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TEXTILE CALCULATIONS

INSTRUCTION PAPER

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TEXTILE CALCULATIONS.

SIZES OF YARNS—NUMBERING.

The sizes of yarns are designated by the terms *cut*, *run*, *hank*, *count*, *skein*, *dram*, *grain*, *etc.*, all of which are based upon two elementary principles, *i.e.*, weight and length. Each term represents a certain length of yarn for a fixed weight, or *vice versa;* but unfortunately there are different standards of weights and measures, which results in a great deal of confusion. The largest variety of terms is found in the woolen industry. In the United States we have woolen cut, run, grain, etc., when all may be reduced to a common basis. There is no doubt that the adoption of an international standard would benefit the textile industry, but which standard to adopt is a question on which manufacturers disagree.

A simple method would be 1,000 metres as the unit of length, to be called count or number, and the number of units which weigh one kilogram to represent the counts or number of yarn. By this method the counts of the yarn would always show at a glance the number of metres per gram, as

No. 1— 1,000 metres = 1 kg.
No. 2— 2,000 metres = 1 kg.
No. 2½—2,500 metres = 1 kg.

WOOLEN COUNTS.

The simplest method in use at present is the one used in the New England States, in which No. 1 woolen yarn represents 100 yards to the ounce, or 1,600 yards to the pound, as a standard. The number of the yarn is the number of yards contained in one ounce, divided by 100. The yarn is spoken of as so many hundred yards to the ounce. Thus,

No. 4 = 400 yards to 1 ounce.
No. 4½ = 450 yards to 1 ounce.
No. 5 = 500 yards to 1 ounce.
No. 5⅛ = 512.5 yards to 1 ounce.

A comparison of Troy and Avoirdupois weights may be made by the following tables. The Avoirdupois table should be committed to memory, as it is used very extensively in Textile Calculations.

AVOIRDUPOIS WEIGHT.

437.5	grains (gr.)	= 1 ounce (oz.)
16	drams (dr.)	= 1 ounce.
7,000	grains	= 1 pound (lb.)
16	ounces	= 1 pound.
100	pounds	= 1 hundredweight (cwt.)
20	hundredweight	= 1 ton (t.)

NOTE.—25 pounds are sometimes called a quarter.

TROY WEIGHT.

24	grains (gr.)	= 1 pennyweight (pwt.)
20	pennyweights	= 1 ounce (oz.)
5,760	grains	= 1 pound (lb.)
12	ounces	= 1 pound.

It is necessary to familiarize one's self with the standard numbers of the various yarns; also, as in the case of woolen yarns, where different standard numbers are used for the various terms, it is well to be familiar with the standard number of each term, as by this means a great deal of confusion will be avoided.

TABLE OF RELATIVE COUNTS OF YARN.

Yarn.	Size.	Standard Number.
Woolen	No. 1 run	= 1,600 yards per lb.
"	No. 1 cut	= 300 " " "
"	No. 1 skein	= 256 " " "
Worsted	No. 1 count	= 560 " " "
Cotton	No. 1 count	= 840 " " "
Linen	No. 1 lea	= 300 " " "
Spun silk	No. 1 count	= 840 " " "

Such fibres as linen, jute, hemp and ramie fibre are usually figured by the lea of 300 yards to the pound. In the grain system the weight in grains of 20 yards designates the counts. Thus, if 20 yards weigh 20, 25, or 30 grains the counts would be No. 20, No. 25 or No. 30 grain yarn respectively.

SILK COUNTS.

Spun Silk is based upon the same system as cotton, *i.e.*, hank of 840 yards, and the number of such hanks which weigh one pound denotes the counts.

NOTE.—Silk that has been re-manufactured or re-spun is called spun silk.

Dram Silk. The system adopted in the United States for specifying the size of silk is based on the weight in drams of a skein containing 1,000 yards. Thus a skein which weighs 5 drams is technically called 5-dram silk. The number of yards of 1-dram silk in a pound must accordingly be $16 \times 16 \times 1{,}000$ or 256,000.

NOTE.—1,000 is multiplied by (16×16) because there are 16 drams in one ounce and 16 ounces in one pound.

Tram Silk is based on a system in which 20,000 yards per ounce is used as a standard.

WORSTED COUNTS.

This system is based upon the hank of 560 yards, the counts being determined by the number of such hanks contained in one pound of yarn.

No. 1 = 560 yards in 1 pound.
No. 2 = 1,120 yards in 1 pound.
No. 3 = 1,680 yards in 1 pound.

COTTON COUNTS.

Cotton is based upon the hank of 840 yards, and the number of such hanks which weigh one pound denotes the counts. The following tables are used when calculating cotton yarns:

1½ yards = the circumference of reel, or 1 wrap.
120 yards = 1 lea or 80 wraps of the reel.
840 yards = 7 leas or 1 hank.

No. 1 cotton = 840 yards in 1 pound.
No. 2 cotton = 1,680 yards in 1 pound.
No. 3 cotton = 2,520 yards in 1 pound.

Linen and Similar Fibres such as *jute*, *hemp*, *ramie fibre*, and *China grass* are numbered by using as a base the lea of 300 yards; the number of such leas which weigh one pound being the counts.

No. 1 = 300 yards in 1 pound.
No. 2 = 600 yards in 1 pound.
No. 3 = 900 yards in 1 pound.

English Woolen or Skein System.—This system is based upon the skein of 256 yards, the number of such skeins which weigh one pound being the counts. In England the yarn is spoken of as so many yards to the dram, or so many skeins, which is the same thing when referring to its size. Thus 6 skeins or 6 yards to the dram; 10 skeins or 10 yards to the dram.

No. 1 = 256 yards to the pound.
No. 2 = 512 yards to the pound.
No. 3 = 768 yards to the pound.

The standard weight is one dram, and the number of yards to that weight is regulated according to requirements.

The Philadelphia or Cut System is based upon the cut of 300 yards, the number of such hanks which weigh one pound denoting the counts.

No. 1 = 300 yards to the pound.
No. 2 = 600 yards to the pound.
No. 3 = 900 yards to the pound.

Rule 1. To find the yards per pound of any given counts of woolen run, woolen cut, worsted, cotton, linen, and spun silk. Multiply the standard number by the given counts.

Example. How many yards per pound in No. 15 cotton, 3 run woolen, No. 20 worsted? No. 15 cotton, $840 \times 15 = 12{,}600$ yards. 3 run woolen, $1{,}600 \times 3 = 4{,}800$ yards. No. 20 worsted, $560 \times 20 = 11{,}200$ yards.

Rule 2. To find the weight of any number of yards of a given counts, the number of yards being given. Divide the given number of yards by the counts × the standard number.

Example. What is the weight of 107,520 yards of No. 32 cotton?

$$107{,}520 \div (32 \times 840) = 4 \text{ pounds.}$$

Find the weight of 12,400 yards of 30's worsted, 11,960 yards of 20 lea linen, and 7,200 yards of $4\frac{1}{2}$ run woolen.

Rule 3. It is often necessary to know the weight in ounces of a small number of yards. Multiply the given number of yards by 16, and divide by the counts × the standard number.

Example. What is the weight in ounces of 2,800 yards of No. 20 worsted?

$$(2{,}800 \times 16) \div (20 \times 560) = 4 \text{ ozs.}$$

The woolen-run system is the most simple of all textile yarn calculations, as 100 yards per ounce = No. 1 run.

Rule 4. To find the weight in ounces of a given number of woolen-run yarn. Add two ciphers to the counts and divide into the given number of yards.

Example. What is the weight of 2,700 yards of 2-run woolen?

$$2{,}700 \div 200 = 13.5 \text{ ozs.}$$

Rule 5. Grain System. To find the counts of a woolen thread, the number of yards and weight being known. (The weight in grains which 20 yards weigh designates the counts.) Multiply the given weight by grains in 1 lb. and by 20 yards, and divide by the given number of yards of yarn.

Example. What is the counts of 28,000 yards which weigh 4 pounds?

$$\frac{4 \times 7{,}000 \times 20}{28{,}000} = 20 \text{ grains per 20 yards.}$$

20's counts. Ans.

EXAMPLES FOR PRACTICE.

1. How many yards of yarn in 1 lb. of each of the following numbers: No. 23 cotton, No. 5 run woolen, No. 32 worsted, No. 22 lea linen, No. 25 spun silk?

2. Obtain the counts of the following yarns: 12,600 yards cotton = 1 lb.; 11,200 yards worsted = 1 lb.; 12,000 yards linen = 1 lb.; 13,440 yards spun silk = 1 lb.

3. How many yards per pound in 4 dram silk, 5 dram silk, and 3 dram silk?

4. Woolen grain system. How many yards per pound in 7 grain woolen, and 5 grain woolen?

5. If 16,800 yards of yarn weigh 1 pound, what counts would represent this length and weight in worsted, cotton, and woolen?

6. The weight of 1,680 yards of worsted is 3 ounces. What is the counts?

7. Find the respective weights of 800 yards, 4,200 yards, and 6,300 yards of (*a*) 4-run woolen, (*b*) No. 30 worsted, (*c*) No. 30 cotton.

8. What is the weight of 4,200 yards of 30's cotton; 3,600 yards of 32's worsted; 1,850 yards of $2\frac{1}{2}$ woolen?

9. What is the weight of 1,840 yards of $3\frac{1}{4}$ run woolen yarn, 2,100 yards of $4\frac{1}{2}$ run, 3,640 yards of $3\frac{1}{2}$ run?

10. Find the cotton counts of these yarns: 14,000 yards weigh $3\frac{1}{2}$ pounds; 37,620 yards weigh $4\frac{1}{4}$ pounds; 29,640 yards weigh 4 pounds.

NOTE.—The terms count, counts, number, numbers, etc., are used when speaking of the size of yarn. They are written in various ways, for instance, No. 1 counts, 1's, No. 1's, and No. 1. All represent the same thing.

METRIC MEASUREMENTS AND WEIGHTS.

Linear Measure.

		1 millimeter	(mm.)
10 millimeters	=	1 centimeter	(cm.)
10 centimeters	=	1 decimeter	(dm.)
10 decimeters	=	1 meter	(m.)
10 meters	=	1 decameter	(decam.)
10 decameters	=	1 hectometer	(hm.)
10 hectometers	=	1 kilometer	(km.)

Measures of Weight.

		1 milligram	(mg.)
10 milligrams	=	1 centigram	(cg.)
10 centigrams	=	1 decigram	(dg.)
10 decigrams	=	1 gram	(g.)
10 grams	=	1 decagram	(decag.)
10 decagrams	=	1 hectogram	(hg.)
10 hecograms	=	1 kilogram	(kg.)

The Continental method for worsted is based upon 1,000 metres per kilogram, *e.g.*, No. 1 counts contains $1{,}000 \times 1$ metre. No. 2 counts contains $1{,}000 \times 2$ metres. No. 3 counts contains $1{,}000 \times 3$ metres, etc.

TABLE OF EQUIVALENTS.

1 dm.	=	3.937 inches.
1 dm.	=	15.4999 inches.
1 oz.	=	28.35 grams.
1 oz.	=	437.5 grains.
1 gram	=	15.432 grains.
1 kg.	=	2.2046 pounds or 15432.2 grains.
1 m.	=	1.094 yards.
1 m.	=	39.37 inches.
1,000 m.	=	1 kg. or 2.2046 pounds worsted yarn.
1,000 m.	=	1,094 yards.

In the metric system, woolen counts are based on the same principle as worsted counts, that is, 1,000 metres of No. 1 woolen weigh 1 kg. or 1,000 grams. This also applies to cotton, linen, silk, jute, etc.

It will be seen from this that the metric system possesses a great advantage over the many varied systems now in use, inasmuch that it is simpler in calculations, decimals doing away with the more complicated fractions of the English system (such as $\frac{5}{8}$, $\frac{13}{16}$, $\frac{27}{32}$, $\frac{39}{64}$, etc.), and the uniformity of difference between kilograms, hectograms, decagrams, etc., is simpler than the complex system of tons, hundred-weights, pounds, ounces, drams, and grains.

To reduce kilograms to grams, it is only necessary to multiply the given number by 1,000, while to reduce from pounds to drams in English the given number must be multiplied by 16×16. With metric numbers the difference may be easily computed. Taking 2.25 kg. of yarn and wishing to find the weight in grams, the following simple process is all that is required:

$$2.25 \times 1{,}000 = 2{,}250 \text{ grams.}$$

This weight represents approximately 4 pounds 8 ounces, and wishing to find the weight in drams the following complicated equation is necessary:

$$4\tfrac{1}{2} \times 16 \times 16 = \text{drams.}$$

Another advantage of the metric system is that while a No. 1 in the English system equals 1,600 yards woolen, 560 yards worsted, 840 yards cotton, 300 yards linen, etc., to the pound, in the metric system a No. 1 count has 1,000 metres to the kilogram in every variety of yarn, which gives a simple basis of comparison between the yarns.

THROWN SILK.

The Continental Europe system of numbering thrown silk is based upon the hank of 400 French ells. The skein or hank is 476 metres, or 520 yards, and the weight of this hank in deniers denotes the counts.

533.33 deniers equal 1 ounce.

If 1 hank of the above length weighs 10 deniers, the counts equal No. 10 denier.

Approximately No. 1 denier $= 533\frac{1}{3} \times 520 = 277{,}333$ yards per ounce.

No. 40 denier = $(533\frac{1}{3}\times520)\div40 = 6{,}933\frac{1}{3}$ yards per ounce.
No. 60 denier = $(533\frac{1}{3}\times520)\div60 = 4{,}622\frac{2}{3}$ yards per ounce.

CHANGING THE COUNTS OF YARNS.

The three great fibres, wool, worsted, and cotton, are mixed to a large extent. There are goods composed of woolen filling and cotton warp, worsted filling and cotton warp, woolen and worsted filling combined with cotton warp, and also woolen and worsted warps combined with cotton and woolen fillings; so it is important that the calculations pertaining to each should be thoroughly understood. The calculations in this work are directed towards these requirements. There are shorter methods of calculation which may be used by those fully conversant with the various particulars concerning textile manufactures, but it matters little which system is used if it is simple and reliable.

Changing the Counts of one System of Yarn into the Equivalent Counts of Another System of Yarn.

Rule 6. To change cotton counts into woolen runs. Multiply 840 by the known cotton counts and divide by 1,600, the standard yards per pound of No. 1 run woolen.

Example. What is the size of a woolen thread equivalent to a 20's cotton?

$$(20\times840)\div1{,}600 = 10\tfrac{1}{2}\text{ run woolen.}$$

Rule 7. To change cotton counts into worsted counts. Multiply 840 by the known cotton counts, and divide by 560, the standard yards per pound of No. 1 worsted counts.

Example. What is the equivalent in a worsted thread to a 30's cotton?

$$(30\times840)\div560 = 45\text{'s worsted.}$$

Rule 8. To change woolen runs into worsted counts. Multiply 1,600 by the known woolen runs, and divide by 560, the standard yards per pound of No. 1 worsted counts.

Example. What is the equivalent in a worsted thread to a 7 run woolen?

$$(7\times1{,}600)\div560 = 20\text{'s worsted.}$$

Rule 9. To change woolen runs, worsted counts, and cotton counts into their equivalents in linen or Philadelphia cuts. Multiply by the woolen, worsted, or cotton standard, and divide by 300, the standard number of yards which equals 1 lea linen and 1 cut woolen.

Example. What are the equivalents in linen counts to a 3 run woolen, 20's worsted, and 24's cotton?

$$(3 \times 1{,}600) \div 300 = 16 \text{ lea linen.}$$

Rule 10. To change woolen, worsted, linen, or cotton counts to their equivalents in the grain system. Multiply 7,000 grains by 20 (the yards representing the grain standard) and divide by the standard of the other yarn.

Example. What is the equivalent in the grain system to a 20's cotton?

$$\frac{7{,}000 \times 20}{20 \times 840} = 8.33 \text{ counts.}$$

What is the equivalent in the grain system of the following yarns, 24's worsted, 4 run woolen, 16 lea linen?

Rule 11. To change woolen, worsted, linen, or cotton counts to their equivalents in the dram system. Multiply the given weight by drams per pound and by the yards in one dram, then divide by the given length of yarn.

