The

'otton Textile Worker's Handbook

A CONVENIENT REFERENCE BOOK

For All Persons Interested In

he Spinning of Cotton Yarns, the Weaving of Cotton Fabrics, and the Yarn and Cloth Calculations Incidental Thereto

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BY

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PREFACE

In this work, the publishers have not attempted to produce a condensed cyclopedia covering the extensive field of cotton manufacturing, but they have aimed to present a useful reference book convenient to carry in the pocket—a pocketbook in truth—and containing information, especially rules, tables, etc., often used and required by superintendents, overseers, fixers, and, in fact, all persons engaged or interested in the great cotton textile manufacturing industry and its many ramifications.

The intention has been to select from a vast amount of material only that which is most likely to be of use in connection with daily work or to which reference will be made most frequently. The treatment of many subjects is of necessity brief, but these matters have been covered to the full extent of the available space, and the text relating thereto includes that which is most valuable for frequent reference. The material on yarn calculations, cloth calculations, and draft calculations presents, in each case, a finished treatise that, it is hoped, will prove of great value. Many tables are included and a great number of these, such as, for instance, the cotton-yarn numbering table, the cotton-roving numbering table, and the many tables indicating the production of various machines under a wide range of conditions, should prove of daily use. Other tables and much information and data relative to the timing, setting, and adjustment of textile machinery will be of importance on many occasions. Great care has been taken to insure the accuracy of the large number of rules included, and these will be found entirely trustworthy.

This handbook has been prepared by, and under the supervision of, Mr. C. J. Brickett, Principal of our School of Textiles.

International Correspondence Schools

January, 1920

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The Cotton Textile Worker's Handbook

YARN CALCULATIONS

SINGLE YARNS

The word *counts*, when used in connection with yarn, refers to the number, or size, of a yarn as determined by the relation that exists between the length and the weight of a given quantity of that yarn. Thus, in the almost universally-adopted system of numbering cotton yarn, the counts of any given yarn are determined by the number of times that a standard length of 840 yd., known as a *hank*, is contained in the number of yards of that yarn required to weigh 1 lb. The length of the hank, 840 yd., is always constant; for instance, a cotton yarn may be of fine, medium, or coarse counts, but a hank of that yarn always contains 840 yd.

The method of numbering is that of calling a yarn that contains 1 hank, or 840 yd., in 1 lb. a *No. 1 yarn*. If the yarn contains 2 hanks, or 1,680 yd., in 1 lb., it is known as a *No. 2 yarn;* if it contains 3 hanks, or 2,520 yd., in 1 lb., it is known as a *No. 3 yarn*. Thus the number of hanks that it takes to weigh 1 lb. determines the counts of the yarn.

The counts of a yarn are generally indicated by placing a letter *s* after the figure representing the number of the yarn. Thus, 26s shows the counts of a yarn and indicates that the yarn contains 26 hanks (26×840 yd.) in 1 lb.

Rule.—*To find the counts of a yarn when the length and weight are given, divide the total length of yarn, expressed in yards, by the weight, expressed in pounds, times the standard length.*

EXAMPLE.—If 168,000 yd. of yarn weighs 5 lb., what are the counts?

SOLUTION.—

$$\frac{168{,}000 \text{ (length of yarn, in yards)}}{5 \text{ (weight, in pounds)} \times 840 \text{ (standard)}} = 40\text{s, counts}$$

Rule.—*To find the weight of yarn when the length and counts are known, divide the length, in yards, by the counts times the standard length.*

EXAMPLE.—What is the weight of 42,000 yd. of number 5s yarn?

SOLUTION.— $$\frac{42{,}000 \text{ (length, in yards)}}{(5 \text{ counts}) \times 840 \text{(standard)}} = 10 \text{ lb.}$$

Rule.—*To find the length of yarn when the weight and counts are known, multiply the weight, in pounds, counts, and standard length together.*

EXAMPLE.—What is the length of yarn contained in a bundle that weighs 8 lb., the counts of the yarn being 26s?

SOLUTION.— 8 (weight, in lb.) $\times$ 26 (counts) $\times$ 840 (standard) $= 174{,}720$ yd.

In yarn calculations it is frequently of advantage to subdivide the standard length of the hank, 840 yd., and the standard weight of 1 lb. Hence, two tables are used, as follows:

TABLE OF LENGTH

$1\frac{1}{2}$ yards (yd.)	= 1 thread, or circumference of wrap reel		
120 yards	= 80 threads	= 1 skein, or lea	
840 yards	= 560 threads	= 7 skeins, or leas	= 1 hank

TABLE OF WEIGHT

27.34 grains (gr.)	= 1 dram (dr.)		
437.5 grains	= 16 drams	= 1 ounce (oz.)	
7,000 grains	= 256 drams	= 16 ounces	= 1 pound (lb.)

SIZING YARN AND ROVING

A *yarn* is a thread composed of fibers uniformly disposed throughout its structure and having a certain amount of twist for the purpose of enhancing its strength. *Roving*, however, although its size is determined in a similar manner to that of yarn, is a term used to designate a loosely-twisted strand of fibers, the latter lying more or less parallel with each other, in which form the cotton is placed at various processes previous to the actual spinning of the yarn. In order that the yarn and roving may be kept of the correct size, it is generally the custom to weigh a certain length of the product of each machine, at least once a day, and by this means ascertain whether the roving or yarn is being kept at the required weight. This process is known as *sizing*, and is a matter that should always be carefully attended to.

From the rules and explanations previously given it will be plain that if 840 yd. (1 hank) were always the length weighed, in order to learn the counts of the yarn, it would simply be

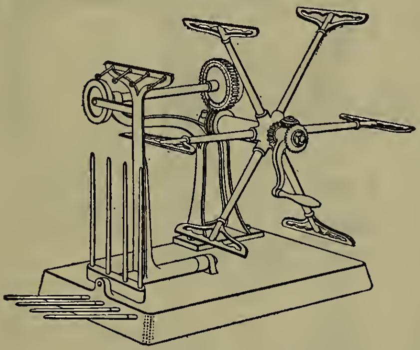


FIG. 1

necessary to divide the weight, expressed in pounds, into 1 lb., or if expressed in grains, into 7,000 (the number of grains in 1 lb.). It will readily be seen that to measure off 840 yd. of yarn would not only require considerable time, but would also produce an unnecessary waste of material. To overcome these difficulties, when sizing yarn, it is customary to measure off one skein (120 yd.) or one-seventh of 840 yd.; to weigh this amount; and divide its weight in grains into one-seventh of 7,000, or 1,000. The result obtained in this manner will be the same as if 840 yd. were taken and the weight, in grains, divided into 7,000.

When sizing yarns, a *wrap reel* is used to measure the yarn. As its name indicates, this instrument consists of a reel, generally $1\frac{1}{2}$ yd. in circumference. The yarn is wound on this reel and a finger indicates on a disk the number of yards reeled. Fig. 1 shows an ordinary type of wrap reel, and Fig. 2 shows yarn and roving scales. These scales are suitable for weighing by tenths of grains.

EXAMPLE.— 120 yd. of yarn is reeled and found to weigh 40 gr.; what are the counts?

SOLUTION.— $1,000 \div 40 = 25$s

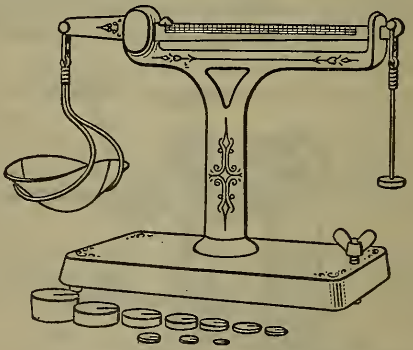


FIG. 2

The size of cotton roving is determined in a similar manner and indicated on the same basis as is the size of cotton yarn, although, when sizing roving, a shorter length is used. It is customary in this case to measure off one-seventieth of 840 yd., or 12 yd., and divide the weight, in grains, of this length of roving into one-seventieth of 7,000, or 100.

EXAMPLE.— 12 yd. of roving is found to weigh 20 gr.; what are the counts?

SOLUTION.— $100 \div 20 = 5$-hank roving

To avoid calculation when sizing yarns, a table showing the weight by grains and tenths of grains of 120 yd., or 1 skein, of yarn is ordinarily employed. The accompanying cotton-yarn numbering table is a well-arranged and complete table for this purpose.

COTTON-YARN NUMBERING TABLE

Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn
5	200.0	9.1	109.9	13.2	75.8	17.3	57.80
5.1	196.1	9.2	108.7	13.3	75.2	17.4	57.47
5.2	192.3	9.3	107.5	13.4	74.6	17.5	57.14
5.3	188.7	9.4	106.4	13.5	74.1	17.6	56.82
5.4	185.2	9.5	105.3	13.6	73.5	17.7	56.50
5.5	181.8	9.6	104.2	13.7	73.0	17.8	56.18
5.6	178.6	9.7	103.1	13.8	72.5	17.9	55.87
5.7	175.4	9.8	102.0	13.9	71.9	18	55.56
5.8	172.4	9.9	101.0	14	71.4	18.1	55.25
5.9	169.5	10	100.0	14.1	70.9	18.2	54.95
6	166.7	10.1	99.0	14.2	70.4	18.3	54.64
6.1	164.0	10.2	98.0	14.3	69.9	18.4	54.35
6.2	161.3	10.3	97.1	14.4	69.4	18.5	54.05
6.3	158.7	10.4	96.1	14.5	69.0	18.6	53.76
6.4	156.2	10.5	95.2	14.6	68.5	18.7	53.48
6.5	153.8	10.6	94.3	14.7	68.0	18.8	53.19
6.6	151.5	10.7	93.5	14.8	67.6	18.9	52.91
6.7	149.3	10.8	92.6	14.9	67.1	19	52.63
6.8	147.1	10.9	91.7	15	66.67	19.1	52.36
6.9	144.9	11	90.9	15.1	66.23	19.2	52.08
7	142.9	11.1	90.1	15.2	65.79	19.3	51.81
7.1	140.8	11.2	89.3	15.3	65.36	19.4	51.55
7.2	138.9	11.3	88.5	15.4	64.94	19.5	51.28
7.3	137.0	11.4	87.7	15.5	64.52	19.6	51.02
7.4	135.1	11.5	87.0	15.6	64.10	19.7	50.76
7.5	133.3	11.6	86.2	15.7	63.69	19.8	50.51
7.6	131.6	11.7	85.5	15.8	63.29	19.9	50.25
7.7	129.9	11.8	84.7	15.9	62.89	20	50.00
7.8	128.2	11.9	84.0	16	62.50	20.1	49.75
7.9	126.6	12	83.3	16.1	62.11	20.2	49.50
8	125	12.1	82.6	16.2	61.73	20.3	49.26
8.1	123.5	12.2	82.0	16.3	61.35	20.4	49.02
8.2	122	12.3	81.3	16.4	60.98	20.5	48.78
8.3	120.5	12.4	80.6	16.5	60.61	20.6	48.54
8.4	119.0	12.5	80.0	16.6	60.24	20.7	48.31
8.5	117.6	12.6	79.4	16.7	59.88	20.8	48.08
8.6	116.3	12.7	78.7	16.8	59.52	20.9	47.85
8.7	114.9	12.8	78.1	16.9	59.17	21	47.62
8.8	113.6	12.9	77.5	17	58.82	21.1	47.39
8.9	112.4	13	76.9	17.1	58.48	21.2	47.17
9	111.1	13.1	76.3	17.2	58.14	21.3	46.95

Table—*(Continued)*

Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn
21.4	46.73	25.5	39.22	29.6	33.78	33.7	29.67
21.5	46.51	25.6	39.06	29.7	33.67	33.8	29.59
21.6	46.30	25.7	38.91	29.8	33.56	33.9	29.50
21.7	46.08	25.8	38.76	29.9	33.44	34	29.41
21.8	45.87	25.9	38.61	30	33.33	34.1	29.33
21.9	45.66	26	38.46	30.1	33.22	34.2	29.24
22	45.45	26.1	38.31	30.2	33.11	34.3	29.15
22.1	45.25	26.2	38.17	30.3	33.00	34.4	29.07
22.2	45.05	26.3	38.02	30.4	32.89	34.5	28.99
22.3	44.84	26.4	37.88	30.5	32.79	34.6	28.90
22.4	44.64	26.5	37.74	30.6	32.68	34.7	28.82
22.5	44.44	26.6	37.59	30.7	32.57	34.8	28.74
22.6	44.25	26.7	37.45	30.8	32.47	34.9	28.65
22.7	44.05	26.8	37.31	30.9	32.36	35	28.57
22.8	43.86	26.9	37.17	31	32.26	35.1	28.49
22.9	43.67	27	37.04	31.1	32.15	35.2	28.41
23	43.48	27.1	36.90	31.2	32.05	35.3	28.33
23.1	43.29	27.2	36.76	31.3	31.95	35.4	28.25
23.2	43.10	27.3	36.63	31.4	31.85	35.5	28.17
23.3	42.92	27.4	36.50	31.5	31.75	35.6	28.09
23.4	42.74	27.5	36.36	31.6	31.65	35.7	28.01
23.5	42.55	27.6	36.23	31.7	31.55	35.8	27.93
23.6	42.37	27.7	36.10	31.8	31.45	35.9	27.86
23.7	42.19	27.8	35.97	31.9	31.35	36	27.78
23.8	42.02	27.9	35.84	32	31.25	36.1	27.70
23.9	41.84	28	35.71	32.1	31.15	36.2	27.62
24	41.67	28.1	35.59	32.2	31.06	36.3	27.55
24.1	41.49	28.2	35.46	32.3	30.96	36.4	27.47
24.2	41.32	28.3	35.34	32.4	30.86	36.5	27.40
24.3	41.15	28.4	35.21	32.5	30.77	36.6	27.32
24.4	40.98	28.5	35.09	32.6	30.67	36.7	27.25
24.5	40.82	28.6	34.97	32.7	30.58	36.8	27.17
24.6	40.65	28.7	34.84	32.8	30.49	36.9	27.10
24.7	40.49	28.8	34.72	32.9	30.40	37	27.03
24.8	40.32	28.9	34.60	33	30.30	37.1	26.95
24.9	40.16	29	34.48	33.1	30.21	37.2	26.88
25	40.00	29.1	34.36	33.2	30.12	37.3	26.81
25.1	39.84	29.2	34.25	33.3	30.03	37.4	26.74
25.2	39.68	29.3	34.13	33.4	29.94	37.5	26.67
25.3	39.53	29.4	34.01	33.5	29.85	37.6	26.60
25.4	39.37	29.5	33.90	33.6	29.76	37.7	26.53

TABLE—(*Continued*)

Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn
37.8	26.46	41.9	23.87	46	21.74	50.1	19.96
37.9	26.39	42	23.81	46.1	21.69	50.2	19.92
38	26.32	42.1	23.75	46.2	21.65	50.3	19.88
38.1	26.25	42.2	23.70	46.3	21.60	50.4	19.84
38.2	26.18	42.3	23.64	46.4	21.55	50.5	19.80
38.3	26.11	42.4	23.58	46.5	21.51	50.6	19.76
38.4	26.04	42.5	23.53	46.6	21.46	50.7	19.72
38.5	25.97	42.6	23.47	46.7	21.41	50.8	19.69
38.6	25.91	42.7	23.42	46.8	21.37	50.9	19.65
38.7	25.84	42.8	23.36	46.9	21.32	51	19.61
38.8	25.77	42.9	23.31	47	21.28	51.1	19.57
38.9	25.71	43	23.26	47.1	21.23	51.2	19.53
39	25.64	43.1	23.20	47.2	21.19	51.3	19.49
39.1	25.58	43.2	23.15	47.3	21.14	51.4	19.46
39.2	25.51	43.3	23.09	47.4	21.10	51.5	19.42
39.3	25.45	43.4	23.04	47.5	21.05	51.6	19.38
39.4	25.38	43.5	22.99	47.6	21.01	51.7	19.34
39.5	25.32	43.6	22.94	47.7	20.96	51.8	19.31
39.6	25.25	43.7	22.88	47.8	20.92	51.9	19.27
39.7	25.19	43.8	22.83	47.9	20.88	52	19.23
39.8	25.13	43.9	22.78	48	20.83	52.1	19.19
39.9	25.06	44	22.73	48.1	20.79	52.2	19.16
40	25.00	44.1	22.68	48.2	20.75	52.3	19.12
40.1	24.94	44.2	22.62	48.3	20.70	52.4	19.08
40.2	24.88	44.3	22.57	48.4	20.66	52.5	19.05
40.3	24.81	44.4	22.52	48.5	20.62	52.6	19.01
40.4	24.75	44.5	22.47	48.6	20.58	52.7	18.98
40.5	24.69	44.6	22.42	48.7	20.53	52.8	18.94
40.6	24.63	44.7	22.37	48.8	20.49	52.9	18.90
40.7	24.57	44.8	22.32	48.9	20.45	53	18.87
40.8	24.51	44.9	22.27	49	20.41	53.1	18.83
40.9	24.45	45	22.22	49.1	20.37	53.2	18.80
41	24.39	45.1	22.17	49.2	20.33	53.3	18.76
41.1	24.33	45.2	22.12	49.3	20.28	53.4	18.73
41.2	24.27	45.3	22.08	49.4	20.24	53.5	18.69
41.3	24.21	45.4	22.03	49.5	20.20	53.6	18.66
41.4	24.15	45.5	21.98	49.6	20.16	53.7	18.62
41.5	24.10	45.6	21.93	49.7	20.12	53.8	18.59
41.6	24.04	45.7	21.88	49.8	20.08	53.9	18.55
41.7	23.98	45.8	21.83	49.9	20.04	54	18.52
41.8	23.92	45.9	21.79	50	20.00	54.1	18.48

TABLE—*(Continued)*

Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn
54.2	18.45	58.3	17.15	62.4	16.03	66.5	15.04
54.3	18.42	58.4	17.12	62.5	16.00	66.6	15.02
54.4	18.38	58.5	17.09	62.6	15.97	66.7	14.99
54.5	18.35	58.6	17.06	62.7	15.95	66.8	14.97
54.6	18.32	58.7	17.04	62.8	15.92	66.9	14.95
54.7	18.28	58.8	17.01	62.9	15.90	67	14.93
54.8	18.25	58.9	16.98	63	15.87	67.1	14.90
54.9	18.21	59	16.95	63.1	15.85	67.2	14.88
55	18.18	59.1	16.92	63.2	15.82	67.3	14.86
55.1	18.15	59.2	16.89	63.3	15.80	67.4	14.84
55.2	18.12	59.3	16.86	63.4	15.77	67.5	14.81
55.3	18.08	59.4	16.84	63.5	15.75	67.6	14.79
55.4	18.05	59.5	16.81	63.6	15.72	67.7	14.77
55.5	18.02	59.6	16.78	63.7	15.70	67.8	14.75
55.6	17.99	59.7	16.75	63.8	15.67	67.9	14.73
55.7	17.95	59.8	16.72	63.9	15.65	68	14.71
55.8	17.92	59.9	16.69	64	15.63	68.1	14.68
55.9	17.89	60	16.67	64.1	15.60	68.2	14.66
56	17.86	60.1	16.64	64.2	15.58	68.3	14.64
56.1	17.83	60.2	16.61	64.3	15.55	68.4	14.62
56.2	17.79	60.3	16.58	64.4	15.53	68.5	14.60
56.3	17.76	60.4	16.56	64.5	15.50	68.6	14.58
56.4	17.73	60.5	16.53	64.6	15.48	68.7	14.56
56.5	17.70	60.6	16.50	64.7	15.46	68.8	14.53
56.6	17.67	60.7	16.47	64.8	15.43	68.9	14.51
56.7	17.64	60.8	16.45	64.9	15.41	69	14.49
56.8	17.61	60.9	16.42	65	15.38	69.1	14.47
56.9	17.57	61	16.39	65.1	15.36	69.2	14.45
57	17.54	61.1	16.37	65.2	15.34	69.3	14.43
57.1	17.51	61.2	16.34	65.3	15.31	69.4	14.41
57.2	17.48	61.3	16.31	65.4	15.29	69.5	14.39
57.3	17.45	61.4	16.29	65.5	15.27	69.6	14.37
57.4	17.42	61.5	16.26	65.6	15.24	69.7	14.35
57.5	17.39	61.6	16.23	65.7	15.22	69.8	14.33
57.6	17.36	61.7	16.21	65.8	15.20	69.9	14.31
57.7	17.33	61.8	16.18	65.9	15.17	70	14.29
57.8	17.30	61.9	16.16	66	15.15	70.1	14.27
57.9	17.27	62	16.13	66.1	15.13	70.2	14.25
58	17.24	62.1	16.10	66.2	15.11	70.3	14.22
58.1	17.21	62.2	16.08	66.3	15.08	70.4	14.20
58.2	17.18	62.3	16.05	66.4	15.06	70.5	14.18

TABLE—*(Continued)*

Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn
70.6	14.16	74.7	13.39	78.8	12.69	82.9	12.06
70.7	14.14	74.8	13.37	78.9	12.67	83	12.05
70.8	14.12	74.9	13.35	79	12.66	83.1	12.03
70.9	14.10	75	13.33	79.1	12.64	83.2	12.02
71	14.08	75.1	13.32	79.2	12.63	83.3	12.00
71.1	14.06	75.2	13.30	79.3	12.61	83.4	11.99
71.2	14.04	75.3	13.28	79.4	12.59	83.5	11.98
71.3	14.03	75.4	13.26	79.5	12.58	83.6	11.96
71.4	14.01	75.5	13.25	79.6	12.56	83.7	11.95
71.5	13.99	75.6	13.23	79.7	12.55	83.8	11.93
71.6	13.97	75.7	13.21	79.8	12.53	83.9	11.92
71.7	13.95	75.8	13.19	79.9	12.52	84	11.90
71.8	13.93	75.9	13.18	80	12.50	84.1	11.89
71.9	13.91	76	13.16	80.1	12.48	84.2	11.88
72	13.89	76.1	13.14	80.2	12.47	84.3	11.86
72.1	13.87	76.2	13.12	80.3	12.45	84.4	11.85
72.2	13.85	76.3	13.11	80.4	12.44	84.5	11.83
72.3	13.83	76.4	13.09	80.5	12.42	84.6	11.82
72.4	13.81	76.5	13.07	80.6	12.41	84.7	11.81
72.5	13.79	76.6	13.05	80.7	12.39	84.8	11.79
72.6	13.77	76.7	13.04	80.8	12.38	84.9	11.78
72.7	13.76	76.8	13.02	80.9	12.36	85	11.76
72.8	13.74	76.9	13.00	81	12.35	85.1	11.75
72.9	13.72	77	12.99	81.1	12.33	85.2	11.74
73	13.70	77.1	12.97	81.2	12.32	85.3	11.72
73.1	13.68	77.2	12.95	81.3	12.30	85.4	11.71
73.2	13.66	77.3	12.94	81.4	12.29	85.5	11.70
73.3	13.64	77.4	12.92	81.5	12.27	85.6	11.68
73.4	13.62	77.5	12.90	81.6	12.25	85.7	11.67
73.5	13.61	77.6	12.89	81.7	12.24	85.8	11.66
73.6	13.59	77.7	12.87	81.8	12.22	85.9	11.64
73.7	13.57	77.8	12.85	81.9	12.21	86	11.63
73.8	13.55	77.9	12.84	82	12.20	86.1	11.61
73.9	13.53	78	12.82	82.1	12.18	86.2	11.60
74	13,51	78.1	12.80	82.2	12.17	86.3	11.59
74.1	13.50	78.2	12.79	82.3	12.15	86.4	11.57
74.2	13.48	78.3	12.77	82.4	12.14	86.5	11.56
74.3	13.46	78.4	12.76	82.5	12.12	86.6	11.55
74.4	13.44	78.5	12.74	82.6	12.11	86.7	11.53
74.5	13.42	78.6	12.72	82.7	12.09	86.8	11.52
74.6	13.40	78.7	12.71	82.8	12.08	86.9	11.51

TABLE—(*Continued*)

Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn
87	11.49	91.1	10.98	95.2	10.50	99.3	10.07
87.1	11.48	91.2	10.96	95.3	10.49	99.4	10.06
87.2	11.47	91.3	10.95	95.4	10.48	99.5	10.05
87.3	11.45	91.4	10.94	95.5	10.47	99.6	10.04
87.4	11.44	91.5	10.93	95.6	10.46	99.7	10.03
87.5	11.43	91.6	10.92	95.7	10.45	99.8	10.02
87.6	11.42	91.7	10.91	95.8	10.44	99.9	10.01
87.7	11.40	91.8	10.89	95.9	10.43	100	10.00
87.8	11.39	91.9	10.88	96	10.42	100.2	9.98
87.9	11.38	92	10.87	96.1	10.41	100.4	9.96
88	11.36	92.1	10.86	96.2	10.40	100.6	9.94
88.1	11.35	92.2	10.85	96.3	10.38	100.8	9.92
88.2	11.34	92.3	10.83	96.4	10.37	101	9.90
88.3	11.33	92.4	10.82	96.5	10.36	101.2	9.88
88.4	11.31	92.5	10.81	96.6	10.35	101.4	9.86
88.5	11.30	92.6	10.80	96.7	10.34	101.6	9.84
88.6	11.29	92.7	10.79	96.8	10.33	101.8	9.82
88.7	11.27	92.8	10.78	96.9	10.32	102	9.80
88.8	11.26	92.9	10.76	97	10.31	102.2	9.78
88.9	11.25	93	10.75	97.1	10.30	102.4	9.77
89	11.24	93.1	10.74	97.2	10.29	102.6	9.75
89.1	11.22	93.2	10.73	97.3	10.28	102.8	9.73
89.2	11.21	93.3	10.72	97.4	10.27	103	9.71
89.3	11.20	93.4	10.71	97.5	10.26	103.2	9.69
89.4	11.19	93.5	10.70	97.6	10.25	103.4	9.67
89.5	11.17	93.6	10.68	97.7	10.24	103.6	9.65
89.6	11.16	93.7	10.67	97.8	10.22	103.8	9.63
89.7	11.15	93.8	10.66	97.9	10.21	104	9.62
89.8	11.14	93.9	10.65	98	10.20	104.2	9.60
89.9	11.12	94	10.64	98.1	10.19	104.4	9.58
90	11.11	94.1	10.63	98.2	10.18	104.6	9.56
90.1	11.10	94.2	10.62	89.3	10.17	104.8	9.54
90.2	11.09	94.3	10.60	98.4	10.16	105	9.52
90.3	11.07	94.4	10.59	98.5	10.15	105.2	9.51
90.4	11.06	94.5	10.58	98.6	10.14	105.4	9.49
90.5	11.05	94.6	10.57	98.7	10.13	105.6	9.47
90.6	11.04	94.7	10.56	98.8	10.12	105.8	9.45
90.7	11.03	94.8	10.55	98.9	10.11	106	9.43
90.8	11.01	94.9	10.54	99	10.10	106.2	9.42
90.9	11.00	95	10.53	99.1	10.09	106.4	9.40
91	10.99	95.1	10.52	99.2	10.08	106.6	9.38

Table—(*Continued*)

Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn
106.8	9.36	115	8.70	128	7.81	148.5	6.73
107	9.35	115.2	8.68	128.5	7.78	149	6.71
107.2	9.33	115.4	8.67	129	7.75	149.5	6.69
107.4	9.31	115.6	8.65	129.5	7.72	150	6.67
107.6	9.29	115.8	8.64	130	7.69	151	6.62
107.8	9.28	116	8.62	130.5	7.66	152	6.58
108	9.26	116.2	8.61	131	7.63	153	6.54
108.2	9.24	116.4	8.59	131.5	7.60	154	6.49
108.4	9.23	116.6	8.58	132	7.58	155	6.45
108.6	9.21	116.8	8.56	132.5	7.55	156	6.41
108.8	9.19	117	8.55	133	7.52	157	6.37
109	9.17	117.2	8.53	133.5	7.49	158	6.33
109.2	9.16	117.4	8.52	134	7.46	159	6.29
109.4	9.14	117.6	8.50	134.5	7.43	160	6.25
109.6	9.12	117.8	8.49	135	7.41	161	6.21
109.8	9.11	118	8.47	135.5	7.38	162	6.17
110	9.09	118.2	8.46	136	7.35	163	6.13
110.2	9.07	118.4	8.45	136.5	7.33	164	6.10
110.4	9.06	118.6	8.43	137	7.30	165	6.06
110.6	9.04	118.8	8.42	137.5	7.27	166	6.02
110.8	9.03	119	8.40	138	7.25	167	5.99
111	9.01	119.2	8.39	138.5	7.22	168	5.95
111.2	8.99	119.4	8.38	139	7.19	169	5.92
111.4	8.98	119.6	8.36	139.5	7.17	170	5.88
111.6	8.96	119.8	8.35	140	7.14	171	5.85
111.8	8.94	120	8.33	140.5	7.12	172	5.81
112	8.93	120.5	8.30	141	7.09	173	5.78
112.2	8.91	121	8.26	141.5	7.07	174	5.75
112.4	8.90	121.5	8.23	142	7.04	175	5.71
112.6	8.88	122	8.20	142.5	7.02	176	5.68
112.8	8.87	122.5	8.16	143	6.99	177	5.65
113	8.85	123	8.13	143.5	6.97	178	5.62
113.2	8.83	123.5	8.10	144	6.94	179	5.59
113.4	8.82	124	8.06	144.5	6.92	180	5.56
113.6	8.80	124.5	8.03	145	6.90	181	5.52
113.8	8.79	125	8.00	145.5	6.87	182	5.49
114	8.77	125.5	7.97	146	6.85	183	5.46
114.2	8.76	126	7.94	146.5	6.83	184	5.43
114.4	8.74	126.5	7.91	147	6.80	185	5.41
114.6	8.73	127	7.87	147.5	6.78	186	5.38
114.8	8.71	127.5	7.84	148	6.76	187	5.35

Table—*(Continued)*

Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn	Wt. in Gr. of 120 Yd.	C'nts of Yarn
188	5.32	238	4.20	300	3.33	455	2.20
189	5.29	240	4.17	305	3.28	460	2.17
190	5.26	242	4.13	310	3.23	465	2.15
191	5.24	244	4.10	315	3.17	470	2.13
192	5.21	246	4.07	320	3.13	475	2.11
193	5.18	248	4.03	325	3.08	480	2.08
194	5.15	250	4.00	330	3.03	485	2.06
195	5.13	252	3.97	335	2.99	490	2.04
196	5.10	254	3.94	340	2.94	495	2.02
197	5.08	256	3.91	345	2.90	500	2.00
198	5.05	258	3.88	350	2.86	510	1.96
199	5.03	260	3.85	355	2.82	520	1.92
200	5.00	262	3.82	360	2.78	530	1.89
202	4.95	264	3.79	365	2.74	540	1.85
204	4.90	266	3.76	370	2.70	550	1.82
206	4.85	268	3.73	375	2.67	560	1.79
208	4.81	270	3.70	380	2.63	570	1.75
210	4.76	272	3.68	385	2.60	580	1.72
212	4.72	274	3.65	390	2.56	590	1.69
214	4.67	276	3.62	395	2.53	600	1.67
216	4.63	278	3.60	400	2.50	620	1.61
218	4.59	280	3.57	405	2.47	640	1.56
220	4.55	282	3.55	410	2.44	660	1.52
222	4.50	284	3.52	415	2.41	680	1.47
224	4.46	286	3.50	420	2,38	700	1.43
226	4.42	288	3.47	425	2.35	725	1.38
228	4.39	290	3.45	430	2.33	750	1.33
230	4.35	292	3.42	435	2.30	775	1.29
232	4.31	294	3.40	440	2.27	800	1.25
234	4.27	296	3.38	445	2.25	850	1.17
236	4.24	298	3.36	450	2.22	900	1.11

The size of roving is indicated in a somewhat different manner from the counts of yarn. Thus, if five times 840 yd. of roving weighs 1 lb. it is known as *5-hank roving*, indicating that 5 hanks weigh 1 lb.

The following cotton-roving numbering table gives the hank roving as determined by the weight in grains and tenths of grains of 12 yd.

COTTON-ROVING NUMBERING TABLE

Wt. in Gr. of 12 Yd.	Hank of Rov.	Wt. in Gr. of 12 Yd.	Hank of Rov.	Wt. in Gr. of 12 Yd.	Hank of Rov.	Wt. in Gr. of 12 Yd.	Hank of Rov.
3	33.33	7.1	14.08	11.2	8.93	15.3	6.54
3.1	32.26	7.2	13.89	11.3	8.85	15.4	6.49
3.2	31.25	7.3	13.70	11.4	8.77	15.5	6.45
3.3	30.30	7.4	13.51	11.5	8.70	15.6	6.41
3.4	29.41	7.5	13.33	11.6	8.62	15.7	6.37
3.5	28.57	7.6	13.16	11.7	8.55	15.8	6.33
3.6	27.78	7.7	12.99	11.8	8.47	15.9	6.29
3.7	27.03	7.8	12.82	11.9	8.40	16	6.25
3.8	26.32	7.9	12.66	12	8.33	16.1	6.21
3.9	25.64	8	12.50	12.1	8.26	16.2	6.17
4	25.00	8.1	12.35	12.2	8.20	16.3	6.13
4.1	24.39	8.2	12.20	12.3	8.13	16.4	6.10
4.2	23.81	8.3	12.05	12.4	8.06	16.5	6.06
4.3	23.26	8.4	11.90	12.5	8.00	16.6	6.02
4.4	22.73	8.5	11.76	12.6	7.94	16.7	5.99
4.5	22.22	8.6	11.63	12.7	7.87	16.8	5.95
4.6	21.74	8.7	11.49	12.8	7.81	16.9	5.92
4.7	21.28	8.8	11.36	12.9	7.75	17	5.88
4.8	20.83	8.9	11.24	13	7.69	17.1	5.85
4.9	20.41	9	11.11	13.1	7.63	17.2	5.81
5	20.00	9.1	10.99	13.2	7.58	17.3	5.78
5.1	19.61	9.2	10.87	13.3	7.52	17.4	5.75
5.2	19.23	9.3	10.75	13.4	7.46	17.5	5.71
5.3	18.87	9.4	10.64	13.5	7.41	17.6	5.68
5.4	18.52	9.5	10.53	13.6	7.35	17.7	5.65
5.5	18.18	9.6	10.42	13.7	7.30	17.8	5.62
5.6	17.86	9.7	10.31	13.8	7.25	17.9	5.59
5.7	17.54	9.8	10.20	13.9	7.19	18	5.56
5.8	17.24	9.9	10.10	14	7.14	18.1	5.52
5.9	16.95	10	10.00	14.1	7.09	18.2	5.49
6	16.67	10.1	9.90	14.2	7.04	18.3	5.46
6.1	16.39	10.2	9.80	14.3	6.99	18.4	5.43
6.2	15.13	10.3	9.71	14.4	6.94	18.5	5.41
6.3	15.87	10.4	9.62	14.5	6.90	18.6	5.38
6.4	15.63	10.5	9.52	14.6	6.85	18.7	5.35
6.5	15.38	10.6	9.43	14.7	6.80	18.8	5.32
6.6	15.15	10.7	9.35	14.8	6.76	18.9	5.29
6.7	14.93	10.8	9.26	14.9	6.71	19	5.26
6.8	14.71	10.9	9.17	15	6.67	19.1	5.24
6.9	14.49	11	9.09	15.1	6.62	19.2	5.21
7	14.29	11.1	9.01	15.2	6.58	19.3	5.18

TABLE—*(Continued)*

Wt. in Gr. of 12 Yd.	Hank of Rov.	Wt. in Gr. of 12 Yd.	Hank of Rov.	Wt. in Gr. of 12 Yd.	Hank of Rov.	Wt. in Gr. of 12 Yd.	Hank of Rov.
19.4	5.15	23.5	4.26	27.6	3.62	33.4	2.99
19.5	5.13	23.6	4.24	27.7	3.61	33.6	2.98
19.6	5.10	23.7	4.22	27.8	3.60	33.8	2.96
19.7	5.08	23.8	4.20	27.9	3.58	34	2.94
19.8	5.05	23.9	4.18	28	3.57	34.2	2.92
19.9	5.03	24	4.17	28.1	3.56	34.4	2.91
20	5.00	24.1	4.15	28.2	3.55	34.6	2.89
20.1	4.98	24.2	4.13	28.3	3.53	34.8	2.87
20.2	4.95	24.3	4.12	28.4	3.52	35	2.86
20.3	4.93	24.4	4.10	28.5	3.51	35.2	2.84
20.4	4.90	24.5	4.08	28.6	3.50	35.4	2.82
20.5	4.88	24.6	4.07	28.7	3.48	35.6	2.81
20.6	4.85	24.7	4.05	28.8	3.47	35.8	2.79
20.7	4.83	24.8	4.03	28.9	3.46	36	2.78
20.8	4.81	24.9	4.02	29	3.45	36.2	2.76
20.9	4.78	25	4.00	29.1	3.44	36.4	2.75
21	4.76	25.1	3.98	29.2	3.42	36.6	2.73
21.1	4.74	25.2	3.97	29.3	3.41	36.8	2.72
21.2	4.72	25.3	3.95	29.4	3.40	37	2.70
21.3	4.69	25.4	3.94	29.5	3.39	37.2	2.69
21.4	4.67	25.5	3.92	29.6	3.38	37.4	2.67
21.5	4.65	25.6	3.91	29.7	3.37	37.6	2.66
21.6	4.63	25.7	3.89	29.8	3.36	37.8	2.65
21.7	4.61	25.8	3.88	29.9	3.34	38	2.63
21.8	4.59	25.9	3.86	30	3.33	38.2	2.62
21.9	4.57	26	3.85	30.2	3.31	38.4	2.60
22	4.55	26.1	3.83	30.4	3.29	38.6	2.59
22.1	4.52	26.2	3.82	30.6	3.27	38.8	2.58
22.2	4.50	26.3	3.80	30.8	3.25	39	2.56
22.3	4.48	26.4	3.79	31	3.23	39.2	2.55
22.4	4.46	26.5	3.77	31.2	3.21	39.4	2.54
22.5	4.44	26.6	3.76	31.4	3.18	39.6	2.53
22.6	4.42	26.7	3.75	31.6	3.16	39.8	2.51
22.7	4.41	26.8	3.73	31.8	3.14	40	2.50
22.8	4.39	26.9	3.72	32	3.13	40.2	2.49
22.9	4.37	27	3.70	32.2	3.11	40.4	2.48
23	4.35	27.1	3.69	32.4	3.09	40.6	2.46
23.1	4.33	27.2	3.68	32.6	3.07	40.8	2.45
23.2	4.31	27.3	3.66	32.8	3.05	41	2.44
23.3	4.29	27.4	3.65	33	3.03	41.2	2.43
23.4	4.27	27.5	3.64	33.2	3.01	41.4	2.42

TABLE—*(Continued)*

Wt. in Gr. of 12 Yd.	Hank of Rov.	Wt. in Gr. of 12 Yd.	Hank of Rov.	Wt. in Gr. of 12 Yd.	Hank of Rov.	Wt. in Gr. of 12 Yd.	Hank of Rov.
41.6	2.40	56	1.79	76	1.32	128	.78
41.8	2.39	56.5	1.77	77	1.30	130	.77
42	2.38	57	1.75	78	1.28	132	.76
42.2	2.37	57.5	1.74	79	1.27	134	.75
42.4	2.36	58	1.72	80	1.25	136	.74
42.6	2.35	58.5	1.71	81	1.23	138	.72
42.8	2.34	59	1.69	82	1.22	140	.71
43	2.33	59.5	1.68	83	1.20	145	.69
43.2	2.31	60	1.67	84	1.19	150	.67
43.4	2.30	60.5	1.65	85	1.18	155	.65
43.6	2.29	61	1.64	86	1.16	160	.63
43.8	2.28	61.5	1.63	87	1.15	165	.61
44	2.27	62	1.61	88	1.14	170	.59
44.2	2.26	62.5	1.60	89	1.12	175	.57
44.4	2.25	63	1.59	90	1.11	180	.56
44.6	2.24	63.5	1.57	91	1.10	185	.54
44.8	2.23	64	1.56	92	1.09	190	.53
45	2.22	64.5	1.55	93	1.08	195	.51
45.5	2.20	65	1.54	94	1.06	200	.50
46	2.17	65.5	1.53	95	1.05	210	.48
46.5	2.15	66	1.52	96	1.04	220	.45
47	2.13	66.5	1.50	97	1.03	230	.43
47.5	2.11	67	1.49	98	1.02	240	.42
48	2.08	67.5	1.48	99	1.01	250	.40
48.5	2.06	68	1.47	100	1.00	260	.38
49	2.04	68.5	1.46	102	.98	270	.37
49.5	2.02	69	1.45	104	.96	280	.36
50	2.00	69.5	1.44	106	.94	290	.34
50.5	1.98	70	1.43	108	.93	300	.33
51	1.96	70.5	1.42	110	.91	320	.31
51.5	1.94	71	1.41	112	.89	340	.29
52	1.92	71.5	1.40	114	.88	360	.28
52.5	1.90	72	1.39	116	.86	380	.26
53	1.89	72.5	1.38	118	.85	400	.25
53.5	1.87	73	1.37	120	.83	425	.24
54	1.85	73.5	1.36	122	.82	450	.22
54.5	1.83	74	1.35	124	.81	475	.21
55	1.82	74.5	1.34	126	.79	500	.20
55.5	1.80	75	1.33				

If other than 120 yd. is weighed in the case of yarn or 12 yd. in the case of roving, the preceding tables are not applicable. The following table of dividends for numbering cotton yarn and roving, however, shows various numbers that are used as dividends when various lengths of yarn or roving, are weighed. For instance, the weight in grains of 30 yd. of yarn or roving divided into 250 gives as a quotient the counts of the yarn or hank of the roving.

TABLE OF DIVIDENDS FOR NUMBERING COTTON YARN AND ROVING

Yards Weighed	Divide Weight in Grains Into	Yards Weighed	Divide Weight in Grains Into
1	$8\frac{1}{3}$	15	125
2	$16\frac{2}{3}$	20	$166\frac{2}{3}$
3	25	30	250
4	$33\frac{1}{3}$	40	$333\frac{1}{3}$
6	50	60	500
8	$66\frac{2}{3}$	120	1,000
10	$83\frac{1}{3}$	240	2,000
12	100	480	4,000

Other Methods of Finding Counts of Cotton Yarn.—The following numbered paragraphs give various methods of finding the counts of cotton yarn:

1. Multiply number of yards weighed by $8\frac{1}{3}$ and divide by weight in grains.

2. Multiply number of yards weighed by 25 and divide by 3 times the weight in grains.

3. Add two ciphers (multiply by 100) to the number of yards weighed and divide by 12 times the weight in grains.

4. Divide the number of yards weighed by .12 times the weight in grains.

5. Multiply the number of inches that are required to weigh 1 gr. by .2315.

6. Divide the number of inches of yarn that are required to weigh 1 gr. by 4.32.

SILK YARNS

The use, in cotton mills, of silk yarns in connection with cotton yarns in the production of high-grade and fancy fabrics is constantly increasing. These yarns frequently are used for filling in fabrics woven with combed and mercerized cotton warps, such as fine shirtings. In addition, silk yarns are used in many cotton fabrics as ornamental, or figuring, threads in both warp and filling.

Several methods of designating the size, or counts, of silk yarns are employed in the United States. Raw silk, as imported into this country, is numbered in accordance with the so-called "denier" system. Thrown silks, that is, silk yarns prepared by the reeling, doubling, twisting, etc. of raw silk, are prepared in various ways for many different purposes. Those intended for warp yarn are known as *organzine;* those to be used as filling yarn are called *tram.* Thrown silks usually are designated according to size by a method known as the "dram" system, but sometimes the denier system is employed. Spun silk yarns, produced by carding and spinning processes from waste silk, and pierced, tangled, broken, and inferior cocoons of the silk worm, are numbered in a manner exactly similar to that employed in the case of cotton yarns. That is, the size of these yarns is indicated by the number of hanks, each 840 yds. in length, that are required to weigh 1 lb.

The Denier System.—The denier system of designating the size, or counts, of raw silks is based upon a skein of yarn having a fixed length of 450 meters, and upon a standard weight of 5 centigrams. The skein of yarn for weighing usually is wound upon a reel having a circumferential dimension of 112½ centimeters, thus requiring 400 revolutions of the reel to produce a skein of yarn containing the required length of 450 meters. If this skein of yarn weighed 5 centigrams (.05 gram) it would be a 1-denier silk; if the skein weighed 10 centigrams, the yarn would be a 2-denier silk, etc. Practically, of course, a silk yarn as fine as 1 denier in size is impossible, since the individual filaments of silk as unwound from the cocoon of the silkworm vary in size from 2 deniers to 4 deniers, or even coarser. The filament from the cocoon is said to have an average size of about 2¼ deniers, so that if six of these filaments are reeled together to produce a commercial raw silk yarn, the size of that yarn will be about 13½ deniers. The counting of the cocoon filaments in raw silks to determine the denier, however, may be considered only as corroborating more accurate tests. It should never be accepted as a certain indication of the denier, since the cocoon filament not only varies in size in different varieties of silk but also at different seasons of the year, and under other conditions. An 8/10-denier silk, made from, perhaps, three cocoons, is about the finest silk used in actual practice.

Raw silk is irregular, or uneven, in size to a considerable extent on account of the natural variation in the size of the silk filaments produced by the silkworm. While careful reeling reduces this variation to a considerable degree, raw silk yarns do not possess the degree of uniformity in size and number of yards to the pound that is characteristic of drawn and spun yarns, such as cotton yarns. Therefore, the denier of a raw silk yarn is always expressed by covering three deniers, as, for instance, a 13/15-denier silk yarn, a 14/16-denier silk, a 15/17-denier yarn, etc. These expressions mean, in the first instance, that the silk varies in size from 13½ to 14½ deniers; in the second case, the possible variation is from 14½ to 15½ deniers; and, in the last example, the size varies from 15½ to 16½ deniers. In making calculations the average denier of raw silk yarns should be considered. Thus, a 13/15-denier silk should be figured as a 14-denier yarn, that is, as a silk 450 meters of which will weigh 70 centigrams ($14 \times 5 = 70$).

Because of the variation in the size of raw silks a single test to determine the denier of the yarn is unreliable and extremely unlikely to indicate the average denier of the silk in any one bale. It is customary, therefore, in determining the size of raw silks, to draw

10 skeins from each bale, taking the skeins from different parts of the bale. From each of these skeins, three reelings are made and, to their absolutely dry weight, 11 per cent. is added for normal moisture regain. The average denier of these reelings is the denier of that bale of silk and the variation in the weight of the reelings indicates the variation in the size of the silk in that particular bale, or the uniformity in size, or otherwise, of the silk.

In addition to the foregoing test, a sizing test in which long reelings are made serves to indicate more accurately the yardage per given weight of raw silks, although it does not so clearly show the variation in the size of the silk in a single bale. This is known as the compound-sizing test and consists of making 20 reelings of 4,500 meters each from skeins drawn from different parts of each bale. Since the varying inequalities in size are overrun by long reelings, this test is very reliable in giving the correct average size and average number of yards per pound of the silk in a bale.

In making calculations relative to raw silks in accordance with the denier system, the following metric conversion table will be found useful:

DENIER SYSTEM CONVERSION TABLE

Standard length of reeling	=450 meters=492.13 yards
Standard weight, or "denier"	=5 centigrams=.771618 grain
One meter	=39.3704 inches=1.093623 yards
One gram	=20 "denier" weights (.05 gram each)
One gram	=15.43236 grains
One ounce	=567 (practically) "denier" weights
One ounce	=437.5 grains
One pound	=9,072 (practically) "denier" weights
One pound	=7,000 grains
One pound	=453.592 grams

Since the standard length for reeling is equal to 492.13 yd. and the standard weight, or "denier," is equal to .771618 gr., the length per pound (7,000 gr.) of a theo-

AVERAGE YARDS PER POUND, DENIER SYSTEM

Denier of Silk	Average Denier	Yards per Pound (Calculated Average)	Denier of Silk	Average Denier	Yards per Pound (Calculated Average)
9/11	10	446,453	34/36	35	127,558
10/12	11	405,866	35/37	36	124,015
11/13	12	372,044	36/38	37	120,663
12/14	13	343,425	37/39	38	117,488
13/15	14	318,895	38/40	39	114,475
14/16	15	297,635	39/41	40	111,613
15/17	16	279,033	40/42	41	108,891
16/18	17	262,619	41/43	42	106,298
17/19	18	248,029	42/44	43	103,826
18/20	19	234,975	43/45	44	101,467
19/21	20	223,226	44/46	45	99,212
20/22	21	212,597	45/47	46	97,055
21/23	22	202,933	46/48	47	94,990
22/24	23	194,110	47/49	48	93,011
23/25	24	186,022	48/50	49	91,113
24/26	25	178,581	49/51	50	89,291
25/27	26	171,713	50/52	51	87,540
26/28	27	165,353	51/53	52	85,856
27/29	28	159,447	52/54	53	84,236
28/30	29	153,949	53/55	54	82,676
29/31	30	148,818	54/56	55	81,173
30/32	31	144,017	55/57	56	79,724
31/33	32	139,517	56/58	57	78,325
32/34	33	135,289	57/59	58	76,975
33/35	34	131,310	58/60	59	75,670

retical 1-denier silk would be as indicated by the following calculation:

$$\frac{492.13 \text{ (yd.)} \times 7{,}000 \text{ (gr. per lb.)}}{.771618 \text{ (gr. per denier)}} = 4{,}464{,}527.7$$

or, practically, 4,464,528 yd.

The following rules, therefore, may be used in connection with the denier system, and are especially adapted to cotton-mill practice.

Rule.—*To find the denier of raw silk yarns, divide 4,464,528 by the yards per pound of the silk.*

Example.—If 600 yd. of raw silk weighs 21 grains, what is the size of the silk?

Solution.—

$$\frac{600 \text{ (yd.)} \times 7{,}00 \text{ gr. per lb.)}}{21 \text{ (gr.)}} = 200{,}000 \text{ yd. per lb.}$$

$$4{,}464{,}528 \div 200{,}000 \text{ (yd. per lb.)} = 22.32\text{-denier silk}$$

Rule.—*To find the yards per pound of raw silk yarns, divide 4,464,528 by the average denier of the silk.*

Example.—How many yards are contained in one pound of 14/16 denier raw silk?

Solution.—The average size of the silk in this case can be assumed to be 15-denier. Then,

$$4{,}464{,}528 \div 15 = 297{,}635.2 \text{ yd. per lb.}$$

Rule.—*To find the weight in pounds of raw silk, divide 4,464,528 by the denier of the silk and divide the quotient thus obtained into the total number of yards.*

Example.—What is the weight in pounds of 557,066 yards of 20-denier silk?

Solution.— $4{,}464{,}528 \div 20 = 223{,}226.4$ yd. per lb.

$$892{,}912 \div 557{,}066 = 2\tfrac{1}{2} \text{ lb.}$$

The Dram System.—The dram system of designating the size of thrown silk yarns is based upon a standard length, or reeling, of 1,000 yards and the size of the silk is determined by the weight in drams of this length of yarn. For instance, if 1,000 yards of thrown silk weigh 4 drams, the yarn is a 4-dram silk, etc. A 1,000-yd. reeling is always made except in cases where the silk is very coarse and a reeling of this length would result in a bulky skein and cause excessive waste in sizing the yarn. Under these circumstances, 500 yards or 250 yards are reeled and the weight in drams of these lengths multiplied by two or four, as the case may be, in order to obtain the true size of the silk.

Since one pound contains 256 drams, one pound of one-dram silk will contain 256 times 1,000 yards, or

256,000 yards. Therefore, the following rules, especially arranged for use in cotton mills, are applicable to thrown silks numbered by the dram system.

Rule.—*To find the dramage of thrown silk yarns, divide 256,000 by the yards per pound of the silk.*

Example.—If 32,000 yards of thrown silk are required to weigh one pound, what is the dramage of the yarn?

Solution.— 256,000÷32,000=8-dram silk

Rule.—*To find the yards per pound of thrown silk yarns, divide 256,000 by the dramage of the silk.*

Example.—How many yards of yarn are there in one pound of 2½-dram silk?

Solution.— 256,000÷2½=102,400 yd.

Rule.—*To find the weight in pounds of thrown silk, divide 256,000 by the dramage of the silk and divide the quotient thus obtained into the total number of yards.*

Example.—What is the weight in pounds of 819,200 yards of 5-dram silk?

Solution.— 256,000÷5=51,200 yd. per lb.
819,200÷51,200=16 lb.

It will be noted that both the denier system and the dram system of numbering silk yarns differ materially in principle from the systems employed in numbering cotton, woolen, worsted, spun silk, etc., since in the former cases the higher the number of the yarn the coarser it is, and, in the latter systems, the higher the counts the finer the yarn and the greater the number of yards per pound that it contains.

In both the denier and the dram systems the weight of the silk is taken "in the gum," that is, the natural gum, or *sericin,* of the silk fiber is not removed by any "boiling-off" process, nor is any compensation made for the removal of the gum in calculations for finding the size of the yarns. For this reason, silk yarns that have been boiled off and, also, dyed will be finer and contain a greater number of yards per pound than the indicated size of the yarn warrants. The exact amount of this change in the true counts and yards per pound of boiled-off silks depends upon the variety of the silk and the extent to which the boiling-off process is carried as well as its nature, but will average fully 25 per cent. in the case of dyed thrown silk.

The size of silks is sometimes designated in accordance with the number of yards per ounce. Thus, a 20,000-yd. silk is one 20,000 yards of which weigh one ounce. Schappe, or spun waste, silk yarns imported from Continental European countries, are usually numbered with a standard hank, or skein, length of 500 meters and a standard weight of ½ kilogram. This is practically equal to 496 yd. per pound.

Denier and Dram Equivalent Counts.—Since a one-denier silk contains 4,464,528 yd. per lb. and a one-dram silk has 256,000 yd. per lb., the constant for converting the counts of one system into the equivalent counts of the other system is equal to 4,464,528÷256,000, or 17.44, and the following rules apply:

Rule.—*To convert a silk yarn, numbered by the denier system, to equivalent counts in the dram system, divide the deniers by 17.44.*

Example.—What is the equivalent in the dram system of a 24/26-denier silk?

Solution.—Considering the average size of the silk to be 25 deniers,

$$25 \div 17.44 = 1.433\text{-dram silk}$$

Rule.—*To convert a silk yarn, numbered by the dram system, to equivalent counts in the denier system, multiply the dramage by 17.44.*

Example.—What is the equivalent in the denier system of a 2-dram silk?

Solution.— $2 \times 17.44 = 34.88$-denier silk

Artificial Silk.—Artificial silk is produced by a combination of various chemical and mechanical processes. These operations, and the basic materials employed in them, vary according to the desired nature of the finished product, there being several varieties of artificial silk.

Cellulose artificial silk, which is produced in large quantities, involves, in its manufacture, the chemical treatment of some form of cellulose, such as cotton or wood. The latter is generally employed, and is utilized in the form of sulphite wood pulp which is chemically and mechanically treated so as to form a viscous solution, that is technically called *viscose*. This viscose is forced under pressure through very fine orifices, called "spinnerets," into a solution that coagulates it into a continuous strand of a gelatinous nature. Further treatment of a cleansing and finishing nature produces the artificial silk of commerce.

Artificial silk is numbered by the denier system as in the case of raw silk, and is seven or eight times coarser in size than natural silk. These yarns are produced in sizes from about 60 deniers to 600 deniers. The finer sizes are not often obtainable, being imported from Europe. The coarser sizes are in more frequent use, the 300-denier and 500-denier silks being quite often employed and regularly produced.

OTHER YARN-NUMBERING SYSTEMS

Yarns made of materials other than cotton are numbered in a similar manner to cotton yarns, with the one exception that the standard length is different. The accompanying table gives the standard lengths used for various yarns and as in each case higher numbers indicate finer yarns, as in the cotton system, the same rules used in cotton-yarn numbering may be applied, the standard length only being altered as given in the table.

STANDARD LENGTHS OF YARNS

Yarns	Standard Length Yards
Cotton	840
Spun silk	840
Worsted	560
Woolen (run system)	1,600
Woolen (cut system)	300
Linen	300

The run system is the standard American method of numbering woolen yarns; the cut system is used principally in Philadelphia and vicinity. Woolen yarn is also numbered in some districts by stating the weight in grains of a fixed length. In the "New Hampshire" system this length is 50 yd.; in the "Little Falls" system, 25 yd.; in the "Amsterdam" system, 12½ yd.. and in the "Cohoes" system, 6¼ yd. A length of 20 yd. also is occasionally used in connection with the system of expressing the weight in grains.

The size of coarse jute, flax, or hemp yarns is determined by the weight in pounds of a standard length of 14,400 yd., known as a *spindle*. Thus, if 14,400 yd. weighs 4 lb., the yarn would be known as a 4-lb. yarn; if it weighs 5 lb. it is a 5-lb. yarn, etc. In this system and in the woolen grain systems, it will be noted that higher numbers indicate coarser yarns.

METRIC SYSTEM OF YARN NUMBERING

From time to time there has been considerable agitation relative to the adoption of one system and the unification of the methods of indicating the degree of fineness of yarns produced from the various fibers used in the textile industry of the whole world. The chief objection is that, from long usage, the methods at present adopted are too well developed for a single corporation or a single country to take on itself such a reform, without being assured that its neighbors and competitors will simultaneously and unanimously do the same thing.

The method usually advocated is that of numbering all classes of yarns by what is known as the **metric system,** in which 1 meter of No. 1 yarn weighs 1 gram, the meter being the unit of length in the metric system and the gram the unit of weight. The equivalents of the meter and the gram are as follows:

1 yard = .914 meter, 1 pound = 453.59 grams

To find the number of yarn in any present standard system that corresponds to the number of yarn in the metric standard system:

Rule.—*Multiply the counts, given in the metric system, by 453.59 (grams in 1 lb.) and divide by the standard number of yards to the pound in the present system multiplied by .914 (meter in 1 yard).*

Example.—A cotton yarn numbered according to the metric system is marked 40s. Find the counts in the present system.

Solution.— $\frac{40 \times 453.59}{840 \times .914} = 23.631\text{s}.$ Ans.

To find the number of yarn in the metric standard system that corresponds to the number of yarn in any present standard system:

Rule.—*Multiply the counts, given in the present system, by the present standard number of yards to the pound and by .914 (meters in 1 yd.) and divide by 453.59 (grams in 1 pound).*

Example.—A worsted yarn numbered according to the present system is marked 46s. Find the counts in the metric system.

Solution.— $\frac{46 \times 560 \times .914}{453.59} = 51.907\text{s}.$ Ans.

EQUIVALENT COUNTS

Often it becomes necessary to place the counts of one yarn in the system of another. That is, it may be necessary to learn what the counts of a certain cotton yarn would be if it were numbered similarly to a worsted thread. When two, three, or more threads made from different raw stock and numbered according to different methods are placed in the same system, they are said to be reduced to *equivalent counts.*

Rule.—*To find the counts of one system that is equivalent to that of another, multiply the given counts by the number of yards in the standard length of the specified* *system and divide by the number of yards in the standard length of the system required.*

EXAMPLE 1.—Find the equivalent of a 40s cotton in worsted counts.

SOLUTION.— 840×40=33,600

33,600÷560=60s, worsted

EXPLANATION.—Since there are 840 yd. of yarn in 1 lb. of 1s cotton, there will be 40×840, or 33,600, yd. in 1 lb. of 40s. The question then is to find the worsted counts of a yarn containing 33,600 yd. to the pound. Since length divided by (standard multiplied by weight) equals counts, then 33,600÷(560×1) must equal the counts.

EXAMPLE 2.—Find the equivalent of a 16s cotton yarn in the woolen run system.

SOLUTION.— 840×16=13,440

13,440÷1,600=8.4-run, woolen

SHORT METHODS OF FINDING EQUIVALENT COUNTS

The accompanying table of multipliers, divisors, and dividends may be used for finding quickly the equivalent cotton counts of any yarn the counts of which are ex-

CONSTANTS FOR EQUIVALENT COTTON COUNTS

Yarn-Numbering System	Multiplier	Divisor	Dividend
Linen	.357 or $\frac{5}{14}$	2.8	
Worsted	.667 or $\frac{2}{3}$	1.5	
Schappe Silk (496 yd.)	.59 or $\frac{3}{5}$	1.7	
Silk (yards per ounce system)	.019 or $\frac{2}{105}$	52.5	
Woolen (run system)	1.905 or $\frac{40}{21}$	.525	
Woolen (cut system)	.357 or $\frac{5}{14}$	2.8	
Woolen (New Hampshire system)			416.67
Woolen (Little Falls system)			208.33
Woolen (Amsterdam system)			104.17
Woolen (Cohoes system)			52.083
Woolen (20 yd. grain system)			166.7
Silk (denier system)			5,315
Silk (dram system)			304.8
Coarse jute, flax, and hemp			17.14

pressed in some other system. For instance, multiplying the counts of a worsted yarn by .667 ($\frac{2}{3}$), or dividing the counts by 1.5 ($\frac{3}{2}$), gives the equivalent cotton counts of the yarn. In a similar way, the counts of a silk yarn, numbered by the denier system, if divided into 5,315 gives as a quotient the equivalent cotton counts.

TWIST IN YARNS

To impart to yarn the required strength it is necessary to insert a certain amount of twist. Warp yarn requires more twist than filling yarn, because it must withstand a greater strain during the weaving process. The turns of twist per inch vary with different mills and in various kinds of yarn, but all systems are based on the following rule:

Rule.—*To find the twist to be inserted in any counts of yarns multiply the square root of the counts by the standard, or constant, adopted.*

In American mills, the twist constant adopted for ring-spun warp yarn is usually 4.75, and for filling yarn 3.75. Other constants frequently employed are shown in the accompanying twist table, which also shows the turns of twist per inch to be inserted in various counts of yarn.

Occasionally a twist constant of 4.50 is used for ring-spun warp yarn and sometimes extra-twist mule-spun warp yarn is produced with a constant of 4.00. For the production of yarns for special purposes, twist constants are varied as the case may demand.

Twist may be imparted to a yarn in either a right-hand or a left-hand direction. There is some confusion as to what constitutes a right-hand or a left-hand twist, but the general custom is to follow the universal machine-shop practice in this matter, that is, a right-hand twist in a yarn lies in the same direction as a right-hand thread on a bolt or screw, etc. Right-hand twist is often spoken of as "regular" twist.

TWIST TABLE

Counts, or Number, of Yarn	Ordinary Ring-Spun Warp Yarn	Ring-Spun Filling and Mule-Spun Warp Yarn	Mule-Spun Filling Yarn	Hosiery Yarn	Square Root of Counts
Twist Constant	4.75	3.75	3.25	2.50	
1	4.75	3.75	3.25	2.5	1.00
2	6.7	5.3	4.6	3.5	1.41
3	8.2	6.5	5.6	4.3	1.73
4	9.5	7.5	6.5	5.0	2.00
5	10.6	8.4	7.3	5.6	2.24
6	11.6	9.2	8.0	6.1	2.45
7	12.6	9.9	8.6	6.6	2.65
8	13.4	10.6	9.2	7.1	2.83
9	14.3	11.3	9.8	7.5	3.00
10	15.0	11.9	10.3	7.9	3.16
11	15.8	12.5	10.8	8.3	3.32
12	16.4	13.0	11.2	8.7	3.46
13	17.2	13.5	11.7	9.0	3.61
14	17.8	14.0	12.2	9.4	3.74
15	18.4	14.5	12.6	9.7	3.87
16	19.0	15.0	13.0	10.0	4.00
17	19.6	15.5	13.4	10.3	4.12
18	20.1	15.9	13.8	10.6	4.24
19	20.7	16.4	14.2	10.9	4.36
20	21.2	16.8	14.5	11.2	4.47
21	21.8	17.2	14.9	11.5	4.58
22	22.3	17.6	15.3	11.7	4.69
23	22.8	18.0	15.6	12.0	4.80
24	23.3	18.4	15.9	12.3	4.90
25	23.8	18.8	16.3	12.5	5.00
26	24.2	19.1	16.6	12.8	5.10
27	24.7	19.5	16.9	13.0	5.20
28	25.1	19.8	17.2	13.2	5.29
29	25.6	20.2	17.5	13.5	5.39
30	26.0	20.6	17.8	13.7	5.48
31	26.5	20.9	18.1	13.9	5.57
32	26.9	21.2	18.4	14.2	5.66
33	27.3	21.5	18.7	14.4	5.74
34	27.7	21.9	18.9	14.6	5.83
35	28.1	22.2	19.2	14.8	5.92
36	28.5	22.5	19.5	15.0	6.00
37	28.9	22.8	19.8	15.2	6.08

TABLE—(*Continued*)

Counts, or Number, of Yarn	Ordinary Ring-Spun Warp Yarn	Ring-Spun Filling and Mule-Spun Warp Yarn	Mule-Spun Filling Yarn	Hosiery Yarn	Square Root of Counts
Twist Constant	4.75	3.75	3.25	2.50	
38	29.3	23.1	20.0	15.4	6.16
39	29.7	23.4	20.3	15.6	6.25
40	30.0	23.7	20.5	15.8	6.32
41	30.4	24.0	20.8	16.0	6.40
42	30.8	24.3	21.1	16.2	6.48
43	31.2	24.6	21.3	16.4	6.56
44	31.5	24.9	21.5	16.6	6.63
45	31.9	25.2	21.8	16.8	6.71
46	32.2	25.4	22.0	17.0	6.78
47	32.6	25.7	22.3	17.2	6.86
48	32.9	26.0	22.5	17.3	6.93
49	33.3	26.3	22.8	17.5	7.00
50	33.6	26.5	23.0	17.7	7.07
51	33.9	26.8	23.2	17.9	7.14
52	34.2	27.0	23.4	18.0	7.21
53	34.6	27.3	23.7	18.2	7.28
54	34.9	27.6	23.9	18.4	7.35
55	35.2	27.8	24.1	18.6	7.42
56	35.5	28.1	24.3	18.7	7.48
57	35.9	28.3	24.5	18.9	7.55
58	36.2	28.6	24.8	19.1	7.62
59	36.5	28.8	25.0	19.2	7.68
60	36.8	29.1	25.2	19.4	7.75
61	37.1	29.3	25.4	19.5	7.81
62	37.4	29.5	25.6	19.7	7.87
63	37.7	29.8	25.8	19.9	7.94
64	38.0	30.0	26.0	20.0	8.00
65	38.3	30.2	26.2	20.2	8.06
66	38.6	30.5	26.4	20.3	8.12
67	38.9	30.7	26.6	20.5	8.19
68	39.2	30.9	26.8	20.6	8.25
69	39.5	31.2	27.0	20.8	8.31
70	39.8	31.4	27.2	20.9	8.37
71	40.0	31.6	27.4	21.1	8.43
72	40.3	31.8	27.6	21.2	8.49
73	40.6	32.0	27.8	21.4	8.54
74	40.9	32.3	28.0	21.5	8.60

TABLE—*(Continued)*

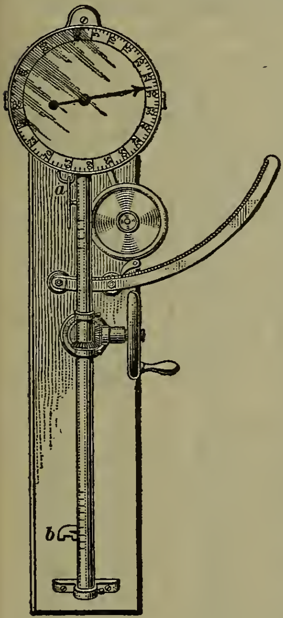
Counts, or Number, of Yarn	Ordinary Ring-Spun Warp Yarn	Ring-Spun Filling and Mule-Spun Warp Yarn	Mule-Spun Filling Yarn	Hosiery Yarn	Square Root of Counts
Twist Constant	4.75	3.75	3.25	2.50	
75	41.1	32.5	28.1	21.7	8.66
76	41.4	32.7	28.3	21.8	8.72
77	41.7	32.9	28.5	22.0	8.78
78	41.9	33.1	28.7	22.1	8.83
79	42.2	33.3	28.9	22.2	8.89
80	42.5	33.5	29.1	22.4	8.94
81	42.8	33.8	29.3	22.5	9.00
82	43.0	34.0	29.4	22.7	9.06
83	43.3	34.2	29.6	22.8	9.11
84	43.6	34.4	29.8	22.9	9.17
85	43.8	34.6	30.0	23.1	9.22
86	44.0	34.8	30.1	23.2	9.27
87	44.3	35.0	30.3	23.3	9.33
88	44.6	35.2	30.5	23.5	9.38
89	44.8	35.4	30.6	23.6	9.43
90	45.1	35.6	30.8	23.7	9.49
91	45.3	35.8	31.0	23.9	9.54
92	45.6	36.0	31.2	24.0	9.59
93	45.8	36.2	31.3	24.1	9.64
94	46.1	36.4	31.5	24.3	9.70
95	46.3	36.6	31.7	24.4	9.75
96	46.6	36.8	31.9	24.5	9.80
97	46.8	37.0	32.0	24.6	9.85
98	47.0	37.1	32.2	24.8	9.90
99	47.3	37.3	32.3	24.9	9.95
100	47.5	37.5	32.5	25.0	10.00
101	47.7	37.7	32.7	25.1	10.05
102	48.0	37.9	32.8	25.3	10.10
103	48.2	38.1	33.0	25.4	10.15
104	48.5	38.3	33.2	25.5	10.20
105	48.7	38.4	33.3	25.6	10.25
106	48.9	38.6	33.5	25.8	10.30
107	49.1	38.8	33.6	25.9	10.34
108	49.4	39.0	33.8	26.0	10.39
109	49.6	39.2	33.9	26.1	10.44
110	49.8	39.4	34.1	26.2	10.49
111	50.1	39.5	34.3	26.4	10.54

TABLE—(*Continued*)

Counts, or Number, of Yarn	Ordinary Ring-Spun Warp Yarn	Ring-Spun Filling and Mule-Spun Warp Yarn	Mule-Spun Filling Yarn	Hosiery Yarn	Square Root of Counts
Twist Constant	4.75	3.75	3.25	2.50	
112	50.3	39.7	34.4	26.5	10.58
113	50.5	39.9	34.5	26.6	10.63
114	50.7	40.1	34.7	26.7	10.68
115	50.9	40.2	34.8	26.8	10.72
116	51.2	40.4	35.0	26.9	10.77
117	51.4	40.6	35.2	27.1	10.82
118	51.6	40.7	35.3	27.2	10.86
119	51.8	40.9	35.5	27.3	10.91
120	52.0	41.1	35.6	27.4	10.95
121	52.3	41.3	35.8	27.5	11.00
122	52.5	41.4	35.9	27.6	11.05
123	52.7	41.6	36.0	27.7	11.09
124	52.9	41.8	36.2	27.9	11.14
125	53.1	41.9	36.3	28.0	11.18
126	53.3	42.1	36.5	28.1	11.23
127	53.5	42.3	36.6	28.2	11.27
128	53.7	42.4	36.8	28.3	11.31
129	54.0	42.6	36.9	28.4	11.36
130	54.2	42.8	37.1	28.5	11.40
131	54.4	42.9	37.2	28.6	11.45
132	54.6	43.1	37.3	28.7	11.49
133	54.8	43.2	37.5	28.8	11.53
134	55.0	43.4	37.6	29.0	11.58
135	55.2	43.6	37.8	29.1	11.62
136	55.4	43.7	37.9	29.2	11.66
137	55.6	43.9	38.0	29.3	11.70
138	55.8	44.1	38.2	29.4	11.75
139	56.0	44.2	38.3	29.5	11.79
140	56.2	44.4	38.4	29.6	11.83
141	56.4	44.5	38.6	29.7	11.87
142	56.6	44.7	38.7	29.8	11.92
143	56.8	44.9	38.9	29.9	11.96
144	57.0	45.0	39.0	30.0	12.00
145	57.2	45.2	39.1	30.1	12.04
146	57.4	45.3	39.3	30.2	12.08
147	57.6	45.5	39.4	30.3	12.12
148	57.8	45.6	39.6	30.4	12.17

BREAKING WEIGHT OF COTTON WARP YARN

The strength of warp yarn is of great importance and these yarns should be frequently tested to determine whether the proper standard of strength for the various counts is being maintained. An instrument for determining the strength of a yarn is shown in the accompanying illustration. In testing



the strength of the yarn, it is the custom to wrap, or reel, one skein of 120 yd. of yarn, the reel being $1\frac{1}{2}$ yd. in circumference, and place this skein on the hooks *a*, *b* of the tester. By turning the handle until the yarn breaks, the number of pounds required to break the skein is registered on the dial. To obtain fairly accurate results, skeins from four or five bobbins should be reeled and broken and the results averaged. Care should be taken to operate the tester at as nearly a uniform speed as possible or the results will be erroneous; a power-driven tester gives more reliable results than one operated by hand. The skeins of yarn should be carefully straightened out when placed on the tester and no twisted or tangled skeins should be broken. The results obtained by this machine are averages only and do not show whether a yarn is evenly spun and has a uniform strength throughout; only a single-thread test can do that. Single-thread tests, however, are difficult to make and of little value unless an exhaustive number of tests are made.

When finding a standard breaking weight for carded warp yarns, the following rule may be employed.

Rule.—*Divide the counts of the yarn into 1,800, and to the quotient thus obtained add 3 lb. The result is a fair average breaking weight in pounds of a standard skein of yarn.*

AVERAGE BREAKING WEIGHT OF AMERICAN COTTON WARP YARNS

Counts of Yarn	Carded Warp Yarn	Combed Warp Yarn	Counts of Yarn	Carded Warp Yarn	Combed Warp Yarn	Counts of Yarn	Combed Warp Yarn
6	303.0	414.0	36	53.0	66.4	66	34.9
7	260.0	354.0	37	51.6	64.6	67	34.3
8	228.0	310.0	38	50.4	62.8	68	33.8
9	203.0	275.0	39	49.2	61.1	69	33.2
10	183.0	247.0	40	48.0	59.5	70	32.7
11	167.0	224.0	41	46.9	58.0	71	32.2
12	153.0	205.0	42	45.9	56.5	72	31.7
13	142.0	189.0	43	44.9	55.1	73	31.2
14	132.0	176.0	44	43.9	53.8	74	30.8
15	123.0	164.0	45	43.0	52.6	75	30.3
16	116.0	153.0	46	42.1	51.3	76	29.9
17	109.0	144.0	47	41.3	50.2	77	29.5
18	103.0	136.0	48	40.5	49.1	78	29.1
19	97.7	129.0	49	39.7	48.0	79	28.6
20	93.0	122.0	50	39.0	47.0	80	28.2
21	88.7	116.0	51	38.3	46.0	82	27.5
22	84.8	111.0	52	37.6	45.1	84	26.8
23	81.3	106.0	53	37.0	44.2	86	26.1
24	78.0	101.0	54	36.3	43.3	88	25.4
25	75.0	97.0	55	35.7	42.5	90	24.8
26	72.2	93.2	56	35.1	41.6	92	24.2
27	69.7	89.6	57	34.6	40.9	94	23.6
28	67.3	86.3	58	34.0	40.1	96	23.0
29	65.1	83.2	59	33.5	39.4	98	22.5
30	63.0	80.3	60	33.0	38.7	100	22.0
31	61.1	77.6	61	32.5	38.0	104	21.0
32	59.3	75.1	62	32.0	37.3	108	20.1
33	57.5	72.8	63	31.6	36.7	112	19.3
34	55.9	70.5	64	31.1	36.1	116	18.6
35	54.4	68.4	65	30.7	35.5	120	17.8

When it is desired to find a standard breaking weight for combed warp yarns the following rule may be used:

Rule.—*Divide the counts of the yarn into 2,500, and from the quotient thus obtained subtract 3 lb.*

The accompanying table, worked out by the preceding rules, gives fair average breaking weights in pounds for standard skeins of 120 yd., wrapped on a reel $1\frac{1}{2}$ yd. in circumference.

PLY YARNS

Method of Numbering.—Often two or more threads are twisted together to form one coarser thread. Such yarns are commonly known as *ply yarns*, also sometimes called *folded*, or *twisted*, yarns. The method of numbering cotton ply yarns is that of giving the counts of the single yarns that are folded and placing before these counts the number that indicates the number of threads folded; thus, 2/40s indicates that two threads of 40s single yarn are folded together, the folded yarn being equal, in weight, to a single 20s yarn. During the process of twisting a slight contraction takes place. Consequently, to make the resultant counts 20s, the single yarns that are folded must necessarily be slightly finer than, or spun on the light side of, 40s. However, this contraction will not be considered in the rules and examples to be given, since it is so slight as not to be a matter of mathematics.

PLY-YARN CALCULATIONS

Folded Yarns of the Same Counts.—It is not customary in mills to fold yarns of different counts, since, unless novelty or special yarns are required, single yarns of equal counts make the best double, or ply, yarns. Consequently, when yarns of the same counts are folded, in order to find the counts of the resulting ply yarn, it is simply necessary to divide the counts of the yarns folded by the number of threads that constitute the ply yarn. For example, if three threads of 90s cotton are folded to form a ply yarn, the resultant yarn will be equivalent in weight to a single 30s ($90 \div 3 = 30$). The counts of the ply yarn and the counts of the single yarn that equal it in weight should be carefully distinguished; thus, the above yarn is equal in weight to a single 30s, but is spoken of as a 3/90s, or 3-ply 90s.

The method of finding the counts, weight, and length of ply yarns is similar to that explained in connection with single yarns, with the exception that the counts of the ply yarn do not indicate the actual counts of the thread but instead indicate the counts of the single yarns folded. Consequently, when figuring to find these particulars, the actual weight of the ply yarn must be taken into consideration, and, on this account, the counts of the single yarn that the ply yarn equals are considered and not the counts of the single yarns that are folded.

Example 1.—What is the weight of 642,000 yd. of 2-ply 40s cotton yarn?

Solution.— $\frac{642{,}000}{20 \times 840} = 38.21$ lb.

Explanation.—To make a 2-ply 40s, two ends of 40s are twisted together; consequently, a yard of the ply yarn will weigh just twice as much as a yard of one of the single yarns folded, which will make the ply yarn equal in weight to a 20s single yarn. Therefore, 20, which is the actual counts of the ply yarn, is used in the calculation. Since length divided by (counts multiplied by standard) equals weight, then $642{,}000 \div (20 \times 840)$ must equal the weight of the yarn.

Example 2.—What is the length of 20 lb. of 2-ply 36s cotton?

Solution.— $20 \times 18 \times 840 = 302{,}400$ yd.

Explanation.—A 2-ply 36s is composed of two threads of 36s folded together; consequently, the weight of a yard of the ply yarn must be just twice that of a yard of one of the ends folded to make the ply yarn. This will make the ply yarn equal in weight to an 18s single yarn, and 18s must be used as the counts of the ply yarn in the calculation. Since weight times counts times standard equals length, then $20 \times 18 \times 840$ must equal the number of yards in 20 lb. of 2-ply 36s.

Example 3.—What are the counts of a 2-ply cotton yarn, 352,800 yd. of which weighs 10 lb.?

Solution.— $\frac{352{,}800}{10 \times 840} = 42$s, or 2-ply 84s

Explanation.—Since length divided by (weight times standard) equals counts, then $352{,}800 \div (10 \times 840)$ must give the actual counts of the ply yarn; that is, this result gives the counts of the ply yarn considered as a single yarn, but since two single yarns are folded and each of these is just half as heavy as the folded yarn, then two ends of 84s must be folded to make the ply yarn, which, consequently, will be known as a 2-ply 84s.

Folded Yarns of Different Counts.—Although not a common practice, in some cases, especially when it is desired to make a fancy yarn, two yarns of different counts are folded and sometimes two yarns of different materials.

Suppose, for illustration, that it is desired to find the resultant counts of a 40s cotton folded with a 20s cotton. Take as a basis 840 yd. of each yarn; then 840 yd. of the 40s weighs $\frac{1}{40}$ lb.; 840 yd. of the 20s weighs $\frac{1}{20}$ lb. Consequently, after these yarns are folded, there will be 840 yd. of a ply yarn the weight of which is $\frac{1}{40}+\frac{1}{20}=\frac{3}{40}$ lb.

The example now resolves itself into the following: What are the counts of a yarn 840 yd. of which weighs $\frac{3}{40}$ lb? Since length divided by (weight times standard) equals counts, then,

$$\frac{840}{\frac{3}{40}\times 840}=13.33\text{s, counts of the ply yarn.}$$

This example has been worked out to some length in order that the method of numbering ply yarns may be thoroughly understood. A shorter method, however, is as follows:

Rule—*To find the resultant count when two threads of different numbers are folded, multiply the two counts together and divide the result thus obtained by the sum of the counts.*

EXAMPLE.—Same as previous example.

SOLUTION.— $$\frac{40\times 20}{40+20}=13.33\text{s, counts}$$

Ply Yarns Composed of More Than Two Threads.—In many cases it will be necessary to find the counts of a ply yarn made from more than two single threads, when a somewhat different process must be folllowed. For example, suppose that three single threads—24s, 36s, and 72s, respectively—are folded to form a ply yarn and it is required to ascertain the counts of the resultant yarn. This may be done by following the rule previously given and performing two operations as follows:

First find the counts of the yarn that would result from folding the 24s with the 36s as follows:

$$\frac{24\times36}{24+36}=14.4s$$

The example then resolves itself into the following: What are the counts of a ply yarn made from one thread of 14.4s and one of 72s?

$$\frac{14.4\times72}{14.4+72}=12s$$

A somewhat shorter method than this may be applied to 3 or more ply yarns made from different counts.

Rule.—*Take the highest counts and divide it by itself and by each of the other counts. Add the results thus obtained and divide this result into the highest counts.*

NOTE.—Although it is common practice to use the highest counts as a dividend, this is not absolutely esssential, as any counts, or in fact any number, may be used as the dividend and the correct answer obtained.

EXAMPLE.—Same as given previously.

SOLUTION.—

$$72\div72=1$$
$$72\div36=2$$
$$72\div24=\underline{3}$$
$$6$$
$$72\div6=12s$$

Rule.—*To find the resultant counts when more than one end of the different counts are folded, divide the highest counts by itself and by each of the other counts. Multiply the result in each case by the number of ends of that counts. Add the results thus obtained and divide this result into the highest counts.*

EXAMPLE.— 4 ends of 80s and 3 ends of 60s are folded to form a ply yarn; what are the resultant counts?

SOLUTION.—

$$80\div80=1;\quad 1\times4=4$$
$$80\div60=1\tfrac{1}{3};\quad 1\tfrac{1}{3}\times3=\underline{4}$$
$$8$$
$$80\div8=10s, \text{ resultant counts}$$

When dealing with ply yarns it often becomes necessary to find the counts of a yarn to be folded with another to produce a given counts.

Rule.—*Multiply the two counts together and divide by their difference.*

EXAMPLE.—What counts must be folded with a 50s to produce a ply yarn equal in weight to a 30s?

SOLUTION.— $\frac{50\times30}{50-30}=75\text{s}$

PROOF.—What are the counts of a ply yarn made by twisting a 50s with a 75s?

$$\frac{50\times75}{50+75}=30\text{s}$$

Another calculation is that of finding the required weight of each thread folded in order to produce a required weight of the ply yarn.

Rule.—*Find the counts resulting from folding the two or more threads; then, as the counts of one thread is to the resultant counts so is the total weight to the weight required of that thread.*

EXAMPLE.—It is desired to produce 100 lb. of a ply yarn composed of an 80s and a 32s twisted together; what will be the required weight of the 80s and also of the 32s?

SOLUTION.— $\frac{80\times32}{80+32}$ = 22.85s, resultant counts

$$32:22.85=100:x$$

$$x=\frac{100\times22.85}{32}=71.40 \text{ lb. of 32s}$$

$$80:22.85=100:x$$

$$x=\frac{100\times22.85}{80}=28.56 \text{ lb. of 80s}$$

In a case similar to the example given above, after the weight of one thread has been obtained, it is of course only necessary to subtract that weight from the total weight in order to obtain the weight of the other thread; or, in case more than two threads are folded, then the weight of one of these threads may always be obtained by subtracting the combined weight of the other threads from the total weight of the ply yarn.

NOTE.—In the previous example the weight of the 80s yarn plus the weight of the 32s yarn should equal the weight of the ply yarn, but owing to the use of decimals, examples of this kind seldom give exact results. Thus, 71.40 lb.+28.56 lb. =99.96 lb.; whereas the total weight should be 100 lb.

Although the preceding rule states the logical method of solving examples of this character, a short-cut method of finding the weight of the single yarns in any given weight of ply yarn is as follows:

Rule.—*Divide any count by itself and by each of the other counts; add the quotients thus obtained and divide their sum into the total weight of the ply yarn. The final result is the weight of that component yarn the counts of which was used as a dividend.*

Calculation of Cost of Ply Yarns —If the price of each yarn is given and it is required to find the price per pound of the resultant yarn, it becomes necessary to multiply the weight of each count of yarn by its price, add the results, and divide by the total weight. The answer will be the price per pound of the ply yarn.

Example.—If in the example previously given, the 80s yarn is worth 72c per pound and the 32s is worth 48c per pound, what will be the cost per pound of the ply yarn?

Solution.—

71.40 lb. of 32s at 48c per lb. = $34.27, cost of the 32s yarn

28.56 lb. of 80s at 72c per lb. = $20.56, cost of the 80s yarn

$34.27 + $20.56 = $54.83, total cost of ply yarn

$54.83 ÷ 100 = 54.8c per lb., cost of the ply yarn

Another rule for finding the price of 2-ply yarns when the threads to be twisted together are of different values and different counts is as follows:

Rule.—*Multiply the highest counts by the price of the lowest counts and the lowest counts by the price of the highest. Add the results thus obtained and divide this result by the sum of the counts. The answer will be the price of the ply yarn.*

Example.—A 32s yarn costs 42c per pound and a 16s yarn costs 18c per pound; what will be the cost per pound of a ply yarn resulting from twisting these two?

Solution.— 32 × $.18 = $5.76; 16 × $.42 = $6.72

$5.76 + $6.72 = $12.48; 32 + 16 = 48

$12.48 ÷ 48 = 26c.

PLY YARNS OF SPUN SILK

The numbering of ply yarns made from spun silk will be found to differ somewhat from the methods previously explained.

Thus, when numbering silk ply yarns, the counts resulting after folding the yarns is given and this number is followed by the number that indicates how many threads are folded.

For example, 60/2 spun silk indicates that two threads of 120s have been folded together. Thus, it will be seen that the actual counts of the ply yarn are given instead of the counts of the single yarn, as is the case in cotton, woolen, and worsted ply yarns.

EXAMPLE 1.—What is the weight of 642,000 yd. of a 40s 2-ply sun silk?

