# TEXTILE CALCULATIONS

BY

E. A. POSSELT.

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SIXTH EDITION.

# TEXTILE CALCULATIONS,

BEING A GUIDE TO CALCULATIONS RELATING TO

## THE CONSTRUCTION OF ALL KINDS OF YARNS AND FABRICS, THE ANALYSIS OF CLOTH, ETC.


BY

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WITH NUMEROUS ILLUSTRATIONS

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# YARN AND CLOTH CALCULATIONS.

## Grading of the Various Yarns Used in the Manufacture of Textile Fabrics According to Size or Counts.

The size of the yarns, technically known as their "*Counts*" or numbers, are based for the different raw materials (with the exception of raw silks) upon the number of yards necessary to balance one (1) lb. avoirdupois. The number of yards thus required (to balance 1 lb.) are known as the "*Standard*" and vary accordingly for each material. The higher the count or number, the finer the yarn according to its diameter.

### COTTON YARNS.

Cotton yarns have for their standard 840 yards (equal to 1 hank) and are graded by the number of hanks 1 lb. contains. Consequently if 2 hanks, or 2 × 840 yards = 1680 yards are necessary to balance 1 lb. we classify the same as number 2 cotton yarn. If 3 hanks or 3 × 840 or 2520 yards are necessary to balance 1 lb., the thread is known as number 3 cotton yarn. Continuing in this manner, always adding 840 for each successive number gives the yards the various counts or numbers of cotton yarn contain for 1 lb.

#### Table of Lengths for Cotton Yarns.

(From number 1 to 240's.)

| No. | Yds. to 1 lb. | No. | Yds. to 1 lb. | No. | Yds. to 1 lb | No. | Yds. to 1 lb. | No. | Yds. to 1 lb. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 840 | 17 | 14,280 | 33 | 27,720 | 50 | 42,000 | 85 | 71,400 |
| 2 | 1,680 | 18 | 15,120 | 34 | 28,560 | 52 | 43,680 | 90 | 75,600 |
| 3 | 2,520 | 19 | 15,960 | 35 | 29,400 | 54 | 45,360 | 95 | 79,800 |
| 4 | 3,360 | 20 | 16,800 | 36 | 30,240 | 56 | 47,040 | 100 | 84,000 |
| 5 | 4,200 | 21 | 17,640 | 37 | 31,080 | 58 | 48,720 | 110 | 92,400 |
| 6 | 5,040 | 22 | 18,480 | 38 | 31,920 | 60 | 50,400 | 120 | 100,800 |
| 7 | 5,880 | 23 | 19,320 | 39 | 32,760 | 62 | 52,080 | 130 | 109.200 |
| 8 | 6,720 | 24 | 20,160 | 40 | 33,600 | 64 | 53,760 | 140 | 117,600 |
| 9 | 7,560 | 25 | 21,000 | 41 | 34,440 | 66 | 55,440 | 150 | 126,000 |
| 10 | 8,400 | 26 | 21,840 | 42 | 35,280 | 68 | 57,120 | 160 | 134,400 |
| 11 | 9,240 | 27 | 22,680 | 43 | 36.120 | 70 | 58,800 | 170 | 142,800 |
| 12 | 10,080 | 28 | 23,520 | 44 | 36,960 | 72 | 60,480 | 180 | 151,200 |
| 13 | 10,920 | 29 | 24,360 | 45 | 37,800 | 74 | 62,160 | 190 | 159,600 |
| 14 | 11,760 | 30 | 25,200 | 46 | 38,640 | 76 | 63,840 | 200 | 168,000 |
| 15 | 12,600 | 31 | 26,040 | 47 | 39,480 | 78 | 65,520 | 220 | 184,800 |
| 16 | 13,440 | 32 | 26,880 | 48 | 40,320 | 80 | 67,200 | 240 | 201,600 |

#### Grading of 2-ply, 3-ply, etc., Cotton Yarns.

Cotton Yarns are frequently manufactured into 2-ply. In such cases the number of yards required for 1 lb. is one-half the amount called for in the single thread.

*For Example.*—20's cotton yarn (single) equals 16,800 yards per pound, while a 2-ply thread of 20's cotton, technically indicated as 2/20's cotton, requires only 8400 yards, or equal to the amount called for in single 10's cotton (technically represented as 10's cotton). Single 7's cotton yarn has 5,880 yards to 1 lb., and thus equals 2-ply 14's cotton yarn; or 2/14's cotton yarn equals one-half the count (14÷2=7), or number 7 in single yarn.

If the yarn be more than 2-ply, divide the number of the single yarn in the required counts by the number of ply, and the result will be the equivalent counts in a single thread.

*Example.*—Three-ply 60's, or 3/60's cotton yarn, equals in size

| {Number of single yarn in required counts.} | | {Number of ply.} | | {Equivalent counts in a single thread} |
|---|---|---|---|---|
| (60 | ÷ | 3 | = | 20) |

single 20's cotton yarn, or 16,800 yards of single 20's cotton yarn weigh 1 lb., and 16,800 yards of 3/60's cotton yarn weigh also 1 lb. Again, 4-ply 60's or 4/60's cotton yarn equals in size

| {Number of single yarn in required counts.} | | {Number of ply.} | | {Equivalent counts in a single thread.} |
|---|---|---|---|---|
| (60 | ÷ | 4 | = | 15) |

single 15's cotton yarn; or single 15's cotton yarn has 12.600 yards, weighing 1 lb., which is also the number of yards required for 4/60's cotton yarn.

## Rule for finding the Weight in Ounces of a given Number of Yards of Cotton Yarn of a known Count.

Multiply the given yards by 16, and divide the result by the number of yards of the known count required to balance 1 lb.

*Example* (single yarn).—Find weight of 12,600 yards of 30's cotton yarn. 12,600×16=201,600; 1 lb. 30's cotton yarn=25,200 yards. Thus, 201,600÷25,200=8.
*Answer.*—12,600 yards of 30's cotton yarn weigh 8 oz.

*Example* (2-ply yarn).—Find the weight of 12,600 yards of 2/30's cotton yarn. 12,600×16=201,600; 1 lb. 2/30's cotton yarn=12,600 yards. Thus, 201,600÷12,600=16.
*Answer.*—12,600 yards of 2/30's cotton yarn weigh 16 oz.

*Example*—(3-ply yarn).—Find the weight of 12,600 yards of 3/30's cotton yarn. 12,600×16=201,600; 1 lb. 3/30's cotton yarn=8,400 yards. Thus, 201,600÷8,400=24 oz.
*Answer.*—12,600 yards of 3/30's cotton yarn weigh 24 oz.

Another rule for ascertaining the weight in ounces for a given number of yards of cotton yarn of a known count is as follows: Divide the given yards by the number of yards of the known count required to balance one ounce (being yards per lb.÷16).

*Example* (single yarn).—Find the weight of 12,600 yards of 30's cotton yarn. 25,200÷16=1,575 yards 30's cotton yarn=1 oz.; 12,600÷1,575=8.
*Answer.*—12,600 yards of 30's cotton yarn weigh 8 oz.

*Example* (2-ply yarn).—Find the weight of 12,600 yards of 2/30's cotton yarn. 12,600÷16=787½ yards 2/30's cotton yarn=1 oz.; 12,600÷787½=16.
*Answer.*—12,600 yards of 2/30's cotton yarn weigh 16 oz.

*Example* (3-ply yarn).—Find the weight for 12,600 yards of 3/30's cotton yarn. 8,400÷16=525 yards 3/30's cotton yarn=1 oz.; 12,600÷525=24.
*Answer.*—12,600 yards of 3/30's cotton yarn weigh 24 oz.

## Rule for finding the Weight in Pounds of a given Number of Yards of Cotton Yarn of a known Count.

Divide the given yards by the number of yards of the known count required to balance 1 lb.

*Example* (single yarn).—Find the weight of 1,260,000 yards of 30's cotton yarn. 30's cotton yarn=25,200 yards to 1 lb. Thus, 1,260,000÷25,200=50.
*Answer.*—1,260,000 yards of 30's cotton yarn weigh 50 lbs.

*Example* (2-ply yarn).—Find the weight of 1,260,000 yards of 2/30's cotton yarn. 2/30's cotton yarn=12,600 yards to 1 lb. Thus, 1,260,000÷12,600=100.

*Answer.*—1,260,000 yards of 2/30's cotton yarn weigh 100 lbs.

*Example* (3-ply yarn).—Find the weight of 1,260,000 yards of 3/30's cotton yarn. 3/30's cotton yarn=8,400 yards to 1 lb. Thus, 1,260,000÷8,400=150.

*Answer.*—1,260,000 yards of 3/30's cotton yarn weigh 150 lbs.

### To find the Equivalent Size in Single Yarn for Two, Three, or More, Ply Yarn Composed of Minor Threads of Unequal Counts.

In the manufacture of fancy yarns the compound thread is often composed of two or more minor threads of unequal counts. If so, the rules for finding the equivalent in single yarn is as follows:

*Rule.*—If the compound thread is composed of two minor threads of unequal counts, divide the product of the counts of the minor threads by their sum.

*Example.*—Find the equal in single yarn to a two-fold thread composed of single 40's and 60's. $40 \times 60 = 2400 \div 100\ (40+60) = 24$.

*Answer.*—A two-fold cotton thread composed of single 40's and 60's equals a single 24's.

*Rule.*—If the compound thread is composed of three minor threads of unequal counts, compound any two of the minor threads into one, and apply the previous rule to this compound thread and the third minor thread not previously used.

*Example.*—Find equal counts in a single thread to a 3-ply yarn composed of 20's, 30's and 50's. $20 \times 30 = 600 \div 50\ (20+30) = 12;\ 12 \times 50 = 600 \div 62\ (12+50) = 9\frac{21}{31}$.

*Answer.*—A 3-ply cotton yarn composed of 20's, 30's and 50's equals in size a single $9\frac{21}{31}$'s thread.

A second rule for finding the equivalent counts for a yarn when three or more minor threads are twisted together is as follows: Divide one of the counts by itself, and by the others in succession, and afterwards by the sum of the quotients. To prove the accuracy of this rule we give again the previously given example.

*Example.*—Find equal counts in a single thread to a 3-ply yarn composed of 20's, 30's and 50's.

$$\begin{array}{r} 50 \div 50 = 1 \\ 50 \div 30 = 1\frac{4}{6} \\ 50 \div 20 = 2\frac{3}{6} \\ \hline 5\frac{1}{6} \end{array} \qquad 50 \div 5\frac{1}{6} = 9\frac{21}{31}$$

*Answer.*—A 3-ply cotton thread composed of 20's, 30's and 50's equals in size a single $9\frac{21}{31}$'s thread.

*Example.*—Find equal counts in a single yarn for the following 3-ply yarn composed of 40's, 30's, and 20's cotton threads.

$$\begin{array}{r} 40 \div 40 = 1 \\ 40 \div 30 = 1\frac{1}{3} \\ 40 \div 20 = 2 \\ \hline 4\frac{1}{3} \end{array} \qquad 40 \div 4\frac{1}{3} = 9\frac{3}{13}$$

*Answer.*—The 3-ply yarn given in the example equals a single $9\frac{3}{13}$ cotton thread.

*Memo.*—In the manufacture of twisted yarns (composed either out of two, three, or more minor threads) a certain amount of shrinkage will take place by means of the twisting of the threads around each other. No doubt if both minor threads are of equal counts this shrinkage will be equal for both, but if the sizes of the yarns, or the raw materials of which they are composed, are different, such "*take-up*" will be different for each minor thread. For example: a strong and heavy minor thread twisted with a fine soft thread; in this case the finer thread will wind itself (more or less) around the thick or heavy thread, not having sufficient strength to bend the latter, thus the finer thread will take up more in proportion than the heavy thread. Twisting a woolen thread with a cotton thread, both supposed to be of the same counts, will stretch the former more than the latter; *i. e.* it will lose less in length during twisting compared to the latter. Again two or more minor threads twisted with different turns per inch will accordingly take up differently. In giving rules for any of the yarn calculations in 2, 3, or more ply yarn, no notice of shrinkage or take-up by means of twisting the minor threads is taken in account, since otherwise an endless number of rules of the most complicated character would be required with reference to raw materials, the different counts of threads, turns of twist per inch and tension for each individual minor thread during the twisting operation. Such rules would thus be of little value to the manufacturer since his practical experience regarding this subject will readily assist him to calculate quickly and exactly by rules given, with a proportional allowance for a take up of minor threads as the case may require.

## WOOLEN YARNS.

### A. "Run" System.

Woolen yarns are with the exception of the mills in Philadelphia and vicinity, graded by "*runs*" which have for their standard 1600 yards. Consequently 1 run yarn requires 1600 yards to 1 lb., 2 run yarn—3200 yards to 1 lb., 3 run yarn—4800 yards to 1 lb., etc., always adding 1600 yards for each successive run. In addition to using whole numbers only as in the case of cotton and worsted yarn, the run is divided into halves, quarters, and occasionally into eighths, hence—

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 200 | yards | equal | $\frac{1}{8}$ | run | 1000 | yards | equal | $\frac{5}{8}$ | run |
| 400 | " | " | $\frac{1}{4}$ | " | 1200 | " | " | $\frac{3}{4}$ | " |
| 600 | " | " | $\frac{3}{8}$ | " | 1400 | " | " | $\frac{7}{8}$ | " |
| 800 | " | " | $\frac{1}{2}$ | " | 1600 | " | " | 1 | " &c. |

### Table of Lengths for Woolen Yarns (*Run System*).

(From one-fourth Run to fifteen Run).

| Run. | Yds. to 1 lb. | Run. | Yds. to 1 lb. | Run. | Yds. to 1 lb. | Run. | Yds. to 1 lb. |
|---|---|---|---|---|---|---|---|
| ¼ | 400 | 3 | 4,800 | 5¾ | 9,200 | 8½ | 13,600 |
| ½ | 800 | 3¼ | 5,200 | 6 | 9,600 | 8¾ | 14,000 |
| ¾ | 1,200 | 3½ | 5,600 | 6¼ | 10,000 | 9 | 14,400 |
| 1 | 1,600 | 3¾ | 6,000 | 6½ | 10,400 | 9½ | 15,200 |
| 1¼ | 2,000 | 4 | 6,400 | 6¾ | 10,800 | 10 | 16,000 |
| 1½ | 2,400 | 4¼ | 6,800 | 7 | 11,200 | 10½ | 16,800 |
| 1¾ | 2,800 | 4½ | 7,200 | 7¼ | 11,600 | 11 | 17,600 |
| 2 | 3,200 | 4¾ | 7,600 | 7½ | 12,000 | 12 | 19,200 |
| 2¼ | 3,600 | 5 | 8,000 | 7¾ | 12,400 | 13 | 20,800 |
| 2½ | 4,000 | 5¼ | 8,400 | 8 | 12,800 | 14 | 22,400 |
| 2¾ | 4,400 | 5½ | 8,800 | 8¼ | 13,200 | 15 | 24,000 |

### Rule for Finding the Weight in Ounces of a Given Number of Yards of Woolen Yarn of a Known Count Graded After the Run System.

The run basis is very convenient for textile calculations by reason of the standard number equaling 100 times the number of ounces that 1 lb. contains; thus by simply multiplying the size of the yarn given in run counts by 100, and dividing the result into the number of yards given (for which we have to find the weight), gives us as the result the weight expressed in ounces.

*Example.*—Find the weight of 7200 yards of 4 run yarn—$4\times100=400$. $7200\div400=18$.
*Answer.*—7200 yards 4 run yarn weigh 18 ounces.

*Example.*—Find the weight of 3750 yards of 3$\frac{3}{4}$ run woolen yarn—$3750\div375=10$.
*Answer.*—3750 yards of 3$\frac{3}{4}$ run woolen yarn weigh 10 ounces.

### Rule for Finding the Weight in Pounds of a Given Number of Yards of Woolen Yarn of a Known Count Graded After the Run System.

If the weight of a given number of yards and of a given size of woolen yarn, run system, is required to be calculated in pounds, transfer the result obtained in ounces into pounds or fractions thereof.

*Example.*—Find the weight of 100,000 yards of $6\frac{1}{4}$ run yarn—100,000÷625=160 oz.÷16=10.
*Answer.*—100,000 yards of $6\frac{1}{4}$ run yarn weigh 10 lbs.

### B. "Cut" System.

As heretofore mentioned, woolen yarn is also graded by the "cut" system. 300 yards is the basis or standard, consequently if 300 yards of a given woolen yarn weigh 1 lb., we classify it as 1 cut yarn; if 600 yards weigh 1 lb. we classify it as 2 cut yarn; if 900 yards weigh 1 lb. we classify it as 3 cut yarn, and so on; hence the count of the woolen yarn expressed in the cut multiplied by 300 gives as the result the number of yards of respective yarn that 1 lb. contains.

### Table of Lengths for Woolen Yarns (*Cut System*).

(From 1 cut to 50 cut Yarn.)

| Cut. | Yards to lb. | Cut. | Yards to lb. | Cut. | Yards to lb. | Cut. | Yards to lb. | Cut. | Yards to lb. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 300 | 12 | 3,600 | 23 | 6,900 | 34 | 10,200 | 45 | 13,500 |
| 2 | 600 | 13 | 3,900 | 24 | 7,200 | 35 | 10,500 | 46 | 13,800 |
| 3 | 900 | 14 | 4,200 | 25 | 7,500 | 36 | 10,800 | 48 | 14,400 |
| 4 | 1,200 | 15 | 4,500 | 26 | 7,800 | 37 | 11,100 | 50 | 15,000 |
| 5 | 1,500 | 16 | 4,800 | 27 | 8,100 | 38 | 11,400 | 54 | 16,200 |
| 6 | 1,800 | 17 | 5,100 | 28 | 8,400 | 39 | 11,700 | 58 | 17,400 |
| 7 | 2,100 | 18 | 5,400 | 29 | 8,700 | 40 | 12,000 | 60 | 18,000 |
| 8 | 2,400 | 19 | 5,700 | 30 | 9,000 | 41 | 12,300 | 65 | 19,500 |
| 9 | 2,700 | 20 | 6,000 | 31 | 9,300 | 42 | 12,600 | 70 | 21,000 |
| 10 | 3,000 | 21 | 6,300 | 32 | 9,600 | 43 | 12,900 | 75 | 22,500 |
| 11 | 3,300 | 22 | 6,600 | 33 | 9,900 | 44 | 13,200 | 80 | 24,000 |

### Rule for Finding the Weight in Ounces for a Given Number of Yards of Woolen Yarn of a Known Count Figured by the "Cut" Basis.

This rule is similar to the one given for cotton yarn. "Multiply the given yards by 16 and divide the result by the original number of yards for the given count of cotton yarn that 1 lb. contains."

*Example.*—Find the weight of 12,600 yards of 40-cut woolen yarn. 12,600×16=201,600; 1 lb. of 40-cut woolen yarn=12,000 yards. Thus, 201,600÷12,000=16.8.
*Answer.*—12,600 yards of 40-cut woolen yarn weigh 16.8 oz.

The other rule for ascertaining the weight in ounces for a number of yards of cotton yarn of a known count is as follows: Divide the given yards by the number of yards of the known count required to balance one ounce.

*Example.*—Find the weight for 12,600 yards of 40-cut woolen yarn. 12,000÷16=750 12,600÷750=16.8.
*Answer.*—12,600 yards of 40-cut woolen yarn weigh 16.8 oz.

### Rule for Finding the Weight in Pounds of a Given Number of Yards of Woolen Yarn of a Known Count, Graded by the Cut Basis.

This rule is also similar to the one previously given for cotton yarn. Divide the given yards by the original number of yards for the given count of woolen yarn (cut basis) in 1 lb. The result expresses the weight in pounds, or fractions thereof.

*Example.*—Find the weight of 1,260,000 yards of 40-cut woolen yarn. 40-cut woolen yarn= 12,000 yards to 1 lb. Thus, 1,260,000÷12,000=105.

*Answer.*—1,260,000 yards of 40-cut woolen yarn weigh 105 lbs.

### Grading of Double and Twist or more Ply Woolen Yarn.

Woolen yarns are sometimes manufactured in double and twist (*d&tw.*), seldom in a more ply.

If produced in *d&tw*, and if both single threads are of the same counts, the established custom is to consider the compound thread one-half the count of the minor. Thus, a *d&tw.* 6-run woolen yarn will equal a single 3-run; or either yarn figures 4,800 yards to a lb. A *d&tw.* $7\frac{1}{2}$-run woolen yarn will equal a single $3\frac{3}{4}$-run woolen yarn; or either yarn requires 6,000 yards per lb. A *d&tw.* 30-cut woolen yarn equals a single 15-cut, or both kinds of yarn required 4,500 yards per lb.

If the compound thread is composed of three or more single threads, divide the number of the single yarn by the number of ply, and the result will be the required counts in a single thread.

*Examples.*—Three-ply 10-run woolen yarn equals a (10÷3) $3\frac{1}{3}$-run single thread, or requires $5,333\frac{1}{3}$ yards per lb. A 3-ply 45-cut woolen yarn equals a (45÷3) 15-cut single yarn, or requires 4,500 yards per lb.

Double and twisted woolen yarns, used in the manufacture of "fancy cassimeres," are frequently composed of two minor threads of unequal counts. If so, the rule for finding the equal in a single thread as compared with the compound thread is as follows: Divide the product of the counts of the minor threads by their sum.

*Example.*—Find the equal counts in single woolen yarn (run basis) for a double and twist thread composed of single 3-run and 6-run woolen yarn. $3\times6=18\div9(3+6)=2$.

*Answer.*—A 3-run and 6-run woolen thread being twisted equal a single 2-run woolen thread.

*Example.*—Find the equal counts in single woolen yarn (cut basis) for a double and twist thread composed of single 20-cut and 30-cut yarn. $20\times30=600\div50\ (20+30)=12$.

*Answer.*—A 20-cut and 30-cut woolen yarn twisted equal single 12-cut woolen yarn.

As previously mentioned, we may in a few instances be called on to calculate for a 3-ply yarn. If such a compound thread is composed of three minor threads of unequal counts, compound any of the minor threads into one, and apply the previously-given rule for *d&tw.*

*Example.*—A 3-run, 6-run and 8-run thread being twisted together, what are the equal counts in one thread for the compound thread?

$3\times6=18\div9(3+6)=2$. (A 3-run and a 6-run thread compounded equal a 2-run single thread) Thus, $2\times8=16\div10(2+8)=1\frac{6}{10}=1\frac{3}{5}$.

*Answer.*—Compound thread given in example equals $1\frac{3}{5}$ run.

*Example.*—A 20-cut, 30-cut and a 36-cut thread, being twisted together, what is its equal size in a single yarn? $20\times30=600\div50(20+30)=12$, and $12\times36=432\div48(12+36)=9$.

*Answer.*—Compound thread given in example equals a single 9-cut thread.

As already mentioned, under the head of cotton yarns, a second rule for finding the equivalent counts for a yarn where three or more minor threads are twisted together is as follows: Divide one of the counts by itself, and by the others in succession, and afterwards by the sum of the quotients.

To prove this rule, we will use examples heretofore given.

*Example.*—Find equal counts in one thread for the following compound thread, composed of a 3-run, 6-run and 8-run thread.

$$\begin{aligned} 8 \div 8 &= 1 \\ 8 \div 6 &= 1\tfrac{1}{3} \\ 8 \div 3 &= 2\tfrac{2}{3} \\ \hline &\ \ \ 5 \end{aligned} \qquad\qquad 8 \div 5 = 1\tfrac{3}{5}$$

*Answer.*—Compound thread given in example equals $1\frac{3}{5}$ run.

*Example.*—A 20-cut, 30-cut and 36-cut thread, being twisted together, what is its equal size in a single yarn?

$$36 \div 36 = 1$$
$$36 \div 30 = 1\tfrac{1}{5} \qquad\qquad 36 \div 4 = 9$$
$$36 \div 20 = 1\tfrac{4}{5}$$
$$\overline{\phantom{0}4}$$

*Answer.*—Compound thread given in example equals a single 9-cut thread.

## WORSTED YARNS.

Worsted yarns have for their standard measure 560 yards to the hank. The number of hanks that balance one pound indicate the number or the count by which it is graded. Hence if 40 hanks each 560 yards long, weigh 1 lb. such a yarn is known as 40's worsted. If 48 hanks are required to balance 1 lb. it is known as 48's worsted. In this manner the number of yards for any size or count of worsted yarns is found by simply multiplying the number or count by 560.

### Table of Lengths for Worsted Yarn.

(From No. 1 to 200's).

| No. | Yds. to 1 lb. | No. | Yds. to 1 lb. | No. | Yds. to 1 lb. | No. | Yds. to 1 lb. | No. | Yds. to 1 lb. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 560 | 15 | 8,400 | 29 | 16,240 | 46 | 25,760 | 74 | 41,440 |
| 2 | 1,120 | 16 | 8,960 | 30 | 16,800 | 48 | 26,880 | 76 | 42,560 |
| 3 | 1,680 | 17 | 9,520 | 31 | 17,360 | 50 | 28,000 | 80 | 44,800 |
| 4 | 2,240 | 18 | 10,080 | 32 | 17,920 | 52 | 29,120 | 85 | 47,600 |
| 5 | 2,800 | 19 | 10,640 | 33 | 18,480 | 54 | 30,240 | 90 | 50,400 |
| 6 | 3,360 | 20 | 11,200 | 34 | 19,040 | 56 | 31,360 | 95 | 53,200 |
| 7 | 3,920 | 21 | 11,760 | 35 | 19,600 | 58 | 32,480 | 100 | 56,000 |
| 8 | 4,480 | 22 | 12,320 | 36 | 20,160 | 60 | 33,600 | 110 | 61,600 |
| 9 | 5,040 | 23 | 12,880 | 37 | 20,720 | 62 | 34,720 | 120 | 67,200 |
| 10 | 5,600 | 24 | 13,440 | 38 | 21,280 | 64 | 35,840 | 130 | 72,800 |
| 11 | 6,160 | 25 | 14,000 | 39 | 21,840 | 66 | 36,960 | 140 | 78,400 |
| 12 | 6,720 | 26 | 14,560 | 40 | 22,400 | 68 | 38,080 | 160 | 89,600 |
| 13 | 7,280 | 27 | 15,120 | 42 | 23,520 | 70 | 39,200 | 180 | 100,800 |
| 14 | 7,840 | 28 | 15,680 | 44 | 24,640 | 72 | 40,320 | 200 | 112,000 |

### Grading of 2-ply, 3-ply, etc. Worsted Yarns.

Worsted yarn is like cotton yarn, very frequently produced in 2-ply. If such is the case, only one-half the number of yards as required per pound for the single yarn are required to balance the pound of 2-ply yarn. Hence 40's worsted (technically for single 40's worsted) requires 22,400 yards per lb. and 2/80's worsted (technically for 2-ply 80's worsted) requires also 22,400 yards per pound. 2/60's worsted has 16,800 yards per pound corresponding to single 30's worsted.

If the yarn be more than 2-ply, divide the number of yards of single yarn by the number of ply.

*Examples.*—3-ply 90's (3/90's) worsted yarn equals in size (90÷3) a single 30's thread; or both kinds of yarn require 16,800 yards to balance 1 lb.—4/80's worsted yarn equals a (80÷4) single 20's.

### Rule for Finding Weight in Ounces for a Given Number of Yards of Worsted Yarn of a Known Count.

Multiply the given yards by 16, and divide the result by the number of yards the given count of worsted yarn contains balancing 1 lb.

*Example* (single yarn).—Find the weight for 12,600 yards of 40's worsted. $12{,}600 \times 16 = 201{,}600$. 1 lb. of 40's worsted=22,400 yards, thus:—$201{,}600 \div 22{,}400 = 9$.
*Answer.*—12,600 of 40's worsted weigh 9 oz.

*Example* (2-ply yarn).—Find the weight of 12,600 yards of 2/40's worsted. $12{,}600 \times 16 = 201{,}600$. 1 lb. of 2/40's=11,200 yards. Hence $201{,}600 \div 11{,}200 = 18$
*Answer.*—12,600 yards of 2/40's worsted weigh 18 oz.

*Example* (3-ply yarn).—Find the weight of 12,600 yards of 3/40's worsted. $12{,}600 \times 16 = 201{,}600$. 1 lb of 3/40's=$7{,}466\frac{2}{3}$ yards, thus $201{,}600 \div 7{,}466\frac{2}{3} = 27$.
*Answer.*—12,600 yards of 3/40's worsted weigh 27 oz.

Another rule for ascertaining the weight in ounces for a given number of yards of worsted yarn of a known count is as follows: Divide the given yards by the number of yards of the known count required to balance 1 oz.

*Example* (single yarn).—Find the weight for 12,600 yards of 40's worsted. $22{,}400 \div 16 = 1{,}400$. $12{,}600 \div 1{,}400 = 9$.
*Answer.*—12,600 yards of 40's worsted weigh 9 oz.

*Example* (2-ply yarn).—Find the weight of 12,600 yards of 2/40's worsted. $11{,}200 \div 16 = 700$ $12{,}600 \div 700 = 18$.
*Answer.*—12,600 yards of 2/40's worsted weigh 18 oz.

*Example* (3-ply yarn).—Find the weight of 12,600 yards of 3/40's worsted. $7466\frac{2}{3} \div 16 = 466\frac{2}{3}$ and $12{,}600 \div 466\frac{2}{3} = 12600 \div \frac{1400}{3} = \frac{12600 \times 3}{1400} = 27$.
*Answer.*—12,600 yards of 3/40's worsted weigh 27 ounces.

## Rule for Finding the Weight in Pounds of a Given Number of Yards of Worsted Yarn of a Known Count.

Divide the given yards by the number of yards of the known count required to balance 1 lb.

*Example* (single yarn).—Find the weight of 1,260,000 yards of 40's worsted yarn, 40's worsted= 22,400 yds. to 1 lb. Thus, $1{,}260{,}000 \div 22{,}400 = 56\frac{1}{4}$.
*Answer.*—1,260,000 yds. of 40's worsted weigh $56\frac{1}{4}$ lbs.

*Example* (2-ply yarn).—Find the weight of 1,260,000 yards of 2/40's yarn. 2/40's worsted= 11,200 yards to 1 lb. Thus, $1{,}260{,}000 \div 11{,}200 = 112\frac{1}{2}$.
*Answer.*—1,260,000 yards of 2/40's worsted yarn weigh $112\frac{1}{2}$ lbs.

*Example* (3-ply yarn).—Find the weight of 1,260,000 yards of 3/40's worsted yarn. 3/40's worsted=7,467 yards to 1 lb. Hence, $1{,}260{,}000 \div 7{,}467 = 168\frac{3}{4}$.
*Answer.*—1,260,000 yards of 3/40's worsted yarn weigh $168\frac{3}{4}$ lbs.

## To Find the Equivalent Size in Single Yarn of Two, Three or More Ply Yarn Composed of Minor Threads of Unequal Counts.

Worsted yarn is also occasionally manufactured in 2, 3, or more ply yarn in which the minor threads are of unequal counts; if so the rules for finding the equivalent in a single yarn are similar to those given for cotton and woolen yarns.

If the compound thread is composed of two minor threads of unequal counts, divide the product of the counts of the minor threads by their sum.

*Example.*—Find the equal in single yarn to a 2-fold thread composed of single 20's and 60's. $20 \times 60 = 1200 \div 80\ (20+60) = 15$.

*Answer.*—A 2-fold worsted yarn composed of 20's and 60's equals a single 15's.

If the compound thread is composed of 3 minor threads of unequal counts, compound any two of the minor threads into one, and apply the rule given previously to this thread and the third minor thread not previously used.

*Example.*—Find equal counts in a single thread to a 3-ply yarn composed of 20's, 40's, and 60's. $20 \times 40 = 800 \div 60\ (20+40) = 13\frac{1}{3}$. $13\frac{1}{3} \times 60 = 800 \div 73\frac{1}{3}\ (13\frac{1}{3}+60) = 10\frac{10}{11}$.

*Answer.*—A 3-ply 20's, 40's, and 60's worsted thread equals in size a single $10\frac{10}{11}$'s.

These examples can be proved by the second rule, viz.: Divide one of the counts by itself and by the others in succession, and after this by the sum of the quotients.

*Example.*—Find equal counts in a single thread to a 3-ply yarn composed of 60's, 40's and 20's worsted.

$$\begin{array}{l} 60 \div 60 = 1 \\ 60 \div 40 = 1\frac{1}{2} \\ 60 \div 20 = 3 \\ \hline \qquad\quad 5\frac{1}{2} \end{array} \qquad\qquad 60 \div 5\frac{1}{2} = 10\frac{10}{11}.$$

*Answer.*—A 3-ply 20's, 40's and 60's worsted thread equals in size a single $10\frac{10}{11}$'s.

## SILK YARNS.

### A. Spun Silks.

Spun silks are calculated as to the size of the thread, on the same basis as cotton (840 yards to 1 hank), the number of hanks one pound requires indicating the counts. In the calculation of cotton, woolen or worsted, double and twist yarn, the custom is to consider it as twice as heavy as single; thus double and twisted 40's (technically 2/40's) cotton, equals single 20's cotton for calculations. In the calculation of spun silk the single yarn equals the two-fold; thus single 40's and two-fold 40's require the same number of hanks (40 hanks equal 33,600 yards). The technical indication of two-fold in spun silk is also correspondingly reversed if compared to cotton, wool and worsted yarn. In cotton, wool and worsted yarn the 2 indicating the two-fold is put in front of the counts indicating the size of the thread (2/40's), while in indicating spun silk this point is reversed (40/2's), or in present example single 80's doubled to 40's.

### B. Raw Silks.

The adopted custom of specifying the size of raw silk yarns is in giving the weight of the 1000 yards hank in drams avoirdupois; thus if one hank weighs 5 drams it is technically known as "5 dram silk," and if it should weigh $8\frac{1}{2}$ drams it is technically known as "$8\frac{1}{2}$ dram silk." As already mentioned the length of the skeins is 1000 yards, except in fuller sizes where 1000 yard skeins would be rather bulky, and apt to cause waste in winding. Such are made into skeins of 500 and 250 yards in length and their weight taken in proportion to the 1000 yards; thus if the skein made up into 500 yards weighs $8\frac{1}{2}$ drams, the silk would be 17-dram silk; if a skein made up into 250 yards weighs 4 drams the silk would be 16-dram silk. The size of yarn is always given for their "gum" weight; that is their condition "before boiling off," in which latter process yarns lose from 24 to 30 per cent. according to the class of raw silk used; China silks losing the most and European and Japan silks the least. The following table shows the number of yards to the pound and ounce from 1 dram silk to 30 dram silk. The number of yards given per pound in the table is based on a pound of gum silk.

### Length of Gum Silk Yarn per Pound and per Ounce.

(From 1 dram to 30 drams.)

| Drams per 1000 yards. | Yards per lb. | Yards per oz. | Drams per 1000 yards | Yards per lb. | Yards per oz. | Drams per 1000 yards. | Yards per lb. | Yards per oz. |
|---|---|---|---|---|---|---|---|---|
| 1 | 256,000 | 16,000 | 5 | 51,200 | 3,200 | 16 | 16,000 | 1,000 |
| 1¼ | 204,800 | 12,800 | 5½ | 46,545 | 2,909 | 17 | 15,058 | 941 |
| 1½ | 170,666 | 10,667 | 6 | 42,667 | 2,667 | 18 | 14,222 | 889 |
| 1¾ | 146,286 | 9,143 | 6½ | 39,385 | 2,462 | 19 | 13,474 | 842 |
| 2 | 128,000 | 8,000 | 7 | 36,571 | 2,286 | 20 | 12,800 | 800 |
| 2¼ | 113,777 | 7,111 | 7½ | 34,133 | 2,133 | 21 | 12,190 | 762 |
| 2½ | 102,400 | 6,400 | 8 | 32,000 | 2,000 | 22 | 11,636 | 727 |
| 2¾ | 93,091 | 5,818 | 8½ | 30,118 | 1,882 | 23 | 11,130 | 696 |
| 3 | 85,333 | 5,333 | 9 | 28,444 | 1,778 | 24 | 10,667 | 666 |
| 3¼ | 78,769 | 4,923 | 9½ | 26,947 | 1,684 | 25 | 10,240 | 640 |
| 3½ | 73,143 | 4,571 | 10 | 25,600 | 1,600 | 26 | 9,846 | 615 |
| 3¾ | 68,267 | 4,267 | 11 | 23,273 | 1,455 | 27 | 9,481 | 592 |
| 4 | 64,000 | 4,000 | 12 | 21,333 | 1,333 | 28 | 9.143 | 571 |
| 4¼ | 60,235 | 3,765 | 13 | 19,692 | 1,231 | 29 | 8,827 | 551 |
| 4½ | 56,889 | 3,556 | 14 | 18,286 | 1,143 | 30 | 8,533 | 533 |
| 4¾ | 53,368 | 3,368 | 15 | 17,067 | 1,067 | | | |

### LINEN YARNS.

Linen yarns are graded, or have for their standard 300 yards to the hank or "lea," which is the same basis for calculations with reference to size, count, or diameter of thread, as the one given for the woolen yarn, viz., (cut system); hence, rules given for woolen yarn (cut system), will also apply to linen yarns by simply changing the denomination.

### Jute Yarns, Chinagrass and Ramie

Are also graded similar to the woolen yarn (cut system), with 300 yards to the hank, the number of hanks required to balance 1 lb. indicating the size or count of the yarn.

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**For Reproducing Fabrics in a Required Material From a Given Fabric Made Out of Another Material it is Often Necessary to Find the Equivalent Counts, Thus we Give**

## Rules for Finding the Equivalent Counts of a Given Thread in Another System.

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### A. COTTON, WOOLEN AND WORSTED YARN.

*Rule.*—The counts of a given thread are the counts of an equal thread (in size) of a different material, or a thread of the same material but figured after the different "standard" in the same proportion as the "standard number" of the one to be found is to the "standard number" of the one given.

*Example.*—**Cotton-Worsted.** Find equal size in worsted yarn to 20's cotton yarn.

(Cotton standard.) : (Worsted standard).

840 : 560 = 3 : 2

Thus 20:x::2:3 and 3×20=60÷2=30.

*Answer.*—A thread of 20's cotton yarn equals (in size) a thread of 30's worsted yarn.

*Example.*—**Cotton-Wool** (run system). Find equal size in woolen yarn (runs) to 10's cotton yarn.

| (Cotton standard.) | : | (Run standard.) | |
|---|---|---|---|
| 840 | : | 1,600 | =21 : 40 |

Thus 10:x::40:21 and 21×10=210÷40=5¼.

*Answer.*—A thread of 10's cotton equals (in size) a thread of 6¼-run (wool).

*Example.*—**Cotton-Wool** (cut system). Find equal size in woolen yarn (cut basis) to 10's cotton yarn.

| (Cotton standard.) | : | (Cut standard.) | |
|---|---|---|---|
| 840 | : | 300 | = 14 : 5 |

Thus 10:x :: 5:14 and 14×10=140÷5=28.

*Answer.*—A thread of 10's cotton yarn equals (in size) a thread of 28-cut woolen yarn.

*Example.*—**Worsted-Wool** (run system). Find equal size in woolen yarn (run basis) to 20's worsted yarn.

| (Worsted standard.) | : | (Run standard.) | |
|---|---|---|---|
| 560 | : | 1,600 | =7:20 |

Thus 20:x :: 20:7 and 7×20=140÷20=7.

*Answer.*—A thread of 20's worsted equals (in size) a thread of 7-run woolen yarn.

*Example.*—**Worsted-Wool** (cut system). Find equal size in woolen yarn (cut basis) to 15's worsted yarn.

| (Worsted standard.) | : | (Cut standard.) | |
|---|---|---|---|
| 560 | : | 300 | =28:15 |

Thus 15:x :: 15:28 and 15×28=428÷15=28.

*Answer.*—A thread of 15's worsted equals (in size) a thread of 28-cut woolen yarn.

*Example.*—**Worsted-Cotton.** Find equal size in cotton yarn to 30's worsted.

30:x :: 3:2and 30×2=60÷3=20.

*Answer.*—A thread of 30's worsted equals (in size) a thread of 20's cotton yarn.

*Example.*—**Wool** (run system) **-Cotton.** Find equal size in cotton yarn to a 5¼-run woolen yarn

5.25:x :: 21:40 and 5.25×40=210÷21=10.

*Answer.*—A 5¼-run woolen yarn equals (in size) a 10's cotton yarn.

*Example.*—**Wool** (run system) **-Worsted.** Find equal size in worsted yard to a 7-run woolen yarn.

7:x :: 7:20 and 7×2=140÷7=20.

*Answer.*—A 7-run woolen yarn equals in size a 20's worsted yarn.

*Example.*—**Wool** (run system) **-Wool** (cut system). Find equal size in the cut basis for a 6-run woolen thread.

6:x :: 3:16 and 6×16=96÷3=32.

*Answer.*—A 6-run woolen thread equals (in size) a 32-cut thread of the same material.

*Example.*—**Wool** (cut system) **-Cotton.** Find equal size of cotton yarn to a 28-cut woolen yarn.

28:x :: 14:5 and 5×28=140÷14=10.

*Answer.*—A 28-cut woolen yarn equals (in size) a 10's cotton yarn.

*Example.*—**Wool** (cut system) -**Worsted.** Find equal size worsted yarn to a 28-cut woolen yarn.

28 : x :: 28 : 15 and 28×15=420÷28=15.

*Answer.*—A 28-cut woolen yarn equals (in size) a 15's worsted yarn.

*Example.*—**Wool** (cut system) -**Wool** (run system). Find equal size of the run basis for a 32-cut woolen yarn.

32 : x :: **16** : 3 and 3×32=96÷16=6.

*Answer.*—A 32-cut woolen yarn equals (in size) a 6-run woolen yarn.

## B. SPUN SILK YARNS COMPARED TO COTTON, WOOLEN OR WORSTED YARNS.

As already stated in a previous chapter the basis of spun silk is the same as that of cotton; therefore the rules and examples given under the heading of "Cotton" refer at the same time to spun silk.

## C. LINEN YARNS, JUTE AND RAMIE.

These yarns have the same standard of grading as woolen yarn (cut system); thus examples given under the latter basis will also apply to the present kind of yarns.

## D. RAW SILK YARNS COMPARED TO SPUN SILK, COTTON, WOOLEN OR WORSTED YARNS.

*Rule.*—Find the number of yards per pound (in table previously given) in raw silk and divide the same by the standard size of the yarn basis to be compared with.

*Example.*—**Raw Silk-Cotton** (or spun silk). Find equal size in cotton yarn to 9-dram raw silk. 9-dram raw silk=28,444 yds. per lb. Thus 28,444÷840 (cotton standard)=33$\frac{6}{7}$.

*Answer.*—2-dram raw silk equals (nearly) 34's cotton.

Or if calculating without a table proceed as follows: 1 lb.=16 oz. 1 oz.=16 drams. Thus 16×16=256 drams per lb.

| (Counts given.) | : | (Yards in 1 hank.) | :: | (Drams per lb.) | : | (Yards per lb.) |
|---|---|---|---|---|---|---|
| 9 | : | 1000 | :: | 256 | : | x |

256×1000=256,000÷9=28,444$\frac{4}{9}$ yds. per lb. of 9 drams raw silk.

| (Yards per lb.) | :: | (Basis of yarn to compare with.) | |
|---|---|---|---|
| 28,444 | ÷ | 840 | =33$\frac{6}{7}$ |

being with the same result as before.

*Example.*—**Spun Silk or Cotton to Raw Silk.** Find equal size in raw silk to 38's cotton. 38's cotton=(38×840) 31,920 yds. per lb. Refer to previously given table for raw silk, where you will find 8 drams to equal 32,000 yards per lb.

*Answer.*—A 38's cotton thread equals (nearly) an 8-dram raw silk thread.

Or if calculating without table find result by:

*Rule.*—Divide the standard measure (number of yards per lb.) of the given yarn by 1000 (yards in one hank) and the quotient thus obtained into 256. (drams in 1 lb.)

*Example.*—Find the answer by this rule for previously given question. 38's cotton=31,920 yards. Thus 31,920÷1000=31.92 and 256÷31.92=8.02.

*Answer.*—A 38's cotton thread equals (nearly) an 8-dram raw silk thread.

# Ascertaining the Counts of Twisted Threads Composed of Different Materials.

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The above question may often arise when manufacturing fancy yarns and of which it is requisite to know the compound size for future calculations.

**RULE A.---If the compound thread is composed of two minor threads of different materials,** one must be reduced to the relative basis of the other thread and the resulting count found in this system.

*Example.*—Find equal counts in a single worsted thread to a 2-ply thread composed of 30's worsted and 40's cotton yarn.

40's cotton=60's worsted. Thus, $30\times60=1800\div90\ (30+60)=20$.

*Answer.*—Compound thread given in example equals a single 20's worsted thread.

*Example.*—Find the equal counts in single cotton yarn to a 2-ply thread composed of single 30's worsted and 40's cotton yarn.

30's worsted=20's cotton. Thus, $40\times20=800\div60\ (40+20)=13\frac{1}{3}$.

*Answer.*—Compound thread given in example equals a single cotton thread of number $13\frac{1}{3}$.

*Example.*—Find the equal counts in single woolen yarn (run basis) to a 2-ply thread composed of single 20's cotton yarn and 6-run woolen yarn.

20's cotton=$10\frac{1}{2}$-run woolen yarn. Thus, $10\frac{1}{2}\times6=63\div16\frac{1}{2}\ (10\frac{1}{2}+6)=3\frac{9}{11}$.

*Answer.*—Compound thread given in example equals a single woolen thread of $3\frac{9}{11}$-run.

*Example.*—Find the equal counts in single woolen yarn (cut basis) to a 2-ply thread composed of single 40's cotton and 28-cut woolen yarn.

40's cotton=112-cut. Thus, $28\times112=3136\div140\ (28+112)=22\frac{4}{10}$.

*Answer.*—Compound thread given in example equals a single woolen yarn of $22\frac{2}{5}$-cut.

*Example.*—Find the equal counts in single worsted yarn to a 2-ply thread composed of single 20's worsted and 60's spun silk. 60's silk=90's worsted. Thus, $20\times90=1800\div110\ (20+90)\ 16\frac{4}{11}$.

*Answer.*—Compound thread given in example equals a single $16\frac{4}{11}$'s worsted.

**RULE B.---If the compound thread is composed of three minor threads of two or three different materials,** they must by means of their relative length be transferred in one basis and the resulting count found in this system.

*Example.*—Find equal counts in single woolen yarn, run basis, for the following compound thread composed of a 3-run, a 6-run woolen thread, and a single 20's cotton twisted together.

$$3\times6=18\div9\ (3+6)=2.$$

(3-run and-6 run threads compounded, equal a single 2-run thread.)

20's cotton equals $10\frac{1}{2}$-run, thus $2\times10\frac{1}{2}=21\div12\frac{1}{2}\ (2+10\frac{1}{2})\ =1\frac{17}{25}$.

*Answer.*—The three-fold thread given in example equals in count a single woolen yarn of $1\frac{17}{25}$ (nearly $1\frac{3}{4}$) run.

The previously given example may also be solved as follows:—20's cotton=$10\frac{1}{2}$-run woolen yarn, thus,

$$\begin{aligned} 10\tfrac{1}{2}\div10\tfrac{1}{2} &= 1 \\ 10\tfrac{1}{2}\div6 &= 1\tfrac{3}{4} \\ 10\tfrac{1}{2}\div3 &= 3\tfrac{1}{2} \\ \hline & \ \ 6\tfrac{1}{4} \end{aligned} \qquad 10\tfrac{1}{2}\div6\tfrac{1}{4}=1\tfrac{17}{25}.$$

*Answer.*—A 3-run, a 6-run woolen thread, and a single 20's cotton twisted together equal in size a $1\frac{17}{25}$-run woolen thread.

# Ascertaining the Counts for a Minor Thread to Produce, with Other Given Minor Threads, Two, Three, or More Ply Yarn of a Given Count.

## A. ONE SYSTEM OF YARN.

In some instances it may be required that the compound thread produced out of two, three, or more, minor threads must be of a certain count. We may be requested to twist with a minor thread of a given count a minor thread of unknown count (to be ascertained); both threads to produce a compound thread of known count. If such is the case proceed after the following *Rule*: Multiply the counts of the given single thread by the counts of the compound thread, and divide the product by the remainder obtained by subtracting the counts of the compound threads from the counts of the given single thread.

*Example.*—Find size of single yarn required (run basis) to produce with a 4-run woolen yarn a compound thread of 3-run. $4 \times 3 = 12 \div 1 (4 - 3) = 12$.

*Answer.*—The minor thread required in the present example is a 12-run thread, or a 4-run and a 12-run woolen thread compounded into a 2-fold yarn, are equal in counts to a 3-run single woolen thread.

*Proof.*—$4 \times 12 = 48 \div 16 = 3$-run, or compound thread, as required.

*Example.*—Find size of single yarn required (worsted numbers) to produce with a 48's worsted thread a compound thread the equal of 16's worsted yarn. $48 \times 16 = 768 \div 32 (48 - 16) = 24$.

*Answer.*—The minor thread required in the present example is a 24's worsted thread, or a 48's worsted thread and a 24's worsted thread compounded into a two-fold yarn, are equal in counts to a single 16's worsted thread.

*Proof.*—$48 \times 24 = 1152 \div 72 = 16$'s worsted or compounded size required.

*Example.*—Find size of single yarn required (cotton numbers) to produce with an 80's cotton thread a 2-fold yarn of a compound size of equal 30's cotton yarn. $80 \times 30 = 2400 \div 50 (80 - 30) = 48$.

*Answer.*—The minor thread required in the present example is a 48's cotton thread compounded into a 2-fold yarn equal in this compound size to a single 30's cotton thread.

*Proof.*—$80 \times 48 = 3840 \div 128 = 30$'s cotton, or compound size required.

If one of the minor threads is to be found for a 3-ply thread of which two minor threads are known, use the following *Rule:* Compound the two minor threads given into their equal in a single thread, and solve the question by the previously given rule.

*Example.*—Find minor thread required to produce with single 30's and single 60's worsted a 3-ply yarn to equal single 12's worsted. 60's and 30's worsted compound $= (60 \times 30 = 1800 \div 90 - (60 + 30) = 20)$ single 20's worsted.

| Thus | | | | | | | |
|---|---|---|---|---|---|---|---|
| Thus | 20 | × | 12 | =240÷8 | (20 | — | 12) =30 |
| | {Compound two minor threads of which size is known.} | × | {Known size of ply yarn.} | | {Compound two minor threads of which size is known.} | — | {Known size of 3-ply yarn.} |

*Answer.*—The size of the third minor required to be ascertained in the given example is single 30's worsted yarn, or a 3-ply thread composed of single 30's, 60's, and 30's worsted yarn equals single 12's worsted counts as shown by the

*Proof.*—

$$60 \div 60 = 1$$
$$60 \div 30 = 2 \qquad 60 \div 5 = 12\text{'s worsted.}$$
$$60 \div 30 = 2$$
$$\overline{\phantom{0}5\phantom{0}}$$

### B. TWO SYSTEMS OF YARNS.

In the manufacture of fancy yarns we may be called on to select the proper minor thread required in another material. This, however, will not change previously given rules, for after finding the counts in the given system we only have to transfer the same to the required system.

*Example* (2-ply yarn).—Find the size of single worsted yarn required to produce with an 8-run woolen yarn a compound thread of 6-run yarn.

$8 \times 6 = 48 \div 2\ (8-6) = 24$-run woolen yarn required.

24-run woolen yarn=38,400 yards per lb. and $38{,}400 \div 560 = 68\frac{4}{7}$.

*Answer*.—The single worsted thread required in given example is $68\frac{4}{7}$'s.

*Example* (3-ply yarn).—Find the size of the spun silk required to produce with a 40's and 60's worsted a 3-ply yarn of equal count to single 12's worsted. $40 \times 60 = 2{,}400 \div 100\ (40+60) = 24 =$ compound size of 40's and 60's. $24 \times 12 = 288 \div 12\ (24-12) = 24$'s worsted size required to be transferred in spun silk.

$$24 \times 560 = 13{,}440 \div 840 = 16$$

*Answer*.—16's spun silk is required in present example.

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# Ascertaining the Amount of Material Required for Each Minor Thread in Laying Out Lots for Two, Three, or More Ply Yarn.

### A. DOUBLE AND TWIST YARN.

#### Composed of Minor Threads of the Same Material.

For producing a certain amount of fancy double and twist yarn it is necessary to ascertain the amount of stock required for each minor thread. This question will readily be solved by—

*Rule*.—The sum of both counts is to the one of the counts, in the same proportion as the amount of double and twist yarn required is to the amount of the yarn required for producing the other minor thread.

*Example*.—Find amount of material required for each minor thread for producing 1000 lbs. of double and twist yarn made out of 6 and 7-run minor threads.

$$(6+7) = 13 : 6 :: 1{,}000 : x$$
$$(6+7) = 13 : 7 :: 1{,}000 : x$$
$$6 \times 1{,}000 = 6{,}000 \div 13 = 461\tfrac{7}{13}$$
$$7 \times 1{,}000 = 7{,}000 \div 13 = 538\tfrac{6}{13}$$
$$\overline{\phantom{0}1{,}000}$$

*Answer*.—In previously given example the following amount of yarn (of minor threads) is required :—$461\frac{7}{13}$ lbs. of 7-run yarn.

$536\frac{6}{13}$ " " 6-run yarn.

*Proof*.— $461\frac{7}{13}$ lbs. of 7-run yarn=$(461\frac{7}{13} \times 11{,}200) = 5{,}169{,}230\frac{10}{13}$ yds.

$538\frac{6}{13}$ lbs. of 6-run yarn=$(538\frac{6}{13} \times 9{,}600) = 5{,}169{,}230\frac{10}{13}$ yds.

*Example*.—Find amount of material required for each minor thread for producing **250 lbs. of** double and twist yarn made out of 32's and 40's worsted for the minor threads.

$$(32+40) = 72 : 32 :: 250 : x$$
$$(32+40) = 72 : 40 :: 250 : x$$
$$32 \times 250 = 8{,}000 \div 72 = 111\tfrac{1}{9}$$
$$40 \times 250 = 10{,}000 \div 72 = 138\tfrac{8}{9}$$
$$\overline{\phantom{0}250}$$

*Answer.*—For producing 250 lbs. of double and twist worsted yarn composed of 32's and 40's for minor threads,

$111\frac{1}{9}$ lbs. of 40's and $138\frac{8}{9}$ lbs. of 32's are required.

*Proof.*— $111\frac{1}{9}$ lbs. of 40's worsted equal $(111\frac{1}{9}\times22{,}400)=2{,}488{,}888\frac{8}{9}$ yds.
$138\frac{8}{9}$ lbs. of 32's worsted equal $(138\frac{8}{9}\times17{,}920)=2{,}488{,}888\frac{8}{9}$ yds.

*Example.*—Find amount of material required for each minor thread for producing 1,000 lbs. of double and twist cotton yarn made with 60's and 80's for minor threads.

$$(60+80)=140:60::1{,}000:x$$
$$(60+80)=140:80::1{,}000:x$$
$$60\times1{,}000=60{,}000\div140=428\tfrac{4}{7}$$
$$80\times1{,}000=80{,}000\div140=571\tfrac{3}{7}$$
$$\overline{1{,}000}$$

*Answer.*—For producing 1,000 lbs. of double and twist cotton yarn made out of single 60's and 80's the following amount of each are required:

$428\frac{4}{7}$ lbs. of 80's
$571\frac{3}{7}$ lbs. of 60's

*Proof.*— $428\frac{4}{7}$ lbs. of 80's cotton equal $(428\frac{4}{7}\times67{,}200)=28{,}800{,}000$ yards.
$571\frac{3}{7}$ lbs. of 60's cotton equal $(571\frac{3}{7}\times50{,}400)=28{,}800{,}000$ yards.

### Composed of Minor Threads of Different Materials.

If the minor threads are of different materials transfer either one to the relative length of the other, and solve example by previously given rule.

*Example.*—Find amount of material required for each minor thread to produce 100 lbs. double and twist yarn made out of 40-cut woolen yarn and 60's spun silk.

60's spun silk equals 168-cut. Thus,

$$(40+168)=208:40::100:x$$
$$(40+168)=208:168::100:x$$
$$40\times100=4{,}000\div208=19\tfrac{3}{13}$$
$$168\times100=16{,}800\div208=80\tfrac{10}{13}$$
$$\overline{100}$$

*Answer.*—To produce 100 lbs. of double and twist yarn as mentioned in example, $19\frac{3}{13}$ lbs. of 60's spun silk and $80\frac{10}{13}$ lbs. of 40- cut woolen yarn are required.

*Proof.*— $19\frac{3}{13}$ lbs. of 60's spun silk equal to $(19\frac{3}{13}\times50{,}400)=969{,}230\frac{10}{13}$ yards.
$80\frac{10}{13}$ lbs. of 40-cut woolen yarn equal $(80\frac{10}{13}\times12{,}000)=969{,}230\frac{10}{13}$ yards.

As already mentioned in a previous chapter, if twisting silk yarn with a woolen yarn the former thread will twist proportionately more around the latter, thus we must add an allowance for it to the silk yarn, which in turn we must deduct from the woolen yarn. But as this difference (or allowance) is regulated by the turns of twist per inch, also the tension of the yarn when twisting it will vary (as little as it will be) in each different *d & tw.* yarn; but will be readily ascertained by the manufacturer in his practical work.

## B. THREE-PLY YARN.

### Composed of Minor Threads of the Same Material.

Sometimes it may be required to find the amount of material for each minor thread for a given weight of a 3-ply yarn. If so the example must be solved by

*Rule.*—Transfer the given three counts to their equivalent in a single thread and find number of yards required to balance given weight. Afterwards divide each standard (number of yards necessary to balance 1 lb.) of the three given minor threads in the number of yards required, the result being pounds necessary for each count.

*Example.*—Find amount of material required for each minor thread for 100 lbs. of 3-ply yarn, produced out of 5, 6 and 7-run woolen yarn for the minor threads.

5, 6, and 7-run.

$7 \div 7 = 1$

$7 \div 6 = 1\frac{5}{30}$

$7 \div 5 = 1\frac{12}{30}$

$3\frac{17}{30}$ $7 \div 3\frac{17}{30} = 1\frac{103}{107}$ equivalent count in a single thread for 5, 6 and 7-run.

$1\frac{103}{107} \times 1{,}600 = 3{,}140\frac{20}{107}$ yards per lb., $\times 100$ lbs. (total amount of yarn wanted) $= 314{,}018\frac{74}{107}$ total number of yards of 3-ply yarn required.

$314{,}018 \div 8{,}000$ (Standard for 5-run) $= 39.25$

$314{,}018 \div 9{,}600$ (Standard for 6-run) $= 32.71$

$314{,}018 \div 11{,}200$ (Standard for 7-run) $= 28.04$

100.00

*Answer.*—The amount of yarn for each minor thread in given example is as follows:

39.25 lbs. of 5-run woolen yarn.

32.71 lbs. of 6-run woolen yarn.

28.04 lbs. of 7-run woolen yarn.

100 lbs. Total amount of yarn wanted.

### Composed of Minor Threads of Different Materials.

If in a 3-ply yarn one of the minor threads is of a different material (compared to the other two), transfer this thread to its equivalent count of the other basis, and solve example by previously given rule.

*Example.*—Find amount of material required to produce 1,000 lbs. of 3-ply yarn made out of 30's worsted, 45's worsted and 60's spun silk.

60's spun silk equals 90's worsted yarn, thus:

30—45—90

$90 \div 90 = 1$

$90 \div 45 = 2$

$90 \div 30 = 3$

6

$90 \div 6 = 15$'s equivalent count in single thread.

