\cdot4 \text{ lbs.}$$

(10) Ends of face warp $= \frac{60 \times 28}{33} = 51$ per inch in loom.

(11) Picks of face weft $= \frac{60 \times 57}{63} = 54\frac{2}{7}$ per inch out of loom.

(12) Ends of back warp $= \frac{30 \times 28}{33} = 25\frac{1}{2}$ per inch in loom.

(13) Picks of back weft $= \frac{30 \times 57}{63} = 27\frac{1}{7}$ per inch out of loom.

(14) Counts of face warp $= \frac{51 \times 33 \times 68}{12 \times 560} = 17$s count or 2/34s

(15) Counts of face weft $= \frac{54\frac{2}{7} \times 33 \times 63}{12 \times 560} = 16\cdot8$s counts

(16) Counts of back warp $= \frac{25\frac{1}{2} \times 33 \times 68}{560 \times 10\cdot1} = 10\cdot1$s or 2/20s worsted.

(17) Counts of back weft $= \frac{27\frac{1}{7} \times 33 \times 63}{256 \times 11\cdot4} = 19\cdot3$s Y.S. woollen

Example 7.—A sample of cotton cloth weighs $3\frac{1}{2}$ ozs. per yard (38″ × 36″). It contains 110% of sizing material, $52\frac{1}{2}$ threads and 42 picks per inch. It is assumed to have contracted 5% in length and width. The relative weight of warp and weft is as 3 is to 2 in the same area of cloth. Find the reed width, the ends and picks per inch in loom, and the twist or counts of warp and weft used in its construction.

(1) Actual w'ght of 1 yd. cloth less sizing $= \frac{7}{2}$ oz. $\times \frac{100}{(100+110)} = \frac{5}{3}$ oz.

(2) ,, ,, warp in 1 yd. less sizing $= \frac{5}{3} \times \frac{3}{5}$ parts $=$ 1 oz.

(3) ,, ,, weft ,, ,, ,, $= \frac{5}{3} \times \frac{2}{5}$,, $= \frac{2}{3}$ oz.

(4) Reed width $= \frac{38'' \times 100}{95} = 40$ inches.

(5) Ends per inch $= \frac{52\frac{1}{2} \times 38''}{40} = 50$ in loom.

(6) Picks per inch $= \frac{42 \times 95}{100} = 40$ in loom.

(7) Counts of warp by formula I. $= \frac{50 \times 40 \times 16 \text{ ozs. per lb.}}{840 \times 1 \text{ oz.}} = 38$s cotton.

(8) Counts of weft by formula I. $= \frac{42 \times 40}{840} \times \left(\frac{3 \times 16}{2 \times 1}\right) = 48$s cotton.

EXERCISES.

A

1. A sample of costume cloth 2 inches × 2 inches weighs 7·6 grains. Find the weight per yard for 56 inches wide and 37 inches per yard.

Ans., 9.

2. 2 square inches of heavy suiting weigh 10.1 grains. Find the weight per yard for 57 inches × 37 inches, and 29 inches × 37 inches.

Ans., 24·34; 12·37.

3. A Scotch tweed sample, 3 inches × 2 inches, weighs 27 grains. Find the weight per yard for 55 inches × 37 inches.

Ans., 20·9.

4. If it is found by comparison that 8 threads of 2/36 cotton are approximately equal to 10 threads extracted from a small sample of cotton cloth, what are the counts of the latter?

Ans., 2/45s.

5. 10 threads, each 5 inches long, extracted from a Scotch tweed, weigh 2·5 grains. What are the counts Galashiels and Hawick, assuming the loss in weight by scouring and finishing neutralises the increased relative weight due to shrinkage in length?

Ans., $19\frac{4}{9}$; 21.

6. 7 threads of woollen warp, each 3 inches long, weigh ·91 grains. What are the counts Y. S. and Halifax Rural District?

Ans., 17·5, 4·55.

7. A weighted cotton fabric contains 66 ends and 72 picks per inch, finished. The take-up in warp and weft is 4 per cent. 1 square inch weighs 1·96 grains. It contains 75 per cent. of sizing. The weights of warp and weft for the same area of cloth are equal. What are the counts of warp and weft, the ends and picks per inch in the loom, and the weight per yard (38 inches × 36 inches)?

Ans., $28\frac{2}{5}$; 31; 63·36; 69·12; $8\frac{3}{4}$.

B

8. 1 square inch of a woollen fabric weighs 3·7 grains. It contains 42 ends and 38 picks per inch. The piece loses 18 per cent. in scouring and finishing. The weight of warp and weft for the same area of cloth are equal. The take-up in warp and weft is $\frac{1}{6}$. Find the weight per yard for 55 × 37 inches, and the counts and threads per inch in loom of warp and weft.

Ans., $17\frac{1}{5}$; $16\frac{1}{2}$; 15; 35; $32\frac{2}{3}$.

9. A union dressed face cloth contains 44 ends and 48 picks per inch, finished. 1 square inch weighs 3·6 grains. The relative weight of warp to weft is as 1 to 2. The loss of weight in scouring, cutting, and

finishing, is 25 per cent, of weft and 5 per cent. of warp. 70 yards of warp produce 68 out of loom, and 67 finished. 70-inch reed width is required to produce 54 inches finished. Find the counts of cotton warp and woollen weft, the ends and picks in loom, and the weight per yard for 54 × 36 inches.

Ans., $8\frac{3}{7}$; $14\frac{3}{4}$; 34 ; $47\frac{1}{3}$; 16.

10. A Scotch tweed weighs 5·6 grains per square inch. The weight of warp to weft is as 3 to 2. There are 76 ends and 56 picks per inch finished. 80 yards of warp produce 70 yards out of loom and 60 yards finished. 75-inch reed gives 55 inches finished. The loss of weight in scouring and finishing is 20 per cent. Find the counts of warp and weft in Gala., and weight per yard for 56 × 37 inches.

Ans., $23\frac{3}{7}$; $26\frac{1}{2}$; $26\frac{1}{2}$.

11. A square inch of fancy worsted cloth weighs 1·9 grains. It contains 50 ends and 44 picks of two-fold warp and weft respectively. The relative weight of warp to weft in the same area of cloth is as 10 to 9. The loss of weight in scouring and finishlng is 10 per cent. The take-up in length of warp and weft is $\frac{1}{10}$. Find the counts of yarn. *Ans.*, 2/35 ; 2/34.

12. A fancy tweed (double-cloth) contains 88 ends and 95 picks per inch. 1 square inch weighs 5·3 grains. The relative weight of warp to weft for the same area of cloth is as 25 to 28. The loss in scouring and finishing is 12 per cent. The take-up in length of warp and weft is $\frac{1}{7}$. Find the counts of yarn in Galashiels. *Ans.*, 35 ; $33\frac{5}{8}$.

13. A cotton cloth contains 105 ends and 96 picks per inch. 2″ × 3″ weigh 16·2 grains. The weights of

warp and weft in the same area of cloth are equal. The weight of size which the same contains is 90 per cent. The take-up in length of warp and weft is $\frac{1}{15}$. What are the actual counts of warp and weft?

Ans., $36\frac{1}{2}$; $33\frac{1}{3}$.

14. A Scotch tweed contains 25 ends and 23 picks per inch. It is finished 55 inches wide including lists. It shrinks 15 per cent. in length after leaving the loom and 20 per cent. in width. Find the number of ends and picks per inch, and the width of piece in the loom.

Ans., 20; $19\frac{1}{2}$; $68\frac{3}{4}$.

15. A single fancy costume worsted cloth weighs 2·4 grains per square inch. It contains 66 ends and 54 picks per inch. The relative weight of warp to weft for the same area of cloth is as 15 to 14; the take-up in length of warp and weft is 10 per cent.; the loss of weight in scouring and finishing is 10 per cent. Find the weight per yard in ounces for 57×37 inches; the counts of warp and weft and the ends and picks per inch used in weaving.

Ans., 18·4; $16\frac{1}{8}$; 59·4; 48·6.

16. A black worsted coating contains 96 ends and 104 picks per inch. 1 square inch weighs 4·5 grains. 70 yards of warp produce 64 yards (36 inches) grey, and 57 yards (36 inches) finished. The width in the reed required to produce 57 inches is 66 inches. Supply the ends and picks per inch in loom; counts of warp and weft; and weight per yard for 57×37 inches. The nett gain in weight of the piece after dyeing and finishing is 5 per cent., and the weights of warp and weft are equal for the same area of sample.

Ans., 83; $92\frac{5}{8}$; 19; $19\frac{1}{2}$; 21·69

17. If 4 square inches of a 38″ linen cloth, 14/14, weigh 7 grains, find the weight of a web of 85 yards, 37″ measure. Allow for shrinkage 10% in length and 5% in breadth and give the lea number.

Ans., 29·9 lbs.; 59; $59\frac{1}{4}$; say 60/60.

18. A 36 inch grey linen, counts 47 threads per inch of warp and 54 threads per inch of weft; the fabric weighs $27\frac{1}{2}$ lbs. per 100 yards, 37″ measure; assuming 110 yards of warp and 38″ reed are required to produce this fabric, what suitable lea number of yarn warp and weft, would be required if the weight of warp and weft in the cloth are equal?

Ans., 45s warp; 51·1s weft, use 50s.

19. A jute hessian fabric weighs $10\frac{1}{2}$ ozs. per 37″ yard, 40 inches wide. It counts 12 ends and 14 picks per inch finished. Allow for contraction $\frac{1}{11}$ in width and $\frac{1}{12}$ in length, 2% of which contraction in length has occurred since the fabric left the loom. Find (a) the porter reed 37″ scale and the shots per inch in loom, (b) the lbs. per spindle of warp and weft, estimating the weight of warp and weft to equal each other.

Ans., 10; $13\frac{3}{4}$; 8·8; $7\frac{1}{2}$.

C

20. A small sample (8-end sateen weave) of silk brocade, 3 inches × $2\frac{1}{2}$ inches, weighs 15 grains. It contains 248 ends and 312 picks per inch. The relative weight of warp to weft is as 2 to 3. The weight of dye, size, gum, etc., is equal to one half of the original weight. The take-up in length of warp is 8 per cent., and of weft 3 per cent. The pattern is warped 2 threads black organzine and 1 thread yellow organzine.

Weft or filling is 1 pick blue, 1 ,, black, 1 ,, light green } Tram silk.

Find the original counts in Denier and Dram Systems, ends and picks per inch in loom, and weight per yard, exclusive of lists (24 inches × 36 inches).

Ans., 45; 56; 2·6; 3·26; 240; 287; 3·94.

21. A heavy double fancy worsted cloth contains 81 ends and 75 picks of warp and weft; there are 2 ends and picks of face to 1 end and pick of back. The weight of 1 square inch of cloth is 6 grains. The relative weight of face to back cloth is as 8 to 7, and the weights of face warp and weft, and back warp and weft are equal for the same area of cloth. The face warp loses $\frac{1}{10}$. The face weft and back warp and weft shrink $\frac{1}{9}$. Find the weight per yard for 57 inches × 36 inches, the counts of warp and weft, and the total ends and picks per inch in loom. The loss of weight in scouring and finishing is 10 per cent.

Ans., 28; 11·7; 11; $6\frac{3}{4}$; $6\frac{1}{3}$; 72; $66\frac{2}{3}$.

22. A woollen suiting weighs 6·12 grains per square inch. It contains 34 ends and 32 picks per inch finished. The weight of warp and weft for the same area of cloth are equal. The take-up of the warp and weft are each $\frac{1}{6}$, and the loss of weight in scouring and finishing is 15 per cent. Find the counts of warp and weft, ends and picks per inch, and the weight per yard for 55 × 37 inches.

Ans., $8\frac{5}{9}$; $8\frac{1}{10}$; $28\frac{1}{3}$; $26\frac{2}{3}$; $28\frac{1}{2}$.

23. A single cloth with 64 ends and picks per inch is woven in 64-inch reed, with 2/48s worsted warp and 2/36 worsted weft. It is required to increase the

weight by adding a woollen back to it. There must be 2 ends and picks of face to 1 end and pick of back. The relative weights of face and back cloth must be as 2 to 3 respectively. Find the counts of warp and weft required for the back cloth.

Ans., $17\frac{1}{2}$; $13\frac{1}{8}$.

24. A double cloth weighs 24 ounces per yard when it leaves the loom. It is woven with 60 ends and picks per inch of face and 30 ends and picks per inch of back. Reed width 64 inches. The weight of face to back cloth is as 3 to 4. The counts of face warp and weft are equal as are also the back warp and weft. The take-up in length and width is $\frac{1}{9}$. Find the sizes of twist for face and back in worsted and woollen respectively.

Ans., 24; $19\frac{11}{16}$.

25. If a piece of linen counting 17×19 and measuring 6 inches square, weighs 50 grains, find the weight in lbs. per web of 75 yards, 37″ measure and 38″ cloth; assuming that the yarns have lost 10% due to boiling, that the weight of warp and weft in the web are equal and that 85 yds. of warp and 40″ reed are necessary to produce the given fabric, find the nearest standard lea counts,

Ans., 20·92; 82·8; 90·8 say 85/90.

26. A dress linen measuring 3×2 inches weighs 15·6 grs.; it counts 47 ends and $32\frac{1}{2}$ picks per inch; the width of the fabric is 32 inches; the nett loss of weight in the yarns due to treatment is estimated at 8%; the contraction in width and length is 4%. Find nearest practical sett on 40″ scale and the shots on 37″ glass and the nearest lea count of warp and weft; the

relative weight of warp to weft in the same area of cloth is as 3 to 5. Assume the finished and loom length of web to be equal.

Ans., 9^{00}; 6; 30; 2/25.

27. A sample of bleached huckaback 3×2 weighs 23·75 grs.; the weight of warp to weft in the same area of cloth is as 3 to 7; the estimated loss of weight due to bleaching is 15%; $18\frac{1}{4}''$ finished from 20 inch reed and counting 82 ends and 28 double shots of weft. Find the sett on 40 inch scale, the shots on $37''$ glass and the lea number warp and weft. Contraction in length to be estimated at 5%. Loom to finished length 2% contraction.

Ans., 15^{00}; 10 or 5 double; 40; 12.

CHAPTER X.

CONDITIONING; OR THE STANDARD ALLOWANCE OF MOISTURE IN TEXTILE MATERIALS.

The fibres composing yarns, all articles manufactured from wool, cotton, flax, silk and every other textile material under normal conditions, contain a certain amount of moisture. This hygroscopic propensity is of such a character that under favourable conditions these materials will rapidly absorb additional moisture when exposed to dampness, and even take up in considerable quantities water that may be sprinkled upon them artificially; on the contrary, when exposed to dry air, natural or artificial, they lose with corresponding rapidity much of their natural moisture, consequently, the relative weight of any material is repeatedly changing with the temperature of the air in which it is exposed. These varying factors are necessarily a constant source of inconvenience and trouble to dealers, spinners, and manufacturers.

Take as an example the reeling of silk in Japan, which commences with the rainy season. It is difficult to correctly estimate the amount of moisture which the silk fibre has absorbed during the ocean transit, in addition to the amount absorbed in the damp climate of Japan. Subsequently the material loses a considerable amount of moisture and therefore weight during its passage through the several processes of preparation into yarn, and of manufacture into fabrics, with the result that the manufacturer is apt to err in his calculation of the cost of the raw material. The wool fibre has possibly the greatest affinity for moisture. It is capable of absorbing and retaining water to an extent which is slightly over $\frac{1}{3}$ of its absolute dry weight, or an increase of about 35%. This hygroscopic affinity of wool, and all other textile fibres, has unfortunately made it possible for unscrupulous dealers in raw and manufactured textile products to excessively moisten their goods and so pass off water for the genuine article.