SOLUTION.— $$\frac{642{,}000}{40 \times 840} = 19.107 \text{ lb.}$$

EXPLANATION.—40s 2-ply spun silk is equal in weight to a single thread of 40s. Consequently, 40 should be considered as the counts of the ply yarn when finding weight or length. Since length divided by (counts times standard) equals weight, the solution given must be correct.

EXAMPLE 2.—What is the length of 20 lb. of a 30s 2-ply spun silk?

SOLUTION.— $840 \times 30 \times 20 = 504{,}000$ yd.

EXPLANATION.—A 30s 2-ply spun silk is equal in weight to a single 30s; consequently, 30 should be considered as the counts of the ply yarn. Since standard times counts times weight equals length, $840 \times 30 \times 20$ must equal the length of the yarn.

EXAMPLE 3.—What are the counts of a 2-ply silk yarn if 352,800 yd. weighs 10 lb.?

SOLUTION.— $$\frac{352{,}800}{10 \times 840} = 42\text{s 2-ply}$$

EXPLANATION.—The counts of the 2-ply yarn would be indicated as follows: 42/2 spun silk, which shows that two ends of 84s have been twisted to make the ply yarn.

PLY YARNS OF DIFFERENT MATERIALS

In all cases where threads of different materials are twisted together, in order to perform any of the calculations previously explained, it becomes necessary first to place these counts in the same system of numbering yarns.

Example.—A 36s cotton and a 48s worsted are twisted to form a ply yarn; what are the counts of the resultant yarn?

Solution.—It is first necessary to ascertain in which system the resultant yarn should be placed. In this case the counts of the ply yarn will be found in both the worsted and cotton systems. In the first case, then, to find the worsted counts of the ply yarn resulting from twisting these two yarns it is necessary to find the equivalent counts of the 36s cotton in the worsted system.

$$\frac{36 \times 840}{560} = 54s$$

The 36s cotton is found to equal a 54s worsted, so that the question resolves itself into the following: What are the counts of a ply yarn resulting from twisting a 54s worsted and a 48s worsted?

$$\frac{54 \times 48}{54 + 48} = 25.41, \text{ worsted counts of the ply yarn}$$

Since in this example it is also required to find the counts of the ply yarn in the cotton system, it is therefore necessary first to find the equivalent counts of the 48s worsted in cotton.

$$\frac{48 \times 560}{840} = 32s$$

Having placed the 48s worsted in the cotton system, treat the worsted as if it were cotton and find the counts of a ply yarn that will result from folding a 32s and a 36s cotton.

$$\frac{32 \times 36}{32 + 36} = 16.94, \text{ cotton counts of the ply yarn}$$

From this it is seen that if a 36s cotton and a 48s worsted are twisted together, the counts of the resultant ply yarn will be either 25.41s worsted or 16.94s cotton.

BEAMED YARNS

Warp yarn before being woven into cloth is placed on what are known as *loom beams*, a large number of ends of the same length being placed on one beam. The calculations necessary in connection with the yarn on a beam will be found to be similar to those used in connection with the length, weight, and counts of single ends, the difference being that in the previous cases only a single end was dealt with and in the case of beamed yarns a large number of ends must be taken into consideration. Thus, for example, if each end on a beam is 1,000 yd. long and there are 2,000 ends, then there must be $2{,}000 \times 1{,}000 = 2{,}000{,}000$ yd. of yarn. This point should always be taken into consideration when dealing with yarn placed on a beam.

Rule.—*To find the counts of the yarn on a beam containing only one size of yarn, the weight, length, and number of ends being given, multiply the length, expressed in yards, by the number of ends on the beam, and divide the result thus obtained by the weight, expressed in pounds, times the standard number of yards to the pound.*

Example.—A warp beam contains 2,400 ends of cotton each 200 yd. long. The weight of this yarn is 15 lb.; what are the counts?

Solution.— $$\frac{200 \times 2{,}400}{15 \times 840} = 38.095\text{s}$$

Explanation.—Since there are 2,400 ends and each end is 200 yd. long, there must be $2{,}400 \times 200 = 480{,}000$ yd. in all. The question then resolves itself into finding the counts of a yarn 480,000 yd. of which weighs 15 lb. Since length, in yards, divided by (weight, in pounds, times standard) always equals counts, 480,000 divided by (15×840) must give the counts.

In some cases the weight given will be found to include not only the weight of the yarn but also that of the beam on which the yarn is placed. When this occurs, it is necessary first to deduct the weight of the beam from the weight given, in order to obtain the true weight of the yarn.

Rule.—*To find the number of ends on a beam when weight, length of the warp, and size of the yarn are known, multiply the weight, in pounds, by the standard number and by the size of the yarn. Divide the result thus obtained by the length of the warp, in yards.*

Example 1.—A cotton warp is 1,200 yd. long and weighs 200 lb. exclusive of the beam. If the warp is composed of 20s yarn, how many ends does it contain?

SOLUTION.— $\frac{200\times840\times20}{1,200}=2,800$ ends

Rule.—*To find the weight of yarn on a beam when length, number of ends, and counts are given, multiply the length, expressed in yards, by the number of ends on the beam, avd divide the result thus obtained by the standard number of yards times the counts of the yarn.*

EXAMPLE.—A beam contains 2,400 ends of 20s cotton, the warp being 500 yd. long; find the weight of the yarn.

SOLUTION.— $\frac{500\times2,400}{840\times20}=71.428$ lb.

EXPLANATION.—By multiplying the length of the warp by the total number of ends on the beam the total length of yarn on the beam is obtained; and since the length, expressed in yards, divided by the standard times the counts equals the weight, in pounds $(2,400\times500)\div(840\times20)$, will give the weight of the yarn on the beam.

Rule.—*To find the length of a warp when weight, number of ends, and size of the yarn are known, multiply the weight of the warp, in pounds, by the standard number and by the size of the yarn, and divide the result thus obtained by the number of ends in the warp.*

EXAMPLE.—A cotton warp contains 2,400 ends of 18s yarn and weighs 200 lb.; how long is it?

SOLUTION.— $\frac{200\times840\times18}{2,400}=1,260$ yd.

Rule.—*To find the length of warp that can be placed on a beam, find the weight of yarn that the beam will contain, by weighing a beam of the same size when filled with yarn and deducting the weight of the beam itself. Then apply the rule previously given.*

EXAMPLE 2.—A certain size beam when filled with yarn weighs 140 lb., the beam itself weighing 50 lb. What length of a warp composed of 1,800 ends of 20s cotton can be placed on it?

SOLUTION.— $140-50=90$ lb. of yarn

$$\frac{90\times840\times20}{1,800}=840 \text{ yd.}$$

AVERAGE NUMBERS

In case different counts of yarns are placed on the same beam, as very frequently occurs, it will be found necessary to first find the average number, or average counts, of the different yarns before making other calculations. By the term *average number*, or *average counts*, is meant a count of yarn that will give the same weight, provided that the same number of ends and the same length occur in both cases. Thus, if 400 ends of 10s and 800 ends of 20s weigh a certain number of pounds, then 1,200 (400+800) ends of the average counts will weigh the same, provided that the ends are the same length in both cases.

Rule.—*To find the average counts of the ends on a beam when the ends are of different counts, divide the total number of ends of each count by its own count. Add these results together and divide the result thus obtained into the total number of ends in the warp.*

EXAMPLE.—There are placed on the same beam 1,800 ends of 60s cotton and 800 ends of 40s cotton; what are the average counts?

SOLUTION.—

$$\begin{array}{r} 1800 \div 60 = 30 \\ \underline{800} \div 40 = \underline{20} \\ 2600 \qquad\quad 50 \end{array}$$

2,600÷50=52s, average counts

In case more than two different counts are placed on the same beam, the same rule will be found to apply.

EXAMPLE.—What are the average counts in case 200 ends of 20s, 1,000 ends of 40s, and 900 ends of 45s are placed on the same beam?

SOLUTION.—

$$\begin{array}{r} 200 \div 20 = 10 \\ 1000 \div 40 = 25 \\ \underline{900} \div 45 = \underline{20} \\ 2100 \qquad\quad 55 \end{array}$$

2,100÷55=38.18s, average counts

In cases where the order of arranging the different counts of yarn in the warp is given, the total number of ends in the warp not being known, the same rule will be found to apply by considering the number of ends in the arrangement, or pattern, as the total number of ends.

Example.—A warp is arranged 48 ends of 36s and 2 ends of 10s; find the average number.

Solution.—

$$\begin{array}{rcl} 48 \div 36 &=& 1.333 \\ 2 \div 10 &=& .2 \\ \hline 50 & & 1.533 \end{array}$$

$$50 \div 1.533 = 32.615\text{s, average number}$$

If the yarn is of different materials, such as cotton and worsted, then it is necessary first to place the different counts in the same system before applying the rule for finding the average number.

Example.—There are placed on a beam 2,000 ends of 40s cotton and 450 ends of 45s worsted; what are the average counts in the cotton system?

Solution.—First find the equivalent cotton counts of 45s worsted.

$$\frac{45 \times 560}{840} = 30\text{s cotton}$$

This example then resolves itself into finding the average counts of 2,000 ends of 40s and 450 ends of 30s.

$$\begin{array}{rcl} 2000 \div 40 &=& 50 \\ 450 \div 30 &=& 15 \\ \hline 2450 & & 65 \end{array}$$

$$2{,}450 \div 65 = 37.69\text{s, average counts}$$

FANCY WARPS

When more than one color of yarn is placed on the same beam, it frequently becomes necessary to find the total number of ends of each color and the weight of each particular yarn.

In order fully to understand the explanations given in this connection it will be necessary first to consider a few terms that will frequently be met with. The yarn that is placed on the loom beam is known as the *warp*, or *warp yarn*. It is this yarn that forms the threads running lengthwise in the cloth and is thus distinguished from the yarn running across the cloth, which is known as the *filling*. In case the warp yarn is composed of different colors or different counts, the order in which the different counts or colors are placed on the beam is known as the *pattern of the warp*. Thus, if the warp is arranged 4 ends of black, 4 ends of white, 4 ends of black, 4 ends of white, and so on across the cloth, the warp pattern is said to be 4 black, 4 white.

To find the number of ends of each color of yarn on a beam when the warp pattern and total number of ends are given, apply the following rule:

Rule.—*As the number of ends in one pattern is to the number of ends of any one color in the pattern, so is the total number of ends in the warp to the total number of ends of that color.*

EXAMPLE.—The yarn on a beam is arranged 16 ends black, 8 ends white, 16 ends black, 8 ends gray, how many ends of each color are there if there are 2,400 ends on the beam?

SOLUTION.— 16 ends black
8 ends white
16 ends black
8 ends gray

48 = total number of ends in one pattern.

There are 32 ends of black in one pattern.

Therefore, $48 : 32 = 2{,}400 : x$

$$x = \frac{32 \times 2{,}400}{48} = 1{,}600 \text{ ends of black}$$

There are 8 ends of white in one pattern.

Therefore, $48 : 8 = 2{,}400 : x$

$$x = \frac{8 \times 2{,}400}{48} = 400 \text{ ends of white}$$

There are 8 ends of gray in one pattern.

Therefore, $48 : 8 = 2{,}400 : x$

$$x = \frac{8 \times 2{,}400}{48} = 400 \text{ ends of gray}$$

If it is desired to find the weight of the ends of each color, after having obtained the total number of ends of each color, apply the rule for finding weight when length, counts, and number of ends are given.

CLOTH CALCULATIONS

Definitions.—After the warp yarn has been wound on the loom beam, the separate ends are drawn through the *harnesses* and afterwards through the *reed*. The warp is then ready to be placed in the loom. The harnesses are attached to mechanisms that raise and lower them; and, since some of the harnesses are up while others are down, a division of the warp yarn must necessarily take place. It is through the space formed by this division that the filling passes. This division of the ends is known as the *shed*, and as the harnesses change positions, according to the weave desired, several different sheds are obtained. By this manner of interlacing, the cloth is formed.

The threads of a cloth that run lengthwise of the piece, or the warp, are always spoken of as the *ends*, while those that run from side to side are known as the *picks*. A cloth is said to have a certain *sley*, which means that it contains so many ends per inch. It is also spoken of as being such a *pick cloth*, by which it is meant that the cloth has so many picks per inch. Thus, regular print cloth is said to be 64-sley and 64-pick, which means that the cloth contains 64 ends and 64 picks per inch; this is known as the *counts of the cloth*. When cloth contains the same number of ends per inch as picks it is spoken of as being so many *square*. Thus, the print cloth just referred to is known as 64 square.

When specifying the counts of a cloth in writing, the number of ends per inch is always placed first and is followed by the multiplication sign after which the number of picks per inch is placed. Thus, if a cloth contains 80 ends and 60 picks per inch, it is written 80×60 and, in speaking of the counts of this cloth, it is said to be *eighty by sixty*.

In speaking of the weight of cotton cloth, the number of yards in a pound is considered and the cloth is said to be a so many *yard cloth*. Thus, ordinary print cloth is spoken of as being a *7-yard cloth*, which means that it takes 7 yd. of the cloth to weigh 1 lb. This method differs very materially from that in practice in the woolen and worsted trades, where a cloth is said to be a so many *ounce cloth;* that is, if a piece of cloth weighs 12 oz. to the yard it is said to be a *12-ounce cloth.* This method of expressing the weight of woolen and worsted fabrics is also sometimes used for heavy cotton goods, such as duck. A second method of expressing the weight of duck fabrics is to consider the weight of a square yard; that is, a piece of duck weighing 7 oz. to the square yard, is spoken of as *7-ounce duck.*

A third method that is largely used in connection with sail ducks is arranged, or taken, from a standard duck, known as a No. 3 duck that weighs 16 oz., or 1 lb. for 1 yd. of cloth 22 in. wide. For each ounce variation in the weight per yard, 22 in. wide, the number is altered by 1. Thus a No. 4 duck will weigh 15 oz., a No. 5 duck will weigh 14 oz; a No. 2 duck will weigh 17 oz.; and a No. 1 duck will weigh 18 oz. Duck fabrics heavier than the above are indicated thus: No. 1/0 duck will weigh 19 oz.; No. 2/0 duck will weigh 20 oz.; No. 3/0 duck will weigh 21 oz.; and so on.

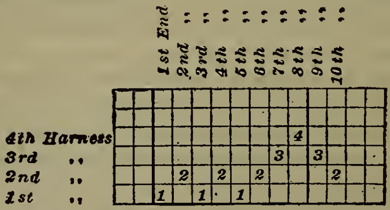
A linear yard is considered by the first method irrespective of width. A square yard is considered by the second method, and the weights of all other widths must be expressed in proportion to 36 in.; that is, a piece of duck 1 yd. long, 27 in. wide, weighing $5\frac{1}{4}$ oz., would be spoken of as a 7-ounce duck because $(5\frac{1}{4}\times36)\div27=7$ oz. per sq. yd. A duck 1 yd. long, 22 in. wide, is considered by the third method, and the weights of all other widths must be expressed in proportion to 22 in. in exactly the same manner as shown in the square-yard method.

The other specifications necessary in reproducing a piece of cloth are the width, the counts of the warp yarn, and the counts of the filling. In giving these specifications they are shown as follows: 48×52–36″–4.15 yd.–18s warp–22s filling. The counts of the warp and filling are sometimes written in the following form: 18s/22s. These specifications show that the cloth is 48-sley, 52-pick, 36 in. wide, 4.15 yd. to the pound, the warp being 18s, and the filling 22s.

HARNESS CALCULATIONS

The harnesses consist of small wires, or in many cases, strong threads, known as *heddles*, near the center of which eyes are formed, through which the warp ends are drawn. Whenever a new warp is drawn in, it becomes necessary to find the number of heddles that must be placed on each harness, in order that there may be sufficient heddles for all the warp ends on the beam. In order to perform such a calculation, the manner of drawing in the ends must be known. This is learned by consulting the *drawing-in draft*, which shows through which harness each end in one repeat of the draft is drawn.

The accompanying illustration shows a drawing-in draft, since it indicates through which harness the separate ends are



drawn. Each figure indicates through which harness one particular end is drawn; thus, the first end is drawn through the first harness; the second end through the second harness; the third end through the first harness; and so on through the 10 ends that constitute one repeat of the draft.

The necessary number of heddles on any harness may be found by the following rule:

Rule.—*Find the number of repeats of the drawing-in draft in the warp by dividing the total number of ends in the warp by the number of ends in one repeat. Multiply the result by the number of heddles required on any harness for one repeat. The result will be the total number of heddles required on that harness.*

Example.—If a warp contains 2,400 ends and is drawn in according to the draft shown in the illustration, how many heddles should be placed on each harness?

SOLUTION.— $2400 \div 10 = 240$ repeats of the pattern.
$240 \times 3 = 720$ heddles on first harness
$240 \times 4 = 960$ heddles on second harness
$240 \times 2 = 480$ heddles on third harness
$240 \times 1 = 240$ heddles on fourth harness
2400

The drawing-in draft indicates that there are 3 ends drawn on the first harness, 4 ends on the second harness, 2 ends on the third harness, and 1 end on the fourth harness, in each repeat; hence, 240 repeats times 3 equals 720 heddles on first harness and so on. In all cases, a few extra heddles should be added to each harness in order to meet all additional requirements, for selvages, etc.

REEDS

The reed through which the ends are drawn after being drawn through the harnesses, plays a very important part, not only in the weaving, but also in all calculations connected with cloth. Reeds are made of thin, flat pieces of steel wire set into top and bottom pieces known as *ribs*.

The space between two adjoining wires in the reed is known as a *dent*, and it is the number of these dents that the reed contains in an inch that determines the counts of the reed. Thus, for example, if a certain reed has 40 dents per inch, it is known as a 40s reed. In many cases, however, reeds are numbered by giving the number of dents in a certain number of inches. For example, a reed may be numbered 1,200–30, which indicates that it contains 1,200 dents in 30 in. It will be seen that in both of these cases the counts of the reed are the same.

Reeds are also sometimes spoken of as being such a sley; thus, a reed may be said to be a 64-sley, which means that, with the ends of a warp drawn in two per dent, the cloth will contain 64 ends per inch. This does not indicate that there are 32 dents per inch in the reed, since on account of the contraction that takes place during weaving, the yarn at the reed is slightly wider than it is after it becomes a part of the cloth and, for this reason, the number of dents per inch is slightly less.

The first method, however, is the one generally used and numerous mills that previously used the other systems have adopted this method of ordering reeds with the required number of dents per inch.

Reeds as sent out by the manufacturers are always marked by one of the methods indicated above; that is, either according to the number of dents per inch or the number of dents in so many inches. However, reeds are sold by the bier. The *bier*, as applied to reeds, means 20 dents; consequently, when the price per reed is quoted at so much per bier, it means so much for every 20 dents.

CALCULATIONS FOR WARP YARN

The first calculation necessary when dealing with cloth is to find the total number of ends in the warp when the width of the cloth and the ends per inch, or sley of the cloth, are given. It should be noted that at the sides of all cloths additional ends are placed in order to strengthen the fabric. These ends are known as the *selvage ends*, and it is always necessary to consider these. They are generally ends like those of the body of the warp, where such ends are all alike, or like those forming the plain portion of a fancy cloth containing several varieties or counts of warp yarn. However, they are usually reeded with twice as many ends per dent as similar ends in the body of the warp; thus, if a warp is drawn in two per dent, for about $\frac{1}{4}$ in. in width at each side the ends will be drawn in four per dent. Selvage ends are also drawn double, or two ends per heddle, when drawing them through the harnesses. In some cases, however, where an especially strong selvage is required, ply yarns are used for selvage ends. Selvages are seldom over $\frac{1}{4}$ in. in width, and generally speaking, from 12 to 20 additional ends on each side will be found to be sufficient to allow for the selvages.

The total ends in a cloth when the width and sley are given, may be found by the following rule:

Rule.—*Multiply the sley by the width and to the result thus obtained add a certain number of ends for selvages.*

EXAMPLE.—Find the total number of ends in a cloth 36 in. wide, and containing 48 ends per inch.

SOLUTION.— $48 \times 36 = 1{,}728$ ends. Considering that 32 ends, or 16 double ends, are required at each side for selvages, then $16 \times 2 = 32$ extra ends to be added, making $1{,}728 + 32 = 1{,}760$ ends in cloth.

Contraction.—It is essential to take into account the contraction of the warp that occurs during weaving. This contraction affects both the length and width of the cloth; in connection with the warp yarn it is only necessary to consider the contraction in the length.

Since, in the interlacing of the filling with the warp, the two series of yarns necessarily bend around each other to a certain extent, it naturally follows that a piece of cloth will not be quite as long as the warp from which it is made. This difference between the length of the warp yarn and the cloth made from it is known as the *contraction.*

The factors that will tend to affect the amount of contraction that takes place are: The tension on the yarn during weaving; the comparative counts of the warp and filling, since, if the warp is very much coarser than the filling, the filling will do most of the bending, while the warp yarn will lie in a comparatively straight line; the class of weave, or, in other words, the manner of interlacing the warp and filling, since the warp yarn will not contract so much in a weave where it interlaces with the filling only once in five picks as it will in a weave where it interlaces at every pick. Weaves in which the warp yarns are drawn entirely out of a straight line, such as lenos, will contract the warp yarn much more than will weaves in which the warp yarns lie in a comparatively straight line.

In practice, the actual percentage of contraction can be readily obtained by comparing the length of cut at the slasher with the length of cut after weaving.

The weight of warp yarn contained in a cut of any length may be found by the following rule:

Rule.—*Multiply the number of ends in the cloth by the length of the warp yarn in the cut before weaving, and divide by the standard* *number of yards per hank multiplied by the counts of the warp yarn.*

EXAMPLE.—A cloth 36 in. wide having 48 ends per inch contains with the ends for selvages, 1,760 ends. Assuming that this cloth is woven 50 yd. long from 53 yd. of warp; what is the weight of the warp yarn when the counts are 18s?

SOLUTION.— $\frac{1,760 \times 53}{840 \times 18} = 6.169$ lb. of warp yarn

Allowance for Size.—One point that must be noted is that, before weaving, size is placed on the warp yarn, which adds to its weight. The American custom of sizing yarn differs considerably from that in Europe, where size is often added for the purpose of weighting the cloth. In America, the principal use of size is to strengthen the warp yarn so that it will withstand the strain and chafing that take place during weaving, and, for this purpose, the amount of size added is very much smaller than that used when sizing for weight.

If the percentage of size added were calculated from the weight of the cloth, the result would not be correct, since the size is added only to the warp yarn and not to the filling. Therefore, this additional weight of size must be added to the weight of the unsized warp yarn. Generally, it will be found that from 4% to 10% will cover all cases in America. If the warp yarn in 50 yd. of cloth weighs 6.169 lb. and 6% of size is added at the slasher, then the weight of the sized warp yarn in 50 yd. of cloth will be $6.169 \times 1.06 = 6.54$ lb., nearly.

CALCULATIONS FOR FILLING YARN

Width at Reed.—When figuring the amount of filling that a cut of cloth contains, practically the same particulars are considered that affect the contraction of the warp. Thus, if a cloth is 36 in. wide, the space that the warp yarn occupies in the reed, or, as it is known, the width at the reed, will be in excess of this width. Consequently, to find the exact length of each pick of filling, it is necessary to consider the width at the reed and not the width of the cloth. To find the width at the reed it is first necessary to ascertain the number of dents per inch in the reed or, in other words, the counts of the reed.

The dents per inch in a reed to produce a cloth of a given sley may be found by the following rule:

Rule.—*Subtract 1 from the sley of the cloth, divide the result by the number of ends per dent, and multiply the result thus obtained by .95.*

Example.—If a cloth is 48 sley and is reeded 2 ends per dent, what counts of reed will be necessary to give this sley?

Solution.—

$48 - 1 = 47$

$47 \div 2 = 23.5$

$23.5 \times .95 = 22.325$, or say 22 dents per inch

Explanation.—By always subtracting 1 from the sley of the cloth a sliding scale is obtained, which to a certain extent offsets the difference in the contraction of different counts of yarn. Thus, if the sley is 50 and 1 is subtracted, 2% is deducted whereas if the sley is 100 and 1 is subtracted, only 1% is deducted. Since there are 2 ends per dent, the sley must be divided by this number in order to obtain the dents that are occupied by 1 in. of the warp as measured in the cloth. A safe estimate of the contraction that takes place when running medium counts of yarns is 5%; therefore, the result obtained by dividing by 2 is multiplied by .95 in order to obtain the dents per inch. This percentage can be varied, however, to suit various circumstances.

In many cases, also, the warp ends are drawn more than two per dent throughout the reed. Under such circumstances it is always necessary to divide the result obtained by subtracting 1 from the sley by the number of ends to each dent.

The width occupied by the warp yarn in the reed, including selvages, may be found by the following rule:

Rule.—*Subtract the number of extra ends added for selvages from the total number of ends in the warp. Divide this result by the number of ends per dent and divide the result thus obtained by the number of dents per inch in the reed.*

Example.—If a cloth contains 1,760 ends, including 32 extra ends added for selvages, and the ends are drawn 2 per dent in a 22s reed, what is the width at the reed?

SOLUTION.—

$1{,}760 - 32 = 1{,}728$ ends

$1{,}728 \div 2 = 864$ dents required for the warp

$864 \div 22 = 39.27$ in., width at reed

EXPLANATION.—The 1,728 ends give the desired width in reed when drawn 2 ends per dent throughout. The 16 extra ends that are required for each selvage, or 32 extra ends in all, are simply drawn extra in the dents of the reed at each side of the fabric, making these dents contain 4 ends instead of 2 ends, as in the body of the warp.

Finding the Weight of Filling.—The weight of filling contained in a cloth of any length may be found by the following rule:

Rule.—*Multiply the width in the reed, in inches, by the number of picks per inch. Multiply this result by the length of the cloth, in yards, and divide the result thus obtained by the number of yards to the hank multiplied by the counts of filling.*

EXAMPLE.—What is the weight of filling yarn in 50 yd. of cloth that is 39.27 in. wide in the reed and contains 52 picks per inch of 22s yarn?

SOLUTION.— $$\frac{39.27 \times 52 \times 50}{840 \times 22\text{s}} = 5.525 \text{ lb. of filling}$$

WEIGHT OF CLOTH

From the weights of warp and filling obtained the yards per pound can be ascertained by the following rules:

Rule.—*Add together the weights of warp and filling to find the weight of cut; then divide the length of cut by this weight, and the result will be the yards per pound.*

EXAMPLE.—The weight of sized warp yarn is 6.54 lb.; the weight of filling is 5.525 lb.; the length of cut is 50 yd. Find the number of yards per pound.

SOLUTION.—Weight of 50-yd. cut is $6.54 + 5.525 = 12.065$ lb. $50 \div 12.065 = 4.15$ yd. per lb., nearly.

If it is desired to express the weight in ounces per yard instead of yards per pound the following rules apply:

Rule I.—*Multiply the weight of cloth, in pounds, by 16 (oz. in 1 lb.) and divide by the length of cloth.*

Example.—If 50 yd. of cloth weigh 12.065 lb.; what is the weight in ounces per yard?

Solution.— $\frac{12.065 \times 16}{50} = 3.86$ oz. per yd.

Rule II.—*Divide 16 (ounces per pound) by the yards per pound.*

Example.—A cloth weighs 4.15 yd. per pound; what is the weight expressed in ounces per yard?

Solution.— $16 \div 4.15 = 3.86$ oz. per yd.

FIGURING PARTICULARS FROM CLOTH SAMPLES

When a small sample of cloth is given from which to produce a similar cloth, the particulars that must be learned from it are the sley, pick, number of yards per pound, width of the goods, and the counts of warp and filling yarns.

Sley and Pick.—In ordinary cases, the best method for finding the sley is to use a pick glass, or, in some cases, to cut out a small piece of cloth, say 1 or 2 in. square, pulling out the threads one by one and counting them and in this manner obtaining the number of ends per inch in the cloth. The same methods may be adopted to find the picks per inch.

Yards per Pound.—The yards per pound can be found by weighing a small sample and applying the following rule:

Rule.—*Multiply 7,000 by the number of square inches weighed and divide the result thus obtained by the product of the weight, in grains, of the piece weighed, the width of the cloth, and 36 (the number of inches in 1 yd.).*

Example.—A piece of cloth 3 in. square is found to weigh 9 gr.; what are the yards per pound if the cloth is 28 in. wide?

Solution.—A piece of cloth 3 in. square contains 9 sq. in.

$$\frac{7{,}000 \times 9}{9 \times 28 \times 36} = 6.94, \text{ say 7 yd. per lb.}$$

Width of Cloth.—The width of cloth is usually specified, the designer being furnished with only a small sample of the fabric. As a matter of fact, the selling agents of the mill, who usually submit the cloth sample, in most cases, also submit the sley, pick, yards per pound, and width of cloth, leaving the matter of counts of warp yarn and counts of filling for the designer to determine.

When not specified, the former items may be determined as explained, but the counts of the yarns must always be ascertained. For instance, specifications are given for a standard print cloth as follows: 64×64—28 in.—7 yd. With such specifications as these, the first step in determining the proper counts of warp and filling yarns is to find the average counts of the cloth.

Average Counts.—The average counts of the warp and filling yarns in a fabric can be found by applying the following rule:

Rule.—*Add the sley and pick together and multiply the sum by 7,000 (gr. per lb.) and by the number of square inches weighed. Divide this result by the product of the yards per hank (840), the inches per yard (36), and the weight in grains of sample weighed.*

Example.—A piece of cloth 3 in. square is found to weigh 9 gr., and contains 64 ends and 64 picks per inch. What is the average number of warp and filling in the fabric?

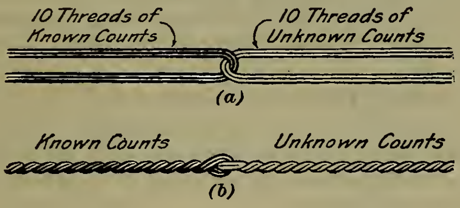
Solution.—A piece of cloth 3 in. square contains 9 sq. in.

$$\frac{(64+64)\times 7{,}000\times 9}{840\times 36\times 9}=29.63 \text{ average counts of cloth}$$

In this solution the contraction in length and width that takes place during weaving has not been considered, so that the actual average number of warp and filling is somewhat coarser than the result obtained. In all cases the warp length is greater than the cloth length, and the width in reed is greater than the width of cloth. No definite allowance can be made for this contraction, because there are several factors that make it impossible to formulate a definite rule to suit all classes of fabrics.

Counts of Warp Yarn.—From the average number, the counts of the warp yarn to use is usually determined according to the class of fabric under consideration. Ordinarily the warp yarn is a little coarser than the filling. However, in fabrics having a warp face, the warp yarn is usually of finer counts than the filling, and in the case of filling-faced cloths the filling is usually of finer counts than the warp. The counts of the warp are often decided on from the average number, that is, in cases where the counts of the warp and filling yarns are nearly equal, and then the counts of filling are found to preserve the yards per pound, as will be explained later.

Another method, and perhaps the one most often used, to determine the counts of warp required to reproduce a fabric is to test the warp yarn in the sample under consideration by comparing it with a known counts of yarn. This is accomplished by taking a number of warp threads, say 10, from the cloth sample, then take 10 threads of known counts of yarn of approximately the same counts as in the cloth sample, or as near as judgment will allow; these threads need not be over 3 in. long. Now loop them together as shown in (*a*) in the accompanying illustration and twist as shown in (*b*). By careful examination of the two series of ends either by the naked eye or by means of a magnifying or pick glass it can be



ascertained whether both are of approximately the same size or not. Assuming in this case that the counts taken are 32s and that the unknown yarn is found by the above comparison to be coarser than the known counts, then untwist the ends and take out one thread from the unknown series and twist them together again and so on until it is determined that both series are of the same size when twisted together. If the known yarn was found to be coarser than the unknown, one thread at a time would be removed from the known counts until both series are of approximately the same size. Assuming that the above comparison shows that both series are of equal size when 9 threads of the unknown yarn balance 10 threads of the known yarn, the unknown must be coarser than the known in the ratio of 10 to 9. Then $10:9 = 32 : x$; = and x will equal 28.8s counts of warp yarn. The general custom in cotton mills is to use the nearest counts of warp yarn that is being produced in that mill, so in this case it will be assumed that 30s warp yarn is selected for the cloth sample under consideration. The preceding method is commonly used in actual practice in cotton mills and gives accurate results when the test is performed by an experienced person. Of course, a definite length of warp yarn may be unravelled from the sample, weighed, and the counts found in this manner. Even in such cases, however, it is customary to use a counts of yarn for the warp that the mill is ordinarily spinning, if this is possible.

Ends in Warp.—Having decided on the counts of warp yarn to use, it is necessary to find the number of ends in the warp.

EXAMPLE.—How many ends in a piece of cloth 28 in. wide, and containing 64 ends per inch?

SOLUTION.— $64 \times 28 = 1{,}792$ ends

Considering that 28 ends, or 14 double ends, are required at each side for selvages, then $14 \times 2 = 28$ extra ends are to be added, making $1{,}792 + 28 = 1{,}820$ ends in warp. (See rule at top of page 46.)

Weight of Warp Yarn.—The weight of warp yarn required to produce 50 yd. of cloth is found as follows:

EXAMPLE.—What weight of 30s warp yarn will be required for 50 yd. of cloth if 52.5 yd. of warp yarn are necessary and the warp contains 1,820 ends?

SOLUTION.— $\frac{1{,}820 \times 52.5}{840 \times 30} = 3.79$ lb. of unsized warp yarn

(See rule at bottom of page 46.) It will be assumed in this case that 4% of size is added to the warp yarn. Then the sized warp yarn will weigh $3.79 \times 1.04 = 3.94$ lb.

Reed.—The number of the reed is calculated according to the rule at top of page 48 as follows:

$$64 - 1 = 63$$
$$63 \div 2 = 31.5$$
$$31.5 \times .95 = 29.925, \text{ say 30 dents per inch}$$

Width in Reed.—According to the rule at bottom of page 48, the width in reed may be found as follows:

$$1{,}792 \div 2 \text{ (ends per dent)} = 896 \text{ dents}$$
$$896 \div 30 = 29.866, \text{ say 30 in. in reed}$$

Weight of Cut.—The weight of 50 yd. of cloth can be found by dividing the length of cloth by the yards per pound. Thus,

$50 \div 7 = 7.14$ lb. Since the weight of the warp yarn is 3.94 lb., $7.14 - 3.94 = 3.20$ lb. of filling is required to produce 50 yd. of cloth.

Counts of Filling.—The counts of filling to preserve the yards per pound can now be found by applying the following rule:

Rule.—*Multiply the width in reed, in inches, by the number of picks per inch and by the length of cloth, in yards. Divide this result by the number of yards per hank and the weight of filling.*

EXAMPLE.—What are the counts of filling required to preserve the yards per pound when the width at reed is 30 in., the length of cloth 50 yd., the picks per inch 64, and the weight of filling 3.20 lb.?

SOLUTION.— $$\frac{30 \times 64 \times 50}{840 \times 3.20} = 35.7, \text{ say 36s filling}$$

Summary.—The manufacturing data relative to the fabric dealt with in the preceding calculations may be summarized as follows:

Sley and pick	64×64
Width of cloth	28 in.
Weight of cloth	7 yd. per lb.
Length of cut	50 yd.
Counts of warp	30s
Ends in warp	1,820
Weight of warp	3.79 lb.
Reed	30 dents per in.
Width at reed	30 in.
Weight of filling	3.20 lb.
Counts of filling	36s.

FANCY WARP PATTERNS

When the number of ends of each color, counts, or material in the warp of a fabric that contains a warp pattern must be ascertained, the following rule is applicable.

Rule.—*Divide the number of ends in the warp, exclusive of selvage ends, by the number of ends in one repeat of the warp pattern. This result and the number of ends of each color, etc., in the warp pattern should be multiplied.*

EXAMPLE.—The warp pattern of a striped gingham is arranged 12 white, 4 orange, 12 white, 4 blue ends; how many ends of each color will be required for a warp containing 2,040 ends?

SOLUTION.—Assuming that 48 ends of white yarn are to be used for selvages (12 double ends at each side of the fabric), the ends in the body of the warp inside selvages will be 2,040 $-48=1{,}992$ ends. In one repeat of this warp pattern there are 24 white ends, 4 orange ends, and 4 blue ends, a total of 32 ends per pattern. The repeats of the pattern in the warp are, therefore, $1{,}992 \div 32 = 62$ repeats and 8 ends over. In a case of this kind the 8 ends over full repeats of the pattern would be considered to be white ends as are also the selvage ends. The calculation of the ends of each color in the warp is, therefore, as follows:

$$\begin{aligned} 62 \times 24 + 8 + 48 &= 1{,}544 \text{ ends of white} \\ 62 \times 4 &= 248 \text{ ends of orange} \\ 62 \times 4 &= 248 \text{ ends of blue} \\ \hline &\ 2040 \text{ ends in warp} \end{aligned}$$

NOTE.—After the 12 double ends are drawn in for one selvage, 10 single white ends should be drawn through the harnesses. This will divide the 8 extra white ends and the first 12 white ends in the pattern, so as to allow 10 white ends to lie adjacent to each selvage. The pattern will then be *balanced*, as it should be in all fabrics that contain a warp pattern.

If desired, the weight of each color, kind, or counts of warp yarn may be found in the usual manner.

IRREGULAR REED DRAFTS

When the warp ends are drawn through the reed in an irregular manner, as is often the case, a method slightly different from that previously described must be followed. Suppose, for instance, that a fabric contains the following warp pattern: 40 ends of white, 40 ends of blue, 40 ends of white, and 20 ends of blue. Assume, also, that the 40 ends of blue occupy exactly one-half as much space in the fabric as 40 ends of white and that the 20 ends of blue occupy a space equal to one-fourth of the space occupied by 40 ends of white. It is apparent, in this case, that the blue ends are reeded with twice the number of ends per dent as the white ends, or, if the white ends are reeded 2 ends per dent, then the blue ends must be drawn 4 ends per dent. Thus, the arrangement of this pattern is as follows:

40 (white) ÷ 2 (ends per dent) =	20 dents
40 (blue) ÷ 4 (ends per dent) =	10 dents
40 (white) ÷ 2 (ends per dent) =	20 dents
20 (blue) ÷ 4 (ends per dent) =	5 dents
140 ends	55 dents

Since 40 ends of white are found to occupy exactly ½ in. in the fabric, it will be assumed that this fabric will be reproduced with a reed that would give an 80-sley fabric if the ends were evenly reeded throughout the width of the cloth. If it is also assumed that the fabric is to be woven 30 in. wide, including selvages, the total number of dents is as follows:

$$\frac{80 \text{ (sley)} \times 30 \text{ (inches wide)}}{2 \text{ (ends per dent)}} = 1{,}200 \text{ dents}$$

If 14 double ends or 28 single ends are allowed on each side for selvages, making 28 double ends or 56 single ends in all, and the selvages are drawn 2 double ends or 4 single ends per dent, 7 dents on each side or 14 dents in all will be occupied by the selvages. This will leave 1,200 − 14 = 1,186 dents for the warp ends forming the body of the cloth. Then, 1,186 ÷ 55 (dents per pattern) = 21 patterns and 31 dents over. The 31 dents over full patterns will accommodate 40 ends of white (20 dents), 40 ends of blue (10 dents), and leave one extra dent which would best be filled with 2 white ends. The pattern, therefore, may be balanced in the cloth as follows:

		Ends	*Dents*
14 white double ends, 2 double ends per dent		28	7
20 white ends, 2 ends per dent		20	10
40 blue ends, 4 per dent 40 white ends, 2 per dent 20 blue ends, 4 per dent 40 white ends, 2 per dent	21 times	2,940	1,155
40 blue ends, 4 per dent		40	10
22 white ends, 2 per dent		22	11
14 white double ends, 2 double ends per dent		28	7
Total		3078	1200

Since there are 60 blue ends per pattern, 21 patterns, and 40 blue ends additional, there are $60\times21+40=1{,}300$ blue ends, and as the total number of ends is 3,078, there are $3{,}078-1{,}300=1{,}778$ white ends.

CONTRACTION IN LENO AND LAPPET FABRICS

The doup ends in leno fabrics and the lappet ends in cloths constructed on the lappet principle are greatly deflected from a straight line and hence, are much longer than the ground ends that form the body of the cloth; the amount of contraction in the weaving of these ends must, therefore, be accurately determined. The best method of ascertaining the relative length of doup ends or lappet ends as compared with the ground ends of a fabric is to remove from a sample of the cloth one or more of the doup ends or the lappet ends, as the case may be, and then compare the length of the end or ends removed with the length of the cloth sample. For instance, suppose that several doup ends are removed from a sample of leno fabric 9 in. in length, and are found to be exactly 11 in. long. In this case, it is evident that whatever the length of cloth to be woven, the doup ends must be longer than the cloth length in the ratio of 11 to 9. For example, if 100 yd. of cloth must be woven, the length of the doup ends must be

$$\frac{100\times11}{9}=122\tfrac{2}{9}\text{ yd.}$$

In some leno fabrics, the ground ends, around which the doup ends are crossed, are deflected from a straight line as well as the doup ends. In such cases they should be treated exactly like doup ends, as previously explained.

As a further illustration of this principle, assume that several lappet ends are removed from a piece of cloth $4\frac{1}{2}$ in. long and are found to measure $28\frac{1}{2}$ in. In this instance, whatever length of cloth is taken, the lappet ends must exceed the cloth length in the ratio of $28\frac{1}{2}$ to $4\frac{1}{2}$. Thus, for 100 yd. of cloth, the length of each lappet end will be $\frac{100\times28\frac{1}{2}}{4\frac{1}{2}}=633\frac{1}{3}$ yd. If two or more sets of doup ends are used in a fabric each set interlacing differently, or if two or more sets of lappet ends are employed in the fabric, each set having a different trailer pattern; then each set must be considered separately when finding the length of yarn required. In all cases where two or more systems of warp yarn are used, the warp length required of each system may be ascertained in the manner explained.

FANCY FILLING PATTERNS

To ascertain the weight of each color, kind, or material of filling yarn, the method of procedure is very similar to that employed for finding similar data relating to warp yarns. The number of picks of each color or kind of filling in one repeat of the filling pattern is ascertained first, and then the picks per inch or relative proportion, of each color or kind, etc., is found, after which the weight of each may be determined in the ordinary manner.

EXAMPLE.—The filling pattern of a gingham fabric is arranged 12 picks of white, 4 picks of orange, 12 picks of white and 4 picks of blue. If the width in reed is 30 in., counts of filling yarn 36s, and picks per inch 68, what weight of each color of filling yarn will be required to weave 100 yd. of cloth?

SOLUTION.—In one repeat of the filling pattern there are 24 picks of white, 4 picks of orange, and 4 picks of blue, making a total of 32 picks in the pattern. In the filling, therefore, $\frac{24}{32}$ of the yarn is white, $\frac{4}{32}$ is orange and $\frac{4}{32}$ blue. Applying the rule given on page 49, the total weight of the filling yarn in 100 yd. of cloth is found as follows:

$$\frac{30 \times 68 \times 100}{840 \times 36} = 6.746 \text{ lb.}$$

Then the weight required of each color of filling will be

$$\begin{aligned} 6.746 \times \tfrac{24}{32} &= 5.060 \text{ lb. white} \\ 6.746 \times \tfrac{4}{32} &= .843 \text{ lb. orange} \\ 6.746 \times \tfrac{4}{32} &= \underline{.843} \text{ lb. blue.} \\ & 6.746 \text{ lb.} \end{aligned}$$

The example may be solved to find the weight of each color in one operation as follows:

$$\frac{30\times68\times100\times24}{840\times36\times32}=5.06 \text{ lb. white}$$

$$\frac{30\times68\times100\times4}{840\times36\times32}=.843 \text{ lb. orange}$$

$$\frac{30\times68\times100\times4}{840\times36\times32}=.843 \text{ lb. blue}$$

$$5.06+.843+.843=6.746 \text{ lb. weight of filling}$$

In some fabrics the filling yarn is not only of different colors, kinds, or materials, but also of different counts; and, in some cases, there may be more picks of certain kinds of filling yarn in a given space than of other kinds. In such cases the calculations for finding the weight of each kind or color of filling yarn in a given length of cloth must of necessity differ from those already dealt with, For illustration, suppose that in a certain fabric the filling pattern is arranged 12 picks of blue, 24 picks of white, 12 picks of tan and 24 picks of white. It will be assumed, also, that a 50-yd. cut of cloth is to be produced and the width in the reed is 30 in. On examination of the fabric it is found that the counts of the different kinds of filling yarn and the space occupied by each in one repeat of the filling pattern are as follows:

	Counts	*Space Occupied*
12 blue	36s	$\frac{1}{8}$ in.
24 white	24s	$\frac{1}{2}$ in.
12 tan	40s	$\frac{1}{8}$ in.
24 white	24s	$\frac{1}{2}$ in.
72 picks in pattern		$1\frac{1}{4}$ in.

The average picks in 1 in. of each color may be found by simple proportion. There are 48 picks of white in $1\frac{1}{4}$ in., which equals $\frac{48\times1}{1.25}=38.4$ picks of white filling per inch. There are 12 picks of blue filling in $1\frac{1}{4}$ in., which equals $\frac{12\times1}{1.25}=9.6$ picks of blue filling per inch. There are also 9.6 picks of tan filling per inch.

The weight of each color of filling yarn can now be found by applying the rule on page 53, thus:

$$\frac{38.4\times30\times50}{840\times24}=2.857 \text{ lb. of 24s filling (white)}$$

$$\frac{9.6\times30\times50}{840\times36}=.476 \text{ lb. of 36s filling (blue)}$$

$$\frac{9.6\times30\times50}{840\times40}=.428 \text{ lb. of 40s filling (tan)}$$

MISCELLANEOUS SHORT RULES FOR CLOTH CALCULATIONS

Average Counts of Cloth.—The average number of yarn in a cloth of ordinary construction may be found by the following rule:

Rule.—*Add the sley and the pick together; multiply this result by the width and the result thus obtained by the yards per pound and divide this result by 760. The answer will be the average number of the yarns.*

In this rule the standard 760 has been used instead of the ordinary standard 840, in order to make allowances for the contraction in length and width during weaving and for the size placed on the warp yarn. This constant will be found applicable to usual cases, but may be varied at will to suit any special range of fabrics.

EXAMPLE.—It is desired to find the average number of a cloth containing 60 ends and 66 picks per inch, the cloth being 30 in. wide and weighing 5 yd. per lb.

SOLUTION.— $60+66=126$; $126\times30=3{,}780$

$3{,}780\times5=18{,}900$; $18{,}900\div760=24.8$s, average number

Counts of Filling to Preserve Weight of Cloth.—Another rule that will be found accurate for cloths of ordinary construction is to find the counts of filling required to preserve the weight of the cloth when the average number of the yarns in the cloth and the counts of the warp are known.

Rule.—*Add the sley and the pick together and divide by the average number. Divide the sley by the counts of the warp. Subtract the result obtained in the second instance from the result obtained in the first and divide the result thus obtained into the* *picks per inch. The answer will be the counts of the filling required.*

EXAMPLE.—With the particulars the same as in the preceding example and taking 22s as the counts of the warp, find the counts of filling required to be used to preserve the weight of the cloth.

SOLUTION.— $60+66=126$; $126\div24.8=5.08$
$60\div22=2.72$; $5.08-2.72=2.36$

$66\div2.36=27.96$s, counts of filling required to preserve weight.

Average Counts of Filling.—When the filling contains different counts of yarn, the average counts of the filling may be found by the same method used to find the counts of filling required to produce cloth of a given weight. Then, with the counts of one of the kinds of filling known, find the counts of the other filling required to produce cloth of the given weight.

Rule.—*Divide the total number of picks in the pattern by the average counts of the filling. Also divide the number of picks of the known counts of filling by its counts. Subtract the result obtained in the second instance from the result obtained in the first, and divide the difference into the number of picks of the unknown counts.*

EXAMPLE.—A piece of cloth, 64×64, is 27 in. wide, and has the warp and filling arranged 46 ends of fine and 3 ends of cord. The counts of the fine yarn in the warp are 30s and of the cord 10s. If the cloth weighs 6.4 yd. to the pound, what counts of fine filling must be used to preserve the yards per pound?

SOLUTION.—First find the average counts of the warp.

$$\begin{array}{rl} 46\div30= & 1.53 \\ \underline{3}\div10= & \underline{.30} \\ 49 & 1.83 \end{array}$$

$49\div1.83=27$s, nearly, average counts of warp.

Next find the average counts of warp and filling.

$$64+64=128$$

$$\frac{128\times27\times6.4}{760}=29.103\text{s, average counts of warp and filling.}$$

Next find the average counts of filling.

$$64+64=128;\ 128\div 29.103=4.398$$
$$64\div 27=2.37;\ 4.398-2.37=2.028$$
$$64\div 2.008=31.558\text{s, average counts of filling}$$

The question now is to find the counts of the cord and the fine yarn in the filling to preserve the yards per pound, the average counts of the filling and the arrangement of the yarn in the filling being known. In cases of this kind it would be unlikely that a mill would employ different counts of cord in both warp and filling, consequently it would be safe to assume the counts of the cord in the filling to be the same as that in the warp, after which it would only be necessary to find the counts of the fine filling.

$$\begin{array}{lcl} 49\div 31.558 & = & 1.552 \\ \underline{\ 3}\div 10 & = & \underline{\ .300} \\ 46 & & 1.252 \end{array}$$

$$46\div 1.252=36.741\text{s, counts of fine filling}$$

Warp Contraction.—The percentage to allow for warp contraction during weaving may be found by the following rule:

Rule.—*Multiply the number of picks per inch by 3 and divide by the counts of the filling. The result will be the percentage to allow for contraction.*

Example.—The number of picks per inch in a certain cloth is 60, the counts of the filling are 36s; what will be the length of the cloth made from 100 yd. of warp yarn?

Solution.— $\frac{60\times 3}{36}=5$, percentage to allow for contraction.

5% of 100=5; 100 yd.−5 yd.=95 yd. of cloth.

This rule, when taking into consideration the points previously mentioned, is comparatively accurate for counts of filling from 25s to 50s and for picks from 40 to 80 per in. and will serve as a basis when finding the contraction of any warp.

By varying the constant 3 to suit special circumstances rules can be formulated to suit requirements; or if the usual rate of contraction in a certain mill on certain goods is found, it will not be difficult to form a good idea of the contraction in other cloths.

Weight of Warp Yarn.—The weight in ounces of warp yarn per yard of cloth may be found by the following rule:

Rule.—*Multiply the counts of the yarn by 105 and divide into twice the number of ends in the warp.*

Example.—A cotton warp contains 2,100 ends of 30s yarn; what is the weight per yard?

Solution.— $$\frac{2{,}100\times 2}{105\times 30}=1\tfrac{1}{3}\text{ oz.}$$

Weight of Filling Yarn.—The weight in ounces of filling yarn per yard of cloth may be found by the following rule:

Rule.—*Multiply the width by the picks per inch and by 2 and divide by 105 times the counts of the yarn.*

Example.—What is the weight of filling in a yard of cloth 28 in. wide if it contains 75 picks per inch of 40s cotton yarn?

Solution.— $$\frac{28\times 75\times 2}{105\times 40}=1\text{ oz.}$$

Hanks of Warp Yarn.—The hanks of warp yarn per cut of cloth may be found by the following rule:

Rule.—*Multiply the ends in the warp by the length of the warp yarn before weaving and divide by 840.*

Example.—A cloth contains 1,680 warp ends and 55 yd. of warp are required to produce a 50-yd. cut of cloth. How many hanks of warp yarn are required?

Solution.— $$\frac{1{,}680\times 55}{840}=110\text{ hanks}$$

Hanks of Filling Yarn.—The hanks of filling yarn per cut of cloth may be found by the following rule:

Rule.—*Multiply the width in the reed, in inches, by the number of picks per inch. Multiply this result by the length of the cloth, in yards, and divide the result thus obtained by the number of yards to the hank.*

Example.—It is desired to learn how much filling there will be in a 50-yd. cut of cloth reeded $26\tfrac{2}{3}$ in. wide and containing 90 picks per inch.

Solution.— $$26\tfrac{2}{3}\times 90=2{,}400$$

$$\frac{2{,}400\times 50}{840}=142.85\text{ hanks}$$

DRAFT CALCULATIONS

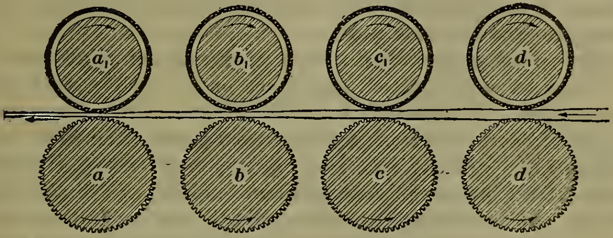
In the manufacture of cotton yarns a principle is adopted that must be considered in connection with almost every process from the opening of the raw cotton to and including the spinning of the yarn—that known as *drafting*. In the cotton-mill business the term drafting refers to the principle of attenuating, or drawing out, a comparatively large mass of cotton fibers into a thinner but longer mass. This may be done by means of air-currents, by which the fibers are separated one from the other and carried along by a current of air and deposited on rotating screens delivering the sheet of cotton at a higher speed than that at which it is fed into the machine; it may be performed by rapidly-rotating cylinders and rolls covered with wire teeth, which elongate the mass of fibers even to the extent of separation, depositing them again at a given rate on a condenser, or doffer; or it may be, and most frequently is, performed by means of revolving rolls. It is to the principles of drafting by means of successive pairs of revolving rolls that most frequent reference will be made.

Objects of Drafting.—In attenuating, or drawing out, a mass of cotton, there are three principal objects: the first is to reduce the lap, sliver, or roving to a less weight per yard, that is, attenuating it gradually to the desired degree of fineness; the second object is that of arranging and improving the arrangement of the fibers in a parallel order so that they may lie side by side and overlap one another; the third object is that of evening the strand of fibers to eliminate thick or thin places, which is done by a combination of drafting and doubling. The use of successive pairs of drawing rolls is largely adopted to arrive at these results. This principle is made use of in most cotton-yarn-preparation machines by having carefully constructed and adjusted rolls, the rear ones holding the mass of fibers and running at a slow speed, the forward ones tightly gripping a portion of the fibers and revolving at a greater speed. This arrangement is duplicated again and again, until in some machines there are as many as four pairs of rolls successively acting on the fibers. The quickly-rotating pair of rolls draws the fibers away from the slowly-rotating rolls, and as the fibers are gripped by their fore ends and pulled forwards, the loose rear ends trail behind and tend to become straightened out as they are drawn from the portion held by the slowly-rotating rolls.

Doubling.—The attenuating and parallelizing of the mass of fibers tends to reduce its thickness and make a thin sheet or strand where there was formerly a thick one, and if continued indefinitely would result in destroying the continuity of the sliver or roving. To prevent this, *doubling* is resorted to in most of the cotton-yarn-preparation machines. Briefly explained, this means that, instead of feeding only one lap, sliver, or roving at the back of each machine, two or more are fed together, making one at the front; this not only helps to compensate for the excessive attenuation, but has the great advantage of helping to correct unevenness in the original mass of fiber fed to the machine. By feeding several together the thick or thin places of any one are combined with other slivers of normal size, or thick places with thin ones, and the combination of two, three, four, five, or six independent slivers or rovings, which are drawn out into one, results in an evenness not attainable in any other manner. *Draft* refers to the ratio of attenuation, and *drafting* refers to the attenuation only, having no reference to the parallelizing or evening features mentioned.

DRAFTING WITH COMMON ROLLS

A section though four pairs of rolls is represented in the accompanying illustration, the lower rolls a, b, c, d, being constructed of steel and fluted longitudinally. The upper rolls a_1, b_1, c_1, d_1, are constructed of iron with a covering of flannel immediately around them, and a thin leather covering outside of the flannel. These rolls are not fluted, and are pressed against the bottom rolls by means of weights. The rolls d, d_1 between which the material is fed should always be spoken of as the *feed-rolls* or *back rolls*, the roll d_1 being distinguished from the roll d by the term *back top roll.* The rolls delivering the material, represented by a and a_1, should always be spoken of as the *delivery rolls* or *front rolls*, the roll a_1 being called the *front top roll*. The first pair of intermediate rolls, is spoken of as the second pair of rolls; and the third pair, as the third pair of rolls. Thus, the roll a is the front, or delivery roll; b, is the second roll; c, the third roll; and d, the back roll, or feed-roll.



The circumferential speed of the upper and lower roll in each pair, is the same; that is, a point on the surface of d moves at the same speed as a point on the surface of d_1, because d_1 is driven by frictional contact with d. The same remarks apply to any other pair in the series.

The back roll, which is the feed-roll, always rotates at the slowest speed and the front roll at the highest, the speed of the other rolls being so arranged that c revolves a little more quickly than d, and b still more quickly than c, but at a less speed than a. The direction of rotation of the rolls is shown by a small arrow within the section of each.

Between d and d_1, a ribbon of cotton is fed and is carried forwards, as shown, between each pair of rolls, until it emerges at the front. The upper rolls are weighted in such a manner as to firmly grip the fibers that pass below them, and thus if the spaces between the centers of each pair of rolls are properly adjusted and the relative speeds of the rolls accurately arranged, the principle of drawing the fibers past one another by means of a firm grip of their fore ends, the rear ends trailing behind, is achieved. The same conditions continuously exist in the machine, because as the forward rolls pass fibers forwards, the rear rolls are supplying new ones, and the results are thus comparatively even and regular.

The illustration shows the gradual attenuation or reduction in size of the mass of cotton, owing to the increased speed of each pair of rolls over the preceding pair. It will be seen that if the surface speed of the back roll is 60 in. per min. and that of the front roll 360 in., the sliver emerging from the front roll will be six times as long and consequently one-sixth as coarse, i. e., of one-sixth the weight per unit of length, as when entering the back roll.

The arrangement just described is only one of many found in cotton-yarn-preparation machinery and is merely given as an example. Draft could be produced between only two pairs of rolls almost contiguous; again, these two rolls, known as the feed-roll and delivery roll, respectively, might have between them a large number of other rolls, or a number of cylinders or rollers, or other means of producing draft, but the draft would be computed between the feed-rolls and the delivery rolls if the total draft were desired.

Methods of Finding Draft.—Draft is the ratio of the speed of the delivery to that of the feed part of a machine. It indicates the ratio between the surface speed of the front, or delivery, roll and the surface speed of the back, or feed, roll, and may be found in different ways, as follows:

1. By dividing the space moved through in a given time by a point on the surface of the feed-roll, into the space moved through in the same time by a point on the surface of the delivery roll.

2. By dividing the weight per unit of length of the product delivered, into the weight of the same length of the material fed into the feed-rolls.

3. By dividing the length delivered by the delivery roll in a certain time, by the length fed into the feed-roll in the same time.

It will be observed that these three methods of finding the draft deal with the ratio between the length, weight, or speed of the material fed and the corresponding condition of the material delivered; and from these examples will be deduced the facts that while the length of material fed into the machine is increased by drafting, the weight per unit of length is always decreased in the same proportion.

Draft may therefore be defined in various ways, thus: (1) The ratio between the length delivered and the length fed in a certain time; (2) the ratio of speed between a point on the delivery roll and a point on the feed-roll; (3) the number of times that a certain length of material is increased while being operated on; (4) the ratio between the weight of a certain length of material fed and the weight of the same length of material delivered; (5) the number of times that the weight of a certain length of material is decreased while being operated on.

GEARING OF ROLLS

Draft calculations are ordinarily performed by taking into consideration the weight per unit of length of the material being fed or delivered and the gearing that connects the delivery and feed-rolls as well as the sizes of the rolls themselves.

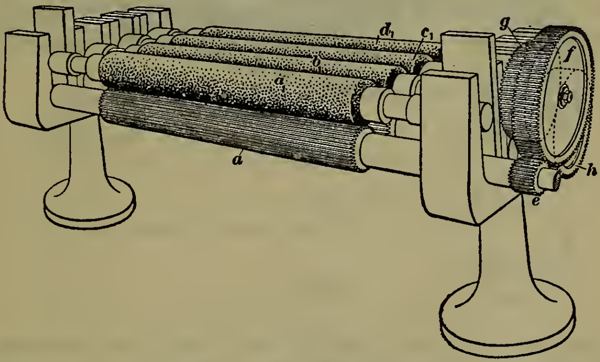


FIG. 1

Figs. 1 and 2 are views of four pairs of rolls and their gearing. The front rolls are marked a and a_1; the second top roll, b_1; the third, c_1; and the back top roll, d_1. The bottom roll a drives the back bottom roll by a train of gears e, f, g, h; e is on the roll a; h is on the back roll; f and g are compounded and revolve on a stud. The third bottom roll is driven from the back roll by means of three gears j, k, l, Fig. 2; j is on the back roll; l is on the third roll; and k is an idler, or carrier, gear revolving on a stud. The second bottom roll is driven from the roll *a* by means of three gears *m*, *n*, *o*; *m* is on the second roll; *o* is on the front roll *a*; and *n* is a carrier gear revolving on a stud.

A carrier gear is usually placed between a driver and a driven gear when it is not convenient to make the latter large enough to mesh with each other, or where it is necessary to change the direction of motion of the driven gear without changing its speed. It is important, in connection with draft calculations, to notice which gears are merely carrier gears, as a carrier gear does not affect the speed, and must be left out of all calculations of trains of gears of which it forms a unit.

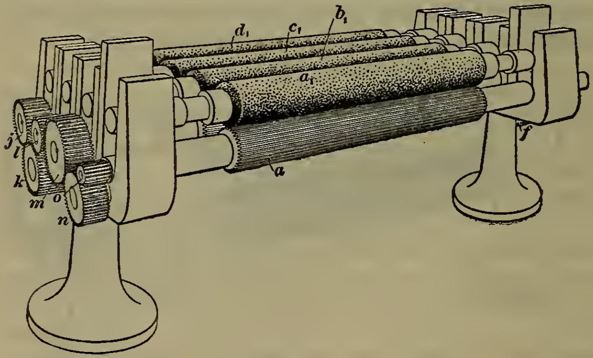


FIG. 2

The sizes of the rolls shown in Figs. 1 and 2 are as follows: Front roll *a*, $1\frac{3}{8}$ in.; second roll, $1\frac{3}{8}$ in.; third roll, $1\frac{1}{8}$ in.; fourth roll, $1\frac{1}{8}$ in. These dimensions represent the diameter of the roll in each case.

The simplest method of showing draft rolls and their gearing, is to make a diagram in which horizontal lines are drawn to show the lines of rolls, and short lines drawn at right angles to these to indicate the gears connecting the rolls.

Fig. 3 shows a diagram that would represent the rolls and gearing shown in both Figs. 1 and 2. This indicates that there are four lines of rolls and that the power is received by the tight and loose pulley shown on the front-roll shaft. It further shows that motion is conveyed to the back roll from the front roll by means of the gears *e*, *f*, *g*, *h*; that the third roll is driven from the back roll by means of the gears *j*, *k*, *l*; and that the second roll is driven from the front roll by the gears *m*, *n*, *o*. The number of teeth in each gear is shown in the figure, as well as the diameters of the rolls. The arrows indicate the places where the driving gears connect with the driven gears and point from the driving toward the driven gears.

DRIVING AND DRIVEN GEARS

It is a matter of great convenience in dealing with calculations of drafts to be able to refer to certain gears as driven gears and others as driving gears, but it is frequently difficult to determine which are driven gears and which are driving gears; for trains of gears driving draft rolls are often complicated, as one gear may transmit motion to two trains of gears and these in turn drive back to other trains of gears. In all cases in connection

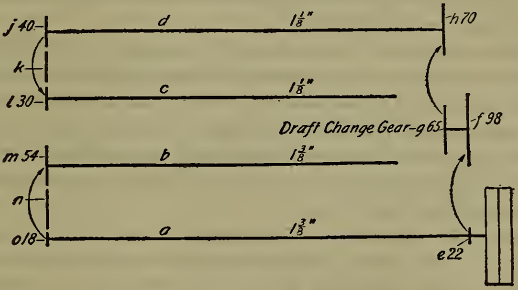


FIG. 3

with draft calculations, therefore, it is advisable to consider that the gear on the end of the delivery roll, which transmits motion to the other roll or rolls, is a driver, whether it is, or is not, in fact; and starting from this point, the next gear would therefore be a driven, the third a driver, the fourth a driven, ignoring carrier, or idler, gears.

For example, if it is desired to find the draft between the third and back rolls in Fig. 3, as only these two rolls are to be considered, the third roll would be considered the delivery roll and the gear *l* the driver, while the gear *j* on the back roll must be the driven, *k* being a carrier and consequently left out of the calculation. The fourth roll would be considered to be the feed-roll.

CALCULATING DRAFT OF COMMON ROLLS

Although in reality the draft between two pairs of rolls represents the ratio of the circumferential speed of one pair to the circumferential speed of the other, it is not necessary to take into consideration the circumference of the rolls when calculating draft, as the circumferences of two circles, or rolls, bear the same relation to each other as do their diameters.

The sizes of rolls also, are usually expressed by their diameters, and it is easier to measure the diameter than the circumference of a roll. In draft calculations only the sizes of the bottom rolls are taken into account. The top rolls are driven by frictional contact with the bottom rolls, and therefore revolve at the same circumferential speed; consequently, the sizes of the top rolls can be ignored.

Another point to be taken into consideration is that the diameters of draft rolls in cotton machinery are always expressed in inches and fractions of an inch. It is, therefore, far simpler, when performing draft calculations, to change the numbers representing the diameters of the rolls to fractions having a common denominator, and then omit these common denominators from the calculations.

In practice, when calculating drafts by means of gears, the diameters of the rolls and the sizes of the gears must be considered, and the following rule will be found to meet almost every possible combination of gears and rolls of which the draft is required to be calculated.

Rule.—*Always assume that the gear on the delivery roll is a driver; multiply all driven gears by the diameter of the delivery roll, expressed in eighths of an inch, and divide by the product of all the driving gears and the diameter of the feed-roll, expressed in eighths of an inch.*

Referring to the arrangement of draft rolls and gears represented by the diagram, in Fig. 3, the application of the rule to finding the draft between *a* and *d* would result in the diameter of the roll *a* and the number of teeth in the gears *f* and *h* being placed as the numerator of a fraction, and the diameter of the roll *d* and the number of teeth in the gears *e* and *g* as the denominator of the fraction; consequently, an increase in the diameter of the front roll would cause an increased draft. An increase in the size of the gears *f* or *h* would also cause an increased draft, and an increase in the size of the feed-roll, or an increase in the size of the gears *e* or *g* would cause a decreased draft.

For instance, assuming that the speed of the front roll remains the same and its diameter is increased, the draft would be increased, as it would deliver a greater length in the same space of time. An increase in the size of the back roll would reduce the draft, because a greater length of material would be fed to the rolls while the same length was being delivered at the front, and consequently the draft must be smaller. Similarly, an increase in the size of the gears *e* or *g* would result in the feed-roll taking in more material in the same space of time, consequently reducing the draft; and an increase in the size of the gears *f* or *h* would result in the feed-roll taking in less material in the same space of time and, as the length delivered at the front would remain the same, the draft would be increased.

In figuring drafts, the gear on the delivery roll may be considered as a driver, and the next gear will be a driven, and so on alternately throughout the train of gears, always provided that the carrier gears in the train, if any, are ignored in consequence of their being simply idlers and not affecting the amount of draft. The delivery roll should be understood as the front roll of those rolls between which the draft is to be calculated. If the draft is being figured between *a* and *d*, Fig. 3, *a* is the delivery roll; if between *b* and *c*, *b* is the delivery roll.

In the combination of rolls shown in Fig. 3, it is possible to calculate several different drafts: (1) the total draft, which represents the extent of attenuation between the back roll and the front roll; (2) the draft between the front roll and the second; (3) the draft between the second and third rolls; and (4) the draft between the third and fourth rolls. The accuracy of the calculation for the total draft can always be proved by multiplying the individual drafts together.

EXAMPLE 1.—Referring to Fig. 3, the front roll is $1\frac{3}{8}$ in. in diameter and carries a 22-tooth gear driving a 98-tooth gear. Compounded with this is a 65 gear driving a 70-tooth gear on the back roll, which is $1\frac{1}{8}$ in. in diameter. What is the total draft, or the draft between the front and back pairs of rolls?

SOLUTION.— $\frac{11\times 98\times 70}{22\times 65\times 9}=5.86$, total draft

EXAMPLE 2.—Referring to Fig. 3, the front roll is $1\frac{3}{8}$ in. in diameter and carries an 18-tooth gear driving a 54 on the second roll, which is also $1\frac{3}{8}$ in. in diameter. What is the draft between these two pair of rolls?

SOLUTION.— $\frac{11\times 54}{18\times 11}=3$, draft

EXAMPLE 3.—Referring to Fig. 3, the second roll is $1\frac{3}{8}$ in. in diameter and carries a 54-tooth gear driving an 18 on the front roll. On the other end of the front roll is a 22 driving a 98 compounded with a 65, which drives a 70 on the back roll. On the other end of the back roll is a 40 driving a 30 on the third roll, which is $1\frac{1}{8}$ in. in diameter. What is the draft between the second and the third rolls?

SOLUTION.—

$$\frac{11\times 18\times 98\times 70\times 30}{54\times 22\times 65\times 40\times 9}=1.466\text{, draft}$$

EXAMPLE 4.—The third roll in Fig. 3 is driven from the back roll. The back roll is $1\frac{1}{8}$ in. in diameter and carries a 40-tooth gear driving a 30 on the third roll, which is also $1\frac{1}{8}$ in. in diameter. What is the draft between these two pairs of rolls?

SOLUTION.— $\frac{9\times 40}{30\times 9}=1.333$, draft

PROOF.—The total draft as found in example 1 may be proved, as already stated, by multiplying together the drafts obtained in examples 2, 3, and 4.

$$3\times 1.466\times 1.333=5.86\text{, total draft}$$

BREAK DRAFT

Break draft is a draft between two contiguous pairs of rolls that are not directly connected by means of gears. Reference to Fig. 3 indicates that the second and third pairs of rolls are adjacent to each other, and yet are not directly connected, the driving of the third pair of rolls being attained by means of a long train of gears from the delivery roll, and the second roll is driven by a short train of gears from the delivery roll. The break draft in this case, therefore, occurs between the second and third pair of rolls, which are not directly connected.

Break draft may be found in two ways, one method being to start with the gear *m*, Fig. 3, and finish with the gear *l*, using the diameters of the rolls *b* and *c*.

The second method is to calculate the total draft between the first and fourth rolls, Fig. 3; then between the third and fourth; and next between the first and second rolls. The drafts between the third and fourth and the first and second rolls are multiplied together and divided into the draft between the first and fourth rolls, or the total draft. The quotient will be the break draft, or the draft between the second and third rolls.

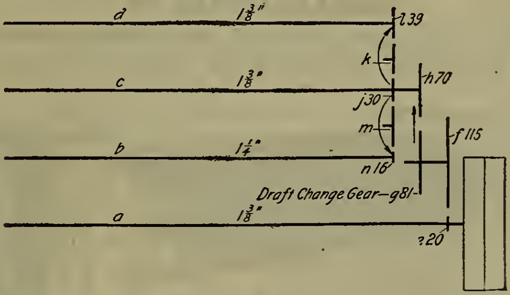


FIG. 4

EXAMPLE.—Find the break draft, or draft between the second and third pairs of rolls shown in Fig. 3.

SOLUTION (*a*).—Figured according to the first method,

$$\frac{11 \times 18 \times 98 \times 70 \times 30}{54 \times 22 \times 65 \times 40 \times 9} = 1.466, \text{ break draft}$$

SOLUTION (*b*).—Figured according to the second method,

$$\frac{9 \times 40}{30 \times 9} = 1.333, \text{ draft between third and fourth rolls}$$

$$\frac{11\times 54}{18\times 11}=3, \text{ draft between first and second rolls}$$

$$\frac{11\times 98\times 70}{22\times 65\times 9}=5.863, \text{ total draft}$$

$$1.333\times 3=3.999;\ 5.863\div 3.999=1.466, \text{ break draft}$$

Fig. 4 shows four pairs of drawing rolls geared in a different manner from that shown in Fig. 3. In this case the gear *e* on the front roll *a* drives the third roll *c* by means of the gears *f*, *g*, *h*; the fourth roll *d* is driven from the third roll by the gears *j*, *k*, *l*; *k* is an idler, or carrier, gear. The second roll *b* is driven from the third roll by the gears *j*, *m*, *n*; the gear *m* is an idler, or carrier, gear. The break draft in this case is located between the first and second rolls and is calculated thus:

$$\frac{11\times 115\times 70\times 16}{20\times 81\times 30\times 10}=2.915, \text{ break draft}$$

METALLIC ROLLS

In recent years metallic rolls have been introduced, especially on the preparatory machines in the processes of cotton-yarn

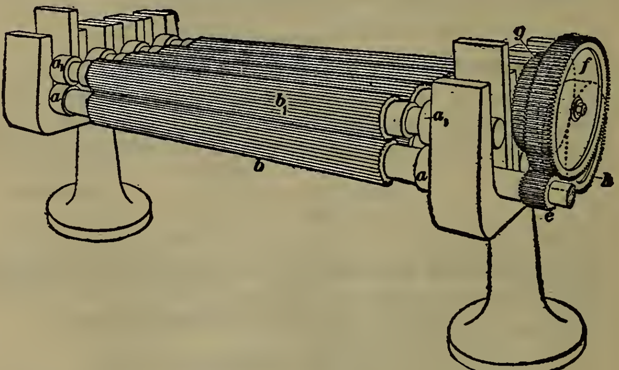


Fig. 5

preparation. Owing to the peculiar construction of these rolls, the rules previously given for figuring draft do not apply to them without modification. Both the upper and lower rolls are, in this case, constructed of steel, and both rolls are fluted longitudinally. These flutes are different in shape and considerably coarser than the flutes in common steel rolls, and when in operation the flutes of one roll project into the flutes of the other roll, the rolls being prevented from coming into too close contact by means of collars.

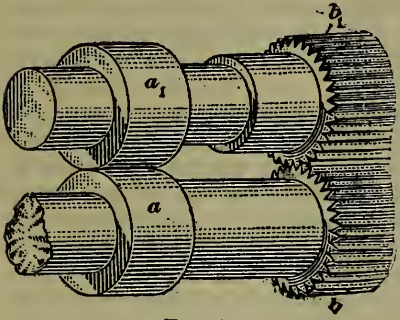


FIG. 6

Fig. 5 is a view of a set of metallic rolls in position. Fig. 6 gives a view of the ends of two rolls; b and b_1 are the fluted portions of the bottom and top rolls, respectively, meshing into one another; a and a_1 are the collars on the rolls, which prevent the flutes from bottoming. The collars are slightly smaller than the outside diameter of the boss, which is the name applied to each fluted portion of the rolls, and thus provides for a certain degree of meshing between the bosses. A section through a portion of the two rolls is shown in Fig. 7. The sliver c as operated on by the rolls is also indicated.

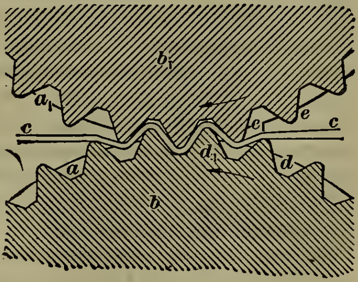


FIG. 7

Allowances Made in Calculating Production and Draft.—The crimping action of metallic rolls causes a greater length to be fed and delivered than in the case of common rolls of the same diameter. It is usually assumed that one-third more material is delivered by a metallic roll than by a common roll of the same diameter on this account, the zigzag lines of the circumference being about 33⅓% longer than the circumference of a circle passing through the points of the teeth. To obtain accurate results in figuring production with metallic rolls, therefore, a certain percentage—usually 33⅓—must be added to the diameter of each roll. A 1-in. roll would be taken as 1.33 in.; 1⅛-in., 1.5 in.; 1¼-in., 1.67 in.; 1⅜-in., 1.83 in.; 1½-in. 2 in. The foregoing allowances are for ordinary metallic rolls, constructed with 32 flutes for each inch of diameter. Metallic drawing rolls are made with flutes of varying pitch, either 16 pitch, 24 pitch, or 32 pitch. This means that for each inch of diameter of the roll there are either 16, 24, or 32 flutes. For instance, 1¼-in. roll of 32 pitch would have 40 flutes in its circumference. The allowance of 33⅓% is made in case of rolls being constructed of 32 pitch, but for 16-pitch rolls this allowance is increased to 50%, and for 24 flutes to the inch, an allowance of 40% is made.

Another feature to consider in connection with metallic rolls is that the extent of the crimping action or attenuation through the interlocking of the rolls is less for heavy slivers than for light slivers, as heavy slivers resist the tendency of the rolls to interlock, and, in some cases where they are insufficiently weighted, will raise the top roll and pass through in almost a straight line. It therefore follows that the drafting action is greater with light slivers than with heavy ones, and that if the front and back rolls of the machine are both the same pitch in the flutes, the drafting action of the back pair of rolls is less than that of the front pair, since the sliver becomes thinner as it passes forwards through the machine, on account of being acted on by the draft between each successive pair of rolls; thus the greater draft of metallic rolls is really caused by the difference in the relative effect of the crimping action at the back rolls and at the front rolls.

The action of metallic rolls as compared with common rolls may be described as follows, assuming that a comparison is being made between a set of four pairs of common and four pairs of metallic rolls all of the same outside diameter, all geared in the same manner, and all running at the same speed. The back metallic rolls would absorb approximately 25% more material fed into them and the front rolls would deliver approximately 33⅓% more material than the common rolls. In this case, therefore, the draft of the metallic rolls would have to be figured in the ordinary way, as for common rolls, and an addition of 33⅓% minus 25% equaling 8⅓%, made to the calculated draft so as to equal the actual draft in the case of the metallic rolls.

In cases where the sliver is between 45 and 70 gr., in weight, the draft between 4½ and 7, the back and front rolls approximately of the same size, and flutes with a 32 pitch used, an allowance of 9% over and above the draft as calculated with common rolls is frequently made, in order to arrive at the actual draft in case of metallic rolls.

From the preceding statements it will be seen that this allowance cannot be arbitrary. The allowance should be increased in case of running very light slivers, in case of rolls being used of coarser pitch than 32, in case of there being a heavy draft in the machines, or where the front rolls are very much larger than the back rolls. The allowance is materially reduced in case of a heavy sliver being run through the machine, in case of a light calculated draft, or in case of the back rolls being larger than the front rolls.

The numerous causes of variation in the allowances render it almost impossible to accurately figure drafts for metallic rolls, and in making changes in machines fitted with metallic rolls or in starting up such machines, it is necessary to experiment somewhat with different gears to arrive at the desired result; but when this result is once obtained, and so long as the conditions remain the same, the results from metallic rolls are just as regular as from common rolls. The accompanying table gives the allowances that should be made, under various conditions, on the calculated draft for common rolls in order to ascertain what the draft would be if metallic rolls of the same diameter were used and assuming that the front and back rolls do not vary greatly in diameter.

The table must not be taken as arbitrary, for slight variations from this must be expected in practice. Drafts from 5 to 8 may be considered medium drafts.

INCREASE IN DRAFT OF METALLIC ROLLS

Weight of Sliver	Light Draft Per Cent.	Medium Draft Per Cent.	Heavy Draft Per Cent.
50-grain sliver..........	8	10	12
60-grain sliver..........	7	9	11
70-grain sliver..........	6	8	10
80-grain sliver..........	5	7	9
90-grain sliver..........	4	6	8
100-grain sliver..........	3½	5½	7
110-grain sliver..........	3	5	7
120-grain sliver..........	3	4½	6
130-grain sliver..........	2½	4	5½
140-grain sliver..........	2½	3½	5
150-grain sliver..........	2	3	4

DRAFT GEARS

In each principal train of gears connecting draft rolls, one gear is always spoken of as the *change gear* or *draft gear*, and this is the one that is usually changed for altering the draft of the machine. The draft gear, as shown at *g*, Figs. 1 and 3, is usually situated on a stud together with another gear *f*, which is known as the crown gear in order to distinguish it from the draft gear.

Any change in the draft gear alters the speed of the feed-rolls, but the speed of the front rolls remains constant. Usually, a larger draft gear will increase the speed of the feed-rolls, thus producing less draft, because more cotton is being fed and there has been no change in the length of the amount delivered. A smaller gear will produce more draft.

It should also be noted that a change in the draft gear *g*, Fig. 3, makes no difference in the ratio of speed between the first and second rolls or between the third and fourth rolls, but it does between the first and fourth and between the second and third rolls. This is also true in regard to Fig. 4; that is any change in the draft change gear *g* will only change the draft between the sets of rolls where the break draft is located and between the front and back rolls.

The following rules apply to drafts and draft gears when the draft gear is a driver, assuming that the gear on the front roll is a driver.

The draft gear required to give a certain draft when the draft gear being used and the draft being produced are known may be found by the following rule:

Rule.—*Multiply the draft gear being used by the draft being produced and divide the product by the draft desired.*

EXAMPLE.—Referring to Fig. 3, a draft gear of 65 teeth produces a draft of 5.86. What draft gear will be required to produce a draft of 7?

SOLUTION.—

$$\frac{65 \times 5.86}{7} = 54.41, \text{ a 54 draft gear}$$

The draft a certain draft gear will produce when the draft gear being used and the draft being produced are known, may be found by the following rule:

Rule.—*Multiply the draft gear being used by the draft being produced and divide the product by the draft gear to be used.*

EXAMPLE.—Referring to Fig. 3, a draft gear of 65 teeth produces a draft of 5.86. What draft will a 54 draft gear produce?

SOLUTION.— $$\frac{65 \times 5.86}{54} = 7.053, \text{ draft}$$

The following rules apply to drafts and draft gears when the draft gear is a driven, and for the purpose of illustration the gear *f*, Fig. 3, which is a driven gear, will be considered as the draft change gear.

The draft gear required to give a certain draft when the draft gear being used and the draft being produced are known, may be found by the following rule:

Rule.—*Multiply the draft gear being used by the draft to be produced and divide the product thus obtained by the draft being produced.*

EXAMPLE.—Referring to Fig. 3, a draft of 5.86 is being produced with a 98-tooth draft gear. What draft gear will be required to give a draft of 7?

SOLUTION.— $$\frac{98 \times 7}{5.86} = 117.06, \text{ a 117 draft gear}$$

The draft a certain gear will give when the draft gear being used and the draft that it is producing are known, may be found by the following rule:

Rule.—*Multiply the draft that is being produced by the draft gear that is to be used and divide the product thus obtained by the draft gear being used.*

Example.—Referring to Fig. 3, a draft of 5.86 is being produced with a 98 draft gear. What draft will be produced with a 117 draft gear?

Solution.— $$\frac{5.86 \times 117}{98} = 6.996, \text{ draft}$$

CONSTANTS

Constants are almost always used to shorten calculations for draft. There are two kinds of constants used in these problems; namely, constant dividends and constant factors. A *constant dividend* is a number which, when divided by the draft, will give the necessary draft gear; or it may be defined as a number which, when divided by the draft gear being used on a machine, will give the draft that the machine is producing. A *constant factor* is a number which, when divided into the draft, will give the draft gear necessary to produce the desired draft; or it may be defined as a number which, when multiplied by the draft gear being used on a machine, will give the draft that the machine is producing.

Each different make of machine and each different kind of machine has a different constant.

Assuming that the gear on the front roll is a driver, the following statements may be made:

When the draft gear is a driver, the constant is always a constant dividend.

When the draft gear is a driven, the constant is always a constant factor.

The draft constant of a machine may be found by the following rule:

Rule.—*Perform the calculations exactly the same as when finding the draft, always considering the draft gear as a 1-tooth gear, or omitting it from the calculation.*

EXAMPLE.—What is the constant dividend of the rolls shown in Fig. 3?

SOLUTION.—

$$\frac{11\times98\times70}{22\times1\times9}=381, \text{ constant dividend}$$

The draft when the constant dividend and draft gear are known may be found by the following rule:

Rule.—*Divide the constant dividend by the draft gear.*

EXAMPLE.—What is the total draft for Fig. 3 with a 65 draft gear at *g*, if the constant dividend is 381?

SOLUTION.— $381\div65=5.86$, draft

The draft gear when the constant dividend and draft are known may be found by the following rule:

Rule.—*Divide the constant dividend by the draft desired.*

EXAMPLE.—What draft gear will be required to produce a draft of 5.86 if the constant dividend is 381?

SOLUTION.— $381\div5.86=65$-tooth draft gear

EXAMPLE.—Figure the constant for Fig. 3, using the same train of gears as in the previous examples but considering the gear *f* as the draft change gear.

SOLUTION.—

$$\frac{11\times1\times70}{22\times65\times9}=.0598, \text{ constant factor}$$

The draft when the constant factor and draft gear are known may be found by the following rule:

Rule.—*Multiply the constant factor by the draft gear.*

EXAMPLE.—What is the total draft for Fig. 3, considering *f* as the draft gear, if the constant factor is .0598, a 98-tooth gear being used at *f*?

SOLUTION.— $.0598\times98=5.86$, draft

The draft gear when the constant factor and draft are known may be found by the following rule:

Rule.—*Divide the draft by the constant factor.*

EXAMPLE.—What draft gear will be required at *f*, Fig. 3, to produce a draft of 5.86 if the constant factor with *f* considered as the change gear is .0598?

SOLUTION.—

$5.86\div.0598=97.99$, a 98-tooth draft gear

From the examples given it will be noticed that a solution does not always give an exact number of teeth for the change gear. In such cases the nearest number is used. For example, if the solution of a draft calculation should show that a 64.84 draft gear is required, then a 65 gear would be placed on the machine, and even if the calculation should show that a 64.52 draft gear is required, a 65 gear would be used, except in cases where extreme accuracy is desired. Under these circumstances either the back-roll gear or the crown gear would be changed. When the crown or the back-roll gear is changed, it is generally considered that one tooth in the draft gear is equal to two teeth in the crown, or the back-roll gear. This allowance is near enough for practical purposes and is the basis generally adopted in the mill. For example, a draft gear figures 42½ with a 60 back-roll gear. A 42½ draft gear cannot be used, so a 42 draft gear and a 59 back-roll gear, or a 43 draft and a 61 back-roll gear would probably be used.

DOUBLING

When calculating the effect of draft on the weight of the sliver or roving, delivered from a machine, it is always necessary to take into consideration the number of ends that are to be drawn into one. For example, six ends of roving are run into one in a certain machine that has a draft of 6; consequently, each end of roving must be drawn out to one-sixth its former weight; but since there are six ends running into one, then the weight per yard of the sliver delivered will be the same as the weight per yard of a single sliver put up at the back. Therefore, if six slivers, each weighing 65 gr. to the yard, are run through a machine having a draft of 6, the sliver that comes out at the front will have the same weight; that is, 65 gr. Hence, when figuring the weight of product in connection with the draft of a machine, it is always necessary to take into consideration the number of ends that are placed at the back and run into a single end at the front.