Example. What is the equivalent in the dram system to a No. 30 cotton?

$$\frac{1 \times 256 \times 1{,}000}{30 \times 840} = 10.15.$$

Find the equivalent in the dram system to 24's cotton, $4\frac{1}{4}$ run woolen, 30's worsted.

Rule 12. To change woolen, worsted, linen, and cotton counts to their equivalents in the denier system. Multiply the yards in one hank (520), deniers in one ounce ($533\frac{1}{3}$), and ounces in 1 pound (16) together and divide the product by the length of 1 pound of yarn of the known counts.

Example. What is the equivalent in the denier system to a 30's worsted?

$$\frac{520 \times 533\frac{1}{3} \times 16}{30 \times 560} = 264.12 \text{ denier yarn.}$$

Rule 13. To change metric counts to English counts. The number of metres in one kilogram (1,000) multiplied by the number of inches in one metre (39.37) will give the total number of inches. This divided by the inches in one yard (36) will give the total number of yards, and again divided by the weight of 1 km.×the standard number will give the English counts, or constant.

Solution:

$$\frac{1{,}000\times 39.37}{36\times 560\times 2.205} = .885 \text{ worsted count.}$$

$$\frac{1{,}000\times 39.37}{36\times 840\times 2.205} = .590 \text{ cotton and spun silk constant.}$$

$$\frac{1{,}000\times 39.37}{36\times 1{,}600\times 2.205} = .3099, \text{ say } .31, \text{ woolen constant.}$$

$$\frac{1{,}000\times 39.37}{36\times 300\times 2.205} = 1.653 \text{ linen and woolen cut constant.}$$

The English	.885	is equal to a No. 1	metric	worsted.
" "	.590	" " " " No. 1	"	cotton or spun silk.
" "	.310	" " " " No 1	"	woolen.
" "	1.653	" " " " No. 1	"	linen, etc.

Proof

1 metre = 1.094 yards. 1 kilogram = 2.205 pounds.
1,000 metres No. 1 = 1 kilogram = 2.205 pounds.
1,000 metres = 1,094 yards.
1,094 ÷ 2.205 = 496.1 yards per pound.
496.1 ÷ 560 = .885 worsted constant.
496.1 ÷ 840 = .590 cotton "
496.1 ÷ 1,600 = .310 woolen "
496.1 ÷ 300 = 1.653 linen "

Rule 14. The English count divided by the constant will give the metric count.

Example. English 20's cotton÷.590=33.89 metric cotton counts.

Find the metric counts of 24's worsted, 6 run woolen, and 18 lea linen.

Rule 15. The metric count multiplied by the constant will give the English count.

.310×20 metric woolen = 6.2 run woolen.

Find the counts in English of the following metric counts: 23.6 cotton, 28.2 worsted, and 16 woolen.

TWISTED, PLY, AND COMPOUND YARNS.

Yarns spun from different fibers are frequently twisted together for decorative purposes, and also for strength, *e.g.*, silk to cotton, worsted to woolen, etc. As yarns may be spun in one place and consigned for use in localities where different systems of numbering yarns are in use, it is necessary to change any given number into the equivalent count of some other denomination.

Worsted and cotton yarns are usually numbered according to the count of the single yarn, with the number of ply, threads, or folds, placed at the left, or before it. Thus 2–40's cotton yarn indicates that the yarn is composed of two threads of 40's single, making a two-fold or two-ply yarn of 20 hanks to the pound, and must be considered as representing 20 times 840 yards; but when written 40's or 1–40's it represents 40 hanks or 40 times 840 yards to the pound.

Spun silk yarns are generally two or more ply, and the number of the yarn always indicates the number of hanks in one pound. The number of ply is usually written after the hanks per pound. Thus 60–2 or 60's–2 spun silk indicates that the yarn is 60 hanks to the pound composed of two threads of other counts.

Two-ply woolen yarns are usually designated "Double and Twist" yarns, thus, 6 run black and white "D & T" would mean that one black thread of 6 run and one white thread of 6 run have been doubled and twisted, and represent a thread which is equivalent to a 3 run minus the take-up.

When two or more single threads are twisted together, the result is a heavier yarn. It is necessary then to find the number of hanks or skeins per pound of the combined thread, but it must be understood that two threads, 20 yards long, twisted together will be much shorter than the original two threads. This can be proved by twisting together two threads of a given length, weighing them, and again measuring the twisted thread, or by obtaining two threads of the original yarn of the exact length of the twisted yarn and comparing their weights. This process is known as *finding the equivalent or resultant counts.*

Ply yarns composed of threads of equal counts. The new count is found by dividing the given counts by the number of ply or threads twisted together, 2-ply 60's = No. 30, written 2–60's;

3-ply 60's = No. 20, written 3–60's; 4-ply 60's = No. 15, written 4-60's.

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

It frequently occurs in fancy novelty yarns that threads of *unequal size* are twisted together. If a No. 60 thread and a No. 40 thread are twisted together, the count of the doubled thread will not be the same as if two threads of No. 50 have been twisted. For instance, when 60 hanks of 60's worsted are used 60 hanks of 40's worsted will also be used, and when these have been twisted together there are still only 60 hanks, but 60 hanks of the former count weigh one pound, while 60 hanks of the latter weigh $1\frac{1}{2}$ pounds, consequently the 60 hanks of twisted threads equal 2.5 pounds.

Rule 16. The product of the given counts divided by their sum, gives the new count of twisted yarn.

$$\frac{60 \times 40}{60+40} = \frac{2{,}400}{100} = \text{No. 24 worsted.}$$

Some allowance must be made for take-up or contraction in twisting, but this will vary with the number of turns of twist per inch in the yarn and the diameter of the threads.

Take-up, contraction, and shrinkages are not considered in these examples.

Rule 17. When three or more unequal threads are twisted together, the counts of the resulting twist thread is found by dividing the highest count by itself and each of the given counts in succession; the quotient in each case representing the proportionate weight of each thread. Then dividing the highest counts by the sum of the quotients, the answer will be the new counts.

Example. Find the counts of a 3-ply thread composed of one thread each of 20's, 30's, and 60's cotton.

$$\begin{aligned} 60 \div 60 &= 1 \\ 60 \div 30 &= 2 \qquad 60 \div 6 = 10\text{'s, count of 3-ply cotton thread.} \\ 60 \div 20 &= \underline{3} \\ & \quad\; 6 \end{aligned}$$

Find the counts of a 3-ply thread composed of one thread each of 120's, 60's, and 40's cotton.

Compound Thread Composed of Different Materials. It is obvious that when threads composed of different materials are twisted together it is necessary to first reduce all to the denomination of the yarn system in which it is required.

Suppose a compound twist thread is made up of one thread of 24's black worsted, one thread 16's red cotton, and one thread 8's green cotton. Find the equivalent counts in worsted as follows:

$$840 \times 16 = 13{,}440 \div 560 = 24 \text{ worsted.}$$
$$840 \times 8 = 6{,}720 \div 560 = 12 \quad \text{"}$$

$24 \div 24 = 1$
$24 \div 24 = 1$ $\quad 24 \div 4 = 6$'s, counts of 3-ply thread in worsted.
$24 \div 12 = 2$
$\quad\quad\quad\quad\; 4$

What is the equivalent in a single woolen thread of a 3-ply yarn composed of 10.5 run woolen, 20's cotton, and 30's worsted?

$$840 \times 20 = 16{,}800 \div 1{,}600 = 10.5.$$
$$560 \times 30 = 16{,}800 \div 1{,}600 = 10.5.$$
$$10.5 \div 3 = 3.5 \text{ run woolen.}$$

EXAMPLES FOR PRACTICE.

1. If a thread of 20's and a thread of 40's single worsted be twisted together, what is the resultant counts?

2. What is the resultant counts (*a*) of 30's and 60's cotton twisted together, (*b*) of 30 lea and 60 lea linen twisted together, and (*c*) of 30's and 60's worsted twisted together?

3. A 3-ply thread is made by twisting the following yarns: one thread $10\frac{1}{2}$ run woolen, one thread 30's worsted, one thread 20's cotton. What would be the equivalent counts of the compound thread in (*a*) single cotton, (*b*) woolen cut, (*c*) single worsted, and (*d*) woolen run?

4. Give the resultant counts of 36's, 45's, and 54's worsted yarn twisted together.

5. How many hanks would there be in 1 pound of 2-ply yarn made by twisting one thread of 32's cotton and one thread 44's cotton together?

6. Given 36 metric cotton counts, find the equivalent counts when twisted with a 60–2 spun silk, the answer to be in cotton counts.

7. What would be the resultant counts in spun silk of 30's worsted, 20–2 spun silk twisted together?

8. Find the equivalent counts of 20's, 32's, and 50's worsted twisted together.

9. A thread is composed of two threads 40's worsted, and one thread 80's–2 spun silk. Find the equivalent counts in cotton.

10. Find the resultant counts of 70's, 60's, 40's, and 20's cotton twisted together.

FANCY AND NOVELTY YARNS.

Novelty yarns, such as knop, spiral, loop, corkscrew, chain, etc., are made from various lengths of threads, and consequently the previous rules will not apply in all cases. If there is no variation in lengths, the same number of hanks will be required of each kind of yarn, but when lengths vary, the counts of the twisted threads will also vary according to the several modifications of take-up in the material used.

For example, if it is desired to make a fancy yarn from three different counts of yarn, say 40's, 30's, and 20's cotton, the take-up in each case being equal, what length and weight of each material is necessary?

Rule 18. First, find the necessary number of pounds of each yarn to give equal length, by dividing the highest counts by itself and the counts of each of the others, the result being the relative weight required of each.

$$
\text{(A)}\qquad
\begin{aligned}
40 \div 40 &= 1 \text{ pound.}\\
40 \div 30 &= 1\tfrac{1}{3} \text{ pounds.}\\
40 \div 20 &= 2 \text{ pounds.}
\end{aligned}
$$

The respective weights of the yarn multiplied by their counts will give the required number of hanks of each.

$$
\text{(B)}\qquad
\begin{aligned}
1 \text{ pound} \times 40 &= 40 \text{ hanks of 40's cotton.}\\
1\tfrac{1}{3} \text{ pounds} \times 30 &= 40 \text{ hanks of 30's cotton.}\\
2 \text{ pounds} \times 20 &= 40 \text{ hanks of 20's cotton.}
\end{aligned}
$$

It is obvious that if a certain length of twist is required the yarns used must be of approximately the same length, whatever the counts, but when the take-up varies, the conditions are more or less complicated.

Suppose a novelty yarn is made by twisting two threads of 40's red cotton, one thread of 30's green cotton, and one thread

No. 30 = 1,050 × 7,000 ÷ 30 × 840 = 291.66 grs.
No. 20 = 840 × 7,000 ÷ 20 × 840 = 350.00 grs.
1,254.16 grs.

Therefore, if one hank of the novelty yarn weighs 1,254.16, the counts will be 7,000 ÷ 1,254.16 = 5.58 counts, the same as given in the above example.

WEIGHT OF MATERIAL TO PRODUCE A GIVEN WEIGHT.

The question of determining the actual quantity of each kind of yarn required to produce a given weight of ply or folded yarn is an important item in textile calculations, and may assume a variety of forms. The simplest form is to assume that the counts of the yarns and the total weight are given, and it is required to find the weight or quantity of each yarn to produce the total weight. For convenience, assume that the counts of the yarns to be twisted together are 30's and 20's respectively, and that the total weight required is 1,000 pounds.

The first step is to ascertain the counts of the folded yarn resulting from this combination, after the manner already described, thus

$$\frac{30 \times 20}{30 + 20} \quad 12\text{'s.}$$

After this the process is quite simple, being a question of proportion, or, as each count in succession is to the count of the folded yarn, so is the total weight to the required weight. To make it clear, the counts of single yarns are 30's and 20's respectively, the folded yarn is 12's, and the total weight 1,000 pounds, then

30 : 12 :: 1,000 : × = 400 pounds of 30's yarn.
20 : 12 :: 1,000 : × = 600 pounds of 20's yarn.

So that the whole is reduced to the simplest possible form.

Rule 19. To find the weight of each material required to produce a given weight of a double and twisted or compound yarn. First ascertain the counts of the two yarns twisted together after the manner laid down in Rule 16, then as each count in succession is to the compound yarn, so is the total weight to the weight required.

Example. What amount of each kind of yarn is required to produce 1,000 pounds of twist yarn made from 60's and 80's cotton?

$$\frac{60 \times 80}{60 + 80} = 34\tfrac{2}{7}$$

$$60 : 34\tfrac{2}{7} :: 1{,}000 = 571\tfrac{3}{7}$$
$$80 : 34\tfrac{2}{7} :: 1{,}000 = 428\tfrac{4}{7}$$
$$\overline{1{,}000}$$

Proof.

$80 \times 840 = 67{,}200$ yards $\times\ 428\tfrac{4}{7} = 28{,}800{,}000$ yards.
$60 \times 840 = 50{,}400$ " $\times\ 571\tfrac{3}{7} = 28{,}800{,}000$ yards.

The following rule is used in many mills:

(*a*) $\dfrac{\text{Given weight} \times \text{lower count}}{\text{Sum of the two counts}} = \text{Weight of the higher count.}$

(*b*) $\dfrac{\text{Given weight} \times \text{higher count}}{\text{Sum of the two counts}} = \text{Weight of lower count.}$

Example. What amount of material will be required for each thread to produce 250 pounds of double and twist yarn made from 32's and 40's worsted ?

$250 \times 32 \div 72 = 111\tfrac{1}{9}$ pounds, weight of higher count.
$250 \times 40 \div 72 = 138\tfrac{8}{9}$ pounds, weight of lower count.

Proof.

$32 \times 560 = 17{,}920 \times 138\tfrac{8}{9} = 2{,}488{,}888\tfrac{8}{9}$ yards.
$40 \times 560 = 22{,}400 \times 111\tfrac{1}{9} = 2{,}488{,}888\tfrac{8}{9}$ yards.

When only two counts are required, the above methods are simple and very useful, but when three or more counts are twisted together, some other method of solution is necessary to find the weight of each material to produce a given weight.

Rule 20. First find the relative weight of each kind of yarn by dividing the highest count by its own number and the other numbers in succession, then multiply the given weight by the relative weight of each count, and divide by the sum of the relative weights. The quotients will be the weights of each kind of yarn.

Example. 533 pounds of twist to be made from 20's, 30's, and 40's; required the weight of each.

$40 \div 40 = 1 \times 533 = 533 \div 4\tfrac{1}{3} = 123$ pounds.
$40 \div 30 = 1^1 \times 533 = 710\tfrac{2}{3} \div 4\tfrac{1}{3} = 164$ pounds.
$40 \div 20 = 2 \times 533 = 1{,}066 \div 4\tfrac{1}{3} = 246$ pounds.
$\overline{4\tfrac{1}{3}}$ $\overline{533}$

Example. 120 pounds of twist is required of 30's, 40's, and 60's worsted. What weight of each count will the compound thread contain?

To Find the Relative Weight of Each Thread in a Compound Yarn When Lengths Vary. By Rule 18, both the resultant counts and the relative weight of the two yarns may be obtained.

Example. A fancy loop yarn is composed of 12's and 60's worsted, 6 inches of the latter being required to 3 inches of the former. What weight of each will be required to produce 200 pounds of twist, and what number of hanks of the loop yarn will weigh 1 pound?

NOTE—The length of 60's is double that of the unit length of 12's.

$$60 + 60 = 120 \div 60 = 2 \text{ pounds.}$$
$$60 + 0 = 60 \div 12 = 5 \text{ ``}$$
$$\overline{7 \text{ pounds.}}$$

or

$$60\text{'s} = 6 \div 3 = 2 \times 60 = 120 \text{ hanks.}$$
$$12\text{'s} = 6 - 6 = 1 \times 60 = 60 \text{ ``}$$
$$120 \div 60 = 2 \text{ pounds of 60's.}$$
$$60 \div 12 = 5 \text{ pounds of 12's.}$$

60 hanks of twist yarn weigh 7 pounds. $60 \div 7 = 8.57$ hanks = 1 pound, using Rule 20 as in previous example.