$15 \times 560 = 8{,}400$ yards per lb. $\times 1{,}000$ lbs. (total amount of yarn wanted) $= 8{,}400{,}000$ total number of yards of 3-ply yarn required.

$8{,}400{,}000 \div 16{,}800$ (Standard for 30's worsted) $= 500.00$

$8{,}400{,}000 \div 25{,}200$ (Standard for 45's worsted) $= 333.33 + (\frac{1}{3})$

$8{,}400{,}000 \div 50{,}400$ (Standard for 90's worsted) $= 166.66 + (\frac{2}{3})$

1000.00

*Answer.*—The amount for each minor thread in given example is as follows:

500 lbs. of 30's worsted.

$333\frac{1}{3}$ lbs. of 45's worsted.

$166\frac{2}{3}$ lbs. of 60's spun silk.

1,000 lbs. Total amount of yarn wanted.

# Ascertaining the Cost of Two, Three, or More Ply Yarn.

### COMPOSED EITHER OF DIFFERENT QUALITIES (AS TO PRICE) OF YARN ONLY, OR OF THE LATTER ITEM IN ADDITION TO DIFFERENT COUNTS OF THE MINOR THREADS.

If a 2-ply yarn is composed of minor threads of equal counts, but different qualities, (as to cost) the average between the two prices will be the cost of the 2-ply thread.

*Example.*—Find the price for 2/40's worsted composed of minor threads worth respectively $1.00 and $1.36.

$$\$1.00+\$1.36=\$2.36\div 2=\$1.18.$$

*Answer.*—The price of the yarn in question is $1.18 per pound.

By means of the average we will also find the price for a three or more ply yarn provided the counts of each minor thread are the same.

*Example.*—Find the price for a 3-ply yarn composed of minor threads of equal counts, but costing respectively 60 cts., 80 cts. and $1.00 per pound.

$$\$0.60+\$0.80+\$1.00=\$2.40\div 3=\$0.80.$$

*Answer.*—The price for the yarn in question is 80 cents.

If a 2-ply yarn is composed of minor threads of unequal counts as well as of different price we must find the cost per pound of the compound thread by—

*Rule.*—Multiply each count by the price of the other yarn, next divide the sum of the products by the sum of the counts.

*Example.*—Find cost per pound for 2-ply yarn composed of 32's and 40's worsted. The price of the 32's to be $1.04 and that of the 40's $1.60.

$$\begin{array}{ll} 40\times\$1.04=\$41.60 & \\ 32\times\ 1.60=\ 51.20 & \quad \$92.80\div 72=\$1.28\tfrac{8}{9} \\ \hline 72 \qquad\quad \$92.80 & \end{array}$$

*Answer.*—The price for the yarn in question is $1.28$\frac{8}{9}$ or nearly $1.29.

*Proof.*—40's and 32's.

$40\times 32=1{,}280\div 72(40+32)=17\frac{7}{9}$ compound size of thread.

$17\frac{7}{9}\times 560=9{,}957$ standard number of yards in compound thread, or number of yards of each minor thread required.

40's worsted = 22,400 yards per lb.

32's worsted = 17,920 yards per lb., thus:

$$22{,}400:1.60::9{,}957:x \text{ or } \frac{9{,}957\times 1.60}{22{,}400} = \$0.7112\text{—} = 71.12 \text{ cents.}$$

$$17{,}920:1.04::9{,}957:x \text{ or } \frac{9{,}957\times 1.04}{17{,}920} = \$0.5777\text{—} = 57.77 \text{ “}$$

*Answer.*— $128\frac{89}{100}$ cents = $1.29.

**If one of the minor threads is of a different material than the other,** reduce the one thread to its equivalent counts in the basis of the other and find the cost per pound of compound yarn by previously given rule.

*Example.*—Find cost per pound for 2-ply fancy cassimere yarn, composed of 5-run woolen yarn and 40's cotton yarn for minor threads. Value of the single woolen yarn 86 cents per pound, and value of the cotton yarn 36 cents.

40's cotton equals 21-run woolen yarn thus:

5-run at 86 cents, and 21-run at 36 cents.

$$\begin{array}{rr} 5\times 36= & 180 \\ 21\times 86= & 1{,}806 \\ \hline 26 & 1{,}986 \end{array} \qquad 1{,}986\div 26=76.38$$

*Answer.*—The price of given 2-ply fancy cassimere yarn is $76\frac{38}{100}$ cents (or about $76\frac{1}{3}$ cents.)

*Probf.*—5 and 21-run.

$5\times 21=\ 105\div 26(5+21)=4\frac{1}{26}$ compound size.

$4\frac{1}{26}\times 1{,}600=$ 6,461.5 yards length of each minor thread.

5 run = 8,000 yards per lb.

21 " =33,600 " " " thus:

$$8{,}000:86::6{,}461.5:\ x \quad\text{or}\quad \frac{86\times 6{,}461.5}{8{,}000} = 69.46 \text{ cents.}$$

$$33{,}600:36::6{,}461.5:\ x \quad\text{or}\quad \frac{36\times 6{,}461.5}{33{,}600} = 6.92 \text{ cents.}$$

*Answer.*— $76\frac{38}{100}$ cents.

**If a 3-ply yarn is composed of minor threads of unequal counts as well as of a different** price, we must find the cost of the compound yarn by

*Rule.*—Find average price and compound counts between any two minor threads given, and afterwards proceed in the same manner between the respective results and the third minor thread.

*Example.*—Find cost per pound of 3-ply fancy yarn composed of the following minor threads: 60's worsted costing \$2.00 per pound; 40's worsted costing \$1.50 per pound; and 30's worsted costing \$1.00 per pound.

60's at \$2.00. 40's at \$1.50

$$\begin{array}{rr} 60\times 1.50= & 90 \\ 40\times 2.00= & 80 \\ \hline 100 & 170.00 \end{array} \qquad 170.00\div 100=1.70.$$

\$1.70 average price between 60's worsted at \$2.00, and 40's at \$1.50.

$60\times 40=2{,}400\div 100\,(60+40)=24$. 24's worsted compound counts for 60's and 40's worsted; thus:

24's worsted at \$1.70. 30's worsted at \$1.00.

$$\begin{array}{rr} 24\times 1.00= & 24.00 \\ 30\times 1.70= & 51.00 \\ \hline 54 & 75.00 \end{array} \qquad 75.00\div 54=1.3888.$$

*Answer.*—The price for the 3-ply yarn given in the example is \$1.3888 or nearly \$1.39.

*Proof.*—60's, 40's and 30's worsted.

$$\begin{array}{l} 60\div 60=1 \\ 60\div 40=1\frac{1}{2} \\ 60\div 30=2 \\ \hline \quad\quad\ 4\frac{1}{2} \end{array}$$

$60\div 4\frac{1}{2}=13\frac{1}{3}$'s worsted compound counts for 60's, 40's and 30's.

$13\frac{1}{3}$ worsted $=13\frac{1}{3}\times 560=7{,}466\frac{2}{3}$ yards per pound.

60's worsted=33,600 yards per lb. at \$2.00
40's worsted=22,400 yards per lb. at \$1.50
30's worsted=16,800 yards per lb. at \$1.00

$$33{,}600 : 2.00 :: 7{,}466\tfrac{2}{3} : x \quad \frac{2.00 \times 7{,}466\frac{2}{3}}{33{,}600} = \$0.4444$$

$$22{,}400 : 1.50 :: 7{,}466\tfrac{2}{3} : x \quad \frac{1.50 \times 7{,}466\frac{2}{3}}{22{,}400} = \$0.5000$$

$$16{,}800 : 1.00 :: 7{,}466\tfrac{2}{3} : x \quad \frac{1.00 \times 7{,}466\frac{2}{3}}{16{,}800} = \$0.4444$$

Answer :—$1.3888

*Answer.*—The price as found before ($1.38) is correct.

**If a 3-ply yarn is composed of minor threads of different materials as well as different prices,** and we must find the cost per pound for the compound yarn, reduce the different counts to their equivalent counts in one basis and find the result by previously given rule.

---

## To Find the Mean or Average Value of Yarns of Mixed Stocks.

In the manufacture of mixed yarns wools of different price are frequently mixed together. **To ascertain the medium price of a mixture when the price and quantity of each ingredient are given,** use—

*Rule.*—Divide the cost of all the ingredients by the sum of the quantities mixed, the quotient will be the average value.

*Example.*—Find the mean or average value of the following wool mixture:

160 lbs. costing 75¢ per lb.
160 " " 86¢ " "
40 " " $1.10 " "
40 " " 1.16 " "

400 lbs. total amount of wool used in this lot.

| | | |
|---|---|---|
| 75¢ × 160 lbs.= | $120.00 |
| 85¢ × 160 lbs.= | 136.00 |
| $1.10 × 40 lbs.= | 44.00 |
| $1.16 × 40 lbs.= | 46.40 |
| 400 lbs. | $346.40 |

(Cost of all the Ingredients.) (Sum of the Quantities.)
$346.40 ÷ 400 lbs. =$0.866

*Answer.*—The value of the wool mixture is $86\frac{6}{10}$¢ per lb.

*Example.*—Find the value per lb. for the following mixture of wool.

680 lbs. costing 65¢ per lb.
300 " " 68¢ " "
20 " " 98¢ " "

1,000 lbs. in lot.

| | |
|---|---|
| 65¢ × 680= | $442.00 |
| 68¢ × 300= | 204.00 |
| 98¢ × 20= | 19.60 |
| | $665.60 |

$665.60 ÷ 1,000 = $0.6656

*Answer.*—Wool mixture in question is worth $66\frac{56}{100}$¢ per lb.

Another question frequently appearing in the mixing of lots for the manufacture of "Mixed Yarns" is—

### To Find the Quantity of Each Kind of Wool to Use in a Mixture of a Given Value.

In such a mixture the total loss on the kinds of wool used of the several prices or qualities must equal the total gain.

*Rule.*—Arrange the prices of the different kinds of wool, we have at our disposal, in a vertical column with the mean price at the left. Next find the gain or loss on one unit of each; take such an additional portion of any as will make the losses balance the gains or *vice versa.*

*Example.*—Two kinds of wool at respective values of 56¢ and 63¢ per pound are required to be mixed to produce a mixture worth 60¢. Find quantities of each kind wanted.

$$60 \left| \begin{array}{ll} 56+4\times1 = 4 & \text{gain.} \\ 63-3\times1\tfrac{1}{3}=4 & \text{loss.} \end{array}\right.$$

*Answer.*—1 part of the wool costing 56¢ and
$1\frac{1}{3}$ " " " " 63¢ are required for
—
$2\frac{1}{3}$ parts to produce a mixture of the required value of 60¢.

*Proof.*—

$$\begin{array}{ll} 1 \text{ lb. @ } 56¢ = 56¢ \\ 1\tfrac{1}{3} \text{ " @ } 63¢ = 84¢ \\ \hline 2\tfrac{1}{3} \qquad\qquad 140¢ \end{array}$$

$$140 \div 2\tfrac{1}{3} = 140 \div \tfrac{7}{3} = \frac{140\times3}{7} = 420 \div 7 = 60¢ \text{ average price of mixture per lb.}$$

*Example*—Three different qualities of wool at respective values of 60¢, 68¢ and 70¢ per lb. are required to be mixed to produce a mixture worth 64¢ per lb. Find quantities of each kind required.

$$64 \left| \begin{array}{ll} 70-6\times1 = 6 & \\ 68-4\times1 = \underline{4} & 10¢ \text{ loss.} \\ 60+4\times2\tfrac{1}{2} = & 10¢ \text{ gain.} \end{array}\right.$$

*Answer.*—To produce mixture of a value of 64¢ per lb., use—

1 part from the wool costing 70¢
1 part from the wool costing 68¢
$2\frac{1}{2}$ parts from the wool costing 60¢ in
—
$4\frac{1}{2}$ parts.

*Proof.*—

$$\begin{array}{l} 1 \text{ lb. @ } 70¢ = 70¢ \\ 1 \text{ " @ } 68¢ = 68¢ \\ 2\tfrac{1}{2} \text{ " @ } 60¢ = 150¢ \\ \hline 4\tfrac{1}{2} \text{ lbs.} \qquad 288¢ \end{array}$$

288 ÷ 4.5 = 64¢ average price of mixture per lb.

*Example.*—Four different qualities of wool at respective values of 80¢, 85¢, 96¢ and 98¢ per lb. are required to be mixed to produce a mixture worth 92¢. Find quantities of each kind required.

$$92 \left| \begin{array}{ll} 80+12\times1 = 12 & \\ 85+7\times1 = \underline{7} & 19¢ \text{ gain.} \\ 96-4\times1 - 4 & \\ 98-6\times2\tfrac{1}{2}-\underline{15} & 19¢ \text{ loss.} \end{array}\right.$$

*Answer.*—To produce mixture of wool of a value of 92¢ use—

1 part of the wool costing 80¢
1 part of the wool costing 85
1 part of the wool costing 92
2½ parts of the wool costing 98 in
—
5½ parts.

*Proof.*—

1 lb. @ 80¢= 80¢
1 lb. @ 85 = 85
1 lb. @ 96 = 96
2½ lbs. @ 98 =245
— ——
5½ lbs. 506¢

506¢÷5.5=92¢ being the average price of mixture per lb.

Another question frequently arising in laying out "wool-lots" is—

### To Find the Quantity of Each Kind to Use When the Quantity of One Kind, the Different Prices of Each Kind and the Prices of the Mixture, are Given.

*Example.*—What quantity of each kind of wool costing 60¢, 80¢ and 90¢ must be mixed with 20 lbs. at 71¢ so as to bring the mixture to a value of 75¢ per lb.

```
        ¢    ¢   lbs.
     | 60+15× 1=15¢
     | 71+ 4×20=80
     |          —     95¢ gain.
 75, | 80— 5× 1— 5¢
     | 90—15× 6—90
     |        —       95¢ loss.
             28
```

*Answer.*—Use

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | part or lb. | of the | wool | costing | 60¢ | |
| 20 | parts or lbs. | " | " | " | 71 | |
| 1 | part or lb. | " | " | " | 80 | |
| 6 | parts or lbs. | " | " | " | 90 | |
| — | | | | | | |
| 28 | parts or lbs. | Mixture so as to bring the price of the latter to 75¢ per lb. | | | | |

*Proof.*—

1 lb. @ 60¢= 60¢
20 lbs. @ 71 =1,420
1 lb. @ 80 = 8
6 lbs. @ 90 = 540 or
— ———
28 lbs. at 2,100¢. Hence 2,100¢÷28=75¢ average price of mixture per lb.

*Example.*—Having four different lots of wool at respective values of 70¢, 74¢, 82¢ and 84¢ on hand, how many lbs. of each kind must we use to make up a lot of 500 lbs. costing us 78¢ per lb.

```
    | 70+ 8×1 =8
    | 74+ 4×1 =4
    |          —   12¢ gain.
 78 | 82— 4×1½=6
    | 84— 6×1 =6
    |       — —    12¢ loss.
           4½
```

$500 \div 4\frac{1}{2} = 111\frac{1}{9}$.

| | | | |
|---|---|---|---|
| $1 \times 111\frac{1}{9} = 111\frac{1}{9}$ | lbs. | @ | 70 |
| $1 \times 111\frac{1}{9} = 111\frac{1}{9}$ | " | @ | 74 |
| $1 \times 111\frac{1}{9} = 166\frac{6}{9}$ | " | @ | 82 |
| $1 \times 111\frac{1}{9} = 111\frac{1}{9}$ | " | @ | 84 |
| 500 | lbs. | | |

*Answer.*—We must use

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $111\frac{1}{9}$ | lbs. | of | the | lot | valued at | 70¢ | per lb. |
| $111\frac{1}{9}$ | " | " | " | " | " | 74 | " |
| $166\frac{2}{3}$ | " | " | " | " | " | 82 | " |
| $111\frac{1}{9}$ | " | " | " | " | " | 84 | " |

to make up a lot of 500 lbs. at a value of 78¢ per lb.

*Proof.*—

$111\frac{1}{9} \times 70¢ = \$77.77\frac{7}{9}$
$111\frac{1}{9} \times 74 = \quad 82.22\frac{2}{9}$
$166\frac{6}{9} \times 82 = 136.66\frac{6}{9}$
$111\frac{1}{9} \times 84 = \quad 92.33\frac{3}{9}$

\$390.00—and 500 lbs. at 78¢ = also \$390.00.

---

## Reed Calculations.

The reed is named by numbers, the number in each case indicating how many splits are in each inch, Thus a number 8-reed means a reed with 8 splits in every inch over the required width. If we call for number $16\frac{1}{2}$-reed, we want a reed having $16\frac{1}{2}$ splits in one inch, equal to 33 dents in every 2 inches over the entire width of the fabric. Whole numbers or half numbers alone are used for grading of reeds.

*Example.*—Suppose we have a number 9-reed, four threads in one split or dent, how many ends are in one inch? How many are in full warp if 70 inches wide in reed?

*Answer.*—

| | |
|---|---|
| $9 \times 4 = 36$ | ends of warp in one inch. |
| $\times 70$ | width of warp in reed. |
| 2,520 | ends in warp. |

**Rule for ascertaining the number of ends in the warp if the reed number, the threads per dent and the width of the warp in the reed are known:** Multiply the reed number by the threads per dent and multiply the result by the width of the warp in reed.

*Example.*—How many ends are in the warp if using $13\frac{1}{2}$-reed, 6 threads per dent, 80 inches wide in reed?

$$13\frac{1}{2} \times 6 = 81 \times 80 = 6{,}480.$$

*Answer.*—6,480 ends are in warp.

**Rule for ascertaining the reed number, if the number of ends in the warp and the width in the reed are known, the threads per dent, either given or to be selected, according to the fabric:** Divide the number of ends in the warp by the width in the reed, which gives the number of threads per inch; divide this result again by the number of threads in one dent according to the weave or pattern required, the answer being the reed (number) required.

*Example.*—6,480 ends in warp, 80 inches wide in reed. How many ends per inch and what reed is required if 6 ends per dent are to be used?

$$6{,}480 \div 80 = 81 \div 6 = 13\tfrac{1}{2}.$$

*Answer.*—81 ends per inch and $13\frac{1}{2}$ is the reed number required.

**Rule for ascertaining the width of the warp in the reed if the reed number, the threads per dent, and the number of threads in the warp are known:** Divide the number of ends in the warp by the number of ends per inch, giving as the result the number of inches the warp will be in the reed.

*Example.*—Find width in reed for fabric made with 3,600 ends in warp, reeded 3 threads per dent in a number 12-reed.

$$12 \times 3 = 36 \quad 3{,}600 \div 36 = 100.$$

*Answer.*—The width of the fabric in reed is 100 inches.

*Example.*—Find width in reed for fabric made with 4,752 ends in warp, reeded 4 threads per dent in a number $16\frac{1}{2}$-reed.

$$16\tfrac{1}{2} \times 4 = 66 \qquad 4{,}752 \div 66 = 72$$

*Answer.*—The width of the fabric in reed is 72 inches.

The number of ends to put in one dent has to be regulated according to the fabric and the weave. Experience is the only guide for this. The coarser the reed, to a certain extent, the easier the picks go into the fabric. The finer the reed, the smoother the goods, and with perfect reeds, the less reed marks.

The same number of ends are not always used in each dent, but in such a case the preceding rules may be used with the average number of threads per dent.

*Example.*—What are the threads per inch? Reed number 20, using one dent, 4 ends—one dent 5 ends.

| | | (Average threads per dent.) | | (Number of reed.) | | |
|---|---|---|---|---|---|---|
| $4+5=9\div 2$ | = | $4\frac{1}{2}$ | × | 20 | = | 90 |

*Answer.*—90 threads per inch.

*Example.*—What are the threads per inch? Reed number 18, using 1 dent, 3 ends—1 dent, 4 ends—1 dent, 3 ends—1 dent, 6 ends.

| | | (Threads in four dents.) | | (Average thread per dent.) | | (Number of reed.) | | |
|---|---|---|---|---|---|---|---|---|
| $3+4+3+6$ | = | 16 | ÷ | 4 | × | 18 | = | 72 |

*Answer.*—72 threads per inch.

Sometimes it happens that the average number of threads includes an inconvenient fraction. To avoid a calculation with this fraction, multiply the sum of the contents of the dents by the dents per inch, and then divide by the dents per set.

*Example.*—What are the threads per inch, warp reeded as follows in number 12-reed: 1 dent, 5 threads—1 dent, 3 threads—1 dent, 3 threads.

$$3+3+5=11 \times 12 = 132 \div 3 = 44.$$

*Answer.*—44 threads per inch.

*Example.*—What are the threads per inch, warp reeded as follows in a number 15-reed:—1 dent, 4 threads—1 dent, 4 threads—1 dent 5 threads.

$$4+4+5=13 \times 15 = 195 \div 3 = 65$$

*Answer.*—65 threads per inch.

# Warp Calculations.

---

## TO FIND WEIGHT OF WARP IF NUMBER OF ENDS, COUNTS AND LENGTH ARE GIVEN.

Multiply number of ends in the width of the cloth by yards in length (dressed), and divide product by the number of yards of the given count per pound.

*Example.*—**Cotton Yarn.** Find weight of warp, 50 yards long, 2,800 ends, single 40's cotton in warp.

$2{,}800 \times 50 = 140{,}000$ yards. $40 \times 840 = 33{,}600$ yards per lb. in 40's cotton.

$140{,}000 \div 33{,}600 = 4\frac{1}{6}$.

*Answer.*—The weight of the warp in the present example is $4\frac{1}{6}$ lbs.

*Example.*—**Woolen Yarn** (run system). Find weight of warp, 40 yards long, 3,600 ends, $4\frac{1}{2}$-run woolen yarn.

$3{,}600 \times 40 = 144{,}000$ yards. $4\frac{1}{2}$-run$=7{,}200$ yards. $144{,}000 \div 7{,}200 = 20$.

*Answer.*—The weight of the warp in present example is 20 lbs.

*Example*—**Woolen Yarn** (cut system). Find weight of warp, 45 yards long, 4,800 ends, 32-cut woolen yarn.

$4{,}800 \times 45 = 216{,}000$ yards. 32-cut$=9{,}600$ yards. $216{,}000 \div 9{,}600 = 22\frac{1}{2}$.

*Answer.*—The weight of the warp in the present example is $22\frac{1}{2}$ lbs.

*Example.*—**Worsted Yarn.** Find weight of warp, 60 yards long, 6,000 ends, 2/60's worsted yarn.

2/60's worsted$=16{,}800$ yards. $6{,}000 \times 60 = 360{,}000$ yards. $360{,}000 \div 16{,}800 = 21\frac{3}{7}$.

*Answer.*—The weight of the warp in present example is $21\frac{3}{7}$ lbs.

**If two or more different kinds of yarn are used,** ascertain number of threads in warp for each kind by proportion, and solve answer (for each kind) by previously given rule.

*Example.*—Find weight of warp, 50 yards long, 6,000 ends.

Dressed.—2 ends 2/60's worsted.
1 end 2/50's cotton.

3 ends in repeat.

$6{,}000 \div 3 = 2{,}000$

$2{,}000 \times 2 = 4{,}000$ ends 2/60's worsted in warp.
$2{,}000 \times 1 = 2{,}000$ ends 2/50's cotton in warp.

6,000, complete number of ends in warp.

$4{,}000 \times 50 = 200{,}000$ yards. 2/60's worsted$=16{,}800$ yards. $200{,}000 \div 16{,}800 = 11\frac{19}{21}$.
$2{,}000 \times 50 = 100{,}000$ 2/50's cotton$=21{,}000$ yards. $100{,}000 \div 21{,}000 = 4\frac{16}{21}$

*Answer.*—The weights of the warp in present example are:

$11\frac{19}{21}$ lbs. of 2/60's worsted.
$4\frac{16}{21}$ " " 2/50's cotton.

$16\frac{14}{21}$ lbs.$=16\frac{2}{3}$ lbs. total weight of both kinds of yarn.

*Example.*—Find weight of warp for each kind of yarn separately in the following example:

Lengths of warp 50 yards. Number of ends 4,800.

| | | | |
|---|---|---|---|
| Dressing.—4 ends | 4-run woolen yarn | | blue |
| 4 " | 4 " " " | | black |
| 4 " | 4 " " " | | brown |
| 4 " | 4 " " " | | black |
| 16 " | 4 " " " | | olive mix |
| 2 " | 4 " " " | | blue |
| 2 " | 4 " " " | | black |
| 2 " | 4 " " " | | brown |
| 2 " | 4 " " " | | black |
| 8 " | 4 " " " | | olive mix |

48 threads in repeat of pattern.

| (Number of ends in warp.) | | (Threads in one repeat of pattern.) | | (Number of repeats of patterns in warp.) |
|---|---|---|---|---|
| 4,800 | ÷ | 48 | = | 100 |

| {Ends of each kind of yarn in one pattern.} | × | {Number of repeats of patterns in warp.} | = | {Threads of each kind of yarn in full warp.} |
|---|---|---|---|---|
| 6 ends blue | × | 100 | = | 600 |
| 6 " brown | × | 100 | = | 600 |
| 12 " black | × | 100 | = | 1,200 |
| 24 " olive mix | × | 100 | = | 2,400 |
| 48 threads in one repeat of pattern. | | | | 4,800 threads in warp. |

4-run woolen yarn=6,400 yards per lb.

$600 \times 50 = 30{,}000 \div 6{,}400 = 4\tfrac{11}{16}$

$600 \times 50 = 30{,}000 \div 6{,}400 = 4\tfrac{11}{16}$

$1{,}200 \times 50 = 60{,}000 \div 6{,}400 = 9\tfrac{6}{16}$ (or $9\tfrac{3}{8}$)

$2{,}400 \times 50 = 120{,}000 \div 6{,}400 = 18\tfrac{12}{16}$ (or $18\tfrac{3}{4}$)

*Proof.*— $4{,}800 \times 50 = 240{,}000 \div 6{,}400 = 37\tfrac{8}{16}$ (or $37\tfrac{1}{2}$)

*Answer.*—The different amounts of yarn required for given example are:

| | | | | | |
|---|---|---|---|---|---|
| $4\tfrac{11}{16}$ | lbs. of | 4-run | blue | woolen | yarn. |
| $4\tfrac{11}{16}$ | " | 4 " | brown | " | " |
| $9\tfrac{3}{8}$ | " | 4 " | black | " | " |
| $18\tfrac{3}{4}$ | " | 4 " | olive mix | " | " |

This method of finding the weight for different warp yarns is no doubt the easiest to understand by any student, and will solve the most complicated arrangements of dressings and variety of yarns used.

The latter example can also be solved by—

*Rule.*—Find total weight of warp yarn required and divide in proportion to each kind of yarn used.

$4{,}800 \times 50 = 240{,}000 \div 6{,}400 = 37\tfrac{8}{16}$ lbs. total weight.

6 blue =1
6 brown=1
12 black =2
24 olive =4
8

$37\tfrac{8}{16} \div 8 = 4\tfrac{11}{16}$ for each part.

*Answer.*—

| | | | | | | |
|---|---|---|---|---|---|---|
| $1 \times 4\frac{11}{16} = 4\frac{11}{16}$ | lbs. of | 4-run | blue | woolen | yarn. |
| $1 \times 4\frac{11}{16} = 4\frac{11}{16}$ | " " | 4 " | brown | " | " |
| $2 \times 4\frac{11}{16} = 9\frac{3}{8}$ | " " | 4 " | black | " | " |
| $4 \times 4\frac{11}{16} = 18\frac{3}{4}$ | " " | 4 " | olive mix | " | " |

$37\frac{8}{16}$ (or $37\frac{1}{2}$) lbs. total weight.

**If weight of warp is required to be found for one yard only,** the answer may be required expressed in ounces; if so, change fraction of pounds in ounces, or use rules given previously under "Grading of the Various Yarns," after finding the number yards of yarn required.

**When required to ascertain the weight of a warp dressed with yarns of various counts, and answer required is for the total weight of warp only,** we may solve question by finding the average counts of the threads in question, and deal with this average count and the entire number of ends dressed, the same as if all the yarns used are of one count.

The average counts of two or more threads we find by—

*Rule A.*—Multiply the compound size of the given counts of yarn by number of threads compounded, or we may use

*Rule B.*—Divide any one of the given counts by itself and by the others given in rotation, multiply each quotient by the numbers of threads of the kind used in one repeat of pattern; next multiply previously used common dividend with the numbers of threads in one repeat of pattern, and divide the product by the sum of the quotients obtained. Either of these two rules will find the average counts. Rule A answers when using short repeats of patterns, and Rule B is adopted for large repeats.

*Example.*—Find average counts for the following dressing of a warp:

2 ends 30-cut woolen yarn.
1 end 20-cut " "

3 ends in repeat of pattern.

**Using Rule A, we get**

$30 \div 30 = 1$ $\quad 30 \div 3\frac{1}{2} = 8\frac{4}{7}$ compound size.
$30 \div 30 = 1$
$30 \div 20 = 1\frac{1}{2}$ $\quad 8\frac{4}{7} \times 3 = 25\frac{5}{7}$ average counts.

$3\frac{1}{2}$

*Answer.*—The average counts are $25\frac{5}{7}$-cut.

**Using Rule B, we get**

| | | Quotient. | | Threads of each kind in pattern. | | |
|---|---|---|---|---|---|---|
| $30 \div 30$ | = | 1 | × | 2 | = | 2 |
| $30 \div 20$ | = | $1\frac{1}{2}$ | × | 1 | = | $1\frac{1}{2}$ |
| | | | | | | $3\frac{1}{2}$ |

$30 \times 3 = 90 \div 3\frac{1}{2} = 25\frac{5}{7}$

*Answer.*—The average counts by Rule B are also $25\frac{5}{7}$-cut.

*Example.*—Find weight per yard for a warp of 3,600 ends,

Dressed.—2 ends face 30-cut woolen yarn.
1 end back 20-cut woolen yarn.

3 ends in pattern.

2/30-cut and 1/20-cut=$25\frac{5}{7}$-cut average size.

$25\frac{5}{7} \times 300 = 7{,}714\frac{2}{7}$ yards per lb.

$3{,}600 \times 16 = 57{,}600 \div 7{,}714\frac{2}{7} = 7.46$

*Answer.*—Weight of warp per yard is 7.46 oz.

*Proof.*—

3,600 ends, dressed: $\begin{cases} \text{2 ends 30-cut.} \\ \text{1 end 20-cut.} \end{cases}$ $3{,}600 \div 3 = 1{,}200$

$1{,}200 \times 2 = 2{,}400$ yards of 30-cut (9,000 yards per lb.) $2{,}400 \times 16 = 38{,}400 \div 9{,}000 = 4.26$ oz.
$1{,}200 \times 1 = 1{,}200$ yards of 20-cut (6,000 yards per lb.) $1{,}200 \times 16 = 19{,}200 \div 6{,}000 = 3.20$ oz.

7.46 oz.

*Example.*—Find weight, per yard, for a warp of 4,800 threads, dressed as follows:

| | |
|---|---|
| 2 ends face 6-run. | $6 \div 6 = 1 \times 2 = 2$ |
| 1 end back 4-run. | $6 \div 4 = 1\frac{1}{2} \times 1 = 1\frac{1}{2}$ |
| 3 ends in pattern. | $3\frac{1}{2}$ |

$6 \times 3 = 18 \div 3\frac{1}{2} = 5\frac{1}{7}$-run $\times 1{,}600 = 8{,}228.57$ yards.
$4{,}800 \times 16 = 76{,}800 \div 8{,}228.57 = 9.33$.

*Answer.*—Weight of warp, per yard is 9.33 oz.

*Proof.*—

4,800 ends, dressed: $\begin{cases} \text{2 ends 6-run.} \\ \text{1 end 4-run.} \end{cases}$ $4{,}800 \div 3 = 1{,}600$

$1{,}600 \times 2 = 3{,}200$ yards of 6-run (9,600 yards per lb.).
$1{,}600 \times 1 = 1{,}600$ yards of 4 run (6,400 yards per lb.).
$3{,}200 \times 16 = 51{,}200 \div 9{,}600 = 5.33$ oz.
$1{,}600 \times 16 = 25{,}600 \div 6{,}400 = 4.00$ oz.

9.33 oz.

*Example.*—Find the average counts for the following dressing of a warp:

| | |
|---|---|
| 2 ends 60's | $60 \div 60 = 1 \times 2 = 2$ |
| 1 end 20's | $60 \div 20 = 3 \times 1 = 3$ |
| 1 end 10's | $60 \div 10 = 6 \times 1 = 6$ |
| 4 ends in repeat of pattern. | 11 |

$$60 \times 4 = 240 \div 11 = 21\tfrac{9}{11}$$

*Answer.*—The average counts are $21\frac{9}{11}$'s.

*Proof.*—(Using the same rule, but a different count, for dividend.)

$$10 \div 60 = \tfrac{1}{6} \times 2 = \tfrac{2}{6}$$
$$10 \div 20 = \tfrac{1}{2} \times 1 = \tfrac{3}{6}$$
$$10 \div 10 = 1 \times 1 = 1$$
$$1\tfrac{5}{6}$$

$$10 \times 4 = 40 \div 1\tfrac{5}{6} = \tfrac{40}{1} \div \tfrac{11}{6} = \tfrac{40}{1} \times \tfrac{6}{11} = 240 \div 11 = 21\tfrac{9}{11}\text{'s.}$$

*Proof.*—(Using Rule A.)

$60 \div 60 = 1$
$60 \div 60 = 1$
$60 \div 20 = 3$
$60 \div 10 = 6$
11

$60 \div 11 = 5\frac{5}{11} \times 4 = 21\frac{9}{11}$'s.

*Example.*—Find weight per yard for a warp of 2,850 ends, dressed as follows.

20 ends 40's cotton
1 end 50's "
16 ends 30's "
1 end 50's "
—
38 ends in repeat of pattern.

$$40 \div 40 = 1 \times 20 = 20 = 20$$
$$40 \div 30 = 1\tfrac{1}{3} \times 16 = 21\tfrac{1}{3} = 21\tfrac{5}{15}$$
$$40 \div 50 = \tfrac{4}{5} \times 2 = 1\tfrac{3}{5} = 1\tfrac{9}{15}$$
$$38 \qquad 42\tfrac{14}{15}$$

$$40 \times 38 = 1{,}520 \div 42\tfrac{14}{15} = 35\tfrac{90}{161}\text{'s average counts.}$$
$$35\tfrac{90}{161} \times 840 = 29{,}869.56 \text{ yards per lb.}$$
$$2{,}850 \times 16 = 45{,}600 \div 29{,}869.56 = 1.52 \text{ oz.}$$

*Answer.*—The weight of given warp in example is 1.52 oz.

*Proof.*— $2{,}850 \div 38 = 75$ repeats of pattern in warp.

$20 \times 75 = 1{,}500$ ends of 40's cotton. (33,600 yards per lb.)
$16 \times 75 = 1{,}200$ ends of 30's cotton. (25,200 yards per lb.)
$2 \times 75 = 150$ ends of 50's cotton. (42,000 yards per lb.)

$$1{,}500 \times 16 = 24{,}000 \div 33{,}600 = 0.71$$
$$1{,}200 \times 16 = 19{,}200 \div 25{,}200 = 0.76$$
$$150 \times 16 = 2{,}400 \div 42{,}000 = 0.05$$

1.52 oz. (being the same answer.)

Rules given refer to finding the weight of a warp in its original length, technically known as "dressed." During weaving and the process of finishing, in most cases, the warp will shrink or "take up," thus if figuring for weight of warp in a cloth from loom, or also when finished, we must calculate back to the original number of yards required dressed, to produce a certain number of yards of cloth either woven or finished; or in other words, take the percentage for either or both "take ups," as the case may require, into consideration. Rules governing the "take ups" in a fabric cannot be given. They are guided by the cloth required, nature of material, twist, amount of intersections in weave, process of finishing, etc., in fact, practical experience is necessary to designate accurately these points.

A table of relative lengths of inches dressed, and one yard woven, with reference to a "take up" during weaving, from 1 per cent. to 50 per cent., (which also can be used for "take up" of warps during finishing) is found in my "*Technology of Textile Design,*" on page 266, in the chapter on "*Ascertaining the weight of cloth per yard from the loom.*

## TO FIND THE COUNTS FOR WARP YARN IF NUMBER OF ENDS IN WARP, AND AMOUNT OF MATERIAL, LENGTH AND WEIGHT TO BE USED, ARE GIVEN.

Multiply the ends in warp by the length, multiply the basis of the yarn in question bv the weight, next divide the latter product in the one previously obtained.

*Example.*—**Cotton Yarn.** Find counts of yarn required—2,800 ends in warp, 50 yards long, weight $4\frac{1}{6}$ lbs.

$$2{,}800 \times 50 = 140{,}000 \div 3{,}500 \ (4\tfrac{1}{6} \times 840) = 40$$

*Answer.*—40's cotton yarn is required.

*Example.*—**Woolen Yarn** (run system). Find counts of yarns required—3,600 ends in warp, 40 yards long, weight 20 lbs.

$$3{,}600 \times 40 = 144{,}000 \div 32{,}000 \ (1{,}600 \times 20) = 4\tfrac{1}{2}$$

*Answer.*—The yarn required to be used in example given, is $4\frac{1}{2}$-run.

*Example.*—**Woolen Yarn** (cut system). Find counts of yarn required—4,800 ends in warp, 45 yards long, weight $22\frac{1}{2}$ lbs.

$$4{,}800 \times 45 = 216{,}000 \div 6{,}750\ (300 \times 22\tfrac{1}{2}) = 32$$

*Answer.*—32-cut yarn is required.

*Example.*—**Worsted Yarn.** Find counts of yarn required—6,000 ends in warp, 60 yards long, weight of warp $21\frac{3}{7}$ lbs.

$$6{,}000 \times 60 = 360{,}000 \div 12{,}000\ (21\tfrac{3}{7} \times 560) = 30$$

*Answer.*—Single 30's (or 2/60's) worsted yarn are required.

## TO FIND NUMBER OF THREADS IN WARP TO USE, IF COUNTS OF YARN, LENGTHS AND WEIGHT OF WARP, ARE GIVEN.

Multiply counts by basis of yarn and weight of warp, and divide product by length of warp.

*Example.*—**Cotton Yarn.** Find number of ends for warp, 40's cotton, 50 yards long to dress, weight of yarn on hand $4\frac{1}{6}$ lbs.

$$40 \times 840 \times 4\tfrac{1}{6} = 140{,}000 \div 50 = 2{,}800$$

*Answer.*—Use 2,800 ends in warp.

*Example.*—**Woolen Yarn** (run system). Find number of ends for warp $4\frac{1}{2}$-run woolen yarn, 40 yards long to dress, weight of yarn to use 20 lbs.

$$4\tfrac{1}{2} \times 1{,}600 \times 20 = 144{,}000 \div 40 = 3{,}600$$

*Answer.*—Use 3,600 threads in warp.

*Example.*—**Woolen Yarn** (cut system). Find number of ends for warp, 32-cut yarn, 45 yards long to dress, $22\frac{1}{2}$ lbs. weight of yarn on hand.

$$32 \times 300 \times 22\tfrac{1}{2} = 216{,}000 \div 45 = 4{,}800$$

*Answer.*—Use 4,800 threads in warp.

*Example.*—**Worsted Yarn.** Find number of ends for warp, 2/60's worsted, 60 yards length of warp required, $21\frac{3}{7}$ lbs. amount of yarn on hand.

2/60's worsted=1/30's; thus: $30 \times 560 \times 21\frac{3}{7} = 360{,}000 \div 60 = 6{,}000.$

*Answer.*—Use 6,000 threads in warp.

## TO FIND THE LENGTH FOR A WARP, IF NUMBER OF ENDS IN WARP, COUNTS AND WEIGHT OF YARN, ARE GIVEN.

Multiply counts by basis of yarn and weignt of warp, and divide product by number of ends in warp.

*Example.*—**Cotton Yarn.** Find length of warp, 2,800 threads in width, 40's cotton yarn, weight of yarn on hand $4\frac{1}{6}$ lbs.

$$40 \times 840 \times 4\tfrac{1}{6} = 140{,}000 \div 2{,}800 = 50.$$

*Answer.*—The length for the warp is 50 yards.

*Example.*—**Woolen Yarn** (run system). Find length of warp, 3,600 threads in width, $4\frac{1}{2}$-run woolen yarn, weight of yarn on hand 20 lbs.

$$4\tfrac{1}{2} \times 1{,}600 \times 20 = 144{,}000 \div 3{,}600 = 40.$$

*Answer.*—The length for the warp is 40 yards.

*Example.*—**Woolen Yarn** (cut system). Find length of warp, 4,800 threads in width, 32-cut yarn, $22\frac{1}{2}$ lbs. weight of yarn on hand.

$$32 \times 300 \times 22\tfrac{1}{2} = 216{,}000 \div 4{,}800 = 45.$$

*Answer.*—The length for the warp is 45 yards.

*Example.*—**Worsted Yarn.** Find length of warp, 6,000 threads in width, 2/60's worsted, $21\frac{3}{7}$ lbs. weight of yarn on hand.

2/60's worsted=1/30's worsted; thus: $30 \times 560 \times 21\frac{3}{7} = 360{,}000 \div 6{,}000 = 60.$

*Answer.*—The length for the warp is 60 yards.

*Example.*—**Cotton Yarn** (2-ply). Find length of warp (for extra super ingrain carpet) 1,072 ends, 2/14's cotton yarn, weight of yarn on hand 50 lbs.

2/14's cotton=1/7's cotton. Thus: $7 \times 840 \times 50 = 294{,}000 \div 1{,}072 = 274\frac{17}{67}$

*Answer.*—The length for the warp is $274\frac{1}{4}$ (actual $274\frac{17}{67}$) yards.

*Proof.*—$\dfrac{274\frac{17}{67} \times 1{,}072}{5{,}880\ (7 \times 840)} = 274\frac{17}{67} \times 1{,}072 = 294{,}000 \div 5{,}880 = 50$, being the amount of lbs. of yarn on hand.

*Example.*—**Worsted Yarn** (3-ply). Find length of warp 4,800 ends in width of fabric, 3/60's worsted yarn, weight of yarn on hand 80 lbs.

3/60's worsted=1/20's worsted. Thus: $20 \times 560 \times 80 = 896{,}000 \div 4{,}800 = 186\frac{2}{3}$.

*Answer.*—The length for the warp is $186\frac{2}{3}$ yards.

*Proof.*— $\dfrac{186\frac{2}{3} \times 4{,}800}{11{,}200\ (20 \times 560)} = 186\frac{2}{3} \times 4{,}800 = 2{,}688{,}000 \div 11{,}200 = 80$, being the amount of pounds of yarn on hand.

**When two or more different materials are used in the construction of a cloth,** previously given rules for warp must be solved by combining one repeat, or the average of one repeat, of pattern in a compound thread; and if required by question, after finding answer in such a compound thread, we must transfer the same to the respective minor threads.

To give a clear understanding to the student, we give, correspondingly to previously given rules, one example in three different changes.

*Example.*—Find counts of yarn required, 4,800 ends in warp.

Dressed.—2 ends face. } Woolen yarn, run basis.
1 end back. }
—
3 ends in repeat.

Back-warp threads to be twice as heavy as to size as face warp threads. Length of warp, 50 yards. Weight of same to be 40 lbs.

$4{,}800 \div 3 = 1{,}600$ repeats of pattern, or 1,600 compound threads.

$1{,}600 \times 50 = 80{,}000 \div 64{,}000\ (1{,}600 \times 40) = 1\frac{1}{4}$-run compound size.

$1\frac{1}{4} \times 4 = 5$ $\quad 1\frac{1}{4} \times 2 = 2\frac{1}{2}$

*Answer.*—The dressing in example given will be {
2 ends face @ 5-run.
1 end back @ $2\frac{1}{2}$-run.
—
3 ends in repeat.

*Proof.*— $5—5—2\frac{1}{2}$

$5 \div 5 = 1$
$5 \div 5 = 1$
$5 \div 2\frac{1}{2} = 2$
—
**4**

$5 \div 4 = 1\frac{1}{4}$ compound size.

4,800 ends in warp÷3 ends in repeat of dressing=1,600 compound threads of $1\frac{1}{4}$-run.

$$\frac{1{,}600 \times 50 \text{ yards long.}}{80{,}000} \qquad 1\tfrac{1}{4} \times 1{,}600 = 2{,}000.$$

2,000 : 1 :: 80,000 : x =80,000÷2,000=40 lbs.=the weight given in the example.

*Example.*—Find number of ends for the following warp:

Dressing.—2 ends face warp, 5-run.
1 end backing warp, $2\frac{1}{2}$-run.
—
3 ends in repeat.

Length of warp 50 yards. Weight of same, 40 lbs.

5÷5 =1
5÷5 =1
5÷$2\frac{1}{2}$=2
—
4

5÷4=$1\frac{1}{4}$ compound size of the 3 threads in repeat of pattern.

$1\frac{1}{4}$-run=2,000 yards per lb., hence

40×2,000=80,000 yards of the compound thread in the amount of weight required.

8,000÷50 (Length of warp.) =1,600

1,600×3 (Number of threads in compound count.) =4,800

*Answer.*—4,800 threads are required for warp given in example.

*Proof.*— 4,800 threads, dressed: 2 face 5-run.
1 backing $2\frac{1}{2}$-run.
—
3 threads in repeat.

4,800÷3=1,600
1,600×2=3,200 threads 5-run (8,000 yards per lb.)
1,600×1=1,600 threads $2\frac{1}{2}$-run (4,000 yards per lb.)

3,200×50 (length of warp) 160,000÷8,000=20 lbs.
1,600×50 (length of warp) 80,000÷4,000=20 lbs.
—
40 lbs. weight given in example.

*Example.*—Find length of warp required—4,800 threads in width of cloth.

Dressing.—2 ends face 5-run woolen yarn
1 end back $2\frac{1}{2}$-run woolen yarn
—
3 ends in repeat.

Weight of complete warp 40 lbs.

5÷5 =1
5÷5 =1
5÷$2\frac{1}{2}$=2
—
4

5 ÷4=$1\frac{1}{4}$ compound size.
$1\frac{1}{4}$-run=2,000 yards per lb.
2,000×40=80,000 yards of the compound thread in the amount of weight required.

80,000÷1,600 (Number of compound threads in width.) =50.

*Answer.*—50 yards, length of warp required in given example.

*Proof.*—

4,800 threads { 2 face, 5-run; 1 back, $2\frac{1}{2}$-run } =1,600 threads $1\frac{1}{4}$-run.
—
3 threads repeat.

1,600×50 {Length of warp required by answer in example.} =80,000÷2,000 {Number of yards in $1\frac{1}{4}$-run or compound count.} =40 lbs. weight of complete warp, as given in example.

# Filling Calculations.

## TO FIND LENGTH OF FILLING YARN REQUIRED FOR PRODUCING ONE OR A GIVEN NUMBER OF YARDS OF CLOTH, IF PICKS PER INCH AND WIDTH OF CLOTH IN REED, (INCLUDING SELVAGE) ARE KNOWN.

*Rule.*—Multiply picks per inch by width of fabric in reed, the product will be number of inches of filling yarn required for one inch cloth, or, at the same time, number of yards of filling yarn required for one yard of cloth. By simply multiplying yards of filling required for one yard of cloth, with the yards of cloth given in example, we get in product number of yards of filling yarn required for given yards of cloth.

*Example.*—Find yards of filling required for *a*, one yard *b*, 8 yards of cloth woven 72 inches wide in reed, with 52 picks per inch.

52×72=3,744 | 3,744×8=29,952

*Answer.*—One yard cloth requires 3,744 yards filling. Eight yards cloth require 29,952 yards filling.

## TO FIND WEIGHT OF FILLING YARN REQUIRED, EXPRESSED IN OUNCES, PRODUCING ONE YARD OF CLOTH, IF PICKS PER INCH, WIDTH OF CLOTH IN REED, AND THE COUNTS OF YARN ARE KNOWN.

*Rule.*—Multiply picks by width of warp in reed, and divide product by number of yards of the known count required to balance 1 oz.

*Example.*—**Cotton Yarn.** Find weight of filling required for one yard cloth of the following description: 64 picks per inch, 68 inches reed space occupied, single 20's cotton yarn.

64×68=4,352 yards. 1/20's cotton=16,800 yards per lb. or 1,050 yards per oz.
4,352÷1,050=4.14.

*Answer.*—The weight of filling required is 4.14 oz. per yard.

*Example.*—**Woolen Yarn.** Find weight of filling required for one yard cloth having 52 picks per inch, 72 inches reed space, 4-run yarn.

4-run=(4×100)=400 yards per oz. 52×72=3,744÷400=9.36

*Answer.*—9.36 oz. is the weight of the filling required per yard.

*Example.*—**Worsted Yarn.** Find weight of filling necessary for one yard cloth having 68 picks per inch, 61 inches reed space, 2/36's worsted yarn.

68×61=4,148. 2/36's worsted=10,080 yards per lb. or 630 yards per oz. 4,148÷630=6.59 oz.

*Answer.*—The weight of filling required is 6.59 oz.

## TO FIND WEIGHT OF FILLING YARN REQUIRED (expressed in pounds or fraction thereof,) FOR ANY NUMBER OF GIVEN YARDS, IF PICKS PER INCH, WIDTH OF CLOTH IN REED, AND THE COUNTS OF YARN, ARE KNOWN.

*Rule.*—Multiply picks by width in reed and the number of given yards, next divide product thus derived by the number of yards of the known count per pound.

*Example.*—**Cotton Yarn.** Find weight of filling required for 40 yards of cloth woven with 68 picks per inch, 70 inches reed space and 30's cotton yarn.

$68 \times 70 = 4,760 \times 40 = 190,400 \qquad 30 \times 840 = 25,200 \qquad 190,400 \div 25,200 = 7\frac{5}{9}.$

*Answer.*—Weight of filling required in given example is $7\frac{5}{9}$ lbs.

*Example.*—**Woolen Yarn.** Find weight of filling required for 120 yards of cloth woven with 44 picks per inch, 71 inches reed space and 22-cut woolen yarn.

$44 \times 71 = 3,124 \times 120 = 374,880 \qquad 22 \times 300 = 6,600 \qquad 374,880 \div 6,600 = 56.8.$

*Answer.*—Weight of filling required in given example is 56.8 pounds.

*Example.*—**Worsted Yarn.** Find weight of filling required for 600 yards of cloth, woven with 64 picks per inch, 62 inches reed space, 2/32's worsted.

$64 \times 62 = 3,968 \times 600 = 2,380,800. \qquad 16 \times 560 = 8,960 \qquad 2,380,800 \div 8,960 = 265\frac{5}{7}.$

*Answer.*—Weight of filling required in given example is $265\frac{5}{7}$lbs.

**If two or more different kinds of filling yarn are used, and it is required to ascertain weight of material for each kind,** the solving of the example depends entirely on the arrangement of colors used and their respective counts.

**If the counts are equal, and lots differ only in color or twist,** ascertain the weight for the entire filling required by previously given rules, and find answer for each kind by proportion of picks as used of each kind.

*Example.*—Find weight (in ounces) for filling required per yard in the following fabric:

Arrangement of filling.—
4 picks brown 6-run woolen yarn.
6 " black 6-run " "
4 " blue 6-run " "
6 " black 6-run " "
——
20 picks in repeat of pattern.

72 inches reed space of fabric. 84 picks per inch.

$84 \times 72 = 6,048$ yards of filling per yard cloth.

$6,048 \div 600$ {Yards of yarn per oz. in 6-run yarn.} $= 10.08$ oz. complete weight of filling required per yard cloth.

In one repeat we find:

| | | |
|---|---|---|
| Brown | 4 picks=1 | thus: $10.08 \div 5 = 2.016$ |
| Blue | 4 picks=1 | |
| Black | 12 picks=3 | |
| | 20 picks. 5 | |

*Answer.*—
$2.016 \times 1$ or 2.016 oz. brown filling
$2.016 \times 1$ or 2.016 oz. blue "
$2.016 \times 3$ or 6.048 oz. black "
} required per yard of cloth woven.

*Proof.*— (+) 10.080 total weight of filling required for one yard cloth woven.

*Example.*—Find weight in pounds of filling required for weaving 2,000 yards of cloth of the following dimensions: Reed space 64 inches—picks per inch 66.

| | | | | | |
|---|---|---|---|---|---|
| Arrangement.— | 2 | picks | 2/32's | worsted | black. |
| | 2 | " | 2/32's | " | brown. |
| | 2 | " | 2/32's | " | black. |
| | 2 | " | 2/32's | " | olive. |
| | 8 | picks in repeat of pattern. | | | |

$66 \times 64 = 4{,}224 \times 2{,}000 = 8{,}448{,}000$ yards of filling required for 2,000 yards of cloth.

2/32's worsted=8,960 yards and $8{,}448{,}000 \div 8{,}960 = 942\frac{6}{7}$ lbs. total weight of filling required for the 2,000 yards cloth.

| | | | |
|---|---|---|---|
| Black | 4 | picks in one repeat of color arrangement | =2 |
| Brown | 2 | " " " " " | =1 |
| Olive | 2 | " " " " " | =1 |
| | 8 picks. | | 4 Thus: |

$942\frac{6}{7} \div 4 = 235\frac{5}{7}$

*Answer.*—

$235\frac{5}{7} \times 1 = 235\frac{5}{7}$ lbs. 2/32's olive worsted
$235\frac{5}{7} \times 1 = 235\frac{5}{7}$ " 2/32's brown "
$235\frac{5}{7} \times 2 = 471\frac{3}{7}$ " 2/32's black "
} Amount of filling required for weaving 2,000 yards cloth.

*Proof.*— (+) $942\frac{6}{7}$ lbs. total weight of all 3 kinds filling for 2,000 yards cloth.

**If filling yarns of different counts or materials are used,** find number of yards of yarn of each kind required for given number of yards, and transfer the same to their respective weight (in oz. or lbs. as required) by means of rules given previously under the heading of "Grading Yarns."

*Example.*—Find weight in ounces for filling required per yard in the following fabric:

Arrangement.—10 picks black 4-run woolen yarn.
2 " blue 6 " " "

12 picks in repeat of pattern.

70 inches reed space of fabric. 64 picks per inch.

$64 \times 70 = 4{,}480$ yards of filling required per yard of cloth.

| | |
|---|---|
| 10 picks black | =5 |
| 2 picks blue | =1 |
| 12 picks in repeat | 6 |

Thus: $4{,}480 \div 6 = 746\frac{2}{3}$

$746\frac{2}{3} \times 1 = 746\frac{2}{3}$ yards blue 6-run
$746\frac{2}{3} \times 5 = 3{,}733\frac{1}{3}$ " black 4-run
} filling required for one yard of cloth.

$746\frac{2}{3}$ yards 6-run=$(746\frac{2}{3} \div 600) = 1.24$ oz.
$3{,}733\frac{1}{3}$ " 4-run=$(3{,}733\frac{1}{3} \div 400) = 9.33$ oz.

*Answer.*—1.24 oz. 6-run blue filling and
9.33 " 4-run black filling, or

10.57 oz. complete weight of filling required for weaving one yard cloth.

*Example.*—Find weight in pounds of filling required for weaving 3,500 yards of cloth of the following details: Reed space 72 inches, 84 picks per inch.

Arrangement.—2 picks 32-cut woolen yarn, brown.
1 pick 14 " " " black.
2 picks 32 " " " blue.
1 pick 14 " " " black.

6 picks in repeat.

84×72=6,048×3,500=21,168,000 complete yards of filling required.

| | | | | |
|---|---|---|---|---|
| 2 picks | 32-cut | brown | = | 1 |
| 2 " | 32 " | blue | = | 1 |
| 2 " | 14 " | black | = | 1 |
| 6 picks in repeat. | | | | 3 Thus: |

21,168,000÷3=7,056,000 yards of filling required of each kind.

7,056,000÷9,600 (standard of 32-cut)=735 lbs.
7,056,000=4,200 (standard of 14-cut)=1,680 lbs.

*Answer.*—In given example the following amounts of filling are required:

| | | | |
|---|---|---|---|
| 735 | lbs. | 32-cut brown woolen yarn. | |
| 735 | " | 32-cut blue " " | |
| 1,680 | " | 14-cut black " " | or |
| 3,150 | lbs. | complete weight of filling required for weaving the 3,500 yards of cloth. | |

## TO FIND THE COUNTS FOR A FILLING YARN REQUIRED TO PRODUCE A CERTAIN GIVEN WEIGHT PER YARD CLOTH (in which also the picks per inch and width in reed are known).

**If such example refers to weight given in ounces for one yard, use—**

*Rule.*—Multiply picks by width of fabric in reed, and divide product by number of oz. given, and the quotient by the sixteenth part of the number of yards in the basis of the yarn in question.

*Example.*—**Worsted Yarn.** Find counts for filling yarn required of following cloth. 90 picks per inch, $58\frac{1}{3}$ inches width of fabric in reed. 5 oz. weight for filling to be used.

$$90\times58\tfrac{1}{3}=5{,}250\div5=1{,}050\div35(560\div16=35)=30.$$

*Answer.*—The counts for filling yarn required are either single 30's or 2/60's worsted yarn.

*Proof.*—$90\times58\frac{1}{3}$=5,250(yards wanted)÷1,050(yards per oz.)=5 oz. weight of filling per yard.

*Example.*—**Woolen Yarn** (cut basis). Find counts for filling yarn required of following cloth: 45 picks per inch, 75 inches width of fabric in reed, 9 oz. weight for filling to be used.

$$45\times75=3{,}375\div9=375\div18\tfrac{3}{4}=20.$$

*Answer.*—The counts for filling yarn required are 20-cut woolen yarn.

**If example refers to a given number of yards and weight is expressed in pounds, use—**

*Rule.*—Multiply width of fabric (in loom or in reed) with the number of picks per inch, and the result with the given yards of cloth to be woven; the result thus obtained divide by the given weight, and the quotient by the basis of the yarn.

*Example.*—**Woolen Yarn** (run basis). Find counts for filling yarn required of following cloth: Reed space occupied $66\frac{2}{3}$ inches, 72 picks per inch, 40 yards length of cloth to be woven, 30 lbs. amount of filling to be used.

$$66\tfrac{2}{3}\times72=4{,}800\times40=192{,}000\div30=6{,}400\div1{,}600=4.$$

*Answer.*—Counts for yarn required are 4-run woolen yarn.

*Example.*—**Cotton Yarn.** Find counts for filling yarn required for following cloth. Reed space occupied 30 inches, 80 picks per inch, 70 yards length of cloth to be woven, 10 lbs. amount of filling to be used.

$$30\times80=2{,}400\times70=168{,}000\div10=16{,}800\div840=20$$

*Answer.*—Counts for yarn required are 20's cotton yarn.

## TO FIND THE PICKS PER INCH FOR A CERTAIN PIECE OF GOODS OF WHICH THE COUNTS OF THE YARN, LENGTH OF CLOTH TO BE WOVEN, ITS WIDTH IN REED, AND THE AMOUNT OF MATERIAL TO BE USED, ARE GIVEN.

In such a case use—

*Rule.*—Multiply counts by basis of yarn and amount of material to be used, the product thus obtained divide by the yards given and the quotient by width of fabric in reed.

*Example.*—**Woolen Yarn** (run basis). Find number of picks necessary to produce the following fabric: 6-run woolen yarn, 80 inches width of cloth in reed, 40 yards length of cloth woven, 20 lbs. weight of filling to be used.

$$6\times1{,}600=9{,}600\times20=192{,}000\div40=4{,}800\div80=60$$

*Answer.*—60 picks are required.

*Proof.*—$60\times80=4{,}800\times40=192{,}000$ yards required.

$6\times1{,}600=9{,}600$. Thus: $192{,}000\div9{,}600=20$ lbs., weight of filling to be used.

