ANALYSIS OF WOVEN FABRICS

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WITH NUMEROUS TABLES, EXAMPLES AND EIGHTY-TWO ILLUSTRATIONS

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PREFACE.

TWENTY years have elapsed since the appearance of my little work on "Pattern Analysis". It would speak badly for our Technical Institutes had they not carried both knowledge of the subject-matter and methods of research on to a much higher and more scientific plane during this period. That the field of knowledge has been most markedly extended and that newer and more satisfactory methods have been introduced into the Textile Industries, the present volume bears witness to.

I feel that I should not be doing justice to those who have followed me did I not here pay some tribute to the work that has been carried out by lecturers in that department of the Bradford Technical College over which I have the honour to preside, and especially to the research work of Mr. Midgley, without which the present treatise would have lost much of its value.

At the time when I wrote my little treatise I could but give a skeleton-sketch of the methods whereby a fabric might not only be analysed in the Finished State but from these Finished Particulars the Loom Particulars ascertained. In the present treatise so fully are the changes from the Finished State back to the Loom Particulars for the various Standard Cloths indicated that the designer may proceed without fear where previously he would not have ventured to tread. Mr. Midgley has also succeeded in bringing the Costing of Cloths up to a previously unthought of state of efficiency.

The present treatise may be regarded as a further step towards the more perfect application of scientific method, ensuring that scientific attribute "pre-vision" in the Textile Industries. The authors offer it as such, and at the same time express the hope that it may be made the basis for further excursions into yet unexplored fields, and that such explorations may result in a still further extension of the field of knowledge, in a more perfect command of the recognised methods, and in that control of results which alone can lead to lasting success.

We can hardly hope that all errors in the text or in the mass of figures involved in the Tables and Examples have been eliminated. We shall therefore feel indebted to any reader who directs our attention to such errors or to any omissions.

The thanks of the authors are also due to Dr. L. L. Lloyd for having revised certain sections of the chapter upon the Qualitative and Quantitative Analysis of Fabrics.

A. F. B.

March, 1914.

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CHAPTER I.

QUALITIES OF RAW MATERIALS.

A GREAT many varieties and qualities of materials are employed in the production of woven fabrics.

The price of the required cloth may be taken to be the chief factor in determining the quality of the raw material to be employed, and the appearance of secondary importance. The quality, handle, elasticity, strength, lustre, and appearance of a cloth, naturally depend, in a primary sense, on the nature of the material or materials employed in its manufacture. Each class of fibre possesses certain individual properties, which, of course, characterize the woven cloth in which they appear.

Raw Materials.—The varieties of fibres in general use are classified as follows :—

Table I.—Animal Fibres.
,, II.—Vegetable Fibres.
,, III.—Re-manufactured Fibres.

TABLE I.—ANIMAL FIBRES.

Material.	Producer.	Length.	Colour and Lustre.	Fineness.	Handle.	Appearance.	Uses.
Long wool .	Sheep	6 in./12 in.	Yellow and lustrous, and demi-lustrous	$\frac{1}{400}/\frac{1}{800}$	Fairly soft	Straight in fibre—lustrous and greasy	Dress goods, coatings, hosiery
Short wool .	Sheep	1 in./6 ,,	White	$\frac{1}{1800}/\frac{1}{2000}$	Very soft	Wavy in fibre—very greasy	Dress goods, coatings (good qualities)
Mohair .	Angora goat	4 in./10 ,,	White and lustrous	$\frac{1}{400}/\frac{1}{800}$	Fairly soft	Straight in fibre—fairly clean	Bright dress fabrics, plushes
Alpaca .	Alpaca goat	8 in./16 ,,	Brown, white, fawn, black, demi-lustrous	$\frac{1}{400}/\frac{1}{1000}$	Soft	Fairly straight in fibre—fairly clean	Bright dress fabrics, linings
Camel's hair (Noil)	Camel	3 in./7 ,,	Brown, yellow, and grey	$\frac{1}{200}/\frac{1}{1000}$	Soft	Ditto	Dress fabrics and coatings
Cashmere .	Tibetan goat	2 in./4 ,,	Brown, white, and grey	$\frac{1}{300}/\frac{1}{1600}$	Very soft	Ditto	Ditto
Hair . .	Cow's, horse's, dog's, rabbit's, and kangaroo's hair	Various	Colour:—various Lustre:—various	$\frac{1}{200}/\frac{1}{400}$ Rabbit's $\frac{1}{800}$	Indefinite, Rabbit's soft	Stiff, straight, and bristly	Carriage rugs, etc., upholsteries
Silk . .	Silk worm	Cultivated, indefinite; wild, and spoils, as required	White and brown, very, very lustrous	$\frac{1}{800}/\frac{1}{2000}$	Soft	In cocoon—much matted	Fine textures in dress, plush, and upholstery fabrics

TABLE II.—VEGETABLE FIBRES.

Material.	Producer.	Length.	Colour and Lustre.	Fineness.	Handle.	Appearance.	Uses.
Cotton .	Cotton plant (Gossypium)	$\frac{1}{2}$ in./$1\frac{3}{4}$ in.	White and brown	$\frac{1}{600}/\frac{1}{1600}$	Soft	Straight in fibre	All types of fabrics for domestic and ornamental purposes
Flax . .	Flax plant (Linum)	Varies from few inches to several feet	Yellowish white	$\frac{1}{400}/\frac{1}{1000}$	Fairly harsh	Ditto	Linen fabrics
Hemp . .	Hemp plant (Cannabis)	Ditto	Yellow, brown, and lustrous	$\frac{1}{300}/\frac{1}{700}$	Harsh	Ditto	Twine bagging, sail cloths, etc.
Jute . .	Jute plant	Ditto	Ditto	$\frac{1}{200}/\frac{1}{500}$	Very harsh	Ditto	Ground structure for carpets
Ramie . .	Nettle plant (Boehmeria)	Ditto	White and very lustrous	$\frac{1}{500}/\frac{1}{1000}$	Fairly soft	Ditto and lustrous	Strong fabrics, part used for dress and coating fabrics

TABLE III.—RE-MANUFACTURED FIBRES.

Material.	Sources.	Fineness.	Length.	Colour, Lustre, and Appearance.	Uses.
Noil	Combed wool	$\frac{1}{400}/\frac{1}{1500}$	$\frac{1}{2}$ in./$2\frac{1}{2}$ in.	According to the type of wool combed	Woollens, dress, and coating fabrics
Mungo	All types of milled cloths	$\frac{1}{400}/\frac{1}{1800}$	$\frac{1}{4}$ in./$\frac{3}{4}$ „	According to the type of cloth pulled	Ditto
Shoddy	All types of unmilled cloths	$\frac{1}{400}/\frac{1}{1800}$	$\frac{1}{4}$ in./2 „	Ditto	Ditto
Extract	Cotton and wool cloths (cotton carbon-ized)	$\frac{1}{400}/\frac{1}{1800}$	$\frac{1}{4}$ in./$1\frac{1}{2}$ „	Ditto	Ditto
Flocks	Finishing processes of wool cloths	$\frac{1}{400}/\frac{1}{1800}$	$\frac{1}{8}$ in./$\frac{3}{4}$ „	According to the type of finish-ing treatment	Blending purposes

Wool.—The wool fibre is the natural product of the sheep and is undoubtedly one of the most important fibres employed in the manufacture of woven fabrics. Wool and hair are different in structure : hair fibre is comparatively straight, smooth, and lustrous : wool fibre is wavy and covered with a scale structure. The wool fibres collect quite naturally together on the back of the sheep in what is known as staple form. Each fibre takes its origin in a tube-like depression of the skin, the physical condition of its growth being such as to account for its waviness and scaly structure. Wool varies in length, strength, colour, fineness, waviness, softness, and lustre, according to breed and to the climatic and physical conditions under which it is grown, few materials being subject to changes in such a marked degree (Fig. 1).

The characteristics of good useful wools are uniformity in length, diameter, and crimpiness. Physically the wool fibre is composed of a large number of spindle-shaped cells, with thin, irregular edges of a horny scale-like appearance on its exterior, as illustrated in Fig. 2. The walls of the wool fibre are very flexible and elastic, thus causing the fibre to respond readily to the influence of heat and moisture, and at the same time permitting free absorption into every portion of the fibre. Water, acids, or alkalies, assisted by heat, readily soften the walls of the cells, causing them to protrude, and as these are numerous and the fibre crimpy, the fibres will curl up, partly interlock, and mat

1 2 3 4 5 6

7 8 9

FIG. 1.—Comparison of the various breeds of wool. (The horizontal divisions = 1 inch.)

(1) Lincoln 36's, (2) Kent 44's, (3) Scotch Blackface 28's, (4) New Zealand Crossbred 36's, (5) Australian Crossbred 46's, (6) South American Crossbred, 56's, (7) Cape Clothing wool, (8) New South Wales merino 64's, (9) Down Ewes 50's.

Note the presence and absence of grease and impurities on these natural wool staples.

together. The matting or felting becomes much more pronounced when pressure is applied. The wool fibre, like all horny substances, becomes plastic with heat and moisture, and will set in any position which may be forced upon it. This plastic nature comes into play in the scouring, crabbing, and milling processes. The various qualities of wool exhibit a diversity in their power to felt; thus there must be some inherent difference in the physical structure of the different qualities of the wool fibre. Fine Australian merino wool is very crimpy in appearance, and possesses marked tendencies to felt. Crossbred and English wool is much straighter, containing fewer scales or serrations, and does not possess the felting property of merino wool, on account of the cells and scales which form the fibre being fewer, coarser, and less flexible and elastic ; consequently, the fibres have less tendency to mat or felt together.

(*a*) (*b*) (*c*) (*d*)

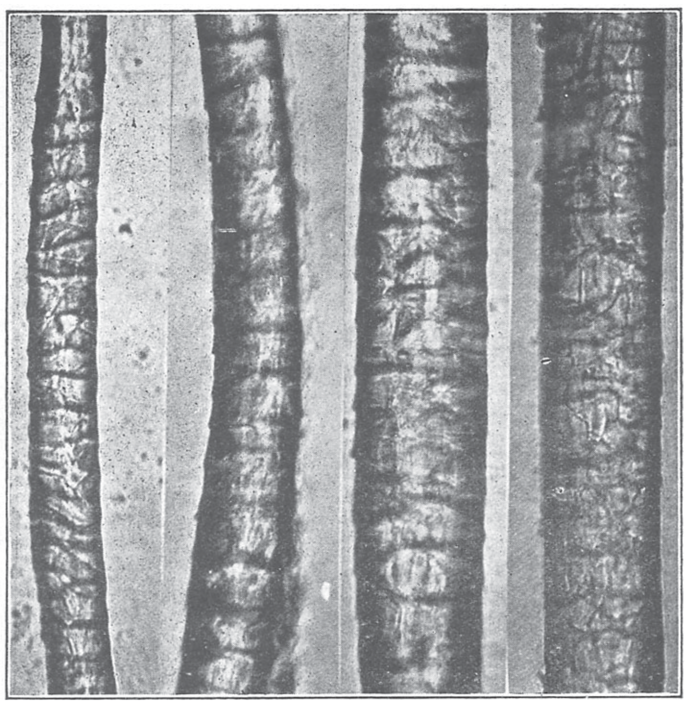

FIG. 2.—Micrographs of wool fibres.

(*a*) Merino fibre, (*b*) Medium Crossbred fibre, (*c*) English Lincoln fibre, (*d*) Mohair fibre.

Varieties of Wools.—The various wools employed in the worsted industry may be classified as follows :—

1. *Short Wools* (*Merino*).—Fine, wavy fibres, each possessing a large number of serrations, which give the material great felting and shrinking properties, but depreciate its lustre.

2. *Medium Wools* (*Crossbred*).—Fibres showing a medium

number of surface markings, consequently they are demi-lustrous and only fair felting wools.

3. *Long Wools* (*Mohair, Alpaca, Lincoln*).—These are very lustrous, contain few surface markings, and lack felting property.

A comparison of the particulars tabulated in Table IV will enable a fairly accurate estimation to be made of the properties of these fibres.

TABLE IV.—GENERAL CLASSIFICATION OF WOOLS EMPLOYED IN THE WORSTED TRADE.

Type of Material.	Top Makers Quality.	Length of Combed Fibre.	Average.	Diameter.	Crimps per Inch.	Scales per Inch.
Short Wool :—						
Merino	60's and upwards	From 3½-5 in.	4 in.	$\frac{1}{1000}$-$\frac{1}{2800}$ in.	16 to 36	4800
Medium Wool :—						
Crossbred	40's-50's	From 6½-9 ,,	7½ ,,	$\frac{1}{750}$-$\frac{1}{1000}$,,	8 to 16	2500
Long Wool :—						
(*a*) Crossbred	40's	From 7½-10½ ,,	9 ,,	$\frac{1}{500}$-$\frac{1}{800}$,,	Straight	1000
(*b*) English Lincoln	36's	From 9½-14 ,,	11 ,,	$\frac{1}{500}$-$\frac{1}{800}$,,	Ditto	800
(*c*) Mohair		From 5-10 ,,	8 ,,	$\frac{1}{800}$,,	Ditto	700

Mohair is the product of the Angora goat; it is fairly long, straight, smooth, and fine in appearance. The scales, which are regular and surround the fibre, are not nearly so marked as in the case of wool. On this account the mohair fibre possesses an almost unbroken circumference, and is the most lustrous of the wool or hair class of fibres. It is extensively employed in the making of lustrous dress fabrics and plushes.

Alpaca.—A fine, soft, silky hair obtained from the Alpaca goat. Its natural colours are: white, grey, brown, and black. The properties of this fibre may be stated to be similar, but on the whole inferior to those of mohair. Commercially it was originally employed as a substitute for mohair, but, possessing a certain subtleness in handle, may now be said to be used on its own merits.

Camel's Hair.—The camel yields a very yellow brown under hair, employed among other purposes for making worsted, dress, and coating fabrics, the coarser hairs being employed for making belting, carpets, etc.

Cashmere Wool.—A fine, soft, silky hair from a goat indigenous to Tibet. Like camel's hair a coarse fibre is found on the outside, and a soft, fine fibre on the inside.

Vicuna and Llama Wool.—This fibre is obtained from a camel-like goat of several species, inhabiting the mountains of Peru and Chili. These hairs or wools on account of their fineness and softness are in demand for the making of worsted and woollen goods. The fibre lends itself to the development of a nap and fibrous surface.

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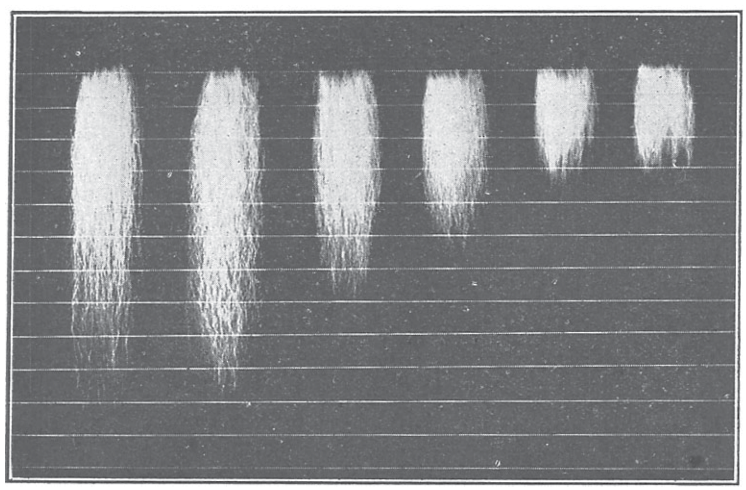

Fig. 3.—Comparison of the various length and fineness of fibres drawn from the following qualities of top. (The horizontal divisions = 1 inch.)
(1) 28's, (2) 36's, (3) 46's, (4) 56's, (5) 64's, (6) 80's.

Bradford Wool Quality Numbers.—The quality number given to combed wool fibre, although primarily based upon length and fineness, conveys some idea of the shrinking, felting, lustrous, and spinning properties it possesses, and at the same time the class to which it belongs.

A wool thick in fibre is not capable of being spun to the same count as a fine wool. When it is required to spin a worsted thread to the extent of, say, 34,000 yards to the pound of material, a fine fibre is of primary importance.

Take for example three typical worsted wools, viz. Australian Merino, Crossbred, and English. In the trade such terms as 60's, 64's, 70's, and 80's Botany or Merino ; 32's low Crossbred to 58's fine Crossbred ; 24's, 36's, 44's English are employed to indicate primarily the spinning capabilities, but indirectly they indicate other qualities. It is known that the fibre of the lowest number in each case is usually finer than the higher numbers of a lower class. For instance 60's Botany fibre is finer than 58's Crossbred, while 58's is finer than 44's English. The numbers are taken in a broad sense to indicate the degree of shrinking, felting, lustrous, and spinning properties possessed. To the spinner the quality number is chiefly useful as roughly indicating the count of yarn to which the material may be spun.

In the worsted industry the standard for counting yarns is based on the number of hanks per lb. the yarn is spun out to, each hank being 560 yds. in length.

Example.—If a yarn on being reeled into a hank of 560 yds. in length weighs 1 lb., the count is stated as 1's. Again, if six hanks are required to weigh 1 lb., the count will be indicated as 6's.

It may be said that all classes of worsted wools may be spun to 6's, but all such could not be spun to 60's count. A good 60's quality may possibly be spun to 60's count (60 × 560 = 33,600 yds. per lb.), but it would be impossible to obtain the same count or length from a 50's quality. Hence, if all combed wool or "top" is up to its stated quality, its maximum spinning property will be as follows :—

Quality.		Hanks.		Yards.		Yards per lb.
80's	=	80	×	560	=	44,800
70's	=	70	×	560	=	39,200
60's	=	60	×	560	=	33,600
50's	=	50	×	560	=	28,000
40's	=	40	×	560	=	22,400
30's	=	30	×	560	=	16,800

But unfortunately the "top" maker or the seller of combed wool is usually guilty of over-estimating the qualities of his products, with the result—especially in the lower numbers—that the spinner is unable to spin to the maximum stated length. For example :—

44's Crossbred top will usually spin to 40's counts
36's English „ „ „ „ 30's or 32's „

and so on. In the higher qualities such as 64's and upwards, it is usual for the spinning properties to be equal to the quality number. Details of fibres which constitute the various qualities of "tops" along with their actual count of yarn limit are given in Table V.

