It is not recommended that granite lintels be used over windows and doorways, as brick arches are a much better construction for mill purposes and more efficient where the weight of the wall above is to be supported. The different qualities of granite vary somewhat in hardness, but as the cost of cutting depends on the hardness, it is unwise to select stone any harder than is necessary. All granite, some kinds to a greater extent than others, has a tendency when exposed to heat and water to flake off, or *exfoliate*. Occasionally a granite bond is run entirely around the mill, either at the ground level or at the level of the first or second story, the wall being offset from the outside instead of from the inside to form a ledge for the stones to rest on. This of course is a little different from the ordinary mill construction, where the walls are perpendicular on the outside, and is done for purely ornamental purposes.

INTERIOR CONSTRUCTION

SLOW-BURNING CONSTRUCTION

65. Ordinarily in the interior construction of a building a large number of small pieces, such as floor timbers, studs, braces, etc. are used, which burn rapidly and fiercely when once a fire is started, while the spaces between the beams and studs form flues that give draft to the fire and rapidly spread it throughout the structure. In a mill constructed in this manner a fire rapidly consumes the floors and allows the heavy machinery to crash to the basement and destroy the whole structure. To avoid this destruction modern mills are constructed on what is known as the **slow-burning construction.**

The fundamental principle of this construction is the omission or alteration of every detail that would tend to make combustion rapid or easy. The beams, columns, etc. are so proportioned that they retain strength enough to do the work required of them even after one-third of their bulk has been charred or burned. Instead of a large number of small pieces, a small number of very large pieces are used.

The ultimate objects of this construction may be summed up as follows: To make the mill strong enough to stand any ordinary stress, even after its timbers are partly burned; to make the floor so tight and strong that when a fire starts in one story, the water poured in to quench it will not run through and ruin goods on the floor below; to avoid any corners, pockets, or flues where a fire could get started without being immediately discovered; and, above all, to provide a building where every part is easily accessible and a fire can be attacked and extinguished at close quarters without flooding the entire structure.

66. The details of this construction can best be understood by referring to Fig. 43, which is a perspective view of a portion of a two-story mill with a basement constructed on the slow-burning principle. In this figure, a is the stone foundation wall and b the brick walls of the mill. Brick piers a_1 support the first-floor timbers c, which are 12″ × 16″ Georgia pine. Resting on each pier is a cast-iron pintle d that supports a 10-inch, round, Georgia pine column e that carries the second-floor timbers f. Placed on each column e is an iron cap on which rests a pintle d_1 that supports a column e_1 that carries the roof timbers g. The outside ends of the floor and roof timbers are supported by the brick walls of the mill.

In mill work the *span*, or distance between the walls and columns or between the centers of the columns measured across the mill, is usually 25 feet or thereabouts, while the *bay*, or distance between the centers of the piers or columns measured lengthwise of the mill, is usually 8, 10, or 12 feet, although the latter is unusual. The construction of the mill is spoken of as an 8-foot bay or a 10-foot bay construction, etc.

Sometimes the floor timbers vary in size, becoming smaller at each story, but as a general rule it is better to make the floor and roof timbers the same size throughout the mill. The same is true of the columns, which are sometimes made of a smaller diameter in the top stories than in the lower.

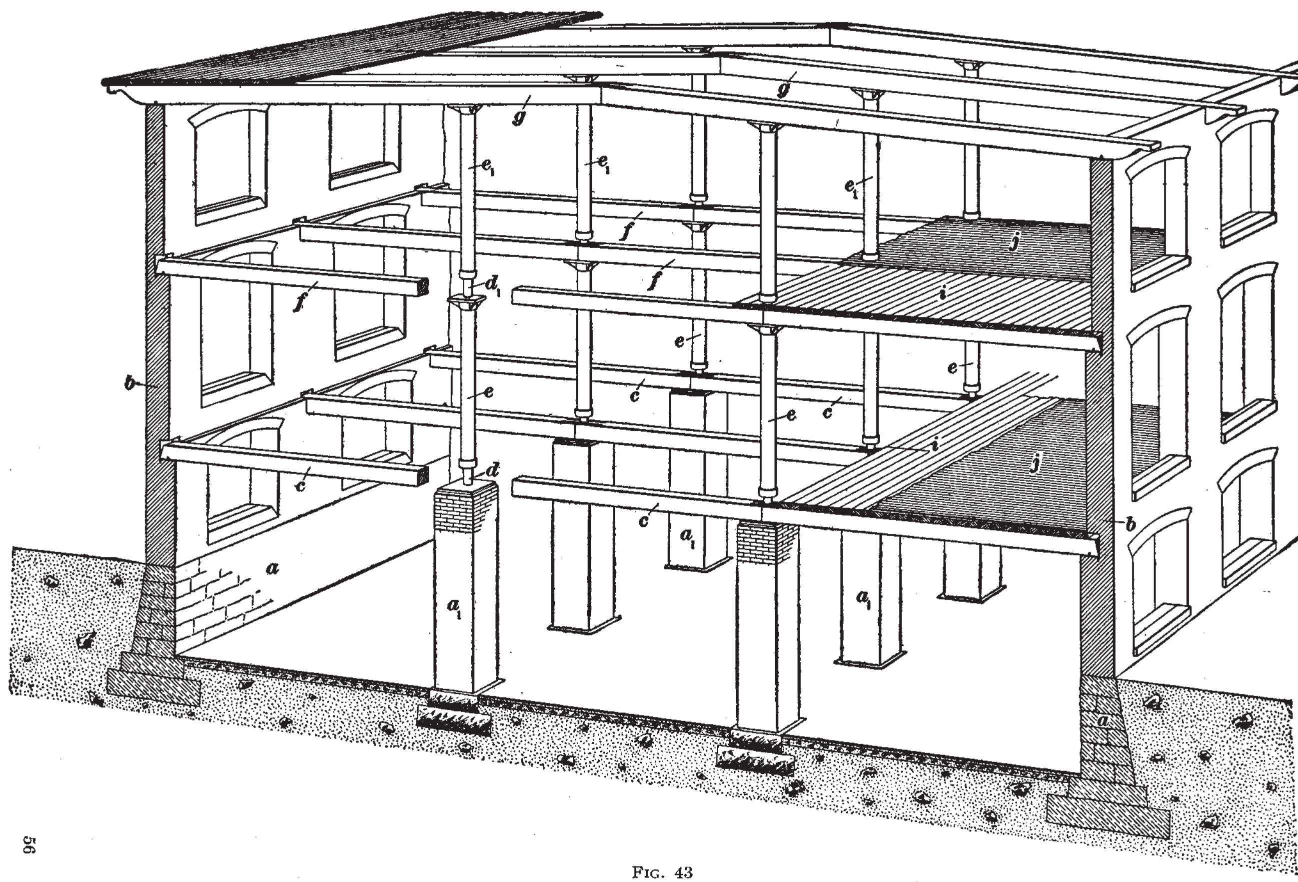


Fig. 43

67. Floor Work.—The floors of a mill are supported by wooden or iron columns, or in the case of the first floor usually by brick piers. Fig. 44 shows the method of supporting the first-floor timbers on a brick pier a_1. A base d_3, in which the column *e* that supports the second-floor timbers rests, is cast in one piece with a pintle *d* that rests on an iron plate or cap d_2 placed on the pier. As the pintle *d* is shaped like a cross, the floor timbers *c*, *c* are fashioned to fit around it. Occasionally a round pintle having a hole through the center is used, in which case a half-round groove is made in the end of each floor timber. In order to hold the floor timbers firmly together and to preserve the continuity of the bond between the two walls of the mill, they are fastened together by means of dogs *k*; these are made of $\frac{3}{4}$- or 1-inch wrought iron and are about 2 feet long after bending, each end being turned up, nearly, but not quite, at right angles to the bar. The bent ends are driven into holes in the tops of the timbers, and since they are bent not quite at right angles, draw the timbers together as they are driven in. The bent portion of the dog is usually from 2 to 3 inches in length, and holes of corresponding depth are bored in the floor timbers. Two of these dogs are generally used at each junction of the floor timbers, one being placed on each side of the pintle.

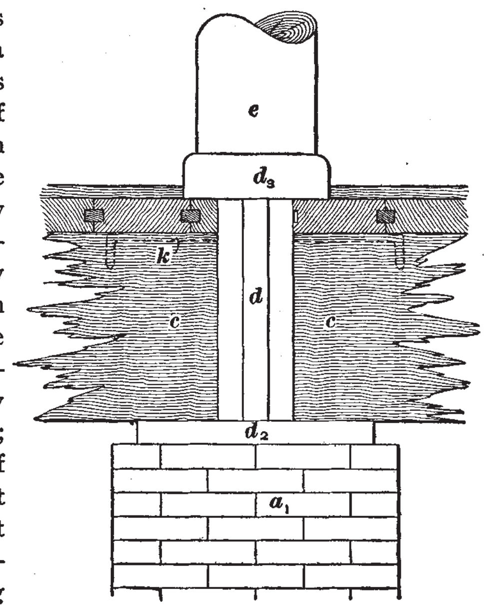


FIG. 44

Fig. 45 shows the method of supporting the floor timbers by means of a wooden column. The column e_1 that supports the floor above, or the roof, rests in a base d_3 that is cast in one piece with the pintle d_1 that rests on a cap d_2 placed on the column e. The pintle shown in Fig. 45 is round in section, while that shown in Fig. 44 is cross-shaped in section. The floor timbers f, f rest on the cap d_2 and are bonded together by dogs k, k, as in the previous instance.

The ends of the floor timbers that are laid into the walls of the mill are beveled off and rest on an iron anchor h built into

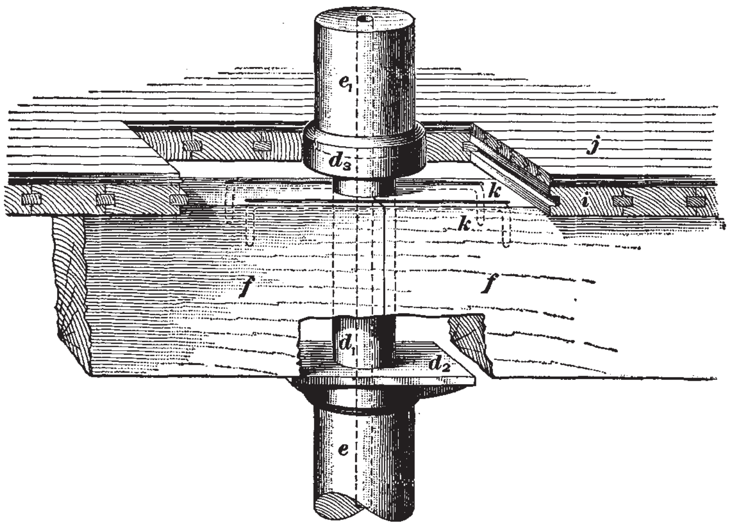


FIG. 45

the brickwork, as shown in Fig. 46. This anchor has a projecting flange extending into the brickwork and a flange that engages with a groove cut in the bottom of the floor timber. This groove is sometimes wide enough for a wedge to be driven in between the side of the groove and the projecting flange to bind the timber tight, but this is not always done. This projecting flange serves to anchor, or tie, the timber to the wall; and as the timbers are tied together by iron dogs, the walls of the mill are securely bonded together. The anchor shown in Fig. 46 is used because the beam, should it become burned through at its center and fall down, can easily fall out of the wall without disturbing the brickwork and thereby endanger the stability of the wall. The advantage of this is illustrated in Fig. 47, where (*a*) shows a perspective view of a beam falling from a wall to which it has been securely anchored by an ordinary type of anchor, such as is bolted to the beam, while at (*b*) the beam is seated on a cast-iron anchor similar to that described in connection with Fig. 46, from which it can fall without damaging the wall in any way, and it leaves the anchor intact to receive a new beam when repairs are made. In order that this arrangement shall work perfectly, sufficient clearance must be left for the end of the timber to cant out of the wall without striking the brickwork.

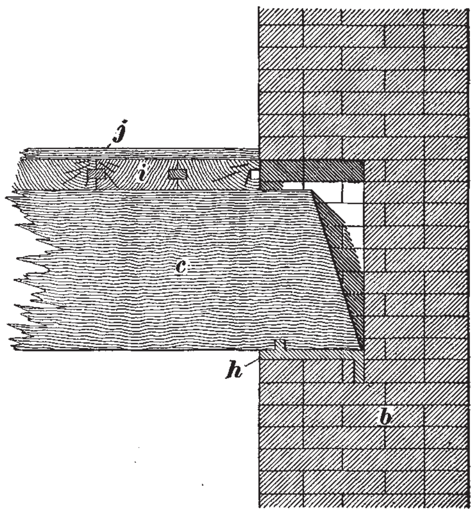


Fig. 46

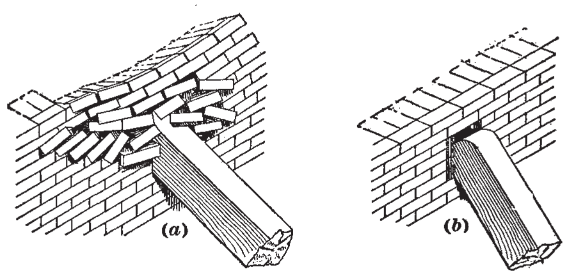


Fig. 47

68. On top of the floor timbers a double floor is laid, as shown in Fig. 43, the first floor consisting usually of 3-inch splined spruce planks *i*, although a thickness of 4 inches is sometimes used and in some cases pine is the material. These planks are usually 6, 8, or 10 inches in width. The second course usually consists of a $1\frac{1}{4}$-inch hardwood floor *j*, preferably of maple, the individual boards being $3\frac{1}{2}$ inches in width and tongued and grooved so as to be matched together.

Splined planks have a groove cut in each edge into which a spline is driven. Thus they serve the same purpose as though tongued and grooved, and are cheaper because there is not so much timber wasted in cutting them. They should be planed on one side and should be long enough to span two bays; that is, 16, 20, or 24 feet, as the case may be. By this means the joints can be broken on the timbers and the strength greatly increased when laying them. About 6-inch spikes should be used in fastening them to the timbers; one keg of 100 pounds will lay about 1,400 square feet of floor.

Between the plank and hardwood floors one or two thicknesses of building paper, or in some cases asbestos felt, is usually laid. The strips of paper should be lapped one-half their width, and make a tight floor through which dirt and dust cannot sift and fall into the bearings of the machinery below and one which is also practically waterproof. A watertight floor is a great advantage in cases where a fire occurs and is confined to one room.

In some cases a layer of mortar $\frac{3}{4}$ inch thick is spread over the planking and the top floor laid on this. The idea is to make a fireproof construction, but as the mortar crumbles and sifts through the floor, and as its presence is undesirable when repairing the floor or in cutting belt holes, this practice is not to be recommended.

The top floor should be laid across the plank floor, in order to give the mill stiffness and solidity. Its boards are generally laid at an angle of 90° with the bottom planks, but are sometimes laid at an angle of 45°, although this is not advisable, as it is much more difficult to repair worn portions of the floor.

69. The maximum weights per square foot of floor area that textile mill structures are liable to be called on to support are given in Table IV.

In actual practice, the floor pressure of textile mills is rarely more than an average of 25 pounds per square foot over the entire mill; the weight of the floor itself, however, is about 20 pounds per square foot. Storage, shipping, and finishing rooms are generally loaded much more heavily than the other rooms of a mill.

70. Columns.—Engineers have arrived at no definite conclusion in regard to the relative merits of iron and wooden columns. The iron columns, of course, take up less space and hence have a much neater appearance and also

TABLE IV

Type of Structure	Weight per Square Foot Pounds
Cotton mill	50
Woolen mill	50
Worsted mill	60
Storehouse for cotton	150
Storehouse for loose wools	100
Storehouse for baled wools	150
Storehouse for woolen cloth (2 cases high)	150
Storehouse for worsted cloth (2 cases high)	200
Storehouse for machinery	200

make the rooms lighter. To offset this they are untrustworthy in case of a fire, as when they become heated if struck by a stream of cold water they immediately crack and collapse, thus letting down the floors above and rendering the damage much more extensive, since if they had remained intact, the fire might possibly have been confined to one room. Wooden columns, when exposed to fire, char on the outside for a depth of 2 or 3 inches; this charred portion seems to protect the rest of the column from burning. In damp places, however, wooden columns are not to be recommended; either iron columns or brick piers should be used.

Wooden columns, although necessarily much larger, are much more to be depended on, as they usually give evidence, by cracking or by the fibers breaking down before giving away. Iron columns are liable to contain flaws, and their section tends to be irregular; thus they are liable to give away without warning.

The best material for wooden columns is Southern pine, which can be obtained straight-grained and free from knots and seams. Oak is not as reliable as Southern pine, as it is apt to be knotty and the grain uneven, causing the column to warp in seasoning. Wooden columns should not be painted until thoroughly seasoned; otherwise, they are much more liable to rot.

Columns are bored in order to remove the heart of the tree, which has no particular strength and is subject to dry rot. An 8-inch column should have about a $1\frac{1}{2}$-inch hole bored through it, this being done from one end only; sometimes with larger columns a 2-inch hole is bored. The reason for not boring a hole in each end is that it is almost impossible to make the two holes meet exactly, and thus the section of the column at some point is liable to be reduced in area. A $\frac{1}{2}$-inch air hole should be bored at the top and is also recommended at the bottom of the column, in order to give free circulation of air, which is necessary to prevent dry rot. Care should be taken to have not only columns but all timbers in a good air circulation, as timbers in confined spaces are subject to dry rot, which will sometimes totally destroy the timber in a short time.

Although cast-iron columns are not recommended in fireproof constructions or in textile structures, they are found in many mills and in some cases are indispensable. The great difficulty with cast-iron columns is not so much in flaws in the metal as unevenness of section, caused by the cores floating when the column is cast. This is liable to make the column very thin on one side, and consequently extremely unreliable. All cast-iron columns should be tested with a pair of long calipers before being used, in order that it may be determined whether the section is uniform or not.

Care should also be taken that the ends of a column are square with its axis. In the mill under consideration round wooden columns are used, the round column having more resistance to fire than the square column. If square columns are to be used in mill construction, the corners should be chamfered so that they will not become defaced from contact with trucks, etc. For the same thickness, a square column is stronger than a round one, but round ones are generally used in textile mill buildings.

71. Roof Work.—For textile mills the so-called *flat roof*, shown in Fig. 43, having a pitch of only $\frac{1}{2}$ inch to the foot for drainage, is most appropriate. It is supported by timbers exactly the same as the floor timbers of the mill except for this pitch; that is, they rest on a cast-iron cap placed on wooden columns, the cap being secured to the timbers either by projecting flanges that enter slots in the timbers or by being bolted to them. The roof timbers should be covered with about 3-inch white-pine planks, rough on the upper side and planed on the lower. The planks should be 6 or 8 inches in width and grooved to be fitted with splines. They may be heavily beaded on each edge and in the center of each plank on the under side, in order to give the appearance of sheathing, if so desired. They should be the length of two bays and laid so as to break joints, as were the floor planks.

The so-called *gravel roof* five- or six-ply in thickness is recommended for mill structures. It is made as follows: Three thicknesses of tarred paper are laid so that each layer overlaps the one underneath it one-third of its width; this should be tacked down with $1\frac{1}{2}$-inch nails and $1\frac{1}{4}$-inch tin washers about every 2 feet. It is covered with a thin layer of hot coal-tar and then with two or three thicknesses of the tarred paper, depending on whether it is five- or six-ply roofing. Over this another layer of hot tar is placed and clean gravel spread over the whole roof. This makes a very durable roof and one that is largely used for protection from rain and snow.

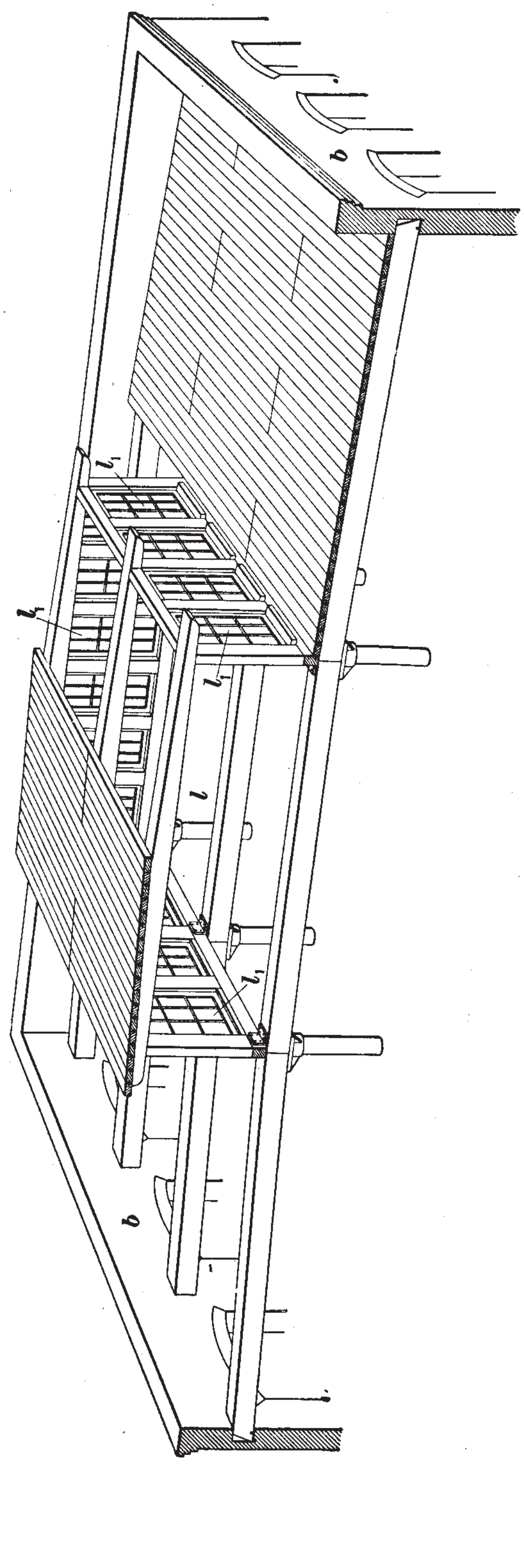


Fig. 48

Another roof that is very durable and that is often used is the *tin roof.* For it the planks are first covered with three thicknesses of tarred paper the same as for gravel roofs; over this a layer of tin with waterproof joints is laid, and afterwards painted.

72. When the mill is more than 50 feet in width it is advisable that a **monitor** be built in the center of the roof for light and ventilation. As shown in Fig. 48, this is a framed structure l raised in the center of the roof and provided on the sides and ends with windows l_1. As the roof planks do not extend under it, a large amount of light is thrown into the center of the upper story, making a very light room for particular processes. The windows are usually swiveled on iron rods, so that they may be opened to allow the heated air to pass out, and ventilate the room. The roof may be constructed exactly the same as the roof of the mill proper and should have the same pitch. Monitors are sometimes built in small detached portions and sometimes as a continuous structure running nearly the whole length of the mill in the center of the roof. Fig. 48 shows a parapet wall extending above the roof, but this is not necessary with a monitor roof nor even customary.

73. Doors.—The outside doors of the mill may be made of any ordinary pattern, but should be especially heavy and strong. All doors should open outwards in order to prevent any possibility of a crush in case of fire or accident. All doors or openings through fire-walls should have automatic fire-doors to prevent the passage of the fire from one room to another. These doors are best constructed of wood and covered with sheet tin with the joints clinched. Iron and steel doors are unreliable, since they warp badly with even a small fire and allow free passage of the fire through the fire-walls.

Fig. 49 shows the ordinary construction of an automatic, or self-closing, fire-door. The door b is constructed of two or three thicknesses of pine boards nailed either at right angles or diagonally across each other. Sometimes asbestos felt is inserted between or over the boards, although this is not customary. The whole door is covered with sheet tin, the separate sheets being clinched and nailed to the door so that when the rib or clinch formed at the juncture of the sheets is turned over it will cover the nail heads. The door is hung on wheels *f* that run on an inclined track *e*, the slant of which should be at least $1\frac{1}{2}$ inches to the foot; it thus has

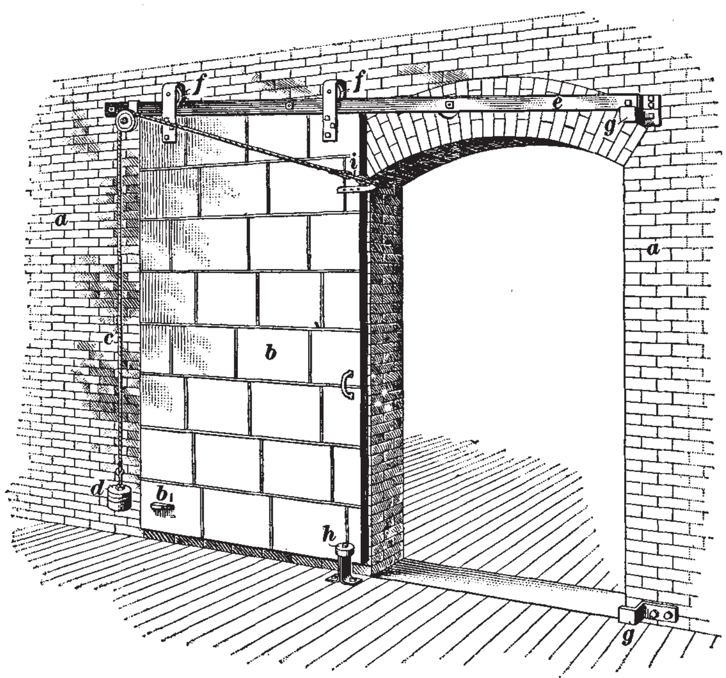


Fig. 49

a tendency to close the doorway, but under ordinary conditions this tendency is counterbalanced by a weight *d* that is attached to the door by a rope *c* and a fusible link *i*. The fusible link is made of an especially prepared metal that melts and allows the door to close when it is subjected to a temperature of 160° F. The two iron pieces *g* engage the edge of the door when it is closed, and a roller *h* engages with a wedge b_1 and holds the door firmly over the opening.

This door may be opened and closed ordinarily without disturbing the fusible link in the least. Fire-doors should be closed each night, but in case of neglect the automatic feature is an almost sure protection against the spreading of fire.

74. Windows. The windows in a textile mill should be of the greatest possible area consistent with preserving the strength of the walls. Fig. 50 shows one of the ordinary type; it is composed of two sashes *a*, *b* and the transom *c*. The sashes are balanced by weights attached to cords running over pulleys in the window frame, and may be raised or lowered, but the transom *c* is pivoted so as to be swung open to ventilate the mill.

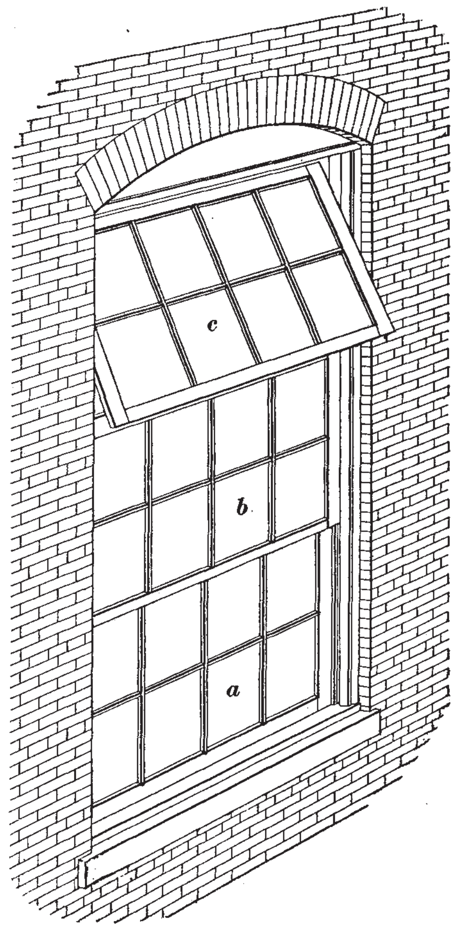


Fig. 50

Sometimes the openings for the windows in the walls of textile mills are made extremely wide and separated by a mullion, since with very wide windows the weight of the sashes is so great as to make them hard to raise. The sashes and window frames for a mill structure should be made nearly double the weight that is required for ordinary dwelling houses, and should always be set with rectangular glass, as glass curved at the top to the arc of the arches, or *segment glass* as it is known, increases the cost of resetting to some extent and is of no particular advantage. Generally a good quality of American glass is suitable, but the use of corrugated or prism glass is being advocated at the present time, and many new mills are equipped with it. While this type of glass is not transparent, but rather might be termed translucent, it makes the rooms much lighter, since the light is diffused throughout the room without casting dark shadows. The sashes and frames of the windows should be kept well painted and the glass periodically washed.

75. Stairways.—Stairways should be separated from the mill proper by fireproof walls or should be located in a separate tower in order to prevent a fire from spreading from floor to floor. For the same reason not only stairways, but all openings from one floor to another should be avoided unless separated from the main mill by fireproof walls. Especially is this true in regard to belt ways and dust flues. Belts that are allowed to run through the floors for many stories sometimes carry the fire with them, and hardly anything will transmit a fire from one part of a room to another or from one floor to another as quickly as a moving belt, owing to the current of air set in motion by it. The belt tower is usually located in the center or at one end of the mill, and is usually arranged so that one line of shaft on each floor can be driven from the engine or from a head-shaft, as by this means the greatest economy of the transmission of power is obtained.

The best method of making stairways is to divide the flight by making a landing half way up. This construction makes short, straight flights and there is much less danger of crowding in the case of fire, while at the same time they will be found convenient on all occasions. In cases where spiral staircases must be used, although they are not to be recommended, care should be taken to have the central pier large enough to insure a proper width of tread on the inside of the stairs.

MILL ENGINEERING

(PART 1)

EXAMINATION QUESTIONS

(1) State some of the natural and artificial advantages that should be taken into consideration in locating a mill.

(2) What is the object of footings?

(3) What proportions of sand, stone, and cement are suitable for the concrete footings of a moderately high mill?

(4) Describe, briefly, how foundations are supported when the soil is marshy.

(5) State the requisite qualities of good building bricks.

(6) Discuss, briefly, the character of the following soils: (*a*) rock; (*b*) gravel; (*c*) clay; (*d*) quicksand.

(7) How should footings partly on rock and partly on gravel be built?

(8) What is the danger in uneven settlements of a mill foundation?

(9) (*a*) How are stone foundation walls bonded? (*b*) Why should the joints in a stone foundation wall be carefully broken?

(10) What precaution should be taken in laying brick in hot weather?

(11) (*a*) What is meant by Flemish bond? (*b*) What is meant by running bond?

(12) (*a*) How thick should be the bed of mortar between the bricks in a wall? (*b*) What is a good proportion of lime and sand for lime mortar?

(13) Describe how the floors are constructed and supported in a mill built on the slow-burning principle.

(14) (*a*) What is a stretcher brick? (*b*) What is a header brick?

(15) What is a monitor and what are its chief objects?

(16) (*a*) Describe an automatic fire-door and state its purpose. (*b*) Why are iron fire-doors unsuitable?

(17) What is meant by bond in brickwork?

(18) What can be said of stairways in mill structures?

(19) What are fire-walls and what is their object?

(20) What is meant by the term slow-burning construction?

(21) What is the object of shoeing piles?

(22) Discuss the relative advantages of iron and wooden columns.

(23) (*a*) Why should a hole be bored through a wooden column? (*b*) Should this hole be bored from one or both ends? Explain.

(24) Describe the construction of a gravel roof.

(25) Why should the outside doors of a mill open outwards?