*Example.*—**Worsted Yarn.** Find number of picks required to produce the following fabric: Single 15's worsted filling, 60 inches width of cloth in reed, 40 yards length of cloth woven, 22 lbs. weight of filling to be used.

$$15\times560=8{,}400\times22=184{,}800\div40=4{,}620\div60=77$$

*Answer.*—77 picks are required.

**In some instances there may be two or more different counts of filling used.** For example in fabrics made with one system of warp and two or more fillings, or fabrics made on the regular double cloth system, etc. **If the arrangement as to counts of a filling is of a simple form,** compound the counts of the respective number of threads in one thread, and solve answer in compound size by previously given rule. Next multiply compound number thus derived by number of picks compounded, and the result will be the answer for picks wanted in fabric.

*Example.*—**Woolen Yarn** (cut basis). Find number of picks necessary to produce the following fabric.

Arrangement of filling.—2 picks 32-cut woolen yarn (face).
1 pick 18 " " " (back).

3 picks in repeat.

36 yards length of cloth woven, $26\frac{5}{24}$ lbs. weight of filling to be used, 74 inches reed space to be occupied.

$32 \div 32 = 1$ | $32 \div 3\frac{7}{9} = 8\frac{8}{17}$-cut compound size.
$32 \div 32 = 1$ | $8\frac{8}{17} \times 300 = 2{,}541\frac{3}{17} \times 26\frac{5}{24} = 66{,}600$
$32 \div 18 = 1\frac{7}{9}$ | $66{,}600 \div 36 = 1{,}850 \div 74 = 25$, compound number of picks required.
$3\frac{7}{9}$ | $25 \times 3$ (number of minor picks compounded) $= 75$

*Answer.*—75 picks are required.

*Proof.*—2 picks 32-cut. | 75 picks per inch.
1 pick 18-cut. | 36 yards length of cloth.

3 picks in repeat. 74 inches reed space occupied. Find weight ($26\frac{5}{24}$).

$75 \times 74 = 5{,}550 \div 3 = 1{,}850.$ $1{,}850$—18-cut—($18 \times 300 = 5{,}400$ yards per lb.)
$3{,}700$—32-cut—($32 \times 300 = 9{,}600$ yards per lb.)

$1{,}850 \times 36 = 66{,}600 \div 5{,}400 = 12\frac{1}{3} = 12\frac{8}{24}$ lbs.
$3{,}700 \times 36 = 133{,}200 \div 9{,}600 = 13\frac{7}{8} = 13\frac{21}{24}$ lbs.

$26\frac{5}{24}$ lbs., being the same weight as given in example.

**If the arrangement of filling has a large number of picks in repeat proceed as follows:** Ascertain weight of filling for one repeat of number of yards required woven and find answer by proportion, for picks in one repeat are to their weight in the same proportion, as picks required (or x) to given weight.

*Example.*—**Cotton Yarn.** Find number of picks required for the following cloth:

Width of fabric in reed 30 inches.
Length of cloth woven 60 yards.
Weight of filling to be used 12 lbs.

Arrangement of filling.—20 picks single 20's cotton.
24 " " 12's "

44 picks in repeat.

$20 \times 30 = 600 \times 60 = 36{,}000$
$24 \times 30 = 720 \times 60 = 43{,}200$ } for one repeat of 44 picks.

20's cotton $= 16{,}800$ yards per lb. and 36,000 yards are required.
12's " $= 10{,}080$ " " " 43,200 " " "

$36{,}000 \div 16{,}800 = 2\frac{1}{7}$ lbs.
$43{,}200 \div 10{,}080 = 4\frac{2}{7}$ lbs.

$6\frac{3}{7}$ lbs., weight required for one repeat (=44 picks) of given counts of cotton yarn.

$44 : 6\frac{3}{7} :: x : 12$ $44 \times 12 = 528 \div 6\frac{3}{7} = 82\frac{2}{15}$

*Answer.*—82 picks (actually $82\frac{2}{15}$ picks) are required.

*Proof.*—$82\frac{2}{15} \times 30 = 2{,}464 \times 60 = 147{,}840 \div 44 = 3{,}360.$

$3{,}360 \times 20 = 67{,}200 \div 16{,}800 = 4$ lbs.
$3{,}360 \times 24 = 80{,}640 \div 10{,}080 = 8$ lbs.

12 lbs., weight of filling to be used in given example.

**To ascertain the number of yards of cloth woven, a certain amount of yarn on hand will give.** Such examples will frequently arise in working up old lots on hand; again every time at weaving the last pieces cloth of large orders, where the superintendent wants a final review before the last or last few looms may have to wait for filling, or cut warps short. In such instances, width of fabric in reed, counts of yarn, and picks per inch are known. Thus : find number of yards for which material on hand by—

*Rule.*—Ascertain weight of filling required per yard, and divide the latter into the total weight of yarn on hand.

*Example.*—**Woolen Yarn** (run system). Find number of yards of cloth we can weave with 92 lbs. 4-run woolen yarn filling in a fabric, which is set 70 inches wide in reed and for which we use 60 picks per inch.

| Picks per inch |  | Width of fabric in reed. |  | Yds of filling wanted for 1 yard cloth. |  | 6,400 ÷ 16 or yards per oz. |  |
|---|---|---|---|---|---|---|---|
| 60 | × | 70 | = | 4,200 | ÷ | 400 | $=10\frac{1}{2}$ oz., weight of filling wanted per yard cloth woven. |

| Lbs. of filling on hand. |  | Oz. in 1 lb |  | Total amount of oz. |  | Oz. of filling in 1 yard of cloth. |  |
|---|---|---|---|---|---|---|---|
| 92 | × | 16 | = | 1,472 | ÷ | 10.5 | =140.19 yards. |

*Answer.*—Filling in hand will weave 140 yards (140.19) of cloth.

*Example.*—**Woolen Yarn** (cut system). Find number of yards of cloth we can weave with 42 lbs. 32-cut woolen yarn filling in a fabric, which is set 72 inches in reed and for which we use 84 picks per inch.

| Picks per inch. |  | Width of fabric in reed. |  | Yds. of filling wanted for 1 yard cloth. |  | 9,600 ÷ 16 or yards per oz. |  |
|---|---|---|---|---|---|---|---|
| 84 | × | 72 | = | 6,048 | ÷ | 600 | =10.08 oz., weight of filling wanted per yard cloth woven. |

| Lbs. of filling on hand. |  | Oz. in 1 lb. |  | Total amount of oz. |  | Oz. of filling in 1 yard of cloth. |  |
|---|---|---|---|---|---|---|---|
| 42 | × | 16 | = | 672 | ÷ | 10.08 | $=66\frac{2}{3}$ yards. |

*Answer.*—Filling on hand will weave 66 yards ($66\frac{2}{3}$) of cloth.

*Example.*—**Worsted Yarn.** Find number of yards of cloth we can weave with 52 lbs. of 2/36's worsted filling in a fabric, which is set 62 inches wide in reed and for which we use 70 picks per inch.

| Picks per inch. |  | Width of fabric in reed. |  | Yds. of filling wanted for 1 yd. of cloth. |  | 10,080 ÷ 16 or yards per oz. |  |
|---|---|---|---|---|---|---|---|
| 70 | × | 62 | = | 4,340 | ÷ | 630 | =6.888 oz., weight of filling wanted per yard cloth woven. |

| Lbs. of filling on hand. |  | Oz. in 1 lb. |  | Total amount of oz |  | Oz. of filling in 1 yard of cloth. |  |
|---|---|---|---|---|---|---|---|
| 52 | × | 16 | = | 832 | ÷ | 6.888 | =120.79 yards. |

*Answer.*—Filling on hand will weave 120 yards ($120\frac{4}{5}$) of cloth.

*Example.*—**Cotton Yarn.** Find number of yards of cloth we can weave with 18 lbs. of single 40's cotton filling in a fabric, which is set 30 inches in reed and for which we use 60 picks per inch.

| Picks per inch. |  | Width of fabric in reed |  | Yds. of filling wanted for 1 yard of cloth. |  | 33,600 ÷ 16 or yards per oz. |  |
|---|---|---|---|---|---|---|---|
| 60 | × | 30 | = | 1,800 | ÷ | 2,100 | $=\frac{6}{7}$ oz., weight of filling wanted per yard cloth woven. |

| Lbs. of filling on hand. |  | Oz. in 1 lb. |  | Total amount of oz. |  | Oz. of filling in 1 yard of cloth. |  |
|---|---|---|---|---|---|---|---|
| 18 | × | 16 | = | 288 | ÷ | $\frac{6}{7}$ | =336 yards. |

*Answer.*—Filling on hand will weave 336 yards of cloth.

**(Answers are given in these examples without reference to any waste of material during the weaving process.)**

# Ascertaining the Amount and Cost of the Materials used in the Construction of Fabrics.

---

A. FIND THE TOTAL COST OF MATERIALS USED, and

B. FIND THE COST OF THE SAME PER YARD, FINISHED CLOTH.

### Fancy Cassimere.

Warp.—3,600 ends 4-run brown mix. Price of yarn, 85 cents per lb. Length dressed, 50 yards. Reed, $12\frac{1}{2}\times 4$.

Selvage.—40 ends, 2-ply 4-run. Reeded, 4 ends per dent. Price of yarn, 50 cents.

Filling.—52 picks, $3\frac{3}{4}$-run gray mix. Price of yarn, 65 cents per lb.

Length of fabric from loom, 43 yards. Length of fabric finished, 40 yards.

{Ends.} {Yards.} {Total yards.} {Yards per lb.} {Total lbs.} {Price per lb.}

Warp.— $\frac{3{,}600\times 50}{6{,}400} = (180{,}000 \div 6{,}400) = 28\frac{1}{8} \times 85¢ = \$23.905$, price of warp.

{Total yards.} {Yards per lb.} {Price per lb.}

Selvage.—$40\times 2 = 80$ ends $\times$ 50 yds. $= 4{,}000 \div 3{,}200 = 1\frac{1}{4}$ lbs. $\times 50¢ = 62\frac{1}{2}¢$, price of selvage.

Filling.—$3{,}600 \div 50 = 72$ inches, width of warp in reed.

$+ 1\frac{3}{5}$ " width of selvage ($80\div 4 = 20 \div 12\frac{1}{2} = 1\frac{3}{5}$).

$73\frac{3}{5}$ inches, width of warp and selvage.

| {Width.} | {Picks} | | {Yards filling per yard cloth.} | | {Yards Woven.} | | {Total yards filling.} | | {Yards per lb.} | | {Weight of filling.} |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $73\frac{3}{5}$ | × 52 | = | $3{,}827\frac{1}{2}$ | × | 43 | = | $164{,}582\frac{1}{2}$ | ÷ | 6,000 | = | 27.43 lbs. |
| | | | | | | | | | | | ×65¢, price per lb. |
| | | | | | | | | | | | $17.8295, price of filling. |

$23.90½, price of warp.
62½, price of selvage.
17.83, price of filling.
$42.36, total cost of all.

$\$42.36 \div 40 = \$1.059$ or $1.06, price of material per yard finished.

*Answer.*—A. $42.36, total cost of all materials.

*Answer.*—B. $1.06, cost of materials per yard of finished cloth.

### Worsted Suiting.

Warp.—3,968 ends, 2/32's worsted. Price of yarn, $1.05 per lb. Length dressed, 45 yards. Reed, $16\times 4$.

Selvage.—30 double ends, 2/30's worsted, 3 double ends per dent. Price of yarn, 75 cents per lb.

Filling.—66 picks, 2/32's worsted. Price of yarn, 95 cents.

Length of fabric from loom, 40 yards. Length of fabric finished, $39\frac{1}{4}$ yards.

Warp.—$3{,}968\times 45 = 178{,}560$ yards of warp wanted.

2/32's worsted=1/16's=8,960 yards per lb. $178{,}560 \div 8{,}960 = 19\frac{13}{14}$ lbs., weight of warp.

$$19\tfrac{13}{14}\times 1.05 = \frac{279}{14}\times 1.05 = \frac{279\times 1.05}{14} = 292.95 \div 14 = \$20.92\tfrac{1}{2}, \text{ cost of warp.}$$

Selvage.—$60 \times 2 = 120 \times 45 = 5{,}400$ yards of selvage are wanted.

2/30's=1/15's=8,400 yards per lb.

$$5{,}400 \div 8{,}400 = \frac{54}{84} \text{ or } \frac{9}{14} \times \underset{\text{(Price per lb.)}}{75¢} = 675 \div 14 = 48\tfrac{3}{14}¢\text{, cost of selvage.}$$

Filling.—$3{,}968 \div 64 = 62$ inches width of warp.

10 dents each side for selvage=20 (both sides) $\div 16 = 1\tfrac{1}{4}$ inches, width of selvage.

62 inches, width of warp.
$1\tfrac{1}{4}$ " " selvage.

$63\tfrac{1}{4}$, total width of fabric in reed, and $63\tfrac{1}{4} \times 66 = 4{,}174.5$ {Yards filling wanted per yard.}
$\times 40$ length of cloth from loom.

166,980 yards of filling wanted.

$166{,}980 \div 8{,}960 = 18\tfrac{285}{448}$ lbs. of filling wanted.

$$18\tfrac{285}{448} \times \underset{\text{\{Price per lb.\}}}{95¢} = 17.70\tfrac{195}{448} \div 100 = \$17.70\tfrac{1}{2}\text{, cost of filling.}$$

| | |
|---|---|
| Warp, | \$20.92½ |
| Selvage, | 0.48 3/14 |
| Filling, | 17.70½ |

$39.11 3/14, total cost of materials.

$\$39.1175 \div 39.25 = \$0.996$ or $99\tfrac{3}{5}¢$, cost of material per yard.

*Answer* A.—\$39.11¾, (practically \$39.12) total cost of all materials.

*Answer* B.—\$ 0.99⅗, (practically \$1.00) cost of materials per yard of finished cloth.

### Cotton Dress Goods.

Warp.—1,392 ends, single 18's cotton. Price of yarn, 22 cents per lb. Length dressed, 60 yards. Reed, $24 \times 2$.

Selvage.—12 ends, 2/20's cotton, 3 ends per dent. Price, 20 cents per lb.

Filling.—54 picks, single 26's cotton. Price, 24 cents per lb.

Length of cloth from loom, 56 yards. Length of cloth finished, $56\tfrac{1}{2}$ yards.

Warp.—$1{,}392 \times 60 = 83{,}520 \div 15{,}120 (840 \times 18) = 5\tfrac{99}{189}$ lbs. $\times 22¢ = \$1.20\tfrac{178}{189}$, price of warp.

Selvage.—$24 \times 60 = 1{,}440 \div 8{,}400 = \tfrac{144}{840}$ or $\tfrac{6}{35}$ lbs.

$\tfrac{6}{35} \times 20 = (120 \div 35) = 3\tfrac{3}{7}¢$, price of selvage.

Filling.—$1{,}392 \div 48 = 29$ inches, width of fabric in reed.
$\tfrac{1}{3}$ inch " " both selvages.

$29\tfrac{1}{3}$ inches, total width of fabric and selvages.

$29\tfrac{1}{3} \times 54 = 1{,}584$ yards of filling wanted per yard.
$\times 56$ " length of cloth from loom.

88,704, total number of yards wanted.

$$88{,}704 \div \underset{\text{\{Yards per lb. in 26's cotton.\}}}{21{,}840} = \underset{\text{(lbs.)}}{4.061} \times 24¢ = .97\tfrac{46}{100}¢\text{, price of filling.}$$

$1.21, price of warp
.03½, " " selvage
.97½, " " filling

$2.22, total price of material used in the fabric.

$\$2.22 \div 56\frac{1}{2} = 3\frac{105}{113}$ or nearly $3\frac{7}{8}$¢, price of material per yard finished.

*Answer A.*—$2.22, total cost of material used.

*Answer B.*—$ .03⅞, (practically 4 cents) cost of materials per yard finished cloth.

### Woolen Tricot Suiting.

Warp.—4,608 ends, 32-cut woolen yarn. Price of yarn, $1.15 per lb. Length dressed, 40 yards. Reed, 16×4.

Selvage.—40 ends, single 10-cut, 2 ends per dent. Price, 54 cents per lb.

Filling.—76 picks, 36-cut woolen yarn. Price, $1.08 per lb.

Length of cloth from loom, 36 yards. Length of cloth finished, 32 yards.

Warp.—4,608×40=184,320÷9,600(300×32)=19.2 lbs×$1.15=$22.08, price of warp.

Selvage.—40×2=80×40=3,200÷3,000(300×10)=1 1/15 lbs.×$0.54=$0.576, price of selvage.

Filling.—4,608÷64=72 inches, width of warp.
2½ " " " selvage. (40×2=80÷2=40÷16=2½)

74½ inches, total width of fabric.
74½×76=5,662 yards filling per yard.
×36 yards of cloth woven.

203,832, total yards filling wanted.
203,832÷10,800=18,873 lbs., weight of filling.
18,873 lbs.×$1.08=$20.383, cost of filling.

Warp, $22.08
Selvage, .576
Filling, 20.383

$43.039, total cost.

$43.039÷32=$1.345, or $1.34½, cost of materials per yard finished.

*Answer A.*—$43.039, (practically $43.04) is the total cost of the materials used; and,

*Answer B.*—$1.34½, is the cost of the same per yard finished.

### Worsted Suiting.

Warp.—3,960 ends. Length dressed, 45 yards. Reed, 16×4. Take up of warp during weaving, 12 per cent.

Dressed.—4 ends black 2/32's } 4 times over=24 ends.
2 " slate 2/36's }
4 " black 2/32's = 4 "
1 " 30/2's lavender spun silk = 1 "
1 " 30/2's red " " = 1 "

30 ends in pattern.

Price of black worsted, $1.05. Price of slate worsted, $1.12. Price of silk, $6.50.

Selvage.—30 double ends, 2/30's worsted each side, 3 double ends per dent. Price of yarn, 75¢ per lb.

**Filling.**—66 picks per inch, 2/32's worsted.

Arrangement of colors.—28 picks black worsted 2/32's (price 95¢ per lb.)
1 pick lavender spun silk 30/2's (price $6.50 per lb.)
1 pick red " " 30/2's (price 6.50 per lb.)

30 picks in repeat. Loss in length during finishing, $1\frac{1}{2}$ per cent.

| | | | | |
|---|---|---|---|---|
| 20 ends | black | 2/32's | worsted | =10 |
| 8 " | slate | 2/36's | " | = 4 |
| 2 " | spun silk | 30/2's | " | = 1 |
| 30 ends in pattern | | | | =15 |

3,960÷15=264 repeats (of half patterns.)

| | | | | |
|---|---|---|---|---|
| 264×10= | 2,640 | ends of 2/32's black worsted | ×45= | 118,800 yards. |
| 264× 4= | 1,056 | " " 2/36's slate " | ×45= | 47,520 " |
| 264× 1= | 132 | " " 30/2's lavender silk | ×45= | 5,940 " |
| | 132 | " " 30/'2s red silk | ×45= | 5,940 " |
| | 3,960 | ends of warp | ×45= | 178,200 yards. |

2/32's=1/16's=16×560=8,960 yards per lb.

$118,800 \div 8,960 = 13\frac{29}{112}$ lbs. $\times \$1.05 = \frac{1,485}{112} \times 1.05 = (1,485 \times 1.05 = 155,925 \div 112 =)$ **$13.921.**

Price of 118,800 yards 2/32's black worsted is $13.92.

2/36's=1/18's=18×560=10,080 yards.

47,520÷10,080=$4\frac{5}{7}$ lbs. × $1.12=$5.28, price of 47,520 yards 2/36's slate worsted.

30/2's silk=25,200 yards per lb. 5,940÷25,200=0.235 lbs.×$6.50=$1.52750.

Price of 5,940 yards 30/2's lavender silk=$1.527. Price of 5,940 yards 30/2's red silk=$1.527.

| | |
|---|---|
| Black worsted, | $13.92 |
| Slate, " | 5.28 |
| Lavender silk, | 1.527 |
| Red silk, | 1.527 |
| | $22.254, total cost of warp. |

Selvage.—2/30's=1/5's=15×560=8,400 yards per lb.

120×45=5,400 yards. $5,400 \div 8,400 = \frac{54}{84} = \frac{9}{14}$ lbs.×75¢=48.2¢, price of selvage

Filling.—3,960÷64=$61\frac{14}{16}$ inches, width of cloth in reed.

60÷3=20 dents÷16=$1\frac{4}{16}$=$1\frac{1}{4}$ inch, width of selvage.

$61\frac{14}{16}$, width of cloth.
$1\frac{4}{16}$, width of selvage.

$62\frac{18}{16}$ inches=$63\frac{1}{8}$ inches, width of cloth and selvage.

$63\frac{1}{8} \times 66 = \frac{505}{8} \times 66 = (505 \times 66 = 33,330 \div 8 =) 4,166\frac{1}{4}$ yards filling wanted for 1 yard cloth from loom.

45 yards length dressed.
— 5.4 " 12 per cent. take up.

39.6 yards, length of cloth woven.

4,166.25×39.6=164,983.5 yards, total amount of filling wanted.

164,983.5÷15=10,998.9 | 10,998.9×14=153,984.6 yards of 2/32's worsted wanted.
10,998.9× 1= 10.998.9 " " 30/2's silk wanted.

164,983.5

153,984.6÷8,960=17.185 lbs.×95¢=$16.326, price of the black worsted filling.

30/2's silk=25,200 yards per lb. 10,998.9÷25,200=0.436 lbs.×$6.50=$2.834, total price of silk.

$2.834÷2=$1.417, price for each kind silk.

$16.326 black worsted filling.
1.417 lavender silk "
1.417 red " "

$19.160, total cost of filling.

Cost of warp, $22.254
" " selvage, .482
" " filling, 19.160

$41.896, total cost of materials.

39.6 yards, length of cloth woven.
.594 " 1½ per cent. loss in finishing.

39.006 yards, finished length.

41.896÷39.006=1.074, cost of materials per finished yard.

*Answer.*—A. Total cost of material, $41.90.

*Answer.*—B. Cost of materials per yard finished cloth, $1.07½.

### Fancy Cassimere.

Warp.—4,032 ends. Reed, 14×4. Length of warp dressed, 50 yards. Take-up of warp during weaving, 10 per cent.

| | | |
|---|---|---|
| Dressed.—4 ends 5-run black / 4 " 5 " brown | 4 times over | =32 ends. |
| 4 ends 5-run black | | = 4 ends. |
| 3 " 5 " brown | | = 3 ends. |
| 1 end twist | 5-run black wool and 30's blue spun silk twisted together; take up of silk, 12 per cent. / " " " wool, 3 per cent. during twisting. | =1 end. |
| 2 ends 5-run black / 2 " 5 " brown | 9 times over | =36 ends. |
| 2 ends 5-run black | | = 2 ends. |
| 1 end 5 " brown | | = 1 end. |
| 1 " twist (the same as above) | | = 1 end. |
| | In pattern | 80 ends. |

Price of the 5-run warp yarn, 96 cents per lb. Price of the 5-run woolen yarn (soft-twist) as used in twist, 96 cents per lb. Price of the spun-silk as used in twist, $5.60 per lb.

Selvage.—40 ends of 2-ply 4-run listing yarn for each side, 4 ends per dent. Price of yarn, 50 cents.

Filling.—The same arrangement as the warp, only using 5½-run yarn in place of the 5-run. For twist use the same material for both minor threads as in warp. 60 picks per inch. Price of the 5½-run filling yarn, 85 cents. Loss in length of fabric at finishing (fulling), 6 per cent.

Warp.—4,032 ends. { 78 ends 5-run / 2 " twist

80 ends in repeat.

4,032÷80=50 repeats plus 32 ends.

50×78=3,900+32=3,932 ends of 5-run 50×2=100 ends twist.

(Ends in warp.) (Yards long.) (Yards wanted.) (5×1,600)
3,932 × 50 = 196,600 ÷ 8,000 = 24,575 lbs. @ 96¢ = $23.592, price of 5-run warp.

100 ends of twist × 50 yards (dressed) = 5,000 yards, total length of twist yarn wanted.

Take-up of silk (during twisting) 12 per cent. Thus: (100 : 88 :: x : 5,000) = 5,681.81 yards of 30's spun silk are wanted.

Take-up of wool (during twisting) 3 per cent. Thus: (100 : 97 :: x : 5,000) = 5,154.64 yards of 5-run woolen yarn are wanted.

(30×840) (Weight wanted.) (Price per lb.)
5,681.81 ÷ 25,200 = 0.2254 lbs. × $5.60 = $1.262, price of silk yarn used in twist for **warp.**

(5×1,600) (Weight wanted.) (Price per lb.)
5,154.64 ÷ 8,000 = 0.6443 lbs. × 96¢ = $0.618, price of the 5-run minor yarn for **twist.**

$23.592 cost of 5-run warp yarn.
1.262 " " 30's spun silk } for twist.
0.618 " " 5-run soft twist }

$25.472, total cost of warp.

Selvage.—80 ends × 50 yards dressed = 4,000 yards of yarn ÷ 3,200 (2×1,600) = $1\frac{1}{4}$ lbs.
$1\frac{1}{4}$ lbs @ 50¢ = $62\frac{1}{2}$¢, price of selvage yarn used.

(Ends in warp.) (14×4)
Filling.—4,032 ÷ 56 = 72 inches, width of cloth in reed.

80 (ends selvage) ÷ 4 (ends per dent) = 20 dents ÷ 14 = $1\frac{3}{7}$ inches, width of selvage.

72 inches, width of cloth,
$1\frac{3}{7}$ " " " selvage,

$73\frac{3}{7}$ inches, total width.

{Width of cloth.} {Picks per inch.}
$73\frac{3}{7} \times 60 = \frac{514}{7} \times 60 = \frac{30,840}{7} \times 45 \left\{ \begin{array}{l} 50 \\ -5 = 10 \text{ per cent. take up} \\ 45 \end{array} \right\} = 198,257\frac{1}{7}$, total number of yards of filling wanted.

$198,257\frac{1}{7}$ ÷ 40 = 4,956.43 × 1 = 4,956.43 yards of twist. } filling yarn are wanted.
and 4,956.43 × 39 = 193,300.77 " " $5\frac{1}{2}$-run. }

$5\frac{1}{2}$-run = 8,800 yards per lb. Thus:

193,300 ÷ 8,800 = $21\frac{85}{88}$ lbs. @ 85¢ = $18.671, price of the $5\frac{1}{2}$-run filling.

Twist yarn. { Silk take-up 12 per cent., thus: (100 : 88 :: x : 4,956.43) = $5,632\frac{27}{88}$ yards are **wanted.**
Wool " 3 " " " (100 : 97 :: x : 4,956.43) = $5,109\frac{70}{97}$ " " "

30's spun silk = 25,200 yards per lb. Hence:

5,632 ÷ 25,200 = 0.2235 lbs., weight of silk wanted @ $5.60 = $1.251, price of silk.

5-run woolen yarn = 8,000 yards per lb. Hence:

5,109 ÷ 8,000 = 0.6386 lbs., weight of woolen yarn @ 96¢ = 61.3¢, price of the woolen yarn.

$18.671 cost of $5\frac{1}{2}$-run filling.
1.251 " " 30's spun silk. } for twist.
0.613 " " 5-run soft twist. }

$20.535, total cost of filling.

| | |
|---|---|
| $25.472, cost of warp. | 45 yards, woven length of cloth. |
| 0.625, " " selvage. | — 2.7 " (6 per cent. shrinkage in ful ing). |
| 20.535, " " filling. | 42.3 yards, length of cloth when finished. |
| $46.632, total cost. | |

46.632÷42.3=1.124

*Answer.*—A. The total cost of materials used are $46.632 ($46.64) and

*Answer.*—B. The cost of the same per finished yard is $1.124 ($1.13.)

## Fancy Cotton Dress Goods.

(27 inches finished width.)

2,204 ends in warp. Reed, 38×2. Length of cloth from loom, 80 yards.

Dressing:

| | | | | |
|---|---|---|---|---|
| 1 end dark blue (ground)<br>1 end white " | ×4 | = 8 ends | 1/20's |
| 1 end light blue | " | = 1 end | 2/30's |
| 2 ends " " | (pile) | = 2 ends | 2/24's |
| 1 end " " | (ground) | = 1 end | 2/30's |
| 8 ends tan | " | = 8 ends | 1/20's |
| 1 end flesh | " | = 1 end | 2/30's |
| 2 ends " | (pile) | = 2 ends | 2/24's |
| 1 end " | (ground) | = 1 end | 2/30's |
| 1 end white | " | = 1 end | 2/30's |
| 2 ends " | (pile) | = 2 ends | 2/24's |
| 1 end " | (ground) | = 1 end | 2/30's |
| 1 end dark blue "<br>1 end white " | ×4 | = 8 ends | 1/20's |
| 1 end maroon | " | = 1 end | 2/30's |
| 2 ends " | (pile) | = 2 ends | 2/24's |
| 1 end " | (ground) | = 1 end | 2/30's |
| 8 ends tan | " | = 8 ends | 1/20's |
| 1 end white | " | = 1 end | 2/30's |
| 2 ends " | (pile) | = 2 ends | 2/24's |
| 1 end " | (ground) | = 1 end | 2/30's |
| 24 ends tan | " | =24 ends | 1/20's |

Dressing:—continued.

| | | | |
|---|---|---|---|
| 1 end dark blue (ground)<br>1 end white " | ×4 | = 8 ends | 1/20's |
| 1 end maroon | " | = 1 end | 2/30's |
| 2 ends " | (pile) | = 2 ends | 2/24's |
| 1 end " | (ground) | = 1 end | 2/30's |
| 8 ends tan | " | = 8 ends | 1/20's |
| 1 end white | " | = 1 end | 2/30's |
| 2 ends " | (pile) | = 2 ends | 2/24's |
| 1 end " | (ground) | = 1 end | 2/30's |
| 1 end light blue | " | = 1 end | 2/30's |
| 2 ends " " | (pile) | = 2 ends | 2/24's |
| 1 end " " | (ground) | = 1 end | 2/30's |
| 1 end dark blue "<br>1 end white " | ×4 | = 8 ends | 1/20's |
| 1 end " | " | = 1 end | 2/30's |
| 2 ends " | (pile) | = 2 ends | 2/24's |
| 1 end " | (ground) | = 1 end | 2/30's |
| 8 ends tan | " | = 8 ends | 1/20's |
| 1 end flesh | " | = 1 end | 2/30's |
| 2 ends " | (pile) | = 2 ends | 2/24's |
| 1 end " | (ground) | = 1 end | 2/30's |
| 24 ends tan | " | =24 ends | 1/20's |

Repeat of pattern, 152 ends.

Take-up of ground-warps during weaving, 8 per cent.
Take-up of pile-warp during weaving, 70 per cent.

Price of warp yarns (including coloring or bleaching) as to their respective counts, are:

1/20's ground, 30 cents.
2/30's ground, 38 cents.
2/24's pile, 36 cents.

**Selvage.**—10 two-ply ends of 2/20's white cotton for each side. 2 double ends per dent. 8 per cent. take up during weaving. Price of yarn, 22 cents.

**Filling.**—78 picks per inch.

Arrangement of colors.—

| | | |
|---|---|---|
| 4 | picks | white |
| 8 | " | tan |
| 4 | " | maroon |
| 8 | " | tan |
| 6 | " | white |
| 8 | " | tan |
| 4 | " | light blue |
| 28 | " | tan |
| 70 | picks in repeat. | |

Counts for all the filling 1/20's cotton.
Price of all the filling yarn, inclusive of coloring and bleaching, 28 cents.
Length of cloth from loom to equal length finished.

**Warp.**—1/20's ground = 112 ends in one pattern
2/30's " = 20 " " " "
2/24's pile = 20 " " " "

152 ends in one repeat of pattern.

2,204 (ends in warp) ÷ 152 (repeat of pattern) = 14½ repeats of pattern in width of fabric.

**Pattern,** with reference as to counts, repeats twice in one repeat of pattern. Thus:

| | Take-up during weaving. | | Yards of yarn wanted per yard cloth woven. | | Length of cloth woven. | | Yards of yarn wanted for the entire piece. |
|---|---|---|---|---|---|---|---|
| 112×14½=1,624 ends of 1/20's cotton— | 8 per cent. | — | 1,765.2174 | × | 80 | = | 141,217.392 yds. |
| 20×14½= 290 " " 2/30's " | — 8 " " | — | 315.2174 | × | 80 | = | 25,217.392 " |
| 20×14½= 290 " " 2/24's " | —70 " " | — | 966.6666 | × | 80 | = | 77,333.328 " |

| Yards of yarn wanted for the entire piece. | | Yards per lb. | | Lbs. of yarn wanted for the entire piece. | | Price of the yarn per lb. | | Value of yarn. |
|---|---|---|---|---|---|---|---|---|
| 141,217.392 yards. | ÷ | 16,800 | = | 8.4058 | × | 30¢ | = | $2.52 |
| 25,217.392 " | ÷ | 12,600 | = | 2.0013 | × | 38 | = | 0.76 |
| 77,333.328 " | ÷ | 10,080 | = | 7.6719 | × | 36 | = | 2.76 |
| | | | | | | | | $6.04, price of warp yarn. |

**Filling.**—29 inches, width of fabric in reed.
$\frac{5}{19}$ " " " selvage in reed.

$29\frac{5}{19}$ inches, total width of cloth in reed.

$$29\tfrac{5}{19}\times 78=\left(\frac{556}{19}\times 78\right)=2{,}282.5263 \text{ yards of filling per yard cloth woven.}$$

| | Length of cloth woven. | | Total yards of filling wanted. | | 20×840 | | Lbs. of yarn wanted. | | Price of yarn per lb. | | Value of total filling yarn. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2,282.5263× | 80 | = | 182,602.1040 yds. | ÷ | 16,800 | = | 10.8691 | × | 28¢ | = | $3.04 |

Selvage.—40 ends. 8 per cent. take-up (100 : 92 :: x : 40) required 43.478 yards yarn per yard cloth woven.

| | | Length of cloth woven. | | Yards of selvage wanted for the entire piece. | | 10×140 | | Total weight of selvage. | | Price per lb. | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 43.478 yards | × | 80 | = | 3,478.24 yards | ÷ | 8,400 | = | 0.414 lbs. | × | 22¢ | =9¢, total price of selvage. |

| | |
|---|---|
| \$6.04 cost of warp,<br>3.04 " " filling,<br>0.91 " " selvage,<br>\$9.99, total cost. | 9.99÷80=12.487. |

*Answer.*—A. The total cost of materials used in fabric is \$9.99, and

*Answer.*—B. The value of this stock, per finished yard, is 12.487 cents, practically 12½ cents.

## Worsted Suiting.

3,968 ends 2/32's worsted. Length of warp dressed, 45 yards. Reed, 16×4.

Arrangement of dressing.—4 ends black,
4 ends brown,
4 ends black,
4 ends indigo blue.

16 ends in repeat.

Price of yarn in the white, (scoured) \$1.05 per lb.

Allowance for waste during spooling, dressing and weaving, 5 per cent.

Selvage.—30 double ends of 2/30's white worsted for each side, 4 double ends per dent. Price, per lb., 75 cents.

Filling.—66 picks, 2/32's worsted. Same arrangement of colors as in warp. Price of yarn in the white, (scoured) 95 cents.

Allowance for waste during spooling and weaving, 6 per cent.

Length of fabric from loom, 40 yards. Length of fabric finished, 39½ yards.

Cost of coloring yarn, black, 6 cents per lb.; brown, 6 cents per lb.; indigo blue, 15 cents per lb. (Weight of yarn before coloring to equal its weight when colored.)

Cost of weaving, 16 cents per yard, from loom. Cost of finishing, 12 cents per yard, finished.

General mill expenses, 10 cents per yard, finished cloth.

Warp.—

| (Ends) | | (Yards dressed.) | | (Total yards.) | | (16×560) | | (Lbs.) | | (Price per lb.) | | (Cost.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3,968 | × | 45 | = | 178,560 | ÷ | 8,960 | = | 19.928 | × | \$1.05 | = | \$20.9244 |
| 19.928 | ÷ 4 = | 4.982 | × | 1 | = | 4.982 lbs. | @ 15¢ | (indigo blue) | | | = | .7473 |
| | | 4.982 | × | 3 | = | 14.946 | " " | 6¢ (black and brown) | | | = | .8967 |
| | | | | | | | | | | | | \$22.5684 |
| | | | | | | | | 5 per cent. allowance for waste, | | | | 1.1284 |
| | | | | | | | | Total cost of warp yarn, | | | | \$23.6968 |

Selvage.—60 double ends 2/30's worsted = 20 single ends 2/30's.

120×45=5,400÷8,400=$\frac{54}{84}$=$\frac{9}{14}$ lb. @ 75¢=48.214¢
5 per cent. allowance for waste, 2.410

Cost of selvage, \$0.562

Filling.—Reed, 16×4=64 warp threads per inch.

(Ends in full warp.)÷(Ends per inch.)
3,968 ÷ 64 =62 inches, width of cloth in reed.
$\frac{15}{16}$ " width of selvage (60÷4=15 dents, reed 16=$\frac{15}{16}$ inch).

62$\frac{15}{16}$ inches, total width of fabric (including selvage) in reed.

| Width in reed. | | Picks per inch. | | Yards of filling wanted per yard of cloth woven. | | Yards from loom. | |
|---|---|---|---|---|---|---|---|
| **$62\frac{15}{16}$** | × | 66 | = | $4,153\frac{7}{8}$ | × | 40 | =166,155 yards of filling wanted in cloth. |
| | | | | | | | + 9,969 yards, 6 per cent. allowance for [waste. |
| | | | | | | | 176,124 yards, total amount of filling wanted. |

(Total length.) (15×560 ) (Total weight.)

176,124 ÷ 8,960 = 19.6567 lbs. @ 95¢ =$18.6739, cost of filling yarn.
19.6567÷4=4.9141×1= 4.9141 lbs. @ 15 = 0.7371, " " indigo blue color.
4.9141×3=14.7426 lbs. @ 6 = 0.8845, " " black and brown colors.

$20.2955, total cost of filling yarn.

40 ×16¢=$6.40, cost of weaving.
$39\frac{1}{4}$×12 =$4.71, " " finishing.
$39\frac{1}{4}$×10 =$3.93, general mill expenses (office insurance, watchmen, mechanics, per cent. on capital, etc.)

$23.70 cost of warp.
0.51 " " selvage.
20.30 " " filling.
6.40 " " weaving.
4.71 " " finishing.
3.93 general mill expenses.

$59.55

$59.55÷$39\frac{1}{4}$=$1.517.

*Answer.*—A. $59.55, total cost of the fabric.

*Answer.*—B. $1.52, cost of fabric per finished yard.

### Beaver Overcoating. (*Piece-dyed.*)

4,800 ends in warp. Reed, 10×6. 42 yards long, dressed.

Arrangement of dressing.—2 ends face, $5\frac{1}{2}$-run. Price of yarn per lb., $1.25.
1 end back, 5-run " " " " " .84.

3 ends in repeat.

Filling.—2 picks face, $5\frac{1}{2}$-run. Price of yarn per lb., $1.18.
1 pick back, $1\frac{3}{4}$-run. " " " " " .40.

3 picks in repeat.

80 picks per inch.

16 cents for weaving.
4 " general weave room expenses.

20 cents per yard from loom for weaving.

Selvage.—40 ends of 2-run listing yarn (each side). Price, 50 cents per lb. 3 ends per dent (outside dent 4).

Take-up of warp during weaving, 11 per cent. Take-up of cloth during finishing (fulling), 10 per cent. Flocks used during fulling process, 20 lbs. at 8 cents per lb. Cost of finishing and dy ing, 25 cents per yard, finished. General mill expenses, 10 cents per yard, finished.

Warp.—4,800÷3=1,600.

(Yards wanted.)
1,600×2=3,200 ends $5\frac{1}{2}$-run×42= 134,400 ÷8,800=$15\frac{3}{11}$ lbs. @ $1.25=$19.09.
1,600×1=1,600 ends 5-run ×42= 67,200 ÷8,000= $8\frac{2}{5}$ lbs. @ .84= 7.06.

Cost of warp, $26.15.

(Yards wanted.)

Selvage.—80 ends 2-run × 42= 3,360 ÷ 3,200 = 1.05 lbs. @ 50¢ = 52½¢ (53¢), cost of selvage.

Filling.—Reed, 10 × 6 = 60 ends per inch and

4,800 ÷ 60 = 80 inches, width of cloth in reed.

2.6 " " " selvage (80 ÷ 3 = 26 dents = 2.6 inches).

82.6 inches, total width.

82.6 × 80 = 6,608 yards (total amount of filling per yard woven).

6,608 ÷ 3 = 2,202⅔ and 2,202⅔ × 2 = 4,405⅓ yards face filling.

2,202⅔ × 1 = 2,202⅔ " backing.

11 per cent. take-up of warp during weaving.

100 : 89 :: 42 : x = 89 × 42 = 3,738 ÷ 100 = 37.38 yards, woven length.

Hence: 4,405⅓ × 37.38 = 164,671.35 yards 5½-run = 18.712 lbs. @ $1.18 = $22.10

2,202⅔ × 37.38 = 82,335.67 " 1¾ " = 29.456 " @ .40 = 11.78

Cost of filling, $33.88

37.38 × 20¢ = $7.47, cost of weaving.

10 per cent. shrinkage of cloth during finishing. Hence:

100 : 90 :: 37.38 : x = (90 × 37.38 =) 3,360.20 ÷ 100 = 33.64 yards, finished length.

| | |
|---|---|
| $26.15 cost of warp. | 33.64 × 25¢ = $8.41 cost of finishing. |
| .53 " " selvage. | 33.64 × 10 = 3.37 general mill expenses. |
| 33.88 " " filling. | 20 × 8 = 1.60 cost of flocks. |
| 7.47 " " weaving. | |
| 8.41 " " finishing. | |
| 3.37 " " general expenses. | 81.41 ÷ 33.64 = 2.42. |
| 1.60 " " flocks. | |
| $81.41 | |

*Answer*.—A. $81.41, total cost of the fabric.

*Answer*.—B. $ 2.42, cost of fabric per yard, finished.

### Ingrain Carpet. (*Extra fine;* Cotton Chain, Worsted Filling)

832 ends in warp, 2/14's cotton, 5 per cent. take-up by weaving and shrinkage in finishing, etc. Finished length of fabric, 60 yards.

| | | |
|---|---|---|
| Cost of yarn, | 17 ¢ | per lb. |
| Cost of color, | 5 | " " (average price). |
| Winding and beaming, | 2½ | " " |

24½¢, price of warp yarn per lb. on beam.

Selvage.—Four ends of 4/10's cotton on each side. Price, 20 cents per lb. (same amount of take-up as warp).

Filling.—10 pair, (in finished fabric) 36 inches, width of fabric in loom.

Yarn used: One-half the amount 5/8's single, light colors (50 yards per oz. in the grease). Price, 16½ cents per lb. in the grease, or 26½ cents per lb. scoured and colored. One-half the amount 5/8's single, dark colors (48 yards per oz. in the grease). Price, 12 cents per lb. in the grease, or 20 cents per lb. scoured and colored.

Loss (average) of weight for filling in scouring and dyeing, 15 per cent. Waste of filling (average) in winding and weaving, 15 per cent.

Length of the yarn to remain uniform from the grease to colored. Weaving and weave-room expenses, 10 cents per yard finished fabric. General mill expenses, 5 cents per yard finished fabric.

Warp.—832 ends 2/14's cotton, 5 per cent. take-up, 60 yards finished length, $24\frac{1}{2}$ cents per lb.

$100:95 :: x:832 = 83{,}200 \div 95 = 875\frac{15}{19} \times 60 = 52{,}547.37$ yards, total amount of yarn wanted.

2/14's=5,880 yards per lb. Hence: $52{,}547.37 \div 5{,}880 = 8.9536$ lbs., total weight of yarn wanted.

8.9536 lbs. @ $24\frac{1}{2}$¢=\$2.1936 (=\$2.20) cost of warp-yarn.

Selvage.—$4 \times 2 = 8 \times 60 = 480$.

$100:95 : x :: 480 = 48{,}000 \div 95 = 505.26$ yards, total length of selvage yarn wanted.

4/10's=2,100 yards per lb. Hence: $505.26 \div 2{,}100 = 0.24$ lbs., total weight.

0.24 lbs. @ 20¢=4.$\frac{8}{10}$¢ (=5¢) cost of selvage.

Filling.—20 picks per inch in finished fabric. 36 inches, width of fabric.

$36 \times 60 = 2{,}160 \times 20 = 43{,}200$ yards, total amount wanted in fabric.

= { 21,600 yards light colored yarn, at 50 yards per oz. in the grease.
 21,600 yards dark colored yarn, at 48 yards per oz. in the grease. }

$50 \times 16 = 800$ yards per lb. for light colors. $48 \times 16 = 768$ yards per lb. for dark colors.

$21{,}600 \div 800 = 27$ lbs., weight in the grease.

$$100:85 :: 27: x = \frac{85 \times 27}{100} = 22.95 \text{ lbs., weight of yarn scoured and colored.}$$

22.95 lbs.@$26\frac{1}{2}$¢=\$6.082, cost of light colored filling used in fabric.

$21{,}600 \div 768 = 28.12$ lbs., weight in the grease.

$$100:85 :: 28.12:x = \frac{85 \times 28.12}{100} = 23.90 \text{ lbs., weight of yarn scoured and colored.}$$

23.9 lbs. @ 20¢=\$4.78, cost of dark colored filling used in fabric.

\$ 6.082 light colored.
 4.780 dark "

\$10.862, total value of filling used in fabric, subjected to 15 per cent. waste of material in winding and weaving. Hence:

$$100:85 :: x:10.86 = \frac{10.86 \times 100}{85} = 12.776, \text{ cost of filling, including of waste made in winding and weaving.}$$

| | | |
|---|---|---|
| Cost of warp, | \$ 2.194 | |
| Cost of selvage, | 0.048 | |
| Cost of filling, | 12.776 | |
| Weaving and weaveroom expenses, | 6.000 | (60 yards × 10 cents) |
| General mill expenses, | 3.000 | (60 yards × 5 cents) |
| | \$24.018 | |

$24.01 \div 60 = 0.40$

*Answer.*—A. \$24.02, total cost of the fabric.

*Answer.*—B. 40 cents, cost of fabric per yard finished.

### Ingrain Carpet. (*Extra Super;* Worsted Chain.)

1,072 ends in warp, 2/14's worsted, 5 per cent. take up by weaving and shrinkage in finishing, etc. Price of yarn, including coloring (average) and winding and beaming, $52\frac{1}{2}$ cents per lb.

Selvage.—Four ends of 4/10's cotton on each side.

Price, 20 cents per lb. (same amount of take up as warp).

Filling.—13 pair (in finished fabric) 36 inches, width of fabric in loom.

Arrangement.—1 pick double reel yarn (60 yards per oz. in the grease.) Price, 22 cents per lb. in the grease, or 33 cents per lb. scoured and dyed.

1 pick, 5/8's single, light color (50 yards per oz. in the grease). Price 16½ cents per lb. in the grease, or 26½ cents per lb. scoured and dyed.

1 pick, double reel (as before).

1 pick 5/8's, single dark color (48 yards per oz. in the grease). Price, 12 cents per lb. in the grease, or 20 cents per lb. scoured and dyed.

Loss of weight (average) for filling in scouring and dyeing, 12½ per cent. Waste (average) of filling in, winding and weaving, 12½ per cent. No shrinkage for yarn during scouring and coloring. Weaving and weaveroom expenses, 12 cents per finished yard. General mill expenses, 6 cents per finished yard.

Warp.—1,072 ends, 2/14's worsted, 5 per cent. shrinkage. Price, 52½ cents per lb.

100:95 :: x :1,072=107,200÷95=1,128.421×60=67,705.26 yards, total amount of warp yarn wanted.

2/14's=3,920 yards per lb. Hence: 67,705.26÷3,920=17.27 lbs., total weight.

17.27 lbs.@52½¢=$9.066, value of warp yarn.

Selvage.—(The same as in previously given Example) 5 cents.

Filling.—26 picks, 36 inches, 60 yards. Hence:

26×36×60=56,160 yards, total amount of filling wanted in fabric.

56,160÷4=14,040. Hence:

14,040×2=28,080 yards of double reel yarn@33¢ per lb.

14,040×1=14,040 " " 5/8's single light color@26½¢ per lb.

14,040×1=14,040 " " 5/8's single dark color@20 per lb.

60×16=960 yards per lb. and 28,080÷960=29¼ lbs. @ 33 ¢=$9.652, value of double reel.

50×16=800 yards per lb. and 14.040÷800=17.55 lbs. @ 26½ =$4.65, value of 5/8's light color.

48×16=768 yards per lb. and 14,040÷768=18.28 lbs. @ 20 =$3.656, value of 5/8's dark color.

$9.652 value of double reel.
4.650 " 5/8's light color.
3.656 " 5/8's dark color.

$17.958, total value of filling used in carpet (subject to 12½ per cent. waste in winding and weaving).

100:87.5 :: x :17.958=1,795.8÷87.5=$20.523, cost of all the filling in fabric and waste.

*Memo.*—The same answer as to the cost of filling, may be obtained by calculating the 12½ per cent. loss of material during winding and weaving to the amount of filling wanted in the fabric, as follows:

56,160 yards total amount of filling wanted. Thus:

100:87.5 :: x :56,160=5,616,000÷87.5=64,182.856÷4=16,045.714.

16,045.714×2=32,091.428÷960=33.428×33 =$11.031
16,045.714÷800=20.057×26.5= 5.315
16,045.714÷768=20.891×20 = 4.178

$20.523, being the same answer as before.

| | | |
|---|---|---|
| Cost of warp, | $ 9.066 | |
| Cost of selvage, | 0.048 | |
| Cost of filling, | 20.523 | 40.437÷60=0.67. |
| Weaving and weaveroom expenses, | 7.200 (60 yards @ 12¢.) | |
| General mill expenses, | 3.600 (60 yards @ 6¢.) | |
| | $40.437 | |

*Answer.*—A. $40.44, total cost of fabric.

*Answer.*—B. 67¢, cost of fabric per yard, finished.

# STRUCTURE OF TEXTILE FABRICS.

To produce a perfect fabric the following points must be taken into consideration: The purpose of wear that the fabric will be subject to, the nature of the raw material to be used in its construction, the size or counts of the yarns and their amount of twist, the texture (number of ends of warp and filling per inch) to be used, the weave and "take up" of the cloth during weaving, the process of finishing and the shrinkage of the cloth during this operation.

## THE PURPOSE OF WEAR THAT THE FABRIC WILL BE SUBJECT TO.

This point must be taken into consideration when calculating for the construction of a fabric for the following reasons: The more wear a fabric is subject to, the closer in construction the same must be; also the stronger the fibres of the raw material as well as the amount of twist of the yarn. For this reason upholstery fabrics, such as lounge covers, must be made with a closer texture and of a stronger yarn than curtains. Woolen fabrics, for men's wear, are in an average more subject to wear than dress goods made out of the same material; hence the former require a stronger structure. Again, let us consider woolen cloth for men's wear by itself, such as trouserings or chinchilla overcoatings. No doubt the student will readily understand that such of the cloth as is made for trouserings must be made of a stronger construction, to resist the greater amount of wear, compared to such cloth as made for the use of overcoatings which actually are subject to little wear, and for which only care must be taken to produce a cloth permitting air to enter and remain in its pores, assisting in this manner in producing a cloth with the greatest chances for retaining the heat to the human body.

## THE NATURE OF RAW MATERIALS.

The selection of the proper quality of the material to use in the construction of a fabric is a point which can only be mastered by practical experience. No doubt a thorough study of the nature of raw materials, as well as the different processes they undergo before the thread as used by the weaver, (either for warp or filling) is produced, will greatly assist the novice to master this subject. For this reason the different raw materials, as used in the construction of textile fabrics and the different processes necessary for converting the same into yarn, have been previously explained.

As known to the student every woven fabric is constructed by raising or lowering one system of threads (technically known as warp) over threads from another system (technically known as filling). This will readily illustrate that the warp threads of any woven cloth are subjected to more or less chafing against each other during the process of weaving.

There will be more chafing the higher the warp texture, and the rougher the surface of the yarn. In some instances the manufacturer tries to reduce this roughness by means of sizing or starching the yarn during the process preceding weaving and known as "dressing;" but sizing will correspondingly stiffen the warp yarns, and reduce their chances for bending easily around the filling, and the warp will take up the filling harder than if the yarn was not sized. If, by means of sizing, the chafing is not dispensed with, we must reduce the warp texture to the proper point where perfect weaving is possible. No doubt the using of proper warp texture is so greatly neglected, that many a poor weaver's family is suffering by its cause.

To illustrate the roughness of the different yarns as used in the manufacture of textile fabrics the five illustrations, Figs. 1 to 5 are given: Fig. 1 represents a woolen thread; Fig. 2 represents worsted yarn; Fig. 3 represents mohair; Fig. 4 represents cotton yarn; Fig. 5 represents silk yarn.

An examination of these five illustrations shows the silk yarn to be the smoothest, followed in rotation, getting gradually rougher by cotton, mohair and worsted, until reaching the woolen thread which represents the roughest surface. These illustrations will also show that (in an average) a woolen fabric requires a lower texture than a worsted cloth, or a cotton cloth, and a silk fabric a higher texture

Fig. 1 | Fig. 2 | Fig. 3 | Fig. 4 | Fig. 5

compared to fabrics made out of other materials. In addition to the roughness of the surface of a thread, we must also take into consideration the pliability of the fibres, for the softer the pile of the yarn the less the chafing will influence the strength of the yarn, whereas a coarse and stiff fibre will produce the reverse result.

## COUNTS OF YARN REQUIRED TO PRODUCE A PERFECT STRUCTURE OF CLOTH.

In speaking of the size or counts of a thread we mean the weight of solidity, or the bulkiness of a thread, or in other words the diameter of the same. These diameters in threads do not vary in the direct ratio to the respective counts, but do vary as to the square roots of their counts. Thus, if we find the diameter of a thread it will be easy for us to ascertain how many of those threads can rest side by side in one inch.

### Rule for finding the number of ends which in Cotton, Woolen, Worsted, Linen and Silk Yarns can lie side by side in one inch.

Find number of yards per pound for the yarn in question and extract the square root of this number. From this square root deduct four per cent. for raw-silk yarns, seven per cent. for cotton, spun silk and linen yarns, ten per cent. for worsted yarns, and sixteen per cent. for woolen yarns. The answer in each case indicates the number of threads that will lie side by side in one inch (without being interlaced at right angles by another system).

*Example.*—Find number of threads of 1's cotton yarn which will lie side by side in one inch.

840 yards per lb. Thus: $\sqrt{840}=28.9$

$$\begin{array}{rl} 28.9 & \\ -\ 2.0 & \text{(7 per cent.)} \\ \hline 26.9 & \end{array}$$

*Answer.*—$26\frac{9}{10}$ threads (practically 27) of single 1's cotton yarn will rest side by side in one inch.

*Example.*—Find number of threads of 2's cotton yarn which will lie side by side in one inch.

$840\times2=1680$ yards per lb. Thus: $\sqrt{1,680}=40.9$

$$\begin{array}{rl} 40.9 & \\ -\ 2.8 & \text{(7 per cent.)} \\ \hline 38.1 & \end{array}$$

*Answer.*—$38\frac{1}{10}$ threads (practically 38) of single 2's cotton yarn will rest side by side in one inch.

*Example.*—Find number of ends of 2/50's cotton yarn which will lie side by side in one inch.

2/50's cotton $=$ 1/25's $= 840 \times 25 = 21{,}000$ yards per lb. Thus: $\sqrt{21{,}000} = 144.9$

$$\begin{array}{rl} 144.9 & \\ -\ 10.1 & \text{(7 per cent.)} \\ \hline 134.8 & \end{array}$$

*Answer.*—134⅘ threads (practically 135) of 2/50's cotton yarn will rest side by side in one inch.

*Example.*—Find nnmber of threads of 6-run woolen yarn which will lie side by side in one inch.

6-run $= 9{,}600$ yards per lb. Thus: $\sqrt{9{,}600} = 97.97$

$$\begin{array}{rl} 97.97 & \\ -\ 15.67 & \text{(16 per cent.)} \\ \hline 82.30 & \end{array}$$

*Answer.*—82 3/10 threads (practically 82) of 6-run woolen yarn will rest side by side in one inch.

*Example.*—Find number of threads of 22-cut woolen yarn which will lie side by side in one inch.

22-cut $= 6{,}600$ yards per lb. Thus: $\sqrt{6{,}600} = 81.24$

$$\begin{array}{rl} 81.24 & \\ -\ 12.99 & \text{(16 per cent.)} \\ \hline 68.25 & \end{array}$$

*Answer.*—68¼ threads (practically 68) of 22-cut woolen yarn will lie side by side in one inch.

*Example.*—Find number of ends of 2/32's worsted that will lie side by side in one inch.

2/32's $=$ single 16's $= 560 \times 16 = 8{,}960$ yards per lb. Thus: $\sqrt{8{,}960} = 94.6$

$$\begin{array}{rl} 94.6 & \\ -\ 9.4 & \text{(10 per cent.)} \\ \hline 85.2 & \end{array}$$

*Answer.*—85 2/10 threads (practically 85) will lie side by side in one inch.

*Example.*—Find number of threads of 40/3-ply spun silk which will lie side by side in one inch.

40/3-ply $= 33{,}600$ yards per lb. Thus: $\sqrt{33{,}600} = 183.3$

$$\begin{array}{rl} 183.3 & \\ -\ 12.8 & \text{(7 per cent.)} \\ \hline 170.5 & \end{array}$$

*Answer.*—170½ threads (practically 170) of 40/3-ply spun silk will rest side by side in one inch.

*Example.*—Find number of threads of 4-dram raw silk which lie side by side in one inch.

4-dram raw silk $= 64{,}000$ yards per lb. Thus: $\sqrt{64{,}000} = 252.9$

$$\begin{array}{rl} 252.9 & \\ -\ 10.1 & \text{(4 per cent.)} \\ \hline 242.8 & \end{array}$$

*Answer.*—242⅘ threads (practically 243) of 4-dram silk will rest side by side in one inch.

To illustrate clearly to the student that the diameter of a thread (*i. e.*, respectively the number of threads which will lie side by side in one inch) does not vary in the direct ratio to its counts, but in the ratio of the square root of its counts, we give three examples, using for the first example a single yarn; for the next the same number in 2-ply; and for the third the same number in 3-ply.

*Examples.*—Find number of threads that will lie side by side for the following yarns: Single 30's cotton, 2/30's cotton, and 3/30's cotton yarn.

30's cotton $= 25{,}200$ yards per lb.

Thus: $\sqrt{25{,}200} = 158.7$

$$\begin{array}{rl} 158.7 & \\ -\ 11.1 & \text{(7 per cent.)} \\ \hline \end{array}$$

147.6 threads (practically 148) of 30's cotton yarn will lie side by side in one inch.

2/30's cotton=12,600 yards per lb.

Thus: $\sqrt{12{,}600}=112.2$

112.2
— 7.9 (7 per cent.)

104.3 threads (practically 104) of 2/30's cotton yarn will lie side by side in one inch.

3/30's cotton=8,400 yards per lb.

Thus: $\sqrt{8{,}400}=91.6$

1.6
— 6.4 (7 per cent.)

85.2 threads (practically 85) of 3/30's cotton yarn will lie side by side in one inch.