The weight of a sliver or roving produced by a machine when the draft of the machine and the number and weight of the ends put up at the back are known may be found by the following rule:

Rule.—*Multiply the weight per yard of the roving or sliver at the back by the number of ends run into one at the back and divide this product by the draft of the machine.*

The draft of a machine when the number of ends at the back, the weight of the sliver at the back, and the weight of the sliver delivered are known may be found by the following rule:

Rule.—*Multiply the weight per yard of the sliver at the back by the number of ends run into one at the back and divide this product by the weight per yard of the sliver delivered at the front.*

The following rules will be found to apply to draft calculations when the weight of the sliver or roving is expressed in hanks.

The hank of a roving made by a machine when the draft of the machine and the number and hank of the ends put up at the back are known may be found by the following rule:

Rule.—*Multiply the hank of the roving at the back by the draft of the machine and divide this product by the number of ends put up at the back.*

The draft of a machine when the number of ends at the back, the hank of the roving at the back, and the hank of the roving delivered are known may be found by the following rule:

Rule.—*Multiply the hank of the roving delivered by the number of ends put up at the back and divide by the hank of the roving used at the back.*

COTTON-YARN PREPARATION

COTTON

Cotton is a vegetable fiber belonging to the order of the Malvaceæ and to the genus *Gossypium*. The principal species cultivated for commercial purposes are: *Gossypium herbaceum*, *Gossypium arboreum*, *Gossypium hirsutum*, and *Gossypium Barbadense*.

Gossypium herbaceum grows from 2 to 6 ft. high and is found native or exotic in Northern Africa and in Asia; it is also largely cultivated in the United States of America.

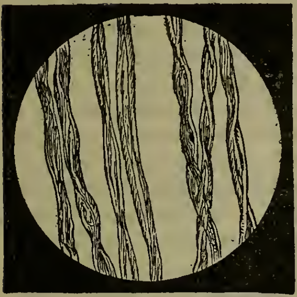
Gossypium arboreum grows to the height of 15 or 20 ft., whence it derives the name of tree cotton. Although the plant is found in Asia, it is most largely cultivated in Central and South America.

Gossypium hirsutum is a shrubby plant, its maximum height being about 6 ft. The young pods are hairy; the seeds are numerous, free, and covered with firmly adhering green down under the long white wool.

Gossypium Barbadense attains a height of from 5 to 10 ft. The seeds of this plant are black and smooth and the fiber the longest known to commerce. The sea-island cotton plant of the United States belongs to this species.

STRUCTURE OF COTTON FIBER

Cotton fiber, which to the naked eye appears to be a fine, smooth, and solid filament, exhibits a somewhat complicated structure when magnified. A microscopic view of cotton fibers is shown in the accompanying illustration. Each fiber appears to be a collapsed tube with corded edges, twisted many times throughout its length. This semispiral construction assists in the formation of a strong yarn, since in the formation of the thread, the convolutions interlock with one another. These convolutions are less and less frequent as the fiber is less matured, and are almost altogether absent in the immature fiber, which has merely the appearance of a flattened ribbon when examined under a microscope. The immature fiber is transparent and has a glossy appearance,



so that when it exists in any quantity in a bale of cotton it can readily be detected with the naked eye.

Ignoring the removable foreign matter contained in raw cotton, such as sand and other mineral substances, leaf, and pieces of boll, or stalk, it is found to be composed of from 87 to 90% of cellulose, permeated by about 1% or less of mineral matter, and that each fiber is surrounded by soluble substances of a waxy or oily nature present to the extent of from 1 to 2%. Cellulose absorbs and retains moisture, the cellulose in the cotton fiber, when in an air-dry condition, containing about 7½%.

The quantity of removable foreign matter in cotton varies greatly with the variety, and even in different growths of the same variety. It is present to the extent of from 1% in carefully-cultivated sea-island to 6%, or more, in coarse, negligently-cultivated East Indian cotton.

Measurements of Cotton Fiber.—Cotton fibers even from the same seed vary considerably in length and in diameter, and only approximate measurements can be given. The diameter of a cotton fiber varies from .0004 to .001 in., and the length of the fiber from ½ in. to 2¼ in. Doctor Bowman is the authority for stating that there are 140,000,000 fibers in a pound.

The strength of individual cotton fibers varies from 75 to 300 gr. Usually the long-stapled, fine cottons break with the least strain, and the short coarse cottons stand the greatest strain. The ordinary American cottons have a breaking strain of from 120 to 140 gr. The specific gravity of air-dry cotton is about 1.5.

SEA-ISLAND COTTON

Sea-island cotton is grown on islands off the coast of the Southern States, and is recognized as being the best cotton grown. It has a long, fine, strong and silky fiber with comparatively regular convolutions, a diameter of from .0004 to .0006 in., and ranges in length from $1\frac{3}{8}$ to $2\frac{1}{4}$ in.

Sea-island cotton is largely used for fine fabrics and for thread and lace-making purposes. It is regularly spun into from 150s to 400s yarn, and occasionally, even for commercial purposes, as high as 600s. Where great strength is required for heavy goods, sea-island cotton is sometimes used, even for coarse yarns; as, for example, the fabrics for tires, sail cloth, and so on.

The variety of so-called Florida sea-island cotton is grown on the mainland of Florida from sea-island seed; this is somewhat inferior to the sea-island proper, but is a very useful cotton for making yarns of a little better quality than those made from Egyptian cotton. It has a white, glossy, strong fiber, a little coarser than the strictly sea-island. It is suitable for yarns from 150s to 200s.

AMERICAN COTTON

Although the sea-island cottons just described are American, this name is seldom applied to them, but is used to indicate the typical cotton of the world, which is grown in the Southern States of the United States and used wherever cotton-spinning mills exist. The cotton described commercially as *American* is suited to medium numbers of yarn; is usually clean, fairly regular in length of staple, satisfactorily graded, and consequently is one of the most reliable and useful cottons for a manufacturer's use. The quantity is greater than that collectively produced in all other parts of the world. American cotton may be divided into three important classes; namely, gulf cotton; uplands, or boweds; and Texas cotton.

Gulf, or *New Orleans*, *cotton* usually consists of cotton raised in the basin of the Mississippi River. Gulf cotton is from 1 in. to $1\frac{1}{4}$ in. in length of staple, from .0004 to .0007 in. in diameter, and is generally used for yarn from 28s to 44s warp and from 50s to 70s filling or ply. This kind of cotton may be subdivided into others, known as Memphis, benders, Allan-seed, Peelers, and so on. The best qualities of gulf cotton are known as Allan-seed and Peelers. These are used for fine yarns, often for fine combed yarns, and by some spinners preferred to Egyptian. The color is bluish white rather than cream-colored, and somewhat resembles short Florida sea-island.

Uplands cotton is grown in the undulating country between the ocean and the mountains in the states of Georgia, North Carolina, South Carolina, Virginia, and Alabama. It is generally used for filling yarns below 40s, although it may be spun higher if required. The length of the staple is from $\frac{3}{4}$ to 1 in. and the fiber is from .0006 to .0007 in. in diameter. This cotton is usually very clean.

The cultivation of *Texas cotton* is largely on the increase, and for coarse warp yarn it is the most suitable cotton. In dry seasons it is apt to be somewhat harsh and brittle and cannot be relied on as much as gulf or uplands cotton. The staple is usually from $\frac{7}{8}$ to 1 in. in length (sometimes exceeding this), and from .0005 to .0007 in. in diameter. Up to 26s and 32s warp yarns and 32s and 40s filling yarns are often made from Texas cotton, although it is eminently useful for warp, Oklahoma cotton is of the Texas style.

BROWN EGYPTIAN COTTON

The cotton used in American mills is largely grown in the United States, but in the fine-spinning districts a quantity of *brown Egyptian cotton* is used. The brown Egyptian cotton is generally used for warp yarns from 50s upwards, and for filling yarns from 60s upwards intended for use in fine-woven cotton goods. Some of this cotton is also used for hosiery yarns and for the manufacture of Balbriggan underwear; in this case it is spun into lower numbers than those just mentioned.

Almost all the Egyptian cotton used in the United States is combed. The features of brown Egyptian cotton are the length of staple and fineness of the fiber, it being very silky and delicate in structure.

TABLE OF COTTON CHARACTERISTICS

<table>
<tr><th rowspan="3">Trade Name</th><th rowspan="3">Where Grown</th><th rowspan="3">Length of Staple Inches</th><th rowspan="3">Diameter in 10,000 Parts of an Inch</th><th rowspan="3">Character of Fiber</th><th colspan="2">Counts, or Numbers, of Yarn</th></tr>
<tr><th colspan="2">Single Yarn</th></tr>
<tr><th>Warp</th><th>Filling</th></tr>
<tr><td>Sea-island........</td><td>Edisto, John, James, Port Royal, and St. Helena, S. C.; Cumberland, St. Simon, Ga.</td><td>$1\frac{3}{8}$ to $2\frac{1}{4}$</td><td>4 to 6</td><td>Silky, fine, strong, and clean</td><td colspan="2">150s to 400s
Generally used for ply yarns</td></tr>
<tr><td>Florida sea-island.</td><td>On mainland of Florida, near coast, from sea-island seed</td><td>$1\frac{1}{4}$ to $1\frac{3}{4}$</td><td>5 to 6</td><td>Silky and clean but not quite equal to sea-island</td><td colspan="2">150s to 200s</td></tr>
<tr><td>Brown Egyptian, or Mako........</td><td>Lower, Middle, Upper Egypt</td><td>$1\frac{1}{8}$ to $1\frac{3}{8}$</td><td>5 to 7</td><td>Golden brown to brown</td><td>50s to 100s</td><td>60s to 150s</td></tr>
<tr><td>Mitafifi...........</td><td>Lower and Middle Egypt</td><td>$1\frac{3}{16}$ to $1\frac{3}{8}$</td><td>5 to 7</td><td>Rich dark brown, long, strong and fine</td><td></td><td></td></tr>
<tr><td>Ashmouni........</td><td>Lower, Middle, Upper Egypt</td><td>$1\frac{3}{16}$ to $1\frac{3}{8}$</td><td>5 to 7</td><td>Light brown, fine</td><td></td><td></td></tr>
<tr><td>Rough Peruvian..</td><td>Peru</td><td>$1\frac{1}{4}$ to $1\frac{1}{2}$</td><td>6 to 8</td><td>Rough and harsh</td><td>40s to 70s</td><td></td></tr>
<tr><td>Gulf cotton, or New Orleans....</td><td>Louisiana, Mississippi, neighboring states</td><td>1 to $1\frac{1}{4}$</td><td>4 to 7</td><td></td><td>28s to 44s</td><td>50s to 70s</td></tr>
</table>

Benders, or bottomland	Mississippi River bottom, Louisiana, and Mississippi				28s to 44s	50s to 70s
Peelers	Varieties originated in Mississippi and grown usually in Mississippi, Louisiana, Arkansas, and Alabama			Bluish-white usually; somewhat resembles short Florida sea-island	28s to 44s	50s to 70s
Allan-seed				Long staple	28s to 44s	50s to 70s
Uplands	Georgia, North Carolina, South Carolina, and Virginia	$\frac{3}{4}$ to 1	6 to 7	Clean, easily manipulated, useful cotton, suitable for filling		30s to 40s
Texas	Texas	$\frac{7}{8}$ to 1	5 to 7	Suited for warp	Below 32s	Below 40s
Bengal	India	$\frac{1}{2}$ to $\frac{5}{8}$	7 to 9	Tinged, dirty, weak fiber	4s to 8s	4s to 8s
Dhollera		$\frac{7}{8}$ to $1\frac{1}{18}$	7 to 9	White; has considerable dirt	4s to 8s	4s to 10s
Comptah		$\frac{3}{4}$ to $\frac{7}{8}$	7 to 9	Dirty	Up to 14s	Up to 18s
Oomrawattee		$\frac{7}{8}$ to 1	7 to 9	Good color, cleaner than Dhollera	Up to 18s	Up to 24s
Dharwar		$\frac{3}{4}$ to 1	7 to 9	Neppy and dirty	Up to 14s	Up to 18s
China and Corea		$\frac{1}{2}$ to $\frac{3}{4}$		Rough, but very clean	6s to 10s	6s to 14s
Camilla	China	$\frac{1}{2}$ to $\frac{3}{4}$		Bright, very clean, harsh, and rough	6s to 14s	6s to 14s

CLASSIFICATION OF COTTON

Cotton is seldom, if ever, purchased from the examination of the bale, but from parcels containing small samples of cotton from each bale, technically known as *papers of samples.* In judging cotton from a sample, the first thing to do is to investigate the authenticity of the sample. The points then determined are: (1) the grade of the sample, (2) the staple, (3) the color, (4) the quantity of sand, (5) the amount of dampness, and (6) whether the cotton is even-running or not.

GRADES OF AMERICAN COTTON

Full Grades	Half Grades	Quarter Grades
Fair		
		Barely fair
	Strict middling fair	
		Fully middling fair
Middling fair		
		Barely middling fair
	Strict good middling	
		Fully good middling
Good middling		
		Barely good middling
	Strict middling	
		Fully middling
Middling		
		Barely middling
	Strict low middling	
		Fully low middling
Low middling		
		Barely low middling
	Strict good ordinary	
		Fully good ordinary
Good ordinary		
		Barely good ordinary
	Strict ordinary	
Ordinary		
	Low ordinary	
		Inferior

American cotton is usually graded according to a standard agreed on in all the leading cotton markets of the world, the highest grade being *fair*, followed by six other grades, the lowest being *ordinary;* cotton of lower grade is called *inferior.* The seven full grades of American cotton are *fair, middling fair, good middling, middling, low middling, good ordinary,* and *ordinary.*

This gradation is not sufficiently fine for the cotton merchant, and consequently each grade is subdivided into what are known as half grades and quarter grades as shown in the accompanying table.

Government Cotton Classification.—In 1910, and subsequently, the United States, through the Department of Agriculture and the Bureau of Plant Industry, promulgated a new system of cotton classification. The intention was to make the grading of cotton a more exact science and to insure that the cotton grower, the mills consuming cotton, and all other parties concerned in trading in cotton, performed their transactions on a more definite basis as to the grade of cotton dealt with in any particular case. It was believed that the various grades of American cotton could be fully classified by a list of nine grades, and the following grades, therefore, were established: *Middling fair, strict good middling, good middling, strict middling, middling, strict low middling, low middling, strict good ordinary, good ordinary.*

Official standards for these grades were established and a number of sets of cotton samples showing the standard grades were prepared. Some of these standard sets were placed in vacuum storage in vaults so that the standards might not be deteriorated by exposure to air, light, heat, etc. Other sets were prepared for practical use and for distribution.

The United States Government standard cotton classification has been adopted by the cotton exchanges in various American cities, but is not recognized in England, Continental European countries, or in any other foreign countries, with the single exception of the rather unimportant Rotterdam cotton exchange at Rotterdam, Holland. Also, with comparatively few exceptions, domestic mills use the old system of classifying cotton in 26 grades in the buying of actual cotton for manufacturing purposes. Thus, the Government system is employed only for the classification of the very small amounts of actual cotton carried by domestic exchanges, tenderable in settlement of contracts, and in the comparatively few cases where disputes as to grade exist and arbitration by the Secretary of Agriculture is involved.

Classifying Cotton.—Grade actually refers to the condition of the cotton as regards cleanliness, that is, the appearance of the cotton as to its freedom from leaf and other impurities. Some graders take into consideration what is known as bloom, or brightness, of the cotton, which adds to the grade; also discoloration, known as *off color,* or *tinges,* which detracts from the grade.

The word *staple* usually means the average length of the bulk of the fibers forming the bale assessed, and is found by taking a small portion of cotton, preparing a tuft of fibers from which the very short fibers have been removed, and then measuring the average length of fibers remaining. Cotton is spoken of by the length of staple; thus, 1-in. cotton, 1¼-in. cotton, and so on. There is something more that is usually implied by the word staple —strength of the fiber. This is determined by holding one end of the tuft between the first finger and thumb of each hand and breaking it. The word staple may therefore be taken to mean the average length of the fibers forming the bale, and may also be understood to include the strength of the fibers; thus the expressions *length of staple* and *strength of staple* are obtained.

The rich, bright, creamy appearance of cotton, especially in the early part of the year, is called the *bloom.* This bloom is only found on certain growths of cotton and adds somewhat to its value, especially where it is to be used for making weft, or filling, yarn, or where the goods are to be sold in their unbleached or undyed state. Tinges, high color, or off color, should be looked for. These are caused where the cotton has become tinged while on the plant, through rain stains, or by having fallen on the ground and become mixed with some of the red clay of the cotton field.

It is necessary to determine the quantity of sand and dirt in the cotton. This is often done by raising the cotton from the paper that holds it and noticing the quantity of sand remaining on the paper, this sand having fallen out by the repeated handling of the cotton. It is, perhaps, better to hold the handful of cotton as high as one's head and shake it so that the sand, if there is any, can be seen to fall from it.

Another test is that for dampness. This can only be detected in the sample paper if the samples are newly drawn, in which case it can be felt by the hand. If the samples have been in stock for some time, the water originally contained in them will have evaporated and cannot be ascertained unless it has previously been so great as to cause a slight formation of mildew on the cotton, in which case it is indicated by the smell.

The last point, and one that is important, is to see that all bales are somewhat alike. Usually a sample paper is made up of a handful of cotton from each of the lot of bales; by testing first one sample and then another it is determined whether the lot of cotton is even running. Occasionally, however, if not graded properly a lot of cotton is found to be mixed; some bales may be higher grade than others, some may be longer-stapled than others, and even in the same bale an abnormal variation in length and strength of staple may be found. Cotton of this kind should be avoided altogether, as it is almost impossible to make satisfactory yarn from such cotton.

World's Production of Cotton.—The world's production of cotton varies in different years, the variation being mainly caused by fluctuations in the crop of the United States, which produces about two-thirds of all the cotton used in the mills of the world. The total production is usually not far from 19,000,000 bales of 500 lb. each. British India produces about 15 per cent. of the total and Egypt about 7 per cent. or a little less. Other countries in comparison produce minor crops. Favorable or unfavorable growing seasons have a marked effect on the world's production of cotton in any specific year.

PROCESSES AND OBJECTS

In order to produce cotton yarn, the fiber is passed through a number of processes, varying from ten in a mill manufacturing coarse yarns to fifteen in one making fine yarns. These processes may be divided into three classes as follows: (1) mixing; (2) cleaning; (3) parallelizing and attenuating.

No arbitrary method can be given for distinguishing between coarse, medium, and fine cotton yarns, but a general classification is to consider yarns below 30s as coarse; from 30s to 60s as medium numbers; and above 60s as fine yarns. The processes in mills vary according to whether coarse, medium, or fine yarns are made. A mill making medium yarns, for instance about 32s, would in most cases use the following machines: automatic feeder, opener, breaker picker, intermediate picker, finisher picker, card, first drawing, second drawing, third drawing, slubber, intermediate, roving frame, spinning frame. In cases where the railway head is used, it comes between the card and the first drawing; in this case the third drawing is omitted. Where the bale breaker is used, it takes a position before the automatic feeder. Where the mule is used, it takes the place of the spinning frame.

The machinery for mills making 10s and below is as follows: automatic feeder, opener, breaker picker, intermediate picker, finisher picker, card, first drawing, second drawing, slubber, roving frame, spinning frame. The railway head may be used instead of the first drawing process.

The machinery used in mills making about 100s is as follows: automatic feeder, opener, breaker picker, finisher picker, card, sliver-lap machine, ribbon-lap machine, comber, first drawing, second drawing, third drawing, fourth drawing (optional), slubber, first intermediate, second intermediate, roving frame, mule. Sometimes a drawing process is used between the card and the sliver-lap machine. Where four processes of drawing are used, the roving frame is not necessary, and where four processes of fly frames (slubber, first intermediate, second intermediate, and roving frame) are used, it is not always necessary to have more than three processes of drawing, although four may be used if required.

The machinery used in yarn mills for making 200s is as follows: automatic feeder, opener, breaker picker, card, sliver-lap machine, ribbon-lap machine, comber, first drawing, second drawing, third drawing, fourth drawing, slubber, first intermediate, second intermediate, roving frame, mule.

Although the foregoing combinations may be considered as the standards for the class of work to which they refer, it occasionally happens that mills are found using different lay-outs. This may be because the mill is intended to make a lower or a higher grade of yarn than is customary for the numbers referred to, or because it is a mill that has been changed over from other numbers and the old machinery has been retained; or there may be many other reasons.

The objects of all cotton-yarn-preparation machines are: (1) the separation of the matted mass of fiber into loose flakes and the removal of the heavier and more bulky impurities, which objects are principally attained in the opening and picking processes; (2) the further cleansing of the stock from light and minute particles of foreign matter by such means as are adopted in the carding and combing processes; (3) the parallelizing, evening, and attenuation of the fibers, as performed in the carding and drawing processes, in the fly frames, and in the spinning process; (4) the strengthening of the product by twisting, as exemplified in ring or mule spinning.

COTTON MIXING

The objects of mixing the cotton from a number of bales are: (1) to allow the cotton to assume its normal condition; (2) to establish an average quality of grade in the lot.

The quantity of cotton used in a mixing should be as large as possible; for the larger the mixing, the easier it is to keep the work uniform for a considerable length of time. In addition to securing regularity, another reason for having large mixings is to give cotton from compressed bales an opportunity to expand.

Mixings when made by hand should occupy a considerable amount of floor space. The first bale should be spread all over this space, the second bale spread to cover the first, the third to cover the second, and so on. When a mixing is used, the cotton should be pulled away in small sections from the top to the bottom of the mixing so as to obtain portions of each bale.

It is a good plan when using bales of different marks, to arrange the mixing so that no two bales of the same mark shall come in contact with each other. The following rule is used to find the number of sections that should be made in order to obtain the correct proportion of each mark in a section.

Rule.—*To find the number of sections of which a mixing should consist, find the largest number that will exactly divide the number of bales of each mark. Then, to find the number of bales of each mark that there should be in each section, divide the number of bales of each mark by the number of sections in the mixing.*

EXAMPLE.—Find a suitable order for mixing 100 bales, the mixing to consist of 40 bales marked A B C; 20, G H I; 10, J K L; and 30, D E F.

SOLUTION.— 10 is the largest number that will exactly divide 40, 20, 10, and 30; therefore, the mixing should be made up of 10 sections, and in order to prevent any two bales of the same mark coming in contact with each other, they could be arranged as follows:

G H I
D E F
A B C
J K L
D E F
A B C } 10 times.
G H I
A B C
D E F
A B C

If it is desired to mix exact proportions of different varieties of cotton, as American with Egyptian, or where dyed stock of one color, or more, is to be blended with white, the cotton may be blended to better advantage at some of the subsequent processes.

American cotton sometimes is mixed with Egyptian in order to cheapen the mixture. Brazilian cotton is sometimes mixed with American in order to increase the strength of the yarn; and rough Peruvian cotton is occasionally mixed with Egyptian in order to give the latter woolly qualities.

Although cotton is often mixed in this way, there is a certain limit to the mixing of harsh and soft cottons; nor is it practical to mix long- and short-stapled cotton, as the machines of the later processes, if set for one length of staple, will either damage cotton of a different length or cause an imperfect product.

A machine known as a *bale breaker* is sometimes used in mixing cotton. Its object is to separate the matted masses of cotton and to deliver it in an open state to the mixing bins. The principle employed in the bale breaker is to have three or four pairs of rolls, each pair revolving at a higher rate of speed than the preceding pair. The cotton fed to the pair that is revolving at a slow speed is pulled apart when it comes under the action of the pair revolving at a faster speed. The circumferential velocity of the second pair is about twice that of the first pair, that of the third pair is about four times that of the second, and that of the last pair is about five times that of the third. The first set of rolls usually makes between 5 and 6 rev. per min.

The space between the different sets of rolls will be found to vary, but usually from the center of one pair to the center of the next is about 9 in.

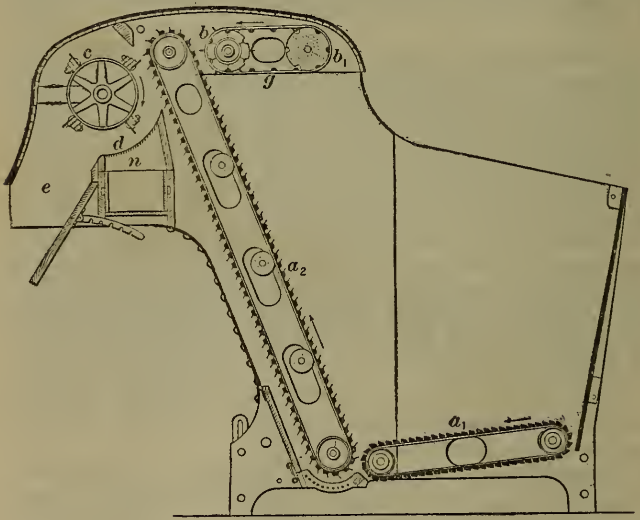
These rolls vary in construction, in some cases being solid with flutes their whole length, and in other cases are made of rings having projecting spikes.

The cotton should not be fed in too thick layers, since this is liable to strain the rolls; all the dirt from underneath the machine, which consists chiefly of sand and other foreign substances, should be removed periodically; and the machine should be properly oiled.

AUTOMATIC FEEDER

The *automatic feeder* is the first machine that receives the cotton after it has been mixed, and is used for the purpose of automatically supplying or feeding the opener or the breaker picker.

The accompanying illustration shows a section of an automatic feeder. The cotton is placed in the hopper *a*, which should be kept at least half full. The bottom apron a_1 tends



to carry the whole mass toward the lifting apron a_2. The spikes in the lifting apron fill with fiber and often retain comparatively large bunches of stock. After filling, they continue to move upwards, and the tendency for so large a number of points acting on the mass of cotton is to impart a rolling motion to it. The stripping roll *b* acts continuously on the cotton carried by the lifting apron. The surface of this roll, moving in the opposite direction from the lifting apron and only about 1 in. from the point of the spikes, strikes off the excess cotton. The cotton remaining on the lifting apron is the quantity necessary to supply the machine to which the feeder is attached, and must be removed from the pins carrying it. This is done by the doffer beater *c*, the surface of which moves in the same direction as the part of the apron nearest to it, but at a greater speed. The fibers removed from the lifting apron are in small tufts, and a certain quantity of sand, etc., is thrown out by the centrifugal force of the doffer beater or drops by its own weight. This passes through the bars of the grating *d* into the chamber *n*. The cotton passes forwards and through the passage *e*.

The capacity of automatic feeders is very great, but since the amount of work they do is governed entirely by the requirements of the machine they feed, they are rarely run at their full capacity. Usually about 3,000 lb. in 10 hr. is the maximum run through a feeder.

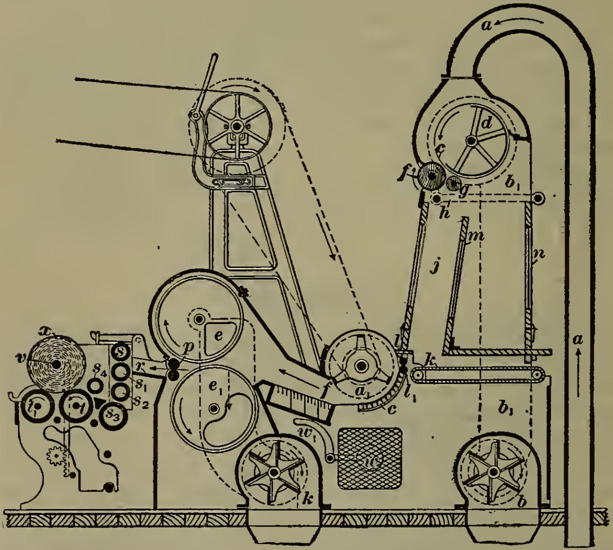
The feeder requires from $1\frac{1}{2}$ to 2 H. P. and occupies a floor space of about 6 ft. 4 in. by 6 ft. 6 in.

OPENER

The *opener* is not used in all mills, as the automatic feeder is often connected directly to the breaker picker. The opener has for its objects the cleaning of the heavy impurities from the cotton and the separating of the cotton into small tufts that are light enough in weight to be influenced by an air-current generated by a fan in the succeeding machine. It attains these objects by presenting a fringe of cotton to a beater that makes from 1,200 to 1,800 rev. per min. This beater usually has two blades, and consequently for every revolution delivers two blows to the fringe of cotton. By this means any foreign substance will be struck from the fringe of cotton as it is held by the feed-rolls, and knocked through grid bars. The tufts of cotton will also be removed from the fringe as soon as they are released from the bite of the feed-rolls, and thus they will be sufficiently light to be acted on by the air-current that conveys the cotton to the next machine.

BREAKER PICKER

The *breaker picker* is the first machine that deals with the cotton after it leaves the opener. This machine may receive the cotton either directly from an automatic feeder or from an opener through a trunk. The objects of the breaker picker are: (1) To remove foreign matter, especially the heavier and larger impurities, such as dirt, pieces of seed, leaf, etc.; (2) to



separate the tufts of cotton so that they may be more easily manipulated at the next process; (3) to form the cotton into a layer and wind it on a roll in a cylindrical form known as a *lap*.

The method used to attain these objects is to have a rapidly revolving *beater* strike a fringe of cotton, which is presented to it by a slowly revolving pair of feed-rolls. The process of cleaning is also aided by an air-current, which draws dust from the cotton.

Pickers are known as *pickers in single section* or *pickers in double section*, according to whether they give the cotton a single or a double beating action.

The manner of feeding the picker by means of a *condenser* and *gauge box*, when the cotton is conveyed through a trunk, is shown in the accompanying illustration. The air-current that draws the cotton from the opener through the trunk *a* is generated by a fan *b*. After leaving the trunk, the cotton first comes in contact with a cylinder of wire netting known as a *cage*, shown at *c*. About two-thirds of the inner circumference of this cage is protected by a cradle *d* of sheet metal, which prevents the cotton from being drawn to this protected part of the cage, the air-current passing out through the ends of the cage and down the passage b_1. The cradle *d* remains stationary, but the cage *c* revolves in the direction shown by the arrow, and thus the cotton, which is drawn to that part of the cage that is not protected by the cradle, is brought around until it comes under the action of the stripping rolls *f*, *g*, which remove it from the cage. The cotton then drops into the gauge box *j* and on to the apron *k*, from which it is removed by the feed-rolls *l*, l_1, of the breaker picker.

The passage of cotton through breaker pickers in single section, whether they are fed by a condenser and gauge box or by a cage section, is the same.

After the cotton delivered by the feed-rolls *l*, l_1 has been struck by the rapidly revolving beater a_1, it passes over grid bars c_2 in order that any dirt or other foreign matter may be separated and fall through the spaces between the bars. Then it is carried over inclined cleaning, or grate, bars *f* so that other foreign matter, too heavy to be carried by the air-current, may have an opportunity of dropping through the spaces between the bars. This cleaning process is continued while the cotton collects in a layer on the surface of two revolving cages or screens, *e*, e_1, through which a current of air is drawn by a revolving fan *k*. The cotton, now in the form of a sheet or layer, is removed by stripping rolls *p* and allowed to pass over a stripping plate *r*, between smooth calender, or presser, rolls

s, s_1, s_2, s_3, between rolls s_4 and t, and round the lap roll v that rests on the fluted calender rolls t, t_1, thus forming the lap x.

The draft of a breaker picker is usually a little less than 2, and is figured from the fluted calender rolls to the feed-rolls.

The floor space of a breaker varies according to the style and make of the machine. One type of a single-beater breaker with a cage section occupies a floor space of 13 ft. 9 in. by 6 ft. 8½ in., allowing for trunk connections. A double-beater machine, other particulars as above, occupies 19 ft. 10 in. by 6 ft. 8½ in. Where a condenser and gauge box are used instead of a cage section, from 7 to 9 in. may be deducted from the length given above. These measurements are for pickers that make laps 40 in. wide.

When in single section, breaker pickers require about 4½ H. P.; when in double section, about 7 H. P.

The production depends on the speed, width of lap, and weight of lap per yard. A common production is about 500 lb. per hour, or 25,000 lb. for a week of 50 hr. actual running time.

INTERMEDIATE AND FINISHER PICKERS

Intermediate and finisher pickers are practically alike in construction and differ very little from a breaker picker in single section. Their objects are the same as those of the breaker picker; the lap that they produce, however, is of a more uniform weight per yard.

Four laps taken from the previous picker are placed on the feed apron and thus the advantage gained by doubling is secured.

EVENER MOTION

After it is delivered by the feed-rolls, the cotton is treated in the same manner as in the breaker picker, but the manner in which it is fed into the intermediate and the finisher picker is somewhat different from that in a breaker picker, on account of the *evener motion*, the object of which is to regulate the speed of the feed-roll in accordance with the weight of cotton fed so that a uniform weight will be presented to the beater.

Fig. 1 is a complete view of all the attachments of an evener motion. The manner in which this evener regulates the speed of the feed-roll in accordance with the weight of cotton fed is as follows: The sectional plates *d* are pressed down on the roll *c* by the weight f_4, shown on the lever *f*, through the connection made by e_4 and the saddles. The distance that these plates are raised from the roll *c* is governed by the quantity of cotton that passes between them and the roll; and the distance these plates are raised will govern the position of the belt on

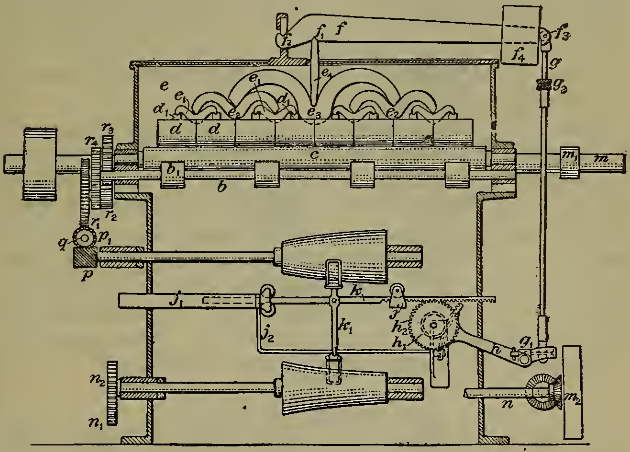


FIG. 1

the cones, and, consequently, the speed of the roll *c* that feeds the cotton.

When the proper weight of cotton is being fed uniformly throughout the length of the feed-roll *c*, the plates are raised the same distance from the roll *c* and the belt should be exactly in the center of the cones. If, however, a portion of cotton 1 in. thicker than the average thickness comes under the section plate at the extreme left, this section plate will be raised 1 in. from its normal position. The result of this will be that the end of the lever e_1 resting on this plate will be raised 1 in., which in turn will raise the end of the lever e_2 connected to e_1 $\frac{1}{2}$ in. The end of the lever e_3 that is connected to this lever e_2 will therefore be raised $\frac{1}{4}$ in., which, by causing the pin e_4 to be raised $\frac{1}{8}$ in., will result in the lever f being raised $\frac{1}{8}$ in. at the point f_1.

As the lever f cannot rise at f_2, its other end must rise and, through the rod g, turn the shaft g_1. The segment h will therefore be moved, and through the gears h_1, h_2, and the rack k, the belt will be guided on to the smaller part of the lower, or driving, cone, thus decreasing the speed of the feed-roll and reducing the weight of cotton fed. As soon as this heavier portion of cotton has passed and the correct weight is fed, the parts will be brought to their normal positions by means of the weight on the lever f.

In this illustration, an extreme case has been taken, as it is seldom that an extra portion of cotton 1 in. thicker than the average comes under one of the section plates; but the belt would be moved the same distance if a portion of cotton $\frac{1}{8}$ in. thicker than the average should come under all the section plates. If four of the plates are raised $\frac{1}{4}$ in. from their normal position, it will have the same effect as raising each plate $\frac{1}{8}$ in. It is therefore obvious that the arrangement is designed to insure a uniform weight of cotton being fed, regardless of the number of plates that are affected.

MEASURING MOTION

The *measuring motion* is used to a greater extent on intermediate and finisher pickers than on breaker pickers. Its object is, when a definite length has been wound on the lap roll, automatically to stop the feed-rolls, the smooth calender rolls, and in some cases the fluted calender rolls, while the beater shaft and fans continue to revolve.

A view of a measuring motion is shown in Fig. 2; a represents the end of the bottom calender roll, carrying a worm b, which through a worm-gear c, a shaft c_1, and a bevel gear d, drives a bevel gear e. The gear e, together with a dog f, is loose on a stud g and carries a projection e_1, the dog f also carrying a projection f_1. The dog, if allowed to do so, would fall because of its own weight so that its point would be down, but as the gear e receives motion from the bottom calender roll, the projection e_1 on the gear e comes in contact with the projection f_1 on the dog f and thus continually forces the dog around ahead of it; consequently, when the projection e_1 is at its highest position, the parts mentioned occupy the position shown.

As the gear e continues to revolve, the dog f will be brought in contact with a projection on a lever h that is connected to the starting lever h_1 fulcrumed at h_2. Connected to h_1 is a rod j, that runs along the side of the picker and connects with a double worm r, Fig. 3. A bracket k, Fig. 2, is also attached to the rod h_2, and attached to this bracket is a rod k_1

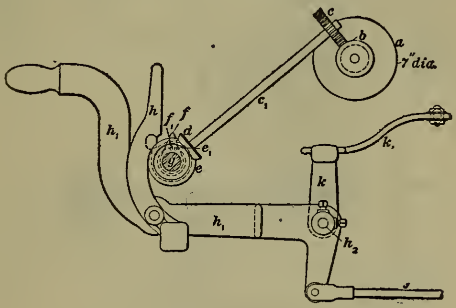


FIG. 2

that connects with the clutch l, Fig. 4, through which the lap head is driven.

When the picker is running, the cut-out, shown in dotted lines, in the lever h, Fig. 2, has a bearing on a casting, and thus the starting lever h_1 is held in such a position that the worm r, Fig. 3, is in contact with the worm-gear r_1 the clutch l, Fig. 4, being closed. When, however, the gear e, Fig. 2, has made one revolution and has brought the dog f into contact with the lever h, any further movement causes the dog f to force the cut-out on h from its bearing. This causes the starting lever h_1 to drop, disconnecting the clutch l; the worm r is also thrown out of gear, causing the calender rolls and the feed-rolls to stop.

GEARING

The gearing of a picker equipped with the evener motion illustrated in Fig. 1, is shown in Fig. 4. The beater shaft *m* is driven from a countershaft, and carries the usual pulleys for driving the fan and feed-rolls.

The feed-pulley m_1 drives a pulley m_2 on a shaft *n* extending

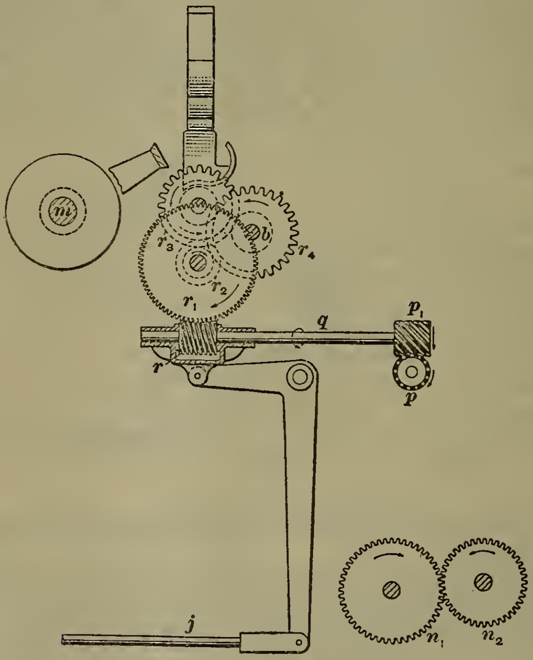


FIG. 3

across the picker. From this shaft, the cones and the feed-rolls, together with the feed-apron, are driven. As the feed-apron is driven through the cones, its speed will always be in accordance with that of the feed-rolls. The lap head, cages, and stripping rolls are driven through a side shaft *p*, which receives its motion from the shaft *n*.

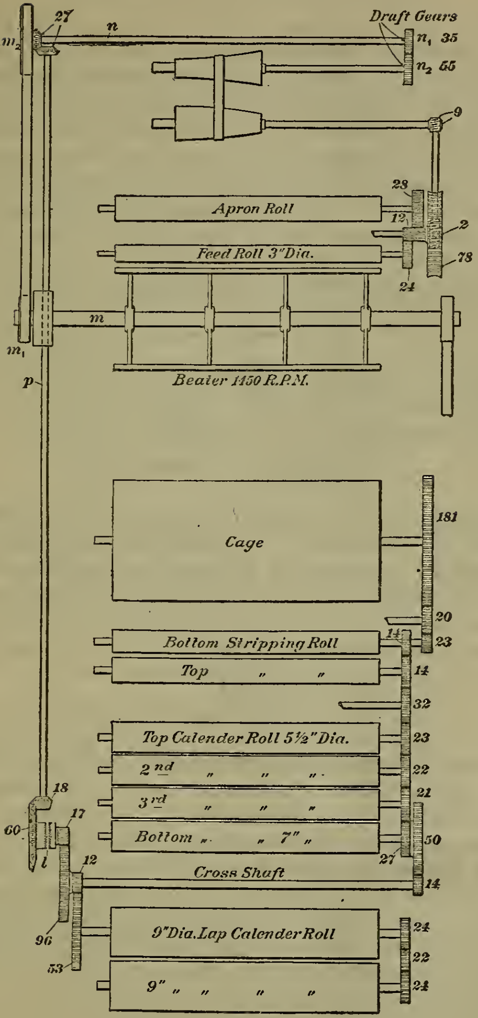

27
n
Draft Gears
n_1 35
n_2 55
m_2
9
28
Apron Roll
12
2
Feed Roll 3"Dia.
78
24
m
m_1
p
Beater 1450 R.P.M.
Cage
181
20
14
23
Bottom Stripping Roll
Top " "
14
32
Top Calender Roll 5½"Dia.
23
2nd " " "
22
3rd " " "
21
18
17
60
Bottom " " 7" "
50
l
27
12
Cross Shaft
14
9"Dia. Lap Calender Roll
24
96
22
53
9" " " " "
24

FIG. 4

The measuring motion is provided with *change gears*, by means of which different lengths of laps can be procured. When finding the length of lap, the number of revolutions made by the bottom calender roll while the knock-off gear is revolving once should first be determined; this result multiplied by the circumference of the roll will give the length of lap. Referring to Fig. 2, the bottom calender roll *a* is 7 in. in diameter, *b* is a single worm, and the worm-gear *c* is the change gear; the gear *d* has 21 teeth, and the knock-off gear *e* has 30 teeth.

The length of lap delivered when using a 45-tooth change gear is as follows: $\frac{30\times 45}{21\times 1}=64.285$ revolutions of roll to one revolution of gear *e*. $64.285\times 7\times 3.1416=1{,}413.704$ in.; $1{,}413.704$ inches $\div 36=39.269$ yd., length of lap.

This example could also be expressed as follows:

$$\frac{30\times 45\times 7\times 3.1416}{21\times 1\times 36}=39.26 \text{ yd.}$$

A constant for the measuring motion may be obtained by omitting the change gear or considering it a 1-tooth gear. This constant, multiplied by the number of teeth in any change gear, will give the length of lap delivered when using that gear, and consequently the gear for producing a certain length may be found by dividing the length of lap required by the constant. The constant is obtained as follows:

$$\frac{30\times (1)\times 7\times 3.1416}{21\times 1\times 36}=.8726, \text{ constant}$$

Draft of Intermediate and Finisher Pickers.—The draft change gears are shown in Fig. 4; there are two change gears n_1, n_2, so that if the proper draft cannot be obtained by changing one gear, the other may be changed. The draft of an intermediate picker is usually about 4.25 and that of a finisher picker about 4.50, when there are 4 laps up at the back.

The total draft of the machine shown in Fig. 4, with a gear of 55 teeth on the lower-cone shaft meshing with a gear of 35 teeth, and with the belt in the center of the cones, is as follows:

$$\frac{9\times 24\times 12\times 17\times 18\times 27\times 55\times 9\times 78\times 24}{24\times 53\times 96\times 60\times 27\times 35\times 9\times 2\times 12\times 3}=4.422, \text{ draft}$$

CALCULATION OF COLORED MIXES

Colored mixtures of stock are often made by the combination of laps on the intermediate and finisher pickers. The following method may be used in finding the percentage of any material or color in the laps from the finisher picker, whatever may be the weight of the laps fed to either the intermediate or finisher picker, the colors or materials fed, etc.

Let A = sum of the weight per yard of the laps of any one color, or kind, fed to the intermediate picker;

B = sum of the weight per yard of all of the laps fed to the intermediate picker;

C = sum of the weight per yard of the "mixture" laps from the intermediate picker that are fed to the finisher picker;

D = sum of the weight per yard of the laps of the same color (as under A) that are fed to the finisher picker;

E = sum of the weight per yard of all of the laps fed to the finisher picker;

F = percentage of any color or stock (as under A and D) in the laps from the finisher picker.

Then,
$$F=\frac{(A\times C)+(B\times D)}{B\times E}\times 100$$

Example.—An intermediate picker is fed with two black laps, each weighing 14 oz. per yard, and also with one white lap and one red lap, each weighing 13 oz. per yard. The finisher picker is fed with two of the "mixture" laps made by the intermediate, each weighing $13\frac{1}{2}$ oz. per yard, and also with one white lap weighing 13 oz. per yard and one black lap weighing 14 oz. per yard. What is the percentage of each color in the laps made by the finisher picker?

Solution.—Considering black, the value of A will be 14 oz. + 14 oz. = 28 oz.; B will equal 14 oz. + 14 oz. + 13 oz. + 13 oz., or 54 oz.; C will have a value of $13\frac{1}{2}$ oz. + $13\frac{1}{2}$ oz. = 27 oz.; D is valued at 14 oz., and the value of E will be $13\frac{1}{2}$ oz. + $13\frac{1}{2}$ oz. + 13 oz. + 14 oz. = 54 oz.

Then,

$$F=\frac{(28\times 27)+(54\times 14)}{54\times 54}\times 100=\frac{1{,}400}{27}=51\tfrac{23}{27}\%\text{ of black}$$

Taking white into consideration, A will have a value of 13 oz. and D will equal 13 oz. Other values will be the same as in the case of black.

Then,

$$F=\frac{(13\times 27)+(54\times 13)}{54\times 54}\times 100=\frac{325}{9}=36\tfrac{1}{9}\%\text{ of white}$$

Finally, in calculating the percentage of red, A will equal 13 oz. and D will have a value of zero; other values are as in the previous instances.

Then,

$$F=\frac{(13\times 27)+(54\times 0)}{54\times 54}\times 100=\frac{325}{27}=12\tfrac{1}{27}\%\text{ of red}$$

PROOF.— $51\tfrac{23}{27}\%+36\tfrac{1}{9}\%+12\tfrac{1}{27}\%=100\%$.

NOTE.—This example purposely has been made more diversified than will likely be encountered in actual mill practice, in order that the operation of the formula may be clearly shown.

When four laps of uniform weight are employed on the intermediate and finisher pickers, a more simple formula may be used, as follows:

Let A=number of laps of any color fed to the intermediate picker;

B=number of laps of the same color fed to the finisher picker;

C=number of "mixture" laps fed to the finisher picker;

D=percentage of color (as under A and B) in laps from finisher picker.

Then, $D=6\tfrac{1}{4}\,A\,C+25\,B$

EXAMPLE.—Assume that an intermediate picker is fed with two laps of black and two white laps. The finisher is fed with one "mixture" lap, one black lap and two laps of white. What is the percentage of black in the finished laps?

SOLUTION.— $D=(6\tfrac{1}{4}\times 2\times 1)+(25\times 1)$

$D=12\tfrac{1}{2}+25$

$D=37\tfrac{1}{2}\%$ of black

CARE OF PICKERS

The making of a good lap is an important point. It should be perfectly cylindrical when removed from the machine, and should feel as firm at one point as at another. It should be built so that the layers will unroll easily at the next process without sticking together. The defect known as *splitting*, or *licking*, is due to various causes, such as excessive fan speed, improper division of the air-currents, oil dropping on the cotton, etc.

The laps delivered should be as near a uniform weight as possible. Each lap from the finisher picker is usually weighed, and a variation of ½ lb. in either direction is allowed; that is, if laps weighing 35 lb. are delivered when they are the correct weight per yard, any laps weighing between 34½ and 35½ lb. are allowed to pass. Laps weighing outside this range should be put back and run over again, and if too many of these laps are uniformly heavy or light, the regulating screw on the evener should be adjusted.

Below is given a table showing for what numbers of yarn certain weights of lap are generally used:

WEIGHT OF LAPS FOR VARIOUS COUNTS OF YARN

Numbers of Yarn	Weight of Lap per Yard From Finisher Picker Ounces
1s to 10s	14.0
10s to 20s	13.5
20s to 30s	13.0
30s to 40s	12.0
40s to 50s	11.5
50s to 60s	11.0
60s to 70s	11.0
70s to 80s	11.0
80s to 90s	10.0
90s to 100s	10.0
100s to 120s	9.5
120s to 150s	9.0

A good production for an intermediate or finisher picker is about 12,500 lb. per week, allowing from 6 to 10 hr. for stoppages. A finisher picker for making 40-in. laps occupies a floor space of about 16 ft. by 6 ft. 8½ in. and requires about 4 H. P. to drive it.

COTTON CARDS

The lap of cotton as it leaves the picker consists of cotton fibers crossed in all directions, together with a small quantity of foreign matter, consisting more especially of lighter impurities such as pieces of leaf, seed, or stalk, and thin membranes from the cotton boll.

The objects of carding are: (1) The disentangling of the cotton fibers, or the separation of the bunches, or tufts, of fiber into individual fibers, and the commencement of their parallelization; (2) the removal of the smaller and lighter impurities; (3) changing the formation of cotton from a lap to a *sliver*, accompanied by the reduction of the weight per yard of the material.

Carding is really a straightening and brushing action, the fibers being operated on by wire teeth, known as card clothing which have the effect of loosely holding a few fibers at a time and striking them as with a comb.

THE REVOLVING-TOP FLAT CARD

The *card* that is almost universally adopted for cotton carding is known as the *revolving-top flat card*, sometimes spoken of as the *revolving flat card*. A section through this card is shown in Fig. 1. At the back of the card is shown the lap a_2, which has a rod a_1 passed through its center and rests on the lap roll a. The lap roll a is constructed of wood and is either fluted or has a rough surface, sometimes produced by covering it with a coat of paint mixed with sand, in order to cause the lap to unroll by friction with the lap roll and without any slippage.

The cotton is drawn over the feed-plate b by the feed-roll b_1, the single layer, or sheet, leaving the lap at the point a_5. The feed-plate b extends under the feed-roll b_1, with its nose projecting upwards in front of the feed-roll almost to the teeth shown on the circumference of the licker c. The feed-roll b_1

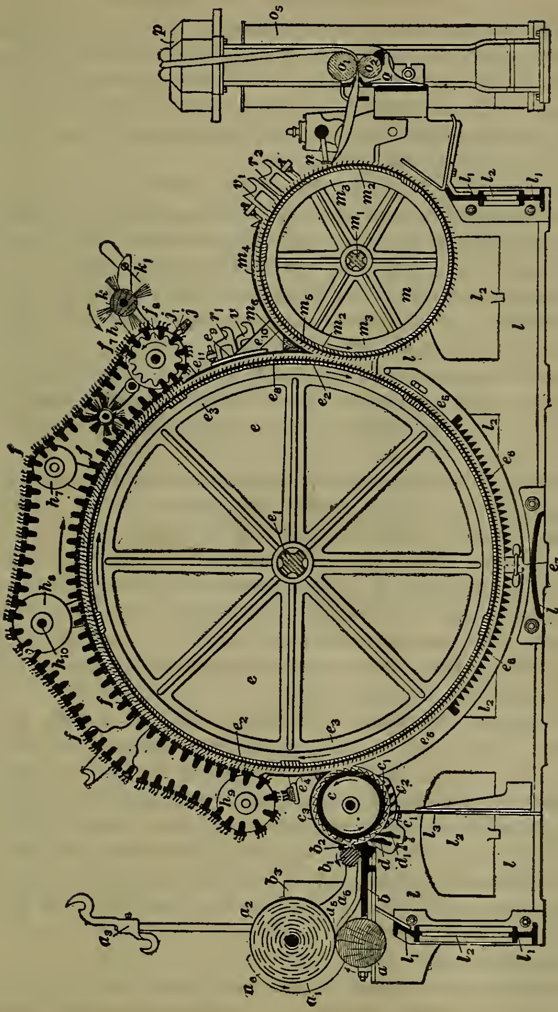


FIG. 1

revolves in the direction indicated by the arrow. Above the feed-roll rests a small iron rod b_2 that is revolved by frictional contact with this roll and, since it is covered with flannel, collects any fiber or dirt that may be carried upwards over the surface of the feed-roll and thus acts as a clearer. It also serves to prevent any air-current from passing between the feed-roll and the licker cover.

The lap roll a is positively geared with the feed-roll b_1 in such a manner that the feed-roll takes up exactly the amount of cotton delivered by the lap roll, without any strain or sagging, and as it revolves carries this cotton over the nose of the feed-plate so that a fringe is brought under the action of the licker c. The distance between the bite of the feed-roll and the lower edge of the face of the feed-plate should be from $\frac{1}{16}$ to $\frac{1}{8}$ in. longer than the average length of the cotton being worked, as it is necessary that the fibers should be free from the bite of the feed-roll before the action of the teeth of the licker exerts its greatest pull.

At the nose of the feed-plate, the licker is moving in a downward direction and the strong, triangular teeth are pointing in the direction of its revolution. Since the fringe of cotton is held by the roll, it will be disentangled as the teeth pass through it. When the cotton is released from the bite of the feed-roll, it will be taken by the teeth of the licker. Any short fibers, however, that are not sufficiently long to be secured by the licker will fall through the space between the two knives d, d_1, which are known as *mote knives.*

Underneath the licker is a casing c_1 known as the *licker screen.* This casing is made of tin and extends across the card. The portion of the screen directly under the licker is composed of transverse bars c_2, triangular in shape with rounded corners and set with their bases inverted. As the licker revolves, heavy impurities that were not previously taken out will be thrown through the openings in the screen. The top of the licker is protected by a metal cover c_3 known as the *licker cover*, or *bonnet*, which is curved to correspond with the curved surface of the licker.

Situated about midway between the back and front of the card, and a prominent feature in its construction, is the cylinder

e, mounted on the shaft e_1. This cylinder is usually 50 in. in diameter; its width depends on the width of the card, being usually 36, 40, or 45 in. The surface of the cylinder is covered with card clothing, which is a fabric with wire teeth embedded in it and projecting through it at an angle. The teeth on the surface of this cylinder point in the direction of its motion. A point on the surface of the cylinder travels about 2,150 ft. per min. The teeth of the clothing are set very closely in the fabric, there being about 72,000 points to the square foot and more than 3,000,000 points on the entire cylinder. The fibers are transferred to the surface of the cylinder, which is rendered possible by the respective directions of motion of the cylinder and licker and by the direction in which their teeth are pointing. The cylinder is also revolving at more than double the surface speed of the licker, and consequently the fibers are swept off the surface of the licker where the surfaces of the licker and cylinder are closest and carried upwards on the surface of the cylinder.

A cover e_4, which is known as the *back knife plate*, protects the cylinder at this point and prevents an air-current from being formed by the motion of the cylinder. Above the cylinder and partly surrounding its upper portion is a chain of flats f. These are the parts that give the name *revolving-top flat card* to the card. They are made of cast iron, approximately **T**-shaped in section, and are partly covered with card clothing about $\frac{15}{16}$ in. wide. The flats are so arranged that they will be supported immediately above the cylinder without coming in contact with it. About forty of the flats rest on a flexible bend at each side of the card.

The chain of flats is not stationary, but moves at a very slow speed, the flats nearest the cylinder moving toward the front of the card, while, of course, the flats that are not working are carried backwards over the top of those that are at work. The cotton is carried upwards and forwards by the cylinder to the point where the flats and cylinder are close together. When the cylinder reaches the first flat, the cotton on its surface has a tendency to project from it on account of the centrifugal force of the cylinder, and comes in contact with the teeth at the toe of the first flat. The stock is gradually drawn through the teeth of the flat, receiving a combing or carding action. Some of the fibers that have not projected sufficiently may not have received any carding action, and the cylinder carries them forwards to the next flat. The fibers that have been carded once may be carded again, with such additional fibers as are brought under the action of the succeeding flat, and so on throughout the entire series. The small impurities are left behind, since they are forced between the teeth of the wire on the flats or cylinder and remain there until the wire is cleaned, or stripped. Thus the short fibers and impurities are retained, and the long, clean fibers are passed forwards.

At the front of the card in Fig. 1 is shown a comb j supported by arms j_1. This comb consists of a thin sheet of steel attached to a shaft and having its lower edge serrated. An oscillating motion is given to the comb by means of a cam, and at each stroke it strips from a flat a portion of the short fiber, leaf, and other impurities that adhere to its face.

After the waste, known as *flat strippings*, has been removed by the comb j, the flats are brushed out by means of the brush k. The brush after it has operated on the flats is cleaned by means of a hackle comb k_1.

Beneath the cylinder is placed a screen e_5. This consists of circular frames on each side of the card, practically corresponding to the curvature of the cylinder and connected by triangular cross-bars e_6. As the cylinder revolves, the fibers that project come in contact with the screen, and thus the dirt and other foreign substances will be struck off or thrown through the openings in the screen.

Directly in front of the cylinder is the doffer m, which is constructed on the same principle as the cylinder. The doffer is covered with card clothing in a similar manner to the cylinder, except that the wire on the doffer is more closely set and somewhat finer. The doffer is the same width as the cylinder, but is of a much smaller diameter, usually 27 in. The doffer revolves in the opposite direction to that of the cylinder, and the teeth of the cylinder and doffer point in opposite directions. The surface speed of the doffer, which varies from 44 to 107 ft. per min., is much less than that of the cylinder. As the cylinder approaches the doffer its surface is covered with separate fibers of cotton. Since it is set within about .005 in. from the doffer and the doffer is revolving so much more slowly, the fibers of cotton are deposited by the cylinder on the face of the doffer.

There is no screen beneath the doffer, as it is unnecessary, but placed above it is a protection consisting of a metal cover m_4 known as the *doffer bonnet.* At the point m_5 it extends to, and is almost in contact with, a plate of steel e_8 placed over the front part of the cylinder. Above this is a plate e_{11} known as the *front knife plate.* A draft strip, or making-up piece, m_6 is placed in the recess formed by the doffer bonnet and the plate e_8, so as to fit the angle between the doffer and the cylinder and thus prevent dirt from entering. It also prevents drafts and thus does away with flyings.

The cotton is carried around by the doffer on its under side until it reaches the doffer comb n, which has an oscillating motion of about 1,800 or 2,000 strokes per min. The comb consists of a thin sheet of steel attached to a shaft by a number of small arms, and has its lower edge serrated. The downward strokes of the comb are in the same direction that the teeth of the doffer are pointing and close to them, thus making the operation of removing the cotton very easy.

The cotton, when it leaves the doffer, is in a web, which must be reduced to a sliver. This is attained by passing the cotton through a guide and then through a trumpet o, on the other side of which are two calender rolls o_1, o_2. The object of these rolls is to compress the sliver so that it will occupy a comparatively small space.

From the calender rolls o_1, o_2 the cotton passes through a hole in the cover p of an upright framework, known as the *coiler head.* It is drawn through the hole in the cover by two coiler calender rolls, which further condense it, and is then delivered into an inclined tube on a revolving plate. The end of the tube that receives the cotton is in the center of the plate, directly under the calender rolls, and the end of the tube from which the cotton is delivered is at the outer edge of the plate. At the bottom of the coiler head is a plate on which rests the can that receives the sliver. In consequence of the sliver being delivered down the rotating tube, it will describe a circle and be laid in the can in the form of coils.

CARD CLOTHING

Card clothing is the material with which the cylinder, doffer, and flats of the card are covered and by means of which the cotton is opened and the fibers straightened and laid parallel to each other. It consists of wire teeth bent in the form of a staple and inserted in a suitable foundation material. The teeth in addition to being bent in the form of a staple, also have a forward bend, or inclination, from a point known as the *knee* of the tooth. The part of the tooth that is on the back of the foundation after the tooth has been inserted is known as the *crown* of the tooth.

The foundation material must be such that it will not stretch after it is applied to the card, for if the clothing becomes loose it will rise in places, or as is commonly said, will *blister*. The foundation generally used is a fabric woven from cotton and woolen yarns, although sometimes cotton and linen are employed; the linen being used on account of its strength and freedom from stretching. The foundation is generally woven three or four ply, in order to obtain the required strength and the thickness that is necessary to secure the teeth. Sometimes the surface of the foundation is coated with a veneer of india rubber.

The wire teeth actually do the carding, the separating of the cotton, fiber from fiber, and the rearranging in a homogeneous mass in which the fibers lie more or less parallel. The material from which the wire is made, the number (diameter) of the wire, the angle at which the wire passes through the foundation, the angle at the knee of the tooth, the relative height of the knee and point, and the method of insertion in the foundation are all important considerations.

Clothing is set with many different kinds of wire, such as iron, brass, mild steel, tempered steel, tinned steel, etc., but for cotton carding hardened and tempered steel, which makes a springy, elastic tooth that will not easily be bent out of place or broken, is the best material. The wire generally used is round in section, but various other shapes have been used.

After the wire has been set in the foundation it is ground to a point, and this alters the form of the section of the tooth at the point, or in some cases as far down as the knee. There are three methods of grinding the clothing, which give to it the following names: (1) top-ground; (2) needle-, or side-ground; (3) plow-ground.

Top-ground wire is obtained by an emery grinding roll having a very slight traverse motion, so that the point of the tooth is ground down only on the top, producing what is known as a *flat*, or *chisel*, point.

In the *needle-*, or *side-*, *ground wire* the thickness of the tooth is reduced at the sides for a short distance from the point and the wire is also ground down at the top. This form of point is known as the *needle point* and is produced by a comparatively narrow emery grinding wheel that, in addition to having

COMPARATIVE DIAMETERS OF ENGLISH AND AMERICAN STANDARD WIRES

Birmingham Diameter in Inches	Number of Wire	American Diameter in Inches
.014	28	.012641
.013	29	.011257
.012	30	.010025
.010	31	.008928
.009	32	.007950
.008	33	.007080
.007	34	.006305
.005	35	.005615
.004	36	.005000

a rotary motion, is rapidly traversed back and forth across the clothing.

Both top and needle grinding are practiced in the mill, the former being accomplished with the so-called dead roll and the latter with the traverse grinding roll, but *plow grinding* is usually done by the manufacturers of the clothing. With this method of grinding, the thickness of the wire is reduced by grinding down each side from the point of the tooth to the knee.

The diameter of the wire varies according to the class of cotton to be carded. There are two gauges employed for numbering wire for card clothing; namely, the Birmingham, which is the English standard, and the American standard. The accompanying table shows the comparative diameters of different numbers of wire of each system:

For an average grade of cotton, No. 33 wire (American gauge) for the doffer and flats and No. 32 for the cylinder will give good results, although some carders prefer one number finer in each instance; for coarse work the wire is increased in diameter, and for finer work decreased. The cylinder should always be covered with wire one number coarser than the doffer and flats, which should have wire of the same diameter.

CALCULATIONS

Card clothing for cotton cards is made in long continuous strips 1 to 2 in. in width known as *fillet* or *filleting*, and in narrow sheets known as *tops;* the former is used for covering the cylinder and doffer and the latter is used for the flats. Fillet clothing is made *rib set;* that is, with the crowns of the teeth, on the back of the clothing, running in staggered ribs, or rows, lengthwise of the fillet. The teeth are set into tops so that the crowns of the teeth on the back side of the foundation are *twilled;* that is, they are set in diagonal lines like a piece of twilled cloth.

Card clothing in America, unless especially ordered, is made with 4 crowns in 1 in. on the back of the clothing, or 8 points in 1 in. on the face, and is known as 8-crown clothing. From this it will be seen that a 2-in. fillet will have 8 ribs on the back and a 1½-in. fillet, 6 ribs, etc. Sometimes in special cases where a large number of points per square foot are desired, the clothing is made 10-crown; that is, with 10 points per in. in width on the face of the clothing, or 5 crowns per in. on the back of the clothing.

The term *nogg*, which is used in connection with card clothing, refers to the distance between the first tooth of one line of twill and the next line. Owing to the manner in which the teeth are set in fillet clothing, there are always one-half the number of teeth per nogg and twice the number of noggs per inch as in clothing for tops with the same number of points per square foot. The number of noggs per inch always governs the number of points per square foot in the clothing. If more points per square foot are wanted, the noggs per inch are increased; if fewer points are wanted, the noggs per inch are decreased, the crowns always remaining the same.

The points per square foot in card clothing may be found by the following rule:

Rule.—*Multiply the crowns per inch by the points per tooth (2), by the teeth per nogg, by the noggs per inch, and by the number of square inches in a square foot (144).*

Example 1.—Find the points per square foot in a sample of rib-set card clothing; the crowns per inch are 4, the teeth per nogg 3, and the noggs per in. 16.

Solution.—

$$
\begin{array}{rl}
4 & \text{crowns per in.}\\
2 & \text{points per tooth}\\
\hline
8 & \text{points per in.}\\
3 & \text{teeth per nogg}\\
\hline
24 & \\
16 & \text{noggs per in.}\\
\hline
144 & \\
24 & \\
\hline
384 & \text{points per sq. in.}\\
144 & \text{in. per sq. ft.}\\
\hline
1536 & \\
1536 & \\
384 & \\
\hline
55296 & \text{points per sq. ft.}
\end{array}
$$

Dividing the points per square foot by the noggs per inch, thus, $55{,}296 \div 16 = 3{,}456$, it will be noticed that with 8-crown fillet (4 crowns per inch) each nogg increases the points per square foot by 3,456. From this it will be seen that in order to find the points per square foot in 8-crown fillet clothing it is only necessary to multiply the noggs per inch by 3,456.

Example 2.—Find the points per square foot in a sample of twill-set card clothing, the crowns per inch being 4, teeth per nogg 6, and the noggs per inch 8.

SOLUTION.—

```
        4 crowns per in.
        2 points per tooth
        8 points per in.
        6 teeth per nogg
      4 8
        8 noggs per in.
    3 8 4 points per sq. in.
    1 4 4
  1 5 3 6
1 5 3 6
3 8 4
5 5 2 9 6 points per sq. ft.
```

Dividing the points per square foot by the noggs per inch, thus, 55,296÷8=6,912, it will be noticed that with 8-crown twill-set clothing each nogg increases the points per square foot by 6,912. To find the points per square foot in twill-set clothing multiply the noggs per inch by 6,912.

POINTS PER SQUARE FOOT IN RIB-SET CLOTHING

Noggs per Inch	Points per Square Foot	American Number of Wire
10	34,560	28
11	38,016	28
12	41,472	29
13	44,928	29
14	48,384	30
15	51,840	30
16	55,296	31
17	58,752	31
18	62,208	32
19	65,664	32
20	69,120	33
21	72,576	33
22	76,032	34
23	79,488	34
24	82,944	35
25	86,400	35
26	89,856	36
27	93,312	36

In the preceding table is given the number of points per square foot of 8-crown, rib-set fillet (4 crowns per inch) with 3 teeth per nogg and with from 10 to 27 noggs per in. The table also shows the numbers of wire (American gauge) generally used in each case.

In the following table is given the number of points per square foot of 8-crown, twill-set clothing with 6 teeth per nogg and with from 5 to 13 noggs per inch.

POINTS PER SQUARE FOOT IN TWILL-SET CLOTHING

Noggs per Inch	Points per Square Foot	American Number of Wire
5	34,560	28
6	41,472	29
7	48,384	30
8	55,296	31
9	62,208	32
10	69,120	33
11	76,032	34
12	82,944	35
13	89,856	36

For an average grade of cotton the doffer should have 20 or 21 noggs per in. and the flats 10 or $10\frac{1}{2}$ noggs per in., which in each case would give 69,120 or 72,576 points per sq. ft. For the main cylinder 18 or 19 noggs per in. are suitable, which would give 62,208 or 65,664 points per sq. ft. The number of points may of course be varied to suit the class of work, but it is generally desirable to have the same number of points in the doffer and flats; and the main cylinder should have a slightly smaller number than either.

English Method of Numbering Card Clothing.—English card clothing for tops is often made with the teeth inserted according to a method known as the *plain,* or *open set,* in which the crowns, or backs, of the teeth overlap each other exactly as bricks in a wall. The clothing is made 10-crown; that is, with 10 points per in. across the card. This method of setting the teeth is often used in America when a large number of points per square inch is desired.

The English system of numbering clothing is based on the plain-set clothing, and designates the clothing by the counts, each count being equal to 720 points per sq. ft. The accompanying table shows the points per square foot in card clothing of various counts and also the number of wire (American gauge) that is usually used.

ENGLISH COUNTS OF CARD CLOTHING

English Counts	Points per Square Foot	American Number of Wire
60s	43,200	28
70s	50,400	30
80s	57,600	31
90s	64,800	32
100s	72,000	33
110s	79,200	34
120s	86,400	35
130s	93,600	36

CLOTHING FLATS

The clothing for the flats is made in sheets with a 1-in. space between the sections of wire; these are afterwards cut up to form the *tops*. The method of fastening the top to the flat is to employ a steel clamp of the same length as the clothing and bent in a **U** shape. One edge of this clamp in some cases is serrated, so as to grip the foundation, and the other edge engages the edge of the flat, holding the clothing and flat securely together.

CLOTHING CYLINDER AND DOFFER

Both the cylinder and doffer, which are covered with filleting, have parallel rows of holes drilled across them, which are plugged with hardwood. The fillet is wound spirally and secured by means of tacks driven in the hardwood plugs. Cylinders are usually covered with 2-in. and doffers with 1½-in. filleting. There are several methods of shaping the *tail-ends*, as they are called, but the best is that known as the *inside taper*, since it is stronger and neater than any other. Three lengths, each equal to one-half the circumference of the cylinder of the doffer, as the case may be, are first marked out on the end of the fillet; in the case of a 50-in. cylinder these distances would be 6.545 ft. each. For the first distance, the fillet is cut exactly through the middle; for the second distance, it is tapered from half the width of the fillet to the full width; for the third distance, a cut is made on the opposite side of the fillet exactly half way through it and the fillet tapered out to its full width again. After one tail-end is cut, the end of the fillet is tacked to the plugs in the cylinder and the fillet wound around the cylinder spirally; the other tail-end is then cut and fastened to the cylinder in the same manner as the first tail-end.

The length of filleting to cover a cylinder, doffer, or other roll may be found by the following rule:

Rule.—*Multiply the diameter of the roll by its width (both expressed in inches) and by 3.1416 and divide the product thus obtained by the width of the fillet multiplied by 12. The result thus obtained will be the required number of feet of filleting.*

Note.—An allowance must be made for tapering the tail-ends, generally a length equal to the circumference of the roll being sufficient.

Example.—What length of 2-in. filleting is required to clothe a cylinder 50 in. in diameter and 40 in. wide?

Solution.— $$\frac{50\times40\times3.1416}{2\times12}=261.8\text{ ft.}$$

Adding a length equal to the circumference of the cylinder, which is 13.09 ft., the length required will be 274.89 ft.

SPEED CALCULATIONS

If the driving shaft makes 340 revolutions per min. and carries a 10-in. pulley, the pulley e_{12}, Fig. 2, will be driven as follows:

$$\frac{340\times10}{20}=170\text{ rev. per min.}$$

As the cylinder is $50\frac{3}{4}$ in. in diameter, allowing $\frac{3}{4}$ in. for clothing, its surface speed will therefore be as follows:

$$\frac{170\times50\frac{3}{4}\times3.1416}{12}=2{,}258.679\text{ ft. per min.}$$

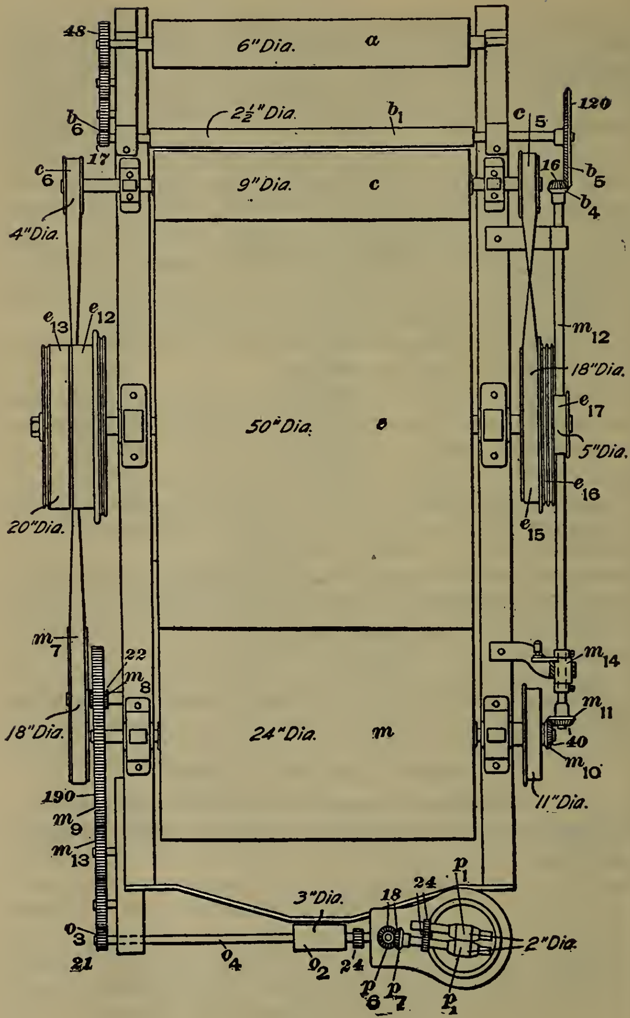

48
6" Dia.
a
2½" Dia.
b1
b6
17
c 5
120
16
b5
b4
c6
9" Dia.
c
4" Dia.
e13
e12
m12
18" Dia.
e17
50" Dia.
e
5" Dia.
e16
20" Dia.
e15
m7
22
m8
m14
m11
18" Dia.
24" Dia.
m
40
m10
11" Dia.
190
m9
m13
p1
24
3" Dia.
18
o3
2" Dia.
21
o4
o2
24
p6
p7
p1

FIG. 2

Licker.—The diameter of e_{15}, Fig. 2, is 18 inches and that of c_5 is 7 in., so that when the cylinder makes 170 rev. per min., the revolutions per minute made by the licker will be as follows:

$$\frac{170\times18}{7}=437.142 \text{ rev. per min.}$$

As the licker is usually 9 in. in diameter, its surface speed will be as follows:

$$\frac{437.142\times9\times3.1416}{12}=1{,}029.993 \text{ ft. per min.}$$

Doffer.—The 4-inch pulley c_6, Fig. 2, on the end of the licker drives the 18-inch barrow pulley m_7, which is compounded with the doffer change gear m_8. This gear, for the purpose of calculation, will be assumed to have 22 teeth; the gear on the end of the doffer contains 190 teeth. With the licker making 437.142 rev. per min., the speed of the doffer will be as follows:

$$\frac{437.142\times4\times22}{18\times190}=11.248 \text{ rev. per min.}$$

As the doffer is $24\frac{3}{4}$ in. in diameter, allowing $\frac{3}{4}$ in. for clothing, its surface speed will be as follows:

$$\frac{11.248\times24\frac{3}{4}\times3.1416}{12}=72.881 \text{ ft. per min.}$$

Flats.—The 5-in. pulley e_{17}, Fig. 2, drives a pulley 10-in. in diameter, not shown. This pulley carries a single-threaded worm that meshes with a 16-tooth worm-gear. On the shaft with this worm-gear is a single-threaded worm that drives a 42-tooth worm-gear on the shaft of the 8-inch pulley driving flats. The speed of the flats, therefore, will be

$$\frac{170\times5\times1\times1\times8\times3.1416}{10\times16\times42}=3.179 \text{ in. per min.}$$

Draft.—The following examples illustrate the manner of finding the draft:

Example 1.—Find the draft between the lap roll and feed-roll, referring to Fig. 2 for data.

Solution.— $\frac{2.5\times48}{6\times17}=1.176$, draft

EXAMPLE 2.—Find the draft between the feed-roll and doffer, using a 16 change gear at b_4.

SOLUTION.— $$\frac{24\times40\times120}{2.5\times40\times16}=72, \text{ draft}$$

EXAMPLE 3.—Find the draft between the doffer and the bottom calender roll.

SOLUTION.— $$\frac{3\times190}{24\times21}=1.13, \text{ draft}$$

EXAMPLE 4.—Find the draft between the bottom calender roll and the coiler calender rolls, when a 27-tooth gear on the calender-roll shaft drives a 17-tooth gear on the vertical shaft of coiler.

SOLUTION.— $$\frac{2\times24\times18\times27}{3\times24\times18\times17}=1.059, \text{ draft}$$

EXAMPLE 5.—Find the total draft of the card, figuring from the coiler calender rolls p_1, to the lap roll a, using a 16 change gear at b_4, and considering the vertical shaft of the coiler to be driven as stated in example 4.

SOLUTION.—

$$\frac{2\times24\times18\times27\times190\times40\times120\times48}{6\times24\times18\times17\times21\times40\times16\times17}=101.433, \text{ draft}$$

PROOF.—To prove that intermediate drafts equal total draft, $1.176\times72\times1.130\times1.059=101.325$.

Waste.—The amount of waste made in carding should not, as a rule, exceed 5% and the work of the card should be closely watched, especially in respect to the waste under the cylinder, which should be examined at frequent intervals to see whether it contains too much good cotton.

Production.—The production of the card varies according to the class of work, a good production on low numbers being from 700 to 1,000 lb. per wk.; for fine yarns it is much lower. The weights of delivered sliver suitable for certain classes of work are as given in the accompanying table.

Weight and Horsepower.—The weight of a single revolving-flat card is about 5,000 lb. It requires from $\frac{3}{4}$ to 1 H. P. to drive it after the initial strain of starting, which requires much greater power.

WEIGHTS OF COTTON CARD SLIVERS

Variety of Cotton	Numbers	Weight per Yard Grains
Average American	1s to 10s	70
	10s to 15s	65
	15s to 20s	60
	20s to 30s	55
	30s to 40s	50
Allan-seed and Peelers	40s to 60s	50
	60s to 70s	45
	70s to 100s	40
Egyptian	40s to 60s	55
	60s to 70s	50
	70s to 100s	45
Sea-Island	70s to 100s	35
	100s upwards	30

CARE OF CARDS

Stripping.—The number of times that a card should be stripped within a stated period depends on two factors. One is that the greater the weight of cotton that is put through the card per day, the more frequently it should be stripped; the other is that on fine work the clothing should be kept as free as possible from short fiber and particles of foreign matter, so that when running fine work the card should receive more frequent stripping, notwithstanding the fact that a lighter weight of cotton is being put through the card than in coarse work. It may be stated as a common practice that for fine work the card should be stripped three times a day unless a very large production is being obtained, when it is advisable to strip four or even five times per day; with a medium production and where a very high grade of work is not called for, it is not necessary to strip the cylinder and doffer more than twice a day.

Grinding.—*Grinding* is the process of sharpening the teeth of the card wire of the cylinder, doffer, or flats by means of rolls called *grinding rolls*, which are of two kinds—the dead roll and the traverse grinder. The *dead roll* consists principally of a hollow shell mounted on a shaft and covered with emery fillet wound spirally on its surface. When grinding, a slight traversing motion is given to the dead roll, which grinds the backs of the teeth with a slight tendency toward grinding the sides.

The *traverse grinder* consists of a roll about 4 in. wide covered with emery fillet and mounted so as to slide on a hollow barrel, or shell, of large diameter. Since the grinding roll presses against the clothing, the result of its traverse motion is to cause the teeth that are in contact with it to be bent, or inclined, toward the side of the card to which the roll is moving. The result of this is that the sides of the points of the teeth are ground down slightly, as well as the top of the points. In consequence of the roll being so narrow, it requires a longer time to grind the card with this mechanism than with the dead roll, other conditions being the same, but the results are so much better that it is very largely used. The length of time required for grinding depends to a great extent on the condition of the wire, since if the points of the teeth are dulled considerably, a longer time will be required than if the clothing is in comparatively good condition. The degree of coarseness of the emery on the grinding roll also governs, to some extent, the time required for grinding, since coarse emery cuts much faster than fine emery. The time is also governed by the extent of pressure exerted by the grinding roll on the clothing. If the grinding roll is set so that it presses heavily on the wire, the grinding will be accomplished in less time, although there is more danger of injuring the wire; such grinding is known as *heavy grinding.* If the grinding roll presses only lightly against the clothing, a greater time will be required to secure the proper point on the teeth, but there is less danger of injuring the wire; this method of grinding is spoken of as *light grinding.*

As a general rule it may be stated that from one-half to one working day, or from 5 to 10 hr., is the usual time required for properly grinding the cylinder and doffer of a card.

The interval between the times of grinding varies. Generally speaking, it is advisable to grind frequently and lightly rather than at more remote intervals and heavily.

Setting.—The setting of the different parts of the card requires careful attention and is one of the most important points in the management of the card room. The principal places where setting is required are as follows: between the cylinder and the flats, between the licker and the cylinder, and between the doffer and the cylinder. Other places for setting are between the mote knives and the licker, between the feed-plate and the licker, between the cylinder screen and cylinder, between the licker screen and the licker, between the back knife plate and the cylinder, between the front knife plate and the cylinder, between the flat-stripping comb and the flats, and between the doffer comb and the doffer.

The exact setting, or distance between certain parts, of the card is determined by the use of gauges; two, and in some cases three, kinds are used. The first one is about 9 in. long and $1\frac{3}{4}$ in. wide and contains four leaves pivoted together. These leaves are made of thin sheet steel and are usually $\frac{5}{1000}$, $\frac{7}{1000}$, $\frac{10}{1000}$, and $\frac{12}{1000}$ in. thick, respectively. The second gauge which is used exclusively for flat setting, consists of a strip of sheet steel about $2\frac{1}{2}$ in. long and $1\frac{1}{4}$ in. in width bent at right angles about $\frac{1}{2}$ in. from one end, with a handle attached to this end. The other end is the part used for setting and is usually $\frac{12}{1000}$, $\frac{10}{1000}$, or $\frac{8}{1000}$ in. thick. The third gauge consists of a quadrant or semicircle mounted on a shaft and is used for setting the top of the cylinder screen to the cylinder and licker, and also in some cases to set the licker screen to the licker.

Since the leaf and flat gauges are very thin, they are easily damaged, and in this condition are of little use, producing faulty settings; consequently, great care should be used to prevent the faces becoming dented, bent, or injured in any way.

The flats are set by means of the flat gauge described, while the card is stopped, and preferably when other machinery in the room is also stopped, so as to prevent any vibration of the floor. The flats are usually set about $\frac{10}{1000}$ in. from the cylinder at the heel of the flat. The flats at the front of the card should be set the closest to the cylinder, while the space between the flats and the cylinder should gradually increase toward the back. If a No. 10 gauge is used, the flats at the back are set loosely to the gauge; those at the top and center, a little closer; and those at the front are set still closer.

The leaf gauge is used for setting the licker and it is generally set to the cylinder with a No. 10 gauge.

The doffer is usually set to the cylinder with a No. 5 or No. 7 leaf gauge by inserting the gauge between the doffer and the cylinder where they are closest. When a No. 7 gauge is used, the doffer is usually set tight to the gauge.

The position of the doffer with relation to the cylinder is an important matter and should receive careful attention. If the doffer is set too far away from the cylinder, a patchy or cloudy web will result, owing to the doffer not taking the fibers evenly from the cylinder.

The mote knives are set to the licker by means of the leaf gauge and the number of the gauge varies from 12 to 17.

The leaf gauge is used to set the feed-plate and is inserted between the licker and the face of the feed-plate. The number of the gauge varies from 12 to 20.

The cylinder screen is set farther from the cylinder at the front than at any other point, the distance being about .25 in., and the screen at the center and back is set about .032 in. from the cylinder. This arrangement prevents the ends of the fibers that have been thrown out by centrifugal force from coming in contact with the front edge of the screen and thus being removed from the cylinder as fly, which would readily occur if this setting were too close.

As the licker and cylinder screens are very close to each other at their nearest point, and as the front end of the licker screen must be set only a short distance below this point, it is nearly impossible to make an accurate setting with the licker in position. The best method is to remove the licker and use a quadrant gauge, the curvature of the outside surface of which should correspond exactly to the curvature of the surface of the licker. This gauge is mounted loosely on a shaft of exactly the same size as the licker shaft. The ends of the shaft rest in the licker bearings and the screens are set to the proper distance from the quadrant gauge by sliding the quadrant along the shaft. The front edge of the licker screen at the point where it is hinged to the cylinder screen is usually set about .011 in. from the licker. The nose, or portion of the licker screen with which the fibers first come in contact, is set $\frac{1}{32}$ to $\frac{1}{8}$ in. from the teeth of the licker, according to the amount of cleaning action desired at this point and the staple of the cotton being used.

The back knife plate is set to the cylinder to about a No. 17 leaf gauge at the lower edge and a No. 32 at the upper edge. This allows the fibers to free themselves and stand out a little from the cylinder before coming in contact with the flats.

The front knife plate is also set with the leaf gauge, its distance from the cylinder at the lower edge being about .017 in. The space between the upper edge of the plate and the cylinder depends on the amount of waste that it is desired to remove as flat strippings, but the usual setting is about .032 in. If the plate is set farther from the cylinder, more and heavier strippings will be made, and if moved too far away, the strips will form one continuous web instead of being connected by merely a few fibers. If the plate is set too close, some of the short fibers and dirt removed from the cotton by the flats will in turn be taken from the flats by the knife and carried around by the cylinder, thus producing bad work.

The distance between the toe of the flat and the stripping comb is determined with the leaf gauge and is usually about .007 in.; although this setting should be close enough to allow the comb to remove the strippings from the flats, it should not be so close that the comb will strike the wire and damage it.

The doffer comb is usually set to the doffer at the point where they are closest to a No. 7 leaf gauge.

The doffer comb, in addition to being adjustable as to its distance from the doffer, is adjustable as to the position of its stroke, which is changed by altering the relative positions of the comb and the eccentric from which it receives its motion. If the web should follow the doffer instead of being removed by the comb, the position of the stroke should be lowered; if the web sags between the doffer and the trumpet, as it sometimes does, owing to atmospheric changes, etc., the position of the stroke should be raised.

The settings given are used only as a basis. The settings of the various parts of the card vary according to the stock being used and the quality and kind of finished work.

Management.—In the management of cards many points should be watched, but more especially those that have for their objects: (1) the production of good work; (2) turning off as large a production as is consistent with the quality of the work required; (3) economy by avoiding unnecessary waste and keeping down the expenses of wages, power, supplies, etc.; (4) maintaining the machinery in good condition.