(*a*) $$\frac{200 \times 2}{7} = 57\tfrac{1}{7} \text{ pounds of 60's.}$$

(*b*) $$\frac{200 \times 5}{7} = 142\tfrac{6}{7} \text{ pounds of 12's.}$$

Example. A loop yarn is composed of 2 threads of 8's worsted and 1 thread of 12's worsted; 21 inches of the former are required to 14 inches of the latter. What weight of each will be required to produce 150 pounds of twist, and what number of hanks per pound will the loop yarn contain?

$$12 + (\tfrac{1}{2} \text{ of } 12) = 18 \div 8 = 2.25 \text{ pounds.}$$
$$12 + (\tfrac{1}{2} \text{ of } 12) = 18 \div 8 = 2.25 \text{ ``}$$
$$12 + 0 = 12 \div 12 = 1. \text{ ``}$$
$$\overline{5.5 \text{ pounds.}}$$

Twelve hanks of loop yarn weigh 5.5 pounds.

$$12 : 5.5 = 2\tfrac{2}{11} \text{ hanks per pounds or loop counts.}$$

and $150 \times 2.25 \div 5.5 = 61\frac{4}{11}$ of 8's worsted.
$150 \times 2.25 \div 5.5 = 61\frac{4}{11}$ of 8's "
$150 \times 1 \div 5.5 = 27\frac{3}{11}$ of 12's "
150 pounds of loop yarn.

To Find the Weight of a Given Yarn to be Twisted With a Yarn, the Weight and Counts Being Known. The problem may now be put in a different way. There may be a given quantity of one of the yarns, and it is required to find what weight will be necessary to twist with it and just use it up. This is obviously the reverse of the above proceeding, and at once resolves itself into a simple proportion, being dependent only upon the relative counts; thus 20's and 30's are to each other as 2 is to 3, and, as the higher number is the lighter yarn, the proportion must be inverse.

Supposing then, that there are 400 pounds of 30's yarn and it is required to find how much 20's would be necessary to twist with it. The problem would be as $20 : 30 :: 400 : \times = 600$. Proof: 600 pounds of 20's would contain $600 \times 20 = 12,000$ hanks, and 400 pounds of 30's would contain 12,000 hanks, so that the length of each would be equal.

Rule 21. Multiply the given weight by its counts and divide by the counts of the required weight and the quotient will be the weight required.

Example. If you have 480 pounds of 30's cotton, what weight of 26's cotton would be required to twist with it to work it all up, and what will be the counts of the resulting twist?

$$480 \times 30 \div 26 = 553\tfrac{11}{13} \text{ pounds.}$$

$$\frac{26 \times 30}{26 + 30} = 13\tfrac{?}{14} \text{ counts.}$$

Proof.

$$480 \times 30 = 14,400 \text{ hanks.}$$

$$553\tfrac{11}{13} \times 26 = 14,400 \text{ hanks.}$$

AVERAGE COUNTS.

When average counts are required, it is assumed that the threads are contiguous in the woven fabric and retain their respective individualities, *e.g.*, when two or more threads of various sizes are used side by side in a fabric. It is frequently necessary to determine the average counts of these threads, that is, the counts which will represent the same weight and length for the combination of several yarns employed in the woven fabric. Suppose a cloth is woven with the pattern as follows: 2 threads of 60's cotton, and 1 thread of 20's cotton. What is the average counts?

Rule 22. Multiply the high count by the number of threads of each count in one repeat of the pattern.

$$60 \times 2 = 120 \text{ hanks.}$$
$$60 \times 1 = 60 \text{ “}$$

Divide each product separately by the given counts.

$$120 \div 60 = 2 \text{ pounds.}$$
$$60 \div 20 = 3 \text{ “}$$
$$\overline{180} \qquad \overline{5} \text{ pounds.}$$

Divide the total number of hanks by the sum of these quotients.

$$180 \div 5 = 36 \text{ average counts.}$$

Rule 23. To find the average counts when any number of threads of different counts are used in the same cloth. Divide the product of the counts by the sum of the unequal counts, then multiply by the number of threads in one repeat of the pattern. The answer is the average counts.

A sample is composed of 1 thread of black 16's cotton, and 1 thread of white 40's cotton. Find the average counts.

$$\frac{40 \times 16 = 640}{16 + 40 = 56} = 11.45 \times 2 = 22.86 \text{ average counts.}$$

The threads are laid side by side in the pattern, and each one retains its individuality, therefore, the average weight of the threads is half that of the compound thread, or the average counts is double the counts of the compound thread.

A pattern is composed of 2 threads of 40's black cotton, and 1 thread of 16's red cotton. Find the average counts.

A sample is composed of 1 thread of black 16's cotton, and 1 thread of white 40's cotton. Find the average counts.

$$\frac{40 \times 16 = 640}{16 + 40 = 56} = 11.43 \times 2 = 22.86 \text{ average counts.}$$

The threads are laid side by side in the pattern, and each one retains its individuality, therefore, the average weight of the threads is half that of the compound thread, or the average counts is double the counts of the compound thread.

A pattern is composed of 2 threads 40's black cotton, and 1 thread 16's red cotton. Find the average counts.

$40 \times 2 = 80$	$80 \div 40 = 2$
$40 \times 1 = 40$	$40 \div 16 = 2.5$
120	4.5

$120 \div 4.5 = 26.66$ average counts.

$40 \div 40 = 1$
$40 \div 40 = 1$
$40 \div 16 = 2.5$
4.5

$40 \div 4.5 = 8.88$ $\quad$ $8.88 \times 3 = 26.64$ average counts.

A pattern is composed of 4 threads of 80's white cotton, 2 threads of 40's black cotton, and 1 thread of 16's red cotton. Find the average counts.

$80 \div 80 = 1 \times 4$ threads $= 4$
$80 \div 40 = 2 \times 2$ threads $= 4$
$80 \div 16 = 5 \times 1$ thread $= 5$
$7 \qquad 13$

$$\frac{80 \times 7}{13} = 43\tfrac{1}{3} \text{ average counts.}$$

Proof. Obtain the weight of one hank of each count given, then the weight of an average hank with the threads of the proportion given, and find what would be the counts of that weight.

1 hank of 80's = 7,000 ÷ 80 = 87.5 grains.
1 hank of 40's = 7,000 ÷ 40 = 175. grains.
1 hank of 16's = 7,000 ÷ 16 = 437.5 grains.

$80 = 87.5 \times 4 = 350$
$40 = 175. \times 2 = 350$
$16 = 437.5 \times 1 = 437.5$
$7 \quad 1137.5$ grains.

$1137.5 \div 7 = 162.5$ grains average.

7,000 grains $\div$ 162.5 = $43\frac{1}{3}$ average counts.

UNKNOWN COUNT IN A COMPOUND OR TWIST THREAD.

Occasionally, it happens that a manufacturer or spinner has given to him the counts of a novelty or fancy twist yarn, also the counts of one or more of the threads of which it is composed. It then becomes necessary to find the size of the unknown thread which, together with the known counts, makes the compound twist yarn.

Rule 24. To find the required counts of a single yarn to be twisted with another, the counts of which is already known, to produce a compound or twist thread of a known count. Multiply the counts of the known single thread by the counts of the compound or twist thread, and divide the product by the known counts of the single thread minus the known counts of the compound thread. The quotient will be the counts of the required single thread.

Example. Having some yarn in stock, the counts of which is 1-30's cotton, it is desired to produce a compound or twist thread equal to 1-12's cotton. Find the count of the required thread.

$$\frac{30 \times 12}{30 - 12} = \frac{360}{18} = \text{20's required thread.}$$

Proof. $$\frac{30 \times 20}{30 + 20} = \frac{600}{50} = \text{12's twist or compound thread.}$$

In the cotton trade, worsted and silk threads are twisted with cotton. In the worsted trade, cotton and silk threads are twisted with worsted. In the woolen trade, cotton, silk, and worsted threads are twisted with woolen.

For the cotton trade, transfer the worsted and silk to cotton counts. For the worsted trade, transfer the cotton and silk to worsted counts. For the woolen trade, transfer the cotton, silk, and worsted to woolen numbers.

Rule 25. Two known single thread, a third thread required to produce a known compound thread. First find the size of the two known threads twisted together, then proceed as in previous examples.

Find the counts of the third thread to twist with a 1-30's cotton thread, and 1-60's cotton thread, to produce a three-ply thread equal to a 12's cotton.

These numbers are also used in reverse order, one being multiplied by, or divided into, the other very frequently. To simplify these calculations, the following constants have been worked out and will prove a valuable reference table:

	Long Method	First Constant	Second Constant.
Woolen	7,000 ÷ 1,600 =	4.375 ÷ 36	— .1215
Worsted	7,000 ÷ 560 =	12.5 ÷ 36	= .3472
Cotton	7,000 ÷ 840 =	8.33 ÷ 36	= .2314
Linen	7,000 ÷ 300 =	23.33 ÷ 36	= .648

Woolen	1,600 ÷ 7,000 = .228
Worsted	560 ÷ 7,000 = .08
Cotton	840 ÷ 7,000 = .12
Linen	300 ÷ 7,000 = .043

Frequently the counts of a very small amount of yarn is required, and to obtain the necessary data, a pair of fine grain scales is one of the most necessary pieces of apparatus required in a manufacturer's or designer's office.

Suppose a sample of woolen cloth contains 40 threads per inch and the sample is 2 inches long, then there would be 40 × 2 = 80 inches of yarn, and these threads weigh 2.5 grains. What is the run of the yarn ?

Rule 26. Multiply the number of inches of yarn by 7,000 (the number of grains in 1 lb.), and divide by the weight (in grains) of the yarn, multiplied by the standard number, and by 36. The answer will be the run of the yarn.

$$\frac{80 \times 7{,}000}{2.5 \times 1{,}600 \times 36} = 3.88 \text{ run.}$$

Example. If a sample of cotton cloth 1 inch long has 40 warp threads in 1 inch, and the yarn weighs 2.5 grains, what is the count ?

$$\frac{40 \times 7{,}000}{2.5 \times 840 \times 36} = \text{No. } 3.7037.$$

Explanation. As there are 7,000 grains in 1 lb. and 840 yards of number 1 yarn in 1 lb. 7,000 ÷ 840 gives the number of grains in one yard of number 1 yarn, or $8\frac{1}{3}$ grains. The constants, as we have 40 warp threads per inch, $8\frac{1}{3}$ grains, multiplied by 40 gives us the weight in grains of one running yard of number 1 warp one inch in width, or $333\frac{1}{3}$ grains.

As one square inch of warp weighs 2.5 grains, one running yard one inch wide would weigh $2.5 \times 36 = 90$ grains. Now, as 90 grains is the actual weight of the yarn, and $333\frac{1}{3}$ grains the weight of an equal quantity of number 1 yarn, the number of our warp yarn is the number of times the weight of number 1 yarn is greater than the given yarn, or

$$333.33 \div 90 = 3.7037 \text{ cotton counts.}$$

Example. Supposing 12 threads worsted were obtained, each 36 inches long with a total weight of 1 grain, what is the counts? *

$$\frac{7{,}000}{560} = 12.5 \text{ grains, the weight of 1 yard of number 1 worsted.}$$

Therefore, if 1 yard of yarn weighs $12\frac{1}{2}$ grains, the counts are 1's, or if 2, 3, 4, or 5 yards weigh $12\frac{1}{2}$ grains, the counts are 2's, 3's, 4's, or 5's respectively, or the number of yards of yarn which weigh $12\frac{1}{2}$ grains is equivalent to the counts in worsted.

Then the counts in the above example would be number $12\frac{1}{2}$, because $12\frac{1}{2}$ yards would be required to weigh $12\frac{1}{2}$ grains.

If 48 inches of woolen yarn weigh 2 grains, what is the run?

Long method. $$\frac{48 \times 7{,}000}{2 \times 1{,}600 \times 36} = 2.916, \text{ say } 2.9 \text{ run.}$$

First constant. $$\frac{48 \times 4.375}{2 \times 36} - 2.916 \text{ run.}$$

Second constant. $$\frac{48 \times .1215}{2} = 2.916 \text{ run.}$$

If 96 inches of cotton yarn weigh 2 grains, what is the counts?

Long method. $$\frac{96 \times 7{,}000}{2 \times 840 \times 36} = 11.10 \text{ counts.}$$

First constant. $$\frac{96 \times 8.33}{2 \times 36} = 11.10 \text{ counts.}$$

Second constant. $$\frac{96 \times .2314}{2} = 11.10 \text{ counts.}$$

If 75 inches of worsted yarn weigh 2.5 grains, what is the count?

Long method. $$\frac{75 \times 7{,}000}{2.5 \times 560 \times 36} = 10.416 \text{ counts.}$$

*NOTE—This subject is again taken up in Yarn Testing.

First constant. $\frac{75 \times 12.5}{2.5 \times 36} = 10.416$ counts.

Second constant. $\frac{75 \times .3472}{2.5} = 10.416$ counts.

YARN TESTING.

The term "Yarn Testing" means a great deal more than the casual observer in a mill supposes. Failure to test yarn, or imperfect testing may cause serious trouble. It is often necessary to test yarns in a variety of ways, and for different purposes. The most common test, and it may be safely said the only test which is applied in a large number of mills, is to ascertain the counts, but there are instances when the yarn should be tested for *strength*, *elasticity*, *evenness*, *and for quality.*

This latter test in some cases is a difficult one, and the question often arises as to what is meant by quality. As applied to yarns, the term quality is difficult to define briefly and accurately, in fact, it may almost be said that it cannot be defined, because as applied to different classes of yarn it has altogether different meanings. Without attempting to give definitions, an effort will be made to show what the different qualities or characteristics of yarn comprise, and so ascertain what tests are necessary to decide their suitability for the purpose to which they are to be applied.

The first step in yarn testing is to test the counts, which means to find the weight and size of the yarn. As previously explained, there must be some standard measurement or weight, and some means of determining the bulk or quantity of yarn. In this case the determination is based upon the length of yarn in a given weight, as, for instance, the number of yards per pound, ounce, or grain; but in different yarns and different sections of the country, this is a variable quantity. For example, the counts of cotton are figured by hanks per lb., and the hank contains 840 yards. Worsted is also figured by the hank, but the length of yarn is 560 yards. The basis of linen calculations is the lea, which is practically equivalent to the hank, but contains 300 yards. Woolen is reckoned in a variety of ways, but chiefly by 1,600 yards to the pound.

There appears then to be only one way of dealing with this subject so as to meet the requirements of students of different districts, and that is, to deal with it on general lines, and illustrate with examples from the best known and generally recognized system of counting yarns, and in such a manner that the student can readily adapt himself to any other system.

Testing for Counts. The process of testing for counts in the cotton and worsted systems, in which the method of indicating the count is general, may now be explained. In testing these yarns in the mill, there are two systems in use; one by what is known as the "quadrant", which is a balance with a graduated scale and upon which a certain number of yards is placed, when a pointer indicates the counts; the other system is by weighing with an ordinary fine balance and grain weights. The latter test is frequently done in a careless manner and very inferior balances employed, with the result that the tests are very unsatisfactory.

The "*quadrant*" arrangement is very useful because the indicator shows the counts the moment the yarn is put on the hook. The arrangement is very simple in principle, being in fact nothing more than an adjusted balance or lever. If it is arranged for cotton or worsted, the two arms of the lever, that is, the hook end and the indicator respectively are so balanced that one is, say, seven times the weight of the other, or more properly speaking that their relation to each other and to the scale is as 7 to 1. Then, if $\frac{1}{\ }$ of a hank is placed upon the hook, the indicator is at once brought to the point on the scale which shows the number of hanks per pound. When cotton is to be tested, 120 yards are measured off and placed upon the balance, and the pointer at once indicates the counts; if worsted, 80 yards are measured off and balanced with a similar result.

It must be clearly understood that the "quadrant" balance is always made for a given class of work, and to weigh a given number of yards; it is not usually made so that it can be applied to every purpose, but, like most special machines, must be applied to the testing of a specified class of yarn, and a specified number of yards weighed. Of course, the operator may vary this with a little ingenuity, but this would involve calculations, and consequently the machine would lose its advantages.