*Answer.*—Single 30's cotton=148 threads per inch.
2/30's " =104 " " "
3/30's " = 85 " " "

### Table Showing the Number of Ends of Cotton Yarn from Single 5's to 2/160's that Will Lie Side by Side in One Inch.

| Counts. | | Yards per Pound. | Square Root. | 7 Per Cent. | Diameter, or Ends per inch. | Counts. | | Yards per Pound. | Square Root. | Per Cent. | Diameter, or Ends per inch. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Single. | Double. | | | | | Single. | Double. | | | | |
| 5 | 2/10 | 4,200 | 64.8 | 4.5 | 60.3 | 22 | 2/44 | 18,480 | 135.9 | 9.5 | 126.4 |
| 6 | 2/12 | 5,040 | 70.9 | 5.0 | 65.9 | 24 | 2/48 | 20,160 | 141.8 | 9.9 | 131.9 |
| 7 | 2/14 | 5,880 | 76.6 | 5.4 | 71.2 | 26 | 2/52 | 21,840 | 147.7 | 10.3 | 137.4 |
| 8 | 2/16 | 6,720 | 81.9 | 5.7 | 76.2 | 28 | 2/56 | 23,520 | 153 3 | 10.7 | 142.6 |
| 10 | 2/20 | 8,400 | 91.6 | 6.4 | 85.2 | 30 | 2/60 | 25,200 | 158.7 | 11.1 | 147.6 |
| 11 | 2/22 | 9,240 | 96.1 | 6.7 | 89.4 | 32 | 2/64 | 26,880 | 163.8 | 11.5 | 152.3 |
| 12 | 2/24 | 10,080 | 100.3 | 7.0 | 93.3 | 34 | 2/68 | 28,560 | 168.9 | 11.8 | 157.1 |
| 13 | 2/26 | 10,920 | 104.4 | 7.3 | 97.1 | 36 | 2/72 | 30,240 | 173.8 | 12.2 | 161.6 |
| 14 | 2/28 | 11,760 | 108.4 | 7.6 | 100.8 | 38 | 2/76 | 31,920 | 178.6 | 12.5 | 166.1 |
| 15 | 2/30 | 12,600 | 112.2 | 7.9 | 104.3 | 40 | 2/80 | 33,600 | 183.3 | 12.8 | 170.5 |
| 16 | 2/32 | 13,440 | 115.9 | 8.1 | 107.8 | 45 | 2/90 | 37,800 | 194.4 | 13.6 | 180.8 |
| 17 | 2/34 | 14,280 | 119.4 | 8.3 | 111.1 | 50 | 2/100 | 42,000 | 204.9 | 14.3 | 190.6 |
| 18 | 2/36 | 15,120 | 122.9 | 8.6 | 114.3 | 60 | 2/120 | 50,400 | 224.4 | 15.7 | 208.7 |
| 19 | 2/38 | 15,960 | 126.3 | 8.8 | 117.5 | 70 | 2/140 | 58,800 | 242.4 | 17.0 | 225.4 |
| 20 | 2/40 | 16,800 | 129.6 | 9.0 | 120.6 | 80 | 2/160 | 67,200 | 259.2 | 18.1 | 241.1 |

For Spun Silks use also above table, but only refer to single count column for reference for any number of ply of spun silk.

### Table Showing the Number of Ends of Woolen Yarn "Run Basis," from 1-run to 10-run, that Will Lie Side by Side in One Inch.

| Run. | Yards per Pound. | Square Root. | 16 Per Cent. | Diameter, or Ends Per Inch. | Run. | Yards per Pound. | Square Root. | 16 Per Cent. | Diameter, or Ends Per Inch. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1,600 | 40.0 | 6.4 | 33.6 | 4¾ | 7,600 | 87.2 | 14.0 | 73.3 |
| 1¼ | 2,000 | 44.7 | 7.2 | 37.5 | 5 | 8,000 | 89.4 | 14.3 | 75.1 |
| 1½ | 2,400 | 49.7 | 8.0 | 41.7 | 5¼ | 8,400 | 91.6 | 14.7 | 76.9 |
| 1¾ | 2,800 | 52.8 | 8.4 | 44.4 | 5½ | 8,800 | 93.8 | 15.0 | 78.8 |
| 2 | 3,200 | 56.5 | 9.0 | 47.5 | 5¾ | 9,200 | 95.8 | 15.3 | 80.5 |
| 2¼ | 3,600 | 60.0 | 9.6 | 50.4 | 6 | 9,600 | 97.9 | 15.6 | 82.3 |
| 2½ | 4,000 | 63.2 | 10.1 | 53.1 | 6¼ | 10,000 | 100.0 | 16.0 | 84.0 |
| 2¾ | 4,400 | 66.3 | 10.6 | 55.7 | 6½ | 10,400 | 101.9 | 16.3 | 85.6 |
| 3 | 4,800 | 69.2 | 11.0 | 58.2 | 6¾ | 10,800 | 103.9 | 16.6 | 87 3 |
| 3¼ | 5,200 | 72.1 | 11.5 | 60.6 | 7 | 11,200 | 105.8 | 16.9 | 88.9 |
| 3½ | 5,600 | 74.8 | 11.9 | 62.9 | 7½ | 12,000 | 109.5 | 17.5 | 92.0 |
| 3¾ | 6,000 | 77.4 | 12.3 | 65.1 | 8 | 12,800 | 113.1 | 18.1 | 95.0 |
| 4 | 6,400 | 80.0 | 12.8 | 67.2 | 8½ | 13,600 | 116.6 | 18.6 | 98.0 |
| 4¼ | 6,800 | 82.4 | 13.1 | 69.3 | 9.0 | 14,400 | 120.0 | 19.2 | 100.8 |
| 4½ | 7,200 | 84.8 | 13.5 | 71.3 | 10 | 16,000 | 126.4 | 20.2 | 106.2 |

## Table Showing the Number of Ends of Woolen Yarn "Cut Basis," from 6-cut to 50-cut that Will Lie Side by Side in One Inch.

| Cut. | Yards per Pound. | Square Root. | 16 Per Cent. | Diameter, or Ends Per Inch. | Cut. | Yards per Pound. | Square Root. | 16 Per Cent. | Diameter, or Ends Per Inch. |
|---|---|---|---|---|---|---|---|---|---|
| 6 | 1,800 | 42.4 | 6.8 | 35.6 | 22 | 6,600 | 81.2 | 13.0 | 68.2 |
| 8 | 2,400 | 49.7 | 8.0 | 41.7 | 23 | 6,900 | 83.0 | 13.3 | 69.7 |
| 9 | 2,700 | 51.9 | 8.3 | 43.6 | 24 | 7,200 | 84.8 | 13.5 | 71.3 |
| 10 | 3,000 | 54.7 | 8.8 | 45.9 | 25 | 7,500 | 86.6 | 13.8 | 72.8 |
| 11 | 3,300 | 57.4 | 9.2 | 48.2 | 26 | 7,800 | 88.3 | 14.1 | 74.2 |
| 12 | 3,600 | 60.0 | 9.6 | 50.4 | 27 | 8,100 | 90.0 | 14.4 | 75.6 |
| 13 | 3,900 | 62.4 | 10.0 | 52.4 | 28 | 8,400 | 91.6 | 14.7 | 77.0 |
| 14 | 4,200 | 64.8 | 10.4 | 54.4 | 29 | 8,700 | 93.2 | 14.9 | 78.3 |
| 15 | 4,500 | 67.0 | 10.7 | 56.3 | 30 | 9,000 | 94.8 | 15.2 | 79.6 |
| 16 | 4,800 | 69.2 | 11.0 | 58.2 | 32 | 9,600 | 97.9 | 15.7 | 82.2 |
| 17 | 5,100 | 71.4 | 11.4 | 60.0 | 34 | 10,200 | 100.9 | 16.1 | 84.8 |
| 18 | 5,400 | 73.5 | 11.8 | 61.7 | 36 | 10,800 | 103.4 | 16.5 | 86.9 |
| 19 | 5,700 | 75.4 | 12.0 | 63.4 | 40 | 12,000 | 109.5 | 17.5 | 92.0 |
| 20 | 6,000 | 77.4 | 12.3 | 65.1 | 45 | 13,500 | 116.1 | 18.6 | 97.5 |
| 21 | 6,300 | 79.3 | 12.7 | 66.6 | 50 | 15,000 | 122.4 | 19.6 | 102.8 |

## Table Showing the Number of Ends of "Worsted Yarn," from Single 5's to 2/160 that Will Lie Side by Side in One Inch.

| Counts. | | Yards per Pound. | Square Root. | 10 Per Cent. | Diameter, or Ends per Inch. | Counts. | | Yards per Pound. | Square Root. | 10 Per Cent. | Diameter, or Ends per inch. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Single. | Double. | | | | | Single. | Double. | | | | |
| 5 | 2/10 | 2,800 | 52.9 | 5.3 | 47.6 | 22 | 2/44 | 12,320 | 110.9 | 11.1 | 99.8 |
| 6 | 2/12 | 3,360 | 57.9 | 5.8 | 52.1 | 24 | 2/48 | 13,440 | 115.9 | 11.6 | 104 3 |
| 7 | 2/14 | 3,920 | 62.6 | 6.3 | 56.3 | 26 | 2/52 | 14,560 | 120.6 | 12.1 | 108.5 |
| 8 | 2/16 | 4,480 | 66.8 | 6.7 | 60.1 | 28 | 2/56 | 15,680 | 125.2 | 12.5 | 112.7 |
| 10 | 2/20 | 5,600 | 74.8 | 7.5 | 67.3 | 30 | 2/60 | 16,800 | 129.6 | 13.0 | 116.6 |
| 11 | 2/22 | 6,160 | 78.4 | 7.8 | 70.6 | 32 | 2/64 | 17,920 | 133.8 | 13.4 | 120.4 |
| 12 | 2/24 | 6,720 | 81.9 | 8.2 | 73.7 | 34 | 2/68 | 19,040 | 137.9 | 13.8 | 124.1 |
| 13 | 2/26 | 7,280 | 85.3 | 8.5 | 76.8 | 36 | 2/72 | 20,160 | 141.8 | 14.2 | 127.6 |
| 14 | 2/28 | 7,840 | 88.5 | 8.8 | 79.7 | 38 | 2/76 | 21,280 | 145.8 | 14.6 | 131.2 |
| 15 | 2/30 | 8,400 | 91.6 | 9.2 | 82.4 | 40 | 2/80 | 22,400 | 149.6 | 15.0 | 134.6 |
| 16 | 2/32 | 8,960 | 94.6 | 9.4 | 85.2 | 45 | 2/90 | 25,200 | 158.6 | 15.9 | 142.7 |
| 17 | 2/34 | 9,520 | 97.5 | 9.7 | 87.8 | 50 | 2/100 | 28,000 | 167.3 | 16.7 | 150.6 |
| 18 | 2/36 | 10,080 | 100.3 | 10.0 | 90.3 | 60 | 2/120 | 33,600 | 183.3 | 18.3 | 165.0 |
| 19 | 2/38 | 10,640 | 103.1 | 10.3 | 92.8 | 70 | 2/140 | 39,200 | 197.9 | 19.8 | 178.1 |
| 20 | 2/40 | 11,200 | 105.8 | 10.6 | 95.2 | 80 | 2/160 | 44,800 | 211.6 | 21.2 | 190.4 |

## Table Showing the Number of Ends of Raw Silk Yarn, from 20 Drams to 1 Dram, that will Lie Side by Side in One Inch.

| Dram. | Yards per Pound. | Square Root. | 4 per Cent. | Diameter, or Ends per inch. | Dram. | Yards per Pound | Square Root. | 11 Per Cent. | Diameter, or Ends per inch. |
|---|---|---|---|---|---|---|---|---|---|
| 20 | 12,800 | 113.1 | 4.5 | 108.6 | 5 | 51,200 | 226.2 | 9.0 | 217.2 |
| 18 | 14,222 | 119.2 | 4.8 | 114.4 | 4¾ | 53,368 | 231.0 | 9.2 | 221.8 |
| 16 | 16,000 | 126.4 | 5.0 | 121.4 | 4½ | 56,889 | 238.5 | 9.5 | 229.0 |
| 14 | 18,286 | 135.2 | 5.4 | 129.8 | 4¼ | 60,235 | 245.4 | 9.8 | 235.6 |
| 12 | 21,333 | 146.0 | 5.8 | 140.2 | 4 | 64,000 | 252.9 | 10.1 | 242.8 |
| 10 | 25,600 | 160.0 | 6.4 | 153.6 | 3¾ | 68,267 | 261.2 | 10.4 | 250.8 |
| 9½ | 26,947 | 164.1 | 6.6 | 157.5 | 3½ | 73,143 | 270.4 | 10.8 | 259 6 |
| 9 | 28,444 | 168.6 | 6.7 | 161.9 | 3¼ | 78,769 | 280.6 | 11.2 | 269 4 |
| 8½ | 30,118 | 173.5 | 6.9 | 166.6 | 3 | 85,333 | 292.1 | 11.7 | 280.4 |
| 8 | 32,000 | 178.8 | 7.1 | 171.7 | 2¾ | 93,091 | 305.1 | 12.2 | 292 9 |
| 7½ | 34,133 | 184.7 | 7.4 | 177.3 | 2½ | 102,400 | 320.0 | 12.8 | 307.2 |
| 7 | 36,571 | 191.2 | 7.6 | 183.6 | 2¼ | 113,777 | 337.2 | 13.5 | 323.7 |
| 6½ | 39,385 | 198.4 | 7.9 | 190.5 | 2 | 128,000 | 357.7 | 14.3 | 343.4 |
| 6 | 42,667 | 206.5 | 8.2 | 198.3 | 1½ | 170,666 | 413.1 | 16.5 | 396.6 |
| 5½ | 46,545 | 215.7 | 8.6 | 207.1 | 1 | 256,600 | 505.9 | 20.2 | 485.7 |

**Table Showing the Number of Ends of Linen Yarns from 10's to 100's that Will Lie Side by Side in One Inch.**

| Counts. | Yards per Pound. | Square Root. | 7 Per Cent. | Diameter, or Ends Per Inch. | Counts. | Yards per Pound. | Square Root. | 7 Per Cent. | Diameter, or Ends Per Inch. |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 3,000 | 54.7 | 3.8 | 50.9 | 40 | 12,000 | 109.5 | 7.6 | 101.9 |
| 12 | 3,600 | 60.0 | 4.0 | 56.0 | 42 | 12,600 | 112.2 | 7.8 | 104.4 |
| 14 | 4,200 | 64.8 | 4.5 | 60.3 | 44 | 13,200 | 114.8 | 8.0 | 106.8 |
| 16 | 4,800 | 69.2 | 4.8 | 64.4 | 46 | 13,800 | 117.4 | 8.2 | 109.2 |
| 18 | 5,400 | 73.5 | 5.1 | 68.4 | 48 | 14,400 | 120.0 | 8.4 | 111.6 |
| 20 | 6,000 | 77.4 | 5.4 | 72.0 | 50 | 15,000 | 122.4 | 8.6 | 113.8 |
| 22 | 6,600 | 81.2 | 5.7 | 75.5 | 55 | 16,500 | 128.4 | 9.0 | 119.4 |
| 24 | 7,200 | 84.8 | 5.9 | 78.9 | 60 | 18,000 | 134.1 | 9.3 | 124.8 |
| 26 | 7,800 | 88.3 | 6.1 | 82.2 | 65 | 19,500 | 139.6 | 9.8 | 129.8 |
| 28 | 8,400 | 91.6 | 6.4 | 85.2 | 70 | 21,000 | 144.9 | 10.0 | 134.9 |
| 30 | 9,000 | 94.8 | 6.6 | 88.2 | 75 | 22,500 | 150.0 | 10.5 | 139.5 |
| 32 | 9,600 | 97.9 | 6.8 | 91.1 | 80 | 24,000 | 154.9 | 10.8 | 144.1 |
| 34 | 10,200 | 100.9 | 7.0 | 93.9 | 85 | 25,500 | 159.6 | 11.2 | 148.4 |
| 36 | 10,800 | 103.9 | 7.2 | 96.7 | 90 | 27,000 | 164.3 | 11.5 | 152.8 |
| 38 | 11,400 | 106.7 | 7.4 | 99.3 | 100 | 30,000 | 173.2 | 12.1 | 161.1 |

## TO FIND THE DIAMETER OF A THREAD BY MEANS OF A GIVEN DIAMETER OF ANOTHER COUNT OF YARN.

If the number of threads of a given count which will lie side by side (*i. e.*, its diameter) in one inch (without riding) are known, the required number of threads (which will also lie side by side) for another count of the same system can be found by—

*Rule.*—The given counts of which we know the diameter are to the counts for which we have to find the diameter in the same ratio as the given diameter squared is to the required diameter squared.

*Example.*—As shown in a previous example, 148 threads of single 30's cotton yarn will lie side by side in one inch (or the diameter of a thread of 30's cotton yarn is the $\frac{1}{148}$ part of one inch); required to find by rule given the number of threads that will lie side by side in one inch for 2/30's cotton yarn.

2/30's=single 15's.

{ Given counts. } : { Required counts. } :: { Diameter squared of the given counts. } : { Diameter squared of the required counts. }

$$30 : 15 :: 148^2 : x$$

$$\sqrt{\frac{15 \times 148 \times 148}{30}} \quad \text{Thus: } 15 \times 148 \times 148 = 328{,}560 \div 30 = 10{,}952, \text{ and } \sqrt{10{,}952} = 104$$

*Answer.*—104 threads of 2/30's, or 1/15's cotton yarn, will lie side by side in one inch.

*Proof.*—2/30 cotton yarn=12,600 yards per lb.

Thus: $\sqrt{12{,}600} = 112.2$ 112.2
— 7.9 (7 per cent.)

104.3 (practically 104) being the same answer as previously received.

*Example.*—85 threads of 2/32's worsted yarn will lie side by side in one inch, required to find the number of threads which will lie side by side in one inch with 2/40's worsted yarn.

2/30's=1/16's 2/40's=1/20's.

$$16 : 20 :: 85^2 : x, \text{ or } \sqrt{\frac{20 \times 85 \times 85}{16}} \text{ and } 85 \times 85 \times 20 = 144{,}500 \div 16 = 9{,}031 \ \sqrt{9{,}031} = 95$$

*Answer.*—95 threads of 2/40's worsted yarn will lie side by side in one inch.

*Proof.*—2/40's worsted=560×20=11,200 yards per lb.

Thus: $\sqrt{11,200}=105$ 105
— 10 (10 per cent.)

95, being the same answer as received by the previous process.

*Example.*—84 threads of 6¼-run woolen yarn lie side by side in one inch, required to find the number of threads which will lie side by side in 4-run woolen yarn.

$6\frac{1}{4}:4::84^2:x$ or $\frac{\sqrt{4\times 84\times 84}}{6.25}$ and $84\times 84=7,056\times 4=28,224\div 6\frac{1}{4}=4,515$ and $\sqrt{4,515}=67.2$

*Answer.*—67 threads (actually 67.2) of 4-run woolen yarn will lie side by side in one inch.

*Proof.*—4-run=4×1,600=6,400 yards per lb.

Thus: $\sqrt{6,400}=80.0$ 80.0
—12.8

67.2, being the same answer as previously received.

*Example.*—68¼ threads per inch is the average number of threads which will lie side by side for 22-cut woolen yarn, required to find the number of threads for 30-cut woolen yarn.

$$22:30::68\frac{1}{4}^2:x \text{ or } \frac{68\frac{1}{4}\times 68\frac{1}{4}\times 30}{22} \text{ and}$$

$$68.25\times 68.25\times 30=139,741.875\div 22=6,351.\ \sqrt{6,351}=79$$

*Answer.*—79 threads of 30-cut woolen yarn will lie side by side in one inch.

*Proof.*—30-cut woolen yarn=9,000 yards per lb.

Thus: $\sqrt{9,000}=94$ 94
—15 (16 per cent.)

79, being the same answer as received by previously given process.

## TO FIND THE COUNTS OF YARN REQUIRED FOR A GIVEN WARP TEXTURE BY MEANS OF A KNOWN WARP TEXTURE WITH THE RESPECTIVE COUNTS OF THE YARN GIVEN.

### A. Dealing with One Material.

If we know the number of ends of a given count of yarn that will lie side by side in one inch (technically their diameter), and we want to ascertain the counts of yarn required for a certain number of threads to lie side by side (diameter), we must use—

*Rule.*—As the given diameter squared is to the required diameter squared, so is the given count to the required count.

*Example.*—85 threads of 2/32's worsted lie side by side in one inch, required to find the counts of yarn for 95 threads per inch.

$$85^2 : 95^2 :: 16 : x$$
$$(85\times 85):(95\times 95)::16:x$$
$$7,225 : 9,025 :: 16 : x$$
$$9,025\times 16=144,400\div 7,225=20$$

*Answer.*—1/20's or 2/40's worsted yarn is the number of yarn wanted.

*Proof.*—2/40's or 1/20's worsted yarn=11,200 yards per lb.

Thus: $\sqrt{11,200}=105$    105
— 10 (10 per cent.)

95 threads of 1/20's worsted will lie side by side; being the same answer as texture given in example.

*Example.*—84 threads of 6¼-run woolen yarn, lie side by side in one inch, required to find the counts of yarn for 68 threads per inch.

$$84^2 : 68^2 :: 6\frac{1}{4} : x$$
$$(84\times84):(68\times68) :: 6\frac{1}{4} : x$$
$$7,056 : 4,624 :: 6.25 : x$$
$$4,624\times6.25=28,900\div7,056=4.09$$

*Answer.*—4-run (actual counts 4.1-run) yarn must be used.

*Proof.*—4.1-run=6,560 yards per lb.

Thus: $\sqrt{6,560}=81$    81
—13

68 threads of 4-run (4.1) woolen yarn will lie side by side in one inch, being the same number as given in example.

### B. Dealing with Two or More Materials.

Frequently it happens that we have to reproduce a cloth from a given sample or texture, etc., in another material. For example, a worsted cloth may be required to be duplicated in woolen yarn. If such is the case, transfer counts of yarn given, or as ascertained from sample given, into its equivalent counts of the required grading, and take care of the difference of 6 per cent. between the diameters of threads that will lie side by side in one inch of a woolen yarn compared to worsted yarn. In a similar manner proceed if dealing with other yarns.

*P. S.*—The allowance for worsted yarn in all the samples given is based (as also previously mentioned) on 10 per cent.; for cotton yarn and spun silk on 7 per cent.; for raw silk on 4 per cent, and for woolen yarn on 16 per cent. These allowances refer to a perfect and smooth $A^1$ yarn; but if such should not be the case, we are required to make, according to the yarn, a proportional allowance of one, two, or three per cent. more.

## INFLUENCE OF THE (AMOUNT AND DIRECTION) TWIST OF YARNS UPON THE TEXTURE OF A CLOTH.

The influence of the twist of a yarn upon the number of warp threads to use per inch depends upon the amount of the twist, as well as the direction of the latter. It will easily be understood by the student that the more twist we put in a yarn the less space the same will occupy; *i. e.*, the smaller its diameter, and the less chances for a chafing; hence, we can use a "heavier" texture (more ends per inch) with a hard-twisted yarn compared to a soft-twisted yarn. But it must be remembered that the amount of twist to use is again regulated by the character of the fabric the yarn is used for, since the yarn will lose on softness the harder we twist it, and that a hard-twisted yarn will reduce the fulling properties of the cloth during the process of finishing. Again, hard-twisted yarn will not bend as easily around the filling during weaving as a soft yarn, which no doubt might injure the general appearance of the face of the cloth. This will also illustrate another point; *i. e.*, the width of the cloth to use in loom. As previously mentioned, the harder we twist a yarn the less chances there are for fulling; hence, fabrics made with hard-twisted yarn must be set narrower in loom than fabrics made with a softer twisted yarn. Thus we will set a fancy worsted suiting (in an average) only from 60 to 62 inches wide in loom, and a fancy cassimere or fancy woolen suiting (in an average) from 70 to 72 inches wide, and yet the finished width for both will be 54 inches.

To explain the influence of the direction of the twist of the yarn upon the texture of a cloth, Figs. 6 and 7 are given. Fig. 6 illustrates the interlacing with yarns spun with its twist in the same direction; *i. e.*, from left to right (technically known as right hand twist.) Fig. 7 illustrates the interlacing of a similar cloth with right hand twist yarn for the warp, but left hand twist yarn (the direction of the twist being from the right to the left) for the filling. It will readily be seen by the student that if, using in both examples the same counts of yarn for warp and filling, the combination, as shown in Fig. 7, will allow a readier compressing of the filling for forming the cloth, compared to the

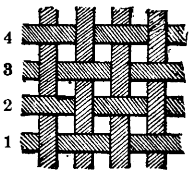


FIG. 6

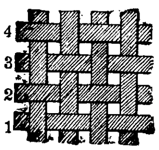


FIG. 7

using of warp and filling, as illustrated in diagram, Fig. 6; *i. e.*, if using the same direction of twist for warp and filling yarn, larger perforations will appear in the cloth than if using opposite twist for both systems, since in the first instance, the twist of both yarns will cross each other, thus resisting compression; whereas, if using opposite twist in the spinning of the two systems of yarns, the twist of both yarns will be in the same direction when interlacing, and thus a falling of the twist in each other be produced.

*Rule.*—We may use a heavier texture for warp and filling, if using opposite twist in the spinning of the yarns, than if using the same direction of twist for both systems.

The finer in quality and the longer in its staple the material is, as used in the manufacture of a yarn, the less twist is necessary to impart to the thread for giving it the requisite strength; whereas, the shorter and coarser the material the more twist we must use. The actual amount of twist to use depends entirely upon the material and counts of yarn, as well as weave and process of finishing required. For a fabric requiring a smooth, clear face, we must use more twist in the yarn than for such as used in the manufacture of cloth requiring a nap; *i. e.*, much giging, or "velvet finish."

## TO FIND THE AMOUNT OF TWIST REQUIRED FOR A YARN, IF THE COUNTS AND TWIST OF A YARN OF THE SAME SYSTEM, (AND FOR THE SAME KIND OF FABRIC) BUT OF DIFFERENT COUNTS ARE KNOWN.

The points as to amount of twist to use for the different counts of yarn manufactured are based between each other upon the fact that the diameters of threads vary in the same ratio as the square roots of their counts.

*Example.*—Find twist required for a 40's yarn, if a 32's yarn of the same material requires 17 turns per inch (twist wanted in proportion the same).

$$32:40::17^2:x, \text{ or } \sqrt{\frac{40\times17\times17}{32}}, \text{ or } \sqrt{361.25}=19.$$

*Answer.*—19 turns per inch are required.

$$\text{or, } \sqrt{32}:\sqrt{40}::17:x \qquad \sqrt{32}=5.65 \qquad \sqrt{40}=6.32.$$

$$\text{Hence: } 5.65:6.32::17:x \qquad 6.32\times17=107.44\div5.65=19.$$

*Answer.*—19 turns per inch are required (being the same answer as previously received.

## INFLUENCE OF THE WEAVE UPON THE TEXTURE OF A FABRIC.

In the previous chapter we have given a clear understanding as to the number of threads of any counts of yarn, and of any kind of material, that will properly lie side by side in one inch. We now take this same item into consideration, but in addition, with reference to the different weaves as used in the manufacture of textile fabrics; *i. e.*, give rules for constructing with a given weave and given count of yarn, a cloth which has a proper texture.

*Rule.*—The less floats of warp and filling (*i. e.*, the greater the number of interlacings between both systems) in a given number of threads of each system, the lower the texture of the cloth (the less number ends and picks per inch) must be; and consequently the less interlacings of warp and filling in a given number of threads of each system, the higher a texture in the cloth we can use. For example, examining the 8-harness twill shown in Fig. 8, we find each thread to interlace twice in one repeat of the weave, thus actually $8+2=10$ threads will lie side by side for each repeat (since by means of the interlacing of the filling with the warp the former takes, at the places of interlacing, the place, with regard to its diameter, of one thread of the latter system). Suppose we used 64 warp threads to one inch, we find the threads that will lie side by side in one inch as follows:

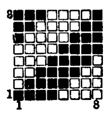


FIG. 8.

| Warp threads in one repeat of the weave. | : | Warp and filling threads in one repeat of the weave. | :: | Warp threads per inch. | : | Threads lying side by side in one inch. |
|---|---|---|---|---|---|---|
| 8 | : | 10 | :: | 64 | : | x |

$$\text{and} \quad \frac{10 \times 64}{8} = 80$$

*Answer.*—8-harness $\frac{4}{4}$ twill, 64 warp threads per inch, equals 80 diameters of threads per inch.

*Example.*—Find the number of diameter of threads per inch, using the same number of warp threads as before (64) per inch, and for weave the plain weave shown in Fig. 9.

The repeat of the latter weave is 2 threads, = 2 interlacings in repeat; thus, with reference to the 64 warp threads per inch used, we find 64 interlacings of the filling.

FIG. 9.

$$\text{Hence: } 2:4::64:x \quad \text{and} \quad \frac{4 \times 64}{2} = 128$$

*Answer.*—Plain weave, 64 warp threads per inch, equals 128 diameters of threads per inch.

No doubt these two examples will readily demonstrate to the designer the value of examining the number of interlacings of any new weave. If, in given examples, the first mentioned "make up" $\frac{4}{4}$ 8-harness twill, 64 warp threads per inch, using the required material and counts of yarn is producing a perfect fabric, and we want to change to plain weaving, using the same yarn, we must deduct $\frac{3}{8}$ of the number of warp threads (and correspondingly also of the filling) to produce the same number of diameters of threads side by side as in previously given example; *i. e.*, we must only use 40 warp threads per inch, since those 40 diameters of the warp yarn, plus 40 diameters of the filling, by means of the principle of the interlacing of the plain weave, produce the (equal number as before) 80 diameters of threads side by side in one inch. Hence we may put down for—

*Rule.*—The weave of a cloth has an equal influence on the number of ends per inch to use as the counts of the yarn we are using. We mentioned previously that by the diameters of threads per one inch we mean the number of ends that could lie side by side per inch, providing there were no interlacings of both systems of threads; but since such interlacing or intertwining of the warp and filling must take place in order to produce cloth, we must deduct the number, or average number, of interlacings per inch from the originally obtained diameters of threads that will lie side by side per inch, to obtain the correct number of warp ends and picks we can use per inch. Thus far given explanations will readily assist the student to ascertain the number of threads of any material that will lie side by side (without riding) in one inch of the fabric (single cloth). Hence:

## TO FIND THE TEXTURE OF A CLOTH USE—

*Rule.*—Multiply the number of threads of a given count of yarn that will lie side by side in one inch by the threads in one repeat of the pattern, and divide the product by the number of threads in repeat, plus the corresponding number of interlacings of both systems of threads found in one repeat of the weave.

By the number of interlacings of a weave we understand the number of changes from riser to sinkers, and *vice versa*, for each individual thread in each system.

*Examples.*—Fig. 10 represents one pick of the common twill known as $\frac{2}{2}\frac{1}{2}\frac{1}{2}$ and shown in one full repeat in Fig. 11. Diagram Fig. 12 illustrates the corresponding section to pick 1 shown in Fig. 10. The full black spots represent one repeat, whereas the commencement of the second repeat is shown in dotted lines. A careful examination of both diagrams, Figs. 10 and 12, will readily illustrate to the student the number of interlacings in one repeat (6), as indicated by corresponding numbers below diagram Fig. 12. Thus, in order to find the number of warp threads of a given count per inch for a cloth made with this weave, we must multiply the number of diameters of threads that will lie side by side with 10 (being one complete repeat of the weave) and divide the product thus derived by 16 (10 plus 6, or repeat plus number of interlacings). The result will be the required number of warp threads per inch. If given illustrations would refer to a 32-cut woolen yarn, we find answer as follows:

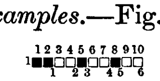


FIG. 10.

FIG. 12.

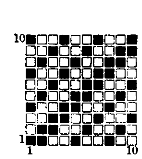


FIG. 11.

32-cut yarn=9,600 yards per lb.

32-cut yarn=82.2 threads will lie side by side.

Thus: 82.2×10=822÷16=51½, or

51 warp threads per inch (or actually 51½ per inch, or 103 threads for every two inches) of 32-cut woolen yarn will be the proper number to use. In diagram Fig. 13 we illustrate a pick of another 10-harness twill weave. Fig. 14 represents the corresponding section, and Fig. 15 one complete repeat of the weave.

FIG. 13

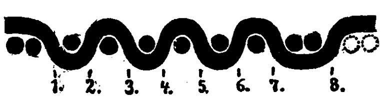


FIG. 14.

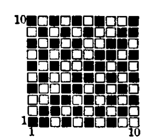


FIG. 15.

All three diagrams show 8 points of interlacings for each thread in one repeat; hence, if applying counts of yarn from previously given example for this case we find:

32-cut yarn=82.2 threads will lie side by side. Thus: 82.2×10=822÷18=45⅔, or 46 warp threads per inch (actually 45⅔) of 32-cut woolen yarn are the proper number of threads if using the $\frac{2}{1}\frac{1}{1}\frac{1}{1}\frac{1}{1}\frac{1}{2}$ 10-harness twill.

*Answers.*—For both given examples are as follows:

Warp yarn used 32-cut woolen yarn.

$\frac{2}{2}\frac{1}{2}\frac{1}{2}$ 10-harness twill=6 interlacings=51½ warp threads per inch.

$\frac{2}{1}\frac{1}{1}\frac{1}{1}\frac{1}{1}\frac{1}{2}$ 10- " " =8 " =45⅔ " " "

A careful examination and recalculation of these two examples will readily illustrate to any student the entire modus operandi.

*Example.*—Find number of threads for warp for a fancy worsted suiting, to be interlaced with the 6-harness $\frac{3}{3}$ twill (see Fig. 16) and made of 2/32's worsted yarn. (Fig. 17 illustrates number 1 pick separated and Fig. 18 its corresponding section.)

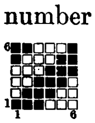


FIG. 16.

FIG. 17.

2/32=1/16=16×560=8,960 yards per lb.

$\sqrt{8,960}$ less 10 per cent.=85 threads of 2/32's worsted yarn will lie side by side in one inch. And

FIG 18.

$$\left\{\begin{matrix}\text{Diameters}\\ \text{per inch.}\end{matrix}\right\} \times \left\{\begin{matrix}\text{Repeat of}\\ \text{weave.}\end{matrix}\right\} \quad \left\{\begin{matrix}\text{Repeat of}\\ \text{weave.}\end{matrix}\right\} + \left\{\begin{matrix}\text{Interlacings}\\ \text{in repeat.}\end{matrix}\right\}$$

$$85 \times 6 = 510 \div 8 \quad (6 + 2) = 64.$$

*Answer.*—64 ends per inch is the proper warp texture for fabric given in example.

*Example.*—Find proper number of threads to use for a woolen dress good, to be interlaced with the 9-harness $\frac{2}{1}\frac{1}{1}\frac{1}{1}\frac{1}{1}$ twill (see Fig. 19), and for which we have to use $6\frac{1}{4}$-run woolen yarn.

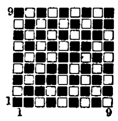


FIG. 19.

FIG. 20.

FIG. 21.

(Fig. 20 represents pick 1 separated, and Fig. 21 its corresponding section.)

6-run=10,000 yards per lb.

$\sqrt{10,000}$, less 16 per cent.=84 threads of $6\frac{1}{4}$-run woolen yarn, will lie side by side in one inch.

$$84 \times 9 = 756 \div 17 (9+8) = 44\tfrac{8}{17}$$

*Answer.*—44 threads per inch (actually $44\frac{8}{17}$) is the proper warp texture for cloth given in example.

*Example.*=Find the proper number of warp threads to use for a cotton dress good, using the plain weave (see Fig. 22), with single 40's cotton yarn for warp.

FIG. 22.

40's cotton=40×840=33,600 yards per lb.

$\sqrt{33,600}$=183—13 (7 per cent.)=170 threads of 40's cotton yarn will lie side by side in one inch.

$$\frac{170 \times 2}{2+2} = 170 \div 2 = 85$$

*Answer.*—85 threads of 40's cotton yarn, and interlaced with the plain, will produce a perfect texture.

It will be proper to mention here another point which must also be more or less taken into consideration. During the process of weaving both systems of threads press more or less against each other, thus each thread is pushed to a certain degree out of position, consequently we may add to each system a slight advance, according to counts, texture and quality of material in question, without influencing the process of weaving or the handling of the fabric; but in all cases such an advance in threads (and picks) will be very small and is readily ascertained after finding, by rules given, number of ends and picks per inch, that could be used if no pressure from one system upon the other was exercised.

If using a soft-twisted yarn for filling, the latter will have less influence for pressing the warp threads (harder-twisted yarn) out of position; *i. e.*, the filling will stretch and thus in proportion reduce the counts of the yarn, consequently a higher texture for such filling may be used. We may thus also mention this fact in the shape of a—

*Rule.*—The softer the filling yarn is twisted, the more readily the same will interweave and the higher a warp texture we can use. Warp yarns are in most all cases harder twisted than the filling yarn as used in the same fabric, for the simple reason that the warp threads are subject to more strain and wear during the process of weaving compared to the filling. The softer a yarn is twisted, the softer the finished cloth will handle; and, if we refer, regarding this soft twist specially to the filling, the easier the same can be introduced in the warp during the process of weaving. This will explain the general method of using a few more picks per inch compared to the warp threads as used per inch in reed. But as everything has a limit we also must be careful not to use too many of these additional picks, for if "piling-in" even a soft filling too hard in a cloth during weaving, it will ultimately result in an imperfect fabric when finished. Frequently we would thus produce fabrics which require too much fulling, or which with all the fulling possible, could not be brought to its required finished width. The same trouble will also refer to the setting of a fabric too wide in reed, for the sake of producing heavier weight of cloth. Again, if setting a cloth too loose, either in warp or filling, or both systems, it will produce a finished fabric handling too soft, flimsy or spongy; consequently great care must be exercised in the "setting of cloth" in order to produce good results, and rules given for foundation weaves (with reference to an average fair and most often used counts of yarn, producing what might be termed staple textures and correspondingly staple fabrics) will form a solid basis to build upon for other fabrics as may be required to be made. Special fabrics, such as Union Cassimeres, Chinchillas, Whitneys, Montagnacs and other pile fabrics, are left out of question.

*Example.*—Fancy Cassimere: Weave $^{2}$——$_{2}$ twill (see Fig. 23). Yarn to use, 22-cut.

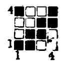


FIG. 23.

*Question.*—Find the proper number of threads for one inch to use.

22-cut=22×300=6,600 yards per lb. And

$\sqrt{6,600}$, less 16 per cent.=68¼ threads of 22-cut woolen yarn will lie side by side in one inch.

$$\frac{68\frac{1}{4}\times 4}{4+2}=68\tfrac{1}{4}\times 4=273\div 6=45\tfrac{1}{2}.$$

*Answer.*—45 threads per inch (actually 91 threads for two inches) are the proper number of threads to use for the cloth given in example. In this weave ($^{2}$——$_{2}$ twill) warp and filling interlace after every two threads. In previously given example (the plain weave) warp and filling interlaced alternately; hence, if comparing the plain weave and the 4-harness even-sided twill we find:

Plain weave=4 points of interlacings in 4 threads.

$^{2}$——$_{2}$ twill=2 points of interlacings in 4 threads.

Previously we also mentioned that the space between the warp threads where the intersection takes place must be (or must be nearly as large) equal to the diameter of the filling yarn (also *vice versa*); thus, if comparing both weaves, using the same yarn for warp and filling in each example, we find in the plain weave:

4 points of interlacings of the filling in
4 warp threads, giving us
—
8 diameters of threads in four threads, or two repeats of the plain weave, and in the 4-harness even-sided twill we only find:

2 points of interlacings of the filling in
4 warp threads, giving us
—
6 diameters of threads in four threads, or one repeat of the $^{2}$——$_{2}$ twill weave.

Again in the plain weave we find:

4 intersections of each warp thread in
4 picks, giving
—
8 diameters of threads in four threads, or two repeats of the plain weave, and in the 4-harness even-sided twill we find:

2 intersections of each warp thread in
4 picks, giving
—
6 diameters of threads in four threads, or one repeat of the $^{2}$——$_{2}$ twill weave.

Hence, the proportion of the texture between a cloth woven with the plain weave and the 4-harness twill will be as 6:8 or 3:4.

Consequently if 60 ends per inch (in each system), woven with the plain weave, produce a well-balanced cloth, and we want to use the same yarn for producing a similar perfect cloth, woven with the $^{2}$——$_{2}$ twill, we find the number of threads required readily by the following proportion:

| Ratio of the plain weave compared to the 4-harness twill. | | :: | Texture used with the plain weave. | : | Texture to be used with the 4-harness twill. |
|---|---|---|---|---|---|
| 3 : | 4 | :: | 60 | : | x |

$$\frac{4\times 60}{3}=4\times 20=80$$ threads must be used in proportion with the 4-harness even-sided twill to produce a well-balanced cloth structure.

This example will also explain that the less points of intersections we find in a given number of threads interlaced with one weave, compared to the same number of threads interlaced with another weave, the higher a texture we must employ, producing at the same time a proportional heavier cloth.

## TO CHANGE THE TEXTURE FOR GIVEN COUNTS OF YARN FROM ONE WEAVE TO ANOTHER.

*Rule.*—The repeat of the given weave multiplied by repeat plus points of intersections of the required weave is to repeat of the required weave, multiplied by the repeat, plus points of intersections of the given weave, the same as the ends per inch of the given cloth are to the ends per inch for the required cloth. Thus we will find answer to previously given example by this rule, as follows·

$$(2\times(4+2):(4\times(2+2)) :: 60: x \text{ and}$$
$$(2\times12) : (4\times4) :: 60: x \text{ and}$$
$$12 : 16 :: 60: x\text{; hence,}$$

$\frac{16\times60}{12}=16\times5=80$ threads must be used, being the same answer as previously received.

*Example.*—Fancy Worsted Suiting. Weave $\frac{3\quad}{\quad3}$ 6-harness twill (see Fig. 24). Warp and filling 2/32's worsted. Texture, 64×64. Question: Find texture required for producing a well balanced cloth using the same counts of yarn with the $\frac{3\quad1\quad}{\quad2\quad3}$ 9-harness twill (see Fig. 25) for weave.

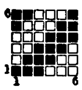


FIG. 24.

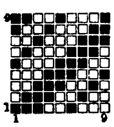


FIG. 25.

$$(6\times(9+4)):(9\times(6+2)) :: 64: x$$
$$(6\times13) : (9\times8) :: 64: x$$
$$78 : 72 :: 64: x$$
$$\frac{72\times64}{78}=\frac{12\times64}{13} \qquad 12\times64=768\div13=59\tfrac{1}{13}$$

*Answer.*—The number of ends to be used with 2/32's worsted, and the $\frac{3\quad2\quad}{\quad2\quad1}$ twill are 59 ends per inch.

## TO CHANGE THE WEIGHT OF A FABRIC WITHOUT INFLUENCING ITS GENERAL APPEARANCE.

Previously we mentioned "the less points of interlacings we find in a given number of threads the higher a texture (more threads per inch) we can use in the construction of a cloth." This will also apply to the use of a heavier count of yarn, or both items (higher texture and heavier yarn) at the same time. In the construction of a new fabric we are frequently required to produce a fabric of a given weight per yard; hence, after we find by rules given that the yarn we intend to use will, with its corresponding texture and weave, produce a cloth either too heavy or too light, we must carefully consider how to remedy this. In some instances the difference could be balanced by either laying the cloth wider or narrower in the reed, or shorter or longer at the dressing, and regulate the weight during the finishing process; *i. e.*, full the flannel to the required weight. By some fabrics (of an inferior grade) we might also regulate the weight to some extent during the fulling process (by adding more or less flocks, the latter of which will felt during the fulling to the back, and partly between both systems of threads the fabric is composed of. But in most fabrics a too heavy or too little fulling or additional flocking (according to the class of cloth) would reduce or destroy the beauty of its face, and thus decrease its value; hence we must regulate texture, weave, and counts of yarn to be used, to a certain extent, to suit the weight per yard of the finished fabric required. Most always the heavier a weight is wanted, the heavier a yarn we must use, and in turn suit texture to the latter. Again, the lighter in weight a cloth is required, the finer counts of yarn we must use, also with a proportional regulation of the texture. If the weight per yard in a given fabric is required to be changed (either increased or reduced) without altering the weave, or the width in reed, or length dressed (*i. e.*, want the new cloth to be fulled about the same amount as the given), we must alter the counts of the yarn in the process of spinning, producing a heavier yarn if a heavier cloth is wanted, and a lighter yarn if a lighter cloth is wanted.

*Rule.*—The ratio between the required weight per yard squared and the given weight per yard squared, is in the same ratio as the counts of yarn in the given cloth are to the counts of yarn required for use in the new cloth.

*Example.*—Suppose we are making the following cloth:

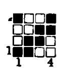


FIG. 26.
Weave $\frac{2}{\quad}{}_2$ twill.

Fancy Cassimere: 3,240 ends in warp. 10 per cent. take-up during weaving. Weave given in Fig. 26. 72 inches width in loom. Warp and filling, 22-cut woolen yarn. Weight of flannel from loom, 17.2 oz.

*Question.*—Find the proper counts of yarn to use if given weight, 17.2 oz., is to be changed to 19.1 oz.; *i. e.*, a flannel of 19.1 oz. is required (from loom).

*Memo.*—In this, as well as the following example, no reference to any selvage is taken.

| Required weight squared. | : | Given weight squared. | :: | Counts of yarn in given cloth. | : | Required counts for the new cloth. |
|---|---|---|---|---|---|---|
| $19.1^2$ | : | $17.2^2$ | :: | 22 | : | x |
| (19.1×19.1) | : | (17.2×17.2) | :: | 22 | : | x |
| 364.81 | : | 295.84 | :: | 22 | : | x |

$$\frac{295.84 \times 22}{364.81} = 17.9$$

*Answer.*—18-cut yarn is required.

*Example.*—Prove previously given example for each texture; *a*, as to weight, and *b*, as to the proper construction according to rules given.

## I. Given Cloth.

### *a. Ascertain given weight* (17.2 *oz.*).

Fancy Cassimere: 3,240 ends in warp. 10 per cent. take-up during weaving. Weave, $\frac{2}{\quad}{}_2$ 4-harness twill. 72 inches width in loom. 48 picks per inch. Warp and filling, 22-cut woolen yarn. 3,240 ends in warp. 10 per cent. take-up. How many yards dressed?

100 : 90=x : 3,240 and 324,000÷90=3,600 yards of warp required dressed per yard of cloth woven.

22-cut=300×22=6,600 yards per lb.÷16=412½ yards per oz.; hence—

3,600÷412.5=8.8 oz. weight of warp.

72×48=3,456 yards of filling required per yard.

3,456÷412.5=8.4 oz., weight of filling.

Warp, 8.8 oz.
Filling, 8.4 oz.

*Answer.*— 17.2 oz., total weight per yard from loom.

### *b. Proof of Proper Structure of Given Cloth.*

22-cut =6,600 yards per lb. and $\sqrt{6,600}$, less 16 per cent. =68¼ threads of 22-cut yarn will lie side by side in one inch.

$\frac{2}{\quad}{}_2$ twill =2 points of interlacings in one repeat of the weave.

Thus: $\frac{68\frac{1}{4} \times 4}{4+2}$=68¼×4=273÷6=45½, or practically—

*Answer.*—45 warp threads per inch should be used, and this is the number of ends used, since.—

| (Threads in full warp.) | ÷ | (Width of cloth.) | = | (Ends per inch.) |
|---|---|---|---|---|
| 3,240 | ÷ | 72 | = | 45 |

### 2. Required Cloth.

*b. Find Proper Texture for Warp.*

18-cut woolen yarn to be used $=18\times300=5{,}400$ yards per lb., $\sqrt{5{,}400}=73.49$, less 16 per cent. $(11.74)=61\frac{3}{4}$ threads of 18-cut woolen yarn will lie side by side in one inch.

4-harness twill contains 2 points of intersections in one repeat.

$$\frac{61\frac{3}{4}\times4}{4+2}=247\div6=41\tfrac{1}{6},\text{ or practically—}$$

*Answer.*—41 threads per inch must be used.

*a. Ascertain Weight for Required Cloth.*

Using the same width in reed as in the given cloth (72 inches).

$41\times72=2{,}952$ ends must be used (10 per cent. take-up).

$100:90::x:2{,}952$ and $295{,}200\div90=3{,}280$ yards warp required for one yard cloth from loom.

18-cut yarn $=5{,}400$ yards per lb. $\div16=337\frac{1}{2}$ yards, per oz.

$3{,}280\div337.5=9.7$ oz. warp yarn required.

$44\times72=3{,}168$ yards filling required, and $3{,}168\div337.5=9.4$ oz., filling required.

Warp, 9.7 oz.
Filling, 9.4 oz.

*Answer.*—19.1 oz., total weight per yard from loom, being exactly the weight wanted.

*Memo.*—In calculating weight for both fabrics we used three additional picks compared to the warp threads, which is done to illustrate practically the softer twist of the filling compared to the warp yarn (and which item has already previously been referred to). In the calculations we only used approximately the decimal fraction of tenth, since example refers only to illustrate the procedure. In examples we exclude any reference to selvage.

*Example.*—The following cloth we are making: Worsted Suiting. 3,840 ends in warp, 8 per cent. take-up, 60 inches width in loom, warp and filling 2/32's worsted, weight of flannel from loom, 14.6 oz. For weave, see Fig. 27. (No reference taken of selvage.)

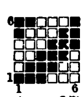


FIG. 27. Weave $\frac{3}{\ }\frac{\ }{3}$ 6-harness twill.

*Question.*—Find the proper yarn to use if given weight, 14.6 oz., must be changed to 16.3 oz. (from loom); *i. e.*, a flannel of 16.3 oz. is wanted (exclusive of selvage).

$$16.3^2 : 14.6^2 :: 16 : x$$
$$(16.3\times16.3):(14.6\times14.6)::16:x$$
$$265.69 : 213.16 :: 16 : x$$
$$213.16\times16=3{,}410.56\div265.69=12.9$$

*Answer.*—1/13's or 2/26's worsted yarn is required.

*Example.*—Prove previously given example for each structure; *a*, as to weight; *b*, as to the proper construction according to rules given.

### 1. Given Cloth.

*a. Ascertain Given Weight* (14.6 *oz.*).

Warp.—3,840 ends, 2/32's worsted, 8 per cent. take-up, weave $\frac{3}{\ }\frac{\ }{3}$ 6-harness twill. 60 inches width of cloth on reed.

Filling.—66 picks per inch, 2/32's worsted.

3,840 ends in warp, 8 per cent. take-up, how many yards dressed?

100:92 :: x :3,840   384,000÷92=4,173$\frac{84}{92}$ yards (practically 4,174) of warp required dressed per yard of cloth woven.

2/32's worsted=16×560=8,960 yards per lb.÷16=560 yards per oz.

Hence: 4,174÷560=7.5 oz., weight of warp.

66×60=3,960 yards of filling required per yard.   3,960÷560=7.1 oz., weight of filling.

Warp, 7.5 oz.
Filling, 7.1 "

*Answer.*—14.6 oz., total weight per yard from loom.

*b. Proof for Proper Structure of Given Cloth.*

2/32's worsted =8,960 yards per lb., and $\sqrt{8,960}$—10 per cent. =85 threads of 2/32's worsted will lie side by side in one inch.

$\frac{3}{3}$ twill=2 points of interlacings in one repeat of the weave. Thus: $\frac{85\times6}{6+2}$=510÷8=64.

*Answer.*—64 threads per inch must be used, and since 3,840÷60=64, this is the number of ends used per inch in given cloth, the structure of the given cloth is perfectly balanced.

### 2. Required Cloth.

*b. Find the Proper Texture for Warp.*

2/26's worsted =13×560=7,280 yards per lb.

$\sqrt{7,280}$=85.3 less 10 per cent. (8.5)=76.8 diameters of threads of 2/26's worsted will lie side by side in one inch.

$\frac{3}{3}$ twill=2 points of interlacings in one repeat. Thus: $\frac{76.8\times6}{6+2}$=460.8÷8=57.6, or practically—

*Answer.*—58 threads per inch must be used.

*a. Ascertain Weight for Required Cloth.*

Using the same width in reed as in the given cloth (60 inches).

58×60=3,480 ends must be used (8 per cent. take-up).

100:92 :: x:3,480. 348,000÷92=3,782 yards required for one yard cloth from loom.

2/26's worsted=7,280 yards per lb.÷16=455 yards per oz.; thus: 3,782÷455=8.3 oz. warp yarn required.

Using 61 picks we find—

61×60=3,660 yards filling (2/32's worsted) wanted. 3,660÷455=8 oz., weight of filling yarn wanted.

Warp, 8.3 oz.
Filling, 8.0 oz.

*Answer.*—16.3 oz., total weight of cloth (exclusive of selvage) from loom, being exactly the weight wanted.

### To Find the Number of Ends per Inch in the Required Cloth.

The two examples previously given will also assist us to illustrate the next rule; *i. e.*, "Finding number of ends per inch in the required cloth."

*Rule.*—The weight per yard of the required cloth is to the weight per yard of the given cloth in the corresponding ratio of the warp ends per inch in the given cloth to the warp ends per inch in the required cloth.

*Example.*—Prove rule by previously given example of a fancy cassimere.

**Given Cloth.**—Weight per yard=17.2 oz. Ends per inch=45½ (for 45).

**Required Cloth.**—Weight wanted, 19.1 oz. Find ends per inch required, or x.

$19.1:17.2::45.5:x.\quad \frac{17.2\times45.5}{19.1}=17.2\times45.5=782.\quad 60\div19.1=40\frac{181}{191}$, or practically—

*Answer.*—41 warp threads must be used, and this is exactly the answer previously derived in the same example (see page 72).

*Example.*—Prove rule by previously given example of a worsted suiting.

**Given structure.**—Weight per yard, 14.6 oz. Ends per inch, 64.

**Required structure.**—Weight wanted, 16.3 oz. Find ends per inch required, or x.

$16.3:14.6::64:x\quad \frac{14.6\times64}{16.3}=14.6\times64=9{,}344\div16.3=57\frac{53}{163}$ (See answer on page 73, being 57.6.)

*Answer.*—58 warp threads (practically) per inch must be used; this being the same number as derived previously in the same example. (See page 73.)

## WEAVES WHICH WILL WORK WITH THE SAME TEXTURE AS THE $\frac{2}{\;\;2}$ 4-HARNESS TWILL.

The following few weaves (given for examples) have the same number of interlacings as the 4-harness even-sided twill:

*Memo.*—Weaves indicated by *u.* are uneven-sided twills. Weaves indicated by *e.* are even-sided twills.

$\frac{3}{\;\;1}$ u. 4-harness twills.

8-harness twills:

$\frac{5\;\;1}{\;\;1\;\;1}$ u.
$\frac{4\;\;1}{\;\;1\;\;2}$ u.
$\frac{3\;\;1}{\;\;1\;\;3}$ e.
$\frac{4\;\;2}{\;\;1\;\;1}$ u.
$\frac{3\;\;1}{\;\;2\;\;2}$ u.
$\frac{3\;\;2}{\;\;2\;\;1}$ u.

12-harness twills:

$\frac{7\;\;1\;\;1}{\;\;1\;\;1\;\;1}$ u.
$\frac{6\;\;1\;\;1}{\;\;1\;\;1\;\;2}$ u.
$\frac{5\;\;1\;\;1}{\;\;1\;\;1\;\;3}$ u.
$\frac{4\;\;1\;\;1}{\;\;1\;\;1\;\;4}$ e.
$\frac{6\;\;2\;\;1}{\;\;1\;\;1\;\;1}$ u.
$\frac{5\;\;3\;\;1}{\;\;1\;\;1\;\;1}$ u.
$\frac{4\;\;4\;\;1}{\;\;1\;\;1\;\;1}$ u.
$\frac{5\;\;2\;\;1}{\;\;2\;\;1\;\;1}$ u.
$\frac{4\;\;2\;\;1}{\;\;2\;\;1\;\;2}$ u.
$\frac{4\;\;3\;\;1}{\;\;2\;\;1\;\;1}$ u.
$\frac{3\;\;3\;\;1}{\;\;3\;\;1\;\;1}$ u.
$\frac{4\;\;2\;\;1}{\;\;3\;\;1\;\;1}$ u.
$\frac{3\;\;2\;\;1}{\;\;2\;\;2\;\;2}$ u.
$\frac{3\;\;3\;\;2}{\;\;1\;\;1\;\;2}$ u.
$\frac{2\;\;2\;\;5}{\;\;1\;\;1\;\;1}$ u.
$\frac{2\;\;2\;\;4}{\;\;1\;\;1\;\;2}$ u.
$\frac{2\;\;2\;\;3}{\;\;1\;\;1\;\;3}$ u.
$\frac{2\;\;2\;\;3}{\;\;2\;\;2\;\;1}$ u.
$\frac{2\;\;2\;\;1}{\;\;3\;\;3\;\;1}$ u.
$\frac{2\;\;2\;\;1}{\;\;5\;\;1\;\;1}$ u.

Proceeding in this manner, the student can readily find the different (common) twills which will work on the same basis of texture as the 4-harness even-sided twill.

Amongst "derivative weaves," working on the same basis of texture as the $\frac{2}{\;\;2}$ twill, we find—

$\frac{3}{\;\;1}$ 4-harness broken twill and the following weaves given in my "*Technology of Textile Design*," Figs. 398, 409, 411, 412, 416, 417, 420, 421, 445, 448, 449, 470 (476 ◘=□), 479, 482, 492, 497, 499, etc., etc.

## WEAVES WHICH WILL WORK WITH THE SAME TEXTURE AS THE $\frac{3}{\;\;3}$ TWILL, $\frac{4}{\;\;4}$ TWILL, Etc.

In the same manner as we previously found some of the different weaves to work on an equal basis with the $\frac{2}{\;\;2}$ twill, it will be advisable for the student to use different other "standard foundation weaves" on the same basis. For example: the $\frac{3}{\;\;3}$ twill, the $\frac{4}{\;\;4}$ twill, etc.

## SELECTION OF THE PROPER TEXTURE FOR FABRICS INTERLACED WITH SATIN WEAVES.

As mentioned in my "*Technology of Textile Design*," fabrics made with satin weaves or "Satins" are characterized by a smooth face. The principles for the construction of satins are to arrange as much as possible distributed stitching, for the more scattered we arrange the interlacing of warp and filling the less these points of intersection will be visible in the fabric. Thus, the method of construction of this third class of foundation weaves is quite different from the other two classes (the plain and twill weaves); hence, the setting of the warp for fabrics interlaced with satins requires a careful studying and possibly a slight modification towards one, two, or three threads more per inch; but such an increase is regulated by the material. If we have an extra good and very smooth yarn we may do this, but if dealing with a rough or poorly carded yarn we must use ends per inch as found by rule.

As previously mentioned, in cloth interlaced with satin weaves we want a smooth face; hence, the warp yarn must cover the filling. Thus, as always one or the other of the threads in the repeat of the weave is withdrawn on every pick the remaining warp threads must cover this spot where the one warp thread works on the back of the cloth and the filling tries to take its place on its face; and, as according to rules given, the interlacing of the filling is dealt with similar to warp threads, the remaining warp threads in this instance would have to be spread so as to cover the filling, which, no doubt, is more readily accomplished by using a heavier texture of the warp; *i. e.*, putting two or three more threads per inch than actually will lie properly side by side, less the customary deduction on account of the nap of the yarn. If we resort to this plan, it will be readily understood by the student that this will produce a closer working of the threads than they properly should; hence, chafing or riding of threads (to a slight extent) will be the result. If, as previously mentioned, we are dealing with an extra good and smooth yarn and the warp yarn is properly sized and dressed, we may make use of those few ends, but otherwise in most every common fabric, threads as found by rule to lie side by side in one inch will do, since the nature of the weave (hence, cloth with it produced) will by itself hide the filling to a great extent by means of the warp being nearly all on the face, the filling forming the back and the one end warp as coming in the lower shed, having little power to pull the filling up, which for the main part forms the back of the structure.