DRAWING ROLLS

COMMON ROLLS

The principle of roll drafting is the most important feature of parallelizing and attenuating machinery. Drawing rolls are of two kinds—common and metallic.

Common top rolls are made in short lengths and are covered with leather. Bottom rolls of the common type are almost always constructed of steel, and are fluted; that is, grooves are cut lengthwise in the surface of the rolls at certain intervals. These flutes aid the bottom rolls in obtaining a better grip on the cotton as it passes between them and the top rolls. Top rolls may be made with one or two bosses, being known as *single-boss* and *double-boss*, respectively; the boss in both single- and double-boss rolls may be detachable. When the boss of a roll is detachable, the roll is known as a *loose-boss*, or *shell, roll;* when the boss is not detachable, the roll is known as a *solid roll.*

Covering of Top Rolls.—As two metal rolls revolving in contact would tend to crush the delicate cotton fibers, a leather covering is necessary for top rolls of the common type. The iron surface of the roll is first covered with a specially woven woolen cloth, which is cemented to the roll, giving a good, elastic foundation. When a thin leather covering that fits very tightly is drawn over this foundation, the roll is capable of gripping the fibers and, owing to the yielding quality of the leather and cloth, does not damage them.

The cloth that lies underneath the leather should be made of the finest and best wool, and it should not be possible to detect by the hand the slightest variation of thickness. In mills covering their own rolls, the old leather should be removed and the cloth carefully examined. If it shows any evidence of disintegration, or wear, or an uneven surface, it should be condemned and removed. When rolls are sent out to be covered, it is considered advisable to cut the cloth with a knife in order to prevent the same cloth being used again.

In covering rolls, the cloth is cut into strips slightly narrower than the boss of the roll. A strip of this cloth is then laid flat on a table and a clean roll, the boss of which is covered with glue, is placed on the end of the strip and the cloth wound on the roll. The roll during this operation should be neither hot nor cold—simply warm. The cloth is cut with a sharp knife at the point where it begins to pass around the roll the second time. After the cloth is put on and the seam pressed together with the fingers, the roll should be put into evening, or smoothing, rolls for the purpose of smoothing out any lumps or foreign matter that may have been in the glue, thereby producing a perfectly true and even surface.

The substance that is most suitable for covering top rolls is the skin of the lamb or the sheep, or the skin of the goat. The outside layer of these skins is thin, tough, and very elastic. The color should be taken into consideration when selecting a skin. English skins usually have a color known as the natural oak-bark color, which is a light brown; a reddish color is given to others by means of dye. American skins are usually of a dark-cream color. The darker the shades the more the grain defects are hidden from view.

The size and color of skins depend on the size and age of the animal from which they are obtained. Lambskin is used for the more delicate work, as it is finer than sheepskin; sheepskin is used for the coarser work.

When placing the leather covering on rolls, the skins are cut into strips rather wider than the boss of the roll so as to allow for burning off the ends. The strips are next cut into small pieces just sufficient to fold around the boss of the roll, and their ends are beveled to make a joint that will not be perceptible to the touch. The beveled ends are then carefully joined together with cement. The leather tube, or cot, is placed in a press for a short time in order to insure a perfect joint.

The next operation is to draw the cot over the boss of the roll—an operation somewhat similar to drawing the finger of a glove on the finger. The roll is then revolved at a high rate of speed and any part of the leather that projects over the boss is burned off by friction with a piece of hard wood. The charred portion of the skin forms a collar at the ends of each boss. The roll must be placed in the machine so that it will not run against the joint, and in some cases the way the lap runs is marked by a dot of ink on the grain side of the skin. In putting cots on double-boss rolls care should be taken that the bevels run the same way and that the cots are of the same thickness.

Varnishing of Top Rolls.—It is the general practice in almost all mills to varnish the rolls that perform the heaviest work; namely, the rolls of the drawing frame, comber, sliver lap, ribbon lap, and in some cases the slubber. Varnished rolls should present a smooth, hard surface that has dried without cracking and that does not cause fiber or dust to adhere to it. Almost every mill has its own system of preparing varnish, and roll coverers have for sale various compositions for this purpose. Three recipes for preparing varnish are:

1. 9 oz. of fish glue; 2 qt. of acetic acid; 2 teaspoonfuls of oil of Origanum. This mixture should stand for about 2 da. in order that the glue may be thoroughly dissolved, after which it may be thickened with fine powdered paint of any color that may be desired.

2. $1\frac{1}{2}$ lb. of fish glue; $\frac{1}{2}$ lb. of gum arabic; $\frac{1}{4}$ lb. of powdered alum; 2 lb. of acetic acid; 4 lb. of water. This mixture should be thoroughly dissolved over a slow fire, after which it may be thickened with paint in the same manner as in the first recipe.

3. 1 oz. of ordinary glue; $\frac{1}{4}$ oz. of fish glue; $\frac{1}{4}$ oz. of gum arabic. This mixture should be dissolved in $2\frac{1}{2}$ gi. of water and allowed to simmer for 1 hr. over a slow fire, after which 6 oz. of thoroughly ground paint of any color may be added to thicken it.

Generally one coat of varnish is put on the rolls, although sometimes where fine numbers are required, two coats are put on, and two or even three coats are put on new or newly-covered rolls before they are put into the frame.

METALLIC ROLLS

The most practical substitute for common rolls is to have flutes in a top steel roll corresponding to those in a bottom roll. The flutes of the rolls mesh together, but in order to prevent the teeth of one roll from reaching to the bottom of the spaces between the teeth of the other roll, the rolls are held slightly apart by collars. On a 16-pitch roll the diameter of the collars is .07 in. less than the diameter of the fluted section, and as both rolls are the same, the amount of overlap is .07 in. With a 24-pitch roll the collars are .06 in. less in diameter than the fluted section, and on a 32-pitch roll they are .044 in. less. Thus, the amount of overlap with 24-pitch rolls is .06 in. and with 32-pitch rolls, .044 in. This amount of overlap is sufficient to grip the sliver.

Advantages of Metallic Rolls.—The top rolls of a metallic set are positively driven by the flutes of the lower roll meshing with the flutes of the upper roll. The cost of roll covering and subsequent varnishing is saved, and the bad work that arises from imperfectly varnished rolls is entirely obviated.

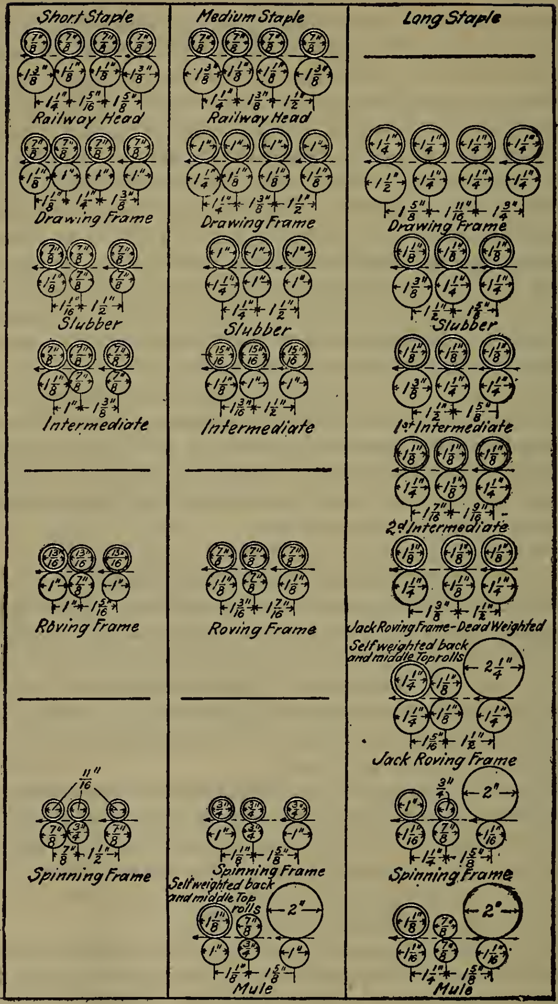
It is claimed that, as metallic rolls run on collars, friction is greatly reduced; that licking, from the presence of electricity and atmospheric changes, is prevented and that consequent waste is avoided. However, metallic rolls at the present time are not used to any large extent except on drawing frames, sliver-lap machines, and slubbers.

SETTING OF DRAWING ROLLS

One of the most important points in relation to drawing rolls is the position of one pair of rolls relative to another, which is governed by the length of the staple and bulk of cotton being used. In setting rolls, there is one broad principle that must always be followed: the distance between the centers of each pair of rolls must always exceed the average length of the staple of the cotton being used.

Rapidly-revolving rolls, also, require wider settings than those having slow speed. When the ends put up at the back are heavily twisted, the settings are wider on the same machine than when the ends fed are slightly twisted. Harsh, wiry cotton requires wider settings than smooth, silky cotton, because it does not draw so easily.

As the rolls are set according to the staple of the cotton used, it is evident that the rolls intended to run on coarse counts from short-staple cotton, must be smaller in diameter than those


Short Staple
Medium Staple
Long Staple
Railway Head
Railway Head
Drawing Frame
Drawing Frame
Drawing Frame
Slubber
Slubber
Slubber
Intermediate
Intermediate
1st Intermediate
2d Intermediate
Jack Roving Frame-Dead Weighted
Roving Frame
Roving Frame
Self weighted back and middle Top rolls
Jack Roving Frame
Spinning Frame
Spinning Frame
Spinning Frame
Self weighted back and middle Top rolls
Mule
Mule

intended to work long-staple cotton, in order that the centers of the rolls may be brought near enough together. The diagram given in the accompanying illustration shows the settings and diameters of rolls for different kinds of cotton. These settings will vary, however, according to conditions.

The settings given in the accompanying table for American cotton of about 1-in. staple are taken from actual measurements in a mill making an average of 32s.

DRAWING-ROLL SETTINGS FOR AMERICAN COTTON

	Speed of Front Roll	Weight of Sliver at Back	Distance Between Centers		
			Front and Second Inches	Second and Third Inches	Third and Back Inches
First drawings...	411	68 grains	$1\frac{7}{16}$	$1\frac{5}{8}$	$1\frac{3}{4}$
Second drawings.	411	68 grains	$1\frac{7}{16}$	$1\frac{5}{8}$	$1\frac{5}{8}$
Third drawings..	411	68 grains	$1\frac{3}{8}$	$1\frac{5}{8}$	$1\frac{5}{8}$
Slubbing........	162	68 grains	$1\frac{1}{4}$	$1\frac{3}{4}$	
Intermediate....	143	.57-hank	$1\frac{3}{16}$	$1\frac{5}{8}$	
Roving.........	116	1.61-hank	$1\frac{1}{8}$	$1\frac{9}{16}$	
Spinning.......	125	5- hank	$1\frac{1}{16}$	$1\frac{3}{8}$	

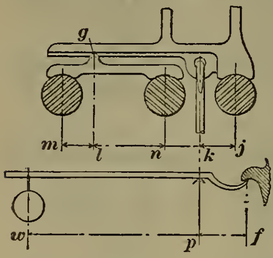
Each case of roll setting must be judged by its requirements. The table shows ordinary settings on the intermediates, roving, and spinning, and excessively wide settings on the drawing and slubber on account of the unusually heavy sliver and high speed.

WEIGHTING OF TOP ROLLS

In order to maintain a grip on the fibers, the top rolls must have a constant pressure on the bottom rolls. This pressure is maintained by means of weights, light weights being applied to slow-running frames and heavier ones to frames where the rolls run at high speeds.

Self-weighting consists of having the top roll heavy enough to maintain the necessary pressure on the fiber, and is used on the center and back rolls of fine roving frames, spinning frames, and mules intended for very fine spinning.

Dead weighting consists of hanging a weight of suitable magnitude directly from the top roll.



Lever weighting, which is a form of dead weighting, consists of exerting pressure by means of a weight acting through a lever. By this means a smaller weight may be used and the same pressure obtained as when a larger weight is employed in the system of dead weighting.

This will be made more clear by reference to the accompanying illustration, and the following data: The weight of w is 4 lb.; the distance of wf is $7\frac{1}{2}$ in.; pf, $\frac{3}{4}$ in.; jk, $\frac{5}{8}$ in.; kl, $1\frac{3}{8}$ in.; lm, $\frac{1}{2}$ in.; mn, $1\frac{1}{2}$ in.; ln, 1 in.; jl, 2 in. The total pressure will equal

$$\frac{\text{Weight}\times wf}{pf}=\frac{4\times 7\frac{1}{2}}{\frac{3}{4}}=40 \text{ lb., total weight on all rolls}$$

Part of this 40 lb. will be distributed on j and the remainder on the point g.

The pressure on j will equal

$$\frac{kl\times 40}{jl}=\frac{1\frac{3}{8}\times 40}{2}=27\frac{1}{2}\text{ lb.}$$

The pressure at g equals $40-27\frac{1}{2}=12\frac{1}{2}$ lb., or the pressure at g will equal

$$\frac{jk\times 40}{jl}=\frac{\frac{5}{8}\times 40}{2}=12\frac{1}{2}\text{ lb.}$$

The pressure at n will equal

$$\frac{lm\times 12\frac{1}{2}}{mn}=\frac{\frac{1}{2}\times 12\frac{1}{2}}{1\frac{1}{2}}=4.166\text{ lb.}$$

The pressure at m will equal $12\frac{1}{2}-4.166=8.33$ lb., or the pressure at m will equal

$$\frac{ln\times 12\frac{1}{2}}{mn}=\frac{1\times 12\frac{1}{2}}{1\frac{1}{2}}=8.33\text{ lb.}$$

Metallic drawing rolls require less weighting than common drawing rolls. The principal reason for this is that the former grip and hold more securely the fibers being operated on than do the latter. This is due to the fact that both the top and bottom rolls are fluted in the case of metallic rolls and the flutes interlocking results in the fibers being more securely held. When common rolls are used, the top roll must be weighted sufficiently to cause it to press firmly on the bottom roll in order that the fibers may be properly gripped. An example of the relative weighting of metallic rolls and common rolls, assuming that drawing frames are being considered, is as follows:

Single-Boss Metallic Rolls

Front rolls,	36 lb.	(18 lb. at each end)
Second roll,	32 lb.	(16 lb. at each end)
Third roll,	28 lb.	(14 lb. at each end)
Back roll,	28 lb.	(14 lb. at each end)

Single-Boss Common Rolls

Front roll,	44 lb.	(22 lb. at each end)
Second roll,	40 lb.	(20 lb. at each end)
Third roll,	36 lb.	(18 lb. at each end)
Back roll,	32 lb.	(16 lb. at each end)

This weighting is subject to some variation, of course, depending on the character of the stock being run, etc.

SCOURING ROLLS

The cleanliness of the fluted as well as the leather-covered rolls is an important matter, since if the dirt and other foreign matter that collects in the flutes and bearings of the rolls is not removed, considerable waste and consequent loss of production and bad work will result.

After the rolls have been removed they should be rubbed with a piece of card fillet in order to remove any dirt, hard oil, or other substances that may collect in the flutes. After cleaning the roll in this manner it should be covered with a paste made of oil and whiting and thoroughly scoured by rubbing with another piece of card fillet, care being taken not to rub around the circumference of the roll but lengthwise, so that the wires of the card fillet will follow the grooves of the flutes and clean them.

After this the roll should be wiped with a piece of dry waste, covered with dry whiting, in order to thoroughly dry the flute before the rolls are replaced. In some cases dry whiting is used in place of the paste. Care should be taken not to allow any of the whiting to collect in the flutes or bearings of the roll.

After the rolls have been scoured they should be examined in order to ascertain whether there are any rough places; if any are found they should be smoothed by using a piece of pumice stone, a piece of very fine emery cloth, or a fine flute file. In most cases the pumice stone or emery cloth will be found sufficient, and the file should not be used unless absolutely necessary.

DRAWING FRAMES

The drawing frame follows the card, except when combed yarn is being made, when it follows the comber.

The objects of the drawing frame are to lay the fibers parallel and to correct, so far as possible, any unevenness in the sliver. These objects are accomplished by drafting and doubling.

The number of drawing frames through which the cotton is passed is governed by the class of work to be produced and the number of preceding processes through which the cotton has passed. If the sliver comes direct from the cards there are usually two processes for coarse counts, three for medium counts, and four for fine counts. If the sliver has passed through the sliver- and ribbon-lap machines and the comber, there are generally only two processes unless for very high counts, when three, and even four, are used.

Fig. 1 is a cross-section of one delivery of a drawing frame; the arrows in this figure indicate the direction in which the stock passes through the machine. Usually six cans similar to *a* are placed behind each delivery, each sliver passing through the guide *b*, over the plate *c*, and the spoon *d*, there being one spoon for each sliver. The slivers next pass over another guide plate *e* and then to the four sets of rolls, f, f_1, f_2, f_3, where the necessary draft is inserted. From these drawing rolls the slivers pass to the trumpet *g*, where they are combined into one, then through the calender rolls h, h_1, through the coiler tube *i*, and to the can *j*.

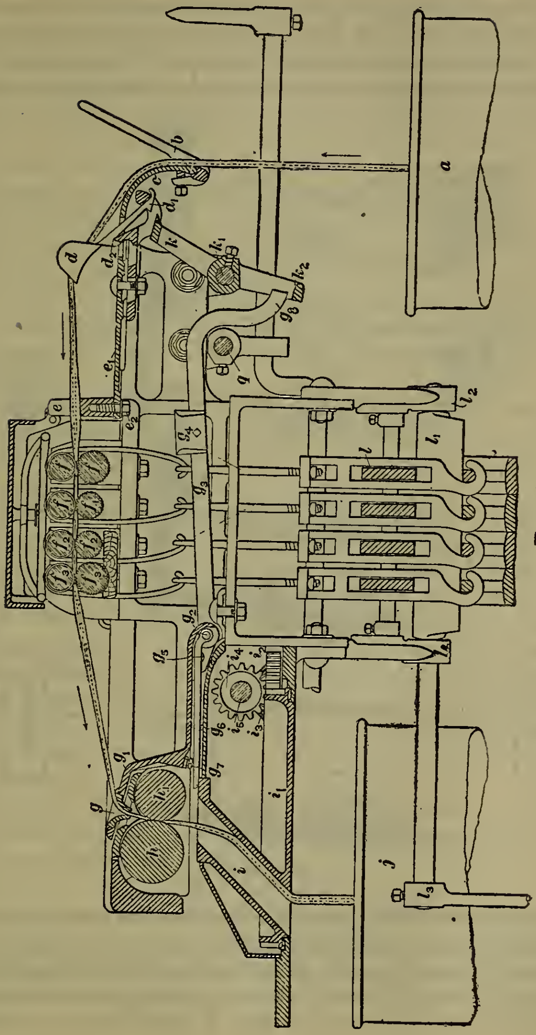


FIG. 1

The drawing rolls are of the ordinary type; leather-covered top rolls are shown in this illustration, although for coarse work metallic rolls are generally preferred. The top rolls are weighted in the manner usually adopted for weighting leather-

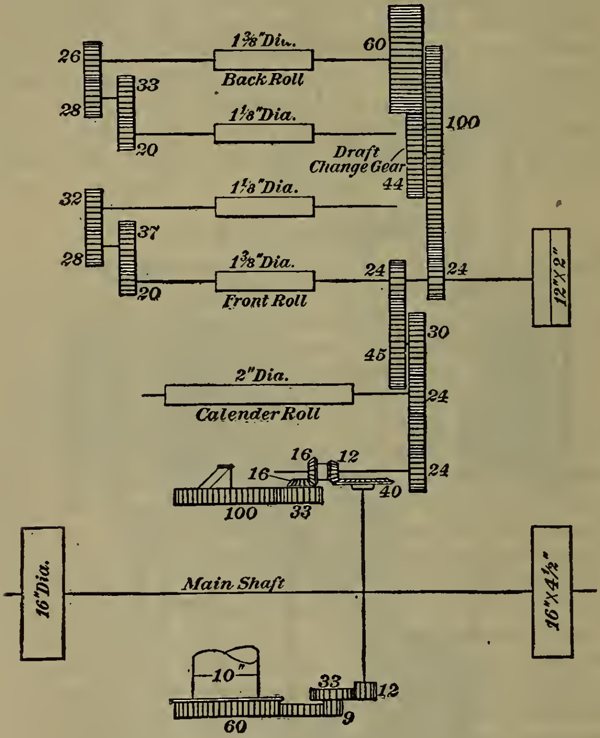


FIG. 2

covered rolls on drawing frames. The weighting arrangement is equipped with a weight-relieving motion, as shown at l, l_1, l_2, l_3. The draft inserted in the sliver by these rolls, though not arbitrary, is usually about equal to the number of doublings, thus producing a sliver at the front of about the same weight as each end fed in at the back. If one of the cans at the back should become empty or if one of the slivers should break before reaching the back rolls and the machine should continue to run, the reduced weight of the sliver delivered at the front would tend to produce unsatisfactory work at the later processes. As it is of vital importance to have the sliver that comes from the drawing frame of a uniform weight, devices are applied to stop the machine when an end breaks or runs out at the back. Additional mechanisms are also applied to stop the machine when the sliver breaks between the front rolls and calender rolls, when the cans at the front of the machine become full, and in some cases when any part of the cotton laps around the calender or the drawing rolls. There are two general classes of stop-motions applied to drawing frames—mechanical and electrical.

Gearing.—Each head in a drawing frame is driven separately from any other head in regard to its individual gearing, but all the heads are driven by the lower or main shaft, which runs underneath the frame.

Referring to Fig. 2, a gear of 24 teeth on the front roll drives, by means of suitable gearing, the calender rolls and the coiler connections. Another gear of 24 teeth, situated on the front roll, drives the back roll. The gear of 26 teeth on this back roll drives the third roll. Thus, the draft between these two rolls is constant, provided that the gears connecting the rolls are not changed. The gear of 20 teeth on the front roll drives the second roll, and consequently the draft between these two rolls is also constant. Thus, it will be seen that the break draft of this machine comes between the second and third rolls.

The draft of a drawing frame with common rolls, and geared as shown in Fig. 2, is as follows, the draft being figured from the calender roll to the back roll:

$$\frac{2\times 30\times 24\times 100\times 60}{24\times 45\times 24\times 44\times 1\frac{3}{8}}=5.509$$

Production.—The accompanying table shows the number of pounds of drawing sliver produced in a day of 10 hr., allowing 20% for cleaning, oiling, etc.

PRODUCTION OF DRAWING FRAMES

Rev. of Front Roll per Min.	Number of Grains in 1 Yard of Sliver											
	40		45		50		55		60		65	
	Com. Roll	Met. Roll	Com. Roll	Met. Roll	Com. Roll	Met. Roll	Com. Roll	Met. Roll	Com. Roll	Met. Roll	Com. Roll	Met. Roll
250	85.3	111.7	96.0	125.7	106.6	139.6	117.3	153.6	127.9	167.5	138.6	181.5
260	88.7	116.2	99.8	130.7	110.9	145.2	122.0	159.7	133.1	174.2	144.1	188.8
270	92.1	120.6	103.6	135.7	115.1	150.8	126.7	165.9	138.2	180.9	149.7	196.1
280	95.5	125.1	107.5	140.7	119.4	156.4	131.4	172.0	143.3	187.6	155.2	203.3
290	98.9	129.6	111.3	145.8	123.7	162.0	136.1	178.1	148.4	194.4	160.8	210.5
300	102.4	134.0	115.1	150.8	127.9	167.5	140.7	184.3	153.5	201.1	166.3	217.8
310	105.8	138.5	119.0	155.8	132.2	173.1	145.4	190.4	158.7	207.8	171.9	225.1
320	109.2	143.0	122.8	160.8	136.5	178.7	150.1	196.6	163.8	214.5	177.4	232.3
330	112.6	147.4	126.7	165.9	140.7	184.3	154.8	202.7	168.9	221.2	183.0	239.6
340	116.0	151.9	130.5	170.9	145.0	189.9	159.5	208.9	174.0	227.9	188.5	246.9
350	119.4	156.4	134.3	175.9	149.3	195.5	164.2	215.0	179.1	234.6	194.1	254.1
360	122.8	160.8	138.2	180.9	153.5	201.1	168.9	221.2	184.2	241.3	199.6	261.4
370	126.2	165.3	142.0	186.0	157.8	206.6	173.6	227.3	189.4	248.0	205.1	268.6
380	129.6	169.8	145.9	191.0	162.1	212.2	178.3	233.4	194.5	254.7	210.7	275.9
390	133.0	174.2	149.7	196.0	166.3	217.8	183.0	239.6	199.6	261.4	216.2	283.2
400	136.5	178.7	153.5	201.1	170.6	223.4	187.7	245.7	204.7	268.1	221.8	290.4
410	139.9	183.2	157.4	206.1	174.9	229.0	192.3	251.9	209.8	274.8	227.3	297.7
420	143.3	187.7	161.2	211.1	179.1	234.6	197.0	258.0	215.0	281.5	232.9	304.9
430	146.7	192.1	165.1	216.1	183.4	240.1	201.7	264.2	220.1	288.2	238.4	312.2
440	150.1	196.6	168.9	221.2	187.7	245.7	206.5	270.3	225.2	294.9	243.9	319.5
450	153.5	201.1	172.7	226.2	191.9	251.3	211.1	276.5	230.3	301.6	249.5	326.7

MANAGEMENT OF DRAWING FRAMES

If empty cans are inserted at the front of a drawing frame at the same time and if they are all taken out at once and fed immediately to the next machine at the same time, it is evident that they will all be emptied at about the same time, necessitating several piecings in a short length of sliver. To remedy this defect, it is better to feed the frames in sections so that some of the cans at the back of any drawing frame will be full, others three-fourths full, still others half full, and so on.

It is the general plan in the drawing frame not to have the draft exceed the doubling; that is, if 6 ends are put up at the back of each delivery, the draft is not generally more than 6.

Both top and bottom metallic rolls should receive careful attention to prevent licking. In this respect metallic rolls require cleaning oftener than common rolls.

Before the leather top rolls are put into the drawing frame, they must be varnished, the frequency of subsequent varnishing depending on the varnish used, the weight of sliver produced, and the speed at which the rolls are run. Any roughness on the surface of these rolls causes licking.

The drawing frames should be kept free from dirt, dust, and short fiber. Oil should not be allowed in places where it is not required. In order to insure clean work, the tender should wipe or brush the frames about every two hours.

A thorough cleaning of all parts of the frame should take place twice a week.

Weighing the sliver at the finisher drawing frame is a very important matter and should be done at least twice a day; in fine work three, and sometimes four, times a day is advisable.

COMBING

For warp yarns finer than 45s and filling yarns finer than 90s, or even for coarser numbers than these when a high grade of yarn is required, it is customary, in addition to the selection of the proper stock, to remove by the process of combing all fibers that are not of the required length.

The process of combing is usually performed immediately after carding and before the drawing process, although in some cases one drawing process is used between the carding and the combing process.

A combing equipment usually includes three kinds of machines: (1) the sliver-lap machine, which has for its object the making of a lap from a number of card slivers; (2) the ribbon-lap machine, the object of which is to combine several of the laps from the sliver-lap machine into a firm and even lap; (3) the comber, the object of which is to remove all fibers that are under a length suitable for the yarn required.

When the drawing frame is introduced, the combing equipment generally consists of drawing frames, sliver-lap machines, and combers.

SLIVER-LAP MACHINE

Before cotton can be combed, it must be placed in the form of a lap for the combing machine, and for this purpose the sliver is taken in cans, either from the card or drawing frame, to the sliver-lap machine.

From 14 to 18 cans of sliver are placed at the back of this machine, the number being governed by the width of lap required, which is usually $7\frac{1}{2}$, $8\frac{3}{4}$, or $10\frac{1}{2}$ in. These slivers are run through the sliver-lap machine and after being subjected to a slight drafting action emerge in the form of a compact lap. This machine is fitted with two stop-motions, one to stop the machine when an end of sliver breaks at the back and the other to stop the machine when the lap is full.

Fig. 1 is the plan of gearing for a sliver-lap machine; the draft, figured from the front fluted calender roll to the back drawing roll, is as follows:

$$\frac{12\times21\times12\times72\times21\times26\times24\times64}{21\times72\times29\times21\times50\times41\times33\times1\frac{1}{2}}=1.954$$

The amount of draft on these machines is usually from 1.75 to 2.5.

Production.—The accompanying table shows the production of the sliver-lap machine per day of 10 hr., allowing 25% for oiling, cleaning, etc.

RIBBON-LAP MACHINE

It is not absolutely necessary to use a ribbon-lap machine in the combing process, as the laps from the sliver-lap machine

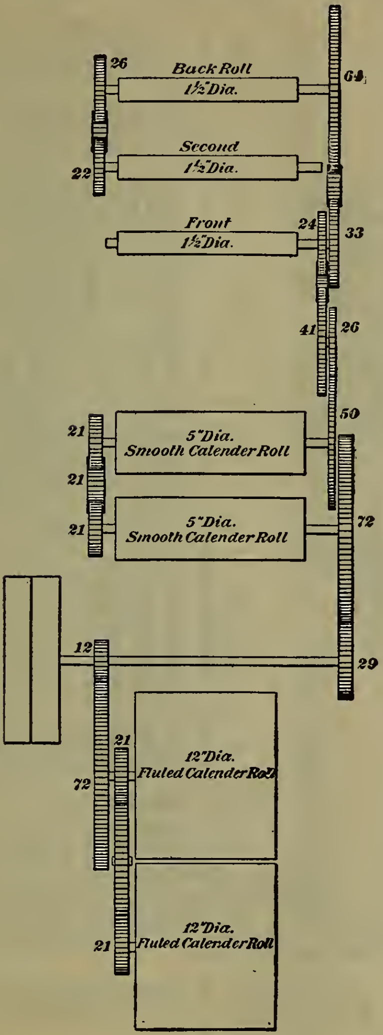

26
Back Roll
1½" Dia.
64
Second
1½" Dia.
22
Front
1½" Dia.
24
33
41
26
50
21
5" Dia.
Smooth Calender Roll
21
21
5" Dia.
Smooth Calender Roll
72
12
29
21
12" Dia.
Fluted Calender Roll
72
12" Dia.
Fluted Calender Roll
21

FIG. 1

PRODUCTION OF SLIVER-LAP MACHINE

Rev. per Min. of 5 In. Calender Roll	Grains per Yard of Lap Produced											
	360	370	380	390	400	410	420	430	440	450	460	470
	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.
85	858.5	882.3	906.1	929.9	953.7	978.3	1001.3	1025.9	1049.7	1073.5	1097.3	1121.1
90	909.0	934.2	959.4	984.6	1009.8	1035.9	1062.2	1086.3	1111.5	1136.7	1161.9	1187.1
95	959.5	986.1	1012.7	1039.3	1065.9	1093.4	1119.1	1146.9	1173.2	1199.8	1226.4	1253.0
100	1010.0	1038.0	1066.0	1094.0	1122.0	1151.0	1178.0	1207.0	1235.0	1263.0	1291.0	1319.0
105	1060.5	1089.9	1119.3	1148.7	1178.1	1208.5	1236.9	1267.3	1296.7	1326.1	1355.5	1384.9
110	1111.0	1141.8	1172.6	1203.4	1234.2	1266.1	1295.8	1327.7	1358.5	1389.3	1420.1	1450.9
120	1212.0	1245.6	1279.2	1312.8	1346.4	1381.2	1413.6	1448.4	1482.0	1515.6	1549.2	1582.8
130	1313.0	1349.4	1385.8	1422.2	1458.6	1496.3	1531.4	1569.1	1605.5	1641.9	1678.3	1714.7
140	1414.0	1453.2	1492.4	1531.6	1570.8	1611.4	1649.2	1689.8	1729.0	1768.2	1807.4	1846.6
150	1515.0	1557.0	1599.0	1641.0	1683.0	1726.5	1767.0	1810.5	1852.5	1894.5	1936.5	1978.5

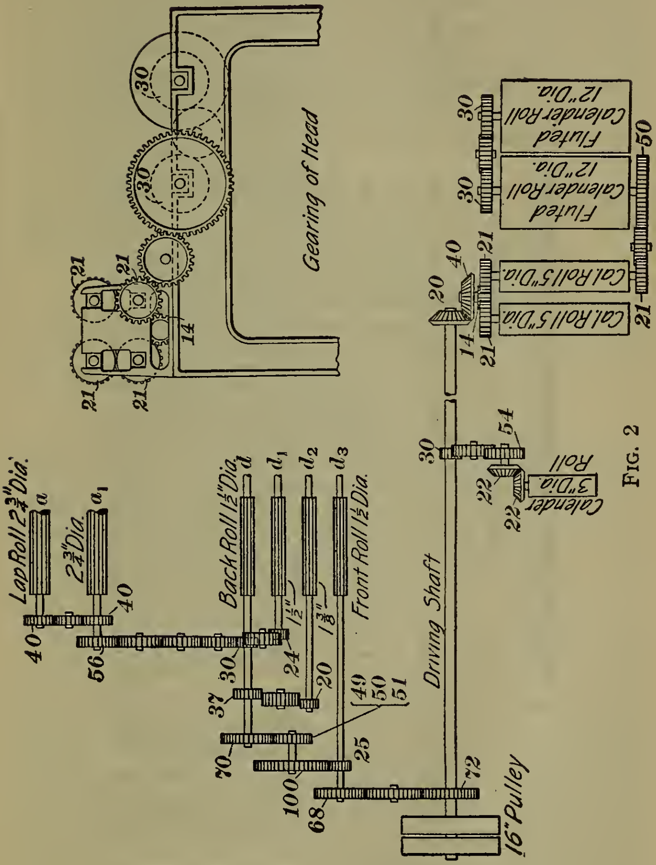

Gearing of Head
Lap Roll 2¾" Dia.
2¾" Dia.
Back Roll 1½" Dia.
Front Roll 1½" Dia.
Driving Shaft
16" Pulley
Fluted Calender Roll 12" Dia.
Fluted Calender Roll 12" Dia.
Cal. Roll 5" Dia.
Cal. Roll 5" Dia.
Calender Roll 3" Dia.

Fig. 2

PRODUCTION OF RIBBON-LAP MACHINE

Rev. per Min. of 5 In. Calender Roll	Grains per Yard of Lap Produced											
	410	420	430	440	450	460	470	480	490	500	510	520
	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.
85	978.3	1001.3	1025.9	1049.7	1073.5	1097.3	1121.1	1144.9	1168.8	1192.6	1216.4	1240.2
90	1035.9	1060.2	1086.3	1111.5	1136.7	1161.9	1187.1	1212.3	1237.5	1262.7	1287.9	1313.1
95	1093.4	1119.1	1146.6	1173.2	1199.8	1226.4	1253.0	1279.6	1306.3	1332.9	1359.5	1386.1
100	1151.0	1178.0	1207.0	1235.0	1263.0	1291.0	1319.0	1347.0	1375.0	1403.0	1431.0	1459.0
105	1208.5	1236.9	1267.3	1296.7	1326.1	1355.5	1384.9	1414.3	1443.8	1473.2	1502.6	1532.0
110	1266.1	1295.8	1327.7	1358.5	1389.3	1420.1	1450.9	1481.7	1512.5	1543.3	1514.1	1604.9
120	1381.2	1413.6	1448.4	1482.0	1515.6	1549.2	1582.8	1616.4	1650.0	1683.6	1717.2	1750.8
130	1496.3	1531.4	1569.1	1605.5	1641.9	1678.3	1714.7	1751.1	1787.5	1823.9	1860.3	1896.7
140	1611.4	1649.2	1689.8	1729.0	1768.2	1807.4	1846.6	1885.8	1925.0	1964.2	2003.4	2042.6
150	1726.5	1767.0	1810.5	1852.5	1894.5	1936.5	1978.5	2020.5	2062.5	2104.5	2146.5	2188.5

may be taken directly to the comber. If, however, the lap from the sliver-lap machine is unrolled for about a yard and held to the light, it will be seen that the slivers merely lie side by side, and that the lap is uneven, showing both thick and thin places. Therefore, to have a more even lap, the ribbon-lap machine is used. The usual doubling on the ribbon-lap machine is 6 into 1, and the laps fed are generally 1 in. narrower than the laps to be made for the comber.

The draft between the front and back drawing rolls usually about equals the doublings.

Fig. 2 is the plan of gearing for a ribbon-lap machine; the draft, figured from the front fluted calender roll to the back drawing roll, with a 50-tooth draft gear, is as follows:

$$\frac{12\times30\times21\times14\times20\times68\times100\times70}{30\times50\times21\times40\times72\times25\times50\times1\frac{1}{2}}=5.923$$

Production.—The preceding table shows the production of the ribbon-lap machine per day of 10 hr., allowing 25% for oiling, cleaning, etc.

COMBER

The several actions of a comber must necessarily work intermittently and may be summarized as follows: (1) The feed-motion, by which the lap is fed to the machine; (2) the nipper motion, which holds the cotton during the combing operation; (3) the combing operation by the half lap; (4) the backward and forward motion of the delivery roll, or the piecing-up motion; (5) combing by the top comb; (6) the delivery of the stock to the calender rolls, draw-box, and coiler.

Fig. 3 shows in section the principal working parts of the single-nip comber. In order to bring the cotton into a position to be combed, it is first necessary that a certain length shall be delivered from the lap by the feed-rolls c, c_1. After the cotton has been fed by these rolls, the nipper knife d descends and not only grips it firmly but also, by depressing the cushion plate h, brings the fringe of cotton into a suitable position to be acted on by the needles o_7 of the half lap o_2. The cylinder o_1 is in such a position that, when the nipper knife d has completed its downward motion, the first row of needles on the half lap enters the end of the fringe of cotton, and, as the cylinder revolves, the successive rows of needles remove all the fibers that are too short to be retained by the nippers, as well as the neps that have been left in the cotton. After the needles on the half lap have passed the fringe of cotton, the ends of the fibers fall into the gap left between the needles and the fluted segment o_3, and the nipper knife, together with the cushion plate, begins to rise. When the cushion plate has reached its uppermost position, the further lifting of the nipper knife releases the fibers at this point. During this operation the portion of the

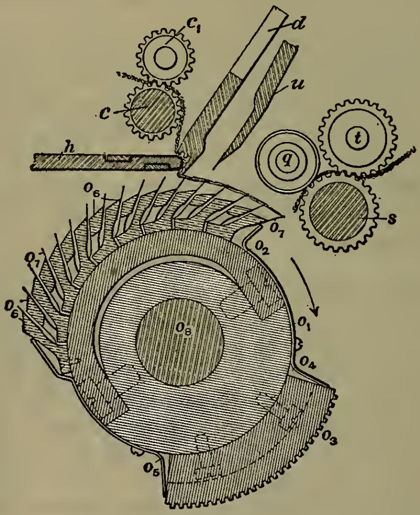


FIG. 3

cotton previously combed has been brought back and is now ready to be pieced up with the cotton that has just undergone the combing operation by the half lap.

The cylinder having revolved until the fluted segment is in the desired position, the detaching roll q descends and grips the cotton firmly between itself and the fluted segment. The further revolving of the fluted segment, together with the detaching roll, draws away the fibers that are not held by the grip of the feed-rolls, and since the top comb u has by this time dropped into such a position that it protrudes into the end of the lap just in advance of the portion that has not been cleaned by the needles of the half lap, it efficiently combs this portion of the fibers. At the beginning of this operation the forward ends of the fibers being combed are carried forwards sufficiently to overlap the rear ends of the fibers that were returned; consequently, the forward rotation of the delivery roll *s*, which occurs while the detaching roll is in contact with the segment, assists in piecing up the fibers just detached to those previously combed, and delivers them into the pan.

It should be clearly understood that all the fibers do not project from the feed-rolls to the same extent at one time. For example, some of the fibers may not be gripped by the feed-rolls at all, while others may project beyond the feed-rolls a quarter of their length, some half of their length, and some three-quarters of their length; consequently, when the detaching action takes place, only those fibers that project entirely beyond the feed-rolls are gripped and drawn forwards by the action of the detaching roll and fluted segment, and those that project only partly beyond and are still gripped by the feed-rolls form a fringe of cotton that is always present in front of the feed-rolls. At the next delivery of the feed-rolls those fibers that previously projected only partly beyond the rolls may now project entirely beyond the rolls, and consequently at the next detaching operation these fibers will be drawn forwards in a manner similar to those previously detached.

From the delivery roll, the cotton passes into a pan, through a trumpet, between the table calender rolls, and is delivered on to a table, along which it is drawn together with the other slivers that have been delivered by the various heads of the comber. From the table the slivers pass to a draw-box, where a slight draft is given to them, after which they pass through a trumpet and between a pair of calender rolls, where they are condensed into one sliver. From the calender rolls the sliver passes to a coiler and then into a can.

Double-Nip Comber.—The cylinder of a double-nip comber contains two half laps and two fluted segments, and the segments and half laps are arranged alternately on the cylinder with slight spaces between them. A comber with a double nip

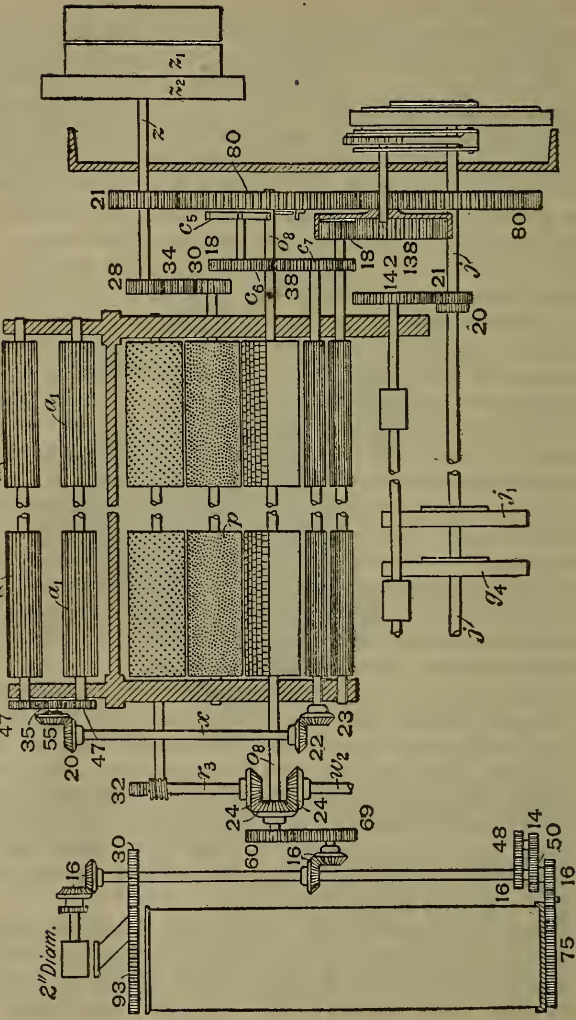


FIG. 4

PRODUCTION OF SINGLE-NIP COMBER

Nips per Min.	Grains per Yard of Combed Sliver												
	46	48	50	52	54	56	58	60	62	64	66	68	70
	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.
100	78.45	81.86	85.27	88.68	92.09	95.50	98.91	102.32	105.73	109.15	112.56	115.97	119.38
105	82.37	85.95	89.54	93.12	96.70	100.28	103.86	107.44	111.02	114.60	118.19	121.77	125.35
110	86.30	90.05	93.80	97.55	101.30	105.05	108.80	112.56	116.31	120.06	123.81	127.57	131.32
115	90.22	94.14	98.06	101.98	105.90	109.83	113.75	117.67	121.59	125.52	129.44	133.36	137.28
120	94.14	98.23	102.33	106.41	110.51	114.60	118.70	122.79	126.88	130.98	135.07	139.16	143.25
125	98.06	102.33	106.59	110.85	115.12	119.38	123.64	127.91	132.17	136.44	140.70	144.96	149.23
130	101.99	106.42	110.85	115.29	119.72	124.16	128.59	133.02	137.46	141.89	146.33	150.76	155.19
135	105.91	110.51	115.12	119.72	124.32	128.93	133.53	138.14	142.74	147.35	151.95	156.56	161.16
140	109.83	114.61	119.38	124.16	128.93	133.71	138.48	143.26	148.03	152.81	157.58	162.36	167.13

gives a greater production than a comber with a single nip, but does not clean the cotton so well, because of a smaller number of needles acting on the fringe.

Calculations.—The gearing of a single-nip comber is shown in Fig. 4. The draft for the gearing shown, with an 18-tooth draft change gear, figuring from the 2-in. coiler calender roll to the $2\frac{3}{4}$-in. lap roll at the back of the comber, is as follows:

$$\frac{2 \times 16 \times 16 \times 60 \times 5 \times 38 \times 22 \times 55 \times 47}{16 \times 16 \times 69 \times 1 \times 18 \times 23 \times 20 \times 35 \times 2\frac{3}{4}} = 23.579$$

As the comber removes a very large percentage of waste from the cotton that passes through it, it is not possible to figure accurately the weight of the sliver produced by simply

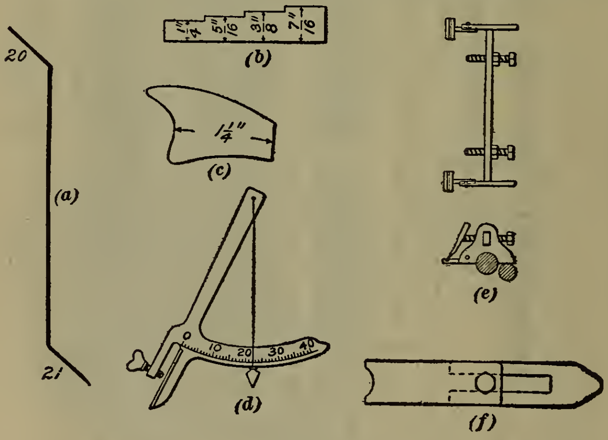


FIG. 5

taking into consideration the weight per yard of the lap fed in, the number of doublings, and the draft of the machine. An example will make this point clearer.

EXAMPLE.—Suppose that a comber with a draft of 23.579 has six laps up at the back, each lap weighing 260 gr. per yard, and it is desired to find the weight per yard of the sliver delivered.

SOLUTION.—Multiplying the weight per yard of the laps fed in by the number of laps, and dividing by the draft gives 66.1605 gr. as the weight per yard of the sliver delivered; $(260 \times 6) \div 23.579 = 66.1605$. If 20% of the cotton that passes through the machine is taken out as waste, the result obtained above must be diminished by 20% in order to obtain the actual weight per

COMBER SETTINGS

Parts to be Set	Gauge	Size of Gauge
Delivery roll from segment.	Comber	No. 23
Front flute of segment from delivery roll............	Finger	$1\frac{1}{8}$ in.
Feed-roll from delivery roll	Finger	According to staple
Cushion plate to nipper knife..................	With paper	
Distance of setscrew that governs position of cushion plate...............	Step	$\frac{1}{4}$ to $\frac{3}{8}$ in.
Cushion plate from delivery roll.............	Finger	According to staple
Distance of nipper from half lap when nipper is in its lowest position....	Comber	No. 20
Brush to half lap.........	Brush	
Top comb set at angle of from 25° to 30°.........	Quadrant	
Top comb from fluted segment..................	Comber	No. 20 or 21
Distance of lifter blocks from bearings of detaching roll when resting on segment...............	Comber	No. 23
Top roll from leather detaching roll.............	Comber	No. 21

yard of the sliver delivered; 20% of 66.1605 is 13.2321, which, deducted from 66.1605, gives 52.9284 as the grains per yard of the sliver produced.

Production.—The accompanying table shows the number of pounds of combed sliver produced per day of 10 hr., by the single-nip comber, allowing 5% for oiling, cleaning, etc.

Setting of Combers.—The several kinds of gauges used in setting a comber are shown in Fig. 5, and include the regular comber gauge (*a*), the step gauge (*b*), the finger gauge (*c*), the quadrant gauge (*d*), the cradle gauge (*e*), and the brush gauge (*f*).

Assuming that a comber has merely been set up and that the cylinders are loose on the cylinder shaft, the parts that require setting with gauges and the gauges used for making each setting are as given in the accompanying table.

The setting of the feed-roll from the delivery roll varies according to the staple and nature of the stock, as follows:

COMBER FEED-ROLL SETTING

Cotton	Length of Staple Inches	Size of Gauge Inches
American................	About $1\frac{1}{4}$	$1\frac{11}{16}$ to $1\frac{13}{16}$
Egyptian................	Up to $1\frac{1}{2}$	$1\frac{13}{16}$ to $1\frac{15}{16}$
Egyptian and sea-island...	$1\frac{1}{2}$ and longer	$1\frac{15}{16}$ to 2

The setting of the cushion plate from the delivery roll must be adjusted according to the length of staple, as shown in the following table:

COMBER CUSHION PLATE SETTINGS

Cotton	Length of Staple Inches	Size of Gauge Inches
American................	$1\frac{1}{4}$	$1\frac{1}{8}$ to $1\frac{3}{16}$
Egyptian................	$1\frac{1}{4}$ to $1\frac{1}{2}$	$1\frac{3}{16}$ to $1\frac{1}{4}$
Sea-island................	Over $1\frac{1}{2}$	$1\frac{1}{4}$ to $1\frac{7}{16}$

Timing of Combers.—The cylinder is taken as a basis for the timing of a comber, as all the intermittent movements are completed within the time occupied by one revolution of the cylinder. A gear of 80 teeth, on the cylinder shaft, is divided into twenty equal parts, or sections, which are numbered on the rim of the gear from 1 to 20, each section containing 4 teeth. This gear is known as the *index gear*. A vertical index finger indicates, by its relation to the position of the index gear, the position of the cylinder.

The numbers are so placed that as the cylinder revolves, No. 1 is first brought opposite the index finger, then No. 2, No. 3, and so on up to 20. Each section of the index gear is spoken of as a whole number, and each tooth in a section is spoken of as $\frac{1}{4}$; that is, if the cylinder has revolved until the comber is said to be at $5\frac{1}{2}$, it indicates that the index finger is at the second tooth beyond the section marked 5 on the index gear, or 22 teeth from the starting position.

The actions to be timed are: (1) The motion of the feed-rolls; (2) the motion of the nippers; (3) the placing of the detaching roll and top roll in position for detaching; (4) removal of detaching roll from detaching position; (5) motions of the delivery roll; (6) movement of the top comb.

The timings vary somewhat according to the nature of the cotton, its length of staple, the amount of waste removed, etc., but are usually adjusted as shown in the accompanying table:

COMBER TIMINGS

Timings	Index Gear
Feed at	$4\frac{1}{2}$ to 6
Nipper knife to leave cushion plate at	About $4\frac{1}{2}$
Nipper knife to touch cushion plate at	About 9
Leather detaching roll to touch segment at	About $6\frac{3}{4}$
Leather detaching roll to leave segment at	About $9\frac{1}{2}$
Delivery roll to reverse at	About $1\frac{1}{2}$
Delivery roll to deliver at	About 6
Top comb down at	5 to 6

SETTING AND TIMING THE WHITIN HIGH-SPEED (MODEL D2) COMBER

The Whitin high-speed comber operates on the Heilmann single-nip principle but embodies improvements in the construction of its actuating mechanisms that enable closer adjustments to be made, increased speed and production to be obtained, and better work to be produced. The following settings and timings apply to this machine, but are not arbitrary and may require some alteration to produce the best results with certain grades of cotton:

Timing Cams.—The actuating cams may be timed by loosening the 80-tooth gear and throwing it out of mesh. The cam-shaft is then turned until the roller on the pawl arm is in contact with the heel of the large cam on the end of the machine. Next the index gear is turned until No. 5 is opposite the pointer and then the 80-tooth gear is meshed and secured.

Setting Steel Detaching Roll.—The steel detaching roll should be free and should be set to the fluted segment with a No. 21 gauge.

Setting and Timing Cylinders.—The index gear should be revolved until No. 5 is opposite the indicator and each cylinder should then be adjusted on the shaft so that the front edge of its segment is $1\frac{1}{8}$ inches from the rear side of the detaching roll. A $1\frac{1}{8}$-inch gauge is used to make this adjustment.

Setting and Timing Leather Detaching Roll.—The leather detaching rolls should be set so that a No. 25 gauge may be inserted between the flat side of the bushings on the ends of the rolls and the adjusting slides. The index gears should be at No. 8 when this adjustment is made. The cam on the end of the comber should be adjusted on its sleeve so that the detaching roll will commence to move forward when No. 6 on the index gear is opposite the pointer. The comber should now be turned over and the inside actuating cam adjusted so that the detaching roll will move forward at No. 6.

Setting and Timing Feed-Roll.—The feed-roll should start to revolve when No. $7\frac{1}{2}$ on the index gear is opposite the indicator. The feed-roll should be set $1\frac{1}{2}$ inches from the detaching roll for short stock and $1\frac{7}{8}$ inches for long stock.

Setting and Timing the Nippers.—The nipper plates should be set so that their front edges are gauged with a No. 22 gauge from the nipper knife lip. The nipper knife should hold a slip of paper on the full length of the plate. The nipper knife may be set with an angle of about 34 degrees by means of the stop-screws. For short stock the front edge of the plate should be set $1\frac{3}{8}$ inches from the detaching roll and for long stock a setting of $1\frac{7}{16}$ inches should be made. The nipper frames should now be leveled with the segment by setting with a No. 19 gauge. Next the nipper frames should be connected with the nipper shaft and the comber shaft turned until the index gear is at No. $14\frac{1}{4}$ and the first row of needles of the half lap point directly to the center of the detaching roll. With the roll in the high part of the nipper cam under the sliver plate the connecting-rods may now be adjusted with a No. 25 gauge under the stop-screws. Also, the nipper frames may now be reset by inserting a No. 21 gauge between them and the needles. The nipper cams should be timed so that the nipper knives touch the plates when No. 11 on the index gear is opposite the pointer.

Setting Top Combs.—The top comb shaft is set $6\frac{3}{4}$ inches from the back side of the detaching roll, measuring to the front side of the top comb shaft. The comber may be turned until the index gear registers No. 8 and the segment is under the needles of the top comb. The top comb may be given an angle of about 24 degrees and set $\frac{1}{32}$ inch from the leather roll for short stock. For long stock, the combs may be given an increased angle. The combs should be adjusted to the segment with a No. 22 or No. 23 gauge.

CARE OF COMBERS

The proper oiling of combers is very important, since if oil is too freely employed on these machines they become very dirty and run poorly. On the other hand, the use of oil in too small quantities causes excessive wear that soon cripples the machines. Combers should be oiled twice a week, at uniform intervals, and the oiling should be done under the direct and constant supervision of a responsible person. Fast running parts should be oiled every morning. All oil that runs out of oil holes and over parts of the comber should be wiped off carefully. Twice each day, at stated times, comber tenders should clean around the rolls of the machine with a finger brush, and clean the backs and fronts and wipe the lint from the machines. Four times a day, at fixed periods, the top combs should be cleaned and the floor swept around the machines.

Twice each week the draw boxes should be thoroughly cleaned and top rolls replaced with newly-varnished rolls. Also, the gearing and cams should be cleaned twice in each week. Every morning the sliver plates, coiler tops, and draw-box covers should be polished with whiting. Laps must never be allowed to run out or the needles of the half laps and top combs will be broken, while if the laps are inserted at the proper time, the needles will remain in good condition.

Comber tenders should be instructed to report at once if a machine is out of order and runs poorly. They are responsible for two sets of combers arranged in pairs and should not leave their machines, even temporarily, without arranging for another tender to care for them during the absent period. The person in direct charge of the combers, generally a third hand, should supervise the tenders, seeing that they oil and clean the machines carefully and in accordance with the prescribed schedule. Combers must not be cleaned when in operation, as this is liable to result in very serious accidents and also causes many breakages. Once each week, the third hand should inspect all half laps and top combs, replacing any that may be found in poor condition. Leather detaching rolls should be varnished and changed once each week. Stop-motions should be kept in working condition at all times, and third hands should always respond quickly to complaints in regard to poor running machines, uneven work, etc. Every Saturday, or at such other times as the machines are to be stopped for a considerable period of time, the pressure should be taken off the rolls with the weight-relieving device. Roller laps should never be cut from steel rolls with a knife; instead, a brass hook should be used for removing these accumulations. Steps should be taken to insure the production of good laps for feeding combers, for poor laps cause serious trouble in the combing operation, damaging the machines and reducing production. The laps should be sized every day under ordinary conditions, but on fine counts they should be sized twice a day in order that they may be kept of uniform weight. The percentage of waste made should be watched and at least once a month the percentage of waste of all the combers should be ascertained.

Combers, sliver-lap machines, and ribbon-lap machines should be given a thorough scouring and overhauling once each year. All rolls, aprons, pans, etc., should be taken off and carefully cleaned. Hoods and casings should be removed and the gearing given a general cleaning. The comber should be reset and any worn parts replaced or repaired.

Waste.—It may be stated that more waste may be removed by feeding at a late period, by nipping later, by closer settings of the nippers and top combs to the cylinders, and by increasing the angle of the top comb. The amount of waste removed when combing different kinds of cotton should be ascertained often enough to insure that the proper percentage of waste is being taken out.

The comber is operated until the doffer comb is at the lowest part of its swing, after which the waste at the back is all removed and the sliver broken at the point where it is leaving the front calender rolls. The comber is next started and allowed to run until it has made about 40 nips. The cotton delivered by the front calender rolls is then kept as one portion, while the waste delivered is taken as another portion. These two portions of cotton are placed on a pair of scales, Fig. 6, which, instead of denoting weight, denotes the percentage of waste.

If the comber is taking out too much or too little waste, any of the settings and timings regulating the amount of waste may be changed. The amount of waste

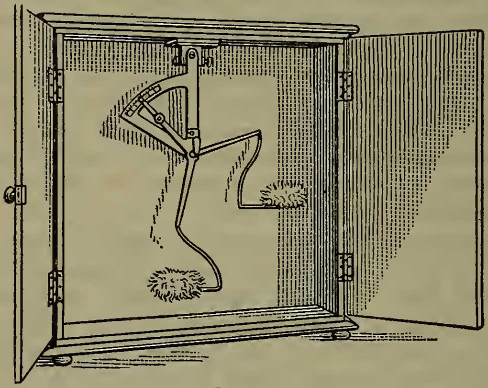


FIG. 6

will vary under the very best circumstances from 1 to 3%, and due allowance should be made for this.

Another method for finding the percentage of waste is to weigh each portion and add the weight of waste to the weight of combed cotton and divide this result into the weight of the waste.

EXAMPLE.—If 60 gr. of sliver is delivered from a certain comber in a given number of nips and the waste amounts to 15 gr., what percentage of waste is being removed?

SOLUTION.— 60 gr. weight of sliver
15 gr. weight of waste

75 gr. total weight
15÷75=.20, or 20%

FLY FRAMES

Fly frames have as their objects: (*a*) the reduction of the thickness of the sliver, (*b*) the evening of the product, (*c*) the twisting of the roving, (*d*) the winding of the roving on a bobbin.

Fly frames include slubbers, intermediates, and roving frames where three frames are used between the drawing and spinning frames. Where four frames are used they are generally known as the slubber, intermediate, roving frame, and jack frame; in this case the word jack is used to indicate a fine roving frame sometimes called a jack roving frame. The frame following the intermediates is sometimes called a fine frame. A much better method of naming the machines is to speak of the first machine after the drawing as the slubber; the last machine before the spinning as the roving frame; and the intermediates, if more than one, are spoken of as the first and second intermediates, respectively.

All fly frames are practically of the same type. One point to be noted, however, is that since the roving is gradually drawn finer at each succeeding process, certain parts of the intermediate frame should be smaller than similar parts of the slubber; the same is also true in regard to the roving frame as compared with the intermediate. With the slubber, the cans from the drawing frames are placed directly behind the machine and the sliver fed from the cans; and with the fly frames that follow the slubber, creels are provided in which to place the bobbins of roving, which is the form in which the cotton is delivered by all of these machines.

Slubber.—A section of the essential parts of a slubber is shown in Fig. 1. The cans from the finisher drawing frame are placed behind the slubber and the sliver *b* passed to the guide board *c*. In the slubber, which in this respect is unlike any of the other fly frames, no doubling takes place, each end of sliver being treated individually. From the guide board *c* the sliver passes over the lifter roll *d*, through the traverse guide *e*, and then through three sets of rolls f_3, f_2, f_1, which insert the necessary draft. From the drawing rolls, the sliver passes through the upper part of the flyer *g* and then out at its lower part, where it is wound around an arm supported by the flyer.

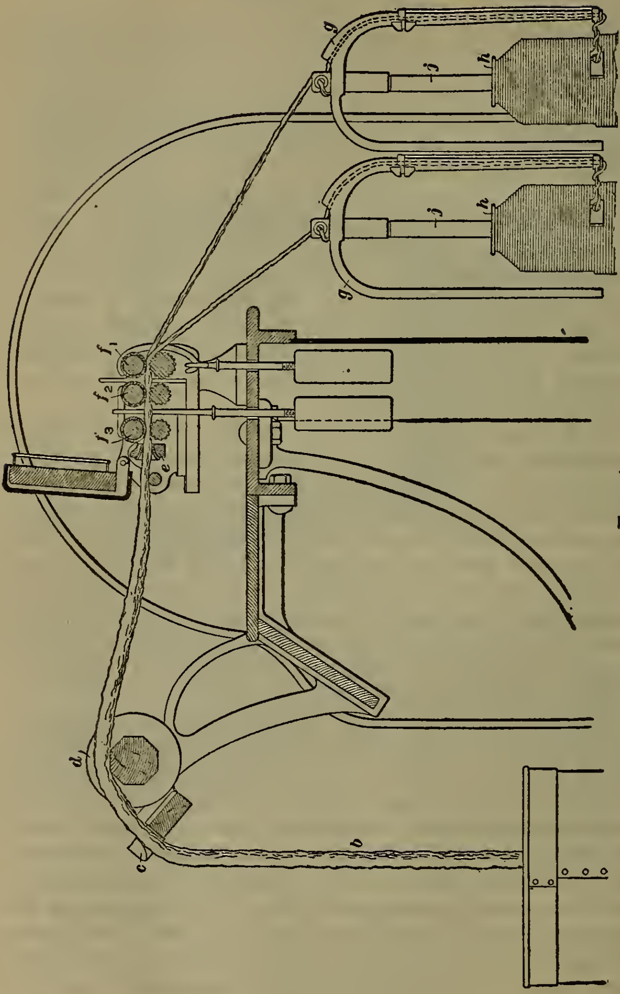


FIG. 1

From this arm, the cotton, which, having been reduced in size by the drawing rolls of the slubber, is now known as roving, passes to the bobbin *h*, on which it is compactly wound. In the illustration two ends are shown at the front, although for convenience only one sliver is shown at the back. Each end shown at the front is produced from a separate sliver fed behind the frame.

It is necessary to insert a small amount of twist in the roving after it leaves the front drawing rolls, to enable the fibers to hold together and withstand the strain of being wound on the bobbin and unwound at the next process. In fly frames, the roving is gripped between the front rolls as it is being delivered, and is also held by the bobbin on which it is being wound, although as the roving passes through the hole in the boss of the flyer and down the hollow leg, the top of the boss of the flyer practically forms the termination of the grip of the roving at this point. Consequently, the roving may be considered as being firmly held here, and since the spindle and flyer are making from 600 to 1,400 rev. per min., the roving is being twisted all the time. In ascertaining the amount of twist per inch inserted in the roving, the number of inches of roving delivered by the rolls during a certain period, and the number of turns made by the spindle during the same period, must be obtained. If, for example, the flyer makes 25 revolutions while the rolls deliver $12\frac{1}{2}$ in. of roving, there will be $25 \div 12\frac{1}{2} = 2$ turns of twist put into an inch of the roving.

The front rolls of a fly frame rotate at a constant speed; hence, a uniform length of roving is being constantly delivered. Suitable means must be provided for winding this roving on to the bobbin as fast as it is delivered, and the mechanism for winding must be such that the roving will not be broken or strained. The roving is wrapped around the bobbin because of the difference in the velocity of the bobbin and the flyer eye, since if both revolved in the same direction and at the same speed the roving could not be drawn through the eye of the flyer and wound around the bobbin. In considering the action of the flyer and bobbin in winding the roving about the latter, it will be found that there are two methods by which this is accomplished.

1. A rotary motion is given to both the flyer and the bobbin, the speed of the flyer being just sufficiently in excess of that of the bobbin to wind the roving on to the latter as fast as it is delivered by the drawing rolls of the frame. Since in this case the flyer is moving faster than the bobbin, or leading it, the arrangement is known as a *flyer lead*, and a frame thus equipped is called a *flyer-lead frame*.

2. Another method of winding the roving on to the bobbin is that in which the bobbin rotates at a speed just sufficiently in excess of that of the flyer to cause it to wind on the roving as fast as it is delivered by the drawing rolls. This is the arrangement that is almost always adopted on modern fly frames, and since in this case the bobbin rotates faster, or leads the flyer, it is known as the *bobbin-lead method*, fly frames thus equipped being known as *bobbin-lead frames*.

In both flyer-lead and bobbin-lead fly frames, the speed of the delivery of the roving and the speed of the flyers are constant. This is necessary, because if the speed of the drawing rolls were made variable the production of the frame would be altered, and also because, in order to produce an even roving, the sliver should be drawn at a regular and uniform speed. A variable speed of the flyers is impracticable, because this would produce a variation in the amount of twist in the roving. In order, therefore, to compensate for the constantly increasing diameter of the bobbin, a variation must be made in its speed, so that the tension on the roving during the winding will be the same whether the bobbin is empty or full. The speed of the bobbin is regulated and controlled by two mechanisms that act in combination. One is known as the *differential motion*, more commonly called the *compound;* the other consists of two cones and connections.

Calculations.—The following examples of necessary fly-frame calculations apply to the gearing shown in Fig. 2 and to a bobbin-lead type of frame.

Example 1.—Find the speed of the jack-shaft when the main shaft makes 300 rev. per min. and carries a 20-in. pulley driving a 16-in. pulley on the jack-shaft.

Solution.— $\frac{300 \times 20}{16} = 375$ rev. per min. of jack-shaft

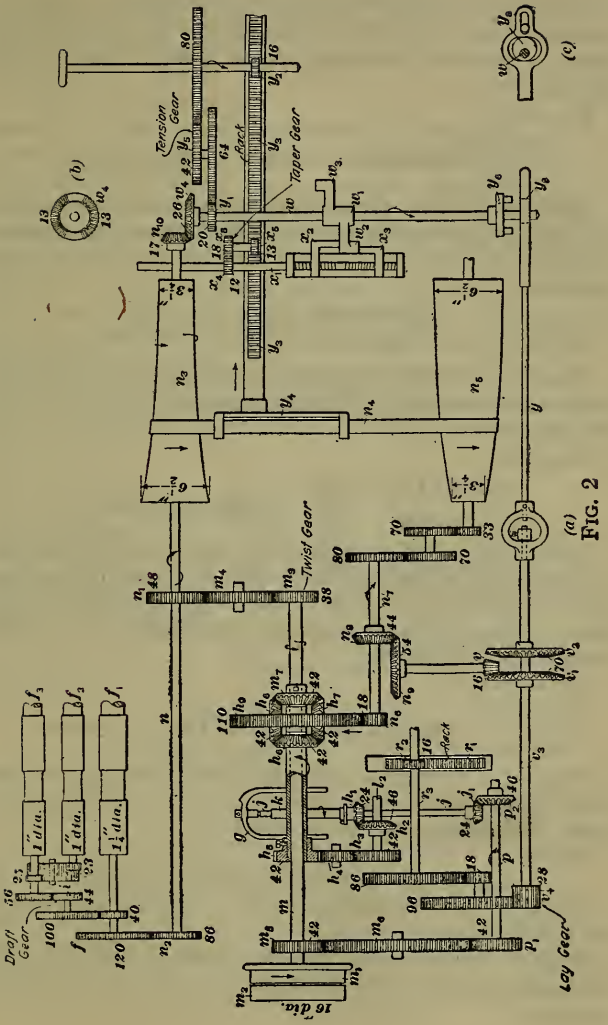

Tension Gear
Rack
Taper Gear
Twist Gear
Rack
Draft Gear
Lay Gear
16" dia.
(a)
(b)
(c)

FIG. 2

Example 2.—Find the revolutions per minute of the top-cone shaft when the jack-shaft makes 375 rev. per min. and carries a 38-tooth twist gear driving a 48-tooth gear on the top-cone shaft.

Solution.—

$$\frac{375\times 38}{48}=296.875 \text{ rev. per min. of top-cone shaft}$$

Example 3.—Find the revolutions per minute of the front roll when the top-cone shaft makes 296.875 rev. per min. and carries an 86-tooth gear driving a 120-tooth gear on the front-roll shaft.

Solution.— $$\frac{296.875\times 86}{120}=212.76 \text{ rev. per min.}$$

Example 4.—Find the length of roving delivered per minute by the front roll when it is 1.25 in. in diameter and makes 212.76 rev. per min.

Solution.—

$$\frac{212.76\times 1.25\times 3.1416}{36}=23.208 \text{ yd. per min.}$$

Example 5.—Find the number of revolutions of the spindles to 1 revolution of the jack-shaft when the jack-shaft carries a 42-tooth gear driving a 42-tooth gear on the spindle-gear shaft, which carries a 46-tooth gear driving a 24-tooth gear on the lower end of the spindle.

Solution.—

$$\frac{1\times 42\times 46}{42\times 24}=1.916 \text{ rev. of spindles to 1 rev. of jack-shaft}$$

Example 6.—Find the revolutions per minute of the spindles when the jack-shaft makes 375 rev. per min. and the spindles make 1.916 turns to one of the jack-shaft.

Solution.—

$$375\times 1.916=718.5 \text{ rev. per min. of spindles}$$

The twist, or turns, per inch in the roving may be found by the following rules:

Rule I.—*Divide the revolutions per minute of the spindles by the length of roving, in inches, delivered by the front roll in the same time.*

EXAMPLE.—Find the turns per inch being placed in the roving if the spindles make 718.5 rev. per min. and the front roll delivers 23.208 yd. per min.

SOLUTION.— $23.208 \times 36 = 835.488$ in. per min.; $718.5 \div 835.488 = .859$ turn per in.

Rule II.—*Taking into consideration all the gears, with the exception of the carrier gears, from the front roll to the spindles, assume that the front-roll gear is a driver. Multiply together all driving gears and divide by the product of all the driven gear. Divide the quotient thus obtained by the circumference of the front roll.*

EXAMPLE.—Find the turns per inch being inserted in the roving with the following arrangement of gears: the front roll is 1.25 in. in diameter; front-roll gear has 120 teeth; gear on end of top-cone shaft, 86 teeth; top-cone gear, 48 teeth; twist gear, 38 teeth; jack-shaft gear, 42 teeth; spindle-shaft gear, 42 teeth; gear on spindle-shaft that drives spindle, 46 teeth; gear on spindle, 24 teeth.

SOLUTION.—

$$\frac{120 \times 48 \times 42 \times 46}{86 \times 38 \times 42 \times 24} = 3.378; \quad \frac{3.378}{1.25 \times 3.1416} = .86 \text{ turns per in.}$$

The constant for twist may be found by the following rule:

Rule.—*Apply Rule II, for finding the twist, considering the twist gear as a 1-tooth gear.*

EXAMPLE.—Find the constant for twist, using the train of gearing given in the preceding example for finding the twist.

SOLUTION.—

$$\frac{120 \times 48 \times 42 \times 46}{86 \times 1 \times 42 \times 24} = 128.372;$$

$$\frac{128.372}{1.25 \times 3.1416} = 32.689, \text{ constant dividend for twist}$$

The constant dividend divided by the twist gear equals the twist per inch; thus, $32.689 \div 38 = .86$, twist per in.

The speed of the bobbins may be found by the following rule:

Rule.—*Find the amount of roving wound on the bobbins per minute and divide by the circumference of the bobbin. Add the result thus obtained to the speed of the spindles per minute, and the answer is the speed of the bobbins per minute.*

EXAMPLE 1.—Find the speed of the bobbins at the beginning of a set when the diameter of the bobbin is 1.75 in.; the speed of the spindles, 718.5 rev. per min.; and the front roll delivers 835.488 in. per min.

SOLUTION.— $\frac{835.488}{1.75 \times 3.1416} = 151.967$ rev. per min. of bobbins over speed of spindles. Speed of the spindles, 718.5 rev. per min.; speed of bobbins over that of the spindles, 151.967. $718.5 + 151.967 = 870.467$, speed of bobbins at beginning of set.

EXAMPLE 2.—Find the speed of the bobbins at the finish of a set when the diameter of the full bobbin is 6.125 in.; the speed of the spindles, 718.5 rev. per min.; and the front roll delivers 835.488 in. per minute.

SOLUTION.— $\frac{835.488}{6.125 \times 3.1416} = 43.419$ rev. per min. of the bobbins over the spindles. The number of revolutions per minute of the spindles is 718.5; the speed of the bobbins over that of the spindles is 43.419. $718.5 + 43.419 = 761.919$ rev. per min. of bobbins at the finish of a set.

The reduction of the speed per minute of the bobbins from an empty bobbin to a full bobbin in the above case is $870.467 - 761.919 = 108.548$ revolutions.

The draft of a fly frame is calculated in the usual manner.

EXAMPLE 1.—Find the total draft of the rolls shown in Fig. 2, using a 44-tooth draft gear.

SOLUTION.— $\frac{1.25 \times 100 \times 56}{40 \times 44 \times 1} = 3.977$, total draft

The constant for draft is found in the same manner as the total draft, except that the draft gear is considered as a 1-tooth gear.

EXAMPLE 2.—Find the draft constant for the rolls shown in Fig. 2.

SOLUTION.— $\frac{1.25 \times 100 \times 56}{40 \times 1 \times 1} = 175$, constant

EXAMPLE 3.—Find the draft between the second and third rolls.

SOLUTION.— $\frac{1 \times 25}{23 \times 1} = 1.086$, draft

EXAMPLE 4.—Find the draft between the front and second rolls if the draft gear contains 44 teeth.

SOLUTION.— $\frac{1.25\times100\times56\times23}{40\times44\times25\times1}=3.659$, draft

Change Gears.—In changing from one hank roving to another some or all of the following gears must be altered (the reference letters apply to Fig. 2): (1) the twist gear m_3, which alters the speed of the rolls and regulates the turns of twist placed in the roving; (2) the tension gear y_5, which regulates the movement of the belt along the cones; (3) the draft gear i, which alters the hank of the roving delivered; (4) the taper gear x_6, which alters the taper of the bobbin; (5) the lay, or traverse, gear v_4, which alters the speed of the traverse of the carriage.

The most important change to make is in the draft change gear, which regulates the size of the roving. It is generally customary at the same time to change the twist gear, because this should vary with every change in the hank of the roving. The tension gear is also frequently changed. It is not customary, however, to change the lay gear unless the change in the hank of the roving is extensive. If the slubber roving is changed .3 hank, the first intermediate roving .5 hank, the second intermediate roving .75 hank, or the finished roving a whole hank, the lay gear will ordinarily be changed.

It is seldom that the taper gear is changed in the mill, since the gear that is placed on the frame by the builders usually serves for the range of roving that the frame is intended for.

The following rules apply to the method of figuring the different change gears when the gears that are on the frame and the hank roving being produced are known. From the calculations previously given it is possible to obtain the draft and twist gears without this data, but for the tension and lay gears this data is always necessary, since the correct gear for starting up a frame was obtained by the builders largely by experiment and not by calculation. Even when the gear to use for a certain hank roving is known, the calculated gear for another hank does not always give satisfactory results, since the changing of these gears is largely a matter of experience and observation, owing to a number of different items affecting the results produced by them.

To find the draft gear to be used for a certain hank roving when the draft gear that is on and the hank roving that it produces are known:

Rule.—*Multiply the draft gear being used by the hank roving that it produces, and divide the result by the hank roving that is to be made.*

EXAMPLE.—If 4-hank roving is being produced with a 32-tooth draft gear, what draft gear will a 6-hank roving require?

SOLUTION.— $32 \times 4 = 128$; $128 \div 6 = 21.333$, or practically a 21-tooth draft gear

To find the twist gear to be used for a certain hank roving when the twist gear that is on and the hank roving that is produced are known:

Rule.—*Multiply the square root of the hank being made by the twist gear, and divide by the square root of the hank required.*

In examples in which the diameter of the roving affects the size of the gear to be used it is necessary to consider the square roots of the hanks, since the diameters of rovings vary inversely as the square roots of their hanks.

EXAMPLE.—If .36-hank roving is being made with a 54-tooth gear, what twist gear is required for a .64-hank?

SOLUTION.— $\sqrt{.36} = .6$; $\sqrt{.64} = .8$; $.6 \times 54 = 32.4$; $32.4 \div .8 = 40.5$. Either a 41-tooth or a 40-tooth gear may be used.

To find the tension gear to be used for a certain hank roving when the tension gear that is on and the hank roving that is produced are known, the frame having the American type of builder:

Rule.—*Multiply the square root of the hank being made by the tension gear, and divide by the square root of the hank required.*

EXAMPLE.—If .36-hank roving is being made with a 50-tooth tension gear, what tension gear is required for a .64-hank?

SOLUTION.— $\sqrt{.36} = .6$; $\sqrt{.64} = .8$; $.6 \times 50 = 30$; $30 \div .8 = 37.5$. Either a 37-tooth or a 38-tooth gear may be used.

To find the tension gear to be used for a certain hank roving when the tension gear that is on and the hank roving that is produced are known, the frame having the English type of builder:

Rule.—*Multiply the square root of the hank required by the tension gear, and divide by the square root of the hank being made.*

EXAMPLE.—If .36-hank roving is being made with a 20-tooth tension gear, what tension gear is required for a .64-hank?

SOLUTION.— $\sqrt{.36}=.6$; $\sqrt{.64}=.8$; $.8\times20=16$; $16\div.66=26.666$. A 27-tooth gear would be used.

To find the lay gear to be used for a certain hank roving when the lay gear that is on and the hank roving that is produced are known:

Rule.—*Multiply the square root of the hank being made by the lay gear, and divide by the square root of the hank required.*

EXAMPLE.—If .36-hank roving is being made with a 33-tooth gear, what lay gear is required for a .64-hank?

SOLUTION.— $\sqrt{.36}=.6$; $\sqrt{.64}=.8$; $.6\times33=19.8$; $19.8\div.8=24.75$. A 25-tooth gear should be used.

Production.—To find the production of a fly frame, in pounds:

Rule.—*Multiply the hanks per spindle, as indicated by the hank clock, by the number of spindles, and divide by the hank roving.*

EXAMPLE.—A clock on a 72-spindle frame registers 75 hanks of .5-hank roving turned off in a week. What is the production in pounds?

SOLUTION.— $$\frac{75\times72}{.5}=10{,}800\text{ lb.}$$

Average Hank.—To find the average hank, or average number, of the roving when several hanks are being run:

Rule.—*Multiply the pounds of each hank produced by the number of the hank, and divide the sum of the products thus obtained by the sum of the pounds produced.*

EXAMPLE.—If 1,800 lb. of .50-hank, 700 lb. of 1.50-hank, 850 lb. of 2-hank, 800 lb. of 2.25-hank, 750 lb. of 4-hank, and 700 lb. of 10-hank are produced in a week, what is the average hank of the roving?

SOLUTION.—

	1,800 ×	.50 =	900	
	700 ×	1.50 =	1,050	
	850 ×	2.00 =	1,700	
	800 ×	2.25 =	1,800	
	750 ×	4.00 =	3,000	
	700 ×	10.00 =	7,000	
Total	5,600 lb.		15,450	hanks

$15{,}450\div5{,}600=2.758$, average hank

PRODUCTION OF FLY FRAMES

No. of Roving	Gr. per Yard	Twist per Inch	Pounds per Day per Spindle							
			Slubber			Intermediate		Roving		Jack
			10-In. Space	9-In. Space	9-In. Space	$6\frac{1}{2}$-In. Space	6-In. Space	$5\frac{1}{4}$-In. Space	$4\frac{1}{2}$-In. Space	$4\frac{1}{4}$-In. Space
.20	41.67	.54	58.71							
.30	27.78	.66	41.60	39.09						
.40	20.83	.76	31.19	30.69	29.36					
.50	16.67	.85	24.03	24.29	23.99					
.60	13.89	.93	19.32	20.05	19.95					
.70	11.90	1.00	15.75	16.60	16.92					
.80	10.42	1.07	13.25	14.13	14.46					
.90	9.26	1.14	11.24	12.04	12.36	13.92				
1.00	8.33	1.20	9.83	10.64	10.97	12.33	12.88			
1.10	7.57	1.26		10.48	9.75	11.15	11.75			
1.20	6.94	1.31			8.70	10.16	10.65			
1.30	6.41	1.37				9.03	9.50			
1.40	5.95	1.42				8.21	8.75			
1.50	5.55	1.47				7.52	8.15			
1.60	5.20	1.52				6.89	7.64			
1.70	4.90	1.56				5.91	7.19			
2.00	4.16	1.70					5.63	5.87		
2.25	3.70	1.80					4.94	5.21		

2.50	3.33	1.89					4.21	4.45		
2.75	3.03	1.98					3.72	3.86		
3.00	2.77	2.08					3.32	3.54	3.57	
3.50	2.38	2.24						2.93	3.06	
4.00	2.08	2.40						2.39	2.45	
4.50	1.85	2.54						2.07	2.18	
5.00	1.67	2.68						1.75	1.83	
5.50	1.51	2.81						1.54	1.67	
6.00	1.38	2.94						1.37	1.43	
7.00	1.19	3.17							1.15	
8.00	1.04	3.39							.965	
9.00	.92	3.60							.787	
10.00	.83	3.79							.675	.822
11.00	.76	3.98							.614	.747
12.00	.69	4.16								.622
14.00	.59	4.49								.497
16.00	.52	4.80								.410
18.00	.46	5.09								.355
20.00	.42	5.37								.297
22.00	.38	5.63								.262
24.00	.35	5.88								.233
26.00	.32	6.12								.206
Rev. of pulley per min.			344	391	392	490	441	423	456	556
Rev. of flyer per min...			660	750	800	1000	1150	1300	1400	1700
Size of full bobbin....			12″×6⅛″	11″×5⅝″	10″×5⅛″	9″×4⅝″	8″×4⅛″	7″×3⅝″	6″×3⅛″	5″×2½″
Cotton on full bobbin.			46 oz.	33 oz.	27 oz.	21 oz.	16 oz.	10½ oz.	7½ oz.	4 oz.

Twist.—It has been found practical with fly frames to insert a number of turns per inch of twist that is equal to the products of the square root of the hank and certain numbers used as constants. The accompanying table gives the constants that are commonly used for American, Egyptian, and sea-island cotton on the slubber, first intermediate, second intermediate, and roving frames.

TWIST CONSTANTS FOR FLY FRAMES

Cotton	Slubber	First Intermediate	Second Intermediate	Roving Frame
American..........	1.0	1.1	1.20	1.3
Egyptian..........	.9	1.0	1.10	1.2
Sea-island..........	.7	.8	.90 to .95	1.0

Speed.—The speed of the spindles on a slubbing frame may slightly exceed 600 rev. per min.; on a first intermediate frame 900 rev. per min. is a good speed; on a second intermediate, 1,200; and on a roving frame, 1,500 rev. per min. These speeds, of course, are often exceeded in many mills. In some cases it would be more accurate to give the speeds at 800, 1,000, 1,300, and 1,600 rev., respectively, for the four machines.

Sizing.—It is customary to test the hank of the roving, or in other words to *size roving*, by reeling off a standard length from bobbins. The length usually taken in case of slubber and first intermediate roving is 12 yd.; for second intermediate or fine roving, 24 yd.

In some cases the sliver is sized at the drawing frame, and in other cases the slubber is taken as the starting point. In the latter case, the roving delivered is weighed two or sometimes three times a day, two bobbins being taken from a doff. Twelve yards are reeled off each bobbin and weighed and the average taken. If the average varies considerably either way from the correct weight of that number of yards of the hank being made, the draft gear is changed. The bobbins from frames finer than the slubber are weighed generally once a day, two or even more bobbins being taken from each frame. Where there is a difference from the standard of 2½ gr. in hanks from 1.5 to 4, or a difference of 2 gr. in hanks from 4 to 12, a change is made.

There are various systems of keeping numbers and various limits set for the number of grains that roving should be allowed to vary from either side of the standard before changing the draft gear. The one explained may be taken as a basis.

STANDARD SIZES OF FLY FRAMES

Frame	Size Inches	Space Between Spindles Inches	Number of Spindles
Slubber	12×6	10	24 to 68
Slubber	12×6	9½	24 to 68
Slubber	11×5½	9	28 to 72
Slubber	10×5	9	32 to 76
Slubber	9×4½	7½	30 to 96
First intermediate	10×5	8	40 to 104
First intermediate	10×5	7½	42 to 108
First intermediate	9×4½	7	48 to 114
First intermediate	9×4½	6½	48 to 114
First intermediate	8×4	6	48 to 136
First intermediate	8×4	5⅞	48 to 136
First intermediate	8×4	5⅔	66 to 132
Second intermediate	8×3½	5¼	56 to 144
Second intermediate	7×3½	5¼	64 to 152
Second intermediate	7×3½	5	64 to 152
Second intermediate	7×3	4¾	72 to 160
Second intermediate	7×3	4½	72 to 160
Second intermediate	6×3	4½	80 to 168
Roving	6×2½	4¼	88 to 176
Roving	5×2½	4¼	96 to 184
Roving	4½×2¼	4	112 to 200

Dimensions of Fly Frames.—Fly frames are spoken of not only according to the name of each kind of frame, but also by the number of spindles, the length of the bobbin that the first layer of roving covers (known as the *traverse* of the bobbin), and the diameter of the full bobbin. Thus, a frame spoken of as a 96-spindle 9 in.×4½ in. indicates that the frame has two rows of spindles, 48 in each row; that the greatest possible traverse on the bobbin is 9 in. in length; and that when the bobbin is full it cannot exceed $4\frac{1}{2}$ in. in diameter.

The table gives the standard sizes of frames of one builder.

RING SPINNING

Cotton yarn usually is spun on two kinds of spinning machines; namely, the *ring frame* and the *self-acting mule.*

The objects of spinning machinery are: (1) Completing the

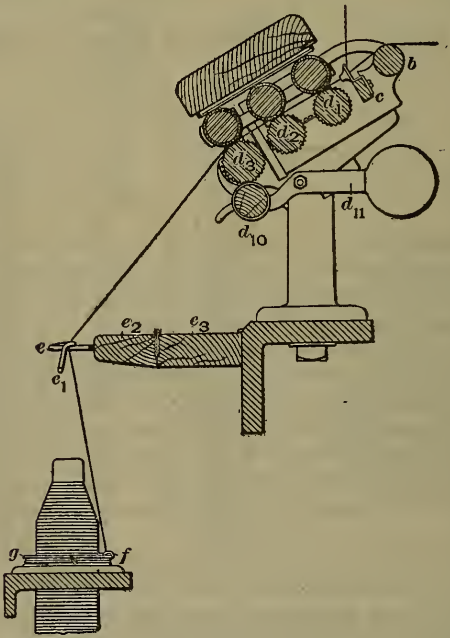


FIG. 1

attenuation of the roving so as to form a thread, or yarn; (2) twisting the yarn that is formed so as to give it the required strength; (3) winding or building the yarn in suitable form for use at the next process.