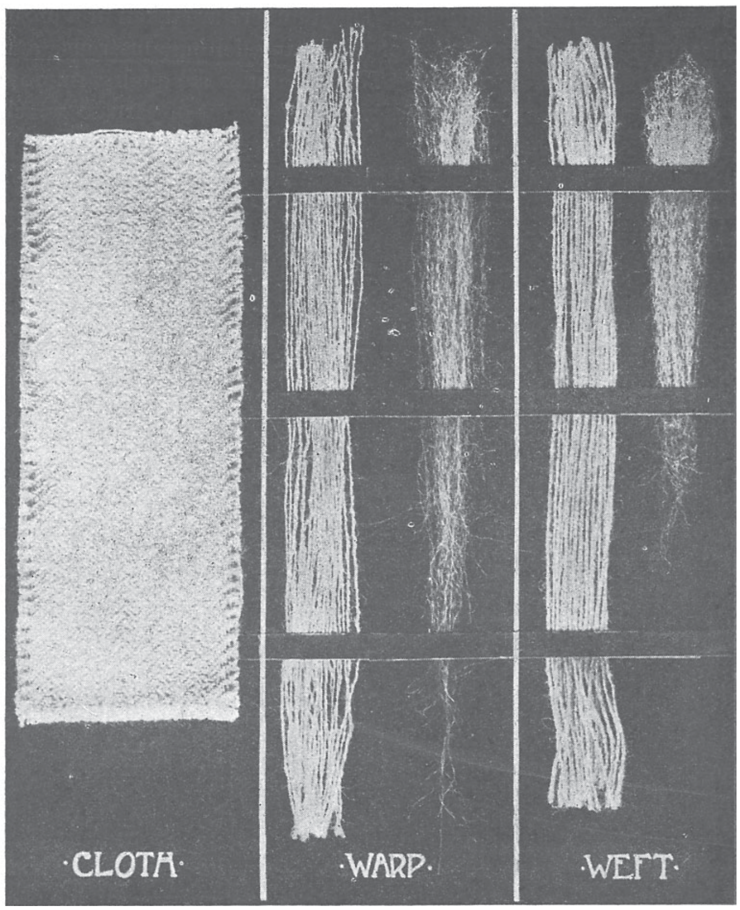

FIG. 4.—Comparison of quality of wool fibre drawn from the warp and weft yarns of a worsted cloth.

Noils.—Noils are a by-product of wool-combing. In the preliminary processes of worsted yarn production it is necessary to subject the wool fibre to a combing process in order to

TABLE V.—RANGE OF BRADFORD TOPS: DETAILS OF QUALITIES.

This table has been compiled by Mr. E. Priestley, Ex-Lecturer in preparing, combing, and spinning, Bradford Technical College, from actual experience of and experiment with a large variety of qualities of tops. It is here offered in the hope that it may prove useful to the cloth analyst in ascertaining the quality of worsted cloths.

Quality No.	Length (in inches). Extremes. Long.	Short.	Mean.	Lustre or Colour.	Handle.	Fineness (Average).	Waviness.	Uniformity.	Count of Yarn Limit.	
28's	15	5	10	Greyish Non-lustrous	Harsh	1/200 to 1/400 in.	Straight	Irregular	16's	
32's	13½	6	9	Fairly lustrous	Fairly harsh	1/400 ,,	Ditto	Ditto	24's	
36's	12½	8½	10	Ditto	Fairly soft	1/500 ,,	Ditto	Fairly uniform	28's	Standard for Comparison —40's (28's to 50's)
40's	12	8½	10	Very lustrous	Soft	1/600 ,,	No waviness clearly defined	Uniform	36's	
44's	11	8½	10½	Ditto	Ditto	1/650 ,,	No clear waviness	Very uniform	40's	
50's	7½	3½	6	Lustrous	Fairly harsh	1/750 ,,	10 Waves per in.	Fairly uniform	46's	
56's	6½	2½	5½	Yellowish in colour	Fairly soft	1/900 ,,	14 ,, ,,	Ditto	48's	
60's	5¼	2¼	3½	Fairly white in colour	Soft	1/1000 ,,	24 ,, ,,	Ditto	56's	
64's	5	2¼	3½	White in colour	Ditto	1/1200 ,,	28 ,, ,,	Uniform	64's	Standard for Comparison —60's (50's to 90's)
70's	4¾	2½	3½	Ditto	Very soft	1/1200 to 1/1400 in.	32 ,, ,,	Ditto	80's	
80's	4½	3	3½	Very white	Very, very soft	1/1400 to 1/1700 in.	36 ,, ,,	Very uniform	100's	
90's	4½	3	4	Ditto	Ditto	1/1700 to 1/2200 in.	36 ,, ,,	Very, very uniform	150's	

average up the fibre length in the "top" and to obtain as much parallelization of fibre as possible.

There is a limit to the length of fibre which may be treated on the various types of wool-combing machines, and in all cases the short fibre combed out is termed "noil".

As there are a number of wools employed in the worsted trade (List IV), each possessing its individual properties and characteristics, so there will be a corresponding number and qualities of noil as illustrated in Table VI.

TABLE VI.—QUALITIES OF NOILS.

Quality.	Average Length of Fibre.	Quality.	Average Length of Fibre.
English		Merino	
1	1¾ in.	1	1 in.
2	1½ ,,	2	¾ ,,
3	1 ,,	3	½ ,,
Crossbred		Alpaca	
1	1¼ ,,	1	2 ,,
2	1 ,,	2	1¾ ,,
3	¾ ,,	3	1 ,,
Mohair		Camel's hair	
1	2 ,,	1	2 ,,
2	1¾ ,,	2	1¾ ,,
3	1 ,,	3	1¼ ,,

Shoddy and Mungo.—These fibres are understood to be the result of "pulling" or beating to pieces soft hosiery, dress goods, and many looser types of woollen and worsted goods.

In technical terms—

Shoddy is the product of unmilled fabrics;

Mungo is the product of all types of cloths which have been subjected to the milling process.

Mungo is usually shorter and finer in fibre than shoddy, because, in the first place, milled cloths are nearly always made from the shorter kinds of wool; secondly, because the fibres of a milled cloth are very difficult to separate from one another. They are therefore always considerably broken in the process of pulling. Both shoddy and mungo are rather comprehensive terms than names for any special type of material, for both classes have an infinite number of special divisions with different names.

The rag trade which naturally forms the basis of these materials is divided into "old" and "new," and is concerned not only in home-collected but also in continental-collected rags.

Flocks. — These are the fibres cast out by the different machines employed in the finishing of wool goods. The processes of "milling," "raising," and "cropping" are responsible for the goods treated losing a certain amount of fibre. The value of these by-products may be taken in the order given. The fibre lengths obtained in "milling" are complete, from "raising" they are both complete length and broken, while the fibres which are "cropped" from wool cloths are very short and have a very limited use in the textile industry.

Extract is another comprehensive term to indicate a special class. It covers every type of "pulled" material, whether of milled or unmilled origin, but always indicates that the cloth from which it came was partly composed of cotton, this having been destroyed by the treatment which is known as carbonizing.

Cotton.—Amongst the vegetable fibres, the first place must be assigned to cotton. It is a product of the cotton, a shrub of the *Malvaceae* genus, *Gossypium* class. There are several varieties of this plant, but the growth of the raw material in each case is the same. The cotton-seed pods are divided by membraneous walls into three parts, each containing three or four seeds, covered with fibres attached by one end to the seed. The fibre during growth consists of a hollow tube gradually tapering to a fine point; the internal channel which supplies the nutriment to the growing cells narrows as it approaches the end of the fibre, leaving a solid portion. When the fibre is ripe, the supply of sap through the canal ceases, and as the residual sap is absorbed a vacuum is created in the channel, causing the walls of the fibre to collapse, and during drying and contraction the fibre twists itself into a spiral form. By means of the microscope the collapsed twisted tube appearance can be readily recognized as illustrated in Fig. 6*a*.

Wax, seed oil, and natural colouring matter are the chief impurities of the cotton fibre, and are evenly distributed over its surface. When the external impurities have been removed the chemical composition of the cotton fibre is pure cellulose.

The property of cotton to withstand severe treatment, especially during dyeing and finishing, is due to the fact that cotton cellulose is insoluble in ordinary solvents, such as water, ether, alcohol, benzine, etc. At the same time the cotton fibre when treated in certain solvents will change in its chemical and physical character.

Grades of Cotton.—Cotton is graded in different classes, depending chiefly upon its cleanliness and properties.

The chief classes are known as :—

Sea Island,
Egyptian,
American,
Brazilian,
Peruvian,
East Indian,

the first mentioned being the highest and the last the lowest quality, each class being designated into qualities as follows :—

1. Fair.
2. Middling Fair.
3. Good Middling.
4. Middling.
5. Low Middling.
6. Good Ordinary.
7. Ordinary.

The lengths of the various types of cotton fibres vary from an average of half an inch in the East Indian type to two inches in the Sea Island quality: whereas the diameter of the East Indian fibre is about three times that of the Sea Island (see Fig. 5). The twists on the cotton fibre become more irregular and decrease in number in proportion to the shortness of the fibre and increased thickness of the cell walls and diameter of the cavity. It is almost impossible to ascertain the average twists on the various types of cotton, but it is estimated that there are 300 in the Sea Island cotton fibre to 150 in the East Indian. Hence it is obvious that the spiral markings of the latter will be of a different character, and much more evident than in the former type of cotton.

Mercerized Cotton.—When the cotton fibre has been subjected to the action of caustic soda of a suitable strength by padding, immersion, or any other manner, and then freed from the alkali by washing, the fibre will be found to have acquired certain new properties. The action of the alkali causes the fibre to undergo a remarkable change. The physical alteration is a thickening and swelling of the walls of the fibre, with a tendency to become gelatinous and much more transparent. Each individual fibre loses its twisted, tube-like appearance, and assumes the form of a fibre possessing few surface markings. The action which takes place is as follows: A chemical reaction is brought about by the cellulose absorbing the alkali (forming alkali-cellulose, an unstable body) thus permitting a physical alteration in the fibre. By suitable washing the alkali is removed and the fibre becomes again a stable body. A feature observed in the washing is that the fibre contracts considerably. The shrinkage and contraction of the fibre are responsible for the twists and surface markings being

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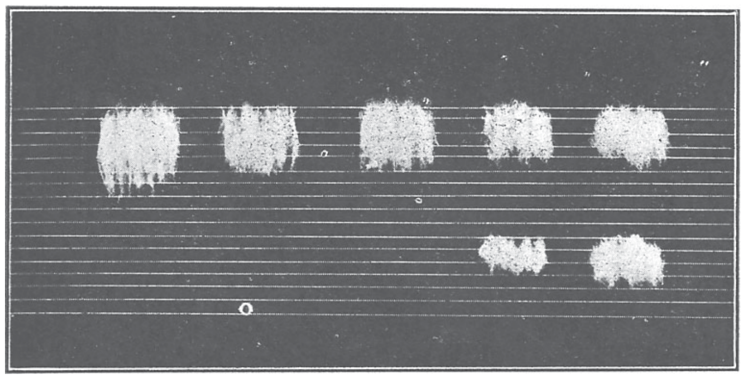

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FIG. 5.—Comparison of the various types of cotton fibre. (The horizontal divisions = $\frac{1}{4}$ inch.)

(1) Sea Island, (2) White Egyptian, (3) Brown Egyptian, (4) Peruvian, (5) Brazilian, (6) East Indian, (7) American.

recreated. This shrinking and recreating of surface markings is obviated by conducting this operation whilst the cotton is under tension: thus the smooth surface is maintained and a highly lustrous fibre developed (Fig. 6*b*).

Ramie, Rhea, China-grass.—This fibre is obtained from the stem of the various species of nettle plant grown principally in China and India. It is only of late that this fibre has attained any degree of importance. The difficulties involved in its preparation have stood in the way of its commercial success, but these difficulties are slowly being overcome. The strength and lustre of China-grass make it a valuable fibre for some classes of goods.

Silk.—This is the product of the silkworm, and in reality consists of a longitudinal body of flexible gum. This fibre possesses the least diversity of all fibres. Microscopically it has

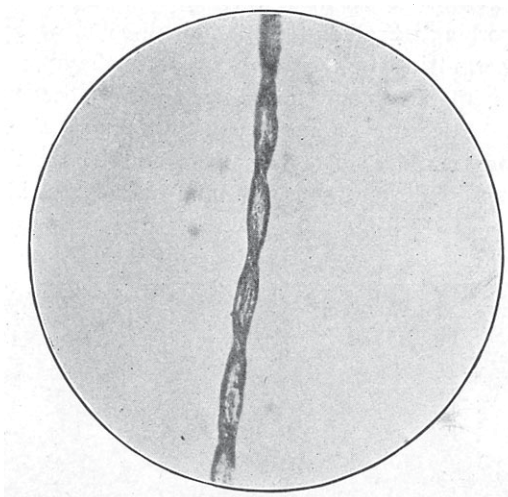

Fig. 6*a*.—Micrograph of ordinary ripe cotton fibre.

Fig. 6*b*.—Micrograph of mercerised cotton fibre.

the appearance of a transparent glass rod illustrating few surface markings, and is totally void of cellular structure (Fig. 6*c*). On examining a silk fibre longitudinally, it will frequently be seen to divide into two parts, this being due to the silk fluid coming from the two sides of the silkworm's body but always uniting to form one fibre. In certain wild silks a breaking-up of the fibres into fibrils may sometimes be noted under the microscope.

Strength and lustre are the distinguishing characteristics of the silk fibre. There is no textile fibre in proportion to its fineness comparable in elasticity and strength with that obtained from this material.

Artificial Silks: Viscose, Imitation Horse Hair, etc.—Many attempts have been made during recent years to imitate

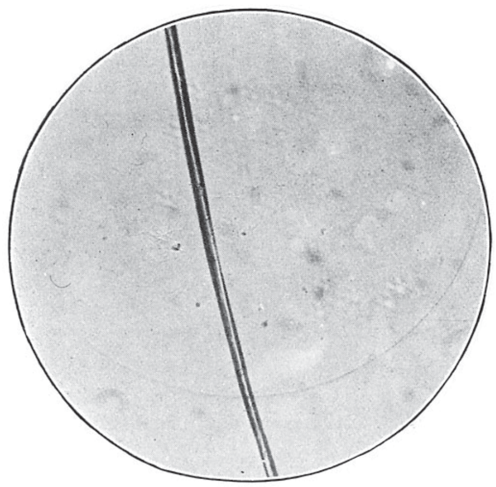

FIG. 6c.—Micrograph of silk fibre.

the silk produced by the silkworm. There are several methods of obtaining this artificial product and many differences in detail of manufacture, but the main outline is as follows:—

White wood pulp is first steeped in caustic soda and, in this wet state, stored so as to give the alkali a good chance of thoroughly impregnating the material. After being cut up into small pieces and exposed to the action of carbon disulphide it is placed in a strong solution of caustic soda, in which it dissolves. In this solution it is allowed to remain for a certain length of time during which a number of changes take place, the changes having an important effect upon the nature of the fibre ultimately produced (Fig. 6*d*).

When the solution has been reduced to its correct consistency it is squirted through holes in a platinum plate.

The diameter of the holes is about $\frac{1}{250}$th of an inch, and the pressure can be so arranged that it is possible to obtain filaments of various thicknesses from one and the same hole. Immediately after escaping from the holes the filaments pass quickly through solutions for the neutralization of the alkali and the consequent freeing of the gelatinous filament. A number of these filaments,

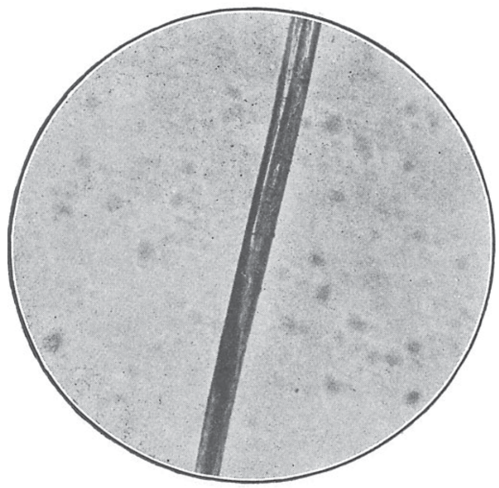

FIG. 6*d*.—Micrograph of artificial silk fibre.

according to the thickness or count of yarn required, are twisted together to form one thread.

The large number of patents which have been obtained in one or other branch of this important industry have not closed the field to other improvements for which there is ample room.

The strength of the fibre when in a moist condition still leaves much to be desired, and it is to be expected that many other improvements in detail will be brought about as the industry increases. At the present time, however, Viscose artificial silk has been found to so nearly fulfil all requirements that it is rapidly ousting most other artificial silks from the market.

CHAPTER II.

THE QUALITIES OF YARNS.

Influences which Determine Quality.—The influences, which determine or modify the quality of yarns, may be conveniently classified as follows:—

1. The nature of the raw material.
2. The method of preparing and spinning the raw material.
3. The twist put into the yarn.
4. The folding of the yarn.
5. Special treatments and preparations (Gassing, mercerizing, etc.).

1. *The Nature of the Raw Material.*—Practically the nature of the raw material determines not only the method of preparation and spinning of the yarn, but also the use the yarn may be put to, when spun.

Thus long wool such as Lincoln or other English wool is spun on the flyer frame for lustres, whereas botany may best be spun on either the cap or mule for soft goods.

2. *The Method of Preparing and Spinning.*—According to the method of preparing and spinning, vastly different results may be obtained from the same raw material, e.g. the French dry-combed mule-spun botany as compared with the cap-spun botany, worked up with oil. The former is fuller in appearance and softer in handle than the cap frame-spun yarn, this latter being an altogether "sadder" and more compact yarn.

Or to give another example, Merino wool may be prepared and spun as a woollen as well as a worsted yarn, as will be explained later. In this instance two quite different yarns are obtained. A yarn combed and gassed will give a very smooth and compact yarn, whereas a carded yarn, although the same raw material is used, is much fuller, looser, and more irregular.

3. *The Twist.*—The handle of a cloth and the appearance also may be varied greatly by altering the twist or turns of the yarn.

Almost any yarn, by the introducing of an undue amount of twist, may be made harsh in handle.

This may be desirable under special circumstances, but as a rule only the number of turns necessary to secure the firm adhesion of the fibres should be introduced.

In weft yarn (singles particularly) as little twist as possible is put in—just sufficient in most cases to enable the yarn to bear the drag of the shuttle.

In warp yarns, particularly in single counts, more twist is required than in a weft yarn of the same count, to enable the yarn to withstand the drag, friction, and strain during weaving.

Examples.—For Cheviots a very soft twist is employed, to give a full and soft handle in finishing and a rough surface; whereas for voiles a hard twist yarn is used, in order to obtain the crisp handle typical for voiles.

4. *Folding of Yarns.*—Yarns may be single, two-fold, or for special purposes many fold.

The reasons for using folded yarns instead of singles are:—

(*a*) To impart strength.
(*b*) To add weight.
(*c*) To give a special handle and appearance.
(*d*) For fancy effects (Grandrelle, etc.).

5. *Special Treatments.*—Wool or cotton yarns for special purposes are submitted to special treatments, in order to obtain novelty, e.g. the mercerizing, also the polishing and waxing of cotton yarns. In worsted the genapping or singeing may be specially noted.