*Example.*—Find threads of warp to use for weaving a "Kersey," with the 7-leaf satin (see Fig. 28), using 6-run woolen yarn. Width of cloth in reed (setting) to be 84 inches (exclusive selvage). 6-run woolen yarn $=84$ ends per inch, side by side. $84\times7=588\div9=65\frac{1}{3}$, or say 66 threads per inch. $66\times84=5{,}544$.

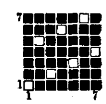


FIG. 28.

*Answer.*—5,544 threads texture for warp to use, but which may be increased to 5,700 ends if dealing with a good smooth yarn. 5,700 ends in warp equals nearly 68 threads per inch. $(68\times84=5{,}712)$ which is about 2 threads per inch in excess of proper number ascertained by the regular procedure.

## SELECTION OF THE PROPER TEXTURE FOR FABRICS INTERLACED WITH RIB WEAVES.

As mentioned in my "*Technology of Textile Design*," fabrics interlaced with rib weaves require, for either one system of threads (warp or filling), a high texture.

Rib weaves classified as "warp effects," must have a high texture for warp, and

Rib weaves classified as "filling effects," must have a high texture for filling.

### Warp Effects.

In the manufacture of fabrics interlaced with warp effect rib weaves, the warp forms the face and back of the fabric, whereas the filling rests imbedded, not visible on either side. This being the case there is no necessity for calculating (in the setting of the warp) for a space for the filling to interlace; thus, the texture is ascertained by the number of threads that will lie side by side per inch.

*Example.*—Find the warp texture for a fabric interlaced with the rib weave (warp effect) as shown in Fig. 29, using for warp 6-run woolen yarn.

6-run=9,600 yards per lb., and $\sqrt{9,600}$, less 16 per cent.=82.3.

*Answer.*—82 warp threads per inch must be used.

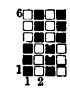


FIG. 29.

*Example.*—Find texture for a fabric interlaced with the rib weave, shown in Fig. 30, using for warp 2/40's worsted yarn.

2/40's worsted=11,200 yards per lb., and $\sqrt{11,200}$, less 10 per cent.=95.

*Answer.*—95 warp threads per inch must be used.

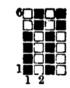


FIG. 30.

### Filling Effects.

As previously mentioned, for filling effects we require a high number of picks, since the latter system has to form face and back of the cloth, and the warp the interior. In most instances the filling yarn as used for these fabrics is softer spun than the warp, for allowing a freer introducing of the former; thus, we may use even a few more picks per inch compared to the texture previously found for rib weaves warp effects.

### Figured Rib Weaves.

If dealing with figured rib weaves, their texture for warp and filling is found by ascertaining the number of threads for both systems that will lie side by side in one inch.

*Example.*—Find texture for a cloth to be interlaced with the figured rib weave, shown in Fig. 31, using for warp and filling 2/36's worsted yarn.

2/36's=10,080 yards per lb., and $\sqrt{10,080}$, less 10 per cent.=90.

*Answer.*—90 warp threads and 90 picks per inch must be used.

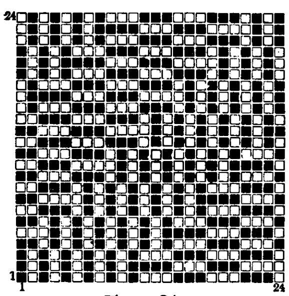


FIG. 31.

## SELECTION OF THE PROPER TEXTURE FOR FABRICS INTERLACED WITH CORKSCREW-WEAVES.

On page 68 of my "*Technology of Textile Design*" I mentioned, amongst other points, referring to the method of construction of corkscrew weaves, "this sub-division of the regular 45° twills is derived from the latter weaves by means of double draws, which will reduce the texture of the warp for the face in the fabric; hence, a greater number of those threads per inch (compared to fabrics interlaced with the foundation weaves) are required."

A careful examination of the different corkscrew weaves (see Figs. 345 to 383 in "*Technology of Textile Design*,") with regard to their setting in loom, will readily illustrate their near relation to the warp effect rib weaves as explained in the previous chapter. In both systems of weaves (speaking in a general way) the warp forms the face and back of the cloth and the filling rests imbedded between the former; the only difference between both being that the break-line, as formed by the exchanging of the warp threads from face to back, is in the rib-cloth in a horizontal direction compared to the running of the warp threads, whereas in the corkscrews this break-line is produced in a oblique direction. But as this is of no consequence regarding structure (in fact only in preference of the forming of a better shed with the corkscrew weave, since not all the threads break—exchange positions—at the same time) we may readily use the setting of the number of warp threads per inch in corkscrews the same as done in rib weaves warp effects; *i. e.*, use the number of warp threads that will lie side by side in one inch for the texture of warp and again increase this texture one, two, three, or four ends, if dealing with an extra good yarn.

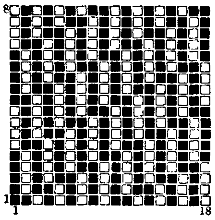


FIG. 32.

*Example.*—Find warp texture required for a fabric made with weave Fig. 32. Yarn to be used is 2/40's worsted. 2/40's worsted =11,200 yards per lb., and $\sqrt{11,200}$, less 10 per cent. =95.

*Answer.*—95 warp threads per inch must be used, and in case of extra good yarn we may increase this warp texture to 98 ends per inch.

*Example.*—Find number of threads in warp if fabric in previously given example is made 61 inches wide in loom. $95 \times 61 = 5,795$.

*Answer.*—5,800 threads in warp must be used to produce a perfect cloth; *i. e.*, perfect fabric, and 5,950 to 5,980 ends can be used with an extra good yarn ($98 \times 61 = 5,978$).

*Example.*—Find *a*, texture of warp per inch; *b*, threads in warp to use if 61 inches wide in loom, for fabric interlaced with fancy corkscrew weave Fig. 33, using 2/60's worsted for warp.

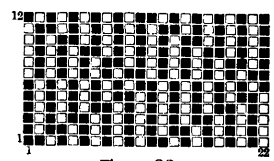


FIG 33

2/60's worsted=16,800 yards per lb., and $\sqrt{16,800}$, less 10 per cent.=117.

*Answer.*—*a*, 117 warp threads per inch must be used; and $117 \times 61 = 7,137$; thus *b*, 7,140 threads must be used in full warp.

*Memo.*—In such fine yarn, and correspondingly high texture, it will be hardly necessary to use those two to four additional threads as made use of if dealing with a lower count of yarn.

## SELECTION OF THE PROPER TEXTURE FOR FABRICS BACKED WITH FILLING; i. e., CONSTRUCTED WITH TWO SYSTEMS OF FILLING AND ONE SYSTEM OF WARP.

A thorough explanation of the construction of weaves for these fabrics has been given in my "*Technology of Textile Design*," on pages 105, 106, 107 and 108. Thus, we will now consider these points with reference to the setting of cloth in the loom, since, no doubt, the additional back filling will have more or less influence upon the setting of the face cloth. Weave Fig. 34 (corresponding to weave Fig. 558 and section Fig. 557 in Technology) illustrates the common 4-harness twill $\frac{2}{2}$ for the face structure, backed with the 8-leaf satin.

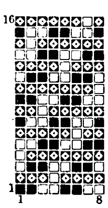


FIG. 34.

In this weave, as well as any similar combinations, the texture of the face warp can remain nearly the same as if dealing with single cloth, a deduction of 5 per cent. from the number ends per inch found for the single cloth is all that is required to be deducted for the same cloth made with a backing.

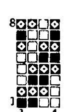


FIG. 35.

If we exchange the 8-leaf satin, as used for backing, with a twill, $\frac{3}{1}$ as shown in weave Fig. 35, we must deduct 10 per cent. from the warp texture, as found for the face of the cloth, to produce the proper chances for weaving. If we back the 4-harness $\frac{2}{2}$ twill with the arrangement of 2 picks face to alternate with 1 pick back, and use for the interlacing of the latter filling (and warp) the $\frac{3}{1}$ 4-harness twill, (using every alternate warp thread only for interlacing) see weave Fig. 36, no deduction of the warp texture compared to single cloth is required; or, in other words, if using a weave 2 picks face to alternate with 1 pick back, and in which the backing is floating from $\frac{7}{1}$ to $\frac{15}{1}$ (or a similar average), no reference must be taken of the back filling in calculating the setting of the warp; or, in other words, the fabric is simply to be treated as pure single cloth. The most frequently used proportions of backing to face are: 1 pick face to alternate with 1 pick back, and 2 picks face to alternate with 1 pick back. Seldom we find other arrangements, as 3 picks face to alternate with 1 pick back; or irregular combinations, as 2 picks face 1 pick back, 1 pick face 1 pick back,=5 picks

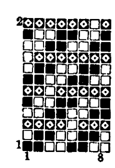


FIG. 36.

in repeat, etc. If using the arrangement "1 pick face to alternate with 1 pick back," be careful to use a backing yarn not heavier in its counts than the face filling; for a backing heavier in its counts than the face filling will influence the closeness of the latter, and in turn produce an "open face" appearance in the fabric.

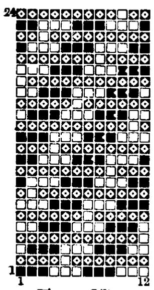


FIG. 37.

Weave Fig. 37 shows the $^{3}$——$_{3}$ 6-harness twill for the face structure, backed with the 12-leaf satin. Arrangement: 1 pick face to alternate with 1 pick back. It will readily be seen by the student that this combination of weaves (also any similar ones) will be very easy on the warp threads; thus, the setting of the latter per inch in the reed is (about) designated by the counts of yarn used with reference to the single cloth weave ($^{3}$——$_{3}$ twill), being the same as if dealing with no backing, for the most allowance we would have to make for fabrics interlaced with this weave would be a deduction of 2 to $2\frac{1}{2}$ per cent. from the single cloth warp texture.

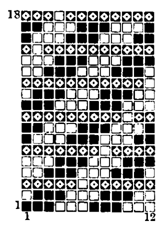


FIG. 38.

Weave Fig. 38 shows the same face weave ($^{3}$——$_{3}$ twill), arranged with 2 picks face to alternate with 1 pick back. There will be no difference experienced in the number of threads (warp) to use per inch between this weave and the single face weave (*i. e.*, the face weave if treated as single cloth); hence, the setting of the warp for both will be the same.

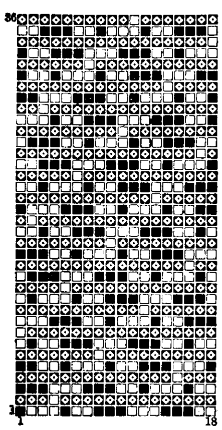


FIG. 39.

*Example.*—Find the proper number of warp threads to use for a worsted suiting, to be interlaced with the granite weave shown in Fig. 39. For warp yarn use 2/50's worsted.

2/50's worsted=14,000 yards per lb. and $\sqrt{14,000}$ less 10 per cent.=106.5

Points of interlacing in face weave=8

Warp threads in repeat of weave=18

106.5×18=19,170÷26 (8+18)=73.7

— 3.7 (5 per cent.)

70.0

*Answer.*—70 warp threads per inch of 2/50's worsted are required.

*Example.*—Ascertain for the previously given fabric the proper filling texture, if using the same counts of yarn as used for warp, and find weight of cloth per yard from loom (exclusive of selvage).

Required { Face filling, 74 picks per inch (2/50's worsted).
Backing, 74 " " " (single 24's worsted).

Width in loom, 60 inches (exclusive of selvage). Take-up of warp during weaving, 12 per cent.

70×60=4,200 warp threads in cloth. 100:88 :: x :4,200.

4,200×100=420,000÷88=4,772 yards of warp are wanted dressed for 1 yard cloth from loom.

14,000 yards per lb. in 2/50's worsted=875 yards per oz.

4,772÷875=5.45 oz., weight of warp,
74 × 60=4,440 yards face filling wanted,
4,440÷875=5.07 oz., face filling,
24's worsted=13,440 yards per lb.=840 yards per oz.
4,440÷840=5.28 oz., weight of backing.

| | |
|---|---|
| Warp, | 5.45 oz. |
| Face filling, | 5.07 " |
| Backing, | 5.28 " |
| | 15.80 oz. |

*Answer.*—Weight of cloth per yard from loom (exclusive of selvage) is 15.8 oz.

*Example.*—Find the proper texture for warp and filling, and also ascertain the weight of flannel per yard from loom (exclusive of selvage). Cloaking: Warp 5-run, filling 5-run, backing $2\frac{1}{2}$-run. Weave, see Fig. 40 (8 warp threads and 12 picks in repeat). Take-up of warp, 10 per cent. Width of cloth in reed, 72 inches (exclusive of selvage).

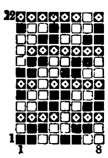


FIG. 40.

5-run=8,000 yards per lb.

$\sqrt{8,000}$, less 16 per cent.=75 ends of 5-run yarn will lie side by side in one inch.

75× 4= 300÷6=50 ends of warp must be used per inch, and

50×72=3,600 ends must be used in full warp.

100:90 :: x :3,600

3,600×100=360,000÷90=4,000 yards of warp yarn are required per yard cloth woven.

5-run yarn=500 yards per oz. 4,000÷500=8 oz. of warp yarn are wanted.

52 picks (50+2 extra) of face filling,
26 picks (corresponding to face picks) of back filling, } are wanted per inch

52×72=3,744 yards of face filling are wanted.

3,744÷500=7.5 oz., weight of face filling.

26×72=1,872 yards of backing are required.

1,872÷250 (yards of $2\frac{1}{2}$-run filling per oz.)=7.5 oz., weight of backing.

| | |
|---|---|
| Warp, | 8.00 oz. |
| Face filling, | 7.50 " |
| Backing, | 7.50 " |
| | 23.00 oz. |

*Answer.*—Total weight of cloth per yard from loom (exclusive of selvage), 23 oz.

## SELECTION OF THE PROPER TEXTURE FOR FABRICS BACKED WITH WARP; i. e., CONSTRUCTED WITH TWO SYSTEMS OF WARP AND ONE SYSTEM OF FILLING.

To ascertain the texture of the warp in these fabrics we must first consider the counts of the yarn as used for the face structure, and secondly the weave.

After ascertaining this texture (for the single cloth) we must consider the weave for the back warp; *i. e.*, the stitching of the same to the face cloth. If dealing with a weave of short repeat for the back warp (for example a $\frac{1}{3}$ twill) we must allow a correspondingly heavy deduction from the threads as ascertained for the face cloth (about 20 per cent. for the $\frac{1}{3}$ twill); whereas, if dealing with a far-floating weave for the back (for example the 8-leaf satin) we will have to deduct less (about 10 per cent. for the 8-leaf satin) from the previously ascertained texture of the face cloth. Since the 8-leaf satin is about the most far-floating weave, as used for the backing, thus, 10 per cent. will be about the lowest deduction, and as the $\frac{1}{3}$ twill is the most frequently interlacing weave, in use in the manufacture of these fabrics, thus, 20 per cent. deduction from the respectively found texture of the face cloth is the maximum deduction. To illustrate the subject more clearly to the student we will give both weaves as previously referred to with a practical example.

*Example.*—Find warp texture for the following fabric: Fancy worsted trousering.

Weave, see Fig. 41. Face warp, 2/36's worsted. Back warp, single 20's worsted.

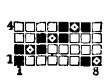


FIG. 41.

2/36's worsted =90 threads (side by side per inch).

Face weave $\frac{2}{2}$ twill =4 threads in repeat and 2 points of interlacing.

90×4=360÷6=60 threads, proper warp texture for the single structure.

60
—12 (20 per cent. deduction caused by the back warp ($\frac{1}{3}$) stitching in the face structure).
—
48

Face warp per inch, 48 threads 2/36's worsted.
Back warp " 48 " single 20's worsted.

96

*Answer.*—96 warp threads must be used per inch.

Picks per inch must be 52 (4 extra over the texture of the face warp). Use 2/36's filling and find weight of cloth per yard from loom (exclusive of selvage), allowing 10 per cent. take-up for face warp, and 12 per cent. for back warp, using 62 inches as the width of cloth in loom.

$48 \times 62 = 2,976$ ends of face warp, and
2,976 " " back warp.

5,952, total number of ends in the entire warp.

100 : 90 :: x : 2,976  $297,600 \div 90 = 3,306\frac{2}{3}$ yards or face warp are wanted per yard of cloth woven.
2/36's worsted=10,080 yards per lb. $\div 16 = 630$ yards per oz. $3,306.66 \div 630 = 5.25$ oz., weight of face warp.
100 : 88 :: x : 2,976  $297,600 \div 88 = 3,381\frac{9}{11}$ yards of back warp yarn are wanted per yard of cloth woven.
1/20's worsted=11,200 yards. 11,200 yards per lb. $\div 16 = 700$ yards per oz.

$3,381.81 \div 700 = 4.83$ oz., weight of the back warp.
52 picks per inch $\times 62 = 3,224$ yards of filling wanted.
$3,224 \div 630 = 5.12$ oz., weight of filling per yard of cloth woven.

| | | |
|---|---|---|
| Warp, | Face, | 5.25 oz. |
| | Back, | 4.83 " |
| Filling, | | 5.12 " |
| | | 15.20 oz. |

*Answer.*—15.2 oz. is the weight of the cloth per yard (from loom exclusive of selvage).

To illustrate the difference regarding the weave as selected for interlacing the back warp, we will next calculate the previously given example with the same counts of yarn but with the weave as given in Fig. 42.

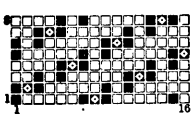


FIG. 42.

This weave contains the same face weave ($^{2}$——$_{2}$ twill) as previously used, the only difference being the interlacing of the back warp, for which we use the 8-leaf satin in place of the $^{1}$——$_{3}$ twill as used in the former example.

Face warp and filling, 2/36's worsted. Back warp, single 20's worsted.

2/36's worsted=90 threads will lie side by side per inch.

Face weave $^{2}$——$_{2}$ twill. $90 \times 4 = 360 \div 6 = 60$ threads is the proper texture for face structure, and
60
— 6 (10 per cent. deduction by means of the back warp stitching with the 8-leaf satin in the face structure).

54   Warp threads per inch 54 threads 2/36's worsted, for face.
54 " 1/20's " " back.

108   Thus: 108 warp threads per inch must be used.

Picks per inch, 58 (the same 4 extra pick as in previous given example).

Filling, 2/36's worsted. Take-up of face warp 10 per cent. Take-up of back warp 8 per cent. $62\frac{1}{2}$ inches for width of cloth in loom, since the 8-leaf satin will permit a readier milling (during the process of scouring) than the $^{1}$——$_{3}$ twill.

*Question* :—Find weight of cloth per yard and compare it with previously given example.

$54 \times 62.5 = 3,375$ threads each of face and back warp are wanted.

100 : 90 :: x : 3,375.  $337,500 \div 90 = 3,750$ yards of face warp are wanted per yard of cloth woven.
2/36's worsted=630 yards per oz. $3,750 \div 630 = 5.95$ oz., weight of face warp.
100 : 92 :: x : 3,375.  $337,500 \div 92 = 3,668\frac{1}{2}$ yards of back warp are wanted per yard of cloth woven.
1/20's worsted=700 yards per oz.

$3,668.5 \div 700 = 5.24$ oz., weight of back warp per yard of cloth woven.

58 picks per inch $\times 62.5$ inches width of cloth in reed=3,625 yards of filling wanted, and $3,625 \div 630 = 5.75$ oz., weight of filling per yard of cloth woven.

| | |
|---|---|
| Face warp, | 5.95 oz. |
| Back warp, | 5.24 " |
| Filling, | 5.75 " |
| | 16.94 oz. |

Thus: **16.94 oz.** (or practically 17 oz.) is the weight of cloth per yard from loom.

A comparison between both cloths results as follows:

| | (Using weave Fig. 41.) | (Using weave Fig. 42.) | (Difference.) |
|---|---|---|---|
| Face warp, | 5.25 oz. | 5.95 oz. | 0.70 oz. |
| Back warp, | 4.83 " | 5.24 " | 0.41 " |
| Filling, | 5.12 " | 5.75 " | 0.63 " |
| Weight per yard, | 15.20 oz. | 16.94 oz. | 1.74 oz. |

Or, the difference between using the 8-leaf satin or $\frac{1}{\quad 3}$ twill for the weave for the back warp is 1.74 oz.

Given two examples will readily illustrate to the student that he must select the weave for the backing with the same care as the face weave, for, as shown in examples given, we produced a difference of $1\frac{3}{4}$ oz. simply by changing the weave for the back warp, using the same counts of yarn for warp and filling, leaving the face weave undisturbed.

The most often used proportion of the arrangement between face and back warp is the one previously explained; *i. e.*, 1 end face to alternate with 1 end back, but sometimes we also use—

| | | |
|---|---|---|
| 2 ends face warp | | 1 end face warp. |
| 1 end back warp | or | 1 end back warp. |
| — | | 2 ends face warp. |
| 3 ends in repeat. | | 1 end back warp. |
| | | — |
| | | 5 ends in repeat, or any similar arrangement. |

If using the arrangement "1 end face warp to alternate with 1 end back warp," never use a heavier size of warp yarn for the back warp than for the face warp. (See previously given example and you find face yarn 2/36's worsted, (= single 18's) and for back warp, single 20's worsted yarn used.)

If using "2 ends face warp to alternate with 1 end back warp" a proportional heavier yarn can be used for the back warp. (See the previous example where 2 ends face warp, 2/36's worsted, alternate with one end back warp, $3\frac{1}{2}$-run woolen yarn).

Great care must be exercised in selecting the stock for the face warp and back warp for such fabrics as require any fulling during the finishing process. The material in the back warp, which can be of a cheaper grade, must have about, or as near as possible, the same tendency for fulling as the "stock" which is used in the face warp. The student will also readily see that there will be a smaller deduction (after finding the face texture) necessary if using the arrangement of 2 ends face to alternate with 1 end back than if using the simple alternate exchanging of face and back warp explained at the beginning of the chapter.

For example, take weave Fig. 43, illustrating an 8-harness Granite weave, backed 2 ends face warp, 1 end back warp. The back warp interlaces 1 pick up and 7 picks down = 8 picks in the repeat. Examining rules as given for the arrangement 1 and 1, we find a call for a deduction for the face texture of 10 per cent. (see weave Fig. 42), but which, if using the present arrangement, must be reduced to 5 per cent.; this being one-half less reduction to make for 2 face 1 back compared to 1 face 1 back.

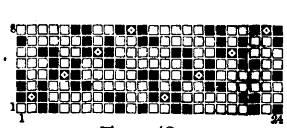


FIG. 43.

Weave Fig. 44 illustrates the $\frac{2}{\quad 2}$ twill, backed 2 ends face warp and 1 end back warp. The back warp interlaces 1 pick up, 3 picks down=4 picks in the repeat. Examining rules as given for the arrangement of 1 and 1, we find a call for a deduction from the face texture of 20 per cent. (see weave Fig 41), but which, if using arrangement to suit weave Fig. 44, must be reduced one-half; *i. e.*, deduct only 10 per cent.

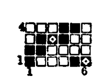


FIG. 44.

*Example.*—Find warp threads per inch for the following cloth: Worsted suiting, Face warp, 2/36's worsted yarn. Back warp, $3\frac{1}{2}$-run woolen yarn. Use *a*, weave shown in Fig. 43; *b*, weave given in Fig. 44.

2/36's worsted$=\frac{1}{90}$ inch diameter. Face weave, { 8 threads in repeat, 4 points of interlacing.

$\frac{90\times 8}{12}=60$ threads, proper warp texture for face.

60
— 3 (5 per cent.)

57

*Answer.*—If using weave Fig. 43, use 57 warp threads per inch for face.

Thus: 58 ends 2/36's worsted for face, and
+29 " $3\frac{1}{2}$-run woolen yarn for back, giving us

87 ends of warp to be used per inch.

2/36's worsted$=\frac{1}{90}$ inch diameter. Face weave, { 4 threads in repeat, 2 points of interlacing.

$\frac{90\times 4}{6}=60$ threads, proper warp texture for face.

60
— 6 (10 per cent.)

54

*Answer.*—If using weave Fig. 44, use 54 warp threads per inch for face.

Thus: 54 ends 2/36's worsted for face,
+27 " $3\frac{1}{2}$-run woolen yarn for back, gives us

81 ends of warp as total number of ends to be used per inch.

## SELECTION OF PROPER TEXTURE FOR FABRICS CONSTRUCTED ON THE DOUBLE CLOTH SYSTEMS; i. e., CONSTRUCTED WITH TWO SYSTEMS OF WARP AND TWO SYSTEMS OF FILLING.

Under double cloth we comprehend the combining of two single cloths into one fabric. Each one of these single cloths is constructed with its own system of warp and filling, while the combination of both fabrics is effected by interlacing some of the warp threads of the one cloth at certain intervals into the other cloth; hence, in ascertaining the warp texture of these fabrics we have to deal with a back warp and back filling, both exercising their influence upon the texture of the fabric at the same time.

As mentioned and explained in my "*Technology of Textile Design*," double cloth may be constructed with:

1 end face to alternate with 1 end back, in warp and filling.
2 ends face to alternate with 1 end back, in warp and filling.
2 ends face to alternate with 2 ends back, in warp and filling.
3 ends face to alternate with 1 end back, in warp and filling, etc.

The two first mentioned arrangements are those most often used; hence, we will use the same for illustrating the selection of the proper warp texture for the present system of fabrics.

### 1 End Face to Alternate with 1 End Back in Warp and Filling.

For face warp use 4-run woolen yarn. For back warp use $4\frac{1}{2}$-run woolen yarn.

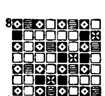


FIG. 45.

*Question.*—Find texture for warp yarn: *a*, if using weave Fig. 45; *b*, if using weave Fig. 46.

First we have to ascertain the warp texture for the face cloth, dealing with the same as with pure single cloth.

Face weave for both weaves is the $\frac{2}{\quad}{}_{2}$ 4-harness twill, and the yarn to use is 4-run woolen yarn.

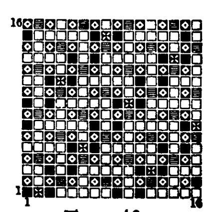


FIG. 46.

4-run=6,400 yards per lb.

$\sqrt{6,400}=80$

—12.8 (16 per cent.)

67.2

| $\underline{2\quad}_{2}$ twill = | repeat of weave, 4 threads, points of interlacing in one repeat, 2. |

$\frac{67.2\times4}{6}=268.8\div6=44.8$ threads (or practically 45) required to be used if dealing with a single cloth.

The next to be taken into consideration is the stitching of both cloths. In both weaves the back warp interlaces into the face cloth. In weave Fig. 45, we find the $\underline{1\quad}_{3}$ twill used for stitching, the proper allowance for the same is a deduction of 24 per cent. from the face structure; hence, in example:

45 threads, proper warp texture for face cloth, treated as single cloth.
—11 " (24 per cent. deducted for $\underline{1\quad}_{3}$ stitching).

34 threads per inch must be used for each system if using weave given in Fig. 45.

In weave Fig. 46, we find the 8-leaf satin used for stitching the same face cloth as previously used, the proper allowance for the same is a deduction of 16 per cent. from the face structure; In example given, we find—

45 threads, proper warp texture for face cloth, treated as single cloth.
— 7 threads (16 per cent. deducted for the $\underline{1\quad}_{7}$ stitching).

38 warp threads per inch must be used for each system if using weave given in Fig. 46.

*Answer.*—Double cloth fabrics given in question require the following warp texture:

*a.* If using weave Fig. 45, we must use—
34 warp threads 4 -run woolen yarn for face,
+34 warp threads 4¼-run woolen yarn for back.
or 68 warp threads per inch.

*b.* If using weave Fig. 46, we must use—
38 warp threads 4 -run woolen yarn for face,
+38 warp threads 4¼-run woolen yarn for back;
or 76 warp threads per inch.

### 2 Ends Face to Alternate with 1 End Back in Warp and Filling.

For face warp use 4-run woolen yarn (same counts as used in previously given example).
For back warp use 2¼-run woolen yarn.

*Question.*—Find texture for warp yarn: *a*, if using weave Fig. 47; *b*, if using weave Fig. 48.

The face weave in both weaves is the same as given in previous weaves, Figs. 45 and 46, or the $\underline{2\quad}_{2}$ twill, the counts of yarn being also the same; thus, we can use texture for face cloth required from previous example, being 45 threads per inch in loom.

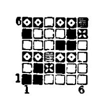


FIG. 47.

In weave Fig. 47, we used the plain weave for stitching, the proper allowance for the same is a deduction of 8 per cent. from the face structure; hence,

45 threads, proper warp texture for face cloth (single cloth),
— 3 " 8 per cent. (3.6 actual) deducted for the stitching $\underline{1\quad}_{1}$.

42 threads per inch to be used for the face system if using weave given in Fig. 47.

In weave Fig. 48, we find the 8-leaf satin used for stitching the same face cloth as previously used. The manner in which the stitching is done in this example will be of very little, if any, consequence to the face cloth; hence, the full number of ends (or as near as posible) as ascertained for the face cloth, treated as if single cloth, must be used. In the present example this would be 44 or 45 threads per inch to be used for face system if using weave shown in Fig. 48.

*Answer.*—Double cloth fabrics given in question require the following warp texture: *a.* If using weave Fig. 47, we must use—

42 warp threads 4-run woolen yarn for face.
+21 warp threads 2¼-run woolen yarn for back; or

63 warp threads per inch.

*b.* If using weave Fig. 48, we must use—

44 warp threads 4-run woolen yarn for face.
+22 warp threads $2\frac{1}{4}$-run woolen yarn for back; or
—
66 warp threads per inch must be used.

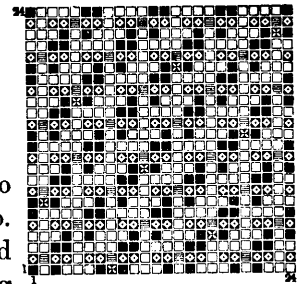


FIG. 48.

*Example.*—Ascertain texture of warp required for a worsted suiting, to be made with 2/40's worsted for face warp, and 2/28's cotton for back warp. Arrangement of warp and filling to be 2 ends face to alternate with 1 end back. Weave to be used, Fig. 48. Next, ascertain the proper counts of filling and the number of picks per inch, take-up of warp, width of cloth in reed, and ascertain total amount of each kind of material required per yard from loom (exclusive of selvage).

2/40's worsted=11,200 yards per lb. $\sqrt{11,200}$, less 10 per cent.=95 threads will lie side by side in one inch.

Face weave (in Fig. 48) is the $^{2}$——$_{2}$ twill=4 threads in one repeat, with 2 points of interlacings; hence, $\frac{95 \times 4}{6}=380 \div 6=63\frac{1}{3}$, warp texture to be used for the face cloth, the same being treated as if single cloth.

In weave Fig. 48, the arrangement between face and back is 2:1; the weave used for the back is the 8-leaf satin, and, as we mentioned when laying down rules and examples, for setting double cloth fabrics in the loom, that the $^{1}$——$_{7}$ requires no deduction on account of the stitching of the back warp in the face cloth, texture to use in this example must be

64 face warp threads (2/40's worsted), and
+32 back warp threads (2/28's cotton); hence,
—
96 warp threads per inch must be used.

Take-up of warp during weaving 12 per cent. for face and 10 per cent for back. The width of cloth to use in reed will be 62 inches.

For face filling use the same counts as for face warp, and for back filling use 3-run woolen yarn.

Picks, 66 face.
+33 back.
—
99, total picks to be used per inch.

64×62=3,968 threads in face warp—12 per cent. take-up. Thus:
3,968×100=396,800÷88=4,509 yards of face warp yarn are necessary for 1 yard cloth woven
2/40's worsted=11,200 yards per lb.÷16=700 yards per oz.
4,509÷700=6.44 oz., weight of face warp.
32×62=1,984 threads in back warp—10 per cent. take-up. Thus:
198,400÷90=2,204 yards of back warp yarn necessary for 1 yard cloth woven.
2/28's cotton=11,760 yards per lb.÷16=735 yards per oz.
2,204÷735=3 oz., weight of back warp.
66×62=4,092 yards of face filling are wanted.
4,092÷700=5.85 oz., weight of face filling. 33×62=2,046 yards of back filling are wanted.
3-run woolen yarn=300 yards per oz. 2,046÷300=6.82 oz., weight of back filling.

Hence: 6.44 oz., weight of face warp (2/40's worsted).
3.00 " " " back " (2/28's cotton).
5.85 " " " face filling (2/40's worsted).
6.82 " " " back " (3-run wool).
—
22.11 oz.

*Answer.*—Fabric given in example will weigh 22.11 oz. per yard from loom.

# ANALYSIS.

## How to Ascertain the Raw Materials Used in the Construction of Textile Fabrics.

In many instances an examination of the threads (liberated during picking-out) with the naked eye, will be sufficient to distinguish the material used in the construction of the fabric, yet sometimes it is found necessary to use either the microscope, or a chemical test for their detection.

As a means for merely distinguishing between the fibres the simplest and most generally applicable test is to make a microscopical examination of the fabric ; and for this reason it is necessary for the analyst to be acquainted with the appearance of the individual fibres. By means of the microscope the fibre used in the construction of a fabric is at once ascertained on account of the different surface structures of the various fibres used in the manufacture of textiles. This characteristic surface structure cannot be distinguished with the naked eye ; a common magnifying glass will not do either, but an enlargement of about 200 times will in most instances suffice. In order to prepare a fabric for examination with the microscope liberate (pick out), the threads forming the fabric ; next untwist a few threads so as to liberate the individual fibres composing the same. Place these fibres upon a slide of the microscope, carefully wet them with a drop of distilled or rain water, and cover them with a cover glass ; or smear the surface of a slide with glycerine or gum water, upon which the fibres, adhering slightly, may readily be arranged for examination.

### MICROSCOPICAL APPEARANCE OF FIBRES.

#### Cotton.

Examining cotton fibres under the microscope shows them to be spirally twisted bands, containing thickened borders and irregular markings on the surface. The fibre is as a rule thicker at the edges than in the centre, and has, therefore, a grooved or channeled appearance. The spiral character is much more highly developed in some varieties than in others.

Care must be taken not to mistake *wild silk* for cotton, since wild silk frequently has a similar spiral band like appearance. If any time in doubt remember that these two kinds of fibres can readily be distinguished by other tests.

The accompanying illustration, Fig. 49, shows cotton fibres magnified.

In fully ripe cotton the twisted form is regular and uniform, compared to unripe, half ripe or structureless cotton, which are now and then found amongst a lot of cotton, yarns or fabrics.

For illustrating this subject the accompanying illustration, Fig. 50, is given. *A* represents an unripe cotton fibre ; *B*, a half ripe fibre, having a thin cell wall ; and *C* represents the ripe fibre having a full twist and a properly defined cell-wall. Fig. 51 shows a structureless fibre as found occasionally. Half ripe, unripe, and structureless fibres, if found in a lot of cotton, yarn, or

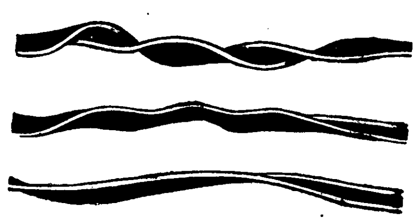


FIG. 49.

A. B. C.

FIG. 50.

fabric, will greatly depreciate its value on account of their poor dyeing and spinning qualities, producing poor yarns and fabrics.

### Silk.

In its natural state silk is a double fibre (see the accompanying illustration, Fig. 52) being two threads which are glued together. In the preparatory process of scouring or boiling off these two threads are separated and when examined by the microscope appear as structureless, transparent, cylindrical little glass rods, without whatever

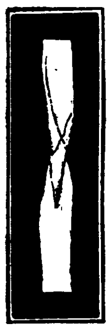


FIG. 51.

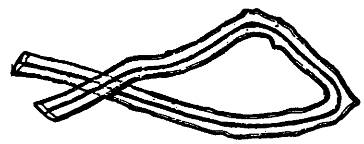


FIG. 52.

FIG. 53.

a spiral character, some rather straight and of uniform thickness whereas others are slightly bent and irregular as to their diameter. Specimens of silk fibres as appearing under the microscope are given in the accompanying illustration, Fig. 53.

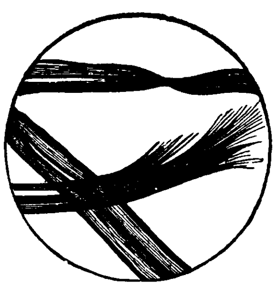


FIG. 54.

**Wild Silk.**—The most important of these is Tussah. Its natural color is a silver drab, which requires bleaching of the fibres for bright colors. The accompanying illustration, Fig. 54, shows its microscopic appearance.

**Weighted Silk** is readily distinguished by means of the microscope, the accompanying illustration, Fig. 55, representing weighted silk waste as appearing when viewed with the microscope.

FIG. 55.

### Wool

is readily distinguished from other fibres by means of the microscope, being built up of an immense number of epithelial cells, scales or serrations as shown in the accompanying illustration Fig. 56, representing a typical wool fibre viewed under the microscope. The amount of scales found per square inch varies with reference to quality—the finer grades having more, and the coarser less. If these scales can not be readily seen treat the fibres in question with *ammoniac copper*, and the scales will become distinctly visible to the eye during the swelling up of the fibres. Another prominent feature characteristic to wool is its

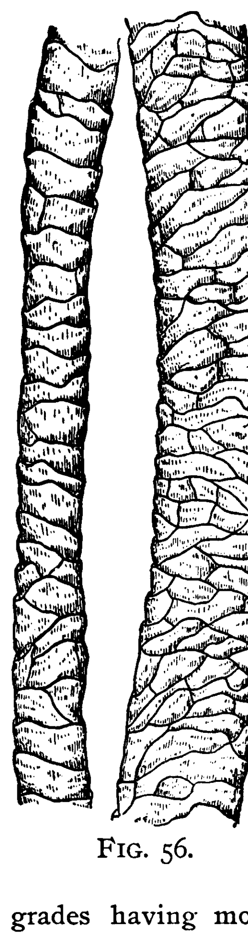


FIG. 56.

*wave of the crimp*  which again varies with reference to the different grades of wool found in the market. The more scales per inch, and the more wavy in construction the fibre, the more its felting capacity.

**Untrue Fibres** (caused either by neglected or sick sheep,) now and then found in wool are readily ascertained by means of the microscope as seen by the accompanying illustration, Fig. 57, representing two such fibres as termed untrue, and which readily show that where these abnormal forms occur, there are changes in the form and size of the epithelial scales of the outer layer as well as in the diameter of the fibre, consequently the internal structure of the fibre must be equally affected, thus reducing the strength and elasticity of such fibres, and consequently decreasing the value and strength of such lots of wool, as well as fabrics, in which these fibres are more or less frequently found.

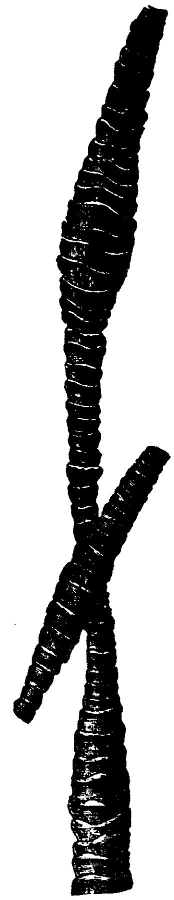


FIG. 57.

**Kemp or Kempy Wool Fibres** are another kind of imperfect fibres found in wool. Kemp fibre is a hair of dead silvery white, thicker and shorter than the regular wool. They do not seem to differ in their chemical composition from the good or true wool fibres, but they present such different mechanical arrangement, and possess no absorbent power, thus resisting either entirely or partly, the entrance of dye-stuffs, and in the latter case even producing a different shade from the good fibres of the same lot, hence they will be readily detected in lots of wool, yarns, or fabrics. The accompanying Figs. 58 and 59, are given to illustrate the various degrees of these kempy fibres. Fig. 58, A, is a fibre where the kempy structure continues throughout the entire fibre which looks like a glass rod, yet has short and faint transverse lines which indicate the margins of the scales. When the change is a complete one, even the application of caustic alkali fails to bring out the lamination of the scales with any degree of distinctness and they seem to be completely attached to the body of the fibre up to the top of the scale. In some instances even the margins of the scales are quite obliterated, and the entire surface of the fibre has a silvery appearance resembling frosted silver. In Fig. 58, B, a fibre is shown where the change from true wool to kemp is only partial. The lower part of the illustration shows wool structure (the scales being distinctly visible,) whereas the upper portion of the fibre shows the kemp structure (having the scales closely attached to the surface, giving the fibre the usual ivory-like appearance). Both illustrations, Figs. 58, A, and B, are representations of fibres seen by reflected light. In Figs. 59, A, and B, illustrations are given of kemps seen by transmitted light. In Fig. 59, A, a kempy fibre is seen with transmitted light and where we see a gradual passage of the kemp into wool. In this case

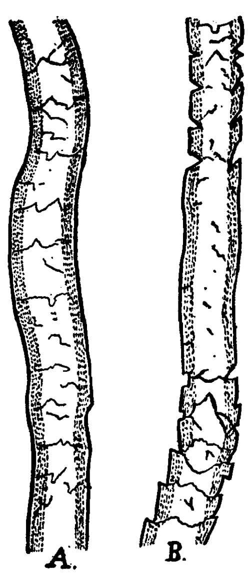



FIG. 58.

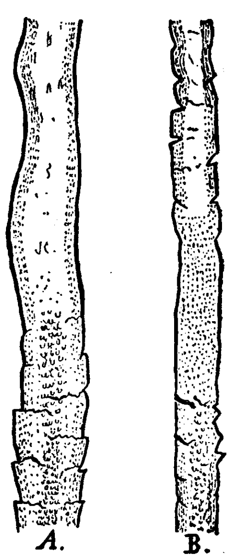



FIG. 59.

with transmitted light the kempy part retains almost the same transparency as the wool, but exhibits none of the interior arrangement of cells. Frequently fibres are noticed which have a tendency to kemp and which possess an unusual distinctness in medullary cells. Indeed, it frequently happens that the kempy structure tails off in the same fibre, not so much as we should have supposed so much on the outer surface, but down the interior of the fibre, as though the change commenced in the central cells and was gradually extended to the outer surface as the fibre grew. At the extremity, where the kempy structure first appears, the central cells are often not contiguous, as though the change commenced in a few cells first and then became more numerous both in the longitudinal as well as a diametrical direction. These kempy fibres often have a considerable degree of transparency when viewed with transmitted light, and in this respect they vary very much, but they are very seldom as transparent as the adjacent wool fibres.

Sometimes, however, they are very opaque, as will be seen in the fibre shown in Fig. 59, B, where the light seems hardly to penetrate the centre of the fibre although it is refracted at the thinner edges, while the true wool, both above and below, is quite transparent to the same light. In this case, the same fibre, when viewed with reflected instead of transmitted light, exhibited no more signs of a dark color in the kempy than the true wool part, so that the want of transparency was not due to coloring matter.

Kempy fibres are not always white, they are frequently found in coarse, dark colored, foreign wools, and even in colored fibres of more cultivated sheep.

**Shoddy** are wool fibres re-manufactured out of soft woolen rags which have yet felting properties. Shoddy consists of long fibres of various diameter ; fibres are now and then found spoiled by scales being gone or the ends broken. If examining the shoddy-wool more closely its color will betray the inferior article compared to wool. The rags had previously to the redyeing different colors and which will influence the second color accordingly. Of the

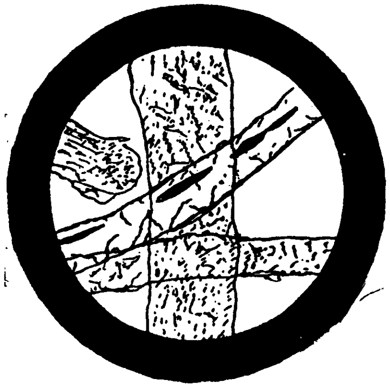


FIG. 60.

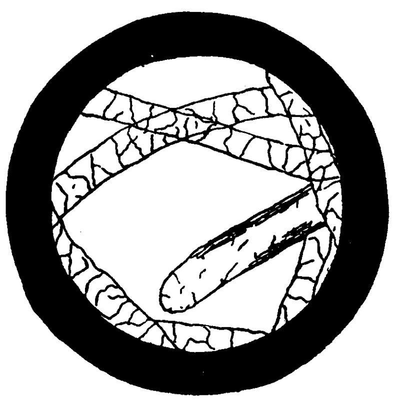


FIG. 61.

FIG. 62.

accompanying illustrations Fig. 60, shows Cheviot shoddy, Fig. 61, Thibet shoddy as visible under the microscope when magnified.

**Mungo** is the name for wool fibres re-manufacture out of hard woolen rags, *i. e.*, a cheaper grade of shoddy, made out of rags from fulled cloth. During the process of re-manufacturing said rags into wool by means of picking, carding or garnetting a great many fibres get hurt, broken. Besides, on account of the rags coming from fulled cloth, this mungo wool has no more fulling properties left. The point regarding color previously mentioned at shoddy wool will also distinguish mungo wool from wool. Frequently cotton fibres will be found amongst said Mungo, in some cases also silk fibres. Fig. 62, gives us a typical illustration of Mungo when seen under the microscope.

**Wool Extract** also called Extract is such artificial wool produced from mixed rags from which the vegetable fibres were extracted by means of carbonizing. An examination of a sample of extract by means of the microscope will show traces of the process of carbonizing, by means of the carbonized vegetable refuse found.

All three divisions of artificial wool are by some manufacturers simply collectively graded as shoddy, and in this manner will mostly be taken into consideration when dissecting woven or knitted fabrics with reference to materials used in their construction.

### Foreign Wools.

Amongst these we find Mohair, Cashmere, Alpaca, Vicugna and Llama wool.

**Mohair** is obtained from the Angora goat. The epidermal scales are extremely delicate and can only be noticed by giving the greatest of care to the experiment. The fibre gets smaller in diameter towards the top end, although not forming a point, and is of bright metallic lustre. Characteristic to it are the fine spots found all over the surface as shown in the accompanying specimen, Fig. 63.

FIG. 63.

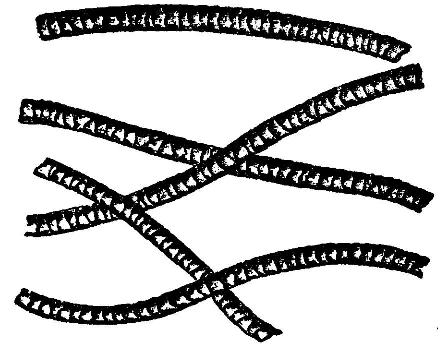


FIG. 64.

**Cashmere** is the product of the Cashmere goat. The fur of this animal is of two sorts, *viz.*, a soft wooley under coat of grayish hair, and a covering of long silken hair, that seems to defend the interior coat from the effects of winter.

The under coat, *i. e.*, the fine fibres, are readily distinguished by means of the structure of their epidermal scales, besides there is no central or medullary portion found. Fig. 64, gives us a specimen of these fibres. They are used only in the manufacture of the finest textiles on account of their high value.

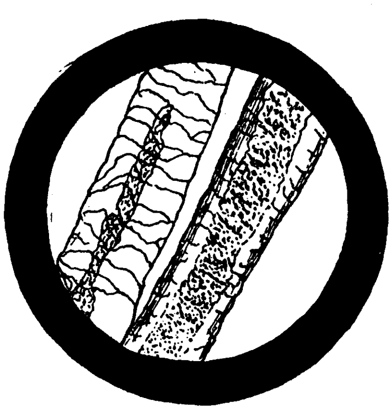


FIG. 65.

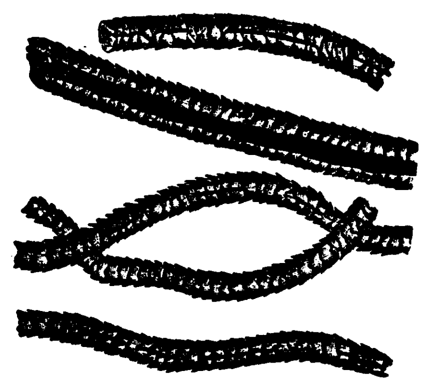


FIG. 66.

The outer coat, which is of a coarser nature, is used in the manufacture of cheaper yarns, and shows under the microscope fibres containing the central or medullary portion as seen by the accompanying illustration Fig. 65.

**Alpaca Wool** possesses less lustre than Mohair and only shows its fine scales by strong magnifying. In white fibres, grayish colored medullary cells are seen. Fig. 66, gives us a specimen of this fibre.

**Vicugna Wool** looks at a first glance like alpaca wool; it is a delicate soft structure. The scales are fine, closely resembling those of wool. The medullary cells are visible. Fig. 67 is a specimen of this fibre.

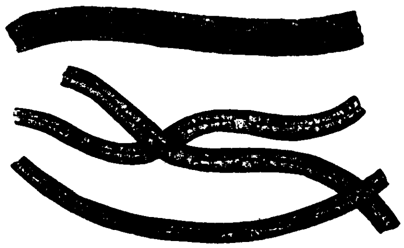


FIG. 67.

**Llama Wool** is coarser in structure compared to vicugna wool and of less value, being only used in the manufacture of cheap yarns.

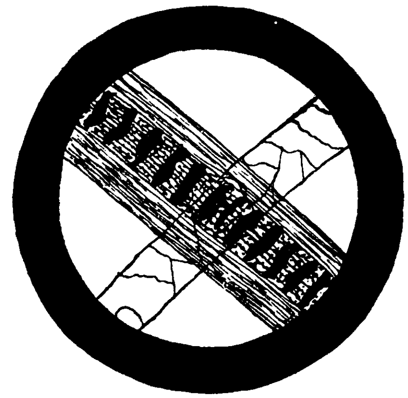


FIG. 68.

**Camel's Hair** is frequently used in the manufacture of lower grades of yarns for backing purposes. The accompanying illustration, Fig. 68, shows camel's hair fibres magnified.

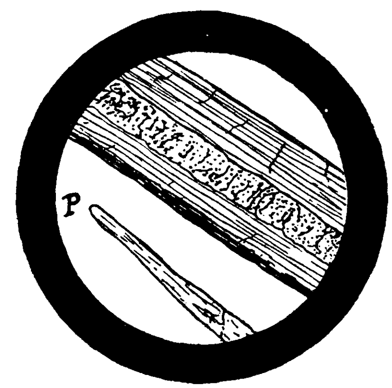



FIG. 69.

Sometimes we find what is claimed to be finer grades of Camel's hair in the market; this material, however, refers to fibres of the outer cover of the Angora, the fur of the vicugna and alpaca; whereas the fur of the llama joins more toward the camel's hair. Now and then the case may come up where, in low backing yarns,

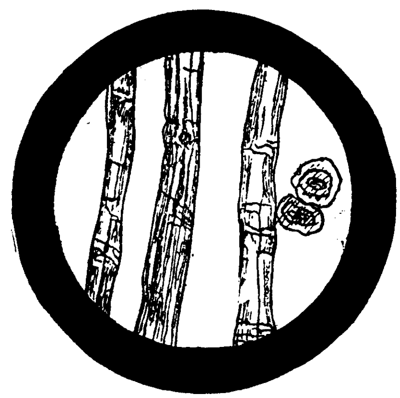


FIG. 70.

**Cow's Hair** is used. For this purpose we give in the accompanying illustration, Fig. 69, specimens of this fibre, which in their natural state are of a white, red or black color, and possess slight lustres. They clearly show their central or medullary portion. *P*, indicates the point of a hair.

The fibres mentioned thus far will cover all materials a manufacturer will come in dispute with. However, in order to make this paper as complete as possible, we thus reproduce microscopical views of

**Flax Fibre,** in Fig. 70, of

**Hemp Fibre,** in Fig. 71, of

**Jute Fibre,** in Fig. 72, of

**China Grass,** in Fig. 73; besides a representation of these fibres we also show their sections.

The microscopical examination of fibres, yarns and fabrics is in the absence of experience, sometimes misleading, hence it is well in all doubtful cases to apply some corroborative test

FIG. 71.

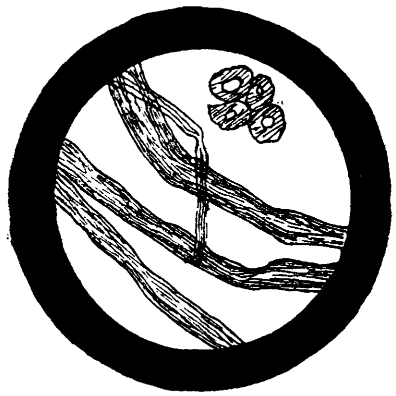


FIG. 72.

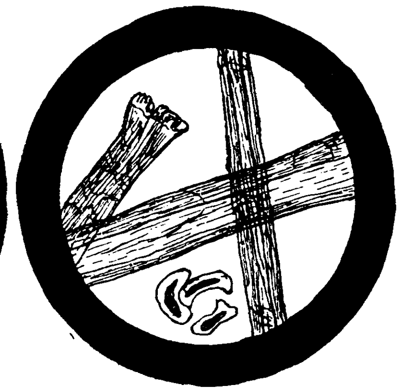


FIG. 73.

of a more definite character. They are supplied by making use of certain chemical reactions of the fibres.

In chemical constitution, cotton is the simplest, and wool the most complex of the textile fibres.

**Cotton** consists of but three elements, carbon, hydrogen and oxygen, in the proportion represented by the formula $C_6H_{10}O_5$. In the

**Silk** substance another element, nitrogen, is present, and the molecule is at the same time much more complex, as is shown by the formula for fibroin, $C_{15}H_{23}N_5O_6$.

**Wool** contains still another constituent, sulphur, and the simplest formula which will conform to the percentage composition contains 39 atoms of carbon.

## TESTS FOR ASCERTAINING THE RAW MATERIALS USED IN THE CONSTRUCTION OF YARNS OR FABRICS.

### Cotton, Linen, Jute, China Grass, Silk and Wool.

1. By burning the threads, given for testing, in a flame the cotton (or any vegetable) fibre will change in carbonic acid and water, and this without smell, while those of animal origin (wool and silk) change in combinations containing nitrogen, which element readily makes itself known by its disagreeable odor, similar to burnt feathers.

2. Another point which it is well to note, is the rapidity (flash like) with which cotton yarn burns compared to the poor burning of a thread having animal substances for its basis. Such a thread will shrivel up, forming a bead of porous carbon at the end submitted to the flame.

In some instances a more exact analysis may be required; if so proceed after one or the other of the following formulas:

3. Boil the sample to be tested in a concentrated solution of caustic soda or potash, and the wool or silk fibre will rapidly dissolve, producing a soapy liquid. The cotton or other vegetable fibre therein will remain undisturbed, even though boiling in weak caustic alkalies for several hours, care being taken to keep the samples below the surface of the solution

during the operation, since if exposed to the air, the cotton fibre becomes rotten, especially when the exposed portions are at the same time also brought under the influence of steam. (Any cotton fibres remaining from testing, if colored, may be bleached in chlorine water, and afterwards dissolved with cupro-ammonia.)

4. To determine whether woolen cloth contains flax or cotton, immerse the sample in a bath containing a solution of concentrated sulphide of sodium. This has the effect of dissolving the wool, and the sample can then be entirely freed from it by merely washing in hot water; the residuum will be cotton or linen fibre.

5. To determine whether a woolen or a linen fabric contains cotton, place the sample of the fabric to be tested into a mixture of two parts sulphuric acid, and one part saltpeter for eight or ten minutes. After removing it, wash thoroughly and dry, then immerse it in a bath of ether containing alcohol, which has the effect of dissolving the cotton (if there is any present), while the woolen or linen fibres remain uninjured.

6. Schweitzer's reagent (ammoniacal solution of oxide of copper) dissolves cotton and silk but not wool. Cellulose is reprecipitated by gum, sugar or acids, but the silk substances by acids alone.

7. Concentrated zinc chloride, 138° Tw. (Sp. Gr. 1.69) made neutral or basic by boiling with excess of zinc oxide, dissolves silk slowly if cold, but very rapidly if heated, to a thick, gummy liquid. This reagent may serve to separate or distinguish silk from wool and cotton, since these latter fibres are not affected by it. If water be added to the zinc chloride solution of silk, the latter is thrown down as a floccu-precipitate. Dried at 230° to 235° F., the precipitate acquires a vitreous aspect, and is no longer soluble in ammonia.

8. A solution of cotton in concentrated sulphuric acid gives a purple coloration with an alcoholic solution of alpha naphthol. This reaction really indicates the presence of sugar, and is therefore not given by silk or wool.

9. Millon's reagent (mercurous-mercuric nitrate) gives a red color with silk or wool but not with cotton.

10. Wool (also hair and fur) is blackened by heating with a dilute solution of plumbite of soda, which is prepared by dissolving litharge in caustic soda. Silk and cotton, not containing sulphur, are unaffected in color.

11. To distinguish wool and silk fibres from cotton and flax, treat a sample of the material with picric acid, which will have the effect of dyeing the former almost a fast yellow, while the latter will remain unaltered in color.

12. An acid solution of indigo extract dyes wool and silk, but not cotton.

13. To decide whether a linen fabric contains cotton, immerse a sample of the fabric in a light alcoholic solution of aniline red for a short time, after which wash thoroughly, and then soak it in caustic ammonia for two hours. The treatment will dye the linen fibres a rose red, while the cotton fibres will show no trace of color.

14. In linen and cotton mixed fabric, a strong potash solution will only impart a very slight yellowish tinge to the cotton fibre, while the other will be dyed a deep yellow. A mixed cloth, after being removed from this solution, would present a striped or spotted appearance.

15. Another easy method to distinguish between linen and cotton is to soak a sample of the material in olive or rapeseed oil. Under this process the flax fibre, which in its natural condition, is opaque, becomes transparent; while the cotton, which in its natural condition is transparent, becomes under this operation opaque.

16. Silk fibres become dissolved when treated with concentrated muriatic acid.

**Flax,** being cellulose, the action of various chemical agents on it are much the same as on cotton, but generally speaking, linen is more susceptible to disintegration especially under the influence of caustic alkalies, calcium hydrate, and strong oxidizing agents as chlorine, hydrochlorides, etc. Treated with sulphuric acid and iodine solution, the thick cell wall is colored blue, while the secondary deposits, immediately enclosing the central canal, acquire a yellow color.

**Jute** may be considered as consisting of cellulose, a portion of which has become more or less modified throughout its mass, into a tannin-like substance. Alkalies actually resolve jute into insoluble cellulose and soluble bodies allied to the tannin matters. It is distinguished from flax by being colored yellow, under the influence of sulphuric acid and iodine solution. Under the influence of chlorine, a chlorinated compound is produced, which, when submitted to the action of sodium sulphite, develops a brilliant magenta color.

**China Grass** is colored blue by sulphuric acid and iodine solution, hence it seems to consist essentially of cellulose.

## HOW TO ASCERTAIN THE PERCENTAGE OF EACH MATERIAL CONSTITUTING THE FABRIC.

### Test for Wool and Cotton or Silk and Cotton.

Cut sample for testing to a known size with a sharp pair of scissors, or stamp out the desired quantity with a die of which you know the exact size. Next weigh the sample upon a sensitive scale, and make a memorandum of its weight; then dry at a temperature of from 212° to 230° F., till no further loss of weight is possible, and weigh sample again. This weight deducted from the first will give you the amount of moisture in the sample. The dried fabric is next boiled for about five minutes in a solution containing about 10 per cent. of caustic soda, calculated to the weight of the material, and which will be strong enough to entirely dissolve the animal (wool or silk) fibre. The remainder being the cotton the fabric contained, which wash well with water, and next with dilute acetic acid and again with water. Dry this refuse at 212° to 230° F. and when perfectly dry, weigh, thus giving you the amount of cotton present, which, if added to the amount of moisture and deducted from the original weight of the fabric, will give you the amount of animal (wool and silk) fibre, the fabric contains.

