MILL ENGINEERING

(PART 3)

COTTON-MILL PLANNING

INTRODUCTION

1. Perhaps no portion of an expert cotton-mill engineer's work is of more importance than that of planning the layout of the machinery. This is not a matter to be attempted by inexperienced persons, but is a task in which the services of an expert are of the utmost value. The construction of mill structures and the installation of the machinery constitute the principal duties of the textile-mill engineer, a profession that is followed by many able men in different parts of the country. For a mill official to attempt to perform this work, especially at the commencement of a new enterprise, is very unwise, and the few hundred dollars of expert's fees that would be saved would probably be expended over and over again before the mill was in operation, in expensive construction, waste space, the provision of an excessive number of machines, or unsuitable machinery, in addition to the subsequent and constant unnecessary expense of operating the plant. It is, of course, unnecessary to engage the services of an outside expert if some official of the mill is a competent and trained mill engineer, or if the construction to be attempted is merely an extension of an existing plant where former plans can be followed, or where previous work is to be duplicated. In many cases a knowledge of the method of planning the machinery of a mill is of value to a superintendent in rearranging the machinery in various rooms, in which cases the services of a mill engineer are not requisite.

PRELIMINARY CONSIDERATIONS

2. In order 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. There are several important matters that should be carefully considered at the outset in connection with planning a cotton mill; some of these are the following: (1) The type of mill, whether a yarn mill or cloth mill; (2) the class of goods to be made; (3) the size of the mill, as determined by the number of spindles; (4) the machines necessary to be operated in connection with this number of spindles in order to produce the goods desired; (5) the space that this machinery will occupy; (6) the extra expense to be incurred in addition to the building and equipment of the mill—the land to be purchased, tenement houses to be erected, capital to be left available for the operation of the mill, etc.; (7) the total cost of the undertaking.

When these matters are decided it may be found that financial considerations will greatly affect the original plans and cause the revision of the entire scheme. It is important, therefore, to plan each of the above-named subjects and have specifications for them submitted to and approved by the proprietors or directors before commencing to plan the building. In fact, a preliminary consideration of these leading points and their relation to one another is one of the most important duties of a mill engineer.

3. Type of Mill.—There are several types of cotton mills, and it may be decided to construct either a yarn mill, for the production of cotton yarns only, the product to be disposed of to the trade; or a cloth mill, for the production of woven fabrics. If a yarn mill is decided on, it may be intended to produce carded yarns only, combed yarns only, or both carded and combed yarns. It may be a yarn mill producing only frame-spun yarns or mule-spun yarns, or a warp-yarn mill, a hosiery-yarn mill, or a combination of any or all of these. In any case the character of the product desired will have a material influence on the equipment necessary for the successful and economical operation of the plant. If the mill is to be a cloth mill it will probably be a yarn mill also, as the majority of cloth mills produce their own yarns. It may or may not be intended to bleach, dye, or finish the woven products, but if it is, bleaching, dyeing, or finishing works must be included in the mill plans.

4. Class of Goods.—Assuming that a cloth mill has been decided on, the class of goods to be manufactured is the next most important consideration, as a mill equipped with machinery for making coarse goods is unsuitable for the manufacture of fine fabrics; that is, without very extensive changes. It is not out of place here to refer to a few of the leading makes of cotton cloth, the preparation for the manufacture of which comes within the duties of the mill engineer.

Coarse goods, such as are now generally manufactured in the South and in some of the older mills in the New England and Middle States, include principally what are known as *sheetings*, *drills*, *osnaburgs*, and similar fabrics. **Sheetings** are usually from 2.85 to 4 yards to the pound, 30 to 36 inches in width, and made from yarns ranging from 12s to 24s. **Drills** are usually about 2.85 or 3 yards to the pound, 30 inches in width, and made from 12s to 15s yarn. **Osnaburgs** are the same width as drills but are made from much coarser yarns and average about 2 yards to the pound.

Another class is **medium-weight goods,** the best known variety of which is **print cloth,** about 28 inches in width, weighing 7 yards to the pound, and made from 28s warp and 36s filling yarns. In this class is also a wide variety of shirtings and irregular print cloths, varying from 4 to 8 yards to the pound and from 28 inches upwards in width, while the numbers of the yarns range from 28s to 40s. Many mills are engaged on fabrics of this character.

Still another classification is that of **fine goods,** made in all weights from 8 to 20 yards to the pound and higher, with various weaves, and from various numbers of yarns up to 100s, and even finer.

In order to have a standard to work on, it will be assumed that it is required to lay out the machinery for a mill to make 4-yard goods, 39 inches wide, 28s warp and 36s filling, 72 sley, and 80 picks to the inch.

5. Size of Mill.—The size of the mill is the next consideration. Cotton mills are usually spoken of by the number of spindles, and in this case it will be assumed that 10,000 spindles have been decided on as the size of the mill. It will also be assumed that the capital to be invested amounts to $180,000, of which $20,000 is to be used for the purchase of the land and the erection of tenement houses for the operatives, and $20,000 to be reserved for working capital. It will also be understood that the mill will be operated by steam power and that there are no unusual difficulties in connection with the engineering of the work because of an unsuitable location.

ORGANIZATION

6. There now remain three important matters to 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; (3) the space that is to be provided in the mill building to accommodate this machinery. The first of these, namely, the organization of the mill, must be determined before the others can be decided on.

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. To figure out such an organization, it is necessary to have a knowledge of the processes of manufacture through which the raw cotton must pass. A suitable style of organization to make the numbers of yarn desired, namely, 28s and 36s, and the weight of goods required is as follows.

The counts of the warp yarn to be made is 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.

7. For the counts of yarn to be spun, the lap from the finisher picker should weigh from 12 to 14 ounces per yard; in this case a 13-ounce 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-ounce 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.

Table I gives the hank of laps commencing with a 12-ounce lap and ending with a 16-ounce lap.

TABLE I

HANK OF LAPS

Weight of Lap per Yard Ounces	Hank	Weight of Lap per Yard Grains
12	.00158	5,250
12½	.00152	5,468¾
13	.00146	5,687½
13½	.00141	5,906¼
14	.00136	6,125
14½	.00131	6,343¾
15	.00126	6,562½
15½	.00122	6,781¼
16	.00119	7,000

The hank of different card slivers is given in Table II.