Reeling. By this system any length of yarn may be reeled off and weighed and the exact counts found by calculation.

This operation is carried on by means of a reel; one of the best examples of which is shown at Fig. 1. A sufficient length of yarn can be readily measured on this machine to test the counts to the greatest degree of accuracy.

The reel is 54 inches, or one and one-half yards, in circumference, and the dial is graduated into 120 parts to indicate the number of yards reeled from each spindle. While feeding yarn upon the reel, the yarn guides and the spindles are kept in line with each other, this being very desirable, in fact, necessary when reeling fine yarns. The extra length of the yarn guides is useful in increasing the friction upon the yarn by taking a half turn or more around them. The automatic feed motion lays the yarn flat upon the reel, thus securing accurate and uniform measurement, and consequently correct results as to stretch, strength, and numbering. When the skein is taken off the reel, it is weighed and the counts calculated from the weight.

It is a common practice to reel yarn upon a machine of very inferior construction, and in a very rough manner, which of course produces doubtful results. For example, in reeling worsted yarns, it is a common practice to use a reel with a circumference of one yard, and which does not distribute the yarn in the manner indicated. The number of yards which will correspond to the intended counts of the yarn is measured off by counting the turns of the reel, then this yarn is weighed in a common apothecaries' balance against a weight of $12\frac{1}{2}$ grains, and if it balances or approximately balances the $12\frac{1}{2}$ grains, it is said to be of the counts indicated by the number of yards weighed. Similar systems are sometimes used in the cotton and woolen industries, and, in some cases, the methods are, if possible, even more crude. But, although this is the common practice, it is not sufficient for good work, therefore, we must have more complete systems.

The first question which suggests itself is, how is the $12\frac{1}{2}$ grains found to be the constant weight, and what weight would be employed for other yarns? The grain weight, being the lowest of the recognized standard weights, is made use of, and as there are 7,000 grains in one pound (Avoirdupois), this is divided by 560 (the number of yards in one hank) which gives $12\frac{1}{2}$. For cotton $8\frac{1}{3}$ grains would be the constant; for woolen, $4\frac{3}{8}$ grains.

How to ascertain the number of cotton yarn. Reel, or measure off, and weigh 9, 18, 30, 90, or any number of yards of the yarn, observing that the greater the number the more accurate the result will be.

Rule 27. Multiply the number of yards by $8\frac{1}{3}$ and divide the product by the weight of the sample in grains; the quotient will be the number of the yarn, *i.e.*, the number of hanks in a pound.

Example. Suppose 9 yards weigh 5 grains; then $9 \times 8\frac{1}{3} =$

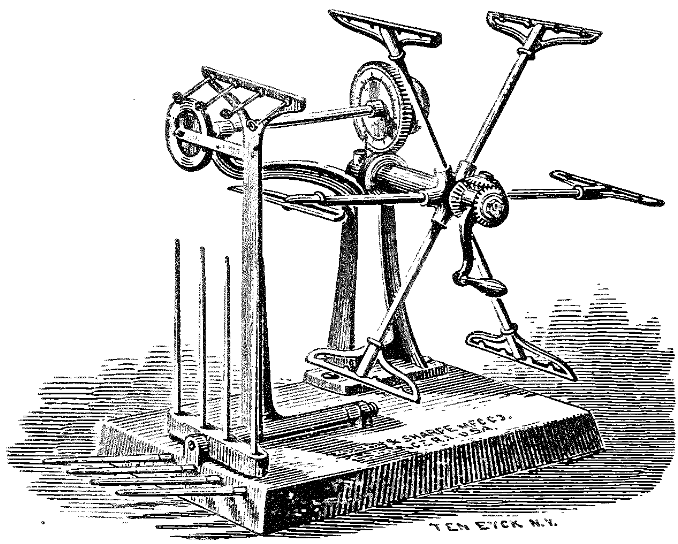


Fig. 1. Brown & Sharpe Yarn Reel.

75. $75 \div 5 = 15$'s, the number of yarn, *i.e.*, the number of hanks to a pound.

Rule 28. *To ascertain the number of linen yarn.* Reel, or measure off, and weigh 9, 18, 30, 90, or any number of yards, the greater the number the more accurate the result will be. Multiply the number of yards by $23\frac{1}{3}$ and divide the product by the weight of the sample in grains; the quotient will be the number of the yarn.

Examples. Suppose 12 yards weigh $17\frac{1}{2}$ grains; then $12 \times 23\frac{1}{3} = 280$. $280 \div 17\frac{1}{2} = 16$, the number of counts per pound. Suppose 9 yards weigh 5 grains; then $9 \times 23\frac{1}{3} = 210$. $210 \div 5 = 42$, the count of the yarn.

Rule 29. *To find the number of worsted yarn.* Reel, or measure off, and weigh 9, 18, 30, 90, or any number of yards, the greater the number the more accurate the result will be.

Multiply the yards by $12\frac{1}{2}$ and divide the product by the weight of the sample in grains; the quotient will be the number of the yarn, *i.e.*, the number of hanks or skeins to the pound.

Example. Suppose 9 yards weigh 5 grains; then $9 \times 12\frac{1}{2} = 112.5$. $112.5 \div 5 = 22\frac{1}{2}$, the number of the yarn.

Rule 30. *To find the run or number of woolen yarn.* Reel, or measure off, and weigh any number of yards of the yarn, observing that the greater the number the more accurate the result will be. Multiply the number of yards by $4\frac{3}{8}$ and divide the product

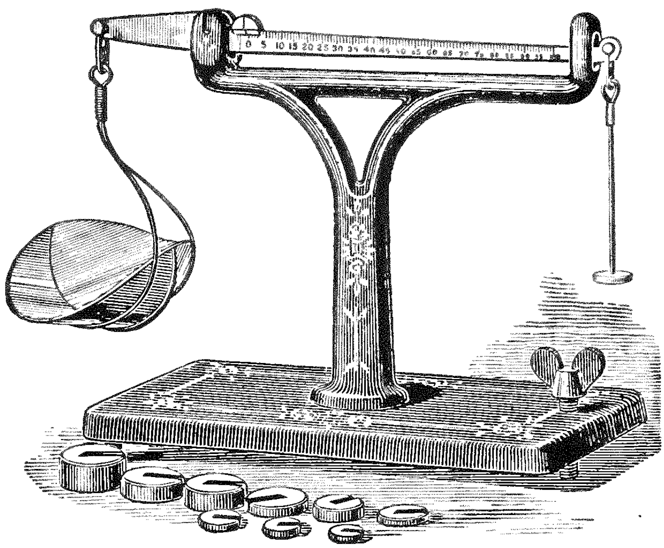


Fig. 2. Sample Scales.

by the weight of the sample in grains; the quotient will be the number of hanks per pound.

Examples. Suppose 90 yards weigh 45 grains; then $90 \times 4\frac{3}{8} = 393.75$. $393.75 \div 45 = 8\frac{3}{4}$, the number of run of the yarn. Suppose 9 yards weigh 5 grains; then $9 \times 4.375 = 39.375$. $39.375 \div 5 = 7.875$ or $7\frac{7}{8}$, the number of the yarn.

The common practice in testing yarns is what might be termed a rough and ready one, yet it is often considered sufficient in ordinary practical work, but for good analysis a more perfect and delicate system must be used.

Suppose, for instance, that it is required to reproduce a cloth, or for any purpose to make a complete analysis of it. The operation ought to be conducted with as much care and nicety as a chemist makes a quantitative analysis; in fact, it must be a quantitative analysis. The counts of the yarn must be ascertained with

When a very small quantity of yarn is available, say one or two yards, it must be weighed with great care. Of course, when a large quantity is available, find now many yards will weigh $12\frac{1}{2}$ grains, if the yarn is worsted; $8\frac{1}{3}$ grains if cotton; and so on for other yarns, according to the system of counting. Suppose, for instance, that it is required to test the yarn in a cloth, and only a small piece can be obtained, say two or three square inches. This

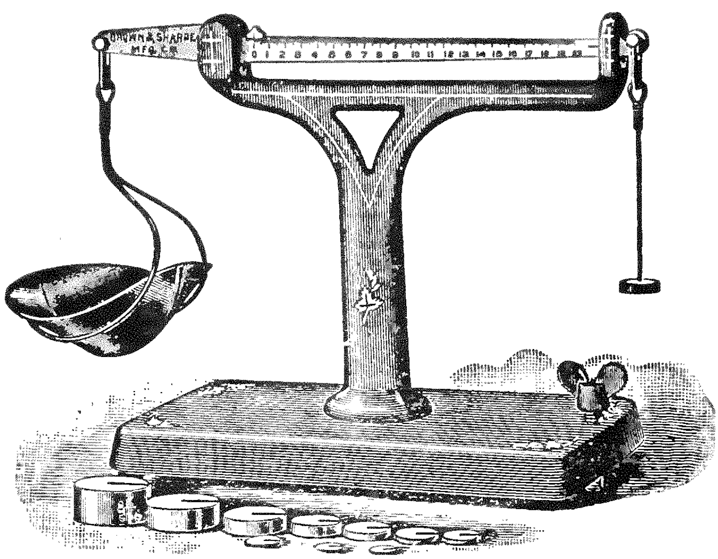


Fig. 3. Brown & Sharpe Scales.

must be measured carefully, and as many threads taken out as will make one yard, two yards, or as much as possible. For example, let it be two yards of worsted weighing $1\frac{39}{100}$ grains. Find the counts. If two yards weigh $1\frac{39}{100}$ grains, how many yards will weigh 7,000 grains? Putting it in the usual form of a proportion as $1\frac{39}{100} : 7{,}000 :: 2 : 10{,}072$ yards, or there are that number of yards in one pound. As there are 560 yards per hank in worsted, and the counts are indicated by the number of hanks per pound, the 10,072 must be divided by 560, thus $10{,}072 \div 560 = 18$ hanks nearly, then the counts would be called 18's, as it is near that number. If it were cotton, the same rule would apply, but instead of dividing by 560, the yards would have to be divided by 840 thus, $10{,}072 \div 840 = 12$ hanks, or equal to 12's counts. If it were woolen on the run system, it would be divided by 1,600, and so on for other varieties of yarn. In such small quantities as this, there is always some slight liability to error, but with careful work this should not exceed 2 per cent.

The problem may be simplified by putting it in the form of an equation. Let Y represent the number of yards or length weighed, and W the weight in grains found. There are 7,000 grains in one pound and a fixed number of yards per hank in the system upon which the yarn is counted, then

$$\frac{7{,}000 \times Y}{560 \times W} = \text{counts in worsted,}$$

$$\frac{7{,}000 \times Y}{840 \times W} = \text{counts in cotton, etc.}$$

This may be further simplified as the 7,000 grains and the yards per hank are constant numbers. Let the grains be divided by the yards per hank and find one constant number, thus for worsted

$$\frac{7{,}000}{560} = 12\tfrac{1}{2} \text{ as the constant; for cotton}$$

$$\frac{7{,}000 \times Y}{840 \times W} = 8\tfrac{1}{3} \text{ for constant.}$$

Now let C represent the constant, and the formula will stand

$$\frac{C \times Y}{W} = \text{counts.}$$

TESTING BY COMPARISON.

As we have said that in some mills yarns are tested by comparison, this lesson would not be complete without giving an idea as to the method employed.

It consists in taking a few threads from the fabric, and these are crossed and folded over the same number of threads of some known count, the two ends of each respective group of threads being held between the fingers, the group of the unknown in one hand and the known in the other. The two groups are then twisted simultaneously so as to compare their relative diameters.

Fig. 4 illustrates this method of comparing known with unknown counts. A represents the known and B the unknown counts. Take one, two or more threads of each kind of yarn and placing them together, as shown in the illustration, twist them, making, as it were, one continuous thread. By this simple act of twisting it is natural to make a comparison of the area and solidity of the threads. It is advisable to wet the yarns at the point where they are crossed, previous to twisting. During comparison, threads are added or taken from one or the other of the sets and again twisted as directed and compared until the two sets appear to make a similar thickness of thread.

It follows that when the number of threads of a known count are of equal thickness to some other number of threads of unknown counts, these numbers bear a simple and direct proportion to each other.

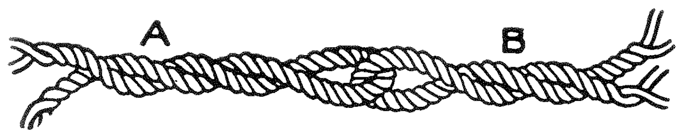


Fig. 4. Testing by Comparison.

Example. 6 threads of 2-30's worsted are found by twisting and comparison to equal 8 threads of some unknown count. What is the count of the unknown threads? 2-30's = 15. Then as 6 : 8 :: 15 : × = 20's, or 2-40's worsted *i.e.*, 8 threads twisted together of 2-40's are equal in thickness to 6 threads 2-30's worsted twisted together.

This method of testing is used practically, because a mill-man usually uses the nearest counts he has in stock to the counts of yarn in the sample to duplicate. Others do not trust to the eye when comparing yarns, but prefer to use a magnifying glass or microscope.

Constants for Testing Yarns for Counts by Weighing Short Lengths of Cotton.

1. 1,000 divided by weight in grains of 1 lea = counts.

2. The number of inches that weigh 1 grain × .2314 = counts.

3. Number of yards weighed ÷ .12 × weight in grains = counts

4. The number of strands of yarn, each $4\frac{5}{16}$ inches or 4.32 inches long that weigh 1 grain = counts.

5. The number of yards weighed × $8\frac{1}{3}$ ÷ weight in grains = counts.

STRUCTURE OF CLOTH.

Structure of cloth does not mean the fabric, nor the yarns from which the fabric is constructed, but it designates the materials from which the fabric is made, together with the system of interweaving. It has been explained that no woven fabric can be produced without crossing, or interweaving at right angles, two distinct sets of threads. In the Instruction Papers on Textile Design several systems of interweaving are given and the meaning of plain or cotton weave, prunella twill, cassimere twill, basket or hopsack weave, five-harness sateen, etc., are explained. Now, the object is to find the *quantity and kind of yarn*, which, when used with certain weaves will produce a fabric of good structure.

The *plain weave* is the simplest texture, requiring only two threads of warp and two picks of filling to complete the full weave. Not only is it the simplest, but it is the most limited in size. If two threads are drawn in on the same harness side by side, or two picks are placed in the same opening or shed, it is not a plain weave, and if one thread is taken away, the fabric is left without any means of binding or interweaving.

Adding to the plain structure and only admitting of one additional thread and pick, we enter on the first lesson of figure and twill weaving, and the weave is designated as the *three-harness twill or prunella twill*. This is the first form of diagonal or rib effect at an angle of 45 degrees, and with the variations of this weave we can work out designs on a figured basis by twilling to the right for a number of threads and then reversing the twill, using either the warp-flush or the filling-flush weaves or combining the two.

The addition of one more thread forms the *swansdown weave*, which is a regular four-harness filling-flush twill, advancing one thread and one pick in regular consecutive order, forming a twill or diagonal at an angle of 45 degrees. We may say that with this number of threads, or this weave, the field for new combinations is unlimited, for with four harnesses, an endless variety of fabrics are constructed, such as dress goods, men's wear, etc. Weaves which repeat on four harnesses are very useful in cotton, woolen, and worsted manufacture.

Adding one more thread and one more pick gives five threads in the warp, and five picks in the filling; the smallest number on which a *sateen weave* may be constructed. There is in use a weave of four harnesses called the crowfoot weave, which is sometimes called a sateen or doeskin, but as the first and second threads run consecutively to the right, and the third and fourth run consecutively to the left, it cannot be a sateen. A true sateen must in no instance have two threads running consecutively either to the left or to the right.

Sateens generally have a warp-flush surface, which gives a soft and full appearance to the fabric and are used more or less in the construction of fancy figured goods and piece-dyed fabrics, such as damasks and table linen, covert coatings, beavers, etc. As the weave is either a warp-flush or a filling-flush face, the character of the cloth is always of a limited nature.

The derivatives of the sateen are very diversified in character, but more perfect in structure than those obtained from other weaves or modes of interweaving.

So far, we have been considering simple weaves or cloths constructed on a one-weave basis, but the method of constructing fabrics from a combination of several weaves, is a most comprehensive one and the effects produced cover a wide range of fabrics.