Wool Yarns.—Wool is spun into two types of yarn—(*a*) worsted, and (*b*) woollen. In preparing and spinning a worsted yarn, the idea is to arrange the fibres parallel to each other. The woollen yarn, however, is spun so that the fibres are in all possible directions, with the result that the latter possesses more loose fibre than the former, and is of rougher appearance, which assists the shrinkage and felting of a fabric, as the fibres which compose the woollen yarn have a better opportunity of laying hold of each other than those which form the worsted yarn. The amount of twist or twine put into a yarn has also its influence on the contracting properties of the cloth into which it is made. The yarn in which the fibres are loosely twisted together may have a better opportunity to shrink, or contract, than the yarn where the fibres are tightly twisted together; consequently the variation during finishing of such dress fabrics as crêpons, voiles, and crêpe-de-chines (which are made from hard twisted yarns) will be different from that of dress fabrics composed of ordinary twisted yarns of the same material. There is also a difference in the shrinking property of yarns in the undyed and dyed condition, although spun from identical material. The yarn composed of coloured fibres has already been subjected to fibre shrinkage whilst being dyed in the top or yarn state; thus, it is necessary when making a piece-dyed cloth which is to be equal to a mixture cloth, or one composed of solid coloured yarns, to make a suitable allowance. For example, a fabric composed of undyed yarn would be 66 in. wide in the loom, whilst the fabric composed of coloured yarn would be set 64 in. wide in the loom, both structures to finish 56 in. wide. This point is also important in the designing of soft handling structures, also worsted coatings styles.

The amount of felting which may be developed during the milling process is largely dependent on the mechanical structure of the thread employed in the production of the fabric. This effect is illustrated in worsted and woollen goods, where, although both cloths may be made from the same class of wool, and whilst both may be identical in build and subject to the same finishing operations, they will be almost as distinct in the finished state as if they had been made from totally distinct materials and structure of fabric. This difference is entirely due to the structure of the yarns employed. Woollen and worsted yarns may be said to be as dissimilar as possible in formation.

The basis of the woollen thread is an entangled arrangement of fibres, a micro-photograph of which is illustrated in Fig. 7, whereas in constructing a worsted thread the aim is to lay the fibres in a uniform line with each other in a longitudinal direction. Fig. 8 illustrates a micro-photograph of a flyer-spun worsted yarn made from crossbred wool. The operations of spinning a woollen yarn all tend to cross and recross the fibres, whilst in preparing and spinning a worsted thread the fibres of which it is composed are mechanically arranged according to one regular order of parallelism, producing by this method a smoother and more level yarn than in the case of the woollen, where the fibres project from the main body of the thread to all points of its circumference. The cloth made from the woollen yarn will felt or mill more readily, and to a greater degree, as the fibres are crossed and recrossed, and are more easily acted upon than in the case of

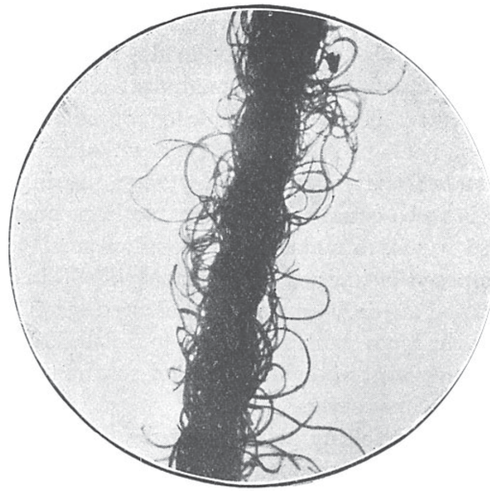

FIG. 7.—Micrograph of a woollen thread.

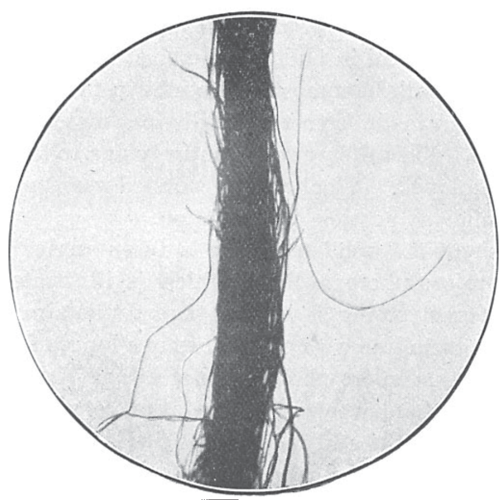

FIG. 8.—Micrograph of a flyer-spun worsted thread.

the cloth made of worsted yarns, where the fibres are bound down throughout their length by the necessary twist, and in consequence have not the opportunity to mat or felt together.

Worsted Yarns.—There are four distinct methods of spinning a worsted thread :—

Cap Spinning is the system from which a great output may be obtained, for which advantage the condition of the resultant yarn is often sacrificed. The spindles of the cap-spinning frame run at something like 5000 to 7000 revolutions per minute, and the high speed is responsible for the yarn being beardy or fibrous in appearance. In "clear" finishing goods made from that yarn, a large quantity of fibre is cut from the fabric, resulting in a certain loss of weight, nevertheless the cloth is often harsh and hard in handle.

Cap spinning is employed for short and medium length wools such as botany and fine and medium crossbred.

Ring spinning is the system employed for spinning fine and short materials. The cap and ring-spun yarns are somewhat alike in appearance, if any difference prevails it is that the ring-spun yarn is smoother, chiefly on account of the speed of the spindle being reduced, which is about 5000 revolutions per minute.

Flyer-spun Yarns are chiefly made from long wools and mohair. The speed of the flyer spindle is 2000 to 3500 revolutions per minute; the reduction in speed and method of winding the yarn, producing a cleaner, soft, and more uniform thread. The solid sound structure of this yarn readily lends itself to the production of several effects during the finishing of the fabric. The development of a "bright" finish in lustre cloths is dependent to a certain extent on the lustre yarn being smooth and the fibres parallel. A fibrous or rough yarn produces a cloth which will absorb light, whilst the yarn composed of fibres which are straight will produce a cloth presenting a greater reflecting surface.

Mule Spun.—Botany wool may be spun on the mule. In this system of spinning specially prepared worsted slivers are fed on to the machine. The twist is inserted over a distance of about 60 in. In other systems there is only a distance of about 5 to 8 in. between delivery rollers and spindle. Worsted mule spinning is in part a woollen method, therefore the fibres of a mule-spun botany yarn are not so straight and parallel as are cap-spun botany yarns. This feature of the fibre being to some extent crossed and recrossed, in addition to making a fuller, produces a stronger yarn, on which account single twist mule-spun botany yarns are in demand.

TABLE VII.—CLASSIFICATION OF WORSTED YARNS.

Type of Material.	Shrinking and Felting.	Lustre.
Short wool :—		
(*a*) Cap spun	Standard	Standard
(*b*) Mule spun	Increased	Decreased
(*c*) Ring spun	Standard	Increased
Medium wool :—		
(*a*) Cap spun	Standard	Standard
(*b*) Flyer spun	Increased	Increased
(*c*) Mule spun	,,	Decreased
Long wool :—		
(*a*) Cap spun	nil	Decreased
(*b*) Flyer spun	,,	Increased
Degrees of twist :—		
(*a*) Hard twist	Decreased	Decreased
(*b*) Medium twist	Standard	Standard
(*c*) Soft twist	Increased	Increased

Table VII indicates a comparison of the shrinking, felting, and lustrous properties of the differently spun worsted yarns.

Counts of Worsted Yarns.—Botany or merino wool is spun in counts up to 1/130's. The general counts in singles being, 1/20's, 1/30's, 1/40's, 1/50's, 1/60's, 1/64's, 1/72's, 1/80's, and in two-fold, 2/36's, 2/48's, 2/60's, 2/70's, 2/80's.

Crossbreds, generally speaking, are spun into standard 1/28's, and two-fold counts up to 2/40's.

Lincoln wool and mohair possess a spinning property about equal to that of crossbreds. Standard counts from these materials as spun for "bright" dress fabrics in such counts as 1/8's, 1/14's, 1/20's, and 1/32's.

Alpaca yarn is spun to a standard count of 1/40's.

Woollen Yarn.—This is spun as a rule from wool shorter in length than that employed for worsted yarns. Hence fibres which are too short for combing purposes are utilized in the production of woollen yarns. In construction the aim is the opposite to that of worsted, i.e. the fibres are mixed up as much as possible. The yarn on this account is fuller and more fibrous and uneven than that of a worsted construction.

On account of the method of spinning, the woollen yarn cannot be spun to the same fineness as the worsted thread. About 40 skeins woollen is a standard fine count. Yarns spun from low materials such as shoddy, mungo, extract, etc., are in most

* 256 yards to the skein.

cases spun up to their utmost. Thus the count of a low woollen yarn indicates the quality of the material employed.

Cotton Yarns are spun from combed or carded slivers and two-fold yarns may be twisted twiner, ring or flyer.

Sea Island cotton is spun up to counts of about 1/120's to 1/160's.

Egyptian Cotton is suited for counts up to about 1/120's.

The above yarns are invariably constructed on the worsted principle, and on account of the fibre being straight and parallel are most suitable yarns for being subjected to mercerizing.

American Cotton is used for counts ranging from about 1/20's to 1/80's.

Indian Cotton is employed for thick counts.

Silk Yarns.—There are two distinct classes of silk yarns, i.e.:—

(*a*) Pure or net silk.
(*b*) Spun silk.

(*a*) *Net Silk Yarns.*—These are constructed from fibres reeled straight from the cocoon, and in the case of organzine or warp yarns, three to eight fibres are lightly twisted together; subsequently two or more of these compound threads ("singles" as they are termed) are folded together to form the silk yarn employed as warp.

Weft yarns, known as tram silk, are made from two or more strands, each made from three to twelve cocoon fibres, which have undergone no preliminary twisting, so that tram silk is much straighter, softer, and more lustrous than organzine.

(*b*) *Waste and Spun-Silk Yarns.*—The fibre is obtained from entangled cocoons, through which the silkworm has eaten its way; also from wild cocoons, known as *Tussah* silk. These yarns are prepared and spun on a special principle, several qualities being produced according to the "drafts" produced on the dressing frame. The low qualities are short fibred and are only suitable for weft yarns, while the longer drafts produce higher quality yarns well suited for warp.

Union Yarns.—These are composed, as the name suggests, of two or more materials. Wool and vegetable fibre such as cotton are the materials which are usually combined. There are two distinct forms of union yarns; the two materials may be intermingled in the fibre state or a thread of each material may be twisted together. Some so-called woollen threads are composed very largely of cotton fibre. The cotton is scribbled with the wool—in some cases to add strength and in others to reduce cost.

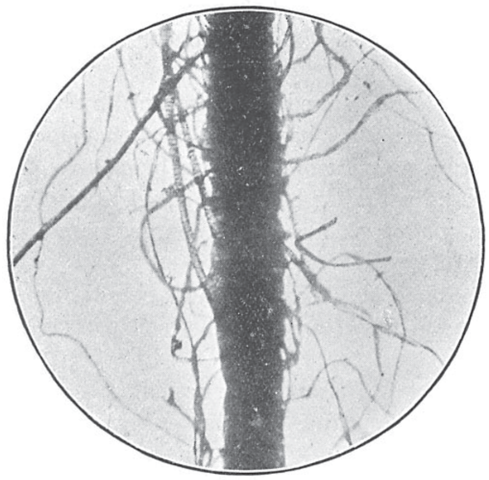

FIG. 9*a*.—Union yarn. Micrograph of cotton and wool mixture yarn.

(*a*) (*b*)

FIG. 9*b*.—Union yarn. Micrograph of cotton (*a*) and wool (*b*) yarns twisted together.

Angola Yarns are acknowledged to be composed of cotton and wool fibres. The wool present consists of mungo or shoddy and the addition of a finer fibre such as cotton assists the spinning of the yarn for finer counts (see Fig. 9*a*).

Union Twist Yarn.—For producing special designs in union fabrics, yarns may be employed composed of one thread worsted and one cotton. The union thread is arranged in the warp according to requirements (see Fig. 9*b*). When a wool fabric composed totally or partly of such yarns is dyed, the cotton remains its original colour.

The following forms a typical example :—

Warp.

1 thread 56's botany } twisted
1 ,, 72's cotton } together.

100 threads per in.

65 in. loom width.

56 in. finished width.

Weft.

1/40's botany.

65 picks per in.

Weave.—5 end venetian or warp sateen.

Dye.—Any required colour.

Coloured Yarns.—The most important coloured woollen and worsted yarns are :—

(*a*) Mixtures.
(*b*) Melanges.
(*c*) Marls.
(*d*) Twists.

(*a*) *Mixtures.*—A mixture yarn is one composed of fibres of two or more colours which have been thoroughly blended. In woollens the wool is dyed after scouring and the mixing accomplished during the carding process. For producing worsted mixture yarns, the usual method is to slubbing dye the wool, and then to recomb it, thus producing coloured "tops". During the drawing processes the required colours of tops are placed behind the first gill box and these are run together through two or three more gill boxes producing a vari-coloured sliver, or mixture as it is termed. Thus the various-coloured tops are doubled and drafted such a number of times, that the different colours of fibre are thoroughly mixed, and the colour of the resultant yarn resembles none of the component parts; it is only by a close investigation that the separate colours may be detected.

(*b*) *Melange.*—This is a fine mixture yarn produced from a top-printed sliver. The result is obtained by printing at regular intervals the required colours on to the top (see Fig. 10). The mixing of the fibres and colours is brought about during the drawing and spinning processes. As a rule only long fibres, such as mohair, are subjected to this method of treatment. In these yarns on many fibres two or more colours may be clearly seen under the microscope.

(*c*) *Marls.*—A term sometimes applied to three-fold twist yarns but more correctly applied to a yarn which is between a twist and the mixture yarn. It is produced by combining two or

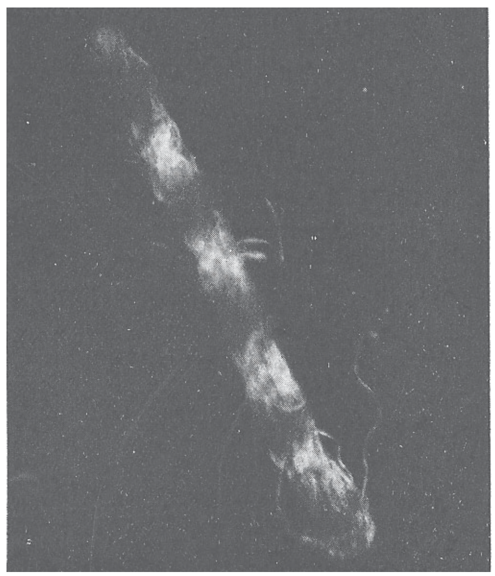

Fig. 10.—Melange printed top.

more slivers of different colour in the later drawing operations, and in consequence the colours are not so thoroughly blended as in the case of mixture yarns.

(*d*) *Twists* are produced by simply twisting or folding together two or more yarns of different colours.

Another method of making what may be termed a twist-marl yarn is to place two rovings of different colours on the spinning frame and run a thread from each through back and front or through one pair of guide rollers only and on to one spindle, and thus obtain a yarn of two colours.

Special Yarns.—These are made by folding two or more yarns together. They may be either different in quality, material, or structure, but the result of any of these is a yarn which is employed for the production of novel or fancy effects in textures; such yarns are known as: Tinsel, tinsel and cotton twist, loop, spiral, canvas, slub, flaked, knop, and cloud yarns (see Fig. 11).

Matching Coloured Yarns and Fabrics.—In matching off solid colours little difficulty will be experienced; but the colour to be matched should always, if possible, be separated from its

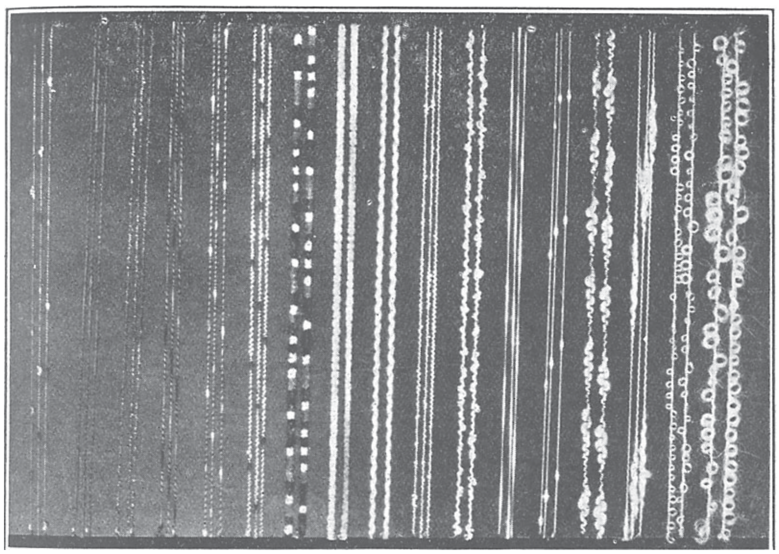

FIG. 11.—Fancy yarns.

surroundings, since its tone may be altogether different in the cloth and out of the cloth. This may be effected at times by cutting two holes in a piece of cardboard (as shown in Fig. 12) at such a distance that upon placing the cardboard upon the pattern supplied for analysis one colour appears at A and another at B. This method, however, is not so effective as might be supposed in matching colours from cloth, as the cloth to be matched should be held up to the light and judged by looking over; but at times it will prove very useful. The "tintometer" has of late been much thought of as an advance in the right direction in the matching of colours. The idea is simply to match colours by slips of coloured glass, suitably graded and numbered; but since it is a fact that the nature of the raw material in textile fabrics influences very considerably the colour employed, it is apparent that its application is very limited.

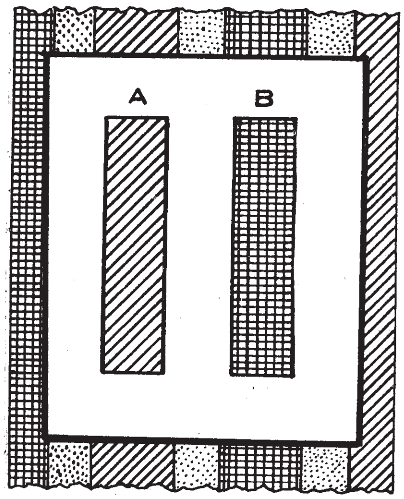

FIG. 12.—Matching coloured yarns in cloth.

Mixtures may be more difficult to deal with, especially if compounded of several shades. Microscopic examination will reveal the several colour-constituents, and matching under these conditions is difficult but possible: judgment and experience are here most essential.

In order to match practically any desired mixture, a pair of hand cards (as shown in Fig. 13) or a small gill-box should be at hand, along with a well-graded set of dyed wools (or, preferably, botany tops or drawings), so that a selection may be made of the colours supposed to be present in the combination, and the mixture effect obtained in a few minutes. This is a much handier

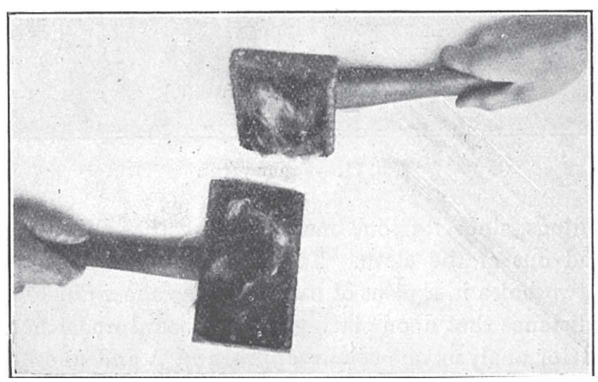
FIG. 13.—Mixing coloured fibres with hand cards.

method than running a small batch through a carder, although perhaps this latter procedure is more certain. Careful note should be made of both the colours and materials.