It was in the silk industry where the question of "condition" was first seriously considered, possibly on account of its relatively greater value than other textile fibres.

In October of the year 1750, an establishment was founded at Turin to test the "CONDITION" of silk from which the term "CONDITIONING" originated. To-day, CONDITIONING HOUSES are common in all the leading centres of the textile industry; many spinners and manufacturers have their own conditioning apparatus.

The object of a conditioning house is to test the amount of moisture contained in raw material, yarn, or fabric, and afterwards, to compare with the official standard allowances for moisture the material which has been tested.

Elaborate tests extending over a series of years have been made by persons engaged in the trade, and their conclusions demonstrate that after absolute dryness has been obtained, regain of moisture will take place on exposure to the average temperature of the climate of the country, usually in a warehouse. The various materials will regain different percentages according to the nature of the material which is tested. These regains have been tabulated, officially acknowledged, and fixed as the standard amount of moisture which the respective materials must contain as commercial articles.

The following table shows the standard allowances of moisture or amount of regain for the several textile fibres used in this country.

TABLE V.

Raw wool,	amount	of regain	16%,	direct loss	13·77%
Combed tops in oil,	,,	,,	19 ,,	,,	16·01 ,,
Combed tops, dry,	,,	,,	18¼ ,,	,,	15·43 ,,
Noils,	,,	,,	14 ,,	,,	12·3 ,,
Yarn and fabrics,	,,	,,	18¼ ,,	,,	15·43 ,,
Silk, all processes,	,,	,,	11 ,,	,,	9·86 ,,
Cotton, all processes,	,,	,,	8½ ,,	,,	7·91 ,,
Flax and Hemp,	,,	,,	12 ,,	,,	10·71 ,,
Tow, spun,	,,	,,	12½ ,,	,,	11·11 ,,
Jute,	,,	,,	13¾ ,,	,,	12·09 ,,

The operation of conditioning is simple. The best way is to obtain absolute dryness, then the difference between the original and absolute dry weight reveals the amount of water contained in the material before testing.

The apparatus which is used for the purpose of acquiring absolute dryness consists of an oven about 40 inches high by 30 inches in diameter; the oven for conditioning silk is 30 inches by 16 inches respectively. Inside the oven is a cylindrical hot air chamber, the distance between the two chambers being about 1½ inches, which allows the hot air to freely circulate all round the inner chamber.

The heat is obtained from a Bunsen gas burner, which uses about 75 per cent. of air, and the lights, about 80 in number, are arranged in a circular form under the inner oven. A thermometer is arranged so that the bulb reaches half-way down the oven, the degrees of temperature having a range from 10 to 400 Fahrenheit.

A pair of balances is firmly fixed immediately above the oven, so that one arm is directly over the centre of the oven. Suspended from this arm is a small wire which passes through the centre of the cylinder cover, with a reel attached to it for tops or yarns, and a creel substituted for wool, noils, cotton, flax, or loose materials. The balance is in equilibrium when either the reel or creel is attached to this arm, whilst to the opposite arm is suspended the scale pan for the ordinary weights. The measure of deflection or sensibility of the balance should be 1 grain.

For *Wool* the oven may be heated up to 230° F. or 110° Centigrade.

For *Cotton* and *Flax* up to 220° F. or $104\frac{4}{5}$ C. is the limit of temperature to avoid scorching.

For *Silk* the temperature is sometimes maintained as high as 248° F. or 120° C.

In no case must the temperature be less than boiling point 212° F. or 100° C. or the moisture will not be all evaporated.

The method of procedure consists in selecting equal portions of wool from the top, centre and bottom, or from the centre and sides so as to secure a fair sample of the average amount of moisture contained in the bulk. This sample of top is then very accurately weighed, without loss of time, wound on the reel and placed in the oven suspended from its balance arm. The temperature is increased until it exceeds the boiling point, but it must be kept within the prescribed limits to avoid scorching or discolouriug. The period of subjection to heat is variable, frequently 30 to 45 minutes is sufficient, but to fix the time is scarcely possible.

The material being now in the oven and the balance weights adjusted, a change in the weight is soon observed which is due to the moisture that is being driven off. This loss of weight will continue until all the moisture has been dispersed, after which the material should still remain in the oven for 5 or 6 minutes. Then, so long as the temperature in the oven has been maintained above 212°F. or 100°C., the wool may be considered absolutely dry. Provision is made on the same arm to which the reel is fixed for the reception of small weights, which are placed on it as the wool continues to lose weight. These therefore indicate at a glance the moisture which is gradually being lost, whilst the ordinary scale pan retains the original weight.

Then by simple arithmetic we can obtain the amount of moisture per cent. which the material contained, and this, when compared with the standard allowance of moisture for the particular wool tested, readily reveals any excess of moisture which was contained in the material.

When testing yarns, loose wool, noils, silk, cotton, flax, or other material, the same conditions apply, the main object being to obtain for the purpose a fairly representative sample of the bulk.

When a lb. or any number of lbs. of the material can be procured, it simplifies the calculation, otherwise, the most convenient portion of warp, number of hanks of yarn or weight of loose material must be taken and tested as above. When the yarn is in the form of hank, a certain number of hanks are selected; when on spools, tubes or bobbins, it is reeled into the form of hanks, but if warp in the ball, then a convenient number of threads are split off, weighed, reeled and tested in the ordinary way.

The following examples will demonstrate the essential principles and make the subject more clearly understood.

Example 1.—Assume 2 lbs. of combed top, in oil, tested in the conditioning oven; when absolute dry weight has been obtained the direct loss in weight is observed to be 5 ozs. 6 drs. What is (1) the direct loss per cent., (2) the absolute dry weight per cent., (3) the amount of regain necessary to produce the original weight, (4) the excess or loss per cent. of moisture it contained as compared with the standard allowance of 19 per cent.?

(1) *Direct loss per cent.*

Loss on original weight, 5 ozs. 6 drs. = 86 drs.
Original weight = 512 drs.
Dry weight = 512 − 86 = 426 drs.

Then, if loss of moisture on 512 drs. be 86 drs., the loss per cent. therefore equals

As 512 : 100 : : 86 : x

Or, expressed as a formula it would read thus :—

FORMULA XXVI.

$$\frac{\text{Loss on original weight} \times 100}{\text{Original weight.}} = x \text{ or direct loss } \%$$

$$\therefore \quad x = \frac{86 \times 100}{512} = 16{\cdot}8\% \text{ direct loss.}$$

(2) *Absolute dry weight per cent.*

$$= 100 - 16{\cdot}8 = 83{\cdot}2.$$

(3) *Amount of regain* in moisture on 426 drams of absolute dry weight necessary to produce the original weight, 512 drams, equals 86 drams.

$\therefore$ Amount of moisture per cent. =

As 426 : 100 : : 86 : x, where x equals the regain per cent., or, expressed as a formula it reads :

FORMULA XXVII.

$$= \frac{\text{Loss on original weight} \times 100}{\text{Absolute dry weight}} = \text{Regain } \%$$

$$= \frac{86 \times 100}{426} = 20{\cdot}19\%$$

(4) *Excess of moisture per cent.* The 100 units of absolute dry weight with a regain of 20·19% equals 100 + 20·19 = 120 units of weight of the material tested. But the standard allowance is only 19, therefore 100 units of absolute dry weight should equal 100 + 19 = 119 units of weight commercially, which shews that the excess of moisture in 119 commercial units of weight = 120·19 − 119 = 1·19.

$$\therefore \text{ The excess per cent.} = \frac{1{\cdot}19 \times 100}{119} = 1$$

(4a) *Regain.*

Regain allowed on 83·2 at 19 per cent.

$$= \frac{83{\cdot}2 \times 19}{100} = 15{\cdot}8.$$

Then the absolute dry weight per cent. plus the regain officially allowed equals

$83 \cdot 2$ absolute dry weight per cent.
$15 \cdot 8$ official allowance on $83 \cdot 2$ units weight.

99 units of weight out of every 100 of the bulk, or 1 unit of weight in excess of moisture on every 99 lbs., which is, practically, 1 per cent.

Example 2.—The standard allowance of regain for noils is 14 per cent. What should be the loss per lb. of moisture, also its loss per cent. and the absolute dry weight per cent. to fulfil the above conditions?

For convenience, find the gain on 1 lb. dry weight at 14 per cent.

$$= \frac{\text{absolute dry weight} \times \text{regain \%}}{100} = \text{total regain on dry weight.}$$

$$= \frac{256 \text{ drams} \times 14}{100} = 36 \text{ drams regain on 1 lb.}$$

and 256 drs. + 36 drs. = 292 drams.

= The original weight necessary to produce 1 lb. dry weight.

(1) The percentage of dry weight $= \dfrac{\text{dry weight} \times 100}{\text{original weight.}}$

$$= \frac{256 \times 100}{292} = 87 \cdot 7\% \text{ of dry yarn.}$$

(2) And $100 - 87 \cdot 7 = 12 \cdot 3\%$ = loss of weight in testing.

(3) Then, $\dfrac{\text{Loss on original weight (1 lb.)} \times \text{loss \%}}{100} =$

$$\frac{256 \text{ drs.} \times 12 \cdot 3\%}{100} = 31 \cdot 5 \text{ drams} = 1 \text{ oz. } 15\tfrac{1}{2} \text{ drams.}$$

Example 3.—Find the direct loss per cent. and per lb. in a regain of 12 per cent. as in flax.

Let 100 = dry weight,

Then 100 + 12 per cent. = 112 original weight necessary to produce 100 lbs. dry weight.

(1) Direct loss% $= \dfrac{\text{Loss on original weight} \times 100}{\text{Original weight}} = \dfrac{12 \times 100}{112} = 10{\cdot}71\%$

(2) Direct loss per lb. $= \dfrac{\text{Original weight} \times \text{loss }\%}{100}$

$= \dfrac{256 \times 10{\cdot}71}{100} = 27{\cdot}5$ drams $= 1$ oz. $11\frac{1}{2}$ drams.

Example 4.—If 9 hanks taken from a bundle of yarn weigh $\frac{3}{4}$ lb., and they lose 30 drams of moisture during testing, what is the direct loss per cent.; the absolute dry weight per cent., and how does it compare with the standard regain of moisture for worsted yarn.

(1) Original weight $= \frac{3}{4}$ lb. $= \dfrac{256 \times 3}{4} = 192$ drams.

(2) Dry weight $= 192 - 30 = 162$ drams.

(a) Then direct loss % $= \dfrac{30 \times 100}{192} = 15{\cdot}625$

(b) The absolute dry weight % $= 100 - 15{\cdot}625 = 84{\cdot}375$

(c) Regain allowed on $84{\cdot}375$ at $18\frac{1}{4}\%$

$$= \frac{84{\cdot}375 \times 18\frac{1}{4}}{100} = 15{\cdot}4$$

Then absolute dry weight per cent. plus the regain officially allowed equals

$84{\cdot}375 + 15{\cdot}4 = 99{\cdot}775$ units of wght. out of every 100 of the bulk.

Or, $100 - 99{\cdot}775 = 0{\cdot}225$ excess of moisture in every $99{\cdot}775$ lbs. which is so small that it can be practically ignored.

Example 5.—420 ends are taken from a warp 70 yards long. The counts of warp are ticketed 2/60s cotton. When absolute dry weight has been obtained they show a loss of 23 drams. If the original weight corresponds with the calculation weight and the sample is typical of the bulk, does the material accord with the standard allowance of moisture of $8\frac{1}{2}\%$?

(1) Calculation and original weights =

By formula XXI.,

$$\frac{420 \text{ ends} \times 70 \text{ yards}}{30 \times 840} = \tfrac{7}{6} \text{ lb. and } \frac{7}{6} \times \frac{256}{1} = 298\tfrac{2}{3} \text{ drs.}$$

Then the dry weight $\therefore = 298\frac{2}{3} - 23$ drs. $= 275\frac{2}{3}$ drs.

And by formula XXVI.,

$$\text{Direct loss \%} = \frac{23 \times 100}{298\frac{2}{3}} = 7{\cdot}7\%$$

Absolute dry weight per cent. $= 100 - 7{\cdot}7 = 92{\cdot}3$

The regain allowed on 92·3 at $8\frac{1}{2}\% = \dfrac{92{\cdot}3 \times 8\frac{1}{2}}{100} = 7{\cdot}84.$

Then absolute dry weight per cent. plus the regain officially allowed equals

$92{\cdot}3 + 7{\cdot}84 = 100{\cdot}14$ units of weight which 100 actual units of the above material ought to weigh with the standard allowance of moisture for cotton.

The warp is therefore deficient in moisture to the extent of 0·14 on 100·14 units of weight which is about $\frac{7}{50}$ per cent.

The deficiency of moisture is slight, yet at the same time it is to the seller's advantage to get the warps up to the standard weight, and so obtain the full benefit in price for his material.

In conditioning houses tests are made, in addition to that of moisture for percentages of all foreign matter such as grease, oil, soap, gum and size, and also for twist, strength, elasticity, and counts of yarn.

Example 6.—If 6 lbs. of greasy wool is thoroughly scoured and cleansed of all sand, dirt, lime, etc., and absolutely dried, the total loss of weight is 60 per cent.; find the nett commercial weight, also the nett loss per cent. of foreign matter.

(1) Then 6 lbs. of greasy wool less 60 per cent.

$$= 6 - \left(\frac{6 \times 60}{100}\right) = 6 - 3{\cdot}6 = 2{\cdot}4 \text{ lbs. absolutely dry wool.}$$

(2) The commercial weight of 2·4 lbs. of absolutely dry wool

$$= \frac{(\text{Dry weight}) \times (\text{Standard regain } \% + 100)}{100}$$

$$= \frac{2{\cdot}4 \times 116}{100} = 2{\cdot}784 \text{ lbs. Answer.}$$

(3) The nett loss of foreign matter on 6 lbs. greasy weight $= 6 - 2{\cdot}784 = 3{\cdot}216$ lbs.

Then, since 3·216 lbs. represents the nett loss on 6 lbs., the loss per cent. equals

$$\text{As } 6 : 100 :: 3{\cdot}216 : x$$

$$= \frac{3{\cdot}216 \times 100}{6} = 53\tfrac{3}{5} \text{ lbs. \%. Answer.}$$

When testing hanks of yarn for length, they are very carefully measured by winding the thread on a reel, the circumference of which is exactly 1 yard. Revolving around the axis of the reel is a single toothed worm which controls a small train of wheels, which, in their turn, set in motion the needle of an indicator. When the needle is opposite any number inscribed on the disc or clock face, that number exactly corresponds with the revolutions made by the wheel. The tension is very accurately regulated to coincide with the tension put upon the yarn during the reeling process, *i.e.*, in the department where the yarn is made into hanks.

Example 7.—1 Hank of 20s worsted is tested for length and counts. It measured exactly 548 yards and weighed 12·8 drams. What is the exact count?

Then 1 lb. = 256 drs., and $\frac{256}{12 \cdot 8} = 20$ hanks per lb.

But these hanks are 8 yards short in length, therefore the weight must be made up by the increased thickness of the yarn.

Then 20 hanks, each 548 yards, represent the total length.

Then by formula I.,

$$\frac{548 \times 20}{560} = 19\tfrac{1}{2} \text{ cts.} \quad \text{Answer.}$$

EXERCISES.

B and C.