In Fig. 1, a section of the essential parts of a ring frame are shown. The bobbins of roving from the last fly-frame process are placed in a creel and the ends of roving from the bobbins in the lower set are passed over the guide rod *b* and through trumpets on the traverse guide rod *c*, while the roving from the upper set of bobbins passes over another guide rod not shown in the illustration and then to the traverse rod. In passing the roving to the traverse rod, when spinning from double roving, an end from a bobbin in the top row is taken together with an end from a bobbin of the bottom row and passed through a trumpet. They then pass through the drawing rolls, where a certain amount of draft is inserted, and emerging at the front are twisted into one strand, or thread. The thread, or *yarn*, as it is now called, passes through the guide wire *e*, through the traveler *f*, which is mounted on the ring *g*, and is finally wound on the bobbin. In some cases only a single end of roving is passed through a trumpet and thence to the bobbin. This is known as spinning from single roving.

The path of the yarn while passing through the rolls, that is, the working plane of the rolls, makes an angular inclination with a horizontal plane varying from 15° to 35°, commonly spoken of as the angle, or pitch, of the rolls. For frames spinning warp yarn, the angle is usually about 24°; for frames spinning filling yarn, the usual angle is about 31°. With warp yarn, especially when considerable twist is being inserted, the angle at which the rolls are set does not very materially affect the yarn, but with filling yarn, especially if slack-twisted and spun from short-staple cotton, a considerable pitch is required.

The ring is caused to rise and fall by a builder motion and the yarn is wound around the bobbin in two different forms. In winding the yarn on a warp-wind bobbin it is wound in layers that extend nearly the entire length of the bobbin, each succeeding layer being slightly shorter than the preceding, which gives to the full bobbin a taper at both ends. When winding the yarn on a filling-wind bobbin each layer instead of extending from one end of the bobbin to the other extends only a short distance, and each succeeding layer is moved slightly higher on the bobbin.

Since the bobbin tends to wind on itself more yarn than is delivered, a tension is maintained in the yarn, and this tension being transmitted to the traveler causes the latter to revolve around the ring on which it is mounted. The traveler is made just sufficiently heavy to make it necessary that the yarn exert

SIZES OF TRAVELERS

No.	Wt. of 10 Trav. Gr.	No.	Wt. of 10 Trav. Gr.	No.	Wt. of 10 Trav. Gr.	No.	Wt. of 10 Trav. Gr.
25–0	1	$1\frac{1}{2}$–0	$8\frac{1}{2}$	24	60	49	110
24–0	$1\frac{1}{4}$	1–0	9	25	62	50	112
23–0	$1\frac{1}{2}$	1	10	26	64	51	114
22–0	$1\frac{3}{4}$	2	11	27	66	52	116
21–0	2	3	12	28	68	53	118
20–0	$2\frac{1}{4}$	4	13	29	70	54	120
19–0	$2\frac{1}{2}$	5	14	30	72	55	122
18–0	$2\frac{3}{4}$	6	16	31	74	56	124
17–0	3	7	18	32	76	57	126
16–0	$3\frac{1}{4}$	8	20	33	78	58	128
15–0	$3\frac{1}{2}$	9	23	34	80	59	130
14–0	$3\frac{3}{4}$	10	26	35	82	60	132
13–0	4	11	30	36	84	61	134
12–0	$4\frac{1}{4}$	12	33	37	86	62	136
11–0	$4\frac{1}{2}$	13	36	38	88	63	138
10–0	$4\frac{3}{4}$	14	39	39	90	64	140
9–0	5	15	42	40	92	65	142
8–0	$5\frac{1}{4}$	16	44	41	94	66	144
7–0	$5\frac{1}{2}$	17	46	42	96	67	146
$6\frac{1}{2}$–0	$5\frac{3}{4}$	18	48	43	98	68	148
6–0	6	19	50	44	100	69	150
5–0	$6\frac{1}{2}$	20	52	45	102	70	152
4–0	7	21	54	46	104	71	154
3–0	$7\frac{1}{2}$	22	56	47	106	72	156
2–0	8	23	58	48	108	73	158

some strain before causing the traveler to revolve, and yet this strain is not great enough to break the yarn. If the front rolls deliver 471 in. per min. and the bobbin is $\frac{3}{4}$ in. in diameter, $471 \div (3.1416 \times \frac{3}{4}) = 200$, nearly, revolutions of the bobbin will be taken up in winding on this roving, and if the bobbin make 9,000 rev. per min., the traveler will make $9{,}000 - 200 = 8{,}800$

revolutions as it is carried around by the yarn. This will have exactly the same effect as if 471 in. of yarn were held firmly at one end and the other end twisted 8,800 times.

Travelers.—As travelers are often run at a speed of 50 mi. an hour, day in and day out, they should be carefully made. Travelers are prepared from the highest grade steel wire drawn to the correct size and gauged to .001 in. This wire

TRAVELERS FOR WARP YARN

Number of Yarn	Revolutions of Spindles	Diameter of Ring	Number of Traveler	Weight of 10 Travelers in Grains.	Number of Yarn	Revolutions of Spindles	Diameter of Ring	Number of Traveler	Weight of 10 Travelers in Grains.
4	4950	2″	14	39	32	9500	$1\frac{3}{4}$″	7–0	$5\frac{1}{2}$
6	5900	2	12	33	34	9600	$1\frac{3}{4}$	9–0	5
8	6700	2	9	23	36	9700	$1\frac{3}{4}$	11–0	$4\frac{1}{2}$
10	7250	2	8	20	38	9800	$1\frac{3}{4}$	13–0	4
11	7500	2	7	18	40	9700	$1\frac{5}{8}$	14–0	$3\frac{3}{4}$
12	7750	2	6	16	45	9700	$1\frac{1}{2}$	15–0	$3\frac{1}{2}$
13	7950	2	6	16	50	9700	$1\frac{1}{2}$	16–0	$3\frac{1}{4}$
14	8100	2	5	14	55	9600	$1\frac{1}{2}$	16–0	$3\frac{1}{4}$
15	8300	2	4	13	60	9600	$1\frac{1}{2}$	17–0	3
16	8450	2	3	12	65	9600	$1\frac{1}{2}$	17–0	3
17	8600	2	2	11	70	9500	$1\frac{1}{2}$	18–0	$2\frac{3}{4}$
18	8750	2	1	10	75	9500	$1\frac{1}{2}$	18–0	$2\frac{3}{4}$
19	8850	2	1–0	9	80	9300	$1\frac{1}{2}$	19–0	$2\frac{1}{2}$
20	8900	2	$1\frac{1}{2}$–0	$8\frac{1}{2}$	85	9100	$1\frac{1}{2}$	19–0	$2\frac{1}{2}$
21	9050	2	2–0	8	90	9100	$1\frac{3}{8}$	20–0	$2\frac{1}{4}$
22	9100	2	3–0	$7\frac{1}{2}$	95	9000	$1\frac{3}{8}$	21–0	2
23	9150	2	4–0	7	100	8700	$1\frac{3}{8}$	22–0	$1\frac{3}{4}$
24	9200	2	5–0	$6\frac{1}{2}$	110	8500	$1\frac{3}{8}$	23–0	$1\frac{1}{2}$
28	9500	$1\frac{3}{4}$	6–0	6					

is flattened, rolled, and annealed, after which it is cut and bent on automatic machines to the shape desired. The travelers are then hardened, tempered, scoured, and polished, each process requiring the greatest skill and exactness.

Travelers are numbered by one maker, as shown in the accompanying table.

It is impossible to give a definite rule by which to find the weight of traveler to use for certain counts of yarn. The following are general principles, however: (1) A larger ring requires a lighter traveler. (2) A coarser yarn requires a heavier traveler. (3) Putting more twist into the yarn may require a heavier traveler. (4) A better grade of stock will stand a heavier traveler. (5) Old rings require heavier travelers than new ones. (6) During moist, sticky weather travelers run hard and fly off; under these circumstances a lighter

TRAVELERS FOR FILLING YARN

Number of Yarn	Revolutions of Spindles	Diameter of Ring	Number of Traveler	Weight of 10 Travelers in Grains.	Number of Yarn	Revolutions of Spindles	Diameter of Ring	Number of Traveler	Weight of 10 Travelers in Grains.
4	4000	$1\frac{1}{2}''$	16	44	32	7900	$1\frac{3}{8}''$	9–0	5
6	4800	$1\frac{1}{2}$	13	36	34	7900	$1\frac{3}{8}$	11–0	$4\frac{1}{2}$
8	5450	$1\frac{1}{2}$	10	26	36	7900	$1\frac{3}{8}$	13–0	4
10	5950	$1\frac{1}{2}$	8	20	38	7900	$1\frac{3}{8}$	14–0	$3\frac{3}{4}$
11	6150	$1\frac{1}{2}$	7	18	40	7900	$1\frac{1}{4}$	15–0	$3\frac{1}{2}$
12	6350	$1\frac{1}{2}$	6	16	45	7900	$1\frac{1}{4}$	16–0	$3\frac{1}{4}$
13	6500	$1\frac{1}{2}$	5	14	50	7900	$1\frac{1}{4}$	17–0	3
14	6700	$1\frac{1}{2}$	4	13	55	7900	$1\frac{1}{4}$	17–0	3
15	6850	$1\frac{1}{2}$	3	12	60	7900	$1\frac{1}{4}$	18–0	$2\frac{3}{4}$
16	6950	$1\frac{1}{2}$	2	11	65	7800	$1\frac{1}{4}$	18–0	$2\frac{3}{4}$
17	7100	$1\frac{1}{2}$	1	10	70	7800	$1\frac{1}{4}$	19–0	$2\frac{1}{2}$
18	7200	$1\frac{1}{2}$	1–0	9	75	7800	$1\frac{1}{4}$	19–0	$2\frac{1}{2}$
19	7300	$1\frac{1}{2}$	2–0	8	80	7700	$1\frac{1}{4}$	20–0	$2\frac{1}{4}$
20	7400	$1\frac{1}{2}$	4–0	7	85	7600	$1\frac{1}{4}$	20–0	$2\frac{1}{4}$
21	7500	$1\frac{1}{2}$	4–0	7	90	7400	$1\frac{1}{4}$	21–0	2
22	7600	$1\frac{1}{2}$	5–0	$6\frac{1}{2}$	95	7400	$1\frac{1}{4}$	22–0	$1\frac{3}{4}$
23	7700	$1\frac{1}{2}$	5–0	$6\frac{1}{2}$	100	7200	$1\frac{1}{4}$	23–0	$1\frac{1}{2}$
24	7800	$1\frac{1}{2}$	6–0	6	110	6900	$1\frac{1}{4}$	24–0	$1\frac{1}{4}$
28	7900	$1\frac{3}{8}$	7–0	$5\frac{1}{2}$					

traveler should be used. (7) Short stock, weak staple, or heavily-drafted yarns require a lighter traveler than the same numbers spun under better conditions. (8) The higher the speed the lighter the traveler, and vice versa; the variation is in the proportion of one or two grades of travelers to each 1,000 rev. of spindle. (9) Without separators a few grades heavier traveler will be required.

The accompanying tables are given as guides in selecting the size of traveler to be used for warp and for filling yarns.

Spindles.—The spindles form one of the most important parts of a ring spinning frame, and on them depends to a great extent the successful and economical operation of ring spinning frames. The modern ring-frame spindle is known as a *gravity spindle*, sometimes called a *top*, an *elastic*, or a *flexible* spindle, which indicates that it is allowed to find its own best center of rotation within certain limits, thus reducing or removing the liability of excessive vibration and wear. The older style of spindle was a rigid spindle, and this vibration and wear was a frequent occurrence when the spindle became slightly out of balance.

SIZES OF BOBBINS

Number of Yarn	Diameter of Barrel	
	Warp Inch	Filling Inch
4s to 16s	$\frac{3}{4}$	$\frac{1}{2}$
16s to 30s	$\frac{3}{4}$	$\frac{1}{2}$
30s to 40s	$\frac{3}{4}$	$\frac{5}{8}$
40s to 100s	$\frac{7}{8}$	$\frac{5}{8}$

Bobbins.—The bobbin should fit the top of the spindle closely, but not tightly, and should fit snugly the sleeve bearing for a distance of about $\frac{5}{8}$ in. Where a cup is used it should project into the cup about $\frac{1}{8}$ in. The accompanying table gives suitable sizes of bobbins for various numbers of yarn, both warp and filling, assuming that the proper size of ring is used. A larger ring requires a larger bobbin.

Dimensions.—The length of the traverse should be less for fine yarns than for coarse yarns; $5\frac{1}{2}$ in. is about the average, 7 in. being about the maximum traverse and $4\frac{1}{2}$ in. the minimum. The speed of the spindle has to be higher in making fine yarns than in the case of coarse yarns and higher for warp yarns than for filling yarns, because the additional amount of twist that has to be put in the fine yarn or warp yarn will seriously reduce the speed of the front roll, and consequently the production of the frame, if the spindle speed is not high.

DIMENSIONS OF RING SPINNING FRAMES

<table>
<tr><th colspan="3">Warp</th><th rowspan="2">Number of Yarn</th><th colspan="3">Filling</th></tr>
<tr><th>Gauge of Spindles Inches</th><th>Diameter of Ring Inches</th><th>Length of Traverse Inches</th><th>Gauge of Spindles Inches</th><th>Diameter of Ring Inches</th><th>Length of Traverse Inches</th></tr>
<tr><td rowspan="2">3¼</td><td rowspan="2">2¼</td><td rowspan="10">7</td><td>4</td><td rowspan="28">2¾</td><td rowspan="3">1⅝</td><td rowspan="9">6½</td></tr>
<tr><td>9</td></tr>
<tr><td rowspan="4">3</td><td rowspan="4">2⅛</td><td>10</td></tr>
<tr><td>11</td><td rowspan="7">1½</td></tr>
<tr><td>15</td></tr>
<tr><td>16</td></tr>
<tr><td rowspan="22">2¾</td><td rowspan="2">2</td><td>17</td></tr>
<tr><td>20</td></tr>
<tr><td rowspan="3">1⅞</td><td>21</td></tr>
<tr><td>25</td><td rowspan="10">6</td></tr>
<tr><td rowspan="12">6</td><td>26</td><td rowspan="13">1⅜</td></tr>
<tr><td rowspan="6">1¾</td><td>27</td></tr>
<tr><td>28</td></tr>
<tr><td>30</td></tr>
<tr><td>31</td></tr>
<tr><td>35</td></tr>
<tr><td>36</td></tr>
<tr><td rowspan="2">1⅝</td><td>37</td></tr>
<tr><td>39</td></tr>
<tr><td rowspan="4">1½</td><td>40</td><td rowspan="4">5½</td></tr>
<tr><td>41</td></tr>
<tr><td>44</td></tr>
<tr><td rowspan="4">5½</td><td>45</td></tr>
<tr><td rowspan="5">1⅜</td><td>50</td><td rowspan="5">1¼</td><td rowspan="5">5</td></tr>
<tr><td>51</td></tr>
<tr><td>60</td></tr>
<tr><td rowspan="2">5</td><td>70</td></tr>
<tr><td>80</td></tr>
</table>

The accompanying table indicates approximately the customary gauge of the spindles, the diameter of the rings, and the length of traverse for the principal numbers of warp and filling yarns between 4s and 80s.

The term *gauge* used in connection with spinning frames implies the distance from the center of one spindle to the center of the next spindle in the same row. Frames are usually built

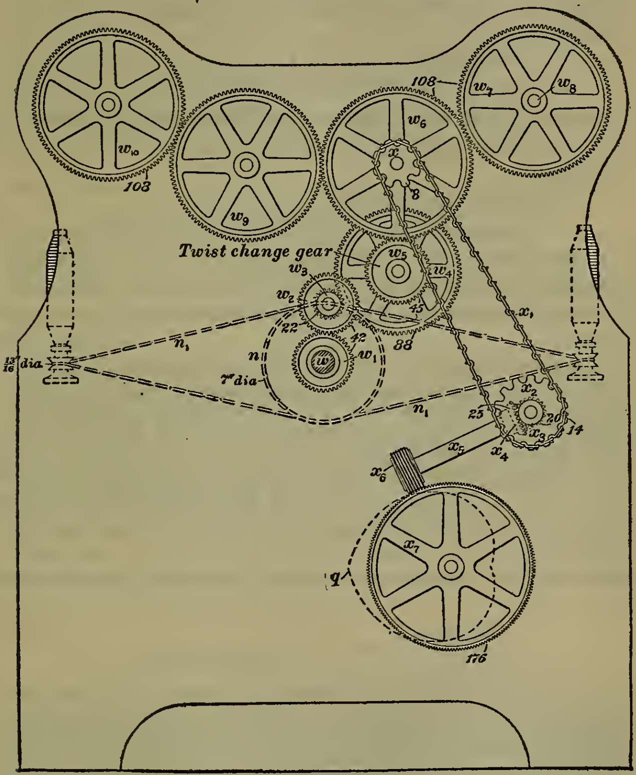


FIG. 2

with from 160 to 288 spindles, although they may be built with a greater or less number. In speaking of the number of spindles of a ring frame, both sides are included; consequently, a frame of 288 spindles would have 144 spindles on a side.

Calculations.—Speed calculations for ring frames are illustrated by the following examples:

EXAMPLE 1.—Find the speed of the cylinder *n*, Fig. 2, when the driving shaft makes 400 rev. per min. and carries a 30-in. pulley that drives a $10\frac{3}{4}$-in. pulley on the cylinder shaft *w*.

SOLUTION.—

$$\frac{400\times 30}{10\frac{3}{4}}=1{,}116.279 \text{ rev. per min.}$$

EXAMPLE 2.—If the cylinder *n*, Fig. 2, makes 1,116.279 rev. per min., find the speed of the front roll shaft w_8.

SOLUTION.—

$$\frac{1{,}116.279\times 42\times 22\times 45}{42\times 88\times 108}=116.279 \text{ rev. per min.}$$

EXAMPLE 3.—If the cylinder *n*, Fig. 2, is 7 in. in diameter and makes 1,116.279 rev. per min., find the speed of the spindles if the whorl around which the band passes is $\frac{12}{16}$ in. in actual diameter.

NOTE.—In connection with finding the speed of spindles a question arises as to where the diameter of the whorl should be taken. It is customarily taken at the bottom of the groove, although theoretically the diameter should be considered a little larger than this, in order to allow for the thickness of the spindle band; consequently, the calculation should be made with the diameter taken at the center of the band, about $\frac{1}{16}$ in. being added to the diameter of the whorl in order to make allowance for this, this dimension being termed the *working diameter*.

SOLUTION.— $\frac{12}{16}$ in. $+\frac{1}{16}$ in. $=\frac{13}{16}$ in., working diameter of whorl.

$$\frac{1{,}116.279\times 7}{\frac{13}{16}}=9{,}617.172 \text{ rev. per min.}$$

NOTE.—The question of slippage also arises in connection with the speed of the spindles. This is a variable quantity, depending on the tension of the bands, the oiling of the spindles, the number of the yarn being spun, the weight of the travelers, and other factors. The loss from the calculated speed of the spindles, due to slippage, will vary from 5 to 10%, but as 5% is the customary allowance it will be adopted in these calculations. Making this allowance, example 3 would be completed as follows:

$$100\%-5\%=95\%, \text{ or } .95$$
$$9{,}617.172\times .95=9{,}136.313 \text{ rev. per min.}$$

To find the speed of the traveler when the speed of the spindle, the speed of the front roll, and the diameter of the bobbins are known:

Rule.—*Find the number of revolutions per minute of the bobbin necessary to take up the amount of yarn delivered per minute by the front roll. Subtract this number of revolutions per minute of the bobbin from the revolutions per minute of the spindle.*

Example.—If the spindles make 9,136.313 rev. per min. and the front roll delivers 365.302 in. per minute, what is the speed of the travelers when the bobbins are $\frac{7}{8}$ in. in diameter?

Solution.— $\frac{365.302}{\frac{7}{8} \times 3.1416} = 132.890$, the rev. per min. of bobbins necessary to take up amount delivered by front roll.

$9{,}136.313 - 132.890 = 9{,}003.423$ rev. per min. of traveler

Twist calculations for ring frames are not entirely accurate on account of several variable factors that affect the amount of twist in the yarn.

To find the turns of twist per inch being placed in the yarn:

Rule I.—*When figuring from the gears, consider the gear on the end of the front roll as a driver. Multiply all the driving gears and the diameter of the cylinder together and divide by the product of all the driven gears, the working diame er of the whorl, and the circumference of the front roll.*

Example 1.—What is the twist per inch that is being placed in yarn spun on a frame geared as shown in Fig. 2, if the diameter of the front roll is 1 in., the cylinder 7 in., and the working diameter of the whorl $\frac{13}{16}$ in?

Solution.—

$$\frac{108 \times 88 \times 42 \times 7}{45 \times 22 \times 42 \times \frac{13}{16} \times 3.1416 \times 1} = 26.326, \text{ turns per in.}$$

Rule II.—*In case the speed of the spindles and the number of inches of yarn delivered by the front roll are known, divide the speed of the spindles, without any allowance for slippage, by the inches delivered per minute by the front roll.*

Example 2.—What is the twist per inch that is being inserted in yarn if the spindles make 9,617.172 rev. per min. and the front roll delivers 365.302 in. per min.?

Solution.— $9{,}617.172 \div 365.302 = 26.326$, turns per in.

To find the constant for twist from the gears:

Rule.—*Consider the gear on the end of the front roll as a driver and the twist gear as a 1-tooth gear. Multiply together all the driving gears and the diameter of the cylinder and divide by the product of all the driven gears, the working diameter of the whorl, and the circumference of the front roll.*

Example.—What is the constant for twist with the frame geared as shown in Fig. 2, if the diameter of the front roll is 1 in., the cylinder 7 in, and the working diameter of the whorl $\frac{13}{16}$ in.?

Solution.—

$$\frac{108\times88\times42\times7}{1\times22\times42\times\frac{13}{16}\times3.1416\times1}=1{,}184.697\text{, constant}$$

To find the twist per inch when the constant for twist and the twist gear are known:

Rule.—*Divide the constant by the number of teeth in the twist gear.*

Example.—What is the twist per inch that is being inserted in yarn if the constant for twist is 1,184.697 and the twist gear contains 45 teeth?

Solution.— $1{,}184.697\div45=26.326$, turns per in.

To find the necessary twist gear to give a required number of turns per inch when the constant is known:

Rule.—*Divide the constant by the twist required.*

Example.—If the constant for a train of gears is 1,184.697, what size twist gear will be required to give 20 turns per inch in the yarn?

Solution.—

$1{,}184.697\div20=59.2$, or a 59-tooth gear (practically)

The calculations given in connection with twist make no allowance for any slippage that may occur, or for any loss caused by the traveler speed being slightly less than the spindle speed. These points are sometimes taken into consideration, although the contraction of the yarn, due to the twist inserted, generally compensates for any loss due to these causes.

In determining the amount of twist to be placed in either warp or filling yarn spun on a ring frame, a constant is used that multiplied by the square root of the counts gives the required number of turns per inch. For ordinary warp yarn spun on ring frames the constant is usually 4.75, but for filling it is 3.25. These figures, however, are varied according to the twist required, the quality of the yarn to be made, or the kind of stock being used. Long stock does not require so much twist in proportion as short stock. Filling yarn from carded stock requires, as a rule, from $1\frac{1}{2}$ to $2\frac{1}{2}$ turns per inch more twist than the square root of the counts multiplied by

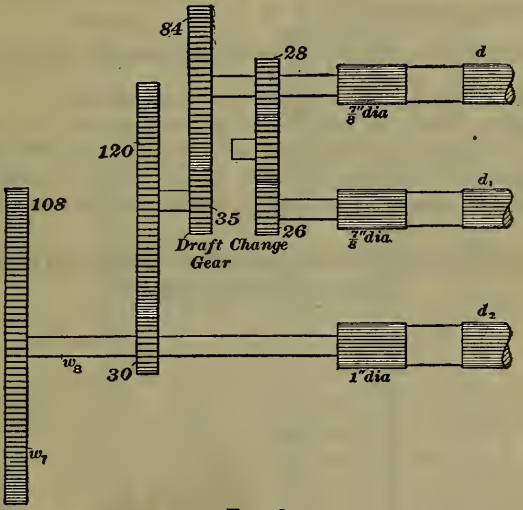


FIG. 3

3.25. On combed stock the standard number of turns is sufficient, since combed stock does not require so much twist for the same numbers as carded stock. Fine filling yarns or yarns for twisting are spun with less twist than 3.25 times the square root of the counts.

EXAMPLE 1.—What is the standard twist in 28s warp yarn?

SOLUTION.—

$\sqrt{28} = 5.291$. $5.291 \times 4.75 = 25.132$, turns per in.

EXAMPLE 2.—What is the standard twist in 36s filling yarn?

SOLUTION.— $\sqrt{36} = 6$. $6 \times 3.25 = 19.5$, turns per in.

Draft calculations are of importance in connection with ring spinning frames, as the draft together with the hank of the roving, governs the size of the yarn produced.

EXAMPLE 1.—Find the draft for rolls geared as shown in Fig. 3.

SOLUTION.— $\frac{1\times 120\times 84}{30\times 35\times \frac{7}{8}}=10.971$, draft

EXAMPLE 2.—Find the draft constant for the rolls when geared as shown in Fig. 3.

SOLUTION.— $\frac{1\times 120\times 84}{30\times 1\times \frac{7}{8}}=384$, constant for draft

To find the hanks per spindle produced per day:

Rule.—*Divide the product of the circumference of the front roll, the number of revolutions per minute of the front roll, the minutes per hour, and the hours per day by the product of the number of inches in 1 yd. and the number of yards in one hank.*

ALLOWANCES ON CALCULATED PRODUCTION OF RING SPINNING FRAMES

Warp Yarn		Filling Yarn	
Numbers	Allowance Per Cent.	Numbers	Allowance Per Cent.
5s to 10s	11	5s to 10s	14
10s to 20s	10	10s to 15s	12
20s to 30s	9	15s to 20s	11
30s to 40s	8	20s to 30s	10
40s to 55s	7	30s to 35s	8
55s to 85s	4	35s to 45s	7
85s to 100s	2	45s to 60s	6

EXAMPLE.—How many hanks per spindle, per day of 10 hr., will be produced by a frame with a front roll 1 in. in diameter that makes 116.279 rev. per min.?

SOLUTION.— $\frac{1\times 3.1416\times 116.279\times 60\times 10}{36\times 840}=7.248$ hanks

When figuring the production of ring frames from the speed of the front roll it is necessary to make certain allowances, since the frame is not running continually, owing to the stoppages necessitated by cleaning, oiling, and doffing. These allowances will vary with the yarn spun, since coarse yarn requires more frequent doffing than fine yarn, owing to the bobbins being filled more rapidly. The accompanying table gives the allowances usually made for different counts of yarn.

PRODUCTION OF WARP SPINNING FRAMES

Number of Yarn	Weight per Yard in Grains	Twist per Inch	Rev. of Front Roll per Minute	Rev. of Spindle per Minute	Hanks per Day per Spindle	Pounds per Day per Spindle
10	.833	15.02	146.2	6,900	8.295	.829
12	.694	16.45	143.2	7,400	8.214	.685
14	.595	17.77	139.7	7,800	8.013	.572
16	.521	19.00	137.3	8,200	7.875	.492
18	.463	20.15	134.2	8,500	7.698	.428
20	.417	21.24	131.8	8,800	7.560	.378
22	.379	22.27	128.6	9,000	7.376	.335
24	.347	23.27	124.5	9,100	7.141	.298
26	.320	24.22	122.2	9,300	7.085	.272
28	.297	25.13	117.8	9,300	6.830	.244
30	.277	26.02	115.0	9,400	6.668	.223
32	.260	26.87	112.4	9,500	6.516	.205
34	.245	27.69	109.1	9,500	6.326	.186
36	.231	28.50	106.1	9,500	6.218	.173
38	.219	29.28	103.2	9.500	6.048	.159
40	.208	30.04	100.6	9,500	5.896	.147
42	.198	30.78	98.2	9,500	5.755	.137
44	.189	31.50	96.0	9,500	5.626	.128
46	.181	32.21	93.8	9,500	5.556	.121
48	.174	32.90	91.9	9,500	5.443	.113
50	.166	33.58	90.9	9,600	5.384	.108

To find the total production, in pounds, of several frames when the number of hanks produced by each spindle is known:

Rule.—*Find the production, in pounds, of each frame by multiplying the number of spindles in the frame by the hanks produced by each spindle and dividing the result by the counts being spun. Add the results obtained for each frame.*

Example.—If four frames of 160 spindles produce, respectively, 37 hanks per spindle of 36s, 33 hanks per spindle of 50s, 28 hanks per spindle of 70s, and 27 hanks per spindle of 80s, in 1 wk., what is the total production for the week?

Solution.— $\frac{160 \times 37}{36} = 164.444$ lb. of 36s.

$\frac{160 \times 33}{50} = 105.6$ lb. of 50s

$\frac{160 \times 28}{70} = 64$ lb. of 70s

$\frac{160 \times 27}{80} = 54$ lb. of 80s

$164.444 + 105.6 + 64 + 54 = 388.044$ lb., total production for 1 wk.

PRODUCTION OF FILLING SPINNING FRAMES

Number of Yarns	Weight per Yard in Grains	Twist per Inch	Rev. of Front Roll per Minute	Rev. of Spindle per Minute	Hanks per Day per Spindle	Pounds per Day per Spindle
10	.833	10.27	161.2	5,200	8.945	.894
12	.694	11.26	158.2	5,600	8.778	.731
14	.595	12.16	156.9	6,000	8.706	.622
16	.521	13.00	155.4	6,350	8.719	.545
18	.463	13.79	152.2	6,600	8.540	.476
20	.417	14.53	148.8	6,800	8.444	.422
22	.379	15.24	146.1	7,000	8.290	.376
24	.347	15.92	139.9	7,000	7.938	.331
26	.320	16.57	138.2	7,200	7.927	.305
28	.297	17.20	134.1	7,250	7.692	.275
30	.277	17.80	129.6	7,250	7.514	.250
32	.260	18.38	126.3	7,300	7.323	.229
34	.245	18.95	122.4	7,300	7.097	.208
36	.231	19.50	119.1	7,300	6.980	.194
38	.219	20.03	117.6	7,400	6.892	.181
40	.208	20.55	115.4	7,450	6.835	.171
42	.198	21.06	113.3	7,500	6.711	.160
44	.189	21.56	110.7	7,500	6.557	.149
46	.181	22.04	108.3	7.500	6.414	.139
48	.174	22.52	105.9	7,500	6.272	.131
50	.166	22.98	103.9	7,500	6.218	.124

To find the average number of yarn being produced:

Rule.—*Multiply the number of pounds produced by each frame by the counts of yarn being spun. Add the results thus obtained and divide by the total number of pounds.*

EXAMPLE.—What is the average number of yarn being spun if four frames produce, respectively, 164.444 lb. of 36s, 105.6 lb. of 50s, 64 lb. of 70s, and 54 lb. of 80s?

SOLUTION.—

$$\begin{array}{rcr} 164.444 \times 36 &=& 5919.984 \\ 105.600 \times 50 &=& 5280.000 \\ 64.000 \times 70 &=& 4480.000 \\ 54.000 \times 80 &=& 4320.000 \\ \hline 388.044 & & 19999.984 \end{array}$$

19,999.984 ÷ 388.044 = 51.540s, average number of yarn

MULE SPINNING

The chief difference between the ring spinning frame and the mule is that the former is a constant, and the latter an intermittent, spinning machine. There is also a difference in the form in which the yarn is produced. The ring spinning frame winds it on a wooden or paper bobbin, and the mule produces yarn in the form of a cop. In the mechanism by which the yarn is produced, the ring spinning frame differs very considerably from the mule; in fact, the two machines are radically different in principle, construction, and operation.

The mule has three principal objects: (1) the reduction of the roving to the counts of yarn desired; (2) twisting the yarn to give it sufficient strength for the purpose intended; (3) winding the yarn in suitable form for use at the next process.

A sectional view of the essential parts of the mule is given in Fig. 1. Generally speaking, the machine proper consists of a *headstock*, which contains most of the mechanism for operating the various parts; a *creel* b for holding the roving that is to be drawn and converted into yarn; *drawing rolls* c, c_1, c_2 for inserting the required amount of draft to reduce the size of the roving; and a *carriage* d that carries spindles for twisting and winding the yarn, a cylinder for driving the spindles, and

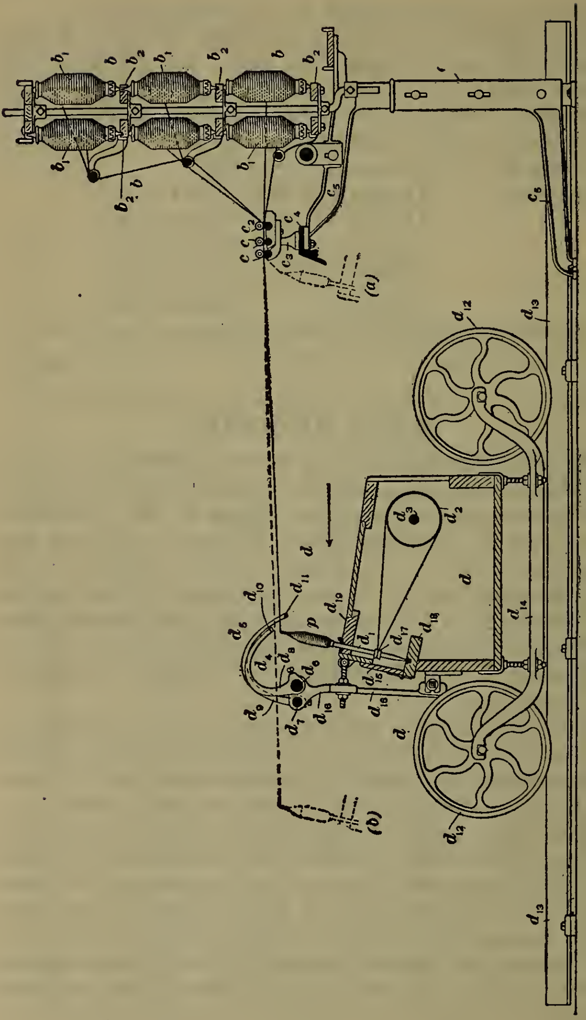


FIG. 1

fallers for guiding the yarn on to the spindles and keeping it under tension during winding.

The bobbins of roving b_1 from the last fly-frame process are placed in the creel b and the ends conducted to the drawing rolls c_2, c_1, c, through which they pass, in order that they may be drafted as required. After leaving the front drawing rolls, the stock passes to the spindles d_1, which are carried by the carriage. The carriage recedes from the rolls, as the stock is being delivered, but after the rolls cease to deliver, it returns. When the rolls first commence to deliver, the spindles occupy position (*a*), shown in dotted lines, and gradually recede in the direction shown by the arrow, until position (*b*) is reached, when the rolls stop delivering and the carriage ceases to move outwards. The extent of the outward movement of the carriage, known as the *draw*, or *stretch*, varies from 53 to 68 in., the general length being about 62 or 64 in.

During the outward run of the carriage, the spindles are revolving and inserting twist in the yarn, which is accomplished by having the upper ends of the spindles slightly below the delivering point of the rolls, as shown by the dotted lines in position (*a*), and the spindles inclined, with the upper end nearer the rolls than the lower.

Since the spindle is inclined toward the rolls and is revolving as the stock is being delivered, a few open spirals of yarn are wound on its blade between the *nose*, or upper end, of the cop and the point of the spindle. If the spindle were extended, the yarn would wind on it in open spirals until it formed a right angle with the spindle; but since the spindle is not thus extended, after the coils of yarn have reached its upper end, every time it makes one revolution the upper coil is slipped off just as it is being completed, thus inserting one turn of twist in the yarn. The spindles by receding from the rolls keep the yarn under tension as it is being delivered, and since they are continually revolving during this time, they are continually inserting twist. The inclination of the spindles assists in allowing the yarn to pass easily over their ends, especially when the carriage is near the end of its outward run, as the angle between the yarn and the spindles approaches nearer to a right angle than when the carriage is first starting out. This is shown by positions (*a*) and (*b*). The spindles are driven by bands passing around the revolving cylinder d_2 and the whorls on the spindles.

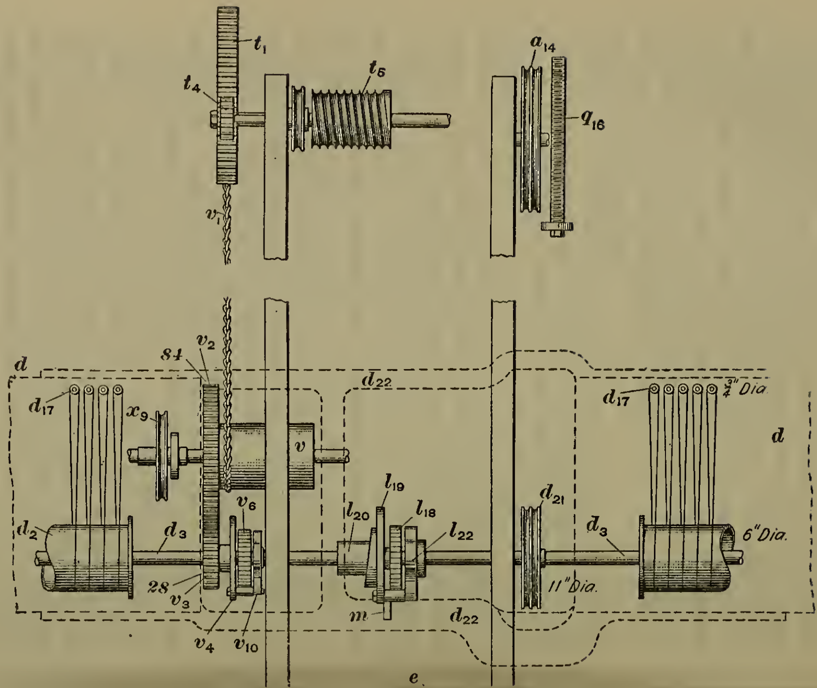
While the carriage is running out, the fallers d_4, d_5, known as the *winding* and *counter fallers*, respectively, are not in contact with the yarn, but occupy the positions shown, the winding-faller wire being above the yarn and the counter-, or tension-, faller wire, below. The winding faller is for the purpose of guiding the yarn on to the spindles in the proper form to build up a cop, while the counter faller keeps the yarn under tension during winding.

When the carriage has reached position (*b*), the spindles and rolls are stopped and the spinning is completed. In order that the yarn may be wound on the spindles, the open coils of yarn between the nose of the cops and the ends of the spindles must be unwound; this is done by causing the spindles to make a few revolutions in the opposite direction to that in which they revolve during spinning and winding, and is known as *backing off*. After the open coils are entirely unwound, the spindles stop revolving in this direction, the fallers in the meantime having assumed their proper positions for winding. Winding commences as the carriage starts to run in and continues, the yarn being guided on to the spindles by the winding faller, until position (*a*) is reached, when the carriage and spindles stop, which completes the cycle of operations. The rolls now begin to deliver, the spindles to revolve, and the carriage to move outwards, as before.

Calculations.—To find the number of turns of twist being inserted in the yarn, the following rule may be applied:

Rule.—*Assuming the front-roll gear to be a driving gear, divide the product of the driving gears and the diameters, in inches, of the rim pulley and cylinder by the product of all the driven gears and the diameters, in inches, of the cylinder pulley, whorl, and the front roll multiplied by 3.1416 to give its circumference.*

EXAMPLE.—Find the number of turns of twist per inch being inserted in the yarn, with a deduction of 5% for slippage of bands, belts, etc., according to the data given in Fig. 2.



t1
t4
t5
v1
a14
q16
d
84
v2
d17
x9
v
v6
d2
d3
28
v3
v4
v10
d22
l19
l20
l18
l22
m
d21
11" Dia.
3/4" Dia.
6" Dia.
e

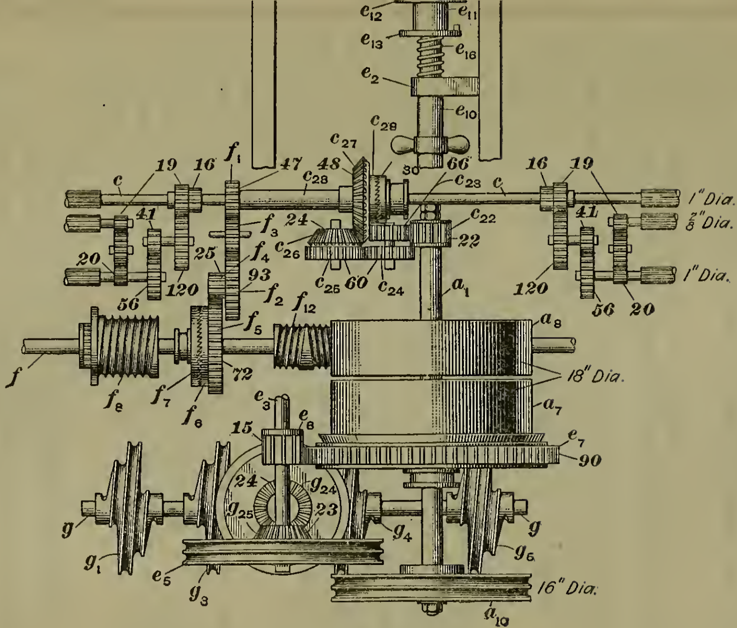


Fig. 2

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SOLUTION.— $$\frac{48\times 60\times 66\times 16\times 6}{24\times 60\times 22\times 11\times \frac{3}{4}\times 1\times 3.1416} = 22.223$$

5% of 22.223 = 1.111. 22.223 − 1.111 = 21.112, turns of twist.

To find the number of turns of twist per inch being inserted in the yarn when the number of revolutions per minute of the spindles and the number of inches of stock delivered per minute are known:

Rule.—*Divide the number of revolutions per minute of the spindles by the number of inches of stock delivered per minute by the front roll.*

EXAMPLE.—Find the number of turns of twist per inch being inserted in the yarn when the spindles make 9,819.786 rev. per min. and the front roll delivers 465.113 in. of stock.

SOLUTION.—

$$9{,}819.786 \div 465.113 = 21.112, \text{ turns of twist per in.}$$

The twist is generally altered by changing the rim pulley or the speed gear. The speed gear is the one changed under ordinary conditions, which require only a slight alteration in the amount of twist, but for a considerable change the rim pulley is altered; in extreme cases both are changed. Referring to Fig. 2, the spur gear c_{23}, of 66 teeth driven by the 22-tooth gear c_{22} on the front end of the rim shaft is the speed gear.

To find the constant for twist for the rim pulley when the sizes of the gears, pulleys, etc. are known:

Rule.—*Perform the calculations in exactly the same manner and select exactly the same data as when finding the twist, except that the rim pulley should be considered as 1 in. in diameter.*

EXAMPLE.—Find the constant for twist for the rim pulley according to the data given in Fig. 2.

SOLUTION.—

$$\frac{48\times 60\times 66\times 1\times 6}{24\times 60\times 22\times 11\times \frac{3}{4}\times 1\times 3.1416} = 1.3889, \text{ constant}$$

To find the constant for twist for the speed gear when the sizes of the gears, pulleys, etc. are known:

Rule.—*Perform the calculations in exactly the same manner and select exactly the same data as when finding the twist, except that the speed gear should be considered as having only 1 tooth.*

EXAMPLE.—Find the constant for twist for the speed gear c_{23} according to the data given in Fig. 2.

Solution.—

$$\frac{48 \times 60 \times 1 \times 16 \times 6}{24 \times 60 \times 22 \times 11 \times \frac{3}{4} \times 1 \times 3.1416} = .3367, \text{ constant}$$

To find the number of turns of twist per inch being inserted in the yarn when the constant for the rim pulley and the size, or diameter, of the rim pulley are known:

Rule.—*Multiply the diameter of the rim pulley being used by the constant for twist for the rim pulley.*

Example.—Find the turns of twist per inch being inserted in the yarn, making a deduction of 5% for slippage of bands, belts, etc., when a 16-in. rim pulley is used and the constant is 1.3889.

Solution.— $16 \times 1.3889 = 22.222$. 5% of $22.222 = 1.111$; $22.222 - 1.111 = 21.111$, turns of twist per in.

To find the number of turns of twist per inch being inserted in the yarn when the constant for the speed gear and size of the speed gear are known:

Rule.—*Multiply the size of the speed gear being used by the constant for twist for the speed gear.*

Example.—Find the turns of twist per inch being inserted in the yarn, making a deduction of 5% for slippage of bands, belts, etc., when a 66-tooth speed gear is being used and the constant is .3367.

Solution.— $66 \times .3367 = 22.222$. 5% of $22.222 = 1.111$. $22.222 - 1.111 = 21.111$, turns of twist per in.

To find the diameter of the rim pulley being used when the calculated twist and the constant for twist for the rim pulley are known:

Rule.—*Divide the number of turns of twist per inch by the constant for twist for the rim pulley.*

Example.—Find the diameter of the rim pulley required to produce 22.223 turns of twist per inch when the constant for twist for the rim pulley is 1.3889.

Solution.— $22.223 \div 1.3889 = 16$ in., dia. of rim pulley.

To find the size of the speed gear being used when the calculated twist and the constant for twist for the speed gear are known:

Rule.—*Divide the number of turns of twist per inch by the constant for twist for the speed gear.*

EXAMPLE.—Find the size of the speed gear required to produce 22.223 turns of twist per inch when the constant for twist for the speed gear is .3367.

SOLUTION.—

$22.223 \div .3367 = 66.002$, or practically a 66-tooth gear

To find the twist to be inserted in a certain class of yarn, the square root of the counts to be spun and the standard multiplier for that class of work must be known, in which case the square root of the counts is multiplied by the standard multiplier. The standard multiplier varies for different classes of work and kinds of cotton; the following are not absolute, but are given as a guide: For warp and filling yarns spun on the mule from American cotton, 3.75 and 3.25 respectively, are used; for Egyptian cotton, 3.6 and 3.18, respectively; and 2.75 for filling yarns spun from sea-island cotton. For hosiery yarns the multiplier ranges from 2.25 to 2.6, as hosiery yarns are softer than weaving yarns and require less twist. Long stock requires less twist than short stock, and combed stock less than carded stock. In many cases the constant multiplier is given with each order, especially with those for hosiery yarns.

EXAMPLE.—Find the standard number of turns of twist per inch for 39s filling yarn spun from American cotton.

SOLUTION.— $\sqrt{39} = 6.244$. $6.244 \times 3.25 = 20.293$, standard number of turns of twist per in.

If carded stock is being used, the above result will be increased about 1 or $1\frac{1}{2}$ turns per inch; thus, $20.293 + 1 = 21.293$ turns of twist per inch for carded stock.

The following examples illustrate the methods of finding the total draft, constant for total draft, size of change gear required to produce any desired draft, and the draft produced by a certain size of change gear:

EXAMPLE.—Find the total draft, or the draft between the front and back drawing rolls, according to the data given in Fig. 2.

SOLUTION.— $\frac{1 \times 120 \times 56}{19 \times 41 \times 1} = 8.626$, total draft

EXAMPLE.—Find the constant for the total draft according to the data given in Fig. 2, considering the 41-tooth gear as the draft gear.

SOLUTION.—

$$\frac{1 \times 120 \times 56}{19 \times 1 \times 1} = 353.684, \text{ constant for total draft}$$

EXAMPLE.—Find the size of the draft gear required to produce a draft of 8.626 when the constant is 353.684.

SOLUTION.— $353.684 \div 8.626 = 41.002$, or practically a 41-tooth draft gear.

EXAMPLE.—Find the draft produced by a 41-tooth draft gear when the constant is 353.684.

SOLUTION.— $353.684 \div 41 = 8.626$, draft

The production of mules may be found in three general ways: (1) by taking into consideration the number of stretches per minute, the length of each stretch, the number of spindles per mule, the counts of yarn being spun, and the length of time run; (2) by using indicators, or hank clocks; (3) by keeping an account of the weight of each doff for a given period, adding the estimated amount on the spindles at the end of this time, and deducting the amount on the spindles at the beginning.

To find the production for a given length of time according to the first method:

Rule I.—*Divide the product of the number of stretches per minute, the length of each stretch, 60 (the number of minutes per hour), the number of hours run, the number of spindles per mule, and the number of mules by the product of 36 (the number of inches in a yard), 840 (the number of yards in a hank), and the counts of the yarn being spun. Usually a deduction of about 10% is made for stoppages, such as doffing, cleaning, etc.*

EXAMPLE.—Find the total number of pounds produced in a week of 60 hr., making a deduction of 10% for stoppages, etc., by 6 mules of 780 spindles each. The yarn being spun is 39s and each mule makes $5\frac{1}{2}$ draws, or stretches, of 62 in., per minute.

SOLUTION.— $$\frac{5\frac{1}{2} \times 62 \times 60 \times 60 \times 780 \times 6}{36 \times 840 \times 39} = 4{,}871.428 \text{ lb.}$$

10% of $4{,}871.428 = 487.142$. $4{,}871.428 - 487.142 = 4{,}384.286$ lb.

To find the production for a given length of time according to the second method, that is, using indicators:

Rule II.—*Multiply the number of hanks per spindle produced by each mule by the number of spindles in that mule and divide by the counts of yarn being spun to find the number of pounds produced. To find the total number of pounds produced, add the number of pounds produced by each mule. Usually a deduction of from 2½% upwards is made for waste, etc.; although in some cases the indicators are constructed so as to provide for this allowance.*

EXAMPLE.—Find the total number of pounds produced by 6 mules of 780 spindles each, making a deduction of 3½% for waste, etc. The hank clock on each mule registers, respectively, 38.25, 37.5, 37, 37.25, 38.75, and 38.5 hanks, and the counts of the yarn being spun are 39s.

SOLUTION.—

$$\frac{38.25 \times 780}{39} = 765 \text{ lb.}$$

$$\frac{37.5 \times 780}{39} = 750 \text{ lb.}$$

$$\frac{37 \times 780}{39} = 740 \text{ lb.}$$

$$\frac{37.25 \times 780}{39} = 745 \text{ lb.}$$

$$\frac{38.75 \times 780}{39} = 775 \text{ lb.}$$

$$\frac{38.5 \times 780}{39} = 770 \text{ lb.}$$

765+750+740+745+775+770=4,545 lb. 3½% of 4,535 =159.075. 4,545−159.075=4,385.925 lb. of 39s yarn

Rule III.—*Multiply the sum of the hanks per spindle produced by each mule by the number of spindles per mule and divide by the counts of the yarn. The usual deduction for waste should be made.*

EXAMPLE.—Same as example under Rule II.

SOLUTION.— 38.25+37.5+37+37.25+38.75+38.5= 227.25, total number of hanks. $\frac{227.25 \times 780}{39} = 4{,}545$ lb. 3½% of 4,545=159.075. 4,545−159.075=4,385.925, total number of lb. of 39s yarn.

To find the production for a given length of time according to the third method:

Rule IV.—*Find the total number of pounds doffed for the given time, add to this the estimated number of pounds on spindles at the end of this time, and then deduct the number of pounds on the spindles at the commencement of this time.*

Example.—Find the total number of pounds of yarn produced in 1 wk. by 6 mules that have produced 121 doffs of practically 36 lb. each. At the end of the week there is approximately 100 lb. of yarn on the spindles, and at the end of the previous week, or the beginning of the week under consideration, there was 71 lb.

Solution.— $36 \times 121 = 4{,}356$ lb. doffed. $4{,}356 + 100 = 4{,}456$. $4{,}456 - 71 = 4{,}385$ lb. produced.

Changing Counts.—To find the size of the draft gear required to produce a yarn of certain counts when the counts of the yarn being spun and the draft gear in use are known and when the hank of the back roving remains the same:

Rule.—*Multiply the counts of the yarn being spun by the draft gear in use and divide by the counts of the yarn desired.*

Example.—Find the size of the draft gear required to produce 45s yarn when 39s is being spun with a 41-tooth draft gear. The hank of the back roving is the same in both cases.

Solution.—

$$\frac{39 \times 41}{45} = 35.533, \text{ or practically a 36-tooth draft gear}$$

To find the size of the draft gear required to produce a yarn of certain counts when the hank of the back roving is to be changed, and the counts of the yarn being spun, the draft gear in use, the hank of the back roving being used, and the hank of the back roving to be used are known:

Rule.—*Divide the product of the counts of the yarn being spun, the gear being used, and the hank of the back roving to be used by the product of the counts of the yarn required and the hank of the back roving being used.*

Example.—Find the size of the draft gear required to produce 45s yarn with a 6-hank back roving when 39s is being spun from 4.5-hank back roving with a 41-tooth draft gear. The back roving is running single; that is, one end per spindle.

PRODUCTION OF MULES

No. of Yarn	Stretches per Minute, 64-Inch Stretch	Hanks per Spindle per Day	Pounds per Spindle per Week	
			Without Roller Motion	With 5 Per Cent. Roller Motion
6	6.00	6.85	6.85	7.20
8	6.00	6.85	5.13	5.39
10	6.00	6.85	4.11	4.31
12	6.00	6.85	3.42	3.59
14	5.50	6.28	2.69	2.82
16	5.50	6.28	2.35	2.47
18	5.50	6.28	2.09	2.20
20	5.50	6.28	1.88	1.97
22	5.50	6.28	1.71	1.79
24	5.50	6.28	1.57	1.64
26	5.25	6.00	1.38	1.45
28	5.25	6.00	1.28	1.34
30	5.25	6.00	1.20	1.26
32	5.25	6.00	1.12	1.17
34	5.25	6.00	1.05	1.11
36	5.125	5.85	.97	1.02
38	5.125	5.85	.92	.97
40	5.00	5.71	.85	.89
42	5.00	5.71	.81	.85
44	4.75	5.42	.73	.77
46	4.75	5.42	.70	.74
48	4.50	5.24	.65	.68
50	4.50	5.24	.62	.66
52	4.25	4.85	.55	.58
54	4.25	4.85	.53	.56
56	4.25	4.85	.51	.54
58	4.25	4.85	.50	.52
60	4.125	4.71	.47	.50
62	4.125	4.71	.45	.47
64	4.125	4.71	.44	.46
66	4.125	4.71	.42	.44
68	4.00	4.57	.40	.42
70	4.00	4.57	.39	.41
72	4.00	4.57	.38	.40
74	4.00	4.57	.37	.38
76	4.00	4.57	.36	.37
78	4.00	4.57	.35	.36

NOTE.—Allowance has been made for stoppage for cleaning and doffing.

SOLUTION.—

$$\frac{39\times 41\times 6}{45\times 4.5}=47.377, \text{ or practically a 47-tooth draft gear}$$

To find the size of the speed gear required to give the proper twist for any counts of yarn without changing the rim pulley, when the counts of the yarn being spun, the counts of the yarn to be spun, and the size of the speed gear being used are known:

Rule.—*Multiply the size of the speed gear being used by the square root of the counts required and divide by the square root of the counts being spun.*

EXAMPLE.—Find the size of the speed gear required for 45s yarn when 39s is being spun with a 66-tooth speed gear.

SOLUTION.— $\sqrt{39}=6.244$; $\sqrt{45}=6.708$

$$\frac{66\times 6.708}{6.244}=70.904, \text{ or practically a 71-tooth speed gear}$$

To find the size, or diameter, of the rim pulley required to give the proper twist for any counts of yarn without changing the speed gear, when the counts of the yarn being spun, the counts of the yarn to be spun, and the diameter of the rim pulley being used are known:

Rule.—*Multiply the diameter of the rim pulley being used by the square root of the counts required and divide by the square root of the counts being spun.*

EXAMPLE.—Find the diameter of the rim pulley required for 45s yarn when 39s is being spun with a 16-inch rim pulley.

SOLUTION.— $\sqrt{39}=6.244$; $\sqrt{45}=6.708$

$$\frac{16\times 6.708}{6.244}=17.188, \text{ or practically a 17-inch rim pulley}$$

To find the size of the builder gear to give the required rate of movement to the builder for any counts of yarn, when the counts of the yarn being spun, the size of the builder gear being used, and the counts of the yarn required are known:

Rule I.—*Multiply the builder gear being used by the square root of the counts of the yarn required and divide by the square root of the counts of the yarn being spun.*

EXAMPLE.—Find the size of the builder gear required to spin 45s yarn when 39s yarn is being spun with a 28-tooth builder gear.

SOLUTION.— $\sqrt{45}=6.708$; $\sqrt{39}=6.244$

$$\frac{28\times 6.708}{6.244}=30.08, \text{ or practically a 30-tooth builder gear}$$

Rule II.—*Multiply the square of the builder gear being used by the counts of yarn that it is desired to spin and divide by the counts of yarn being spun. Extract the square root of the result thus obtained.*

EXAMPLE.—Same as example **1.**

SOLUTION.— $$\frac{28^2\times 45}{39}=904.615$$

$\sqrt{904.615}=30.077$, or practically a 30-tooth builder gear.

Another method of finding the size of the builder gear for any counts of yarn requires that the constant for the builder gear shall first be found.

To find the constant for the builder change gear when the length of the screw being used and the pitch, or number of threads to the inch, in the screw are known:

Rule.—*Multiply the length, in inches, of the part of the screw that is being used by the pitch of the screw.*

EXAMPLE.—Find the constant for the builder change gear when $7\frac{1}{2}$ in. of a 4-pitch screw is being used during the formation of a set of cops.

SOLUTION.— $7.5\times 4=30$, constant

To find the number of stretches, or draws, in a cop of any counts of yarn when the weight of the cop, the counts of the yarn, and the length of the stretch are known:

Rule.—*Divide the product of the weight of the cop, in grains, 840 (the number of yards in 1 hank), 36 (the number of inches in 1 yd.), and the counts of the yarn by the product of 7,000 (the number of grains in 1 lb.) and the number of inches in one stretch.*

EXAMPLE.—Find the number of 62-in. stretches required to produce a 330-gr. cop of 39s yarn.

SOLUTION.— $$\frac{330\times 840\times 36\times 39}{7{,}000\times 62}=896.748 \text{ stretches}$$

To find the size of the builder change gear required for any counts of yarn when the constant for the change gear, the weight of a full cop of yarn, the length of one stretch, and the counts of the yarn required are known:

Rule.—*First find the number of stretches required for a full cop of yarn of the weight and counts required, and then divide the number of stretches required by the constant.*

EXAMPLE.—Find the size of the builder gear required for a 62-in. stretch mule to spin a 330-in. cop of 45s yarn when the constant for the builder change gear is 30.

SOLUTION.— $\frac{330\times 840\times 36\times 45}{7{,}000\times 62}=1{,}034.709$ stretches

$1{,}034.709\div 30=34.49$, or practically a 34-tooth builder gear

NOTE.—It will be seen that the results obtained by these rules vary somewhat. Since, however, the proper size of builder gear is influenced by many other factors, such as the tension on the yarn during winding (which is governed by the amount of weight on the counter faller and action of the quadrant), the amount of twist inserted in the yarn, etc., no rule will give absolutely accurate results. Rules for finding the size of the builder gear must therefore be considered as giving approximate results only, and it may often be found necessary to slightly increase or decrease the calculated size of the builder gear as the case may require.

The horsepower required to drive a mule varies, especially during the different periods in its actions. It is generally estimated, however, to be about 1 H. P. for every 100 to 110 spindles for coarse counts, 110 to 120 for medium counts, and 120 to 130 for fine counts. Generally speaking, a mule of about 700 spindles, spinning medium counts, with a spindle speed of about 9,000 rev. per min., under favorable conditions will require, during the drawing-and-twisting period, about 25 H. P. for the first 2 or 3 sec. as the carriage starts out; after that it decreases to about 10 or 12 H. P. until the carriage completes its outward run, when the horsepower is reduced to about 1 or $1\frac{1}{2}$ until backing off is completed. As winding commences and the carriage starts in, the power required is increased from 1 or $1\frac{1}{2}$ to about 3 H. P. This continues until the winding is completed, when the power is decreased to practically nothing.

TWISTING

The name ply yarns is given indiscriminately to all threads that are composed of two, three, or more single yarns twisted together at one operation, and they are distinguished from one another by the terms two-ply, three-ply, and so on. When two or more ply threads are twisted together the resulting yarns are spoken of as *cabled yarns*.

The twisting process may be performed on machines of various types, depending on two distinct factors: (1) the condition of the yarn when it is being twisted, and (2) the method employed to insert the twist. The yarn is twisted in two conditions—wet or dry—giving the names *wet twisters* and *dry twisters* to the two types of machines.

The machine most commonly used for twisting is that known in America as a *ring twister*. The object of the twister is to form the ply yarn by inserting a sufficient amount of twist in the required direction and to wind the resulting yarn on a twister bobbin.

The principle on which the ring twister is constructed and operated is to pass the yarn from a creel to delivery rolls and twist it by passing it through a traveler that is revolved rapidly around a ring, by means of a rotating spindle carrying a bobbin; the difference between the circumferential speed of the bobbin and the speed of the traveler causes the twisted yarn to be wound on the bobbin.

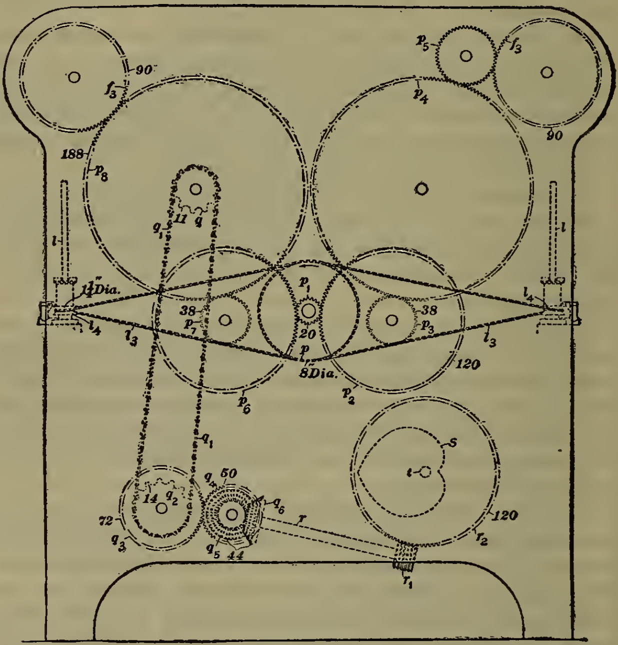
The twister closely resembles the ring spinning frame, a large number of parts and motions of which are duplicated on a twister. Ring twisters for both wet and dry twisting are similar in construction, with the exception that in the wet twister, the yarn immediately before being twisted is moistened by being passed through a trough containing clean water.

Calculations.—The only calculations that are of importance in connection with twisters are: (1) those that are useful in determining the twist per inch inserted in the ply yarn, and (2) those that are useful in determining the production of a twister. As there are no draft rolls in a twister, the subject of drafts, of course, does not enter into any calculations.

Example.—If the speed of the front, or delivery, roll of a twister corresponds with that of the 90-tooth gear f_3, shown in the accompanying illustration, what is its speed when the cylinder makes 1,185 rev. per min.

Solution.—

$$\frac{1,185 \times 20 \times 38}{120 \times 90} = 83.388 \text{ rev. per min. of the front roll}$$



Example.—Find the number of inches delivered per minute by the front roll when it makes 83.388 rev. per min. and is $1\frac{1}{2}$ in. in diameter.

Solution.— $83.388 \times 1\frac{1}{2} \times 3.1416 = 392.957$ in. per min.

Example.—Find the speed of the spindles when the cylinder is 8 in. in diameter and makes 1,185 rev. per min., the spindle whorl being $1\frac{1}{4}$ in. in diameter.

SOLUTION.—If the exact diameter of the cylinder and the smallest diameter of the whorl are taken, accurate results are not obtained, as some allowance should be made for the diameter of the spindle band, which is usually $\frac{1}{8}$ in. The most nearly correct way is to make an allowance for this both on the diameter of the cylinder and of the spindle whorl, but it is more convenient and gives sufficiently accurate results to use the actual diameter of the cylinder but add $\frac{1}{8}$ in. to the diameter of the spindle whorl at its smallest part. This is the practice that is followed here.

$$\frac{1{,}185 \times 8}{1\frac{3}{8}} = 6{,}894.545 \text{ rev. per min. of the spindles}$$

EXAMPLE.—What is the twist per inch being inserted in the yarn, if the front roll delivers 392.957 in. per min. and the spindles make 6,894.545 rev. per min.?

SOLUTION.— $6{,}894.545 \div 392.957 = 17.545$ turns per in.

NOTE.—Some millmen make a deduction from the calculated result of 5% to allow for slippage and loss in winding, but this should not be done, as the yarn contracts during the process of twisting in about the correct proportion to compensate for such slippage.

EXAMPLE.—Find the twist per inch being inserted in the yarn by figuring through the gears from the front roll to the spindles, thus ascertaining the number of revolutions of the spindles per inch delivered by the front rolls.

SOLUTION.—

$$\frac{36 \times 90 \times 120 \times 8}{36 \times 38 \times 20 \times 1\frac{3}{8} \times 1\frac{1}{2} \times 3.1416} = 17.545 \text{ turns per in.}$$

EXAMPLE.—Find the constant for twist by figuring through the gears from the front roll to the spindles, adding $\frac{1}{8}$ in. to the diameter of the whorl and considering p_1 as the twist change gear.

SOLUTION.—

$$\frac{36 \times 90 \times 120 \times 8}{36 \times 38 \times 1 \times 1\frac{3}{8} \times 1\frac{1}{2} \times 3.1416} = 350.901, \text{ constant}$$

EXAMPLE.—Find the twist per inch being inserted in the yarn with a 20-tooth twist gear, if the constant is 350.901

SOLUTION.— $350.901 \div 20 = 17.545$ turns per in.

EXAMPLE.—Find the twist gear required to produce 17.545 turns per inch if the constant is 350.901.

SOLUTION.— $350.901 \div 17.545 = 20$-tooth twist gear.

The amount of twist to be inserted in ply yarns is specified by a *multiplier*, which, when multiplied by the square root of the counts of the single yarn to which the ply yarn under consideration would be equal, approximately indicates the turns per inch to be inserted. The range of multipliers is from 2.5 to 6.5. The smallest are used for mending yarns, knitting yarns, and embroidery yarns, since these are commonly required to be soft, full yarns; larger multipliers are used for yarns intended for sewing threads, and the largest are for such yarns as those intended for fishing nets, macramé, and other hard twines, harness yarn, etc.

EXAMPLE.—Find the turns per inch to be inserted in 2-ply 72s using 5 as a multiplier.

SOLUTION.—Considering the 2-ply yarn as a single yarn its counts would be

$$72s \div 2 = 36. \quad \sqrt{36} = 6. \quad 6 \times 5 = 30 \text{ turns per in.}$$

EXAMPLE.—What twist per inch should be inserted in 5-ply 85s with a multiplier of 6?

SOLUTION.—

$$85s \div 5 = 17 \quad \sqrt{17} = 4.1231 \quad 4.1321 \times 6 = 24.738$$

In some districts in the United States, it is customary to take as a multiplier a number that, when multiplied by the square root of the counts of the single yarn used to form the ply yarn, gives the turns per inch in the ply yarn; this is also a common method in Europe. It is therefore always important to understand whether a multiplier is to be considered as multiplying the square root of the counts of the single yarn, forming the ply yarn, or of a single yarn that would be equivalent to the completed ply yarn, since in the latter case the multiplier is larger than in the former.

EXAMPLE.—What multiplier would be used with which to multiply the square root of the single yarn in order to give 30 turns per inch in 2-ply 72s?

SOLUTION.— $\sqrt{72} = 8.485 \quad 30 \div 8.485 = 3.5$

The multiplier in this case, 3.5, when multiplied by the square root of the counts of the single yarns forming the ply yarn, gives 30 turns per inch, just as the multiplier 5 gave 30 turns per inch in a previous example when multiplied by the square root of 36, which was considered as the counts of a single yarn equivalent to 2-ply 72s.

Production.—As twisters are not provided with hank clocks the production is generally figured directly from the front roll, which gives only a theoretical production.

Rule.—*To find the number of hanks per spindle, multiply the number of inches delivered per minute by the total number of minutes run, and divide the product thus obtained by the number of yards per hank multiplied by 36 (the number of inches per yard). From this calculated production, a certain percentage should be allowed for stoppages.*

EXAMPLE.—If the front roll delivers 392.957 in. per min., what is the production for 1 wk. of 60 hr., allowing 6% for stoppages?

SOLUTION.— $\frac{392.957\times60\times60}{840\times36}=46.780$ hanks per spindle per wk. $.94\times46.780=43.973$ hanks.

The allowance of 6% in this example is not accurate for all kinds of twisting, for this varies from 5 to 20%. The allowance is intended to compensate for the amount of time lost in stopping the frame for doffing and various other purposes. It is least in the case of fine yarns, as the frames do not require doffing so frequently, and greatest in the case of coarse yarns. It is also greater when several single yarns are being twisted than when 2-ply yarns are being made. For example, the allowance for 2-ply 6s is usually 14%; for 3-ply, 15%; for 4-ply, 17%; and for 6-ply, 20%. For number 20s, the allowances are 10%, 11%, 12%, and 13% for 2-, 3-, 4-, and 6-ply, respectively. For 40s, the allowances are 6% for 2-ply, 7% for 3-ply, and 8% for 4- or 6-ply; for number 80s, 4% for 2-ply, 5% for 3- and 4-ply, and 6% for 6-ply. This allowance should not be confused with an allowance sometimes made for slippage.

Rule.—*To find the number of pounds per spindle, divide the number of hanks per spindle by the resultant counts.*

EXAMPLE.—If a frame produces 43.973 hanks per spindle per week, what is the production per spindle in pounds if two strands of 40s are twisted together?

NUMBER OF POUNDS OF 2-PLY YARN PRODUCED IN 10 HOURS

No. Yarn to be Twisted	Rev. of Spindle per Min.	Multiplier 4			Multiplier 5			Multiplier 6		
		Rev. per Min.		Lb. per Spindle	Rev. per Min.		Lb. per Spindle	Rev. per Min.		Lb. per Spindle
		$1\frac{3}{8}''$ Roll	$1\frac{1}{2}''$ Roll		$1\frac{3}{8}''$ Roll	$1\frac{1}{2}''$ Roll		$1\frac{3}{8}''$ Roll	$1\frac{1}{2}''$ Roll	
6	4,500	150.3	137.8	3.97	120.3	110.3	3.18	100.3	91.9	2.65
7	4,750	147.0	134.8	3.33	117.6	107.8	2.67	98.0	89.8	2.22
8	5,000	144.7	132.6	2.87	115.7	106.1	2.29	96.4	88.4	1.91
9	5,200	141.8	130.0	2.50	113.4	104.0	2.01	94.6	86.7	1.67
10	5,300	137.2	125.8	2.18	109.7	100.6	1.75	91.4	83.8	1.46
11	5,500	135.8	124.5	1.96	108.5	99.5	1.57	90.5	83.0	1.30
12	5,500	130.0	119.1	1.71	103.9	95.2	1.38	86.6	79.4	1.15
13	5,650	128.2	117.5	1.57	102.6	94.1	1.25	85.5	78.4	1.05
14	5,750	125.8	115.3	1.43	100.6	92.2	1.14	83.9	76.9	.96
15	5,900	124.7	114.3	1.31	99.8	91.5	1.06	83.0	76.1	.88
16	6,000	122.8	112.6	1.22	98.2	90.0	.98	81.8	75.0	.81
18	6,050	116.6	106.9	1.03	93.5	85.7	.82	77.8	71.3	.69
20	6.150	112.5	103.1	.91	90.0	82.5	.73	75.0	68.8	.60
22	6,300	109.9	100.7	.80	87.9	80.6	.64	73.3	67.2	.54
24	6,500	108.5	99.5	.73	86.8	79.6	.58	72.4	66.4	.49
26	6,650	106.7	97.8	.66	85.4	78.3	.53	71.2	65.3	.44
28	6,800	105.1	96.3	.60	84.1	77.1	.48	70.1	64.3	.40
30	6,900	103.0	94.4	.55	82.4	75.5	.44	68.7	63.0	.37
32	7,000	101.3	92.9	.51	81.0	74.3	.41	67.6	62.0	.34
34	7,000	98.2	90.0	.46	78.5	72.0	.37	65.5	60.0	.31
36	7,000	95.5	87.5	.42	76.4	70.0	.34	63.6	58.3	.29
38	7,000	92.9	85.2	.39	74.3	68.1	.32	61.9	56.7	.26
40	7,000	90.6	83.1	.37	72.5	66.5	.30	60.4	55.4	.24
50	7,500	86.8	79.6	.28	69.4	63.6	.22	57.9	53.1	.19
60	7,500	79.2	72.6	.22	63.4	58.1	.17	52.8	48.4	.15
70	7,500	73.4	67.3	.18	58.7	53.8	.14	48.9	44.8	.12

NOTE.—Allowance has been made for waste, cleaning, oiling, and doffing.

NUMBER OF POUNDS OF 3-PLY YARN PRODUCED IN 10 HOURS

No. Yarn to be Twisted	Rev. of Spindle per Min.	Multiplier 4			Multiplier 5			Multiplier 6		
		Rev. per Min.		Lb. per Spindle	Rev. per Min.		Lb. per Spindle	Rev. per Min.		Lb. per Spindle
		$1\frac{3}{8}''$ Roll	$1\frac{1}{2}''$ Roll		$1\frac{3}{8}''$ Roll	$1\frac{1}{2}''$ Roll		$1\frac{3}{8}''$ Roll	$1\frac{1}{2}''$ Roll	
6	4,000	163.6	150.0	6.48	130.9	120.0	5.18	109.1	100.0	4.33
7	4,300	162.9	149.3	5.54	130.3	119.4	4.43	108.6	99.6	3.69
8	4,550	161.2	147.8	4.80	129.1	118.3	3.83	107.5	98.5	3.20
9	4,800	160.4	147.0	4.23	128.3	117.6	3.38	106.9	98.0	2.82
10	5,000	158.6	145.4	3.77	126.7	116.2	3.02	105.7	96.9	2.51
11	5.200	157.1	144.0	3.39	125.8	115.3	2.71	104.8	96.1	2.26
12	5,350	154.8	141.9	3.07	123.8	113.5	2.46	103.2	94.6	2.05
13	5,500	152.8	140.1	2.80	122.3	112.1	2.24	101.9	93.4	1.87
14	5,600	150.0	137.5	2.54	120.0	110.0	2.03	100.0	91.7	1.69
15	5,750	148.8	136.4	2.36	119.0	109.1	1.89	99.2	90.9	1.57
16	5,850	146.6	134.4	2.18	117.2	107.4	1.74	97.7	89.6	1.45
18	5,950	140.5	128.8	1.86	112.4	103.0	1.49	93.7	85.9	1.24
20	6,000	134.5	123.3	1.60	107.6	98.6	1.28	89.7	82.2	1.07
22	6,000	128.2	117.5	1.39	102.5	94.0	1.12	85.5	78.4	.93
24	6,000	122.8	112.6	1.22	98.2	90.0	.98	81.9	75.1	.81
26	6,100	120.1	110.1	1.09	95.9	87.9	.87	80.0	73.3	.73
28	6,250	118.4	108.5	1.01	94.7	86.8	.81	78.9	72.3	.67
30	6,400	117.1	107.3	.94	93.7	85.9	.75	78.1	71.6	.63
32	6,500	115.2	105.6	.86	92.1	84.4	.69	76.8	70.4	.57
34	6,500	111.8	102.5	.79	89.4	82.0	.63	74.5	68.3	.53
36	6,500	108.5	99.5	.73	86.9	79.7	.58	72.4	66.4	.49
38	6,500	105.6	96.8	.67	84.5	77.5	.54	70.5	64.6	.45
40	6,500	102.9	94.3	.62	82.4	75.5	.50	68.7	63.0	.41
50	7,000	99.2	90.9	.47	79.3	72.8	.38	66.2	60.7	.31
60	7,000	90.5	83.0	.37	72.5	66.5	.30	60.4	55.4	.25
70	7,000	83.8	76.8	.30	67.1	61.5	.24	55.9	51.2	.20

NOTE.—Allowance has been made for waste, cleaning, oiling, and doffing.

SOLUTION.— $40 \div 2 = 20s$, resultant counts. $43.973 \div 20 = 2.198$ lb. per spindle per wk.

The floor space occupied by twisters depends on the number of spindles in the frame and the space between the spindles, or the gauge of the frame. The number of spindles varies from

DIMENSIONS OF TWISTERS

Size of Rings Inches	Gauge of Spindles Inches	Size of Rings Inches	Gauge of Spindles Inches
4½	5½	2½	3½
4	5	2¼	3¼
3½	4½	2	3
3	4	1¾	2¾

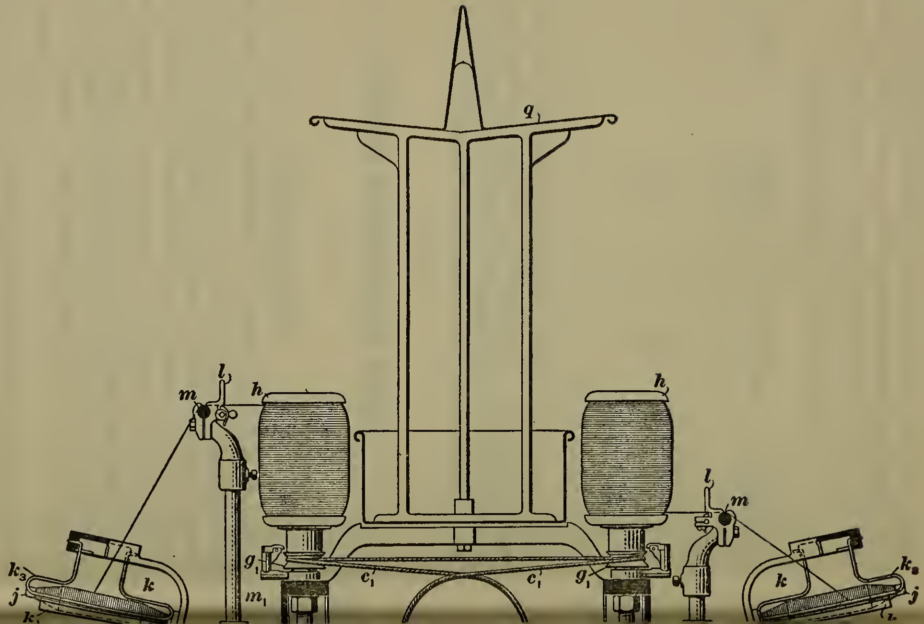
64 to 240, one-half being on each side of the frame; the regular sizes contain either 180, 208, or 240 spindles. The sizes of rings generally used and the corresponding gauges, or spaces between the centers of the spindles, are given in the accompanying table.

WARP PREPARATION

SPOOLING

Warp yarn must ultimately be placed either on the loom beam to be woven or put up in the form of a bundle to be shipped from the mill where it is spun. In either case it must first be spooled, in order to obtain a greater length of yarn and thus facilitate later processes. The object of the spooler, therefore, is to place a suitable length of yarn on a spool, this yarn being taken from the bobbin or cop on which it has previously been wound at the spinning process, or, in some cases, at the twister.

As shown in the accompanying illustration, spoolers are so made that many of the parts on one side are duplicated on the other, thus permitting the yarn to be spooled on both sides of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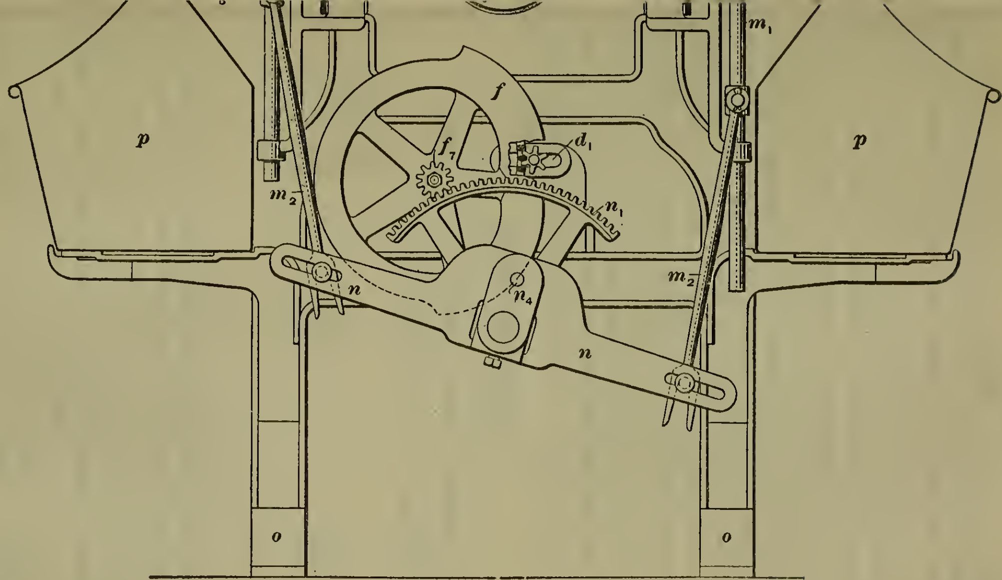

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the machine. The bobbins *j*, as they come from the spinning frame are placed in the bobbin holder *k*, the end of yarn being passed under a swinging arm similar to k_3, and then carried to the thread guide *l*, from which it passes to the spool *h*. As the spool revolves, the yarn is wound on it. The traverse of the yarn on the spool is obtained by imparting an up-and-down motion to the rail *m* on which the thread guides *l* are secured. This motion is given to the traverse rail by means of the rods m_1, motion being imparted to these rods by the rods m_2, which are connected to the arms *n*; these arms are acted on by a mangle gear *f* and quadrant n_1. The bobbin boxes, in which the bobbins are kept, are shown at *p*; *q* shows the creels on which the spools are placed as they become full. In cases where the yarn to be spooled is wound on cops or bobbins with a filling wind, from which the yarn must be pulled off at the nose, the cops or bobbins are placed on spindles and the yarn carried through the guides to the thread guide on the traverse rail and then to the spool.

SIZES OF SPOOLS

Counts	Length of Traverse Inches	Diameter of Head Inches
8s to 16s	6	5
18s to 34s	5	4
36s to 54s	4½	3½
56s to 80s	3½	3¼
90s to 100s	3	2¾

In spooling, the larger the spool can be made, the more yarn it will hold, and consequently the greater will be the production of the spooler; but there is a limit to the size of the spool, due to the fact that at the next process the yarn is obliged to turn the spool, and if too much tension is brought on it, it will break frequently and thus defeat the object of having a large spool. From this it will readily be apparent that the coarser the yarn the larger will be the spool that can be used. Good sizes of spools for different counts of yarn are as given in the accompanying table.

Settings.—To set the mangle-gear arrangement shown in the illustration, have the pinion gear d_1 just at the point of reversing the mangle gear f, then find the difference between the number of teeth on the segment n_1, and on the stud gear f_7 and set the stud gear so that it will be half this number of teeth away from the end of the segment. At this point the top of the traverse rail on one side of the spooler should be about $\frac{1}{16}$ in. below the top heads of the spools, and the top of the traverse rail on the other side should be the same distance above the bottom heads of the spools on that side of the machine.

The gear f_7 meshing with the segment is known as the change gear, and it is this gear that is altered when a change in the traverse is desired. A larger gear drives the quadrant more quickly, and consequently makes it travel a greater distance while the mangle gear is making one revolution. This gives a longer traverse of the traverse rail. A smaller gear has, of course, the opposite effect. In case the change gear does not give the exact traverse required, any slight change may be obtained by moving the studs in the lever n, that support the rods m_2. By this method of changing the traverse, the traverse on one side may be altered independently of that on the other, which cannot be done by changing the change gear. This, of course, is often of advantage.

Another adjustment, but one that alters only the point at which the rail reverses without altering the traverse, can be made by dropping or raising the lifting rods. If, for example, the traverse rail is a little too high at both the top and bottom points at which it reverses, then the rods may be dropped until the traverse rail assumes its correct position. Care should be taken, however, to have the traverse rails perfectly horizontal and the studs in the slots of the lever n all set at the same point on one side of the frame.

The upper and lower plates of each thread guide should be set at such a distance apart that the yarn will just pass through without chafing. It is a good plan to use a No. 7 or No. 9 card gauge to set these on fine yarns and No. 11 on coarse yarns, or even No. 7 and No. 9 together, equaling No. 16, on very coarse yarns. The settings of these plates should be looked over frequently.

Calculations.—To find the gear required to give a desired length of traverse when the gear being run and the length of traverse it gives are known:

PRODUCTION OF SPOOLERS

Number of Yarn	Revolutions per Minute of		
	Cyl. 167, Spindle 750	Cyl. 184, Spindle 825	Cyl. 200, Spindle 900
	Pounds per Day per Spindle		
8	10.8	11.8	12.9
10	8.6	9.5	10.3
12	7.2	7.9	8.6
14	6.2	6.8	7.4
16	5.4	5.9	6.5
18	4.8	5.3	5.8
20	4.3	4.8	5.2
22	3.9	4.3	4.7
24	3.6	4.0	4.3
26	3.3	3.7	4.0
28	3.1	3.4	3.7
30	2.9	3.2	3.5
32	2.7	3.0	3.3
34	2.6	2.8	3.1
36	2.4	2.7	2.9
38	2.3	2.5	2.7
40	2.2	2.4	2.6
44	2.0	2.2	2.4
50	1.8	1.9	2.1
60	1.5	1.6	1.8
70	1.3	1.4	1.5
80	1.1	1.2	1.3
90	1.0	1.1	1.2
100	.9	1.0	1.1

Rule.—*Multiply the traverse gear being used by the length of traverse desired and divide the result by the length of the traverse being run.*

EXAMPLE.—An 11-tooth gear is being used and gives a $5\frac{1}{2}$-in. traverse. What gear will be required for a $4\frac{1}{2}$-in. traverse?

SOLUTION.— $\frac{11 \times 4\frac{1}{2}}{5\frac{1}{2}} = 9$-tooth gear.

To find the length of traverse that a certain gear will give when the gear being used and the length of traverse it gives are known:

Rule.—*Multiply the length of traverse being run by the gear to be used and divide this result by the gear being used.*

EXAMPLE.—An 11-tooth gear gives a $5\frac{1}{2}$-in. traverse. What traverse will a 9-tooth gear give?