Of great use to the textile designer are twists composed of two, three, or even four colours. Two-fold are used most extensively; but three-fold in both plain and fancy twist may be

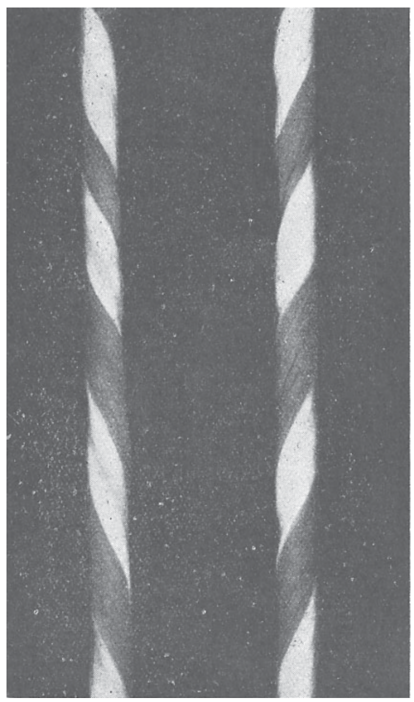

Fig. 14.—A, openband (right twist); B, crossband (left twist).

introduced with effect at times. The attention of the analyst should always be given to this point when analysing goods where colour plays a prominent part; as, for example, in Scotch tweeds, for in such goods the most careful toning of colours is often effected by twisting coloured threads of varying thickness together, thus obtaining an effect not otherwise producible.

Fancy yarns are made in such variety that a minute analysis is usually necessary. The principle of most, however, is simply holding one thread tight and twisting the other round it, and then reversing the yarns—thus continually reversing the colours.

The Influence of Twine of Yarn on Woven Fabrics.— The direction of the twine of the yarns which constitute a woven fabric—particularly in worsteds and woollens—has an important bearing on the appearance of the design in the fabric. If two cloths were made from yarns, with the direction of the twist in one case opposite to the direction of the twist in the other case, and identical in all other respects, it would be found that the two fabrics were of different appearance.

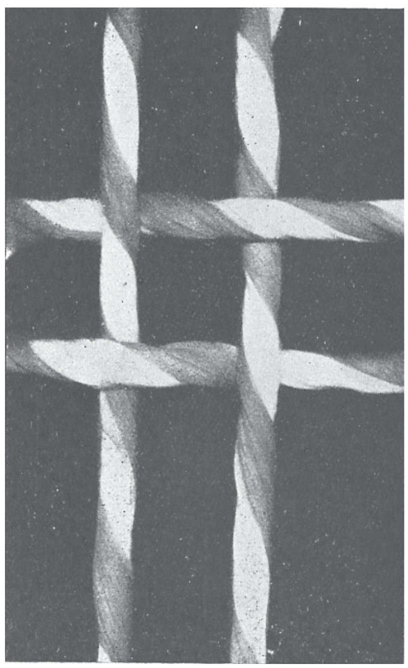

Fig. 15*a*.

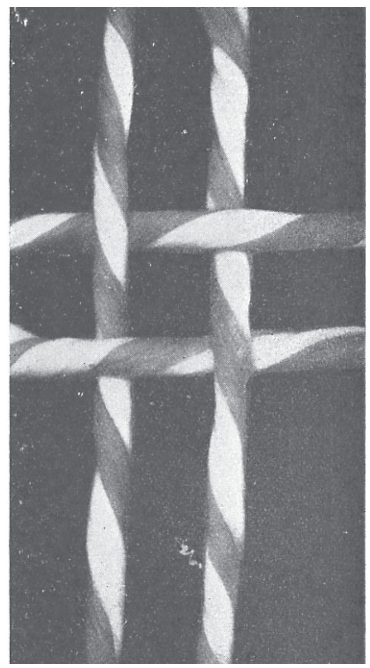

Fig. 15*b*.

Yarns may be twisted to the right (openband) or to the left (crossband) according to whether the spindle bands of the spinning frame are in an open or crossed condition, or the machine running reverse twist or not as illustrated in Fig. 14. When warp and weft yarns are twisted in opposite directions, upon being laid across at right angles (as they will be in the cloth), the twists cross one another, since the upper surface of one is in contact with the under surface of the other yarn (Fig. 15*a*): hence they tend to stand off one another, leaving the yarns distinct. This separation is further accentuated by causing the twill to oppose the surface direction of the twist of the yarns.

In woollen goods where a compact structureless texture is required, the best conditions are to have the warp and weft twisted in the same direction (Fig. 15*b*), so that in the cloth they bed into one another.

The effect of direction of twist on twills is illustrated in Fig. 16, where the direction of the twine of warp and weft are in opposite directions. It will be observed that by reversing the twill a stripe pattern is produced which is due to two factors, i.e. to the twill running to the right showing up more distinctly than that which

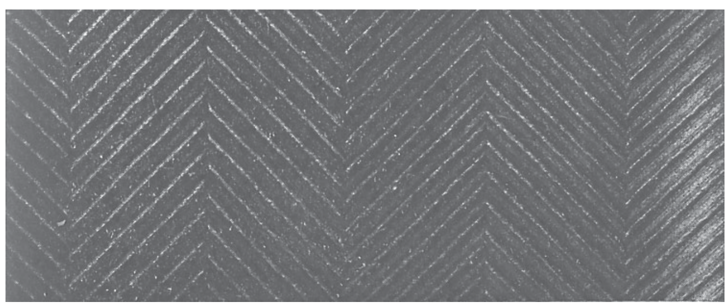

FIG. 16.—Illustrating the influence of direction of twist on twill.

runs to the left, and to the differently reflected light from the two angles of twill.

Right (openband) and Left (crossband) Twist Effects.—Optical effects due to different reflections of light are produced in woven fabrics by employing two yarns, as warp or weft or both, which have been twisted to the right and to the left respectively. Yarns are twisted as shown in Fig. 14. When light is thrown on to the two twists of yarn from one position, the reflection of light will be in opposite directions as indicated by the diagonal lines C in Fig. 17.

This optical effect is taken advantage of and largely employed in the production of "shadow" stripes and checks. An illustration of this effect in an "amazon" dress fabric is given in Fig. 18. The particulars of production are:—

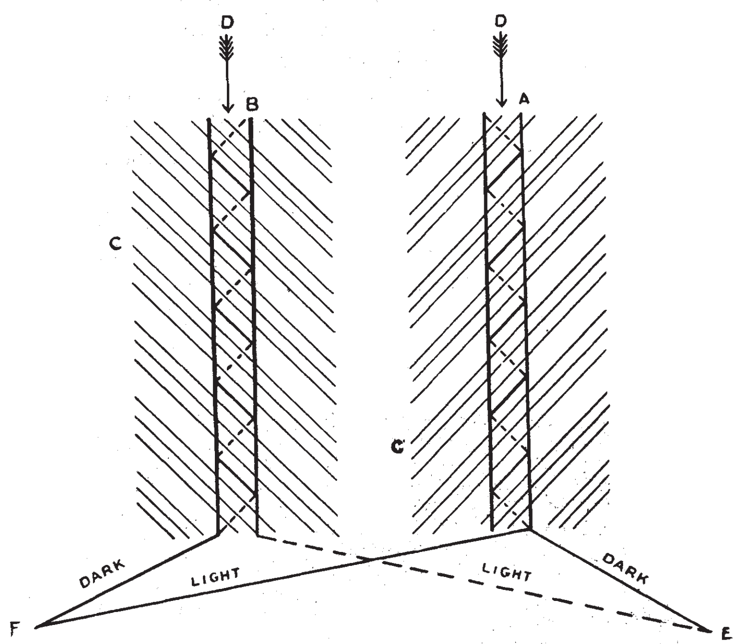

FIG. 17.—Light reflection from twills.

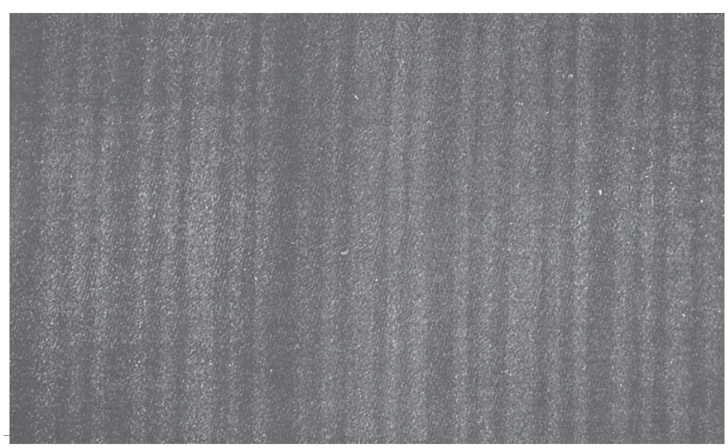

FIG. 18.—Pattern due to right and left twist yarns.

Warp.

1/32's grey botany worsted.
84 threads per in.

Weft.

40 skeins grey woollen.
38 picks per in.

The weave is 5 warp sateen, and is piece dyed to shade. The warp threads are arranged in the following order:—

	20 threads	twist A
twice	10 ,,	,, B
	10 ,,	,, A
	20 ,,	,, B
twice	10 ,,	,, A
	10 ,,	,, B

The effect in the cloth is dark and light stripes alternately, which at the first appearance suggest that two shades of yarn or two weaves have been employed. As the cloth is piece dyed one solid colour, and the weave is the same throughout, it is evident that the dark and light stripes are entirely due to the deflection of light in opposite directions created by the warp threads being arranged in a suitable order of "right" and "left" twisted threads. Another feature in connection with these optical effects of dark and light stripes is that they counterchange when held to the light at opposite angles. This will be understood by reference to Fig. 17. In this illustration light is shown reflected on to the yarn A "right" twist and B "left" twist in the direction marked by arrows D. The action of the "right" twist is to reflect the light falling upon it to the left, whilst the "right" twist turns the light in an opposite direction. As a consequence when the yarns are viewed from the angle E the "left" twist B will reflect the light in that direction and appear in the cloth to be lighter in shade than the yarn A of opposite twist. From the opposite angle F the light and dark appearances will be vice versa.

The only difficulty in producing these goods is that, owing to the warp being all of one colour, the weaver is likely to piece up crossband broken threads with openband threads. In order to avoid this, one of the yarns, either the openband or the crossband threads, are tinted with a fugitive colour or tint.

CHAPTER III.

CALCULATIONS RELATING TO YARNS.

The Counting of Yarns.—By the terms "count," "cut," "lea," "run," "skein," etc., the ratio of length of yarn to weight is indicated. Usually 1 lb. (avoirdupois) is taken for the standard weight and the "count," etc., indicates the length to which this weight of material has been extended.

Yarn calculations are further complicated by the count of a yarn not indicating the exact length say in yards but in hanks per lb. A hank is best defined as a convenient number of yards for bundling together. Thus the "count," etc., of a yarn usually represents the number of hanks which weigh 1 lb. and thus indirectly the yards per lb.

The many methods of numbering or counting yarns are bewildering. As to the advantage and simplicity of a uniform standard and method of counting yarns, there is no doubt. Of the many systems in vogue Tables VIII*a* and VIII*b* illustrate the principal methods.

Take an example in the case of worsted, in which 1 lb. of yarn is drawn out to 560 yds. This will give 1's count and is the basis of all calculations (see Fig. 19). Similarly if 1 lb. of yarn is drawn to 5600 yds. the count will be :—

$$5600 \text{ (yds. per lb.)} \div 560 \text{ (yds. per hank)}$$
$$= 10 \text{ (hanks per lb.) or } 10\text{'}s \textit{ count}.$$

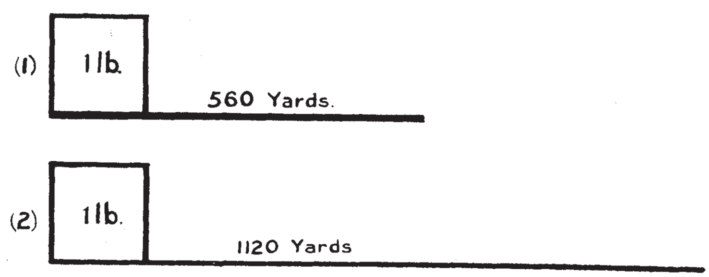

FIG. 19.—Graphic illustration of yarn counts.

The various systems of counting yarns at present in use are indicated in the following list:—

TABLE VIIIA.—VARIOUS SYSTEMS OF COUNTING YARNS (FIXED WEIGHT).

System and Material.	Fixed Weight.	Length of Hank.	Examples.
Worsted	1 lb.	560 yds.	10's = 5600 yds. per lb.
Woollen:—			
(*a*) Leeds or Yorkshire skein	1536 yds. = 6 lb.	256 „	10 skn. = 2560 „ „
(*b*) Galashiels	300 „ = 24 oz.	200 „	10's = 2000 „ „
(*c*) West of England	1 lb.	320 „	10's = 3200 „ „
Cotton	1 „	840 „	10's = 8400 „ „
Linen	1 „	300 „	10's = 3000 „ „
Silks:—			
(*a*) Spun	1 „	840 „	10's = 8400 „ „
(*b*) Organzine	1 oz.	nos. of yd.	1000's = 1000 yds. per oz.
Metric	1 kg. = 2·204 lb.	1 km.	10's = 10,000 metres per kg.
French	½ „ = 1·102 „	1 „	10's = 20,000 „ „

TABLE VIIIB.—VARIOUS SYSTEMS OF COUNTING YARNS (FIXED LENGTH).

System and Material.	Standard Weight.	Fixed Length.	Examples.
Tram or weft silks	1 dram	1000 yds.	3 dram silk indicates 1000 yds. = 3 drams
Organzine or net silks	1 gram (½ denier)	476 or 500 metres	20 denier silk indicates 500 metres = 10 grams
Artificial fibres	„	„ „	„ „

Example 1.—If 1 lb. of raw material is spun out to 33,600 yds. What is the count in the (1) worsted, (2) cotton, (3) Yorkshire skeins woollen, (4) linen, and (5) Galashiels woollen methods of counting?

(1) $33{,}600 \div 560 = 60$'s worsted.
(2) $33{,}600 \div 840 = 40$'s cotton.
(3) $33{,}600 \div 256 = 131\frac{1}{4}$'s Yorkshire skeins woollen.
(4) $33{,}600 \div 300 = 112$'s linen.
(5) $33{,}600 \div 200 = 168$'s Galashiels woollen.

Example 2.—The weight of a length of 32's worsted is 7 oz. What is its length?

1 lb. of 1's count = 560 yds.
1 lb. of 32's count = 32 × 560 yds. = 17,920 yds.
as 1 lb. (16 oz.) : 7 oz. : : 17,920 yds. : 7840 yds.

Example 3.—Find the yards per lb. of 56's count in (1) worsted, (2) West of England woollen, (3) linen.

(1) 56 × 560 = 31,360 yds. worsted.
(2) 56 × 320 = 17,920 yds. West of England.
(3) 56 × 300 = 16,800 yds. linen.

Testing a Given Count.—The simplest method of testing a given count is as follows :—

Rule.—Reel as many yards as there are hanks per lb. in the count to be tested, and weigh against 12·5 grains for worsted, 8·33 for cotton, and 27·34 for woollen (Yorkshire skein). The reason for this is as follows: There are 7000 grains in 1 lb. avoirdupois. Now, 1 yd. of 1's worsted would weigh 7000 ÷ 560 = 12½ grains, and 10 yds. of 10's worsted, 20 yds. of 20's, etc., should weigh exactly the same. A similar reasoning applies to the other systems of counting yarns.

Scales and Weights.—In the factory very crude scales will often be found, upon which the carder, comber, or spinner depends. This, however, is not as it should be, and every day sees the introduction of more perfect systems into our factories; and the manufacturer who is alive to his own interests will provide for his workpeople all that is necessary for conducting accurate tests, for he is then justified in expecting accurate results. Scales may be purchased from most opticians at prices varying from 2s. 6d. to £10 and upwards. Neither of these extremes is necessary or perhaps desirable. A good, substantial pair may be purchased for about £1 which should be quite accurate enough for all ordinary purposes, yet not so finely adjusted but that they will stand a little rough usage. Weights may be obtained in boxes at various prices. The analyst should be provided with the following grain weights: 50, 20, 20, 10, 5, 2, 2, 1, ·5, ·2, ·2, ·1, ·05, ·02, ·02, ·01; and he should be careful to lift them about with the tweezers supplied, since handling is very liable to affect their accuracy.

Method of Obtaining the Counts of Yarn from a Small Sample of Cloth.—The foregoing particulars only apply to testing the count of yarn before weaving. To test yarn taken from a cloth is a more difficult matter. Let us suppose that it is required to obtain the count of yarns in a cloth of which we have a pattern cut 3 in. × 3 in. Then proceed thus :—

1. Examine the cloth carefully to ascertain if warp is all one count and if weft is all one count.

2. Obtain as great a length as convenient of each of the yarns present in the cloth.

3. Weigh these lengths carefully to the hundredth part of a grain.

4. Divide 7000 grains by the weights thus obtained and multiply by the yards of yarn weighed, and the result will be the yards per lb., from which the counts may be readily obtained.

Example 1.—(1) An examination of the 3 in. × 3 in. pattern reveals that it is a serge cloth composed of crossbred worsted yarns.

(2) From this 36 threads of warp and 36 picks of weft are taken, thus obtaining 3 yds. of each.

(3) Each is found to weigh 3·15 grains.

(4) 7000 ÷ 3·15 = 2222 × 3 = 6666 yds. per lb. ÷ 560 = nearly 12's count worsted.

Example 2.—A cotton warp and mohair weft cloth is submitted for analysis. After being cut 3 in. × 3 in. 36 threads of warp are found to weigh 1·2 grains and 36 picks of weft 3·7 grains. What are the counts of warp and weft respectively ?

Warp.

As 1·2 grains : 7000 grains : : 3 yds. : 17·500 yds. per lb.

17·500 ÷ 840 = 20's count of cotton warp.

Weft.

As 3·7 grains : 7000 grains : : 3 yds. : 5676 yds. per lb.

5,676 ÷ 560 = 10's count of mohair weft.

Gauge Points.—From the above examples it will be observed that the multiplying by 7000 grains and dividing by the number of yards per hank, according to the system of counting, is involved in each calculation. This may be obviated and the calculation made more direct and simplified by instituting a gauge point for each method of counting yarns.

7000 grn. per lb. ÷ 560 (yds. per hank) = 12·5 worsted gauge point.
,, ,, ,, ÷ 840 ,, ,, = 8·33 cotton gauge point.
,, ,, ,, ÷ 256 ,, ,, = 27·43 Yorkshire, skein, woollen gauge point.

Then—

As (weight of yarn) : (gauge point) : : (yds. weighed) : count of yarn.