MILL ENGINEERING

(PART 2)

INTRODUCTION

1. The mill structure, or building, represents but a small part of the equipment of the mill, nor do the machines actually necessary for transforming the raw stock into yarn or cloth constitute the entire equipment, for in addition to these there are many appliances that comprise what might be termed the *auxiliary equipment* of the mill. Among these may be mentioned the power plant, the heating and ventilating plants, the plumbing and water-supply systems, and the fire-protection apparatus. Though the installation of these lies within the province of the engineer, and the work in its details does not concern the millman, he should have a general idea of the most desirable apparatus and of the methods that are considered the best mill practice, not only with the object of acquiring a general knowledge of their installation, but to be able to know how afterwards to maintain them at their highest efficiency and secure economical operation.

The importance of installing proper equipments for the generation of power, for heating and ventilating, for fire-protection, etc. cannot be overestimated. The equipment should be such as to furnish an ample supply of power for driving all the machines, shafting, etc. of the mill as economically as possible and such apparatus should be selected as is not liable to serious breakdowns. Heating and ventilating equipments should be such as to make working conditions comfortable in summer or winter. The water supply should be ample, and the plumbing sanitary.

POWER PLANT

STEAM POWER

BOILERS

2. The generation of power in suitable quantities for operating the machinery of the mill is a problem of primary importance, and in general may be said to be accomplished in mill work by one of two methods. The first, and the one commonly employed, is *steam power* and necessitates the combustion of coal, wood, or other fuel under boilers. The steam thus generated operates some form of steam engine that furnishes the motive power for the mill. The second method is the utilization of the energy of a stream of water that, in passing from a high to a low elevation, will, under suitable conditions, drive a waterwheel or turbine, furnishing motive power to the shafting and machinery. The power thus generated is termed *water-power*.

What may possibly be a third method is found in the *gas engine*, but as yet this type of engine has not been sufficiently developed for use in mill work.

Electricity, while used as a motive power to some extent, involves the use of water-power or steam power for its generation, and cannot therefore be considered as a primary source of power.

Steam power is by far the most reliable means of operating a mill and for this reason may be said to be not much more expensive than water-power, except in unusual cases where the water-power is unlimited, the outlay for installation and repairs reduced to a minimum, and the water supply reliable the year round. The equipment of a steam-power plant includes primarily the *boilers* for generating the steam, and the *engines* for converting the potential energy of the steam into actual motive power.

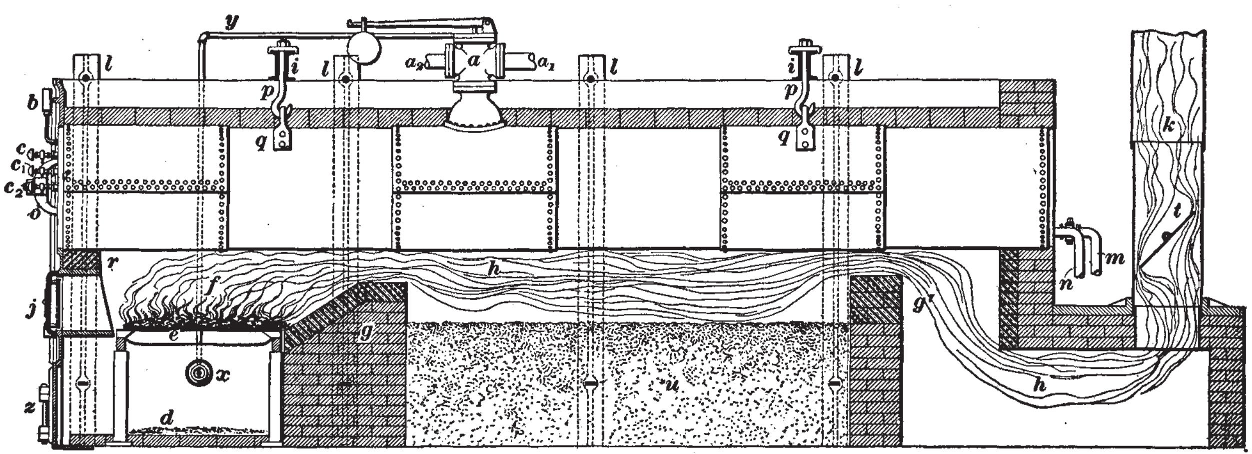


Fig. 1

In general there are three types of steam boilers—stationary, locomotive, and marine, the first being the type adopted in mill practice. Of *stationary boilers*, there are several kinds, varying in construction and principle.

3. The **plain cylindrical boiler,** shown in Figs. 1, 2, and 3, consists essentially of a long cylinder, called the *shell*, that is made of iron or steel plates riveted together as shown in Fig. 1; the ends are closed by flat or hemispherical plates called the *heads* of the boiler. One of the heads is shown in Fig. 2, carrying the fittings b, c, c_1, c_2. In this type of boiler the heads are made of wrought-iron or steel plate; the hemispherical, or dished, form of head, is generally used, since it is stronger than the flat head.

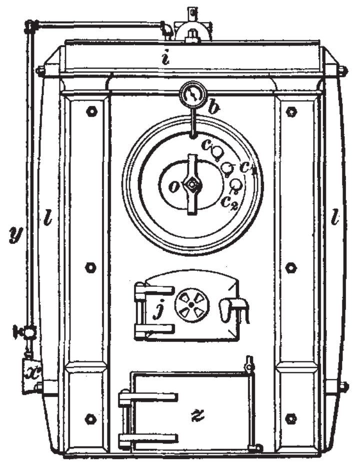


FIG. 2

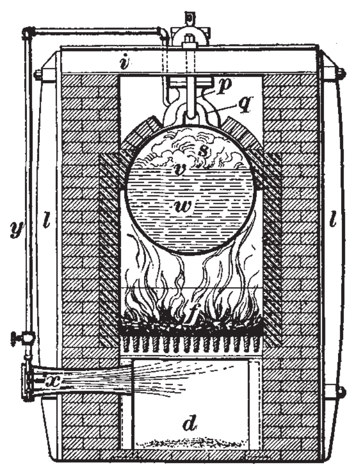


FIG. 3

The manner of suspending the boiler is shown in Figs. 1 and 3. The boiler is enclosed by brick side walls across which are laid channel beams i, i from which the boiler is suspended by means of the hooks p, p and eyes q, q, the latter being riveted to the shell. The side walls are supported and prevented from buckling by the *binders*, or *buckstaves*, l, l, which are cast-iron bars of **T** section that are bolted at the top and the bottom. The eyes q, q are placed about one-fourth of the length of the shell from each end. This method of suspending the shell allows it to expand and contract freely when heated or cooled.

The wall built around the rear of the shell, as shown in Fig. 1, forms the chamber *h* into which opens the chimney or stack *k*. The *boiler front*, which is of cast iron, is shown in Fig. 2; Fig. 1 shows a section of it. The front end of the shell is partly surrounded by the firebrick *r*. The weight of the shell comes on the hooks *p*, *p*, the rear wall and fire-brick *r* simply keeping it in position.

The *furnace f* is placed under the front end of the boiler shell. The fuel is thrown in through the door *j* and burns on the grate *e*, through which the ashes fall into the ash-pit *d*. To insure sufficient air for the complete combustion of the fuel, the furnace is sometimes supplied with a *blower x*; this consists of a cylinder leading into the ash-pit *d*, into which is led a jet of steam through the pipe *y*. The steam rushes into the ash-pit with great velocity, carrying a quantity of air with it. The pressure of the air in the ash-pit is thus increased, more air is forced through the fire, and the combustion of the fuel is more rapid and complete.

Behind the furnace is built a brick wall *g*, called the *bridge*, that serves to keep the hot gases in close contact with the under side of the boiler shell; as boilers of this type are generally quite long, a second bridge is usually added. The gases arising from the combustion of the fuel flow over the bridges into the chamber *h*, and through the chimney *k*; their flow is regulated by the damper *t* placed within the chimney. The space *u* between the bridges is filled with ashes or some other good non-conductor of heat. The door *z* in the boiler front gives access to the ash-pit for the removal of the ashes. The tops of the bridges, the inner surface of the side and rear walls, and, in general, all portions of the brickwork exposed to the direct action of the hot gases are made of firebrick (shown in Figs. 1 and 3 by the dark section lining), since it is able to withstand a very high temperature.

The firebrick work covers the upper portion of the boiler shell in such a manner as to prevent the hot gases from coming in contact with the shell above the water-line *v*. It is a general rule in boiler construction and setting that under no circumstances should the fire-line be carried above the water-line. The top of the shell is covered by brickwork or some other non-conducting material to prevent radiation of heat. Water is forced into the boiler through the feed-pipe *n* which leads from a pump or injector. When in operation the water stands at about the level *v*, the space *s* above being occupied by the steam.

The *safety valve* is shown at *a*; its office is to prevent the steam pressure from rising above the desired point. The pipe a_1 is the main steam pipe leading to the engine; the pipe a_2 provides for the escape of the waste steam when the safety valve blows off.

The *steam gauge b* indicates the pressure of the steam in the boiler; it is attached to a pipe that passes through the front head into the steam space.

The *gauge-cocks* c, c_1, c_2 placed in the front head of the shell are used to determine the water level; for instance, if the cock c_1 is opened and water escapes it is evident that the water-line is above it, while if steam escapes, the water-line is below it.

The *manhole o* is an opening in the front head through which a man may enter and inspect or clean the boiler; it is closed by a plate and yoke.

The blow-off pipe *m* permits the boiler to be emptied of its water or sediment.

Plain cylindrical boilers are usually from 30 to 42 inches in diameter, and from 20 to 40 feet long, though they have been constructed with a diameter of 48, or more, inches, and a length of 60, and even 100, feet. They are only used in districts where fuel is very cheap, as on account of their small heating surface, they are very uneconomical. Their advantages are: cheapness of construction, strength, durability, and ease of access for cleaning and repairs.

4. The **flue boiler** differs from the plain cylindrical in having one or more large flues running lengthwise through

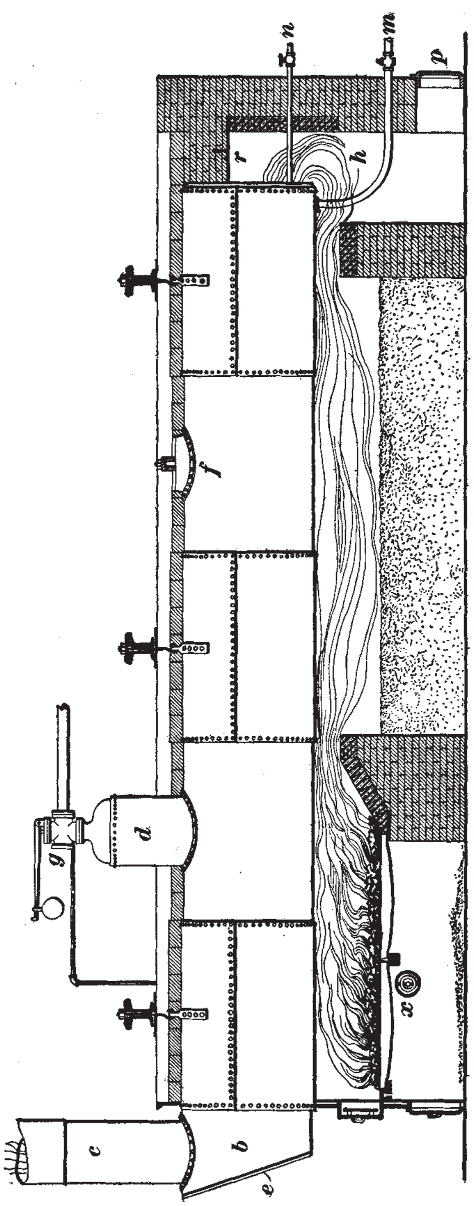


Fig. 4

the shell below the water-line; such a boiler is shown in elevation and section in Figs. 4, 5, and 6. The ends of the flues *a, a* are fixed in the front and rear heads of the shell. The front end of the shell is prolonged beyond the head, forming the *smokebox b* into which opens the smoke-stack *c*; the front of the smokebox is provided with a door *e*. The boiler shell is provided with the *dome d*, which forms a chamber where steam collects and frees itself from its entrained water before passing to the engine. The manner of supporting the shell and the construction of the furnace

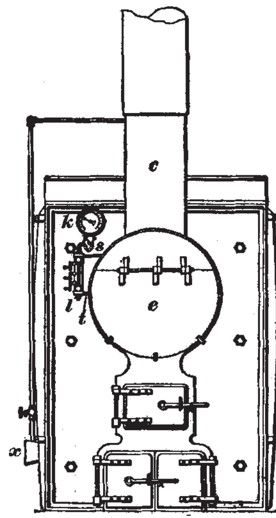


FIG. 5

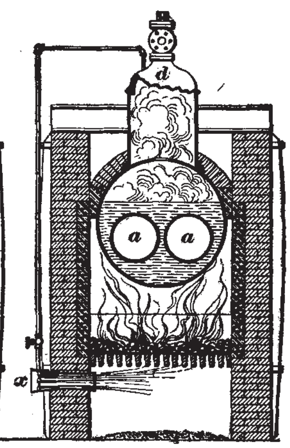


FIG. 6

and bridges are the same as were described for the plain cylindrical type. The hot gases, however, pass over the bridges to the chamber *h* and then through the flues *a, a* into the smokebox *b*, and out of the stack *c*. It is plain, therefore, that the heating surface is greater than that of the plain cylindrical boiler by the cylindrical surface of the flues *a, a*.

As shown in Fig. 5, the boiler has a cast-iron front, to which the furnace and the ash-pit doors are attached. A safety valve *g*, Fig. 4, is attached to the top of the dome;

from it are led two steam pipes—one to the engine, the other to carry the escaping steam outside the building.

The steam gauge *k* and gauge-cocks are placed on a column *l*, Fig. 5, that communicates with the interior of the shell through the pipes *s* and *t*, the former entering the steam space and the latter the water. The manhole *f*, Fig. 4, is placed on top of the shell instead of in the head. The feed-pipe is shown at *n*, the blow-off pipe at *m*; both pass through the rear wall. Access is given to the rear end of the shell and to the pipes *m* and *n* through the door *p*. This form of boiler may be provided with a blower, as shown at *x*.

The brick wall is built and supported in about the same manner as the wall of Fig. 1. The cast-iron *flue plate r*, Fig. 4, rests on the side and rear walls and supports the brickwork above it.

5. The **return tubular boiler** is a development of the flue boiler, the two large flues of the latter being replaced by

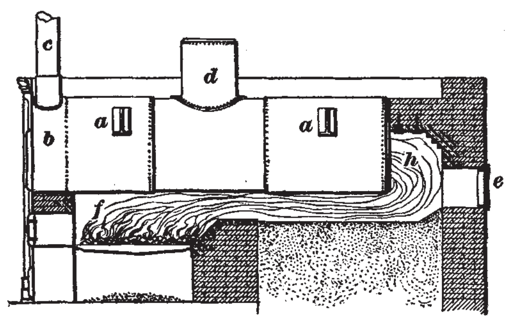


FIG. 7

a large number of small tubes, thus increasing the heating surface of the boiler. A side view of it is shown in Fig. 7; a cross-section through the boiler is shown in Fig. 8. The tubes extend the whole length of the shell, the ends being expanded into holes in the heads of the boiler. The front end of the shell projects beyond the head, forming the smokebox *b*, into which opens the stack *c*.

The shell is supported by the side walls through the brackets *a*, *a*, which are riveted to the shell and usually rest on iron rollers. The boiler is generally provided with a dome *d*, though this is sometimes left off. The walls are built and supported by buckstaves in practically the same manner as those previously described. Since this type of boiler is generally short, one bridge only is used. Firebrick is used for all parts of the wall exposed to the fire or heated gases. The fittings are not shown in the figures. The safety valve is placed on top of the dome, and the pressure gauge and gauge-cocks placed on the front of the boiler. The manhole is either in one of the heads or on top of the shell. The feedpipe enters the front head, the rear head, or the bottom of the rear end of the shell, while the blow-off pipe is placed at the bottom of the shell at the rear end. Access is given to the rear end of the boiler through the door *e*.

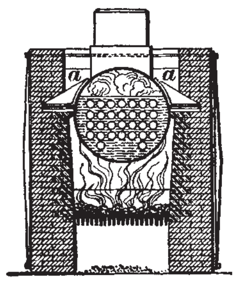


FIG. 8

As usual, the furnace *f* is placed under the front end of the boiler. The gases pass over the bridge, under the boiler into the chamber *h*, then through the tubes to the smoke-box *b*, and out of the stack *c*. The return tubular boiler is probably used more in mill work than any other.

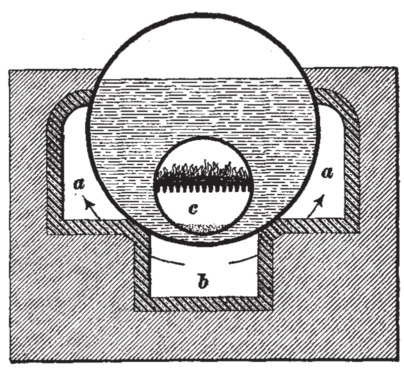


FIG. 9

6. Cornish and Lancashire Boilers. In the three forms of boilers so far considered, the furnace is placed outside of the shell of the boiler; such boilers are said to be **externally fired.** On the invention of the single-flue boiler, the idea was conceived of placing the fire in the flue, and the result is the so-called **Cornish boiler**, a cross-section of which is shown in Fig. 9. The boiler is set in masonry in such a manner as to form the passages *a*, *a*, *b*. The grate is supported in the single large flue *c*. The heated gases pass from the furnace to the rear through the flue *c*, and then return beneath the boiler through the flue *b*; they again return to the rear through the side flues *a*, *a*, and thence out of the chimney. This path of the gases constitutes the *split draft*.

It was formerly the general practice to arrange the brickwork setting so that the gases returned to the front through the side flues *a*, *a* and to the rear through the lower flue *b*. It was found, however, that this practice retarded the circulation of the water and rendered the shell more liable to strains due to unequal expansion and contraction. Consequently, the first method of producing the split draft is used almost exclusively in modern practice.

As shown in the figure, the brickwork passages are lined with firebrick.

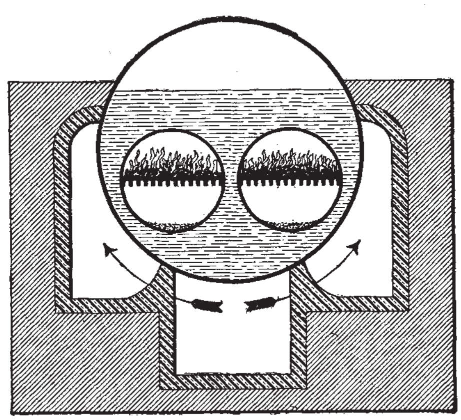


FIG. 10

7. The **Lancashire boiler** is a modification of the Cornish type. In order to give a large grate area and a large heating surface for the same diameter of shell, two large furnace flues are substituted for the one flue of the Cornish type. The brickwork setting, Fig. 10, is similar to that of the Cornish boiler, Fig. 9; the split draft is also formed in the same manner.

8. The **Galloway boiler** is a modification of the Lancashire type. It has two internal furnace flues fitted with grates, ash-pit, etc. in the usual manner. Instead of extending through the whole length of shell, the two flues unite just behind the bridge into one large kidney-shaped flue, which extends from this junction to the rear head of the shell. This large flue is strengthened by a large number of water legs of the form shown in Fig. 11. The setting of the Galloway boiler is similar to that shown in Figs. 9 and 10. The draft is split as previously described.

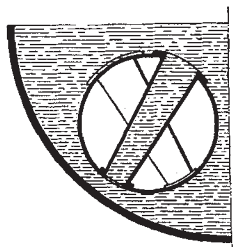


FIG. 11

9. The Cornish, Lancashire, and Galloway boilers belong to the general class known as **internally fired boilers.** The chief objection to these boilers is the liability of the collapse of the internal flues, and the straining actions set up by the expansion and contraction of these flues. The chief point in their favor, and in favor of internally fired boilers generally, is their economy in the use of fuel. Generally speaking, all conditions being the same, an internally fired boiler is 10 per cent. more economical than an externally fired boiler; this fact is due to the loss of heat by radiation through the brickwork setting of the latter class of boilers. These boilers are extremely popular in England, and on the continent of Europe, but they are little used in the United States.

10. Water-Tube Boilers.—The various types of boilers described have been developed from the original plain cylindrical boiler by the addition of flues and tubes, for the purpose of increasing the water-heating surface; they are, in general, known as **fire-tube boilers.** A similar development along a different line has given rise to a distinct class of boilers, known as **water-tube boilers.**

11. The **Babcock and Wilcox water-tube boiler,** shown in Fig. 12, consists essentially of a main horizontal drum, or shell, *b* and of a series of inclined tubes *t*, *t*. (Only a single vertical row of tubes is shown in the figure, but it will be understood that there are usually seven or eight of these rows to each horizontal drum.) The ends of the tubes of a vertical row are expanded into hollow iron castings *h*, called *headers*, that are placed in communication with the drum by tubes, or *risers*, *c*, *c*. A handhole is placed in the header in front of each tube for the purpose of cleaning, inspecting, or removing the tubes.

The usual method of supporting the boiler, which is not shown in the figure, is to hang it from wrought-iron girders resting on vertical iron columns; the brickwork setting is not depended on as a means of support. This make of boiler, in common with all others of the water-tube type, requires a brickwork setting to confine the furnace gases to their proper field.

The furnace is of the usual form and is placed under the front end of the nest of tubes. The bridge wall *g* is built

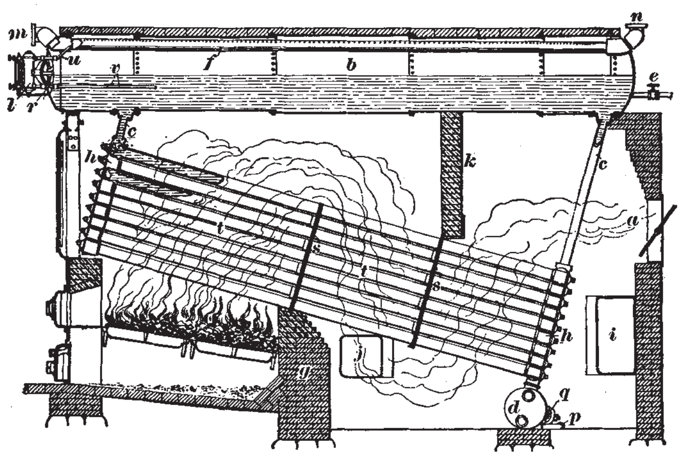


Fig. 12

up to the bottom row of tubes; another firebrick wall *k* is built between the top row of tubes and the drum. These walls and the baffle plates *s*, *s* force the hot furnace gases to follow a zigzag path back and forth between the tubes. The gases finally pass, through the opening *a* in the rear wall, into the chimney flue.

The feedwater is introduced through the feedpipe *e*. The steam is collected in the *dry pipe f*, which terminates in the *nozzles m, n*, to one of which is attached the main steam pipe, and to the other the safety valve. The pressure gauge, cocks, etc. are attached to the column *l*, which communicates with the interior of the shell by the small pipes *u, v*—the former of which extends into the dry pipe, the latter into the water.

At the bottom of the rear row of headers is placed the *mud-drum d*. Since this drum is the lowest point of the water space, most of the sediment naturally collects there and may be blown out from time to time through the blow-off pipe *p*. The drum *d* is provided with a handhole *q*, while a manhole *r* is placed in the front head of the drum *b*. The heads of the drums are of hemispherical form, and, therefore, do not require bracing. Access may be had to the space within the walls through the doors *i, j*.

The circulation of water takes place as follows: The cold water is introduced into the rear of the boiler; the furnace being under the higher end of the tubes, the water in that end expands on being heated, and is also partly changed to steam; hence, a column of mingled water and steam rises through the front headers to the front end of the drum *b*, where the steam escapes from the surface of the water. In the meantime, the cold water fed into the rear of the drum descends to the rear headers through the long tubes *c* to take the place of the water that has risen in front. Thus, there is a continuous circulation in one direction, sweeping the steam to the surface as fast as it is formed, and supplying its place with cold water.

12. The **Heine water-tube boiler,** shown in Fig. 13, differs in many respects from those described. It consists of a large drum *a* placed above, and parallel with, the nest of tubes *t, t*, and inclined at an angle with the horizontal that brings the water level to about one-third its height in front and about two-thirds its height in the rear. The ends of the tubes are expanded into the large wrought-iron water legs *b, b* that are flanged and riveted to the shell, which is cut out for about one-fourth of its circumference to receive them, the opening being from 60 to 90 per cent. of the total cross-sectional area of the tubes. The drum heads are of a hemispherical form and, therefore, do not need bracing. The water legs form the natural support of the boiler, the front water leg being placed on a pair of cast-iron columns *e* that form part of the boiler front, while the rear water leg rests on rollers *f* that move freely on a cast-iron plate bedded in the rear wall; these rollers allow the boiler to expand freely when heated.

The boiler is enclosed by a brickwork setting in the usual manner. The bridge *g*, made largely of firebrick, is hollow,

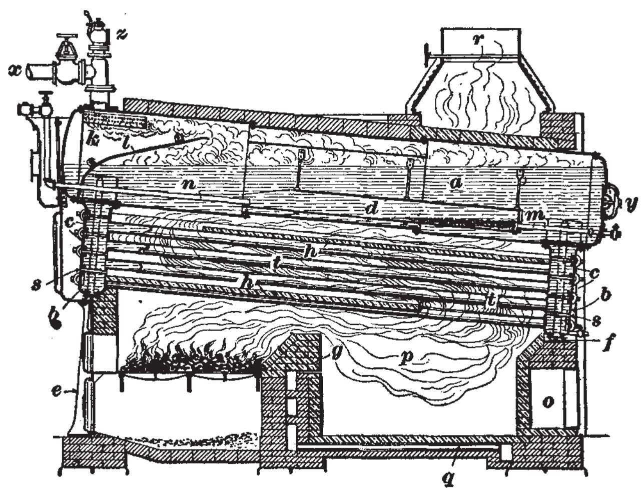


Fig. 13

and has openings in the rear to allow air to pass into the chamber *p* and mix with the furnace gases. This air is drawn from the outside through the channel *q* in the side wall and is heated in passing through the bridge. In the rear wall is the arched opening *o*, which is closed by a door and is further protected by a thin wall of firebrick; this may be removed when it is necessary to enter the chamber *p*, and afterwards replaced.

The feedwater is brought in through the feedpipe *n*, which passes through the front head. As the water enters, it flows into the mud-drum *d*, which is suspended in the main drum below the water-line, and is thus completely submerged in the hottest water in the boiler. This high temperature precipitates the impurities contained in the feedwater; these settle in the mud-drum *d* and may be blown out through the blow-out pipe *m*.

Layers of firebrick *h, h* act as baffle plates and force the furnace gases to pass back and forth between the tubes; the gases finally escape through the chimney *r* placed above the rear end of the boiler. The drum in the vicinity of the chimney is protected by firebrick, as shown in the figure, to protect the steam space from the action of the hot gases.

The steam is collected and freed from water by the perforated dry pipe *k*. The main steam pipe, with its stop-valve, is shown at *x*, the safety valve at *z*. In order to prevent a combined spray of mixed water and steam from spurting up from the front header and entering the dry pipe, a deflecting plate *l* is placed in the front end of the drum. A manhole *y* is placed in the rear head of the drum. The flat sides of the water legs are stayed together by the stay-bolts *s, s*. A handhole *c* is placed in front of each tube to give access to its interior; the covers for these holes have been omitted in the illustration in order to avoid confusion.

Where a battery of several of these boilers is used, an additional steam drum is placed above and at right angles to the drums *a*.

13. The **Stirling boiler,** shown in Fig. 14, is a departure from the regular type of water-tube boilers. It consists of a lower drum *a* connected with three upper drums *b, b, b* by three sets of nearly vertical tubes; these upper drums are in communication through the curved tubes *c, c, c*. The curved forms of the different sets of tubes allow the different parts of the boiler to expand and contract freely without strain.

The boiler is enclosed, as shown, in a brickwork setting, which is provided with various holes *h, h*, so that the interior may be inspected or repaired. The boiler is suspended from a framework of wrought-iron girders not shown in the figure.

The bridge *e* is lined with firebrick, and is built in contact with the lower drum *a* and the front nest of tubes. An arch *d* built above the furnace, in connection with the bafflers *f*, *f*, causes the heated gases to pass up and down between the tubes. The arch and the bafflers are made of firebrick.

The cold feedwater enters the rear upper drum through the tube *x* and descends through the rear nest of tubes to

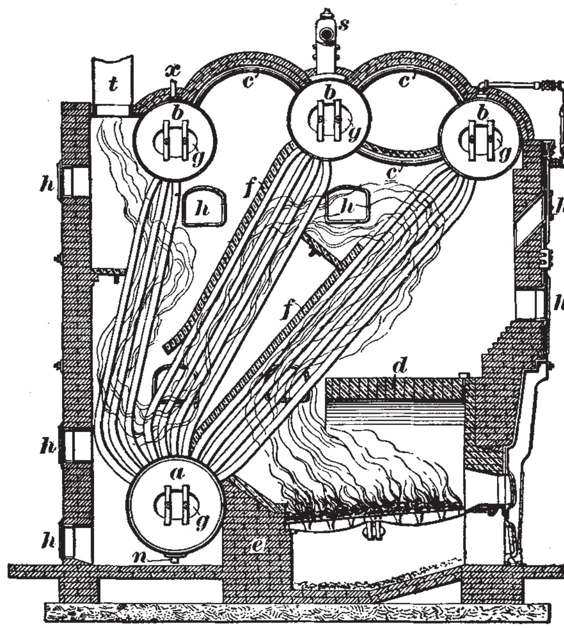


Fig. 14

the drum *a*, which acts as a mud-drum and collects the sediment brought in by the water, which is removed by means of the blow-off pipe *n*. The steam collects in the front upper drums *b*, *b*. The steam pipe and safety valve *s* are attached to the middle drum. The chimney *t* is located behind the rear upper drum; therefore, the cold feedwater enters the coolest part of the boiler, and the circulation of the water is directly opposite to that of the escaping hot gases. The water column *l*, with its fittings, is placed in communication with the front upper drum. All the drums are provided with large manholes. The boiler is made with a cast-iron front.

The following advantages are claimed for the Stirling boiler: (1) The vertical position of the tubes prevents the collection of sediment and at the same time encourages the rapid rise and separation of the steam as soon as it is formed. (2) The boiler is very simple and easy to construct; there are no flat surfaces to be stayed, and there is little or no machine work required in its manufacture. (3) It is easy of access for cleaning or repairs; any part of the boiler may be inspected by removing the necessary manhole plates.

The water-tube boilers described are coming into extensive use. The most important points in their favor are their safety from disastrous explosion and their economy in the use of fuel. An objection sometimes urged against them is that they require more attention; since they usually have much less cubic capacity than cylindrical boilers of the same power, the water level must be closely watched.

14. The Feed-Apparatus.—Water is supplied to a boiler either by a steam pump, by an injector, or by both. Every boiler should have two independent feeds, in order to prevent accident should one get out of order.

The feedwater pipe may enter the boiler either through one of the heads or through the shell. By some engineers it is placed in the front head directly over the *furnace sheet* of cylindrical, flue, or return tubular boilers, while others place it on top in the shell; still others place it as low as possible in the back head, or through the front or back head, just below the water-line near the shell. It is not good practice, however, to deliver the cold feedwater near the hot furnace plates, as the strains set up by the sudden cooling of the plates may seriously injure them. Feedpipes should not terminate immediately at the plate into which they are screwed, but between the center of the boiler and the rear head; sometimes 2 or 3 feet of the end of the feedpipe is perforated for the purpose of diffusing the feedwater.

The position of the feedwater pipe, and likewise the point where the feedwater discharges into the boiler, have been shown in the illustrations of some of the boilers described.