If the sample contains the cotton added in a special structure, for example double cloth, the cotton in itself will form a coherent fabric throughout the process. The same, if the percentage of cotton in warp and filling of single cloth structures predominates, or any way is sufficient to hold the structure by itself together, no difficulty is apparent. However, if after boiling with caustic soda the texture transforms itself into individual fibres or threads floating about the liquid, care must be exercised not to lose any of these individual fibres, they must be carefully filtered, and the greatest care taken that no fibres get lost in the subsequent washing, drying and weighing processes.

### How to Ascertain the Percentage.

The amount of each kind of fibre in a sample is in proportion to the percentage of each fibre in a full piece of cloth.

*Example.*—Required to ascertain the percentage of cotton and wool fibre in a fabric.

Sample for testing weighs 60.24 grains; after drying at 212° F., *i. e.*, extracting all moisture, it weighs 55.32 grains. The refuse of cotton after drying at 212° F. weighs 20.08 grains.

60.24 grains = total weight of sample
— 55.32 " = weight of dried sample

4.92 " = moisture.

20.08 grains = weight of dried cotton in sample
+ 4.92 " = moisture found in original sample

25.90 " = weight of cotton and moisture.

60.24 grains = total weight of sample
— 25.00 " = weight of cotton and moisture

35.24 " = weight of wool fibre in sample.

*Answer.*—The sample in question contains

35.24 grains wool fibre
20.08 " cotton fibre, and
+ 4.92 " moisture

60.24 " total weight.

And

20.08 : 55.32 :: x : 100 = 36.29 per cent. cotton.
35.24 : 55.32 :: x : 100 = 63.71 per cent. wool.

*Answer.*—The sample in question contained

36.29 per cent. (about 36⅓ per cent.) cotton.
63.71 per cent. (about 63⅔ per cent.) wool.

### Test for Wool and Silk.

Weigh your sample, next dry it at 212–230° F., weigh it again, and deduct this weight from the weight first gotten, and thus obtain the moisture of the fabric. Next dissolve out the silk from the fabric by boiling the latter in a solution containing

850 parts of water
400 " " zinc chloride
40 " " zinc oxide.

Then wash sample thus treated in water, next in dilute hydrochloric acid, and finally in water; dry and weigh. The percentage of silk the fabric contains will be found somewhat too low, for the reason that the zinc is permanently absorbed by the wool fibre.

### Test for Fabrics Composed of Cotton, Silk and Wool.

Proceed with the fabric as in the case before; after separating the silk and thus ascertaining the amount of wool and cotton left, the first (wool) is dissolved in caustic soda and the amount of cotton in the fabric thus readily obtained.

## HOW TO TEST THE SOUNDNESS (i. e. THEIR STRENGTH) OF FIBRES OR YARNS.

The soundness or strength of a fibre (*i. e.* its elasticity) is of the greatest importance to a manufacturer.

Most often this point will become of importance when selecting or buying a lot of raw materials, yet it also will be a necessity to test either fibres used in the construction of yarns, or fibres or yarns used in the construction of fabrics.

**Illustration and Description of a Testing Machine.**—In order to ascertain exactly the strength of the various fibres or yarns, the amount of their elasticity, the use of a little machine, as shown in the accompanying illustration, Fig. 74, will be found of great advantage. Letters of reference in the illustration indicate as follows: A, is a base board of hard wood (generally leaded) upon which is fixed a pillar B. The top end is forked into a jaw, carrying on each side a screwed centre-piece, into which is fixed the fulcrum of the lever C, D. These two center-pieces can be screwed closer together, or further apart, as required, and the pivot which forms the fulcrum E, of the lever is pointed at each end, and fits into a hollow in the two ends of the center-pieces and enables it to work perfectly free, and yet can have no lateral motion as would be the case if knife edges were used.

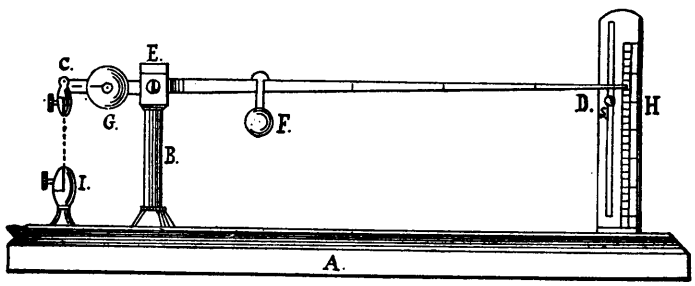



FIG. 74.

The lever from E, to D, is divided into five equal parts, each of which is equal to the distance of the center of the jaws C, from the centre of the fulcrum at E. G, is a balance weight to counterpoise the longer arm E, D, of the lever. Each of the five divisions of the lever E, D, are divided into ten parts. The range of the instrument depends upon the weight of the sliding weight F, and which can be varied when desirable. Three different weights, *viz.*, 50 grains, 100 grains, and 1,000 grains are most frequently used, and the range of the instrument with these different weights is as follows:

| Weight. | First Division. | Second Division. | Third Division. | Fourth Division. | Fifth Division. |
|---|---|---|---|---|---|
| Grains. | Grains. | Grains. | Grains. | Grains. | Grains. |
| 50 | 50 | 100 | 150 | 200 | 250 |
| 100 | 100 | 200 | 300 | 400 | 500 |
| 1,000 | 1,000 | 2,000 | 3,000 | 4,000 | 5,000 |

By using the intermediate decimal divisions of spaces on the levers, we obtain in the case of the 50 grains weight, an increase of 5 grains for each division; with the 100 grains weight, 10 grains for each division, and with the 1,000 grains weight, 100 grains for each division; so that the range is from 50 grains up to 5,000 grains, with difference of not less than 2.5 grains when the 50 grain weight is used, 5 grains when the 100 grain weight is used, and 50 grains when the 1,000 grain weight is used. At the end of the lever D, a graduated scale H, is placed, divided into spaces which enable the elasticity of the fibre to be measured in terms of the distance of the two jaws C, and I, from each other. The generally used arrangement is that if the jaws C, and I, are separated one-tenth of an inch it will indicate half an inch on the scale H, thus enabling very small ranges of elasticity to be readily seen.

A small stop S, adjusted by a thumb screw at the back of the plate, is inserted in a long slot in the divided plate so as to prevent the lever from falling when the point of fracture is reached.

For moving the weight along the lever a fine silk thread (attached to the ring which slides along the lever) is generally used so as to avoid any pressure which otherwise would be exercised if using the fingers. Generally two or three experimental tests are made previously to the final ones as required for reference.

## HOW TO TEST GIVEN COUNTS OF YARNS.

The simplest method of testing a given count is thus:—

*Rule.*—Reel as many yards as there are hanks to the pound in the count to be tested, and weigh against 12½ (12.5) grains for worsted; 8⅓ (8.33) grains for cotton; 4⅜ (4.375) grains for woolen yarn run system, and 23⅓ (23.33) grains for woolen yarn cut system. For spun silk proceed as per cotton; for linen, as per woolen cut system. The reason for the above shortenings of the process is found in the fact that there are 7,000 grains in one pound avoirdupois. For this reason, 1 yard of 1's worsted would weigh 7,000 ÷ 560 = 12½ grains, and 10 yards of 10's worsted, 20 yards of 20's, 60 yards of 60's, etc., all should weigh the same. The same reasoning applies to the other system of grading (counting) yarns.

## HOW TO ASCERTAIN THE WEIGHT OF CLOTH PER YARD FROM A SMALL SAMPLE.

Frequently it happens to the manufacturer to ascertain from a small sample the weight of the fabric in ounces per yard. The more experienced manufacturer will promptly judge said weight by simply handling the sample between his thumb and forefinger, *i. e.*, ascertaining its bulk; again, by lifting, as to its weight with reference to size of sample in question. However, it will also be of benefit to the most experienced manufacturer to test the correctness of his practical guesswork by weighing the sample on hand on accurate scales, and ascertaining from it, by figuring in proportion, the weight in ounces per yard for the fabric.

**How to Proceed.**—Trim your sample most accurately to the greatest possible size, for the greater the amount of surface you can obtain the more accurately you can figure. After you have thus carefully trimmed your sample to a known size, put it on the scales and ascertain the weight in grains; from the size of sample and its weight in grains ascertain by proportion the weight in ounces per yard.

The whole procedure will be best explained by

**A Practical Example.**—Suppose we trimmed our sample, which was a 6/4 fancy cassimere, to 3 × 3 inches = 9 square inches, and found it to weigh 45 grains; thus—

*Rule:*— $\begin{pmatrix}\square'' \\ \text{in sample}\end{pmatrix} : \begin{pmatrix}\text{its weight} \\ \text{in grains}\end{pmatrix} :: \begin{pmatrix}\square'' \text{ in one yard} \\ \text{of the piece of cloth}\end{pmatrix} : \begin{pmatrix}\text{its weight} \\ \text{in grains}\end{pmatrix}$

*Our example:*— $9 : 45 :: 1944 : x$ and

$45 \times 1944 = 87480 \div 9 = 9720$ grains

$9720 \div 437\frac{1}{2}$ (grains in one oz.) $= 22.21$

*Answer:*—The fabric in question weighs 22.21 ounce or practically 22¼ ounces per yard.

Above rule given in the proportion might thus be expressed for a standing

*Rule:*—Multiply weight in grains of sample with number of square inches in one yard of the piece of cloth and divide the product by number of square inches in sample; the quotient divide by 437½ thus obtaining the weight of the fabric for one yard expressed in ounces.

The same result is obtained if proceeding after

*Another Rule:*—Cut your sample to a known size and divide the number of square inches thus derived into the number of square inches one yard of the fabric contains, multiply the quotient of this division with the weights in grains of your sample and divide the product by 437½.

The previously given example will figure according to this calculation:—

54″ fabric = 1944 □″

1944 ÷ 9 = 216 × 45 = 9720 ÷ 437.5 = 22.21 oz. weight of fabric per yard, being the same answer as before obtained.

## HOW TO CALCULATE THE WEIGHT OF FINISHED CLOTH.

Little if anything on this subject can be found in print, since the subject is one which must be mastered mostly by experience, again rules would be hard even to apply to every fabric of a certain grade of cloth; however points thus given will assist the student in his calculations.

After mastering the rudiments of the grading of yarns it is an easy matter to ascertain the weight of cloth from the loom, since this is nothing but common arithmetic, however, it is not so easy for the novice to calculate the weight per yard for finished cloth. In cloth made of wool the variation in weight are caused by the loss of oil, grease and dirt in scouring; loss of fibres in fulling, gigging; increase in weight on account of take up warp-ways of the fabric at fulling, and which contraction again may be varied at will according to circumstances. With reference to cotton and linen the influences above mentioned are of no account since these materials have little, if any, felting properties. The only modifying influence to be taken into account by these materials is, the bending of warp or filling, or of both systems during weaving, and the amount of sizing, starching, put into the cotton, etc., during the process of sizing. With reference to silks, variation will also occur, regulated by the condition of the yarn, if the same contains a great amount of saliva (gum) left on the fibres quite a loss in weight to the fabric may be expected, whereas properly boiled-off silk will lose little, if any, during the process of finishing (especially at scouring) of these fabrics.

With reference to woolen and worsted yarn, as previously mentioned already, the loss of oil, etc., which all yarns of this class contain, must be carefully taken into account. The best plan will be to reel off a small amount of yarn, weigh it, next scour the same with soap at about 96° F., dry and leave the yarn lay for a few days, in order to regain its natural moisture, then weigh again, and calculate shrinkage. If you want to be very accurate, test a second sample, and proceed as before, and if not obtaining the same result, strike an average between both losses for the loss to use in your calculation.

The next process which will influence the weights of woolen cloths is that of finishing and which is a subject that only can be mastered by experience on account of the various finishes to which said fabrics are subjected. In fact the only way for a test of this subject is the finishing of a sample piece. As previously already alluded to the weight of woolen cloth can be varied during the process of fulling by means of shrinking the fabric lengthways, also by tentering, crabbing, etc.; however there are limits to the modifying influences of these operations, and these limits must be understood if good results are to be obtained.

This fact of shrinking (take-up) fabrics warp ways during the process of fulling is of the greatest influence to the finished weight. Since cloth is sold at a certain price for a certain weight, and width of the fabric, any shrinkage (take-up) filling ways, will not influence the weight of the cloth per yard. The previously referred to shrinkage of a fabric warp-ways will best be explained by an

*Example.*—A fabric from the loom 50 yards long weighs 14 ounces per yard. Less in oil, fibres, etc., during fulling and scouring 12 per cent. Fabric fulled up to 40 yards.

*Question.*—Find weight of cloth per yard after fulling.

50 yards length of cloth from loom.

× 14 ounces weight of cloth per yard from loom.

700 ounces total weight of the piece from loom; and

$100 : 88 :: 700 : x$

$\frac{88 \times 700}{100} = 616$ and

$616 \div 40$ (yards in finished fabric) $= 15.4$ ounces.

*Answer.*—15.4 ounces weight of cloth per yard after fulling.

The average loss in weight for woolen cloth, which is generally taken into consideration at calculations is thus; for ordinary goods allow about $\frac{1}{5}$ on the calculation weight which will bring a fabric of a total weight of 100 pounds from loom down to 80 pounds. For clear face finished cloth allow about $\frac{1}{4}$ on the calculation weight, hence a piece of cloth weighing 100 pounds from the loom will weigh 75 pounds finished. However, these weights will vary.

After picking out a sample of cloth, the student will find on pages 263–268 of "Technology of Textile Design," all the information necessary on the subject of "How to ascertain from a finished sample its texture required in loom; how to ascertain counts of yarn required, and the amount and direction of twist; how to ascertain the weight of cloth per yard from loom, etc."

## HOW TO TEST AND ANALYZE THE VARIOUS FINISHES OF COTTON GOODS.

The first to be done when required to ascertain how a fabric has been finished, is to examine the external or physical properties, since a practical eye can detect at once if the fabric in question has been simply calendered or glazed, or if starched on the reverse side, etc. By examining the fabric against the light, it is easy to observe whether it has been filled or not, besides a heavily weighted cloth will lose much of its stiffness by rubbing it between the fingers. If, in tearing the sample, a lot of dust flies off, this indicates a weighted finish; and by the aid of the microscope we can readily see whether the thickening is superficial or whether it has penetrated into the fabric, and if it contains mineral substances.

Next we must ascertain the amount of moisture the fabric contains by carefully weighing a sample of a known size, drying it in a stove until there can be no further loss of weight, then re-weighing the dried piece. The difference of weight is the amount of moisture in the cloth.

Although we cannot come to a conclusion as to the quality of the finish by this process, yet it is better to make it, since cellulose by itself is less hygrometric than wheat and other starches. If there be a great difference in the weight, this is a certain indication of the cloth being heavily starched.

To know exactly how much foreign matter a cloth contains, treat a large sample of the fabric with distilled water containing malt, let it disaggregate, wash afterwards and weigh. In this first experiment the difference in weight will indicate the quantity of foreign substances deposited on the fabric; but even after this treatment, certain insoluble soaps may still remain in the fabric and it is necessary to again boil in weak acid to remove all fatty matters. Weigh again to obtain the actual total loss, and, from the difference in weight, the percentage of dry finishing substances is determined. In testing printed or dyed goods, we must bear in mind that all colors are more or less attacked by acids.

The next process is to examine the components, and for which two operations are necessary; first treat with boiling water for a few hours, this removes the feculae, starches, thickenings, gums, soluble salts, alum, sulphates, chlorides, etc., and minerals or earthy matters; secondly, by filtering, separate the soluble from the insoluble substances. Soluble substances are detected in the following manner:—evaporate part of the liquid, treat a few drops with tincture of iodine, which will reveal starchy substances by turning blue; if no starch be found, again concentrate the whole and add two or three times its volume of alcohol, when glue, dextrine and gum are precipitated. Gelatine is detected by a tannin solution which precipitates it.

To distinguish gum from dextrine, use the Polariscope, when dextrine is diverted to the right, gum to the left. The mixture of the two can be sufficiently indicated by basic acetate of lead, which, when cold, precipitates gum, but not dextrine; when warm, both are precipitated; if no precipitation be obtained, but an organic substance be still shown by the incineration on the platinum blade, this indicates the presence of mosses, lichens, etc. Sugar is found by Fehling's liquor, before and after interversion; add to the tolerably concentrated aqueous liquor a few cubic centimetres of pure hydrochloric acid, ordinary concentration, warm in water bath, in an apparatus with reflux refrigerator and treat with copper solution.

If it is desired to examine still more closely the soluble mineral substances, recourse must be had to the usual methods of analytical chemistry.

In the residue insoluble in water, we again find the earthy matters, which it is unnecessary to examine closer, as generally the most economical are employed and China clay is one of the only substances which fulfils almost all the conditions and therefore is also the most frequently used; alabaster, gypsum and talc or French chalk, are also found in this residue.

If it is desired to detect resin, take a sample of the cloth, boil it with carbonate of soda, which dissolves the resin the presence of which is shown by the precipitate of sylvic acid obtained from the liquor when treated by an acid. The other fatty matters do not give any precipitate, but an oily fluid which swims on the surface of the liquor. Glycerine is found in the watery solution and can be detected, after the damping of the drying process by the acroleine reaction, which takes place after treating with sulphate of potash.

To ascertain the quantity of fatty matters contained in a certain finish, a second operation is performed by ether, which dissolves all fatty matters. After evaporation the weight of the residue expresses the quantity of fatty matter. An exact analysis of this mixture is not possible practically; we must be satisfied with treating with boiling water and thus ascertain that there are no soluble substances in the water.

In analysing the quality of a certain finish it is almost impossible to obtain the quantitative proportions: the various qualities of cloth requiring such varied treatment. The principal point is to know what substances are incorporated and this determination once made, it is for the practitioner to discover by preliminary experiments, the proportion of the various ingredients.

## THE BEST SIZE FOR COTTON GOODS

consists of:

*Farina* or flour.

*Chloride of magnesium* to give the necessary moisture and consequent suppleness and pliability to the warp.

*Chloride of Zinc* (Antiseptic) to prevent mildew in damp weather, consequent upon the necessary use of magnesium.

*Neutralized Fat* (in place of Tallow) to prevent the yarn from sticking to the cylinder and breaking in the opening rods. This neutralized fat mixes readily with the size and does not swim on top same as tallow or oil.

*Sizing Wax* (specially made to melt and dissolve in the size at a low temperature) used to smooth the yarn and lubricate the heddles and reed.

*Gum* (white) to give additional strength.

*China Clay* (or French chalk) for extra heavy weight.

*Size Glue* (Gelatine) or bone size, used for the purpose of fixing the other ingredients. The amount of each ingredient required is regulated by the kind of yarn used and cloth to be woven.

## TO ASCERTAIN THE PERCENTAGE OF SIZE

(or finish) in a piece of cotton cloth, weigh sample, then wash and dry it and weigh it again, and the difference represents the amount of size or finish in the sample.

*Example:*—Sample for testing 6″ × 6″ = 36□″ weighs 7.46 grains. After scouring and drying this sample weighs only 5.32 grains.

*Question:*—Ascertain percentage of size employed

5.32 : 7.46 : : 100 : x = 140.22

*i. e.* according to sample 100 pounds yarn have been sized to 140.22 pounds giving us

*Answer:*—The fabric requires 40 per cent. (actually 40.22 per cent.) sizing.

## SUBSTANCES USED IN FINISHING COTTON CLOTH.

*For Stiffening:*—Corn, wheat, rice, acorn, maize, barley, chestnut, potato or farina starches and diverse flours—Arrow-root, salep, sago, tapioca, linseed—Gums, dextrine, leiogomme, gelatine, isinglass, lichens, Iceland moss, algae, apparatim, dulcine, albumen, casein.

*For Softening:*—Glycerine, glucose, fatty matters, tallow, paraffin, stearine, spermaceti, cocoa-nut oil, soluble oil, olive oil, bees or Japan wax, soda ash, ammonia, chloride of calcium or zinc.

*For Weighting:*—Gypsum, plaster of Paris, chalk, Spanish clay, the sulphates of lime, baryta, magnesia, soda, zinc or lead, talc, china-clay, chloride of magnesia or barium, carbonate of barium, cellulose.

*For Coloring Size:*—Ultramarine, blues, pinks, violets, greens, Prussian blues, indigo blues, Paris blue, soluble indigo blue, aniline blues of all kinds, cobalt blues, indigo carmine, ammoniacal cochineal, black, grey and dark mineral matters, etc. Ochres of all colors.

*Antiseptics:*—Carbolic, salicylic, tannic, oxalic, boracic, formic, arsenic and arsenious acids, reosote, camphor, sulphate of zinc, chloride of zinc, borate of soda, alum, sulphate of alumina, chloride of sodium.

*To make Fabrics Water-proof:*—Greasy matters of all natures, resin, paraffin, tannic acid, drying oils, salts of alumina, alums, carbonate of magnesia.

*To render Fabrics Incombustible:*—Boracic acid, borax, phosphate of soda, lime or ammonia, carbonate of magnesia, alum, sulphate of soda or zinc, silicates in general, gypsum, salts of magnesia.

*To give Metalic Lustre:*—Sulphides of lead, silver, tin, antimony, etc. Bronze, silver, copper and gold powders, argentine, etc.

# COTTON SPINNING.

## Power Required to Drive the Various Machines in a Cotton Mill.

| | |
|---|---|
| Pickers | 6 to 8 horse power |
| Cards | 3 to 5 cards per horse power |
| Railway Head | ¾ to 1½ horse power |
| Drawing Frame | 4 to 6 deliveries per horse power |
| Coarse Speeder | 27 to 33 spindles per horse power |
| Intermediate Speeder | 37 to 50 spindles per horse power |
| Fine Speeder | 42 to 51 spindles per horse power |
| Slubber Fly Frame | 40 to 50 spindles per horse power |
| Intermediate Fly Frame | 70 to 80 spindles per horse power |
| Fine Fly Frame | 100 to 120 spindles per horse power |
| Ring Spindles, Common | 70 to 120 spindles per horse power |
| Ring Spindles, Sawyer | 90 to 130 spindles per horse power |
| Ring Spindles, Rabbeth | 70 to 90 spindles per horse power |
| Spooler | 250 to 400 spindles per horse power |
| Warper | 4 to 6 per horse power |
| Slasher | 1½ to 1¾ horse power |
| Loom | 4 to 6 looms per horse power |

## Speed of the Various Machines in a Cotton Mill.

| | Revs. per Min. | | Revs. per min. |
|---|---|---|---|
| Picker, Beater | 1,300 to 1,600 | Fine Fly Frames, Flyers | 1,100 |
| Picker, Fan | 1,400 to 1,700 | Ring Spindle, Common | 6,000 to 7,000 |
| Card, Cylinder | 120 to 150 | Ring Spindle, Sawyer | 7,000 to 7,800 |
| Railway Head, Front Roll | 400 to 500 | Ring Spindle, New Rabbeth, | 7,000 to 10,000 |
| Drawing Frame, Front Roll | 300 to 400 | Mule Spindles | 5,000 to 10,000 |
| Coarse Speeder, Flyer | 720 | Spooler Spindles | 700 to 900 |
| Intermediate Speeder, Flyer | 900 | Warper, Drum | 30 to 40 |
| Fine Speeder, Flyer | 1,250 | Slasher, Pulley | 350 to 400 |
| Slubber Fly Frame, Flyers | 600 | Looms on Prints | 170 to 190 |
| Intermediate Fly Frames, Flyers | 900 | Looms on Sheetings | 150 to 170 |

## Heat and Moisture Required for Good Cotton Spinning and Weaving.

*In Spinning* use 68° F with 65 per cent. moisture;
*In Weaving* use 68° F with 80 per cent. moisture.

## SLIVER TABLE.

| Grains Per Yard. | Number. | Grains Per Yard. | Number. | Grains Per Yard. | Number. | Grains Per Yard. | Number. |
|---|---|---|---|---|---|---|---|
| 120 | 0.069 | 86 | 0.097 | 66 | 0.126 | 52 | 0.160 |
| 110 | 0.076 | 83.3 | 0.100 | 62 | 0.134 | 50 | 0.167 |
| 102 | 0.082 | 82 | 0.103 | 60 | 0.139 | 45 | 0.185 |
| 98 | 0.085 | 78 | 0.107 | 58 | 0.144 | 40 | 0.208 |
| 94 | 0.089 | 74 | 0.113 | 56 | 0.148 | 35 | 0.238 |
| 90 | 0.093 | 70 | 0.119 | 54 | 0.154 | 30 | 0.278 |

## ROVING TABLE.

(This can be used with one or ten yards readily.)

| Grains Per Yard. | No. of Roving. | Grains Per Yard. | No. of Roving. | Grains Per Yard. | No. of Roving. | Grains Per Yard. | No. of Roving. |
|---|---|---|---|---|---|---|---|
| 83.33 | 0.10 | 6 41 | 1.3 | 2.38 | 3½ | 1.234 | 6¾ |
| 55.56 | 0 15 | 5.95 | 1.4 | 2.22 | 3¾ | 1.190 | 7 |
| 41.66 | 0.20 | 5.55 | 1.5 | 2.08 | 4 | 1 149 | 7¼ |
| 27.77 | 0 30 | 5.20 | 1.6 | 1.96 | 4¼ | 1.111 | 7½ |
| 20 83 | 0.40 | 4.90 | 1.7 | 1.85 | 4½ | 1.075 | 7¾ |
| 16.66 | 0.50 | 4.62 | 1.8 | 1 75 | 4¾ | 1.041 | 8 |
| 13.88 | 0.60 | 4 38 | 1.9 | 1.66 | 5 | 1.010 | 8¼ |
| 11.90 | 0.70 | 4.16 | 2 | 1.58 | 5¼ | 0 980 | 8½ |
| 10.41 | 0.80 | 3.70 | 2¼ | 1.51 | 5½ | 0.952 | 8¾ |
| 9 25 | 0.90 | 3.33 | 2½ | 1.44 | 5¾ | 0 925 | 9 |
| 8.33 | 1.00 | 3.03 | 2¾ | 1.38 | 6 | . . . | . . . |
| 7 57 | 1.10 | 2.77 | 3 | 1.33 | 6¼ | . . . | . . . |
| 6.94 | 1 20 | 2.56 | 3¼ | 1.28 | 6½ | . . . | . . . |

### Calculation for Yarns 20's to 26's from the Lap to the Yarn.

Lap 11 ounces per yard, sliver 54 grains per yard, will give draft on card about 89, including loss by waste.

In this example we will take three processes of drawing, leaving it optional whether we use two processes or three; some spinners only using two, especially when there are three frames following.

Doubling 6 and drawing 6 will produce the sliver at all the heads about the same weight, 54 grains or 0.154 hank. Product, 1000 pounds per delivery per week of 60 hours.

Draft in slubbing 4.0 and 54 grains drawing, will give 0.62 hanks slubbing. Product, 87 pounds per spindle per week.

Draft on intermediate 4.5 and 0.62 double slubbing will give 1.4 hank intermediate. Product 40 pounds per spindle per week.

Draft in roving 5.3 and 1.4 double intermediate will give 3.7 roving. Product, 12½ pounds per week.

Draft in spinning 7, from this roving will give 26's yarn.

Production of Ring Throstles 1⅜ to 1½ pounds per spindle per week.

Production of Self-acting Mule 1 pound to 1⅛ pounds per spindle per week.

### How to Ascertain the Capacity of a Carding Engine.

*Rule.*—Multiply the speed of the delivery roller by its circumference, which will give the inches turned off per minute; multiply this result by 60 (minutes per hour), then by 60 (hours worked per week), this result by 36 (inches in a yard), multiply this again by the weight of 1 yard of sliver, and the result equals the card's capacity.

### How to Find the Number of Carding Engines Required to Give Regular Supply of Cotton to Each Drawing Frame.

Multiply the inches taken in by the back roller per minute by the number of ends put up; and divide the product by the inches delivered by each carding engine per minute.

### How to Find the Quantity of Filleting Required to Cover a Card Cylinder or Doffer.

*Rule.*—Add the thickness of the filleting to the diameter of the cylinder or doffer, which total take for the diameter; then the circumference of the cylinder or doffer, multiplied by its length, and divided by the breadth of the filleting, will give the length required.

## Traveller Table for Spinning at Medium Speeds.

Such as 4,000 per minute for 10's counts of yarn; 5,000 for 12's; 5,500 for 14's; 6,000 for 16's; 6,500 for 20's; 7,000 24's; 7,500 for 30's; 8,500 for 40's; 9,000 for 50's.

| Counts of Yarn | Diam. of Rings 1 ½ in. Number of Traveler | Diam. of Rings 1¾ in. Number of Traveler | Counts of Yarn | Diam. of Rings 1½ in. Number of Traveler | Diam. of Rings 1¾ in. Number of Traveler |
|---|---|---|---|---|---|
| 10's require | 8's or 7's | 7's or 6's | 30's require | 3/0 or 4/0 | 4/0 or 5/0 |
| 11's " | 8's or 7's | 7's or 6's | 31's " | 3/0 or 4/0 | 4/0 or 5/0 |
| 12's " | 7's or 6's | 6's or 5's | 32's " | 4/0 or 5/0 | 5/0 or 6/0 |
| 13's " | 7's or 6's | 6's or 5's | 33's " | 4/0 or 5/0 | 5/0 or 6/0 |
| 14's " | 6's or 5's | 5's or 4's | 34's " | 5/0 or 6/0 | 6/0 or 7/0 |
| 15's " | 6's or 5's | 5's or 4's | 35's " | 5/0 or 6/0 | 6/0 or 7/0 |
| 16's " | 5's or 4's | 4's or 3's | 36's " | 6/0 or 7/0 | 7/0 or 8/0 |
| 17's " | 5's or 4's | 4's or 3's | 37's " | 6/0 or 7/0 | 7/0 or 8/0 |
| 18's " | 4's or 3's | 3's or 2's | 38's " | 7/0 or 8/0 | 8/0 or 9/0 |
| 19's " | 4's or 3's | 3's or 2's | 39's " | 7/0 or 8/0 | 8/0 or 9/0 |
| 20's " | 3's or 2's | 2's or 1's | 40's " | 8/0 or 9/0 | 9/0 or 10/0 |
| 21's " | 3's or 2's | 2's or 1's | 41's " | 8/0 or 9/0 | 9/0 or 10/0 |
| 22's " | 2's or 1's | 1's or 1/0 | 42's " | 9/0 or 10/0 | 10/0 or 11/0 |
| 23's " | 2's or 1's | 1's or 1/0 | 43's " | 9/0 or 10/0 | 10/0 or 11/0 |
| 24's " | 1's or 1/0 | 1/0 or 2/0 | 44's " | 10/0 or 11/0 | 11/0 or 12/0 |
| 25's " | 1's or 1/0 | 1/0 or 2/0 | 45's " | 10/0 or 11/0 | 11/0 or 12/0 |
| 26's " | 1/0 or 2/0 | 2/0 or 3/0 | 46's " | 11/0 or 12/0 | 12/0 or 13/0 |
| 27's " | 1/0 or 2/0 | 2/0 or 3/0 | 47's " | 11/0 or 12/0 | 12/0 or 13/0 |
| 28's " | 2/0 or 3/0 | 3/0 or 4/0 | 48's " | 12/0 or 13/0 | 13/0 or 14/0 |
| 29's " | 2/0 or 3/0 | 3/0 or 4/0 | 50's " | 13/0 or 14/0 | 14/0 or 15/0 |

NOTE.—When spinning long stapled cotton, such as Sea Island or Egyptian, a Traveler from four to six grades or numbers heavier than is shown in the above table may be used.

### To Calculate Loss of Twist in Ring Spinning.

The usual way of calculating loss of twist through the various dias. of the bobbin as it fills is as follows: Each coil of yarn deposited on the bobbins is equal to a loss of 1 turn in twist in that length of yarn constituting the coil. Let it be assumed that the yarn (20's) has 16.75 turns per inch according to roller and spindle speed.

Smallest circum. of bobbin 2½ inches × 16.75 turns = 1 turn lost in 41.87 turns.
Largest " " 4.75 inches × 16.75 " = 1 " " 79.56 "

Average mean loss . . . . = 1 " " 60.7 "

This calculation, however, is not correct, as the actual loss is more, and in order to get at the truth the layers of yarn deposited in one up and down motion of the ring rail must be measured and multiplied by the number of turns per inch, and the number of coils in the 2 layers of yarn must be counted, and divided into total number of turns. Thus, if the up motion of the ring rail deposits 72 inches of 20's yarn with 16.75 calculated turns per inch, then 72 × 16.75 = 1,206 ÷ 20 coils = 1.8 per cent. of loss, and if the down motion deposits 178 inches of yarn with 16.75 calculated turns, then 178 × 16.75 = 2,981.5 ÷ 46 coils = 1.6 per cent., or an average for one up and down motion of the ring rail of 1.7 per cent. Of course, the finer the yarn spun the less the percentage of loss in twist, as the rings are smaller and the difference between the diameter of empty and full bobbin is less, and the number of turns per inch is more.

### To Find the Percentage Cotton Yarn Contracts in Twisting.

*Rule.*—Divide the number of the yarn by the product of the draught and hank roving, and subtract the quotient from 1.

*Example.*—28's yarn spun from 4 hank rove, draught 7.25.

$$7.25 \times 4 = 29$$
$$28 \div 29 = 0.965$$
$$1.000 - 0.965 = 0.035$$

*Answer.*—The contraction in length amounts to 3½ per cent.

### How to Ascertain the Number of Yards of Cotton Yarn on a Bobbin.

*Rule.*—Multiply circumference of front roll (inches) with the number of revolutions per minute, and the product by time (minutes) required to fill the bobbin; divide by 36 and deduct the contraction in twisting, the result being the amount (number of yards) of yarn on the bobbin.

### TWIST TABLE.

| Counts. | Extra Warp Twist. | Warp Twist. | Extra Mule Twist. | Mule Twist. | Filling Twist. | Twist for Doubling. | Twist for Hosiery Yarn. |
|---|---|---|---|---|---|---|---|
| 1 | **4.75** | **4.50** | **4.00** | **3.75** | **3.25** | **2.75** | **2.50** |
| 2 | 6 72 | 6.36 | 5.66 | 5.30 | 4.60 | 3.88 | 3 53 |
| 3 | 8.23 | 7 79 | 6.93 | 6.50 | 5 63 | 4.76 | 4.33 |
| 4 | 9 50 | 9.00 | 8.00 | 7.50 | 6.50 | 5.50 | 5.00 |
| 5 | 10.62 | 10.06 | 8.94 | 8 39 | 7.27 | 6.14 | 5.59 |
| 6 | 11.64 | 11.02 | 9.80 | 9 19 | 7 96 | 6 73 | 6.12 |
| 7 | 12.57 | 11.91 | 10.58 | 9.92 | 8.60 | 7.27 | 6 61 |
| 8 | 13 44 | 12.73 | 11.31 | 10.61 | 9 19 | 7.77 | 7.07 |
| 9 | 14.25 | 13 50 | 12.00 | 11.25 | 9.75 | 8.25 | 7 50 |
| 10 | 15 02 | 14.23 | 12.65 | 11.86 | 10 28 | 8.79 | 7 90 |
| 11 | 15.75 | 14.92 | 13.27 | 12.44 | 10.78 | 9.12 | 8 29 |
| 12 | 16 45 | 15 59 | 13 86 | 12.99 | 11 26 | 9.52 | 8 66 |
| 13 | 17 13 | 16.22 | 14.42 | 13.52 | 11.72 | 9.91 | 9 01 |
| 14 | 17.77 | 16.84 | 14.97 | 14.03 | 12.16 | 10.28 | 9 35 |
| 15 | 18.40 | 17.43 | 15 49 | 14.52 | 12 59 | 10.65 | 9.68 |
| 16 | 19 00 | 18.00 | 16.00 | 15.00 | 13 00 | 11.00 | 10.00 |
| 17 | 19 58 | 18.55 | 16.49 | 15.46 | 13.40 | 11.33 | 10.30 |
| 18 | 20.15 | 19 09 | 16.97 | 15 91 | 13.79 | 11.66 | 10.60 |
| 19 | 20 70 | 19.62 | 17.44 | 16.35 | 14 17 | 11.98 | 10 89 |
| 20 | 21.24 | 20.12 | 17.89 | 16.77 | 14 53 | 12.29 | 11 18 |
| 22 | 22.28 | 21.11 | 18 76 | 17 59 | 15.24 | 12.89 | 11.72 |
| 24 | 23 27 | 22.05 | 19 60 | 18 37 | 15.92 | 13.47 | 12.24 |
| 26 | 24.22 | 22 95 | 20.40 | 19.12 | 16.57 | 14.02 | 12 74 |
| 28 | 25 13 | 23 81 | 21.17 | 19 84 | 17.2[illegible] | 14.55 | 13 22 |
| 30 | 26 02 | 24.65 | 21 91 | 20.54 | 17 8[illegible] | 15.06 | 13.69 |
| 32 | 26 87 | 25.46 | 22.63 | 21 21 | 18 38 | 15.56 | . . . |
| 34 | 27.70 | 26.24 | 23.32 | 21 87 | 18.95 | 16.03 | . . . |
| 36 | 28.50 | 27.00 | 24 00 | 22 50 | 19.50 | 16.50 | . . . |
| 38 | 29.28 | 27.74 | 24.66 | 23 12 | 20.03 | 16.95 | . . . |
| 40 | 30 04 | 28.46 | 25.30 | 23.72 | 20.55 | 17.39 | . . . |
| 45 | 31.86 | 30.19 | 26.83 | 25.16 | 21.80 | 18 44 | . . . |
| 50 | 33.59 | 31 82 | 28.28 | 26.52 | 22.98 | 19 44 | . . . |
| 60 | 36.79 | 34.86 | 30.98 | 29.05 | 25.17 | 21.30 | . . . |
| 70 | 39.74 | 37.65 | 33.47 | 31.37 | 27.19 | 23 00 | . . . |
| 80 | 42 49 | 40.25 | 35.78 | 33 54 | 29 07 | 24 59 | . . . |
| 90 | 45 06 | 42.69 | 37.95 | 35 58 | 30 83 | 26.08 | . . . |
| 100 | 47.50 | 45.00 | 40.00 | 37.50 | 32.50 | 27 50 | . . . |
| 120 | 52.03 | 49.30 | 43.82 | 41.08 | 35.60 | 30.12 | . . . |
| 130 | 54.16 | 51.31 | 45 61 | 42.76 | 37.06 | 31 35 | . . . |
| 140 | 56.20 | 53 24 | 47 33 | 44.37 | 38.45 | 32 54 | . . . |
| 160 | 60.08 | 56.91 | 50.59 | 47.43 | 41.10 | 34 78 | . . . |
| 180 | 63.72 | 60.37 | 53.66 | 50.31 | 43.60 | 36.89 | . . . |
| 200 | 67 17 | 63 63 | 56 56 | 53.03 | 45.96 | 38.89 | . . . |

## DRAPER'S TABLE OF THE BREAKING WEIGHT OF AMERICAN COTTON WARP YARNS PER SKEIN.

(Weight given in pounds and tenths.)

| No. | Breaking Weight. | No. | Breaking Weight. | No. | Breaking Weight. | No. | Breaking Weight. | No. | Breaking Weight. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | . . . | 21 | 83 8 | 41 | 43.8 | 61 | 31.3 | 81 | 24.3 |
| 2 | . . . | 22 | 79.7 | 42 | 43.0 | 62 | 30.8 | 82 | 24.0 |
| 3 | 530.0 | 23 | 75.9 | 43 | 42.2 | 63 | 30.4 | 83 | 23.7 |
| 4 | 410 0 | 24 | 72.4 | 44 | 41.4 | 64 | 30.0 | 84 | 23.4 |
| 5 | 330.0 | 25 | 69 2 | 45 | 40.7 | 65 | 29.6 | 85 | 23 2 |
| 6 | 275.0 | 26 | 66.3 | 46 | 40.0 | 66 | 29.2 | 86 | 22.8 |
| 7 | 237.6 | 27 | 63.6 | 47 | 39.3 | 67 | 28 8 | 87 | 22 6 |
| 8 | 209.0 | 28 | 61.3 | 48 | 38.6 | 68 | 28 5 | 88 | 22.4 |
| 9 | 186.5 | 29 | 59.2 | 49 | 37.9 | 69 | 28.2 | 89 | 22.2 |
| 10 | 168.7 | 30 | 57.3 | 50 | 37.3 | 70 | 27.8 | 90 | 22.0 |
| 11 | 154 1 | 31 | 55.6 | 51 | 36.6 | 71 | 27.4 | 91 | 21.7 |
| 12 | 142.0 | 32 | 54.0 | 52 | 36 1 | 72 | 27 1 | 92 | 21.5 |
| 13 | 131.5 | 33 | 52.6 | 53 | 35 5 | 73 | 26.8 | 93 | 21.3 |
| 14 | 122.8 | 34 | 51.2 | 54 | 34.9 | 74 | 26.5 | 94 | 21.2 |
| 15 | 115.1 | 35 | 50.0 | 55 | 34.4 | 75 | 26.2 | 95 | 21.0 |
| 16 | 108.4 | 36 | 48.7 | 56 | 33.8 | 76 | 25.8 | 96 | 20.7 |
| 17 | 102.5 | 37 | 47.6 | 57 | 33.4 | 77 | 25.5 | 97 | 20.5 |
| 18 | 97.3 | 38 | 46.5 | 58 | 32.8 | 78 | 25.3 | 98 | 20.4 |
| 19 | 92.6 | 39 | 45.5 | 59 | 32.3 | 79 | 24.9 | 99 | 20.2 |
| 20 | 88.3 | 40 | 44.6 | 60 | 31.7 | 80 | 24.6 | 100 | 20.0 |

### Table Giving the Amount of Twist for the Various Kinds of Twisted Yarn.

| Number of Yarn to be Twisted | 2 Ply | 3 Ply | 4 Ply | 5 Ply | 6 Ply | Number of Yarn to be Twisted | 2 Ply | 3 Ply | 4 Ply | 5 Ply | 6 Ply | Number of Yarn to be Twisted | 2 Ply | 3 Ply | 4 Ply | 5 Ply | 6 Ply |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 2.83 | 2 30 | 2.00 | 1.79 | 1.65 | **25** | 14.14 | 11.54 | 10.00 | 8.94 | 8.17 | **49** | 19 80 | 16.16 | 14.00 | 12.52 | 11.43 |
| **2** | 4.00 | 3.28 | 2.83 | 2.53 | 2 30 | **26** | 14 42 | 11.78 | 10 20 | 9 12 | 8.32 | **50** | 20.00 | 16.33 | 14.14 | 12.65 | 11.54 |
| **3** | 4 90 | 4.00 | 3.46 | 3.10 | 2.83 | **27** | 14.70 | 12.00 | 10.39 | 9.30 | 8.48 | **51** | 20 20 | 16.49 | 14 28 | 12.78 | 11.66 |
| **4** | 5 66 | 4.61 | 4.00 | 3 58 | 3 28 | **28** | 14.96 | 12.22 | 10 58 | 9.46 | 8 64 | **52** | 20.40 | 16 65 | 14.42 | 12 90 | 11 78 |
| **5** | 6 32 | 5.17 | 4.47 | 4.00 | 3.64 | **29** | 15.23 | 12.44 | 10.77 | 9 63 | 8.79 | **53** | 20 59 | 16.82 | 14.56 | 13 02 | 11.89 |
| **6** | 6 93 | 5.66 | 4 90 | 4 38 | 4.00 | **30** | 15.49 | 12.65 | 10.96 | 9.80 | 8 94 | **54** | 20 78 | 16.97 | 14 70 | 13 14 | 12.00 |
| **7** | 7 48 | 6.10 | 5.29 | 4.73 | 4.33 | **31** | 15.75 | 12.86 | 11.14 | 9.96 | 9.10 | **55** | 20.98 | 17 12 | 14 83 | 13 26 | 12 11 |
| **8** | 8.00 | 6.54 | 5 66 | 5.06 | 4.61 | **32** | 16 00 | 13.06 | 11.31 | 10.12 | 9.24 | **56** | 21.16 | 17.28 | 14 96 | 13 39 | 12 22 |
| **9** | 8 48 | 6.93 | 6.00 | 5.37 | 4.90 | **33** | 16.25 | 13.26 | 11.49 | 10 28 | 9.38 | **57** | 21.36 | 17.43 | 15 10 | 13.50 | 12 33 |
| **10** | 8.94 | 7.30 | 6.32 | 5.66 | 5.17 | **34** | 16 49 | 13.46 | 11.66 | 10.43 | 9 52 | **58** | 21.54 | 17.59 | 15.23 | 13.62 | 12 44 |
| **11** | 9.38 | 7 66 | 6.63 | 5.93 | 5.41 | **35** | 16.73 | 13.66 | 11 83 | 10.58 | 9.66 | **59** | 21.72 | 17.74 | 15.36 | 13 74 | 12 54 |
| **12** | 9.80 | 8.00 | 6.93 | 6.20 | 5.66 | **36** | 16.97 | 13.86 | 12 00 | 10.73 | 9.80 | **60** | 21.91 | 17.89 | 15 49 | 13 86 | 12 65 |
| **13** | 10.20 | 8 32 | 7 21 | 6 45 | 5 89 | **37** | 17 20 | 14.04 | 12.16 | 10.88 | 9.94 | **61** | 22 09 | 18.04 | 15 62 | 13 97 | 12.76 |
| **14** | 10.58 | 8 64 | 7.48 | 6.69 | 6 10 | **38** | 17.43 | 14.24 | 12 33 | 11.03 | 10.06 | **62** | 22.27 | 18 18 | 15.75 | 14.08 | 12.86 |
| **15** | 10 96 | 8.94 | 7.75 | 6.93 | 6.32 | **39** | 17.66 | 14.42 | 12 49 | 11.17 | 10.20 | **63** | 22 45 | 18 33 | 15 88 | 14 20 | 12.96 |
| **16** | 11.31 | 9 24 | 8 00 | 7 16 | 6 54 | **40** | 17.89 | 14 60 | 12.65 | 11 31 | 10 33 | **64** | 22.62 | 18 47 | 16.00 | 14.31 | 13 06 |
| **17** | 11.66 | 9.52 | 8.25 | 7.38 | 6.73 | **41** | 18 11 | 14 79 | 12 81 | 11.46 | 10 45 | **65** | 22.80 | 18.62 | 16 12 | 14.42 | 13 16 |
| **18** | 12.00 | 9 80 | 8 48 | 7.59 | 6.93 | **42** | 18 33 | 14.96 | 12 96 | 11.59 | 10.58 | **66** | 22 98 | 18 76 | 16.25 | 14 53 | 13.26 |
| **19** | 12 33 | 10.06 | 8 72 | 7 80 | 7.12 | **43** | 18.55 | 15.14 | 13.12 | 11 73 | 10.71 | **67** | 23.15 | 18 90 | 6.37 | 14.64 | 13 37 |
| **20** | 12.65 | 10.33 | 8.94 | 8 00 | 7 30 | **44** | 18.76 | 15.32 | 13 26 | 11.87 | 10.83 | **68** | 23.32 | 19 04 | 16 49 | 4 75 | 13.46 |
| **21** | 12.96 | 10.58 | 9.16 | 8.20 | 7 48 | **45** | 18.97 | 15.49 | 13.42 | 12.00 | 10.96 | **69** | 23 50 | 19 18 | 16 61 | 14 86 | 13 56 |
| **22** | 13 26 | 10 83 | 9.38 | 8 39 | 7.66 | **46** | 19 18 | 15 66 | 13.56 | 12.13 | 11.08 | **70** | 23.66 | 19 32 | 16 73 | 14.96 | 13.66 |
| **23** | 13 56 | 11.08 | 9.59 | 8 58 | 7.83 | **47** | 19.39 | 15.84 | 13.71 | 12.26 | 11.19 | **71** | 23.83 | 19.46 | 16.85 | 15.07 | 13.76 |
| **24** | 13 86 | 11.31 | 9.80 | 8 76 | 8 00 | **48** | 19.59 | 16 00 | 13 86 | 12.39 | 11.31 | **72** | 24 00 | 19 59 | 16.97 | 15.18 | 13 86 |

### Production of Drawing Frames.

The front rollers of these frames vary from 1¼ to 1⅜ inches; 1⅜ inches diameter is taken; this with 60 grains sliver will produce in 60 hours as follows:

| Front Roller, 1⅜ inches. | | Front Roller, 1⅜ inches. | |
|---|---|---|---|
| Revolutions per minute. | Production, 60 hours. | Revolutions per minute. | Production, 60 hours. |
| 300 | 1,000 lbs. | 360 | 1,200 lbs. |
| 320 | 1,065 lbs. | 380 | 1,265 lbs. |
| 340 | 1,135 lbs. | 400 | 1,335 lbs. |

Lighter or heavier slivers in proportion.

## Table Giving Production per Spindle for Warp and Filling Yarn from 4's to 60's.

| Number of Yarn. | Warp Yarn Ring Frame. Revolutions per minute of Front Rolls. | Warp Yarn Ring Frame. Revolutions per minute of Spindle. | Warp Yarn Ring Frame. Production :—Pounds per Spindle per day. | Filling Yarn Ring Frame. Revolutions per minute of Front Roll. | Filling Yarn Ring Frame. Revolutions per minute of Spindle. | Filling Yarn Ring Frame. Production :—Pounds per Spindle per day. | Filling Yarn Mule. Stratches per minute 65 inches each. | Filling Yarn Mule. Hanks per day per Spindle. | Filling Yarn Mule. Production : Pounds per Spindle per day. | Number of Yarn. |
|---|---|---|---|---|---|---|---|---|---|---|
| 4 | 155.0 | 4600 | 2.160 | 169.1 | 3400 | 2.305 | 4.610 | 5.322 | 1.330 | 4 |
| 5 | 153.5 | 5100 | 1.716 | 168.0 | 3775 | 1.835 | 4.575 | 5.291 | 1.058 | 5 |
| 6 | 152.0 | 5600 | 1.418 | 166.6 | 4100 | 1.520 | 4.540 | 5.260 | .866 | 6 |
| 7 | 150.4 | 5900 | 1.205 | 165.5 | 4400 | 1.297 | 4.505 | 5.229 | .747 | 7 |
| 8 | 148.9 | 6300 | 2.043 | 163.6 | 4650 | 1.124 | 4.470 | 5.198 | .650 | 8 |
| 9 | 147.4 | 6600 | .921 | 162.5 | 4900 | .994 | 4.435 | 5.166 | .574 | 9 |
| 10 | 145.9 | 6990 | .822 | 160.5 | 5100 | .885 | 4.400 | 5.134 | .513 | 10 |
| 11 | 144.3 | 7100 | .741 | 159.0 | 5300 | .799 | 4.365 | 5.102 | .464 | 11 |
| 12 | 142.8 | 7400 | .673 | 158.0 | 5500 | .729 | 4.330 | 5.071 | .423 | 12 |
| 13 | 141.3 | 7600 | .616 | 157.3 | 5700 | .671 | 4.295 | 5.038 | .388 | 13 |
| 14 | 139.7 | 7800 | .566 | 155.6 | 5850 | .618 | 4.260 | 5.006 | .358 | 14 |
| 15 | 138.2 | 8000 | .524 | 154.2 | 6000 | .573 | 4.225 | 4.974 | .332 | 15 |
| 16 | 136.7 | 8200 | .486 | 151.7 | 6100 | .529 | 4.190 | 4.941 | .309 | 16 |
| 17 | 135.1 | 8300 | .453 | 149.6 | 6200 | .492 | 4.155 | 4.908 | .289 | 17 |
| 18 | 133.6 | 8500 | .424 | 147.8 | 6300 | .460 | 4.120 | 4.876 | .271 | 18 |
| 19 | 132.1 | 8600 | .398 | 146.1 | 6400 | .432 | 4.085 | 4.843 | .255 | 19 |
| 20 | 130.6 | 8700 | .374 | 144.6 | 6500 | .407 | 4.050 | 4.810 | .241 | 20 |
| 21 | 129.0 | 8800 | .353 | 143.3 | 6600 | .385 | 4.015 | 4.776 | .227 | 21 |
| 22 | 127.5 | 8900 | .333 | 142.1 | 6700 | .365 | 3.980 | 4.743 | .216 | 22 |
| 23 | 126.0 | 9000 | .315 | 139.0 | 6700 | .342 | 3.945 | 4.709 | .205 | 23 |
| 24 | 124.4 | 9100 | .299 | 136.1 | 6700 | .321 | 3.910 | 4.676 | .195 | 24 |
| 25 | 122.9 | 9200 | .284 | 135.3 | 6800 | .307 | 3.875 | 4.642 | .186 | 25 |
| 26 | 121.4 | 9200 | .270 | 134.6 | 6900 | .295 | 3.840 | 4.608 | .178 | 26 |
| 27 | 119.8 | 9300 | .257 | 132.1 | 6900 | .279 | 3.805 | 4.574 | .169 | 27 |
| 28 | 118.3 | 9300 | .245 | 130.7 | 6950 | .266 | 3.770 | 4.539 | .162 | 28 |
| 29 | 116.8 | 9400 | .234 | 128.4 | 6950 | .253 | 3.735 | 4.505 | .155 | 29 |
| 30 | 115.3 | 9400 | .224 | 126.2 | 6950 | .241 | 3.700 | 4.470 | .149 | 30 |
| 31 | 113.7 | 9400 | .214 | 125.1 | 7000 | .232 | 3.665 | 4.435 | .143 | 31 |
| 32 | 112.2 | 9500 | .205 | 123.1 | 7000 | .221 | 3.630 | 4.401 | .138 | 32 |
| 33 | 110.7 | 9500 | .196 | 121.2 | 7000 | .212 | 3.595 | 4.366 | .132 | 33 |
| 34 | 109.1 | 9500 | .188 | 119.4 | 7000 | .203 | 3.560 | 4.331 | .127 | 34 |
| 35 | 107.6 | 9500 | .181 | 117.7 | 7000 | .195 | 3.525 | 4.295 | .123 | 35 |
| 36 | 106.1 | 9500 | .173 | 116.1 | 7000 | .187 | 3.490 | 4.260 | .118 | 36 |
| 37 | 104.5 | 9500 | .166 | 115.3 | 7050 | .181 | 3.455 | 4.224 | .114 | 37 |
| 38 | 103.0 | 9500 | .160 | 114.6 | 7100 | .175 | 3.420 | 4.188 | .110 | 38 |
| 39 | 101.5 | 9500 | .154 | 113.1 | 7100 | .169 | 3.385 | 4.152 | .107 | 39 |
| 40 | 100.0 | 9500 | .148 | 112.5 | 7150 | .164 | 3.350 | 4.116 | .103 | 40 |
| 42 | 98.0 | 9500 | .138 | 110.5 | 7200 | .154 | 3.280 | 4.044 | .096 | 42 |
| 44 | 96.0 | 9500 | .130 | 108.0 | 7200 | .144 | 3.210 | 3.971 | .090 | 44 |
| 46 | 94.0 | 9500 | .122 | 105.6 | 7200 | .135 | 3.140 | 3.897 | .085 | 46 |
| 48 | 82.0 | 9500 | .115 | 103.4 | 7200 | .128 | 3.070 | 3.823 | .080 | 48 |
| 50 | 90.0 | 9600 | .108 | 101.3 | 7200 | .120 | 3.000 | 3.748 | .075 | 50 |
| 52 | 89.0 | 9600 | .103 | 100.7 | 7300 | .115 | 2.930 | 3.672 | .070 | 52 |
| 54 | 88.0 | 9600 | .099 | 98.8 | 7300 | .110 | 2.860 | 3.597 | .066 | 54 |
| 56 | 87.0 | 9600 | .094 | 97.0 | 7300 | .104 | 2.790 | 3.520 | .062 | 56 |
| 58 | 86.0 | 9800 | .090 | 95.4 | 7300 | .099 | 2.720 | 3.421 | .059 | 58 |
| 60 | 85.0 | 9800 | .086 | 93.8 | 7300 | .094 | 2.650 | 3.364 | .056 | 60 |

## Production of Cards at Various Speeds with Various Weights of Slivers.

| Speed of Doffer. | Production in lbs. in 60 hours. 60 grs. Sliver. | 55 grs. Sliver. | 50 grs. Sliver. |
|---|---|---|---|
| 10 revolutions | 665 | 610 | 555 |
| 11 " | 730 | 670 | 610 |
| 12 " | 800 | 730 | 665 |
| 13 " | 865 | 790 | 720 |
| 14 " | 930 | 850 | 775 |
| 15 " | 1,000 | 915 | 835 |
| 16 " | 1,065 | 975 | 890 |
| 17 " | 1,130 | 1,035 | 940 |
| 18 " | 1,200 | 1,100 | 1,000 |

With slivers of other weights the production will be relative.

# SPEED, BELTING, POWER, ETC.

## SPEED.

### How to Find the Circumference of a Circle, or of a Pulley.

*Rule.*—Multiply the diameter by 3.1416; or as 7 is to 22 so is the diameter to the circumference.

### How to Compute the Diameter of a Circle, or of a Pulley.

*Rule.*—Divide the circumference by 3.1416; or multiply the circumference by .3183; or as 22 is to 7 so is the circumference to the diameter.

### How to Compute the Area of a Circle.

*Rule.*—Multiply the circumference by one-quarter of the diameter; or multiply the square of the diameter by .7854; or multiply the square of the circumference by .07958; or multiply half the circumference by half the diameter; or multiply the square of half the diameter by 3.1416.

**How to Determine the Speed of a Driven Shaft** when the speed of a driving shaft or wheel and the size of the gearing transmitting the power is given.

*Rule.*—Multiply the speed of the first driving shaft by the size of the driving wheel or wheels, and divide by the size of the driven wheel or wheels.

*Example.*—A line shaft in a weave room revolves 120 times per minute, and carries pulley 12 inches in diameter. The looms driven by them carry pulleys 10 inches in diameter.

*Question.*—Find the speed of the looms?

*Answer.*—The speed of the looms is $\frac{120 \times 12}{10} = 144$ revolutions.

The term *size of the wheel* in before given rule includes either the number of teeth, diameter, radius, or pitch circle, and refers equally to bevel and other cog-wheels or rope or strap driving.

**A Pair of Mitre Wheels** are bevels which have the same number of teeth, and which reverse the direction of the motion, consequently make no change in the speed.

**How to Compute the Velocities,** etc., of toothed gears. The relative velocities of gears is as the number of their teeth.

Where *idle* or intermediate gears intervene they are not reckoned.

**The Pitch of a Gear** is the distance apart of the teeth from each other, and gears of unequal pitch cannot run together.

**Bevel Gears** are employed for shafts fixed at various angles, and running at different velocities, governed by the respective bevels, which may vary in size, as with spur gearing.

N. B.—These rules are practically correct. Though, owing to the slip, elasticity, and thickness of the belt, the circumference of the driven seldom runs as fast as the driver.

Belts, like gears, have a pitch-line, or a circumference of uniform motion. This circumference is within the thickness of the belt, and must be considered if pulleys differ greatly in diameter, and a required speed is absolutely necessary.

In computing the velocities of gear-wheels their diameters on the pitch line may be taken instead of the number of their teeth.

**The Pitch Line** of a gear is a circle struck from the centre, and passing through the middle of the teeth. It defines the diameter of a gear, which is not, as many suppose, the whole distance across from point to point of teeth, but half way from bottom to top of teeth.

**To Measure the Diameter of a Gear** it is only necessary to take the distance from the bottom of the teeth on one side to the top of the teeth on the opposite side of the gear.

**To Ascertain the Pitch of a Gear.**—Find the diameter as above, then count the teeth, and divide their number by the diameter.

*Example.*—If a gear of 21 teeth measures 3 inches diameter on the pitch line, then the gear is 7 pitch.

**Driving-Driven.**—The manner of describing the driving wheel must also be applied to the driven. If the diameter of the driving wheel be taken, we must also use the diameter for the driven wheel, and neither the radius or circumference.