SOLUTION.— $\frac{5\frac{1}{2} \times 9}{11} = 4\frac{1}{2}''$ traverse

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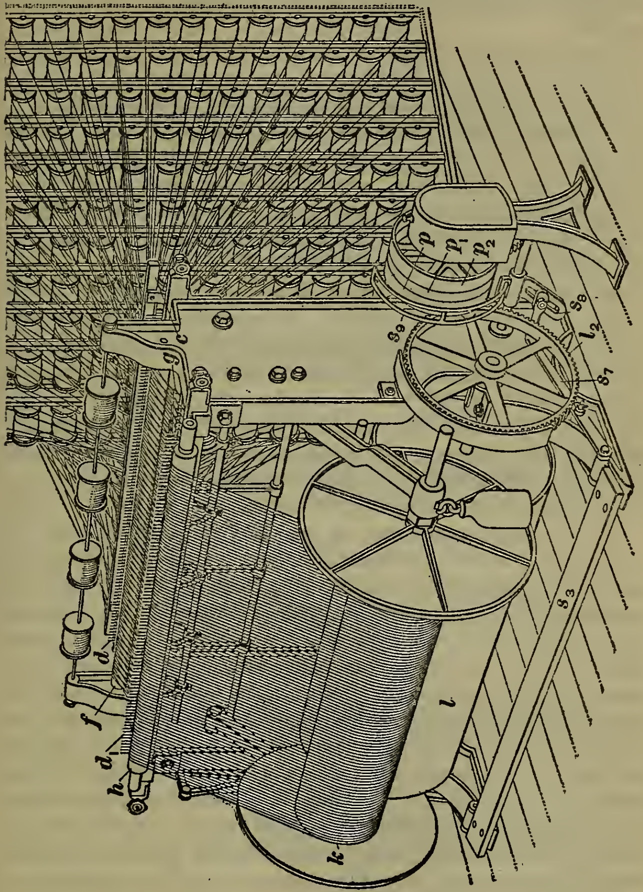
BEAM WARPING

As the yarn comes from the spooler, it is taken to a machine known as a *warper*, the object of which is to unwind the yarn from a large number of spools and place it in an even sheet on a beam, known as a section beam. Warping is divided into several different classes according to the manner in which the yarn is treated. The operation known as *beam warping* derives its name from the fact that the yarn as it is unwound from the spools is wound on a beam.

The principle of beam warping is simple; it consists of arranging spools of yarn in a creel so that they revolve with the least possible resistance, and the yarn is wound on a roll, or beam, rotated by contact with a revolving cylinder.

The accompanying illustration shows the creel and warper as they appear when in operation. The ends are gathered from the spools and passed between the guide rods c; they then pass through the expansion comb d, under a drop roll, over the guide roll f, through the drop wires g, through the expansion comb d_1, over the measuring roll h, and then to the beam k, on which they are wound in an even sheet.

The first important part of the warper with which the yarn comes into contact as it passes from the creel is the expansion comb d, which is arranged so that the spaces between the wire teeth may be enlarged or reduced, and the gauge of the comb regulated to uniformly distribute the sheet of yarn over the whole width of the machine, irrespective of the number of ends being run. Passing from the expansion comb, the yarn comes



into contact with a drop roll, which takes up any slack yarn that may be let off by the spools, When the warper is stopped for any cause, the momentum of the spools causes considerable yarn to be unwound, which, if not taken care of in some manner, may become snarled and break when the warper is again started.

As the principal object of a warper is to wind on a beam an even sheet of yarn that consists of the same number of ends at all times, all modern warpers are supplied with *stop-motions*, which stop the machine if a single end breaks while passing from the creel to the beam. The yarn, after passing through the drop wires of the stop-motion, next passes through the expansion comb d_1 and then over the *measuring roll h*, which is driven by the friction of the yarn. Connected with this roll is a device for measuring the yarn wound on the beam.

Attachments are provided on all warpers by means of which they may be run at two speeds. In starting a warper, the belt is shifted to the slow-motion pulley, and the yarn immediately begins to wind on the beam, gradually pulling up the drop roll as the tension of the yarn counteracts the weight of the roll. As soon as the roll has resumed the position that it should occupy while the warper is running, and after the spools have acquired some momentum, the belt is moved to the tight pulley, and the machine will run at full speed.

A cone-drive attachment is provided on some warpers by means of which the beam may be driven at a slower speed as the spools become nearly empty. The advantage of such an arrangement is clearly seen, for a spool filled with yarn is larger in diameter than an empty spool; consequently, if the same length of yarn is being unwound from each in the same time, the spool that is nearly empty must make more revolutions per minute than the other, which is undesirable. In addition, as the diameter of the spool decreases the amount of pull necessary to turn it is increased, which naturally brings more strain on the yarn. If, therefore, the same length of yarn is to be unwound from the spools at all times this length cannot exceed what the yarn will stand when being unwound from the nearly empty spools; consequently, when the spools are full, the warper is not run at its full capacity.

The aim in warping should be to produce hard and level beams, free from ridges or soft sides near the beam head. The

PRODUCTION OF BEAM WARPERS

No. of Ends	260	300	320	340	360	380	410	440
No. of Yarn	Pounds Warped in 60 Hours							
8	5,015	5,785	6,171	6,557	6,943	7,329	7.907	8,485
10	4,011	4,629	4,937	5,246	5,555	5,863	6,325	6,789
12	3,343	3,857	4,181	4,372	4,629	4,885	5,271	5,657
14	2,865	3,305	3,527	3,747	3,967	4,188	4,519	4,849
16	2,507	2,893	3,085	3,279	3,471	3,664	3,953	4,243
18	2,229	2,571	2,743	2,915	3,085	3,257	3,515	3,771
20	2,005	2,315	2,468	2,623	2,777	2,931	3,163	3,395
22	1,823	2,104	2,244	2,385	2,525	2,665	2,875	3,085
24	1,671	1,925	2,057	2,185	2,315	2,433	2,636	2,829
26	1,543	1,780	1,899	2,017	2,136	2,255	2,433	2,611
28	1,433	1,653	1,763	1,873	1,983	2,094	2,259	2,425
29	1,383	1,596	1,703	1,809	1,915	2,021	2,181	2,341
30	1.337	1,543	1,645	1,749	1,851	1,955	2,109	2,263
32	1,253	1,447	1,543	1,639	1,736	1,832	1,977	2,121
34	1,180	1,361	1,452	1,543	1,633	1,725	1,861	1,997
36	1,115	1,285	1,371	1,457	1,543	1,629	1,757	1,885
38	1,056	1,219	1,299	1,380	1,461	1,543	1,665	1,787
40	1,003	1,157	1,235	1,311	1,389	1,465	1,581	1,697
44	912	1,052	1,123	1,192	1,262	1,332	1,437	1,543
50	806	925	987	1,049	1,111	1,171	1,265	1,357

existence of ridges indicates a wrong division of the ends in the comb, and soft sides show that the comb has not been adjusted to suit the width of the beam. All knots that are made during the filling of the beam should be made as small as possible in order to facilitate the weaving process.

The actual production of warpers should be estimated at from 65 to 75% of the production figured on the basis that the machines are run constantly, as warpers are stopped from $1\frac{1}{2}$ to 2 hr. for creeling after each set of spools has been run off. The production is usually figured at 70 yd. per min. for 20s; 60 yd. per min. for 40s; 50 yd. per min. for 60s; 45 yd. per min. for 80s; and 40 yd. per min. for 100s. This estimate will vary in different mills, according to the speed of the machines, the quality of the yarn, and the number of warpers being run by each tender.

The accompanying table gives the production per week of 60 hr. for yarns from 8s to 50s, the number of ends on the beam varying from 260 to 440 and the speed of the warper being about 54 yd. per min. The production with other speeds can easily be figured by proportion. This table provides for an allowance of $33\frac{1}{3}$% lost time for stoppages.

SLASHING

The machine that treats the warp yarn as it comes from the beam warper is known as a *slasher*; its objects are as follows: (1) To coat each thread of warp yarn evenly with an adhesive, strengthening compound known as size in such a manner that the size will partly penetrate and adhere to the thread without the threads adhering to one another; (2) to dry the sheet of warp after it has been sized; (3) to run the desired number of threads on a loom beam in an even sheet and in such a manner that the sheet will unwind at the loom without obstruction and pass through the harnesses and reed without unnecessary breakage and with the least trouble to the weaver.

Fig. 1 shows a sectional view of a two-cylinder slasher, through which the passage of the yarn is as follows: The required number of section beams a_1, a_2, a_3, a_4, a_5, a_6 are placed in the creel a and the ends from these beams passed over the guide rolls b, b_1. The yarn then passes through the size box c, which contains the size c_1, being guided under the immersion roll c_2, between the size roll d and squeeze roll e, and then between the size roll d_1, and squeeze roll e_1. From the size box it passes to the steam-heated cylinders h, j, but in order to keep it under the influence of these drying cylinders as long as possible it is carried in a circuitous path, first to the large cylinder h, and then to the small cylinder j, passing partly around both. About 50 ft. of warp is under the influence of the drying arrangement at one time. From the cylinder j the yarn passes under the fan k and around guide rolls b_2, b_3, b_4,

The method of sizing and drying the warp tends to cause the individual threads to stick together; consequently, to remedy this, *split rods*, also known as *separating bars*, m, m_1, m_2, m_3, m_4, are introduced to divide the warp horizontally into as many sheets as there are section beams in the creel. The warp next passes through the expansion comb n, over and under tension rods b_6, b_7, around the measuring roll p, the drag roll r and guide roll r_1, from which it passes to the loom beam s, on which it is wound in an even sheet.

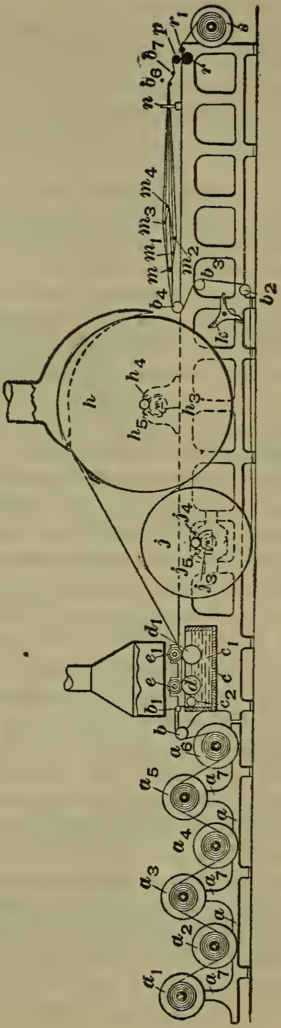


FIG. 1

When the slasher is in operation, the size box is partly filled with size c_1, and the immersion roll c_2 placed in such a position that the yarn in passing partly around it passes through the size, becomes coated with it, and to a certain extent absorbs the mixture in excess of the requirements. The excess of size is pressed out as the yarn passes between the two sets of rolls d, e and d_1, e_1, and flows back into the box.

The squeeze rolls e, e_1, are first covered with three or four layers of ordinary cotton sheeting, which is either glued on or thickly coated with white paint, the paint preventing the size from striking through and reaching the roll. One of the chief objects of the squeeze rolls is to cause the size to penetrate the yarn, and in order to accomplish this there is placed outside of the cotton cloth covering a woolen blanket especially made for this purpose and technically known as *slasher cloth.* For the rear roll from 3½ to 4 yd. of 16-oz. cloth and for the front roll from 4 to 5 yd. of 12-oz. cloth will be found to give good satisfaction. In placing the cloth on the rolls, care should be taken to have the laps follow on the outside, so that they will not be roughed up. It is hardly necessary to fasten the cloth in any manner, as the size will soon stick the laps together, but should any part of the outer edge of the cloth become folded, thus causing a bunch on the roll, it may be laid smooth by passing the end from a bobbin of yarn around the roll a number of times. Slasher cloth, through being in constant contact with the size, soon becomes stiff and unpliable; to remedy this it should frequently be taken off and soaked in water.

The cylinders h, j are made of rolled copper except the heads, which are of steel plate. These heads should be well stayed with iron rods. The cylinders should be kept hot enough to dry the yarn satisfactorily, but not so hot as to make it brittle. Pressure of steam practically regulates this, as a higher pressure of steam means a higher temperature. Better work can be done with a machine running slowly, and the cylinders at a moderate temperature than by having a high temperature and running the yarn through very quickly. Yarn should never be run on the beam unless perfectly dry. If damp it tends to mildew and rot, making bad weaving and spoiling the goods. The pressure of steam used in the cylinders varies from 4 to 15 lb. A high pressure of steam is used when coarse yarn is being slashed; when a large percentage of size is applied; for a warp with a large number of ends; and when a slasher is being run at a high speed, even with a medium number of yarn or a medium sheet. Low pressure is used for fine yarns, thin sheets, or slow-running machines. About 8 lb. is the usual pressure.

Calculations.—

Example.—Referring to Fig. 2, find the speed of the drag roll if the driving shaft makes 250 rev. per min. and the change gear has 36 teeth.

Solution.— $\frac{250\times 36}{105}=85.714$ rev. per min.

Example.—Find the number of yards slashed per minute if the drag roll makes 85.714 rev. per min.

Solution.— $\frac{85.714\times 6\times 3.1416}{3\times 12}=44.879$ yd.

Example.—Find the speed of the size rolls when the driving shaft makes 250 rev. per min. and the change gear has 36 teeth.

Solution.— $\frac{250\times 36\times 20\times 32}{105\times 30\times 32}=57.142$ rev. per min.

Example.—Find the number of yards per minute that pass the size rolls when they make 57.142 rev. per min.

Solution.— $\frac{57.142\times 9\times 3.1416}{3\times 12}=44.879$ yd.

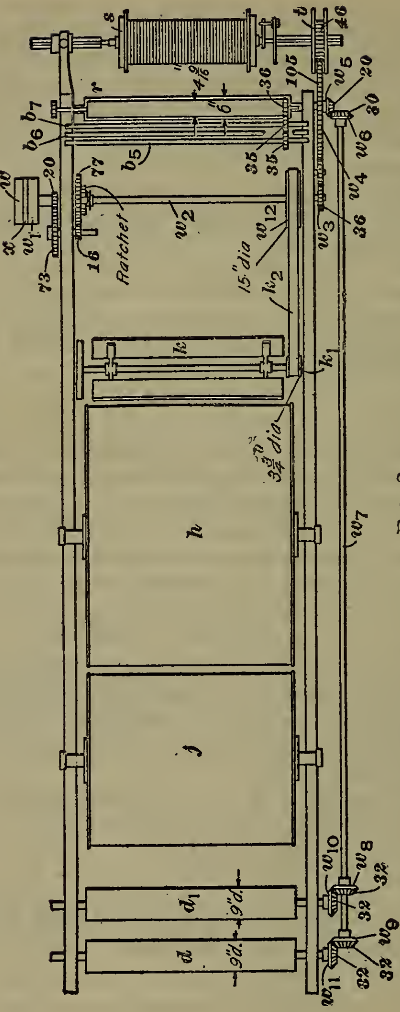
It will be noticed from the above calculations that the amount of yarn taken up by the drag roll exactly equals the amount passed forwards by the size rolls. This, of course, is necessary in order to keep the yarn at the proper tension between these two points.

Example.—Referring to Fig. 2, find the speed of the fan *k* when the driving shaft makes 250 rev. per min.

Solution.— $\frac{250\times 15}{3.75}=1{,}000$ rev. per min.

Example.—Referring to Fig. 2, find the speed of the driving shaft when the belt is on the slow-motion pulley, if this pulley is driven 250 rev. per min.

Solution.— $\frac{250\times 20\times 16}{73\times 77}=14.232$ rev. per min.



s
t
46
r
105
36
w5
20
30
w6
b7
b6
b5
35
35
w4
w
20
77
x
w1
73
16
Ratchet
w2
w12
15" dia
k2
w3
36
k
k1
3¾" dia
h
w7
j
w10
w8
32
d1
9" d.
32
w9
d
9" d.
w11
32
32

FIG. 2

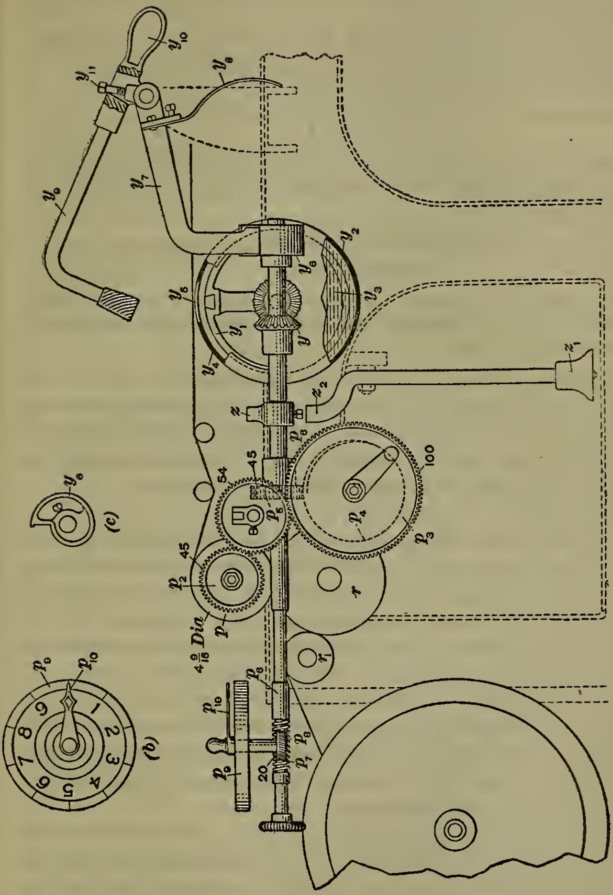


FIG. 3

From the preceding calculation it will be seen that the slow-motion arrangement makes a very appreciable difference in the speed of the machine.

Example.—Referring to Fig. 3, find the length of yarn that passes the measuring roll between successive cut marks.

Solution.— $$\frac{4\frac{9}{16}\times 3.1416\times 100\times 45}{12\times 3\times 45\times 1}=39.815 \text{ yd.}$$

Example.—Considering the 45-tooth gear on the end of the measuring roll to be the change gear, find the constant for the measuring motion.

Solution.— $$\frac{4\frac{9}{16}\times 3.1416\times 100\times 45}{12\times 3\times 1}=1{,}791.693, \text{ constant}$$

Note.—The constant for the measuring motion in this slasher is usually considered as 1,800, and will be so considered in these calculations.

Example.—If the constant for the measuring motion is 1,800, what change gear will be required to give 64-yard cuts?

Solution.— $1{,}800\div 64=28.125$; a 28 gear would be used

Example.—If the constant for the measuring motion is 1,800, what length of cut will a 35 change gear give?

Solution.— $1{,}800\div 35=51.428$ yd.

Production.—In connection with any calculations dealing with the production of a slasher, it should be understood that a certain percentage must be deducted from the calculated production in order to make allowance for stoppages due to such causes as changing the loom beams or changing the sets at the back of the slasher. This allowance will, of course, vary with different classes of yarn, but for ordinary work, such as plain white warps, about 35 % will be found to be a fair allowance. The slasher is a machine of large production and in all ordinary cases it is customary to estimate that one slasher will prepare warps for 500 looms.

Size.—The requirements of a good size mixing are good adhesive qualities, good color, uniform consistency, and the property of leaving the yarn smooth, tenacious, and pliable, even when heavily sized.

Sizing materials may be divided into five classes: (*a*) starches, or the adhesive substances, forming the body of the mixing; (*b*) softening substances, used to avoid harshness in the dried warp and preserve the softness and pliability of the yarn; (*c*) weighting substances, used in medium and heavy sizing to add the weight that the adhesive substances cannot give; (*d*) antiseptics, or substances that tend to destroy micro-organisms and vegetable life, and thus prevent the growth of mildew or the decomposition of the size; (*e*) miscellaneous ingredients, used for coloring and other purposes.

Considering the first group of substances, the principal ingredients are corn starch, potato starch (sometimes called farina), wheat flour, sago flour, or rice flour. In the United States, corn starch and potato starch are the principal adhesive substances used, some mill men preferring one, some another. Either is convenient for use in light sizing, but each requires a softener to counteract the harshness that it gives to the warp when used alone. Wheat flour is very largely used in heavy sizing, as it is more glutinous and fixes weighting substances on the yarn better than any other material; it also does not tend to make the warp as harsh as starches of other grains; on the other hand, it has a tendency toward mildew and does not give as bright a color to the warp as some of the other materials.

Perhaps the most useful material for a softener is tallow, beef or mutton tallows being the principal ones used for this purpose. The various kinds of wax are also useful; for example, Japanese wax, a vegetable product that is a light, hard substance of a slightly yellow color, and paraffin wax, which is a clear and semitransparent product obtained in the manufacture of mineral oils. A high melting point of wax used for sizing is desirable, 110° F. being a suitable standard. Other softeners sometimes used are glycerine, castor oil, palm oil, and soap. Many softeners are sold under a patented name used as a trade mark.

Weight-giving substances are not much used in American mills; of those used china clay, sometimes called kaolin, is perhaps the most valuable. Among other substances sometimes, but not often, used for weighting are sulphate of lime, sulphate of magnesia, sulphate of soda, and sulphate of baryta. Chloride of magnesium (which is often called antiseptic, though it possesses no antiseptic properties) and other metallic salts are also sometimes used.

Antiseptics are substances that tend to destroy vegetable life and micro-organisms and thus prevent the decomposition of the size or the growth of mildew. The antiseptic substance that is most largely used in size mixing is known as muriate, or chloride, of zinc. This is also valuable as a weight-giving substance, for since it is a metallic salt, really consisting of zinc dissolved in muriatic acid, it has a high specific gravity. Another antiseptic is carbolic acid, but this is not so largely used as the muriate of zinc.

Among the miscellaneous substances used for tinting the size in case it is desired to imitate piece goods or to produce what are known as *shot effects* are aniline dyes of various colors. For tinted warps, a blue dye is sometimes used in very small proportions for the purpose of correcting a tendency to yellowness in the size mixing; the blue dye changes it to a bluish white.

Sometimes soda is used with the idea of preventing iron stains. Turpentine is often used in small quantities to cut the softening materials and cause a proper blending of the constituents of the mixture; from 1 gi. to 1 pt. per 100 gal. of water is sufficient. It is found to be especially useful in sizing Egyptian cotton yarn, which carries a wax or fatty matter on its surface in sufficient quantities to repel the application of liquid size.

In considering a size mixing, the proportion of each of the five classes of sizing materials should be considered with relation to the quantity of water used. Also, the following points should be considered: Ply warp yarn can be woven with very little size, in some cases even without size. Single warp yarn of medium counts in a cloth of light sley and pick can be woven with a minimum of size. A warp that must be woven in a fine reed, or in other words, one that contains a large number of ends per inch, requires a strong size. The same applies to a cloth with a heavy pick, that is, a large number of picks per inch. A warp of fine, hard-twisted yarn, especially Egyptian yarn, requires a stronger mixing than a medium yarn, as it has not the same tendency to absorb size as a yarn of medium counts spun from American cotton. A very coarse warp, being loosely twisted, tends to fray in the loom more easily than a yarn of medium counts and twist, and thus requires a stronger size.

The following fundamental principles govern all cases: (*a*) A size mixing is weakest and is applied with the smallest percentage for medium yarns, say from number 20s to 40s, and for a cloth of light sley and pick; (*b*) if the cloth is woven with a heavy sley and pick, even with the same numbers, the mixing must be made stronger; (*c*) if the yarn is very fine, the mixing must also be made stronger; (*d*) if the yarn is very coarse but very light-twisted, the mixing must be made stronger.

The accompanying table gives approximately the weights of starch and softening materials that ought to be used to each 100 gal. of water on various numbers of warps from 10s to 100s for pure sizing only, that is, when the yarn is sized only for the purpose of enhancing its weaving qualities.

WEIGHT OF SIZING MATERIALS

Counts of Yarn	Light Sley and Pick		Medium Sley and Pick		Heavy Sley and Pick	
	Starch Lb.	Softening Lb.	Starch Lb.	Softening Lb.	Starch Lb.	Softening Lb.
10s to 25s	40	5	45	6	50	6
25s to 30s	30	4	35	5	40	5
30s to 40s	35	4	40	5	50	6
40s to 60s	45	5	50	5	65	7
60s to 80s	50	6	65	7	80	10
80s to 100s	65	7	80	10	90	12

To each of the mixings given in the table, other ingredients may be added for special purposes; for example, turpentine, not more than 1 qt. and often only 1 gi. to 100 gal. of water; aniline blue, from $\frac{1}{4}$ to $\frac{1}{2}$ oz. to 100 gal. of water; alum, not more than 4 lb. to 100 gal. of water; dextrine, about 2 lb. to 100 gal.; soap, about 1 lb. to 100 gal.; blue vitriol, not more than 1 gi. to 100 gal. Only the turpentine and the aniline blue are of much use, and then only in special cases.

When considering the question of sizing for the purpose of adding weight to the fabric, the same remarks as to varying the proportions of the ingredients according to the numbers of yarns and the sley and pick hold good, but in this case the mixing must be made considerably stronger, not only by the addition of a larger proportion of starch materials, which necessitates a larger proportion of softening materials, but in some cases by the addition of weight-giving materials. The following mixings are given as examples of medium and heavy sizing: To apply 50% to the warp, that is, ½ lb. of size for each pound of warp yarn: Water, 100 gal.; wheat flour, 320 lb.; china clay, 150 lb.; tallow, 40 lb.; chloride of magnesium, 3 gal.; muriate of zinc, 1 gal.; soda, 5 lb.

For heavy size, say 100%, that is, 1 lb. of size for each pound of warp yarn: Water, 100 gal.; wheat flour, 560 lb.; china clay, 560 lb.; tallow, 130 lb.; chloride of magnesium, 20 gal.; muriate of zinc, 10 gal.; soda, 10 lb.; aniline blue, ½ oz.

For a mixing that will give from 150 to 200% on the warp the following materials should be used: Wheat flour, 560 lb.; china clay, 1,600 lb.; tallow, 1,600 lb.; soap, 20 lb.; soda, 30 lb.; chloride of magnesium, 40 gal.; muriate of zinc, 20 gal.; aniline blue, ¾ oz. In this latter case barely sufficient water to liquefy the mixture would be used. The water in which the flour has been steeped, together with the chloride of magnesium and the muriate of zinc, probably would not exceed 100 gal. in all.

In making a heavy size mixing, a different method is employed than in making pure size mixing. The wheat flour is sometimes steeped alone for 3 wk., at the end of which time the muriate of zinc is added to it, together with the soda, and the mixture heated. The clay, tallow, and other ingredients are mixed separately in the size kettle and boiled, after which the two compounds are mixed together and boiled.

COTTON WEAVING

PLAIN LOOMS

The principle on which looms are constructed is that of manipulating two series of yarns—the warp and the filling—so that the warp will be slowly drawn through the loom and interlaced with the filling to form a fabric. In order to make cloth, some of the warp threads must be raised and others lowered to produce the space through which the filling, which is carried by a shuttle, can be passed. This space is called a *shed*, and through it the filling is thrown from side to side, the operation being known as *picking*. The shuttle leaves the filling some distance from the edge, or fell, of the cloth. It is therefore necessary to push it forwards to the cloth, that is, to the picks that have previously been put in and that help to form the fabric. This process is known as *beating up* and completes the round of fundamental operations necessary to produce cloth.

Looms, in addition to performing the essential operations of shedding, picking, and beating up, have certain other movements in order to render their operation more automatic. For example, *take-up motions* are applied to draw the cloth forwards after it has been woven; *let-off motions* are used to release the warp at the desired rate of speed; *automatic stop-motions* are provided to cause the loom to cease operating when the filling breaks, and in some cases when an end of the warp breaks; *temples* are provided to extend the cloth sidewise; all of these attachments are found on a *plain loom*.

Shedding by Cams.—The shedding mechanism of a plain loom is shown in Fig. 1. The manner in which the cams s, s_1 cause the rise and fall of the harnesses q, q_1 should be considered. Each cam moves the harness, which it actuates, in one direction only, straps and roller connections being necessary to bring the harness back to its original position. Thus, when the camshaft t revolves so that the cam s_1 is in the position shown in this figure, the harness q will be lowered by the direct action of this cam, forcing down the treadle p. The raising of the harness

q is accomplished by means of the strap-and-roller connections. As the cam s revolves, it forces down the treadle p_1, which in turn lowers the harness q_1. As this harness is lowered it turns

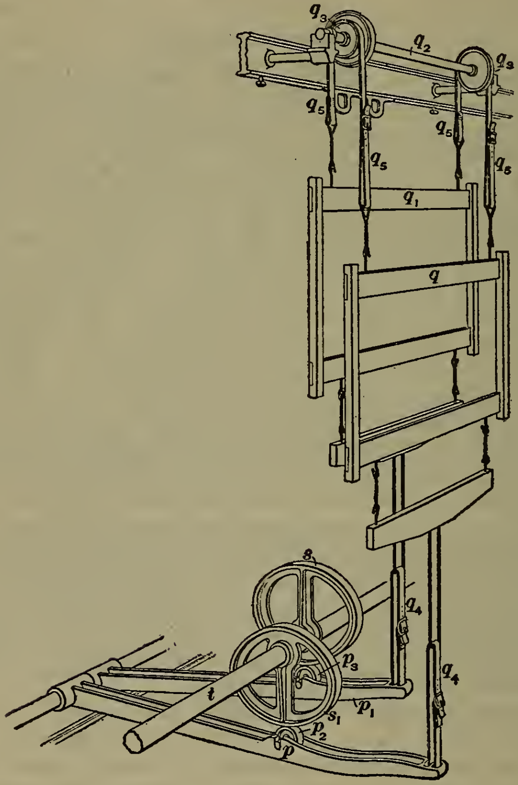


FIG. 1

the rollers q_3. The revolving of the rollers winds up the top strap connected to q, which raises that harness. Thus the downward motion of the harness q_1 produces an upward motion of the harness q, and, consequently, as one harness is depressed to allow the yarn drawn through it to form the bottom of the shed, the other harness is raised in order to form the top of the shed. The warp yarn is drawn through eyes in cotton harnesses or in wire heddles supported by the harness frames and since one harness is down while the other is up, a diamond-shaped opening is made in the warp, through which the shuttle, carrying the filling, is thrown.

The difference in the diameters of the rolls q_3 is required in order to compensate for the extra rise that must be given to the back harness so that the yarn drawn through it will rise to the same height as the yarn in the front harness. This would be more noticeable if several harnesses were employed. For the same reason the cam that actuates the back harness should always be larger than the one that actuates the front.

The ideal movement that can be given to a harness is to commence to lift or depress slowly, gradually increasing in speed to the center of the shed, when the movement again gradually becomes slower until the shed is formed.

The treadles of a loom may be considered as levers of the third class, since they have their fulcrum on a bracket bolted to the back girt of the loom, the weight being applied at the point where the harnesses are connected and the power exerted between these two. If the length of the treadle and the length from stud or fulcrum to point of contact with the cam are known, the throw of the cam necessary to give the desired size of shed is easily obtained.

Rule.—*To obtain the desired throw of cam, multiply the size of shed required by the length of the treadle from the stud or fulcrum to the point of contact, and divide this result by the whole length of the treadle.*

Example.—The length of treadle is 30 in., distance from stud to contact 18 in., and the shed required 3 in.; what should be the throw of the cam?

Solution.—According to the rule: $18 \times 3 = 54$. Dividing by the length of the treadle, $54 \div 30 = 1.8$ in., the throw of the cam.

Picking.—After the harnesses have been opened and a shed formed, the shuttle that contains the filling must be thrown from one side of the loom to the other, passing through this opening and leaving a pick of filling. This action of the loom is known as *picking*. There are several styles of picking motions in general use on power looms at the present time. In America, the two principal ones are the *shoe*, or *bat-wing*, *pick*, and the *cone pick*, but the cone pick is in general use on plain cotton looms.

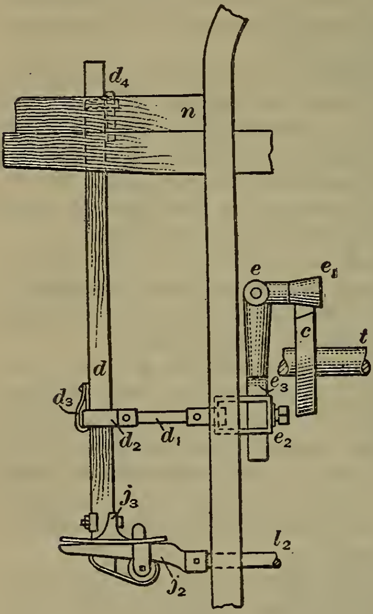


FIG. 2

The action of the picking motion, as shown in Fig. 2, is as follows: As the projecting part, or nose, of the cam *c* in revolving on the camshaft *t* strikes the cone e_1, it forces it upwards. This, in turn, throws the bottom of the arm e_3 inwards, which movement draws the picker stick *d* toward the loom by means of connections consisting of a lug stick d_1 and lug strap d_2. The picker stick, by means of the force with which it is drawn in and through the picker d_4, delivers a blow to the shuttle sufficient to send it across the loom and into the opposite box. A mechanism of exactly the same construction will then throw the shuttle back again across the loom.

The object of the parallel motion, which consists of the shoe j_2, rocker j_3, etc., is to move the picker in a direction as nearly as possible parallel to the race plate on which the shuttle travels across the loom. Without some such arrangement, the picker in traveling from one end of the box to the other would describe an arc of a circle. This would give it a higher position at one part of its movement than at another, thereby resulting in a very unsatisfactory pick.

The shoe of the parallel motion is perfectly level, and the rocker to which the picker stick is fastened is curved. This curve of the rocker is such that it forms the arc of a circle that would be drawn by using the picker as a center, and a radius equal to the distance from the picker to the shoe of the parallel motion. Thus, it will be seen that as the picker stick moves forwards and backwards, its fulcrum being at the rocker, the upper end, or the picker, will be at the same level when at the back of the box as at any other point.

Beating Up.—After the filling has been laid in the cloth by the shuttle it must be forced up to the cloth previously woven; this operation is known as beating up and is performed by the *lay of the loom*, in which is placed the reed, a grate-like device that divides and evenly spreads the warp threads.

The lay consists of a heavy piece of wood extending from the outside end of one shuttle box to the outside end of the opposite box. This is supported by pivoted arms, termed *lay swords*, and is given a swinging motion by means of cranks on the crank-shaft of the loom. The lay serves two purposes: first, it beats up the filling, and, second, it acts as a rest on which the shuttle may slide in passing from one box to the other.

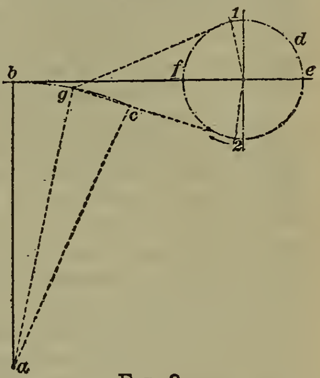


FIG. 3

Eccentricity of Lay.—In Fig. 3, *ab* represents the position of the lay and lay sword when at their forward throw, and *ac*, when at their backward throw; *d* represents the circle described by the crank in revolving.

When the lay is at its forward throw, the crank must be at its front center, which is *f*. This gives the length of the pitman arm, which is *bf*. If the center *g* of the throw of the lay is taken as a center, and an arc described with a radius equal to the length of the pitman arm, it will cut the circle of the crank at *1* and *2*. Therefore, while the lay is moving from *g* to *b* and back to *g* again, which is half a stroke, the crank moves from *2* through *f* to *1*.

On the other hand, while the lay is moving from *g* to *c* and back to *g* again, which also is half a stroke, the crank is moving from *1* through *e* to *2*. But it will be noticed that the arc *2f1* is smaller than the arc *1e2*, and since the crank revolves at the same rate of speed, the shorter distance must be traveled in a shorter time. Therefore, the lay in moving through its forward stroke, or from *g* to *b* and back to *g*, will travel faster than while accomplishing its backward stroke, or from *g* to *c* and back to *g*. This is known as the *eccentricity of the lay*, and the amount of this eccentricity is indirectly proportional to the length of the pitman arm, and directly proportional to the diameter of the circle described by the crank. The larger the circle and the shorter the pitman arm, the greater will be the eccentricity.

Two or three other important points connected with the eccentricity of the lay should be carefully noted. It is essential that this eccentricity should be great enough to allow the shuttle time to pass from one box to the other; on the other hand, if the throw of the crank should be increased, the distance through which the lay moves would be increased proportionately. This would produce a greater chafing of the warp yarns, which should be avoided as much as possible. The method adopted by loom builders to overcome this difficulty is to place the crank-shaft in a lower plane than the point where the crank-arm is connected with the lay. By increasing the diameter of the circle described by the crank in proportion to the length of the crank-arm, the requisite amount of eccentricity is obtained, and at the same time the crank is taken out of the way of the warp.

Calculations.—The picks per inch that are inserted in the cloth depend on the rate at which the sand roll is driven forwards, taking up the cloth as it is woven. To determine the driving and driven gears of the take-up motion, always commence with the sand roll, which in all cases is considered as a driver.

In obtaining the change gear for a take-up motion, a certain percentage is generally taken from the actual measurement of the sand roll to allow for any contraction that takes place in the length of the cloth after it is taken from the loom. About 2% will cover all cases, although different builders allow different rates.

In figuring the change gear for a loom, it is always necessary to notice what part of the loom is working the pawl that drives the ratchet wheel. The cam-shaft revolves only once while two picks are being placed in the cloth; consequently, if the take-up motion is driven from the cam-shaft, it will operate but once in two picks. On this account, it is necessary when figuring change gears that are driven from the cam-shaft, to multiply the number of teeth in the ratchet wheel by 2.

When the take-up motion is driven by any part of the loom that operates every pick, such as the lay sword, the ratchet wheel is figured with its exact number of teeth.

To find the change gear to give the number of picks required when it is a driver, apply the following rule:

Rule.—*Multiply the driven gears together, and divide by the drivers, circumference in inches of sand roll, and picks per inch required.*

Example.—Find the change gear necessary to give 64 picks per inch with the take-up motion shown in Fig. 4, considering g_4 as the change gear.

Solution.—The ratchet gear g_1 is driven from the cam-shaft and, consequently, will be considered as a gear of double the number of teeth that it actually contains. Deducting 2% from the circumference of the sand roll gives 14.21 as the circumference to be used when figuring for the change gear. The change gear g_4 is a driver; therefore,

$$\frac{48\times27\times200}{14.21\times16\times64}=18\text{-tooth change gear}$$

To find the change gear when it is a driven gear, apply the following rule:

Rule.—*Multiply the driving gears, circumference in inches of sand roll, and picks required together, and divide the result by the driven gears.*

Example.—Find the change gear necessary to give 56 picks with the take-up motion illustrated in Fig. 4, considering the gear g_3 as the change gear.

Solution.—The change gear g_3 is a driven gear; therefore

$$\frac{16\times16\times14.21\times56}{48\times200}=21\text{-tooth gear necessary}$$

To find the constant of a take-up motion, apply the following rule:

Rule.—*Multiply the driven gears together, and divide by the drivers and circumference in inches of sand roll, leaving change gear and picks per inch out of the calculation.*

When the change gear is a driver, the constant will be divided by the picks per inch to obtain the change gear.

When the change gear is a driven, the picks per inch required will be divided by the constant, in order to obtain the change gear.

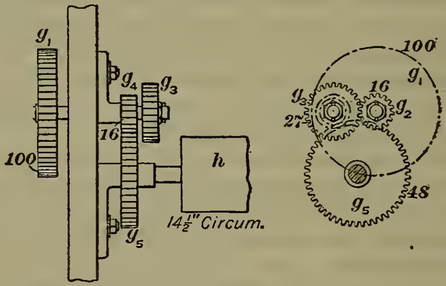


FIG. 4

EXAMPLE.—Find the constant for the take-up motion illustrated in Fig. 4, considering the gear g_3 as the change gear.

SOLUTION.— $\dfrac{48 \times 200}{14.21 \times 16 \times 16} = 2.639$, constant

To find the production of a loom apply the following rule:

Rule.—*Multiply the number of picks per minute of the loom by the number of minutes in 1 hr. and by the number of hours, and divide by the number of picks per inch being inserted in the cloth, and then by the number of inches in a yard. Deduct from this an allowance for stoppages.*

The allowance for stoppages varies according to the class of goods being woven, but it is usually assumed that 10% is sufficient on ordinary plain cloth.

EXAMPLE.—A loom runs 180 picks per min., 48 hr. per week, and the cloth contains 64 picks per in. The loom runs 90% of the possible time. Find the number of yards produced in a week.

SOLUTION.— 180 picks per min.×60 (min. in hr.) = 10,800 picks per hr. 10,800 picks×48 (hr. per wk.) = 518,400 picks per wk.

518,400÷64 (picks per in.) = 8,100 in. per wk.
8,100÷36 (in. in 1 yd.) = 225 yd. per wk.
90% of 225 = 202.5 yd.

Short Method of Finding Production of Looms.—A short method of finding the production of looms makes use of a table of previously-calculated constants and the following rule:

Rule.—*Multiply the speed of the loom by the constant given in the accompanying table and divide by picks per inch in the fabric.*

CONSTANTS FOR FINDING LOOM PRODUCTION

Hr.	Percentages of Theoretical Production								
	100%	95%	90%	85%	80%	75%	70%	65%	60%
70	116.7	110.8	105	99	93.3	87.5	81.7	75.8	70
66	110	104.5	99	93.5	88	82.5	77	71.5	66
62	103.3	98.1	93	87.8	82.6	77.5	72.3	67.1	62
60	100	95	90	85	80	75	70	65	60
58	96.7	91.9	87	82.2	77.4	72.5	67.7	62.8	58
56	93.3	88.6	84	79.3	74.6	70	65.3	60.6	56
54	90	85.5	81	76.5	72	67.5	63	58.5	54
52	86.7	82.4	78	73.7	69.3	65	61	56.3	52
50	83.3	79.1	75	70.8	66.6	62.5	58.3	54.1	50
48	80	76	72	68	64	60	56	52	48
46	76.7	72.8	69	65.2	61.3	57.5	53.7	49.8	46
44	73.3	69.7	66	62.3	58.7	55	51.3	47.7	44
42	70	66.5	63	59.5	56	52.5	49	45.5	42
40	66.7	63.3	60	56.7	53.3	50	46.7	43.3	40

EXAMPLE.—Same as the preceding example.

SOLUTION.—

$$\frac{180 \text{ (picks per min.)} \times 72 \text{ (constant)}}{64 \text{ (picks per in.)}} = 202.5 \text{ yd.}$$

LOOM PRODUCTION

Picks per Inch	Picks per Minute of Loom: 120	130	140	150	155	160	165	170	175	180	190	200
30	60.0	65.0	70.0	75.0	77.5	80.0	82.5	85.0	87.5	90.0	95.0	100.0
32	56.3	60.9	65.6	70.3	72.7	75.0	77.3	79.7	82.0	84.4	89.1	93.8
36	50.0	54.2	58.3	62.5	64.6	66.7	68.8	70.8	72.9	75.0	79.2	83.3
40	45.0	48.8	52.5	56.3	58.1	60.0	61.9	63.8	65.6	67.5	71.3	75.0
42	42.9	46.4	50.0	53.6	55.4	57.1	58.9	60.7	62.5	64.3	67.9	71.4
44	40.9	44.3	47.7	51.1	52.8	54.5	56.3	58.0	59.7	61.4	64.8	68.2
46	39.1	42.4	45.7	48.9	50.5	52.2	53.8	55.4	57.1	58.7	62.0	65.2
48	37.5	40.6	43.8	46.9	48.4	50.0	51.6	53.1	54.7	56.3	59.4	62.5
50	36.0	39.0	42.0	45.0	46.5	48.0	49.5	51.0	52.5	54.0	57.0	60.0
52	34.6	37.5	40.4	43.3	44.7	46.2	47.6	49.0	50.5	51.9	54.8	57.7
54	33.3	36.1	38.9	41.7	43.1	44.4	45.8	47.2	48.6	50.0	52.8	55.6
56	32.1	34.8	37.5	40.2	41.5	42.9	44.2	45.5	46.9	48.2	50.9	53.6
58	31.0	33.6	36.2	38.8	40.1	41.4	42.7	44.0	45.3	46.6	49.1	51.7
60	30.0	32.5	35.0	37.5	38.8	40.0	41.3	42.5	43.8	45.0	47.5	50.0
62	29.0	31.5	33.9	36.3	37.5	38.7	39.9	41.1	42.3	43.5	46.0	48.4
64	28.1	30.5	32.8	35.2	36.3	37.5	38.7	39.8	41.0	42.2	44.5	46.9

66	27.3	29.5	31.8	34.1	35.2	36.4	37.5	38.6	39.8	40.9	43.2	45.5
68	26.5	28.7	30.9	33.1	34.2	35.3	36.4	37.5	38.6	39.7	41.9	44.1
70	25.7	27.9	30.0	32.2	33.2	34.3	35.4	36.4	37.5	38.6	40.7	42.9
72	25.0	27.1	29.2	31.3	32.3	33.3	34.4	35.4	36.5	37.5	39.6	41.7
74	24.3	26.4	28.4	30.4	31.4	32.4	33.4	34.5	35.5	36.5	38.5	40.5
76	23.7	25.7	27.6	29.6	30.6	31.6	32.6	33.6	34.5	35.5	37.5	39.5
78	23.1	25.0	26.9	28.8	29.8	30.8	31.7	32.7	33.7	34.6	36.5	38.5
80	22.5	24.4	26.3	28.1	29.1	30.0	30.9	31.9	32.8	33.8	35.6	37.5
82	22.0	23.8	25.6	27.4	28.4	29.3	30.2	31.1	32.0	32.9	34.8	36.6
84	21.4	23.2	25.0	26.8	27.7	28.6	29.5	30.4	31.3	32.1	33.9	35.7
86	20.9	22.7	24.4	26.2	27.0	27.9	28.8	29.7	30.5	31.4	33.1	34.9
88	20.5	22.2	23.9	25.6	26.4	27.3	28.1	29.0	29.8	30.7	32.4	34.1
90	20.0	21.7	23.3	25.0	25.8	26.7	27.5	28.3	29.2	30.0	31.7	33.3
92	19.6	21.2	22.8	24.5	25.3	26.1	26.9	27.7	28.5	29.3	31.0	32.6
94	19.1	20.7	22.3	23.9	24.7	25.5	26.3	27.1	27.9	28.7	30.3	31.9
96	18.8	20.3	21.9	23.4	24.2	25.0	25.8	26.6	27.3	28.1	29.7	31.3
98	18.4	19.9	21.4	23.0	23.7	24.5	25.3	26.0	26.8	27.6	29.1	30.6
100	18.0	19.5	21.0	22.5	23.3	24.0	24.8	25.5	26.3	27.0	28.5	30.0
102	17.6	19.1	20.6	22.1	22.8	23.5	24.3	25.0	25.7	26.5	27.9	29.4
104	17.3	18.8	20.2	21.6	22.4	23.1	23.8	24.5	25.2	26.0	27.4	28.8
106	17.0	18.4	19.8	21.2	21.9	22.6	23.3	24.1	24.8	25.5	26.9	28.3
108	16.7	18.1	19.4	20.8	21.5	22.2	22.9	23.6	24.3	25.0	26.4	27.8
110	16.4	17.7	19.1	20.5	21.1	21.8	22.5	23.2	23.9	24.5	25.9	27.3
112	16.1	17.4	18.8	20.1	20.8	21.4	22.1	22.8	23.4	24.1	25.4	26.8

NOTE.—The table is based on a 90% production and a 10-hr. day.

CAM LOOMS

Although the plain loom is a cam loom, this term is applied more particularly to looms employing cams on three-, four-, five-, and six-harness work for the production of twills, sateens, etc. When cams are employed on three-, four-, five-, or six-harness work and it is necessary for each cam to make only one revolution during the time that the loom is making three, four, five, or six picks, it is not possible to operate these cams on the cam-shaft of the loom, which makes one complete revolution during every two picks; therefore, a properly-geared auxiliary shaft must be employed for the harness-cams.

A rule for finding the required size of gears on cam-shafts when driving auxiliary shafts may be stated as follows:

Rule.—*Multiply the number of teeth in the gear on the auxiliary shaft by two and divide by the number of picks to the round.*

Example.—What must be the gear of the cam-shaft on five-harness work, if the auxiliary shaft has a 60-tooth gear?

Solution.—Applying the rule just stated,

$$60 \times 2 = 120$$

$$120 \div 5 = 24\text{-tooth gear}$$

To set the cams on work that contains more than two harnesses, turn the crank-shaft until it is on its bottom center; then turn the cams on the auxiliary shaft until the harnesses that are changing are level.

Selvage Motions.—When cloth is being woven in which the ends change only once in three or more picks some arrangement, in addition to the harnesses, must be used in order to produce a selvage, since it is necessary for the ends that form the selvage to change every time the filling is thrown across in order to catch and hold the filling. When the ends interlace frequently with the filling, the *plain selvage motion* may be used.

When cloth is being woven in which the filling does not interlace with each end more than once in five picks, as is the case with a five-harness satin, some other arrangement must be used, since if the warp ends are interlacing with the filling only once in five picks and the selvage ends are interlacing at every pick, owing to the contraction being so much greater on the selvage ends by reason of their more frequent interlacings with the filling, the selvage ends will become so much tighter than the warp ends for the body of the cloth that it will be impossible to weave them. To overcome this difficulty a *tape selvage motion* is used. With this motion two picks of filling are placed in one shed of the selvage; consequently the selvage ends interlace only once every two picks, yet the selvage will change each time the shuttle is on the side with that selvage; that is, the two selvages change independently of each other, the selvage on one side changing one pick and the selvage on the other side changing the next.

To set the selvage cams on such a motion proceed as follows: With the crank-shaft on the bottom center, set the cams that are on the same side as the shuttle in such a position that the selvage harnesses on that side will be level at that point. Turn the crank-shaft one complete revolution; with the shuttle in the opposite box and the crank-shaft on the bottom center, set the two remaining cams so that the selvage harnesses operated by these cams will be level or just passing each other at this point.

LOOM FIXING

Size of Shed.—When regulating the size of the shed, have the shed large enough to clear the shuttle, by, say, about $\frac{1}{8}$ in. In some cases, however, when the work is light, it will be found to be an advantage to reduce the size of the shed, the chafing due to the shuttle rubbing against the yarn being more than compensated for by the fact that less strain will be placed on the yarn, due to the harnesses not lifting so high.

The size of the shed may be regulated, within certain limits, by changing the point at which the jack strap is connected to the treadle, since the farther this point is from the fulcrum of the treadle, the greater is the distance through which the harness will be moved and the greater will be the size of the shed.

Timing the Shedding.—When timing the harness cams for ordinary work, turn the crank-shaft until it is on its bottom center; then turn the harness cams on the cam-shaft until the treadles and harnesses are exactly level. Fasten the cams when the loom is in this position. This will bring the harnesses level when the reed is about $2\frac{1}{2}$ in. from the fell of the cloth. If the harness cams are set so that the harnesses will be level before the reed reaches this point, that is, before the crank-shaft reaches its bottom center, the harnesses are said to be set early and the warp yarn will be subjected to additional strain and chafing; on the other hand, if the harnesses do not become level until the crank-shaft has passed its bottom center, the harnesses are said to be set late, and there will be less chafing of the warp.

Regulating the Shed.—The crank-shaft should be turned until it is on its back center; the lay will then be in its backward position and the harnesses should be open to their fullest extent. When in this position the yarn that forms the bottom shed should just clear the race plate of the lay. If the yarn presses on the race plate it will be chafed, and breakage of the ends will result. On the other hand, if the yarn is too high, it is liable to give the shuttle an upward tendency as it enters the shed, which often results in the shuttle either being thrown from the loom or not passing straight from one box to the other.

The crank-shaft should next be turned over one pick. This will bring the yarn, which formed the top shed, at the bottom. This bottom shed should be regulated in the same manner as the previous one.

Position of Warp Line.—The *warp line* may be defined as an imaginary line drawn from the top of the whip roll to the top of the breast beam and passing through the shed when open. The position that the warp line assumes forms an important point in the production of cloth on which there is to be more or less *cover*. If, when the shed is open, the warp line passes through its center there will be an equal strain on both sets of warp threads, since both harnesses move an equal distance from the point at which they become level. Except in special cases, this is not desirable.

When the warp line occupies this position, it generally results in the cloth having a hard, reedy appearance, the warp ends having the appearance of being laid in the cloth in pairs, since two ends will be close together and a space between these and the next two. If, however, the whip roll and the breast beam are raised, the warp line will pass through the upper half of the shed. This will result in the yarn in the top shed being more slack than the yarn in the bottom shed, and as the pick of the filling is beaten up by the reed it will spread the yarn that forms the top shed between the ends that form the bottom shed. This will tend to give the cloth an even appearance and cover.

Any setting of the loom to produce cover or a full appearance in the cloth, puts a greater strain on the warp ends, and care should be taken not to go to an extreme.

Timing the Picking Motion.—To time a picking cam, turn the crank-shaft until it is on its top center; then set the picking cam so that it will just start to move the picker stick. Turn the crank-shaft until it is on its top center again, when the picking cam on the other side of the loom should be set in the same manner.

If the picking cams are set so that the point of the cam starts to raise the pick cone before the crank-shaft reaches its top center, the loom is *picking early*. If the picking cam does not start the pick cone until the crank-shaft has passed its top center, the loom is *picking late*.

Adjusting the Lug Strap.—The lug strap should be adjusted in such a position that the point where connected to the picker stick will be level with where it is fastened to the picking-shaft arm. If possible, the lug strap where attached to the picker stick should never be on a lower level than the rest of the connections, since when in this position it has a tendency to slide up on the picker stick, due to the force coming from above the point where it is connected. This is very liable to result in a weak pick and the shuttle not receiving sufficient power to reach the opposite box.

If the lug strap is raised on the picker stick there will be less power imparted to the shuttle, and if it is lowered the opposite effect will be the result.

In placing lug straps on a loom, care should be taken that they have a little play. Under no condition should they be tight when the picker stick is at rest at the outer end of the box.

Starting Pickers.—To place a picker on the picker stick, have the picker stick at its backward throw, and place the picker so that its under side will just clear the bottom of the box. Bring the shuttle up hard against the picker so as to mark it. Where this mark comes on the picker, cut a small circular hole for the reception of the shuttle point. It is generally the practice to have the hole in the picker, when the picker stick is at the limit of its forward throw, a little higher (say about $\frac{1}{16}$ in.) than that point of the shuttle with which the picker is in contact. This will slightly depress the forward end of the shuttle, or the end first entering the shed, and consequently render the shuttle less liable to fly out.

Adjusting the Binders.—The *binder* holds the tip of the shuttle in actual contact with the picker while the shuttle is in the box. The shuttle should commence to press against the binder only when its widest part comes in contact with that part of the binder that projects into the box. It should then steadily press out the binder until that part of the shuttle which first came in contact with the binder has reached the other end of the projection on the binder. When set in this manner the binder will present its full face to the side of the shuttle when the shuttle is at rest in the box.

Adjusting of Protector Motion.—To set the protector motion, have the shuttle out of the box; then adjust the fingers at the back of the boxes in such a manner that they will press against the binders; bring the lay forwards and see that the dagger engages with the bunter on the frog. Next insert the shuttle in the box and see that the dagger clears the bunter, by about $\frac{1}{4}$ in., when the lay is brought forwards.

Timing of Filling Stop-Motion.—To time the filling stop-motion, have the shuttle on the filling-fork side of the loom; then bring the lay up to the full throw of the crank, so that it is on its front center. When the loom is in this position, turn the filling-fork cam on the cam-shaft until its point is just commencing to raise the lever on which it acts. Notice the position of the finger of this lever in relation to the back end of the filling fork. There should be a space of about $\frac{1}{4}$ in. between them.

Banging Off.—Banging off is caused by the shuttle not entering the box in time to prevent the dagger of the protector motion engaging with the frog. It may be due to any one or more of the following: (1) Picking too early or too late; (2) picking cam worn or slipped; (3) shed too early or too late; (4) shed too small or not adjusted correctly; (5) boxes too tight or too loose; (6) power of pick too great or too little; (7) imperfect or dirty shuttle; (8) imperfect picker; (9) driving belt slack; (10) protector motion out of adjustment.

Shuttles Flying.—Any obstruction, however slight, will serve to throw the shuttle out of its course, and very probably out of the loom. The principal causes of this are: (1) Bottom shed too high; (2) broken and tangled warp ends; (3) shedding too late or picking too early; (4) picker adjusted too low or badly worn; (5) reed damaged or out of position; (6) the race plate higher than box; (7) obstructions on race plate, etc.

Thin Places in Cloth.—Thin places in cloth may result when the loom is started after replacing the filling, or they may occur while the loom is running. The thin places occurring when the loom is running are not at all times easily overcome. When a friction let-off is being used, the cause for this defect is frequently found in the rope that is wound around the beam head. In such a case the rope should be thoroughly cleaned of all foreign substances and rubbed with graphite. If an automatic let-off is being used, the gears should be carefully examined and all the setscrews tightened. The gears of the take-up motion should also be examined. These are very apt to become clogged, and should be thoroughly cleaned.

Knocking off Filling.—If the shuttle is being sent across the loom at a high speed and is then suddenly stopped, the filling that it carries on the spindle will have a tendency to leave the spindle; consequently, anything to lessen this blow will also lessen the liability of the filling knocking off. As light a pick as will do the required work should be given to the shuttle, and when the shuttle is entering the box it should be checked in as gradual a manner as possible. Frequently, when cop filling is being used, it will be knocked off on account of the spindle of the shuttle not being large enough to firmly retain the cop.

Kinky Filling.—Kinky filling is usually the result of too much twist. When such is the case, the filling should be thoroughly dampened, either by being steamed or having water sprinkled on it. If the filling is allowed to run out of the shuttle too freely, more than the required length for one pick is very liable to be given off, and when beaten up by the reed it will be sure to rise in ridges.

Another cause of kinky filling is the shuttle rebounding in the box sufficiently to cause slack filling, but not enough to result in the loom banging off.

Filling Cutting.—The box sides should be carefully examined, to ascertain whether there are any projections or rough places that will cut the filling.

The filling fork should also be examined to determine whether it is passing through the grid freely. If it does not, but comes in contact, it is apt to cut the filling. The pin that holds the spindle in the shuttle may become loose and project a short distance from the side of the shuttle.

The shuttle spindle should not be thrown up when the shuttle is checked in the box. If it is, the spring in the heel of the shuttle, known as the *spindle spring*, should be tightened.

Sometimes the heel of the temple may be set in such a manner that the temple will come in contact with the reed. When this happens, the filling is very liable to be cut.

DOBBIES

The number of harnesses that can be operated by a cam-loom is limited, hence, if the number of ends that interlace differently exceeds 6 but does not exceed 25, a dobby is generally employed. Also, when looms are frequently changed from one weave to another, such changes are much more easily accomplished with dobby looms than with cam-looms.

A section of a dobby shedding arrangement, which is attached to a loom of ordinary construction, is shown in Fig. 1. The operation of this mechanism may be explained as follows:

Assume that the different parts are in the position shown with a peg in the pattern chain under the finger k operating the bottom hook h_3. This peg throwing up the outer end of the finger allows the inner end, on which the hook rests, to drop; this allows the outer end of the hook h_3 also to drop. As the dobby crank-shaft revolves and operates the rocker h, the lower

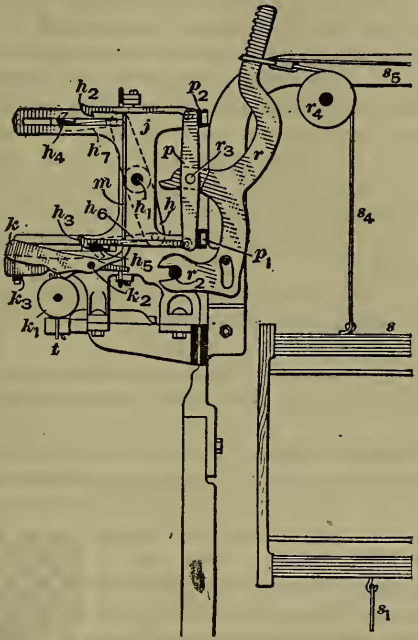


FIG. 1

arm of the rocker h in being pushed out will carry with it the knife h_5, which will engage with the hook h_3 and thus take with it the lower end of the jack p. The upper end of the jack bearing against the girt p_2 will be fulcrumed at this point, so that as its lower end is brought out by the action of the knife it will operate the lever r, which is connected to the jack p at the point r_3. The lever r in being pulled outwards will, through the strap connections, raise the harness connected to that lever. If on the next pick it is desired that this harness be down no peg will be inserted in the pattern chain to operate the finger k_3; consequently, the knife h_4, which is moving out on this pick. will escape the hook h_2, and the bottom knife h_5 in returning will allow the pull of the springs attached to the bottom of the harness to pull the harness down to its lowest position. If, on the other hand, it is desired to have this harness remain up on the second pick, a peg is inserted in the pattern chain to raise the outer end of the finger operating the top hook. The outer end of the finger in being raised causes its inner end to drop, and this motion, being imparted to the top hook h_2 through the wire m, allows this hook to engage with the top knife and be carried out on this pick; this brings the upper arm of the jack p outwards at the same time that its lower arm is moving inwards and holds the harness in its upper position.

Dobbies are said to be *double-lift* or *single-lift*, according to whether the jack is operated by two hooks, as in Fig. 1, or if only one hook is attached to the jack.

Dobbies are *double-index* or *single-index* according to whether or not there is a separate index finger for each hook, both top and bottom.

Pegging Harness Chains.—The order of lifting and lowering the harnesses with a dobby is marked on design paper and is known as the *chain draft*, as it is from this draft that the harness chain is made. Fig. 2 shows a harness chain draft for a weave. Each row of squares running vertically represents the order in which 1 harness is raised and lowered, while each row of squares running horizontally shows what harnesses are up on each pick; the bottom horizontal row of squares generally indicates the first pick. The filled-in squares show that a harness is up, and the blank squares that a harness is down.

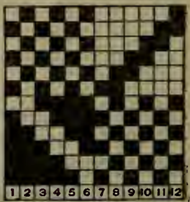


FIG. 2

When building a harness chain, the first thing to determine is the first harness and the first pick, as shown on the draft. It next becomes necessary to peg the pattern chain in such a manner that the bar containing the first pick will be placed on the cylinder first, and the pegs that control the first harness must come at the front of the loom so that the pegs will operate the first lever. When the first harness and the first pick are not designated on the draft, it is safe to assume that the lower left-hand corner will give the position of these two.

In Fig. 3, the draft given in Fig. 2 is pegged for a double-index dobby that is placed at the right-hand side of the loom. The first, or front, harness is operated by the vertical rows of pegs marked *a*, a_1; *b* indicates the first pick. In Fig. 4, the same draft is shown pegged for a single-index dobby that is

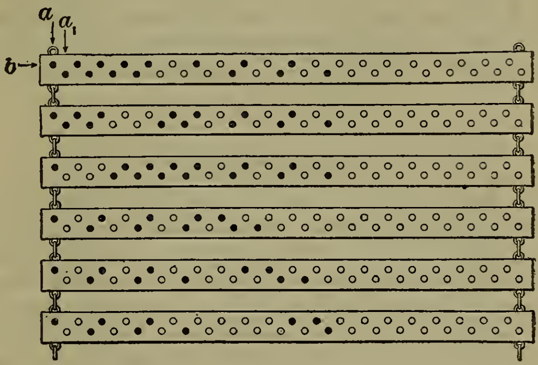


FIG. 3

located on the left-hand side of the loom. The order of raising and lowering the front harness is shown at *a*; *b* indicates the harnesses that are raised or lowered on the first pick.

Timing a Dobby.—In case the dobby is driven from the crank-shaft, turn the loom until its crank-shaft is on the bottom center; keeping the loom in this position, move the connecting-rod on the dobby until the dobby crank-shaft is on its back center. When in this position, the rockers should be perpendicular. Should they not be in this exact position, they may be adjusted by loosening the setnuts at the bottom of the connecting-rod and then moving the rocker until it is in the desired position. When the dobby is driven from the cam-shaft, place the loom crank-shaft on its bottom center. Have the crank to which the connecting-rod of the dobby is attached on its back center, and adjust the rockers so that they will be perpendicular when the different parts are in the positions stated.

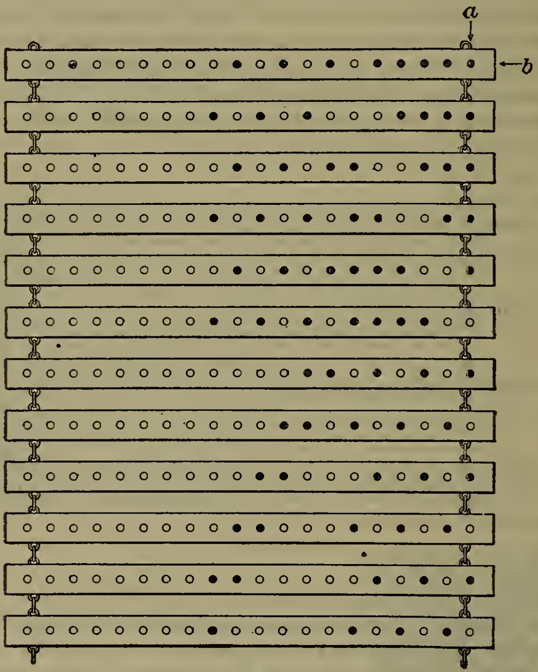


FIG. 4

Adjusting the Knives.—Turn the loom until the bottom knife is at its extreme inward position and then set the knife about $\frac{1}{4}$ in. back of the notches in the hooks; turn the loom over and set the top knife similarly. If set in this manner, the top knife will be directly over the bottom knife when the rocker is perpendicular; both knives will have an equal lift at this point and the harnesses that are changing will consequently be level. Thus, the harnesses that are changing are level when the crank-shaft of the loom is on its bottom center.

Timing the Cylinder.—When timing the dobby cylinder, have one of the knives as far in as it will move. Loosen the gears that drive the cylinder and turn the cylinder until the pegs operating the hooks for the knife that is in are giving the fingers of the dobby their full lift. With the, cylinder in this position, turn the worm until the straight part or that portion that gives the pause, is operating on the worm-gear on the end of the cylinder.

Considerable care should be taken to have the chain bar directly under the fingers when the cylinder stops, so that the pegs will lift the fingers and bring down the hooks, causing them to be caught by the knife when it starts on its outward stroke.

BOX LOOMS

The principle of box looms is that of having at one or both ends of the loom a number of boxes, which are generally operated by levers and other suitable mechanism that will bring the bottom of the desired box in line with the race plate of the loom and thus allow the picker to act on the shuttle contained in that box. By this means, several shuttles, each containing a different kind or color of filling, can be operated, and the one to be used at any given time selected automatically. On looms weaving cotton goods, the drop boxes are generally placed only at one end of the loom. The number of shuttles that can be operated in a box loom is one less than the total number of boxes; thus, six is the largest number of shuttles that can be run in a 6×1 loom; four in a 4×1 loom; two in a 2×1 loom; etc. The statements made in the following pages should be accepted as referring to a 4×1 drop-box loom.

The method of operating the boxes with the Crompton 4×1 box motion is illustrated by Fig. 1. In this view the first box is shown level with the race plate, and if it is desired to raise the lifting rod a_2, and consequently the boxes a, so that the picker b will act on the shuttle carried by the second box, the front shaft d of the box motion will be given a half revolution. This will cause the eccentric d_2 on the shaft to raise the collar g_1 and consequently the lever g at its forward end. As no motion is given to the crank-arrangement at the back end of the lever g, the forward end of the lever will be

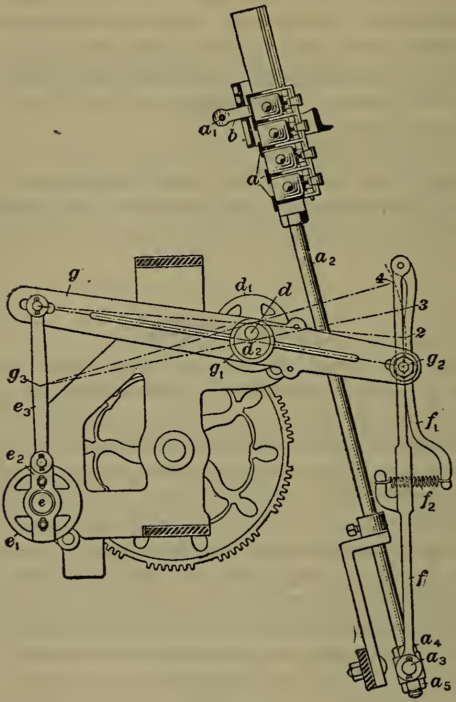


FIG. 1

brought up to the point 2, this lift being sufficient to bring the bottom of the second box level with the bottom of the race plate. When it is desired to bring the third box into position the eccentric arrangement of the front shaft d remains in the position shown, and a half revolution is given to the back shaft *e*, causing the crank-arrangement e_2, e_3 to lower the back end of the lever *g* to the point g_3, and the front end of the lever to be raised to the point *3*, which lift is sufficient to bring the bottom of the third box level with the race plate. If the different parts of the box motion are in the position shown and it is desired to bring the fourth box into position for the picker to act on the shuttle contained by that box, both the front and back shafts will be given a half revolution, which will result in the eccentric on the front shaft raising the lever *g* at this point, and the crank-arrangement on the back shaft will drop the back end of the lever *g* to the point g_3. This action of the two shafts will result in the forward end of the lever *g* being raised to the point *4*, which lift will be sufficient to bring the bottom of the fourth box level with the race plate.

In dropping the boxes, the motion given to the lever *g* will, of course, be opposite to that described for raising them, the motion being positive in both directions.

The motion of the front shaft *d* and back shaft *e* is obtained by suitable mechanism and is controlled by levers operated by a box chain. As each bar of the box chain serves for only 2 picks of the loom, if the pattern being woven contains a large number of picks of each color, it would be necessary to build a very long box chain. To overcome this difficulty, a mechanism known as the *multiplier motion* is applied to most box looms. By means of this motion, the box-chain bar that controls the box containing the required color will not have to be built for every 2 picks, since it will be possible to build any bar in such a manner that in addition to raising the required box it will also multiply the number of picks that that bar of the chain governs.

1st	*Blue*	24						12		4		4		12												
2d	*White*		24				12		4		4		4		12				24							
3d	*Red*			12		12										12		12								
4th	*Yellow*				12												12									

FIG. 2

Building Box Chains.—Box chains are built from pattern drafts, which show the number of picks of each color in one repeat and the order in which they are placed in the cloth.

A box-chain draft is shown in Fig. 2. With this draft as a guide, it is necessary to build the box chain in such a manner that the exact number of picks of each color shown in the draft will be placed in the cloth in their proper order. One other point that should be noted is that in many cases the colors are so arranged that it is a difficult matter to build the chain without serious jumps in the boxes, for although it is possible to raise the boxes from the first to the fourth or to lower them from the fourth to the first, this should be avoided as much as possible; consequently, when building a box chain care should always be taken to place the different colors in the different boxes in such a manner that the least possible number of jumps will be necessary. A jump occurs when the boxes are moved through a greater space than is occupied by one box. By referring to Fig. 2, it will be noticed that by placing blue in the first box, white in the second, red in the third, and yellow in the fourth, the boxes will be lifted in regular order and no jumps will occur; whereas, if the red is placed in the second box and the white in the third, it will be necessary to jump the boxes in many cases.

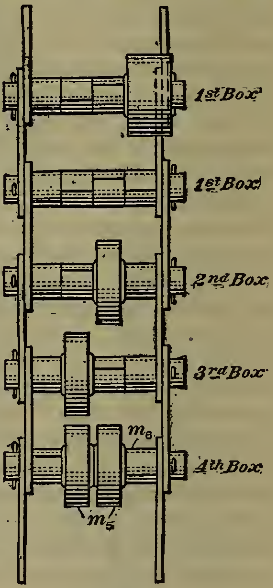


Fig. 3

Fig. 3 shows five bars of a filling chain, each bar showing a different arrangement of rollers and washers; the first, or top, bar contains a multiplier roll for placing the multiplier motion in operation. It will be seen that, with the exception of this roll, the bar consists of washers; consequently, a bar built in this manner will give 12 picks of the first box if a 12-pick multiplier motion is used. The next bar contains washers only, and, as a result, the first box will be on a line with the race plate. The next bar contains a roll that will operate the

FIG. 4

lever of the box motion that will raise the second box. The next bar contains a roll that will operate the lever of the box motion that will result in the third box being brought into position. The bottom bar is built to give the fourth box, as it operates both levers.

When building a box chain for a loom, the side on which the box mechanism is placed should be carefully noted and the chain built in such a manner that the rollers and washers will come under their correct levers.

Fig. 4 shows the complete chain built according to the chain draft. The first color called for in the draft is 24 picks of blue; this color is in the first box. To obtain these 24 picks of blue the first two bars of the chain, reading from the top, are built to give the first box and on the end of each bar is placed a multiplier roll. Since each bar containing a multiplier roll will give 12 picks, these first two bars of the chain will give 24 picks of the first box. The next color in the draft is 24 picks of white, which is in the second box. These two bars are built in the same manner as the first two, with the exception that there is placed on each a roll that will raise the inside lever of the box motion and thus give the second box. By comparing each bar of the box chain with the filling draft it will be seen that the desired result will be given. However, it should be noted that when it is necessary to place only 4 picks of a color in the cloth, the multiplier cannot be used. In this case, two bars are built to give the desired box and, since each bar operates for 2 picks, the desired 4 picks will be given.

In case it is necessary to place a certain number of picks of one color in the cloth, this number being greater than 12 and yet not a multiple of 12, as many bars as possible will be built with multipliers and then the desired number will be completed by building a sufficient number of bars without multipliers. For example, suppose it is desired to place 30 picks of one color in the cloth; two bars containing multipliers will be built, which will give 24 of the required picks, and in addition to these, three bars without multipliers will be built, which will give 6 more picks, thus completing the 30 picks.

Timing of Box Motions.—The boxes should be timed in such a manner that they will not start to change before the shuttle is well into the box and will be completely changed before the loom commences to pick. If the boxes commence to change before the shuttle is well boxed, the shuttle will be caught in the mouth of the box and will thus prevent the changing. On the other hand, if the loom commences to pick before the boxes are completely changed, the bottom of the box will not be level with the race plate when the shuttle is thrown.

There are several methods of timing the boxes, one probably being as good as another, so long as it accomplishes the result of changing the boxes in time. One method is to set the box-changing device so that the boxes will have moved about $\frac{1}{4}$ in. when the dagger on the protector rod strikes the bunter.

Leveling the Boxes.—After the boxes have been timed so that when changing they will start and stop correctly, it is necessary to level them; that is, the lifting parts should be so adjusted that whenever a box is brought into position, the bottom of that box will be on an exact level with the race plate of the loom. This will sometimes be found to be difficult, since in many cases all the boxes, with the exception of one, may be in a correct position, and yet changing the one that is a little out of true may so alter the lift of the others that, when they are again brought into operation, they will be found to be either above or below the correct position. The leveling of the boxes is a matter of leverage, and the different arms of the levers must be so set that they will give the throw required.

The boxes should work freely in the grooves in which they slide and yet not be so loose as to result in an uneven throw being given to the shuttle when acted on by the picker. If they are tight in the grooves, they will be raised and lowered in a jerky manner, which may cause the picker to be caught in its throw, thus preventing the lifting of the boxes.

THE NORTHROP LOOM

In power looms of ordinary construction it is necessary that the supply of filling be replenished by hand whenever it breaks or the cop, or bobbin, in the shuttle becomes exhausted. To accomplish this the loom must be stopped, usually by the filling stop-motion, and the weaver, after immediately giving the loom proper attention, must again place it in operation. In the Northrop, or Draper, loom, the filling yarn is automatically renewed in the event of breakage or exhaustion, and without stopping the loom or requiring the attention of the weaver. Looms of this class are called automatic looms.

When automatic looms are employed, the weaver can supply them with large quantities of filling at convenient intervals, and this can be accomplished with but little labor. Because of this fact, it is possible for each weaver to attend to a much larger number of automatic looms than is possible when common looms are employed. The number of automatic looms that can be attended by one weaver doubtless will average fully three times as many as in the case of common looms.

As a result of the increase in the productive capacity of weavers through the installation of automatic looms, the cost of weaving is greatly reduced. Savings of from 40 to 50 per cent. have been made in many cases, and under favorable conditions the gain is even greater. Also, because of the increased production of the weaver, it is possible, and the general custom is, to grant him greater compensation.

Filling-Changing Mechanism.—The principal feature of the Northrop loom is, of course, the filling-changing mechanism. This is shown in perspective in Fig. 1, which illustrates the battery, comprising a hopper, in which the supply of filling for replenishing the shuttle is carried, and mechanism for transferring the bobbins; also devices for controlling the transfer of filling when required.

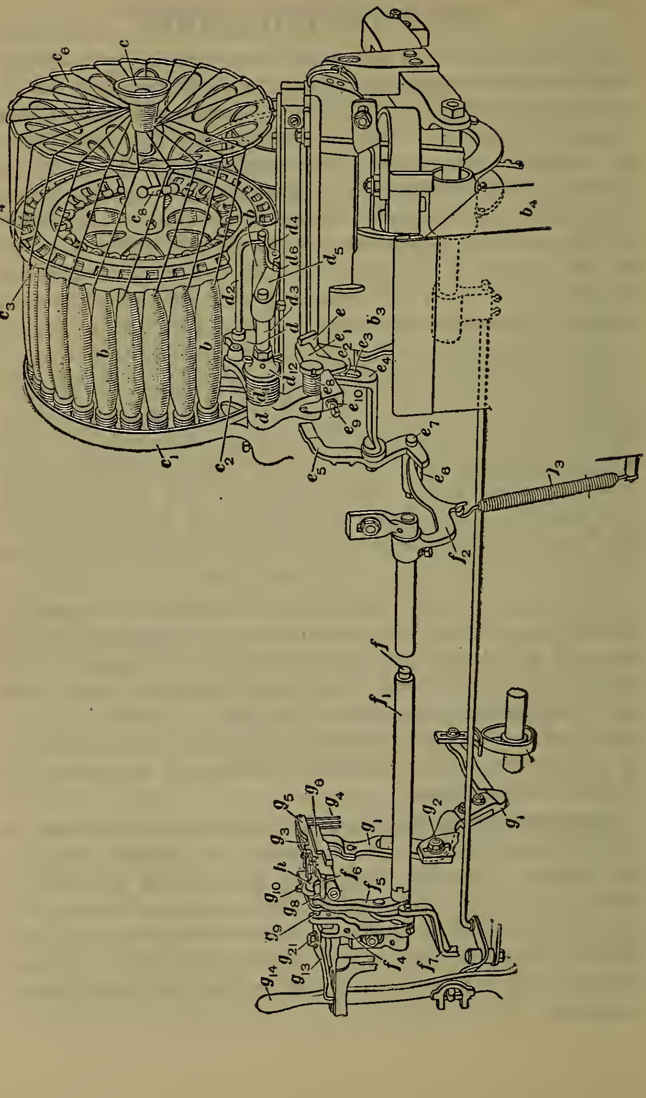

c
c6
c4
c8
c3
b
c1
c2
d4
d6
d5
d3
d2
d
d12
d1
e
e1
e2
e3
e4
b3
b4
e8
e10
e9
e7
e6
e5
f2
f
f1
g1
g2
g3
g4
g5
g6
g8
g9
g10
g13
g14
g21
h
f4
f5
f6
f7

FIG. 1

The bobbins b on which the filling yarn is wound are carried in the revolving hopper, which is capable of being rotated on its axis. This hopper is always on the right-hand side of the loom and consists of a stationary flanged end plate c_1 that carries the support on which the circular disks c_2 and c_3 rotate.

In filling the hopper, the weaver first unwinds a foot or so of filling from the bobbin, places the heel of the bobbin in the recess in the disk c_2, and presses the tip of the bobbin firmly into the clip c_4 in the disk c_3. The end of filling yarn is then passed over a notched disk c_6 that holds the yarn in proper position to be threaded in the shuttle and is secured by being wound several times around the stud c_7.

The number of bobbins contained in the hopper varies in looms of different models; most looms are equipped with what is known as the 25-bobbin hopper, which contains twenty-eight spaces for bobbins.

The transfer of the bobbin from the hopper to the shuttle is effected, as shown in Fig. 2, by the transferrer d and transferrer fork d_2, which, by the motion of the lay of the loom, are forced downwards for a short distance, swinging on the stud d_3, and thus pushing the bobbin out of the hopper and into the shuttle.

The head of the transferrer engages with the heel of the bobbin in the hopper and the transferrer fork comes in contact with the tip of the bobbin. The filled bobbin, in being pressed into the top of the shuttle, forces the empty bobbin out through the bottom of the specially-designed shuttle, which has no spindle, and it passes through an opening in the bottom of shuttle box, over the guide b_3 and into the sheet-metal receptacle b_4.

The operation of the transferrer and attached mechanism is governed by the starting rod f, Fig. 1. Normally, the shuttle-feeler finger f_2, which is setscrewed to to the starting rod, is held in its lowest position by the spring f_3. The finger presses down on the stud e_6 (also, see Fig. 2), holding the shuttle feeler e_5, which swings on the stud e_7, away from the lay and, by means of the slot e_3 and stud e_2, causing the latch depressor e_4 to hold the latch finger e_1 in a depressed position, where it will not be in the path of a bunter e attached to the lay. Whenever

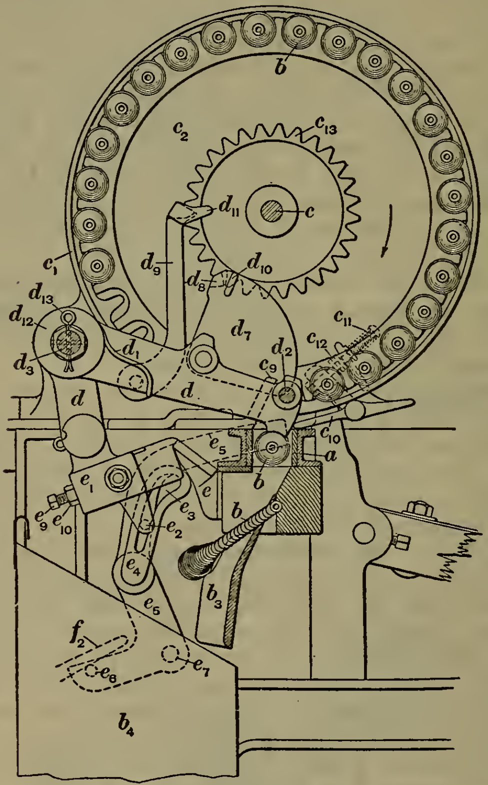


FIG. 2

the filling is missing, however, a partial revolution is given to the starting rod f and the finger f_2 is raised against the tension of the spring f_3. When this takes place, the shuttle-feeler finger releases its pressure on the stud e_6

and the spring e_8 raises the latch finger e_1 into an operative position so that it will be struck by the bunter e on the lay and forced toward the front of the loom for a short distance as the lay moves forwards. The movement of the latch finger imparted by the motion of the lay causes the transferrer d and transferrer fork d_2 to be forced downwards, transferring the bobbin from the hopper to the shuttle.

In Fig. 2 the transferrer, latch finger, and other parts are shown in the positions that they occupy after the bunter has engaged the latch finger and forced it forwards to the full extent of its movement, thus causing the transferrer to assume its lowest position, placing the bobbin in the shuttle as shown.

Shuttle Feeler.—If the transfer of a bobbin from the hopper to the shuttle were to take place with the shuttle in such a position as not to properly receive the bobbin, it is very probable that parts of the transferring mechanism or the shuttle, etc. would be broken. To prevent the transfer of the bobbin under this condition, the shuttle feeler e_5 is employed. As the spring e_8 causes the latch finger e_1 to rise into its operative position, the stud e_2, which is on an extended arm of the latch finger, operates the shuttle feeler e_5 by means of the latch depressor e_4. The stud e_2 engages with the slot e_3 in the latch depressor and the upward movement of the latch finger causes the latch depressor to swing the shuttle feeler on the stud e_7 so that its upper end passes directly in front of the shuttle box until it nearly reaches the back plate of the box.

If the shuttle a is not far enough in the box for the transfer of a bobbin to take place properly, the tip of the shuttle will project from the box and the end of the shuttle feeler will come in contact with it as the lay comes forwards. When this occurs the shuttle feeler will be pushed forwards by the shuttle and, by means of the latch depressor and stud e_3, will depress the latch finger so that it will not engage with the bunter e on the lay. Instead, the upper rounded corner of the latch finger will engage with the inclined under surface of the bunter and, as the lay moves forwards, the latch finger, shuttle feeler, and other parts will be thrown downwards into the positions that they occupy during the normal operation of the loom. Under this condition the transfer of a bobbin from the hopper to the shuttle, of course, cannot take place and the loom will be stopped in the ordinary manner for want of filling.

Hopper.—The manner in which the hopper is rotated on its axis c to bring the next bobbin in contact with the stop c_9 after the preceding bobbin has been inserted in the shuttle may be understood by referring to Fig. 2. A ratchet gear c_{13}, cast integral with the bobbin heel plate c_2, is operated by a pawl d_7 having a projection, or tooth, d_8 engaging with the teeth of the ratchet. The pawl is swiveled on a stud in the transferrer d and is large and heavy so that when the transferrer is thrown down by the bunter on the lay engaging the latch finger, the tooth d_8 will become disengaged from the ratchet and the pawl will fall forwards and downwards. This causes the tooth d_8 to take up a tooth on the ratchet and when the bunter releases the latch finger and the coil spring d_1 raises the transferrer and pawl, the ratchet and hopper will be turned in the direction indicated by the arrow in Fig. 2 until the next bobbin in the hopper strikes the stop c_9. A stop pawl d_9 attached to the frame also engages with the ratchet c_{13} and serves to hold the hopper securely in position.

Shuttle.—The shuttles required by the Northrop loom are of the self-threading type and are designed to utilize filling yarn supplied on bobbins or in cop form. One of these shuttles is illustrated in Fig. 3.

The shuttle a is open on the bottom, and is formed to receive a bobbin of filling from the top and eject it through the opening in the bottom. It does not contain the usual spindle; instead, a shuttle spring a_1, made in the form of a fork with its tines extending on each side of the shuttle, is placed in the end opposite the eye. The shuttle spring contains notches designed to engage with metal rings b_1 securely placed on the heel of the bobbin *b*. When the transferrer forces a fresh bobbin from the hopper into the shuttle, the heel of the bobbin is forced between the tines of the shuttle spring, and the notches in the latter, by engaging with the rings placed on the bobbin, securely hold the bobbin in its proper position in the shuttle. At the same time the new bobbin, by striking on top of the bobbin already in the shuttle, forces the latter out of the shuttle spring so that it falls through the openings in the bottom of the shuttle and in the lay, into the empty-bobbin can.

If the shuttle should happen to be a trifle too far in the box when the transfer takes place, the heel of the bobbin will strike the bent and inclined shuttle-spring cover a_2, which, by either forcing the shuttle in one direction or the bobbin in the other, or both, will guide the bobbin into the shuttle so that the rings on the former will be properly gripped by the shuttle spring.