15. In Fig. 15 is shown an ordinary method of arranging the feedwater pipes, where several boilers are supplied by the same pump. The pump discharges the feedwater into the main pipe *p*, *p*, which runs along the fronts of the boilers; the branch pipes that enter the front head *c* of each

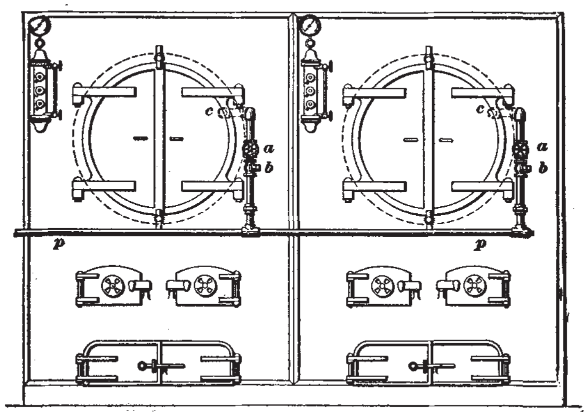


FIG. 15

boiler are provided with a globe valve *a* and a check-valve *b*. The globe valve shuts off the water from the boiler, while the check-valve allows the water to enter the boiler when the globe valve is open, but prevents its return.

16. Feedwater Heaters.—It is important that the feedwater should be introduced into the boiler at as high a temperature as possible; for by this means the strains produced in different parts by the introduction of cold feedwater may be avoided and a saving in fuel effected. Feedwater heaters are of two classes: (1) Those that use exhaust steam from the engine; (2) those that use the waste furnace gases. Heaters of the first class usually consist of a vessel, generally of cylindrical form, filled with rows or coils of tubes. In some heaters, the steam passes through tubes that are surrounded by the feedwater; in others, the water is pumped through the tubes, which are, in this case, surrounded by the exhaust steam.

A common form of feedwater heater is shown in Fig. 16, which gives two views—a longitudinal section through the shell and a section taken along a line through the manhole *h* and the inlet feedpipe *f*. It consists of an outer cylindrical shell and an inner shell fitted with numerous tubes. The feedwater enters through *f* and fills the space in the inner shell not occupied by the tubes. The exhaust steam enters at *a*, flows through the tubes, then back through the space between the inner and outer shells, and out through *b*. The

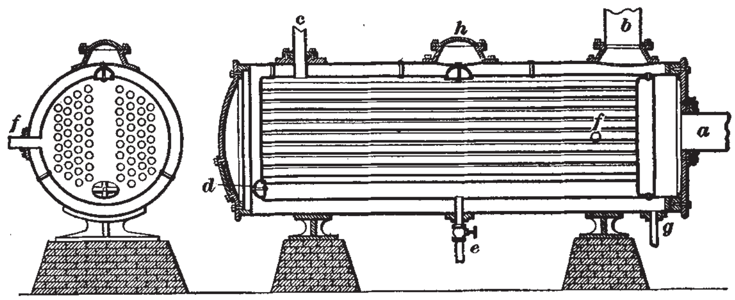


Fig. 16

feedwater flows through *c* into the boiler; *d* is a handhole; *e* the blow-off pipe; and *h* a manhole. When it is desired to economize space, vertical feedwater heaters are used instead of the horizontal pattern shown.

17. Economizers use the heat in the waste furnace gases to raise the temperature of the feedwater. The temperature of the gases on entering the chamber is usually from 450° to 650° F., and by lowering it to 250° or 300° a marked saving of fuel must result. The draft of the chimney, however, depends on the temperature of the gases, but the loss in draft consequent on the reduction of temperature may be made up by increasing the height of the chimney.

Fig. 17 shows the location of an economizer with respect to the boilers and chimney; it is placed directly in the flue. The water enters at *f*, where the economizer is coolest, and

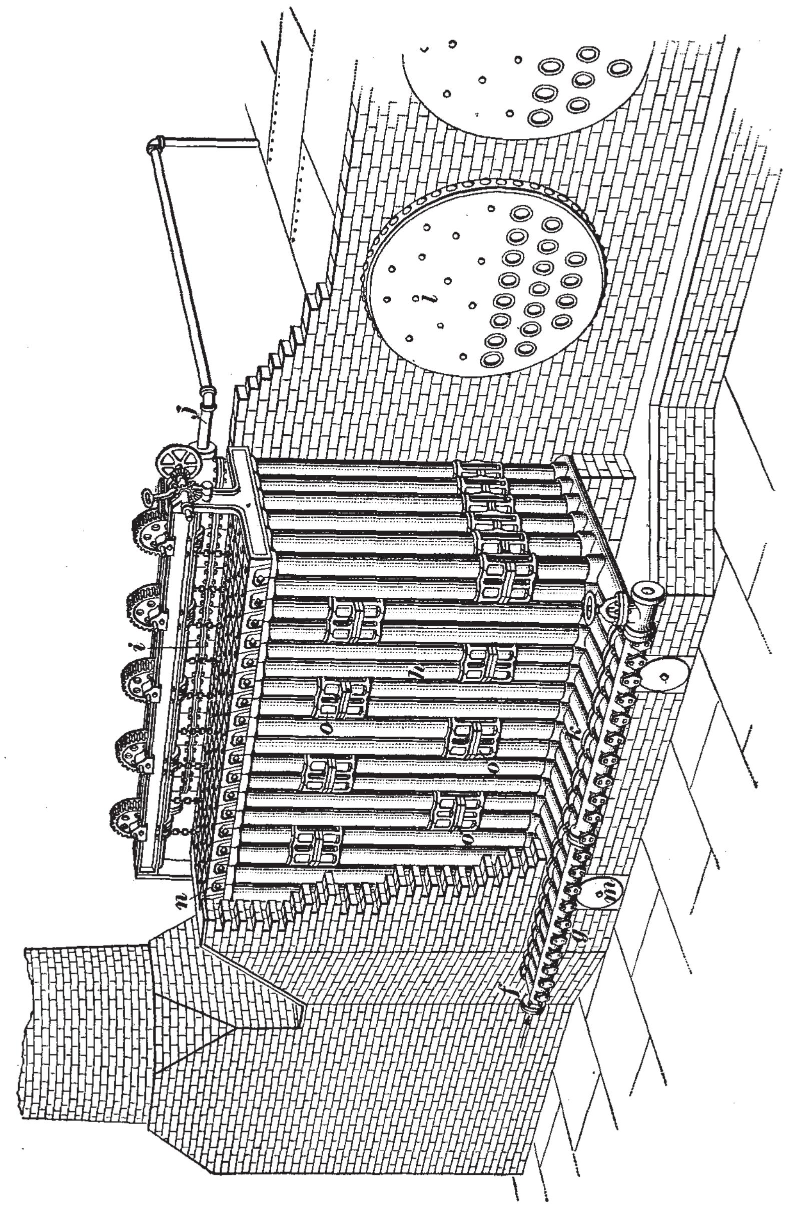


Fig. 17

flows along the pipe *g*, from which it flows, at right angles to its former direction, through a series of horizontal radiating headers *k* and up the rows of vertical tubes *h* that connect with them. Each of these vertical rows has an upper header *n* that has one outlet into the delivery pipe *i*, to which is connected the pipe *j* leading to the boilers *l*. The hot gases from the boilers pass through the rows of tubes on their way to the chimney, coming in contact with the rows containing the hottest water first. The feedwater may be heated by this means to as high as 300° F. and the temperature of the gases reduced from the neighborhood of 600° to 250°, or 300°. The fragment of the brick wall, shown at the left, is supposed to continue to the right in front of the

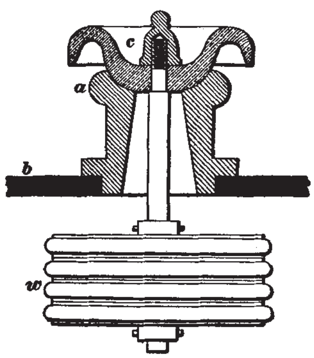


FIG. 18

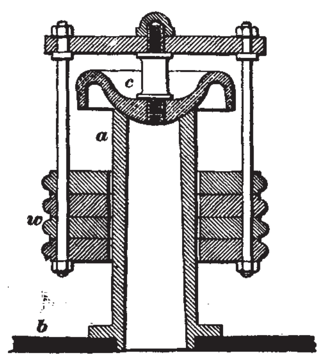


FIG. 19

economizer and also in front of the boilers over the low wall there indicated, thereby completing the flue leading from the boilers to the chimney.

The hot gases deposit soot and other unconsumed particles on the tubes. Since these are bad conductors of heat, the efficiency of the economizer would soon be greatly impaired unless means were provided for removing the soot. This is accomplished by scrapers *o, o* that are moved up and down by means of suitable mechanism on top of the economizer; the opening *m*, with other similar openings, is for the removal of the soot scraped from the tubes.

18. The **dead-weight safety valve,** shown in Fig. 18, consists of a hollow seat *a* attached to the boiler shell *b*, over which is fitted the valve disk *c*. The disk is loaded with a heavy weight *w* that hangs into the steam space of the

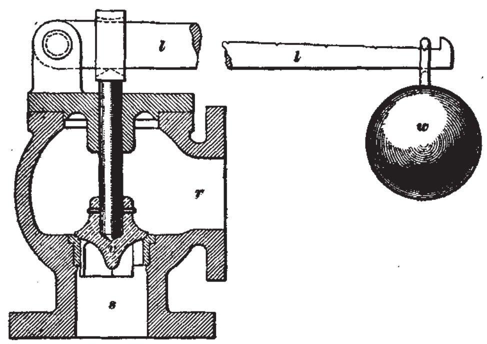


FIG. 20

boiler. Fig. 19 shows another form of dead-weight valve, in which the weight is carried outside of the boiler shell.

Two forms of **lever safety valves** are shown in Figs. 20 and 21. In Fig. 20, the valve *v* is held to its seat by the weighted lever *l*. The position of the weight *w* is adjustable,

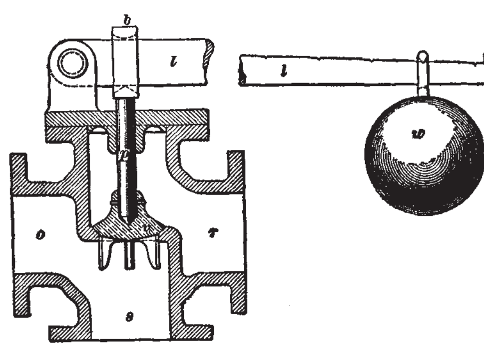


FIG. 21

so that the valve may be set to blow off at different steam pressures. The valve shown in Fig. 20 is attached directly to the boiler shell; the steam enters from the boiler at *s* and is discharged through the orifice *r*. That shown in Fig. 21

differs from the other in being attached to the supply pipe. The steam passes on its way from the boiler through the passage *s*. When the pressure rises above the normal, the valve *v* opens and the steam escapes into the air through the opening *r*.

19. The **steam gauge** indicates the pressure of the steam contained in the boiler; the most common form is the *Bourdon pressure gauge*, Fig. 22. It consists of a tube *a*, of elliptical cross-section, that is filled with water and connected at the point *b* with a pipe leading to the boiler. The

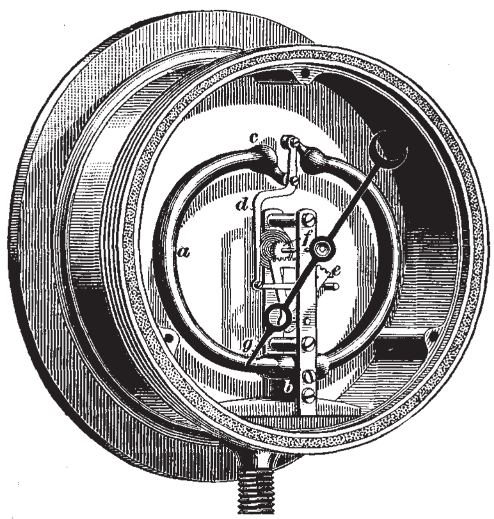


FIG. 22

two ends of the tube *a* are closed and attached to a link *d* that is, in turn, connected with a sector *e*; the latter gears with a pinion *f*, which is attached to the shaft carrying the index pointer *g*. When the water contained in the elliptical tube is subjected to pressure, the tube tends to take a circular form, and the tube as a whole straightens out, throwing out the free ends a distance proportional to the pressure. The movements of the free ends are transmitted to the pointer by the link, sector, and pinion, and the pressure is recorded on the graduated dial.

20. The **gauge glass** is a glass tube so placed that its lower end communicates with the water space of the boiler, while its upper end communicates with the steam space. Hence, the level of the water in the gauge should be the same as in the boiler.

Boilers should be provided with both cocks and gauge glasses; Fig. 23 shows an arrangement recommended by the Hartford Boiler Insurance Company. *a* is a round cast-iron column, the inside diameter of which is about 4 inches. The upper end communicates with the steam space of the boiler by means of the pipe connection *b*, and the lower end with the water space through the pipe connection *c*; *d* is a drip pipe for removing the condensed steam from the column. The water glass *e* communicates with the column through the connections *f*, *g*. There are three gauge-cocks, *h*, *i*, *j*. The center line of the lowest, *j*, should be located at least 3 inches above the level of the tops of the upper row of tubes in a tubular boiler to insure their always being covered with water. The gauge *l* is connected to the pipe *b* by means of the inverted siphon pipe *k*.

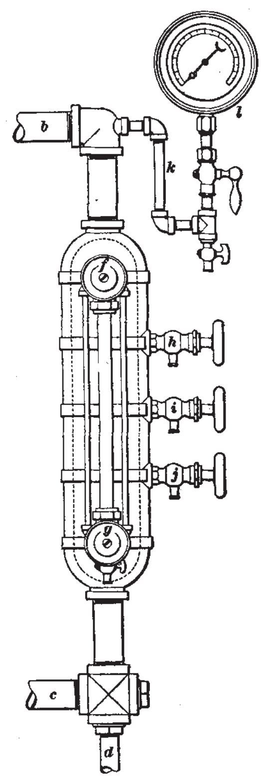


FIG. 23

21. **Fusible plugs** are placed in the upper plates, or *crown sheets*, of furnaces as a safeguard against overheating through shortness of water; they consist of an alloy of tin, lead, and bismuth, which melts at a comparatively low temperature. So long as the crown sheet is well covered with water, the plug is kept from melting by the comparative coolness of the water;

but should the water sink low enough to uncover the top of the plug, it quickly melts and allows the steam and water to rush into the furnace, thus relieving the pressure and extinguishing the fire.

22. The **grate,** which supports the fuel, is usually made of cast-iron bars *a*, Fig. 24, placed side by side and supported by wrought-iron bearers. The lugs cast on each bar determine the size of the air spaces in the grate. For anthracite coal, the air space is $\frac{3}{8}$ to $\frac{1}{2}$ inch wide; while for coals that cake much, the width of space may be $\frac{3}{4}$ inch. The bars are about $\frac{3}{4}$ inch wide at the top and taper toward the bottom. For long furnaces, the bars are generally made in lengths of about 3 feet each, with a bearer in the middle of the grate.

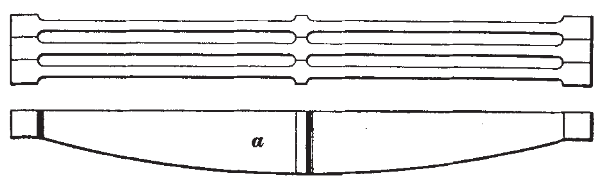


Fig. 24

Long grates are generally set with the slope toward the bridge to facilitate the firing. Shaking grates are to some extent taking the place of the ordinary grate. By their use the fire may be cleaned with little labor and without opening the fire-door.

STEAM ENGINES

23. A **steam engine** is a machine for converting the *potential*, or stored, energy of steam under pressure into *kinetic*, or actual, energy as a source of motive power for driving the machines of the mill or for performing such other work as may be desired. In a general way, engines may be divided into three classes—stationary, locomotive, and marine—the first class being the type generally used in mill work. Stationary engines are designated, according to the number and arrangement of the cylinders, as *simple*, *compound*, *triple expansion*, etc., or, according to the type of

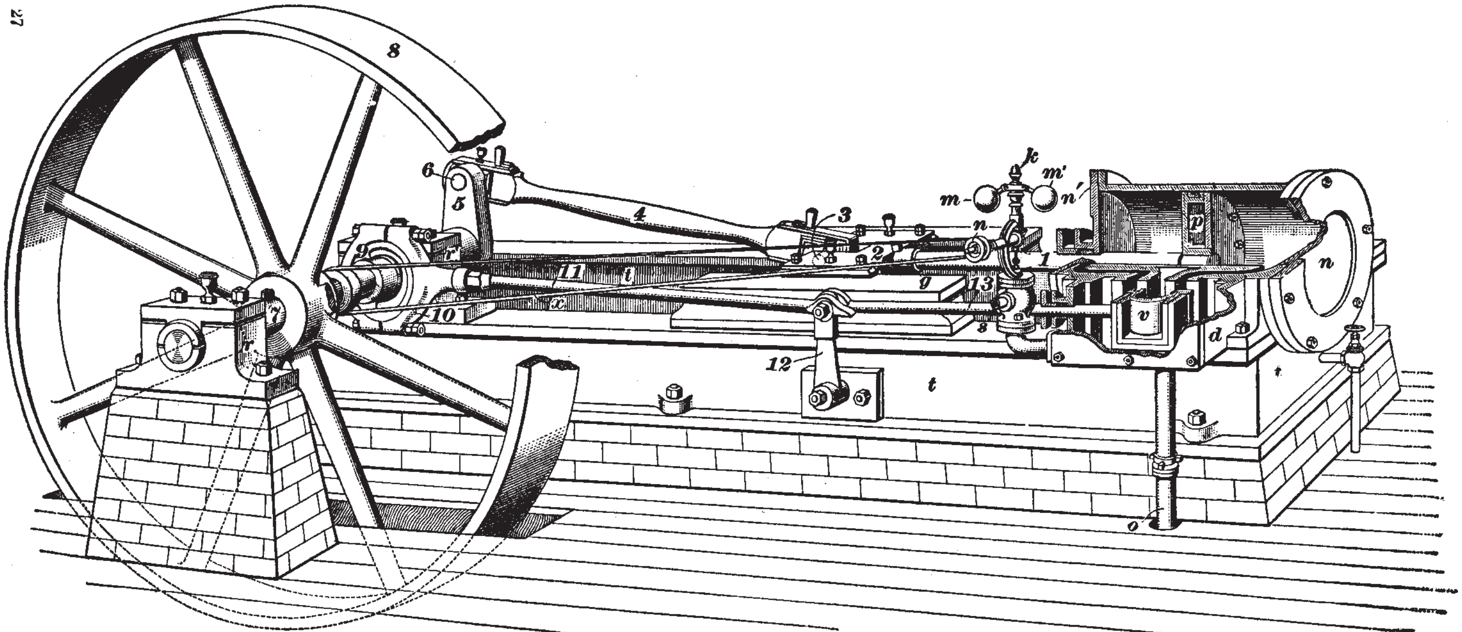


Fig. 25

valve used, as *plain slide-valve*, *automatic cut-off*, *Corliss*, etc.; they may be horizontal or vertical, condensing or non-condensing, single-acting or double-acting. All these types involve essentially the same principles and therefore only those that are commonly met with in mill work will be described.

24. Simple Slide-Valve Engine.—In Fig. 25 a simple, plain, slide-valve engine is shown, while in Fig. 26 is shown a section through the cylinder. *h* is the head end and *c* the

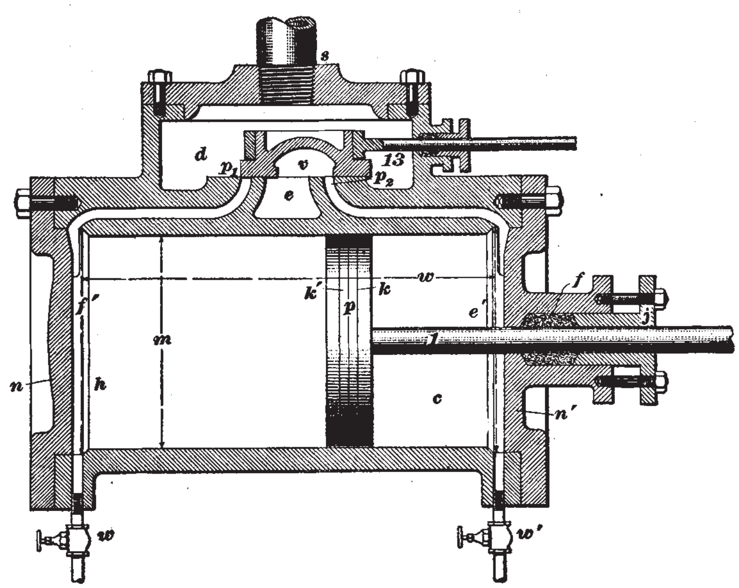


Fig. 26

crank end of the steam cylinder; p_1, p_2 are the steam ports; *d* is the steam chest; *e*, the exhaust port; *n*, *n'*, the cylinder heads; *s*, the steam supply pipe; *o*, Fig. 25, the exhaust pipe that connects with the exhaust port *e*; *g*, one of the two guide bars; *r*, *r'*, the shaft bearings; and *t*, the bed, or frame, of the engine. These parts do not change their relative positions when the engine is in motion. *p* is the piston; *1*, the piston rod; *2*, the crosshead; *3*, the crosshead pin; *4*, the connecting-rod; *5*, the crank; *6*, the crankpin; *7*, the crank-shaft; *8*, the flywheel; *9*, the eccentric; *10*, the eccentric strap; *11*, the eccentric rod; *12*, the rocker; *13*, the valve rod, or stem; and v, the slide valve. These parts are movable and change their relative positions when the engine is in motion. The working length w of the cylinder is slightly less than the distance between the cylinder heads, since a small space must be left between the head and the piston when the latter is at the end of its stroke; this space, together with the volume of the steam port, which leads to it, is called the *clearance*. The diameter, or bore, is m.

The *stroke* of the engine is the travel of the piston p; it is equal to the diameter of the circle described by the crankpin *6*, or, what is the same thing, it is equal to twice the length of the crank *5*, this length being measured from the center of crankpin *6* to the center of the crank-shaft *7*. Since the piston and crosshead are rigidly fastened to the piston rod, the stroke must also be equal to the travel of the crosshead.

The size of an engine is generally expressed by giving the diameter of the cylinder and the stroke, in inches; thus, an engine having a cylinder diameter of 16 inches, and a stroke of 22 inches, is called a $16'' \times 22''$ engine.

At the ends e', f', the cylinder is *counterbored;* that is, for a short distance, the bore is greater than m. The piston projects partly into this counterbore at the end of each stroke. Were it not for the counterbore, the piston would not wear the cylinder walls their entire length, and shoulders would be formed at each end of the cylinder, with the result that when it became necessary to take up the wear of the joints in the connecting-rod, and thus slightly increase the length of the connecting-rod, the piston being shoved slightly toward the head end of the cylinder, would strike the shoulder and thus cause an undesirable pounding. Drain cocks w, w' are fitted in each end of the cylinder for the discharge of the condensed steam.

The piston fits loosely in the cylinder and has split rings k, k' inserted, which spring out so as to press against the wall of the cylinder and prevent leakage of steam between the wall of the cylinder and piston; they are usually held in place by a follower plate, which is bolted to the head end of the piston *p*. The piston rod *1* is a round bar rigidly connected to both the piston *p* and the crosshead *2*.

The *stuffingbox f*, in which packing is placed, is fitted with a gland *j* that, when bolted down, compresses the packing around the piston rod *1* and makes a steam-tight joint. This packing usually consists of split rings that are so placed that the split of one ring is covered by the solid part of the next. The crosshead *2* is given an easy sliding fit between the guide bars *g*, which are in line with the path of the piston rod, and combine with the crosshead to relieve the piston rod of all bending stresses.

The connecting-rod *4* joins the crosshead and crank *5*; it is fastened to the crosshead by the crosshead pin *3*, and to the crank by the crankpin *6*. Connecting-rods are usually from four to six times the length of the crank, or from "4 to 6 cranks" in length.

25. In operation, the steam at the boiler pressure is admitted to the steam chest *d*, through the main steam pipe *s*. As the slide valve *v*, known as a **D**-*slide valve*, is moved to the right (Fig. 26) by the valve rod *13*, which is operated by the eccentric on the crank-shaft, the port p_1 is uncovered. This admits the steam to the head end *h* of the cylinder and forces the piston from the head end to the crank end of the cylinder. As the piston moves in this direction, the exhaust steam from the previous stroke of the piston is forced through the port p_2, and the exhaust port *e*, the under side of the valve *v* being hollowed out to allow the exhaust steam to pass from the cylinder. As the valve *v* is moved in the opposite direction by the eccentric *9* and valve rod, the port p_1 is closed. This usually takes place a little before the piston reaches the end of its stroke, so as to gain the benefit of the expansion of the steam as well as of its initial, or boiler, pressure, and is known as the *cut-off*. The continued movement of the valve then opens the port p_2 and allows the steam to enter the crank end *c* and force the piston from the crank end to the head end of the cylinder, the exhaust steam from the previous

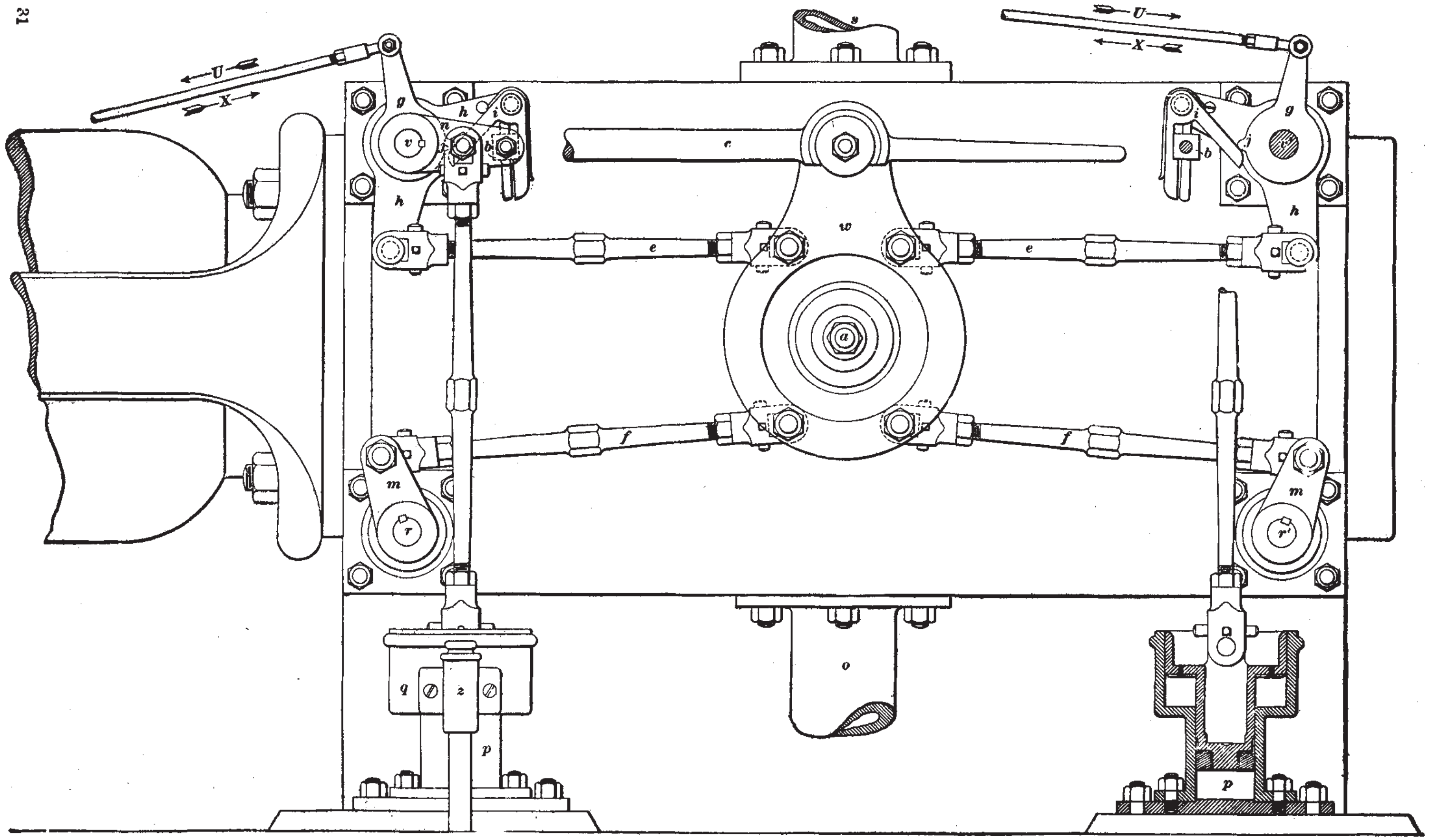


FIG. 27

stroke moving in front of the piston and escaping through the port p_1 and exhaust port *e*. While the piston is moving from the crank end of the cylinder the steam is cut off nearly in the same manner as when it is moving from the head end, and the piston finishes its stroke by virtue of the expansion of the steam that has been admitted to the cylinder.

In Fig. 26, the piston is moving from the head end to the crank end of the cylinder, while the valve is moving from the crank end to the head end, having just reached the point where it cuts off the further admission of the steam to the cylinder. The repetition of these movements results in the

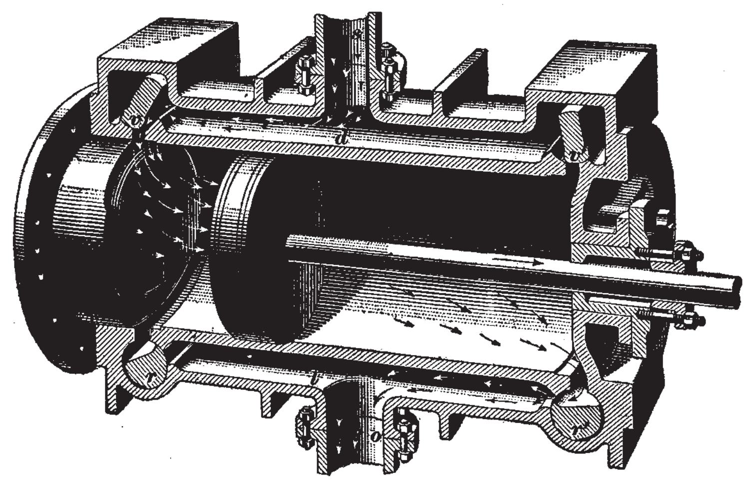


FIG. 28

piston being alternately forced forwards and backwards, the motion being imparted by the piston rod *1*, to the cross-head *2*, connecting-rod *4*, and crank *5*, and finally resulting in a rotary motion of the crank-shaft *7* and flywheel *8*.

26. Corliss Engine.—The Corliss simple engine differs from the simple slide-valve engine in that the steam is admitted into and removed from the cylinder by means of the Corliss valve gear, a mechanism that is used in a large number of engines of different makes. A side elevation of it is shown in Fig. 27, and a section through the cylinder and valves, in Fig. 28. It has four separate and distinct valves. Two of these, *v*, *v′*, Fig. 28, connect directly with the steam chest *d* and steam pipe *s*, and are called *steam valves*. They are rigidly connected with the cranks *n*, Fig. 27, one of which is removed in order to show more clearly the disengaging link *i*. The other valves, *r*, *r′*, Fig. 28, connect directly with the exhaust chest *l* and the exhaust pipe *o*, and are called *exhaust valves;* they are rigidly connected with the cranks *m*, Fig. 27. All the valves are cylindrical in form and extend across the cylinder above and below, respectively.