Combination of Weaves. In all cases when a fancy figured effect is required in cloth made from the same shade of yarn, this principle is invariably adopted, as every plan of interweaving, whether twill, basket, diamond, herring-bone, spotted or all-over effects, can be produced by a combination of weaves.

The essential points to be noticed in combining or amalgamating two, three, or more weaves are (*a*) class of fabrics to be constructed, (*b*) the capabilities of each weave intended to be combined with other weaves.

Some weaves are specially adapted for cotton effects, others for silk, woolen, or worsted. To combine weaves without due consideration as to their utility is a useless toil. To amalgamate weaves for fulled-woolen goods is a waste of time, as weaves for woolen goods should be of a regular and uniform character, and those nearly approaching each other are preferable. In cotton and worsted goods the opposite characteristics are desired, and the manner of interlacing is of the utmost importance; the principal feature of a worsted fabric being its decided and clearly defined weaves.

Our considerations have thus far been the structure of a fabric as affected by the weave. For our next consideration we will take the structure of a fabric as affected by its relation to warp and filling.

The *strength*, *utility*, and the *purpose of the structure* must be considered. Generally speaking, the smaller the yarns, the larger the flushes in weaves which may be employed. A cloth constructed with yarn 2,560 yards to the pound, 24 threads to the inch using the plain weave would be firm and regular in construction, but if it were woven in an 8-harness twill, 4 up and 4 down, it would be very loose, coarse and open in construction. This clearly shows that weaves that are useful for one class of yarn, are not suitable for all, so we must have in mind the quality of texture required, when laying out or constructing a cloth.

When combining weaves the importance of the filling capacity must not be lost sight of, and when several weaves are combined, the complete design must possess a similar capacity for the admission of the filling.

The construction of a cloth in its broadest sense is, to consider the weave, size of yarns and materials of which they are made, and also to enter into the details and calculations required in connection with the correct method of building a perfect structure. *The following points should be noted when constructing a fabric:*

Weave, or combination of weaves.

Judgment in selecting weaves for combination.

The class of fabric intended to be produced, whether wool, worsted, cotton, or silk.

The weaving capabilities of the separate weaves to be combined.

Weaves combined to have an equal filling capacity.

The purpose and utility of the fabric.

Nature of the raw material to be used.

The size of the yarns for warp and filling.

The number of turns of twist to be put in warp and filling yarns.

The number of threads in the warp per inch.

The number of picks of filling per inch.

The take-up in weaving.

The process in dry finishing.

Scouring, fulling shearing.
Finishing shrinkage.

DIAMETER OF THREADS.

The square root of the yards per lb. will give the diameter of the yarn, or the number of threads which will lie side by side in one inch without being interlaced with another set of threads.

Example. Suppose a cloth is to be made from 80's cotton, and it is desired to ascertain the number of threads that will lie side by side in one inch of space.

$80 \times 840 = 67{,}200$ yards of 80's cotton in 1 lb. Extracting the square root of 67,200

$$\sqrt{67{,}200} = 259.22.$$

Allow 7 per cent for shrinkage of yarn from first spin.

$$259.22 - 7\% = 241.07.$$

NOTE.—When the tension, which is put on yarn in spinning, is removed, cotton shrinks 7 per cent; worsted 10 per cent; woolen 14 per cent; and silk 4 per cent.

As a fraction, it will give the diameter of the thread, as $\frac{1}{241}$ of an inch, therefore, 241 threads of 80's cotton would lie side by side in one-inch space. The same rule will apply to woolen and worsted yarns, where the basis of the calculations is of a similar character.

Example. Suppose a cloth is wanted from 40's worsted.

$$40 \times 560 = 22{,}400 \text{ yards per lb.}$$

$$\sqrt{22{,}400} = 149.66 - 10\% = 134.70 \text{ (approximately 135.)}$$

Therefore 135 threads of 40's worsted will lie side by side in 1 inch.

Rule 31. To find the diameter of any yarn use the square root of 1 counts in yarn required, as a constant number, and multiply the square root of the counts of the required diameter by the constant. Thus the square root of 1's worsted is $\sqrt{560} = 23.66$.

$$23.66 - 10\% = 21.30$$

What is the diameter of 16's worsted yarn?

$$\sqrt{16} = 4. \quad 21.30 \times 4 = 85.20.$$

Proof. $560 \times 16 = 8{,}960. \quad \sqrt{8{,}960} = 94.65 - 10\% = 85.19.$

for they may be in *actual contact*, and the number of threads per inch determined by the diameter of the threads, without any allowance for space between them. Poplins are a good illustration of this construction. In this class of goods the cords run across the cloth, and instead of the warp threads having a space between them equal to the diameter of the threads, they must be set very closely together, and the filling threads some distance apart, otherwise the clear cord will not be produced. Care must also be taken that the filling threads are not too far apart, or the corded effect will be destroyed. When producing a cord parallel to the length of the cloth the procedure is exactly the reverse.

From these two examples we come to another conclusion, *i.e.*, on the warp cord, the warp is present in larger quantities than the filling, while on the filling cord, the filling is the larger quantity. It has been stated that as the warp or filling preponderates, it must be *increased in quantity*, and that which is least seen must be *decreased*. This rule holds good for nearly all makes of cloth.

Twilled Cloths differ very much from plain fabrics. By the construction of the weave the threads must be closer together, for the same counts of warp and filling, to produce a cloth of equal firmness. A plain cloth is interwoven at every thread and pick whereas in a twill cloth, the picks pass over a number of threads before they are interwoven, therefore, weaves which produce long floats require heavier yarn or a closer set to produce an approximate firmness of texture. The number of threads and picks per inch must be increased in proportion to the length of the floats.

In twilled cloths, the warp or filling may be made to preponderate on the face of the fabric in two ways, (*a*) as in plain cloth by having more threads of one set than of the other, at the same time decreasing the diameter of one set of threads, and increasing the diameter of the other, or (*b*) by weaving the desired set of threads on the face.

To Change From One Weave to Another and Retain the Same Perfection of Structure. As has been explained in regard to the plain fabric, when it was desired to change from the plain weave to a fancy twill or diagonal, it may occur that one of these fancy twills may be desired in some other effect, and at the same time be necessary that no alteration of the structure of the fabric take place.

A heavier or bolder twill may be desired, or it may be that the twill is too deep or prominent, or that a still lighter fabric is in demand. The layout or texture of the original fabric is known and it is required to construct a new fabric of exactly the same character, and also to use the same size and quality of yarns as in the first cloth, thus saving the expense of making new yarns. For example, we have a cloth woven with the 4-harness cassimere twill, 80 threads per inch, warp and filling being equal. We now desire the same build of cloth, made from a design that will give a bolder twill, so the 6-harness common twill $\frac{\quad}{3}$ is used. How many threads and picks per inch must be used in the new fabric?

(*a*) Obtain the number of threads and units in known weave.
(*b*) Obtain the number of threads and units in required weave.
(*c*) Obtain the number of threads and picks per inch in known fabric. (Threads and picks per inch is known as texture.)

Rule 32. Multiply the number of known threads or texture by the units of the known weave, and by the threads of the required weave, and divide the product by threads of known weave, multiplied by the units of required weave.

The term unit is given to the threads and intersections of a weave. For example, the plain weave has one thread up one thread down, expressed —|‾x‾|—. Each pick of filling passes over threads 1, 3, 5, 7, etc., and under threads 2, 4, 6, 8, etc., or *vice versa*, thus forming a space between every thread and those on either side. To find the number of units, the weave should be expressed x|‾x‾|— the crosses representing threads, and the vertical lines representing intersections. It will be seen that the plain weave contains two threads and two intersections, or four units.

The cassimere twill would be two threads up and two threads down, expressed xx|‾xx‾| which shows four threads and two intersections, or six units.

The three up and three down twill would be xxx|‾xxx‾| or six threads and two intersections, or eight units.

Proceeding with the problem given above

$$\frac{\text{Texture (80)} \times \text{known weave units (6)} \times \text{threads of required weave (6)}}{\text{Threads of known weave (4)} \times \text{required weave units (8)}} = 90$$

Thus 90 threads and picks per inch on a 6-harness twill will give the same texture as 80 threads and picks per inch on a cassimere twill with the same counts of yarn.

It is required to change from the weave, 2 up, 1 down, 1 up, 2 down; to the weave 2 up, 1 down, 1 up, 1 down, 1 up, 4 down. The texture is 72 threads and 72 picks per inch.

First weave has 6 threads and 4 intersections = 10 units.

Second weave has 10 threads and 6 intersections = 16 units.

$$\frac{72 \times 10 \times 10}{6 \times 16} = 75 \text{ threads and picks per inch.}$$

If it is necessary to make the cloth lighter and maintain the structure of the heavier cloth, and to use the same yarn, a firmer weave must be used to reduce the number of threads per inch. Proceed in the following manner:

(*a*) Obtain the number of threads and units in known weave.

(*b*) Obtain the number of threads and units in the required weave.

(*c*) Obtain the texture of known weave by finding threads and picks per inch.

Rule 33. Multiply the known texture by the threads of the required weave and by the units of the known weave, and divide the product by the units of the required weave multiplied by the threads of known weave.

If a fabric woven with the weave 3 up, 1 down, 1 up, 3 down, 3 up, 1 down, 1 up, 3 down, has 80 threads per inch, and we wish to use the weave 2 up, 1 down, 1 up, 2 down, 2 up, 1 down, 1 up, 2 down, how many threads will be required to maintain the exact structure of the original cloth?

First weave has 16 threads and 8 intersections = 24 units.

Second weave has 12 threads and 8 intersections = 20 units.

$$\frac{\text{Texture (80)} \times \text{threads required weave (12)} \times \text{units of known weave (24)}}{\text{Units of required weave (20)} \times \text{threads of known weave (16.)}} = 72$$

Thus 72 threads per inch will give the same texture on the second weave that is produced by 80 threads per inch on the first weave; using same counts of yarn.

In all these examples it is assumed that the warp and filling are equal in size, quality, and texture of the fabric, and the fabric is built on the principle of what is generally understood as a square cloth.

Having determined that a truly balanced cloth is where the number of threads and picks are equal and of the same diameter, and having determined what sett of reed will give the best result for a given number of yarn, it is easy to find what sett will suit any other count of yarn to produce a similar result. For example, we will take four threads of a plain cloth.

```
x |   | x |   |      4 threads        = 4 units.
----------------
  | x |   | x |      4 intersections  = 4 units.
                                        -------
                                        8 units.
```

In a fixed rule, we assume that the proportions of size of yarn warp and filling, and spaces are equal, therefore we will take the diameter or size of yarn as the unit of measurement. Supposing our sample of plain cloth to have 60 threads per inch, and we wish to change the weave to the 4-harness cassimere twill.

```
xx |    |      4 threads        = 4 units.
-----------
   | xx |      2 intersections  = 2 units.
                                  -------
                                  6 units.
```

Four threads of plain cloth equal 8 units, while the same number of threads of the cassimere twill equals 6 units, therefore the twill weave will require a greater number of threads to make as perfect a fabric as the plain weave, and the increase is in proportion as 6 is to 8. Our example supposed the plain cloth to have 60 threads per inch, then to have an equal fabric with the twill weave, the problem will be 6 : 8 :: 60: $\times$ or 80 threads per inch.

As the cloth is built square, what has been said of the warp applies equally to the filling. The 4-harness cassimere twill interweaves regularly, the twill moving from end to end consecutively. Warp and filling flushes are equal, as in the plain weave, and the quantities of warp and filling on the face are equal.

Take another example—5-harness twill, 3 up and 2 down.

```
xxx |    |      5 threads        = 5 units.
------------
    | xx |      2 intersections  = 2 units.
                                   -------
                                   7 units.
```

Two repeats of the weave would equal 14 units. Ten threads of the plain weave would equal 20 units, therefore the 5-harness twill requires a *greater number of threads.*

The increase is in proportion as 14 : 20 :: 60: × or 85 $\frac{71}{100}$.

We will take a final example on the 6-harness common twill basis, three threads up and three threads down, the filling passing over and under three threads alternately, therefore there will be only 2 intersections; xxx | ooo | = 6 threads and 2 intersections equals 8 units. In a plain weave, there would be 6 threads and 6 intersections, equaling 12 units, so this weave would require an *increase* as 8 : 12 :: 60 : × which equals 90 threads.

It must be thoroughly understood that the examples given herewith are all supposed to be made from the same material, same kind of yarn in weight and diameter, and the structure of the fabrics is exactly the same as far as the build is concerned, but as the 4, 5, and 6-harness weaves require more threads per inch to form as perfect a structure as the plain weave, the fabric when woven must necessarily be heavier. This is one of the important considerations when laying out a new fabric. The weight per yard has to be taken into account, therefore the size of yarn and weave are two very important factors.

In order to make proper use of previous calculations, and to put them into practice, it is necessary that the actual size of threads should be known, that is, the size, counts, and diameter to produce a perfect structure. Threads composed of different substances vary greatly in proportion to their weight. The specific gravity of cotton and linen is about $1\frac{1}{2}$ times the weight of water. Animal fibers, silk and wool, have a specific gravity of 1 $\frac{30}{100}$ or nearly $1\frac{1}{3}$.

The *diameters* of linen threads are similar to cotton. Woolen yarns present a thicker thread for the same weight. Spun silk has about the same diameter as cotton.

We must now consider the diameter of yarns. Threads vary as to the square root of their counts. After finding the diameter of a thread, find how many threads will lie side by side in one inch. For any counts of yarn, find the number of yards per pound and extract the square root. The square root of number 1 cotton would be $\sqrt{840} = 28.98$. This is without any allowance for shrinkage, and without any allowance for space.

Rule 34. To change a plain weave into a fancy twill or diagonal and retain the same perfection of structure:

(*a*) Obtain the number of threads in required weave.

(*b*) Obtain the number of intersections in required weave.

(*c*) Add threads and intersections together and call them units.

(*d*) Obtain the units there would be in the number of threads of the plain weave that are occupied by the required weave.

Example. If a plain fabric has 80 threads per inch, what number of threads will it require for the weave 3 up, 3 down, 2 up, 1 down?

Multiply the units of the known weave by the threads per inch, and divide by the units of the required weave.

Explanation. In two patterns of the above weave, there would be 18 threads and 8 intersections = 26 units. a plain weave on 18 threads would have 18 intersections = 36 units.

$$26 : 36 :: 80 : \times = 110\tfrac{77}{100}.$$

Thus 110 threads will be required to produce a fabric on the required weave, which is equal in texture to 80 threads on a plain weave; the same yarn being used in each case.

DISSECTING AND ANALYZING.

In the manufacture of textile fabrics, there are at least two important divisions of a designer's work: (*a*) *designing*, (*b*) *dissecting and analyzing*.

Designing consists in the building of a fabric from designs, more or less original, and the weaves, texture of the fabric, and colors used in its manufacture are limited only by the looms and yarns under the designer's control.

Dissecting and Analyzing differs widely from designing and is the most important work in a design office. In this case the designer must reproduce or imitate a fabric; which is a difficult problem if not worked in the right way. A thorough knowledge of designing in all its branches, and a theory of the many calculations necessary, together with the most expedient manner in which the theory may be put into practical use are essential for a successful analysis.

Many designers perform their work without any special method, which causes great inconvenience to themselves, and results in a useless waste of time and material. A methodical designer can perform his work in a comparatively short time with far better results, saving the manufacturer considerable time and expense. The first principle of a designer should be *method*, for method leads to economy, which is one of the foundations of a mill-man's success. Too much stress cannot be laid upon this point, and if the beginner is methodical and continues so, dissecting and analyzing will prove comparatively easy to him.

When analyzing a fabric, many important facts must be considered, especially when it is desired to reproduce the fabric. The nature of the fiber from which the yarn is spun, the quality and twist of the yarn, colors, and weaves used to produce the desired effect, and the character of the finishing processes should all be carefully studied, in order that the reproduction may be perfect in every detail.