TABLE II

HANK OF CARD SLIVERS

Grains per Yard	Hank
50	.1666
55	.1515
60	.1388
65	.1282
70	.1190

The 13-ounce lap is therefore .00146 hank, and is equal to 13 × 437.5 (grains in 1 ounce) = 5,687½, grains to the yard. This, when operated on by a 100 draft at the card gives, mathematically, a 56.87-grain sliver, but as there is at least 3 per cent. of waste at the card, the actual weight of the sliver delivered will not exceed 55 grains. 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-grain sliver, or .151-hank, since if the doublings equal the draft the weight of the sliver will remain unchanged.

8. The next question to be considered is the series of drafts between the sliver delivered at the third drawing frame and the yarn. 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; that is, the draft of the slubber should be 4, or thereabouts; of the intermediate and roving frames, approximately 5 and 6, respectively; and of the spinning frame, about 12. 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.

9. 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.

10. Summary.—The complete organization is shown in the following summary: Finisher picker, 13-ounce lap, .00146 hank; cards, draft 100, 3 per cent. loss in waste, 55-grain 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

11. Calculation of Cotton Consumed.—The mill engineer is now in a position to determine the number of machines necessary for each process, an item that depends on the productive capacity of each machine and the amount of stock to be manipulated. The weight of the product per spindle at each process is determined largely by the hank of the sliver or roving, or the counts of the yarn, which is the reason for the necessity of working out the organization of the mill as a preliminary to estimating the amount of machinery required.

In order to figure on 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

TABLE III

PRODUCTION OF WARP SPINNING FRAMES

Number of Yarn	Weight per Yard Grain	Twist per Inch	Revolutions of Front Roll per Minute	Revolutions of Spindle per Minute	Hanks per Day per Spindle	Pound per Day per Spindle	Number of Yarn
10	.833	15.02	146.2	6,900	8.295	.829	10
12	.694	16.45	143.2	7,400	8.214	.685	12
14	.595	17.77	139.7	7,800	8.013	.572	14
16	.521	19.00	137.3	8,200	7.875	.492	16
18	.463	20.15	134.2	8,500	7.698	.428	18
20	.417	21.24	131.8	8,800	7.560	.378	20
22	.379	22.27	128.6	9,000	7.376	.335	22
24	.347	23.27	124.5	9,100	7.141	.298	24
26	.320	24.22	122.2	9,300	7.085	.272	26
28	.297	25.13	117.8	9,300	6.830	.244	28
30	.277	26.02	115.0	9,400	6.668	.223	30
32	.260	26.87	112.4	9,500	6.516	.205	32
34	.245	27.69	109.1	9,500	6.326	.186	34
36	.231	28.50	106.1	9,500	6.218	.173	36
38	.219	29.28	103.2	9,500	6.048	.159	38
40	.208	30.04	100.6	9,500	5.896	.147	40
42	.198	30.78	98.2	9,500	5.755	.137	42
44	.189	31.50	96.0	9,500	5.626	.128	44
46	.181	32.21	93.8	9,500	5.556	.121	46
48	.174	32.90	91.9	9,500	5.443	.113	48
50	.166	33.58	90.9	9,600	5.384	.108	50

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.

Table III gives the production of warp spinning frames per spindle per day, making suitable allowances for all stoppages for doffing, oiling, cleaning, etc.; Table IV gives the

TABLE IV

PRODUCTION OF FILLING SPINNING FRAMES

Number of Yarn	Weight per Yard Grain	Twist per Inch	Revolutions of Front Roll per Minute	Revolutions of Spindle per Minute	Hanks per Day per Spindle	Pound per Day per Spindle	Number of Yarn
10	.833	10.27	161.2	5,200	8.945	.894	10
12	.694	11.26	158.2	5,600	8.778	.731	12
14	.595	12.16	156.9	6,000	8.706	.622	14
16	.521	13.00	155.4	6,350	8.719	.545	16
18	.463	13.79	152.2	6,600	8,540	.476	18
20	.417	14.53	148.8	6,800	8.444	.422	20
22	.379	15.24	146.1	7.000	8.290	.376	22
24	.347	15.92	139.9	7,000	7.938	.331	24
26	.320	16.57	138.2	7,200	7.927	.305	26
28	.297	17.20	134.1	7,250	7.692	.275	28
30	.277	17.80	129.6	7,250	7.514	.250	30
32	.260	18.38	126.3	7,300	7.323	.229	32
34	.245	18.95	122.4	7,300	7.097	.208	34
36	.231	19.50	119.1	7,300	6.980	.194	36
38	.219	20.03	117.6	7,400	6.892	.181	38
40	.208	20.55	115.4	7,450	6.835	.171	40
42	.198	21.06	113.3	7,500	6.711	.160	42
44	.189	21.56	110.7	7,500	6.557	.149	44
46	.181	22.04	108.3	7,500	6.414	.139	46
48	.174	22.52	105.9	7,500	6.272	.131	48
50	.166	22.98	103.9	7,500	6.218	.124	50

production of filling spinning frames. Referring to these tables, the production of a warp spinning frame on 28s yarn is .244 pounds per spindle per day, which equals 1,220 pounds per day for 5,000 spindles. The production of a filling spinning frame on 36s yarn is given as .194 pound per spindle per day, which equals 970 pounds per day for 5,000 spindles, making a total production of warp and filling yarn of 2,190 pounds 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 pounds of yarn. Allowing for 5 per cent. of waste in the various machines between the finisher picker and the spinning frames gives a total of 13,831 pounds (13,140 ÷ .95 = 13,831.578) of cotton that must be passed through the finisher picker per week, and allowing 5 per cent. more for waste in the picking processes will necessitate 14,559 pounds (13,831 ÷ .95 = 14,558.947) being passed through the breaker picker per week.

PREPARATORY PROCESSES

12. Considering first the number of machines necessary in the preparatory processes, a bale breaker will handle 15,000 pounds of cotton per day of 10 hours, or 90,000 pounds per week; therefore, one bale breaker will be more than sufficient for a mill of this size. An automatic feeder and opener will handle 3,000 pounds per day of 10 hours, or 18,000 pounds per week; consequently, only one machine is necessary, since the mill is to consume only 14,559 pounds of cotton per week. A breaker picker will handle 500 pounds per hour, which, allowing for the time consumed in cleaning, etc., will give a total production of about 25,000 pounds per week, 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 pounds per week, allowing from 6 to 10 hours for cleaning. In this case about 14,500 pounds 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, and as these machines are somewhat expensive, it is better to economize here.

CARDING AND SPINNING

13. Cards.—The number of cards required to deal with 13,831 pounds 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 card will be used, the production of which varies in different mills, from 300 pounds for very fine yarns to 1,000 pounds per card per week for coarse yarns. In this case, 28s and 36s yarns are to be spun, and as 800 to 850 pounds per week is an appropriate production for such yarns, seventeen cards will be required to card 13,831 pounds of cotton per week.