The disk, or wristplate, *w*, Fig. 27, is made to rock on a stud *a* by the eccentric rod *c* connecting it with an eccentric on the crank-shaft. There are four valve rods: *e*, *e*, which connect the wristplate *w* with the bell-cranks *h* of the steam valves, and *f*, *f*, which connect the wristplate *w* with the cranks *m* of the exhaust valves. The valve rods can be lengthened or shortened as the case may require, and the action of any one valve can be regulated independently ofthe others. As the wristplate *w* rocks backwards and forwards, the exhaust valves *r*, *r′*, which are rigidly connected with their cranks *m*, rock with it. The bell-cranks *h*, which are provided with the disengaging links shown at *i* are also given this rocking motion, and by hooking on to the blocks *b*, which are rigidly connected to the cranks *n*, open the steam valves *v*, *v′*.

The projections *j* on the two trip collars *g* unhook these disengaging links *i* after they have rotated the valves *v*, *v′* through a certain angle, and the cranks *n* are pulled to their first positions by the vacuum dashpots *p* against the resistance of which the valve cranks *n* were raised. The movements of the valves open and close the steam and exhaust ports of the cylinder at the proper intervals. The pins of the valve rods are so located on the wristplate that the steam valves *v*, *v′* have their quickest movement while the exhaust valves *r*, *r′* have their slowest, and the exhaust valves have their quickest movement while the steam valves have their slowest. As a consequence of this arrangement, the steam and exhaust valves have entirely independent movements, and the inlet ports may be suddenly opened full width by the quick movement of the steam valves, while the exhaust valves are practically motionless. The advantage of this valve gear is that it permits an earlier cut-off, with a greater range, a more perfect steam distribution, and a smaller clearance space than is attained with the plain slide valve. Engines fitted with the Corliss valve gear cannot be run at much more than 90 revolutions per minute.

27. Governors.—When a steam engine is running at a uniform speed, the work done by the steam in the cylinder must just equal the resistance overcome at the flywheel rim. Should the resistance become less than the work, the amount of work in excess of that necessary to overcome the resistance will cause the moving parts to move faster and faster, and the engine will *race*, or *run away*. If, on the contrary, the resistance should exceed the work, the engine will slow down, and finally stop. The work required of the engine cannot, of course, remain always constant; hence, it is necessary to have some means of automatically adjusting the steam supply to the variation of the resistance; this is accomplished by the **governor.**

Steam-engine governors may be divided into two classes: (1) *throttling governors*, which throttle the steam in the supply pipe, and (2) *automatic*, or *adjustable cut-off*, *governors*, which regulate the steam supply by changing the point of cut-off of the valve.

The ordinary throttling governor, shown in Fig. 25, consists of a balanced throttle valve placed on the steam pipe *s* and attached to the spindle *k*, at the upper end of which are the two flyballs m, m'; the spindle and flyballs form what is known as a *revolving pendulum*. The spindle and balls are driven from the main shaft by the belt x through bevel gears. If the engine moves faster than the desired speed, the flyballs are forced to revolve at a higher speed, and will, consequently, move outwards and upwards through the action of centrifugal force; this forces the spindle *k* downwards, and partly closes the throttle valve.

The engine thus takes less steam, and the speed falls to the desired point, the governor balls in the meantime returning to their original position. Should the resistance become greater than the power of the engine, it slows up slightly, the balls drop and open the valve wider; more steam is thus admitted and the engine immediately regains its original speed. The chief objection to the throttling governor is that the steam is *wire drawn*, or *throttled*, these being the terms applied to cases in which the steam pressure is reduced owing to the insufficiency of valve opening. Steam is more or less wire drawn in all engines fitted with plain slide valves because the movement of the valve is comparatively slow when closing the ports. With Corliss and other releasing-gear engines, the valve movement at cut-off and release is very rapid, and the wire drawing very slight.

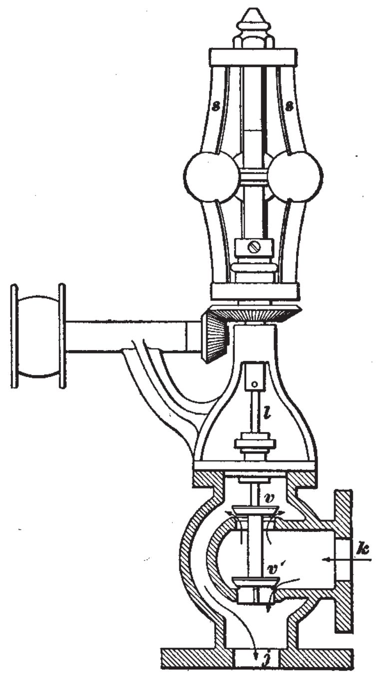


FIG. 29

The well-known *Pickering governor* is shown in Fig. 29. As the three balls move outwards against the resistance of gravity and the three flat springs *s*, they lower the valves *v*, *v′*. The steam enters at *k*, flows in the direction of the arrows, and then through *j* into the steam chest. Since steam is on both sides of the valves, they are balanced. The object of using two valves instead of one is to afford a large opening with a small lift of the valve.

28. As applied to the Corliss type of engines, the revolving pendulum or flyballs vary the point of cut-off instead of throttling the steam supply. The method of operation is shown in Fig. 30; the flyballs *m*, *m′* are here given a rotary motion by a belt, pulleys, and gears, in the same manner as in Fig. 25.

Let it be supposed that the engine is running at its proper speed; the flyballs will be held in their normal position by the balance existing between the centrifugal and gravity forces acting on them. Should the speed of the engine increase from any cause whatever, the centrifugal force acting on the flyballs will also increase and will throw them out; that is, increase the diameter of the circle in which they rotate, until a new balance is effected between the centrifu-

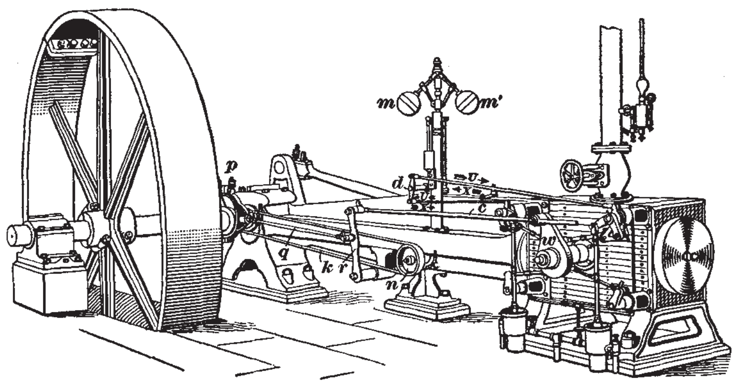


FIG. 30

gal force and the attraction of gravity. This movement of the flyballs will be transmitted to the lever *d*, Fig. 30, causing it to turn slightly about its center, thereby moving the rods, connecting it with the trip collars *g*, Fig. 27, in the direction *X*, compelling the collars to turn through a small angle in such a direction that their projections *j* will unhook the disengaging links *i*, earlier in the stroke. This will cause the point of cut-off to occur earlier in the stroke and a decrease in the speed of the engine, on account of the reduction in the amount of steam admitted to the cylinder, and an increased ratio of expansion of the steam under the same initial pressure. Should the speed from any cause diminish, a reverse operation will be the result. The flyballs will drop slightly; *d*, Fig. 30, with the rods, will move in the directions indicated by the arrow *U*, and the trip collars *g*, Fig. 27, will be rotated in such a manner as to cause their projections *j* to unhook the disengaging links *i* later in the stroke; the cut-off will then occur later in the stroke, and a diminished ratio of expansion at the same pressure will again bring the speed up to its proper point.

29. Condensers.—As already stated, engines may be of the non-condensing or of the condensing type. In the former, the exhaust steam from the cylinder passes directly into the atmosphere; therefore, the back pressure, or pressure against the motion of the piston, must at least equal the pressure of the atmosphere, which is 14.7 pounds per square inch. Since the exhaust steam has a slight pressure after passing through the engine, the back pressure in non-condensing engines is usually from 16 to 19 pounds per square inch. In a condensing engine, the exhaust steam from the cylinder is condensed to water, so that a partial vacuum, or pressure less than that of the atmosphere, is formed in front of the moving piston. In good condensing engines, the back pressure in the engine is sometimes as low as 2 pounds per square inch.

There are two types of condensers in general use—the *surface condenser* and the *jet condenser*. In the former, the exhaust steam comes in contact with a large area of metallic surface, which is kept cool by contact with cold water; in the latter, the exhaust steam, on entering the condenser, comes in contact with a jet of cold water. In either case, the entering steam is condensed to water, forming a partial vacuum. If a sufficient amount of cold water were used, the steam, on entering, would instantly condense and a practically perfect vacuum would be obtained, were it not for the fact that the feedwater of the boiler always contains a small quantity of air, which passes with the exhaust steam into the condenser and partly destroys the vacuum. To get rid of this air, the condenser is fitted with an air pump, which pumps out both the air and the water into which the steam condenses.

30. Compound engines are sometimes used for driving textile mills; they have two cylinders in which the steam expands. The first, or *high-pressure, cylinder* takes the steam from the boiler at a high initial pressure, while the second, or

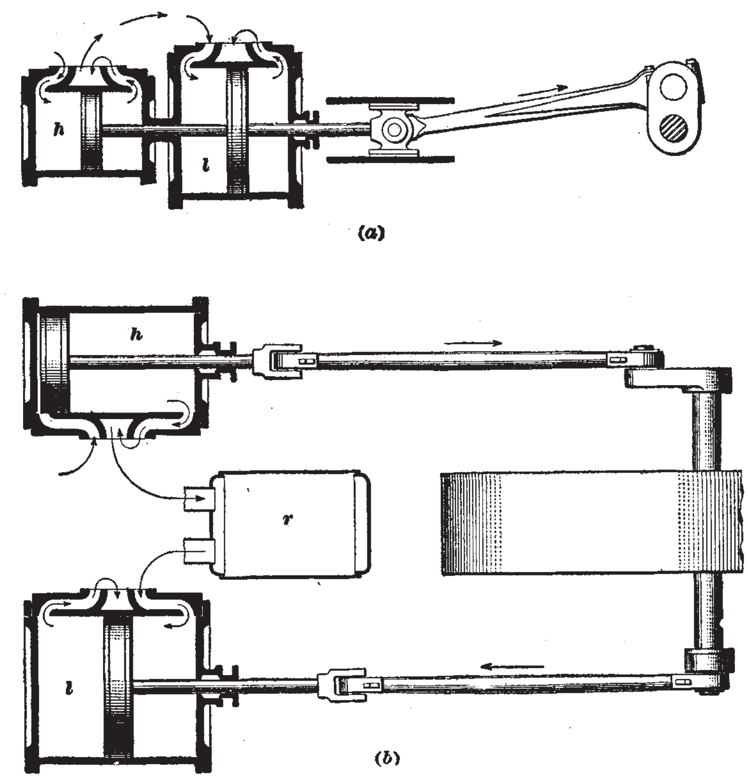


FIG. 31

low-pressure, cylinder is of a larger diameter and is arranged to take the exhaust steam from the first cylinder and expand it still further. When the expansion takes place in two cylinders the engine is said to be *compound;* but if the expansion takes place in three cylinders, it is said to be a *triple-expansion engine,* or if in four cylinders, a *quadruple-expansion engine.*

Compound engines are usually made in one of the two types shown in Fig. 31. In (*a*) the two cylinders are placed in line, the two pistons being attached to the same piston rod. The steam passes from the boiler into the high-pressure cylinder *h*; after it has expanded, it passes into the low-pressure cylinder *l*, from which it is exhausted into the atmosphere or into a condenser.

Fig. 31 (*b*) shows what is known as the *receiver compound engine*. The steam passes from the high-pressure cylinder *h* into a receiver *r*, and then into the low-pressure cylinder *l*, from which it exhausts into the atmosphere or into a condenser. A receiver compound engine has two piston rods and two cranks; the cranks may be placed at any angle with each other. The compound engine, without a receiver, may have one piston rod and one crank, as shown in the tandem type, or it may have two piston rods and two cranks, the cylinders being placed side by side. In any compound engine without a receiver, the two pistons must begin and end their stroke at the same time, and the cranks must be placed together or 180° apart.

When one cylinder is placed behind the other, as shown in Fig. 31 (*a*), the engine is called a *tandem compound*. When the cylinders are placed side by side, as shown in (*b*), and the piston rods are attached to separate crossheads, the engine is called a *cross-compound;* if both piston rods are attached to the same crosshead, the engine is called a *twin compound*. If any of these types of engines have a condenser, they are called *tandem*, *cross-*, or *twin*, *compound condensing engines*. Without a condenser, they are called *non-condensing engines*. They all may or may not have a receiver.

In giving the size of a multiple-expansion engine, the stroke is always written last. Thus, a compound engine whose high-pressure cylinder is 11 inches in diameter; low-pressure cylinder, 20 inches in diameter; and stroke 15 inches will be expressed as a 11″ and 20″×15″ compound. In the same manner a 14″, 22″, and 34″×18″ triple-expansion engine would indicate that the diameters of the cylinders are 14, 22, and 34 inches, and that they have a common stroke of 18 inches.

WATER-POWER

31. The utilization of **water-power** for driving the machinery of a mill necessitates the location of the mill near a suitable stream, preferably where there is an existing dam and canal system, as otherwise the mill will have to install its own system. The value of a water-power depends on the steady power that it will furnish at all seasons of the year. When a stream is so located that the surplus water of freshets and storms can be easily stored by means of reservoirs, it can be made to furnish at all times a power whose maximum value depends on the mean discharge of the stream. In some locations, a stream that would be of no practical value as a source of power, owing to the fact that the rainfall from which it is supplied varies greatly at different seasons of the year and the watershed is of such a nature that the water flows off rapidly, may be made to furnish a uniform and reliable supply of water by the means of reservoirs. It is seldom that these reservoirs can be located where the water can be used from them directly, but during periods of high water they store a surplus that can be drawn on to furnish a supply during low water.

The value of a proposed location for a water-power plant must be based on the following considerations: (1) the available fall; (2) the minimum flow of the stream; (3) the effect of high water on the available fall; (4) the possibility of building storage reservoirs for the purpose of regulating the flow and furnishing a supply of water during periods of drought.

It is very important that the pipes or channels leading the water from the dam, or weir, to the waterwheel be made amply large and so arranged that as little *head* as possible will be lost through friction. If a canal or sluice that is to lead water from a dam to a flue or waterwheel is too small to carry the required amount of water, great loss of power will result. In the case of a long pipe, the frictional resistances may be so great that the pressure at the end of the pipe will be greatly reduced, thus greatly reducing the power. In short pipes leading from dams to wheel cases, flumes, or penstocks, the velocity of flow is often comparatively high, but the loss of head due to resistances at entrance of pipe, bends, sudden changes of section, etc. is more serious than in the case of long pipes and low velocities. A careful computation, in which all the conditions are considered, should always be made for each case in order to provide against losses of head between the supply and the wheel.

For motors, the *turbine* has replaced the older overshot, breast, and undershot waterwheels in American mill practice. The impulse wheel, of which the Pelton and Leffel Cascade waterwheels are notable examples, give very efficient service under high heads and small quantities of water, but as these conditions are rarely met with in mill work they are seldom used.

TURBINES

32. Types of Turbines.—The several types of **turbines** differ mainly in the method of passing the water through the machine. Fig. 32 shows the general arrangement of an *outward-flow turbine*, also called a *Fourneyron turbine*, from its inventor, with a plan of the wheel vanes and guide vanes. The water is brought in at the center, passes outwards between the curved guide vanes *b*, *b* to the wheel vanes *c*, *c*, and is discharged at the circumference of the wheel. The flow of water is regulated in the wheel shown by a cylindrical gate that can be raised or lowered in an annular space between the wheel and guides. Various other methods of regulating the flow are also used, some of which will be described.

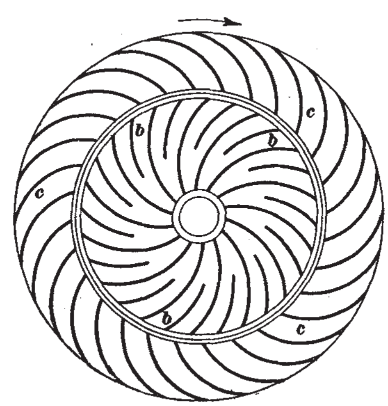


FIG. 32

Fig. 33 shows a vertical section of an *inward-flow*, or *Francis*, *turbine*. Here the water enters the guides *b* from the outside, passes inwards to the wheel vanes *c*, and is discharged near the center of the wheel. These wheels are often placed some distance above the level of the tail-water, as shown, and discharge into an air-tight tube, commonly called a *draft tube*. This places the wheel at a point where it can be easily inspected or repaired and at the same time utilizes the total fall. The supply of water in the wheel shown is regulated by a gate *g* at the outlet of the draft tube.

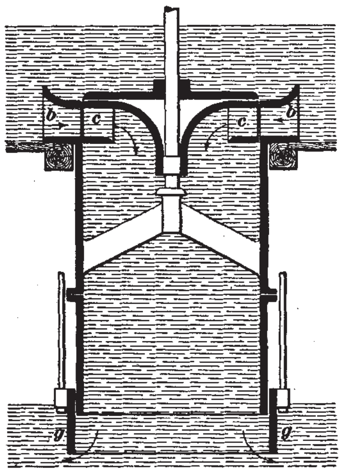


FIG. 33

In Fig. 34 is shown a *downward-flow*, or *Jonval*, *turbine*. Here the general direction of the flow of the water is always parallel to the shaft *a*, or axis; hence, wheels of this class are also known as *parallel-flow*, and *axial*, *turbines*. The water usually enters the guides *b* from above and is discharged, downwards, through the wheel *c* into a draft tube *d*, as shown. The discharge may also take place into the air or tail-water without the use of a draft tube.

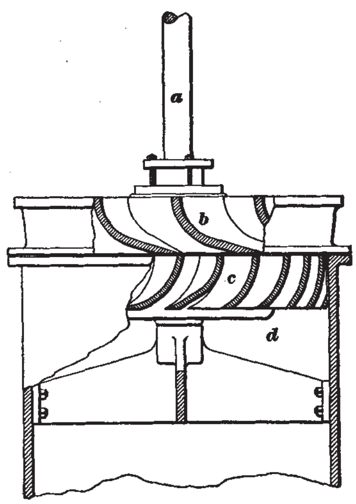


FIG. 34

Many American turbines are made with the wheel vanes so curved that the water enters the wheel in a radial direction, like an inward-flow turbine, and is discharged in a downward or axial direction. These are called *mixed-flow turbines.*

Fig. 35 shows the wheel of a *Risdon turbine* with the double curvature of the vanes. This wheel is cast in one piece. The band *a* serves the double purpose of strengthening the wheel and of making the proper form for the passage of the water through the lower part of the wheel, confining it on all sides.

33. Regulating Turbines.—The method of regulation has an important bearing on the efficiency of a turbine. In general, the best efficiency for a given head is obtained only when the wheel is running at the speed for which it was designed and at *full gate*, that is, with the gate wide open. A partial closing of the gates reduces the available head or increases the frictional losses in the wheel itself, either of which results in a loss in the energy available for doing useful work. If the supply of water is unlimited, the loss in efficiency with partly closed gates is a matter of little or no importance, since the only object is a reduction of the power of the wheel to correspond with the work to be done. When, as is more often the case, however, it is desirable to obtain the greatest possible work from the stream at low water, and this work is less than the wheel is designed to furnish at full gate, it becomes necessary to run the wheel at partly closed gate, or part gate, the loss in efficiency becomes more serious.

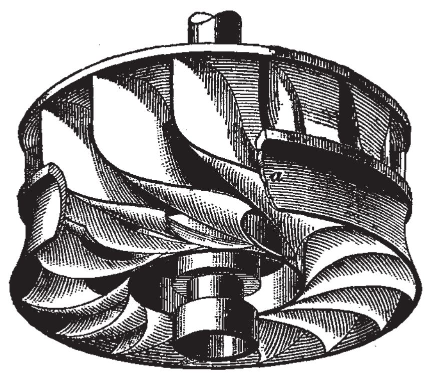


FIG. 35

One of the simplest methods of regulation is shown in Fig. 36. The area of the passages through the wheel is not changed, but the head is reduced by varying the opening of the gate that admits the water to the flume, or penstock, *b*. The flow through the wheel is thus reduced, but there is a loss of head equal to the distance between the level of the water in the sluice and the level in the penstock.

When turbines are governed by regulating the discharge from the draft tube, as shown in Fig. 33, the head above the wheel is not reduced when the discharge is decreased, but the pressure in the draft tube is increased, which has the

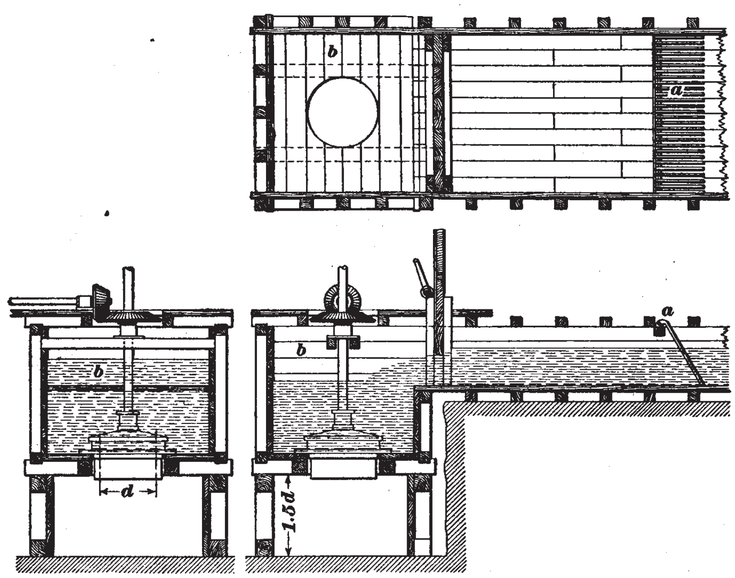


FIG. 36

same effect as raising the level of the tail-water. The result is a loss in the available head and a consequent loss in efficiency.

Regulation by means of a cylindrical gate between the guides and wheel vanes produces a sudden change in the cross-section of the passages at part gate. This absorbs energy by the production of eddies and foam and the contraction of the stream as it flows from the reduced section. When the turbine runs above the tail-water and without a draft tube, this method of regulation may reduce the flow through the wheel so much that the space between the buckets will be but partly filled, in which case it becomes an impulse wheel and its action similar to the action of an impulse turbine.

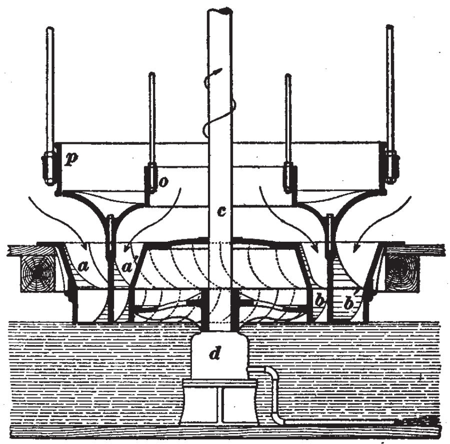
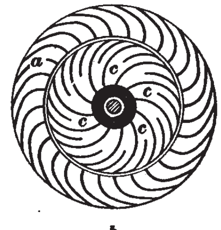


FIG. 37



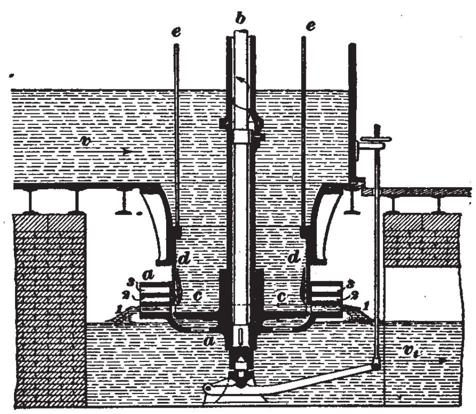


FIG. 38

A method of regulation that gives better results is to have the wheel made in sections. Fig. 37 shows a double downward-flow turbine known as the *Geyelin-Jonval*, in which both guide and wheel vanes are in two independent, concentric sections. The inner section *a' b* may be closed by lowering the cylindrical gate *o*, or the outer section *a b'* by lowering the gate *p*. In this way, either section may be used alone or both may be used together, and a wide range of power may thus be obtained without a serious sacrifice of efficiency.

Fig. 38 shows an outward-flow turbine in three sections *3*, *2*, *1*, formed by dividing the spaces between the wheel vanes by horizontal partitions; *d* is a cylindrical gate between the wheel and guide vanes that entirely closes the successive passages as it is lowered.

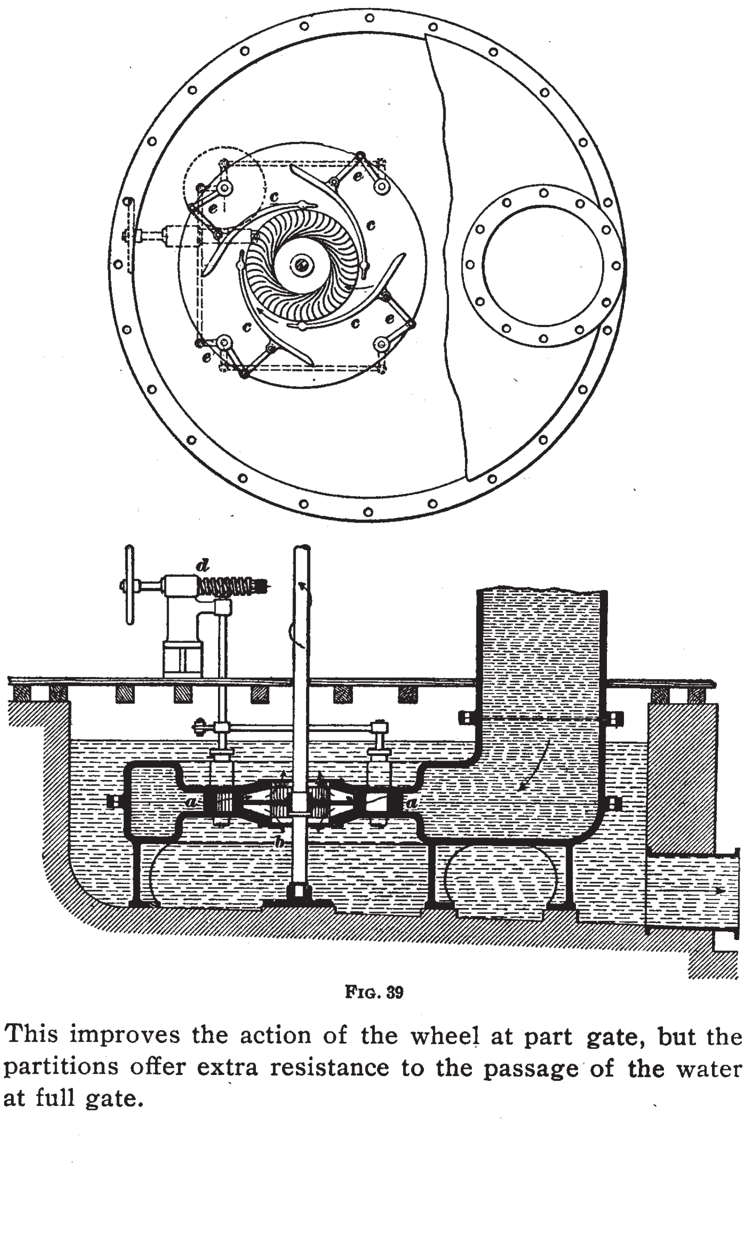


Fig. 39

This improves the action of the wheel at part gate, but the partitions offer extra resistance to the passage of the water at full gate.

Fig. 39 shows a plan view partly in section and a sectional elevation of the *Thompson vortex wheel*, an inward-flow turbine in which the flow is regulated by varying the opening between the guide vanes. The four guide vanes *c* are pivoted near their inner ends and the opening between them is regulated by the hand wheel *d*, which swings the outer ends of the guides by means of the combination of worm, worm-gear, links, and levers. This forms what is known as the *register gate*, from its resemblance to a register used in regulating the flow of air through a heating flue from a furnace. It will be seen that this change in the position of the guide vanes changes the angle of the entering water so that, with a given number of revolutions of the wheel, entrance of the water without shock can only occur for a certain gate opening.

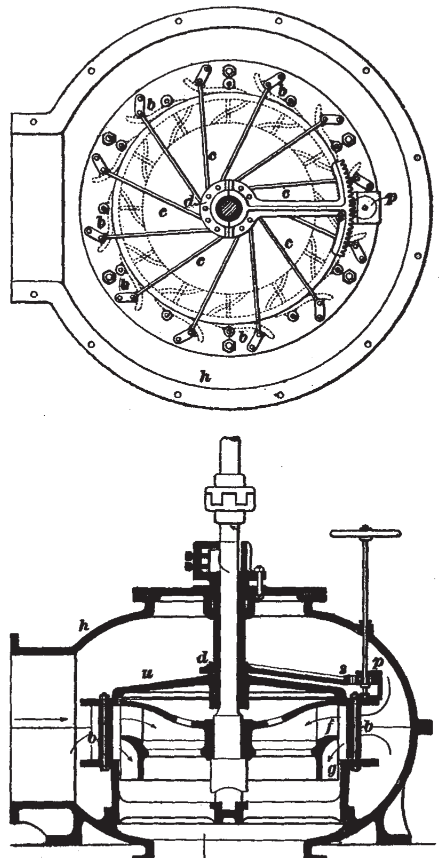


FIG. 40

34. Examples of Turbines.—Fig. 40 shows a top view and a vertical section of a *Leffel turbine* with a somewhat spherical-shaped cast-iron casing *h*. The wheel has two sets of vanes, one *f*, shown in the section, discharging inwards and the other *g*, discharging downwards. The two sets of buckets are separated by a partition that forms part of the rim of the wheel, the wheel being a solid casting. For these two sets of wheel buckets there is but one set of guides and the water is admitted equally to each set of wheel vanes at all gate openings. The guide vanes are made to swing in a manner similar to the guide vanes of the Thompson vortex wheel. A pinion *p* that is operated by a hand wheel or governor, gears into a sector *s* that rotates a collar *d*, to the under side of which are attached the rods *c* that transmit the motion of the collar to the vanes. In this way, the vanes, being pivoted near their inner ends, open and close in a manner similar to the vanes of a register; consequently, this belongs to the class of register-gate turbines.

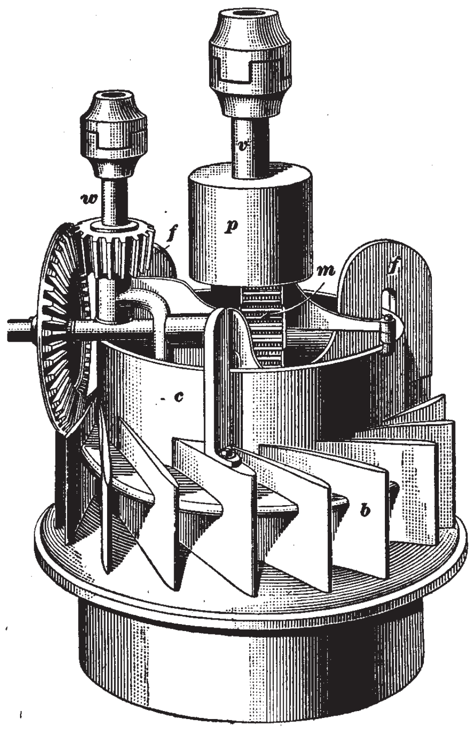


Fig. 41

Fig. 41 is a general view and Fig. 42 a section of a *cylinder-gate Risdon turbine;* this is a mixed inward- and downward-flow turbine, the wheel of which is illustrated in Fig. 35. The gate consists of a cylinder *c* that works in a space between the wheel *a* and the guide vanes *b*. Projections *d*, cast on the cylinder *c*, move up and down between the guides and guide the water into the wheel with less resistance and contraction than would occur if the water were forced to enter past the sharp edge of a thin cylinder.