The first thing to determine is the *class and nature of the fabric*. Double, triple, and backed cloths may be easily determined by a close inspection of the sample, one side usually being woven with coarser yarn than the other. Heavily napped fabrics should first be singed, care being taken to singe the nap without injuring the yarn in any way; while single cloths need but a glance to classify them as such.

The next step is to decide upon the face and the back of the fabric. Double and triple cloths usually are woven with a heavier yarn on the *back* to add weight and strength to the material. This is especially true of the so-called "two and one" system. Frequently "one and one" cloths are woven with yarn of equal counts, and the face is determined only by one or more of the several tests described later. The conditions which apply to double cloths also apply to backed cloths.

Worsted dress goods and similar fabrics often prove confusing, but in many cases a close examination will show that one side is smoother to the touch than the other, and the "draw" is very noticeable. By passing the fingers one way of the cloth a smooth feeling is noticeable and this is termed the "draw". Passing the fingers the other way of the cloth a slight resistance is felt, which is termed the "bite". These conditions are caused by shearing,

and yarn left twist the other way. The former is invariably the warp.

Exceptions to these tests seldom occur. In many fabrics, varying conditions prevail, but the reasons for such variations are so pronounced, especially with yarn, that little examination is required to distinguish the warp from the filling.

Warp yarn is usually stronger and finer than filling yarn, with a harder twist, and made from the best and strongest material on hand.

Texture. The density of a fabric is controlled by the texture, and its required weight and thickness. The sample should be cut to a certain size, usually 1 inch square, and each thread drawn out of the fabric separately and laid aside in its proper order. Each thread should be examined in turn, and the *twist*, *nature*, and *color* determined as it is drawn out of the sample. This will save a repetition of the work later on. When only a small sample is available the texture and color scheme must necessarily be determined at the same time.

Having drawn out each set of yarn, warp, and filling, the texture may be ascertained by counting the number of threads in each lot. If in the sample on hand there are 56 threads in the warp and 48 threads in the filling, the texture will be 56 threads and 48 picks per inch. It is not always convenient to cut the sample 1 inch square, and the threads and picks per inch may be determined by accurately measuring the length and width of the sample, and dividing the picks and threads respectively by these measurements. A sample may be $\frac{3}{4}$-inch long and $1\frac{1}{2}$ inches wide and contain 36 and 84 threads respectively. The calculations would be

$$36 \div \tfrac{3}{4} = 48 \text{ picks per inch.}$$
$$84 \div 1\tfrac{1}{2} = 56 \text{ threads per inch.}$$

NOTE.—This is not a reliable method and, if possible, should be avoided.

As the threads are drawn out, care should be taken to find the number of each variety and color of yarn, and in their exact order. When a repeat has been found by adding the number of threads of each color and variety, the threads in a pattern are determined. Suppose the threads in a sample are as follows:

Twist cotton	2		2		= 4
White worsted		2			= 2
Green worsted				2	= 2
					8

Thus there are 8 threads in a pattern, 4 twist cotton, 2 white worsted, 2 green worsted.

Fabrics, such as plaids, frequently have a fancy arrangement of warp and filling, and the threads in a pattern exceed in number the threads and picks per inch. Determine the extent of the repeat in the sample and measure it accurately. By dividing the number of threads in a pattern by the number of inches the pattern occupies, the texture may be found. Thus, a pattern $2\frac{1}{2}$ inches wide contains

Red cotton	18						= 18
Blue cotton		36					= 36
Yellow cotton			4				= 4
Dark tan				54			= 54
White					48		= 48
Light tan						80	= 80
							240

$240 \div 2.5 = 96$ threads per inch.

The easiest way to ascertain the woven construction of a fabric, is to take it from the face or from the figure presented on the surface of the fabric; but this requires experience and familiarity with the many kinds of weaves. Constant practice in constructing cloths from designs, and noticing the woven effects of each particular "*sign*", "*riser*", or "*sinker*" used on the point or design paper is the best way to become familiar with weaves. But sometimes, the sinkers and risers are so intermingled, several individualities being contorted and merged into one eccentric combination, that even experts find it necessary to resort to unravelling or "*picking-out*" each warp and filling thread, in order to find the true character ot the weave.

The picking out of samples presents no difficulties except those of concentrated sight and steady application. This only refers, however, to fast-woven and much felted cloths, in which all the crossings have become nearly, if not totally, obliterated. If the texture were as open as mosquito netting, there would be no difficulty, because every crossing of the threads, warp, and filling could be distinctly seen and marked.

Of course there are gradations from the most openly constructed to the finest setted fabrics, and from the least to the most heavily felted cloths; still the principle of dissection is the same in all.

There are other particulars to be obtained from a sample, besides the weave or figure, and upon which the figure depends for its appearance. These are the relative fineness of the warp and filling, and the number of threads per inch, and also the amount and kind of finish to be given to the fabric to gain solidity and handle, as well as effect. We say nothing here of the materials of which the threads are composed.

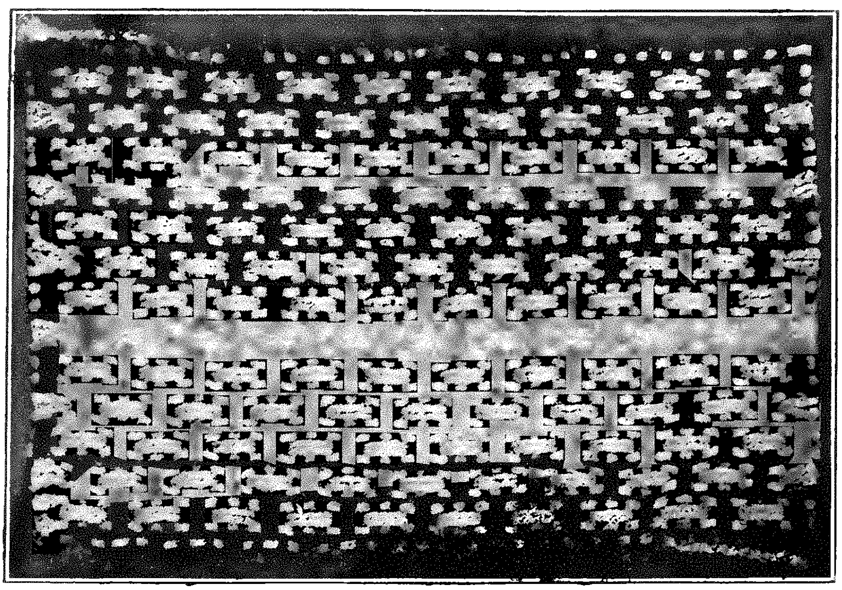


Fig. 5.

Now, suppose a sample of finished cloth exactly 1 inch square is to be analyzed. The first procedure is to weigh it in very fine (grain) scales, and record the weight. Assuming that the weight of one square inch is 5 grains and that the finished cloth is 56 inches wide, we proceed to find the weight of one yard of cloth.

Rule 35. To find the weight of 1 yard of cloth, weight of 1 square inch and width being known. Multiply the grains per inch by the given width of cloth $\times$ 36, and divide by 437.5 grains. The answer will be weight in ounces per yard.

$$\frac{5 \times 56 \times 36}{437.5} = 23.04 \text{ ozs. per yard.}$$

Or the constant found by dividing 437.5 by 36 may be used as follows:

$$5 \times 56 \div 12.153 = 23.04 \text{ ozs. per yard.}$$

NOTE.—The weight of woven fabrics is usually expressed in ounces, and as there are 7,000 grains in one pound Avoirdupois, 7,000 ÷ 16 = 437.5 grains per ounce.

Rule 36. To find the weight of one yard of cloth when the weight of any number of square inches is known; weight in grains of sample × width × length, divided by square inches × 437.5 grains.

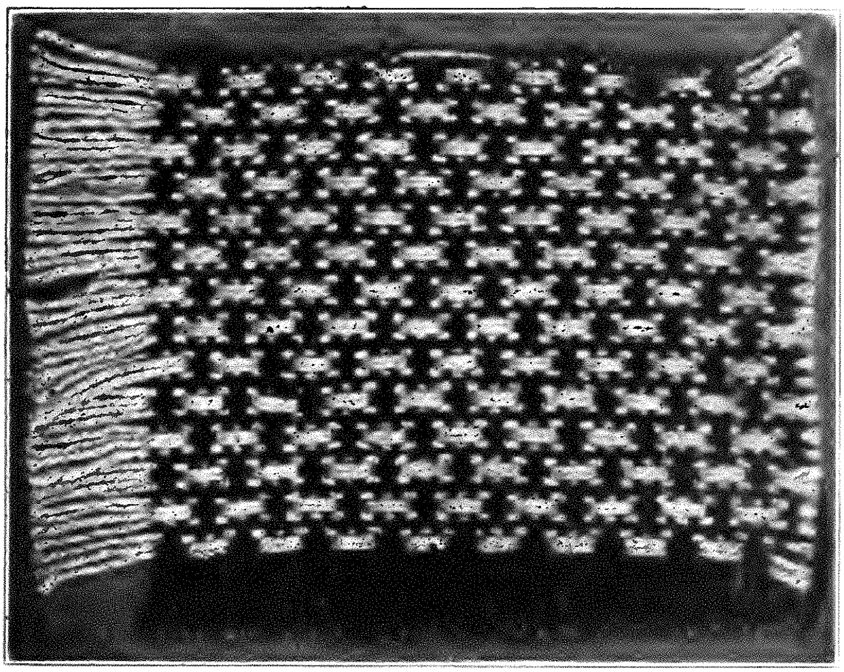


Fig. 6.

Assuming that a sample which contains 4 square inches weighs 20 grains and the cloth is 56 inches wide the process would be as follows:

$$\frac{20 \times 56 \times 36}{4 \times 437.5} = 25.04 \text{ ounces per yard.}$$

The above explains the general principles which underlie the method of obtaining the weight per yard of any fabric, woolen, worsted, cotton, linen, or silk, of any given width, and should be thoroughly understood by all who are employed in the designing room, weave rooms, or in the superintendent's or manager's office.

This simple formula with explanations will apply to all fabrics.

$$\frac{\text{Grains} \times \text{width} \times 36''}{\text{sq. inches} \times 437.5} = \text{ounces per yard.}$$

PICKING-OUT.

(*a*) Trim the edges of the sample perfectly square with the warp and filling threads. (See Fig. 5.)

(*b*) Unravel, by taking out about one-quarter of an inch of warp threads from the left side of the sample and about one-quarter of an inch of filling threads from the bottom part of the sample. (See Figs. 6 and 7.)

(*c*) Take the sample in the left hand between the finger and the thumb, placing the warp threads in a vertical position, that is, the first thread of weave on the left and first pick of weave nearest your body.

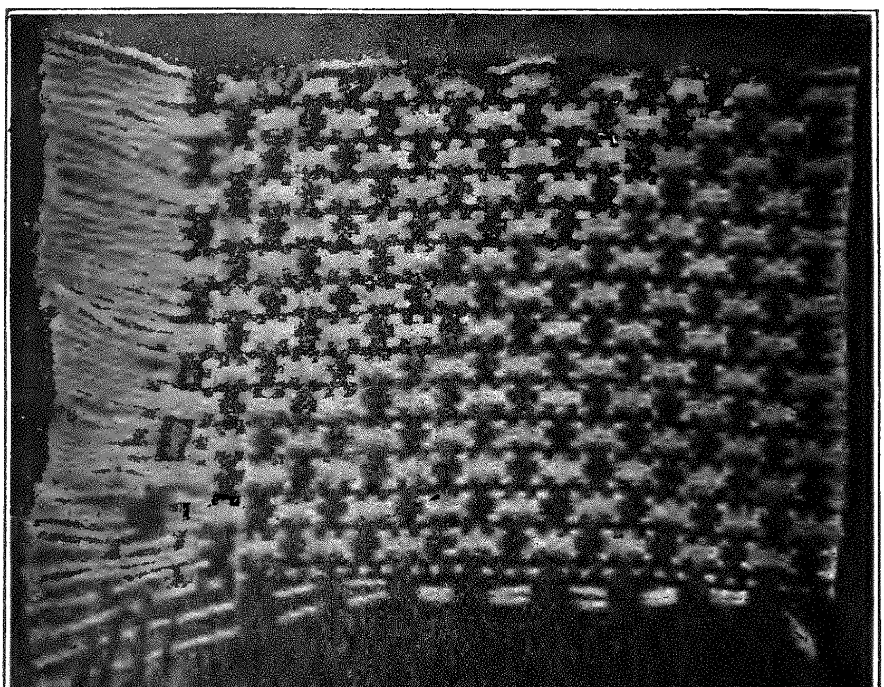


Fig. 7.

A piece of design paper must be at hand to mark down the result of the pick-out, as shown in the diagrams. With a small pointed instrument, say a needle, commence at the *left hand bottom corner* and lift the first thread away from the body of the cloth so that the filling crossing can be seen.

Now notice which filling threads this first thread is over and under, and mark on the design paper (commencing at the left hand bottom corner) those picks which are down; the up picks, of course, will be represented by the blanks or vacant squares. For instance, the first warp thread is over the first and second picks, under the third pick, over the fourth pick, under the fifth pick and sixth pick, over the seventh pick, and under the eighth pick: that is, over two, under one, over one, under two, over one and under one. The ninth and tenth are like the first and second, the eleventh is like the third and so on; so the first eight picks represent one repeat of the weave on the first thread, and is represented on the design paper by the black filled-in squares on thread A, Fig. 8.

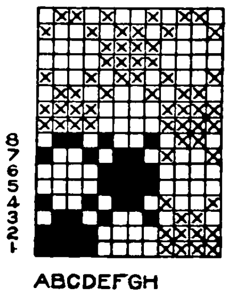


Fig. 8.

Now remove the first thread, lift the second thread to the front, and proceed as before. The second thread is over the first 3 picks under 4 over 4 and so on as shown at the thread marked B. Each succeeding thread is treated in the same manner until the weave or design repeats.

When the pattern is found to be repeating in either direction, the pick-out need not be continued, yet for safety it is advisable to go far enough both ways and then fill in the design at the repeats and disregard the other crosses. This design is complete on 8 threads and 8 picks, as shown at Fig. 9.

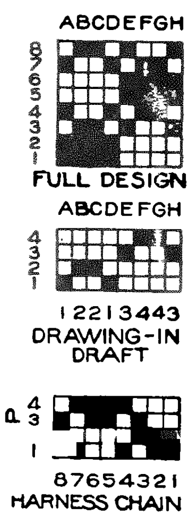


Fig. 9.

Fig. 9 also shows the drawing-in draft and harness chain. The design is reduced to four harnesses to work it easily. The letters above the drawing-in draft correspond with those in Fig. 8 and denote the order of the threads and the order of their drawing-in upon the harness, and the figures under the draft the number of the harness upon which each thread must be drawn, according to the design, while those on the left hand side show the number of harnesses employed. The numbers on the left of the reduced chain show the condensation of the design and draft. Fig. 10 shows the interweaving of the threads.

However intricate the sample or design may be in its woven construction, this method will simplify it. Sometimes the design will not repeat on so small a number as 8 × 8, and if the sample is not large enough to obtain one-half repeat, a larger sample must be obtained if possible, unless it is seen that the design runs in regular order, when a few threads taken out are sufficient to show the principle of construction without going further.

With constant practice in the analysis or picking-out of samples, the character of the figure or weave may be ascertained almost as well as in its production in the loom, as in both cases one becomes familiar with signs, sinkers, and risers and their effects.

The preceding remarks have had reference to comparatively easy and simple textures for analysis, such as worsted or cotton goods, but with the more heavily felted woolen fabrics a little preparation is necessary before proceeding with the above method. Any fibers which obstruct the clearness of the design and prevent the interweaving of the threads from being clearly seen must be removed by singeing or shaving the surface; care being taken that the threads are not destroyed, or damaged so that they cannot be removed, or followed in their regular course.

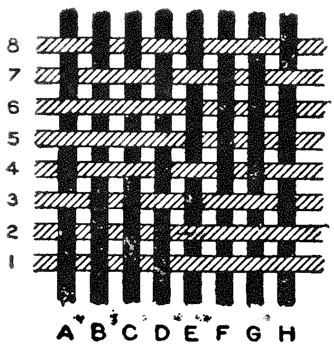


Fig. 10.