Example 1*a*.—What is the count of 3 yds. of worsted warp which weighs 3·15 grains?

As 3·15 grains : 12·5 (gauge point) : : 3 yds. = 11·9 worsted counts.

Example 2*a*.—3 yd. of cotton warp weighs 1·2 grains and 2 yds. of mohair weft weighs 6·7 grains. What are the counts of both yarns?

Warp.

As 1·2 grn. : 8·33 (gauge point) : : 3 yds. : 20's count of cotton warp.

Weft.

As 3·7 grn. : 12·5 (gauge point) : : 3 yds. : 10's count of mohair weft.

The results obtained in the foregoing examples are not absolutely the count of yarn employed to make the cloth. Owing to the contraction and bending of the yarns during weaving and finishing the actual lengths of yarn weighed are more than those indicated. Further a certain loss in weight is involved during the finishing processes. Hence the two factors mentioned must be taken into account before the count of yarn as employed in the loom can be ascertained. This somewhat difficult matter will be dealt with later.

Estimating the Counts of Yarn.—A method of estimating the counts of the yarn is to compare it with known counts. By taking a number of threads of a known count and twisting them with a varying number of threads of the unknown count until the two, twisted, appear to make a thread of similar thickness, the count of the unknown yarn may be obtained. Practice enables the analyst to estimate the count with great accuracy by such comparison in the case of low and medium numbers; but in the higher numbers some more certain method is necessary.

A combination of the two methods may also prove useful. Thus: judge as nearly as possible the counts of the yarn—say 20's; reel 20 yd. and weigh against 8·33 grains, if for cotton. If it weighs more (say 9·5), the counts are less in the proportion.

As 9·5 : 8·33 : : 20 : x = the true counts.

If it weighs less (say 7·5), the counts are a higher number, in the proportion.

As 7·5 : 8·33 : : 20 : x = the true counts.

Although grain weights are invariably employed for fine tests in dealing with yarns and cloths, in the works the ordinary avoirdupois weights are more frequently met with, the method of testing being this: Since there are 256 drams in 1 lb., and 560 yd. per hank of worsted, therefore 1 yd. of 1's will weigh $\frac{256}{560}$ drams, or about 3/7 dram, but this would evidently be too short a length and too small a weight to favour any degree of accuracy, therefore a convenient practical part of the hank—say 70 yds. (1/8 of the hank)—should be taken, then proceed as follows:—

$$\frac{256 \text{ drams}}{8} = \text{the weight of 70 yds. of 1's,}$$

$$\text{therefore } \frac{256 \text{ drams}}{8 \times 20\text{'s}} = \text{the weight of 70 yds. of 20's,}$$

and, consequently, putting the desired count in the place of the 20's, the drams that 70 yds. should weigh will be obtained; and should the sample, being tested, weigh more or less, the count will be less or more in direct proportion, as explained further on.

Worsted Spinners use what is termed a "gauge point," obtained as follows:—

Taking 70 yds. as a convenient number to reel:—

$$\frac{256 \times 70}{560} = 32 \text{ drams or 2 oz. weight of 70 yds. of 1's.}$$

Consequently the count of any given yarn, divided into this, will give the drams which 70 yds. should weigh.

Example.—Find the correct weight of 70 yds. of 2/16's yarn (= 8's).

$$32 \div 8 = 4 \text{ drams.}$$

This may be readily proved, for if 70 yds. = 4 drams, 560 yds. = 32 drams, and $256 \div 32 = 8$ hanks per lb., or 8's count.

Of course there is no need to reel 70 yds.; 80 yds. (or 1/7 of 560), or 140 or 280 yds. will do equally well.

In the case of **Cotton and Spun-Silk Yarns** proceed in the same manner, reeling a convenient practical part of the 840 yds. —say 84 yds. = $\frac{1}{10}$th of 840; then

$$\frac{256 \times 84}{840} = 25\tfrac{1}{2} \text{ drams weight of 84 yds. of 1's.}$$

Consequently any count divided into $25\frac{1}{2}$ gives the weight of 84 yds.

Example.—$25\frac{1}{2} \div 20 = 1\frac{1}{4}$ drams weight of 84 yds., of 2/40's or 20's.

This may be proved thus: 84 yds. = $1\frac{1}{4}$ drams, 840 yds. = $12\frac{1}{2}$ drams, and $256 \div 12\frac{1}{2} = 20$ hanks per lb., or 20's count.

In the woollen trade the skein always equals the yards per dram; thus 20 skeins = 20 yds. per dram, 30 skeins = 30 yds. per dram.

Changing the Denomination.—From what has already been given, it will be evident that counts are used simply as a means of accurately estimating the thickness or size of yarns in relation to weight; and it will also be evident that in reality the yards to which 1 lb. of the material is drawn is used as the measure. For instance, as shown in Fig. 19 in (1) 1 lb. of material is drawn out to 560 yds. = 1's count; in (2) 1 lb. of material is drawn out to 1120 yds. = 2's count; consequently, 1 yd. of 1's is double the weight of 1 yd. of 2's, or weight is inversely to count.

Upon these lines the manufacturer bases the calculations for his cloths. But from the particulars already given it will be evident that a 20's yarn in worsted count is a very different yarn to a 20's yarn in cotton or other counts; consequently, the designer cannot estimate the relative thicknesses of any two such threads until they are in the same denomination, i.e. both stated in either worsted or cotton count (see Fig. 20). Remembering that counts are really based upon yards per lb., the rule for this will be as follows:—

To Change the Count in any Given System to Equivalent Count in any other System.

Rule.—Ascertain the yards per lb. in the count to be changed and divide by the yards per hank in the system into which the required change is to be made.

Example.—Change a 20's worsted into woollen count.

$$20 \times 560 = 11{,}200 \text{ yds. per lb.}$$
$$11{,}200 \div 256 = 43\tfrac{3}{4} \text{ woollen counts.}$$

Example.—Change a 60/2 silk into worsted counts.

$$\frac{60 \times 3}{2} = \frac{180}{2} = 90\text{'s worsted.}$$

[Note.—560 is to 840 as 2 : 3, therefore 2 and 3 are used in the above calculation instead of 560 and 840.]

From Fig. 21 any desired conversion may be read off almost at a glance.

The Counts of Two-fold Yarns.—The usual practice in two-folding yarns is to twist two or more threads of like count together, thereby obtaining a stronger, evener, and usually a heavier thread. The actual count in this case will be just half the stated count, i.e. two-fold 40's yarn (written 2/40's) equals in weight single 20's. (*Exception*—2/60's silk, usually written 60/2 = 60's.)

In twisting together yarns varying in thickness, and consequently counts, they must all first be brought to one denomi-

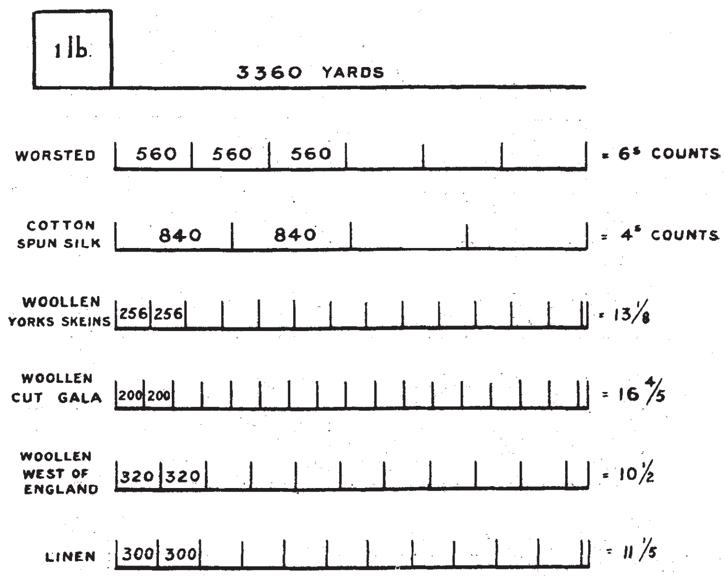

FIG. 20.—Graphic illustration of changing denominations.

nation, i.e. worsted, woollen, or cotton, as required, and then the resultant count will be obtained as follows :—

Rule.—Multiply the two counts together, add the two counts together, and divide one by the other for the answer.

Example.—What is the resultant count of 20's twisted with 40's?

$$\frac{20 \times 40}{20 + 40} = \frac{800}{60} = 13\tfrac{1}{3} \text{ count.}$$

The following is the reason for this method of procedure: 40 lb. of 20's is equal in length to 20 lb. of 40's; therefore the resultant yarn will be composed in the proportion of 20 lb. of 40's yarn to 40 lb. of 20's yarn. Now, the length of 20 lb. of 40's and 40 lb. of 20's will be the same, i.e. $20 \times 40 = 800$

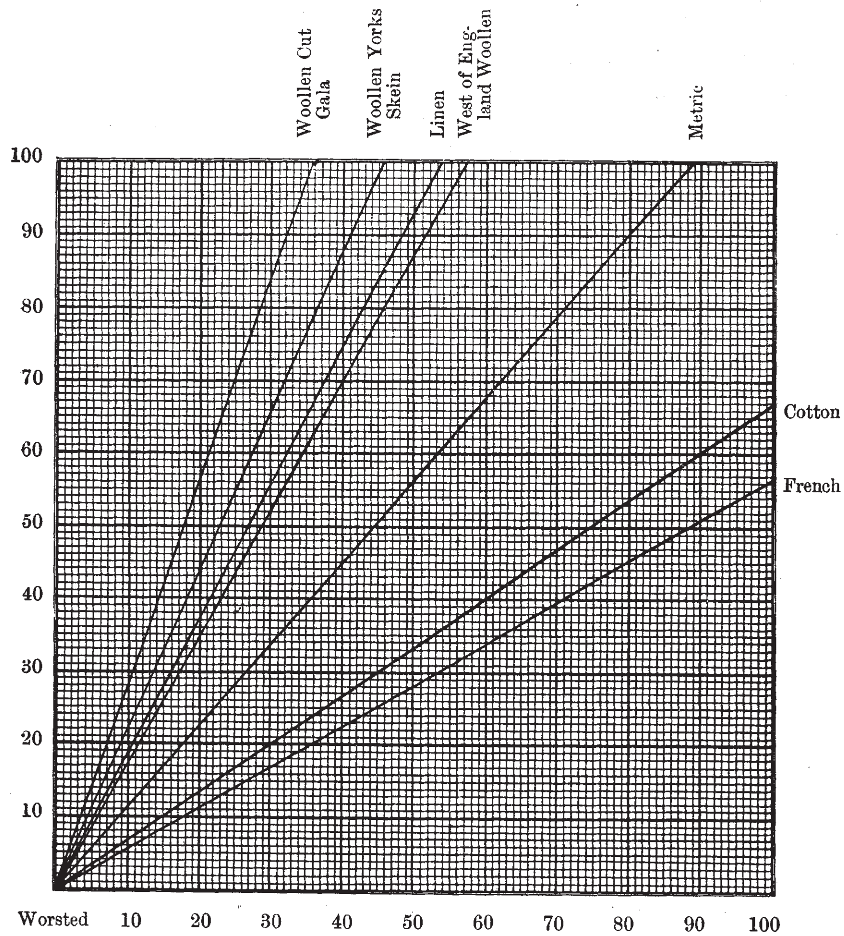

FIG. 21.—Graphic illustration of changing the denomination.

hanks; therefore the sum, simplified, is: if 800 hanks weigh 60 lb., what are the counts? and the answer is $800 \div 60 = 13\frac{1}{3}$ hanks per lb.

Another method of arriving at the same result is to divide one of the counts—preferably the highest—by itself, and by each of the others, and the result thus obtained divided into these counts will be the answer, thus :—

$$\begin{array}{l} 40 \div 40 = 1 \\ 40 \div 20 = 2 \\ \hline 40 \div \quad\quad 3 = 13\tfrac{1}{3} \text{ count.} \end{array}$$

In this case also the reason is very apparent: the 40 hanks equal 1 lb. being taken as the length; thus, 2 lb. of 20's is requisite to give the same length, and 40 hanks weighing 3 lb. = $13\frac{1}{3}$ hanks per lb.

In the case of three or more threads twisted together, proceeding by the first rule, the resultant counts of two must be first ascertained, and then of this and the third thread and so on.

Example.—What is the resultant count of 20's, 40's, and 80's ?

$$\frac{20 \times 40}{20 + 40} = 13\tfrac{1}{3} \text{ resultant count of first two threads.}$$

$$\frac{13\frac{1}{3} \times 80}{13\frac{1}{3} + 80} = 11\tfrac{3}{7} \text{ resultant count of three threads.}$$

By the second method, however, the result may be much more easily obtained—

$$\begin{array}{l} 80 \div 80 = 1 \\ 80 \div 40 = 2 \\ 80 \div 20 = 4 \\ \hline 80 \div \quad\quad 7 = 11\tfrac{3}{7} \text{ counts.} \end{array}$$

Another case in which it may be necessary to apply the above principles is as follows :—

Example.—What thread twisted with a 40's yarn will give $13\frac{1}{3}$ count ? Then,

$$\frac{40 \times 13\frac{1}{3}}{40 - 13\frac{1}{3}} = 20\text{'s count.}$$

This may be reasoned out as follows: 40 lb. of $13\frac{1}{3}$ counts (= $13\frac{1}{3}$ lb. of 40's counts) is taken for the length, i.e. $533\frac{1}{3}$ hanks, weighing 40 lb.; but of this 40 lb., $13\frac{1}{3}$ lb. represents the 40's or given count, so the remainder or component is $533\frac{1}{3}$ hanks, weighing (40 − $13\frac{1}{3}$ lb. =) $26\frac{2}{3}$ lb. = 20's count.

N.B.—Note that in the above no denomination is given—

the calculations apply equally to all denominations; but all the threads twisted together must be reduced to the same denomination before the calculation is made.

Bearing these points in mind it will be evident that this calculation may be solved on similar lines to that given above, **thus**:—

$40 \div 13\frac{1}{3} = 3$

$40 \div 40 = 1$

40 hanks weighing 2 lb. = 20 hanks per lb. of 20's count.

The Cost of Two and Many Fold Yarns.—If the prices of the yarns combined are given it will evidently be an easy matter to calculate the cost of the folded yarn, since the above calculation gives the relative weight of each yarn in the combination. An example will best demonstrate this.

Example.—Calculate the cost of a yarn composed of 20's yarn at 2/- and 40's yarn at 3/-:

$40 \div 40 = 1$ lb. at 3/- = 3/-

$40 \div 20 = 2$ lb. at 2/- = 4/-

3 lb., costing 7/- = 2/4 per lb.

Count of yarn = $13\frac{1}{3}$, costing 2/4 per lb.

A more difficult calculation is as follows: Required the price per lb. of a three-fold twist yarn, made as follows: one thread of 44's worsted at 3s. 8d. per lb., one thread of 36's spun silk at 17s. per lb., and one thread of 36 skeins (Yorkshire) at 2s. 6d. per lb.; allowing $17\frac{1}{2}$ per cent for twisting-up in worsted and 15 per cent for twisting-up in silk.

Evidently the first thing to be done is to bring all the counts to one denomination; so first reduce the silk and worsted to woollen counts, thus:—

$$\text{44's worsted} = \frac{44 \times 560}{256} = 96\tfrac{1}{4} \text{ skeins woollen counts.}$$

$$\text{36's silk} = \frac{36 \times 840}{256} = 118\tfrac{1}{8} \text{ woollen counts.}$$

Now the weight for any given length must be obtained: let the given length be $118\frac{1}{8}$ hanks and proceed on the principles already laid down, thus:—

	lb.	oz.	dr.	
$118\frac{1}{8} \div 96\frac{1}{4} = \dfrac{118\frac{1}{8}}{96\frac{1}{4}} + \dfrac{17\frac{1}{2}}{100}$ (for per cent) $=$	1	7	$14\frac{1}{4}$	of worsted.
$118\frac{1}{8} \div 118\frac{1}{8} = 1 + \dfrac{15}{100}$ (for per cent) $=$	1	2	$6\frac{2}{5}$	of silk.
$118\frac{1}{8} \div 36 = \dfrac{118\frac{1}{8}}{36}$ $=$	3	4	8	of woollen.
$118\frac{1}{8}$ hanks	5	14	$12\frac{13}{20}$	

From this the counts may be readily obtained, for $118\frac{1}{8}$ hanks $= 118\frac{1}{8} \times 256 \div 1516$ dr. = about 20 yds. per dram, or 20 skeins.

The cost per lb. will now readily be ascertained as follows :—

lb.	oz.	dr.			d.
1	7	$14\frac{1}{4}$	at 3/8 per lb.	$= \dfrac{382}{256} \times \dfrac{44}{1} =$	$65\frac{21}{32}$
1	2	$6\frac{2}{5}$	at 17/- per lb.	$= \dfrac{294}{255} \times \dfrac{204}{1} =$	$234\frac{9}{32}$
3	4	8	at 2/6 per lb.	$= \dfrac{840}{256} \times \dfrac{30}{1} =$	$98\frac{14}{32}$
5	14	$12\frac{13}{20}$	costing	- - -	$398\frac{12}{32}$

$(398\frac{3}{8} \div 1516) \times 256 =$ 5s. 8d. per lb. for 3-fold yarn.

To test the correctness of this answer reduce all to worsted counts, and proceed as follows :—

	lb.	oz.	dr.
Silk $= 54 \div 54 + \dfrac{15}{100}$ $=$	1	2	$6\frac{2}{5}$
Woollen $= 54 \div 16\frac{2}{7}$ $=$	3	4	8
Worsted $= 54 \div 44 + \dfrac{17\frac{1}{2}}{100}$ $=$	1	7	$14\frac{1}{4}$
54 hanks $=$	5	14	$12\frac{13}{20}$

or—

30,240 yds. ÷ 1516 dr. = 20 yds. per dram, or 20 skeins woollen ;

$$\text{and } \frac{20 \times 256}{560} = 9\tfrac{1}{7} \text{ counts in worsted.}$$

For the price proceed as follows :—

	lb.	oz.	dr.		d.
Silk - - -	1	2	$6\frac{2}{5}$	at 17/- =	$234\frac{9}{32}$
Woollen - - -	3	4	1	at 2/6 =	$98\frac{14}{32}$
Worsted - - -	1	7	$14\frac{1}{4}$	at 3/8 =	$65\frac{21}{32}$
	5	14	$12\frac{13}{20}$,	costs	$398\frac{12}{32}$

or about 5s. $7\frac{1}{2}$d. per lb., thus proving the previous answer.