The gate is raised and lowered by means of a rack and pinion *m*, operated by a hand wheel or governor acting through the shaft *w* and the bevel gearing; **U**-shaped

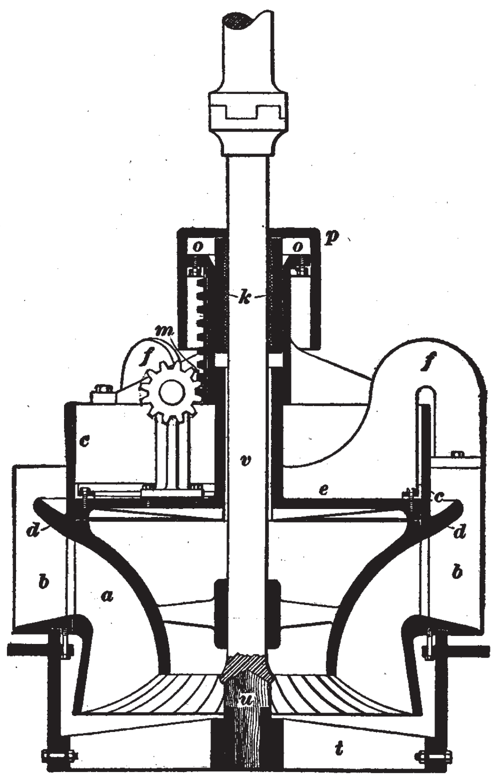


FIG. 42

pieces *f*, *f* support the *crown e* and rest on the guide vanes. A stationary cylinder *p* is supported by the crown plate and contains a piston *o*, *o* that balances the weight of the gate by the action of the pressure of the water under it. The wheel shaft *v* is supported by the wooden step *u* and the bearing *k*. Fig. 43 shows the *McCormick turbine*, a cylinder-gate wheel in which the gate is operated through the bars *b*, *b* by means of the two racks and pinions and the bevel gearing.

Fig. 44 is a perspective view, Fig. 45 a horizontal section through the guide vanes and wheel, and Fig. 46 a top view

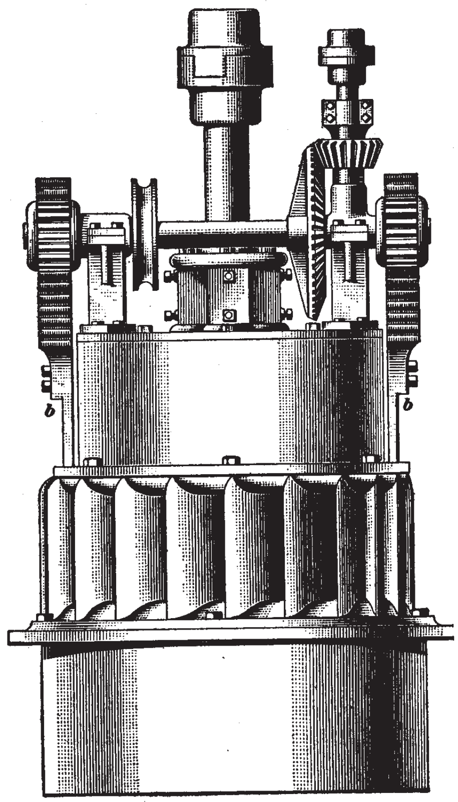


FIG. 43

of the *New American turbine*. This is a modified form of register gate, in which the guide vanes consist of a fixed portion *a* and a swinging gate *b*. The gates are operated through the shaft *s*, the pinion *p* and sector *r*, the collar *c*, and the rods *d*. An adjustable bearing *o* is provided for the wheel shaft. Fig. 47 is a perspective view of the wheel

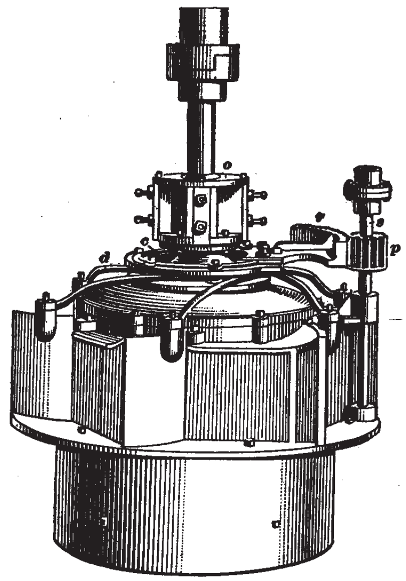


Fig. 44

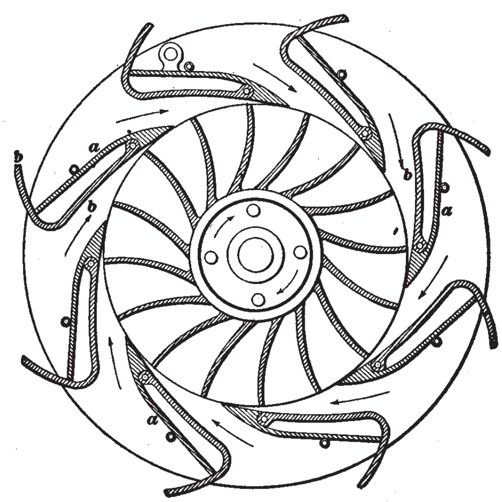


Fig. 45

of the New American turbine, showing the step bearing *e*, which rests on a conical wooden step in the wheel case.

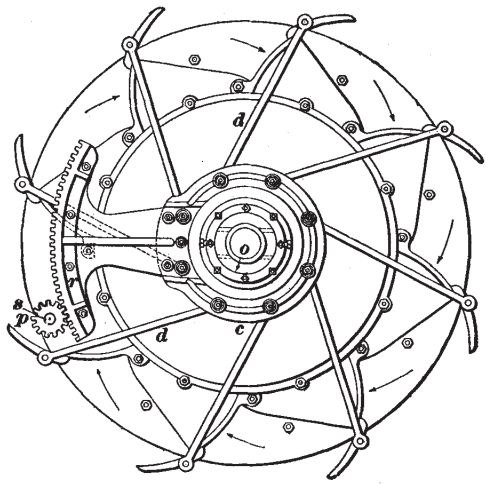


Fig. 46

Formerly turbines were mounted on a vertical shaft, but owing to the difficulty in transmitting large amounts of power from a vertical shaft, they are now commonly mounted on horizontal shafts, sometimes singly and sometimes in pairs. The water is usually led to the turbine through an iron flume or penstock and removed from it through an air-tight draft tube, the lower end of which is a few inches below the surface of the tail-water. When the load is at all variable, an automatic speed governor should be applied to turbines.

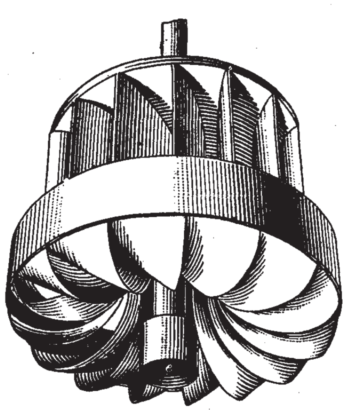


Fig. 47

HEATING, VENTILATING, AND LIGHTING

HEATING

DIRECT SYSTEM OF HEATING

35. The **heating** of a mill is necessary only during the colder months of the year, and in some parts of the South only for a very brief period even then. Artificial heat is necessary during a period of cold weather, in order to raise the temperature high enough to make working conditions comfortable for the help; to enable the stock to be worked to advantage, which is not possible when the fibers are in a cold condition; and in some localities, where very humid atmospheric conditions are liable to occur, to protect the delicate parts of the machinery, such as card wire, from dampness and prevent the collection of moisture on polished surfaces.

Two methods of heating are in use in textile mills; namely, the *direct* and the *indirect systems*. With the **direct system**, the mill is heated by means of lines of uncovered steam pipes arranged around each room and supplied with live steam from the boiler or exhaust steam from the engine, the atmosphere of the rooms being heated by the radiation of heat from the surface of these pipes. With the **indirect system**, air heated at some central station is conveyed to the rooms to be warmed by means of flues or air ducts, which are usually built into the walls of the structure. With an equipment of this kind arrangements are usually made for the foul air to pass out through other air ducts, thus insuring a good system of ventilation. The indirect system is often spoken of as the *hot-air system*, while the direct system is known under the general name of *steam heat*.

36. Live Steam.—The direct system of heating may be subdivided into heating with *live steam* and heating with *exhaust steam*. In the case of a mill heated with live steam, the steam from the boiler is passed through a reducing valve so that the pressure is reduced from the extremely high pressure at which it is generated to a pressure that it is safe to apply to the steam piping throughout the mill. To send steam into ordinary steam-heating pipes in a mill at a pressure of 100 pounds, or more, to the square inch, would result in burst pipes and broken joints. Therefore, at some point near the boiler a reducing valve is inserted in the supply pipe that will reduce the pressure to from 25 to 35 pounds to the square inch.

37. Exhaust Steam.—When exhaust steam is used for heating, it is taken from the engine and is already at a low pressure, as it is the steam that has been expanded in, and exhausted from, the cylinder. Heating with exhaust steam can only be done in mills that have so-called high-pressure engines; that is, an engine without a condenser. In those engines where a condenser is used, the steam, of course, is condensed into water and ceases to exist as steam. In mills where exhaust steam is used for heating purposes there is a back pressure on the engine proportionate to the pressure of the heating system. In other words, the pressure of the live steam on one side of the piston has to overcome the back pressure on the other side of the piston, thus reducing the efficiency of the engine; many millmen do not approve of the use of exhaust steam on this account. However, if this system is properly installed, with large heating pipes and all arrangements made so as to use as low a pressure of steam as possible in the heating system, the back pressure can be reduced to a minimum and the mill heated economically without excessive detriment or waste of coal.

38. Condensation Water.—As will be readily understood, there is considerable condensation of steam in the heating pipes, whether live or exhaust steam is used, and this condensation water must be automatically removed.

Where live steam is used all, or almost all, the steam pipes in the mill can be so arranged that the condensation water will flow directly back to the boiler, as the pressure on the pipe can be made sufficiently high to force this water back if a gradual fall is given to the piping in each room and its subsequent connection to the boiler. The object of this is to utilize the warm water from the heating pipes to feed the boiler and thus save coal by not having to raise the temperature of the feedwater from the normal temperature to the boiling point. Besides this it is much better for the boiler itself to be fed with warm water instead of cold, as it prevents unnecessary strain through unequal expansion and contraction caused by feeding cold water.

Where exhaust steam is used there is not sufficient initial pressure on the heating system to force the condensation water back to the boiler and in this case the hot water of condensation is conducted to a tank, called a receiver, from which it is returned to the boiler by an automatic pump so arranged as to operate only when there is sufficient water stored in the receiver to make it necessary to return the same to the boiler. Such a plan is much superior to that adopted in some mills, especially small ones, of conducting the condensation water to a steam trap that allows it to flow into the drains. The heat contained in this water is thus wasted.

39. The whole system of steam heating should be considered with relation to the locality in which the mill is built. If a mill in a warm climate is equipped with an exhaust system of steam heating, when the heat is only required for a short time, the system is useless throughout the remainder of the year and the exhaust steam is wasted and unnecessary back pressure is put on the engine, unless arrangements are made to change this back pressure when the heating of the mill no longer becomes a necessity. For mills in a warm climate, therefore, the live-steam system of heating is preferable.

In mills in colder climates the exhaust system can be used to advantage for a much longer period and therefore is more desirable; but even in such climates, where there is a good supply of water for condensing purposes, it is better to generate the greatest possible power in the engine, by condensing the exhaust steam, and heat the mill with live steam.

In installing a steam-heating system it should always be borne in mind that to raise water to a high temperature requires the consumption of coal or wood, and that any waste of heated water means a waste of fuel.

40. Details of Direct-Heating System.—The following description of a direct system of heating is applicable to either a live-steam or an exhaust-steam system, since the chief difference is that with exhaust steam larger piping is generally used because the pressure of steam in the pipes is lower, the condensation greater, and the radiation per square inch less with a low pressure than with a high one. As the satisfactory heating of a mill depends on the amount of heat radiated by the pipes, a larger radiating area must be provided when the amount of heat radiated per square inch is less.

The main supply pipe from the boiler or engine is run vertically through the mill, usually at some point near the boiler house, and at each floor is provided with suitable connections by which the supply can be taken for each room. This main supply pipe is the largest in the whole system and its largest diameter is at the point nearest the boiler. It may be reduced in size at points farther from the boiler after one or more feedpipes have been taken from it. Between the main supply pipe and the boiler is a valve that regulates the entire supply of steam to the whole system, and also the reducing valve previously referred to. The former is, of course, closed during the summer months, thus saving all heating expense and having no detrimental effect on the efficiency of the power plant during this time.

It is usual to run several lines of pipe down the sides of each room, not far from the ceiling and as near as possible to the windows, so that the cold air that percolates through the window sashes will be warmed at once, and also because the rooms are chilled more in the neighborhood of the windows than at any other point. The motion of the belts and pulleys near the ceiling keeps the air in motion and transfers the heated air toward the center of the room.

By this system very little fresh air is admitted to the room, and in consequence of the same air being kept in motion and being breathed over and over again it becomes vitiated and foul, which is not the case with an indirect, or hot-air, system of heating. On each floor is a horizontal supply pipe that is provided with a valve and connected with the main supply pipe. It is large enough to supply all the smaller lines, which are connected to it by a manifold branch **T**. The lines of pipe are suspended from the ceiling by vertical rods holding a number of rolls on a horizontal rod in such a way that the lines of piping are placed horizontally, there being three, four, five, or six lines of small pipe, generally from 1 inch to 1¼ inches in diameter. These are supplied from the main supply pipe and are hung so as to have a gradual fall lengthwise of the room of about ⅛ inch to the foot. Thus, in the case of a room 200 feet long the supply end will be perhaps 6 inches from the ceiling and at the other end of the room the pipe will hang 31 inches from the ceiling.

The object of suspending the piping on supports carrying rollers that can revolve on a rod is so that the pipe may expand or contract in different temperatures with a minimum of strain throughout its length. It should also be arranged so that in some part of the system, between the connections to the supply and to the return pipes, the lines of pipe will form a right angle, so that when heated they may expand without breaking any joints or putting strain on the vertical supply or return pipes, as would otherwise be the case. The increased length merely bends the short connecting piece at the angle out of its normal position.

41. To provide for the removal of the water of condensation, at the lower end of the lines of pipe after they are bent at right angles, all the pipes are conducted into a manifold **T** to which the return pipe is connected. This is a vertical pipe running through each floor of the mill and carried down far enough to take all the returns from each room; but in case of heating with live steam it never runs low enough to deliver at a lower point than the top of the boilers, as it has to be conducted with a gradual fall so that the water may flow back into the boiler. This is on the gravity system. The return pipe is always as small as possible and certainly should always be smaller than the main supply pipe, because condensed steam occupies less space than does live steam, and consequently can be returned through a smaller pipe.

A valve should be placed at the supply end of each series of the heating piping so that the heat can be shut off. A check-valve should also be placed at the return end. This will allow steam and condensation water to pass through it in an outward direction from the room, but closes on its seat and will not allow steam or water to enter in the opposite direction. The object of this is to prevent any part of the supply of steam, when shut off from a certain room, finding its way back into the system from the return pipe, as it otherwise might do from some other room or from the boiler. In addition to the check-valve it is also advisable to have an ordinary valve placed on the return pipe, so that it can be used in case the check-valve should be out of order or require repairs at any time; air valves should also be placed on each series of heating pipes, made so as to open when the heat is shut off and the steam in the pipes condenses and tends to form a vacuum.

42. The description that has been given of the lines of heating pipe on one side of the room applies also to those on the other side of the room, and to those in different rooms of the mill. These lines of heating pipe are fed from the main supply pipes, and all ultimately return into the same return pipe, so that steam can be admitted to all or any one or more of them at the same time and the condensation water flow back to the boiler from the whole or a portion of them concurrently. One or more systems can thus be shut off and only certain rooms heated as desired. It is important in the erecting and hanging of this pipe that at no point in the whole system should there be what is called a *pocket;* that is, a place where the pipe begins to rise again, thus allowing the water to collect without having any means of flowing away. Any such pocket in piping will cause what is called *hammering*, the steam supply being forced against this body of water, in such cases making the system noisy and ultimately breaking the joints.

The number of lines of piping that are required in each room depends on the location of the mill as regards climate; also, on the size of the room and other circumstances. Southern mills require fewer lines of piping than Northern, and narrow mills fewer than wide mills. It may be stated as a general rule that in the North for a mill 50 feet wide there would probably be four or more lines of $1\frac{1}{4}$-inch pipe on each side of the room; for a mill 75 feet wide, five lines of $1\frac{1}{4}$-inch pipe; and for a mill 100 feet wide, five lines of $1\frac{1}{2}$-inch pipe. In Southern mills three lines of 1-inch pipe would be sufficient on each side of a room 50 feet wide; in a mill 75 feet wide, three lines of pipe $1\frac{1}{4}$ inches in diameter; while a 100-foot mill would have four lines of $1\frac{1}{4}$-inch pipe. Upper floors usually have an extra line of pipe.

43. Where low-pressure exhaust steam is used the same method of installing the pipe is adopted, but all the returns are conducted to a tank connected to an automatic pump. When sufficient water is gathered in this tank it raises a float and admits steam to the pump, which begins to operate and pump the water back to the boilers. This system is also adopted in those mills where the boilers are at a higher elevation than certain lower rooms of the mill or basement and from which, consequently, the water cannot flow back to the boiler.

In some mills the pipes are placed underneath the windows along each side of the room. In some respects this is an advantage, because the heated air always has a tendency to rise and the rooms can be kept warm more easily by such a plan, but the piping takes up valuable space and is an obstruction in some cases.

INDIRECT SYSTEM OF HEATING

44. The direct system of heating does not provide any means of ventilating the rooms, although in some cases the outward flow of the foul air of the room through the cracks of the windows and doors, combined with the inward flow of the outer air by the same channels, will produce a complete change of air within certain periods. In the best modern mills, however, the indirect system of heating is adopted. In the descriptions of heating and ventilating that have been given as well as those that are to follow, the word *duct* indicates a line of piping that runs horizontally, while the word *flue* indicates those pipes that run vertically.

The principle of the indirect system of heating is that of constantly supplying the rooms of the mill with fresh air that has been warmed to a certain temperature by a suitable apparatus. This apparatus usually consists of a heating chamber, or duct, situated in the lower part of the mill, that is supplied with a number of heating coils; and a fan, by which cold air is drawn from the outer atmosphere, forced through these coils of piping, becoming heated at the same time, and then conducted to each room of the mill by means of ducts and flues. Fans are not always used, as a circulation can be induced by the heated air rising through the flues, but fans are preferable, as the flow of air is then positive and can thus be conducted to the extreme portions of the mill. The ideal method of heating buildings by this means is to have the warm air discharged from openings that are situated in the center of the room near the ceiling and pointing toward the walls of the building. By this means, the warm current of air is discharged directly toward the coldest part of the room—the walls.

In buildings that are divided by partitions, this method of distributing the warm air can be readily accomplished. In textile mills, however, the uniform size and arrangement of the machines within such a building requires straight and roomy passageways between the different machines, as well as sufficient space around them for their operation; consequently, there is no practical opportunity for the introduction of heating flues anywhere within the center of the building, because of their interfering with this desired uniformity. In order to overcome this difficulty, it is the custom in mills heated in this manner to conduct the warm air through flues that are located in the walls of the building.

45. As has been previously stated, the heating apparatus of the indirect system consists of a large duct placed in the lower part of the mill. When the mill contains a basement it may be situated in this part, and the wall of the basement will serve as one side of the duct. When, however, the mill does not contain a basement, it is necessary to have this duct situated above ground, but in this case also the wall of the mill may serve as one side of the duct. There are two methods of running flues from this main duct, one of which employs galvanized-iron flues running up the walls of the mill and distributing air to each room. The second method, and the one that is recommended, is that of having openings in the brickwork of the walls, which serve as flues for conducting the warm air. These flues may be placed along one side of the structure only and at intervals of from 40 to 70 feet, according to the character and construction of the building. They decrease in size as they extend upwards, in order to compensate for the air delivered to the various floors.

At a distance below the floorbeams, sufficient to avoid weakening the construction, outlets are provided from the flues into each of the rooms. Each opening is also fitted with a special damper, which consists of a cast-iron frame bricked into the wall and sufficiently strong to prevent weakening the same. Pivoted to the top of this frame and swinging out toward the center of the room is a sheet-iron plate, which serves as a damper and deflector and is adjustable by means of a worm on the end of a vertical rod acting on a gear on the axis of the damper to move it to any desired position. The velocity with which the warm air passes from these openings makes it possible to heat the side of the mill farthest from the flues, since the smooth ceilings (the beams being in the direction of the air-current) do not in any way interfere, while the swiftly revolving shafting and pulleys break up the air-currents just enough to distribute the air thoroughly throughout the room.

VENTILATION

46. The ventilating of the mill is most satisfactorily performed by the fan-and-heater system of both heating and ventilating that has just been described, but when the direct system of heating is adopted ventilation must depend on the opening of windows, and consequently there is practically no ventilation in the winter time. At other times of the year the windows can be opened, and for this purpose the windows of such mills should be constructed with transoms swinging on central pivots and with suitable attachments to open them to various distances and lock them in position.

The problem of ventilating the upper rooms of a mill in the summer time where the monitor-roof construction is used is comparatively simple, as hot air naturally rises and flows out of the monitor windows, fresh air finding an entrance through the windows on the sides of the room.

Many mills are now adopting the *fan system* of ventilating, entirely independent of the heating system. In such cases, cool, fresh air is taken from the basement of the building or some point in the mill yard shaded from the direct rays of the sun, and by means of a fan, forced through large galvanized pipes into each room of the mill, the hot and foul air passing out through the windows. In order to make such a system work successfully, it is necessary to study the prevailing winds through the summer time and arrange the supply and exit of air so that these will aid rather than hinder the system.

A plentiful supply of fresh air is beneficial in a mill at any time of the year, tending to produce more and better work on the part of the operatives. In the summer time it is an absolute necessity to have some form of ventilation to reduce the temperature of the rooms.

LIGHTING

WINDOWS

47. The **lighting** of a mill constructed on modern principles is not at all a difficult problem in the daytime, as mills now have large window space, larger in many cases than the amount of wall space. The windows are run up almost to the ceiling so that the rays of light may be admitted as high as possible and thus reach the center of the room, and in such mills the machinery in the middle of the room is almost as well lighted as that at the side. In old mills the problem is more difficult, since in many of these the windows are small and the panes of glass in each sash are also small. In such cases it is often advisable to replace old windows with new ones having large panes of glass.

The placing of machinery in such mills is also of importance; machines with large creels should be placed across the room, rather than lengthwise, so that the light is not obstructed by the creel. In many cases the use of prism glass is of advantage in diffusing the light so that it reaches all parts of the room.

ARTIFICIAL LIGHTING

OIL AND GAS

48. Artificial lighting is either by *oil lamps*, *gaslight*, or *electric light*. **Oil lamps** are used only in antiquated or remote country mills, are not approved by fire-insurance companies, and should be replaced by electric lights whenever possible.

Gas lighting is still largely used, although being rapidly supplanted by electric lighting. Many mills have their own gas plant, and with mills already piped for gas it is often not desirable to incur the expense of installing an electric-lighting system. The same is also true of smaller mills where an electric-lighting system would not be economical and where gas can be obtained from a city supply. The disadvantages of gas lighting are principally on account of the risk of fire, since it is necessary to carry around a lighted lamp or to adopt some other equally dangerous method in order to light the gas; the gathering of fly around the gas piping, which may become ignited by a puff of air bringing it in contact with the gas jet, also adds to the possibilities of fires. These dangers can be minimized by the use of electric lighters for lighting the gas and by a proper system of brushing down the gas pipes daily.

ELECTRIC LIGHTING

49. Electric lighting in textile mills is undoubtedly the best system, being the most convenient and, for a large plant, if properly installed, the most economical method of lighting. It is also the only practicable method in mills, especially in the South.

Electric lighting and the explanation of the necessary machinery and principles of the same cannot here be described in detail, but it may be said by way of a definition that while a current of electricity may be produced in various ways for lighting purposes, it is almost exclusively generated by the application of the power of a steam engine or waterwheel to the driving of a dynamo. The electric current thus produced is transmitted by wires to lamps which are of two kinds—the *incandescent* and the *arc*.

50. In **incandescent lighting,** the light is produced by passing the electric current through a fine filament of carbonized vegetable fiber enclosed in a glass bulb from which the air has been exhausted. The lighting capacity of incandescent lamps is usually only small, generally about

16 candlepower, so that a mill lighted on the incandescent system has to be equipped with a large number of small lamps. These lamps are distributed throughout the mill and are often used in connection with a lamp shade placed above, the best form of which is of tin, painted white underneath and green on top; these deflect the light where it is most desired and are preferable to porcelain shades, because the latter are so easily broken.

51. In **arc lamps,** the light is produced by passing an electric current across a small space that separates two pieces of carbon. This produces an intense light, generally about 1,000 candlepower, resulting in the burning away of the carbons at a slow rate. These lamps are usually placed near the ceiling of the room and are provided with large reflectors, each lamp lighting a considerable area of floor space. This system of lighting, if properly installed, is very effective for some purposes, but one of the disadvantages is the casting of shadows and the consequent leaving of dark spaces under and around machines, through the light not being so well diffused as is the case with incandescent lighting. Attempts have been made to overcome this, successfully in some cases, by using what is known as the *inverted arc lamp.* In this case the ceiling is painted white, so as to form a good reflecting surface, and thus the light, which is directed from the arc lamp to the ceiling of the room, is reflected and gives a well diffused illumination throughout the room.

52. Dynamos.—For either of these systems of lighting, in case the mill corporation manufactures its own light, it is necessary to install one or more **dynamos.** In case only one dynamo is used it may be driven by a belt from an engine separate from that which drives the shafting of the mill, or may be directly connected; that is, its revolving parts placed on the main shaft of the separate engine. Either of these plans is a convenient method of installing the plant, as light can thus be produced at any time, whether the main engine of the mill is in operation or not; but it is not so economical as to drive the dynamos from the main engine, since the power necessary can be produced so much more cheaply in a large engine.

Generally speaking, the dynamo, or *generator* as it is sometimes called, is a belt-driven machine located near the engine (in small mills often in the engine room), belted from a countershaft driven directly from the engine. By means of a friction clutch or tight and loose pulleys the machine can be operated when desired. The dynamo is mounted on an iron frame, along which it can be moved so as to tighten the belt that drives it. It generally produces an electric current of about 125 volts, and is ordinarily a compound-wound, multipolar, generator, although machines are now used of many other types and producing currents of different voltage.

Insurance companies require that dynamos be located in a dry place and insulated by being placed on non-conducting material, such as a wooden floor or base frame; they are not allowed to be placed in a room where any hazardous process is carried on or where they would be exposed to inflammable gases or the flying of combustible material, and are to be covered with a waterproof fabric when not in use.

53. Switchboard.—The wires from the generator are conducted to the **switchboard,** usually of slate or marble, which is not placed too near the floor, the ceiling, or the wall of the room, is readily accessible from all sides, and is kept free from moisture. On this switchboard a hand regulator, or *rheostat*, is usually placed. The voltmeter is also attached, indicating to the attendant the voltage of the current that is being produced. In addition to this the switchboard is provided with what is called a *pilot light*, which is so wired that it cannot be shut off by any of the switches lighting up the various parts of the mill; thus the operator always has a light to work by as long as the machine is in operation, and can see at once whether any current is being produced.

The switchboard always contains, as its name indicates, a number of switches, generally of the type known as the *double-pole jaw* type, for all the main circuits of the mill, usually one for each room with a separate one for all passageways and entrances; thus the lighting of the whole mill is controlled from the dynamo room and can be switched on or off from there, either the whole at once or each room separately.

54. Wiring.—From these switches separate wires are conducted to the different rooms of the mill that are required to be on a separate circuit, the wires differing in size according to the number of lamps that they carry and the distance that the current is conveyed. One or more main supply wires run the length of the room, branches being taken off at intervals to supply several lamps in each bay of the mill. The size of the wire gradually diminishes, but the fire-insurance companies do not allow a smaller wire than what is known as number 14 B. & S. gauge, or a wire .06408 inch in diameter, to be used. The lamps are hung, from a rosette attached to the ceiling, by drop cords regulated to the height desired.

In wiring a mill for electric lighting, it is of importance to use wire sufficiently large to carry an electric current of the required strength for all the lamps that are likely to be supplied from it. The wires should also be well insulated; not only should they be covered with an insulated covering, but when they pass through walls or timbers, a porcelain or other tube should intervene between the wire and the structure. At one or more points on each circuit a *fuse* should be placed; this is a contrivance by which the current of electricity is passed through fusible metal, which will only allow a current of a certain strength to be conveyed. Should a current of a higher potential, and therefore of greater strength, be accidentally turned on to this circuit, the fusible metal will melt, thus breaking the circuit and saving the wiring and lamps from being burned out.

The number of lamps necessary for the different machines will depend of course on the size of the machines and on the importance of closely watching the work that they do.

Some machines can be dimly lighted without seriously affecting the running of the work, while others require the best of light.

Occasionally a mill engineer has to plan on lighting buildings separated from the main mill, or lighting the mill yard. In this case specially insulated weather-proof wire must be used, and it is also advisable to provide lightning arresters.

FIRE-PREVENTION AND PROTECTION

FIRE-PREVENTION

55. It is very important that a mill should be so constructed as to minimize the risk of fire, and so equipped that a fire may be extinguished at the earliest possible moment. At the present time the prevention of fire in textile mills has been reduced to a science, and the number of serious fires in mills is only a small percentage of the number that formerly occurred. Often the chief object in adopting means of fire-protection and prevention is merely to secure the lowest possible rate of insurance, which in itself is very desirable, as it permanently reduces the expense of conducting the business of the mill; but the construction of a mill so that there is the least possible risk of damage by fire also prevents serious loss of business and trade connections that would occur should the mill be destroyed by fire, even though the amount of insurance be sufficient to rebuild the structure, and it is also the means of preventing the risk of loss of life.

It is now customary among all mill engineers to submit the plans of a mill to the mutual insurance associations before commencing to build the structure; and these associations decide whether those departments in which there is the greatest risk of fire are sufficiently well separated from other parts of the mill by fire-walls, and also whether each room of the mill and each floor of the mill is sufficiently isolated from the others, by avoiding any unnecessary openings in the floors or other means by which fire may pass from one room to another.

Fire-doors are called for, and in some cases the windows must be protected by fire-shutters, if they are close to other buildings. These provisions are all made either to prevent the occurrence of fire or to reduce the risk of fire spreading when it does occur, but another important feature of fire-protection is the providing of means by which fire can be extinguished promptly.

OUTSIDE FIRE-PROTECTION

56. Fire-protection may be divided into *inside* and *outside protection*, the former being accomplished chiefly by means of an adequate sprinkler system, while the latter necessitates an equipment of hydrants and hose piping. The establishment of two or more independent sources of water supply that may be utilized for either the inside or the outside fire-protection systems is also necessary. No mutual companies accept risks with one source of supply. Some mills, however, have only high and low public water systems, but these are few and are not insured in the best companies. Two city systems are also considered as two sources of supply. The great majority of mills in large towns are supplied by tank, public water, and pump. In others either of the first two is omitted. The companies insist that the water supplies must be independent of each other, so that if one fails utterly the other can fully meet the demands.

57. Hydrants and Hose.—The hydrants of the outside fire-protection system are connected to a line of cast-iron pipe, usually entirely surrounding the mill premises. These hydrants, which carry one, two, or three branches to which hose pipes may be attached, must be sufficiently far from the mill so that they will not be put out of commission in case of a wall falling outwards during a fire, and not too far away so as to require an unnecessary length of hose pipe to reach the mill. The usual distance is about 50 feet from the mill wall. As a rule, hydrants are located about 200 or 300 feet apart, but their exact position depends entirely on the nature of the property. The general statement may be made that hydrants are so placed that a stream may be directed into any window or to any roof without using excessive lengths of hose. The tendency is toward more hydrants and less hose, as hydrants are cheaper and short lines of hose more desirable. In large properties, roof hydrants are used; this gives a vantage point from which to fight a fire.