1. If the standard allowance of regain be $12\frac{1}{2}\%$, what is the direct loss per cent. and per lb.?

Ans., 11·11; $28\frac{1}{3}$.

2. If the absolute dry weight of a textile material is 87·7, what amount of regain *per cent.* is necessary to bring the material up to 100.

Ans., 14.

3. The regain per cent. for wool is 16. What weight in drams should 1 lb. of wool lose in testing, and what is the percentage of absolute dry material?

Ans., $35\frac{1}{4}$; 86·23.

4. If 2 lbs. of yarn lose 79 drams of moisture in testing, what is the direct loss per cent. and the amount of regain per cent. necessary to produce the original weight?

Ans., 15·43; 18·24.

5. What is the loss per lb., and the direct loss per cent. when the standard allowance for jute is $13\frac{3}{4}\%$?

Ans., 31 drams; 12·09.

6. 240 ends of 2/40s worsted warp are taken from a warp 140 yards long. Their actual weight coincides with the calculation weight. When absolute dry weight has been obtained they reveal a loss of $7\frac{1}{2}$ ozs. What is the absolute dry weight per cent.?

Ans., 84·38.

7. A quantity of greasy wool weighing 5 lbs. loses in sand, dirt, grease, etc., 2·5 lbs. When the standard allowance of moisture is added to the absolute dry weight, what is the commercial weight?

Ans., 2·7 lbs.

8. 1 Hank of worsted weighs $\frac{1}{24}$ of a lb. It is supposed to be 24s, but it only reels 540 yards. What are the actual counts?

Ans., $23\frac{1}{7}$.

9. A pack (240 lbs.) of unscoured wool is sent to be tested. 7 lbs. are made up from 3 separate parts of the bale, being typical of the bulk. This sample loses 4 lbs. in weight when all the grease, sand, dirt, and moisture are extracted. If the standard allowance for greasy wools be now added, what is the nett commercial weight of wool?

Ans., 119·3.

10. If 1 lb. of cotton yarn loses $23\frac{1}{4}$ drams in the testing oven when absolute dry weight is obtained, what is the direct loss per cent., the absolute dry weight, the amount of regain necessary to produce the original weight, and the excess or deficiency per cent. of moisture as compared with the standard allowance for cotton.

Ans., 9·08; 90·92; 10; 1·38 excess.

CHAPTER XI.

The Construction of Woven Fabrics. A. The Diameter of Threads.

The chief factors to consider in the production of a properly constructed fabric are :—Weave, or method of interlacing, diameter or thickness of yarns employed, together with the relative bending powers of the warp and weft threads, and in a minor degree the quality, elasticity, strength, and the amount of twist in the materials used. The *strength* of a yarn is represented by the amount of force which it is capable of resisting up to the breaking point. The *elasticity* of a yarn is represented by its *regain* after being subjected to tension, though as a result of a series of experiments I find that a yarn will stretch more when tension is applied from each end, than it will when the force is applied at one end only. *Twist* is put into yarn primarily to increase its strength. The *quality* of any wool is represented by the counts to which it will spin, which is governed by the length, fineness, strength, elasticity, waviness and mechanical structure of the fibre. All these in a greater or less degree exercise a modifying influence upon the diameter or thickness of the yarn. Before producing a new cloth, it is necessary to consider to what purpose it is to be subsequently applied. In some cases the fabric must be firm and smart in appearance, in others, soft and full in the handle, which means a corresponding looseness in the setting, in others, open in texture as in the case of gauzes, some tapestries and decorative fabrics. Since woven fabrics consist of a series of threads arranged in one direction, and a second series which run crosswise and interlace with the first, it is very necessary to know the diameter of the threads in conjunction with the weave and the relative bending powers of warp and weft, in order to correctly determine the number of threads which can naturally be arranged side by side of either warp or weft in a given unit of space—the most rational unit being one inch. Several methods have been adopted for the purpose of determining the diameter of yarns. I have little hesitation in stating that it is scarcely possible to formulate a principle which will apply to all yarns and which is absolutely correct, and yet it is possible to establish a system which will be sufficiently accurate for all practical purposes. The *first method*, which is old and somewhat crude, consisted in selecting a series of cloths which were considered to be satisfactorily constructed, and then, knowing the number of warp threads plus intersections of the weft threads in the full width of the piece, the average diameter of the threads was obtained.

A *second method* for determining the diameter of a thread is purely mechanical, and consists in obtaining the diameter of threads by a series of measurements, then totaling *these* measurements and striking an average. The results are then tabulated for future use. This method is best accomplished by the use of a microscope and micrometer, by which approximate results may be obtained, if care is *exercised*.

A *third method* is the widely accepted empirical rule, the chief feature of which being that the square root of the yards per lb. produces a number which, after making a deduction of 10 per cent. for worsted, 8 per cent. for cotton and flax, and 15 per cent. for woollen yarns, gives a result which is accepted as approximately correct. For example: there are 560 yards in 1 lb. of 1s worsted; and the $\sqrt{560} = 23{\cdot}6$. Then $23{\cdot}6 - 10\%$ $= 21{\cdot}3$ threads per inch. But this is, as previously stated, an empirical rule, and such rules are never satisfactory unless they can be proved by the application of some external method, either of practice or theory. For this purpose, therefore, I have conducted a number of experiments upon another method which, though the most scientific, does not, for obvious reasons to which I will presently refer, yield exactly the correct diameter of the yarn. Nevertheless, it is not only interesting and instructive. but useful, inasmuch as it enables us to test the accuracy of the former rule and to formulate a basis for determining the true diameter together with the factors which influence its variation. In other words, this system consists in determining the diameter of any given yarn from the specific gravity of the material.

Specific gravity indicates the density of any substance which is represented by its relative weight as compared with an equal volume of some standard substance. The standard substance for solids and liquids is usually that of water, of which 1 cubic foot, at a temperature of 60° F., weighs 1000 ounces.

The specific gravity of wool, as recorded by Dr. Ure, is given at 1·3, and that of cotton at 1·5. That is, wool is 1·3 times heavier than water when equal volumes of each are taken, while that of cotton is 1·5 times heavier than water. As regards the general correctness of this there is little doubt, but it must, however, be obvious that the specific gravity of wool is not always the same, though the difference is not very great. Having made a series of tests, I am enabled to come to the conclusion that the specific gravity of an English wool is approximately 1·3. But how do you determine the specific gravity of wool? is a question which I have frequently been asked. This will be better explained by first showing how to find the specific gravity of a solid substance. Suppose, for example, we select a small piece of brass. Suspend this brass by a very fine silken thread from the under side of one of the scale pans and it is found to weigh 1700 grains in air (better in vacuo). Now immerse the body, still in suspension, in water, and it will be found necessary to remove some of the weights in the opposite scale pan. When these have been removed the weight of the solid body in water is found to be 1457 grains, showing a loss of $1700-1457=243$ grains. This apparent loss in weight is equal and is due to the upward force which the water exerts upon the body immersed. This upward force is necessarily and always equal to the weight of water which the immersed body displaced, otherwise the water previous to its displacement could not have been in equilibrium, for if it had been heavier it would have sunk to the bottom, and if lighter it would have risen to the top. Further, the amount of water displaced is equal in volume to the body which displaces it; therefore, if we compare the weight of the solid substance in air with the weight of an equal volume of water, we have a number which indicates their relative densities, that is, the specific gravity of the solid substance as compared with water. Take this example: weight of solid body in air divided by its loss of weight in water:

$$\frac{1700 \text{ grs. (weight in air)}}{1700-1457 \text{ grs. (weight of an equal volume of water)}}=\frac{1700}{243}=7.$$

When finding the specific gravity of wool the principle is essentially the same, the only difference being that owing to the fact that wool is not in a solid mass, more care is necessary, and on account of the air space there is within any quantity of wool which may be taken, the wool will not at first sink in water. Consequently, a "sinker," *i.e.*, a heavy solid body, has to be employed so as to immerse the wool and keep it under the water until all the air bubbles within the wool or yarn have made their escape to the surface of the water. The experiment may be quickened by squeezing the wool with a small instrument immediately it is immersed. The whole should now be allowed to stand for a time until the body in water ceases to lose weight.

The following are examples worked on the principle explained:

The first consists in taking an unknown quantity of Botany wool, containing the standard allowance of moisture, thus:

Weight of wool in air =	89 grains.
,, ,, brass sinker in air =	1700 grains.
,, ,, ,, ,, ,, water =	1457 grains.

Weight of brass and wool in water =		1478 grains.
,, ,, wool in water = (1478 − 1457) =		21 grains.
,, ,, the volume of water displaced by the wool	(89—21) =	68 grains

Therefore specific gravity of wool

$$= \left(\frac{\text{weight of wool in air}}{\text{weight of an equal volume of water}}\right) = \frac{89}{68} = 1{\cdot}3 \text{ nearly.}$$

The second example consists in taking a portion of a hank of 2/36 Botany wool with the following particulars:

Weight of yarn in air =	100 grains.
,, ,, brass sinker in air =	1700 grains.
,, ,, ,, ,, water =	1457 grains.
,, ,, brass and wool in water =	1481 grains.
,, ,, yarn in water (1481—1457) =	24 grains
,, ,, volume of water displaced by yarn =	76 grains.

Therefore the specific gravity of yarn

$$= \left(\frac{\text{weight of wool in air}}{\text{weight of an equal volume of water}}\right) = \frac{100}{76} = 1{\cdot}3 \text{ about.}$$

Assuming then that the specific gravity of wool is 1·3, let it be required to find the diameter of any given counts of yarn. For example, take 1s worsted, *i.e.*, a yarn which contains 560 yards per lb. Then, since the yarn is cylindrical in form and mathematics teach us that π radius^2 = area of a circle (where $\pi = \frac{22}{7}$), and knowing the length for a given weight, we are in a position to determine the number of cubic inches, etc., in the given weight of yarn. If these be compared with the same number of cubic inches in the same weight of yarn, as is indicated by its specific gravity, there will be sufficient data then to enable us to find the value of the radius^2 from which the diameter of the yarn may be easily extracted. The following is an example:

Weight of 1 cubic foot of water at 60° F. = 1000 ounces.
" " 1 " " wool (S. G. 1·3) = 1300 ounces.

Also the number of cubic inches in 1 lb. of 1s worsted equals :

CASE I.

Length multiplied by area of cross section of thread, thus :

$560 \times 36\ \pi r^2$ (where $\pi = 22 \div 7$, and r = the radius).

CASE II.

$$\frac{\text{No. of cubic inches in 1 cubic foot} \times \text{ounces in 1 lb.}}{\text{Weight of 1 cubic foot of wool in ounces}} = \frac{1728}{1300} \times 16.$$

Then since Case I. and Case II. are each equal to the number of cubic inches in 1 lb. of 1s worsted, they are equal to each other ; and if these be equated, we may easily find the value of r^2.

$$560 \times 36\pi r^2 = \frac{1728}{1300} \times \frac{16}{1}, \quad \text{or} \quad r^2 = \frac{1728 \times 16 \times 1 \times 7}{1300 \times 560 \times 36 \times 22} = \frac{1}{2979}$$

$$\therefore \quad r = \sqrt{\frac{1}{2979}} = \frac{1}{54 \cdot 6} \quad \text{and}$$

$$\text{Diameter} = \frac{1}{54 \cdot 6} \times 2 = \frac{1}{27 \cdot 3} \text{ or } 27 \cdot 3 \text{ threads per inch.}$$

which result is 6 threads per inch finer than is obtained from the previous method given.

Now, if wool were a solid substance this theory would be absolutely correct, but since the wool fibre is of a cellular structure it necessarily contains air spaces within its circumference ; and since the yarn is composed of fibres, there are numerous small air recesses within the circumference of the yarn, consequently, the actual diameter of the yarn is greater than is revealed by its specific gravity. If it were possible to correctly determine the amount of air space there is within the circumference of the yarn threads, then the absolute diameter of the threads would be readily ascertained. Taking the full range of yarns made, the air space may be anything from 20 to 30 per cent. In most of the two-fold worsted yarns it is generally about 20%, but not less. This percentage of air space within the circumference of the yarns may be useful in assisting us to a determination of the maximum amount of compression to which the yarn should be subjected,

NO. OF DIAMETERS PER INCH OF STANDARD LINEN YARNS.

Lea Number.	Nearest Diameters.	Actual Diameters.	Nearest Equivalent.		Diameters for Worsted No.
			Cotton No.	Worsted No.	
12	55	55·2	4·3	6·4	54·2
16	64	63·75	5·7	8·6	62·5
20	71	71·26	7·2	10·7	70
25	80	79·67	9	13·4	78
30	87	87·27	10·7	16	85·5
35	94	94·26	12·5	18·8	92·5
40	101	100·77	14·2	21·4	98·7
45	107	106·88	16	24	104·5
50	113	112·67	18	27	110·5
55	118	118·17	19·4	28·5	116
60	123	123·42	21·4	32	121
65	128	128·46	23·2	35	126
70	133	133·31	25	37·5	131
75	138	138·	27	40	135·7
80	143	142·51	28	42	140
85	147	146·9	30	45	144
90	151	151·16	32	48	148
95	155	155·3	34	51	152
100	159	159·34	36	54	156

NOTE.—The boiled flax yarn is relatively smaller and softer and may be sett from 3 to 5% finer.

either by twist in the yarn or proximity of threads in the cloth.

I have no hesitation in saying that the diameter of threads thus obtained gives a result which may be safely applied to the construction of woven textures. The foregoing theory gives a result which agrees with the 2nd and 3rd methods referred to, in the generality of cases, but the diameter as obtained by the 3rd method is an unchangeable one, while in reality, the diameter of the yarn is a constantly varying quantity, even though yarns of the same counts be selected. In the last theory given, this varying factor is taken into account.

Relative Diameter of Threads.

Having established a theory for finding the diameter of any given thread, it is comparatively easy to find that of any other. The general idea is that the diameters of threads vary inversely as the square root of their counts, and this would be correct did the density of yarns remain constant. There are two important factors which mainly influence the relative diameters of threads. (I.) The diameters of threads vary inversely as the square root of their counts, based upon the well known principle of the variation of circles. (II.) Apart from any change in the counts of yarn, its relative diameter varies in the inverse ratio of the square root of its specific gravity. In this treatise I only purpose dealing with number (I.)

Example 1.—Compare circle A of 1 inch diameter with circle B of 2-inch. Area of a circle $= \pi r^2$. $\pi = \frac{22}{7}$.

$$\text{Then, } \frac{\text{Area of A}}{\text{Area of B}} = \frac{\pi r^2}{\pi r^2} = \frac{\frac{22}{7} \times (\frac{1}{2} \times \frac{1}{2})}{\frac{22}{7} \times (1 \times 1)} = \frac{\frac{1}{4}}{1} = \frac{1}{4}$$

$$\frac{\text{The diameter of A}}{\text{The diameter of B}} = \frac{1}{2}, \text{ but area of } \frac{A}{B} = \frac{1}{4},$$

which, it will be seen, is in the ratio of the squares of their diameters. This means then that the diameters of circles vary as the square roots of their areas. Now, since the cross section of a thread may be represented by a circle, and since, as the counts increase, the diameters of the threads decrease, it follows that the diameter of threads must vary inversely as the square roots of the areas of their cross sections. Consequently, if counts be substituted for *area of cross section* of thread, it will be obvious that the diameters of threads (other things remaining constant) vary inversely as the square roots of their counts.

Example 2.—If the number of diameters of 16s worsted be 85, what is the relative diameter of 25s?