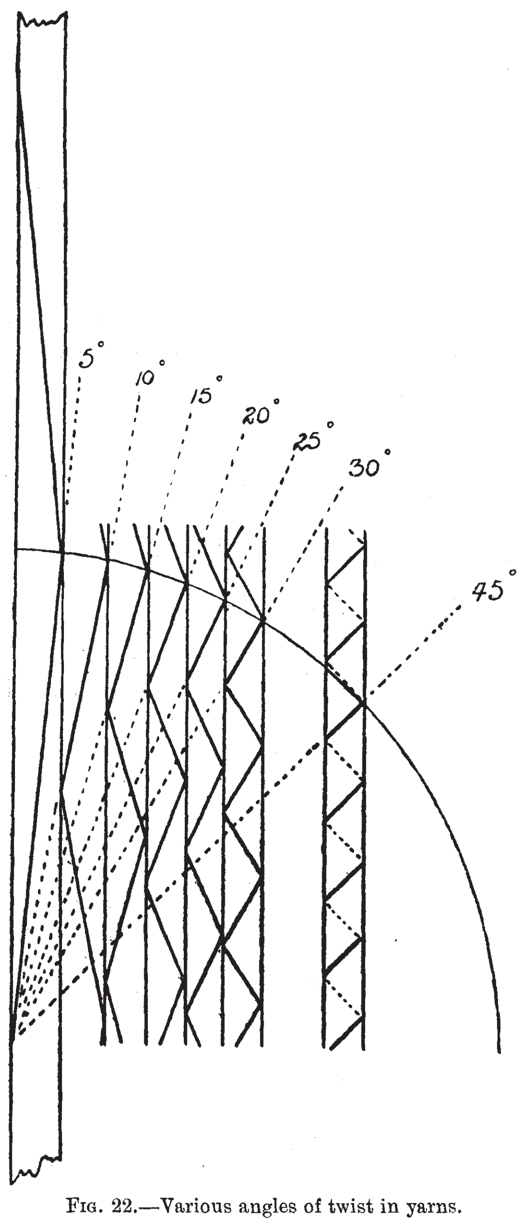

FIG. 22.—Various angles of twist in yarns.

5° Very soft twist, 10° soft twist, 15° soft medium twist, 20° medium twist, 25° hard medium twist, 30° hard twist, 45° very hard twist.

Yarn Twists,—The importance of the twist in yarns cannot well be overestimated. For example, if inadvertently, two yarns of exactly the same quality and counts but spun with a different number of turns per inch, be woven bobbin by bobbin into the same cloth a wonderful stripe effect is developed—dark on light ground when viewed from one side of the piece, light on dark ground when viewed from the other side of the piece (see Fig. 17). Probably one of the two twists gives the better fabric, so that problems of twist resolve themselves into first deciding upon the most suitable twist and secondly defining what this twist is and how it may be produced on the spinning frame.

The cloth constructor should undoubtedly look at twist from the "angle of twist" point of view. Thus, as shown in Fig. 22, angles of twist may be stated with a concomitant indication of hardness or softness.

With this diagram before him the cloth constructor can firstly decide upon the angle of twist most suitable for any fabric he may have in hand; and secondly, give the turns per inch to produce the required angle to the spinner by working upon the following formula:—

$$\frac{D}{\pi \times \text{Cot. of B.}} = T$$

in which—

D = diameter of yarn as a whole number;
π = ratio of circumference to diameter (3·1416);
Cot. of B. = cotangent of longitudinal angle, i.e. of twist angle;
T = turns per inch (whole number).

Example.—A cloth is to be constructed from 2/30's botany yarn (1/84 in. diat.) and as a hard cloth is required an angle of 30° is selected. What turns per inch to give this twist angle will be required?

$$\frac{84}{3{\cdot}1416 \times 1{\cdot}732} = 15 \text{ turns per inch.}$$

The converse is also true, thus—

$$\frac{D}{\pi \times T} = \text{Cot. of B., i.e. } \frac{84}{3{\cdot}1416 \times 15} = 1{\cdot}732 \text{ Cot. of } 30°.$$

The following list of angles and cotangents will enable the cloth constructor to employ the above formulæ according to requirements:—

Angle.	Cotangent.	Suggested definition.
5°	11·43	Very soft twist (SSS).
10°	5·67	Soft twist (SS).
15°	3·73	Soft medium twist (S).
20°	2·75	Medium twist (M).
25°	2·14	Hard medium twist (MH).
30°	1·73	Hard twist (H).
35°	1·42	Hard twist (HH).
43°	1·00	Very hard twist (HHH).

The above formulæ may be usefully employed for both single and two-fold yarns, but the cloth constructor should think clearly and carefully respecting the differences between the two. In dealing with single yarns, for example, the fibre angle and the twist angle are one and the same, but in two-fold yarns there is a fibre angle and a twist angle, and both should be taken into consideration. It should also be noted that the natural or balanced twist for any two strands of single yarn will be half the number of turns in the single yarn. If for example a 1/30's yarn with 12 turns per inch be allowed to snarl or kink-up, it will be found to take naturally 6 turns per inch in the two-fold state. Thus if a balanced inert two-fold yarn is required, the two-fold twist should be half the single twist. If, for example, a 2/24's yarn with 9 turns per inch is required, the single should be spun with 18 turns reverse twist, and these conditions will yield a better balanced yarn than 12 turns reverse twist in the single and 12 turns in the two-fold, while the frame production will be approximately the same. Three-fold and many fold yarns are subject to the same laws.

The foregoing is the safest basis for the cloth constructor to design his cloths upon, but the following are particulars which may be usefully considered :—

FORMULA FOR ASCERTAINING STANDARD TURNS PER INCH.

For hosiery yarns	$\sqrt{\text{counts}} \times 2{\cdot}5$
For single yarns for doubling .	$\sqrt{\text{counts}} \times 2{\cdot}75$
For medium weft yarns . .	$\sqrt{\text{counts}} \times 3{\cdot}25$
For fine weft yarns . . .	$\sqrt{\text{counts}} \times 3{\cdot}8$
For medium warp yarns . .	$\sqrt{\text{counts}} \times 3{\cdot}75$
For fine warp yarns . . .	$\sqrt{\text{counts}} \times 3{\cdot}6$

These formulæ apply more particularly to cotton yarns and are only approximately correct for worsted yarns. Upon the whole the cloth constructor will do better to base his twists on his own judgment with the aid of the foregoing particulars.

Mistakes and misapprehensions are so common with reference to twists that special attention should be directed to the principles demonstrated in Fig. 23. In A a graphic illustration of a yarn with a twist-angle of 45° is given. B demonstrates that for a thread four times the thickness the same number of turns as in A will give a much greater *exterior* angle of twist, but *the same interior angle and binding of the fibres.* On the other hand C and D show that if the same exterior fibre angle is to be retained the interior angle will be very different, and that as a consequence the binding of the fibres in the centre of the thread

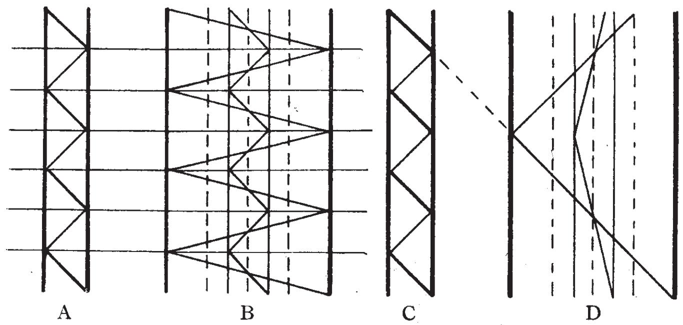

Fig. 23.—Illustration of relative twist in yarns.

will be very different. The cloth constructor must use his judgment in making twist changes in the light thrown upon this problem by these diagrams.

CHAPTER IV.

WEIGHTS OF CLOTHS.

Calculations Relating to the Weights of Cloths.—Having indicated as clearly as possible the various methods of finding the count of yarn and sett of any cloth, two very important matters have still to be fully dealt with, viz. the weight of the various yarns employed in any given cloth, and the weight of the same cloth finished. This question has been treated by other writers at some length, and we should be tempted to be very brief but for the fact that it has usually been treated under one heading instead of under the two indicated above. As those engaged in the trade are aware, the weight of cloth in the loom and the weight in the finished state vary considerably; thus, in the present chapter, calculations relating to cloths as woven are dealt with, and in the succeeding chapters the calculations dealing with the relationship of greasy and finished cloths.

Ordinary Warp and Weft Calculations.—The simplest form in which a question may occur under this heading is that in which, having a cloth made to given particulars, the weight of warp and weft is required.

Example.—A cloth is made of 2/40's worsted for warp, and 20's single worsted for weft. Sett 64 threads per inch in loom, 64 picks per inch, 34 in. wide, 50 yds. of cloth from 56 yds. of warp. Find the weight of the cloth. This question evidently involves the finding of the weight of both warp and weft, which two together give the weight of the cloth.

Rule 1.—To find the weight of warp :—

1. Ascertain yards of material in the warp, i.e. threads per inch × inches wide = threads in warp ; × length of warp in yards = the yards of material in the warp.
2. The yards of material in the warp divided by the yards in 1 lb. of such material gives the total weight of warp in 1 lb.

In the above example

(1) $64 \times 34 \times 56 = 121{,}856$ yds. of material in piece.

$560 \times 20 = 11{,}200$ yds. in 1 lb. of material.

Therefore $121{,}856 \div 11{,}200 = 10$ lb. 14 oz. $\frac{17}{25}$ dr. of warp in piece.

Rule 2.—To find weight of weft :—

1. Ascertain the yards of the material in the piece by multiplying the picks per inch by the width in inches and by the length of the cloth.
2. The yards of material thus obtained, divided by the yards in 1 lb. of such material, gives the total weight of weft in lb.

In the above example

(1) $64 \times 34 \times 50 = 108{,}800$ yds. of weft in cloth.

(2) $560 \times 20 = 11{,}200$ yds. per lb.

Therefore $108{,}800 \div 11{,}200 = 9$ lb. 11 oz., diam. $6\frac{6}{7}$ of weft in piece. Then 10 lb. 14 oz. + 9 lb. 11 oz. = 20 lb. 9 oz. weight of 50 yds. of cloth, and 20 lb. 9 oz. 8 diam. $\div 50 = 6\frac{3}{5}$ oz. per yard of cloth.

It will be well for the analyst, wherever possible, to work upon the basis of a square yard, since the weights for all the various widths may be obtained by direct proportion, while at the same time it forms a useful standard for comparisons.

In the above rules prominence is given to the reason for the procedure rather than to the shortest possible statement, since we cannot impress too strongly the advantage of working by reason rather than by rule. Two points in the above, however, need further explanation. In the first place, the reason for the weft rule is not as clear as it might be, since there is an apparent mixing-up of yards and inches, which to the uninitiated is very confusing. If the sum be thought out as follows, the reason for the abbreviation will be evident :—

64 picks per inch × the width will give the inches of weft in 1 in. of cloth, and therefore the yards in 1 yd. of cloth for $64 \times 36 = 2176$ in. in the inch, and $2176 \div 36 =$ yards in the inch $= 60\frac{4}{9} \times 36 = 2176$ yds. per yard, from which it is very evident that by dividing 36 in one case and multiplying in another may be dispensed with altogether ; thus the abbreviated rule above is obtained.

The other matter to which attention was directed is the fact that, although the warp calculation is for 56 yds. the weft is only 50 yds., since 56 yds. of warp are assumed to yield only 50 yds. of cloth; therefore weft will only be required for 50 yds. Since this is fully dealt with in Chapters VIII, IX and X, there is no need to go further into the matter here.

Having indicated the principles, the simplest method of stating the calculations for both warp and weft may now be given :—

$$\text{Warp} = \frac{64 \times 34 \times 56}{560 \times 20} = 10 \text{ lb. } 14 \text{ oz. weight of warp.}$$

$$\text{Weft} = \frac{64 \times 34 \times 50}{560 \times 20} = 9 \text{ lb. } 11 \text{ oz. weight of weft.}$$

And the two together give 20 lb. 9 oz. weight of 50 yds. of cloth.

A calculation simpler in principle than the above cannot well be imagined, but the basis of all subsequent warp and weft calculations is present, and this being so, its thorough comprehension is most necessary.

Complicated Calculations.—Attention may now be directed to calculations for more complicated warps, two modifications on the above practically including all possible warp calculations.

Coloured Warp Calculation.—The first modification of the foregoing is the introduction of coloured threads or picks in either stripe or check form, under which circumstances the weight of each coloured yarn must be obtained.

Rule 3.—To find the weights of the various colours of yarn in a given warp :—

1. Find the number of ends of each colour in the warp, i.e. divide the threads in the warp by the threads in one repeat of the colouring, thus obtaining the number of repeats of the pattern across the piece, and this, multiplied by the ends of each colour in the pattern, gives the number of ends of each colour in the warp.
2. Multiply the ends of each colour by their length, i.e. the length of warp, and divide by the yards per lb. according to the counts of the yarn.

Example.—Find the weight of each colour of yarn in the following :—

Warp.

8	threads	2/40's black.
2	,,	2/40's black and white twist.
4	,,	2/40's black.
2	,,	2/40's black and orange twist.
		16's reeds 4's.
16	threads in repeat of pattern.	

Weft.

All 20's black, 64 picks per inch.

Sett 34 in. wide, warp to be 56 yds. long, to yield 50 yds. of cloth.

(1) $64 \times 34 = 2176$ threads in warp.

$2176 \div 16 = 136$ repeats of colour pattern.

$136 \times 12 = 1632$ threads of black in the warp.

$136 \times 2 = 272$ threads of black and white twist in the warp.

$136 \times 2 = 272$ threads of black and orange twist in the warp.

2176 ends in warp.

(2) $\frac{1632 \times 56}{20 \times 560} = 8$ lb. $2\frac{1}{2}$ oz. weight of black yarn.

$\frac{272 \times 56}{20 \times 560} = 1$ lb. $5\frac{3}{4}$ oz. weight of black and white yarn.

$\frac{272 \times 56}{20 \times 560} = 1$ lb. $5\frac{3}{4}$ oz. weight of black and orange yarn.

10 lb. 14 oz. total weight of warp.

For the weft $\frac{64 \times 34 \times 50}{20 \times 56} = 9$ lb. 11 oz. of weft.

The same method of working may be adopted whatever the order of colouring may be, but it is usually advisable to work out the calculations as for a solid to compare with the total weights of the various colours. The same principles may also be readily applied to weft colourings.

Cloths with Yarns of Two or more Counts.—The second complication in warp calculation is the not unfrequent system of using yarns of two or more counts in the same warp. Two methods of finding the weight of the warp under these circumstances present themselves :—

1. The average counts of the two or more yarns may be found, and the weight calculated for the average counts on the ordinary system.
2. Should the order of warping, etc., be very complicated, the system employed for finding the weights of various colours may be adapted to these conditions.

Backed and Double Cloths.—The cloths most easily dealt with under the first conditions are backed and double cloths, in which the warping plan seldom exceeds three or four threads.

Example.—A warp is composed of alternate ends of 2/40's and 2/30's worsted, sett 120 ends per inch. Find the weight if made 60 in. wide, 60 yds. long.

Rule 4. To find the average counts. Find the resultant counts of the 2, 3, or 4 ends combined, and then multiply by 2, 3, or 4, according to the number of ends given.

In the above example

$$\frac{15 \times 20}{15 + 20} = 8\tfrac{2}{3}, \text{ and } 8\tfrac{2}{3} \times 2 = 17\tfrac{1}{3}, \text{ the average counts; and}$$

$$\frac{120 \times 60 \times 60}{17\frac{1}{3} \times 560} = 45 \text{ lb. total weight of warp.}$$

Or, by taking each count separately :—

	lb.	oz.	dr.	
$\frac{60 \times 60 \times 60}{20 \times 560} =$	19	4	$9\frac{1}{7}$	fine warp (2/40's).
$\frac{60 \times 60 \times 60}{15 \times 560} =$	25	11	$6\frac{6}{7}$	thick warp (2/30's).
Total weight	45	0	0	

Crammed Stripes—A large number of fancy dress fabrics, usually included under the heading "crammed stripes," require distinct treatment under the second heading given above, since whether they are true crammed stripes, or only those in which two distinct materials are employed, the treatment of each material separately is much to be preferred.

The method of finding the weight of the latter class of goods —viz. those in which two distinct materials are employed—is very easy, as the following example will demonstrate :—

Warp.

12	threads	2/50's salmon worsted.
12	,,	2/50's white worsted.
12	,,	2/50's green worsted.
12	,,	2/50's white worsted.
12	,,	40/2 blue silk.
12	,,	2/50's white worsted.
12	,,	2/50's green worsted.
12	,,	2/50's white worsted.

96 threads in pattern.

12's reed 4's.

Weft.

Same as warp, 48 picks per inch.

Piece to be woven 48 in. wide in loom, 60 yds. long.

Then 48 threads per inch ÷ 96 threads in pattern $= \frac{1}{2}$ pattern per inch, or 1 pattern = 2 in.

Therefore, 48 ÷ 2 = 24 patterns in piece, and

	lb.	oz.	dr.	
$\frac{48 \times 24 \times 60}{25 \times 560} =$	4	15	0	white worsted.
$\frac{12 \times 24 \times 60}{25 \times 563} =$	1	3	12	of salmon worsted.
$\frac{24 \times 24 \times 60}{25 \times 560} =$	2	7	8	of green worsted.
$\frac{12 \times 24 \times 60}{40 \times 840} =$	0	8	4	of blue silk.
Total	9	2	8	

The weight of the weft yarns will be exactly the same minus the take-up in the weaving of the warp (p. 131).

The above is not a true "crammed stripe," since a true cram has more threads in one portion than in another, as instanced in the following:—

Warp.

40	threads of	mohair,	4 in a reed	=	10	reeds.
20	,,	cotton,	2 ,,	=	10	,,
12	,,	mohair,	4 ,,	=	3	,,
40	,,	cotton,	2 ,,	=	20	,,
12	,,	mohair,	4 ,,	=	3	,,
20	,,	cotton,	2 ,,	=	10	,,
			Reeds in pattern		56	

Piece to be woven 56 in. wide. Now it is very evident that here also the extent of pattern must first be found, so if the number of reeds occupied by the pattern be ascertained, this, divided into the reeds across piece, will give the required answer, i.e. :—

$56 \times 14 = 784$ reeds across the piece,

And $784 \div 56 = 14$ patterns across the piece.

Then 14×16 splits of mohair $\times$ 4 threads in a split $= 896$ ends of mohair.

14×40 splits of cotton $\times$ 2 threads in a split $= 1120$ ends of cotton.

Total number of ends in warp 2016

Having the counts of mohair and cotton with the length of warp, etc., the weight of cloth may now readily be found as previously shown.

Other necessary Calculations.—There are many other forms in which warp and weft calculations may occur, but the following formula will prove all that is necessary :—

Let C = counts, W = width in loom, L = length, N = number of ends or picks per inch, P = weight in lb.;

Then $\frac{N \times W \times L}{C \times 560} = P$, or $N \times W \times L = P \times C \times 560$ for worsted, 256 for woollen, 840 for cotton, or 300 for linen.