Hose houses should be provided, containing about 250 feet of hose attached to the hydrant, and also axes, spanners, lanterns, nozzles, etc. Rubber-lined hose must not be kept in the mill, since the heat causes excessive deterioration, and in case of fire the hose should be readily reached. Only such hose should be purchased as is made by leading manufacturers under the specifications of the mutual insurance companies, and especially designed for mill use. Cheap hose is not economical in case of fire.

58. Underwriters' Pump.—The outside fire-protection system is supplied with water by means of a fire-pump known as the **Underwriters' pump** which is designed especially for fire-protection. It is of the type known as *duplex* and is built especially strong and designed so that it will start easily even after a period of inactivity. Its steam and water passages are made larger than in trade pumps, so that it may run at high speeds without causing water hammer. It is rust-proof, so that it may start instantly after disuse, by making its piston and valve rods of Tobin bronze and its water pistons, stuffingboxes, and bearings of brass. No cast iron is used in its valve gear, steel or forgings being substituted; this prevents breakage through carelessness, which often accompanies the excitement during a fire. It has a large number of valves and many extra attachments, such as a vacuum chamber, pressure gauges, safety valve, priming pipes, hose valves, etc., not found on ordinary pumps. Underwriters' steam pumps are built in the sizes given in Table I.

TABLE I

Dimensions Inches			Capacity	
Dia. of Cylinder	Dia. of Plunger	Stroke	Gallons per Minute	Fire-Streams
14	× 7	× 12	500	2
16	× 9	× 12	750	3
18	× 10	× 12	1,000	4
20	× 12	× 16	1,500	6

Some makers use a 10-inch stroke in place of the 12-inch, which necessitates larger cylinders and plungers. The 1,000-gallon pump is in most general use. It requires about a 150-horsepower boiler and at least 45 pounds of steam at the pump; 70 revolutions per minute is a usual speed, but in case of necessity higher speed can be reached.

The following table gives the pipe sizes for Underwriters' pumps:

TABLE II

Capacity Gallons	Suction Inches	Discharge Inches	Steam Supply Inches
500	8	6	3
750	10	7	$3\frac{1}{2}$
1,000	12	8	4
1,500	14	10	5

A priming tank of 300 gallons capacity is placed over the pump and connected with the priming pipe, so as to enable the pump to quickly catch its suction. A fire-pump must be connected to the hydrant system by means of an indicator gate valve of the type subsequently to be described. A check-valve is always placed on the discharge, so that the pressure in the system will not enter the pump and cut the rubber valves by forcing them into their seats.

59. If no pond or river is available the insurance requirements call for a reservoir of not less than 50,000 gallons capacity from which the pump may be supplied with water; the suction pipe must be carried into a well at the bottom of this tank, so that the reservoir may be entirely emptied, and a rose, or suction, screen be placed at the foot of the suction pipe to prevent the pumps being clogged. The whole area of this screen should be at least five times the area of the suction pipe, and even more if possible.

INSIDE FIRE-PROTECTION

SPRINKLER SYSTEMS

60. An approved sprinkler installation is an absolute necessity to the modern mill or, for that matter, to older mills. A **sprinkler system** consists ordinarily of two sources of water supply, one of which is generally a supply tank placed at least 15 feet higher than the highest sprinkler in the mill and holding not less than 10,000 gallons of water. From this tank a pipe, at least 6 inches in diameter, runs to the sprinkler system. This supply pipe runs vertically to the basement of the mill and then horizontally to the vertical pipes, called *risers*, that supply each section of the sprinkler system throughout the building with water. It is preferred by the insurance companies for this supply pipe, if possible, to run outside the mill and reenter to the supply risers. A still better arrangement is for the tank itself and all connections to be outside the mill, either on a trestle in the mill yard or on a slope of a hill adjacent to the mill, if such be available. By this means the water supply for the sprinklers is not affected, no matter how serious the fire.

A check-valve should be placed on all tank discharges to prevent the tank filling from other supplies and overflowing. A gate valve, of the indicator pattern, is also placed in the pipe and sealed open. If the valve is outside in the ground an indicator post is placed on it, thus allowing it to be found in deep snow and to be operated easily. This applies to all outside valves.

Fire-pumps are so connected as to supply the sprinklers as well as the hydrants, and the supply tank is only used to operate the sprinklers until the pump is started. When the pump is started, this raises the pressure in the system until the pressure exceeds that given by gravity from the tank. Then, of course, the check-valve under the tank will close, shutting out the tank and at the same time preventing waste from the pump through it.

Insurance requirements call for the sprinkler system to be complete and isolated in all sections of the mill divided by fire-walls; that is, if the picker room is separated by fire-walls from the remainder of the mill, the picker room and all rooms within that part of the building separated by a fire-wall from the remainder of the mill must have a separate riser to supply the sprinklers in that section with water—they must not be fed through fire-walls from some other rooms. The object of this is that, if one portion of the mill is destroyed, the sprinkler system may be complete and intact in other parts of the mill, and water may be shut off from any open or broken pipe caused by fire without depriving other rooms of protection.

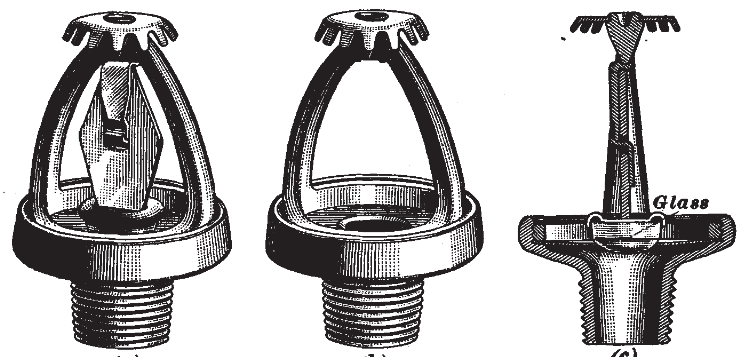
The risers run vertically from the main supply pipe to the roof of the mill, passing through each floor and supplying the sprinklers in each story with water. Insurance requirements call for this riser to be of sufficient size to supply all the sprinkler heads on any floor in each section. Formerly it was the custom to have a valve in each room to shut off the water from that room, but for a number of years the requirements have called for only one valve to control all the piping in each section of the building supplied from one riser. This valve should be placed outside and, if possible, 20 or 30 feet away from the building. Valves inside the building cannot always be reached in case of fire, add to the expense of installation, and require more care in seeing that they are kept open; the supply of water also can be better controlled from the outside.

In describing fire-protection, the statements that are made refer to general practice, as of course special conditions, such as isolated rooms, dust rooms, storage rooms, and others, are protected differently and form exceptions to the general rules.

The water is distributed by a feedpipe taken from the riser by means of a **T** on each floor; branch lines are taken from this feedpipe and the sprinkler heads attached at intervals on these branches. In narrow- and medium-width mills this feedpipe is carried alongside the windows, but as only six heads are allowed on one branch pipe, a different arrangement must be adopted in very wide mills, by running a feedpipe down the center of the room and taking branches from each side. Branches are run along the middle of each bay in all cases. All branches and feeders must be so hung that when the water supply is shut off and pressure removed, all water will flow backwards, toward the riser, to a suitable drip valve, which is kept closed and sealed. Thus, when water is shut off, the pipes may be drained to enable repairs to be made without water entering the room.

61. Sprinkler Heads.—A **sprinkler,** often called a *sprinkler head* or, briefly, a *head*, is an appliance that can be attached to a pipe, and really consists of a small valve held to its seat by a soldered lever. This solder is prepared so that it will melt when it reaches a temperature of 155° F., or in special cases, for boiler-house work and in other hot rooms, so that it will melt at from 265° to 280°. When the solder melts, the valve is forced from its seat and a supply of water under pressure passes through the sprinkler against a brass disk so constructed as to deflect the water, distributing it in a spray about 10 feet in every direction. This spray is not effective, from the fire-protection point of view, over the circular area of 20 feet diameter, as the preceding statement would imply, since the outer edge of the circle would only receive a few scattering drops. It is customary to assume that the sprinkler is not effective outside of a circular area of 15 feet diameter. Very often the rule of allowing 80 to 90 square feet of floor space per head is adopted. It will be seen that each sprinkler only protects a comparatively small amount of floor space and that sprinklers must be installed at intervals throughout the mill and also in such a manner that the water may spread as widely as possible; for instance, a sprinkler should be placed in the middle of the bay rather than close to the floor timbers, which would prevent the water spreading in one direction. All concealed spaces or pockets that cannot be reached by the water from sprinklers placed in the middle of the bay must have additional sprinklers provided. This applies to supply closets, passageways, belt ways, and similar places.

The insurance requirements for mills constructed with 12-foot bays, measuring from center to center of the timbers, are that the distance between the sprinklers of each branch shall not exceed 7 to 8 feet; in mills with 11-foot bays, that the sprinklers shall not be more than 8 or 9 feet apart; and in mills with bays varying from 6 to 10 feet, that the sprinklers shall not be more than 10 feet apart. This applies to the regular mill construction of building, with smooth, solid plank and timber construction; it is also stipulated that sprinklers shall be placed in the center of each bay.



(a) (b) (c)

Fig. 48

62. Grinnell Sprinkler.—A closed **Grinnell sprinkler,** showing the glass valve, or button, held down on its seat in a flexible diaphragm by a strut, or lever, is illustrated in

Fig. 48 (*a*). When this lever gives away, owing to the heat of the fire, which melts the fusible metal, the glass valve is thrown out by the spring of the flexible diaphragm, aided, of course, by the pressure of the water in the feedpipe. When this happens the sprinkler is opened, as shown in Fig. 48 (*b*), and a solid ½-inch stream of water is thrown against the brass disk and thus distributed in a spray, as previously explained. Fig. 48 (*c*) shows a section of this sprinkler and illustrates the method of seating the valve on the flexible diaphragm. Most other makes of sprinklers have the valve resting on the seat, which is a part of the main casting, and the buttons on all heads depend more or less on the water pressure to throw them off.

TABLE III

Size of Pipe Inches	Number of Heads Allowed
¾	1
1	2
1¼	3
1½	5
2	10
2½	20
3	36
3½	55
4	80
4½	110
5	140
6	200

63. In all fire-protection work, inside and outside, it is of the utmost importance to have piping sufficiently large to carry any volume of water that is ever likely to be required, and also to avoid sharp angles in piping as much as possible. It is found in practice that if water is throttled by being forced through too small a pipe at any point, the supply of water is insufficient, especially when many sprinklers or hydrants are in operation at the same time; and the same thing occurs if water must pass around a right angle in the pipe. Bends with long turns should be placed at all angles, especially of the supply pipes and feedpipes; for this reason the insurance companies limit the number of sprinklers that may be placed on each branch pipe. Table III shows the size of the pipe and the maximum number of sprinklers that may be supplied by it.

It is, of course, always understood that any feeder or supply pipe at any point shall not be smaller than the pipe that it feeds.

From the description that has just been given, it will be seen that there is a direct connection between the sprinkler tank at the top of the mill and each sprinkler within the mill, as it is possible for water to pass from the tank, down the main supply pipe to the outside of the building, along the supply pipe placed under ground, and thence to each riser, feeder, and branch pipe.

64. All visible fire-pipe valves are now of the outside screw-and-yoke, or rising-stem, pattern; no other type is accepted by the mutual insurance companies. This is a reliable type of valve and always shows the position of the gate in the pipe. Outside valves are always required to be of the type known as the indicator gate valve, which shows, by means of plates containing the words *open* and *shut*, whether the valve is open or closed; these valves are only placed for the purpose of shutting off the water of any system in case of making repairs or after a fire has been extinguished, and are not to be closed at any other time. It is of the utmost importance that valves placed on the main supply pipe or the riser should be kept open and sealed. This is done by having them strapped open with a riveted strap.

65. Many minor requirements are made by the insurance companies with regard to the details of the installation of fire-protection systems that are outside the province of this description. Sufficient has been said, however, to show that if the requirements of the insurance associations are followed, almost every inch of space in the mill, inside or outside, can be deluged with water, and thus the possibility of fires spreading in textile mills is very remote.

It is of the utmost importance, of course, that all these appliances be kept in working order and periodically tested; also, that a certain number of employes of the mill be detailed as a fire-department, each knowing his own station, and that they practice periodically in operating the outside fire-protection system.

Some of the miscellaneous points in connection with fire-protection and other matters on which the insurance companies make certain requirements are the following: Fire-pails must be placed at frequent intervals throughout the mills and kept filled with water, so as to be available for use to check a blaze when it first starts and before the temperature rises sufficiently to put the sprinklers in operation; all electric wiring and installations for the production or the use of electricity must be approved by the insurance company; elevator wells must be closed with automatic hatches; stand pipes and hose must be provided at intervals throughout the inside of the mill.

PLUMBING AND WATER SUPPLY

66. Plumbing.—The plumbing of the mill is a comparatively small matter and the expense is very moderate in comparison with most of the other items of equipment. Most cities have rules and regulations that govern the plumbing of all large buildings, such as factories, and as these are usually thoroughly efficient, they should be followed as closely as possible.

In mills it is customary to provide lavatories on each floor, usually situated in a tower. Especial care should be taken to provide sanitary conditions and to adequately provide for the flushing of all bowls, closets, etc. Suitable sinks and an ample supply of water for washing purposes should also be provided. Pains should also be taken that the pipes, traps, etc. form a perfect system of drainage, in order that no stagnant matter may be collected to endanger the health of the operatives.

67. Water Supply.—A satisfactory and sufficient supply of water to any textile mill is of great importance. Water is required for the following purposes as well as for fire-protection: (1) To supply boilers; (2) for water closets; (3)

for size mixing and use around the slashers; (4) in woolen and worsted mills, for the scouring and finishing departments; (5) in all mills, for the sinks, for drinking water, etc.; (6) in mills that have dyeing, bleaching, or finishing plants attached, an adequate supply of good water is of paramount importance.

Regarding the supply of water to a mill, the problem is simplified when it can be taken from city mains. Where the mill is to provide its own source of water supply it must usually be pumped from a spring, creek, or river; if this source is near the mill, the simplest method is to install a steam pump near the water supply and carry a steam supply pipe to it. If the source of supply is at some considerable distance, the best plan is to install an electric pump near the water and a generator in the mill. The electric current from this generator can be transmitted by wire to the pump and thus the necessary supply of water obtained.

MILL ENGINEERING

(PART 2)

EXAMINATION QUESTIONS

(1) (*a*) What are the two general methods of developing motive power in textile mills? (*b*) Of these two systems, which is in more general use?

(2) Make a sketch of a return tubular boiler, and describe the principles involved in its construction and the passage of the flame and gases with reference to the sketch.

(3) What is meant: (*a*) by an internally fired boiler? (*b*) by an externally fired boiler?

(4) What is meant: (*a*) by a fire-tube boiler? (*b*) by a water-tube boiler?

(5) What is a bridge in a boiler setting and what is its object?

(6) State some of the advantages of the water-tube boiler.

(7) Make a sketch, similar to Fig. 26, of the cylinder of a simple slide-valve engine, and explain its action with reference to the sketch.

(8) How does the Corliss engine differ from the plain slide-valve engine?

(9) What is: (*a*) a non-condensing engine? (*b*) a condensing engine? (*c*) the advantage of the condenser to an engine?

(10) (*a*) How does a compound engine differ from a simple engine? (*b*) Explain the difference between a tandem and a cross-compound engine.

(11) What is meant by: (*a*) a register-gate turbine? (*b*) a cylinder-gate turbine?

(12) What is meant: (*a*) by a direct-heating system? (*b*) by an indirect system?

(13) Name some of the advantages and disadvantages of using exhaust steam for heating purposes.

(14) Why is the exhaust-steam system of heating impossible with a condensing engine?

(15) Why does an exhaust-steam system of heating require larger heating pipes than a system employing live steam?

(16) Describe the indirect system of heating a mill and state some of its advantages.

(17) What is meant by the fan system of ventilation?

(18) (*a*) What is the best method of lighting a mill? (*b*) Discuss briefly this system.

(19) (*a*) What is a sprinkler? (*b*) Describe its action.

(20) Give a brief description of the methods you would employ for fire-protection and prevention in a textile mill.

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) $= 5,687\frac{1}{2}$, 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

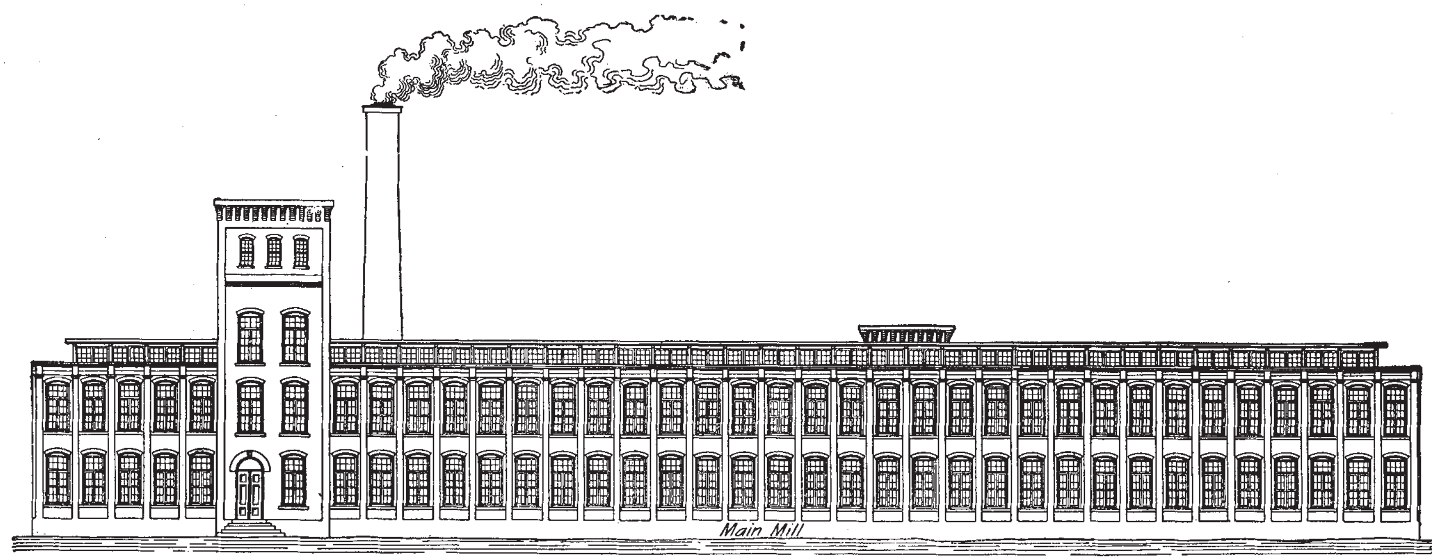


Fig. 1

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

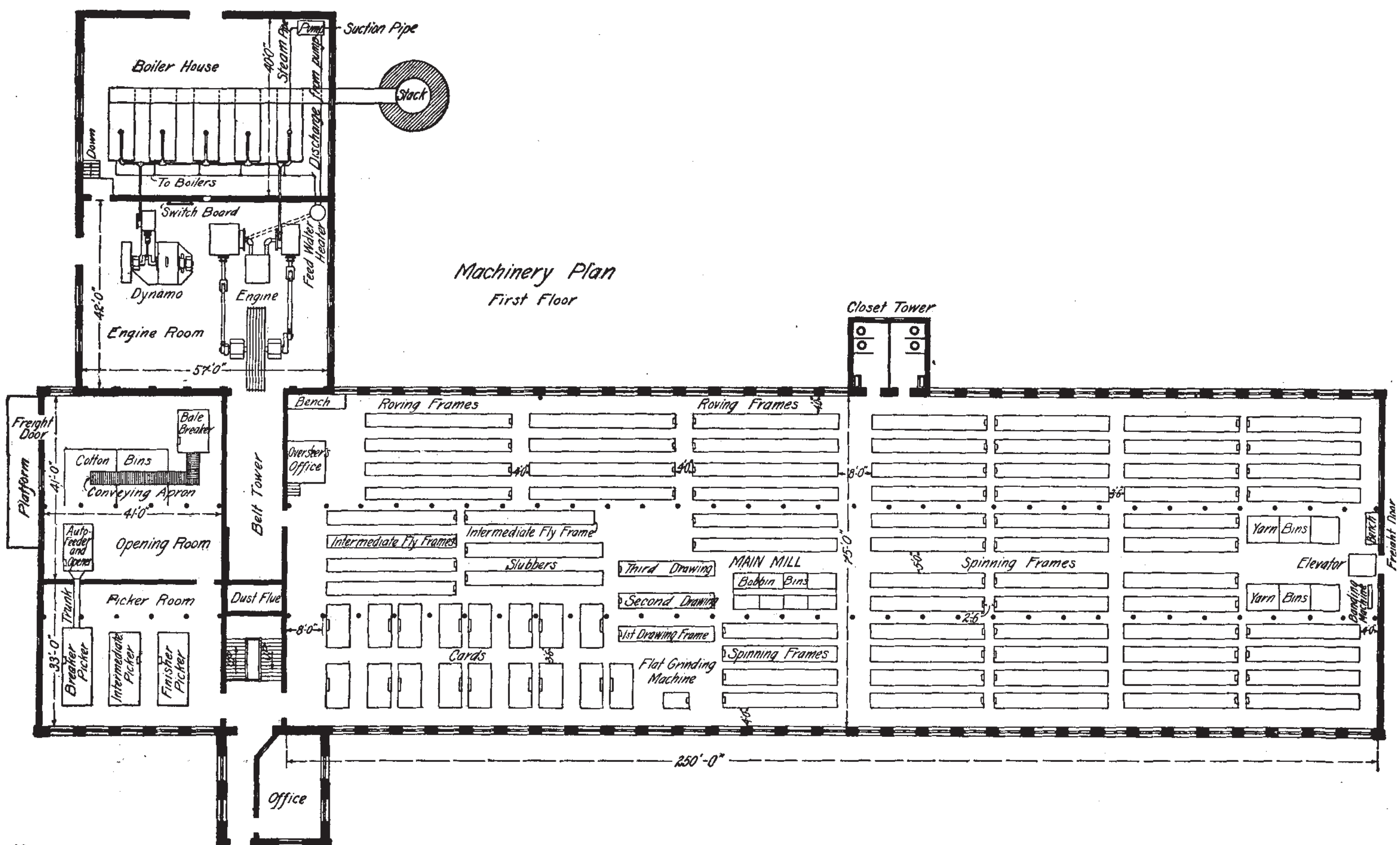

Machinery Plan
First Floor
Boiler House
Suction Pipe
Stack
Steam Pipe
Discharge from pump
Pump
Down
To Boilers
Switch Board
Dynamo
Engine
Feed Water Heater
Engine Room
42'-0"
57'-0"
40'-0"
Closet Tower
Bench
Overseer's Office
Belt Tower
Dust Flue
Roving Frames
Roving Frames
Intermediate Fly Frames
Intermediate Fly Frame
Slubbers
Third Drawing
Second Drawing
1st Drawing Frame
MAIN MILL
Bobbin Bins
Spinning Frames
Spinning Frames
Cards
Flat Grinding Machine
Yarn Bins
Yarn Bins
Elevator
Bench
Banding Machine
Freight Door
Freight Door
Platform
Bale Breaker
Cotton Bins
Conveying Apron
41'-0"
Auto-Feeder and Opener
Opening Room
Picker Room
Trunk
Breaker Picker
Intermediate Picker
Finisher Picker
33'-0"
8'-0"
75'-0"
250'-0"
Office

FIG. 3

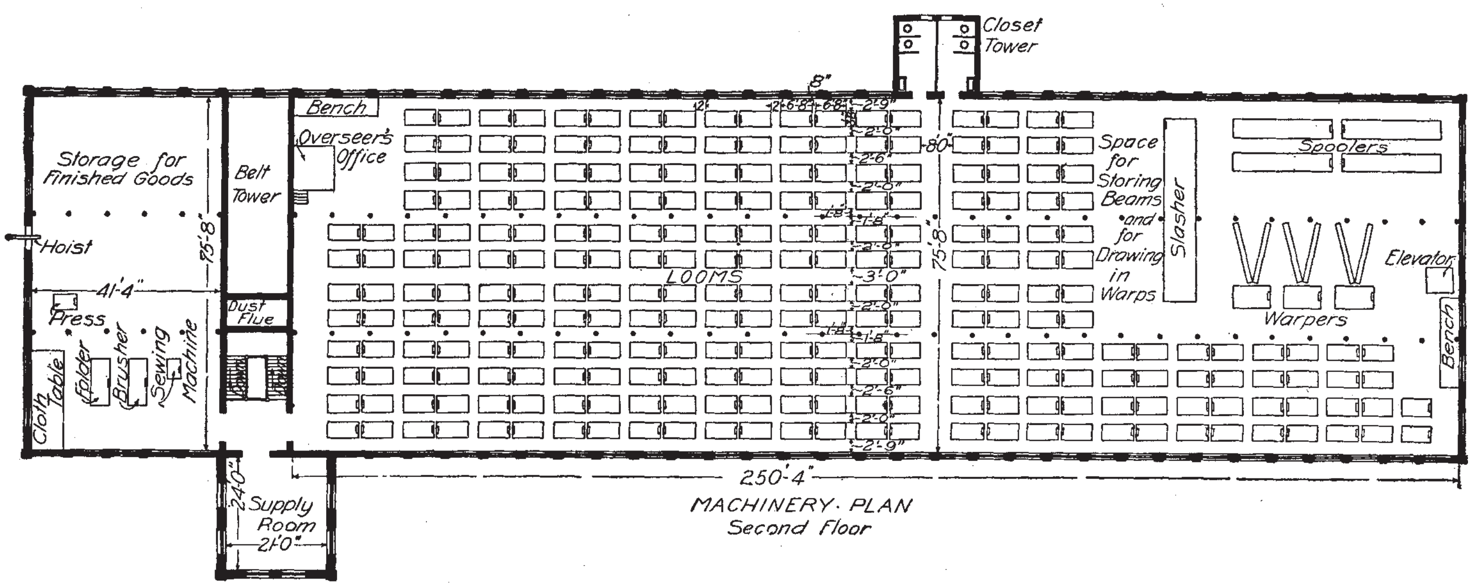

Closet
Tower
8"
2'-9"
2'-0"
2'-6"
2'-0"
1'-8"
3'-0"
8'0"
75'-8"
Storage for
Finished Goods
Hoist
41'-4"
Press
Cloth
Table
Folder
Brusher
Sewing
Machine
Belt
Tower
Dust
Flue
Bench
Overseer's
Office
LOOMS
Space
for
Storing
Beams
and
for
Drawing
in
Warps
Slasher
Spoolers
Warpers
Elevator
Bench
24'0"
Supply
Room
21'0"
250'-4"
MACHINERY · PLAN
Second Floor

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 monkeywrench; 1 12-inch monkeywrench; 2 cold-chisels (different sizes); 2 sets of files (assorted); 2 hammers; 1 10-inch screwdriver; 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 $12'' \times 1''$ 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, $\frac{1}{2}$-inch to $\frac{3}{4}$-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, $\frac{1}{8}$ 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 $2\frac{1}{2}$-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; $\frac{1}{2}$ 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.

REELING AND BALING

REELING

INTRODUCTION

1. A *skein* is one of the forms in which yarn is put up for sale or for convenient handling at a future process. Yarn mills adopt this method of putting up yarn to a large extent for convenience in transportation to their customers, as the skeins can be packed in bags or bales and transported without damage; often, also, customers require the yarn to be put up in this manner, since it is the most convenient form in which filling yarn for certain kinds of goods can be subjected to such processes as bleaching, dyeing, mercerizing, polishing, printing, and so on. Yarn intended for filling is sold in skein form more frequently than yarn intended for warp, although this depends somewhat on the fabric to be woven; for some goods it is customary to put up warp yarn in skeins. Knitting yarn that has to be passed through the processes named is also made into skeins.

The **skein** is made by a process of reeling, and the word indicates a continuous coil of yarn that has been wound around a revolving frame of a known circumference. It is tied around at one or more points in its circumference, so that when removed from the frame on which it is made it forms a loose coil that may be treated or handled without damage and unwound at a succeeding process. Skeins vary in circumference, in the length of the yarn composing them, and also in the manner in which the yarn is arranged.

In the United States, the name skein is applied to any length or description of skein, and the process of making it is called *reeling*. In other English-speaking countries, the word *hank* is more frequently given to a skein when it contains exactly 1 hank, as for example, 840 yards of cotton or 560 yards of worsted, or multiples of these lengths, such as double hanks, containing 1,680 yards of cotton or 1,120 yards of worsted; but the process of making hanks is always called reeling. When lengths that are not complete hanks or multiples of hanks are made, it is customary in these countries to speak of the process as *skeining* or *skein reeling* and of the product as skeins. These terms indicate that the skeins are made of a certain weight or a certain length usually less than that of complete standard hanks.

Reeling is a process common to cotton, woolen, worsted, linen, silk, and other materials, the machine in common use for making skeins being known as a *reel*.

REELS

2. The **reel** is one of the simplest machines used in textile-mill work, its essential parts consisting only of a revolving framework around which the yarn can be wound, a creel to hold the yarn being reeled, and some smaller attachments, such as doffing arrangement, traverse motion, measuring motion, etc.

3. Passage of the Yarn.—An ordinary type of reel used in the United States is shown, in perspective, in Fig. 1 and, in section, in Fig. 2. The yarn passes from the bobbin *a*, which is supported by the spindle *b*, through an eye in the guide wire *c*, and around the revolving framework *d*, which is called a *swift;* the yarn forming the skein is shown at *e*. In American types of reels, the yarn passes downwards from a creel fitted with spindles in the upper part of the reel. In European reels, the creel sometimes is below the swift, the yarn passing upwards to it, but in other cases the arrangement is the same as the American type.

4. **Creels** are of various types, depending on whether the yarn has to be wound from a cop, a filling-wind bobbin, a warp-wind bobbin, a spool, or from some other formation. The ordinary type of creel is the one shown in Figs. 1 and 2. In this case the machine is shown reeling from warp-wind spinning bobbins, but the creel is so constructed that winding

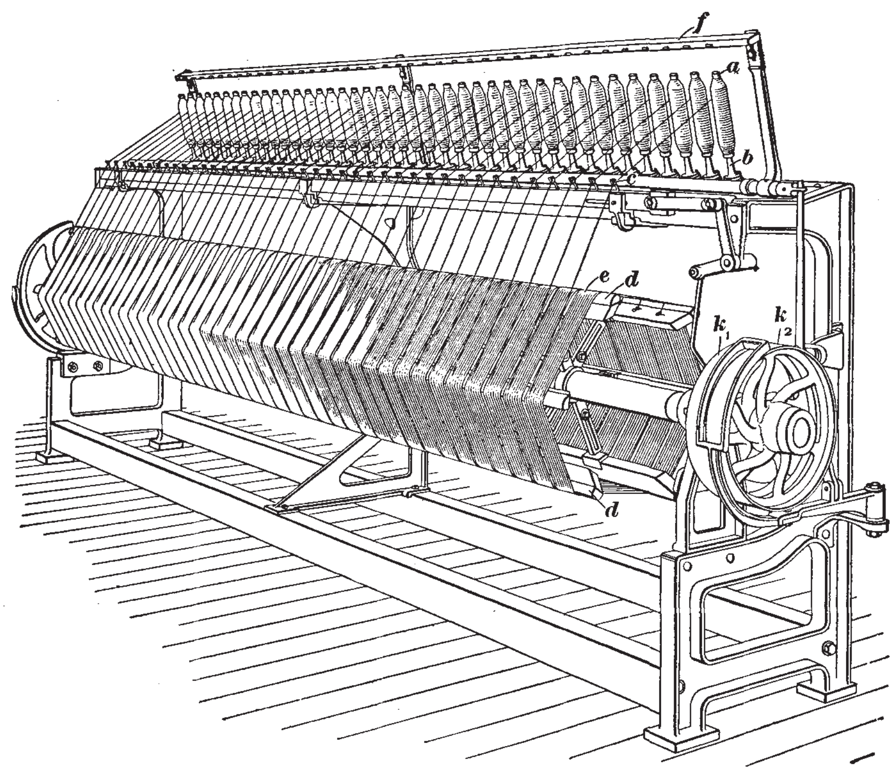


FIG. 1

can take place from warp-wind bobbins, spools, or parallel tubes, or, by using the guide rail *f*, from filling-wind bobbins, or conical tubes.