Then stated according to the principle above,

$$\text{As } \sqrt{25} : \sqrt{16} :: \tfrac{1}{85} : x$$

$$= \tfrac{1}{85} \times \frac{\sqrt{16}}{\sqrt{25}} = \tfrac{1}{106}.$$

But if the 85 diameters of 16s be taken instead of $\frac{1}{85}$ which is the diameter of each thread of 16s, it will be obvious that the number of diameters per inch vary *directly* as the square roots of their counts thus:—

$$\sqrt{16} : \sqrt{25} :: 85 : x$$

$$= \frac{85}{1} \times \frac{\sqrt{25}}{\sqrt{16}} = 106$$

The same expressed as a formula is as follows:—

Formula XXVIII.

$$\frac{\text{No. of diameters per inch of given counts} \times \sqrt{\text{of required counts}}}{\sqrt{\text{Given count.}}}$$
$$= \text{No. of diameters per inch of required counts.}$$

By first ascertaining the diameter of 1s lea, cotton or worsted, etc., and then using this number as a gauge point to mentally find the diameter of any other required thread, the following short method will be found useful in practice:—

Linen $16 \times \sqrt{\text{Counts}}$ = Approximate diam. of yarn.
Cotton $26 \times \sqrt{\text{Counts}}$ = ,, ,, ,,
Worsted $21\frac{1}{2} \times \sqrt{\text{Counts}}$ = ,, ,, ,,

e.g. Find the diameter per inch of 25s lea yarn,

Then $16 \times \sqrt{25} = 16 \times 5 = 80$.

Elementary Principles of Setting Cloths.

There are two great classes of woven fabrics:—

I. Those which contain relatively an equal number of warp and weft threads.

II. Those which contain relatively an unequal number of warp and weft threads.

Each of these cases may be sub-divided thus:—

1. Where thickness of warp and weft threads is equal.

2. Where it is unequal.

The relative number of threads in each of these classes depends principally upon the angles of curvature formed by the warp and weft threads. These may be classed as follows:—

(a) Where one set of threads lie perfectly straight while the other performs all the bending.

(b) Where both sets of threads form equal angles.

(c) Where each set of threads form unequal angles of curvature.

The structure of the weave is sometimes a factor in determining to which of the great classes (I. or II.) a cloth belongs, though not infrequently the same design is used in both classes, the canvas or plain weave being the most typical example.

Example 1.—Find the number of threads per inch which a cloth should contain if the diameter of the warp and weft be $\frac{1}{60}$ of an inch and the weave plain, a cross section through the warp of which is shown at Fig. 4.

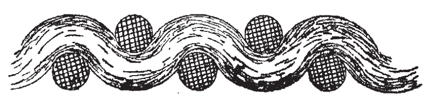


Fig. 4.

If the angles of curvature and of compression be ignored for the present it will be evident that the cloth would be made up of equal threads of warp and *space* occupied by the weft. Thus, since the diameter of the threads equals $\frac{1}{60}$ of an inch, the space occupied by the warp and weft amounts to $\frac{1}{60} \times 2$, which equals $\frac{1}{30}$ or allows 30 threads of warp per inch. But this applies only where the number of intersections of warp and weft are equal to the number of threads in each repeat of the design; then, to find the average space available for each thread of warp when the diameters of warp and relative number of intersections of weft are known, divide the number of diameters of warp which occupy 1 inch by the number of threads plus intersections of weft in each repeat of the design, the result consequently equals the number of repeats of weave in each inch, and this, multiplied by the number of threads in each repeat of the design therefore supplies us with the number of threads of warp in each inch, exclusive of the intersections, thus:—

$$\frac{60 \times 2}{2 + 2} = 30 \text{ threads per inch.}$$

The following formula is a simplification of this reasoning:—

FORMULA XXIX.

$$\frac{\text{No. of diameters of threads per in.} \times \text{ends in 1 repeat of design.}}{\text{Ends} + \text{intersections in 1 repeat of design}} = \text{ends or picks per inch in fabric.}$$

This method gives results sufficiently accurate for all practical purposes in all cloths woven on the '*square*' or thereabouts.

Example 2.—What number of ends and picks are required to produce a cloth in a weave having 10 ends and 4 intersections, when the counts of warp and weft are 2/40s worsted?

Diameter of 20s worsted $= (\sqrt{20 \times 560}) - 10\% = 95$.

Then by Formula XXIX.,

$$\frac{95 \times 10}{10 + 4} = 68 \text{ ends and picks.}$$

Example 3.—Given 2/24s worsted warp and 2/16 weft and $\frac{4}{4}$ twill, find sett and picks per inch.

Diameter of 2/24s worsted $= \frac{1}{72}$ inch.

" " 2/16s " $= \frac{1}{60}$ "

Warp = 8 warp threads + 2 intersections of weft.

Weft = 8 weft " + 2 " " warp.

$\therefore$ Warp = As $(\frac{8}{72} + \frac{2}{60}) : \frac{8}{72} :: 72 : 53{\cdot}3$ ends.

And Weft = As $(\frac{8}{60} + \frac{2}{72}) : \frac{8}{60} :: 60 : 49{\cdot}6$ picks.

Example 4.—Required, the most suitable two-fold worsted yarn for a fabric which must contain 60 ends and picks per inch, woven in the $\frac{2}{2}$ twill.

Let $x =$ the counts of the yarn required.

Equation 1. Then $\sqrt{560x}$—10% = No. of diameters per inch

„ 2. Also $\dfrac{\text{Sett} \times (\text{Ends} + \text{Intersections})}{\text{Ends in one repeat of pattern.}}$

= No. of diameters per inch.

$$= \frac{60 \times (4 + 2)}{4} = 90 \text{ diameters.}$$

∴ Equation 1. is equal to Equation 2.

$$\text{Then } \sqrt{560x} - 10\% = 90.$$

$$= \sqrt{560x} = 90 + 10\% = 99.$$

Square each side of the equation.

$$\text{Then } 560x = 99 \times 99.$$

$$\therefore x = \frac{99 \times 99}{560} = 18 \text{ or } 2/36\text{s worsted.}$$

EXERCISES.

1. What is the average diameter of 2/24s worsted, 2/30s cotton, and 1300 yds. per oz. raw silk?

Ans., $\frac{1}{72}$; $\frac{1}{104}$; $\frac{1}{182}$.

2. The diameter of 20s worsted is equal to $\frac{1}{95}$ of an inch, find the relative diameter of 2/48s worsted.

Ans., $\frac{1}{104}$.

3. If 146 threads of 30s cotton laid side by side exactly cover 1 inch, what number of threads of 40s cotton would be required to cover the same unit?

Ans., 169.

4. What is the relative diameter of 36s worsted if the thickness of 16s is $\frac{1}{85}$ part of 1 inch.

Ans., $\frac{1}{128}$.

5. Find a suitable Sett Bradford for a cloth woven

with $\frac{3}{2}$ twill design, the warp and weft being 2/32s worsted.

Ans., 54·6.

6. If 2/24s worsted and the Mayo twill design (8 ends, 4 intersections) be used in the production of a cloth. What number of ends and picks are required to produce a suitable cloth?

Ans., 48.

7. Find suitable ends and picks per inch for (a) 50s linen warp and 65s weft, for 38″ plain linen; (b) 55s linen warp and 70s weft, with diaper weave on 4 end drill base.

Ans., 60/60 or 55/65; 82/85.

8. What leas warp and weft of bleached and dyed yarn would be suitable for a dress material made in 900 reed, 40 inch scale, 11 shots to 37″ glass?

Ans., 35/55 or 30/60 approximately.

9. Find suitable counts of yarn for the warp and weft of the following linen cloths. (a) Heavy interlining, counting about 37 threads per inch in warp, and 48 threads per inch in weft; (b) Huck-towelling, counting about 47 threads per inch in warp and 54 threads per inch in weft; (c) Light blouse linen, counting about 63 threads per inch in warp and 70 threads per inch in weft.

Ans., 20/35; 35/45; 65/80 approximately.

10. A 10/6 union cloth is made from 22s line, 100 yds. warp laid 30″ in reed, giving 90 yds. of cloth. What number of cotton should be used as weft to make quantities of cotton and linen equal in weight?

Ans., 4·7.

CHAPTER XII.

Construction of Woven Fabrics. B. Modifications in Fineness and Weight of Yarns and Cloth.

The chief advantage of a study of problems under this heading is the exercise and familiarisation of the mind with the fundamental principles which underlie the structure of woven fabrics.

(1) Changing the yarns or Sett.

Any alteration in the counts of yarn involves a modification in the Sett and picks and *vice versa.*

It has been demonstrated in Chapter XI. that the *Sett* and *picks* are obtained on the basis of the diameter, and they have in reality become substitutes, respectively, for the number of diameters per inch, since the Sett or picks represent in the aggregate a certain number of diameters of threads. Therefore the Sett and picks will vary in exactly the same ratio as the diameters of threads, *i.e.*, as the square root of their counts. Consequently, any change in the counts of warp or weft will necessitate an alteration in the Sett and picks in the direct ratio of the square roots of their counts, and conversely, any alteration of the Sett and picks will require a change in the counts of yarn in the direct ratio of the squares of the Sett and picks, which is equivalent to saying that the counts of the yarn vary as the squares of their diameters.

Example 1.—A fabric is produced with 60 ends per inch. The yarn employed is 2/50s. It is required to change to 2/72s. What number of ends would be necessary to retain the same relative conditions of fabric structure or proximity of threads?

2/50s = 25s, and 2/72s = 36s.

Then since 25s yarn is woven with 60 threads per inch, 36s yarn, which is finer, will require more, and since their diameters *per inch* vary directly as the square root of their counts.

$\therefore$ As $\sqrt{25} : \sqrt{36} :: 60 : x$, where x = the required sett

And the means of a proportion always equal the extremes thus:—

$$\sqrt{25} \times x = \sqrt{36} \times 60$$

$$\therefore\ x = \frac{6 \times 60}{5} = 72 \text{ ends.}$$

FORMULA XXX.

$$\frac{\text{The sq. root of the required counts} \times \text{given Sett}}{\text{The sq. root of the given counts}} = \text{The required Sett.}$$

In the foregoing example the extraction of the square root is a simple matter, since each evolve in whole numbers of 5 and 6 respectively. In most examples the extraction of the square root of the counts would evolve an inconvenient fraction, and to avoid this, it is better to square both sides of the equation. It is an axiom, if equals be multiplied by equals, then the products are also equal to each other.

Then in the above example $x = \dfrac{\sqrt{36} \times 60}{\sqrt{25}}$

By squaring both sides of the equations, *i.e.*, multiplying each side of the equation by itself, we obtain,

$$x^2 = \frac{36 \times 60 \times 60}{25} = 5184$$

$$\therefore x = \sqrt{5184} = 72 \text{ ends}$$

Which is the same result as obtained above.

Example 2.—If a plain linen fabric is woven 16/18 (16^{00} reed, 18 shots 37″ glass) with 65s lea warp and 100s weft, what change in counts is necessary to retain the same balance of structure if the sett and picks be reduced to 8/9.

Frequently in the linen trade, setts and picks are expressed as 7/9, 8/10, etc., which means that the sett is 7^{00} and the shots 9 per glass of scale used, generally 40″ scale and 37″ glass. If ends and picks per inch are adopted as in Damasks the sett and picks are written 70/80, 80/90, etc. In a similar way the counts of warp and weft are frequently written 30/40, 35/45, 50/60, etc.; the first number indicates the warp and the second the weft.

Then as $1600 : 800 :: \sqrt{65} : \sqrt{x}$.

Where x = the required counts of warp.

$$\sqrt{x} = \frac{\sqrt{65} \times 800}{1600} = 4 \therefore x = 16\text{s warp.}$$

And as $18 : 9 :: \sqrt{100} : \sqrt{x}$.

Where x = the required counts of weft.

$$\sqrt{x} = \frac{\sqrt{100} \times 9}{18} = 5 \therefore x = 25\text{s lea weft.}$$

Example 3.—A cloth is woven with 40s cotton in a 60 Sett Blackburn, what counts of cotton will be required if the Sett be altered to 80s Blackburn?

Then, if 60s Sett requires 40s yarn, 80s Sett being finer, will require a finer counts of yarn, and these counts vary as the squares of their diameters or Setts (explained previously), then :—

As $60^2 : 80^2 :: 40 : x$ where $x =$ the required counts.

By multiplying *extremes* for equation 1, and *means* for equation 2, we obtain

$$60 \times 60\, x = 80 \times 80 \times 40.$$

$$\therefore x = \frac{80 \times 80 \times 40}{60 \times 60} = 71\tfrac{1}{9} \text{ counts.}$$

FORMULA XXXI.

$$\frac{\text{Given counts} \times \text{squares of required Sett}}{\text{Square of given Sett.}} = \text{The required counts.}$$

NOTE.—The above theory is not modified in any respect by the Sett system or yarn denomination in which any question may be expressed so long as the factors of each equation do correspond. If in any given question these conditions are not fulfilled, then it is simply necessary to first reduce the Setts to the same system and the yarns to the same denomination. This method will frequently be found the easiest and the best.

(2) CHANGING THE DESIGN.

Any change in the *weaving plan* involves a corresponding variation in the *Sett* and *picks* or counts of *warp* and *weft*, assuming that the same relative balance of fabric structure is to be maintained.

I.—When counts of warp and weft remain constant.

Example 1.—If a fabric is woven with 60 ends and picks per inch, plain weave (2 ends, 2 intersections), and it is thought advisable to change to the Cassimere twill, which contains 4 ends and 2 intersections in 1 repeat of the design, what number of ends and picks would be necessary to retain the same relation of structure between the 2 cloths ?

The solution of this problem is simple enough, but a somewhat lengthy explanation is necessary to make it clear to the reader.

In the *plain weave* there are 2 ends and 2 intersections of weft in each repeat, making a total of 4 diameters in the cloth to every 2 threads of warp, whereas in the $\frac{2}{2}$ twill there are 4 ends and 2 intersections of weft, making a total of 6 diameters in the cloth to every 4 threads of warp. It is therefore necessary to find the the relative number of diameters occupied by each design for the same number of warp threads or some other equivalent before the *required Sett* can be correctly ascertained. Then find the *least common multiple* of the number of ends in 1 repeat of the designs and add their respective intersections to the L. C. M.

Then the given Sett will form a *simple proportion* with these two numbers.

The L.C.M. of these two weaves is 4.

Then in the given weave (plain) there are

2 repeats of the design = 4 ends + 4 intersections = 8 diameters

And in the required weave ($\frac{2}{2}$ twill) there is

1 repeat of the design = 4 ends + 2 intersections = 6 diameters

i.e., the plain weave with 60 ends per inch occupies 8 diameters to every 4 threads of warp, while the $\frac{2}{2}$ twill weave only occupies 6 diameters for the same threads of warp. Consequently it is possible to make a cloth with more threads of warp in the proportion,

As $6 : 8 :: 60 : x = 80$ ends per inch.

From this reasoning the following simple formula may be deduced.

FORMULA XXXII.

(1) Find the L.C.M. of the two weaves.

(2) $\dfrac{\text{Given Sett} \times (\text{Ends in L.C.M.} + \text{Intersections in given cloth})}{\text{Ends in L.C.M.} + \text{Intersections in required cloth}} = \text{Required Sett.}$

Applied to the foregoing example,

(1) The L.C.M. of the plain weave and cassimere = 4

(2) $\frac{60 \times (4 + 4)}{4 + 2} =$ 80 ends and picks.