Now this is a complete equation; consequently, if one of the terms be missing, the sum worked out will give that term, i.e. the number which will complete the equation, so that all the following questions are here involved :—

1. To find the counts when ends or picks per inch, width, length, and weight are given :—

$$\frac{N \times W = L}{P \times 560} = \text{counts in worsted.}$$

2. To find the length when ends or picks per inch, width, weight, and counts are given :—

$$\frac{N \times W}{P \times C \times 840} = \text{length, if yarn is cotton or silk.}$$

3. To find the width when ends per inch, length, counts, and weight are given :—

$$\frac{N \times L}{P \times C \times 256} = \text{width for a given weight of woollen yarn.}$$

4. To find the ends per inch when width, length, counts, and weight are given :—

$$\left.\frac{W \times L}{P \times C \times 200}\right\} = \left\{\begin{array}{l}\text{ends per inch if the counts of yarn are Gala-} \\ \text{shiels system.}\end{array}\right.$$

With these formulæ not only should the analyst be able to work out any calculations which are likely to occur, but he should also be able to reason the matter out on reference to the particulars already given.

As already intimated, the above systems, although answering all requirements when dealing with cloths in the loom, require certain modifications in application to the cloth in the finished state. These modifications are considered later.

Weights of Fabrics.—The following may be taken as a guide in indicating light, medium, and heavy fabrics :—

Light fabrics up to 9 oz. for 56 in. wide.

Medium fabrics 9 oz. up to 18 oz. for 56 in. wide.

Heavy fabrics above 18 oz. for 56 in. wide.

Changing the Weights of Cloths.—The weights of cloths may usually be varied in two distinct ways :—

(*a*) They may be woven opener or closer, thereby giving less or more weight,

(*b*) They may be made thinner or thicker.

There are, however, several variations, whichever method be adopted. Thus (*a*) may be varied as follows :—

1. Putting in fewer or more picks per inch. This is a common method in producing a range of qualities as in the case of Cashmeres, Italians, etc.

2. Varying the set; i.e. putting in fewer or more threads per inch.

3. Employing a thinner or thicker weft yarn.

4. Employing a thinner or thicker warp yarn.

5. Combinations of two or more of these methods.

The practical possibilities of each and every one of the above methods should be thoroughly realized by the cloth constructor, for the full knowledge of such gives him a control over weight which is the envy of the less observant and unmethodical designer.

All these five methods, however, have very serious limitations which should be at once studied and realized if an attempt at the impossible is to be avoided. Thus with reference to (1) the argument may run: 60 picks gives a summer weight, 120 picks will give a winter weight. But can 120 picks per inch be got into the cloth with the heaviest loom built? Probably not; or if so 60 picks will have produced a very flimsy, slipping fabric! The truth is that this method—as a rule—may only be employed for comparatively slight decreases or increases in weight, and the same remarks apply to (2).

Again the employment of a thinner or thicker yarn has very similar limitations. For example, if a cloth woven with a 20's yarn equals 16 oz. per yard, a cloth woven with a 10's yarn will equal 32 oz. per yard, sett, picks, and width being the same in each case. That is to say that the weight will vary *inversely* as the count of the yarn employed. But if the 20's yarn made a presentable cloth we may be certain that the 10's cannot be made into a cloth at all—it will almost certainly be too thick for the sett and picks. Then comes in the idea of balancing up sett and picks and counts of warp and weft. Much may be done in this way but there will probably at once arise in the mind of the designer the question as to whether it is possible to balance these, say, to produce greater weight. For if the 10's count of yarn be too thick to go into the cloth then it will be necessary to employ fewer threads and picks per inch; and if fewer threads and picks per inch are employed where does the increased weight come in? *Will not the decrease in threads and picks just balance increase in the thickness of the yarn and as a result the cloth remain the original weight?*

When the cloth constructor has got thus far he is ready for the second method (*b*) of changing the weights of cloths, and should stop his reasoning sharp and turn to this for the solution of his difficulties.

It seems a simple thing to make a cloth thinner or thicker and thereby increase its weight. Possibly the simplest way is to weave two cloths together, with suitable bindings, thereby doubling the weight of the original cloth. Or a weft or a warp back may be added—1 and 1 or 2 and 1, etc.—thereby increasing the weight of the cloth—other things being equal by $\frac{1}{2}$ or by $\frac{1}{4}$. Or again resort may be made to both double-cloth and wadding threads or picks for extremely heavy structures.

But if the cloth must remain a single cloth—what then?

Simply decrease or increase its thickness directly in the required proportion.

This will be evident from Fig. 24*a*. Taking (*a*) as the original cloth, then (*b*) will be double the weight, and (*c*) will be four times the weight—simply because they are respectively double and four times the thickness.

But this increase in thickness must be expressed in terms of counts of yarn and sett and picks. This is the difficulty.

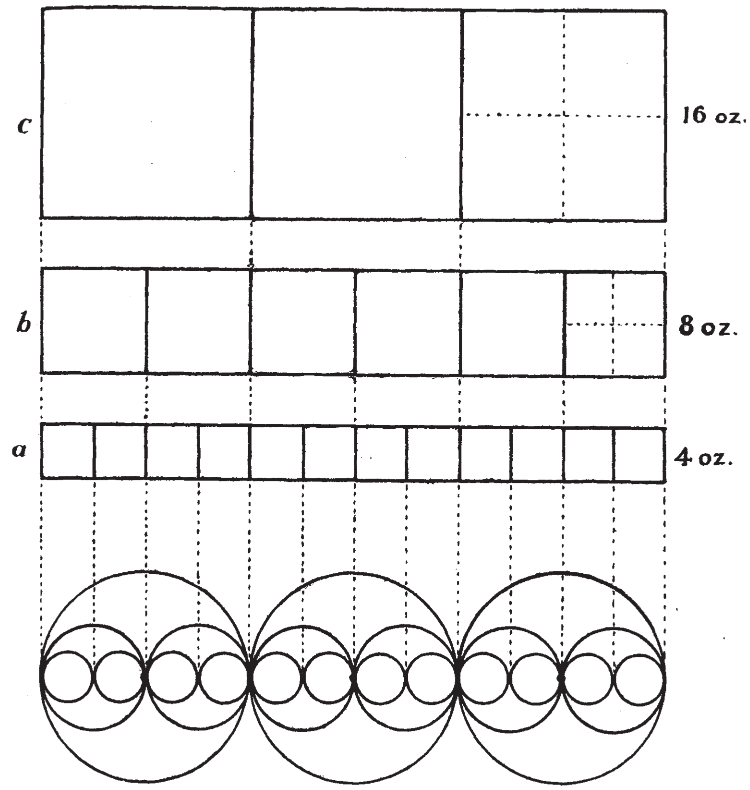

FIG. 24*a*.—Weight changes in cloth.

But after all the difficulty is not great. For (*a*), double thickness equals double the original yarn diameter, and as double the diameter equals four times the area, and as counts and area are synonymous, four times the yarn count, i.e. a yarn four times the weight of the original; (*b*) but as the yarn is double the thickness of the original, therefore half the number of threads and picks must be employed to maintain a correctly balanced structure in accordance with original cloth (see Fig. 24*b*).

Therefore it is evident that doubling the yarn diameter quadruples the weight, but the reduction in the sett and picks to half just balances half this increase leaving the cloth just double the weight.

Thus, to decrease or increase a cloth in weight maintaining the correct balance of structure :—

1. Decrease or increase the diameter of the yarn (i.e. the square root of the counts, *inversely*) directly in the required proportion ; and

2. Increase or decrease the sett and picks directly in the required proportion.

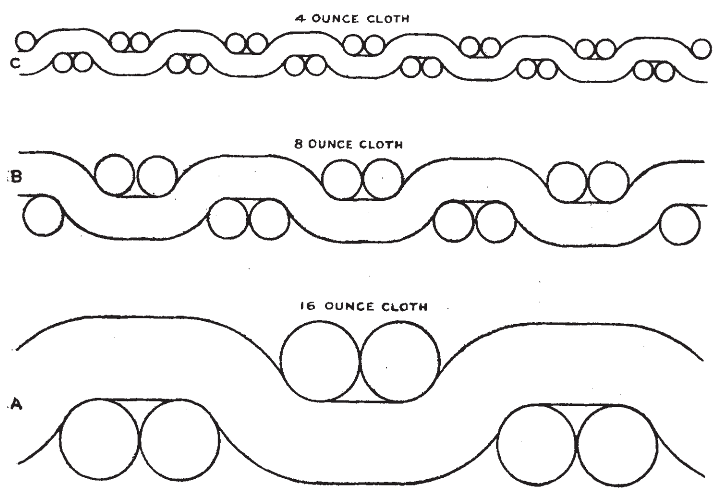

FIG. 24*b*.—Setting of fabrics.

Example.—A cloth is made to the following particulars :—

Warp and Weft.

All 1/36's botany.

64 threads and picks per inch.

A cloth $\frac{1}{6}$th heavier is required, then

As $\frac{6}{6}$ must become $\frac{7}{6}$ correct proportion is as 6 : 7.

As $7 : 6 :: \sqrt{36} : \sqrt{x} = \frac{1}{26}$ counts required for cloth $\frac{1}{6}$th heavier ; and

As $7 : 6 :: 64 : x = 55$ threads and picks per in. for cloth $\frac{1}{6}$th heavier.

It seems ridiculous for a heavier cloth to be arrived at by employing fewer threads and picks per inch and conversely for a lighter cloth to be arrived at by employing more threads and picks per inch, but a few moments study of Fig. 24*b* will clearly show why this is, and once the reason is fully realized the cloth constructor can readily control weight changes within the limits of possibilities. But just as we saw there were limits to increase in yarn, setts, and picks, so here again must it be realized that there are limitations; for example, in the cloth just given, if the weave be 2/2 twill then it will obviously be a finer twill in the original cloth with sixty-four threads and picks per inch as compared with the heavier cloth with fifty-five threads and picks per inch; and it might be just this difference to which the merchant would object.

This brings into question the method of changing both weight and weave of a fabric, still maintaining the correct balance of structure.

Example.—A cloth is woven in a 2/2 twill weave theoretically perfect, i.e. with seventy-six threads and picks per inch of 2/50's yarn, and a cloth is required in the 4/4 twill, giving an increased weight of $\frac{1}{5}$th. What counts of yarn, sett, and picks should be employed?

This problem resolves itself into three simple stages:—

1. Change the original cloth (1st cloth) to $\frac{1}{5}$th heavier on the principles already demonstrated (2nd cloth).

2. Increase the sett and picks of the 2nd cloth in accordance with the requirements of the 4/4 twill, retaining the count of the new cloth without change (3rd cloth).

3. As the 3rd cloth is too heavy just in proportion to the weave change, change the 3rd cloth to a lighter cloth in this proportion by the ordinary method (i.e. change in both counts, sett, and picks) (4th cloth and required cloth).

1. As $\frac{5}{5}$ must become $\frac{6}{5}$ correct proportion is as 5 : 6.

$$\text{As } 6 : 5 :: \sqrt{25} : \sqrt{x} = 17\tfrac{13}{16} \text{ counts, or}$$
$$[\text{As } 6 : 5 :: \sqrt{25} : \sqrt{x}]^2$$
$$= \text{As } 6^2 : 5^2 :: 25 : x = 17\tfrac{13}{16} \text{ counts.}$$

Note.—This latter method is useful when the original count is an awkward number involving fractions.

$$\text{As } 6 : 5 :: 76 : x = 63\tfrac{1}{3} \text{ threads and picks per inch.}$$

Thus 2nd cloth is—$17\frac{13}{16}$ counts,
$63\frac{1}{3}$ threads and picks per inch, and
2/2 twill weave.

2. As indicated in Fig. 25 the 2/2 twill, *for eight threads* occupies 10·928 units of space,* while the 4/4 twill, *for eight threads*, occupies only 9·464 units of space. Therefore the 4/4 twill will require a closer set in this proportion.

As $9{\cdot}464 : 10{\cdot}928 :: 63\frac{1}{3} : x = 73$ threads per inch for 4/4 twill.

Thus the 3rd cloth is—$17\frac{13}{16}$ counts,
73 threads and picks per inch,
4/4 twill weave.

3. As the 3rd cloth is too heavy just in proportion to the sett increase as compared with the 2nd cloth it must be reduced in this proportion, or what is the same thing in the weave change proportion, thus :—

Correct proportion for reduction—As $73 : 63\frac{1}{3}$, or
As $10{\cdot}928 : 9{\cdot}464$.

As $63 : 73$ or
As $9{\cdot}464 : 10{\cdot}928 :: \sqrt{17\frac{13}{16}} : \sqrt{x^2}$, or
As $63^2 : 73^2$: or
As $9{\cdot}464^2 : 10{\cdot}928^2 :: 17\frac{13}{16} : x = 23$'s or 2/46's yarn. And
As $63 : 73$ or
As $9{\cdot}464 : 10{\cdot}928 :: 73 : x = 84$ threads per inch.

Thus 4th and required cloth is—2/46's counts,
84 threads and picks per inch, and
4/4 twill.

This cloth will be found to be of a perfect structure and of the correct weight required. This may be tested as follows :—

For Structure—

Diameter of 2/46's or 2/23's $= \frac{1}{102}$ in.

$$\text{And } \frac{102 \times 8}{9{\cdot}464} = 84 \text{ to } 85 \text{ threads per inch.}$$

For Weight of One Square Yard—

$$\frac{76 \times 36 \times 1}{25 \times 560} + \frac{1}{5} = \frac{84 \times 36 \times 1}{23 \times 560}.$$

From this working the following simple rule for changing the weight and weave of fabrics is originated :—

For Counts.—Change the $\sqrt{}$ count of the original cloth inversely according to the required weight change and directly according to the weave change.

For Sett and Picks.—Change the sett and picks of the original cloth inversely according to the required weight change and directly according to the weave change squared.

* Note.—The weft intersection is taken as ·732 of a yarn diameter unit.

With these principles at his finger ends the cloth constructor will readily do what is possible in the matter of changing the weights of cloths. But in order that he may not get too much into one groove and be bound too much by rule the following examples of breaking away from the rule are given :—

Example.—The following 3/3 twill cloth is required $\frac{1}{4}$ less in weight *and of a similar appearance.* What counts, sett, and picks and weave should be employed ?

Warp and Weft.
All 2/32's worsted.
48 threads and picks per inch.
Weave = 3/3 twill.

As $3 : 4 :: \sqrt{16} : \sqrt{x} = 28$ or 2/56's worsted, warp, and weft (new cloth).

As $3 : 4 :: 48 : x = 64$ threads and picks per inch (new cloth).

As $3 : 4 :: 6 : x = 8$ ends in weave—say 4/4 twill (new cloth).

In this case it will be noticed that the perfect structure has been sacrificed to the weave appearance ; but as this latter is usually the dominant feature in the eyes of the merchant it may frequently be necessary to adopt some such method as this. Of course care must be taken that the new cloth is not too tightly or too flimsily built : slipping must certainly be avoided. The following example is of a similar character :—

Example.—The following 4/4 twill cloth is required double the weight *and of a similar appearance.* What counts, sett, and picks and weave should be employed ?

Warp and Weft.
All 2/50's botany.
64 threads and picks per inch.
Weave = 4/4 twill.

As $2 : 1 :: \sqrt{25} : \sqrt{x} = 6{\cdot}25$ or 2/12·5's botany, warp, and weft (new cloth).

As $2 : 1 :: 64 : x = 32$ threads and picks per inch (new cloth).

As $2 : 1 :: 8 : x = 4$ ends in weave—say 2/2 twill (new cloth).

Note.—These cloths should be drawn out diagrammatically as illustrated in Fig. 25.

The designer will also be well advised if he makes himself thoroughly acquainted with the natural weight change incident on weave change with the other factors remaining the same. The

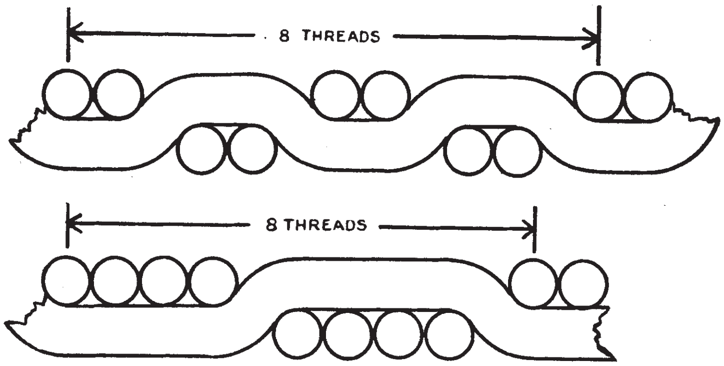

FIG. 25.—Setting of fabrics.

following lists are exceedingly interesting from this point of view and should be memorized.

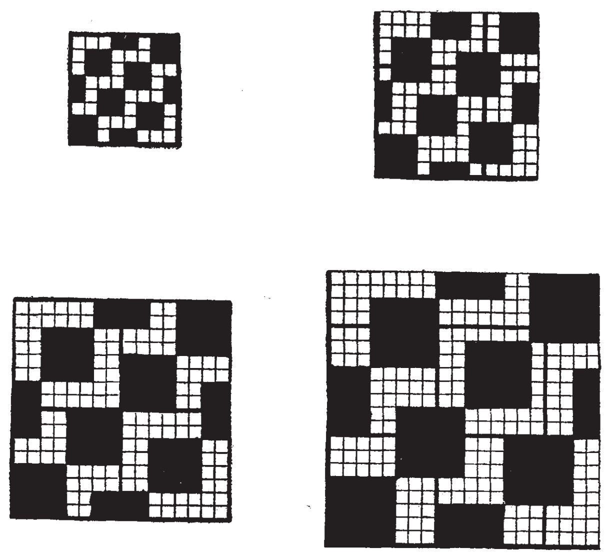

FIG. 26.—Hopsacks of various sizes.

Perfect sets for 2/36's botany (1/90 in. diameter).

Heavier.

1/1 (Plain weave)	52 threads and picks per inch						
2/2 Twill	66 ,, ,, ,,			1/4			1/11
3/3 ,,	72 ,, ,, ,,		1/3				
4/4 ,,	76 ,, ,, ,,	1/2			1/18	1/7	

Lighter.

1/1 (Plain weave)	52 threads and	picks per inch		1/3	1/4	1/5			
22 Twill	66 ,,	,,	,,					1/8	1/12
3/3 ,,	72 ,,	,,	,,				1/19		
4/4 ,,	76 ,,	,,	,,						

Note.—These fractional weights are only very approximate but fully demonstrate the principles involved.

Particular note should be made of the fact that, for example, an increase in weight of $\frac{1}{11}$th will need a decrease of $\frac{1}{12}$th to arrive at the original figure, $\frac{1}{8}$th will require $\frac{1}{9}$th and so on through the range of fractions.

In problems involving changes in the weights of cloths it is also most important to remember that the various hopsacks such as 2/2, 3/3, and 4/4 may be employed in a variety of ways, thus varying the weights of hopsack cloth along with the weave appearance, and further that most weaves may be modified to give lighter or heavier structures as exampled in the range of twilled hopsacks A, B, C, and D (Fig. 26).

CHAPTER V.

SETTS AND THE SETTING OF CLOTHS.

ATTENTION must now be directed to the methods of indicating the number of ends and picks, i.e. warp and weft threads, in a piece, since these particulars, in conjunction with the count of the yarn, indicate the weight of the resultant cloth.

The ends in a piece are indicated in such a number of ways that in order to render our remarks clear the simplest method shall first be considered, and the more intricate ones explained by means of this.