Pattern. Having found the construction of the weave, so far as figure or design is concerned, the next procedure is to note the number of threads which complete the pattern in each direction.

Referring to Fig. 11, the analysis of which is given on the analysis sheet, it will be noticed that the scheme or pattern of warp is, 2 threads of light, 1 thread of dark, 2 threads of light and 2 threads of dark, or

Light 2 2 = 4
Dark 1 3 = 3
7 threads in pattern, or scheme of warp.

The pattern or scheme of the filling is 3 picks of dark and 2 picks of light, or

Dark 3 = 3
Light 2 = 2
5 picks in pattern, or scheme of filling.

Referring again to the analysis sheet for data the analysis is as follows:

1. Weight of 1 yard, given width.

NOTE.—Pattern refers to color only, design or figure refers to weave. In the first example the warp is dark and the filling light, which is termed solid colors. Pattern is the arrangement of colors as they lie side by side in the warp and filling.

$$\frac{\text{Grains} \times \text{width} \times 36}{437.5} = 5.03 \text{ ozs. weight per yard.}$$

2 and 3. Pick-out, drawing-in draft and chain (see Fig. 12.)

4. System or pattern of warp according as the colors lie side by side in the fabric. (See Page 56.)

5. System or pattern of filling, according as the colors lie side by side in the fabric. (See Page 56.)

6. Threads in warp. Width (36) × threads per inch (56) = 2.016.

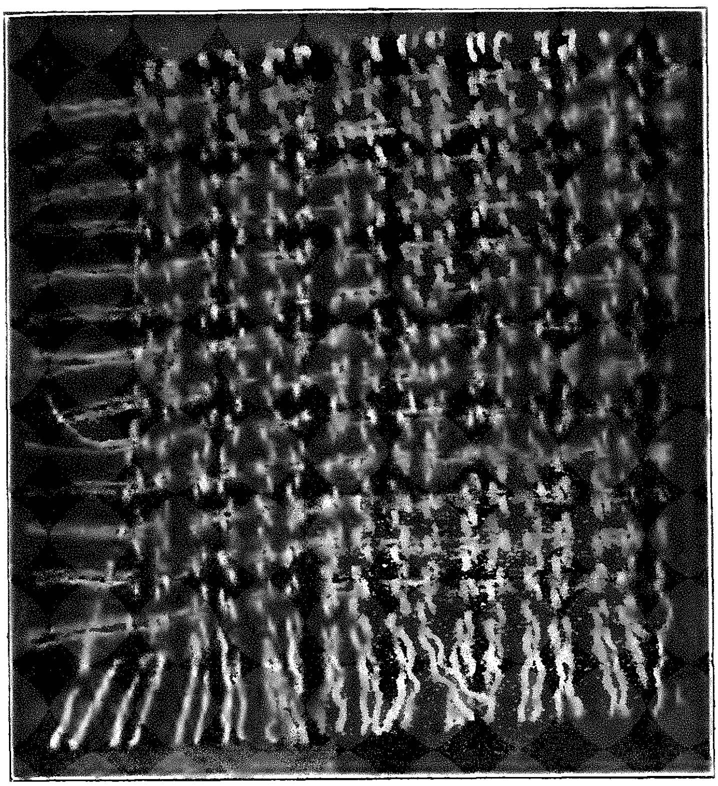


Fig. 11.

7. See No. 4 for warp and No. 5 for filling.

8. Patterns in warp. Threads in warp (2,016) ÷ threads in pattern (7) = patterns (288).

9. Size (counts or run) of warp in finished cloth 21.6.

NOTE.—See rules for the various ways of obtaining counts from small quantities or short lengths of yarn.

10. Size (counts or run) of filling in finished cloth 21.7.

11. Weight of warp yarn in one yard of finished cloth. Width of goods (36″) multiplied by threads of warp per inch (56) gives the total number of yards of warp yarn in one yard of goods, or

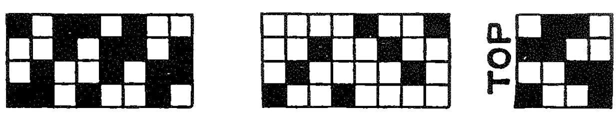
2,016 yards. As the warp yarn is numbered 21.6, or as it takes 21.6 times 560 yards to equal 1 pound of yarn, the weight of above 2,016 yards would be $\frac{2,016}{21.6 \times 560}$ = lbs., or multiplied by 16 = 2.66 oz. of warp yarn in one yard of cloth.

12. Weight of filling yarn in one yard of cloth. The picks of filling per inch (50) times width of cloth (36) gives the length in inches of filling in one running inch of the cloth or 1,800 inches. Multiplying this amount by 36 inches gives the number of inches of filling in one running yard of cloth. Again dividing by 36 inches, reduces it to yards.

$$\frac{1,800 \times 36}{36} = 1,800 \text{ running yards of filling in one yard of cloth.}$$

NOTE.—As multiplying and dividing by 36 would be superfluous, it is omitted from the formula.

Following our reasoning in the explanation given in a previous



Pick-out Drawing-in Draft Chain

Fig. 12.

paragraph, counts of filling × 560 yards gives the number of yards in 1 pound of filling, therefore,

$$\frac{1,800}{21.7 \times 560} = \text{lbs., or multiplied by } 16 = 2.37 \text{ ounces, filling}$$

yarn in one yard of cloth.

Weight of warp yarn in one yard	=	2.66
Weight of filling yarn in one yard	=	2.37
Weight of yarn in one yard		5.03 ozs.

The weight of yarn in one yard should equal the weight of finished cloth per yard.

Take-up. So far the analysis has been simply as the yarn stood in the cloth. Yarn in a finished piece of cloth must have more or less crimps or corrugations in it according to the weave or design used.

The plain weave which interlaces at every thread and pick will require a longer warp than the 4-harness swansdown weave, to produce a fabric of equal length, provided all other things are equal.

This is a very important point in the analysis of any fabric. It must be remembered that a *yard of yarn will not weave a yard of cloth*, so cloth is always shorter than the original length of warp from which it was woven, which is due to the take-up by its being bent around the filling.

The *cloth is always narrower than the width the warp was spread in the reed* previous to being woven, which is due to the filling pulling in the edges of the cloth and to the filling bending around the warp threads. It is a well-known fact, that cloth from two looms working side by side may vary in width and length, and each loom working apparently under same conditions.

The material of which yarn is made and the manner in which it is spun, dressed, and manipulated in the loom, has much to do with the take-up in the weaving and finishing processes. The finer the quality of the filling and the softer it is spun, as compared with the warp, the greater take-up there will be in the width. Increased tension on the warp increases the length of the cloth, and makes the width narrower, up to a certain limit. If the filling is hard twisted and of a coarse nature, or coarser than the warp, the cloth will not take up much in the width.

The warp for plain stripes and sateen stripes should not be placed on the same beam nor reeded in the same manner, as the plain weave will take up much faster than the sateen portion. Care should be taken in reeding weaves of variable intersections.

The difference in temperature, weather, system of sizing, kind of loom used. tension of warp, tension of filling, also number of reed and picks per inch as compared with each other will affect the amount of take-up.

The yarns in weaves of the rib and cord type, where three, four, or more threads or picks work together, act like heavy yarns and tend to retain a straight line, the finer yarns bending around them, consequently the fine yarns have the greater take-up.

Rules may be given which will give good results and which have been proved to be practical, to some extent, for finding the various items necessary for the reproduction of a fabric, yet they are only approximately so, the best results being obtained by experience and using the records of other fabrics.

NOTE.—Take-up will be further explained under the heading "Take-up and Shrinkage".

SETTS AND REEDS.

Having found the weave, draft, chain and counts of yarn as they appear in the finished fabric, the next important step is to find the "sett" in loom, which includes reed, dents per inch, threads per dent, approximate counts of the warp and filling yarns previous to being woven, and finally the picks per inch in loom.

The density of the warp threads in the process of weaving and subsequently in the woven fabric, is represented by the relative number of heddles on the harness shafts, and the dents in the reed distributed over a fixed unit of space, which will include the number of warp threads passed through each dent in the reed.

The system of numbering reeds now almost universal in all the textile industries (perhaps with the exception of silk) is known as the "*threads per inch*" system. The number of dents per inch in the reed with two threads in each dent is the basis of the sett. If the reed has 40 dents per inch it is called a 40's reed or 80's sett.

$$40 \text{ reed} \times 2 \text{ threads} = 80 \text{ threads per inch.}$$

Obviously, the "dents per inch" is the simplest basis for a sett system and should be adopted where English measurements are used.

For all reed calculations in this work, one inch is given as the unit of measurement, and the number of warp threads contained in that space, forms the basis of the sett. When the threads per inch are of an equal number, the reed for the divisions is easily found, that is for ordinary requirements. For instance, if 40 threads per inch are required, a 20's reed 2, 10's reed 4, or 8's reed 5 may be employed; that is, a reed having 20 dents, 10 dents, or 5 dents per inch, each dent containing 2, 4, or 5 threads respectively.

By this method the number of threads for the whole warp is easily ascertained as follows: A warp is required to be 70 inches wide, with 40 threads per inch, then $70 \times 40 = 2{,}800$ threads are required for the warp.

A cloth has to be woven in a 100's sett, 4 threads in each dent. How many dents per inch must the reed contain?

$$\text{Sett} \div \text{threads in dent} = \text{Reed.}$$
$$100 \div 4 = 25$$

A cotton fabric is woven 3 threads in a dent, 42 inches wide, and warp contains 2,520 threads. What is the sett and what is the reed?

Warp threads (2,520) ÷ width (42) = sett (60)
Sett (60) ÷ threads (3) = reed (20)

A reed contains 1,320 dents in 33 inches, 2 threads in each dent. What is the reed?

$$\frac{\text{Dents } (1{,}320)}{\text{Inches } (33) \times \text{Threads } (2)} = 20 \text{ reed.}$$

Given 120 threads per inch, to be laid 72 inches wide in loom. How many threads in warp? Threads per inch (120) × width (72) = threads in warp (8,640).

Unevenly Reeded Fabrics. The requirements of design and the construction of the cloth are so various as to sizes of yarn, and the number of threads per inch employed in the warp, that the number of dents per inch in the reed is dependent upon it. But the number of threads in each division of the reed is not always uniform, that is, not always the same number in each dent throughout the whole width of the warp, this depending upon the pattern to be woven. For example, in the production of a fancy sateen stripe while 2 threads in each dent may be required, say for $\frac{3}{4}$-inch space, the following dents may require 3, 4, 5, or 6 threads in them, and then repeat with 2's and so on through the width of the reed. This will show that no hard and fast rule can be laid down which will cover every requirement.

Example. A worsted stripe is made in which the warp contains 1,920 threads; it is laid 40 inches wide in the reed, and reeded as given below. Find the average number of threads per inch, and the number of reed.

Pattern	1 dent	= 4 threads	black.	1,920 ÷ 24 =	80 patterns.
	1 "	= 4 "	white.	80 × 6 =	480 dents.
	1 "	= 6 "	black.	480 ÷ 40 =	12 reed.
	1 "	= 4 "	white.	1,920 ÷ 40″ =	48 average.
	1 "	= 4 "	black.	48 ÷ 12 =	4 average in each dent.
	1 "	= 2 "	white.		
	6 dents	24 "	in pattern.		

Rule 37. To find average threads per dent, and reed for cloth, number of threads per dent varying. First find the number of threads in one pattern and the number of dents which they occupy,

then divide the total number of threads in the warp (1,920) by the number of threads in the pattern (24) which gives the number of patterns in the warp (80), this multiplied by the dents in a pattern (6) gives the total number of dents required to reed the warp (inside selvedges). The number of dents (480) divided by the width of the cloth (40) gives the number of reed (12). Dividing the threads in the warp (1,920) by the width of the cloth (40) gives the average threads per inch (48), and dividing this by the reed (12) gives the average threads in each dent. Dividing the number of threads in a pattern (24) by the dents in a pattern (6) will also give the average number of threads in each dent.

A fabric is made with 3,264 threads in the warp; set 40 inches wide in the reed, and is reeded as given below. Find the number of dents per inch in the reed.

30 threads	2 in a dent	=	15 dents
20 "	1 " " "	=	20 "
12 "	2 " " "	=	6 "
Miss one dent	0 " " "	=	1 "
12 threads	2 " " "	=	6 "
Miss one dent	0 " " "	=	1 "
12 threads	2 " " "	=	6 "
20 "	1 " " "	=	20 "
30 "	2 " " "	=	15 "
136 threads in 1 pattern.			90 dents in 1 pattern.

3,264 ÷ 136 = 24 patterns.
24 × 90 = 2,160 dents.
2,160 ÷ 40 = 54 reed.

A cotton sateen stripe fabric has 3,520 threads in the warp and is reeded in a 40's reed as given below. What is the width in reed?

22 threads white		2 in dent.
6 " lt. blue		
6 " " pink		
6 " " blue		
12 " white		6 in dent.
12 " lt. blue		
12 " " straw		
12 " " blue		
12 " white		

4	"	pink	2 in dent.
4	"	blue	
4	"	pink	
4	"	blue	
4	"	pink	
12	"	white	6 in dent.
12	"	lt. blue	
12	"	" straw	
12	"	" blue	
12	"	white	
6	"	lt. blue	2 in dent.
6	"	" pink	
6	"	" blue	
22	"	white	

TAKE-UP AND SHRINKAGE.

Cotton Cloth. In cotton cloth, the take-up depends chiefly upon the character of the weave, and quality and counts of yarn used. The term "sley" is used to denote the number of threads per inch in the cloth.

Suppose we have analyzed a cotton sample, and there are 100 threads per inch, or 100 sley. Find the number of dents per inch in the reed to give this texture, using 2 threads in 1 dent.

Deduct 1 from the given sley and divide by 2.1.

$$100 - 1 = 99. \quad 99 \div 2.1 = 47.14 \text{ reed.}$$

As an illustration of how cotton cloths will vary in the amount of take-up according to the construction in weaving, the following examples are given:

1. A fabric made with 48's warp and 2-15's filling, 34 inches in reed, 88 threads per inch, 50 picks per inch, 5 harness sateen weave, gives $33\frac{1}{2}$ inches of cloth. Showing a take-up of about $1\frac{1}{2}$ per cent. $34 - 33.5 = .5$. $.5 \div 33.5 = .0148$ or 1.48%.

2. 48's warp and 15's filling. 33 inches in loom, 64 threads by 40 picks. 5-harness $\frac{4}{\quad 1}$ weave, gives 32 inches of cloth, showing a take-up of $3\frac{1}{8}$ per cent or $33 - 32 = 1$. $1 \div 32 = .03125$ or $3\frac{1}{8}$ per cent.

3. 2-26's warp and 48's filling. $31\frac{1}{8}$ inches in loom. 48 threads by 128 picks. 6-harness broken twill, filling face, gives

$$\frac{126 \times 4 \times 2}{14} = 72 \text{ sley reed.}$$

$$72 \div 2 = 36 \text{ actual reed}$$

When figuring cotton fabrics, allowances must be made for quantity of size, starch, and other substances used.

Worsted Cloth. In the analysis and construction of worsted fabrics, that is, those composed of worsted warp and worsted filling, the same principles are to be observed as in cotton cloths.

Piece dyed worsted goods usually gain as much in weight in the dyeing operation as they lose in the process of scouring, so the weight of the cloth from the loom may be taken as net, and the calculations based accordingly.

The width of the warp in the reed depends upon the class of goods to be made, the required width ot the finished piece, and the structure of the design. In ordinary worsted textures, the shrinkage of the cloth from the loom to the finished state, varies from 8 to 12 per cent.

A sample of finished cloth contains 80 threads and 80 picks per inch. Allow 10 per cent for shrinkage in the width and length. Find the width of the warp in the reed, and the number of threads and picks per inch with which it must be woven. The cloth is 56 inches wide finished.

$100\% - 10 = 90\%$ $\frac{80 \times 90}{100} = 72$ threads and picks per inch in loom.

$$\frac{\text{Threads (80)} \times \text{width (56)}}{\text{threads per inch (72)}} = \frac{\text{threads in loom (4,480)}}{72} = 62\tfrac{2}{9}$$
inches.