Example 2.—A cloth is woven in the $\frac{2}{2}$ twill and contains 80 ends and picks per inch. It is required to change the weaving plan to a 6-end twill with 2 intersections in each repeat of the weave. Find the Sett and picks.

Then by formula XXXII.,

(1) L.C.M. of 4 and 6 = 12 ends.

In 12 ends of $\frac{2}{2}$ twill there are

12 ends + 6 intersections = 18 diameters.

In 12 ends of the 6-end twill there are

12 ends + 4 intersections = 16 diameters.

$$\therefore \frac{80 \times (12 + 6)}{12 + 4} = 90 \text{ threads and picks per inch.}$$

II. When the Sett and picks remain constant.

Example 3.—Suppose that in each of the two foregoing illustrations the Sett and picks remain at 60. For the plain weave the warp and weft is 2/64s. What counts of warp and weft would be necessary to retain the same relative structure of cloth assuming that the weave is changed (1) from plain to $\frac{2}{2}$ twill, (2) from $\frac{2}{2}$ twill to a weave having 6 ends and 2 intersections in each repeat of the design?

It has just been proved that when the counts of yarn remain the same, any change in the weave involves an alteration in the Sett and picks in direct proportion to the relative number of threads and intersections of each weave. Consequently, if the Sett and picks remain constant, but a change in the weave occurs, then the counts of yarn will vary in exactly the *same ratio* as they do when only an alteration of the Sett and picks is made. I have previously proved that the counts of warp or weft varies with any change of Sett in direct proportion to the squares of each Sett.

Therefore, when the ends and picks remain unchanged the counts of warp and weft will vary with any modification of the weave in direct proportion to the squares of their relative ends and intersections, which latter is easily obtained on the principle embodied at formula XXXII.

Then, *first*, changing from plain weave to $\frac{2}{2}$ twill.
L.C.M. of the two weaves = 4.
In 4 ends of the plain weave, there are
4 ends + 4 intersections = 8 diameters.
In 4 ends of the $\frac{2}{2}$ twill, there are
4 ends + 2 intersections = 6 diameters.

The relative number of intersections in the $\frac{2}{2}$ twill being fewer than those of the plain weave, a thicker material will therefore be necessary, i.*e*., a lower count.

Formula XXXIII.

$$\text{As}\begin{pmatrix}\text{Ends in L.C.M.} + \text{inter-}\\ \text{sections of given weave}\end{pmatrix}^2 : \begin{pmatrix}\text{Ends in L.C.M.} + \text{inter-}\\ \text{sections of req'd. weave}\end{pmatrix}^2 :: \begin{matrix}\text{Given}\\ \text{counts}\end{matrix} : x$$

Where x equals the required counts.

Thus, As $(4+4)^2 : (4+2)^2 ::$ 32 counts : 18s counts or 2/36s warp and weft.

Then, *second*, changing from $\frac{2}{2}$ twill to 6-end weave with 2 intersections.
L.C.M. of the two weaves = 12.
In 12 ends of the $\frac{2}{2}$ twill there are
12 ends + 6 intersections = 18 diameters.
In 12 ends of the 6-end weave there are
12 ends + 4 intersections = 16 diameters.

By formula XXXIII.,

$\therefore$ As $(12+6)^2 : (12+4)^2 :: 18 : 14\frac{2}{9}$ or 2/28.

(3) Changing the Weight of a Cloth.

Where only a slight increase or decrease in the weight is necessary, using a few more or less ends and picks or slightly increasing or decreasing the counts of warp or weft (or both) is a common practice. Sometimes the weave is altered, and in many instances a backing warp or weft (or both) is added to a face cloth where a large increase of weight is required and where the same surface weave and fineness of texture has to be maintained. But if a cloth has to be altered in weight, without any change of weave, and when the same relative balance of cloth structure is to be maintained, then the only correct method which will retain the same theoretical conditions is to modify the counts of the material and to alter the Sett and picks so as to coincide with this changed thickness of yarn. This last assertion is proved by the fact that *theoretically* there can only be one make of cloth for any given yarns and weave.

Example 1.—A fabric is made with 84 ends per inch and woven with 49s yarn. It is required to produce another cloth of similar weave structure but $\frac{1}{6}$ heavier. Find the counts and Sett.

If in this example the weight of the counts of warp and weft were increased $\frac{1}{6}$ without any alteration in the Sett and picks, or, on the other hand, if the Sett and picks were increased $\frac{1}{6}$ without any alteration in the counts of warp and weft, then an increase of $\frac{1}{6}$ of cloth would be obtained in a very simple way, but the theoretical structure of the fabric would be interfered with.

Obviously, then, the only course open is to increase the weight of yarns to such an extent that when the Sett and picks are reduced to suit the changed diameters of yarn, the weight of the fabric will exactly coincide with the required weight of cloth. Therefore if, instead of simply increasing the weight of the yarn $\frac{1}{6}$, we increase its diameter by this amount, *i.e.*, increase the weight of the yarns in proportion to the square root of their counts, and afterwards reduce the fineness of Sett and picks by formula XXX. to compensate for the extra thickness of warp and weft, it will then be found that the counts of yarns and number of ends and picks per inch thus obtained, are such that they will produce a new cloth of the exact weight required and of the same relative balance of structure, but *not of fineness* in texture, since increased weight necessarily involves increased coarseness and *vice versa* so long as the weave structure remains constant. The solution of the foregoing example as given below will assist in making the subject clearer.

Then, to increase the weight of the cloth $\frac{1}{6}$, requires a lower count.

Let x = the required count.

Then as 7 units of weight : 6 units of weight : : $\sqrt{49}$: $\sqrt{x}$
Or as 7^2 : 6^2 : : 49 : x

$$\therefore x = \frac{49 \times 6 \times 6}{7 \times 7} = 36\text{s count.} \quad \text{Ans.}$$

With 49s yarn, the original cloth contained 84 ends and picks per inch, but with 36s yarn the threads of warp and weft must necessarily be less in proportion to the square roots of these counts as by formula XXX.

Thus $\dfrac{84 \times \sqrt{36}}{\sqrt{49}}$ = 72 threads per inch.

NOTE.—The square roots of the original counts and of the required counts are in the exact ratio of the required weight to given weight and these conditions are maintained in all examples of this class, consequently the simplest expression of formula is as follows :—

FORMULA XXXIV.

(a) $\frac{\text{Original counts} \times \text{square of original weight}}{\text{Square of required weight}} = \text{Required counts.}$

(b) $\frac{\text{Original Sett} \times \text{original weight}}{\text{Required weight}} = \text{Required Sett.}$

As an aid to memory it might be noted that in each case the products of the *originals* are equal to the corresponding products of the *required*.

Example 2.—A cloth is made with 1/30s cotton warp and weft; it contains 90 ends and picks per inch. Assuming that it is required to produce a new texture which shall retain the same relative balance of structure but to be $\frac{1}{10}$ lighter, what counts of yarn and ends and picks per inch will be required?

By formula XXXIV.,

(a) $\frac{30 \times 10 \times 10}{9 \times 9} = 37\frac{1}{27}$ counts.

(b) $\frac{90 \times 10}{9} = 100$ ends and picks.

(4) SIMULTANEOUS CHANGE OF WEIGHT AND FINENESS.

Example.—A cloth is made from 2/36s Botany warp and weft and woven in the $\frac{2}{2}$ twill. It contains 15 twills per inch being constructed according to theoretical conditions. It is required to produce a lighter cloth but containing the same number of twills per inch. Find the required alteration in the set together with the changes in the yarn and weight of fabric that would be involved if the same balance of structure be maintained.

Assume that the $\frac{3}{3}$ twill design be used,

Then since the $\frac{2}{2}$ twill design contains 15 twills per inch which equals $15 \times 4 = 60$ ends per inch.

Also the $\frac{3}{3}$ twill contains 15 twills per inch $= 15 \times 4 = 60$ ends per inch.

$$\left.\begin{array}{l} \text{Further the } \frac{2}{2} \text{ twill contains } 15 \times 4 = 60 \text{ ends per inch} \\ \quad ..|.. \quad 15 \times 2 = 30 \text{ intersections} \;\;,, \end{array}\right\} = \begin{array}{c} \text{90 diameters} \\ \text{per inch.} \end{array}$$

$$\left.\begin{array}{l} \text{and the } \frac{3}{3} \text{ twill contains } 15 \times 6 = 90 \text{ ends per inch} \\ \quad ...|... \quad 15 \times 2 = 30 \text{ intersections} \;\;,, \end{array}\right\} = \begin{array}{c} \text{120 diameters} \\ \text{per inch.} \end{array}$$

Then since the diameter of threads vary as the square root of their counts and since 90 diameters per inch represents the 2/36s warp and weft.

$\therefore$ As $90 : 120 :: \sqrt{18} : \sqrt{x}$, where $x =$ the required counts.

or $90^2 : 120^2 :: 18 : x$.

$$\therefore x = \frac{120 \times 120 \times 18}{90 \times 90} = 32\text{s or } 2/64\text{s worsted.}$$

Then to find the relative weights of the two fabrics, let A represent that of the $\frac{2}{2}$ twill cloth and B the $\frac{3}{3}$ twill.

$$\left.\begin{array}{r} \text{Then as A : B} :: \dfrac{60}{18} : \dfrac{90}{32} \\ \therefore \text{ A : B} :: 32 : 27 \end{array}\right\} \text{or } \frac{A}{B} = \frac{\dfrac{60 \text{ ends}}{18 \text{ counts}}}{\dfrac{90 \text{ ends}}{32 \text{ counts}}} = \frac{32}{27}$$

i.e. If the first cloth weighed 16 ozs., the second would weigh $13\frac{1}{2}$ ozs. and contain the same number of twills per inch.

(5) Simultaneous Change of Weight and Weave.

Example.—Given 2/36s warp and weft, woven in a $\frac{2}{2}$ twill with 60 ends and picks per inch, it is required to change to $\frac{3}{3}$ twill and increase the weight $\frac{1}{6}$, find the counts of warp and weft, and ends and picks per inch.

(1) Find yarns and sett for increased weight of $\frac{1}{6}$.

By Formula XXXIV.

Then counts of warp and weft $= \dfrac{18 \times 6 \times 6}{7 \times 7} = 13{\cdot}2$

And setts and picks $= \dfrac{60 \times 6}{7} = 51\frac{3}{7}$.

(2) Find increase in sett due to changing from $\frac{2}{2}$ to $\frac{3}{3}$ twill $= 8$ to 9. See formula XXXII.

Then sett and picks $= \dfrac{51\frac{3}{7} \times 9}{8}$ $57\frac{6}{7}$.

This number of ends and picks increases the weight $\frac{1}{8}$ more than required, which, while it retains the same balance of structure, must be reduced by this amount to bring it to the required increased weight. See Formula XXXIV.

(3) Find yarns and sett for reduced weight of $\frac{1}{8}$.

By Formula XXXIV.

Then counts of warp and weft $= \dfrac{13{\cdot}2 \times 9 \times 9}{8 \times 8} = 16{\cdot}7$

And sett and picks $= \dfrac{57\frac{6}{7} \times 9}{8} = 65$.

The whole may be simplified and stated thus :—

1. Counts of warp and weft $= \dfrac{18 \times 6 \times 6}{7 \times 7} \times \dfrac{9 \times 9}{8 \times 8} = 16{\cdot}7$

2. Setts and picks $= \dfrac{60 \times 6}{7} \times \dfrac{9}{8} \times \dfrac{9}{8} = 65$.

EXERCISES.

1. A worsted fabric is made from 1/15s warp and weft, and contains 64 ends and picks per inch. If the

yarn is changed to 18s Y. S. woollen, how many threads per inch warp and weft are necessary to retain the same relative balance of structure?

Ans., 47·4.

2. A worsted cloth is made from 2/50s and contains 72 ends per inch. It is required to make a cloth possessing the same relative balance of structure from 2/60s cotton, what number of ends are required?

Ans., 96.

3. A cloth is woven with 36s yarn, in 18s reed 4s. It is required to reduce the fineness of Sett to 58 ends per inch. What count of yarn is required?

Ans., 24s.

4. Required the counts of warp and weft when a cloth made from 2/60s cotton and woven in 60s Sett Blackburn is required to be increased in fineness of pitch $\frac{1}{2}$.

Ans., 2/135.

5. If a cloth is woven in a 54 Sett Bradford or 12^{00} Belfast, with a twill design which contains 8 ends and 4 intersections, what number of ends per inch will be required if the counts remain the same but the weaving is altered to 12 ends and 4 intersections?

Ans., $67\frac{1}{2}$; 13^{50}.

6. A woven texture is made with 72 ends and picks per inch in a twill weave of which the first pick is given herewith $\frac{3}{2}\frac{1}{1}$. It is required to change the plan to the following $\frac{2}{4}\frac{2}{3}\frac{1}{1}$. Assuming that the counts of warp remain constant, what number of ends and picks per inch will retain the same relative balance of structure?

Ans., 77·4.

7. A cloth is made from 2/48s yarn in 80s Sett. The design contains 5 ends and 2 intersections. It is desired to alter the weave to 3 ends and 2 intersections but to retain the same Sett. What two-fold counts of yarn will produce a new fabric with the relative balance of structure?

Ans., 2/68.

8. A worsted fabric is composed of 2/40s warp and 1/32s weft. There are 64 ends and 56 picks per inch. What counts of warp and weft, and ends and picks per inch will be required to produce a new cloth of the same relative structure but $\frac{1}{4}$ heavier?

Ans., $12\frac{4}{5}$; $20\frac{12}{25}$; $51\frac{1}{5}$; $44\frac{4}{5}$.

9. A cloth is made with 25s yarn in 72s Sett, what counts of yarn and Sett would be required to make it $\frac{1}{5}$ heavier?

Ans., $17\frac{13}{36}$; 60.

10. A woollen cloth is made with 23 Y. S. in $7\frac{7}{8}$ Portie Leeds, the weight of the cloth is 16 ozs. per yard. It is required to produce a similar cloth weighing 14 ozs. per yard. Find counts of yarn and Sett.

Ans., 30; 9.

11. Given a cloth woven with 2/36s Botany warp and weft, 60 ends and picks per inch, cassimere twill, change the weave to $\frac{3}{2}$ twill and decrease the weight $\frac{1}{7}$. Find the Sett and picks, and counts of warp and weft.

Ans., 80·3; 28·1 or 2/56.

12. Given a plain linen cloth containing 40 ends and picks per inch of 30s lea warp and weft, it is required to change to a 3 end twill and increase the

weight $\frac{1}{4}$, find the counts of yarn, and ends and picks per inch necessary to retain a corresponding balance of structure.

Ans., 27·6 ; 46.

13. Required a range of linens in 6/7 ; 7/8 ; 8/9 ; 9/10 ; 10/11 and 11/12 Setts and picks (40″ scale and 37″ glass), find the nearest suitable lea counts of warp and weft for each of the above cloths, assuming that the 6^{00} sett and 7 shots per 37″ glass is woven with 16s lea warp and 20s weft.

Ans., 22/26 ; 28/33 ; 36/40 ; 44/49 ; 54/59
Nearest whole number.
say 20/25 ; 30/35 ; 35/40 ; 45/50 ; 55/60
Nearest standard lea number.

14. If a cloth is made 70 threads per inch of 25s twist cotton, and it is required to make one with single 16s yarn, how many threads per inch will be required to maintain the same balance of structure ?

Ans., 56.

15. If 7/9 is made from 25/30, what yarns will make 11/13 ?

Ans., 61·75 ; 62·6, say 60/65.