The manner in which the self-threading feature of the shuttle operates may be described as follows: When a fresh bobbin is transferred from the hopper to the shuttle, the end of the filling yarn is held by being wound around the stud c_7, Fig. 1, and as it is placed in the proper notch in the plate c_6 when the hopper is filled, the filling thread will be held in exact line with the shuttle, as shown by the dotted line at b_5, Fig. 3, when

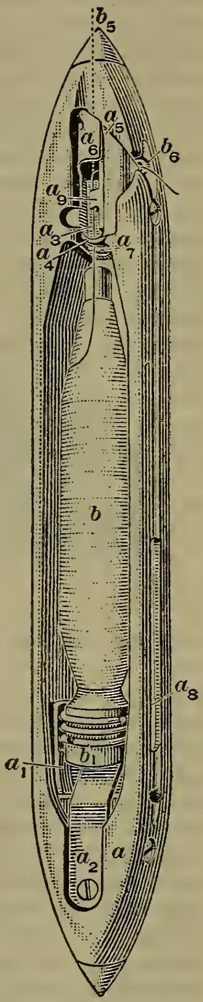


FIG. 3

the latter is picked across the loom. On the first pick after the transfer and as the shuttle moves away from the battery side of the loom, therefore, the filling will fall into the longitudinal slot a_8 and pass beneath the horns, or projections, a_4, a_5, and a_6 of the sheet-metal stamping and also beneath the projection a_9 of a small cast-iron piece. As the shuttle is driven back toward the battery side of the loom, the threading is completed and the end is drawn through the eye b_6 as indicated. A projection (not shown) on the casting carrying the projection a_9 prevents the filling from being thrown out of the shuttle eye when the shuttle is checked in the box during the ordinary operation of the loom. The customary friction flannel is inserted at a_7 to control the running of the filling.

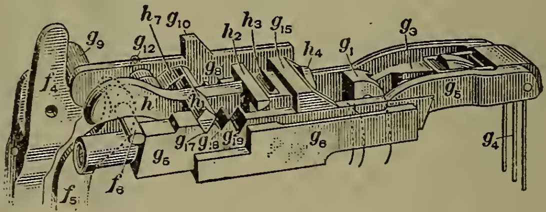


Fig. 4

Filling Motion.—The filling motion of the Northrop loom, which is of peculiar and original construction, serves a dual purpose. First, it must be arranged to impart motion to the starting rod and shuttle-feeler finger which control the operation of the transferring mechanism, and, second, it must be devised in such a manner as to throw the shipper handle of the loom from its retaining notch in the event of a failure to transfer.

The action of the filling-motion mechanism, Fig. 4, in controlling the transferring device and the stopping of the loom may be described as follows: The rotation of the filling cam on the cam-shaft of the loom causes the cam-follower g_1 to move the follower hook g_3 toward the front of the loom on every alternate pick, that is, every time that the shuttle comes to rest in the box on the left-hand side of the loom. Whenever a pick of filling is left in the shed, as in the normal operation of the loom, the filling fork will not enter the grate on the lay and will be tilted so that it will escape being caught by the hook g_3 as the latter is moved toward the front of the loom. Assuming, however, that the filling becomes broken or exhausted, then, as the shuttle enters the box on the left of the loom, it will leave behind it no pick of filling and the filling fork g_4 will not be tilted to escape the follower hook g_3. Under this condition, as the hook moves toward the front of the loom, it will engage the filling fork and draw it and the fork slide g_5 forwards. As this takes place, the stud g_9 on the dog g_8, which is attached to the fork slide, will operate the arm f_4, causing the starting rod f, Fig. 1, to make a partial revolution, raising the shuttle-feeler finger f_2 and allowing the transferring mechanism on the next pick and with the shuttle on the battery side of the loom to operate, as has been previously described.

As the filling-fork slide g_5 is forced forwards by the follower hook g_3, a notch in the filling-motion trip h will engage with a boss of the guide plate g_6. The fork slide in being moved forwards, therefore, will cause the angular bar h, of the filling-motion trip to rise out of the notch g_{17} in the fork slide, in which it normally is at rest and fall into the slot g_{18}.

As the motion of the filling-cam follower g_1 moves the hook g_3 in the opposite direction, the fork slide is brought back to its normal position by a spring. Suppose that the transfer to the shuttle of a fresh supply of filling was successfully accomplished, when the transferring mechanism was thrown into operation. Under this condition, the shuttle will leave a pick of filling in the shed when it again enters the box on the left of the loom and the filling fork will be tilted so that the follower hook will not engage with it and the transferring mechanism will not again be put into operation. Moreover, in moving forwards the head of the filling-cam follower g_1 will strike the end of the filling-motion trip and replace it in its normal position, with the bar h engaging the notch g_{17}. On the other hand, assume that for some reason the transfer of fresh filling to the shuttle was not properly accomplished and the shuttle is again driven into the box. on the left-hand side of the loom without leaving behind it a pick of filling. In this case, the filling fork will again fail to be disturbed and will be engaged by the follower hook g_3, the filling-fork slide being forced forwards for the second time and again operating the arm f_4 so as to turn the starting rod and again throw the transferring device into operation.

As the filling-fork slide is moved forwards the second time, another notch h_9 of the filling-motion trip will engage with a fixed boss and the fork slide in moving forwards will cause the angular bar h_1 of the trip to rise out of the notch g_{18} of the fork slide and fall into the notch g_{19}. It will be noticed that the notch g_{19}, in addition to being farther back than the notches g_{17} and g_{18}, is much deeper. Thus, when the bar h_1 of the filling-motion trip is engaged with this notch, the dog h_7 of the filling-motion trip is placed in a position directly back of the end of the lever that operates the shipper handle of the loom.

If the second attempt to transfer fresh filling to the shuttle fails and the shuttle again enters the left-hand box without leaving a pick filling in the shed, the filling fork will again engage the cam-follower hook and the fork slide will be brought forwards for the third time. In this case, however, the filling-motion trip has already assumed its extreme position relative to the filling-fork slide, and therefore it will, in this case, be moved forwards with the slide. Since the dog h_7 of the trip is now engaged with the end of the knock-off lever, the latter will be moved a sufficient amount to cause the shipper handle to be forced from its retaining notch and stop the loom. It will be noted, however, that if the second attempt to transfer fresh filling to the shuttle is successful, the pick of filling left by the shuttle as it enters the box will cause the filling fork to miss the filling-cam-follower hook and the fork slide will not be moved forwards. The head of the cam-follower g_1, however, will replace the filling-motion trip, as previously described. It will be noted from the foregoing description that, in the event of the filling breaking or running out, this device will cause the loom to make two distinct attempts to replenish the filling and, in the event of consecutive failure, will stop the loom.

Feeler Filling-Changing Device.—When the transfer of filling is controlled by a filling fork and the customary grate, or grid, the transferring mechanism will not be placed in operation until the fork has detected the absence of filling, due either to breakage or exhaustion. Since the transfer of fresh filling cannot take place instantaneously, but at least one shed must be left empty and very likely only a portion of a pick inserted in another shed, a mispick will be made in the cloth. Moreover, whenever the very last end of the filling yarn is woven from the bobbin, a bunch is liable to be formed in the cloth on account of the last few turns of yarn on the bobbin slipping off at once and being woven into the cloth in a lump.

Since the transferring mechanism is operated much more frequently because of the exhaustion of the filling than on account of the filling becoming broken, a large number of mispicks and other defects in the cloth—in fact, the bulk of them—will be prevented if the transferring mechanism is set in operation just before the filling in the shuttle becomes exhausted. This, therefore, is the object of the feeler filling-changing mechanism, sometimes called the mispick preventer, and its use renders entirely practicable the weaving of perfect cloth on an automatic loom.

This mechanism is not necessary for looms used for weaving plain fabrics, such as print cloths, sheeting, etc., because in such fabrics the few mispicks made by an automatic loom are not seriously objectionable.

When fabrics involving the use of more harnesses, including fancy fabrics in which the weaves are produced by dobby or jacquard shedding mechanisms, are woven, however, mispicks are of serious consequence and the loom should be equipped with the feeler filling-changing mechanism.

This device is so arranged that a filling feeler that projects through the front-box plate and a slot in the side of the shuttle, feels for the filling wound on the bobbin. When only a layer, or so, of yarn remains on the bobbin, the starting rod is operated by a suitable mechanism and fresh filling is supplied to the shuttle; thus the filling in the shuttle is never allowed to become exhausted.

Shuttle-Feeler Thread Cutter.—An attachment known as a shuttle-feeler thread cutter is necessary on all looms equipped with the filling-feeler device for operating the transferring mechanism. Whenever the latter mechanism is placed in operation by the filling-feeler motion, and not by the breaking of the filling as detected by the filling motion, a thread of filling extends from the selvage of the cloth through the shuttle eye to the bobbin contained in the shuttle. When the fresh bobbin of filling is inserted in the shuttle, not only must the old bobbin be removed, but the shuttle eye must be cleared to allow the yarn from the new bobbin to be properly threaded in the eye. To accomplish this the thread extending from the selvage of the cloth must be cut as closely as possible to the shuttle so that the old bobbin, in being ejected, will draw the short length of yarn, left extending from the shuttle, through the shuttle eye, leaving the latter entirely clear and free.

The temple thread cutter alone cannot accomplish this result, as it cuts the thread at too great a distance from the shuttle eye and it does not positively operate at the correct time. The object is attained by means of a thread cutter, mounted on the shuttle feeler, which not only severs the filling yarn close to the shuttle at the time of the transfer of filling, but also clamps and holds the end extending to the cloth so that the temple thread cutter will again cut the yarn close to the selvage.

Dual Function of Straddle Bug.—The straddle bug g_8, Fig. 4, is so designed as to be placed on its stud g_{12} in two positions, that is, with the stud g_9 at the left, engaging with the arm f_4 on the starting rod, or with the stud at the right, in which position it will not engage with the arm f_4. When the straddle bug is placed in the former position, the transferring mechanism will be set in operation by the filling motion when the filling breaks or becomes exhausted, since the stud g_9 will operate the arm f_4 and turn the starting rod.

When the filling-feeler device is applied to the loom the filling, of course, will not become exhausted, as the loom is caused to transfer just before the bobbin in the shuttle becomes empty. As on many fabrics the possible mispicks from a comparatively few breakages of the filling are not of vital importance, the straddle bug is often placed in the position shown in Fig. 4 on many looms equipped with the filling-feeler attachment. That is, the latter device prevents the majority of defects, and a few mispicks, caused by the breaking of the filling, are tolerated in order to preserve fully the automatic features of the loom.

When, however, fabrics are woven in which it is absolutely necessary that the pick be matched, as in fancy weave effects, fine napped goods, etc., the straddle bug is removed from stud g_{12} and replaced with the stud g_9 at the right. In this position the stud g_9 will not engage the arm f_4, and the projection g_{10} will rest directly behind the lever which throws the shipper handle from its retaining notch and stops the loom. Thus, whenever the filling breaks, the loom will not transfer, as stud g_9 will not operate arm f_4 and the starting rod, but instead the loom will be stopped as in the case of common looms.

Double Filling-Fork Arrangement.—A single filling fork placed at one side of the loom can detect the presence or absence of only every alternate pick of filling. Naturally, the filling may break when the shuttle is traveling toward either side of the loom. As the transfer of filling can take place only when the shuttle is at rest on the hopper side of the loom and because of the peculiar action of the filling motion, shuttle feeler, etc., which may delay the transfer, from one to three picks of filling may be missed in the fabric before fresh filling is supplied. The number of picks, and possibly portions of picks, varies, of course, and it is clearly evident that a single filling fork operating at one side of the loom will be unable to detect all of these variations. When, therefore, cloth in which the slightest defect is objectionable is woven, an additional filling fork operating on the right-hand side of the loom is supplied. This extra filling fork is applied to looms equipped with the filling-feeler device, and, also, is very often attached to looms having only the single-fork filling-changing mechanism, because it not only affords extra protection against possible improper functioning of various parts but, in addition, furnishes a double control over the take-up motion. By virtue of this latter fact, the slightest thin place or crack in the fabric is prevented.

Warp Stop-Motions.—When an end of the warp breaks in a loom of ordinary construction, the machine continues to run until the defect is observed and the loom stopped by the weaver. If a considerable period of time elapses before this is accomplished, not only will a more or less prominent defect be formed in the fabric but the broken end often will become entangled with adjacent ends, which also may become broken, and a more serious imperfection will be made in the cloth. To obviate this fault and automatically stop the loom whenever a warp end breaks, warp stop-motions are applied to many looms. Such devices are especially necessary when automatic, or filling-replenishing, looms are employed, because, in such cases, the weaver attends to so many looms that the prompt observance of broken warp ends is difficult, and the immediate stopping of the loom is otherwise impossible.

There are several different types of warp stop-motions, but those ordinarily employed in connection with the

Northrop loom are mechanically operated and of two principal kinds, namely, the cotton-harness warp stop-motion and the steel-harness warp stop-motion.

FIXING NORTHROP LOOMS

The adjustment, timing, and repair of many parts of the Northrop loom are not different from the care of the similar parts of an ordinary loom. The additional and typical devices and mechanisms of this loom, however, require special care on the part of the loom fixer. Incorrect timing and setting will result not only in failure to replenish the filling when required but in some cases will cause parts to be broken.

Adjustment of Filling-Changing Mechanism.—In adjusting this mechanism, first the lay should be pulled forwards to the front center and the filling fork carefully adjusted so that the prongs of the fork will freely pass through the grate, or grid. The filling-motion cam g, Fig. 1, on the cam, or bottom, shaft of the loom is timed in the ordinary manner. The filling-motion arm, or finger, f_4 now should be placed against the stud g_9 of the straddle-bug g_8 carried by the filling-fork slide g_5 and the finger secured to the starting rod f. Next, the loom should be turned forwards with the filling-motion fork g_4 engaged with the hook g_3, which will push back the finger f_4 and turn the starting rod into its operative position.

The next operation is to loosen and raise the shuttle-feeler finger f_2 until the shuttle feeler e_5 passes in front of the mouth of the shuttle box, whereupon the finger should be securely fastened to the starting rod. By means of the slotted latch depressor e_4, attached to the shuttle feeler, the latch finger e_1 should now be adjusted so that it will be in position to be struck by the bunter e on the lay and the latter should be brought forwards to its front center, thus operating the transferrer d.

The latch finger should be adjusted by means of the adjusting screw e_9 and locknut e_{10} so that the transferrer and transferrer fork will have a downward movement just sufficient to force the empty bobbin from the shuttle and place the fresh bobbin in correct position in the shuttle spring. The proper adjustment is to have the head of the transferrer just clear the head of the bobbin when the latter is in its lowest position; this clearance should not exceed $\frac{1}{16}$ inch.

Position and Care of Shuttle.—It is important to have the shuttle stopped in the box in exactly the correct position to receive the bobbin when the latter is pushed into it by the transferrer. If the pick is too weak, the shuttle may not fully enter the box, and if too strong, the shuttle may be rebound. When adjusting the shuttle feeler and latch finger, therefore, the shuttle should be pulled from the box until the shuttle feeler will strike its tip when thrown upwards. When the shuttle feeler is in this position—that is, in contact with the protruding shuttle—great care should be taken to see that the latch finger will not engage the bunter on the lay in such a manner as to cause the transfer to take place. Should the loom be stopped with an empty bobbin in the shuttle, it is an indication that the transfer has been prevented by the shuttle feeler, and steps should be taken at once to insure that the shuttle will be properly boxed.

The metal parts of the shuttle should be kept securely fastened, especially the shuttle spring, which must be kept tight in order properly to receive and hold the bobbin. The eye of the shuttle and the thread passages to the eye must always be kept open and free. Sometimes these become clogged with lint and occasionally the thread passages to the eye are closed by jamming or bruising of the metal.

Any defect that prevents the filling from entering the shuttle eye will cause misthreading to take place, which will not only break the filling, but will cause a mispick to be made in the cloth. If the loom misthreads several times in succession, a defect in the cloth is sometimes made that is beyond repair, necessitating the cutting of the cloth. When the shuttle misthreads, the filling fork will be operated correctly on the first pick after the transfer, but as the shuttle is returned on the next pick, the filling will be broken and the transferring mechanism will again be placed in operation, which may continue until all of the bobbins have been transferred from the hopper.

Setting of Feeler Filling-Changing Mechanism.—In looms in which the filling feeler and feeler thread-cutting mechanisms are used, the filling-cam-follower trip should be so adjusted on the upper end of the filling-cam follower that the notch will engage the feeler slide when the latter has been raised into its active position by the filling-feeler mechanism, and this contact should take place just as the crank-shaft of the loom reaches its front center.

To adjust the filling feeler itself, an empty bobbin should be placed in the shuttle and the latter inserted in the box. With the loom on the front center and the lay in its extreme forward position, the adjusting screw should be turned until there is a distance of about the thickness of one layer of yarn between the feeler and the bobbin in the shuttle. Several bobbins containing a small amount of yarn now may be taken, and the loom started after one of them has been inserted in the shuttle. If the bobbin is ejected before the filling yarn has been woven down close enough, or if the filling weaves entirely off before the transfer takes place, the screw can be adjusted one way or the other as may be required. A number of trials may be necessary before the feeler is correctly adjusted.

The filling feeler should be set to pass through the slots in the box plate and in the shuttle, without touching either part. For the same reason, care should be taken that the shuttle boxes properly on the left-hand side of the loom. It is good practice to set the feeler as closely as possible to the upper edge of the slot in the shuttle, because the latter may rise slightly in entering the box. This may cause the feeler to strike the lower edge of the slot in the shuttle and force back the feeler so that the transfer of filling will be prevented when the filling in the shuttle is exhausted.

Adjusting Shuttle-Feeler Thread Cutter.—In looms equipped with the filling feeler and shuttle-feeler thread cutter, the starting rod and shuttle feeler will be operated in the same manner as when the former is functioned by the filling-fork slide. However, the feeler thread cutter, which is carried by the shuttle feeler on looms having the filling-feeler device, must be so adjusted that the bunter on the lay will operate the thread cutter and cause the filling to be cut properly. Also, the shuttle feeler must prevent the operation of the transferring mechanism in case the shuttle is projecting from the box so as not to be in proper position to receive the fresh bobbin of filling. The correct results ordinarily can be obtained without difficulty by changing the angle of the thread cutter so as to place it either farther, or not so far, forwards, or by raising or lowering it. Care should be taken to make the adjustment in such a manner that the thread cutter does not cut the filling unless a bobbin is transferred, as this will make a mispick in the cloth.

The shuttle-feeler thread cutter also must be adjusted so that whenever a bobbin is transferred the thread from the exhausted bobbin will enter the opening in the end of the thread cutter. The thread must not only be cut, but also must be held and drawn back until again cut by the temple thread cutter. Heavy or light filling may require this adjustment to be altered and also may require a slight alteration in the position of the shuttle-feeler thread cutter.

Care of Cotton-Harness Warp Stop-Motion.—In adjusting the cotton-harness warp stop-motion, the first operation is to throw off the driving belt of the loom or else disconnect the belt-shipping mechanism so that the shipper handle can be placed in its retaining notch.

The knock-off link is then drawn forwards against its bearing in the hub of the cam.

Next, the feeler bar is placed in its central position with reference to the two box plates and the loose and tight oscillator fingers adjusted so that they will project evenly from each side of the feeler shaft, or at right angles with the feeler-bar holders.

The oscillator cam now should be loosened in order that the cam may be revolved by hand, and the tight knock-off dog adjusted by its setscrew so as to clear the lug by about $\frac{1}{16}$ of an inch. Next turn the oscillator cam until the cam follower rests on the lowest part, or heel, of the cam, when the feeler should be near the back box plate. The loose oscillator finger now should be connected with the cam follower by means of the oscillator rod and turnbuckle. The latter should be adjusted so that the feeler bar will move equally toward both box plates. The tight oscillator finger now is attached to the loose knock-off dog by means of the oscillator rod and turnbuckle, the adjustment being made so that the loose knock-off dog will just clear the lug on the hub of the oscillator cam. If it now is found that the feeler bar does not move equally toward each box plate, the trouble may be corrected by further adjustment of the oscillator rods by means of the turnbuckles.

The tension of the cam-follower spring should be adjusted so as just to be sufficient to cause the cam follower o_8 to follow the cam contour when the point of contact moves from the toe to the heel of the cam. If the tension of this spring is too great, the drop wire will be struck too hard a blow and will be liable to be bent or injured when trapped between the feeler bar and the rear box plate.

Care of Steel-Harness Warp Stop-Motion.—In adjusting the steel-harness warp stop-motion the shipper handle is placed in its retaining notch and the loom turned over until the feeler bars are moved into their extreme forward positions directly beneath the stop-motion girt. The knock-off link now is drawn forwards against its bearing in the hub of the oscillator cam, and the cam follower should bear against the heel, or lowest part, of the cam. The knock-off dog now should be set so as to just clear the lugs on the hub of the cam.

The setting of the oscillator cam is controlled by the setting of the harness cams that raise and lower the heddle bars to form the sheds in the warp, and this setting should be altered to work with the setting of the harness cams if the latter is changed for any reason.

When the harness that is rising is just passing the harness that is falling, or is level with it, the long axis of the cam should be horizontal, or level, and the cam should be fastened to the cam-shaft in this position. The tension of the oscillator cam-follower spring should be adjusted so that the feeler bars will not strike too hard a blow on the heddle when the latter is allowed to fall by a broken warp end and is trapped between the feeler bar and stop-motion girt.

General Care of Warp Stop-Motions.—As a rule, warp stop-motions occasion but little trouble. There are, however, several minor difficulties that may be remedied easily when the causes are recognized. The lower ends of the steel heddles or of the drop-wire detectors are sometimes badly bent and twisted by the action of the feeler bar. In most cases, this will be found to be due to an improper adjustment of some working part, the fallen heddle or drop wire being struck repeatedly by the feeler bar and the loom failing to be stopped.

The bars supporting the drop wires or heddles should be kept straight, clean, and smooth. In the steel-harness stop-motion, if the heddle bars are not straight, reedy and uneven cloth will be produced. Oil should not be placed on these bars, however, as it is apt to stain the warp. Extra heddles and drop wires are sometimes applied by breaking open the slot and slipping them into position. These always should be removed when drawing in a new warp, as they may catch on other drop wires and interfere with proper action.

Occasionally, a set of drop wires or steel heddles will become magnetized, which makes trouble by causing the individual heddles to stick together. This prevents the formation of clear sheds and interferes with the fall of the heddle or detector if a warp end breaks. The difficulty is remedied by having the heddles demagnetized by passing them through an electrical coil.

Slack warp threads often cause considerable annoyance, the loom being stopped repeatedly and the weaver being unable to find a broken warp thread. This is due to the slackness of the thread allowing the detector to fall just low enough to engage with the feeler bar. Sometimes this trouble is due to the whole warp being woven too slack but more often it is only one thread or a group of threads that gives difficulty. Occasionally, the stop-motion girt or box plates are not in the correct position relative to the whip roll. In some fancy weaves, certain ends do not interlace with the filling as frequently as other ends and, hence, tend to become slack. As such threads are not liable to become broken on account of their slackness, it is well not to draw them through detectors of the stop-motion. Large spooler knots with long tails often cause excessive warp breakage and if automatic knot tiers are not employed, it is desirable to have spooler tenders tie a weaver's knot instead of the customary overhand knot.

When a cotton-harness type of warp stop-motion is used and extra drop wires employed, the warps should be sized a trifle more heavily in order to give the yarn the extra strength required to withstand the additional chafing and wear. This is not necessary in the case of the steel-harness stop-motion.

Speed of Northrop Looms.—The speed at which Northrop looms can be run and the power required to drive them depend largely on the width, weight, and character of the loom and the weight and construction of the fabric being woven. The filling-replenishing devices are capable of operating at any speed at which it is practicable to run the loom. Excessive speed causes a large increase in the number of breakages of warp yarn, and the loom is stopped so often to tie in broken ends that any gain made by increased speed is apt to be more than offset.

COTTON-MILL PLANNING

To explain the method of planning the layout of a mill, a standard cotton mill will be taken as an illustration, and the details of the machinery equipment worked out with reference to this particular type of mill. Hence, it will be assumed that it is required to lay out the machinery for a mill to make 4-yd. goods, 39 in. wide, 28s warp and 36s filling, 72 sley, and 80 picks to the inch. It will be assumed, also, that 10,000 spindles have been decided on as the size of the mill.

Organization.—Two important matters must be figured out: (1) The organization of the mill in order to produce the line of goods; (2) the machinery needed to supply 10,000 spindles and to take care of the product of these spindles and manufacture it into cloth. In mill engineering, the term *organization* is usually applied to the program, or list, of the weights of the product at each machine and the drafts and doublings necessary to produce these results, the whole organization being calculated closely enough so that, after making due allowances for waste, it will show the weight, hank, or number delivered, from the weight of lap in the picker room to the weight of the cloth desired.

The counts of the warp yarn to be made in this case are already known as 28s and that of the filling as 36s; and for making these yarns, a mill usually has the following processes: Bale breaker, automatic feeder and opener, breaker picker, intermediate picker, finisher picker, one process of carding, three processes of drawing, no combing, and three processes of fly frames (slubber, intermediate, and roving). Then follow spinning, spooling, warping, slashing, drawing in, weaving, sewing, cloth brushing, folding, and baling.

For the counts of yarn to be spun, the lap from the finisher picker should weigh from 12 to 14 oz. per yd.; in this case a 13 oz. lap will be taken for the purpose of illustration. The number of processes between the lap and the yarn being known, the hank of the 13 oz. lap must be ascertained and the attenuation between the lap and the yarn so distributed that the yarn will gradually be drawn finer at each process with the least detriment to the fiber and with a maximum of production. Before this can be decided, however, the number of doublings to be made at each process must be known. It is usually understood that at the drawing frames in a mill spinning yarns of medium counts there are 6 doublings at each process, with the draft approximately the same. It is also a general custom to have no doubling at the slubbing frames but to have 2 ends up at the intermediate frames, 2 ends at the roving frames, and generally 2 ends at the spinning frames; that is, yarns of these counts are usually spun from double roving. There is, of course, no doubling in a card, and the card draft is generally about 100.

A 13-oz. lap is .00146 hank, and weighs 5,687½ gr. to the yard. This, when operated on by a 100 draft at the card, gives a 56.87-gr. sliver, but as there is at least 3% of waste at the card, the actual weight of the sliver delivered will not exceed 55 gr. This sliver, after passing through the drawing frames with a doubling of 6 at each delivery and the customary draft of 6, will still remain a 55-gr. sliver, or .151-hank, since if the doublings equal the draft the weight of the sliver will remain unchanged.

At the slubber there is only 1 end up, but at the intermediate frame there are 2 doublings, also 2 at the roving frame and 2 at the spinning frame. An arrangement of drafts for the four processes following the third drawing process must therefore be found that will reduce the .151-hank sliver delivered by the third drawing frame to a 36s yarn with the above doublings. A somewhat elastic rule used by mill engineers is to have the drafts in the processes between the third drawing frame and the spinning frame about 4, 5, 6, and 12, respectively, increasing or decreasing each factor slightly, as may be necessary, to obtain the exact total draft required to produce yarn of the required counts. Arranging a series of drafts in accordance with this rule, drafts of 4.5 in the slubber, 5.5 in the intermediate frame, 6.5 in the roving frame, and 12 in the spinning frame may be selected as practical drafts, which, as shown by the following explanation, will give the desired attenuation of the roving necessary to produce a 36s yarn from the spinning frame.

Adopting these drafts and ignoring the question of waste at each process, as the amount of waste is slight, the hank of the slubbing will be .68, which is determined by multiplying .151 by 4.5 (the draft), which equals .679, or practically .68. The intermediate frame will deliver a 1.87 hank roving, which is determined by multiplying .68-hank slubbing by 5.5 and dividing the result thus obtained by 2 (the number of doublings). The hank of the roving from which the yarn is spun will be 6, determined by multiplying 1.87-hank roving from the intermediate frame by 6.5 and dividing the result thus obtained by 2, which equals 6.077-, or in round numbers 6-hank. The counts of the yarn will be 36s, determined by multiplying 6-hank roving by 12 and dividing the result thus obtained by 2.

The above arrangement provides for the production of the filling yarn, but the warp yarn, which is to be 28s counts, can be made from the same hank roving as the filling yarn by reducing the draft in the spinning frame; although a more satisfactory yarn could be made from slightly coarser roving, for convenience in the mill the same hank roving is often used. In this case the draft at the warp spinning frames will be 9.3, determined by multiplying the number of the yarn by the number of doublings and dividing by the hank roving, as follows: $\frac{28 \times 2}{6} = 9.3$, draft.

Summary.—The complete organization is shown in the following summary: Finisher picker, 13-oz. lap, .00146 hank; cards, draft 100, 3% loss in waste, 55-gr. sliver, or .151 hank; first drawing frame, draft 6, doublings 6, hank .151; second drawing frame, draft 6, doublings 6, hank .151; third drawing frame, draft 6, doublings 6, hank .151; slubbers, draft 4.5, no doublings, hank .68; intermediate fly frames, draft 5.5, doublings 2, hank 1.87; roving frames, draft 6.5, doublings 2, hank 6.07; warp spinning frames, draft 9.3, doublings 2, counts 28s; filling spinning frames, draft 12, doublings 2, counts 36s.

Machinery Equipment.—In order to determine the number of preparatory machines necessary, the number of spindles to be supplied must be known, in this case 10,000. The production of a warp spinning frame on 28s yarn is slightly in excess of that of a filling frame on 36s, but as the goods to be produced contain a slightly greater weight of warp than of filling yarn, it will be assumed that 5,000 spindles are to be operated on warp yarn and 5,000 on filling yarn.

The table on page 189 gives the production of warp spinning frames per spindle per day, making suitable allowances for all stoppages for doffing, oiling, cleaning, etc.; the table on page 190 gives the production of filling spinning frames. Referring to these tables, the production of a warp spinning frame on 28s yarn is .244 lb. per spindle per day, which equals 1,220 lb. per day for 5,000 spindles. The production of a filling spinning frame on 36s yarn is given as .194 lb. per spindle per day, which equals 970 lb. per day for 5,000 spindles, making a total production of warp and filling yarn of 2,190 lb. per day. Considering a week to consist of 6 full days, for convenience in calculation, this will give a total weekly production of 13,140 lb. of yarn. Allowing for 5% of waste in the various machines between the finisher picker and the spinning frames gives a total of 13,831 lb. (13,140÷.95=13,831.578) of cotton that must be passed through the finisher picker per week, and allowing 5% more for waste in the picking processes will necessitate 14,559 lb. (13,381÷.95=14,558.947) being passed through the breaker picker per week.

Considering first the number of machines necessary in the preparatory processes, a bale breaker will handle 15,000 lb. of cotton per day of 10 hr., or 90,000 lb. per wk.; therefore, one bale breaker will be more than sufficient for a mill of this size. An automatic feeder and opener will handle 3,000 lb. per day of 10 hr., or 18,000 lb. per wk.; consequently, only one machine is necessary, since the mill is to consume only 14,559 lb. of cotton per wk. A breaker picker will handle 500 lb. per hr., which, allowing for the time consumed in cleaning, etc., will give a total production of about 25,000 lb. per wk., an amount more than sufficient to meet the needs of a 10,000-spindle mill; hence, one breaker picker is sufficient. Intermediate and finisher pickers produce about 12,500 lb. per wk., allowing from 6 to 10 hr. for cleaning. In this case about 14,500 lb. must be treated each week in the picker room and therefore one intermediate and one finisher picker will be barely sufficient while two would be excessive; however, by reducing the time for cleaning to a minimum, one intermediate picker and one finisher picker will produce good work in sufficient quantity.

The number of cards required to deal with 13,831 lb. of cotton per week must next be determined, and in this considerable latitude is left to the mill engineer. It is assumed that the revolving flat cards will be used, the production of which varies in different mills, from 300 lb. for very fine yarns to 1,000 lb. per card per wk. for coarse yarns. In this case, 28s and 36s yarns are to be spun, and as 800 to 850 lb. per week is an appropriate production for such yarns, 17 cards will be required to card 13,831 lb. of cotton per week.

Dealing next with the drawing frames, the front roll of the machine is usually $1\frac{3}{8}$ in. in diameter and makes about 360 rev. per min. The speed of delivery of the machine, therefore, is 43.197 yd. per min., which is calculated as follows:

$$\frac{360 \times 1.375 \times 3.1416}{36} = 43.197$$

This result multiplied by the weight of the card sliver per yard, 55 gr., and by 3,600, the number of minutes per week, gives 8,553,006 gr. as the total number produced by one delivery in a week. This divided by 7,000, the number of grains in 1 lb., gives nearly 1,222 lb., which divided into 13,831, the number of pounds of cotton to be handled in a week, gives eleven deliveries as the number required. As drawing frames are usually built in sections of five or six deliveries, one first, second, and third drawing frame, each containing two heads of six deliveries each, will answer the requirements and also make an allowance for stoppages.

The next machine through which the cotton passes in the proper sequence of operations is the slubber. The hank of the slubbing, or roving from the slubber, as figured in the organization of the mill, is .68, and it will be assumed in this case that the production is at the rate of 15.86 lb. per da., or 95.16 lb. per wk., per spindle. This, divided into 13,831 lb., gives 145 slubber spindles as the number necessary. Slubber frames are built in various lengths, usually in multiples of 4, the shortest having 40 spindles and the longest 80; so in this case it would be best to have two slubbers, each with 72 spindles.

As 1.87-hank roving is to be produced, it will be assumed that the production of the intermediate frames will be 5.31 lb. per da. per spindle, or 31.86 lb. per wk. This amount divided into 13,831 lb. gives 434 spindles, and as these intermediate frames are built in multiples of 6, five frames of 90 spindles each will be required.

Relative to the roving frames it will be considered that the production for a 6-hank roving is shown as 1.23 lb., per da., or 7.38 lb. per wk., which when divided into 13,831 gives 1,874 spindles. Fourteen frames of 136 spindles each would be most suitable.

Considering next the number of spinning frames, the number of spindles has already been decided on as 10,000. Spinning frames are usually built in sections of 8 spindles, and a frame of about 208 spindles and of the regular gauge is usually preferred. Therefore, in this case 48 frames, each with 208 spindles, would be used, giving a total of 9,984 spindles in the mill.

After the spinning, the filling yarn is ready for the loom; but the warp yarn must pass through several processes before it is ready for weaving. The first machine is the *spooler*. Considering the spindle speed of this machine as 825 rev. per min., 20 lb. per spindle per wk. may be taken as an average production. The production of warp yarn was previously calculated as 1,220 lb. per day, or 7,320 lb. per week; therefore, dividing 20 into 7,320 gives 366 spooler spindles necessary. Spoolers are built in various lengths, for instance, 80, 100, and 120 spindles. In this case four spoolers of 100 spindles each will be necessary.

The production of warpers is given in the table on page 219, and for 28s yarn with 440 ends on a beam is 2,425 lb. per wk. Dividing this into 7,320, the number of pounds of warp yarn produced per wk. gives three warpers to be installed.

A slasher will prepare the warps for about 500 looms weaving cloth similar to that decided on as the product of this mill. In a mill of this size, since it is very improbable that more than 500 looms will be operated one slasher may be assumed to be all that is necessary.

Dealing now with the weaving, it is first necessary to find the production per week of a loom weaving goods having 80 picks per in. In this case it is assumed that the looms will run 185 picks per min.; therefore, the production of a loom per week will be 208.125 yd., as shown by the following calculation: $\frac{185 \times 3{,}600}{80 \times 36} = 231.25$. 10% of 231.25 is equal to 23.125; therefore, 231,25 − 23.125 = 208.125 yd.

MACHINES AND FLOOR SPACE FOR A 10,000-SPINDLE MILL

Number of Machines	Floor Space
1 bale breaker	9′ 9″×7′
1 automatic feeder and opener	10′ 6″×6′ 6″
1 breaker picker	17′ 7″×6′ 6″
1 intermediate picker	16′×6′ 8″
1 finisher picker	16′×6′ 8″
17 cards	9′ 10″×5′ 2″ each
1 first drawing frame, two heads of six deliveries	10′ 10″×3′ 4″ per head
1 second drawing frame, two heads of six deliveries	10′ 10″×3′ 4″ per head
1 third drawing frame, two heads of six deliveries	10′ 10″×3′ 4″ per head
2 slubbers, 72 spindles	31′ 8″×3′ 2″ each
5 intermediates, 90 spindles	29′ 5″×3′ 1″ each
14 roving frames, 136 spindles	32′ 11″×2′ 11″ each
48 spinning frames, 208 spindles	25′ 11″×3′ 3″ each
4 spoolers, 100 spindles	21′ 3″×4′ each
3 warpers	18′×8′ each
1 slasher	38′×8′
266 looms	16′×11′ 10″ for 4 looms
1 sewing and rolling machine	4′×2′ 9″
1 brusher	10′×4′
1 folder	10′×4′
1 baling press	4′ 9″×3′

The production of warp yarn per day is 1,220 lb., or 7,320 lb. per wk., to which must be added 10% to allow for the increased weight occasioned by the size, making 8,052 lb. of warp yarn to be woven per week.

The production of filling yarn is 970 lb. per day, or 5,820 lb. per wk., which, added to the weight of the warp yarn, gives a total production for the weave room of 13,872 lb. per wk. The weight of the cloth is 4 yd. per lb.; therefore, the yards of cloth to be woven per week will be $4 \times 13,872 = 55,488$ yd. Dividing this total yardage by the production of one loom (208.125 yd.) gives practically 266 looms as the number necessary for the weave room.

In the cloth room, a mill of this size would require one sewing and rolling machine, one cloth brusher, one folding machine, and one baling press.

The foregoing description shows how the equipment of machinery is determined so that the production from the machines at each process will almost exactly balance the amount of material supplied to them from the preceding process or taken from them by a later process; therefore, so long as the mill is maintained on the class of goods for which it was originally intended, there will be no idle machinery, neither will there be an oversupply of material, and thus the whole plant will be kept in constant operation with the largest possible output at the least possible expense.

The accompanying table gives the complete list of machines for a 10,000-spindle mill on 4-yd. goods made from 28s warp and 36s filling, together with the floor space occupied by each machine, from which can be determined the total floor space and size of the mill that would have to be erected to accommodate this machinery.

COTTON DESIGNING

ELEMENTS OF TEXTILE DESIGN

The Weave.—All woven fabrics are constructed of two series of yarns; namely, the *warp*, which is the system of parallel threads running lengthwise of the goods, and the *filling*, which is the system of parallel threads running across the cloth at right angles to the warp. By the weaving process the picks of the filling are interlaced with the ends of the warp so as to produce a woven fabric of a texture depending, to a great extent, on the method of interlacing.

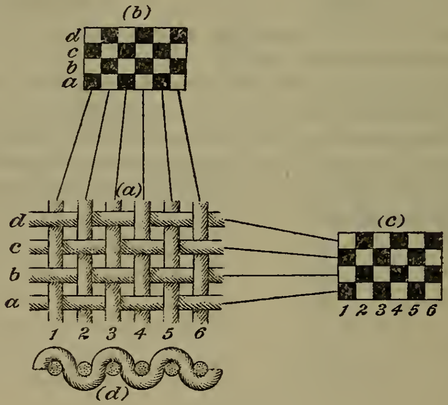


FIG. 1

Plain Weave.—The simplest method of interlacing the warp and filling is by that system known as *plain weave*. Fig. 1 (*a*) is a diagrammatic view of a plain woven fabric in which one pick of filling is over all the odd-numbered ends of the warp and under all the even-numbered ends, while the next pick of filling interlaces with the warp ends in reverse order.

Representation of Weave.—Fig. 1 also illustrates the method of representing a weave on design paper; (*a*) shows the way the ends and picks of the cloth are interlaced, and (*b*) shows the weave. Each vertical row of squares represents a warp end, and each horizontal row represents a pick of filling. The lines drawn from (*a*) to (*b*) show which warp end each vertical row of squares represents; the ends are numbered 1, 2, 3, 4, 5, and 6, at the bottom.

By following the ends from (*a*) to (*b*), it will be seen that when they are up, as shown in (*a*), the corresponding squares in (*b*) are filled in, and on the other hand when the ends are down, the corresponding squares in (*b*) are left blank. When the ends have been shown on design paper, the picks also have been shown, and consequently (*b*) shows where the filling is up and where down in the same manner as it shows where the warp is up and where down. That this is so may be seen by referring to (*c*), which is exactly the same as (*b*) except that in this case the lines are drawn from the picks in (*a*) to the rows of squares in (*c*) that represent the respective picks. If the picks are followed from (*a*) to (*c*) in the same manner as the ends were followed from (*a*) to (*b*), it will be seen that (*c*) shows the interlacings of the picks. (*d*) is a method of showing the interlacing of one pick of filling with the warp and represents the manner in which either of the picks *b* and *d* interlaces with the warp ends, the curved line showing the pick of filling and the circles, sections of the warp ends.

Repeat of Weave.—Every weave is complete on a certain number of ends and the same, or a different, number of picks that have definite interlacings and that are arranged in a fixed order of sequence. The method of interweaving and the order of arrangement of all other ends and picks in the fabric are but repetitions; hence, these ends and picks constitute one repeat of the weave. Thus, it will be noted in Fig. 1 that the plain weave repeats on two ends and two picks.

Drawing-in Draft.—Every end in the warp that interlaces with the filling differently from the others must be drawn through a separate harness in the loom, but every end in the warp that works in a manner similar to some other end may be drawn through the same harness as that other end, provided that it is drawn in its regular order. Thus in the case of the plain weave, if every even-numbered end is drawn through one harness and every odd-numbered end is drawn through another harness and these two harnesses are made to rise and fall alternately, or first one and then the other is lifted, and a pick of filling passed through each opening, cloth similar to that shown in Fig. 1 (*a*) will be formed.

The method, or order, of drawing each end of a weave through the loom harnesses is usually indicated on design paper by means of a draft, called the *harness draft*, or *drawing-in draft*. This is best indicated with figures, but may be shown by means of crosses, dots, etc. In Fig. 2, (*a*) shows the plain weave extended on 8 ends, and (*b*) shows the harness draft. The first end is drawn through the first harness, as shown in the harness draft (*b*), and the second end, as it interlaces with the filling differently from the first, must be drawn through a separate harness, or the second, as shown; the third end in the weave works like the first and therefore can be drawn through the same harness as the first end; the fourth end works like the second and is consequently drawn through the same harness as the second. The harness draft, therefore, is simply a draft showing the person who draws in the warp ends through which harness each end of the warp is to be drawn, being so constructed that ends having the same interlacings are drawn on the same harness. Harness drafts are generally constructed for only one repeat of the weave, since all other ends are drawn in similarly to the ends in that repeat. Consequently, in making out the harness draft for the plain weave only the first two ends need be shown, since the first two ends in the harness draft, Fig. 2 (*b*), show the manner of drawing in all the ends of the warp.

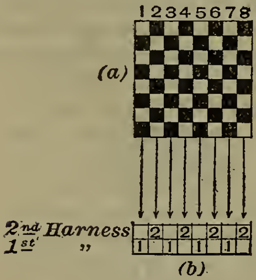
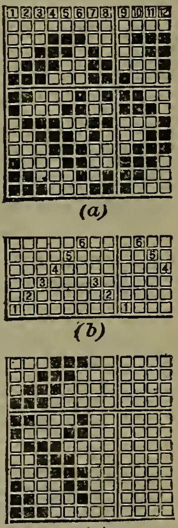


Fig. 2

Chain Drafts.—After the harness draft has been made to show the method of drawing in the warp ends, a plan must be made to show how, or in what order, the harnesses must be lifted so that the ends drawn through them will interlace with the filling according to the desired weave, or in other words a plan showing which harnesses are to be raised and which lowered on each pick. This plan is known as the *chain draft* or *pegging plan*. The chain draft is indicated on design paper, each filled-in square indicating that a harness is raised, and each blank square showing that a harness is lowered. To make a chain draft from the weave and harness draft, commenc with the first end and copy the interlacings of each end in one repeat of the weave that is drawn in through a separate harness as indicated by the harness draft, placing these interlacings of the ends in the same relative position that the harnesses through which they are drawn occupy in the harness draft.



(a) (b) (c)

FIG. 4

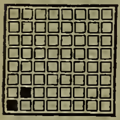


FIG. 3

Fig. 3 is one repeat of the weave shown by the diagram Fig. 1 (*a*), and since the first end is drawn through the first harness, as shown in Fig. 2 (*b*), the interlacings of the first end must be copied to show the manner in which this harness should be raised and lowered. The second end is drawn through the second harness; therefore, to show the workings of this harness the interlacings of this end must be copied. When this has been done it will be noticed that the chain draft is similar to the weave shown in Fig. 3; therefore, this figure can be used to indicatc the chain draft as well as to show the weave.

To illustrate further the method of obtaining the chain draft from the weave and harness draft, refer to Fig. 4, in which (*a*) represents one repeat of a weave; (*b*) shows the harness, or drawing-in draft; and (*c*) shows the chain draft. In (*a*), each vertical row of squares represents one end; each row of squares across the design paper, one pick; and each filled square, an end raised over a pick. In (*b*), each vertical row of squares represents one end, the same as in (*a*), but each row of squares across the design paper represents one harness, and each number the harness through which that particular end is drawn. In (*c*), each vertical row of squares represents the working of one harness, or, in other words, the order of raising and lowering the harness, while each row across the design paper represents one pick, or one bar of the chain that is placed on the loom to govern the operation of the harnesses.

To make a chain draft from a weave it is simply necessary to copy the interlacings of those ends that are drawn on separate harnesses. Therefore, in order to ascertain the number of ends that any chain draft will require it is only necessary to find the number of harnesses that the drawing-in draft occupies. In Fig. 4 (*b*), 6 harnesses are used, and thus only six vertical rows of squares, representing the 6 ends of the weave that have different interlacings, will be required for the chain draft. In copying the interlacings of those ends that are drawn on separate harnesses, since the first end is drawn through the first harness, the first harness shown in (*c*) is marked the same as the first end shown in (*a*). The second end is drawn through the second harness, and consequently the second harness shown in (*c*) is marked the same as the second end shown in (*a*). This method is continued with the first 6 ends, all of which are drawn through separate harnesses. The seventh end of the weave is drawn through the third harness, but since the working of this harness has already been set down, it must not be marked again. The same can be said of the rest of the ends, all of which work in a manner similar to some one of the first 6 ends. Therefore, the chain draft is complete as shown in (*c*).

Standard Types of Drawing-in Drafts.—The simplest method of drawing the warp ends through the harnesses is that known as the *straight draft*, which may be defined as a draft in which the ends are drawn through the harnesses in regular order from front to back. To illustrate this, suppose that a weave occupied 10 harnesses and that the ends were drawn straight from the front harness to the back harness. Then the first end would be drawn through the first harness, the second end through the second harness, the third end through the third harness, and so on, ending with the tenth end, which would be drawn through the tenth harness. The draft would then commence another repeat with the first harness again, and the next, or eleventh, end would be drawn through that harness, the twelfth end would be drawn through the second harness, and so on.

Another method of drawing in warps is known as the *center*, or *point, draft*. In *regular point drafts*, the ends are drawn from the front to the back harness and then the next end, instead of being drawn on the front harness as in the straight draft, is drawn through the next to the back harness and the

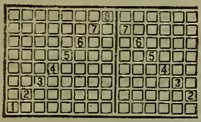


FIG. 5

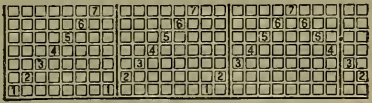


FIG. 6

ends then drawn in regularly from back to front. Fig. 5 is an illustration of a regular point draft on 8 harnesses.

Another type of point draft, illustrated in Fig. 6, is known as the *irregular point draft*. In these drafts the ends are drawn through the harnesses straight for a certain number of times and then reversed as in a regular point draft.

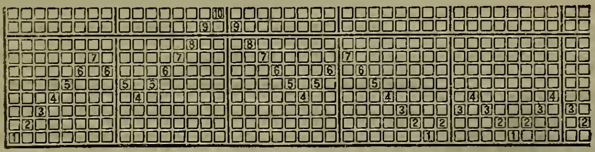


FIG. 7

Still another type of irregular point draft is illustrated in Fig. 7. The method adopted in this case is that of drawing the ends straight for a certain number of harnesses and then reversing, but only running the ends for a few harnesses, when they are again run straight and again reversed, etc.

In the method of drawing in the warp ends known as the *angled draft* they are drawn straight for a certain number of harnesses and then reversed, but instead of the reversing starting with the next to the back harness as in the point draft, it is started on an intermediate harness, generally half way between the first and last harnesses, but depending somewhat on the chain draft that is to be used. Fig. 8 shows an angled draft on 8 harnesses arranged in this manner.

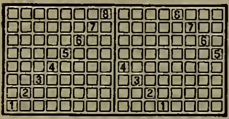


FIG. 8

The skip draft may be considered as a straight draft drawn in sections with one or more harnesses skipped between the sections. Fig. 9 shows a skip draft on 4 harnesses in which the first section of 4 ends is drawn in straight; then 1 harness is skipped and the next section of 4 ends drawn straight, then another harness skipped and the next section drawn in straight, and so on. In Fig. 10, a skip draft on 6 harnesses is shown in which 2 harnesses are skipped between the sections.

FIG. 9

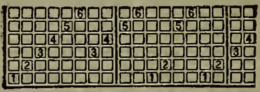


FIG. 10

FIG. 11

Satin drafts are really adaptations of the skip-draft principle in which harnesses are skipped between the ends instead of between sections of ends. Thus in the 5-harness satin draft shown in Fig. 11, the first end is drawn in on the first harness; the second end is drawn in on the third harness, skipping the second harness; the third end is drawn in on the fifth harness, skipping the fourth harness; the fourth end is drawn in on the second harness, skipping the first harness; and the fifth is drawn in on the fourth harness, skipping the third harness. In this satin draft only 1 harness is skipped between the ends, but often more than one harness is skipped. For instance, in the 8-end satin draft shown in Fig. 12, 2 harnesses are skipped between the ends.

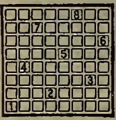


FIG. 12

A section draft may consist of any one or more of the foregoing styles of drafts arranged so as to be repeated in sections throughout the width of the cloth. Thus, Fig. 13 shows a section draft on 12 harnesses, and as indicated by the brackets the method of drawing in the first section of 4 ends is to be repeated three times, and the method of drawing in the second and third sections of 4 ends is to be repeated the same number of times. Thus, it will be seen that this is really a short method of indicating a comparatively large draft, since if this draft were extended fully as indicated, it would occupy 36 ends, as shown in Fig. 14. This section draft is simply an amalgamation of straight drafts in sections, but it is not necessary to use straight drafts, since angled, skip, or satin drafts may be extended in sections in the same manner.

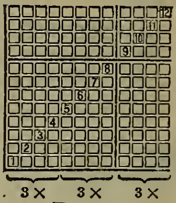


FIG. 13

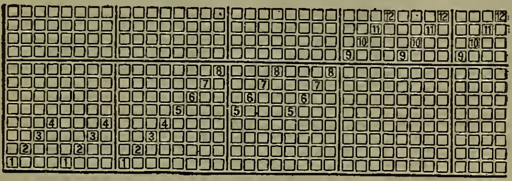


FIG. 14

TWILLED WEAVES

In the plain weave, each end is alternately raised and lowered, but in a twill the warp ends are so raised that the warp and filling floats form diagonal lines across the cloth, known as *twill lines*. In a twill each warp end must be either over or under the filling for at least 2 picks in succession and at least 2 successive warp ends must be raised or lowered on each pick, in order to make the twill line across the cloth. On this account at least 3 harnesses are necessary to weave a twill, or in other words three is the smallest number of harnesses on which a twill effect can be formed in the cloth. Thus, the *3-harness*, or *prunelle, twill*, as it is called, is the simplest twill that can be made.

A weave may be *warp flush*, *filling flush*, or *equally flush*, depending on whether a preponderance of warp or filling or an equal amount of each is brought to the face of the cloth; thus, Fig. 1 (*a*) is a warp-flush prunelle twill, twilled to the right, and Fig. 1 (*b*) is the same weave twilled to the left. Fig. 1 (*c*) shows a filling-flush prunelle twilled to the right, and Fig. 1 (*d*) shows a filling-flush prunelle twilled to the left. A cloth woven with a warp-flush weave shows a filling-flush weave on the back, and if woven with a filling-flush weave shows a warp-flush weave on the back.

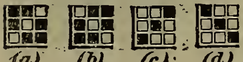


FIG. 1

Regular twills are those that run in regular order; it is, therefore, simply necessary to know the interlacing of any one end or pick, say the first, of a regular twill in order to show the entire weave on design paper.

The interlacings of the first end or pick of any regular twill are conveniently shown by writing numbers above and below a horizontal line. Fig. 2 shows one repeat of the $\frac{2}{3}\frac{1}{2}$ regular twill. A rule for making any regular twill when the interlacings of the first pick are given is as follows:

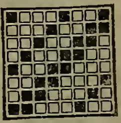


FIG. 2

Rule.—*Mark on the first pick of the weave the ends that are to be lifted on that pick; then above on the second pick place similar marks, moving them one square to the right if the twill is to run to the right, or one square to the left if the twill is to run to the left. Proceed with each pick in the same way, moving one to the right or left, as the case may be, until there are as many picks as ends.*

Angle of Twills.—The angle of the twill is affected: (1) by the manner in which the ends and picks interlace; (2) by the relative number of ends and picks per inch.

Fig. 3 illustrates the method of running up twill lines on design paper so as to form different angles.

A regular 45° twill weave forms a 45° twill in the fabric only when the cloth contains an equal number of ends and picks per inch. Increasing the picks per inch or decreasing the ends per inch decreases the angle of the twill; decreasing the picks or increasing the ends increases the angle.

Weaves in which the angle of the twill is greater than 45 degrees are called *upright twills,* and those in which

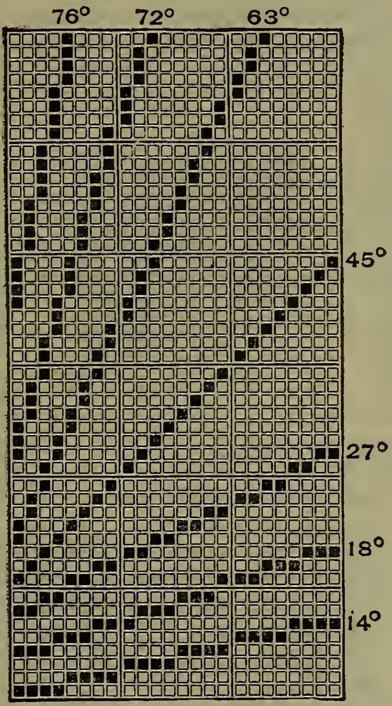


Fig. 3

the angle of the twill is less than 45 degrees are designated as *oblique,* or *reclining, twills.* Upright twills and fancy diagonal weaves, forming twill lines with angles greater than 45 degrees are used in many types of fabrics. Oblique, or reclining, twills are not so frequently employed, but are used in special cases.

To find the twill angle that will be formed in a fabric, the following method may be applied:

Let E = ends in one repeat of weave;
P = picks in one repeat of weave;
e = ends per inch in cloth;
p = picks per inch in cloth;
tan = tangent of angle of twill in fabric;
cot = cotangent of angle of twill in fabric.

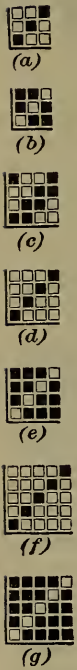


Fig. 4

Then, $$tan = \frac{Pe}{Ep}$$

And $$cot = \frac{Ep}{Pe}$$

Example.—A diagonal, or twill, weave that repeats on 48 ends and 60 picks is to be used in a fabric that will be woven with 72 ends and 54 picks per inch. What will be the angle of the twill in the cloth?

Solution.— $$tan = \frac{60 \times 72}{48 \times 54} = 1.6666$$

And $$cot = \frac{48 \times 54}{60 \times 72} = .60000$$

Reference to a table of natural tangents and cotangents indicates that 1.6666 is the tangent and .60000 the cotangent of an angle of 59° 2′ which, therefore, is the angle of the twill in the fabric mentioned in the question.

Shrinkage or stretch in the length, or in the direction of the warp, or contraction in the width in the direction of the filling, in any finishing process, will affect the twill angle of a fabric in exact accordance with the resulting change in the number of ends or picks per inch.

Standard Twills.—Several twills that are constantly used in the construction of the more common fabrics are known by definite names. Among them are the *filling-flush prunelle*, Fig. 4 (*a*); the *warp-flush prunelle*, Fig. 4 (*b*); the *cassimere*, Fig. 4 (*c*); the *filling-flush crow*, Fig. 4 (*d*); the *warp-flush crow*, Fig. 4 (*e*); the *filling-flush Albert twill*, Fig. 4 (*f*); the *warp-flush Albert twill*, Fig. 4 (*g*); the *filling-flush broken crow*,

Fig. 5 (*a*); the *warp-flush broken crow*, Fig. 5 (*b*); the *Venetian twill*, Fig. 5 (*c*); and the *Mayo*, or *Campbell, twill*, Fig. 5 (*d*). The weaves shown in Fig. 5 are not regular twill weaves.

Fancy Twills.—In addition to the regular 45° twills there are many other twill weaves that are known as *fancy twills*. These weaves generally consist of a regular twill weave between the twill lines of which are placed sometimes

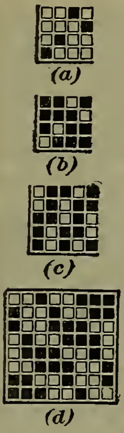


FIG. 5

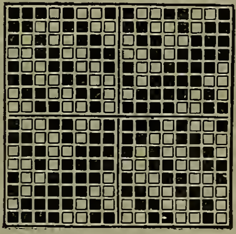


FIG. 6

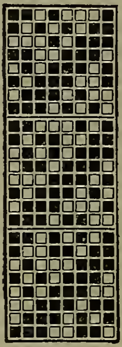


FIG. 7

other twills running in the opposite direction, sometimes small spots, and sometimes other small weaves. Figs. 6 and 7 are twill weaves of this type.

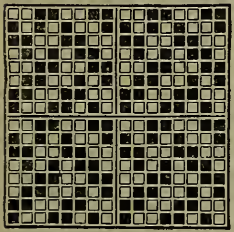


FIG. 8

Entwining Twills.—Twills of the entwining type are constructed from regular twills by running sections of twill lines both to the right and to the left so that each section meets other sections at right angles. As the name indicates, the effects produced by these twills have an entwined or interlaced appearance; the more perfect ones are obtained when the separate sections are composed of equally flushed twills, although in some cases unequally flushed twills give good results. Fig. 8 shows an entwining twill constructed by running two twill lines of the cassimere to the right and two to the left, the weave repeating on 8 ends and 8 picks.

Fancy entwining-twill effects are obtained by omitting one or more twill lines from each section and continuing the remaining twill lines of each section until they meet those of the other section. By this means two blank spaces are made in the weave, in which other weaves may be inserted. A weave of this character is shown in Fig. 9.

Curved Twills.—Curved twills are those in which the twill lines have a wavy, or curved, nature instead of being perfectly straight as in an ordinary twill weave. Fig. 10 (*a*) shows several repeats of a curved twill constructed with the chain draft shown in Fig. 10 (*b*) and the drawing-in draft Fig. 10 (*c*). The first end of the effect in Fig. 10 (*a*) is like the first end of Fig. 10 (*b*); the second end is like the fourth end; the third, like the seventh; the fourth, like the tenth; and so on, each end of Fig. 10 (*b*) being taken in the order indicated by the drawing-in shaft in Fig. 10 (*c*).

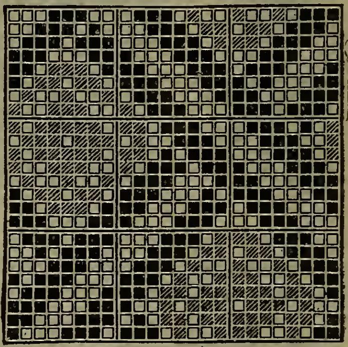
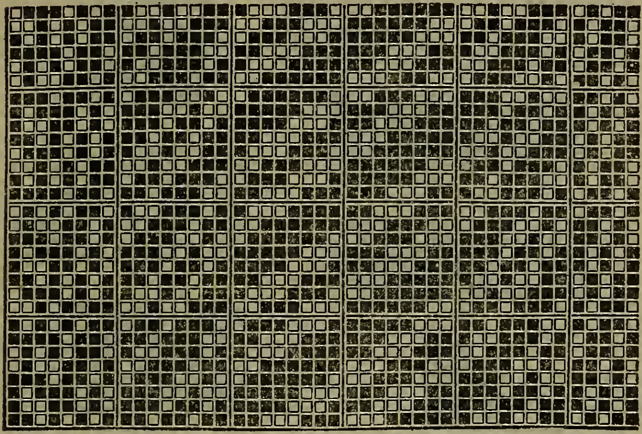


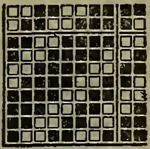
Fig. 9

Skip Twills.—Skip twills are a type of broken twill effects formed by a skip drawing-in draft and a regular twill weave as a chain draft. The draft is so constructed that when the harnesses are skipped, the end in the harness just before the skip will rise and fall exactly opposite to the next end; by this means a broken effect is formed in the cloth. In Fig. 11 (*a*) is shown a skip twill that is made with the 6-end regular twill $\frac{3}{3}$, Fig. 11 (*c*), as a chain draft and the skip drawing-in draft shown in Fig. 11 (*b*).

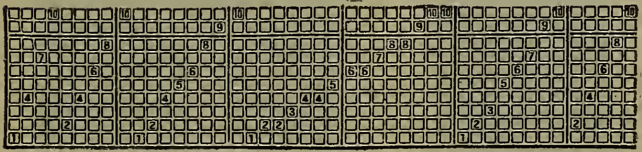
Pointed Twills.—Another class of twill weaves obtained by means of the harness draft includes those weaves obtained by point drafts, which form wave effects across the cloth. These effects are also frequently spoken of as *herring bones*, or *herring-bone stripes*, because the radiating twill lines suggest the radiating bones of a fish's backbone. To make a pointed, or wave, effect with the 45° twill shown in Fig. 12 (*a*) as the chain



(*a*)



(*b*)

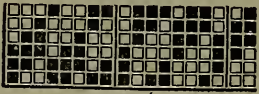


(*c*)

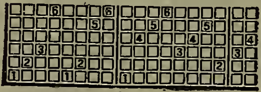
FIG. 10

draft; Fig. 12 (*b*) shows the harness draft that will be used, and Fig. 12 (*c*) shows the effect obtained in the cloth. The same effects may be made to extend lengthwise of the cloth by simply reversing the chain draft in the same manner that the harness draft was reversed when making waves across the cloth. This is illustrated by Fig. 13.

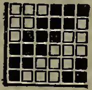
Diamond Weaves.—By reversing both the harness and chain drafts of any regular twill, another class of



(a)

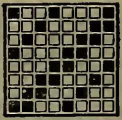


(b)

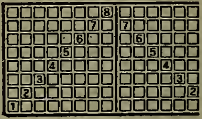


(c)

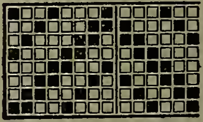
Fig. 11



(a)



(b)



(c)

Fig. 12

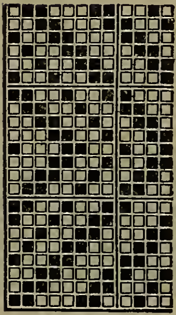


Fig. 13

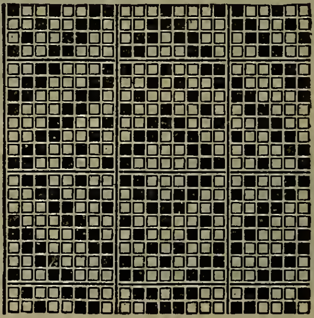


Fig. 14

weaves that is very largely used, and known as *diamond weaves* from the effects formed in the cloth will result. Fig. 14 is a typical diamond weave.

SATIN AND MISCELLANEOUS WEAVES

Satin weaves, in a certain sense, are the exact opposite of twills, since while it is the object of a twill weave to show a twill line running diagonally across the cloth, in the satin weave all twill lines are avoided as far as possible.

In a regular $^{4}_{1}$ twill weave only one interlacing is made on each pick, but the ends support each other, since on the first pick the first end is down and on each succeeding pick the next end is down, thus forming a twill line. With the 5-end warp-flush satin weave shown in Fig. 1, only 1 end is down on each pick, but the interlacing of each end is at least 1 pick apart from the interlacing of either of the 2 ends next to it. Thus on the first pick, the first end is down; on the next pick, the fourth end is down; on the third pick, the second end is down; on the fourth pick, the fifth end is down; and on the fifth pick, the third end is down; consequently, the points of interlacing do not run up in regular order, as is the case in a regular twill weave, but are scattered over the weave. By this means the interlacings of the warp and filling are almost entirely hidden, while the cloth produced is smooth and soft, this being the object of the weave.

FIG. 1

The order in which the ends are raised or lowered when forming a satin weave is generally indicated by a series of figures, in which each figure represents an end, and its position in the series indicates the pick on which it is moved. Thus, referring to the 5-end satin in Fig. 1, the ends would be said to be lowered in 1, 4, 2, 5, 3 order: 1 being the first number, shows that the first end is lowered on the first pick; 4 being the second number, shows that the fourth end is lowered on the second pick; and so on.

Satin weaves may be either *warp-flush* or *filling-flush;* the former having more warp yarn on the face, and the latter more filling on the face. Warp and filling satins, as shown on design paper, may be readily distinguished, for if there are more filled-in than blank squares, as in Fig. 1, the weave will be a *warp satin.* In case there are more blank than filled-in squares, as in Fig. 2, the

FIG. 2

weave will be a *filling satin*, since the blanks represent filling over warp.

The smallest number of ends on which a regular satin can be constructed is 5. It cannot be constructed on 6 ends, although in many cases a weave known as an *irregular satin* is made on 6 ends, the order of moving the harnesses being either 1, 3, 5, 2, 6, 4 or 1, 4, 2, 6, 3, 5. With weaves in which the ends are raised or lowered in either of these orders, no two adjacent ends are moved on successive picks; or in other words, no two ends support each other, and yet the same number of ends are not skipped between successive picks.

The following table gives the different orders of moving the ends in satin weaves complete on 12 ends or less.

5-End Satins

1, 4, 2; 5, 3
1, 3, 5, 2, 4

6-End Satins

1, 3, 5, 2, 6, 4
1, 4, 2, 6, 3, 5

7-End Satins

1, 4, 7, 3, 6, 2, 5
1, 3, 5, 7, 2, 4, 6
1, 6, 4, 2, 7, 5, 3
1, 5, 2, 6, 3, 7, 4

8-End Satins

1, 4, 7, 2, 5, 8, 3, 6
1, 6, 3, 8, 5, 2, 7, 4

9-End Satins

1, 3, 5, 7, 9, 2, 4, 6, 8
1, 8, 6, 4, 2, 9, 7, 5, 3
1, 5, 9, 4, 8, 3, 7, 2, 6
1, 6, 2, 7, 3, 8, 4, 9, 5

10-End Satins

1, 4, 7, 10, 3, 6, 9, 2, 5, 8,
1, 8, 5, 2, 9, 6, 3, 10, 7, 4

11-End Satins

1, 3, 5, 7, 9, 11, 2, 4, 6, 8, 10
1, 10, 8, 6, 4, 2, 11, 9, 7, 5, 3
1, 4, 7, 10, 2, 5, 8, 11, 3, 6, 9
1, 9, 6, 3, 11, 8, 5, 2, 10, 7, 4
1, 5, 9, 2, 6, 10, 3, 7, 11, 4, 8
1, 8, 4, 11, 7, 3, 10, 6, 2, 9, 5
1, 6, 11, 5, 10, 4, 9, 3, 8, 2, 7
1, 7, 2, 8, 3, 9, 4, 10, 5, 11, 6

12-End Satins

1, 6, 11, 4, 9, 2, 7, 12, 5, 10, 3, 8
1, 8, 3, 10, 5, 12, 7, 2, 9, 4, 11, 6

Illustrating the typical satin weaves, Fig. 3 is an 8-end filling-flush satin; Fig. 4, a 9-end warp-flush satin; and Fig. 5, a 10-end filling flush satin.

Double Satins.—Weaves known as *double satins* are sometimes constructed from regular satins. These are made by adding one mark to each mark in a regular satin; that is, in case the satin is a filling satin, each end will be raised an extra time during one repeat of the weave, and in case the satin is a

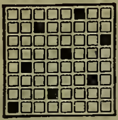


FIG. 3

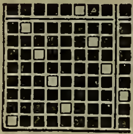


FIG. 4

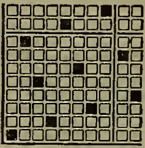


FIG. 5

warp satin, each end will be lowered an extra time during one repeat of the weave. These marks may be placed above, below, or at the side of the regular satin marks. Double satin weaves are principally used when it is desired to increase the strength of the goods and yet retain the satin face. Typical double-satin weaves are shown in Figs. 6 and 7.

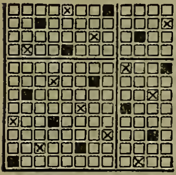


FIG. 6

Satin Derivatives.—Satin weaves provide a ready means for constructing other weaves, or *derivatives*. In almost every case satin derivatives are formed by adding one or more extra risers to the risers of a regular satin. Fig. 8 shows such a derivative, the basic satin weave being indicated by crosses and the added risers by filled squares.

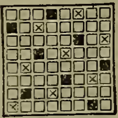


FIG. 7

Basket Weaves.—Basket weaves are used frequently in all classes of woven fabrics; their chief feature is the regular

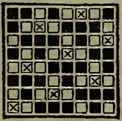


FIG. 8

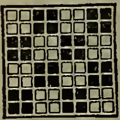


FIG. 9

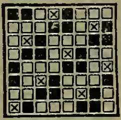


FIG. 10

occurrence of large floats of both warp and filling. The first type of basket weaves consists of those in which the squares of warp and filling are of equal size. These baskets are simply extensions of the plain weave both warp way and filling way, and it is always possible to weave them on 2 harnesses. Fig. 9 is a basket weave of this type.

A second type of basket weaves consists of *twill baskets,* which are generally constructed on a satin base and produce much neater effects than the regular basket. Fig. 10 shows a twill basket weave constructed in this manner from an 8-end satin weave. The crosses show the satin weave, and the filled-in squares show the risers that are added in order to obtain the basket weave.

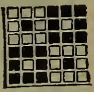


FIG. 12

FIG. 11

A third type of basket weaves consists of *irregular baskets;* in these the squares of warp and filling are not exactly equal. Thus, in Fig. 11, the filled-in squares in one part of the weave occupy 3 ends and 3 picks, and in another part they occupy but 2 ends and 2 picks.

A fourth type of baskets consists of *fancy basket weaves.* In Fig. 12, the squares of filling are broken in the center by a float of warp, and the squares of warp are broken by a float of filling. Fig. 13 shows a fancy basket weave constructed by separating warp floats of 4 ends and 4 picks each by 3 ends and 3 picks and filling in these intervening ends and picks with a suitable weave.

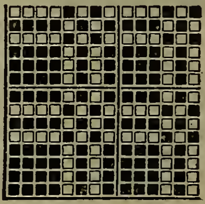


FIG. 13

Rib Weaves.—Rib, or cord, weaves are extensions of the plain weave in either the ends or picks alone and are of two classes—warp ribs and filling ribs. A *warp-rib weave* is an extension of the plain weave in its picks. In order to illustrate the construction of these weaves, Fig. 14, which shows a warp rib weave, has been divided into two sections (*a*) and (*b*). In (*a*), all the odd-numbered ends float over the filling for 4 picks, and the even-numbered ends are down. In (*b*), the reverse is the case. With this class of weaves, a distinct rib is formed across the cloth by means of the ends covering the filling.

To make a perfect fabric with a warp-rib weave there should always be more ends per inch than picks per inch in the cloth.

Filling-rib weaves are the exact opposite of warp-rib weaves. As the filling covers the ends in these weaves, ribs are formed lengthwise of the cloth, and for this reason the cloth should always contain more picks per inch than ends. Fig. 15 is an

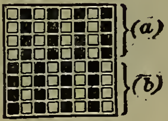


FIG. 14

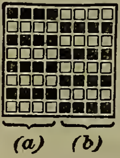


FIG. 15

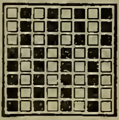


FIG. 16

illustration of a filling-rib weave. In (*a*), all the odd-numbered picks float over the 4 ends, and all the even-numbered picks are under the ends. In (*b*), the exact reverse is the case.

The ribs formed by weaves of this type are not always of equal size, for *unequal rib weaves* are frequently used. Fig. 16 is an illustration of a weave of this kind.

Corkscrew Weaves.—Corkscrew weaves may be considered a class of rib weaves; but while in rib weaves the ribs extend in a straight line either across the cloth or lengthwise of it, in corkscrew weaves the ribs form a twill line, and for this reason are sometimes known as *corkscrew twills*. Although these weaves may be formed on any number of ends or picks above 5, the best effects are obtained with weaves complete on an uneven number of ends and picks.

Fig. 17 shows a typical warp corkscrew weave; filling-corkscrew weaves may be formed in a similar manner. Another

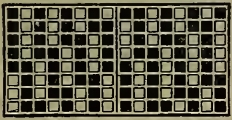


FIG. 17

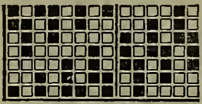


FIG. 18

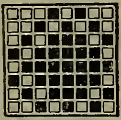


FIG. 19

class of corkscrew weaves includes those known as *warp corkscrews with filling effects*. These weaves may be constructed in such a manner as to form ribs in a twill line across the cloth and also show a distinct line of filling floats as in Fig. 18.

Honeycomb Weaves.—Honeycomb weaves are very common and are extensively used in making towels. When coarse, soft-twisted yarns are employed they make a spongy cloth well suited to this purpose. It is possible to make honeycomb weaves on any number of ends from 4 upwards, but the best effects are obtained with an even number of ends. A weave of this type is shown in Fig. 19.

COMBINATION WEAVES

In the formation of combination weaves, however widely the weaves that are to be combined may differ in respect to the effects that they produce in the cloth, they must be somewhat similar as regards the number of interlacings of the warp and filling, otherwise they cannot be made to weave together evenly. For this reason, closely-woven and loosely-woven weaves should rarely, if ever, be combined if the warp yarns are all run from the same beam, as they can be made to weave only with great difficulty.

Stripe Weaves.—*Stripes* are continuous effects running lengthwise of the cloth, or in the direction of the warp. One method of combination that is as satisfactory as any for certain classes of weaves is to combine two weaves, one of which is the reverse of the other in regard to the warp and filling flushing. These weaves can always be made to cut. By *cutting* is meant that, where the weaves join, the warp floats of one weave will oppose, or come against, the filling floats of the other, and the filling floats oppose the warp floats. Fig. 1 shows 8-end warp-flush and filling-flush satin weaves combined to form a stripe weave.

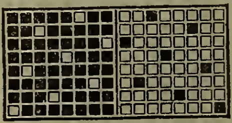


Fig. 1

Another good method of forming combination stripes with warp- and filling-flush weaves is to combine two twill weaves in one of which the warp flushes to an extent equal to the filling flushes of the other weave. Fig. 2 shows a weave of this kind.

Very frequently stripe weaves are formed by using an equally-flush twill as a chain draft and arranging the drawing-in draft so as to produce the required stripe effect. Fig. 3 (*a*) shows a stripe weave made in this manner. The stripe is obtained by

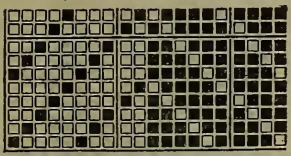


FIG. 2

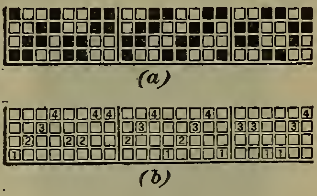


FIG. 3

using the cassimere twill as the chain draft and drawing the warp ends through the harnesses, as indicated by the drawing-in draft shown in Fig. 3 (*b*). In all places where this weave changes, the ends cut. By this means a perfect stripe is obtained.

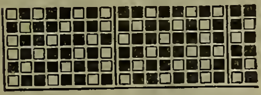


FIG. 4

Another class of stripe designs includes weaves known as *single-end stripes*. These are generally formed by opposing a warp-flush weave with a single end of a filling-flush weave, or vice versa, having the ends cut where the two weaves oppose each other; the effect of this is to form a *cut mark*, or fine indented line, which is generally arranged to run warp way of the cloth. Fig. 4 illustrates one of these weaves.

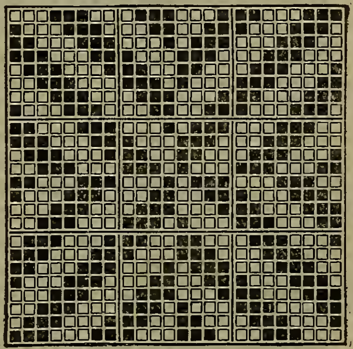


FIG. 5

Check Weaves. Check weaves may be made in a variety of ways, many of these weaves having a twill or satin base. Often the figure on one part of the check will be produced by the warp, while the figure on the other part will be made by the filling.

Fig. 5 shows a check-weave made by cutting and reversing an equally-flushed twill. In Fig. 6, a check-weave is shown that is made with warp-flush and filling-flush twills cut and

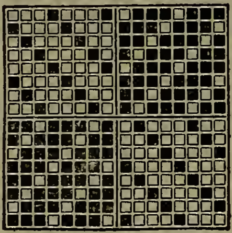


FIG. 6

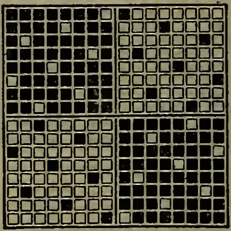


FIG. 7

reversed. Warp-flush and filling-flush satin weaves are often combined to form checks. Fig. 7 shows such a weave.

SPOT WEAVES

Weaves that produce fabrics of a spotted character, that is, cloths with spots distributed over the face, are known as *spot weaves*. These weaves are formed by bringing a certain series of yarn, either the warp or the filling, to the surface of the cloth at certain points and allowing it to float for a number of ends or picks, as the case may be, thus producing a spotted effect on the cloth. The manner in which the yarn is allowed to float on the face will determine the shape and appearance of the spot, and the places where these floats are made will determine the arrangement, or distribution, of the spots on the surface of the fabric. Spots may be made by floating either the warp or the filling on the face of the cloth; the former are known as *warp spots*, and the latter, as *filling spots*.

The first consideration when making a spot weave is the arrangement, or order of distribution, of the spots on the surface of the cloth. Spots may be arranged in plain order, satin order, broken crow order, etc.; by this is meant that the spots appear on the surface of the cloth in the same order that the ends are either raised or depressed in a plain, satin, or broken crow weave, as the case may be.

After the spots have been placed on the design paper, the blank spaces must be filled in with some simple weave, known as the *ground weave*, in order to give the fabric the required firmness of texture.

The weave shown in Fig. 1 is a warp-spot weave having the spots arranged in 5-end satin order and a plain ground weave.

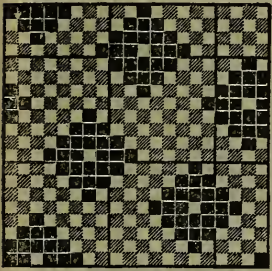


FIG. 1

In constructing filling-spot weaves, the arrangement of the spots on the surface of the cloth is determined in exactly the same manner as with warp-spot weaves; in fact, the construction of a filling-spot weave very closely resembles that of a warp-spot weave with the single exception that in the former the filling floats on the surface of the cloth to form the spots, instead of the warp, as in the latter.

Spot Effects With Extra Warp.—In many fabrics of a spotted character, the ground is woven with one warp and one filling, and the spots, which are often of a different color from the ground, are produced by the use of an extra, or figuring, warp or filling, or both. In these cloths, the ground, or body, of the fabric is produced in the ordinary manner, the extra system of yarn, either warp or filling, that produces the spot figures being allowed to float at the back of the cloth except at those places where the spots occur, where it floats on the face in such a manner as to produce a spot of the required shape and size.

Assume that it is desired to construct a spotted fabric with the spots produced by an extra system of warp yarn. Fig. 2 (*a*) shows a spot figure arranged in 5-end satin order, which, for the purpose of illustration, will be converted into an extra-warp spot design. The first step in arranging this spot for extra warp is to separate the ends of the spot design, as shown in Fig. 2 (*a*), by blank ends, as shown in Fig. 2 (*b*). The next step is to insert the ground weave, which forms the body of the

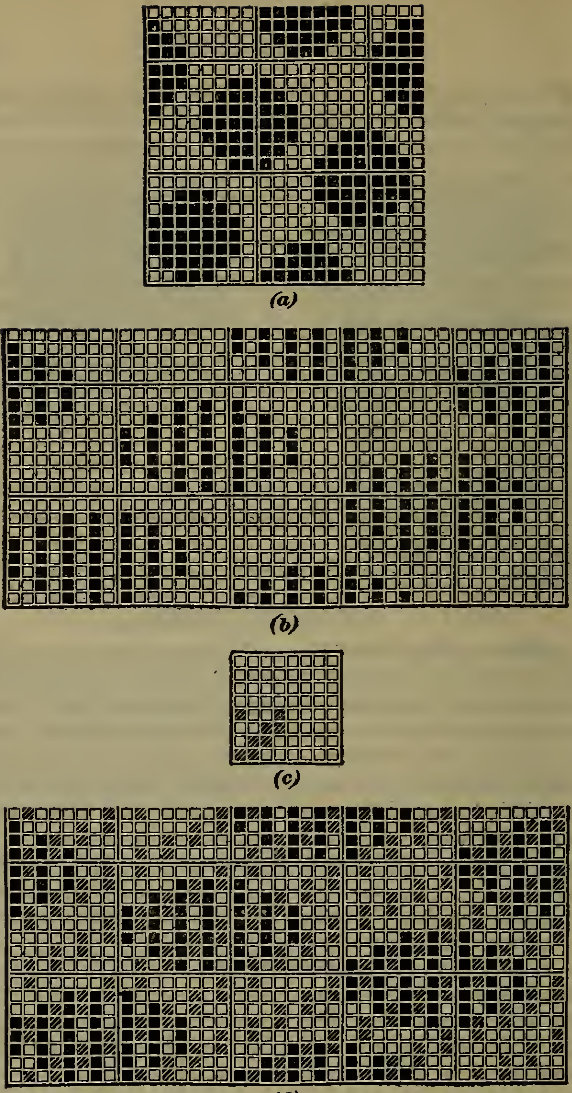
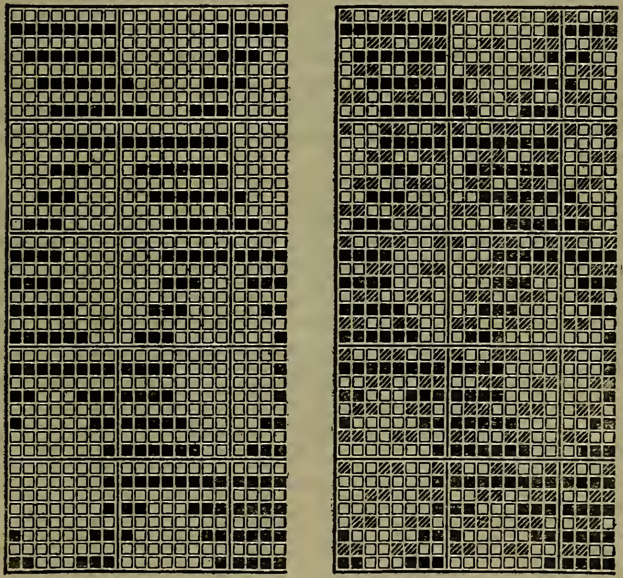


FIG. 2

cloth; in this case, the cassimere twill, Fig. 2 (*c*), will be used. The ground weave is inserted on the ends of Fig. 2 (*b*) that were left blank, or, in this case, the even-numbered ends, as shown in Fig. 2 (*d*), which is the completed design. If this weave is warped 1 end of white and 1 end of green throughout the warp, and a solid-green filling used, it will be seen that white spots arranged as in Fig. 2 (*a*) will be produced on the surface of a



(*a*) (*b*)

FIG. 3

solid-green twilled fabric. The extra, or white, warp floats on the face only to form the spot, and when not producing the spot is carried to the back of the fabric.

Harness and Chain Drafts.—In making harness, or drawing-in, and chain drafts for extra-warp fabrics, it is advisable to separate the harnesses carrying the ground ends from those carrying the extra-warp ends, since fabrics of this description require two beams, owing to the difference in take-up between the ground warp and the extra, or figuring, warp. It is customary to draw the ground ends on the front harnesses and the extra-warp ends on the back harnesses.

Spots Formed by Extra Filling.—Cloths in which the spot is formed on the surface by an extra, or figuring, series of filling yarn are constructed very similar to extra-warp fabrics, except that the spots are produced by filling yarn instead of warp yarn. The structure of the fabric may be said to be practically the same; that is, the cloth consists of a ground, or body, woven with a simple weave, and spots produced by flushes of extra filling on the face at certain points, while when the figuring filling is not to be used to form a spot, it floats on the back of the cloth.

For instance, suppose that it is desired to arrange Fig. 2 (*a*) for an extra-filling design. Separate the picks and place them on design paper, as shown in Fig. 3 (*a*); wherever it is desired to have the spot appear, the filling is allowed to flush on the face, and at every other place the entire warp is raised over the pick of filling so that the latter will float on the back of the cloth. Fig. 3 (*a*) represents the exact reverse of Fig. 2 (*a*), with the exception, of course, that Fig. 3 (*a*) is opened out, the picks being separated by blank picks. To complete the design it is now only necessary to insert the ground weave on the blank picks that are left for its reception. The completed design is shown in Fig. 3 (*b*), in which the 4-harness, or cassimere, twill has been inserted as a ground weave.

PIQUÉS AND BEDFORD CORDS

Piqués.—A piqué cloth has a separate system of filling, known as the *wadding filling*, and also has a separate system of warp ends for the purpose of holding the wadding filling and also to assist in forming ridges across the cloth.