The original length and width represented 100%. The shrinkage was 10%, so the finished cloth is 90% of the original length and width. As there are 80 threads and picks per inch in the finished cloth, there must have been a smaller number per inch when the length and the width were greater. Therefore, multiply the number of threads and picks by the finished width and length and divide the product by the original length and width.

To find the width in reed: First find the number of ends in the warp by multiplying the finished width by number of threads per inch in the finished cloth; then divide the product by the threads per inch in the loom.

Example. A worsted cloth contains 64 warp and filling threads. Shrinkage 9%. Finished width 55 inches. Find the reed width, and the number of threads and picks with which it should be woven.

Fancy worsted cloths are made from yarns dyed in the hank, or from yarns where the material has been dyed in the raw state or in the worsted top, therefore, the loss in scouring and finishing must be considered.

Fulled Woolen Goods. Fabrics which come under this head may have a finishing shrinkage of 20% to 35%, and in some cases even more. Such goods are said to be "made" in finishing, for the cloth as produced by the loom would not be recognized in the finished condition.

When analyzing a small sample of woolen goods, it is very important that the shrinkage be accurately found, or the reproduction will not be a success.

Method of finding picks in loom.

$$\frac{\text{Picks in finished cloth} \times \text{finished length}}{\text{length out of loom}} = \text{picks in loom.}$$

A finished woolen coating has 71 picks per inch. 63 yards of cloth out of loom gives 57 yards finished.

$$\frac{71 \times 57}{63} = 64 \text{ picks in loom.}$$

Or, a finished woolen suiting has 80 picks per inch, and it has had a shrinkage in length in the warp, or number of picks, of 20%. What was the number of picks in the loom?

$100 - 20 = 80\%$. $80 \times 80\% = 64$ picks in loom.

There is a large number of fabrics for heavy clothing, that are made with a back stitched to the original or face fabric in order to gain weight and warmth. When analyzing such fabrics the counts and weight of the back cloth yarns are calculated as a separate cloth.

CONSTANTS.

Constants for the customary width of any fabric, whereby the weight per yard may be easily obtained from a small sample.

Formula.

$$\frac{\text{Width} \times \text{inches in 1 yard} \times \text{ounces in 1 lb.}}{\text{Grains in 1 lb. (Avoirdupois)}} = \text{constant.}$$

$54 \times 36 \times 16 \div 7{,}000 = 4.44$ constant.

Rule 41. Weight of sample $\times$ the constant $\div$ sq. in. of sample -- weight of yard, given width (54″).

Sample. 3×2 inches $= 24$ grains.

$$\frac{24 \times 4.44}{6} = 17 \text{ oz. per yard.}$$

TABLE OF CONSTANTS.

Inches wide.		Inches wide.	
12 =	.98	42 =	3.45
14 =	1.15	44 =	3.62
16 =	1.31	46 =	3.78
18 =	1.48	48 =	3.95
20 =	1.65	50 =	4.12
24 =	1.97	52 =	4.27
27 =	2.22	54 =	4.44
28 =	2.30	55 =	4.52
30 =	2.47	56 =	4.60
32 =	2.63	58 =	4.77
34 =	2.79	60 =	4.94
36 =	2.96	62 =	5.10
38 =	3.13	64 =	5.26
40 =	3.30	66 =	5.42

Example. A small sample 1 square inch = 5 grains. What is the weight of a yard of cloth 56 inches wide?

Constant $4.6 \times 5 = 23$ ozs.

The utility of this rule is at once apparent when applied to the solution of the above example, or to the following: A given sample is 3×3 inches and weighs 27 grains. What is the weight if the fabric is 28 inches wide?

$$3 \times 3 = 9. \qquad \frac{27 \times 2.3}{9} = 6.9 \text{ ozs.}$$

EXAMPLES FOR PRACTICE.

1. A sample is 4×1.5 inches and weighs 18.5 grains. What will one yard of the fabric weigh, 54 inches wide?

2. What will one yard of cloth, 36 inches wide, weigh, if a small sample $2\frac{1}{2} \times 2$ inches weighs 6.7 grains?

3. A yard of cloth 40 inches wide weighs 10.3 ozs. What will be the weight of a sample $4 \times 2\frac{3}{4}$ inches?

4. What will one yard of cloth, 72 inches wide, weigh, if a $4 \times 2\frac{1}{3}$-inch sample weighs 30 grains?

ANALYSIS OF PATTERN.

Cloths composed of one-color warp and one-color filling are said to be of solid color, but when there are two or more colors in the warp or in the filling, the arrangement of the colors is termed the pattern. Where several shades of colors of yarn are used in fancy fabrics, to produce certain effects, the order of the threads must be carefully noted to make a correct reproduction. Of course the order of arrangement of these threads may be ascertained during the process of dissection.

One thing to be attended to is, that the leading thread in the pattern should be found, with reference to the style of the design or weave employed. Sometimes particular threads are intended to show either prominently or the reverse and a special arrangement in the weave is made to produce this result. In such cases the *relation of the thread to its working arrangement* must be strictly observed, or the attempt at reproduction will be a failure. If the style of weave is all one kind, as in an ordinary twill or sateen weave, the above may be disregarded.

An additional consideration, with regard to these differently colored threads in the warp, and one which must receive attention is that, whatever number of threads there may be in the pattern, it must be repeated an even number of times in the width of the warp, so that if the edges of the cloth, minus the selvedges, were brought together so as to form a tube, the pattern would be continuous all around.

Suppose that it is necessary to produce a fabric which contains 16 threads in one repeat of the pattern, as follows: 4 threads black, 2 threads drab, 2 threads slate, 4 threads black, 2 threads slate, 2 threads drab. This arrangement must be repeated as many times as is made necessary by the required width. A few extra threads may be disposed of by casting out, or a few may be added to make up even patterns.

Suppose a warp contains 1,920 threads and the pattern is composed of 16 threads.

Threads divided by number of threads in pattern equals number of patterns. 1,920 $\div$ 16 = 120 patterns.

Suppose a warp fabric is measured and found to be $32\frac{1}{4}$ inches wide and there are 48 threads per inch and 16 threads in the pattern.

$$48 \times 32\tfrac{1}{4} = 1{,}548 \text{ threads.}$$
$$1{,}548 \div 16 = 96 \text{ patterns} + 12 \text{ threads.}$$

The 12 extra threads must be cast out.

A fabric 35 inches wide contains 2,380 threads in the warp and is dressed 2 black, 2 white, 2 black, 1 red. (*a*) How many patterns are there in the warp? (*b*) How many threads per inch?

Relative Weights of Warp and Filling. There is yet another essential consideration in reference to these varied threads, for, in addition to finding the number of each kind, their weight also must be obtained, for the purpose of warping and dressing, as well as in making out the cost of the fabric. To the designer, spinner, and manufacturer calculations of this kind are very useful.

Find the weight of a warp 64 yards long, made of 2–32's worsted, and woven in a 16's reed, 4 threads in a dent, 66 inches wide in reed.

$$16 \times 4 = 64 \text{ threads per inch.} \quad 2\text{–}32\text{'s} = 16\text{'s.}$$

$$\frac{64'' \times 66'' \times 64 \text{ (threads per inch)}}{16 \times 560} \quad 30.1 \text{ lbs.}$$

or

$$\frac{\overset{4,224}{\text{threads in the warp}} \times \overset{64}{\text{the length}}}{\underset{16}{\text{counts}} \times \underset{560}{\text{standard}}} = 30.1 \text{ lbs.}$$

Example. Find the weight of filling required to weave a piece 64 yards long, 64 inches wide in the reed, 80 picks per inch of 1-18's worsted. Add 5 per cent to cover the waste in weaving.

$$\frac{80 \times 64'' \times 64 \text{ (yds)} \times (100 + 5\%)}{18 \times 560 \times 100} = 34.1 \text{ lbs. of filling yarn.}$$

It must be remembered that a yard of warp will not weave a yard of cloth, and in making calculations, sometimes the length of the warp is taken instead of the loom length, the difference in length being considered sufficient to cover extra cost of waste of filling during the weaving.

EXAMPLES FOR PRACTICE.

1. Find the weight of warp and filling required to weave a piece 63 yards long, 64 inches in the reed, made from 70 yards of warp and containing 84 picks per inch, plus 5% for extra filling to cover the waste in weaving. Yarn is all 16's worsted.

2. A fabric 72 yards long is 56 inches wide in the reed, and contains 80 picks per inch. Waste in weaving 5%. 80 yards of warp are used in the fabric. Find the weight of warp and filling if both are 2-40's worsted.

3. 64 yards of warp are woven into a fabric 56 yards long. In the loom the cloth is 64 inches wide, and contains 50 picks per inch. 5% waste in weaving in filling. Find the weight of warp and filling if both are 14's cotton.

4. A woolen fabric is set 56 inches wide in the reed, and is woven with 40 picks per inch; 72 yards of warp finish to 64 yards of cloth. 5% waste in filling. What is the weight of warp and filling if both are 3-run woolen?

5. A 2-48's worsted warp 65 yards long is warped to the following pattern: Woven in a 12 reed, 4 threads in a dent, 60 inches wide.

2 black }
2 dk brown } × 4

2 dk. brown }
2 dk. drab } × 2

24 threads in pattern.

12 × 4 = 48. 48 × 60 = 2,880 ends in warp.

2,880 ÷ 24 = 120 patterns.

Find the weight of each color of yarn.

The following is the most convenient form to write out the scheme of warp and filling, as the summary of the threads can be obtained more easily. It is very essential to ascertain he weight, of each color and sort of material used, especially in the warp where the number of threads of each color and sort must be known, so that the several calculations can be made for spooling and warping.

Black	2		2		2		2			= 8	threads.
Dk. brown		2		2		2		4	2	= 12	"
Dk. drab								2	2	= 4	"
										24	" in pattern.

120 patterns × 8 threads = 960 Black.
120 " × 12 " = 1,440 Dk. brown.
120 " × 4 " = 480 Dk. drab.
2,880

The weight of each kind can now be obtained by the regular method.

$$\frac{960 \times 65}{24 \times 560} = 4.64 \text{ lbs.}$$

$$\frac{1,440 \times 65}{24 \times 560} = 6.96 \text{ lbs.}$$

$$\frac{480 \times 65}{24 \times 560} = 2.32 \text{ lbs.}$$

13.92 total weight of warp.

There is another method of obtaining the number of threads of each color.

$$\frac{\text{Total number of warp threads} \times \text{threads of any color in one repeat}}{\text{Number of threads in pattern.}}$$

$$\frac{2,880 \times 12}{24} = 1,440.$$

In patterns where there is a large number of threads of one color, as may be the case in a Scotch or Tartan plaid, it is advisable to commence the color scheme by *dividing the largest number of threads*, commencing with one-half and ending with the other.

A plaid is made from 2-24's worsted warp and filling, 12's reed, 4 in one dent, 44 picks per inch, width within selvedges 36 inches, plus 24 threads on each side for selvedges. The warp take-up is 15% during weaving, 60 yds. of warp before weaving. Selvedges, white 2-24's worsted.

Black	24			6		20		20		6		24	= 100
White		12			6		68		6		12		= 104
Red			6							6			= 12
													216

This pattern has purposely been started with 24 threads of black (note the selvedges are white), and finished with the same number and color. If the selvedges had been ordered black, the pattern would have commenced with 34 white.

$48 \times 36 = 1,728.$ $1,728 \div 216 = 8$ repeats.

Black	$100 \times 8 = 800 \times 60 \div$	$(12 \times 560) =$	7.14 lbs.
White	$104 \times 8 = 832 \times 60$	$(12 \times 560) =$	7.43 lbs.
Red	$12 \times 8 = 96 \times 60$	$(12 \times 560) =$	.86 lbs.
	1,728		15.43 lbs.
	Selvedges white $48 \times 60 \div$	$(12 \times 560) =$	.43 lbs.
			15.86

NOTE.—The selvedge may be added to white in body of warp.

There are 46 picks of black and 2 picks of brown in the pattern. Find the amount of yarn required of each color.

$$\begin{array}{rl} 36'' & \\ 40 & \text{picks per inch} \\ \hline 1{,}440 & \text{" " yard} \\ 60 & \\ \hline 86{,}400 & \text{picks in 60 yards} \end{array}$$

$$\frac{\text{Total number of picks (86,400)}}{\text{Picks in pattern (48)}} = 1{,}800 \text{ repeats.}$$

Brown $\frac{1{,}800 \times 2 \times 72}{36} = 7{,}200$ yards.

$$\frac{7{,}200}{400} = 18 \text{ ounces.}$$

Black $\frac{1{,}800 \times 46 \times 72}{36} = 165{,}600$ yards.

$$\frac{165{,}600}{400} = 414 \text{ ounces.}$$

The same rule applies to the picks of worsted and cotton by using their respective counts and standard numbers.

EXAMINATION PAPER

TEXTILE CALCULATIONS

Read carefully: Place your name and full address at the head of the paper. Any cheap, light paper like the sample previously sent you may be used. Do not crowd your work, but arrange it neatly and legibly. *Do not copy the answers from the Instruction Paper; use your own words, so that we may be sure that you understand the subject.*

1. Find the worsted counts of the following yarns: 10,080 yards weigh 1 lb.; 9,240 yards weigh 12 ozs; 17,500 yards weigh $1\frac{1}{4}$ lbs.

2. Find the woolen runs of the following yarns: 6,400 yards weigh 1 lb.; 2,100 yards weigh 4 ounces; 8,400 yards weigh $5\frac{1}{4}$ lbs.

3. Find the cotton counts of the following yarns: 33,600 yards weigh 1 lb.; 20,160 yards weigh $\frac{1}{2}$-lb.; 100,800 yards weigh $1\frac{1}{2}$ lbs.

4. What is the weight of 21,840 yards of 13's worsted yarn? 31,500 yards of 15's cotton yarn? 4,800 yards of 6-run woolen yarn? and 134,400 yards of 20's spun silk?

5. Change the following yarns to cotton counts: 60's worsted; 10-run woolen; and 14-lea linen.

6. Change the following yarns to worsted counts: 16's cotton; 7-run woolen; and 24's spun silk.

7. Give the metric counts of the following yarns: 28's worsted; 5-run woolen; and 32's cotton.

8. Give the counts of the compound threads when the following yarns are twisted together: 36's and 30's worsted; 120's and 60's cotton; 30's and 60's spun silk.

9. Find the counts of a 3-ply thread composed of 60's, 30's, and 15's worsted; 72's, 36's, and 24's cotton; 12-run, 6-run, and 4-run woolen.

10. What is the counts of a novelty yarn composed of one thread each of 60's, 48's, and 36's cotton? The relative lengths of yarn used are 5, 4, and 2 inches. The 36's thread of which 2 inches are used is straight or 100%.

11. If a mill has 600 lbs. of 24's worsted, what weight of 18's worsted will be required to twist with it to work it all up, and what is the counts of the compound thread?

12. Find the average counts in a pattern composed of 4 threads of 60's cotton, 2 threads of 48's cotton and 1 thread of 30's cotton.

13. Find the diameters of the following yarns: 32's worsted, 100's cotton, and 8-run woolen.

14. How many threads of each of the yarns in Problem 13 will lie side by side in a cloth woven with the plain weave?

15. A sample of worsted cloth contains 60 threads, and 60 picks per inch. Allow 5% for shrinkage in width and length and find the number of threads and picks per inch with which the cloth was woven.

16–20. Analysis of Worsted Trousering.

Data. One square inch = 3.5 grains.
Width within selvedges, 28 inches.
68 threads per inch = 1.9 grains.
64 picks per inch = 1.6 grains.
Warp pattern; 3 slate; 2 black; 2 mix; 1 black = 8 threads.
Filling; solid black.

Find the following particulars:

(*a*) Weight of one yard inside selvedges.
(*b*) Threads in the warp.
(*c*) Patterns in the warp.
(*d*) Counts of warp in finished cloth.
(*e*) Counts of filling in finished cloth.
(*f*) Weight of warp yarn in one yard of finished cloth.
(*g*) Weight of filling yarn in one yard of finished cloth.

After completing the work, add and sign the following statement:

I hereby certify that the above work is entirely my own.

(Signed)