The creel consists of the framework that supports the spindles *b*, the guide rail *f*, and the receptacle *g* for holding both full and empty bobbins. The spindles are of the common

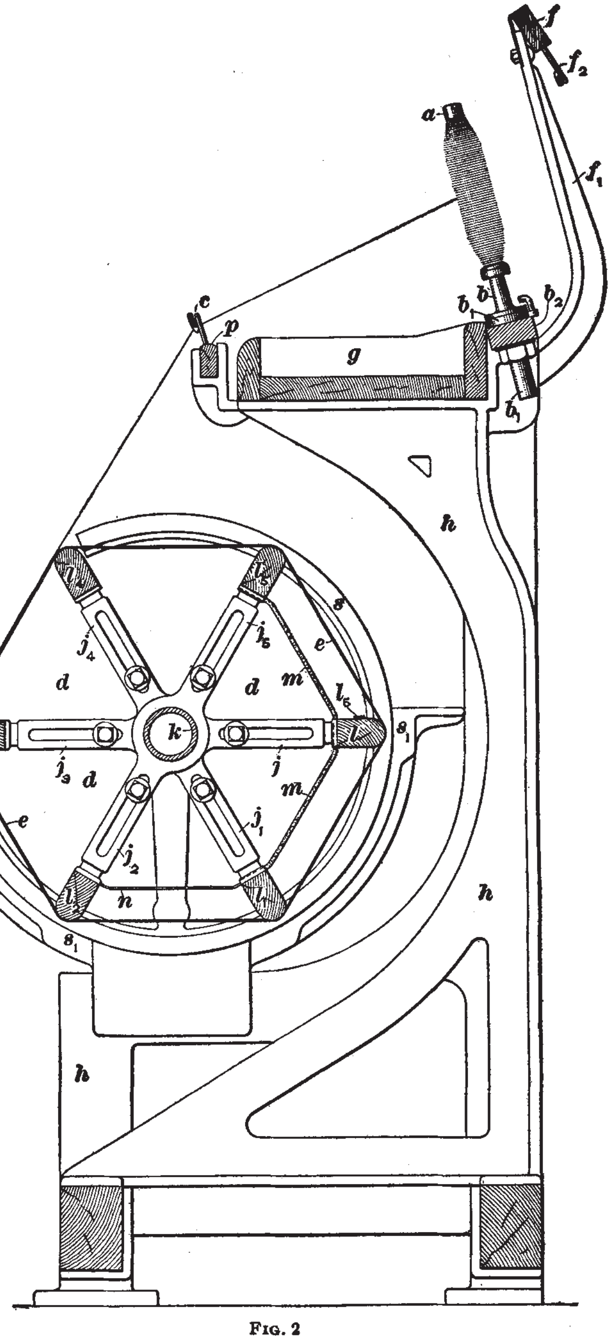

a
f
f_2
f_1
c
p
g
b_1
b
b_2
b_1
h
l_4
l_5
s
j_4
j_5
e
d
d
m
s
l_6
e_1
l_3
k
l
s_1
j_3
d
j
m
j_1
e
j_2
l_2
n
l_1
h
s_1
h

FIG. 2

type and rest in the base b_1, which is supported by the rail b_2. They are made to suit the form of bobbin that is to be used and are constructed to revolve easily by means of a light, uniform pull exerted by the yarn. The spindle shown in use for warp-wind spinning bobbins in Fig. 2 can be used in the same manner for worsted, mohair, and other yarn wound on bobbins with a straight traverse.

The guide rail f is supported by three arms similar to f_1 and carries the same number of guide wires f_2 as there are spindles. In Fig. 2, the rail is shown thrown out of position, as it is only intended to be used in reeling from those forms of yarn in which the end has to be drawn over the nose, such as cops and filling-wind bobbins. When in use, it is in the position shown in Fig. 3. In this case the yarn is shown passing from a cop through the guide wire f_2 in the guide rail f and thence to the guide c in the traverse. When a reel is intended to be used for cops, the revolving spindle and base, such as are shown in Fig. 2 at b and b_1, respectively, are not used, but the creel is constructed with a number of sockets b_2 in which a steel or wooden skewer b_3 can be fitted, as shown in Fig. 3; the cops b_4 are placed on these skewers. These skewers are spoken of as *dead spindles* to distinguish them from the revolving, or *live, spindles*. When winding from a wooden bobbin in which the yarn is built with a short traverse, as in the case of filling-wind spinning bobbins, it is not necessary

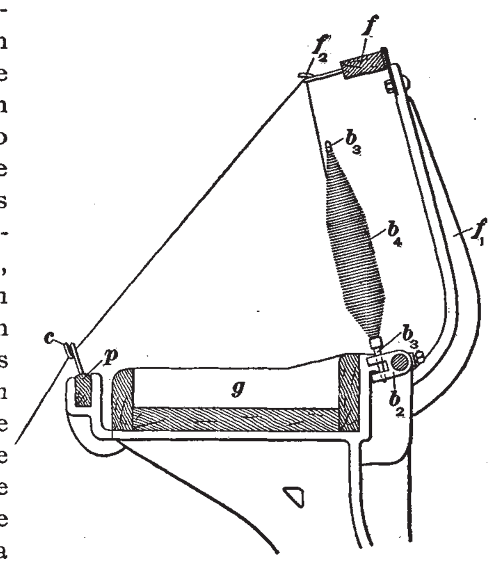


FIG. 3

to adopt the creel construction shown in Fig. 3, as the style shown in Fig. 2 may be used by placing the bobbins on the spindle and drawing forwards the guide rail, passing the end through the eye of the guide wire f_2.

The receptacle *g* is a long, shallow, wooden box extending the entire length of the frame and supported by the sampsons *h*. The guide wires *c*, of which there are the same number as there are spindles, guide the yarn in its passage from the bobbins to the swift; they are of the ordinary type and are screwed into a long wooden rod *p* that extends the entire length of the frame and forms a part of the traverse motion.

5. The **swift** of the reel, on which the yarn is wound, is shown in Figs. 2, 4, and 5. It consists of several groups of supporting arms evenly distributed throughout the length

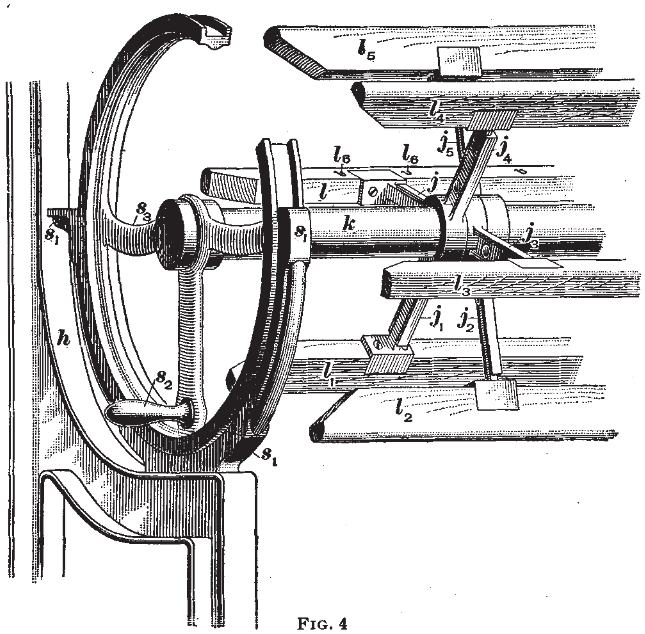
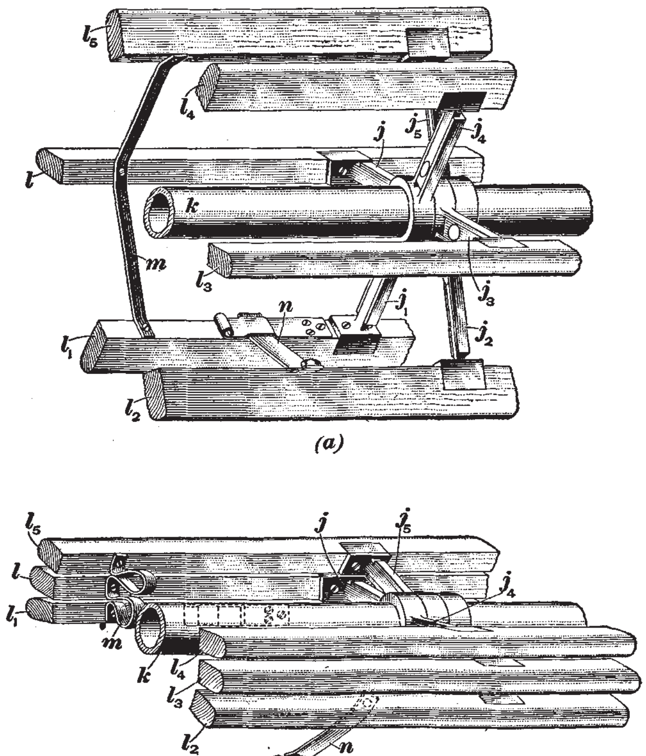


Fig. 4

of the reel. Each group, as shown in Fig. 2, consists of three sets of these arms, j, j_3; j_1, j_4; j_2, j_5; bolted to the arms are extension pieces that carry at their outer ends long wooden rails $l, l_3, l_1, l_4, l_2, l_5$, respectively. These extension pieces can be moved inwards or outwards, and thus the distance around the swift (usually spoken of as the circumference, although this is not a strictly accurate term) decreased or increased, so that different sizes of skeins can be made. The standard sizes of skeins are 54 inches, 60 inches,



(a)

(b)

FIG. 5

72 inches, and 90 inches, but only specially constructed reels can be adjusted to make all sizes. Reels are ordinarily constructed to make either 54-inch, 60-inch, or 72-inch skeins.

The arms j, j_3 of the swift are parts of a casting that is fastened on a long, hollow shaft k; the arms j_1, j_4 and the arms j_2, j_5 are similarly constructed, but instead of being fastened to the shaft k are free to swing on it, and must therefore, in some way, be held rigidly in place when the yarn is being wound on the swift. This is accomplished by means of the leather strap m, Fig. 2 and Fig. 5 (a), and the steel latch n, both of which are attached to the rails, generally at about the middle of the swift. The strap connects the rails l_5, l, l_1, while the latch connects the rails l_1, l_2; thus, each rail is held in its proper position, with an equal distance between each two. When the strap is tightened and the latch n is in position, the arms are held rigidly, as shown in Figs. 2, 4, and 5 (a), and can be revolved in that position. The shaft k revolves in bearings situated at each end of the frame, the tight and loose driving pulleys k_1, k_2 being situated on this shaft, as shown in Figs. 1 and 6.

6. The **traverse motion** used on this reel is shown in Fig. 6 and is very simple. The yarn from each bobbin is wound on the swift over a short section of its length, as shown in Fig. 1. This is accomplished by imparting a slight, but rapid, reciprocating motion to the rail p in which the guide wires c are fastened, which results in the yarn being wound in a zigzag path on the swift, thus producing what is known as *cross-reeling*. In ordinary cross-reeling, the crossings do not occur in the same place with each succeeding layer. The width of the skein depends on the throw of the traverse, which is usually about $2\frac{1}{4}$ inches, depending on the space between spindles.

The rail p receives its reciprocating motion as follows: The shaft k carries a 38-tooth spur gear q, which drives a spur gear q_1 of 62 teeth. On the shaft with q_1 is a crank-arm q_2 connected at q_3 to a connecting-rod q_4, which, in turn, is attached at the point r_1 to a bell-crank lever r pivoted at r_2. Connected to the bell-crank lever at the point r_3 is a connecting arm r_4 that is pivoted to a casting r_5 attached to the rail p. In this manner a rapid traverse is imparted to the guide c as the shaft k rotates.

The crank-arm q_2 is provided with a slot so that the stud q_3 may be moved nearer the center around which it revolves,

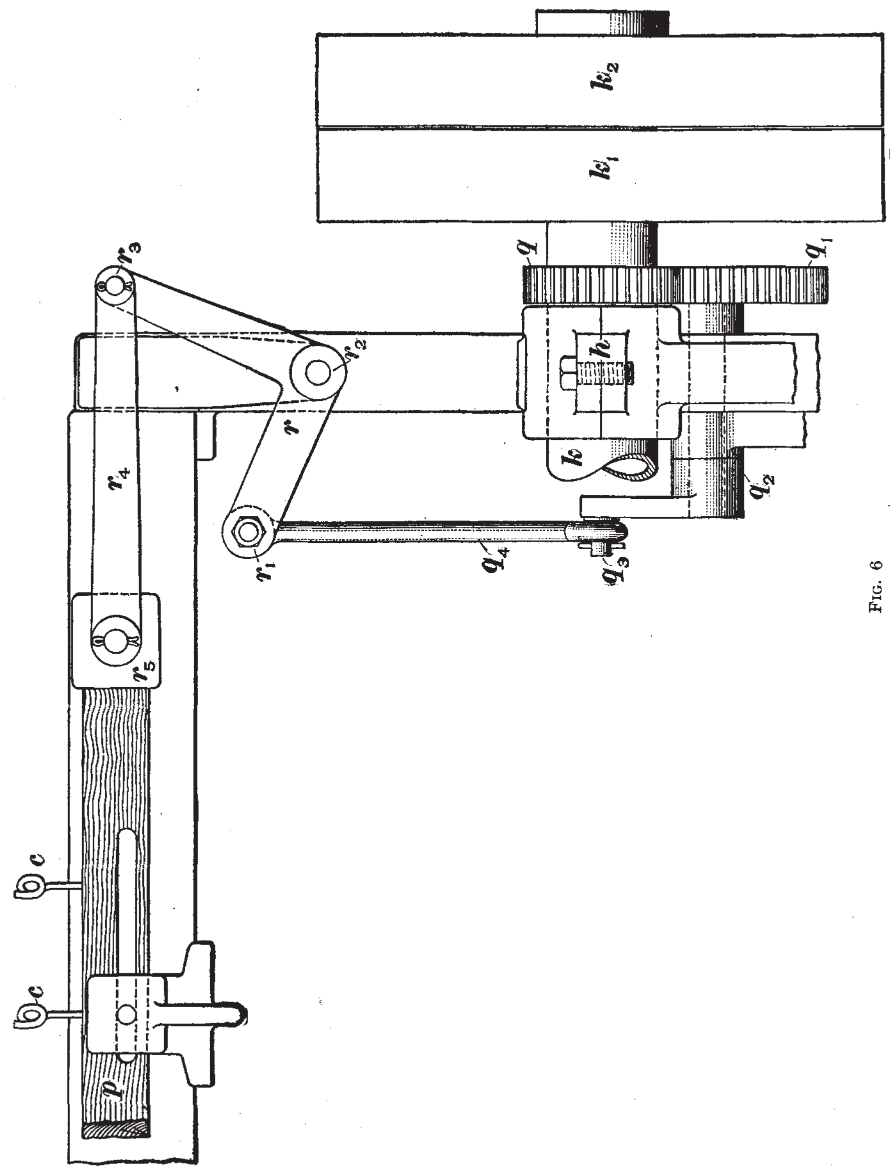


Fig. 6

thus reducing the throw of the crank and consequently lessening the distance through which the guides *c* move, and producing a shorter traverse.

METHODS OF REELING

7. Both the expressions *plain reeling* and *cross-reeling* are frequently applied, in American mills, to the method of making skeins by a machine arranged as described. Plain reeling is often understood to refer to the making of a skein with a narrow traverse, which is usually done in the case of skeins of a short length or skeins through which tie-yarn will not be passed. Cross-reeling is often applied to skeins made on the same machine and with the same traverse motion, but so set as to produce a skein with a wide traverse, which is necessary when the yarn has to be spread sufficiently to enable leasing to be performed; that is, to allow tie-yarn to be passed through the skein. The traverse is sometimes so long as to extend to the extreme limit of the space allotted each skein on the frame or even beyond, in the latter case preventing the use of every spindle. In such cases, alternate spindles only are used for single reeling; for double reeling, when two ends are to be wound together, a supply of yarn is placed on every spindle, but two ends passed through one guide eye. As a matter of fact, both of these methods are really cross-reeling, the only difference being in the length of the traverse. It is preferable not to apply the expression plain reeling to any kind of cross-reeling, as its use tends toward confusion by creating the impression that some other style of reeling than cross-reeling is referred to, and also conflicts with the English practice, where the expression plain reeling means lea reeling. Cross-reeling by means of the mechanism shown in Fig. 6 is one of the simplest and most commonly used methods of reeling in America, but other methods are in use. Among those that differ according to the method of laying the yarn on the swift of the reel are: (1) *Grant*, or *long-diamond*, *reeling*, and (2) *lea*, or *wrap*, *reeling;* while among those that depend on the length wound on the swift are: (3) *French reeling*, in either cross-reeling or lea reeling, and (4) *skeining*, or *grain reeling*.

8. Grant, or long-diamond, reeling is really a variety of cross-reeling by which the yarn is arranged on the swift with well-defined crossed layers in an elongated-diamond form. This is obtained by giving a quick reciprocating motion to the traverse rod, the time of which has a definite relation to the time occupied by one revolution of the swift; this causes each new layer of yarn to wind on the same part of the swift as some previous layer, thus forming a series of layers in different positions but having the crossings coming together. Some of the longest skeins are made on this system, the reel not being stopped when a hank has been wound, as in some systems, but allowed to run until the skein is sometimes composed of thousands of yards, as many as ten hanks of fine yarn being often made into one skein.

9. Lea reeling is the name given to a method of reeling cotton yarn in which the yarn is arranged on the swift of the reel in separate leas of 120 yards each. As a cotton reel is usually arranged with a circumference of 54 inches, 80 turns of the swift are required to wind 120 yards. The most common method is to reel yarn in 7-lea skeins. For this the cross-traverse motion of the reel is disconnected and an arrangement adopted by means of which the traverse rod remains stationary until the swift of the reel has revolved 80 times, which winds 120 yards around it. Then the traverse is moved slightly and quickly so as again to wind 80 revolutions of yarn, or 1 lea, around the swift, when the traverse is again moved a short distance. This is repeated until there are 7 leas arranged on the swift, consisting of a continuous thread of yarn from the bobbin on one spindle; this arrangement is, of course, repeated along the surface of the swift as many times as there are spindles. A view of a portion of a 7-lea skein is shown in Fig. 7 (*b*). When the reeling of the skein is completed, the swift is stopped automatically. In 6-lea reeling, the yarn is reeled in the same way as in

7-lea, the difference being in the method of tying up, as shown in Fig. 7, where (*c*) represents 7-lea and (*b*) 6-lea; the length of the skein is the same in both cases. The table of measurement for cotton yarn is as follows:

$1\frac{1}{2}$ yards = 1 thread, or circumference of a cotton reel
120 yards = 80 threads = 1 lea
840 yards = 560 threads = 7 leas = 1 hank

10. Wrap reeling, as applied to worsted yarn, is on the same general principles as lea reeling for cotton. A worsted reel, however, is usually arranged with a circumference of 72 inches and a wrap, as shown by the table, contains only 80 yards. The table for worsted yarn is:

2 yards = 1 thread, or circumference of a worsted reel
80 yards = 40 threads = 1 wrap
560 yards = 280 threads = 7 wraps = 1 hank

11. French reeling corresponds to ordinary reeling except that the swift is adjusted with a circumference of 1 meter (39.37 inches); yarn is reeled in this way for consumption and sale in those countries in which the meter is the standard of measurement. French reeling may be either cross-reeling or lea reeling. If the latter, the swift is usually revolved 100 times for each division, giving 1 hectometer, and 10 of these divisions (1 kilometer) are made into a skein.

12. Skeining, as it is known in England, is sometimes called **grain reeling,** since the skein may be required to weigh a certain number of grains; and is sometimes called *length reeling*, since the skeins are required to be of such a length as gives a designated weight; it is also known as *thread reeling*, since the length required is made up of a certain number of threads, each of which in the case of cotton measures 54 inches, or in the case of worsted, 72 inches. Each skein has to be of an exact weight, generally expressed by the fractional part of an ounce, for example $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, $\frac{1}{6}$, $\frac{1}{8}$, $\frac{1}{10}$, or $\frac{1}{12}$ ounce; it may, however, be expressed in grains, either 200, 100, 75, 50, 25 grains, and so on. In such cases, the length of yarn that comprises the weight required must be determined by calculation. The arrangement of the reel is similar to that for lea reeling, so as to move the traverse when the required number of revolutions have been made by the swift.

Skeining, or grain reeling, should not be confused with the usual American method of defining the weight of an ordinary cross-reeled skein. It is frequently the custom for American buyers of skeined yarn to specify that each skein shall weigh a certain number of ounces; for instance, $1\frac{1}{2}$, $2\frac{1}{2}$, 3, or 5 ounces, or any other reasonable weight. These weights greatly exceed the customary weights of skeins made by the grain- or thread-reeling systems on reels provided with measuring motions so as to give exact lengths. The customary American method is not to use measuring motions on the reel to give the weight of skein required, but to determine this by supplying to the reel tender cops or bobbins containing a certain weight of yarn. For example, if a 5-ounce skein were required, the mule cops might be spun $2\frac{1}{2}$ ounces in weight and the reel tender instructed to wind two cops on each skein; if a 1-ounce skein were required, a cop might be spun 2 ounces in weight and the reel tender instructed to make two skeins from each cop; or if a 2-ounce skein were required to be made from ring-spun yarn, the bobbins would be doffed from the spinning frame when 2 ounces of yarn had been wound on them, the correct point being predetermined by weighing bobbins of different sizes. This system, of course, is not absolutely accurate and does not produce skeins of absolutely the weight required, but it produces results sufficiently satisfactory for the general buyer of skeined yarns.

13. The terms **single** and **double reeling** refer to the number of ends passing to each skein at the reel; generally each skein contains only one end, so that almost all reeling is single reeling. Occasionally, however, the ends from two or more spindles or skewers are passed together through one guide eye and thence to the reel; this constitutes double reeling. When two or more ends have been wound together on a spool or tube and then skeined, this also is called double reeling.

TYING

14. After yarn has been reeled on the swift and before it is removed it becomes necessary to tie together the first and last ends of the skein and in some cases to pass an additional piece of yarn around or through the various portions of the skein. This is known as **tying,** or **tying up.** As the object of skeining yarn is to prepare it for handling at some other process, very often a process in which the threads tend to become more or less entangled, such as bleaching, dyeing, etc., it is very necessary that when the yarn is used after such treatment there should be a ready means of finding the end so as to unwind the skein without entanglement. In some methods of tying, it is necessary to loop together several skeins, so that they may be handled together at the next process but readily separated before unwinding afterwards. When an extra piece of yarn is used to tie up skeins, it is generally a red-and-white cotton twist, or grandrelle yarn. Any colored yarn is suitable, preferably one dyed a fast color so as to stand bleaching, in which case it can readily be found after a skein has been bleached or otherwise treated. In some cases ordinary undyed coarse ply yarn is used, while in others two or more strands of single yarn, taken from a corresponding number of cops or bobbins, together with the ends of yarn in the skein, are tied around it.

In cross-reeling, the first end of the skein, which was slipped into the catch l_6, Fig. 2, before the reel was started, is removed and tied to the last end, either with or without a band of colored yarn passing around the skein, as in Fig. 7 (*a*). In case an extra piece of twine or band is not used, one end of the yarn is passed once or twice around the skein and then tied to the other end. Each skein is tied in the same way and the swift is then sometimes turned half way around and another band of colored or uncolored yarn tied loosely around the skein at the opposite side to that where the knot is.

Single cross-reeled yarn, when reeled to exact measurements, consists of 1 hank; in case of cotton, 840 yards would be reeled and then tied in. Double cross-reeled yarn consists of 2 hanks reeled one on top of the other before tying in, making, in case of cotton, 1,680 yards. Single cross-reel is sometimes indicated by the sign *X* and double cross-reel, by the sign *XX*. The words single and double, when used in connection with the word cross, have thus a different meaning than when used in the expressions single and double reeling.

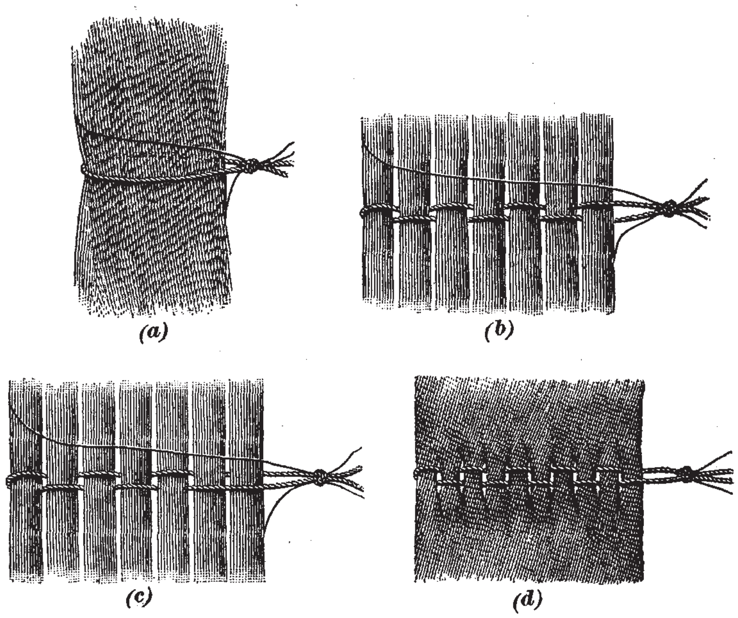
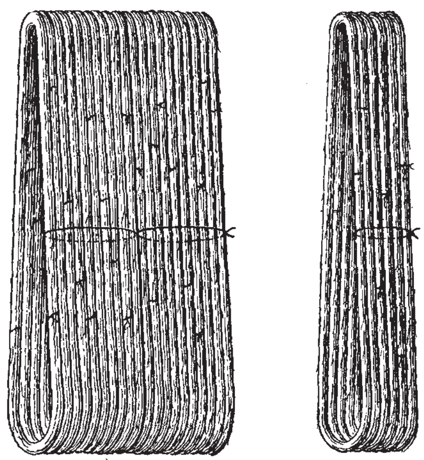


FIG. 7

For tying up yarn that is skeined in 7 leas, two methods are adopted—either 7-lea tying or 6-lea tying. In the *7-lea tying*, a piece of colored yarn is passed up between the first and second leas, down between the second and third, and so on until it encircles the seventh, when it is brought down between the seventh and sixth, and so on alternately until it is brought up between the first and second, as shown in Fig. 7 (*b*). The ends of the tie-yarn are then knotted with the first and last ends of the skein yarn. In *6-lea tying*, the same method is adopted, except that the first and second leas are kept together within the same loop of the tie-yarn, thus making only 6 divisions instead of 7, as in Fig. 7 (*c*).

Grant-reeled yarn is tied by passing a piece of heavy ply yarn through the spaces produced by means of the system of crossing the ends on the swift, in long-diamond form at two points, one on each side of the swift. This system of winding gives an opportunity of passing the tie-yarn through nine openings in the skein, thus making ten portions of yarn, divided from one another, as shown in Fig. 7 (*d*). Of course these are not separate sections of the skein, as in the case of 6- and 7-lea tying, for the ends crossing from one side of the skein to the other are tied in twice; the only object of this method of tying is to hold the yarn securely in position and prevent the threads becoming entangled in case of mercerization or some other process through which the yarn has to pass.



(*a*) (*b*)

Fig. 8

In French reeling the method of tying is somewhat similar to that used for cross-reeling and lea reeling, the difference between the French and the ordinary reeling being in the length of the skein rather than in the method of arranging and tying the yarn.

15. Banding.—After each individual skein has been tied, it is often necessary to band together several skeins. The arms of the swift are closed like a fan and the desired number of skeins slid together and banded with tie-yarn. A common method is what is known as *banding in a figure 8*, because the tie-yarn follows the outline of an 8. Two groups, each containing 10 skeins, are arranged on the swift and a piece of tie-yarn passed alternately down and up and then tied, as shown in Fig. 8 (*a*). This holds the 20 skeins together during the succeeding processes and provides for their separation without entanglement by snapping the band. The number of skeins to a group varies; for instance, in some cases only 6 skeins are tied together by means of a band, which in this case is usually an open one that encircles the entire 6 skeins, as shown in Fig. 8 (*b*). When a number of skeins are fastened together by this or any other system of banding, the group is called a *knot*.

SPECIAL MOTIONS

16. Measuring and Traverse Motion.—In many cases, reels intended for ordinary cross-reeling are not fitted with measuring motions, since it is customary to place in the creel a number of bobbins or cops that have all been doffed at one time from the spinning machine and that consequently contain the same length of yarn. The reel is operated until the cops or bobbins are either entirely or almost entirely exhausted, so that each skein contains approximately the same length of yarn. In the case of lea or grain reeling, however, it is necessary to adopt measuring motions that will move the traverse guide after the correct length has been reeled and also stop the machine when the total amount of yarn desired has been wound on the swift. For this, the rods q_4, r_4, and lever r, shown in Fig. 6, are removed, and in place of them is used a vertical rack t, Fig. 9, having at its upper end six steps. By means of a spring p_1, a small bowl p_2 fixed on a pin at the end of the traverse guide rod p is kept constantly pressed against whichever one of the steps happens to be in line with it. The six steps and the face of t below the steps provide seven faces against which p_2 may rest. At the opposite side of the rack a series of seven teeth t_1 are cast, and by means of a dog k_6 attached to a worm-gear k_4 containing 80 teeth (in the case of 7-lea reeling), which is driven from a single-threaded worm k_3 on the swift shaft *k*, the rack *t* is raised 1 tooth every time that the swift makes 80 revolutions. Each time that the rack is moved up 1 tooth, it is raised a sufficient distance to allow the bowl p_2 to come in contact with the face of the next step of the rack, thus allowing the traverse rod *p* to be

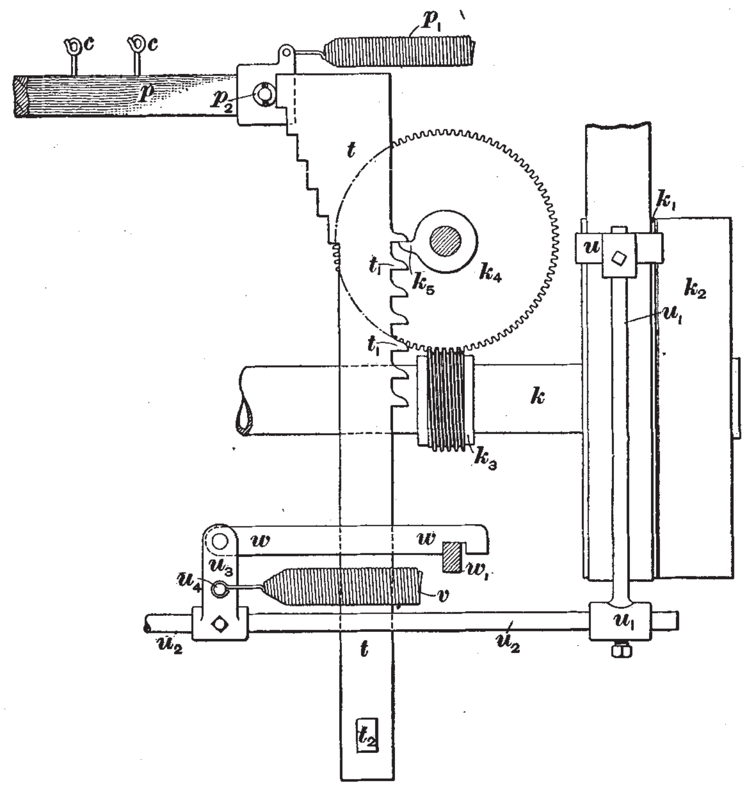


FIG. 9

drawn a short distance nearer the driving end of the reel, which guides the yarn on to a new portion of the swift and gives the lea reeling shown in Fig. 7 (*b*) and (*c*).