16. If 11/13 plain linen is made from 55/90, what yarns would you put into 11/13, 5 end satin, to maintain the same balance of cloth ?

Ans., 27 ; 44.

CHAPTER XIII.

The Construction of Woven Fabrics. C. Angle of Curvature Considered.

Immediately the angle of curvature is taken into consideration it is found that the number of threads of warp or weft which the fabric can naturally contain will vary with that angle.

Experimental research and experience enables the writer to conclude that the angle of curvature which the warp and weft threads form with each other is a factor of considerably more importance than appears to the casual observer. It not only modifies the number of warp and weft threads which the finished cloth must contain but it is very important in developing certain features of many woven fabrics, both in single and double plain weaves.

As as aid in determining the variations of curvature, it is necessary to select a typical method of interlacing, for which purpose the 'plain weave' is chosen. This is because it serves as a basis for the construction of woven fabrics in other weaves, and further, whether the texture be single, double, or multiple, there is constantly a large number of woven fabrics produced in which the variation of angle is a prevailing characteristic.

Example 1.—Assume the diameter of the warp and weft to be $\frac{1}{60}$ of an inch each. Find the correct number of ends and picks which a fabric will contain under natural conditions, *i.e.*, when the two sets of threads are as close to each other as their diameters and angles will permit.

This is illustrated at Fig. 5, which is a cross section through the warp. In this case each set of threads forms equal angles. A consideration of the figure shows that the angle formed by the weft at any point of the intersection is a continually changing one. A

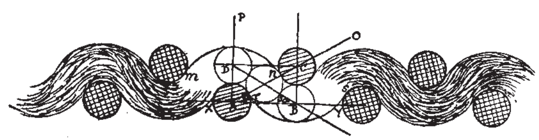


Fig. 5.

straight line drawn through the centre of the weft thread at B, its lowest position on the under side of the fabric, and through D, its highest position on the upper side, distinctly demonstrates that the average angle formed by the weft with the horizontal is one of 30°, and consequently, the angle of the warp will be 30° since they each form equal angles.

Any attempt to increase the natural number of warp or weft threads will cause a decrease in the relative number of the opposite set of threads as well as a decrease in the angle of curvature in those threads, *e.g.* if one set of threads be made to lie perfectly straight, the opposite set will produce an angle of 45°, that is assuming the threads are put as close together as the angle of curvature will permit (see Fig. 8).

If the warp lies perfectly straight the weft may, and occasionally does, in practice produce an angle of 30°. In such cases the fabric is not woven as close as the diameter, etc., permits. The warp and weft threads can each form equal angles of less than 30°, but then the cloth will be looser in proportion which may or may not be detrimental, according to the class of material which is being made, and the purpose it is intended to serve. When this latter angle is desired, it is frequently advisable to use a looser spun yarn as is often done in the manufacture of dress goods, where a mule spun is used in preference to a throstle spun yarn, as it has a relatively greater diameter, and it also produces a fuller and softer handle together with a lighter cloth.

The following is a description of the construction of Fig. 5. Upon the horizontal line X Y, of any length, take any point A and describe a circle representing a cross section of the warp. With the same centre and radius of A + diameter of weft, describe an arc M N; draw a perpendicular line P A meeting X Y in the centre of thread A; from point A draw A O, making an angle of 30° with A B; then, upon the straight line A O, describe a circle C of the same radius as A and so that its periphery shall touch the arc M N at N, the point where M N and A O intersect. From C draw a line at right angles to X Y, meeting X Y at B, and from C draw a line at right angles to C B, joining A P in D; then from centre of thread C describe an arc of a circle R S with radius C + diameter of the weft. The sides A B C D now form a perfect rectangle, and a straight line drawn through the centres of the weft at B and D reveals the angle formed by the weft to be one of 30°. It is now necessary to find the distance from A to B or D to C which represents the amount of space that one warp thread plus one intersection of the weft must occupy in the woven piece.

By construction, we know that the distance from A to C equals two diameters (1 warp + 1 weft), as does also the distance from B to D being diagonals of the same rectangle. Assuming the diameter of warp and weft threads to be $\frac{1}{60}$ of an inch, then the distance B D $= \frac{1}{60} + \frac{1}{60} = \frac{1}{30}$ of an inch, and distance A D equals half the diameter of the warp and half the diameter of the weft, $= \frac{1}{120} + \frac{1}{120} = \frac{1}{60}$ of an inch. If x = length of A B (base), then by proposition 47, Book I, "Euclid," we know that the sum of the squares on the sides (A D + A B) equals the square on the hypothenuse B D. Thus, $AD^2 + AB^2 = BD^2$

$$= \frac{1}{60}^2 + x^2 = \frac{1}{30}^2$$

$$\therefore \quad x^2 = \left(\frac{1}{900} - \frac{1}{3600}\right) \text{ or } \frac{1}{1200}$$

$$\therefore \quad x = \sqrt{\frac{1}{1200}} = \frac{1}{34 \cdot 64} \text{ of an inch.}$$

The same result may be obtained upon the well known theory of trigonometrical ratios.

Let x = the distance A B. Commencing with the knowledge that the cosine of angle in any right angle triangle is always equal to the base ÷ hypothenuse, and that the hypothenuse is always opposite the right angle, the perpendicular is always opposite the angle under consideration and the base is always opposite the complement of this angle.

Then in the triangle A B D

$$\frac{\text{Base}}{\text{Hypothenuse}} = \frac{AB}{BD} = \text{cosine of angle } ABD = 30^\circ$$

And cosine of an angle of $30^\circ = \frac{\sqrt{3}}{2} = \frac{AB}{BD} = \frac{x}{\frac{1}{30}}$

$\therefore x = \frac{\sqrt{3}}{30 \times 2} = \frac{1}{34 \cdot 6}$ as previously.

By adopting the trigonometrical method any problem of this kind can be most readily and correctly solved.

If these results are compared with those worked out by the first rule given in chapter XI., formula XXIX., where the angle of curvature was ignored, it will be observed that by this latter method an additional 4·64 threads per inch are obtained. By formula XXIX. the cloth was found to contain 30 threads of warp plus 30 intersections of weft per inch. From the foregoing we may easily find the relative space which 1 warp thread plus 1 intersection of weft will always occupy, so that the process of finding the Sett for fabrics woven under conditions as shown at Fig. 5 may be very much shortened. Thus, by the first method, 1 warp thread plus 1 intersection of weft $= \frac{1}{30}$ of an inch, and by the second method 1 warp thread plus 1 intersection of weft $= \frac{1}{34 \cdot 64}$ of an inch. Therefore the 2 units of space relatively occupied by the latter will be in the following ratio :

$$\frac{\frac{1}{34 \cdot 64} \times 2}{\frac{1}{30}} = \frac{30 \times 2}{34 \cdot 64} = 1 \cdot 732$$

FORMULA XXXV.

Angle of Curvature of 30° considered.

$$\frac{\text{No. of dia. of threads per inch} \times \text{ends in 1 repeat of design.}}{(\text{No. of intersections} \times 1 \cdot 732) + \text{No. of ends more than intersections in 1 repeat of design.}}$$

= Ends or picks per in. which the finished fabric should contain.

which, when applied to the above example

$$= \frac{60 \times 2}{(1 \cdot 732 \times 2) + 0} = 34 \cdot 64 \text{ threads per inch.}$$

As a proof that the foregoing agrees with practice take the following example which represents the make of a typical light fancy worsted coating:

Warp and weft 2/40s worsted.

Ends and picks per inch in loom, 48.

Weave plain as Fig. 5. Reed width 60 inches.

Finished width 54 inches.

Ends and picks per inch finished, 53 to 54.

PROOF. 2/40 = 20s = $\frac{1}{95}$ diameter.

∴ Ends and picks per inch

$$= \frac{95 \times 2}{(2 \times 1 \cdot 732) + 0} = 54.$$

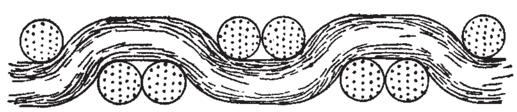


Fig. 6.

Both this and formula XXIX are applicable to all classes of woven fabrics which are of a regular character and where warp and weft each form angles of 30°. Formula XXIX only gives approximate results, whilst XXXV yields very accurate results.

The greatest difference obtained by the two methods is when the number of intersections in one repeat of the pattern is equal to the number of threads in the same repeat. But this difference gradually decreases as the number of threads in one repeat of the pattern increases over the number of intersections. Thus, for example:—Consider Figs. 6 and 7, which are sections through the warp of the 2-and-2 and 4-and-4 twill respectively.

In each case the angle formed by the warp and weft at the points of intersection is one of 30°.

By formula XXIX.

Fig. 6 .... $[60 \times 4] \div [4 + 2] = 40$

Fig. 7 .... $[60 \times 8] \div [8 + 2] = 48$

By formula XXXV.

Fig. 6 .... $[60 \times 4] \div [(2 \times 1{\cdot}732) + 2] = 44$

Fig. 7 .... $[60 \times 8] \div [(2 \times 1{\cdot}732) + 6) = 50$

Observe the relative increase in Fig. 6 $= 40 \div 44 = 0{\cdot}9$, which indicates a difference of 10 per cent.; whilst in Fig. 7, $48 \div 50 = 0{\cdot}96$, which shows a variation of 4 per cent.

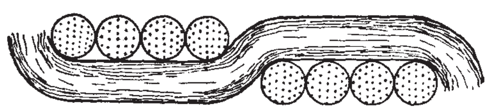


Fig. 7.

The chief factors which cause the two sets of yarns to produce unequal angles in a fabric may be enumerated as follows ;—

1. A difference in the diameters of the two yarns, in which case their relative bending powers would be in the ratio of the cubes of their diameters, other factors remaining constant.

2. A variation in their relative powers of resistance, due to a difference in quality or material.

3. The weave structure.

4. The construction of the fabric so that it shall contain relatively more threads of one set than of the

other set, warp or weft, than would be obtained by the application of the principle involved in formula XXXV. previously demonstrated.

WARP STRAIGHT, WEFT BENDING, AND VICE VERSA.

In proceeding, we shall now consider the principle underlying the construction of those fabrics in which one set of threads lie perfectly *straight*, while the other performs all the bending.

An illustration of the structure of such a fabric is shown by a cross section through the warp at Figure 8.

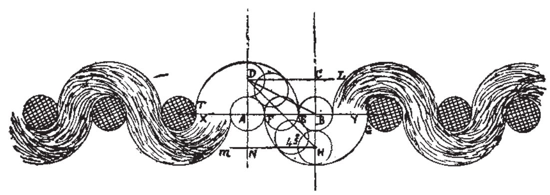


Fig. 8.

An examination of the construction of this diagram not only shows the warp threads to lie in a perfectly straight line, while the weft does all the bending, but it also reveals the average angle of inclination to be 45°, *e.g.* Take any point X and draw from X a straight line X Y, but unlimited towards Y.

In X Y take any point A, then with A as centre and radius equal to half the diameter of warp, describe a circle representing the diameter of the warp; again, with A as centre and radius equal to half the diameter of the warp plus one diameter of weft, describe a semicircle meeting X Y in T and E respectively. Further, in X Y take a point B at a distance from E equal to the radius of the circle circumscribing point A. Then with

B as centre and radius E B, describe a circle to represent the second warp thread. Further, with B as centre and radius A T or A E, describe a second semi-circle so as to meet X Y in the points F and G (repeat the process to show a greater length of weft interlacing with the warp). Then to show the average inclination of the weft proceed as follows:—

From the points A and B draw perpendicular lines to the centre of the weft thread in its highest and lowest position, *viz.*: D and H respectively; then from the points D and H draw straight lines D L, H M unlimited towards L and M respectively and each parallel with X Y or A B.

Produce D A to meet H M in the point N, also H B to meet D L in the point C.

Then because the side A D equals the side B H (each being equal to half the diameter of the warp plus half the diameter of the weft), and also B C and A N being equal (each meeting parallel lines with A B and of equal distances from A B), then the sides D A and A N are together equal to the sides C B and B H.

Further, because the straight line A B equals two diameters, *viz.*, half the diameter of warp plus one diameter of weft plus half the diameter of warp (A F + F E + E B), therefore A B equals D N or C H, and because A B equals D C or N H, therefore D C and N H are each equal to the sides D N or C H.

Again, because the angle D A B is a right angle (construction), and since the straight line D N falls upon the parallel lines X Y and M H, the interior angle D N H is equal to the exterior angle D A B or D A Y ("Euclid" I, 28).

Join H D (the lowest and highest positions of the centre of the weft thread), then the line H D which represents the average angle formed by the curvature of the weft makes an angle of 45° with the horizontal line X Y or A B.

PROOF.—In the triangle D N H, because sides D N, N H are equal to each other (proved) the triangle D N H is Isosceles, therefore the angles N D H, D H N at the base D H are equal, and since the three interior angles of a triangle are together equal to two right angles, Euclid I., 32., and the angle D N H is a right angle (proved) therefore angles D N H, D H N are together equal to

$$180^\circ - 90^\circ\ (\text{D N H}) = 90^\circ$$

$$\therefore \quad \text{Angle N H D} = \frac{90^\circ}{2} = 45^\circ.$$

From the construction of the foregoing example it will be clearly manifest that the distance apart of the warp threads at each intersection is equal to one diameter of warp plus one diameter of weft, *viz.*, $\frac{1}{60} + \frac{1}{60} = \frac{1}{30}$ or 30 threads of warp per inch (assuming the diameter of the warp and weft threads to each equal $\frac{1}{60}$ part of an inch as in the previous examples).

The number of weft threads per inch that would be contained in a fabric constructed under such conditions would be equal to the denominator of the fractional part of one thread in inches, because if the warp threads lie straight the weft threads would touch each other.

Further, it is interesting to note that the average angle produced by the weft remains unchanged whatever be its thickness, providing the warp lies perfectly straight.

This truth is clearly illustrated at Figure 9. In this example the diameter of the warp is represented as before, *viz.* :—$\frac{1}{60}$ of an inch, while the thickness of the

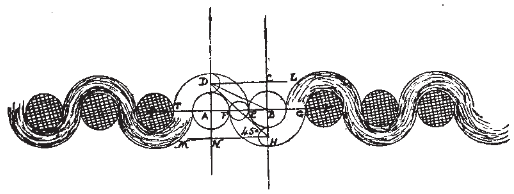


Fig. 9.

weft is reduced to $\frac{1}{120}$ of an inch. The diagram Fig. 9 is constructed in the same way as Figure 8. The same letters in each diagram refer to corresponding parts and the subsequent reasoning is identical in each case, consequently it is not necessary to repeat here the process of construction and reasoning.

The setting of the fabric in this case equals $\frac{1}{60} + \frac{1}{120} = \frac{1}{40}$ or 40 warp threads per inch, and 120 weft threads per inch.

Each of the foregoing examples, including any change in weave, may be reduced to and solved by the application of the following formulæ :—

FORMULA XXXVI. Applies to the Sett of threads which are perfectly straight in the finished fabrics, and is as follows :—

$$\frac{\text{Total dia straight thds.} + \text{total dia. interlacing thds. in 1 rpt. des.}}{\text{Number of threads in one repeat of design}}$$

$= \begin{array}{c}\text{The fractional part of one inch which each straight}\\ \text{thread in the finished fabric should occupy.}\end{array}$

And this applied to the last example equals

$$\frac{\frac{2}{60} + \frac{2}{120}}{2} = \frac{1}{40} \quad \therefore \quad 40 \text{ threads per inch.}$$

FORMULA XXXVII. Applies to the Sett of threads which perform all the bending in the finished fabric and is as follows :—

The denominator of the diameter of the bent thread = the number of threads per inch, thus :—

In the above example, diameter of weft $= \frac{1}{120}$.