14. Drawing Frames.—Dealing next with the drawing frames, the front roll of the machine is usually $1\frac{3}{8}$ inches in diameter and makes about 360 revolutions per minute. The speed of delivery of the machine, therefore, is 43.197 yards per minute $\left(\frac{360 \times 1.375 \times 3.1416}{36} = 43.197\right)$.

This result multiplied by the weight of the card sliver per yard, 55 grains, and by 3,600, the number of minutes per week, gives 8,553,006 grains as the total number of grains produced by one delivery in a week. This divided by 7,000, the number of grains in 1 pound, gives nearly 1,222 pounds, which divided into 13,831, the number of pounds of cotton to be handled in a week, gives eleven as the number of deliveries 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.

15. Slubbers.—The next machine through which the cotton passes in the proper sequence of operations is the slubber; the production of slubbers is shown in Table V, which is formulated for a machine with a traverse of 11 inches and the full bobbins $5\frac{1}{2}$ inches in diameter.

The hank of the slubbing, or roving from the slubber, as figured in the organization of the mill, is .68. Referring to Table V, a .70-hank roving, which is near enough to a .68-hank roving for practical purposes, is produced by the slubber at the rate of 15.86 pounds per day, or 95.16 pounds per week, per spindle. This, divided into 13,831 pounds, 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; therefore, in this case it would be best to have two slubbers, each with 72 spindles.

TABLE V

PRODUCTION OF SLUBBERS

Hank Roving	Revolutions per Minute of Front Roll $1\frac{1}{4}$ Inch Diameter	Pounds per Day per Spindle
.3	270	37.36
.4	234	29.00
.5	212	23.36
.6	194	19.14
.7	178	15.86
.8	166	13.44
.9	156	11.54
1.0	148	10.08
1.1	141	8.88

16. Intermediate Frames.—The production of intermediate frames is shown in Table VI, which is formulated for intermediates with a 9-inch traverse and a diameter of $4\frac{1}{2}$ inches for the full bobbin. Referring to this table and considering that a 1.90-hank roving is near enough to a 1.87-hank roving for practical purposes, the production of the intermediate frames will be 5.31 pounds per day per spindle, or 31.86 pounds per week. This amount divided into 13,831 pounds gives 434 spindles, and as these intermediate frames are built in multiples of 6, five frames of 90 spindles each will be required.

TABLE VI

PRODUCTION OF INTERMEDIATES

Hank Roving	Revolutions per Minute of Front Roll $1\frac{1}{4}$ Inch Diameter	Pounds per Day per Spindle
.9	212	13.08
1.0	202	11.65
1.1	192	10.44
1.2	185	9.47
1.3	177	8.57
1.4	170	7.81
1.5	165	7.20
1.6	159	6.60
1.7	154	6.07
1.8	150	5.67
1.9	147	5.31

TABLE VII

PRODUCTION OF ROVING FRAMES

Hank Roving	Revolutions per Minute of Front Roll $1\frac{1}{8}$ Inch Diameter	Pounds per Day per Spindle
2.0	193	5.33
2.5	171	4.02
3.0	157	3.20
3.5	145	2.61
4.0	136	2.18
4.5	128	1.85
5.0	122	1.60
5.5	116	1.40
6.0	111	1.23

17. Roving Frames.—Table VII gives the production of roving frames with a 7-inch traverse and a diameter of $3\frac{1}{2}$ inches for the full bobbin. In this table, the production for a 6-hank roving is shown as 1.23 pounds per day, or 7.38 pounds per week, which when divided into 13,831 gives 1,874 spindles. Fourteen frames of 136 spindles each would be most suitable.

18. Spinning Frames.—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 forty-eight frames, each with 208 spindles, would be used, giving a total of 9,984 spindles in the mill.

WARP PREPARATION

19. Spoolers.—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 revolutions per minute, 20 pounds per spindle per week may be taken as an average production. The production of warp yarn was previously calculated as 1,220 pounds per day, or 7,320 pounds 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.

20. Warpers.—The production of warpers is given in Table VIII, and for 28s yarn with 440 ends on a beam is 2,425 pounds per week. Dividing this into 7,320, the number of pounds of warp yarn produced per week, gives three warpers to be installed.

21. Slashers.—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; but in larger mills where a number of slashers are required, the

TABLE VIII

PRODUCTION OF WARPERS

Number of Yarn	Number of Ends				
	260	300	340	380	440
	Pounds Warped in 60 Hours				
10	4,011	4,629	5,246	5,863	6,789
12	3,343	3,857	4,372	4,885	5,657
14	2,865	3,305	3,747	4,188	4,849
16	2,507	2,893	3,279	3,664	4,243
18	2,229	2,571	2,915	3,257	3,771
20	2,005	2,315	2,623	2,931	3,395
22	1,823	2,104	2,385	2,665	3,085
24	1,671	1,925	2,185	2,443	2,829
26	1,543	1,780	2,017	2,255	2,611
28	1,433	1,653	1,873	2,094	2,425
29	1,383	1,596	1,809	2,021	2,341
30	1,337	1,543	1,749	1,955	2,263
32	1,253	1,447	1,639	1,832	2,121
34	1,180	1,361	1,543	1,725	1,997
36	1,115	1,285	1,457	1,629	1,885
38	1,056	1,219	1,380	1,543	1,787
40	1,003	1,157	1,311	1,465	1,697
44	912	1,052	1,192	1,332	1,543
50	806	925	1,049	1,171	1,357

actual number of machines necessary cannot be absolutely decided until the number of looms to be operated is determined.

WEAVING AND CLOTH FINISHING

22. Looms.—Dealing now with the weaving, it is first necessary to find the production per week of a loom weaving goods having 80 picks per inch. This may be found by the following rule:

Rule.—*Multiply the speed of the loom by the minutes per week (3,600), and divide by the product of the picks per inch in the fabric and the inches in 1 yard (36). From this result deduct 10 per cent. to allow for the time the loom is stopped for putting in warps, etc.*

In this case it is assumed that the looms will run 185 picks per minute; therefore, the production of a loom per week will be 208.125 yards, as shown by the following calculation: $\frac{185 \times 3,600}{80 \times 36} = 231.25$. 10 per cent. of 231.25 is equal to 23.125; therefore, $231.25 - 23.125 = 208.125$ yards.

The production of warp yarn per day is 1,220 pounds, or 7,320 pounds per week, to which must be added 10 per cent. to allow for the increased weight occasioned by the size, making 8,052 pounds of warp yarn to be woven per week.