In making a design for a piqué, the following points should be noted: (1) When placing the weave on design paper, the first step is to indicate the vertical rows of squares on which the face ends are to be placed and also the vertical rows of squares on which the backing ends are to be placed; this can be done by shading the vertical rows of squares representing the backing ends. (2) The proportion of face ends to back ends in piqués is generally 2 face and 1 back; that is, every third end on the design paper will be a backing end. (3) The picks on which the wadding filling is to be inserted should be indicated in some way. (4) The proportion of face picks to wadding picks depends to a large extent on the kind of yarn to be used for the wadding; in case it is coarser than the yarn for the face picks, the proportion is generally 2 face to 1 wadding, although different proportions are used to suit different requirements. (5) In addition to the face and wadding picks there are what are known as the *cutting picks;* these are the picks on which the backing ends are brought to the face for the purpose of pulling down the face cloth between the wadding picks, thus forming furrows across the cloth, and should be indicated on the design paper in some manner. (6) The number of picks between the cutting picks is determined by the design to be woven; however, if possible, there should be at least 2 picks of the face weave between the wadding picks and the cutting picks. (7) The face weave is placed on all the face ends, neglecting the backing ends and wadding picks entirely. The face weave of piqués is generally the plain weave. (8) All the face ends are raised on the wadding picks. (9) All the backing ends are raised on the cutting picks.

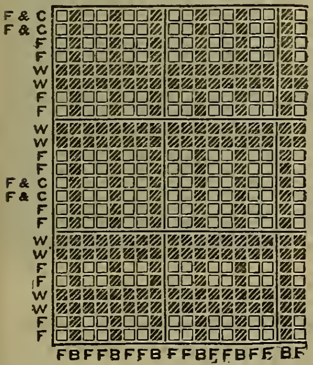


Fig. 1

Fig. 1 shows the design paper marked out for a piqué design occupying 18 ends and 24 picks. The shaded squares indicate those on which the backing warp and the wadding filling are to be placed. The ends and picks are also marked with the letters *F*, face; *B*, back; *W*, wadding; *F & C*, face and cutting. The next step is the placing of the face weave on the squares that are not marked for back ends and wadding picks. Fig. 2 shows the design with the plain weave inserted for the face. The next step is to mark the design to show all the face warp ends raised on the wadding picks, since these are inserted so as to cause the face cloth to be pushed upwards between the cutting picks. The back warp must remain under the wadding picks to bind the wadding picks to the fabric. The next step is to raise the backing ends on the cutting picks. This requires the backing ends to be raised on the eleventh and twelfth, also the twenty-third and twenty-fourth picks. The effect of this is to bind the backing ends to the fabric

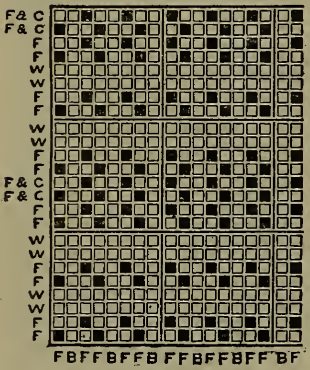


FIG. 2

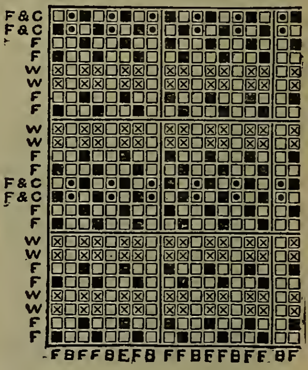


FIG. 3

and pull down the face cloth to form a hollow furrow after a certain number of wadding picks have been inserted, in this case 4 picks, and after a certain amount of face cloth has been woven, in this case 6 picks.

Fig. 3 shows the design complete. The first 2 picks are plain, the backing ends being down and consequently not showing on the face at all. On the third and fourth picks, the wadding is inserted. While this is done all the face warp is raised, as shown by the crosses, and the back warp is down; consequently, the picks of wadding will lie in between these two series of yarns and will not show on the face, but being heavier than the face yarns will tend to raise the cloth constructed by the face weave. The next 4 picks are repetitions of the first 4 picks, and then come 2 more face picks. On the eleventh and twelfth picks, in addition to the plain weave of the face cloth, the backing warp is brought to the surface, as shown by the dots. These are the cutting picks. In weaving a piqué design, the backing warp is generally placed on a separate beam that is weighted heavier than that containing the face warp, thus causing the backing warp to be under greater tension. When this backing warp is brought to the face, as it is under greater tension, it will of course tend to draw down the face yarns, thus causing a furrow between those parts of the cloth that contain the wadding picks.

The next 12 picks are but repetitions of the first 12 picks; Fig. 3 shows 6 repeats of the ends and 2 repeats of the picks, the weave being complete on 3 ends and 12 picks.

It will be understood that the wadding picks do not show on the face of the cloth at any point, but simply lie between the face and back ends. Again, the backing ends do not show on the face of the cloth at all, except where they are raised for the purpose of pulling down the face cloth. Consequently, the face of a cloth woven with a design such as the one shown in Fig. 3 would be similar to plain cloth, with the exception of the raising of the cloth in ridges through the effect of the wadding picks, and the formation of furrows by the floating of the back warp over 2 picks in certain parts of the cloth.

The position that the different ends and picks occupy when woven into cloth with this design is more clearly illustrated

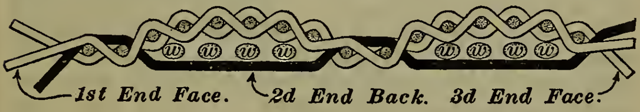


FIG. 4

in Fig. 4, where a sectional view of 3 ends and 24 picks is shown. The heavy, dark line represents the backing end, and the other two lines running in the same direction show 2 face ends. The larger cross-sections marked *w* show the wadding picks, and the smaller cross-sections show the face picks. The face picks interweaving with the face warp crowd over the wadding picks, thus hiding them. The backing end rising over the interlacings of the face filling and face warp draws them down, thus forming a furrow across the cloth.

In making the harness and chain drafts for a piqué weave, the backing and face warps are drawn through separate sets of harnesses. The backing warp is in most cases drawn through the back harnesses and the face warp through the front harnesses.

When piqué cloths are arranged 2 face to 1 back they are as a rule reeded 3 in a dent; that is, 2 face ends and 1 back end are drawn in each dent of the reed in such a manner that there will be 1 face end on each side of the back end in the dent. Piqués are high-pick cloths, the number of picks per inch being largely in excess of the number of ends per inch.

Bedford Cords.—Although Bedford cords have the same general appearance as piqués with the exception that the furrows run lengthwise of the cloth instead of across the cloth, their construction differs to a large extent. Thus, wadding ends are employed instead of wadding picks, and these wadding ends are held in the cloth by means of the same picks that form the face of the cloth instead of using backing picks. Two warp ends working plain throughout the entire length of the cloth form the furrow.

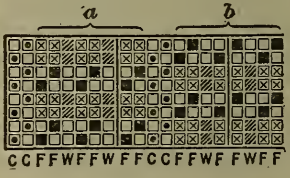


FIG. 5

Fig. 5 shows one repeat of the ends and two repeats of the picks of a Bedford-cord design; the furrows lengthwise of the cloth, which are characteristic of Bedford cords, are formed by the first and second, also, the eleventh and twelfth ends, which work plain throughout the cloth; while the weaves between them form the ridges. The parts of the design between the ends working plain are marked *a* and *b*. In section *a* the fifth and eighth ends, marked *W*, are the wadding ends. The third, fourth, sixth, seventh, ninth, and tenth ends work plain on the first and second picks and are all raised on the third and fourth picks. This being one repeat of the design in its picks, the others are only repetitions of these first 4 picks. The effect of raising the ends in this manner is to cause the second and fifth picks and also the first and sixth to come together and thus produce a plain weave on the face of the cloth. On those picks on which all these ends are raised the wadding ends are also raised. The filling floating at the back will bind the wadding ends to the face cloth, not allowing the wadding ends to show on the face and yet holding them securely in position.

Section *b* corresponds to section *a*, with the exception that the position of the picks is reversed; that is, while in section *a* the face ends are working plain on the first and second picks, in section *b* they are all raised; and while in section *a* all the face ends are raised on the third and fourth picks, in section *b* they are working plain. Thus, the same picks, that are weaving plain to form the face cloth in section *a* are floating at the back to hold the wadding ends in section *b*; and vice versa.

The first, second, eleventh, and twelfth ends, which work plain throughout the cloth, will work tighter than the rest of the ends in the warp, and make the furrows between those parts of the cloth that contain the wadding ends.

When making the drawing-in draft for a Bedford cord, the wadding ends are generally drawn through the back harnesses, and the face ends are drawn through the front harnesses. In reeding these cloths, each wadding end should be drawn into a dent with 2 or more face ends if possible. Fig. 6 shows a drawing-in draft for Fig. 5. In reeding the ends when drawn through the harnesses in this manner the best plan would be to draw 5 ends in a dent, commencing with the second end; that is, the second, third, fourth, fifth, and sixth ends would occupy one dent; the seventh, eighth, ninth, tenth, and eleventh another; the twelfth, thirteenth, fourteenth, fifteenth, and sixteenth, another; and the seventeenth, eighteenth, nineteenth, twentieth, and first, another. This will bring each wadding end in a dent between 2 or more face ends.

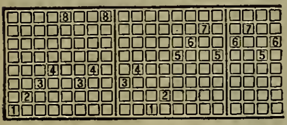


FIG. 6

USEFUL INFORMATION

WEIGHTS AND MEASURES

UNITED STATES MONEY

10 mills (m.) . . . . = 1 cent . . . . ct.
10 cents. . . . . = 1 dime . . . . d.
10 dimes. . . . . = 1 dollar . . . . $
10 dollars. . . . . = 1 eagle . . . . E.

m.	*ct.*	*d.*	*$*	*E.*
10 =	1			
100 =	10 =	1		
1,000 =	100 =	10 =	1	
10,000 =	1,000 =	100 =	10 =	1

United States currency is based on a decimal system, the unit being 1 dollar; thus, one-tenth of 1 dollar is 1 dime and ten times 1 dollar is 1 eagle.

Dollars are separated from cents and mills by a decimal point, cents occupying the first two, and mills the third place to the right of the point, since cents represent hundredth parts of a dollar and mills, thousandth parts; thus, $25.487 is read twenty-five dollars forty-eight cents and seven mills.

When the number of cents in an expression of dollars and decimal parts of a dollar is less than ten, a cipher is inserted between the decimal point and the figure denoting the number of cents, since cents represent hundredth parts of a dollar, thus $14.06.

AVOIRDUPOIS WEIGHT

16 drams (dr.) . . . . = 1 ounce. . . . . oz.
16 ounces. . . . . = 1 pound. . . . . lb.
100 pounds. . . . . = 1 hundredweight. . . . . cwt.
20 hundredweight. . . . . = 1 ton. . . . . T.

dr.	*oz.*	*lb.*	*cwt.*	*T.*
16 =	1			
256 =	16 =	1		
25,600 =	1,600 =	100 =	1	
512,000 =	32,000 =	2,000 =	20 =	1

A long ton is equal to 2,240 pounds and is used in connection with large lots of merchandise, notably iron and coal, when bought and sold by the wholesale. A long hundredweight is 112 pounds. The long ton and long hundredweight are used in the United States Custom Houses. Unless otherwise stated, the short ton (2,000 pounds) and short hundredweight (100 pounds) are always referred to.

An adaptation of avoirdupois weight that is used in mill work for weighing yarn, roving, etc., is as follows:

gr.	*dr.*	*oz.*	*lb.*
27.34+ =	1		
437.50 =	16 =	1	
7,000.00 =	256 =	16 =	1

TROY WEIGHT

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

gr.	*pwt.*	*oz.*	*lb.*
24 =	1		
480 =	20 =	1	
5,760 =	240 =	12 =	1

APOTHECARIES' WEIGHT

20 grains (gr.)	= 1 scruple	sc. or ℈
3 scruples	= 1 dram	dr. or ʒ
8 drams	= 1 ounce	oz. or ℥
12 ounces	= 1 pound	lb. or ℔.

gr.	℈	ʒ	℥	*lb.*
20 =	1			
60 =	3 =	1		
480 =	24 =	8 =	1	
5,760 =	288 =	96 =	12 =	1

LIQUID MEASURE

4 gills (gi.)	= 1 pint	pt.
2 pints	= 1 quart	qt.
4 quarts	= 1 gallon	gal.
31½ gallons	= 1 barrel	bbl.
63 gallons	= 1 hogshead	hhd.

gi.	*pt.*	*qt.*	*gal.*	*bbl.*	*hhd.*
4 =	1				
8 =	2 =	1			
32 =	8 =	4 =	1		
1,008 =	252 =	126 =	31½ =	1	
2,016 =	504 =	252 =	63 =	2 =	1

APOTHECARIES' FLUID MEASURE

60 minims, or drops (♏) . . . . = 1 fluid dram. . . . . f ʒ
8 fluid drams. . . . . = 1 fluid ounce. . . . . f ℥
16 fluid ounces. . . . . = 1 pint. . . . . O.
8 pints. . . . . = 1 gallon. . . . . Cong.

M	*f ʒ*	*f ℥*	*O.*	*Cong.*
60 =	1			
480 =	8 =	1		
7,680 =	128 =	16 =	1	
61,440 =	1,024 =	128 =	8 =	1

DRY MEASURE

2 pints (pt.) . . . . = 1 quart. qt.
8 quarts. . . . . = 1 peck. . . . . pk.
4 pecks. = 1 bushel. . . . . bu.

pt.	*qt.*	*pk.*	*bu.*
2 =	1		
16 =	8 =	1	
64 =	32 =	4 =	1

LINEAR, OR LONG, MEASURE

12 inches (in.) or (″). . . . . . . = 1 foot. . . . . ft. or (′)
3 feet. = 1 yard. . . . . yd.
5½ yards, or 16½ feet. . . . . . . = 1 rod. . . . . rd.
40 rods. . . . . = 1 furlong . . . . fur.
8 furlongs, or 320 rods. . . . = 1 mile. . . . . mi.

in.	*ft.*	*yd.*	*rd.*	*fur.*	*mi.*
12 =	1				
36 =	3 =	1			
198 =	16½ =	5½ =	1		
7,920 =	660 =	220 =	40 =	1	
63,360 =	5,280 =	1,760 =	320 =	8 =	1

SURVEYORS' MEASURE

7.92 inches (in.)	= 1 link	li.
25 links	= 1 rod	rd.
100 links, 4 rods, or 66 feet.	= 1 chain	ch.
10 chains	= 1 furlong	fur.
8 furlongs, or 80 chains	= 1 mile	mi.

in.	*li.*	*rd.*	*ch.*	*fur.*	*mi.*
7.92 =	1				
198 =	25 =	1			
792 =	100 =	4 =	1		
7,920 =	1,000 =	40 =	10 =	1	
63,360 =	8,000 =	320 =	80 =	8 =	1

Gunter's chain, 66 feet in length and divided into 100 links, is used in ordinary land surveys, but for locating roads and laying out public works an *engineer's chain* 100 feet in length is used. At the present day the tendency of engineers is to use a 100-ft. steel tape for measurements.

CLOTH MEASURE

$2\frac{1}{4}$ inches (in.)	= 1 nail	na.
4 nails	= 1 quarter (of a yard)	qr.
4 quarters	= 1 yard	yd.
3 quarters	= 1 ell (Flemish)	E. F.
5 quarters	= 1 ell (English)	E. E.

in.	*na.*	*qr.*	*yd.*	*E. F.*	*E. E.*
$2\frac{1}{4}$ =	1				
9 =	4 =	1			
36 =	16 =	4 =	1		
27 =	12 =	3 =	$\frac{3}{4}$ =	1	
45 =	20 =	5 =	$1\frac{1}{4}$ =	$1\frac{2}{3}$ =	1

The French ell equals 6 qr. and the Scotch ell, 4 qr. 1+in., or practically 37 in.

SQUARE MEASURE

144 square inches (sq. in.)	= 1 square foot	sq. ft.
9 square feet	= 1 square yard	sq. yd.
$30\frac{1}{4}$ square yards, or $272\frac{1}{4}$ square feet	= 1 square rod	sq. rd.
160 square rods	= 1 acre	A.
640 acres	= 1 square mile	sq. mi.

sq. in.	*sq. ft.*	*sq. yd.*	*sq. rd.*	*A.*	*sq. mi.*
144 =	1				
1,296 =	9 =	1			
39,204 =	$272\frac{1}{2}$ =	$30\frac{1}{4}$ =	1		
6,272,640 =	43,560 =	4,840 =	160 =	1	
4,014,489,600 =	27,878,400 =	3,097,600 =	102,400 =	640 =	1

CUBIC MEASURE

1,728 cubic inches (cu. in.)	= 1 cubic foot	cu. ft.
27 cubic feet	= 1 cubic yard	cu. yd.
16 cubic feet	= 1 cord foot	cd. ft.
8 cord feet, or 128 cubic feet	= 1 cord	cd.

cu. in.	*cu. ft.*	*cu. yd.*
1,728 =	1	
46,656 =	27 =	1

MEASURES OF TIME

60 seconds (sec.)	= 1 minute	min.
60 minutes	= 1 hour	hr.
24 hours	= 1 day	da.
7 days	= 1 week	wk.
$365\frac{1}{4}$ days, or 52 weeks $1\frac{1}{4}$ days	= 1 year	yr.

sec.	*min.*	*hr.*	*da.*	*wk.*	*yr.*
60 =	1				
36,000 =	60 =	1			
86,400 =	1,440 =	24 =	1		
604,800 =	10,080 =	168 =	7 =	1	
31,557,600 =	525,960 =	8,766 =	$365\frac{1}{4}$ =	$52\frac{5}{28}$ =	1

NOTE.—For convenience it is customary to reckon 365 da. as a year and call every fourth year 366 da., placing the extra day in the month of February, which then has 29 da. This is known as a *leap year*. A year is equal to 12 months (mo.) and for convenience a month is considered as 30 da.

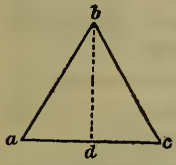
ANGULAR MEASURE

60 seconds (″)	= 1 minute	′
60 minutes	= 1 degree	°
90 degrees	= 1 right angle, or quadrant	∟
360 degrees, or 4∟	= 1 circumference	cir.

MISCELLANEOUS MEASURES

1 pound sterling (£)	= \$4.8665
1 fathom	= 6 feet
1 knot, or nautical mile	= $1\frac{11}{72}$ miles
1 meter	= 39.37 inches
1 decimeter	= 3.937 inches
1 centimeter	= .3937 inch
1 millimeter	= .03937 inch
1 dozen (doz.)	= 12 articles
1 gross	= 12 dozen
1 great gross	= 12 gross
1 quire	= 24 sheets of paper
1 ream	= 20 quires
1 large ream	= 500 sheets
1 perch	= $24\frac{3}{4}$ cubic feet
1 tierce	= 42 gallons
1 puncheon	= 2 tierces
1 carat	= $3\frac{1}{5}$ grains (troy)
1 butt	= 108 gallons
1 bushel	= 2,150.42 cubic inches
1 palm	= 3 inches
1 hand	= 4 inches
1 span	= 9 inches
1 gallon of water (U. S. Standard)	= 231 cubic inches = 8.355 pounds
1 gallon of water (British Imperial gallon)	= 277 cubic inches = 10 pounds
1 cubic foot	= 7.481 gallons

MENSURATION



TRIANGLES

A *triangle* is a plane figure bounded by three straight lines and having three angles. The altitude of a triangle is the distance from its apex to base measured perpendicularly to the base. In the triangle *abc*, the dotted line *bd* represents the altitude, and the line *a c* the base, of the triangle.

Rule.—*To find the area of a triangle, multiply the base by the altitude and divide the product by 2.*

Example.—The base of the triangle is 14 in. in length and the altitude is 12 in.; what is the area?

Solution.— $\frac{14 \text{ in.} \times 12 \text{ in.}}{2} = 84$ sq. in.

Note.—In the above example it will be noticed that by multiplying inches by inches the product obtained is square inches; similarly, feet multiplied by feet or rods by rods equals square feet or square rods, etc. It must be remembered that only like numbers can be multiplied together and that feet can never be multiplied by inches, nor rods by feet; consequently, in all problems dealing with mensuration, all dimensions must be reduced to like terms before multiplying.

Rule.—*To find the area of a triangle when the altitude is unknown but the length of each side is given, from one-half the sum of the three sides, subtract each of the sides separately and multiply the remainders together and by one-half the sum of the sides; the square root of the product will be the area of the triangle.*

Example.—What is the area of a triangle the sides of which are, respectively, 16, 16, and 12 ft. in length?

Solution.— $16+16+12=44$; $44 \div 2=22$; $22-16=6$; $22-16=6$; $22-12=10$;

$$6 \times 6 \times 10 \times 22 = 7{,}920; \quad \sqrt{7{,}920} = 88.99 \text{ sq. ft.}$$

QUADRILATERALS

A *quadrilateral* is a plane figure bounded by four straight lines.

A *parallelogram* is a quadrilateral the opposite sides of which are parallel.

Fig. 1

A *rectangle*, Fig. 1, is a parallelogram having all of its angles right angles.

Fig. 2

A *square*, Fig. 2, is a parallelogram having all of its angles right angles and all of its sides of equal length.

A *rhomboid*, Fig. 3, is a parallelogram having none of its angles right angles.

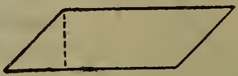


Fig. 3

A *rhombus*, Fig. 4, is a parallelogram having all of its sides of equal length but none of its angles right angles. The altitude of a parallelogram is the distance between two opposite sides measured perpendicularly, as indicated by the dotted lines in Figs. 3 and 4.

FIG. 4

Rule.—*To find the area of a parallelogram, multiply the altitude by the base and the product will be the area.*

EXAMPLE.—Find the area of a parallelogram the base of which is 345 in. and the altitude 423 in.

SOLUTION.— 423 in. × 345 in. = 145,935 sq. in.

A *trapezoid*, Fig. 5, is a quadrilateral having only two of its sides parallel. The altitude of a trapezoid is always measured perpendicularly between the parallel sides, as shown by the dotted line in Fig. 5.

FIG. 5

Rule.—*To find the area of a trapezoid, multiply one-half the sum of the parallel sides by the altitude.*

EXAMPLE.—The parallel sides of a trapezoid are, respectively, 12 and 28 ft. in length, and the altitude is 30 ft.; what is the area of the figure?

SOLUTION.— 12 ft. + 28 ft. = 40 ft.
40 ft. ÷ 2 = 20 ft.
20 ft. × 30 ft. = 600 sq. ft.

A *trapezium*, Fig. 6, is a quadrilateral that has no two sides parallel. A line joining two opposite corners of a quadrilateral, as the line *ab*, Fig. 6, is known as a diagonal.

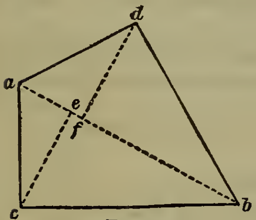


FIG. 6

Rule.—*To find the area of a trapezium, divide the figure into two triangles by means of a diagonal; the sum of the areas of these triangles equals the area of the trapezium.*

EXAMPLE.—What is the area of a trapezium whose diagonal is 43 in. long, the length of the perpendicular lines dropped on the diagonal from the opposite corners being 22 and 26 in. respectively?

NOTE.—The perpendicular lines drawn from opposite corners of a quadrilateral to its diagonal constitute the altitudes of the two triangles into which the diagonal divides the quadrilateral. Thus, in Fig. 6, the line *fd* represents the altitude of the triangle *adb*, and the line *ec* the altitude of the triangle *acb*.

SOLUTION.— 43 in.×22 in. = 946 sq. in.; 946 sq. in.÷2 = 473 sq. in., area of one triangle; 43 in.×26 in. = 1,118 sq. in.; 1,118 sq. in.÷2 = 559 sq. in., area of other triangle.

473 sq. in.+559 sq. in. = 1,032 sq. in., area of trapezium

POLYGONS

A *polygon* is a plane figure bounded by straight lines. The term is usually applied to a figure having more than four sides. The bounding lines are called the *sides*, and the sum of the lengths of all the sides is called the *perimeter* of the polygon. A *regular polygon* is one in which all the sides and all the angles are equal. A polygon of five sides is called a *pentagon*; one of six sides, a *hexagon*, etc. Regular polygons having from five to eight sides are shown in the accompanying illustration.

Pentagon Hexagon Heptagon Octagon

Rule.—*To find the area of a regular polygon, multiply the perimeter by one-half the length of the perpendicular from its center to one of its sides.*

EXAMPLE.—The perimeter of a regular polygon is 28 in. in length and the perpendicular distance from its center to one side is 8 in.; what is its area?

SOLUTION.— 8 in.÷2 = 4 in.; 28 in.×4 in. = 112 sq. in.

THE CIRCLE

A *circle*, Fig. 1, is a plane figure bounded by a curved line, called the *circumference*, every portion of which is equally distant from a point within called the *center*. The *diameter* of a circle is any straight line drawn through its center and terminating at each end in the circumference. Thus the line *ab*, Fig. 2, is a diameter of the circle. A straight line drawn from the

FIG. 1

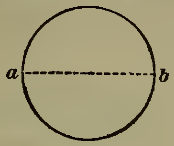


FIG. 2

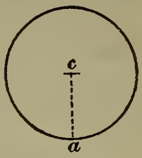


FIG. 3

center to the circumference of a circle, as *ac*, Fig. 3, is called a radius.

Rule.—*To find the circumference of a circle, multiply the diameter by 3.1416.*

EXAMPLE.—What is the circumference of a circle the diameter of which is 48 in.?

SOLUTION.— $48 \text{ in.} \times 3.1416 = 150.7968 \text{ in.}$

Rule.—*To find the diameter of a circle with a given length of circumference, divide the circumference by 3.1416.*

EXAMPLE.—What is the diameter of a circle the length of circumference of which is 8 ft.?

SOLUTION.— $8 \text{ ft.} \div 3.1416 = 2.5465 \text{ ft.}$

Rule.—*To find the area of a circle, multiply the square of the diameter by .7854.*

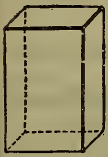
EXAMPLE.—What is the area of a circle the diameter of which is 75 in.?

SOLUTION.— $75 \text{ in.} \times 75 \text{ in.} \times .7854 = 4{,}417.875 \text{ sq. in.}$

Rule.—*To find the length of one side of a square equal in area to a given circle, multiply the diameter of the circle by .886227.*

EXAMPLE.—What is the length of one side of a square that is equal in area to a circle 15 in. in diameter?

SOLUTION.— $15 \text{ in.} \times .886227 = 13.293 \text{ in.}$



THE PRISM

A *prism* is a solid body the ends of which are formed by two similar plane figures that are equal and parallel to each other, and whose sides are parallelograms. Prisms are triangular, rectangular, square, etc., according to the character of the figure forming the ends. The base of a prism is either end, and of solids in general, the ends on which they are supposed to rest.

Rule.—*To find the surface area of a prism, multiply the length of the perimeter of the base by the altitude, and to the product add the area of both ends.*

Example.—What is the surface area of a square prism the base of which is 14 in. square and the altitude 25 in. in length?

Solution.— 14 in.×4=56 in., perimeter of base
56 in.×25 in.=1,400 sq. in., area of sides
14 in.×14 in.=196 sq. in., area of one base
196 sq. in.×2=392 sq. in., area of both bases
1,400 sq. in.+392 sq. in.=1,792 sq. in., total surface area

Rule.—*To find the contents or volume of a prism or rectangular box, multiply the width by the depth and by the length; or find the area of the base according to the rule previously given, which when multiplied by the height equals the contents or solidity of the prism.*

Example.—What is the capacity of a box 36 in. long, the ends being 14 in. by 28 in.?

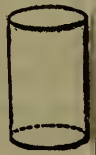
Solution.— 28 in.×14 in.×36 in.=14,112 cu. in.

Note.—It has been stated that inches multiplied by inches equals square inches or, similarly, yards multiplied by yards equals square yards. Continuing still further, as is necessary in finding the contents, volume, solidity, or capacity of solids; square inches or square yards multiplied by inches or yards equals cubic inches or cubic yards, etc.

From this it will be seen that by multiplying together the two dimensions of a surface, such as a rectangle, the area of the figure will be expressed in square units, and if the three dimensions of a solid, as for instance, a square prism, are multiplied together the contents, or solidity, of the solid is expressed in cubical units.

THE CYLINDER

A *cylinder* is a body of uniform diameter the ends, or bases, of which are equal parallel circles.



Rule.—*To find the surface area of a cylinder, multiply the circumference of the base by the height of the cylinder and to this product add the area of the ends.*

Example.—What is the surface area of a cylinder 6 in. in diameter and 13 in. high?

SOLUTION.—

$6^2 \times .7854 = 28.2744$ sq. in., area of one end

28.2744 sq. in. $\times 2 = 56.5488$ sq. in., area of both ends

6 in. $\times 3.1416 = 18.8496$ in., length of circumference

$18.8496 \times 13 = 245.0448$ sq. in., area of convex surface

$245.0448 + 56.5488 = 301.5936$ sq. in., total surface area

NOTE.—The convex surface of a solid is the curved surface; thus, the area of the convex surface of a cylinder is its total surface area less the area of the ends.

Rule.—*To find the contents or volume of a cylinder, first find the area of the base, and then multiply the area of the base by the altitude.*

EXAMPLE.—How many cu. ft. of water will a cylindrical tank 12 ft. in diameter and 14 ft. high hold?

SOLUTION.— $12^2 \times .7854 = 113.0976$ sq. ft., area of base; 113.0976 sq. ft. $\times 14$ ft. $= 1{,}583.3664$ cu. ft.

THE PYRAMID AND CONE

A *pyramid*, Fig. 1, is a solid the base of which is a polygon and the sides of which taper uniformly to a point called the *apex*.

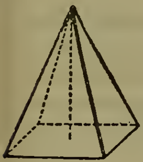


FIG. 1

A *cone*, Fig. 2, is a solid having a circle as a base and a convex surface tapering uniformly to the apex. The altitude of a pyramid or cone is the perpendicular distance from the apex to the base.

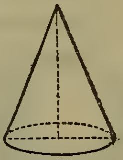


FIG. 2

Rule.—*To find the contents or volume of a cone or pyramid, multiply the area of the base by one-third the altitude.*

EXAMPLE.—What is the solid contents of a cone 30 ft. high and 5 ft. in diameter at the base?

SOLUTION.— $5^2 \times .7854 = 19.635$ sq. ft. area of base

$\frac{1}{3}$ of 30 ft. $= 10$ ft.

19.635 sq. ft. $\times 10$ ft. $= 196.35$ cu. ft.

THE FRUSTUM OF A PYRAMID OR CONE

If a pyramid is cut by a plane parallel to the base, as in Fig. 1, the lower part is called the *frustum* of the pyramid. If a cone is cut in a similar manner, as in Fig. 2, the lower part is called the frustum of the cone.

Rule.—*To find the contents or volume of the frustum of a pyramid or cone, find the areas of the two ends of the frustum; multiply them together and extract the square root of the product. To the result thus obtained add the two areas and multiply the sum by one-third of the altitude.*

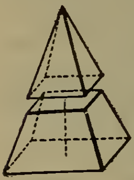


Fig. 1

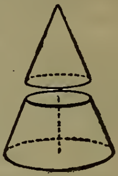


Fig. 2

Example.—What is the capacity of a tank shaped like the frustum of a cone, the inside diameter of the top being 10 ft. and of the bottom 14 ft., and the depth of the tank being 12 ft.?

Solution.— 10 ft.×10 ft.×.7854=78.54 sq. ft., area of small end; 14 ft.×14 ft.×.7854=153.9384 sq. ft., area of large end; 153.9384×78.54=12,090.321936; $\sqrt{12{,}090.321936}$ =109.956 sq. ft.; 109.956+153.9384+78.54=342.4344 sq. ft.; 12 ft.÷3=4 ft.

342.4344 sq. ft.×4 ft.=1,369.7376 cu. ft.

THE SPHERE

A *sphere* is a solid bounded by a continuous convex surface, every part of which is equally distant from a point within called the center. The *diameter*, or *axis*, of a sphere is a line passing through its center and terminating at each end at the surface.

Rule.—*To find the surface area of a sphere, square the diameter and multiply the result by 3.1416.*

Example.—What is the surface area of a sphere 14 in. in diameter?

Solution.—

$14^2 \times 3.1416 = 14 \times 14 \times 3.1416 = 615.75$ sq. in.

Rule.—*To find the contents or volume of a sphere, multiply the cube of the diameter by .5236.*

Example.—How many cubic inches of ivory in a billiard ball 2 in. in diameter?

Solution.— $2^3 \times .5236 = 4.1888$ cu. in.

MENSURATION OF LUMBER

Lumber is measured by *board measure,* which is an adaptation of square measure. A board foot is considered as 1 sq. ft. of board 1 in. thick; therefore 1,000 ft. of lumber is equal to 1,000 sq. ft. of boards 1 in. thick.

Rule.—*To find the number of feet of lumber in 1-inch boards, multiply the length of the board, in feet, by the width, in inches, and divide the product by 12.*

EXAMPLE.—How many feet of lumber are there in a 1-in. board 18 ft. long and 8 in. wide?

SOLUTION.— $\frac{18\times 8}{12}=12$ ft.

Rule.—*To find the number of feet of lumber in joists, beams, etc., multiply the width, in inches, by the thickness, in inches, and by the length, in feet. Divide this product by 12 and the quotient is the number of feet of lumber in the stick.*

EXAMPLE.—How many feet of lumber in a joist 4 in. wide, 3 in. thick, and 12 ft. long?

SOLUTION.— $\frac{4\times 3\times 12}{12}=12$ ft.

MECHANICAL CALCULATIONS

SHAFTING

The shafting used in a mill may be divided into three classes as follows: (1) The *main,* or *head, shaft,* which is driven directly from the source of power; this shaft is sometimes called the *first,* or *prime,* mover. (2) The *second movers,* or *line shafts;* these are the main driving shafts of each room and derive their power from the prime mover. (3) *Countershafts* for simply transmitting power to different parts of the room or for making changes in the speed for driving some particular machine or machines; these are located with reference to the positions of different machines in order to supply them with power as economically as possible. Long countershafts are classed as second movers.

Formerly wrought-iron shafts were largely used, but these are being replaced by turned or cold-rolled steel shafting. The following rules will be found useful in finding the required size of a cold-rolled shaft necessary to transmit a given horsepower.

Rule.—*To find the required diameter of a main shaft, find the cube root of 100 times the required horsepower divided by the desired number of revolutions of the shaft per minute.*

Rule.—*To find the required diameter of line shafts to transmit a given horsepower with the power taken off at intervals and the bearings of the shaft not more than 8 ft. apart, find the cube root of 50 times the required horsepower divided by the desired number of revolutions per minute.*

Rule.—*To find the required diameter of short countershafts for transmitting a given horsepower, find the cube root of 30 times the required horsepower divided by the desired number of revolutions per minute.*

EXAMPLE.—Suppose that it is desired to purchase a line shaft for a weave room requiring 350 H. P.; it is desired to have the shaft make 300 rev. per min. and a cold-rolled shaft is to be used. What diameter of shafting is required?

SOLUTION.—Diameter of shaft equals cube root of $\frac{50 \times \text{H. P.}}{\text{rev. per min.}}$

$$\sqrt[3]{\frac{50 \times 350}{300}} = 3.87 + \text{in.}$$

NOTE.—In a case like this a 4-inch cold-rolled shaft would probably be ordered, as this would allow for the extra power required to overcome the friction of the shaft in its bearings.

The following rules give the methods of finding the required size of turned shafting to transmit a required horsepower.

Rule.—*To find the required diameter of a main shaft, find the cube root of 125 times the required horsepower divided by the desired number of revolutions per minute.*

Rule.—*To find the required diameter of line shafts with the power taken off at intervals and the bearings not more than 8 ft. apart, find the cube root of 90 times the required horsepower divided by the desired number of revolutions per minute.*

Rule.—*To find the required diameter of short countershafts, find the cube root of 50 times the required horsepower divided by the desired number of revolutions per minute.*

EXAMPLE.—What diameter of turned shafting is capable of transmitting 45 H. P., the shaft to be the main driving, or line, shaft of the room and the bearings not more than 8 ft. apart? It is desired that the shaft make 150 rev. per min.

SOLUTION.—Diameter of shaft equals cube root of $\frac{90 \times \text{H. P.}}{\text{rev. per min.}}$

$$\sqrt[3]{\frac{90 \times 45}{150}} = 3 \text{ in.}$$

NOTE.—When the hangers are placed far apart, a larger shaft is necessary in order that it may have stiffness to withstand the bending strain due to its lack of support and to its own weight.

Distance Between Hangers.—When hangers are put up they should be lined perfectly true, both laterally and vertically, and should not be placed too far apart. The distance between the bearings should not be great enough to permit a deflection of the shaft of more than .01 in. per foot of length. Hence, when the shaft is heavily loaded with pulleys, the bearings must be closer than when it carries only a few. Pulleys that transmit a large amount of power should be placed as near a hanger as possible.

The accompanying table gives the maximum distances between the bearings of different sizes of continuous shafts that are used for the transmission of power:

Diameter of Shaft Inches	Distance Between Bearings Feet	
	Wrought-Iron Shaft	Steel Shaft
2	11	11.5
3	13	13.75
4	15	15.75
5	17	18.25
6	19	20.5
7	21	22.25
8	23	24
9	25	26

Speeds and Diameters of Pulleys.—A *driving pulley* is one that furnishes power to a *driven pulley*. The tight side of a belt always travels toward a driving pulley and the slack side toward a driven pulley.

Rule.—*To find the number of revolutions of a driven pulley, multiply the diameter of the driving pulley by its revolutions and divide the product by the diameter of the driven pulley.*

EXAMPLE.—A driving shaft making 350 rev. per min. carries a 24-in. pulley that drives a 14-in. pulley on the main shaft of a machine; find the revolutions of the main shaft of the machine.

SOLUTION.— $\frac{24 \text{ in.} \times 350}{14 \text{ in.}} = 600$ rev. per min.

Rule.—*To find the revolutions of a driving pulley, multiply the diameter of the driven pulley by its speed and divide by the diameter of the driving pulley.*

EXAMPLE.—The shaft of a machine makes 700 rev. per min. The size of the driven pulley is 8 in. and the driving pulley on the main shaft is 14 in.; find the revolutions of the main driving shaft.

SOLUTION.— $\frac{8 \text{ in.} \times 700}{14 \text{ in.}} = 400$ rev. per min.

Rule.—*To find the diameter of a driven pulley, multiply the diameter of the driving pulley by its speed and divide the product by the desired number of revolutions of the driven pulley.*

EXAMPLE.—The main shaft of a room makes 225 rev. per min. and carries a 20-in. pulley from which it is desired to drive a countershaft 300 rev. per min.; what size pulley must be ordered for the countershaft?

SOLUTION.— $\frac{20 \times 225}{300} = 15$-in. pulley

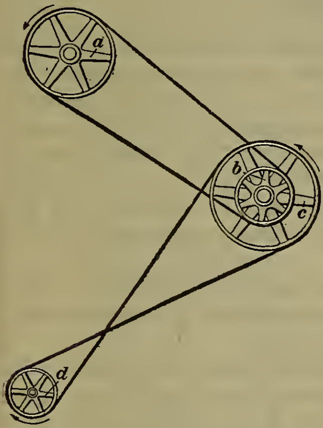
Rule.—*To find the diameter of a driving pulley, multiply the diameter of the driven pulley by the desired speed and divide the product by the speed of the driving shaft.*

EXAMPLE.—Find the size of the pulley required on a driving shaft making 360 rev. per min. in order to drive a machine 600 rev. per min. The size of the driven pulley on the machine is 12 in.

SOLUTION.— $\frac{12 \times 600}{360} = 20$-in. pulley

Effect of Countershafts on Speed.—It often happens that power is transmitted through one or more countershafts, carrying different-sized pulleys, before being applied to the pulley, the speed of which it is desired to find.

Rule.—*To find the speed of a driven pulley when the power is transmitted through countershafts, multiply the speed of the driving shaft by the product of the diameters of all the driving pulleys and divide the result by the product of the diameters of all the driven pulleys.*



EXAMPLE.—Referring to the accompanying figure, assume that the driving shaft makes 375 rev. per min. and that the main driving pulley *a* is 18 in. in diameter and drives a 12-in. pulley *b* on a countershaft. On this countershaft a 22-in. pulley *c* drives the 10-in. pulley *d* of a machine. Find the number of revolutions of the pulley *d*.

SOLUTION.— $\frac{375 \times 18 \text{ in.} \times 22 \text{ in.}}{12 \text{ in.} \times 10 \text{ in.}} = 1{,}237.5$ rev. per min.

Rule.—*To find the surface velocity of a rotating pulley or cylinder or the speed of a belt passing around it, in feet per minute (slip neglected), multiply the diameter of the pulley or cylinder in feet by 3.1416 and by the number of revolutions per minute.*

If the diameter of the pulley or other cylinder is expressed in inches, multiply its diameter by 3.1416 and by the number of revolutions per minute that it makes and divide the product by 12.

EXAMPLE.—Find the surface velocity, in feet per minute, of a 50-in. cylinder making 160 rev. per min.

SOLUTION.— $\frac{50 \times 3.1416 \times 160}{12} = 2{,}094.4$ ft. per min.

Circumferential Speed of Pulleys.—Pulleys over 4 ft. in diameter and flywheels, especially cast-iron ones, should never be speeded so fast that their surface velocity exceeds 5,000 ft. per min., since there will be a danger of their bursting. Many authorities give 3,750 ft. per min. as a limit to the surface speed of large pulleys. Smaller pulleys may have a higher surface velocity, but excesses should be avoided.

BELTS

Care of Belts.—Belts should be run with the smooth, or grain, side next to the pulley for the following reasons: (*a*) There is more friction of the belt on the pulley and, therefore, less slipping and consequent loss of power. (*b*) The center of strength in a belt is located one-third of the distance through the belt from the flesh side and it is better to crimp the grain, or weak, side around the pulley than to strain it. (*c*) The stronger side of the belt receives the least wear when run in this manner.

Some authorities recommend that the flesh side of a belt be run next to the pulleys; this is contrary to general practice, but in some cases it gives good results.

The lower part of a horizontal or inclined belt should be the driving part; then the slack part will run from the top of the driving pulley. The sag of the belt will then cause it to encompass a greater length of the circumference of both pulleys. Long belts, running in any direction other than the vertical, work better than short ones, as their weight holds them more firmly to their work. There is, however, a disadvantage in belts that are too long, since they greatly increase the strain on the bearings of the shaft.

The accumulations of grease and gummy matter should be frequently removed and the belts dressed with castor oil or some other suitable dressing on the side of contact, in order to keep them moist and pliable. It is bad practice to use rosin to prevent slipping; it gums the belt, causes it to crack, and prevents slipping for only a short time.

If a belt properly cared for persists in slipping, a wider belt or larger pulleys should be used; the latter to increase the belt speed. Belts should not be run tight, as the strain thus produced will wear out both the belt and the bearings of the shaft.

Belt Fastenings.—There are many good methods of fastening the ends of belts together, but lacing is generally used, as it is flexible like the belt itself, and runs noiselessly over the pulleys. The ends to be laced should be cut squarely across and the holes in each end for the lacings should be exactly opposite each other when the ends are brought together. Very narrow belts, or belts having only a small amount of power to transmit, usually have only one row of holes punched in each end, as in Fig. 1; *A* is the outside of the belt, and *B* the side running next to the pulley. To lace, the lacing should be drawn

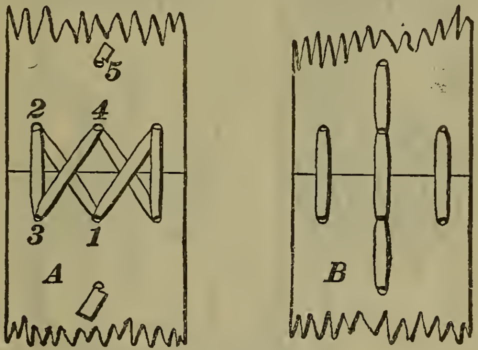


Fig. 1

half way through one of the middle holes, from the under side, as for instance through *1*; the upper end should then be passed through *2*, under the belt and up through *3*, back again through *2* and *3*, through *4* and up through *5*, where an incision is made in one side of the lacing, forming a barb that will prevent the end from pulling through. The other side of the belt is laced with the other end, it first passing up through *4*. Unless the belt is very narrow, the lacing of both sides should be carried on at once.

Fig. 2 shows a method of lacing where double lace holes are used, *B* being the side to run next to the pulley. The lacing for the left side is begun at *1*, and continues through *2*, *3*, *4*, *5*, *6*, *7*, *6*, *7*, *4*, *5*, etc. A 6-in. belt should have seven holes, four in the row nearest the end, and a 10-in. belt, nine holes. The edges of the holes should not be nearer than $\frac{3}{4}$ in. from the sides; and the holes should not be nearer than $\frac{7}{8}$ in. from the ends of the belt. The second row should be at least $1\frac{3}{4}$ in. from the end. Another method is to begin the lacing at one side instead of in the middle. This method will give the rows of lacing on the under side of the belt the same thickness all the way across.

Quarter-Turn Belts.—When the driving and driven shafts are at right angles to each other and are not in the same plane, the pulleys must be so placed that the belt is delivered from

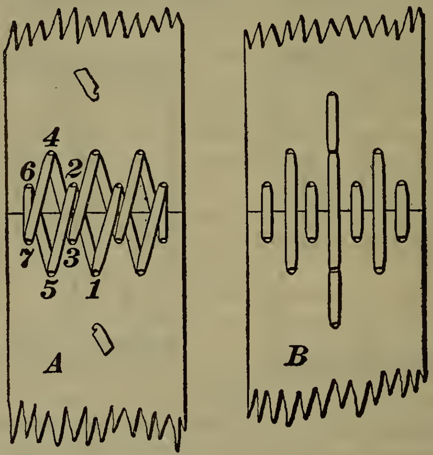


FIG. 2

one pulley into a plane passing through the center of the face of the other pulley. This arrangement is known as a quarter-turn, because, as shown in Fig. 3, a quarter twist is given to the belt. A connection of this kind can only be driven in the direction indicated by the arrows on the belt. If the direction of the belt is reversed it will run off the pulleys unless a guide pulley is used.

The easiest and most convenient way of fixing the position of quarter-turn pulleys is to plumb the leaving sides of each pulley; that is, drop a plumb-line from the center of the face of the leaving side, where the belt leaves the driving pulley, and arrange the driven pulley so that the plumb-line shall just touch the center of its face on the side from which the belt leaves it. This is shown by the two pulleys at the top of Fig. 3, which represents a plan of two quarter-turn pulleys as seen from above.

The objection to a quarter-turn belt is that, when the angle at which the belt is drawn off the pulleys is large, the belt is strained, especially at the edges, and it does not hug the pulleys well. Small pulleys placed some distance apart, with narrow

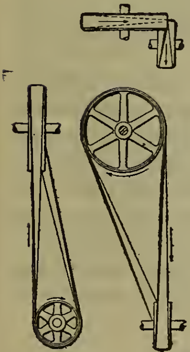


FIG. 3

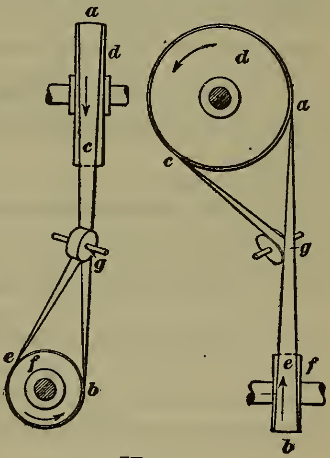


FIG. 4

belts give the best results, from which it follows that quarter-turn belts are not well suited to transmit much power.

Fig. 4 shows how the arrangement can be improved by placing a guide pulley against the loose side of the belt. The driver *d* revolves in a left-hand direction, making *ab* the driving, or tight, side of the belt. To determine the position of the guide pulley, select some point in the line *ab*, as *g*. When the pulleys differ in diameters this point should be somewhat nearer the smaller pulley. Draw lines *cg* and *eg*; the middle plane of the guide pulley should then pass through the two lines. Looked at from a direction at right angles to pulley f, line cg coincides with ab; looking at right angles to pulley d, line eg also coincides with ab.

Length of Belts.—The following rules will enable calculations in connection with belts to be performed.

Rule.—*To find the length of an open belt, multiply half the sum of the diameters of the driving and driven pulleys by 3.1416, and to this product add twice the distance between centers.*

EXAMPLE.—A countershaft is to be driven from the main shaft with an open belt, the distance between the centers of the shafts is 12 ft., and the diameters of the driving and driven pulleys are, respectively, 2 and 3 ft.; how long a belt is required?

SOLUTION.— $\frac{2+3}{2}=2.5;\ 2.5\times 3.1416=7.854$

$$12\times 2=24;\ 24+7.854=31.854 \text{ ft. of belt}$$

NOTE.—In case one pulley is much larger than the other, it is well to cut the belt 2 or 3 in. longer than calculated by the above rule.

Rule.—*To find the length of a crossed belt, to one-half the product of the sum of the diameters of the driving and driven pulleys and 3.1416 add twice the square root of the sum of the square of the distance between the centers of the shafts and the square of one-half the sum of the diameters of the driving and driven pulleys.*

EXAMPLE.—A countershaft is to be driven from the main shaft with a crossed belt, the distance between the centers of the shafts is 12 ft., and the diameter of the driving and driven pulleys are, respectively, 2 and 3 ft.; how long a belt is required?

SOLUTION.— $\frac{(2+3)\times 3.1416}{2}=7.854$

$$2\times\sqrt{12^2+\left(\frac{2+3}{2}\right)^2}=$$
$$2\times\sqrt{144+2.5^2}=$$
$$2\times\sqrt{144+6.25}=$$
$$2\times\sqrt{150.25}=$$
$$2\times 12.25=24.5$$
$$24.5+7.854=32.354 \text{ ft. of belt}$$

NOTE.—These rules, although not absolutely accurate, are near enough for practical purposes when it is impossible to measure the length of belt required.

Horsepower Transmitted by Belts.—As the width of a belt required to transmit a given horsepower depends on the speed and tension of the belt, the size of the smaller pulley, and the relative amount of its surface touched by the belt, no rule can be given that will apply to all cases. A belt that is being constantly shifted from a tight to a loose pulley, or vice versa, must be wider than one running on the same pulley all the time, and innumerable other conditions govern the horsepower capable of being transmitted by a given belt and the life of the belt.

It has been found by exhaustive experiments that a single belt traveling 900 ft. per minute will transmit approximately 1 H. P. per inch of width when the arc of contact on the smaller pulley does not vary much from 180°. This is used by many engineers as a general law for belting and is applied in all cases. From this fact the following rules in connection with belting are obtained.

Rule.—*To find the horsepower transmitted by a given belt, divide the product of the width of the belt, in inches, and the speed, in feet per minute, by 900.*

Rule.—*To find the required width of a belt to transmit a given horsepower, divide the horsepower multiplied by 900 by the speed of the belt, in feet per minute.*

Example.—Two 48-in. pulleys are to be connected by a single belt and make 200 rev. per min.; if 40 H. P. is to be transmitted what must be the width of the belt?

Solution.— $\frac{200 \times 48 \times 3.1416}{12} = 2{,}513$ **ft. per min.** (nearly)

$\frac{40 \times 900}{2{,}513} = 14.3$ in., width of belt

Note.—A 14-inch belt might safely be used, since the rule gives a liberal width when the pulleys are of equal size.

In these rules it has been assumed that the belt is open and also that the driving and driven pulleys are of the same diameter, the belt consequently being in contact with half of the circumference of each pulley. But when one pulley is larger than the other, the horsepower transmitted is reduced as the arc of the smaller pulley that is in contact with the belt is reduced. With a crossed belt the amount of horsepower that can be transmitted by a given width of belt is increased, as there is then more of the surface of the pulleys in contact with the belt.

As the rules for single belts are based on the strength at the lace holes, a double belt, which is twice as thick, should be able to transmit twice as much power as a single belt and, in fact, more than this where, as is very common, the ends of the belt are cemented together instead of being laced. Where double belts are used on small pulleys, however, the contact with the pulley face is less nearly perfect than it would be if a single belt were used, owing to the greater rigidity of the former. More work is also required to bend the belt as it runs over the pulleys than in the case of the thinner and more pliable belt, and the centrifugal force tending to throw the belt from the pulley also increases with the thickness. For these reasons, the width of a double belt required to transmit a given horsepower is generally assumed to be seven-tenths the width of a single belt required to transmit the same power. Therefore, in order to find the width of a double belt required to transmit a given horsepower, proceed as with a single belt and multiply the result by $\frac{7}{10}$; and in order to find the horsepower transmitted by a given width of a double belt, proceed as with a single belt and multiply the result by $\frac{10}{7}$.

ROPE TRANSMISSION

Many American mills are introducing rope drives for transmitting power, especially for the main drives from the engine, for which this method is particularly adapted. The distance to which power can be transmitted by means of sheave pulleys and ropes is practically unlimited, as is also the amount of power. Except for very short distances, rope driving is the cheapest method of transmitting power, being economical not only in the first cost, but in the maintenance. This in itself is an important item. An evenness of motion that cannot be obtained by any other system of power transmission is obtained by transmitting power in this manner; this is due to the lightness, elasticity, and slackness of the rope, which takes up all inequalities between the power and the load. Rope drives are noiseless because of the flexibility and lubrication of the rope and because of the air passage underneath the rope, owing to the V-shaped groove in which it runs. An exact alinement of the driving and driven pulleys is not necessary when ropes are used, and by properly placing idle pulleys power may be transmitted in any desired direction. The security that a rope drive affords against shut-downs due to the crippling of the drive is one of the great advantages of this system. This is due to the fact that before breaking, the rope stretches excessively, though gradually, thus giving warning that it should be replaced. The absence of electrical disturbances and the almost total immunity from slip are among the many advantages that may well be claimed by this system for power transmission.

There are two systems of rope transmission in common use. In the first, the transmission is effected by several parallel, independent ropes that pass around the flywheel of the engine and the pulley or pulleys to be driven. Each rope is made quite taut at first, but stretches until it slips, after which it is respliced.

In the second system of rope transmission, a single rope, having but one splice, is carried around the pulleys as many times as is necessary, to transmit the required power; the necessary tension is obtained by passing a loop of the rope around a weighted pulley.

The first of the above systems of transmission is used chiefly in Europe; the second in the United States. The ropes generally used are of manila, hemp or cotton, sometimes with a wire core. For transmitting power long distances, especially where the rope is exposed to the weather, a wire rope is used. For inside drives the cotton rope without a wire core is suitable.

Next in importance to the rope are the grooved pulleys, or sheaves, on which the rope runs. The grooves are made of metal or wood and must be smooth, in order to prevent the rope from wearing, and true, to keep it from swaying. These grooves are made V-shaped so that they may grip, or bind, the rope and not allow it to slip; the rope does not touch the bottom of the groove but is wedged in between the sides.

Rule.—*To find the horsepower transmitted by a single rope running under favorable conditions in a 45° groove, multiply the speed of the rope, in feet per second, by the square of its diameter,* *in inches, and divide the product by 825. This quotient multiplied by the result obtained by subtracting from 200 the speed of the rope per second, squared, and divided by 107.2 equals the horsepower that can be transmitted with a single rope.*

Example.—A flywheel designed for a rope drive is 22 ft. in diameter and is equipped with 30 grooves; the diameter of the rope is $1\frac{1}{4}$ in. and the flywheel makes 50 rev. per min.; what horsepower can be safely transmitted?

Solution.—

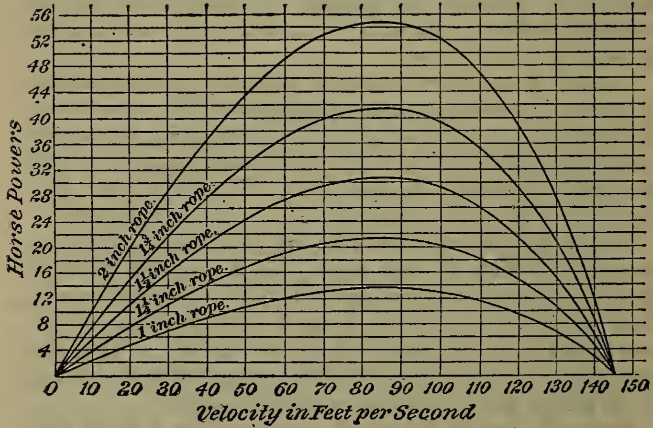
$$\frac{22\times3.1416\times50}{60\text{ (sec.)}}=57.596,\text{ speed of rope in ft. per sec.}$$

$$\frac{57.596\times(1\frac{1}{4})^2}{825}\times\left(200-\frac{57.596^2}{107.2}\right)=$$

$$\frac{57.596\times1.5625}{825}\times\left(200-\frac{3317.299216}{107.2}\right)=$$

$$.109083\times(200-30.9449)=$$

$.109083\times169.0551=18.441$, H. P. for one rope. Since there are 30 grooves in the flywheel, in each of which there is one rope, the total power transmitted will be $18.441\times30=553.23$ H. P.



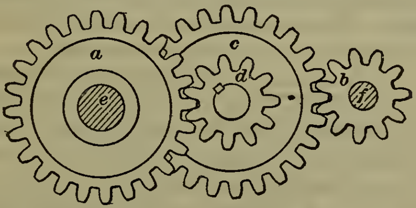
The accompanying figure shows the horsepower transmitted by 1-in., $1\frac{1}{4}$-in., $1\frac{1}{2}$-in., $1\frac{3}{4}$-in., and 2-in. ropes for various velocities.

The horizontal distances represent velocities in feet per second, and the vertical distances the horsepower transmitted by a single rope. It shows that the maximum power is obtained at a speed of about 84 ft. per second. For higher velocities, the centrifugal force becomes so great that the power is decreased, and when the speed reaches 145 ft. per second, the centrifugal force just balances the tension, so that no power at all is transmitted. Consequently, a rope should not run faster than about 5,000 ft. per min., and it is preferable, on the score of durability, to limit the velocity to 3,500 ft. per min.

GEARING

The transmission of power for short distances at slow speeds, as between the driving and driven shaft of a machine, is generally accomplished by means of gears. Gears are ordinarily made of cast iron; if great strength is required, steel may be used. Gears that are called on to resist shocks may be made of gun metal or phosphor bronze. Fast-running gears are sometimes made of rawhide or fiber instead of metal.

For solving problems that deal with gears, use the same rules as are given for pulleys, remembering that the number of teeth



on the driving gear or gears multiplied together and by the speed of the first driver equals the number of teeth on the driven gear or gears times the speed of the last driven gear. Speeds and sizes of gears, like pulleys, should be treated by proportion. Intermediate gears should not be used when finding speeds or sizes of gears.

Rule.—*To find the speed of a driven gear, multiply the speed of the first driving gear by its number of teeth and by the number of* *teeth on each driving gear in the train, if there is more than one, and divide the product by the number of teeth on the driven gear or by the product of the teeth on the driven gears.*

EXAMPLE.—Suppose that the shaft *e* in the accompanying figure is the driving shaft and makes 40 rev. per min.; find the number of revolutions of the driven shaft *f* when *a* and *c* have each 24 teeth and *d* and *b* 11 teeth.

SOLUTION.— $\frac{40\times24\times24}{11\times11}=190.413$ rev. per min.

A good method of determining whether a gear is a driver or driven gear is to notice which side of its teeth are worn, or polished smooth. The driving gear always has its teeth polished on the side facing in the direction in which the gear is moving; a driven gear has the opposite side of the teeth polished; and an intermediate gear has both sides of the teeth worn.

Constants.—It often happens that though a machine contains a more or less complicated train of gears, only one of them is changed for alterations in the speed of the driven gear. This gear is known as a *change gear*, and the arrangement of the train is such that its size may readily be changed without disturbing the other members of the train. If the change gear is a driven gear, an increase in its size will diminish the speed of the driven gear or shaft. If it is a driver, an increase in its size will increase the speed of the driven gear or shaft.

Where a train of gears is employed, the calculation of the required size of change gear to produce a given speed of the driven gear becomes rather long unless some method of shortening the operation is adopted. This may be accomplished by partly performing the operation and securing a number that expresses the value of the train, excluding the change gear, and that needs but one multiplication or division to obtain the desired speed or the desired size of change gear; such a number is called a *constant.*

A constant number may be either a constant factor or a constant dividend. A *constant factor* is a number that, when multiplied by the change gear, gives the speed of the driven shaft of a train of gears and, when divided into the speed of the driven shaft, gives the number of teeth in the change gear. A *constant dividend* is a number that, when divided by the number of teeth in a change gear, gives the speed of the driven shaft of a train of gears, and, when divided by the speed of the driven shaft, gives the number of teeth in the change gear.

For all speed calculations the constant number for a train of gears is a constant factor if the change gear is a driver and a constant dividend if the change gear is a driven gear. Where a constant number is used in connection with some result dependent on the action of a train of gears, it may be either a constant factor or dividend, depending on whether the value of the said result is increased or decreased by an increase in the size of the change gear.

Rule.—*To find a constant, perform the calculation of the train of gears in the ordinary manner, using a theoretical change gear of one tooth.*

EXAMPLE.—A certain roll is driven as follows: The first driving gear has 40 teeth and makes 390 rev. per min.; this gear drives a 39-tooth gear attached to a shaft on which there is also a 64-tooth gear driving a 32-tooth gear on a shaft. On this latter shaft is fastened a 40-tooth gear that drives a 40-tooth gear on another shaft; on this shaft a change gear drives a 128-tooth gear on the shaft of the roll. What is the constant for finding the speed of the roll with various change gears?

SOLUTION.—In this case the constant number must be a constant factor, as the change gear is a driver and an increase in its size increases the speed of the roll.

$$\frac{390\times40\times64\times40\times1}{39\times32\times40\times128}=6.25, \text{ constant factor.}$$

NOTE—If any change gear is used, its size multiplied by 6.25 in this case, will give the speed of the roll; also, if any speed is desired, the required change gear can be found by dividing the desired speed by 6.25.

The *pitch circle* of a gear is an imaginary circle described, with the axis of rotation for a center, through the point of contact of the teeth of one gear with those of another gear. It is the effective circumference of a gear and really determines its ratio of velocity when working with other gears.

The *circular pitch* of a gear is the distance between the centers of two consecutive teeth measured on the pitch circle or, as it is sometimes called, the *pitch line*.

The *diametral pitch* of a gear is equal to the number of teeth on its circumference divided by the number of inches in the diameter of the pitch circle. In order to mesh and run together, gears must be of the same pitch.

Sizing Gear-Blanks.—Many mills are equipped with machines for cutting gears to replace broken or worn ones, making change gears, etc. When it is desired to cut a gear, it is necessary to select a gear-blank of the correct diameter for the desired number of teeth and pitch.

Rule.—*To find the desired diameter of blank for any number of teeth and any diametral pitch, add 2 to the required number of teeth and divide by the desired pitch; the quotient is the diameter, expressed in inches, of the blank required.*

EXAMPLE.—A change gear with 33 teeth and 10-pitch is desired. To what diameter must the gear-blank be turned?

SOLUTION.— $\frac{33+2}{10}=3\frac{1}{2}$ in.

Rule.—*To find the number of teeth the gear-cutter must space to cut a given blank a required pitch, multiply the diameter of the blank by the required pitch and from the product thus obtained subtract 2; the answer is the number of teeth required.*

EXAMPLE.—How many teeth must the gear-cutter space to cut a gear-blank $2\frac{1}{2}$ in. in diameter, 12-pitch?

SOLUTION.— $2\frac{1}{2}\times 12=30$; $30-2=28$ teeth

Worms and Worm-Gears.—A worm is a screw designed to mesh with and turn a gear called a worm-gear. Worms are *single threaded* when they have a single thread cut on them and *double threaded* when they have two threads. A worm is always a driver, a single-threaded worm driving the worm-gear one tooth for each revolution and a double-threaded worm moving it two teeth.

Occasionally worms are met with that have three threads cut on them. Worms furnish a means of reducing a great velocity of a shaft to the slow speed of the worm-gear.

Rule.—*To find the speed of a worm-gear driven by a single- or a double-threaded worm: If the worm is single-threaded, divide its speed by the number of teeth in the worm-gear.*

If the worm is double-threaded, multiply its speed by 2 and divide the product by the number of teeth in the worm-gear.

EXAMPLE.—An 80-tooth worm-gear is driven by a double-threaded worm making 160 rev. per min.; find the number of revolutions per minute of the worm-gear.

SOLUTION.— $\frac{160\times 2}{80}=4$ rev. per min.

A worm is always a driver and reckoned as a one-tooth gear if single threaded and a two-tooth gear if double threaded.

Mangle Gears.—Mangle gears reverse their direction of rotation and are always driven gears. They are either eccentric or concentric. When concentric the center of the pitch circle coincides with the axis of rotation, and when eccentric the center of the pitch circle is removed from the axis of rotation. The speed of a mangle gear is found in the same manner as that of an ordinary gear, except that its size is reckoned as somewhat larger than it really is, because the driving pinion, while rounding each end of the row of pegs, makes a half revolution, which moves the mangle but one peg. A mangle gear is said to perform a complete cycle of its movements in making a double revolution; that is, one revolution in one direction and one in the opposite direction.

Rule.—*To find how many complete cycles, or double revolutions, a mangle gear will make per minute, divide the product of the number of revolutions per minute of the driving pinion and the number of teeth that it contains by the sum of twice the number of pegs in the mangle and the number of teeth in the driving pinion diminished by 2.*

EXAMPLE.—A 10-tooth pinion gear making 216 rev. per min. drives a mangle gear with 176 teeth, or pegs; how many complete cycles per minute does the mangle gear make?

SOLUTION.— $\frac{216\times 10}{(176\times 2)+(10-2)}=\frac{216\times 10}{352+8}=6$ cycles

That is, the mangle gear would make 12 revolutions, 6 in one direction and 6 in the other.

LEVERS

A *lever* is an inflexible bar capable of being freely moved about a fixed point, or line, called the *fulcrum*. The bar is acted on at two points by two forces that tend to rotate it in opposite directions about its fulcrum. Of these two forces, the one that is applied with the purpose of imparting motion is termed the *power*, while the force that is to be overcome is the *weight*, or *resistance*. The parts *af* and *bf*, Fig. 1, are the *arms* of the lever.

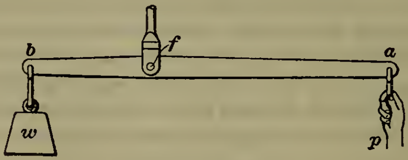


FIG. 1

There are three classes, or varieties, of levers; if the fulcrum is between the power and the weight (*p*, *f*, *w*), as shown in Fig. 1, the lever is of the *first class*. In this combination equilibrium exists if the product of the force *p* times arm *af* equals the product of the force *w* times arm *bf*.

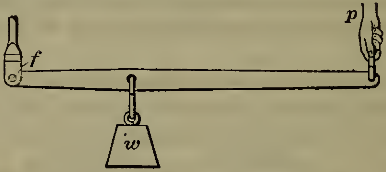


FIG. 2

If the weight is between the power and the fulcrum (*p*, *w*, *f*) as shown in Fig. 2, the lever is of the *second class*.

If the power is between the weight and the fulcrum (*w*, *p*, *f*), the lever is of the *third class*, Fig. 3.

Sometimes it is not convenient to use a lever sufficiently long to make a given power support a given weight. In this case combinations of levers known as *compound levers* are used.

Rule.—*To find the weight supported or the pressure exerted at the weight end of the lever, the length of the weight arm, the length of the power arm, and the power applied being known, multiply the*

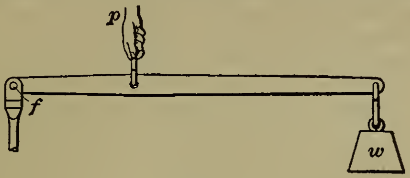


FIG. 3

power by the length of the power arm and divide the product by the length of the weight arm.

EXAMPLE.—A 25-lb. weight is placed on a lever that is so connected as to exert a pressure on a pair of rolls; the weight is 4 ft. from the fulcrum of the lever, and the rod connecting the lever with the rolls is $1\frac{1}{2}$ ft. from the fulcrum of the lever; find the pressure exerted.

SOLUTION.— $\frac{25 \times 4}{1\frac{1}{2}} = 66\frac{2}{3}$ lb. pressure

Any problem of levers may be solved by treating it as a proportion in which the power is to the weight as the weight arm is to the power arm; and, as in proportion the product of the extremes is equal to the product of the means, so the power times the power arm equals the weight times the weight arm.

With compound levers, the continued product of the power multiplied by the power arms is equal to the continued product of the weight multiplied by all the weight arms, every alternate arm of the combination of levers, starting with the power arm, being a power arm and every alternate arm, starting with the weight arm, being a weight arm.

EXAMPLE.—A 40-lb. weight (power) acts through the following power arms: 4 ft., 3 ft., and 3 ft., respectively; the corresponding weight arms being 3 ft., 2 ft., and 2 ft., respectively; what weight is supported, or pressure exerted, at the extremity of the last weight arm?

SOLUTION.— $\frac{40 \times 4 \times 3 \times 3}{3 \times 2 \times 2} = 120$ lb.

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John W. Lord, 175 Newton St., New Bedford, Mass., thinks that any young man who is ambitious cannot do better than to take an I.C.S. Course. When he enrolled with us for the Cotton Spinning and Warp Preparation Course, he was a second hand earning about $12 a week. He is now overseer at the Gornold mills and his salary has increased almost 200 per cent.

SALARY TRIPLED

E. W. Smith, 2410 Whitesboro St., Utica, N. Y., says that the knowledge gained from his Cotton Carding and Spinning Course for which he subscribed with the I.C.S. has enabled him to secure and hold a position as overseer of the carding department of the Utica Fine Yarn Co. He was employed as a third hand when he enrolled.

THE I.C.S. THE MAKING OF HIM

J. B. Batton, Box 23, Rosemary, N. C., enrolled with us for the Cotton Carding and Spinning Course, and got right down to work. He says that what he knows today he learned from the Course which has been the making of him, securing his promotion to the position of overseer for the Rosemary Manufacturing Co. and doubling his salary.

NOW SUPERINTENDENT

Arthur Thrope, Fayetteville, Tenn., was employed as a carder when he enrolled with the I.C.S. for the Cotton Carding and Spinning Course. He says that this gave him the courage to tackle any practical problems that came his way, and enabled him to make one advancement after another, until he is now the superintendent of the Elk Cotton Mills with an increase in salary of 275 per cent.

READY FOR THE OPPORTUNITY

Chas. F. Campbell, Cibsonville, N. C., was running a fly frame when he began to study our Cotton Carding and Spinning Course. The superintendent saw that he was trying to better his job and set him to learn to grind cards. Eighteen months later the overseer resigned and Mr. Campbell was given his position with a large increase in salary. Had he not been prepared he would have been obliged to refuse a position that promises better things in the future.

High Praise From a Successful Student

I wish that I had more education to express my feelings toward the International Correspondence Schools, but I have no words to tell all the good they have done me. It is not easy to study and work at the same time, but I can say that it is better to spend one's evenings in study than to stand on the corner every night. There is no money coming at the end of the week for standing at the corner.

When I enrolled with the I. C. S., October 19, 1907, I could write but very little and I knew almost nothing about figuring. However, I completed the first part of arithmetic with a grade of 100 per cent. Not so bad for a man who did not know anything about arithmetic and who was at work every day. I am also married and have 4 children. But I completed the section on arithmetic with a percentage of 98, and also the section on carding.

When I enrolled with the I. C. S. I was only a fixer. I am at present overseer of carding for I. K. Stewart & Sons and am doing well. My pay has doubled since enrolment—all thanks to the I. C. S. If any one desires to know what the I. C. S. can do, let him write to me.

Every night when I come back from work—even at 10 o'clock, I have to visit my I. C. S. library before taking a rest, and I have done that ever since I signed for my Course in 1907.

MICHAEL BESSETTE,
68 Academy St.,
Amsterdam, N. Y.

SALARY MORE THAN DOUBLED

Jas. R. Frye, Marion, N. C., a graduate of our Cotton Carding and Spinning Course, was earning $1.25 a day as card grinder when he enrolled for the Course. At that time he could barely read and write. He is now overseer of the card room for the Marion Manufacturing Co., and his salary has been increased $1.75 a day.

NOW PARTNER

Erhard M. Mayer, 1731 Milan St., New Orleans, La., was clerking in an office when he enrolled with the I.C.S. for the Cotton Carding and Spinning Course. He is at present in partnership with his brothers, running the National Hosiery Mills, an enterprise which he has helped to establish.

125 PER CENT. INCREASE

Reg. P. Jackson, Yorkville, S. C., was working as a second hand in the spinning room before taking up his Cotton Carding and Spinning Course with the I.C.S. He would not sell at any price his Course which has made him overseer of spinning and twisting for the Neely Manufacturing Co., at an increase in salary of 125 per cent.

ADVANCEMENT CAME THROUGH HIS COURSE

C. C. Tate, Box 5, Cliffside, N. C., had received very little education and was earning only small wages in the card room when he enrolled with the I.C.S. Had it not been for his Cotton Carding and Spinning Course, he would still be earning that small salary, he says. With the help of his Course he has become overseer in the card room of the Cliffside mills, the largest gingham manufacturing plant in the South.

IT PAID

Aloysius A. Dankel, Coplay, Pa., declares that it paid him to subscribe for our Complete Textile Designing Course. He was a loom fixer when he enrolled with the I.C.S., but he is now foreman weaver for the John H. Meyer Silk Co. His wages have been considerably increased.

WORTH TWICE THE PRICE

The Cotton Carding and Spinning Course, for which W. B. Cogart, Roxboro, N. C., enrolled, has been worth to him twice what he paid for it. He was then earning ordinary wages. He became assistant superintendent of the Roxboro Cotton Mills, earning nearly twice as much.

Now an Officer of the Company

I can recommend the Complete Woolen Course, for which I enrolled with the International Correspondence Schools, to any one anxious to improve his position. I received my practical knowledge in the mill and at the same time find your Bound Volumes are of considerable help to me. I was earning small wages as a bookkeeper when I first enrolled, but have now become the secretary and treasurer of the Slingsby Manufacturing Co., and also the manager of our six-set blanket mill, employing 225 persons.

John B. Varey,
Brantford, Ontario, Can.

SALARY NEARLY DOUBLED

N. H. McGuire, Fort Mill, S. C., was a second hand having but little education when he enrolled with us. He now has charge of weaving for the Fort Mill Manufacturing Co., at a salary nearly double what he received at the time of enrolment.

GAINED PROMOTION—SALARY INCREASED

A. R. Drake, Collegepark, Ga., has been promoted from second hand to overseer and his salary has been increased $40 a month, since he completed the Cotton Carding and Spinning Course, for which he subscribed with the I.C.S. He is now employed in the Gate City hosiery mill and is proud of his diploma.

SALARY INCREASED 150 PER CENT.

John Bauer, 325 Earle St., New Bedford, Mass., would still be fixing looms had it not been for his Complete Textile Designing Course with the I.C.S. He is now overseer for the New Bedford Cotton Mills Co., having organized his department when the new mill started. His salary has been increased about 150 per cent. He says his I.C.S. Course did it.

GRADUATE RECEIVES 300 PER CENT. INCREASE

R. H. Armfield, Greensboro, N. C., has been promoted to the position of overseer of carding for the Proximity Manufacturing Co., at White Oak Mills, and his salary has been increased more than 300 per cent. since his enrolment with the I.C.S. for the Cotton Carding and Spinning Course.

BECAME SUPERINTENDENT

C. N. Steed, Rockhill, S. C., was an overseer when he took out his Course in the Theory of Textile Designing. He says this has proved of immense benefit to him, since he has now become superintendent of the Highland Park Manufacturing Co., employing 450 persons. His salary, of course, has been greatly advanced.

SALARY DOUBLED

W. R. Bostian, China Grove, N. C., says that our Cotton Warp Preparation and Plain Weaving Course has advanced him to the position of head loom fixer. His salary has been nearly doubled since he enrolled.

Now Secretary and Treasurer of the Randolph Manufacturing Co.

When I enrolled with the I.C.S. I was employed as shipping clerk by the Randolph Manufacturing Company of Franklinville. Later on I became bookkeeper, still pursuing my studies at odd times.

The instruction I received from my Course has been of much assistance to me. In fact, I feel the Course was indispensable. It has proved far more valuable and useful than my most sanguine expectations.

Since obtaining my Diploma I have become Secretary and Treasurer of the Randolph Manufacturing Company, increasing my income about 500 per cent.

Hugh Parks, Jr.,
Franklinville, N. C.

MULTIPLIED BY TWO

H. G. McNish, 50 Park St., Ware, Mass., held a position as card grinder at the time he enrolled with the I. C. S. for the Cotton Carding and Spinning Course. At present he is employed by the Otis Co. as overseer, and his salary has been multiplied by two.

THREE TIMES HIS FORMER SALARY

E. P. Knowles, Main St., Langley, S. C., was making $1.50 a day fixing fly frames, when he began to study our Cotton Warp Preparation Course. He has advanced to the position of overseer for the Langley Manufacturing Co. He says he could not have made a success of his work if he had not taken our Course.

PROFITABLE STUDY

Willis Herring, Crichton, Ala., could read and write but knew little of arithmetic when he enrolled with the schools for the Cotton Carding and Spinning Course. At that time he was a section hand working for 90 cents a day. His Course not only helped him in his work but improved his general education as well. He is now overseer of spinning with the Mobile Cotton Mills. His salary has been more than doubled. He says if it had not been for his Course he would still be running a section.

WORTH WORKING FOR

R. F. Harris, Lowell, N. C., has been so greatly benefited by completing our Cotton Carding and Spinning Course, that he wishes every boy in the cotton mills could take advantage of an I. C. S. Course. His Course has raised him from a position as operative to that of assistant superintendent of the Lowell Cotton Mills.

DID HIM A WORLD OF GOOD

Christopher J. Wilson, 309 North 14th St., New York, N. Y., says that his Theory of Textile Designing Course with the I. C. S. did him a world of good. He was employed as finish-percher in the Assabeth Mills at the time of enrolment with the I. C. S.; before finishing the Course he became fabric examiner at a salary more than doubled.

FOUR TIMES HIS FORMER SALARY

J. F. Tidwell, La Grange, Ga., could not add up a column of figures correctly and had received but little education at the time he enrolled with the Schools for the Cotton Warp Preparation and Plain Weaving Course. He says that this secured for him the position of overseer of weaving for the Unity Cotton Mills, increasing his salary 400 per cent.

The Gateway to Success

When I enrolled with the International Correspondence Schools I occupied the position of loom fixer. Since then I have become general superintendent of the Ashcraft Cotton Mills, and my salary has been increased more than 400 per cent. I think your method is the gateway to success for a young man that wants to rise and who is not able to stop work to attend a school. It is undoubtedly the best way for a young man or a young woman to get the practical part of manufacturing, together with the technical part, without losing their positions. I am ever ready to speak a word in behalf of your grand and noble institution, which is calculated to lead the working classes to the top, if they will only grasp the golden opportunity and apply themselves; for advancement is sure to come to those who prove their worth.

R. J. Brown,
Florence, Ala.

SPARE-TIME STUDY IS PROFITABLE

G. W. Rollins, Box 44, Caroleen, N. C., was working as a second hand when he enrolled with the I.C.S. for the Cotton Warp Preparation and Plain Weaving Course. He is now assistant superintendent at a big increase in salary.

NOW SUPERINTENDENT

A. T. Brown, Rockhill, S. C., was a second hand in the cotton mill when he enrolled for the Special Cotton Course. He is now superintendent of the Aragon Cotton Mills and his salary has been increased fourfold.

HOLDS HIS POSITION THROUGH HIS COURSE

H. Dietrich, Fleetwood, Pa., recommends the Complete Textile Designing Course, for which he subscribed with the I.C.S. to any one who is ambitious to advance himself. He was working as a twister when he enrolled, but his Course advanced him to his present position as superintendent of the Fleetwood Silk Co., with an increase in salary of about 80 per cent.

HE WAS AMBITIOUS

At the end of 18 years' work in the cotton mills, Henry R. Bolton, Box 113, McColl, S. C., was only a fly-frame tender. At that time his ambition to succeed took hold of him and he remembered that he had seen an I.C.S. advertisement. He enrolled for the Cotton Carding and Spinning Course and devoted every spare moment to study. Within 2 months he was made a card grinder, and within a year was given another promotion. For the past 5 months he has been overseer of carding for the Marlboro Manufacturing Co., and his salary has been doubled.

NOW SUPERINTENDENT

O. L. Wagstaff, Thomasville, N. C., was earning $1 a day in a carding mill when he enrolled for the Cotton Carding and Spinning Course. He is now superintendent of the Amazon Cotton Mills Co., employing 126 persons. His salary has been increased several hundred per cent.

A YOUNG MAN'S PROMOTION

J. C. Jolly, Valmead, N. C., was working as a band boy when he enrolled with the I.C.S. for the Cotton Carding and Spinning Course. He now has full charge at night of the Moore Cotton Mill Co. mill at Lenoir, N. C.

Salary Increased 300 Per Cent.

There is nothing better in this world for any young man who is trying to get ahead in the world, as I have found it a good thing and I feel much pleased over your instructions; I think that this is the only way to learn. I encourage every young man to invest his spare moments in this way. Before I enrolled with the School of Textiles my education was not worth mentioning in regard to calculations, etc. But today I can say that I have learned a great deal from your Schools in regard to calculations, weaves, and machinery. And if I had not enrolled with your Schools I would not have been able to hold my present position today. I advise all men who wish to make this world a success to start in at once and spend a few moments each day at this study, which they will not regret in the future. I have found it a grand study. I have obtained a good position and my salary has increased 300 per cent. since I have enrolled with the Schools. After holding a position as designer I can understand how much your instructions have taught me in every way in regard to calculations, weaves, etc..

O. C. Drechsler,
Box 1121,
Maynard, Mass.

NOW OVERSEER

N. B. Hill, 306 W. Blount St., Kinston, N. C., was working as a second hand in the spinning room when he began to study with the I.C.S. on our Cotton Carding and Spinning Course. This has enabled him to become overseer of spinning for the Caswell Cotton Mill.

NOW SECRETARY AND TREASURER

J. H. Chambliss, West, Tex., was a bookkeeper when he enrolled with the I.C.S. for the Cotton Carding and Spinning Course. He is now secretary and treasurer of the Brazos Valley Cotton Mills, receiving four times as much salary as he did at the time of enrolment.

HIS COURSE HELPED

Wm. Cain, Pine Meadow, Conn., had attended school for only a short time in his eleventh and twelfth years. While he was earning ordinary wages he enrolled with the Schools for the Cotton Carding and Spinning Course. He is now overseer of carding and spinning for D. B. Smith Sons.

NOW SUPERINTENDENT

A. I. McDonald, St. Paul, N. C., had reached the second grade only in public school when he went into the cotton mill, at the age of 11. When 28 years old, he enrolled with the I.C.S. for the Cotton Carding and Spinning Course. He is now the superintendent of the St. Paul Cotton Mill Co., employing 200 persons.

WOULD NOT SELL HIS COURSE FOR $1,000

B. W. Bingham, Ozark, Ala., had only 3 months' schooling before starting work in the cotton mills. He could read but little and could hardly write at all, when he enrolled with us for the Cotton Carding and Spinning Course, from which he graduated. At the time of enrolment he was working as a second hand. He is now general superintendent of the Ozark Cotton Mills and his salary has increased about 900 per cent. He says that if he could sell it for $1,000 he would not take the money and be without his Course.

NOW PROPRIETOR

Rollin R. Rhodabarger, Keyser, W. Va., was employed as an overseer when he enrolled with the I.C.S. for the Woolen Carding, Spinning and Weaving Course, from which he graduated. He is now superintendent, Woolen Department, Patchett Worsted Co., being also a stockholder in that Company. His salary of course has been largely increased.

His Early Promotion Due to the I. C. S.

At the time I enrolled in the I. C. S. for a Complete Cotton Course, I was boss weaver at the Elmira Cotton Mills. Something like one year afterward I was promoted at the same mill to superintendent. I am sure that my early promotion was due to my enrolment in your Schools, and I am equally confident that my ability to fill my position successfully is due to the training I received from you. I had only a very simple education, such as I could get from the old field free schools, up to 10 years of age when I enrolled. The training I received in mathematics alone has been worth the expense and time spent on the entire Course. I was earning the usual wages when I first enrolled. I now earn twice as much, with a nice house furnished free.

John G. King,
Burlington, N. C.

SALARY INCREASED 500 PER CENT.

A. H. McCarrel, Bath, S. C., began the study of our Complete Cotton Course while serving as paymaster for the Aiken Manufacturing Co. He is now general manager of the same company, and also of the Seminole Manufacturing Co., employing about 700 persons. Since enrolment his income has increased more than 500 per cent.

SUPERINTENDENT OF A LARGE MILL

T. E. Gardner, Greensboro, N. C., had been set to work at the age of 13, and had received but little education at the time of his enrolment for the Cotton Carding and Spinning Course. At the time he was a night overseer. Since obtaining his diploma he has become superintendent of the White Oak mills, employing 1,500 persons.

225 PER CENT. INCREASE

Frank E. Heymer, Lando, S. C., was a designer when he enrolled with the I.C.S. for the Complete Cotton Course. Although he had trouble to learn English his Course has enabled him to become superintendent of the Manetta Mills and his salary has increased 225 per cent.

BECAME SUPERINTENDENT

Robt. Wm. Boys, New Market, N. H., started to work in the cotton mills at the age of 10. He was employed as an overseer of weaving at the time he enrolled with us for the Complete Cotton Course. He is now superintendent of the New Market Manufacturing Co., employing 900 hands.

AN AMBITIOUS STUDENT

C. C. Poindexter, Box 539, Winston-Salem, N. C., was working for the Chatham Manufacturing Co. as a stenographer. Being ambitious he took up a Course with the I. C. S. in Woolen Carding, Spinning and Weaving. When the superintendent resigned he was immediately promoted to his position with an increase of 50 per cent. in salary, which has since been increased by one-third.

STEPPING UPWARD

J. Robie Cove, 26 West 6th St., Lowell, Mass., enrolled with the Schools at the age of 16 for the Complete Cotton Course. He had just gone to work as an office boy. Since then he has taken the following steps upward: apprentice, machinist, toolmaker, inspector, draftsman, mill designer, assistant mechanical superintendent, and now master mechanic for one of the largest cotton mills in New England. He says that the rapidity of his advancement was due to the assistance received from his Course and the Library of Technology.

Rapid Promotion Followed Study

When I began studying your Course, I had charge of a beaming room and was doing a little designing for plain looms. I had secured a few books and was reading them, when I decided that a Course in your Schools was the thing that would fit me for advancement. I assure you that from the start your instruction gave me more confidence; I was promoted so fast and had so much new work to do that I had to postpone the last two lessons of my Course for some time. Correspondence instruction is beneficial in many ways. It develops your ideas, gives you more confidence in yourself, and consequently increases your ability. Your training has been very beneficial to me, and I recommend it to all who wish to fit themselves for advancement. I am now getting along very nicely and every day can see the advantages of having taken the Course. I am now one of the proprietors of the Montgomery Worsted Mills.

BENJ. B. CROWTHER,
Conshohocken, Pa.

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