*Example 1.*—An engine has a driving wheel 20 feet in diameter, revolving 40 times per minute, which drives, by means of ropes, a pulley on the second motion shaft 2 feet in radius.

*Question.*—Ascertain the speed of the second motion shaft?

Two feet radius = 4 feet diameter, thus: 40 × 20 feet ÷ 4 = 200.

*Answer.*—200 revolutions speed of the second motion shaft per minute.

*Example 2.*—Speed of under shaft of a loom 80, the same carries a 10-teeth bevel, which gears with a 10 on an upright shaft at the top of which a 32-teeth wheel on a block of tappet wheels, is driven by an 8.

*Question.*—Find the speed at which they revolve?

80 × first driver, 10 × second driver, 8 ÷ first driven 10 and second driven 32.

80 × 10 = 800 × 8 = 6400 ÷ 10 = 640 ÷ 32 = 20.

*Answer.*—20 revolutions per minnte.

**How to Distinguish the Driver from the Driven Wheel.**—If the gearing is in motion a glance will usually suffice to show this, since if a wheel is bright or worn on the front of the tooth, *i. e.*, on the side in the direction of which the wheel is moving, it is the driver; whereas the driven wheel is worn on the side of the tooth further from the direction of motion. With reference to bands or straps, one side of the band or strap is always tighter than the other since the driver is doing the pulling.

**How to Find the Speed of the Driving Wheel,** when the speed of the last driven wheel and the size of the gearing are known.

*Rule.*—Multiply the speed of the last driven wheel by the size of the driven wheels and divide by the size of the drivers.

*Example.*—A spindle revolving 1,500 times per minute, is driven from a line shaft by a 30 inch drum to a 10 inch pulley, which is fixed to a 10 inch tin roller driving the 1¼ inch wharve of the spindle.

*Question.*—Ascertain speed at which the line shaft will revolve?

The drivers being 30 and 10, and the driven 10 and 1¼.

1500 × 10 × 1¼ = 18750.

18750 ÷ 30 = 625 ÷ 10 = 62.5.

*Answer.*—62½ revolutions per minute speed of line shaft.

**How to Obtain the Size of the Driving Wheel** the speed of the driven and driving shaft and the size of the driven pulleys being given.

*Rule.*—Multiply the speed of the driven by the size of the driven pulleys, and divide by the speed of the driver.

*Example.*—A shaft having a speed of 125 per minute, drives another at 100 per minute, on which is a 40-tooth bevel wheel.

*Question.*—Ascertain the size of a bevel wheel on the driving shaft?

$$100 \times 40 \div 125 = 32,$$

*Answer.*—The bevel wheel on driving shaft has 32 teeth.

**How to Obtain the Size of the Driven Wheel** if the speed of the driver and driven wheel or wheels are given and also the size of the driver.

*Rule.*—Multiply the size of the drivers by the speed of the first driver, and divide by the speed of the driven, and by the driven pulleys given, if any.

*Example.*—A shaft making 17 revolutions per minute carries a 15-tooth wheel, which drives a second shaft by means of a wheel the number of teeth in which it is desired to find. On this shaft is a 120-tooth wheel driving one of 64 teeth, which latter revolves at 16 revolutions per minute.

*Question.*—Required the size of the first driven wheel?

Drivers 15 and 120. Driven 64.

$120 \times 15 \times 17 \div 15 \div 64 = 30.$

*Answer.*—30 teeth required in wheel.

**Worm Wheels.**—As drivers only are usually single threaded and are equal to one tooth as a multiplier of speed, worm wheels are used to rapidly diminish speed.

*Example.*—A worm wheel revolving 750 times per minute, drives a 150-tooth wheel.

*Question.*—What is the speed of the latter?

*Answer.*—$750 \times 1 \div 150 = 5$ revolutions per minute.

If the worm wheel had been double-threaded it would have taken two teeth at one revolution, and the result would have been 10, obtained thus: $750 \times 2 \div 150 = 10.$

**A Mangle Wheel** is a driven wheel only, and is used to reverse its own direction of motion. The speed for it is calculated as for an ordinary wheel, but since the tooth at each end is used only once in a double revolution, (all the others being used twice) its size is taken as one tooth less than it actually is.

*Example.*—A 12 pinion revolving 350 times in a minute, drives a mangle wheel of 140 teeth or pegs.

*Question.*—How many times will the mangle revolve in a minute?

$350 \times 12 \div 140 = 30.$

*Answer.*—30 revolutions (equalling 15 in each direction) speed of mangle in a minute.

### How to Change the Speed of a Driven Pulley, Shaft or Wheel.

*Rule.*—Increase the size of the driver or decrease the size of the driven pulley in exact proportion to the increase of speed required.

### To Increase the Speed by Increasing the Size of the Driver.

*Example.*—A loom now running at 85 picks per minute is required to be changed to 95 picks; the diameter of the present driving pulley on the line shaft of the weave room is 15 inches.

*Question.*—Find size of new pulley required?
$95 \times 15 \div 85 = 16\frac{1}{1}$.
*Answer.*—Size of new pulley required $16\frac{13}{17}$.

### To Increase the Speed by Decreasing the Size of Driven Wheel.

*Example.*—The cams of a loom being set for eight-harness twill, it is desired to weave a six-harness twill, thus increasing the speed of the shaft carrying the cams in the proportion of 6 to 8. The driven wheel on the shaft being an 80.

*Question.*—To what size must the driven wheel on the shaft be reduced?
$80 \times 6 \div 8 = 60$.
*Answer.*—The driven wheel must be changed to a 60.

### How to Ascertain the Circumferential Velocity of a Wheel, Driver or Cylinder.

*Rule.*—Multiply the circumference in feet by the number of revolutions per minute.
*Example.*—A roller has a circumference of 4 feet and makes 12 revolutions per minute.
*Question.*—Ascertain its circumferential velocity?
$4 \times 12 = 48$.
*Answer.*—Its circumferential velocity is 48 feet.

**How to Find the Speed of Last Shaft** where several shafts and pulleys intervene.

*Rule.*—Multiply all the drivers into each other and the product by the speed of the first shaft, divide this product by the product of all the given pulleys multiplied into each other.

**How to Ascertain the Number of Revolutions of the Last Wheel** at the **End of a Train of Spur Wheels,** all of which are in a line and mesh into one another.

*Rule.*—Multiply the revolutions of the first wheel by its number of teeth, and divide the product by the number of teeth of the last wheel; the result is its number of revolutions.

**How to Ascertain the Number of Teeth in Each Wheel for a Train of Spur-Wheels,** each to have a given velocity.

*Rule.*—Multiply the number of revolutions of the driving wheel by its number of teeth, and divide the product by the number of revolutions each wheel is to make, to ascertain the number of teeth required for each.

**How to Find the Number of Revolutions of the Last Wheel of a Train of Wheels,** and pinions, spurs, or bevels, when the revolutions of the first, or driver, and the diameter, or the number of teeth, or circumference of all the drivers and pinions, are given.

*Rule.*—Multiply the diameter, the circumference, or the number of the teeth of all the driving wheels together, and this continued product by the number of revolutions of the first wheel, and divide this product by the continued product of the diameter, the circumference, or the number of teeth of all the pinions, and the quotient will be the number of revolutions of the last wheel.

**How to Straighten a Crooked Shaft.**—Set the shaft on the blocks at each end, and under the hollow side make a fire, or apply sufficient heat to make the shaft hot. Now, with a swab, put water on the top, and the contraction will, by repeated operations, finally straighten the shaft.

**How to Cool a Hot Shaft.**—Make a belt of something of a loose, water-absorbing nature, and hang it over the shaft as near the hot journal as possible, allowing it to hang down and run loose on the shaft. A pail of water may now be fixed so the lower part of the belt will run in it, and in this simple way the shaft may be cooled while running.

Another method consists in the use of black antimony and best castor oil; you may, if you like, add a little black lead. Work it up nicely together and lay it on the shaft, first thick, and then taper down to nothing but the oil.

**Cooling Compound for Hot Bearings.**—Mercurial Ointment mixed with black cylinder oil and applied every quarter of an hour, or as often as expedient. The following is also recommended as a good cooling compound for heavy bearings:—Tallow, 2 pounds, plumbago, 6 ounces, sugar of lead, 4 ounces. Melt the tallow with a gentle heat, and add the other ingredients, stirring until cold. For lubricating gearing, wooden cogs, etc., nothing better need be used than a thin mixture of soft soap and black-lead.

**Steel and Iron.**—To distinguish steel from iron pour on the object to be tested a drop of nitric acid; let it act for one minute, then rinse with water. On iron the acid will cause a greyish-white, on steel a black stain.

In case of wire, heat in the gas and dip in water; if hard and brittle it is steel.

**How to Harden Cast Iron.**—Heat the iron into cherry red, then sprinkle on it cyanide of potassium and heat it to a little above red; then dip. The cyanide may also be used to case-harden wrought iron.

## BELTING.

**Rules for Calculating the Width for Leather Belting (single) required for given power.** Multiply horse power with 33,000 and divide by velocity (in feet) of belt per minute and result is the tensional stress on belt; allow for each inch in width a stress of 55 pounds and divide into the stress due to the horse power and given velocity, and the result is width of belt required.

*Example.*—Horse power $75 \times 33{,}000 = 2{,}475{,}000$ pounds $\div$ 2500 feet $= 990$ pounds (mean stress, both pulleys being same diameter) $\div\ 55 = 19$ inch, single belt required to transmit 75-horse power at 2500′ per minute. The actual stress depends, however, entirely on the relative diameters of the driving and of the driven pulley embraced by the belt; the stress becomes less, the more the driven one is embraced (as the leverage of the driver increases) and *vice-versa.*

**Another Rule,** but which only applies to the best quality of belting is thus:

Multiply horse power by 7,000 $\div$ length in feet of that portion of the belt which clips smallest pulley and divide again by velocity in feet per minute.

*Example.*—Wanted width of single belt to transmit 75-horse power indicated (smallest drum 8″ diameter, belt clipping 11′ of the periphery).

75-horse power $\times\ 7{,}000 = 525{,}000 \div 11' = 47{,}727 \div 3{,}000'$ V. $= 15.9$ or 16 inches.

**Table of Safe Actual Width of Single Belts to Transmit Given Power at Given Speeds, allowing for Leather of Very Indifferent Quality.**

N. B.—The body of the table gives the width of the belts in inches.

| Speed in feet per min. | INDICATED HORSE POWER. 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|
| 400 | 20 | 36 | 48 | 60 | | | | | | |
| 600 | 16 | 32 | 40 | 50 | 60 | | | | | |
| 800 | 12 | 20 | 30 | 42 | 48 | 60 | | | | |
| 1000 | 9 | 18 | 24 | 35 | 40 | 50 | 60 | | | |
| 1200 | 8 | 16 | 20 | 28 | 34 | 40 | 50 | 60 | | |
| 1500 | 7 | 14 | 18 | 24 | 28 | 36 | 44 | 50 | 60 | |
| 1800 | 6 | 12 | 16 | 20 | 24 | 30 | 36 | 44 | 50 | 60 |
| 2400 | 5 | 10 | 14 | 18 | 20 | 24 | 30 | 36 | 44 | 50 |
| 3000 | 4 | 8 | 12 | 15 | 18 | 20 | 24 | 28 | 32 | 36 |

(For double belts about half the width of single.)

**To Find the Length of a Driving Belt Before the Pulleys are in Position.**—Add the circumference of the two pulleys, divide the product by 2, and add the quotient thus obtained to double the distance between the centres of the two shafts, which will give the length of belt required. For a cross belt, add the circumference of the two pulleys, multiply the product by 3, and divide by 2; the quotient added to double the distance between the centres of both shafts will give the length required.

**How to Find where to cut Belt-holes in Floors.**—Measure the distance in inches from centre of driving shaft to underside of floor; on the upper side make a mark over the centre of shaft. Now measure the distance from centre of shaft on machine to be driven to floor, making a mark on the floor immediately beneath the centre, then measure the distance between the two marks. Transfer these figures to a board or paper, draw off the driving and driven pulleys after finding their diameters, at the distance from each other and the floor line previously obtained, and draw the lines representing the belt cutting the floor line, which will show where the belt passes through the floor. The drawing can be made to a scale to reduce it to convenient dimensions, maintaining the proportions. The holes may now be marked off on the floor and cut with a certainty of being correct. In making the drawing it is best to make it full size on the floor, if room can be had; and allowance must be made for the thickness of the flooring.

## HOW TO MANAGE BELTS.

It is better for belts to relieve the strain upon them whenever they are out of use, as they last longer and pull better than if kept continually strained up.

*Machines* requiring 3-h. p. and upwards to drive them should be from 16 feet to 25 feet between centre of driving and driven pulleys; the length and width of belt, and diameter and width of pulleys to increase as the power required is greater.

*Avoid Belts* made up of short lengths, varying in quality of leather, as they become crooked, causing trouble and expense.

*A Good Dressing* for Leather Belts is to sponge them on the outside with warm water, then rub in some dubbin. This done once every four or six weeks keeps the belts supple, and prevents them from cracking.

Another good dressing may be made by the use of castor oil mixed about half and half with tallow or other good oil. Castor oil makes not only an excellent dressing, but renders the belts vermin proof.

*For Slipping Belts.*—First cleanse the inside by brushing, and drop a few drops of castor oil on the inside of the belt, or the side next to the pulleys.

*By no means* use resin for belts when slipping, as it hardens the belt, and causes it to crack.

*Belts* made of India-rubber, with plies of strong canvas interposed between their lengths are best in cases were they become constantly wetted.

*A Good Diameter for Drums* or pulleys is 5 to 6 times the width of belt.

*A Good Distance* from centre to centre of drums is from 2 to 2½ times the sum of their two diameters.

*A Pulley Covered with Leather, with the Hair Side of the Belt Turned to it,* offers 50 per cent. more resistance to slipping than a pulley merely polished. When a belt is turned with the hair side to pulley, the contact is greater, from the fact of a more even surface being presented, than when the flesh side is to the pulley; and, again, as the outside of a belt must necessarily stretch more in bending over a pulley, it follows that if the hair side is the outer one it will finally crack; but by reversing it, so that it must contract in wrapping around the pulley, it lays on with great smoothness, and the flesh side, being more open and irregular, experiences no difficulty or injury by the stretch from being outside.

It is claimed, however, that, if belts are run with the flesh side to pulley, and tanner's dubbin applied thereto, they will become as smooth as the hair side, and will become more durable. It is also well to remember that the pliableness of a belt has often more to do with its adhesiveness to the pulley, than the question of which side shall be presented to it, and for that reason they should always be maintained as pliable as possible.

It is reckoned that leather belts, grain or hair side to the pulley, will drive 34 per cent. more than with flesh side to the pulley; 48 per cent. more than rubber; 121 per cent. more than gutta-percha; and 180 per cent. more than canvas.

*Direction of Running.*—Belts where it is possible should always run from the top of the driving to the top of the driven pulley.

Belts always run to the high part of a pulley when the shafts are parallel; but when they are not, the belt will always run toward the ends of the shafts which are nearest together, and this tendency is much stronger than to run to the highest part of the pulley.

*To Ascertain Length of a Roll of Strapping* add inside and outside diameters in inches $\times$ number of coils $\times$ 0.1309 $\div$ 12″ $=$ length in feet.

*In Order to Preserve Belting* in the best condition apply the following mixture while hot and thin, with a common hand brush while the belt is in motion, once every two or three months:

| | |
|---|---|
| Bee's wax | 2-5ths. |
| Castor oil | 2-5ths. |
| Resin | 1-5th. |

*To Keep Ropes from Fraying.*—Apply a cake of paraffin wax once a month for a few minutes while the ropes are running.

The adoption of belt and rope driving has been greatly influenced by the number of breakdowns where gearing was used.

Where rope or strap driving has not been introduced—these instances, however, are very few—cast-steel wheels have been generally substituted for the broken cast-iron ones.

# WATER POWER.

*Velocity of Water*:—To ascertain mean velocity of stream, find surface velocity by observing rate of feet per minute with cork floats; deduct 25 per cent. for friction and multiply by area in feet of cross section of river and product is discharge in cubic feet per minute = number of gallons.

**Water Power.**

*English Rule*:—(33,000 pounds raised 1 foot in 1 minute = 1 H. P.
200 pounds of water (20 gallons) 3 feet fall per second = 1 H. P. or
60 gallons 1 foot fall per second = 1 H. P. Therefore:—

$$224 \text{ gallons} = \frac{\overbrace{2240 \text{ lbs.}}^{1 \text{ ton}} \times 3 \text{ feet} \times 60 \text{ seconds}}{33{,}000} = 12.2 \text{ H. P. calculated.}$$

minus 25 per cent. on account of turbine loss = 9.8 actual or effective H. P.

*French Rule*:—(75 kilos raised 1 metre high in 1 second = 1 H. P.) Therefore,

$$1 \text{ cubic metre } \overbrace{(1000 \text{ kilos or } 1000 \text{ litres})}^{1 \text{ ton approx.}}, 1 \text{ metre fall } 1000$$

$$\text{per second} = \frac{\text{litres} \times 1 \text{ metre fall} \times 60 \text{ seconds}}{75 \times 60 \text{ seconds.}} = 13.33 \text{ H. P. calculated.}$$

minus 20 per cent. on account of turbine loss = 10.67 effective H. P.

| | | | | | |
|---|---|---|---|---|---|
| 6 metres fall of | 1 | cubic metre or | } = 80 H. P. | | minus 20 per cent. turbine loss. |
| 1 " " | 6 | " | | | |
| 6 " " | 4 | " | } = 320 H. P. | | |
| 24 " " | 1 | " | | | |

# STEAM POWER.

For each nominal horse power a boiler should have:—

1 cubic foot of water per hour (at least).
1 square yard of heating surface.
1 square foot of fire-grate area.
1 cubic yard capacity.
28 square inches flue area.
1 pint water evaporates into 206 gallons of steam.
1 gallon of water is converted into 1648 gallons of steam at the mean atmospheric pressure of 14.7 pounds per square inch.

$$\text{Nominal horse power of boiler} = \frac{\text{length in feet} \times \text{diameter in feet.}}{5}$$

*To Ascertain the Chimney Area*

$$\frac{\text{lb. of coal per hour} \times 12}{\sqrt{\text{height in feet}}} = \text{area in square inches.}$$

*To Prevent Incrustation to Boilers* use nothing but common soda. Put a bucket full into the feed water supply tank once daily, or more, according to quantity and quality of the water used.

*To Ascertain the best Size of Injector* for any given boiler, multiply the nominal horse power by 10, which gives the number of gallons of water required per hour.

*To Find the Number of Cubic Feet of Exhaust Steam* emitted from cylinder per minute—multiply area of piston (in square feet) by speed of piston in feet per minute.

*A Horse Power* (H. P.) is equal to 33,000 pounds lifted one foot high in one minute or equivalent motion against resistance.

*To Find the Indicated Horse Power of an Engine*: Multiply mean pressure in pounds per square inch on piston × the area of the piston in square inches × piston speed in feet per minute and the result is number of pounds engine will raise one foot high per minute. Divide by 33,000 for the indicated horse power, and deduct one-sixth for friction, which will then be the effective horse power of the engine.

*To find the maximum efficiency* of a theoretically perfect steam engine use the following *Rule*:— $E = \frac{T - T'}{T}$ of which

$T$ = absolute temperature of steam on admission—*i. e.*, temperature Fahrenheit + 450°.
$T'$ = absolute temperature of exhaust steam—*i. e.*, temperature Fahrenheit + 459°.
$E$ = Maximum efficiency of theoretically perfect steam engine.

## HEAT.

**A Unit of Heat** is the quantity of heat required to raise the temperature of 1 pound of water at or near its temperature of greatest density (31.9° F.) through 1° F.

**How to change degrees of Centigrade or Reaumur into degrees Fahrenheit and vice versa.**

F = Degrees Fahrenheit. C = Degrees Centigrade or Celsius. R = Degrees Reaumur.

*Centigrade into Fahrenheit.*

$$F = \frac{9 \times {}^\circ C \text{ given}}{5} + 32$$

*Example.*—Find degrees F. for 40° C.
$40 \times 9 = 360 \div 5 = 72 + 32 = 104.$
*Answer.*—40° C = 104° F.

*Reaumur into Fahrenheit.*

$$F = \frac{9 \times {}^\circ R \text{ given}}{4} + 32$$

*Example.*—Find degrees F. for 32° R.
$32 \times 9 = 288 \div 4 = 72 + 32 = 104.$
*Answer.*—32° R = 104° F.

*Fahrenheit into Celsius.*

$$C = \frac{5 \times (\text{degrees F. given} - 32)}{9}$$

*Example.*—Find degrees C. for 104 F.
$5 \times (104 - 32)\ 72 = 360 \div 9 = 40.$
*Answer.*—104° F = 40° C.

*Fahrenheit into Reaumur.*

$$R = \frac{4 \times (\text{degrees F given} - 32)}{9}$$

*Example.*—Find degrees R. for 104° C.

$$\frac{4 \times (\text{degrees F given} - 32)}{9}$$

$104 - 32 = 72 \times 4 = 288 \div 9 = 32.$
*Answer.*—104° C = 32° F.

*Reaumur into Celsius.*

$$C = \frac{5 \times \text{degrees R given}}{4}$$

*Example.*—Find degrees C. for 32° R.
$5 \times 32 = 160 \div 4 = 40.$
*Answer.*—32° R = 40° C.

*Celsius into Reaumur.*

$$R = \frac{4 \times \text{degrees C given}}{5}$$

*Example.*—Find degrees R. for 40° C.
$4 \times 40 = 160 \div 5 = 32.$
*Answer.*—40° C = 32° R.

# ARITHMETIC.

## (Specially Adapted for Textile Purposes).

### ADDITION.

Addition has for its object the finding of a number (called sum) equal to two, three, or more numbers.

The symbol + (read plus) is used to indicate the operation of addition. The symbol = (read is equal to, or are) is the sign of equality.

*Example.*— $3 + 4 + 7$ yards=14 yards.

If adding higher numbers than units place figures that represent units in each number in the same vertical line, those representing tens in the same vertical line and continue in this manner with the numbers representing hundreds, thousands, ten-thousands, hundred-thousands and millions. Next draw a horizontal line under the last number, and under this line place (in the same arrangement as to value of positions) the sum of the given numbers; *i. e.*, commencing to add the right-hand column, writing the units of the sum beneath, and adding the tens, if any, to the next column, and continue in this manner with all the columns until writing the entire sum of the last column.

*Examples.*—

| | |
|---|---|
| 206 lbs. | 46 yards. |
| 320 " | 230 " |
| +54760 " | 4377 " |
| | +57698 " |
| 55286 lbs. | 62351 yards. |

*Question.*—Find number of threads in pattern dressed:

| | | |
|---|---|---|
| 10 | threads | black. |
| 2 | " | blue. |
| 4 | " | brown. |
| 24 | " | black. |
| + 2 | " | blue. |

*Answer.*— 42 threads in pattern.

*Question.*—Find total weight for the following lot of wool:

960 lbs. Domestic.
40 " Australian.

*Answer.*— 1000 lbs., total weight.

### SUBTRACTION.

Subtraction is the process of taking away a number (called subtrahend) from a larger number (called minuend). The result of a subtraction is termed difference.

The symbol — (read minus, or less) denotes the operation of subtracting. To prove a subtraction, remember that the difference and subtrahend, added, must equal the minuend.

*Example.*— $8 - 3$ lbs. = 5 lbs. *Proof.*— $5 + 3 = 8$.

If subtracting higher numbers than units, write the subtrahend under minuend, placing units of the same order in the same column. Next draw a horizontal line under the subtrahend and begin to subtract with the units of the lowest order, and proceed to the highest, writing the result beneath.

If any order of the minuend has less units than the same order of the subtrahend, increase its units by ten and subtract; consider the units of the next minuend order one less, and proceed as before.

*Examples.*—

| | | | |
|---|---|---|---|
| 4322 lbs. (minuend) | | 4284 yards | |
| —2111 " (subtrahend) | | —3395 " | |
| 2211 lbs. (difference). | | 889 yards. | |

*Question.*—Weight of cloth required, 21 oz.; weight from loom, 19 oz. Find difference.

21 oz.
—19 "

2 oz.

*Answer.*—The cloth in question is 2 oz. too light.

*Question.*—The weight of a lot of wool in grease is 100 lbs.; its weight after being scoured and dried is 67 lbs. Find loss during scouring process.

100 lbs.
— 67 "

33 lbs.

*Answer.*—The lot of wool in question lost during scouring 33 lbs.

*Question.*—Basis of cotton yarn, 840 yards per lb.; basis of worsted yarn, 560 yards per lb. Find difference.

840 yards.
—560 "

280 yards.

*Answer.*—The worsted yarn basis is 280 yards less than the one for cotton yarns.

## MULTIPLICATION.

Multiplication is the process of taking one number (called multiplicand) as often as another number (called multiplier) contains ones. The sum thus derived, or the result of a multiplication, is called the product or result.

The symbol × (read multiplied, or times) denotes the operation for multiplying.

*Example.*—

| Multiplicand. | | Multiplier. | | Product. |
|---|---|---|---|---|
| 4 | ×. | 3 | = | 12 |

*Proof.*—

4
4
+ 4

12

If multiplying higher numbers than units, begin the process with the ones, and write the ones of the product reserving the tens if any. Next multiply the tens of the multiplicand, adding number of tens reserved from the previous process, write tens in place for tens in product and reserve (if any) the hundreds; continue in this manner, always multiplying the next highest number of the multiplicand, adding number of same value (if any) from the previous part of the operation, until all the numbers of the multiplicand are taken up, writing in full the last operation.

*Example.*—If weaving 212 yards of cloth in one day, how many yards will be woven, under the same circumstances, in 3 days? $212 \times 3 = 636$.

*Answer.*—636 yards.

The product for multiplying a number by 10, is obtained by simply annexing 0 to the multiplicand.

*Example.*— 336 yards × 10 = 3,360 yards.

By annexing 00 to the multiplicand, we multiply the latter by 100; by annexing 000, with 1000, etc.

If required to multiply with a number having tens and zeros (0) for ones, we first multiply with the tens and annex 0 to the result.

*Examples.*— 36 × 30 = 1,080; 36 × 300 = 10,800; 36 × 3,000 = 108,000, etc.

Remember that the multipler and multiplicand can change places, without altering the product; thus, if zeroes are found in the multiplicand reverse factors so as to apply previously given rules.

*Example.*—How many picks per hour does a loom make if running 85 picks per minute? 1 hour = 60 minutes; thus, 60 × 85 = 5,100.

*Answer.*—The speed per hour is 5,100 picks.

If the multiplier contains two parts, for example 5 and 60 (or 65), multiply the multiplicand first with the units (5 in example) and afterwards with the tens, using zero for ones (60 in example). In setting down this second result omit the zero, as it has no effect on the addition to be performed.

*Example.*—If one loom produces 235 yards of cloth in one week, how many yards will 23 looms produce in the same time and on the same work?

$$235 \times 23 \quad \text{Thus: } \begin{array}{r} 235 \times 3 = 705 \\ 235 \times 20 = 4700 \\ \hline 5405 \end{array} \qquad \text{or, } \begin{array}{rl} 235 \times 23 & \\ \hline 705 & = (235 \times 3) \\ 470\phantom{0} & = (235 \times 20) \\ \hline 5405 & \end{array}$$

*Answer.*—23 looms will produce 5,405 yards per week.

If the multiplier is made up of three parts, multiply with the units and tens as before, next the hundreds, using zeros for tens and units, but omitting both zeros in setting down the third result. For similar reasons any future value of figures in the multipler requires corresponding increase of zeros not set down in the respective result.

*Example.*— 783 × 233

$$\begin{array}{rl} 2349\phantom{00} & = (783 \times 3 = 2349). \\ 2349\phantom{0} & = (783 \times 30 = 23490). \\ 1566 & = (783 \times 200 = 156600). \\ \hline 182439 & \end{array}$$

*Answer.*— 182439

In some instances we are requested to find the continued product of three, four, or more numbers. In such instances multiply the first two numbers, and multiply product derived with the third, etc.

*Example.*—Find number of yards of filling wanted to weave 32 yards cloth, 72 inches wide in loom, 45 picks per inch. Thus: 32 × 72 × 45.

$$32 \times 72 = 2,304 \times 45 = 103,680$$

*Answer.*—103,680 yards of filling are wanted.

Some examples call for a number to be multiplied by itself once, twice, three times, or oftener. If so, the resulting products are called the second, third, fourth, etc., powers of the number. The process is termed involution, and the power to which the number is raised is expressed by the number of times the number has been employed as a factor in the operation. The raising of a number to the second power is called square; the raising to the third power being termed cube. Thus:

16 is the square of 4, because 4 × 4 = 16
64 " " cube " 4, " 4 × 4 × 4 = 64

## DIVISION.

Division is the process by which we find how many times one number (called divisor) is contained into another (called dividend) The quotient is the result of a division, and the part of the dividend not containing the divisor an exact number of times, is called the remainder.

The symbol of division is ÷ (read divided by), and is written between the dividend and divisor; for example, 8÷4; but is also frequently substituted, either by writing the divisor at the left of the dividend with a curve, for example, 4)8, or by writing the divisor under the dividend, both numbers to be separated by a horizontal line.

For example, $\frac{8}{4}$

| Dividend. | | Divisor. | | Quotient. |
|---|---|---|---|---|
| 8 | ÷ | 4 | = | 2 |

*Example.*—If dividing higher numbers than units, find how many times the divisor is contained in the fewest left-hand figures of the dividend that will contain it; write answer as the first number of the quotient. Next multiply this number by the divisor; subtract the product from the partial dividend used, and to the remainder annex the next dividend figure for a second partial dividend. Divide and proceed as before, until all the numbers of the dividend are called for, writing the last remainder (if there is one left), with the divisor under it (as common fraction), as a part of the quotient.

*Example.*—Find number of repeats of pattern in the following warp:

3,904 threads in warp. 32 threads in pattern.

```
3904÷32=122
32
——
 70
 64
 ——
  64
  64
```

*Answer.*—In the warp given in the example there are 122 repeats of pattern.

Remember that the dividend is the product of the divisor and the quotient; hence, use this as proof for the division in question.

```
Divisor.   Quotient.
  32    ×    122     =    3,904 (Dividend.)
——————————————
   64
  64
 32
————
3904
```

If we have to divide a number by ten, simply insert a decimal point between the last two figures (toward the right) in the dividend, thus expressing at once the quotient.

*Example.*—4,220 end in warp, dressed with 10 sections. Find number of ends used in each section.

4,220÷10=422.0, or

*Answer.*—422 ends are used in each section.

If the divisor is hundred, thousand, or more, always move the decimal point correspondingly one more point toward the left in the dividend, so as to get the quotient.

*Example.*—125 lbs. of filling must weave 100 yards of cloth, how many pounds must be used per yard, to weave up all this filling?

125÷100=1.25

*Answer.*—1¼ lbs. yarn must be used per yard.

Dividing or multiplying the dividend and the divisor by one number does not alter the quotient; thus, if the divisor contains zeros for either units, units and tens, units, tens and hundreds, etc., we can shorten the process by throwing out such zeros and reducing the dividend correspondingly, by simply placing a decimal point in its proper place.

*Example.*—4,905 threads in warp, 30 threads in pattern. Find number of repeats of pattern in warp.

4905÷30=490.5÷3$\not{0}$=163.5

```
 3
───
 19
 18
───
  10
   9
───
  15
  15
───
```

*Answer.*—There are 163½ repeats of patterns in warp.

Previous example also explains the multiplying of both the dividend and the divisor (without altering the proper quotient) towards the close of the division, when 1.5 is to be divided by 3.

$$\frac{1.5 \times 10 = 15}{3 \times 10 = 30} \text{ or } \frac{1}{2} \text{ or } 0.5.$$

## PARENTHESIS OR BRACKETS.

A parenthesis (expressed by symbol ( ) ), is used in calculations for enclosing such numbers as must be considered together. Hence, the whole expression which is enclosed is affected by the symbol preceding or following the parenthesis.

Hence, $(18\times4)\div(4\times2)=72\div8=9$; whereas without parenthesis example would read as follows:

$$18\times4\div4\times2=(18\times4=72\div4=18\times2=)\ 36$$

If the main operation, as in the present example, is a division, we may use in the place of the parenthesis, the vinculum (expressed by symbol ——), writing the dividend above the line, and the divisor below; thus, previously given example would read $\frac{18\times4}{4\times2}=9$

$240\div(7+4\times2)$ means that twice the sum of $7+4$ equal 22 is to be divided into 240. It might also have been written $\frac{240}{7+4\times2}$

$(3\times4-2)\times(6\times9+4)+43$ means: Subtract 2 from the product of 3 multiplied by 4, and multiply the remainder (10) by the sum of 6 multiplied by 9, plus 4 (58), and add to the product ($10\times58=580$) thus obtained 43, which gives 623 as the result or answer.

Frequently brackets are made to inclose one another, if so, remove the brackets one by one, commencing by the innermost.

*Example.*—

```
(2+5×(4+82)+8)×(3+10).
(2+5×  86   +8)×(3+10).
( 7 ×  86   +8)×(3+10).
(    602    +8)×(3+10).
          610  ×  13
```

*Answer.*—$(2+5\times(4+82)+8)\times(3+10)=7{,}930$.

*Example.*—

$$(3\times(6+9\div2\times(4\times8)+8)\,)\times2.$$
$$(3\times(6+9\div2\times\ \ 32\ \ +8)\,)\times2.$$
$$(3\times(\qquad 248 \qquad)\,)\times2.$$
$$744 \qquad \times2.$$

*Answer.*—$(3\times(6+9\div2\times(4\times8)+8)\,)\times2=1,488.$

## PRINCIPLE OF CANCELLATION.

Example given in previous chapter on brackets $\frac{18\times4}{4\times2}$ we will also use to explain the subject of cancelling or shortening calculations. The rule for this process is: Strike out all the numbers common to both dividend and divisor, and afterward proceed as required by example.

$$\frac{18\times4}{4\times2}=\frac{18\times\not4}{\not4\times2}=\frac{18}{2}=18\div2=9.$$

Another point for cancellation is to ascertain if a number in the dividend and in the divisor have the same common factor.

*Example.*—

$$\frac{36\times9}{18\times5}=\frac{\overset{2}{\not3\not6}\times9}{\underset{1}{\not1\not8}\times5}=\frac{2\times9}{1\times5}=18\div5=3\tfrac{3}{5}.$$

*Proof.*—

$$\frac{36\times9}{18\times5}=\frac{324}{90}=324\div90=3\tfrac{3}{5}.$$

$$\begin{array}{r} 324 \\ 270 \\ \hline \end{array}$$

$$\frac{54}{90}\ \Big|\ \frac{6}{10}\ \Big|\ \frac{3}{5}$$

For reducing fractions to their lowest denomination as in previous example $\frac{54\div9=6\div2=3}{90\div9=10\div2=5}$ as well as for assisting the student quickly to find the same common factor for two numbers, we give herewith rules by which he can quickly ascertain if a number is exactly divisible by 2, 3, 4, 5, 6, 7, 8, 9, 10 or 11.

If the last figure of the number is either zero or an even digit, such a number is exactly divisible by 2.
*Examples.*— $420\div2=210$, $336\div2=168$.

If the sum of the figures is divisible by 3, such a number is exactly divisible by 3.
*Example.*— $38,751\div3=12,917$.

If the last two figures of a given number are divisible by 4, such a number is exactly divisible by 4.
*Example.*— $396,564\div4=99,141$.

If the last digit in a number is either 0 or 5, such a number can be exactly divided by 5.
*Examples.*— $320\div5=64$, $38,745\div5=7,540$.

When the last three figures of a number are divisible by 8, such number can be divided by 8
*Example.*— $376,256\div8=47,032$.

A number is exactly divisible by 9, when the sum of its digits is divisible by 9.
*Example.*— $887,670\div9=98,630$.

A number is exactly divisible by 11, when the difference between the sum of the digits in the uneven places (commencing with the units) and the sum of the digits in the even places, is either zero or divisible by 11.

*Example.*— $514,182,746\div11=46,743,886$.

## COMMON FRACTIONS.

A common fraction is a fraction in which we write the numerator above, and the denominator below, the dividing (— or / ) line.

*Example.*— $\frac{1}{2}$ $\begin{matrix} = \text{numerator of the fraction} \\ = \text{denominator of the fraction} \end{matrix}$ } Both being the terms of the fraction.

The horizontal dividing line is the one most frequently used, but the oblique (½) answers the same purpose.

The *denominator* of a fraction indicates in how many equal parts the unit is divided; and the *numerator* shows how many of those parts are taken.

There are two kinds of fractions:

(*a*) **Proper Fractions,** which have for their terms a numerator which is less than the denominator. For example, $\frac{3}{4}$, $\frac{5}{8}$, $\frac{6}{7}$, etc.

(*b*) **Improper Fractions,** which have for their terms a numerator, which is greater than the denominator. For example, $\frac{4}{3}$, $\frac{8}{5}$, $\frac{7}{6}$, etc.

An *improper fraction* can be changed to a *mixed number* by dividing the numerator by the denominator, setting down the quotient as the integral part, and making the remainder the numerator of the fractional part of the mixed number, whose denominator is the denominator of the original fraction.

An integer (= whole number) can be expressed as an improper fraction, without reducing its value, for example, $6=\frac{6}{1}$, $8=\frac{8}{1}$, etc. The combination of an integer and a fraction is termed a mixed number. For example, $7\frac{3}{4}$ ( 7 Integer. $\frac{3 \text{ Numerator.}}{4 \text{ Denominator.}}$ )

A *mixed number* can be changed to an *improper fraction* by multiplying the integer by the denominator of the fraction, adding to the product the numerator of the fraction. This sum is the numerator of the improper fraction of which the denominator is the denominator of the given fraction.

*Example.*— $2\frac{4}{7} = \frac{2\times7+4}{7} = \frac{18}{7}$ improper fraction.

A fraction is expressed in its lowest terms (*i. e.*, cannot be reduced) when the numerator and denominator have no common factor except unity, or in other words, when both terms are not dividable by any number except one. For example. $\frac{5}{12}$, $\frac{3}{7}$, etc.

Thus, to reduce a fraction to its lowest terms, use

*Rule.*—Divide the numerator and the denominator by their highest common factor.

*The highest common factor* of a fraction is the highest number which will exactly divide each of the terms of a fraction; for such small numbers, as are generally used for fractions, the highest common factor is found at a glance. For example: $\frac{6}{8}$. Readily the student will see that both the 6 and the 8 can be divided by 2. Thus: $\frac{6}{8} \div 2 = \frac{3}{4}$, or $\frac{6}{8} = \frac{3}{4}$.

If dealing with large numbers, the highest common factor cannot always be determined by inspection, but is found by

*Rule.*—Divide the higher number of the fraction by the lower, and the latter (the divisor of the first operation) by the remainder; continue the process until no remainder is left, the divisor used last being the highest common factor for the fraction.

*Example.*—Reduce to its lowest terms $\frac{2166}{2888}$; *i. e.*, find the highest common factor for 2166 and and 2888, by previously given rule.

$$\left.\begin{array}{l} 2166)2888=1 \\ \quad 2166 \\ \quad\quad 722)2166=3 \\ \quad\quad\quad 2166 \end{array}\right\} \text{ or, 722 is the highest common factor.} \qquad \frac{2{,}166\div722=3}{2{,}888\div722=4}$$

*Answer.*— $\frac{2166}{2888}$ expressed in its lowest terms equals $\frac{3}{4}$

Frequently we must change a given fraction to terms of a known denominator; if so, proceed as follows: Divide the required denominator by the denominator of the given fraction and multiply by the quotient thus obtained with both terms of the given fraction.

*Example.*—Change $\frac{5}{12}$ to equivalent fraction expresseed in 60's.

$$60\div12=5 \text{ and } \frac{5\times5}{12\times5}=\frac{25}{60}$$

*Answer.*— $\frac{5}{12}$ equals $\frac{25}{60}$ in value.

If two fractions are to be changed to equivalent fractions (fractions having the same denominator) find the lowest common multiple (see * below for explanation for lowest common multiple) for the two given denominators, which is the new denominator for each fraction. Next find the new numerators for both fractions, by means of previously given method for changing a given fraction to terms of a known denominator. This rule also applies for three or more fractions.

*Example.*—Change $\frac{3}{4}$ and $\frac{5}{7}$ to equivalent fractions, having the same denominator.

$4 \times 7$ (prime numbers) $= 28$, new denominator.

$$28\div4=7 \qquad 28\div7=4$$

$$\frac{3\times7}{4\times7}=\frac{21}{28} \qquad \frac{5\times4}{7\times4}=\frac{20}{28}$$

*Answer.*— $\frac{3}{4}=\frac{21}{28}$ and $\frac{5}{7}=\frac{20}{28}$.

*Example.*—Change $\frac{2}{3}$, $\frac{3}{4}$ and $\frac{5}{7}$ to equivalent fractions, having the same denominator.

$3\times4\times7$ (prime numbers) $= 84$, new denominator.

$$84\div3=28 \qquad 84\div4=21 \qquad 84\div7=12$$

$$\frac{2\times28}{3\times28}=\frac{56}{84} \qquad \frac{3\times21}{4\times21}=\frac{63}{84} \qquad \frac{5\times12}{7\times12}=\frac{60}{84}$$

*Answer.*— $\frac{2}{3}=\frac{56}{84}$ $\qquad$ $\frac{3}{4}=\frac{63}{84}$ $\qquad$ $\frac{5}{7}=\frac{60}{84}$

* *The lowest common multiple* of two or more numbers is the lowest number which is exactly dividable by each of them, and is obtained for two numbers by dividing one of the numbers by the highest common factor, and multiplying the quotient by the other number. If numbers are prime, their product is the lowest common multiple.

If we have to find the lowest common multiple of three or more numbers, find the lowest common multiple of any two, next find the lowest common multiple of the resulting number, and of a third of the original numbers, and so on, the final result being the lowest common multiple wanted.

## ADDITION OF COMMON FRACTIONS.

Only fractions having the same denominators can be added; thus, change fractions given to equivalent fractions having the lowest common denominator. Next add the numerators of the equivalent fractions and place the result as the numerator of a fraction whose denominator is the common denominator of the equivalent fractions.

*Example.*—Find sum of $\frac{1}{8}$ and $\frac{1}{3}$ oz.

8×3=24, lowest common denominator.

$$24 \div 8 = 3 \qquad 24 \div 3 = 8$$

$$\frac{1 \times 3}{8 \times 3} = \frac{3}{24} \qquad \frac{1 \times 8}{3 \times 8} = \frac{8}{24} \qquad \Big| \quad \frac{3}{24} + \frac{8}{24} = \frac{11}{24}$$

*Answer.*— $\frac{1}{8}$ oz. + $\frac{1}{3}$ oz. = $\frac{11}{24}$ oz.

*Example.*—Find sum of $\frac{3}{20}$, $\frac{4}{15}$ and $\frac{1}{10}$ inches.

The lowest common denominator of 20, 15 and 10 is 60, since

$$60 \div 20 = 3 \qquad 60 \div 15 = 4 \qquad 60 \div 10 = 6$$

$$\frac{3 \times 3}{20 \times 3} = \frac{9}{60} \qquad \frac{4 \times 4}{15 \times 4} = \frac{16}{60} \qquad \frac{1 \times 6}{10 \times 6} = \frac{6}{60} \qquad \Big| \quad \frac{9}{60} + \frac{16}{60} + \frac{6}{60} = \frac{31}{60}$$

*Answer.*— $\frac{3}{20} + \frac{4}{15} + \frac{1}{10} = \frac{31}{60}$ inches.

*Example.*—Find the total yards for the following three pieces of cloth containing respectively $3\frac{7}{16}$, $8\frac{2}{16}$, and $108\frac{4}{20}$ yards.

The lowest common denominator of 16 and 20 is 80, since 80÷16=5 and 80÷20=4.

$$\frac{7 \times 5}{16 \times 5} = \frac{35}{80}, \text{ thus: } 3\tfrac{7}{16} = 3\tfrac{35}{80} \qquad \frac{2 \times 5}{16 \times 5} = \frac{10}{80}, \text{ thus: } 8\tfrac{2}{16} = 8\tfrac{10}{80} \qquad \frac{4 \times 4}{20 \times 4} = \frac{16}{80}, \text{ thus: } 108\tfrac{4}{20} = 108\tfrac{16}{80}$$

$$3\tfrac{35}{80} + 8\tfrac{10}{80} + 108\tfrac{16}{80} = 119\tfrac{61}{80}$$

*Answer.*—The total yards for the three pieces cloth given in question are $119\frac{61}{80}$ yards.

If the sum derived is an improper fraction, the same can be changed (if required) to a mixed number, by dividing the numerator by the denominator, the quotient obtained being the integer. The remainder is the numerator of the fraction which has the given denominator of the improper fraction for their denominator.

*Example.*—Find sum of $\frac{5}{7}$ and $\frac{8}{9}$ lb.

The lowest common denominator of 7 and 9 is 63, since 63÷7=9, and 63÷9=7.

$$\frac{5 \times 9}{7 \times 9} = \frac{45}{63} \text{ and } \frac{8 \times 7}{9 \times 7} = \frac{56}{63} \qquad \Big| \quad \frac{45}{63} + \frac{56}{63} = \frac{101}{63} \; (101 \div 63) = 1\tfrac{38}{63}$$

*Answer.*— $\frac{5}{7}$lb. + $\frac{8}{9}$ lb. = $\frac{101}{63}$, or $1\frac{38}{63}$ lbs.

Previously given rule also applies if adding improper fractions.

*Example.*—Find sum of $\frac{8}{5}$ and $\frac{7}{3}$ yards.

The lowest common denominator of 5 and 3 is 15, since 15÷3=5, and 15÷5=3.

$$\frac{8 \times 3}{5 \times 3} = \frac{24}{15} \qquad \frac{7 \times 5}{3 \times 5} = \frac{35}{15} \qquad \Big| \quad \frac{24}{15} + \frac{35}{15} = \frac{59}{15} \; (59 \div 15) = 3\tfrac{14}{15}.$$

*Answer.*— $\frac{8}{5}$ yard + $\frac{7}{3}$ yard = $3\frac{14}{15}$ yards.

If adding mixed numbers, first add the fractions; if their product is a proper fraction, reduce the same to their lowest equal terms; but if an improper fraction, change the same to a mixed number and put the fraction part down for the fraction of the sum. Next add the integral parts of the given mixed numbers plus the integral part from the addition of the fractions.

*Example.*—Find the sum of $3\frac{2}{3}$, $4\frac{6}{8}$ and $2\frac{1}{7}$ inches.

The lowest common denominator of 3, 8 and 7 is 168, since 168÷3=56; 168÷8=21; 168÷7=24.

$$\begin{array}{l} 3\tfrac{2}{3}\left(\tfrac{2}{3} \times \tfrac{56}{56}\right) = 3\tfrac{112}{168} \\ 4\tfrac{6}{8}\left(\tfrac{6}{8} \times \tfrac{21}{21}\right) = 4\tfrac{126}{168} \\ 2\tfrac{1}{7}\left(\tfrac{1}{7} \times \tfrac{24}{24}\right) = 2\tfrac{24}{168} \\ \qquad\qquad + \\ \hline \qquad\qquad 9\tfrac{262}{168} \end{array} \qquad 9\tfrac{262}{168} = \left\{ \begin{array}{r} 262 \div 168 = 1\tfrac{47}{84} \\ +9 \\ \hline 10\tfrac{47}{84} \end{array} \right\} \; 10\tfrac{47}{84}$$

*Answer.*— $3\frac{2}{3} + 4\frac{6}{8} + 2\frac{1}{7}$ inches = $10\frac{47}{84}$ inches.

## SUBTRACTION OF COMMON FRACTIONS.

Only fractions having the same denominator can be subtracted; thus, change fractions given to equivalent fractions having the lowest common denominator. Next deduct the numerator of the smaller of the equivalent fractions from the numerator of the greater fraction. The difference place as the numerator of a fraction whose denominator is the common denominator of the equivalent fraction. This fraction is the difference of the given two fractions (can be reduced to its lowest terms by previously given rule).

*Example.*—Find the difference between $\frac{6}{8}$ and $\frac{2}{7}$.

The lowest common denominator of 8 and 7 is 8×7, or 56; and 56÷8=7; 56÷7=8.

$$\frac{6 \times 7}{8 \times 7} = \frac{42}{56} \qquad \frac{2 \times 8}{7 \times 8} = \frac{16}{56} \quad \Big| \quad \frac{42}{56} - \frac{16}{56} = \frac{26}{56} = \frac{13}{28}$$

*Answer.*— $\frac{6}{8} - \frac{2}{7} = \frac{13}{28}$.

*Example.*—Find the difference between the weight of two pieces of cloth weighing respectively $23\frac{5}{7}$ and $20\frac{2}{9}$ lbs. The lowest common denominator of 7 and 9 is 7×9 or 63.

$$63 \div 7 = 9 \qquad 63 \div 9 = 7.$$

$$23\tfrac{5}{7} = 23\tfrac{45}{63}$$
$$20\tfrac{2}{9} = 20\tfrac{14}{63}$$
$$-$$
$$3\tfrac{31}{63} \text{ lbs.}$$

*Answer.*—The difference between the two pieces of cloth given in example is $3\frac{31}{63}$ lbs.

Previously given rule also applies, if dealing with improper fractions. In some instances we may have to deduct a fraction or a mixed number in which the value of the fraction of the subtrahend is greater than the one of the minuend. If so, we must change the fraction by adding one unit of the integer (changed to a fraction of the same denominator) to the fraction of the minuend.

*Example.*—Find the difference between the weight of two pieces of cloth weighing respectively $28\frac{3}{7}$ and $28\frac{6}{8}$ ounces. The lowest common denominator of 7 and 8 is 8×7, or 56.

$$28\tfrac{3}{7} = 28\tfrac{24}{56} = 27\tfrac{80}{56}$$
$$22\tfrac{6}{8} = 22\tfrac{42}{56} = 22\tfrac{42}{56}$$
$$-$$
$$5\tfrac{38}{56}, \text{ or } 5\tfrac{19}{28} \text{ oz.}$$

*Answer.*—The difference in weight between the two pieces of cloth, given in example, is $5\frac{19}{28}$ ozs.

## MULTIPLICATION OF COMMON FRACTIONS.

A fraction is multiplied by an integer, by multiplying the numerator of the fraction by the integer and leaving the denominator of the fraction unchanged, or divide the denominator of the fraction by the integer and leave the numerator unchanged.

*Example.*—Multiply $\frac{3}{8}$ with 2.

$$\frac{3}{8} \times 2 = \frac{3 \times 2}{8} = \frac{6}{8} \text{ or } \frac{3}{4}$$

Or,

$$\frac{3}{8} \times 2 = \frac{3}{8 \div 2} = \frac{3}{4}$$

*Example.*—If 1 lb. filling weaves $\frac{5}{8}$ yards cloth, how many yards will 26 lbs. weave?

$$\frac{5}{8} \times 26 = \frac{5 \times 26}{8} = \frac{130}{8}, \text{ or } 130 \div 8 = 16\tfrac{1}{4}.$$

*Answer.*—26 lbs. filling will weave $16\frac{1}{4}$ yards cloth.

A fraction is multiplied by a fraction by writing the product of the numerators over the product of the denominators. The product thus divided change either to a fraction of the lowest term, or, if an improper fraction to a mixed number.

*Example.*—Multiply $\frac{3}{13}$ by $\frac{4}{15}$ inches.

$$\frac{3}{13} \times \frac{4}{15} = \frac{3 \times 4}{13 \times 15} = \frac{\not{3} \times 4}{13 \times \not{15}_{5}} = \frac{4}{13 \times 5} = \frac{4}{65}$$

*Answer.*— $\frac{3}{13} \times \frac{4}{15} = \frac{4}{65}$.

*Example.*—Multiply $\frac{7}{8}$ by $2\frac{3}{7}$.

$$\frac{7}{8} \times 2\frac{3}{7} = \frac{7}{8} \times \frac{17}{7} = \frac{7 \times 17}{8 \times 7} = \frac{\not{7} \times 17}{8 \times \not{7}} = \frac{17}{8} \text{ or } 17 \div 8 = 2\tfrac{1}{8}$$

*Answer.*— $\frac{7}{8} \times 2\frac{3}{7} = 2\frac{1}{8}$.

*Example.*—If one pound of filling weaves $\frac{5}{8}$ yards of cloth, how many yards will $38\frac{3}{4}$ lbs. filling weave.

$$\tfrac{5}{8} \times 38\tfrac{3}{4} = (\tfrac{5}{8} \times \tfrac{155}{4}) = \frac{5 \times 155}{8 \times 4} = 775 \div 32 = 24\tfrac{7}{32}$$

*Answer.*— $38\frac{3}{4}$ lbs. of filling will weave $24\frac{7}{32}$ yards.

Previously given rules also apply to improper fractions. In the application of the rules to mixed numbers, change the latter to their equivalent value in improper fractions and proceed as in the foregoing example.

*Example.*—Find square inches for a sample cut to the rectangular shape of $3\frac{2}{5} \times 4\frac{1}{6}$ inches.

| (Mixed numbers.) | | (Improper fractions.) |
|---|---|---|
| $3\frac{2}{5}$ | = | $\frac{17}{5}$ |
| $4\frac{1}{6}$ | = | $\frac{25}{6}$ |

$$\frac{17}{5} \times \frac{25}{6} = \frac{17 \times \not{25}^{5}}{\not{5} \times 6} = \frac{17 \times 5}{6} = \frac{85}{6} \text{ or } 85 \div 6 = 14\tfrac{1}{6}.$$

*Answer.*—The surface of the sample in question is ($3\frac{2}{5} \times 4\frac{1}{6}$) $14\frac{1}{6}$ inches.

## DIVISION OF COMMON FRACTIONS.

A fraction is divided by an integer by multiplying the denominator of the fraction by that number, leaving the numerator unchanged; or by dividing the numerator of the fraction by the integer, and leaving the denominator unchanged.

*Example.*—(**Fraction ÷ Integer.**) Divide $\frac{4}{9}$ by 2.

$$\frac{4}{9} \div 2 = \frac{4}{9 \times 2} = \frac{4}{18} = \frac{2}{9}, \quad \text{or } \frac{4}{9} \div 2 = \frac{4 \div 2}{9} = \frac{2}{9}$$

*Answer.*— $\frac{4}{9} \div 2 = \frac{2}{9}$.

*Example.*— $\frac{7}{8}$ lb. of filling weave 3 yards cloth, ascertain amount used per yard.

$$\frac{7}{8} \div 3 = \frac{7}{8 \times 3} = \frac{7}{24}$$

*Answer.*—The amount of filling used per yard, is $\frac{7}{24}$ lb.

If we have to divide an integer by a fraction, we must change the integer to a fraction, and use the same rule as given next for

## Dividing Fractions by Fractions.

*Rule.*—Invert the divisor and proceed as in multiplication of fractions.

*Example.*—(**Fraction ÷ Fraction**). Divide $\frac{11}{12}$ by $\frac{3}{15}$.

$$\frac{11}{12} \div \frac{3}{15} = \frac{11}{12} \times \frac{15}{3} = \frac{11}{12} \times \frac{\overset{5}{\cancel{15}}}{\cancel{3}} = \frac{11 \times 5}{12} = \frac{55}{12} \text{ or } 4\tfrac{7}{12}$$

*Answer.*— $\frac{11}{12} \div \frac{3}{15} = 4\frac{7}{12}$.

*Proof.*—The product of the quotient and the divisor must equal the dividend, thus:

$$4\tfrac{7}{12} \times \tfrac{3}{15} = \frac{55}{12} \times \frac{3}{15} = \frac{\overset{11}{\cancel{55}} \times \overset{1}{\cancel{3}}}{\underset{4}{\cancel{12}} \times \underset{3}{\cancel{15}}} = \frac{11 \times 1}{4 \times 3} = \tfrac{11}{12} \text{ or}$$

$$4\tfrac{7}{12} \times \tfrac{3}{15} = \tfrac{11}{12}, \text{ the same as } \tfrac{11}{12} \div \tfrac{3}{15} = 4\tfrac{7}{12}$$

*Example* (**Integer ÷ Fraction**). Divide 8 by $\frac{3}{9}$.

$$8 \div \tfrac{3}{9} = \frac{8}{1} \div \frac{3}{9} = \frac{8}{1} \times \frac{9}{3} \text{ or } \frac{8 \times \overset{3}{\cancel{9}}}{1 \times \cancel{3}} = \frac{8 \times 3}{1} = 24$$

*Answer.*— $8 \div \frac{3}{9} = 24$.

In the application of the rules for mixed numbers, change the latter to an improper fraction, and proceed as in the foregoing examples.

*Example.*—(**Mixed Number ÷ Fraction.** Divide $9\frac{3}{8}$ by $\frac{7}{9}$.

$$9\tfrac{3}{8} \div \tfrac{7}{9} = \frac{75}{8} \div \frac{7}{9} = \frac{75}{8} \times \frac{9}{7} = \frac{75 \times 9}{8 \times 7} = \frac{675}{56} = 12\tfrac{3}{56}$$

*Answer.*— $9\frac{3}{8} \div \frac{7}{9} = 12\frac{3}{56}$.

*Example.*—(**Mixed Number ÷ Mixed Number**). Divide $4\frac{7}{8}$ by $1\frac{4}{9}$.

$$4\tfrac{7}{8} \div 1\tfrac{4}{9} = \frac{39}{8} \div \frac{13}{9} = \frac{39}{8} \times \frac{9}{13} = \frac{\overset{3}{\cancel{39}} \times 9}{8 \times \cancel{13}} = \frac{27}{8} = 3\tfrac{3}{8}$$

*Answer.*— $4\frac{7}{8} \div 1\frac{4}{9} = 3\frac{3}{8}$.

## DECIMAL FRACTIONS.

A decimal fraction is a fraction whose unit is divided into tenths, hundredths, thousandths, ten-thousandths, hundred thousandths, etc. and is expressed without a denominator by means of the decimal point.

Value of decimal fractions commonly termed decimals.

| Decimal point. | Tenths. | Hundredths. | Thousandths. | Ten-thousandths. | Hundred-thousandths. | Millionths. |
|---|---|---|---|---|---|---|
| . | 1 | 2 | 3 | 4 | 5 | 6 |

.123456 ( . 1 2 3 4 5 6 ) and so on, each digit decreasing tenfold advancing to the right.

Above number reads: One hundred twenty-three thousand four hundred fifty-six millionths.

*The denominator of a decimal fraction* (which as already mentioned, is not put down, but indicated by the decimal point) is 1 plus as many zeros annexed as there are places in the fraction.

Hence: .4 reads, 4 tenths, $\frac{4}{10}$.

.73 seventy-three hundredths, $\frac{73}{100}$.

.821 eight hundred twenty-one thousandths. $\frac{821}{1000}$, etc.

Some parties also use a zero one point to the left to indicate that the fraction contains no integer parts; thus, foregoing fractions may also be written 0.4, 0.73, 0.821, without changing their value or their reading.

Zeros affixed to a decimal do not change its value.

Hence, .38=.380=.3800, etc., 0.693=0.6930=0.69300 etc.

*Mixed numbers* are made up of an integer and a decimal. For example: 3.25 read, three and twenty-five hundredths. 347.3 reads, three hundred forty-seven and three tenths. 1873.472 reads, one thousand eight hundred seventy-three and four hundred and seventy two thousandths.

To change a decimal fraction to common fraction of equivalent value, omit the decimal point and write the proper denominator as explained previously, next change the fraction to its lower terms.

*Example.*—Change .25 to a common fraction.

$$.25 = \frac{25 \div 25}{100 \div 25} = \frac{1}{4}$$

*Answer.*— .25 equals $\frac{1}{4}$.