The production of filling yarn is 970 pounds per day, or 5,820 pounds per week, which, added to the weight of the warp yarn, gives a total production for the weave room of 13,872 pounds per week. The weight of the cloth is 4 yards per pound; therefore, the yards of cloth to be woven per week will be $4 \times 13,872 = 55,488$ yards. Dividing this total yardage by the production of one loom (208.125 yards) gives practically 266 looms as the number necessary for the weave room.

23. 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.

BALANCE OF PRODUCTION

24. 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 most important point in connection with planning the equipment of a mill is to preserve this balance of production at every process, and when the machinery is installed and started at the speeds calculated to give the required products, the yarn and the cloth will be produced within a very small percentage of the amount determined by calculation.

After the mill has once been started and the machinery operated for a few months and thoroughly *limbered up*, a skilful superintendent with a good corps of overseers and help and a good quality of stock will often be able to increase the production at every process and attain better results than have been figured on, but the balance of the machinery will remain the same, for the improvement will be general throughout the whole of the mill. On the other hand, the opposite conditions to these will produce less than the amount calculated, but the deterioration will probably be general throughout the processes, and thus the balance of product be preserved.

Should it be necessary to change the character of the output of the mill at any time, this layout will not be suitable; for instance, in case coarser numbers of yarn are to be spun, there would be insufficient cards. For finer numbers there would be too many cards, and other changes would also be necessary in nearly every process.

SUMMARY

25. Table IX gives the complete list of machines for a 10,000-spindle mill on 4-yard 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.

TABLE IX

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	31′ 8″ × 3′ 2″ each
5 intermediates	29′ 5″ × 3′ 1″ each
14 roving frames	32′ 11″ × 2′ 11″ each
48 spinning frames	25′ 11″ × 3′ 3″ each
4 spoolers	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′

COST

MACHINERY

26. It is now possible to form an estimate of the cost of the machinery in the mill. In addition to the productive machinery, certain pieces of apparatus are necessary in connection with each and ought to be figured in with the machinery cost. For example, in connection with the breaker picker and opener a length of cleaning and of connecting trunk will be required, while in the card room there should be two card-grinding dead rolls, two card-grinding traverse, or Horsfall, rolls, two stripping rolls, a machine for clothing cards, and a flat grinding machine. In the spinning room, a banding machine for making spindle bands is useful, and in the weave room about four drawing-in frames will be necessary. This is outside of the list of regular mill supplies that will be needed.

Table X gives the approximate cost of the necessary machinery for a 10,000-spindle mill. The prices given must not be considered as absolutely correct, since machinery values vary from year to year. The table should be considered, however, as giving approximate prices and illustrating the method of arriving at the machinery costs of a mill rather than the exact cost of the machinery necessary for a 10,000-spindle mill.

TOTAL COST

27. Besides the cost of the machinery, there must be considered the cost of the building, engine and boilers, shafting, belting, mill supplies, fire-protection, plumbing, and similar expenses, as well as the amount reserved for land and tenement houses. The cost of the building, assuming that it will be constructed on the slow-burning principle, may be estimated at $20,000.

Other expenses may be estimated as follows: Engine, boilers, pump, shafting, and pulleys, $15,000; electric-light plant, $2,500; sprinkling system, heating, plumbing, and supplies, $10,000; miscellaneous and incidental expenses, including freight, erection of machinery, etc., $3,000; this gives a total cost for the mill building and equipment of $140,051. To this add $20,000 for the purchase of land and erection of tenement houses for the operatives, which brings the total cost to about $160,000, or $16 per spindle. The erection of tenement houses is not properly a charge on the cost of the mill and therefore might be omitted in figuring out the cost per spindle, but other unforeseen expenses would probably compensate for this item. With a

TABLE X

COST OF MACHINERY FOR A 10,000-SPINDLE MILL

Number of Machines	Cost
1 bale breaker and conveying apron	$ 450
1 automatic feeder and opener	500
1 breaker picker (two sections)	1,000
Cleaning and connecting trunk	300
1 intermediate picker	700
1 finisher picker	700
17 revolving-flat cards, $580 per card	9,860
2 card grinding dead rolls, $39 each	78
2 card-grinding traverse rolls, $57 each	114
2 stripping rolls, $15 each	30
1 machine for clothing cards	100
1 flat-grinding machine	190
First drawing, one frame, two heads, six deliveries each, $60 per delivery	720
Second drawing, one frame, two heads, six deliveries each, $60 per delivery	720
Third drawing, one frame, two heads, six deliveries each, $60 per delivery	720
2 72-spindle slubbers, $14 per spindle	2,016
5 90-spindle intermediates, $10 per spindle	4,500
14 136-spindle roving frames, $7 per spindle	13,328
48 208-spindle spinning frames, $3.25 per spindle	32,448
1 banding machine	125
4 100-spindle spoolers, $2.75 per spindle	1,100
3 warpers with creels, $250 per warper	750
20 section beams, $10 per beam	200
1 slasher	1,200
1 size kettle and overhead track	250
4 drawing-in frames, $13 each	52
266 looms, $60 per loom	15,960
1 sewing and rolling machine	90
1 cloth brusher	600
1 cloth folder	250
1 baling press	500
Total	$ 89,551

corporation capitalized at $180,000, this would leave a balance of about $20,000 for stocking the mill with cotton, starting it in operation, meeting the initial working expenses of the plant, and leaving a substantial balance for working capital.

The prices and figures given are, of course, estimates only, as many of the items depend on local conditions, while the prices of machinery and other equipments are subject to the fluctuations of the markets.

LAYOUT OF MACHINERY

28. The engineer is now in a position to submit a complete plan to the executive officers of the corporation, and when it has received their approval, the planning of the arrangements of the machinery can be undertaken. It will be assumed that a two-story mill with the monitor-roof construction, similar to that shown in Fig. 1 is to be erected, the engine room and boiler house to be one-story, annexed structures, as shown in the end elevation in Fig. 2. With such a mill, the best arrangement is to have the opening, picking, carding, and spinning departments on the first floor, and the warp preparation, weaving, and cloth room on the second floor, where the light will be better, on account of the monitor-roof of the mill. The first step in arranging the layout of the machinery for the mill is to cut pieces of cardboard or paper to correspond to the dimensions of, or floor space occupied by, each machine to the same scale as the floor plans of the mill. For example, if a machine is 16 feet long and 4 feet wide and the plans for the mill are drawn on the scale of $\frac{1}{4}$ inch to the foot, a piece of cardboard 4 inches long and 1 inch wide is prepared, and so on for the different sizes of machines. If there are ten machines all of one size, ten pieces of cardboard are cut; thus a collection of pieces of cardboard is made equivalent in number to all the machines in the mill.