$\therefore$ Threads per inch equal 120.

The explanations given in connection with formulæ XXXVI. and XXXVII. are especially applicable to ribs, glacies, and dressed face fabrics. The latter formula includes all cloths produced from a sateen basis in which the warp or weft is the predominant surface factor.

Example.—A 15 shaft corkscrew cloth is required to be made from 2/48s Botany warp and 1/30s Botany weft. The diameters of the warp and weft are $\frac{1}{104}$ and $\frac{1}{117}$ respectively. Find ends and picks per inch.

Therefore, the Sett by formula XXXVII. = 104 and 117 threads per inch respectively of warp and weft.

UNEQUAL ANGLES OF CURVATURE.

Suppose now the two sets of threads undergo a change such that they shall form *unequal* angles. For convenience let us assume that the angle formed by the warp has been increased to 45°. The number of threads will necessarily increase while the angle formed by the weft will decrease to 22·5°.

The principle which underlies this theory is demonstrated if we consider the construction of Figure 10 and the solution of the problems connected therewith. Construction :—Take any suitable point X and draw a horizontal line X Y. In X Y take any point A and describe a circle representing the diameter of the warp.

From centre of circle A draw a straight line A P perpendicular to X Y, and also from the same centre draw a straight line A O making an angle of 45° with A Y.

With A as centre and radius equal to the radius of circle A plus 1 diameter of weft, describe an arc of a circle M N.

In A O take a point C, equal in distance to the radius of circle A, from the arc M N at the point where A O passes through M N and describe a circle C, so that its circumference touches the periphery of the arc M N.

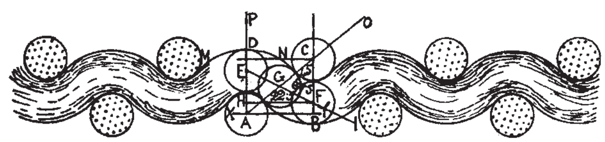


Fig. 10.

Through the centre of circle C draw two straight lines parallel to A Y and A P and cutting A P in D and A Y in B respectively. Then to find the angle produced by the weft, find the centre of the weft threads in the lines C B at F; A D at E and A C at G. Join E G F and produce F to I.

From the point F draw a straight line parallel to A B cutting A D in the point H, then the line E F produced to I represents the average inclination of the weft thread with the horizontal line F H or X Y to be one of 22·5°.

PROOF.—In the triangle A B C,

Angle C A B = 45° by construction.

Angle A B C = 90° by construction.

$\therefore$ Angle B C A $= 180^\circ - (90^\circ + 45^\circ) = 45^\circ$.

In the triangle G F C,

The side C G $= \frac{1}{2}$ diameter of warp $+ \frac{1}{2}$ diameter of weft,
and ,, C F $= \frac{1}{2}$,, ,, $+ \frac{1}{2}$,, ,,
$\therefore$,, C G = the side C F.

$\therefore$ The triangle G F C is Isosceles and the angles at the base of an Isosceles triangle are equal (Euclid I. v.) and further the combined angles C G F and C F G are together equal to 2 right angles minus angle G C F or $180^\circ - 45^\circ$ (G C F) $= 135^\circ$.

$\therefore$ The angles C G F and C F G each equal $\frac{135}{2} = 67{\cdot}5$.

Further, the angle H F C is a right angle (construction) of which the angle G F C forms a part. $\therefore$ The angle H F G $= (90^\circ -$ G F C$)$ $90^\circ - 67{\cdot}5^\circ = 22{\cdot}5^\circ$, which represents the angle produced by the weft with the horizontal H F.

The length of the straight line A B represents the space occupied by one warp thread plus one intersection of weft, and since there are as many intersections of the weft as there are warp threads, the number of such distances (A B) which are contained in one inch represents the number of warp threads per inch which the finished fabric would contain, *e.g.*, Distance A C = 1 diameter of warp plus 1 diameter of weft (construction)

$$= \tfrac{1}{60} + \tfrac{1}{60} = \tfrac{1}{30} \text{ inch.}$$

Let x = distance A B.

Since angle C A B is one of 45°

$$\text{and } \frac{\text{Hypotenuse}}{\text{Base}} = \frac{\text{A C}}{\text{A B}} = \text{Secant of angle C A B}$$

$$= \text{Secant } 45^\circ = \frac{\sqrt{2}}{1}$$

$$\therefore \quad \frac{AC}{AB} = \frac{\sqrt{2}}{1} = \frac{\frac{1}{30}}{\frac{x}{1}} = \frac{1}{30x}$$

$$\therefore \quad \frac{1}{x} = \frac{\sqrt{2} \times 30}{1}$$

$$\text{and } \left(\frac{1}{x}\right)^2 = \frac{2 \times 30 \times 30}{1} = \frac{1800}{1}$$

$$\therefore \quad x = \sqrt{\frac{1}{1800}} = \frac{1}{42 \cdot 4} \text{ inch.}$$

Therefore No. of warp threads + intersections of weft equal 42·4 threads per inch, which shews an increase of $(42 \cdot 4 - 34 \cdot 64) = 5 \cdot 76$ threads per inch when the angle formed by the warp is 45° and the weft 22·5, instead of 30° as previously considered.

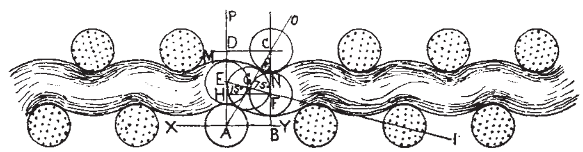


Fig. 11.

In the next example assume the angle formed by the warp to increase from 45° to 60° (see Fig. 11).

A further decrease in the angle produced by the weft will readily be observed, it being now 15° (Fig. 11) instead of 22·5° as in Fig. 10. The angle of 60° may be taken as the limit of curvature which either set of threads can make in single cloths and when both sets of threads form unequal angles.

CONSTRUCTION:—Take any suitable point X and draw a horizontal line X Y unlimited towards Y. In X Y take any point A and with A as centre and radius equal to half the diameter of the warp, describe a circle which shall represent the diameter of the warp. From the centre of circle A, draw a straight line A P perpendicular to X Y and unlimited towards P, also from the same centre draw a straight line A O unlimited towards O, and making an angle of 60° with A Y. Further, with A as centre and radius equal to the radius of circle A, plus one diameter of the weft, describe an arc of a circle M N.

In A O take a point C equal in distance to the radius of circle A from the arc M N at the point where A O passes through M N and describe a circle such that its circumference touches the periphery of M N. Also from the centre of circle C draw two straight lines parallel to A Y and A P cutting A P in D, and A Y in B respectively.

Then to find the angle produced by the weft, find the centre of the weft thread in the lines C B at F; A D at E; and A C at G. Join E G F and produce F to I.

From the point F draw a straight line parallel to A B and meeting A D in the point H. Then the straight line E F produced to I represents the average inclination of the weft thread with the horizontal line F H or X Y which will be found to be one of 15°.

PROOF.—In the triangle A B C,

Angle A B C = 90° by construction.

,, C A B = 60° ,, ,,

,, A C B = 180° − (90° + 60°) = 30°.

And in the triangle G C F,

The side G C = $\frac{1}{2}$ dia. of warp + $\frac{1}{2}$ dia. of weft (construction),
and ,, F C = ,, ,, ,, ,,

∴ The side G C = the side F C.

∴ The triangle G F C is Isosceles, and the angles at the base of an Isosceles triangle are equal.

Then because the three interior angles of a triangle are together equal to two right angles, the angles C G F and C F G are together equal to $180^\circ - 30^\circ$ (G C F) $= 150^\circ$.

Therefore the angles C G F and C F G are each equal to $\frac{150}{2} = 75^\circ$.

Further the angle H F C is a right angle (construction) of which the angle C F G forms a part.

Therefore the angle H F G $= 90^\circ - 75^\circ$ (G F C) $= 15^\circ$ which represents the average angle produced by the weft with the horizontal line H F or X Y and when the warp forms an angle of 60°.

The length of the straight line A B indicates the fractional part of an inch which one diameter of warp plus one intersection of weft occupies in the finished piece, consequently the denominator of such fraction represents the number of warp threads per inch which the fabric would contain.

The following is a solution of the problem.

Distance A C $= \frac{1}{60} + \frac{1}{60} = \frac{1}{30}$ of an inch.

Let $x =$ distance A B in inches.

And since the angle C A B is one of 60°

$$\frac{\text{Base}}{\text{Hypotenuse}} = \frac{\text{A B}}{\text{A C}} = \text{Cosine of angle C A B.}$$

$$\text{Cosine of } 60^\circ = \tfrac{1}{2} = \frac{x}{\frac{1}{30}} = 30x.$$

$$\therefore \quad x = \frac{1}{2 \times 30} = \tfrac{1}{60} \text{ part of an inch.}$$

Consequently if a cloth is to be made under conditions such as above it must contain 60 threads of warp per inch and the number of weft threads per inch would be rather less than is represented by 1 diameter of warp plus 1 diameter of weft, inasmuch as the weft is somewhat bent out of the straight line.

These two examples, Figures 10 and 11, have been selected to demonstrate the theory, that as the angle increases the cloth must contain relatively more threads of warp or weft per inch, or, inversely, an increase in the number of warp or weft threads causes a relatively greater angle of curvature in the respective set of threads in which the increase takes place.

EXERCISES.

1. A dressed face union cloth is required to be produced from 2/36s cotton and 10s Y.S. woollen. Find Sett and picks per inch. Diameters $\frac{1}{111}$ and $\frac{1}{43}$.
Ans., 30; 43.

2. A 13 shaft corkscrew is required to be produced from 2/36s worsted warp and 1/20 worsted weft. Find a suitable number of ends and picks.
Ans., 85; 95.

3. A $\frac{2}{2}$ warp rib cloth complete on 2 ends and 4 picks is required to be made from 60/2 spun silk warp and weft. The former produces all the bending while the latter is perfectly straight. Find a suitable number of ends and picks. Diameter $= \frac{1}{206}$.
Ans., 206, 137.

CHAPTER XIV.

CONSTRUCTION OF WOVEN FABRICS. D.
COMPRESSION CONSIDERED.

In the previous chapter it has been shown that the natural tendency of two threads of unequal diameters —other factors remaining constant—is to cause each other to bend relatively according to the cubes of their diameters. This is quite true. But ' pieces ' are frequently made in which, during the process of manufacture, both sets of threads are somewhat bent out of the straight line, and subsequently in the process of finishing the warp direction of the cloth is drawn out until the warp threads are in a perfectly straight line, and the weft is made to produce all the bending.

The writer has had experience in cases where ' pieces ' produced from 70 yards of warp have, after the first cut of warp, yielded from 69 to 69½ yards of cloth, when returned from the dyeing and finishing operations. Upon extracting a few warp threads from the cloth they presented a perfectly straight line, whereas the weft threads distinctly showed a series of corrugations.

This kind of treatment is particularly adapted to ' glacies ' or lustre goods and certain kinds of Union coatings and many linen fabrics. Examples will be considered in this former class first. In these goods the best result is obtained when the weft is much thicker than the warp.

It has already been shown that the angle of 45° represents the maximum number of degrees which it is possible for the weft to form with the horizontal, when the warp remains perfectly straight. Any increase in this angle would disturb the straight line of the warp; further, the distance apart of the warp threads was shown to be equal to one diameter of warp plus one diameter of weft, when the angle formed by the weft is 45° and the warp is straight, whatever be their relative diameters. It is necessary to remember these facts since their application is involved in a consideration of what follows.

In glacies or lustre goods the cross section of the weft is cylindrical when weaving.

The warp and weft are slightly bent out of their straight line, but during the process of finishing the warp is pulled out to a perfectly straight line, and the weft is made to perform all the bending. Further the weft in the 'piece' is compressed until its cross-section forms an ellipse, and so that the diameter of the weft in the direction of the 'piece' or warp is increased from one-third to one-half of its original thickness. The result of this is that the surface of the weft appears *flattened* and consequently the *lustre* of the yarn is *increased*, which is still further improved by the angle formed by the weft, which usually varies from 30° to 45°.

It will therefore be apparent that if the diameter of the weft is increased in the longitudinal direction of the 'piece' the number of picks put into the fabric cannot equal the number of diameters of the weft when it is being woven but that the number of picks which the 'piece' must contain will be equal to the number of diameters per inch of the altered condition of the weft. Further if the weft is increased in diameter in the direction as above it will be decreased in diameter between the warp threads which of course makes it possible for the fabric to contain more warp threads per inch. It is therefore necessary to find these two diameters of the weft, which is comparatively an easy process, since the area of the cross-section, whether it be circular, or compressed to form an ellipse remains unchanged.

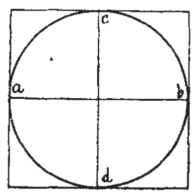


Fig. 12.

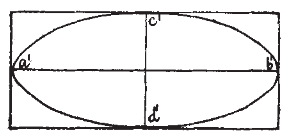


Fig. 13.

If we assume that the circumscribing line which encloses the circle at Fig. 12, be a fine silk thread whose thickness is ignored, and we afterwards arrange this same length of thread so as to enclose an ellipse as at Fig. 13, the area thus enclosed must necessarily be the same—the only difference being in the shape.

It therefore only becomes necessary to determine the increase in the diameter a′ b′ and the decrease in the diameter of c′ d′ (Fig. 13) as compared with the original diameters a b and c d respectively in Fig. 12.

In theoretical mechanics we are taught that the area of a circle is not only equal to πr^2, but also to $\pi \div 4$ multiplied by the circumscribing rectangle, where π equals $\frac{22}{7}$ and r equals radius.

e.g. Assume diameter of circle Fig. 12 = 2 ins.
Hypothesis:—Area of circle $= \pi r^2$. Equation 1.
also ,, ,, ,, $= \pi \div 4 \times$ circumscribing rectangle (a b) (c d). Equation 2.

PROOF: Area of circle in Equation 1 $= \frac{22}{7} \times 1 \times 1 = \frac{22}{7}$

also ,, ,, ,, ,, ,, $2 = \frac{22}{7} \times \frac{1}{4} \times \frac{2}{1} \times \frac{2}{1} = \frac{22}{7}$

Consequently, assuming that the diameter of the circle Fig. 12 be compressed until its form becomes that of an ellipse as at Fig. 13, the area of the ellipse will be exactly the same as that of the circle and by the aid of the formula (Equation 2) we may readily determine the diameter c′ d′ if we know or allow for a given amount of increase in the diameter of the circle across a b due to compression.

NOTE.—In the manufacture of glacies, the picks of weft per inch should be reduced by about $\frac{1}{3}$ the number of diameters of weft threads per inch to allow for *compression* to which the weft is subjected in the process of finishing.