Methods of Indicating the Sett.—Evidently the simplest method will be to state always the threads per inch, since the width of the piece is usually stated in inches; thus the sett multiplied by the width gives the number of ends in the warp.

The "*Stockport* system" is similar to this, only the number of dents or splits in the reed is indicated along with the number of ends through each.

Example.—A 12's reed 4's = 12 reeds per inch, with 4 threads through each = 48 threads per inch.

For the actual weaving operation, this latter method is perhaps preferable, but in all calculations for cloth the number of ends per inch forms a much more convenient standard.

The other important systems are as follows:—

The "*Bradford* system," based upon the number of beers (40 ends) in 36 in.

The "*Blackburn* system," based upon the number of beers (20 splits) in 45 in.

The "*Manchester* system," based upon the dents in 36 in.; but the ends per inch is the now universal system in Lancashire.

The "*Scotch* system," based upon the dents in 37 in.

The "*Leeds* system," based upon the number of porties (38 ends) in 9 in. ($\frac{1}{4}$ yd.).

To show clearly the different meaning of a certain sett, say 40's, in each of the above, the following list is given :—

40's sett in ends per inch		= 40 ends per inch.
40's Bradford	,,	= $44\frac{4}{9}$,, ,,
40's Blackburn	,,	= $17\frac{7}{9}$ splits per inch.
40's Manchester	,,	= $1\frac{1}{8}$,, ,,
40's Scotch	,,	= $1\frac{3}{37}$,, ,,
40's Leeds	,,	= $169\frac{8}{9}$ ends per inch.

From Fig. 27 any desired conversions may be read off almost at a glance.

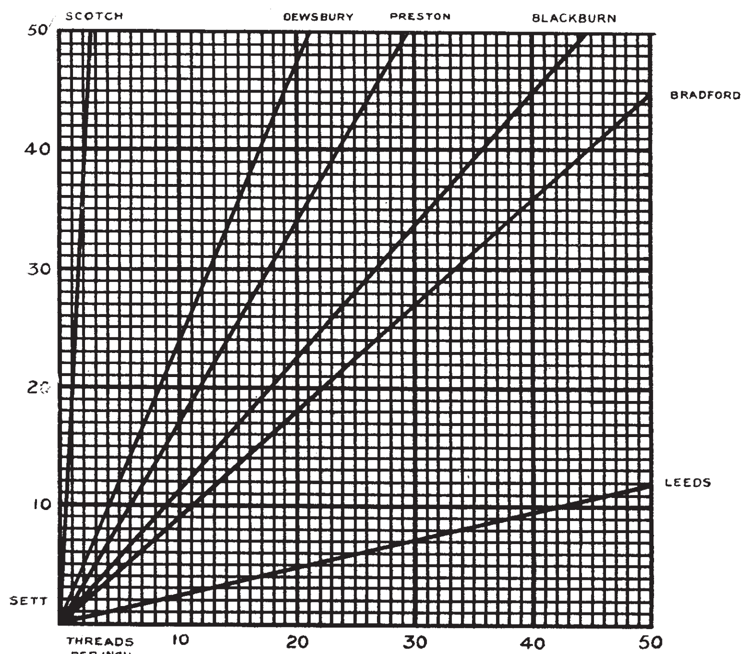

FIG. 27.—Graphic illustration. Changing from one sett system to another, or from any sett system to threads per inch.

In the following calculations, ends per inch and picks per inch will be adopted throughout, since this is simplest and most easily comprehended.

The Setting of Cloths.—Since the analyst will often be required to build cloths in various ways from the knowledge obtained in pulling them to pieces, a brief consideration of the principles of setting fabrics may be of much use in this treatise. This question is one of such wide scope that we can only touch upon the principal features, leaving the reader tó carry out the ideas to their full limits.

Influences to Consider.—There are three modifying influences to consider in setting cloths. Firstly, the characteristics of the yarns to be employed; secondly, the diameter of the yarn; and thirdly, the weave or weaves.

Respecting the characteristics of the yarns employed, little further need be said after the particulars given in Chapter II., but, in the following pages the other two influences are briefly explained.

Diameters of Yarns.—These may be ascertained by finding the yards per lb. in the counts under consideration and extracting the square root. A deduction from this of 16 per cent for woollen, 14 per cent for crossbred worsted, 10 per cent for botany worsted, and 8 per cent in the case of cotton and silk yarns, will give the most approximate results.

Example.—A 40's worsted yarn gives the following result:—

$40 \times 560 = 22{,}400$ yds. per lb. and

$\sqrt{22{,}400} = 149 - 10$ per cent $= 135$ diam., i.e. $\frac{1}{135}$th part of an inch.

Another method of ascertaining the diameters of yarns is to cut a space out of a piece of cardboard, as shown in Fig. 28 exactly 1 in., and wrap the yarn round this, laying each thread close to its predecessor. The diameter of the yarn is thus obtained, and, further than this, it is possible to work as it were backwards and obtain, very approximately, the counts of the yarn.

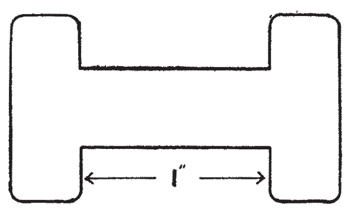

FIG. 28.—For ascertaining yarn diameters.

From the foregoing it is evident that the square root of any counts, *not the counts*, is in direct proportion to the diameter, so that should it be desired to find the diameter of one yarn from another, direct proportion may be employed, using the square root of the counts (or, what amounts to the same thing, squaring the whole equation).

TABLE IX.—COMPARISON OF YARN COUNTS WITH THEIR DIAMETERS.

Diameter.	Worsted.	Cotton.	Woollen Yorkshire skein.	Diameter.	Worsted.	Cotton.	Woollen Yorkshire skein.
48	4	2·6	18¼	142	36	24	78¾
53	5	3·3	11	144	37	24·6	80¾
58	6	4	13	146	38	25·3	83
63	7	4·6	15¼	148	39	26	85¾
67	8	5·3	17½	150	40	26·6	87½
71	9	6	19¾	152	41	27·3	89
75	10	6·6	21¾	153	42	28	90½
79	11	7·3	24	155	43	28·6	93¾
82	12	8	26¼	157	44	29·3	96¼
86	13	8·6	28½	158	45	30	98½
89	14	9·3	30½	160	46	30·6	100½
92	15	10	32¾	162	47	31·3	102¾
95	16	10·6	35	164	48	32	105
98	17	11·3	37¼	165	49	32·6	107¼
101	18	12	39½	167	50	33·3	109½
103	19	12·6	41½	169	51	34	111½
106	20	13·3	43¾	171	52	34·6	113½
109	21	14	45¼	172	53	35·3	115¾
111	22	14·6	48	174	54	36	118
114	23	15·3	50¼	175	55	36·6	120½
116	24	16	52½	177	56	37·3	122½
119	25	16·6	54¾	178	57	38	124¾
121	26	17·3	56¾	180	58	38·6	126¾
123	27	18	59	181	59	39·3	129
126	28	18·6	61¼	183	60	40	131¼
128	29	19·3	63½	185	61	40·6	133½
130	30	20	65½	186	62	41·3	135½
132	31	20·6	67¾	187	63	42	137¾
134	32	21·3	70	189	64	42·6	140
136	33	22	72	191	65	43·3	142¼
138	34	22·6	74¼	192	66	44	144¼
140	35	23·3	76½	193	67	44·6	146½

Example.—If a 40's yarn has a diameter of 135, what is the diameter of a 20's yarn?

$$\text{As } \sqrt{40} : \sqrt{20} : : 135 : 95 \text{ diameter of 20's,}$$

i.e. As $\sqrt{(40\ 560)} : \sqrt{(20 \times 560)} : : 135 : 95$ diameter of 20's, or

$$\text{As } 40 : 20 : 135^2 : x^2 = 95 \text{ diameter of 20's worsted.}$$

These rules apply to every system of counting yarns, but it should be remembered that the results obtained are only approximate: they may be affected in some degree by material or structure, and many other influences. Still, the designer need not fear making these the basis of his calculations, and introducing such slight modifications as experience and reason suggest.

The Weave.—In considering the influence of weave on the sett of a cloth two questions at once present themselves—firstly, is the diameter of yarn modified at all in weaving? and secondly, in any given weave is it possible to ascertain the precise influence of the bending of warp and weft on the sett? Respecting the diameters of yarns the only further remark called for is that common sense is a most necessary adjunct in the application of the rules respecting the diameters of yarns; particularly is this so in the case of woollen yarns.

Class of material, soft or hard twist, old or new spun yarns are a few of the most notable modifying influences, but notwithstanding this, the diameters of yarns as given may within reason be made the basis of all calculations for setts.

Classification of Weave.—The influence of weave upon the relative bending of the warp and weft and consequently upon the

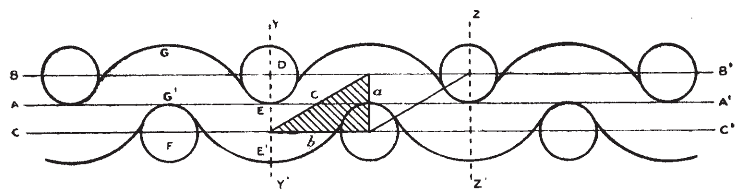

FIG. 29.—Ordinary fabric, section: plain weave.

sett, is most remarkable, and here, as in the case of the diameters, experience is most necessary, although it is now a recognized fact that this matter may be dealt with on scientific principles.

All cloths, as previously shown, may be classed under one of three heads, viz. cloths woven on the square; weft rib cloths, in which the warp lies straight and the weft does all the bending; and warp-rib cloths, in which the weft lies straight and the warp does all the bending. The influence of the weave on the sett in each of these cases must now be considered.

Cloths Woven on the Square.—In cloths woven on the square, i.e. an equal number of threads and picks—if warp and weft are approximately the same counts, as is usually the case, the threads and picks will do an equal amount of bending, as represented in Fig. 29. Now a glance at this diagram shows that the warp threads D, F are separated from each other by the picks, so that taking both warp and weft to have a diameter of, say $\frac{1}{80}$th of an inch (i.e. 80 threads can be laid side by side in 1 in.), only 40 threads can be used, since there will be 40 intersections or units of space occupied by the weft.

The following rule may be made the basis for ascertaining the approximate sett required for any weave :—

Rule.—1. Ascertain the number of units (i.e. threads and intersections) the given plan contains.

2. Divide the number of units as obtained in (1) into the diameter of the yarn to be used, thus obtaining the number of repeats of the plan in 1 in.

3. Multiply (2) by the threads in the given plan, thus obtaining the threads per inch.

Example.—Required the ends per inch to use with the 3/3 twill (Fig. 30). Counts of warp and weft :—

32's worsteds = $\frac{1}{120}$th of an inch diameter.

1. 6 threads + 2 intersections give 8 units in one repeat of 3/3 twill.

2. 120 (diameter of thread) ÷ 8 = 15 repeats of 3/3 twill in 1 in.

3. 15 × 6 = 90 ends per inch to use, the other 30 units of space being occupied by weft intersections.

This is a very simple method, and gives fairly approximate results, but in some classes of goods, particularly lustre dress fabrics, greater accuracy is necessary. The late Mr. T. R. Ashenhurst was the first to point out that the essential condition for the most lustrous effect is that the weft shall make with the warp an angle of 60°, and in the appendix of his work entitled "Textile Calculations and the Structure of Fabrics," shows his application of this theory. The following deductions, however, differ from his to some extent :—

Taking Fig. 29 again as our example, observe in the first place that although the threads are undoubtedly distant from one another by the full diameter of the weft yarn, yet *horizontally* they are not distant from each other the full diameter of the weft.

Construction.—*1st.* Draw A, A′ representing the base line or centre of the cloth ; then warp and weft being equal in thickness and flexibility, will be bent equally out of the straight line, i.e. above and below this line A, A′.

2nd. At a distance ½ the diameter of warp (or weft) from A, A′, rule in lines B, B′, C, C′, representing the centres of the warp threads (or weft picks) in their highest and lowest position respectively.

3rd. Take any convenient position on B and with radius $\frac{1}{2}$ diameter of yarn, describe circle D, representing the highest position of the warp threads.

4th. With radius $\frac{1}{2}$ diameter of yarn $\times$ 3, describe circle E′, representing the bending influence of thread D upon the outer edge of weft, and E for the inner edge of weft.

5th. With $\frac{1}{2}$ diameter of warp (or weft) and upon C, C′, but tangential to E, describe circle F, representing the lowest position of the warp threads.

6th. With radius $\frac{1}{2}$ diameter of yarn $\times$ 3, describe circle G, representing the bending influence of thread F, upon the outer edge of weft and G′ for the inner edge of the weft.

7th. The weft will take the direction compounded of the action of the two spheres of influence D and F and the average angle of the weft with A, A′ will be 30° (or with the known side of triangle 60°).

TO DECIDE THE "SET" OR DISTANCE APART OF THE WARP THREADS.

Construction.—Drop perpendiculars Y, Y′ and Z, Z′ through the centres of the warp threads D and F forming triangle a, b, c, of which a is the known side.

Calculation.—As $a = \frac{1}{2}$ warp $+ \frac{1}{2}$ weft $= 1$.

$\therefore c = 2$ and $a^2 + b^2 = c^2$ (Euclid, Prop. 47).

$\therefore 1^2 + b^2 = 2^2$ or $1 + b^2 = 4$,

i.e. $b^2 = 4 - 1 = 3$ and $\sqrt{3} = 1 \cdot 732$.

That is one repeat of plain weave will occupy 1·732 units of space $\times$ 2.

Example 1.—A 2/40's yarn has a diameter of $\frac{1}{95}$. Find the number of ends per inch for plain.

Then $\frac{1}{95} \times 1{\cdot}732 \times 2 = 95 \div (1{\cdot}732 \times 2) = 27\frac{1}{2}$ repeats, or 55 threads per inch in the finished cloth.

Should the previous rule be adhered to, $95 \div 2 = 47\frac{1}{2}$ ends per inch only would be employed, so that there is evidently a considerable difference in the case of the plain weave. A rough approximation is that the last method is for the finished cloth and the first for the cloth in the loom.

Another example may be taken to show the application to other weaves.

Example 2.—A 32's worsted $= \frac{1}{120}$th part of an inch in diameter. Find the number of ends per inch to use with the 3/3 twill.

As shown in Fig 30, in the 3/3 twill, there are 2 triangles $+ 4$ diameters of the yarn in a repeat.

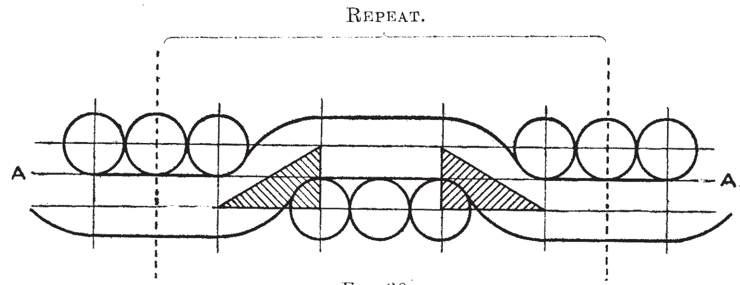

FIG. 30.

Therefore $4 + (2 \times 1{\cdot}732) = 7{\cdot}464$ units of space in the repeat of the weave, and $\frac{1}{120} \times 7{\cdot}464 = 120 \div 7{\cdot}464 = 16$ repeats of twill, and 16×6 (threads in repeat of weave) $= 96$ ends per inch in the finished cloth.

Here owing to the few intersections, there is not such a marked difference between this and the result previously obtained, as in the case of plain weave.

Weft-rib Cloths.—Weft-rib cloths must be treated in a different manner to the foregoing. As shown in Fig. 31 the warp

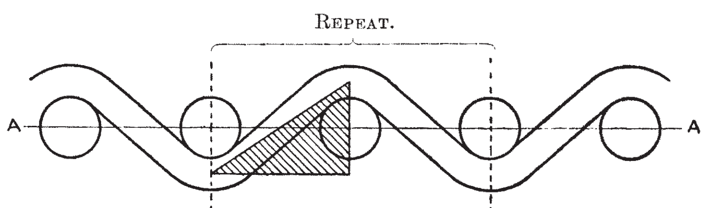

FIG. 31.

lies straight and the weft does all the bending. Therefore, the weft picks may lie close to one another, while each group of threads will be separated by at least the diameter of the weft.

Example.—In plain cloth, the picks per inch to use will be, with a 2/40's yarn with $\frac{1}{95}$th part of an inch diameter, 95, while the threads per inch will be $95 \div 2 = 47$, provided the angle of $30°$ is omitted from the calculation. If the angle of $30°$ be taken into account, then the altitude of the triangle formed, as shown in Fig. 31 = the diameter of both warp and weft, thus the threads per inch will be :—

$(\frac{1}{95} + \frac{1}{95}) \times 1{\cdot}732 = 47 \div 1{\cdot}732 = 27$ threads per inch and 95 picks per inch.

Now these are theoretical conditions, since the warp and weft would at least bend equally during weaving, being the same counts, but a thick warp and thin weft would fulfil these conditions.

Example.—In a French cashmere made as follows :—

Warp.

All 56's botany.
64 threads per inch.

Weft.

All 92's botany.
Picks according to quality.

Taking the warp threads to be quite straight, the following result is obtained. Since 56's botany has a diameter of $\frac{1}{159}$th part of an inch and 92's botany $\frac{1}{205}$th part of an inch, the altitude of the triangle will be :—

$\frac{1}{159} + \frac{1}{205} = \frac{1}{89}$ and $\frac{1}{89} \times 1{\cdot}732 = 89 \div 1{\cdot}732 = \frac{1}{52}$ of an inch for base of triangle.

Then, since the repeat of the cashmere twill contains two triangles and one thread, as shown in Fig. 32—

$(\frac{1}{52} \times \frac{1}{52}) + \frac{1}{159} = \frac{1}{26} + \frac{1}{159} = \frac{159+26}{4134} = \frac{185}{4134} = \frac{1}{22}$ of an inch.

for each repeat of twill, and since each twill contains three threads $22 \times 3 = 66$ threads per inch.

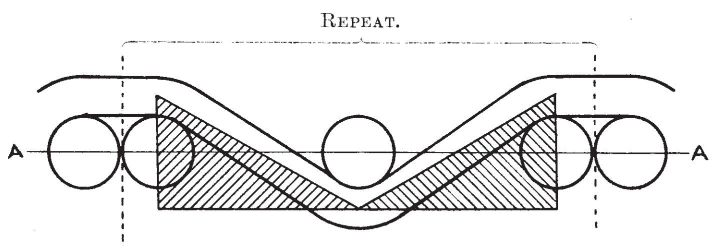

FIG. 32.

This is supposing the warp to lie quite straight, which it does not, as will be seen on referring to the micro-photograph of a thread and pick from a cashmere cloth given in Fig. 50, consequently it may be taken for granted that a few threads should be added to the above for this deflection in the warp. Now, if the warp and weft did an equal amount of bending, the following would be the result :—