29. The floor plans of each floor of the mill are then pinned down flat on a table and the pieces of cardboard

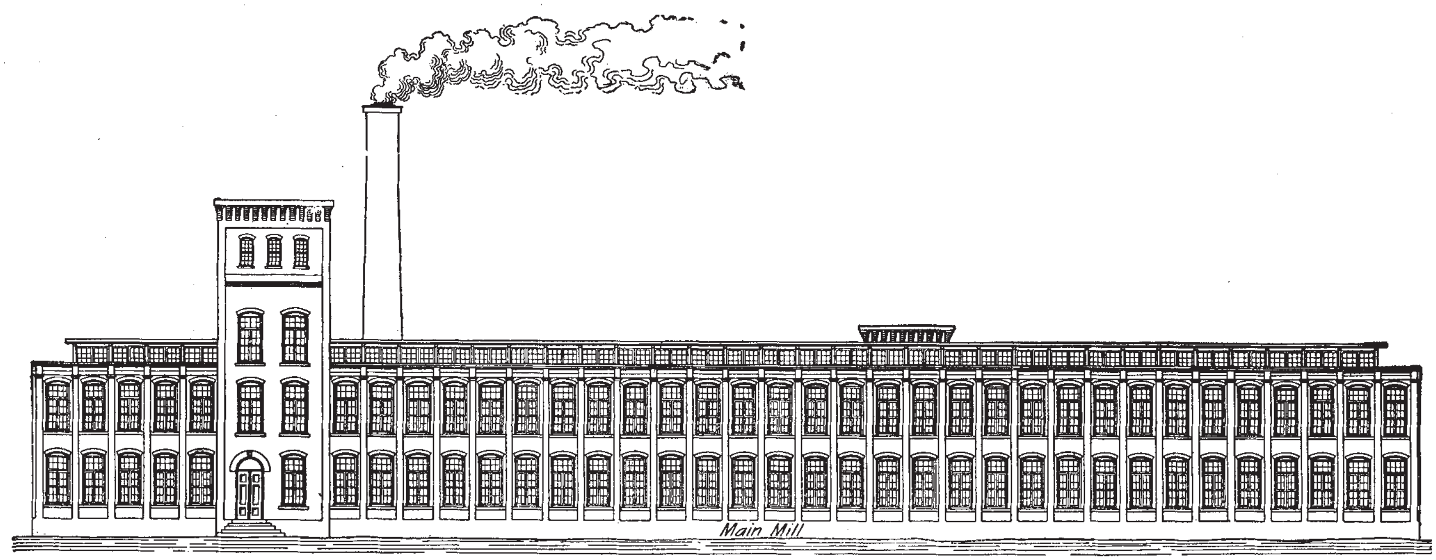

Fig. 1

Fig. 2

placed on them, avoiding columns and leaving adequate space for passageways and storage of material. The cardboard pieces can be moved around and tried in different positions and the spaces between them enlarged or reduced to provide for different widths of passageways between the machines, until the most suitable arrangement is determined, when the outlines of the slips are drawn in on the plans. This method will be found much superior to that of making one drawing after another, each showing the machinery in various positions, and will save considerable time. This is the method followed in Figs. 3 and 4, which are the first- and the second-floor plans of the mill shown in Figs. 1 and 2, showing the arrangement of the machinery for a 10,000-spindle mill, the number of machines being as figured. On these plans all the machinery has been accommodated and ample passageways allowed, as well as space for storing bobbins and other material. The machinery has also been arranged with a view to convenience in operation.

After the positions of the machines are determined and drawn in on the plans, a tracing of this drawing can be made and the lines of shafting shown running between and above the machines in the best positions for driving them, with the positions of the pulleys and couplings marked thereon. The mill plans are then practically complete, assuming that the drawings for the actual construction of the building have been made and accepted by the corporation.

MILL SUPPLIES

30. For the successful operation of each department of the mill, tools and other supplies are necessary. The following lists include supplies that are either necessary or convenient in the operation of the mill, but are by no means complete, since supplies necessary in one mill would not be necessary in others; many items that can be obtained locally have also been omitted from the lists.