Example.—Assume the amount of increase in the diameter a′ b′ is equal to $\frac{1}{2}$ its original diameter, then the diameter of c′ d′ (which it will be necessary to know when constructing cloths) can be determined as follows:—

Area of circle (Fig. 12) $= \pi r^2 = \frac{22}{7} \times 1 \times 1$.
Diameter a′ b′ (Fig. 13) $= 2 + 1 = 3$ inches
Area of ellipse ,, $= \pi \div 4 \times$ (a′ b′) (c′ d′)
$= \frac{22}{7} \times \frac{1}{4} \times \frac{3}{1} \times \frac{x}{1}$

Then since area of circle and area of ellipse are equal to each other

$$\frac{22}{7} \times \frac{1}{4} \times \frac{3}{1} \times \frac{x}{1} = \frac{22}{7} \times 1 \times 1$$

$$\therefore \quad \frac{3}{4} x = 1$$

$$\text{and } \therefore \quad x = \frac{4}{3} = 1\tfrac{1}{3} \text{ inches}$$

where x equals diameter c′ d′.

The proof of this is further confirmed if we consider the area of the square as compared with that of the rectangle.

Area enclosed by the square or rectangle which contains the circle (Fig. 12) = (a′ b′) (c′ d′) = $2 \times 2 = 4$.

Area enclosed by the rectangle which contains the ellipse (Fig. 13) = (a′ b′) (c′ d′) = $3 \times 1\frac{1}{3} = 4$.

If we apply the foregoing knowledge to the construction of those fabrics in which the diameter of the threads undergoes a change due to compression, we shall then be able to construct our fabrics, not only upon scientific principles but we shall eventually see that the results thus obtained coincide with actual fabrics whose perfection in construction is placed beyond all doubt, by their appearance, handle and demand.

Thus consider for example a glacie fabric is composed of 2/22os cotton warp and 1/20s mohair weft—weave plain. Find ends and picks per inch.

A cross section through the warp and weft is shown respectively at A and B, Fig. 14, before compression takes place and similarly at A′ and B′, Fig. 15, after the fabric is finished and where the weft yarn is seen to be compressed. For convenience we shall speak of the *increase* of the diameter of the weft in the direction A B or A′ B′, Figs. 14 and 15 respectively as an increase in the diameter of the weft in the direction of the warp, and a *decrease* in the diameter of the weft across c d or c′ d′ as a decrease in the diameter of the weft at right angles to the warp.

A consideration of the foregoing together with the diagrams Figs. 14 and 15, involves the following.

1. An increase in the diameter of the weft in the direction of the warp, which necessitates a decrease in the number of weft threads per inch.

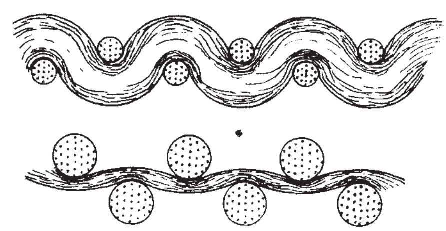


Fig. 14.

2. A decrease in the diameter of the weft at right angles to the warp which makes it possible to increase the number of warp threads per unit of space.

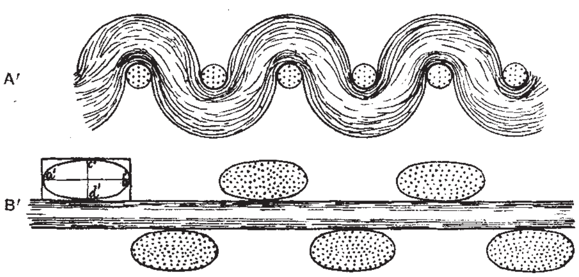


Fig. 15.

Hypothesis:—

Diameter of above warp — 2/22os cotton = $\frac{1}{276}$ in.

" " " — 1/20s mohair = $\frac{1}{95}$ "

Allow for increase in the diameter of the weft in the direction of the warp, one half the original diameter of the weft. This can easily be arranged for, when setting the fabric in the loom; thus, taking the diameter of the weft as given, the piece might contain 95 threads per inch, but if it were woven with an allowance for an increase in its diameter by compression of half its original diameter as above, the fabric would then contain

$$\frac{1}{95} + \frac{1}{190} = \frac{3}{190} = \frac{1}{63\frac{1}{3}} \text{ or } 63 \text{ threads per inch.}$$

During the subsequent processes of finishing, these threads would be subjected to compression so that their peripheries would practically touch each other. Any further compression would prevent the warp threads from producing a perfectly straight line, in which case the best results would not be obtained. Then the diameter of the weft through c′ d′, Fig. 15, can be found by the application of the previous formula.

Let x = diameter of thread through c d,

and since the area of cross section of thread.

$$\text{Fig. } 14 = \frac{\pi}{4} \times (\text{a b}) (\text{c d}) = \left(\frac{1}{95} \times \frac{1}{95}\right) \frac{\pi}{4}$$

$$\text{also ,, ,, ,, Fig. } 15 = \frac{\pi}{4} \times (\text{a}'\text{b}')(\text{c}'\text{d}') = \left(\frac{3}{190} \times x\right) \frac{\pi}{4}$$

$$\therefore\ x \times \frac{\pi}{4} \times \frac{\overset{}{3}}{\underset{2}{190}} = \frac{\pi}{4} \times \frac{\overset{}{1}}{\underset{1}{95}} \times \frac{1}{95}$$

$$\therefore\ x = \frac{2}{3} \times \frac{1}{95} = \frac{1}{142} \text{ of an inch.}$$

Therefore the thickness or diameter of the weft at the point of intersection with the warp $= \frac{1}{142}$ of an inch

It has previously been demonstrated that the maximum number of warp threads which the finished fabric must contain when the warp threads lie perfectly straight is only obtained when the angle formed by the weft is one of 45° (see Fig. 8)—any lower angle requires a relatively less number of threads.

We have also shown that when the angle of 45° is maintained the number of warp threads per inch which the finished piece must contain is equal to the denominator of one diameter of weft + 1 diameter of warp, thus, in the previous example—

$$\text{Diameter of weft} = \frac{1}{142} \text{ in.}$$

$$\text{,,} \quad \text{,, warp} = \frac{1}{276} \text{ in.}$$

Therefore the maximum number of warp threads per inch which the finished cloth would naturally contain equals

$$\frac{1}{142} + \frac{1}{276} = \frac{1}{93} \text{ of an inch} = 93 \text{ threads per inch.}$$

The particulars as above would produce a fabric quite firm in handle, thoroughly balanced in structure and highly satisfactory in most ordinary textures, but for obvious reasons it might frequently be necessary to produce a fabric which is softer in handle.

This might involve one or both of the following conditions, viz. :—(1) A decrease in the angle formed by the weft yarn or (2) A decrease in the amount of compression together with a decrease in the angle of curvature of the weft.

In addition to the above it is frequently found necessary to decrease the angle of curvature of the weft, by relatively reducing the number of warp threads.

These reasons vary with the essential conditions required to be made prominent in each type of cloth. Thus, for instance in the production of fabrics such as we are now considering, lustre or brightness is the principal feature, hence their name "Glacies, Lustres or Bright

Goods." With this purpose in view then, we use a yarn possessing as much lustre as possible having due regard to economy.

Yarns produced from Mohair and Alpaca are typical examples. Through every process of yarn preparation such as washing, preparing, combing, drawing and spinning great care is exercised to retain as much as possible of the original lustre of these wools. In a similar sense the manufacturer desires not only to maintain but display as much of this lustre or brightness as possible in his woven products. Lustre may be said to be perceived when two masses of light are manifest at the same time. One of the chief factors which contributes to the lustre of the above wools is the exceptional length and breadth of the individual epidermal scales; these possess relatively a greater unbroken area than those of most other wools, consequently when these greater and unbroken surfaces are presented to the light they are in return able to reflect more light.

The visible effect and reflection of light is always slightly modified according to the different substances and the condition of the surfaces of the bodies upon which the light falls, *e.g.*, if light falls simultaneously upon silk, cotton, worsted, woollen or velvet material, the visible effect would be quite different, according as the surfaces are smooth, glossy, rough or corrugated; and again if light falls on water at a slight angle the amount of light reflected is considerably more than if it fell perpendicularly to the surface, and the same is true of any other substance, according to the nature of its surface.

Polished surfaces reflect light not only in large quantities, but as it were draw the light well together in sharply defined masses. With unpolished surfaces this is not so, the light which falls on them being scattered about in all directions. In the manufacture of many figured fabrics we, in a certain degree, consciously or unconsciously, make use of the knowledge of this truth, *e.g.*, weft flush or sateen weaves reflect the light in greater masses, since the threads lie close to each other with comparatively small interruption, whilst hopsacks, crapes and broken weaves disperse the light, hence, when these two principles of weave structure are contiguous different degrees of light are visibly reflected. Further, consider the apparently different shades which can be produced in a pile fabric where certain portions of the pile threads are cut whilst others are left uncut. Though the pile threads are of the same material, quality and whiteness throughout the whole woven fabric, two distinct shades, one light and the other darker, are distinctly manifest. This difference is due to the threads of the uncut portions having a greater reflecting surface than those of the cut portions. Consequently the former exhibits more light whilst the latter disperses or breaks it up. Bearing in mind all that is involved in the foregoing, consider their influence on the construction of glacie fabrics. The warp is usually fine cotton varying from 2/100s to 2/220s cotton counts. The weft varies in typical examples, from 16s to 24s worsted counts, thus showing much more of the lustrous than of the non-lustrous material.

The object is to display on the surface of the texture as much of the lustrous material as is possible with the structure of the cloth. To attain this object there are several factors to be considered.

(1) The amount of compression or flattening which the weft receives after being woven.

(2) The amount of reduction in the angle formed by the weft.

(3) The warp must lie straight so as to allow the weft threads to lie close to each other and to apparently cover the warp threads.

In the first case it should be obviously clear that if the surface of the weft threads be compressed or flattened so that their diameters in the direction of the warp be increased, we obtain relatively an increase of unbroken reflecting surface, for the same size or weight of yarn; see Figs. 14 and 15.

Secondly, if the angle formed by the weft as in Figure 8 be reduced from its maximum of 45° to one of 30°, an increase of unbroken surface is also evident and the tendency of the yarn to disperse the light is also lessened. It would be unwise to make any further reduction in this angle inasmuch as it would involve too great a reduction in the number of warp threads in the cloth, and so result in the construction of a texture of too flimsy a character.

The third factor mentioned above is self-evident and involves no further reasoning or consideration.

EXERCISES.

1. A glacie fabric, having a good lustre is made from 2/220s cotton warp and 1/20s mohair weft; the weft is compressed $\frac{1}{2}$ its original diameter so that the peripheries of each successive pick touch each other in the finished woven fabric; a cross section through the

warp shows the angle formed by the weft to be 30°; find respectively the original diameter of warp and weft, the diameter of the weft after compression, both in the direction of the warp and at right angles to it, also the ends and picks per inch finished.

Ans., $\frac{1}{276}$; $\frac{1}{95}$; $\frac{1}{63}$; $\frac{1}{142}$; 54; 63.

2. Assume that the amount of compression in the weft in the previous question to be increased from $\frac{1}{2}$ to $\frac{3}{4}$ of original. Find both diameters of the weft under compression for the same angle of 30° and also the finished ends and picks. *Ans.*, $\frac{1}{54}$; $\frac{1}{166}$; 60; 54.

3. Given 40s lea warp and 14s tow weft, find suitable sett 40 inch scale and shots per 37″ glass for huckaback design single shot, weft performs all the bending, allow $\frac{1}{5}$ for compression of weft.

Ans., 800; $9\frac{1}{4}$.

4. A highly satisfactory glacie fabric is produced from the following:—Warp 2/100s cotton, weft 1/20 mohair, woven 56 ends per inch in loom and 60 picks of weft; the finished fabric is compressed so that the peripheries of the weft in the direction of the warp length touch each other; the ends and picks per inch finished are 60. Find the original diameter of warp and weft, the amount of compression which the weft received, the diameter of the weft after compression and by calculation the angle of curvature produced by the weft in the finished texture.

Ans., $\frac{1}{188}$; $\frac{1}{95}$ $\frac{7}{12}$; $\frac{1}{150}$; $\frac{1}{60}$; 36°.

5. A glacie fabric (plain weave) is to be made from 2/100s cotton and 20s mohair weft, compression $\frac{1}{3}$. Find ends and picks per inch. Diameters = $\frac{1}{188}$ and $\frac{1}{96}$. *Ans.*, 80; 64.

Carpet Manufacture

SYNOPSIS OF CHAPTERS I. & II.

CHAPTER I.

Designing. Pages 17—47.

Introductory notes—general improvement in taste—influence of the commercial standard—progress in taste—Artistic development retarded—advantage of oriental over modern carpets—present day requirements—Principal classes of carpet design—geometrical class of designs—Conventional treatment of natural forms—reproductions and imitations of former designs and masterpiecs—Machine made carpets—classification—general possibilities—repeating patterns—testing the repeat—Bases of construction and distribution of repeating patterns—Simple patterns—distribution of unit figures on a weave basis—simple drop—reverse drop figures—Complex designs—step or half drop—half drop bases—skeleton plans, 'half drop'—Ogee basis emphasised—the 'all over' pattern—multisymmetry—border patterns—width of borders—Chlidema squares—plan of a chlidema.

CHAPTER II.

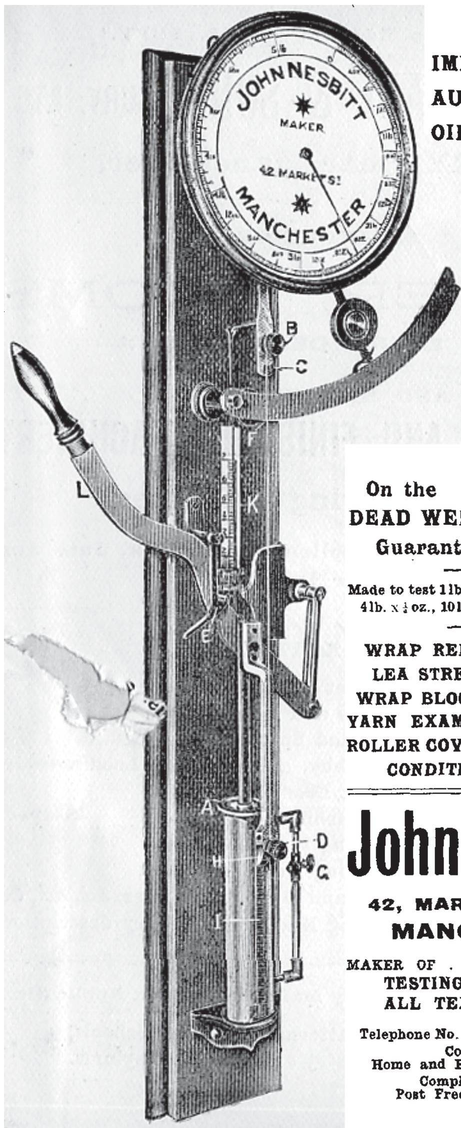
Colour. Pages 48—74.

Taste—an important factor—faculty of taste—natural endowment rare—an improvable faculty—methods of improvement—capriciousness and diversity—standard—perfect taste, delicacy and correctness—Colour theories—successful colourists—colour defined—absorption and reflection—Complementary colours—Pigment colouring materials—simple and compound colourings—mixture of simple and compound colours——Colour scales, simple and compound—classification—Visual modifications of colour—illumination—surface modification—relative proportions and intensities—juxtaposition—Harmonious colouring—harmony by (1) contrast—(2) analogy—(3) gradation—inharmonious combinations modified—Concluding notes.

CHAPTERS III. to IX. Pages 75—301.

The structure, together with a full description and illustrations of the machinery and processes and manufacture of Brussels, Wilton, Tapestry, Royal, Crompton and Chenille Axminsters, Art Squares, Kidderminsters, Scotch and Ingrain Carpets are fully treated in the seven remaining chapters.

Also see page 4.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