*Example.*—Change 43.625 to a mixed number having a common fractional part.

$$43.625 = 43\tfrac{625}{1000} = \left(\tfrac{625}{1000} \div \tfrac{125}{125} = \tfrac{5}{8}\right) \quad 43\tfrac{5}{8}.$$

*Answer.*— 43.625 equals $43\frac{5}{8}$.

To change a common fraction to a decimal fraction, add decimal ciphers to the numerator, divide by the denominator, and point off as many decimal figures in the quotient as there are ciphers annexed.

*Example.*—Change $\frac{1}{4}$ to a decimal.

1.00÷4=0.25

```
10
 8
--
 20
 20
---
```

*Answer.*— $\frac{1}{4}$ equals .25 or 0.25.

*Example.*—Change $43\frac{5}{8}$ to a decimal.

$\frac{5}{8}$=5.000÷8=0.625.

```
50
48
--
 20
 16
 --
  40
  40
  --
```

```
  43.000
+  0.625
--------
  43.625
```

*Answer.*— $43\frac{5}{8}$ equals 43.625.

If the division does not terminate, or has been carried as far as necessary, the remainder may be expressed in the result as a common fraction, or may be rejected if less than $\frac{1}{2}$, or unimportant, and the incompleteness of the result marked at the right of the fraction by +. If $\frac{1}{2}$, or more than $\frac{1}{2}$, the last digit of the decimal may be made to express one more.

*Example.*—Change $\frac{7}{9}$ to a decimal.

7.000÷9=0.777+

```
70
63
--
 70
 63
 --
  70
  63
  --
   7
```

*Answer.*— $\frac{7}{9} = 0.777\frac{7}{9}$, or $\frac{7}{9} = 0.777+$, or $\frac{7}{9} = 0.778$.

## ADDITION OF DECIMAL FRACTIONS.

*Rule.*—Place the decimals to be added one under another, decimal point under decimal point. Next add the figures as if dealing with whole numbers, and place the decimal point for the sum under the others.

*Example.*— Add 0.22, 0.384, and 0.054.

$$\begin{array}{r} 0.220 \\ 0.384 \\ +\ 0.054 \\ \hline 0.658 \end{array}$$

*Answer.*— $0.22 + 0.384 + 0.054 = 0.658$.

If the numbers to be added be mixed numbers, place integers in front of the decimals, in their proper position, and proceed as before.

*Example.*— Add 3468.12; 483.39; 27.0003 and 3.18

$$\begin{array}{r} 3468.1200 \\ 483.3900 \\ 27.0003 \\ +\ \ 3.1800 \\ \hline 3981.6903 \end{array}$$

*Answer.*— $3468.12 + 483.39 + 27.0003 + 3.18 = 3981.6903$.

Find total cost of a piece of cloth in which the value of the warp is $22.32; of the filling, $16.02; of the selvage, $0.64, and (general) manufacturing expenses are $5.00.

$$\begin{array}{r} \$22.32 \\ 16.02 \\ 0.64 \\ +\ 5.00 \\ \hline \$43.98 \end{array}$$

*Answer.*—The total cost of the piece of cloth in question is $43.98.

## SUBTRACTION OF DECIMAL FRACTIONS.

*Rule.*—Place the subtrahend below the minuend, keeping the different values of positions under each other, also point under point. Next subtract as if dealing with whole numbers, and place decimal point for the difference under point of the subtrahend.

*Example.*—Subtract 0.27 from 0.473

$$\begin{array}{r} 0.473 \\ -0.270 \\ \hline 0.203 \end{array}$$

*Answer.*— $0.473 - 0.270 = 0.203$.

If dealing with mixed numbers, place integers in front of the decimals, in their proper place, and proceed as before.

*Example.*—Find cost of filling in a cut of cloth in which the value of warp and filling is $56.32, and the value of the warp is $32.19

$$\begin{array}{r} \$56.32 \\ -\ \ 32.19 \\ \hline \$24.13 \end{array}$$

*Answer.*—The value of the filling in example is $24.13

## MULTIPLICATION OF DECIMAL FRACTIONS.

*Rule.*—Multiply as if dealing with whole numbers, and point off in the product a number of decimal places equal to the sum of the number of decimal places in both factors. If there are not figures enough in the product, prefix the deficiency with zeros, and put the point on the left of these factors. Whole numbers and mixed numbers are dealt with alike.

*Example.*—Multiply 0.26 by 0.35.

```
0.26 × 0.35
----
130
78
----
910
```

Four decimal places are in both factors; hence
*Answer.*— 0.26 × 0.35 = 0.0910, or 0.091.

*Example.*—Multiply 4.32 by 2.81.

```
  4.32 × 2.81
 -------
   432
 3456
 864
 -------
 12.1392
```

Four decimal places in factors; hence
*Answer.*— 4.32 × 2.81 = 12.1392.

*Example.*—Ascertain value of 432 lbs. of wool, costing $1.31 per lb.

```
  432 × 1.31
 ------
  432
 1296
 432
 ------
 565.92
```

*Answer.*—The value of the lot of wool in question is $565.92.

## DIVISION OF DECIMAL FRACTIONS.

*Rule.*—If the dividend is a mixed number, or a fraction, and the divisor an integer, divide as if dealing with whole numbers, and mark off in the quotient as many decimal places as there are decimal places in the dividend.

*Example.*—Divide 39.42 by 2.

```
39.42 ÷ 2 = 19.71
2
--
19
18
--
 14
 14
 --
 002
   2
  --
   0
```

*Answer.*— 39.42 ÷ 2 =19.71.

*Example.*—Divide 0.84 by 4

```
0.84 ÷ 4 = 0.21
  8
 --
 04
  4
 --
  0
```

*Answer.*— 0.84 ÷ 4 = 0.21.

*Rule.*—If the divisor is a decimal, change to a whole number by moving the decimal point a sufficient number of places to the right, annexing zeros if required, and then divide as if dealing with integers. If the dividend is an integer, the quotient will be an integer; and if the dividend is a decimal, the quotient will be a decimal of the same order.

*Example.*—Divide 0.924 by 0.033.

$$0.924 \div 0.033 = 924 \div 33 = 28$$

66
———
264
264
———

Here the quotient is an integer, because the dividend is an integer ; hence

*Answer.*— $0.924 \div 0.033 = 28.$

*Example.*—Divide 38.76 by 10.2.

$$38.76 \div 10.2 = 387.6 \div 102 = 3.8$$

306
———
816
816
———

In this instance the dividend is a decimal of the first order ; hence, the quotient is a decimal of the first order, therefore

*Answer.*— $38.76 \div 10.2 = 3.8$

*Example.*—Divide 3.876 by 10.2.

$$3.876 \div 10.2 = 38.76 \div 102 = .38$$

306
———
816
816
———

Here the dividend is a decimal of the second order ; thus the quotient correspondingly also a decimal of the second order ; therefore

*Answer.*— $3.876 \div 10.2 = 0.38$

*Example.*—Divide 0.0924 by 3.3

$$0.0924 \div 3.3 = 0.924 \div 33 = 0.028$$

66
———
264
264
———

Here the dividend is a decimal of the third order, thus the quotient also a decimal of the third order, hence :

*Answer.*— $0.0924 \div 3.3 = 0.028$

If the divisor does not terminate, or has been carried as far as necessary, the remainder may be expressed as a common fraction being part of the quotient, or may be rejected if less than $\frac{1}{2}$ or unimportant, and the incompleteness of the result marked at the right of the fraction by $+$, or if the remainder is $\frac{1}{2}$ or more, the last digit of the decimal may be made to express one more.

*Example.*—Divide 409.6 by 8.5 to three decimals.

$$409.6 \div 8.5 = 4096 \div 85 = 48.188$$

340
———
696
680
———
160
85
———
750
680
———
700
680
———
20

***Answer.***— $409.6 \div 8.5 = 48.188\frac{20}{85} = 48.188\frac{4}{17}$ or
$409.6 \div 8.5 = 48.188+$ or
$409.6 \div 8.5 = 48.188$

*Example.*—If $437\frac{3}{4}$ lbs. wool cost $\$529.67\frac{3}{4}$ what will one pound cost ?

$$529.67\tfrac{3}{4} \div 437.75 \text{ or } 52967.75 \div 43775 = 1.21$$

43775
———
91927
87550
———
43775
43775
———

*Answer.*—The value of one pound of wool given in example is $1.21

## SQUARE ROOT.

The square root of a given number is such a number which, being multiplied by itself, will produce the given number. Hence, the square root of 36 is 6, because 6×6 (or the square of 6) is 36.

The symbol $\sqrt{\phantom{x}}$ or $\sqrt[2]{\phantom{x}}$ placed at the left of a number denotes that the square root of that number is to be taken; hence, $\sqrt{49}$ reads: take the square root of 49, which is 7, since 7×7=49.

The square root of a number contains either twice as many figures as the root, or twice as many less one. For example:

$\sqrt{64}$ = 8 (since 8×8=64) 2 figures in square. 1 figure in root.

$\sqrt{100}$ =10 (since 10×10=100) 3 figures in square. 2 figures in root.

A small figure 2 placed to the right and above a number is the symbol that the square of that number is to be taken, hence $4^2$ denotes the square of 4 or 4×4=16.

A number which has a whole number for its square root is termed a perfect square, and such perfect squares, not greater than 100, must be committed to memory; *i. e.*, $2^2=4$, $3^2=9$, $4^2=16$, $5^2=25$, $6^2=36$, $7^2=49$, $8^2=64$, $9^2=81$, $10^2=100$. An imperfect square is a number whose root cannot be exactly found.

*Rule.*—**For finding the square root for any number.**

Separate the given number into periods of two figures each, beginning at the unit places.

Find the greater square in the left hand period, and place its root as the first figure of the root; deduct its square from the first period, and to the remainder (if any), bring down the next period for a dividend.

Divide this new dividend, omitting the right hand figure by double the first figure of the root, and place the quotient to the right of the first figure of the root, and also to the right of the partial divisor. Multiply the complete divisor by the last figure of the root, subtract the product from the dividend, and to the remainder bring down the next period for a new dividend.

Divide this new dividend, omitting the right hand figure by double the whole root so far found, and place the quotient to the right of the root, and also to the right of the partial divisor. Multiply the complete divisor by the last figure of the root, subtract product from dividend, and to the remainder bring down next period for a new dividend.

Continue the operation as before until all periods are brought down.

If the last remainder is zero, the given number is a perfect square.

*Example.*—Find square root of 729.

```
√7 | 29  =  27.
  4
 ───
47)329
   329
   ───
   000
```

*Answer.*— $\sqrt{729}$ = 27.

*Proof.*— 27 × 27 = 729.

*Example.*—Find square root of 148,225.

```
√14 | 82 | 25=385
  9
 ───
68)582
   544
   ───
765)3825
    3825
```

**☞ In dividing 58 by 6 the quotient is 9, but if we add this to complete the divisor (6 and 9—69 × 9—621) the latter would become 69, which if multiplied by 9 would give 621, a number larger than the dividend 582, thus 8 in place of 9 must be used.**

*Answer.*— $\sqrt{14 \mid 82 \mid 25}$=385.

*Proof.*— 385×385=148,225.

*Example.*—Find square root of 89,401.

$\sqrt{8 \mid 94 \mid 01} = 299$

```
      4
    ---
 49)494
    441
    ---
589)5301
    5301
    ----
```

☞ The division of 49 by 4 illustrates the same remarks as made in previous example.

☞ The second remainder (53) is in this example greater than the divisor (49), a result not uncommon.

*Answer.*— $\sqrt{89401} = 299$ *Proof.*— $299 \times 299 = 89401.$

If the dividend at any time does not contain the complete divisor, place a zero in the root, and add the next period for a new dividend.

If an integral number is not a perfect square and its root is to be found, annex as many periods of ciphers as there are to be decimal places in the root. The more periods of ciphers we use, the nearer approximation of the root is obtained.

*Example.*—Find square root of 36469521.

$\sqrt{36 \mid 46 \mid 95 \mid 21} = 6039$

```
         36
        ----
  1203)  4695
         3609
        ------
 12069)108621
       108621
       ------
```

☞ Here in the process as 0 occurs in the root, we annex the 0 to the divisor 12, and annex the next period to the corresponding dividend.

*Answer.*— $\sqrt{36469521} = 6039.$

## Square Root of Decimal Fractions.

For finding the square root of a decimal fraction, make the decimal such that the index of its order is an even number; also, since every period of two figures in the square equals one figure in the root, we must use as many periods in the decimal part of the square as there are to be decimals in the root.

*Example.*—Find the square root of 0.139 to three places of decimals.

$\sqrt{0.13 \mid 90 \mid 00} = 0.372+$

```
      9
    ---
 67)490
    469
    ----
742)2100
    1484
    ----
     616
```

*Answer.*— $\sqrt{0.139} = 0.372+$

*Proof.*— $0.372 \times 0.372 = 0.138384$
+ Remainder, 0.000616
0.139000

The square root of a decimal of an odd order is always a non-terminating decimal. See symbol + for it at the right hand of the decimal fraction of the square root in previous example.

*Example.*—Find square root of 0.8436 to two places of decimals.

$\sqrt{0.84 \mid 36} = 0.91+$, or 0.92

```
      81
     ---
 181)336
     181
     ---
     155
```

For this example the index is of an even order but not terminating; hence, symbol + at the right of the root. The last figure of the root is $\frac{1}{100}$, which we may change to $\frac{2}{100}$, as the remainder, 155, is more than $\frac{1}{2}$ of the divisor, 181; thus:

*Answer.*— $\sqrt{0.8436} = 0.92.$

### Square Root of Common Fractions.

If we have to extract the square root of a common fraction, change the fraction to its lowest terms; if both terms are perfect squares, take the root of each; if imperfect squares, change the fraction to a decimal, and find root as before.

*Example.*— $\sqrt{\frac{9}{64}}$ $\quad \frac{\sqrt{9}}{\sqrt{64}} = \frac{3}{8}$ *Answer.*— $\sqrt{\frac{9}{64}} = \frac{3}{8}$

*Example.*—Find square root of $\frac{39}{81}$

$$\sqrt{\frac{39}{81}} = \sqrt{\frac{13}{27}} = \frac{\sqrt{13}}{\sqrt{27}}$$

```
√ 13  =3.60555+
   9
  ---
 66)400
    396
    ---
 7205)40000
      36025
      -----
 72105)397500
       360525
       ------
 721105)3697500
        3605525
        -------
          91975
```

```
√ 27  =5.19615+
  25
  --
101)200
    101
    ---
1029)9900
     9261
     ----
10386)63900
      62316
      -----
103921)158400
       103921
       ------
1039225)5447900
        5196125
        -------
         251775
```

$$\sqrt{\frac{39}{81}} = \sqrt{\frac{13}{27}} = \frac{3.60555}{5.19615} \text{ or } 3.60555 \div 5.19615$$

```
36055500000÷519615=0.69388+
3117690
-------
 4878600
 4676535
 -------
  2020650
  1558845
  -------
   4618050
   4156920
   -------
   4611300
   4156920
   -------
    454380
```

*Answer.*— $\sqrt{\frac{39}{81}} = 0.69388$

To prove the correctness of the above example, we will next find answer by changing the common fraction $\frac{39}{81}$, for which we have to find the square root in a decimal.

```
39/81 = 39.0 ÷ 81 = 0.481481+
        324
        ---
         660
         648
         ---
          120
           81
          ---
           390
           324
           ---
            660
            648
            ---
             120
              81
             ---
              39
```

```
√0.481481 = 0.69388+
  36
  --
129)1214
    1161
    ----
  1383)5381
       4149
       ----
   13868)123200
         110944
         ------
    138768)1225600
           1110144
           -------
            115456
```

*Answer.*— $\sqrt{\frac{39}{81}} = 0.69388 +$ being the same result as before.

Another method of proving this example, is to find the square root out of the common fraction without reducing it to its lowest terms. If correct it will also demonstrate to the student that the reducing of a common fraction (for drawing the square root) to its lowest terms is correct, and either may be made use of or not.

$$\sqrt{\frac{39}{81}} = \frac{\sqrt{39}}{\sqrt{81}}$$

```
√39 = 6.24499+
 36
 --
122) 300
     244
     ---
1244) 5600
      4976
      ----
12484) 62400
       49936
       -----
124889) 1246400
        1124001
        -------
1248989) 12239900
         11241901
         --------
           997999

√81 = 9
 81
 --
```

$$\sqrt{\tfrac{39}{81}} = \frac{6.24499+}{9} \text{ or } 6.24499 \div 9$$

```
9)6.24499=0.69388+
  54
  --
   84
   81
   --
    34
    27
    --
     79
     72
     --
      79
      72
      --
       7
```

*Answer.*— $\sqrt{\tfrac{39}{81}} = 0.69388+$ or the same answer as already proven.

*Note.*—This example will also demonstrate to the student that the reducing of a fraction to its lowest terms is not always the shortest course; *i. e.*, always examine in which fraction you find either one or both terms a perfect square; 81 is a perfect square, whereas 27 is not.

## Square Root of Mixed Numbers.

If we have to extract the square root of a mixed number composed of an integer and a common fraction, change the same to its equivalent value either in an improper fraction, or a mixed number expressed by integer and decimals, and proceed as explained before.

*Example*—Find square root of $9\frac{36}{64}$. *a.* Use decimals. *b.* Use improper fraction.

*a.* $\sqrt{9\frac{36}{64}}$ $\frac{36}{64} = 36 \div 64 = 0.5625$; thus: $9\frac{36}{64} = 9.05625$ and,

$\sqrt{9.56|25} = 3.092+$

9

609) 5625

5481

6182) 14400

12364

2036

*Answer.*— *a.* 3.092+ is the square root of $9\frac{36}{64}$.

*b.* $\sqrt{9\frac{36}{64}} = \sqrt{\frac{612}{64}} = \frac{\sqrt{612}}{\sqrt{64}}$

$\sqrt{6|12} = 24.739+$

4

44)212

176

487) 3600

3409

4943) 19100

13929

49469) 517100

445201

71899

$\sqrt{64} = 8$

$\sqrt{9\frac{36}{64}} = \frac{24.739}{8} +$ and

$24.739 \div 8 = 3.092 +$

24

73

72

19

16

3

*Answer.*— *b.* 3.092 + is the square root of $9\frac{36}{64}$.

### Table of Square Roots.

(From 1 to 240.)

| Number | Square Root. | Number | Square Root. | Number | Square Root. | Number | Square Root. |
|---|---|---|---|---|---|---|---|
| 1 | 1.0000 | 19 | 4.3589 | 37 | 6.0828 | 75 | 8.6603 |
| 2 | 1.4142 | 20 | 4.4721 | 38 | 6.1644 | 80 | 8.9443 |
| 3 | 1.7321 | 21 | 4.5826 | 39 | 6.2450 | 85 | 9.2195 |
| 4 | 2.0000 | 22 | 4.6904 | 40 | 6.3246 | 90 | 9.4868 |
| 5 | 2.2361 | 23 | 4.7958 | 41 | 6.4031 | 95 | 9.7468 |
| 6 | 2.4495 | 24 | 4.8990 | 42 | 6.4807 | 100 | 10.0000 |
| 7 | 2.6458 | 25 | 5.0000 | 43 | 6.5574 | 110 | 10.4881 |
| 8 | 2.8284 | 26 | 5.0990 | 44 | 6.6332 | 120 | 10.9545 |
| 9 | 3.0000 | 27 | 5.1962 | 45 | 6.7082 | 130 | 11.4018 |
| 10 | 3.1623 | 28 | 5.2915 | 46 | 6.7823 | 140 | 11.8322 |
| 11 | 3.3166 | 29 | 5.3852 | 47 | 6.8557 | 150 | 12.2474 |
| 12 | 3.4641 | 30 | 5.4772 | 48 | 6.9282 | 160 | 12.6491 |
| 13 | 3.6056 | 31 | 5.5678 | 49 | 7.0000 | 170 | 13.0384 |
| 14 | 3.7417 | 32 | 5.6569 | 50 | 7.0711 | 180 | 13.4164 |
| 15 | 3.8730 | 33 | 5.7446 | 55 | 7.4162 | 190 | 13.7840 |
| 16 | 4.0000 | 34 | 5.8310 | 60 | 7.7460 | 200 | 14.1421 |
| 17 | 4.1231 | 35 | 5.9161 | 65 | 8.0623 | 220 | 14.8323 |
| 18 | 4.2426 | 36 | 6.0000 | 70 | 8.3666 | 240 | 15.4919 |

## CUBE ROOT.

If a number is multiplied twice by itself, the product is called the cube of the number; hence 216 is the cube of 6, since $6 \times 6 = 36 \times 6 = 216$.

To extract the cube root of a given number, is to find one of the three factors producing.

The symbol $\sqrt[3]{\phantom{x}}$ placed before a given number, indicates that the cube root is wanted.

There are two kinds of cubes, perfect cubes, being such which have an integer for its cube root; and imperfect cubes, containing a mixed number or fraction for its cube root.

The following numbers of less than 1,000 are perfect cubes:

8 is the cube of 2; 27 is the cube of 3; 64 is the cube of 4; 125 is the cube of 5;
216 is the cube of 6; 343 is the cube of 7; 512 is the cube of 8; 729 is the cube of 9.

### Rule for Finding the Cube Root of a Given Number.

Separate the numbers into periods of three figures each, beginning at units place.

Find the greatest cube root of the left hand period and place its root at the right. Subtract the cube of this root from the left hand period, and to the remainder annex the next period for a new dividend. Next place three times the first figure of the root to the extreme left and three times the square of the first figure of the root, with two ciphers affixed to it, to the left near the dividend for a trial divisor. Divide the dividend by this trial divisor and put the quotient at the right of the extreme left situated number and also as the second figure of the root.

Read extreme number and quotient as one number, and multiply the same by the seccnd figure of the root. Put this product below the trial divisor and add both; multiply this sum again by the second figure of the root, and put product below the dividend. Next subtract, and if a remainder, annex a new period, form second extreme left number, second trial divisor and quotient (= next figure for root) and proceed as before.

*Example.*—Find cube root of 110,592.

| (Extreme left number) | (Quotient) | | | Specified figuring. |
|---|---|---|---|---|
| | | | $\sqrt[3]{110 \mid 592}$ = 48 (Cube root) | |
| | | | 64 | $4 \times 4 \times 4 = 64$ |
| | | 4800 | | $4 \times 3 = 12$ |
| 12 | 8 | 1024 | 46592 | $4 \times 4 = 16 \times 3 = 48$ (4800) |
| | | 5824 | 46592 | $128 \times 8 = 1024$ |
| | | | 00000 | $5824 \times 8 = 46592$ |

*Answer.*— $\sqrt[3]{110592} = 48$ *Proof.*— $48 \times 48 = 2304 \times 48 = 110592$

If required to extract the cube root of a decimal fraction, divide the fraction also into periods of three figures each, commencing from the decimal point toward the right. If in the last period only one figure is left, annex two ciphers; if two figures are left over annex one cipher, or in other words, the decimal fraction must be some multiple of 3.

*Example.*—Find cube root of 553.387661.

| | | | | Specified figuring. |
|---|---|---|---|---|
| | | | $\sqrt[3]{553.387 \mid 661} = 8.21$ | $8 \times 8 \times 8 = 512$ |
| | | | 512 | $8 \times 3 = 24$ |
| 24 — | 2 — | 19200 | | $8 \times 8 = 64 \times 3 = 192 = (19200)$ |
| | | 484 | 41387 | $242 \times 2 = 484$ |
| | | 19684 | 39368 | $19684 \times 2 = 39368$ |
| | | | | $82 \times 3 = 246$ |
| 246 — | 1 — | 2017200 | 2019661 | $82 \times 82 = 6724 \times 3 = 20172$ (2017200) |
| | | 2461 | 2019661 | $2461 \times 1 = 2461$ |
| | | 209661 | | $2019661 \times 1 = 2019661$ |

*Answer.*— $\sqrt[3]{553.387661} = 8.21$. *Proof.*— $8.21 \times 8.21 = 67.4041 \times 821 = 553.387661$.

The cube root of a common fraction is found either by taking the cube roots of their terms or by reducing the common fraction to a decimal and proceeding as before.

*Example.*—Find cube root of $\frac{27}{343}$

$$\sqrt[3]{\frac{27}{343}} = \frac{\sqrt[3]{27}}{\sqrt[3]{343}} \quad \Big| \quad \sqrt[3]{27} = 3 \qquad \sqrt[3]{343} = 7 ;\ \text{hence,}$$

$$\sqrt[3]{\frac{27}{343}} = \frac{3}{7}$$

or $\sqrt[3]{\frac{27}{343}}$ change $\frac{27}{343}$ to a decimal. $(27 \div 343 = 0.078717+)$ and find

$$\sqrt[3]{0.078 \mid 717} = 0.42+$$

```
                      64
12  —  2  —  4800   ------
              244 | 14717
             ---- | 10088
             5044   -----
                     4629
```

*Answer.*— $\sqrt[3]{\frac{27}{343}} = 0.42+$

*Proof.*— Change $\frac{3}{7}$ to a decimal $3 \div 7 = 0.42+$

If we have to extract the cube root of a mixed number composed of an integer and common fraction, change the same to its equivalent value, either in an improper fraction or to a mixed number expressed by integer and decimals, and proceed as explained before.

### Table of Cube Roots.

(From No. 2 to 50.)

| Number | Cube Root. | Number | Cube Root. | Number | Cube Root. | Number | Cube Root. |
|---|---|---|---|---|---|---|---|
| 2 | 1.259921 | 14 | 2.410142 | 26 | 2.962496 | 38 | 3.361975 |
| 3 | 1.442250 | 15 | 2.446212 | 27 | 3.000000 | 39 | 3.391211 |
| 4 | 1.587401 | 16 | 2.519842 | 28 | 3.036589 | 40 | 3.419952 |
| 5 | 1.709976 | 17 | 2.571282 | 29 | 3.072317 | 41 | 3.448217 |
| 6 | 1.817121 | 18 | 2.620741 | 30 | 3.107232 | 42 | 3.476027 |
| 7 | 1.912931 | 19 | 2.668402 | 31 | 3.141381 | 43 | 3.503398 |
| 8 | 2.000000 | 20 | 2.714418 | 32 | 3.174802 | 44 | 3.530348 |
| 9 | 2.080084 | 21 | 2.758924 | 33 | 3.207534 | 45 | 3.556893 |
| 10 | 2.154435 | 22 | 2.802039 | 34 | 3.239612 | 46 | 3.583048 |
| 11 | 2.223980 | 23 | 2.843867 | 35 | 3.271066 | 47 | 3.608826 |
| 12 | 2.289428 | 24 | 2.884499 | 36 | 3.301927 | 48 | 3.634241 |
| 13 | 2.351335 | 25 | 2.924018 | 37 | 3.332222 | 50 | 3.684031 |

## AVERAGE AND PERCENTAGE.

**Average.**—The average of two, three or more groups of numbers, is found by adding the numbers and dividing the sum by the number of groups used.

*Example.*—Find average counts between 5 and 6-run yarn.

$$\begin{array}{r} 5 \\ +6 \\ \hline 11 \div 2 = 5\frac{1}{2} \end{array}$$

*Answer.*— $5\frac{1}{2}$-run.

*Example.*—Find average lengths of the following 5 pieces of cloth measuring respectively 42 yards, 43 yards, $42\frac{1}{2}$ yards, $41\frac{3}{4}$ yards, 42 yards.

$$\begin{array}{r} 42 \\ 43 \\ 42\frac{1}{2} \\ 41\frac{3}{4} \\ +42 \\ \hline 211\frac{1}{4} \end{array} \qquad 211\tfrac{1}{4} \div 5 = 42\tfrac{1}{4}$$

*Answer.*— The average length of the pieces of cloth in question, is $42\frac{1}{4}$ yards.

**Percentage.**—The symbol of percentage is %, and reads per cent. For example: 32% white wool, reads 32 per cent. white wool.

Per cent. means by the hundred, thus 32 % means 32 of every hundred. For example, we speak about a mixture of wool as gray mix, 40 % white, the remainder black; this means, that in every hundred pounds wool there are forty pounds white, and sixty pounds black; thus, if the lot of wool contains 450 lbs. wool, we used 180 lbs. white wool, 270 lbs. black wool.

The *Rate* per cent, is the number of hundreths.

The *Base*, is the number on which the percentage is estimated.

*Rule* for finding the percentage: Multiply the base by the rate per cent.

*Example.*—Find 12 per cent. of 430 lbs. $430 \times \frac{12}{100} = 51.60$.

*Answer.*— 12 per cent. of 430 lbs. is 51.6 lbs.

*Proof.*—

$$\begin{array}{rl} 100 & \\ 12 & \text{and 88 per cent. of } 430 = 430 \times \frac{88}{100} = 378.40 \\ \hline 88 & + 12 \quad \text{" of } 430 = (\text{See example.}) = 51.60 \\ & \qquad\qquad\qquad\qquad \overline{430.00} \text{ lbs.} \end{array}$$

**Rule for finding the rate per cent.**—Divide the percentage by the base.

*Example.*—In a lot of wool of 400 lbs., there are 20 lbs. red wool and 380 lbs. black; how many per cent. of red wool are used in this lot?

$$20 \div 400 = \frac{20}{400} = \frac{5}{100}.$$

*Answer.*— 5 per cent. of red wool are used.

*Proof.*— $400 \times \frac{5}{100} = 20$.

**Rule for finding the base.**—Divide the percentage by the rate per cent.

*Example.*—Received 138 lbs. of yarn marked as 8 per cent. of the entire lot, how many pounds are in the whole lot?

$$138 \div \frac{8}{100} = 1725$$

*Answer.*— 1,725 lbs. yarn are in the entire lot of yarn.

*Proof.*— $138 \div 1725 = 0.08 = \frac{8}{100}$ or 8 per cent.

## RATIO.

Ratio is the relation which one number (called the *Antecedent*) has to another number (called the *Consequent*) of the same kind, and is obtained by dividing the first by the second; thus, the ratio of 20 to 5 is 20÷5 or 4.

The symbol of ratio is a colon (:), or the ratio may be written as a fraction; thus, 20 to 5 may be expressed either as 20:5 or $\frac{20}{5}$.

Both terms of a ratio are called a *Couplet.*

**Simple Ratio** is the comparing of two numbers; for example, 18 : 6 = 3.

**Compound Ratio** is the comparison of the products of the corresponding terms of two or more ratios; *for example.*—find the ratio of 2:4, 8:3, and 6:2.

$$\left.\begin{matrix}2:4\\8:3\\6:2\end{matrix}\right\} = \frac{2\times8\times6}{4\times3\times2} = \frac{\overset{2}{\cancel{2}}\times\overset{2}{\cancel{8}}\times\cancel{6}}{\cancel{4}\times\cancel{3}\times\cancel{2}} = \frac{2\times2}{1} = \frac{4}{1} = 4$$

*Answer.*—The simple ratio for example is 4 : 1 or 4.

This example will give us the rule for changing a compound ratio to a simple ratio as follows: Multiply the antecedents together for a new antecedent, and the consequents for a new consequent, and reduce both to their lowest equivalent terms.

As previously mentioned the ratio is a fraction, consequently its terms may be treated like those of a fraction, thus the following

### Principles of Ratio.

The ratio is equal to the antecedent divided by the consequent.
Multiplying the antecedent, multiplies the ratio.
Multiplying the consequent, divides the ratio.
Dividing the antecedent, divides the ratio.
Dividing the consequent, multiplies the ratio.
Multiplying or dividing the antecedent and consequent by the same number, does not effect the ratio.
The product of two or more simple ratios, is the ratios of their products.

## PROPORTION.

Proportion consists in the equality of two ratios, and is expressed by the symbol of equality (=) or the double colon ( :: ).

Every proportion consists of two couplets, or four terms. For example.— 8 : 12 = 4 : 6.

**The Antecedents** are the first and third terms (8 and 4 in example).
**The Consequents** are the second and last terms (12 and 6 in example).
**The Extremes** are the first and last terms (8 and 6 in example).
**The Means** are the second and third terms (12 and 4 in example.)

### Principles of Proportion.

In a proportion the product of the means is equal to the product of the extremes.

( 12 × 4 = 48, product of the means.
8 × 6 = 48, " " extremes. )

The product of the extremes divided by either mean will give the other mean.

| {Product of the extremes.} | ÷ | {One mean.} | = | {The other mean.} |
|---|---|---|---|---|
| 48 | ÷ | 12 | = | 4 |
| 48 | ÷ | 4 | = | 12 |

The product of the means divided by either extreme will give the other extreme.

| {Product of means.} | ÷ | {One extreme.} | = | {The other extreme.} |
|---|---|---|---|---|
| 48 | ÷ | 8 | = | 6 |
| 48 | ÷ | 6 | = | 8 |

There are two kinds of proportions; single and compound proportion.

**Single proportion** is an equality between two simple ratios, and is used to find the fourth term of a proportion where the other three terms are given. Two terms of the given three must be of the same kind and constitute a ratio; and the third term (of the given three) must be of the same kind as the regular term, and constitute with it another ratio equal to the first.

*Example.*— 16,800 yards of yarn weigh 16 oz., find the weight of 3,900 yards.

| Yards. | | Yards. | | oz. | | oz. |
|---|---|---|---|---|---|---|
| 16800 | : | 3900 | :: | 16 | : | x |

$$\left\{\begin{matrix}\text{Product of}\\ \text{the means.}\end{matrix}\right\} \div \left\{\begin{matrix}\text{The given}\\ \text{extreme.}\end{matrix}\right\} = \left\{\begin{matrix}\text{The other}\\ \text{extreme.}\end{matrix}\right\}$$

$3{,}900 \times 16 = 62400$ (product of the means). $\quad 62400 \div 16800 = 3\frac{120}{168}$ or $3\frac{5}{7}$.

*Answer.*— 3,900 yards weigh $3\frac{5}{7}$ oz.

*Proof.*— $3{,}900 \times 16 = 62{,}400$ product of the means.
$16{,}800 \times 3\frac{5}{7} = 62{,}400$ " " extremes.
($16{,}800 \times 3\frac{5}{7} = 16{,}800 \times \frac{26}{7}$ and $16{,}800 \times 26 = 436{,}800 \div 7 = 62{,}400$.)

**A Compound Proportion** is a proportion in which either one or both the ratios are compound.

The rule for finding the answer is as follows: Place the number which is of the same kind or denomination as the answer required for the third term, form a ratio of each remaining pair of numbers of the same kind, the same as done in simple proportion, using each couplet without any reference to the other. Next, divide the product of the means by the product of the given extremes, and the quotient is the fourth term (= answer.)

*Example.*—If weaving 1,536 yards of cloth on 8 looms in 12 days. how many yards will be woven on 34 looms in 16 days.

(Looms to Looms.)
8 : 34
(Days to Days.)
12 : 16

( Yards to Yards. )
1,536 : x

$$\frac{16 \times 34 \times 1{,}536}{12 \times 8} = x \quad \text{or} \quad \frac{\overset{2}{\not{16}} \times 34 \times \overset{128}{\not{1536}}}{\not{12} \times \not{8}} = 2 \times 34 = 68 \times 128 = 8704$$

*Answer.*— 8,704 yards will be woven.

*Proof.*—8 looms 12 days $= 8 \times 12 = 96$ looms running 1 day.
1,536 yards are woven on 96 looms in one day; thus, $1536 \div 96 = 16$ yards per day (per one loom).
34 looms 16 days $= 34 \times 16 = 544$ looms running 1 day; thus,
$544 \times 16 = 8{,}704$ yards will be woven either on 544 looms in 1 day, or on 34 looms in 16 days.

*Example.*—If weaving 9,448 yards of cloth on 12 looms in 9 days, running the looms 10 hours per day, how many yards of cloth will 20 looms, running 11 hours per day, produce in 12 days.

(Looms to Looms.)
12 : 20
(Days to Days.)
9 : 12
(Hours to Hours.)
10 : 11

(Yards to Yards.)
9448 : x

$$\frac{11 \times 12 \times 20 \times 9448}{10 \times 9 \times 12} = x$$

$$\frac{11 \times \not{12} \times \overset{2}{\not{20}} \times 9448}{\not{10} \times 9 \times \not{12}} = \frac{11 \times 2 \times 9448}{9}$$

$$11 \times 2 = 22 \times 9448 = 207856$$

$$207856 \div 9 = 23095\tfrac{1}{9}$$

***Answer.*—23,095$\frac{1}{9}$ yds. will be produced.**

*Proof.*—12 looms, 9 days, 10 hours = 1,080 hours for one loom
9,448 are woven in 1,080 hours on one loom; thus,
9,448 ÷ 1,080 = $8\frac{101}{135}$ yds. per hour on one loom.
20 looms, 11 hours, 12 days = 2,640 hours; thus,
2,640 × $8\frac{101}{135}$ = 23,095$\frac{1}{9}$ yds. will be woven either in 2,640 hours on one loom, or on 20 looms running 11 hours per day in 12 days.

## ALLIGATION.

Alligation has for its subject the mixing of articles of different value and different quantities.

### Alligation Medial.

*Rule.*—Multiply each quantity by its value and divide the sum of the products by the sum of the quantities.

*Example.*—Find the average value per pound for the following lot of wool containing mixed:

380 lbs. @ 74¢ per lb.
400 " " 78 " "
200 " " 79 " "
20 " " 94 " "

380 × 74 = $281.20
400 × 78 = 312.00
200 × 79 = 158.00
20 × 94 = 18.80
———
1000 $770.00

770.00 ÷ 1000 = 0.77

*Answer.*—The price of the mixture is 77¢ per lb.
*Proof.*— 77¢ × 1000 = $770.00.

### Alligation Alternate.

*Rule.*—Place the different values of the articles in question under each other, and the average rate wanted to the left of them. Next find the gain or loss on one unit of each, and use an additional portion (of one, two or more) of any that will make the gains balance the losses.

*Example.*—How much of each kind of wool at respective values of 80¢, 84¢ and 98¢, must be mixed to produce a mixture to sell at 88¢ per lb.

$$88\left\{\begin{array}{c|l} 80 & +\ 8 \times 1 = 8 \\ 84 & +\ 4 \times 1 = +\underline{4} = 12 \text{ gain} \\ 98 & -\ 10 \times 1\frac{1}{5} = \quad = 12 \text{ loss} \end{array}\right.$$

*Answer.*—We must use 1 part wool from the lot @ 80¢.
1 " " " " " " 84
$1\frac{1}{5}$ " " " " " " 98 in
—
$3\frac{1}{5}$ parts, to produce a mixture to sell at 88¢ per lb.

*Proof.*— By alligation medial.
1 lb. × 80¢............ 80¢
1 lb. × 84 ............ 84
$1\frac{1}{5}$ lbs. × 98 ............ $117\frac{3}{5}$
—
$3\frac{1}{5}$ lbs. $281\frac{3}{5}$¢ and $3\frac{1}{5}$ lbs. × 88¢ = also $281\frac{3}{5}$¢

### To Find the Quantity of Each Kind Where the Quantity of One Kind or of the Mixture is Given.

*Example.*—A manufacturer has 200 lbs. of wool of a value of 92 cents on hand which he wants to use up and produce a lot worth 80 cents per lb. He also has another large lot (2400 lbs.) of wool worth 73 cents per lb. on hand. How much of the latter must he use to produce the result; *i. e.*, a mixture worth 80 cents per lb?

$$80 \left\{ \begin{array}{l|l} 92 & -\ 12 \times 200 \quad = 2{,}400 \text{ loss.} \\ 73 & +\ \ 7 \times 342\tfrac{6}{7} = 2{,}400 \text{ gain.} \end{array} \right.$$

*Answer.*—He must mix 200 lbs. of the lot at 92 cents per lb. on hand and add $342\frac{6}{7}$ lbs. of the lot at 73 cents per lb. to produce a mixture worth 80 cents per lb.

*Proof.*— 200 lbs. × 92¢ = $184.00

$342\frac{6}{7}$ lbs. × 73¢ = $250.28\frac{4}{7}$

$542\frac{6}{7}$ — $434.28\frac{4}{7}$ and $542\frac{6}{7}$ lbs. @ 80¢ = also $434.28\frac{4}{7}$.

## U. S. MEASURES.

### Measures of Length.

| | | |
|---|---|---|
| 12 | inches (in.) | = 1 foot (ft.). |
| 3 | feet | = 1 yard (yd.). |
| $5\frac{1}{2}$ | yards | = 1 rod (rd.). |
| 40 | rods | = 1 furlong (fur.). |
| 8 | furlongs | = 1 mile (mi.). |
| 3 | miles | = 1 league (lea.). |
| 1760 | yards | = 1 mile. |
| 6 | feet | = 1 fathom. |

### Avoirdupois Weight.

| | |
|---|---|
| 16 drachms (dr.) | = 1 ounce (oz.). |
| 16 ounces | = 1 pound (lb.). |
| 28 pounds | = 1 quarter (qr.) |
| 4 quarters | = 1 hundred weight(cwt.). |
| 20 hundredweight | = 1 ton. |
| 1 pound *Avoirdupois* | = 7,000 grains, *Troy*. |
| 1 ounce " | = $437\frac{1}{2}$ " " |

### Surface Measure.

| | | |
|---|---|---|
| 144 | square inches (sq. in.) | =1 square foot (sq. ft.). |
| 9 | " feet | =1 " yard (sq. yd.) |
| $30\frac{1}{4}$ | " yards | =1 " rod (sq. rd.). |
| 40 | " rods | =1 rood (ro.). |
| 4 | roods | =1 acre (ac.). |
| 4840 | square yards | =1 acre. |
| 60 | acres | =1 square mile. |

### Measure of Capacity.

| | |
|---|---|
| 60 minims | = 1 fluid drachm (fl. dr.). |
| 8 fluid drachms | = 1 fluid ounce (fl. oz.). |
| 20 fluid ounces | = 1 pint (pt.). |
| 2 pints | = 1 quart (qt.). |
| 4 quarts | = 1 gallon (gall.). |
| 2 gallons | = 1 peck (pk.). |
| 4 pecks | = 1 bushel (bus.). |
| 8 bushels | = 1 quarter (qr.). |

1 minim equals 0.91 grain of water.

### Cubic Measure.

| | |
|---|---|
| 1728 cubic inches (cu. in.) | =1 cubic foot (cu. ft.). |
| 27 cubic feet | =1 cubic yard (cu. yd.). |

### Angle Measure.

| | |
|---|---|
| 60 seconds (″) | are 1 minute (′). |
| 60 minutes | " 1 degree (°). |
| 360 degrees | " 1 circumference (C). |

### Counting.

| | |
|---|---|
| 12 ones | = 1 dozen (doz.). |
| 12 dozen | = 1 gross (gr.). |
| 12 gross | = 1 great gross (gr. grs.). |
| 20 ones | = 1 score. |

### Troy Weight.

| | |
|---|---|
| 24 grains (gr.) | = 1 pennyweight. |
| 20 pennyweights | = 1 ounce. |
| 12 ounces | = 1 pound. |

### Paper.

| | |
|---|---|
| 24 sheets | = 1 quire. |
| 20 quires | = 1 ream. |
| 2 reams | = 1 bundle. |
| 5 bundles | = 1 bale. |

### Apothecaries' Weight.

| | |
|---|---|
| 20 grains | = 1 scruple. |
| 3 scruples | = 1 dram. |
| 8 drams | = 1 ounce. |
| 12 ounces | = 1 pound. |

## METRIC SYSTEM.

The Metric System, of weights and measures, is formed upon the decimal scale, and has for its base a unit called a metre.

*Units.*—The following are the different units with their English pronunciation:

*The Metre* (meter).—The unit of the Metric Measure is (very nearly) the ten millionths part of a line drawn from the pole to the equator.

*The Litre* (leeter).—The unit for all metric measures of capacity, dry or liquid, is a cube whose edge is the tenth of a metre (or one cubic decimetre).

*The Gram* (gram).—The unit of the Metric Weights, is the weight of a cubic centimetre of distilled water at 4° centigrade.

*The Are* (air).—is the unit for land measure. (It is a square whose sides are ten (10) metres.)

*The Stere* (stair).—is the unit for solid or cubic measure. (It is a cube whose edge is one (1) metre.)

### Measure of Length.

| Metric Denominations and Values. | | | Equivalent in Denominations used in the United States. | | |
|---|---|---|---|---|---|
| | Meters. | | Inches. | | |
| Myriametre (Mm.) | or 10000 | equals | 393707.904 | = | 6.21 miles. |
| Kilometre (Km.) | " 1000 | " | 39370.7904 | = | 3.280 ft. 10 in. |
| Hectometre (Hm.) | " 100 | " | 3937.07904 | = | 328 ft. 1 in. |
| Decametre (Dm.) | " 10 | " | 393.707904 | = | 32.8 ft. |
| Metre (M.) | " 1 | " | 39.3707904 | = | 3.28 ft. almost 40 in. |
| Decimetre (dm.) | " 0.1 | " | 3.9370790 | = | almost 4 in. |
| Centimetre (cm.) | " 0.01 | " | 0.3937079 | | |
| Millimetre (mm.) | " 0.001 | " | 0.0393707 | | |

| U. S. Measures. | Metric Measure. | U. S. Measures | Metric Measures. |
|---|---|---|---|
| 1 Inch = | 2.5399 Centimeters. | 1 Foot = | 3 0479 Decimetres. |
| 1 Yard = | 0.9143 Metre. | 1 Mile = | 1609.32 Metres. |

### Measure of Capacity.

| Metric Denominations and Values. | | | | | | | Equivalent in United States Denominations. | | |
|---|---|---|---|---|---|---|---|---|---|
| Myrialitre (Ml.) | = | 10000 | litres | = | 10 | cubic meters | = | 2200.9670 | gallons |
| Kilolitre (Kl.) | = | 1000 | " | = | 1 | " metre | = | 220.0967 | " |
| Hectolitre (Hl.) | = | 100 | " | = | 100 | " decimetres | = | 22.0097 | " |
| Decalitre (Dl.) | = | 10 | " | = | 10 | " decimetres | = | 2.2009 | " |
| Litre (L.) | = | 1 | " | = | 1 | " decimetre | = | 1.7608 | pints |
| Decilitre (dl.) | = | 0.1 | " | = | 100 | " centimetres | = | 6.1027 | cubic inches |
| Centilitre (cl.) | = | 0.01 | " | = | 10 | " centimetres | = | 0.61027 | " " |
| Millilitre (ml.) | = | 0.001 | " | = | 1 | " centimetre | = | 0.061 | " " |

### Measure of Weight.

| Metric Denominations and Values. | | | | | | | Equivalent in United States Denominations. | |
|---|---|---|---|---|---|---|---|---|
| Myriagram (Mg.) | = | 10000 | grams. | = | 10 | cu. decimetres of water | 22.046 | lbs., Avoir. |
| Kilogram (Kg.) | = | 1000 | " | = | 1 | " " " " | 2.204 | " " |
| Hectogram (Hg.) | = | 100 | " | = | 100 | " centimetres " " | 3.527 | oz., " |
| Decagram (Dg.) | = | 10 | " | = | 10 | " " " " | 154.323 | grams. |
| Gram (G.) | = | 1 | " | = | 1 | " " " " | 15.432 | " |
| Decigram (dg.) | = | 0.1 | " | = | 100 | " millimetres " " | 1.543 | " |
| Centigram (cg.) | = | 0.01 | " | = | 10 | " " " " | 0.154 | " |
| Miligram (mg.) | = | 0.001 | " | = | 1 | " " " " | 0.015 | " |

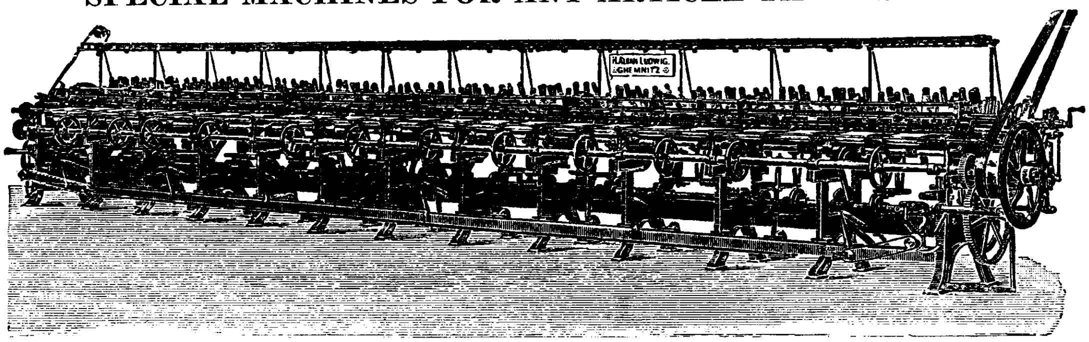
# THE GROSSER KNITTING MACHINE CO.

WOOL EXCHANGE
ROOMS 400-421

## MAX NYDEGGER

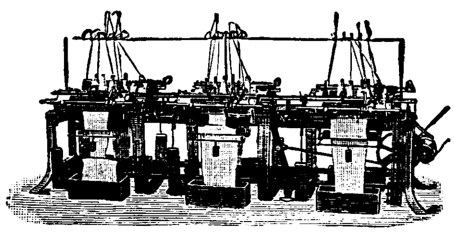
260 W. BROADWAY
NEW YORK.

**SPECIAL MACHINES FOR ANY ARTICLE THAT IS KNIT**



**FULL FASHIONED HOSIERY MACHINES, system "COTTON"**

Built by H. Alban Ludwig, Chemnitz, for Hose and Half Hose (Plain, Striped or Lace work), for Full Fashioned Underwear, fine Sporting and Theatrical goods, etc., etc., in all gauges from 12 to 34 needles per inch, 4 to 24 sections.



**GROSSER FLAT KNITTING MACHINES**

For HAND power or FULLY AUTOMATIC POWER MACHINES. Most productive and best machines for Sweaters, Jackets, Blouses, Wool Hosiery, Gloves, Mittens, Sporting Goods, in Plain, Fancy and Jacquard Work (front, or front and back), Shaker Articles, etc. Large stock on hand. Machines to be seen in operation.

**RASHEL MACHINES AND CHAIN LOOMS, OVERSEAMERS AND LOOPERS, TERROT FRAMES, ETC.**

Parts and Needles immediately supplied from stock.

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## J. & H. BERGE

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**Chemical and Physical Apparatus, &c.**

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**Drying and Sulphur House Poles of "Natural Round Water-Grown Cedar," of all sizes and for all Cotton, Wool and Slub Dyeing, etc. Special grades of Cedar and Hardwoods, in "Selects," without knots, etc., for Silk Dyeing.**

**NOTE.—Since introducing this product, over 20 years ago, our Special Water Cedar has been found far more desirable and superior to any other kind or shape of wood, and much more economical.**

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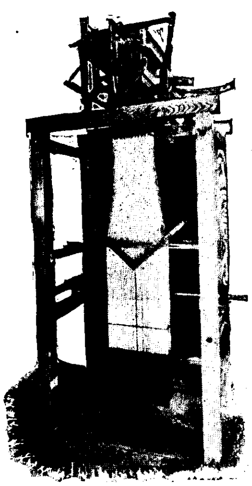

Brauch Harness Contracted.

EDW. CLEAVER WM. A. LEATHER

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## Jacquard Harness Builders

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**The best and most economical of any other in use. By the Brauch System change of harness to different counts can be made in a few minutes at the Cumber Board. Notice views of "Harness Contracted" and "Harness Expanded."**

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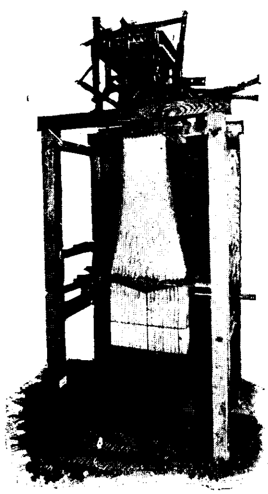

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### *For all Textile Fabrics*

***Repeating for Throw-over for Fine and French Index***

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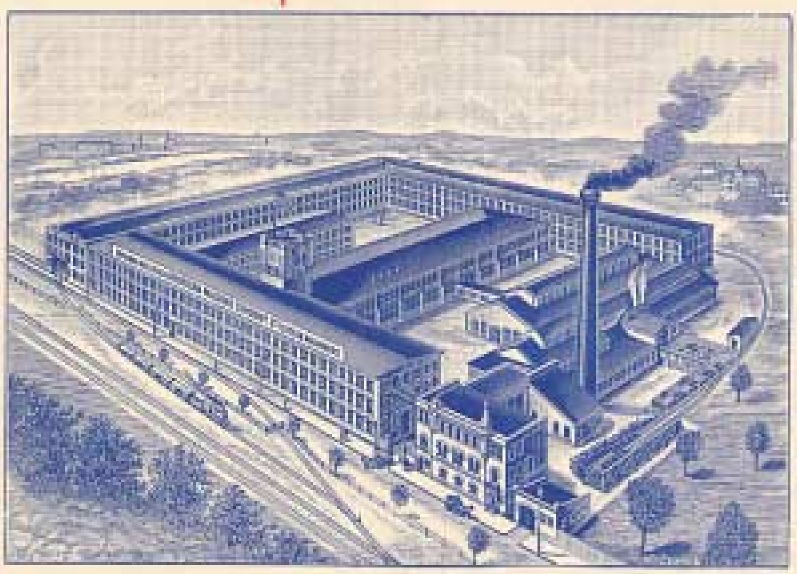

Hopper Bale Openers
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SEND FOR DESCRIPTIVE CIRCULARS WITH LISTS OF USERS.

NEW PATTERN SPINNING FRAMES
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# SLUBBERS, INTERMEDIATES,

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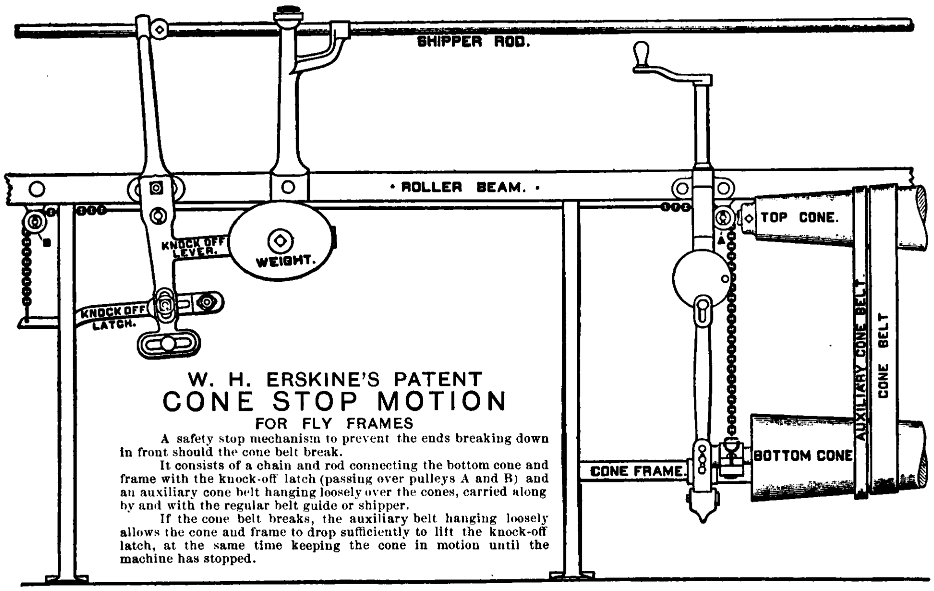


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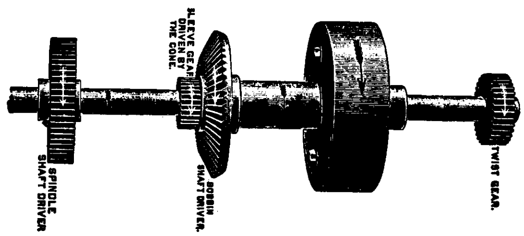
PATENTED MARCH, 1895

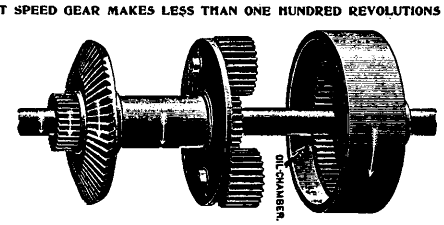
**All motions in one direction, thereby reducing friction and saving oil.**




**The cone is no longer a driver**

THE HIGHEST SPEED GEAR MAKES LESS THAN ONE HUNDRED REVOLUTIONS PER MINUTE.

**Now only a regulator, as the power is taken direct from the main shaft.**




**Gearing is covered from dust.**
**Oil-chambers for oil.**

**No more trouble caused by cone belts breaking or slipping, as the great strain is removed.**

**Manufactured by the**

# WOONSOCKET MACHINE and PRESS CO.,

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# WYANDOTTE TEXTILE SODA

as a wool and cloth scourer and fuller, soap builder, acid neutralizer and assistant in setting and brightening of colors it has no equal.

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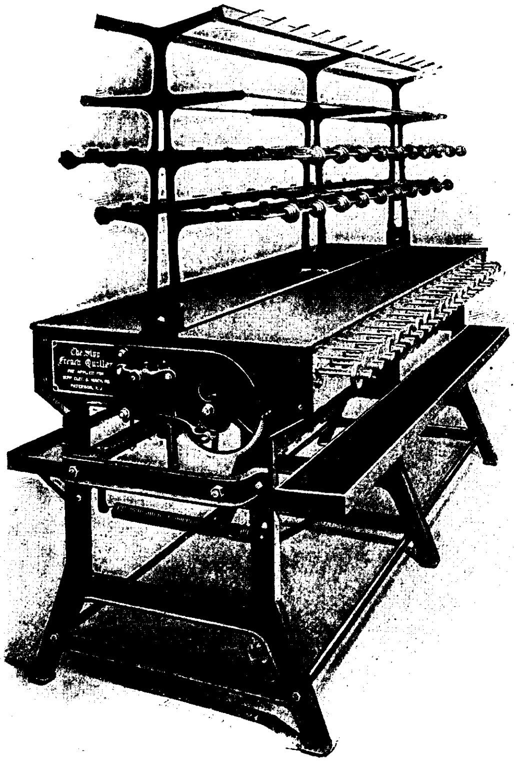



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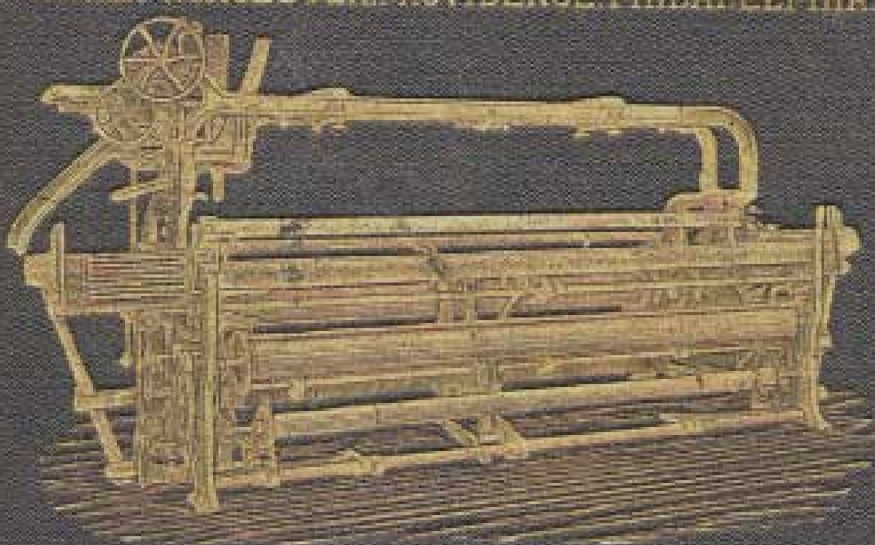

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# WEAVING MACHINERY

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