31. Picker and Card Rooms.—One full-ironed picker truck for cotton bales; 1 lap scale (spring balance to weigh

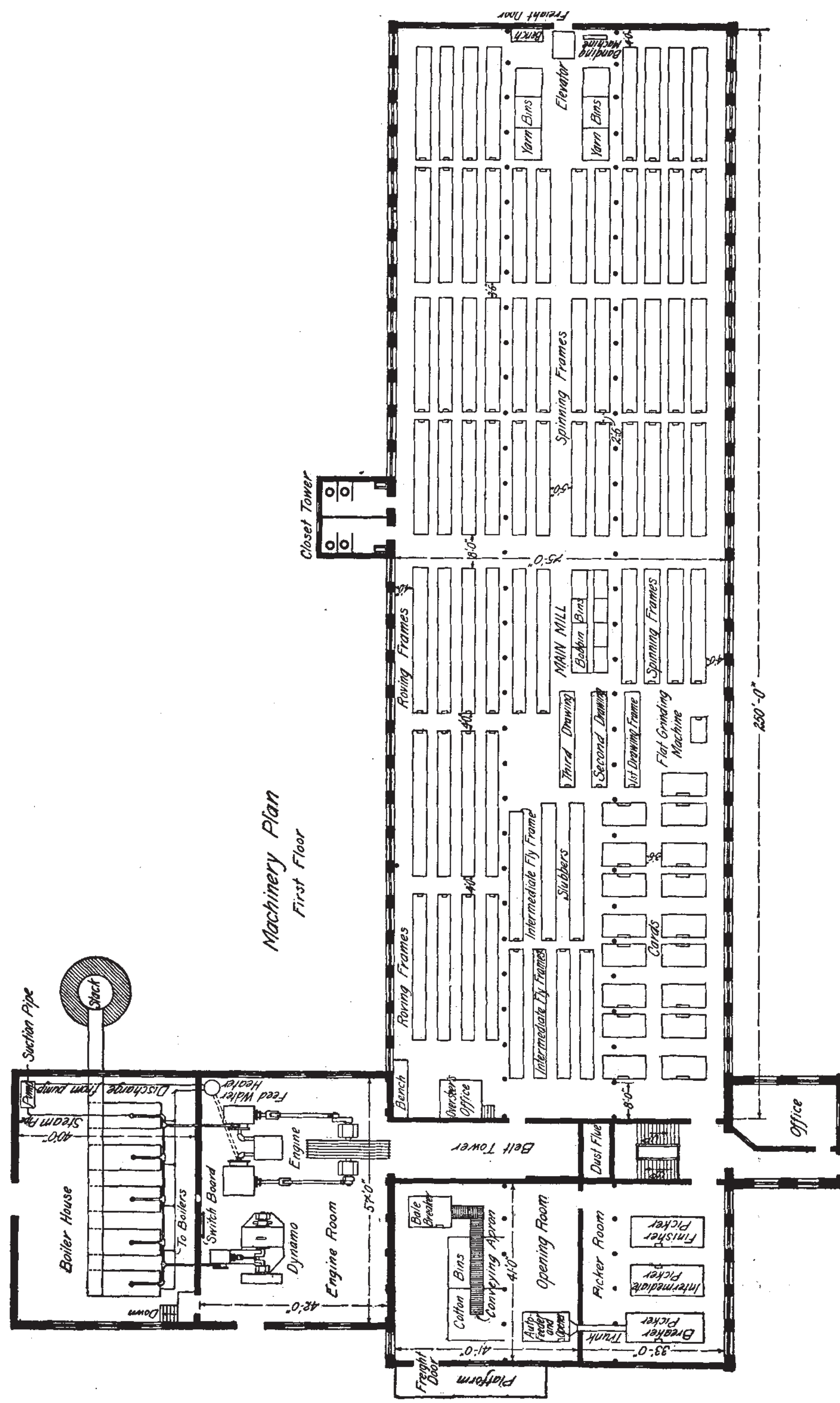
Machinery Plan
First Floor
Suction Pipe
Stack
Boiler House
Steam Pipe
Discharge from pump
To Boilers
Down
Feed Water Heater
Switch Board
Engine
Dynamo
Engine Room
Belt Tower
Dust Flue
Office
Bench
Overseer's Office
Roving Frames
Intermediate Fly Frames
Intermediate Fly Frame
Slubbers
Cards
Flat Grinding Machine
1st Drawing Frame
Second Drawing
Third Drawing
Bobbin Bins
MAIN MILL
Spinning Frames
Closet Tower
Yarn Bins
Elevator
Banding Machine
Bench
Freight Door
Bale Breaker
Cotton Bins
Conveying Apron
Opening Room
Auto Feeder and Opener
Trunk
Picker Room
Breaker Picker
Intermediate Picker
Finisher Picker
Freight Door
Platform
250'-0"
75'-0"
57'-0"
42'-0"
40'-0"
41'-0"
33'-0"

FIG. 3

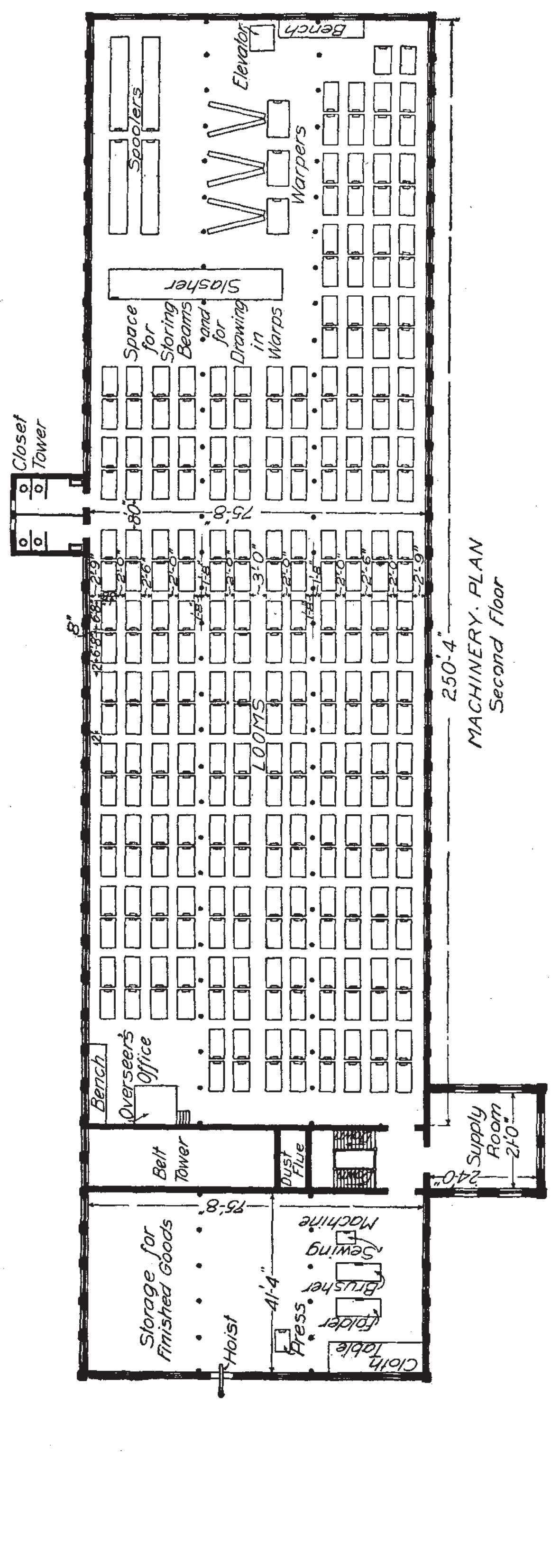
Spoolers
Elevator
Bench
Warpers
Slasher
Space for Storing Beams and for Drawing in Warps
Closet Tower
LOOMS
75'-8"
250'-4"
MACHINERY PLAN
Second Floor
Overseer's Office
Bench
Belt Tower
Dust Flue
Supply Room
21'-0"
24'-0"
Storage for Finished Goods
Hoist
41'-4"
Sewing Machine
Brusher
Folder
Press
Cloth Table

Fig. 4

up to 56 pounds and with scale end for lap); 35 lap sticks; 1 card hammer for fastening card clothing; 5 papers of flat-head card tacks; 2 quarts of card-cylinder plugs; 1 quart of $\frac{3}{8}$-inch shoe pegs; 6 pairs of 21-inch hand cards; 1 set of gauges 5-, 7-, 10-, and 12-thousandth-inch; 2 card brushes for brushing out card wire by hand; 2 wire roller brushes for brushing out card wire by power; 500 feet of $\frac{3}{8}$-inch cotton banding for cards; 2 sets of **S** wrenches; 1 8-inch monkey-wrench; 1 12-inch monkeywrench; 2 cold-chisels (different sizes); 2 sets of files (assorted); 2 hammers; 1 10-inch screw-driver; 1 card knife; 1 stripping truck; 2 waste boxes; 2 rolls of emery fillet; 2 rolls of fillet for stripping brush; 1 vise with $3\frac{1}{2}$-inch jaws.

32. Drawing and Fly Frames.—Two thousand 11-inch slubber bobbins, wired and varnished; 1,000 skewers for same with hardwood tips; 8,000 9-inch intermediate bobbins, wired and varnished; 4,000 skewers for same with hardwood tips; 42,500 7-inch fine-frame bobbins, wired and varnished; 20,000 skewers for same with hardwood tips; 1 roving reel; 1 roving scale; 1 set of **S** wrenches; 1 12-inch monkeywrench; 2 cold-chisels (different sizes); 1 set of files (assorted); 1 hammer; 1 10-inch screwdriver; 1 set of roll gauges; 1 dozen bobbin baskets.

33. Spinning.—Thirty thousand warp bobbins for $6\frac{1}{2}$-inch traverse; 40,000 filling bobbins for $6\frac{1}{2}$-inch traverse; 12 traveler brushes; 50 boxes of assorted travelers, numbers 2 to 12/0, for 28s warp and 36s filling; 1 pair of yarn scales; 1 yarn reel; 1 yarn tester; 1 set of **S** wrenches; 1 12-inch monkeywrench; 2 cold-chisels (different sizes); 1 hammer; 1 set of files (assorted); 1 set of roll gauges; 1 spindle gauge; 4 balls of $\frac{3}{16}$-inch spindle banding; 1 vise with $3\frac{1}{2}$-inch jaws; 1 10-inch screwdriver.

34. Warp Preparation.—Five thousand spools, 6-inch traverse, 4-inch heads bushed; 1,600 skewers for same; 50 slasher combs, 44 inches wide; 1 roll of slasher cloth; 6 drawing-in hooks.

35. Weaving.—Six hundred pickers; 600 picker loops; 4 gross of lug straps; 1,200 loom lagscrews; 1,200 washers for same; 3 sets of **S** wrenches; 3 10-inch monkeywrenches; 3 hammers; 3 cold-chisels; 2 vises with $3\frac{1}{2}$-inch jaws; 1 set of files (assorted); 600 shuttles; 300 sets of loom strapping; 275 pairs of temples with plates; 300 filling forks; 8 gross of single-jointed 3-inch jack-hooks, No. 7; 8 gross of **T** hooks, No. 12; 4 gross of clamps for treadle straps; 350 reeds; 350 sets of harnesses; 500 extra harness eyes; $\frac{1}{2}$ gross of $4\frac{1}{2}$-inch weavers' scissors; $\frac{1}{2}$ gross of weavers' combs; $\frac{1}{2}$ gross of loom dusters; $\frac{1}{2}$ gross of reed hooks; 3 pairs of reed pliers; 1 $\frac{1}{2}$-inch pick glass; 1 1-inch pick glass; 2 short beam trucks.

36. Repair Shop.—One set of 10-inch belt clamps; 6 revolving belt punches; 2 dozen of assorted drive punches; 6 belt awls; 1 stripping gauge; 1 belt lap shave; 4 boxes of copper rivets and washers, Nos. 8, 9, 10, and 12; 1 glue pot; 20 pounds glue; 250 oak-tanned leather slabs; 1 24-inch Stillson wrench; 1 8-inch Stillson wrench; 1 10-inch Stillson wrench; 1 16-inch Stillson wrench; 2 18-inch monkeywrenches; 4 10-inch monkeywrenches; 4 8-inch monkeywrenches; 2 sets of **S** wrenches, No. 76 to No. 81 (No. 76, $\frac{3}{8}$- and $\frac{1}{2}$-inch; No. 77, $\frac{19}{32}$- and $\frac{11}{16}$-inch; No. 78, $\frac{11}{16}$- and $\frac{7}{8}$-inch; No. 79, $\frac{25}{32}$- and $\frac{31}{32}$-inch; No. 80, $\frac{31}{32}$- and $1\frac{1}{16}$-inch; No. 81, $1\frac{1}{16}$- and $1\frac{7}{16}$-inch); 1 bench vise with $3\frac{1}{2}$-inch jaws; 1 bench vise with 6-inch jaws; 1 No. 3 pipe vise; 1 10-pound sledge; 1 3-pound hammer; 3 machinist hammers (assorted); 3 ball-peen hammers, 4, 8, and 16 ounces; 2 riveting hammers, 4, 8, and 12 ounces; 1 No. 1 Saunders' pipe cutter; 1 No. 2 Saunders' pipe cutter; 6 extra cutters for each; 1 set of pipe taps, $\frac{1}{4}$- to $1\frac{1}{2}$-inch; 1 No. 1 stock and die; 1 No. $1\frac{1}{2}$ stock and die; 1 No. 2 stock and die; 1 complete set of taps and dies with tap wrenches and stocks; 1 ratchet-drill stock and assortment of drills; 1 breast-drill stock; 1 upright drilling machine, 21 inches, back-geared; 1 set of straight-shank twist drills, $1\frac{1}{16}$ inches to $\frac{1}{2}$ inch by 32ds; 1 set of taper-shank drills, $\frac{1}{4}$ inch to 1 inch by 16ths; 1 twist drill and wire gauge; 1 set of drill sockets (assorted); 1 No. 2

jack-screw; 1 No. 4 jack-screw; 1 No. 10 jack-screw; 1 18-inch lathe; 8-foot bed engine lathe; 1 drill chuck; 1 4-jaw chuck for a lathe with independent jaws; 1 forge; 1 150-pound anvil; 2 blacksmith sledges; 12 blacksmith tongs (assorted); 1 grindstone frame and stone; 1 emery-wheel frame; 2 12″ × 1″ emery wheels, 1-inch holes; 1 No. 3 emery grinder; 4 bars of solder; 1 bottle of soldering acid; 1 soldering copper; 1 hack-saw frame and 1 dozen blades; 1 set of reamers for brace, ½-inch to ¾-inch; 4 dozen assorted files; 4 pairs of pliers; 1 No. 3 chain tongs; 4 pairs of calipers (2 outside and 2 inside, large and small); 1 pair of tinners' shears; 2 pairs of 10-inch shears; 1 plumb-bob; 1 gear-cutting and drilling machine with a set of cutters; 1 set of cold-chisels; 1 micrometer caliper; 2 machinists' scales, 6-inch and 12-inch; 2 try squares, 4-inch and 8-inch; 1 combination square; 1 machinists' level; 1 screw-pitch gauge; 1 surface gauge; 1 pair of dividers; 1 set of screwdrivers; 2 center punches; 1 set of reamers, ⅛ inch to 2 inches by 16ths; 1 lathe; 1 set of lathe dogs; 1 set of lathe cutters; 1 set of pinch bars; 2 crowbars; 1 set of roll spreaders; 12 coils of steel wire (assorted); 12 coils of brass wire (assorted); 6 coils of copper wire (assorted); 1 oil tank; 1 assortment of spring cotters; 1 assortment of standard size bolts and nuts; 1 assortment of standard size setscrews; 1 assortment of standard size wood screws; 1 set of carpenters' tools.

37. Hose Houses.—Eight hundred feet 2½-inch rubber-lined hose pipe coupled every 50 feet; 8 standard nozzles, Underwriters', 30 inches; 10 hose spanners; 8 bars; 8 fire-axes; 4 lanterns; 1 hose wagon; 2 single ladders; 1 adjustable ladder.

38. Miscellaneous.—Five hundred fiber cans, 10 inches by 36 inches; ½ piece clearer cloth; 2 60-gallon oil tanks; 1 engineers' oiling set of five pieces; 6 No. 16 brass oilers; 3 No. 11 steel oilers; 100 common oilers; 1 bale 8-ounce 40-inch burlap; 1 roll of fiber packing paper; 12 reels of 4-ply sisal, $\frac{5}{16}$ inch; 1 package of twine; 4 dozen picking needles; 2 sides of lace leather; assortment of belt hooks; 2 reams of assorted sandpaper; 1 ream of assorted emery cloth; 1 case of mill crayons (assorted); 1 gross of oil crayons; assortment of belting (single and double); $\frac{1}{2}$ gross of clearer brushes; 1 gross of hand brushes; $\frac{1}{2}$ gross of finger brushes; 1 box of $\frac{1}{4}$-inch packing; 1 box of $\frac{1}{2}$-inch packing; 1 box of $\frac{5}{8}$-inch packing; 1 box of $\frac{3}{4}$-inch packing; 6 balls of asbestos wick packing; 3 yards of $\frac{1}{16}$-inch packing; 2 pounds of gum arabic; 2 pounds of stamping blue; 10 pounds of graphite; 100 galvanized fire-buckets; 72 fire-bucket hooks; 1 gross of mill brooms; 5 8-day time clocks, 10-inch face; 1 double speed indicator; 3 engineers' hand lamps; 2 watchmen's lanterns; 1 medium-size hand truck; 2 coal barrows; 1 1,000-pound scales; 1 600-pound scales; 48 doffer-box rollers and stands; 24 doffer-box casters; 24 oblong leatheroid doffer-boxes, usual size; 1 pair of union balances, 28 pounds; 1 pair of scoop balances; 2 dozen waste cans; 1 box of $\frac{5}{8}$-inch gaskets; 2 cans of belt dressing; assortment of paint; assortment of paint brushes; $\frac{1}{2}$ dozen floor mops and handles; 1 dozen drinking cups; 1 barrel of spindle oil; 1 barrel of machine oil; 1 barrel of cylinder oil; 1 barrel of whiting; 1 barrel of soap powder; 1 stenciling outfit; 2 coal shovels; 1 set of furnace irons; 3 doffers' trucks for spinning frames; 3 beam trucks for loom fixers; 24 wooden bobbin boxes for spinning frames.

MILL ENGINEERING

(PART 3)

EXAMINATION QUESTIONS

In answering those questions involving mathematical solutions where sufficient data is not supplied, the information given in this Instruction Paper, especially in the various Tables, should also be taken into consideration. In stating the questions, it is assumed that the student has a knowledge of cotton-mill machinery, and of yarn and machinery calculations.

(1) What are the first important matters to be considered in connection with the planning of a cotton mill?

(2) What are the different types of cotton mills that may be constructed?

(3) What is meant by the organization of a cotton mill?

(4) How is the size of cotton mills designated?

(5) What are the usual doublings in the machines between the cards and spinning frames in a mill spinning yarns of medium counts?

(6) What are practical drafts for the machines from the cards to the spinning frames inclusive in a mill making yarns of medium counts?

(7) Why is it necessary to determine the organization of a mill before estimating the amount of machinery necessary?

(8) What are good productions per day for breaker, intermediate, and finisher pickers?

(9) In addition to the cost of the machinery, what are some of the other items of expense in constructing a complete cotton mill?

(10) What method is adopted for finding a practical arrangement of the machinery on the floor plans of the mill?

(11) Give a list of processes in their proper sequence for a mill producing 28s warp and 36s filling yarns.

(12) How many spindles will be required to give a daily production of: (*a*) 5,856 pounds of 28s warp yarn? (*b*) 6,208 pounds of 36s filling?

Ans. (*a*) 24,000 spindles; (*b*) 32,000 spindles

(13) What will be the production, per week of 60 hours, of 8 warpers if there are 380 ends of 30s yarn on each section beam? Ans. 15,640 lb.

(14) How many pounds of yarn would be produced per day in a mill operating 16,000 spindles on 24s warp and 22,000 spindles on 32s filling yarn? Ans. 9,806 lb.

(15) How many slubbers of how many spindles each will be required to give a daily production of 8,816 pounds of .40-hank slubbing? Ans. 4 slubbers of 76 spindles each

(16) What is the production, in pounds, in a week of 60 hours, of 1,500 looms weaving 6-yard goods with 80 picks per inch, if the looms are speeded at 160 picks per minute? Allow 10 per cent. for stoppages. Ans. 45,000 lb.

(17) (*a*) How many deliveries of drawing frames running under the conditions stated in Art. **14** will be required to produce 30,000 pounds of sliver per week? (*b*) Into how many heads would this number of deliveries be divided?

Ans. (*a*) Twenty-five deliveries (practically); (*b*) Five heads of five deliveries each

(18) How many roving frames of 152 spindles each will be required to produce 7,296 pounds of 5-hank roving per day? Ans. 30 frames

(19) What is the production, in a week of 6 days, of eight intermediate frames of 114 spindles, each producing $1\frac{1}{2}$-hank roving? Ans. 39,398.4 lb.

(20) Give a program of practical drafts for producing a 30s yarn, from a lap delivered by the breaker picker weighing 14 ounces per yard, with the doublings as follows: intermediate picker, four; finisher picker, four; three drawing frames, six at each; intermediate, roving, and spinning frames, two each.