In English skeining, or grain reeling, other than 7-lea, the required traverse is given to the rod *p* by varying the number of teeth in the gear k_4 so that it will have made one revolution, and the dog k_6 will consequently raise the rack t 1 tooth, when the required length of yarn has been wound on the swift.

17. Stop-Motions.—The belt fork u, Fig. 9, is attached to a vertical rod u_1, which is mounted on a horizontal rod u_2 so arranged that it may slide in suitable bearings and thus move the driving belt from the tight pulley k_1 to the loose pulley k_2, or vice versa. A bracket u_3 is setscrewed to the rod u_2 and carries a pin u_4 to which is attached the coil spring v, which is fastened at its other end to a stationary part of the frame and constantly tends to draw the bracket u_3, together with the belt fork and its connections, toward the loose pulley. Above this spring and also attached to the bracket u_3 is a latch w with a notch at its outer end. When the reel is started, the rod carrying the belt fork is moved far enough along to bring the belt on to the tight pulley and at the same time allow the latch w to drop slightly so that the notch is held against the projection w_1. When the total number of yards required for 1 skein has been wound on the swift, the rack t will have risen a sufficient distance to enable the projection t_2 to raise the latch w, and allow the spring v to ship the belt to the loose pulley.

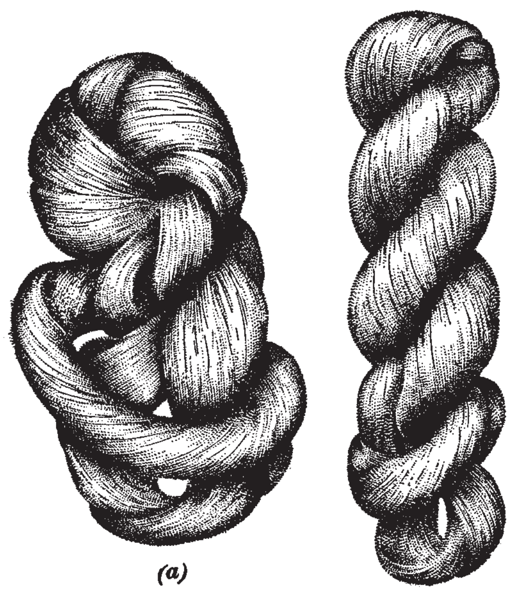
Such an arrangement as this is usually applied only in Europe, in case of lea and skein, or grain, reeling, where accurate measurements are required. For ordinary American cross-reeling, where exact measurements are of less importance, reels are often provided with a simple measuring motion consisting of an arrangement by which a gong is struck when the desired length of yarn has passed on the swift, leaving it for the attendant to stop the machine; or they may have in addition to the measuring motion a simply constructed stop-motion to automatically stop the machine.

DOFFING

18. When the proper amount of yarn necessary to form the skeins has been wound on the swift, and when the necessary tying of the skeins and the ends of the yarn has been performed, it becomes necessary to remove the full skeins; this operation is known as **doffing**; in order to accomplish it, the arms of the swift must be brought together. In Fig. 5 (*a*), the swift is shown with the rails spread in working position and held apart by the extended leather strap *m* and the steel latch *n*, while in Fig. 5 (*b*) it is shown in a folded position, with the latch *n* released, the strap loose, and the rails brought together, with the arms in a folded position. In order to close the swift, the latch *n* is slipped from under the spring that holds it when working and turned so that it lies along the rail l_2; the rails l_2, l_4 are then pulled together and both brought in close proximity to the rail l_3. Consequently, the rails l_1, l, l_6, since they are attached, respectively, to the opposite ends of the arms to which the rails l_2, l_3, l_4 are attached, are also brought close together, thus reducing the distance around the swift and allowing the skeins to rest loosely on it. If the skeins are to be banded, it is done when they are in this position, and sometimes the simpler methods of tying, such as those for cross-reeling, are performed with the skeins hanging loose.

The doffing process is then begun by moving the skeins to the doffing end. As the swift consists of one continuous framework, resting in bearings at each end and encircled by the completed skeins, it becomes necessary to in some way pass one part of the skein over the end of the swift and its bearings. Formerly it was the custom to lift the end of the swift completely out of its support, slip the skeins over the end of the swift and its shaft, and then drop the swift back into position. This was a heavy task for the reelers, who are usually women or girls, and also tended to cause oil stains on the skeins by their coming in contact with the bearing of the reel; consequently, devices are now employed by which one part of the skein can be laid in a suitable recess and passed under the bearing of the swift without raising it.

One style of these doffing devices, shown in Fig. 4, consists of a grooved segment wheel *s* that forms a bearing for one end of the swift shaft *k*. The wheel *s* is supported on four small rollers in the bracket s_1, which is attached to the end sampson *h*, the hub of the wheel forming a bearing for the shaft *k*. The wheel contains three spokes, the central one carrying a handle s_2 that is used to turn the wheel around when doffing, which is the only time that it is necessary to change the position of the wheel from that shown in Fig. 4. A long portion of the rim of the wheel extends beyond the spoke s_3. When it is necessary to remove a skein from the arms of the swift, the skein is first passed over that part of the rim that projects beyond the spoke s_3, and the wheel then



(*a*) (*b*)

FIG. 10

revolved. In this manner the skein will be detached from the swift. Usually several skeins are removed at one operation.

After all the skeins have been removed from the swift, the rails are spread to their proper positions and the arms fastened by sliding the latch *n* into the recess provided for it under the spring. The broken ends of yarn hanging from the guide wires are attached to the catches l_6, Fig. 4, after which the reel is ready to be started again to form another set of skeins.

KNOTTING

19. After the skeins are doffed, it is necessary to twist them into some form in which they can be handled without damaging the ends or running the risk of entangling them. This is known as **knotting.** They are very loosely knotted by holding opposite ends of the skein in each hand, twisting it several times, and then passing one end through the loop in the other end, so as to form a loose knot such as is shown in Fig. 10 (*a*). A tightly twisted skein is formed by performing the same operation more carefully; in this case one end of the skein is passed over a curved hook securely attached to a bench and the opposite end of the skein twisted many times. It is then doubled near its center, in which case the excess twist that has been placed in the twisted skein causes the doubled part to twist around itself, as shown in Fig. 10 (*b*). One end of the skein is passed through the loop formed by the other end, when it is ready for bundling or packing otherwise for transportation.

VARIATIONS IN CONSTRUCTION

20. The reel that has been described is one that is constructed in the simplest manner. Other constructions of reels are supplied by different builders, the principal points of variation from the style described being in the form of the swift used, the methods of opening and closing the swift, the arrangements for doffing, for imparting a traverse to the yarn, for measuring the length of yarn reeled and stopping the machine, and in the weight and strength of the framework supporting the operative portions of the reel. The reel that has been described is known as a *single reel*. *Double reels* are sometimes constructed, in which case there are two swifts, one on each side of the frame. This resembles two single reels placed back to back; otherwise the construction and operation is the same as in the case of a single reel. There is no especial advantage in this style of construction except a slight saving in floor space and a greater solidity of the machine.

Still another form of construction provides for four swifts to each reel. This construction is similar to that of the double reel except that there are two short swifts on each side instead of one long one, both, of course, being in line and each having a bearing near the center of the frame. The driving is performed by means of clutch gearing situated at the center. This construction is sometimes used where children are employed for reeling, who are only competent to tend a small number of ends, or where long skeins are reeled, since this gives an opportunity for the tender to doff one swift while the others are running.

Other styles of reels are those for double reeling and for slack-reeled skeins. For double reeling, the arrangement of the creel provides for its holding more than one cop or bobbin for each guide wire; in other respects the construction and operation of the reel is the same.

Reels adopted for *slack reeling* are required to produce a skein in which not only are two or more ends reeled together, but a slight amount of twist also inserted, as, for example, twenty turns per foot of reeled yarn. In this arrangement, the yarn is usually reeled from cops or more commonly ring-spinning bobbins; the creel is constructed with two or more spindles mounted in a casting, which in turn is mounted on a vertical spindle resting in bearings and capable of being revolved. Immediately beneath the creel is a horizontal shaft extending the whole length of the frame and carrying bevel gears that gear into smaller bevel gears attached to the vertical spindles. The long spindle shaft is driven from one end of the reel and rotates the castings carrying vertical creel spindles; consequently, at the same time that the yarn is being drawn from the cops or bobbins, each group of cops or bobbins is also being revolved, thus imparting a small amount of twist to the yarn passing on to the swift of the reel. In other respects the construction of the reel and its operation is the same as the common single reel. The expression **slack reeling** is an abbreviation of slack-twisted reeling.

CALCULATIONS

21. Production.—Reels are stopped for a large portion of the time, from 35 to 75 per cent. of the time being occupied in doffing, piecing, and creeling. The least loss of time occurs in reeling fine yarns and making long skeins, but the coarser the yarn or the shorter the length of skein, the greater is the loss of time for doffing, since the skein is completed so much more quickly in the case of coarse yarns, as there is less length on the bobbins, or in the case of reeling from small cops or bobbins. In such cases, the time occupied in replacing the supply of yarn in the creel is greater than when reeling fine yarns or reeling from cones or cheeses. The skill or industry of the tender also affects the allowance to be made for loss of production.

22. Before the production of a reel can be ascertained it is necessary to find the number of revolutions per minute of the swift, and also its circumference. Example 1 illustrates how the speed of the swift is calculated; the circumference of the swift is ascertained by measuring.

EXAMPLE 1.—Find the revolutions per minute of the swift when the countershaft makes 250 revolutions per minute and carries a 6-inch pulley driving a 12-inch pulley on the shaft of the swift.

SOLUTION.— $\frac{250 \times 6}{12} = 125$ rev. per. min. of the swift. Ans.

EXAMPLE 2.—Find the length of time consumed in winding one set of skeins that are 840 yards long, if the swift makes 125 revolutions per minute and is 54 inches in circumference.

SOLUTION.— $\frac{840 \times 36}{54 \times 125} = 4.48$ min. Ans.

To find the production, in pounds per spindle, for a given time, when the circumference of the swift, the revolutions per minute, the counts of the yarn, and the allowance for stoppages are given:

Rule.—*Divide the product of the number of revolutions per minute of the swift, its circumference in inches, 60 (the minutes in an hour), and the hours run, by the product of 36 (the inches in a yard), the yards in a hank, and the counts of the yarn being* *reeled; this gives the production in pounds supposing the reel to be running constantly. To find the actual production, multiply the calculated production by the percentage of time during which the reel is running.*

EXAMPLE 3.—Find the number of pounds of yarn delivered per spindle per day of 10 hours when reeling No. 10s yarn in 54-inch skeins on a swift making 125 revolutions per minute, assuming that 55 per cent. of time is lost.

SOLUTION.— $\frac{125 \times 54 \times 60 \times 10}{36 \times 840 \times 10} = 13.392$ lb. per spindle per day; 100 per cent. − 55 per cent. = 45 per cent., time run; $.45 \times 13.392 = 6.026$ lb. Ans.

EXAMPLE 4.—Find the production of a reel per day if it contains 50 spindles and produces 6.026 pounds per spindle per day.

SOLUTION.— $50 \times 6.026 = 301.3$ lb. per day. Ans.

23. The length of reels depends on the number and gauge of the spindles and may be determined by multiplying the number of spindles by the gauge and adding 27 inches for the extra length occupied by the head end and foot-end. Thus, a 50-spindle reel with a $2\frac{3}{4}$-inch gauge occupies $(50 \times 2\frac{3}{4}) + 27$ inches, which equals $164\frac{1}{2}$ inches, or 13 feet $8\frac{1}{2}$ inches.

Reels are made in various sizes from 30 to 60 spindles, the common size containing 50 spindles; the gauge may be either $2\frac{3}{4}$, 3, $3\frac{1}{4}$, $3\frac{1}{2}$, $3\frac{3}{4}$, or 4 inches.

The width of the reel depends on whether it is single or double and also on the size of the swift—whether it is intended to make 54-, 60-, 72-, or 90-inch skeins. A 50-spindle reel with a $2\frac{3}{4}$-inch gauge and adapted to make skeins of as great a circumference as 72 inches, is 28 inches in width. This, of course, does not provide for the space to be allowed for passages between the reels.

From five to eight reels are estimated to require 1 horsepower, according to their size.

MANAGEMENT

24. Although a reel is simple in construction and has but few mechanical motions, it is necessary to see that it receives careful and periodical oiling and cleaning, and especially that this is so performed as to prevent stains on the yarn. The doffing device, swift rails, and creel should be kept clean, in order to prevent the production of dirty skeins. The spindle bases, in case the creel is equipped with revolving spindles, should be cleaned out once a year, and the friction should be properly adjusted at all times in order to insure proper winding.

The tenders should be supervised so as to see that when an end breaks down or runs out it is immediately replaced and pieced up, each knot being carefully tied as small as possible without projecting ends, and not merely replaced in the mass of yarn forming the skein without being tied.

Where the swifts are adjustable in size, as is the usual custom, the circumference of the swift should be measured from time to time to insure the proper size of skein being made and guard against any wilful or accidental change in length of the arms. Waste should be reduced as much as possible at all times, especially in reeling from cops, so as to insure the whole of the yarn, as far as possible, being unwound from the cop tube or cop bottom. Great care should be exercised in tying, banding, doffing, and knotting skeins so that this may be done in accordance with the requirements of the purchaser of the yarn.

BUNDLING AND BALING REELED YARNS

25. When in the form of skeins, yarn is in a suitable state to be packed for transportation without much risk of damage. The yarn is so arranged that it may either be packed loosely in bags or subjected to considerable pressure in bales, in order to compress it into the smallest possible space, with the thread of yarn arranged in such a way and the skein so tied up and banded that after the bale is opened the yarn will not be found to have suffered from the pressure to which it has been subjected. As the skein is a suitable form to withstand such compression, yarn is consequently often reeled merely for the convenience of transit when it has to be transported long distances, especially if by ocean transit.

Three methods of packing skeins are in common use: (1) soft bales, or loose packing in bags; (2) pressed bales subjected to moderate pressure; (3) bundling, succeeded by compressed baling under intense pressure.

SOFT BALES

26. Skeined yarn is commonly packed loosely in bags when it has to be transported by land and not to any great distance. A bag of burlap is made of the required dimensions with a sheet of paper sewed in with the burlap so as to form a lining. The method of packing the yarn is to suspend this bag with the mouth open, from two rods, each having a hook at each end, so as to hold the mouth of the bag open in rectangular form. The skeins loosely knotted, as shown in Fig. 10 (*a*), are thrown into the bag and tramped down until the bag is full, when the mouth is sewed up. The soft or hand-formed bale is preferred to the compressed bale by some purchasers of yarn, because it may be more readily opened. A common size of these soft bags of yarn is from 250 to 300 pounds in weight, $4\frac{1}{2}$ feet in length, $3\frac{1}{2}$ feet in width, and $2\frac{1}{2}$ feet in thickness.

PRESSED BALES

CONSTRUCTION OF BALING PRESS

27. Where yarn has to be transported a considerable distance, either by rail or water, for domestic trade, it is more commonly put up in pressed bales. Fig. 11 is a view of a baling press known as a *togglejoint power press*. The box *a*, in which the skeins are placed while being pressed, is constructed of hardwood and is firmly held together by means of heavy iron ribs on its outer side. The box can be opened or closed when necessary by releasing the eccentric handles a_1, Fig. 11, and a_1, a_2, Fig. 12. Fig. 12 shows the box open after a bale has been removed. The framework of the press is composed of the bed *b*, Fig. 11, and the head *c*, both of which may be made of either cast iron or wood. The upright rods or columns *d* are usually made of steel and serve to connect the bed *b* with the head *c*. Running horizontally across the machine below the head and between the columns is the screw *e*, which imparts motion to the working arms f, f_1, f_2, f_3. This screw has a right- and a left-hand thread

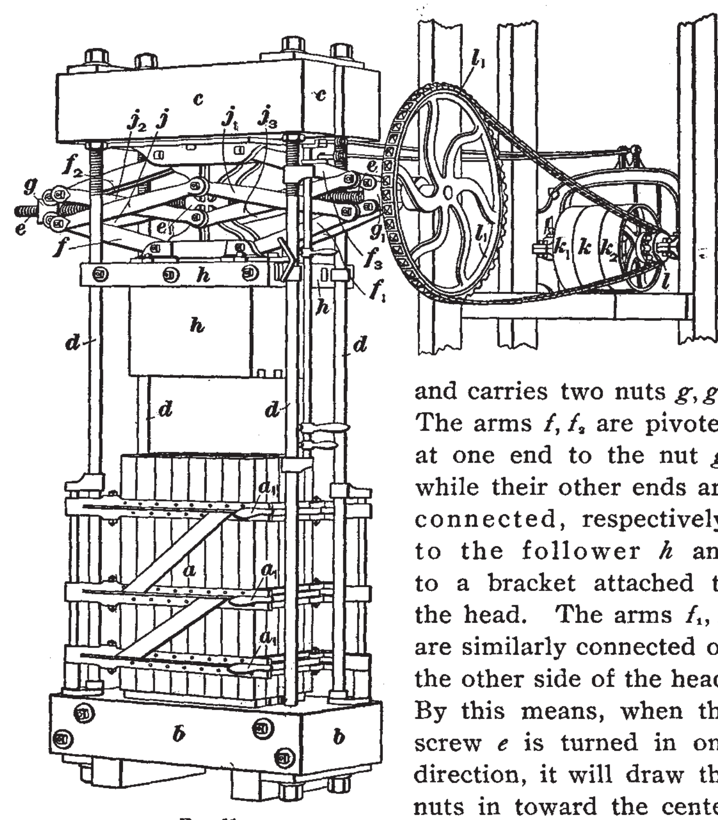


FIG. 11

and carries two nuts g, g_1. The arms f, f_2 are pivoted at one end to the nut *g*, while their other ends are connected, respectively, to the follower *h* and to a bracket attached to the head. The arms f_1, f_3 are similarly connected on the other side of the head. By this means, when the screw *e* is turned in one direction, it will draw the nuts in toward the center of the screw, straighten out the working arms, and force down the follower *h*. When the screw is turned in the opposite direction, it will draw the nuts out, cause the arms to fold up, and thus raise the follower. The arms j, j_1, j_2, j_3 serve merely to steady the working parts. The bed and follower are constructed with recesses through which cords may be passed while the yarn is under pressure and secured before pressure is released.

28. An automatic power attachment is used in connection with the press and consists of a bracket and short shaft carrying three pulleys—*k*, which is attached to the shaft, and k_1, k_2, which are loose on the shaft. The bracket also carries two rods, with belt shippers, springs, and lever attachment for shipping the belts from one pulley to another. One loose pulley is driven by a crossed belt, while the other is driven by an open one and consequently revolves in the opposite direction. On the shaft with the pulleys is a small sprocket gear *l* that drives by means of a chain a large sprocket

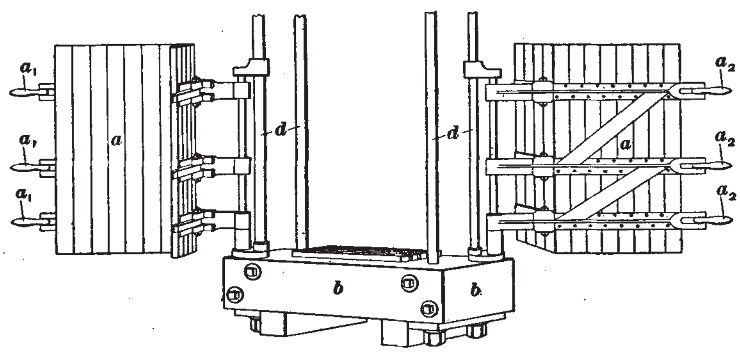


FIG. 12

gear l_1 on the same shaft as the screw *e*. In operation, one belt is first shifted to the tight pulley, which turns the screw in such a direction that the follower is forced downwards until the yarn has been compressed sufficiently, when the belt is automatically shipped to its loose pulley. After the bale has been secured with cords, the other belt is shipped from its loose pulley to the tight pulley, which reverses the screw and raises the follower.

Before closing the box prior to inserting the yarn, the required number of pieces of cord of sufficient length to pass around the entire bale are placed in position in the grooves in the bed. A piece of burlap of sufficient size to cover the lower side of the bale and half of the surrounding four sides is placed in position on top of the bed and covered with paper, after which the box is closed and fastened. The required amount of yarn is deposited in the box and the top covered with paper and a piece of burlap similar to the first piece, after which the follower is allowed to descend and subject the yarn to the necessary pressure to produce a bale of the desired size. The box is then opened and the edges of the two pieces of burlap sewed together so as to cover the bale completely, when it is ready for tying. The cords are passed upwards and drawn through their respective grooves in the follower by means of a hook, after which they are tied tightly around the bale. The follower is allowed to rise so that the bale can be removed and marked, with a stencil or otherwise, indicating the necessary shipping marks and information as to contents of the bale, after which it is ready for shipment. Other methods are in use for covering the bale, but they are all similar to a certain extent to the one described.

The press described, which is the style commonly in use, forms a bale 24 inches long, 20 inches deep, and 24 inches high, weighing from 220 to 270 pounds. It is one of the smallest styles of yarn baling presses in general use. When the follower is in the highest position, the distance between it and the bed of the press is 44 inches. This is spoken of as the *daylight space*, or *piling space*. It is not possible, nor necessary, to bring the follower down to the bed of the press, the exact distance of its movement varying from 20 to 24 inches, this being adjustable according to the position at which the knock-off is set. For example, if the knock-off is set so that the follower has a total downward movement of 21 inches, yarn may be piled in the box to a height of almost 44 inches and reduced by pressure to a height of 23 inches. The pressure capable of being exerted by the follower of this press in compressing the yarn is 70 tons. Yarn bales are made in various sizes, according to the custom of the mill, the requirements of the buyer, and the size of the press. The baling presses are made in many styles and sizes, some of them being considerably larger than the one described, both in length and width of the box, in the distance through which it is possible for the follower to move, in the height of the bale that is made, and in the amount of pressure that can be exerted. A better grade of press is also made, constructed entirely of iron and steel, but the general principles of its construction and operation are the same as already described.

BUNDLES

CONSTRUCTION OF BUNDLING PRESS

29. When yarn is sold in skeins for export, especially when it has to be transported long distances by sea, as for instance to India, China, and Japan, it is customary first to put up the yarn in small bundles of either 5 or 10 pounds in weight, more commonly 10 pounds. A number of these bundles are then packed into bales of from 300 to 600 pounds in weight by means of a heavy baling press. It is customary in foreign countries to sell this yarn to retail customers, in 5- or 10-pound lots, which is the reason for first making up the yarn in bundles. The machine used for putting up the skeins in these small 5- or 10-pound bundles is known as a **bundling press**. A common type of these machines is shown in Fig. 13 and consists of a

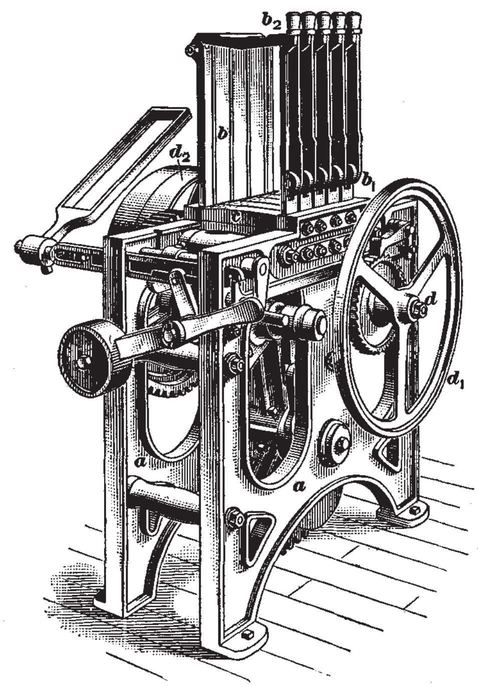


FIG. 13

framework *a* that supports the required mechanism for forming the bundle. Securely attached to the upper part of this framework are two sets of vertical bars *b*, b_1, which form the sides of an open-ended box for holding the yarn. Each set consists of five individual bars, the inner surface of which is polished. The bars are a slight distance apart, so that a piece of twine can be passed between them for tying up the bundle. The top of the box for holding the yarn is formed by a set of five short horizontal bars b_2. These bars are hinged at one end to the vertical bars of the set *b*, while the other ends terminate in slots. Near the lower end of each bar in the set b_1 is hinged a lever that extends upwards and terminates in a handle; these levers serve to lock the horizontal bars b_2 firmly in position while the yarn is being subjected to the pressure of the follower *c*.

The follower in this case, as in most bundling presses, forms the bottom of the yarn box and is raised in order to subject the yarn to the required pressure to produce a bundle of the desired size. This is accomplished by suitable mechanism driven from the shaft *d*, which can be operated by power or hand. When the machine is driven by hand, the required motion is obtained by turning the hand wheel d_1, and when it is operated by power it is driven from the tight pulley d_2, which is attached to the shaft *d*.

30. When it is desired to form a bundle, the follower should be in its lowest position, as shown in Fig. 13; four pieces of twine are then dropped between the vertical bars so that they rest on the upper surface of the follower. On these pieces of twine a piece of heavy paper board, known as a *back*, is placed, and on this back are arranged layers of skeins, which have been knotted as shown in Fig. 10 (*b*), the number of skeins used depending on the size or weight of the bundle required; for example, for a 10-pound bundle of 40s yarn, 40 skeins each containing 10 hanks, or 8,400 yards in the case of cotton, would be used. After the required number of skeins have been properly arranged in the yarn box, another back is placed on top of the yarn and the horizontal bars b_2 turned down and locked in position, by means of the vertical levers attached to the vertical bars b_1; the machine is then started, which raises the follower and compresses the yarn. When the bundle has been reduced to the required size the machine is stopped, the twine drawn tightly around the bundle, between the bars, and the ends of each piece tied together in a square knot. The follower is then lowered, the horizontal bars unlocked and turned back, and the bundle removed, wrapped in wrapping paper, and tied again with twine.

In some cases before the upper *back* is placed in position, a piece of tissue paper a little longer than the yarn box and about the width of it is inserted, which thus hangs down over the ends of the skeins. In certain cases, for foreign trade with India, China, etc., the backs, tissue paper, twine, wrapping paper, etc., must be of specific colors, in order to comply with the demands of the trade in these countries.

BALING

31. When the yarn has been made into bundles, they are shipped to the merchant who prepares them for export in compressed bales. This is done by placing a number of these bundles, from 25 upwards, between the platforms of a very powerful baling press, in which they are compressed between sheets of burlap lined with tarred paper and secured by a number of broad iron bands riveted or buckled around the bale. The ends of the burlap are neatly folded and sewed up, and the bale marked with the necessary shipping marks. By this means the yarn is compressed into very small space, which is desirable for ocean freight; the tarred paper prevents damage from moisture during transit.

WINDING

TUBE WINDING

INTRODUCTION

1. In the textile industries, yarns are wound, for various purposes, in forms and on machines that differ according to the object desired. A form of winding that of late years has assumed considerable importance and appears to be on the increase is that of winding yarn, thread, and twine on wooden or paper tubes (generally the latter) either of the cylindrical or conical type. The word parallel is used in the textile trades for cylindrical when applied to such tubes. A parallel tube containing yarn is generally spoken of as a *tube*, but sometimes as a *cheese*, while a conical tube filled with yarn is generally called a *cone*, although in some places both the parallel and conical tubes are spoken of as cheeses. The process of winding that produces parallel or conical tubes is spoken of as *tube winding* or *cone winding*, respectively. Owing to the method of guiding the yarn to the tube by means of a rapid traversing motion, which causes the yarn to cross the path of yarn previously wound on the tube, still other names are applied to this method of winding; for example, *cross-winding* and *quick-traverse winding*. From the fact that the yarn is wound by means of contact with a revolving drum, it is sometimes called quick-traverse drum winding, but this name is unsuitable and tends to confuse the process with the ordinary method of drum winding on a double-headed spool, for which machine the name of drum winder should be reserved. Throughout this Section the name tube

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winding will be used and should be understood to cover the process of winding yarn, in any machine, on either a parallel or conical tube without heads or flanges.

2. Yarn may be wound on tube winders from either cops, bobbins, skeins, spools, or, sometimes, cheeses. In cases where single yarn that is in the form of a cop or spinning bobbin, ply yarn that is on a twister bobbin, or yarn that has been bleached, dyed, or mercerized and remains in skein form has to be sold and transported a considerable distance, the tube winder is very useful. It is especially advantageous when the yarn has to be used afterwards at a machine or process where it is convenient to take it from a fixed creel or framework capable of holding a considerable supply of yarn. For example, at many knitting machines it is convenient to take a number of ends of yarn from a creel or stand, and the longer the supply of yarn lasts, the better; in such cases the conical-tube formation is frequently used. In some forms of sewing, seaming, edging, or covering machines, it is possible to take the thread from a tube on a fixed stand, as is also the case in the use of twine and small cords; and in these cases also the conical tubes are often used. The parallel-tube form is especially suitable for winding yarn intended for warps, and which is to be transported a considerable distance, since the ends can be warped directly from the parallel tubes placed in an ordinary warper creel, thus saving the transportation and return of wooden warper spools, which is expensive and inconvenient. The largest use of tube winders is for making cones of knitting yarns.

Another object in the use of a tube winder is to perform the duty of a doubler winder. Tube winders are so constructed that one end only may be wound on a tube or, when desired, two or more ends may be wound together side by side, the operation of course being simply one of winding; the ends are not twisted together at this process. The objects of this machine may therefore be said to be: (1) to wind a considerable length of yarn on a tube in such a form that it may be handled without being damaged and unwound easily at the succeeding process; (2) to wind a number of ends together on one tube and at an even tension, in order to prevent corkscrewing or imperfections when twisting these ends together to form a thread or a ply yarn. Large quantities of yarn intended for covering electric wire are wound in this manner.

3. The principle on which the tube winder is constructed and operated is to give to the end or ends being conducted to the tube a rapid reciprocating traverse motion, so that the end of yarn is first carried from one side of the tube to the other and then rapidly reversed and carried back again. By this means one layer of yarn serves to bind the preceding layers, and as the end of yarn is only allowed the briefest possible dwell at each side of the tube, only a small portion of its length remains at the side at each traverse; therefore, the yarn that forms the edges of the tube is held firmly by the succeeding layers, and thus at each side of the tube firm ends are produced, which allow transportation or handling without the yarn becoming entangled at the ends. By this means, a structure of yarn is built up without the use of heads or flanges at the ends of the tube, and at the same time it will satisfactorily unwind at the next process. Tube winding thus differs in two essential features from the older form of winding yarn in parallel coils by means of a slow traverse along the surface of a double-headed wooden spool, either mounted on a vertical spindle, as in case of a spooler, or resting on a drum, as in case of a drum spool winder.

QUICK-TRAVERSE DRUM WINDERS

4. All types of tube winders have many features in common. The object and result in each case is practically the same, the differences being chiefly in the methods of imparting the traverse to the yarn and in the detailed construction of the machine in the matter of stop-motions, etc. In a large number of machines, the yarn is wound on the tube by contact with a revolving drum; while in another style, the yarn is guided along the surface of a tube

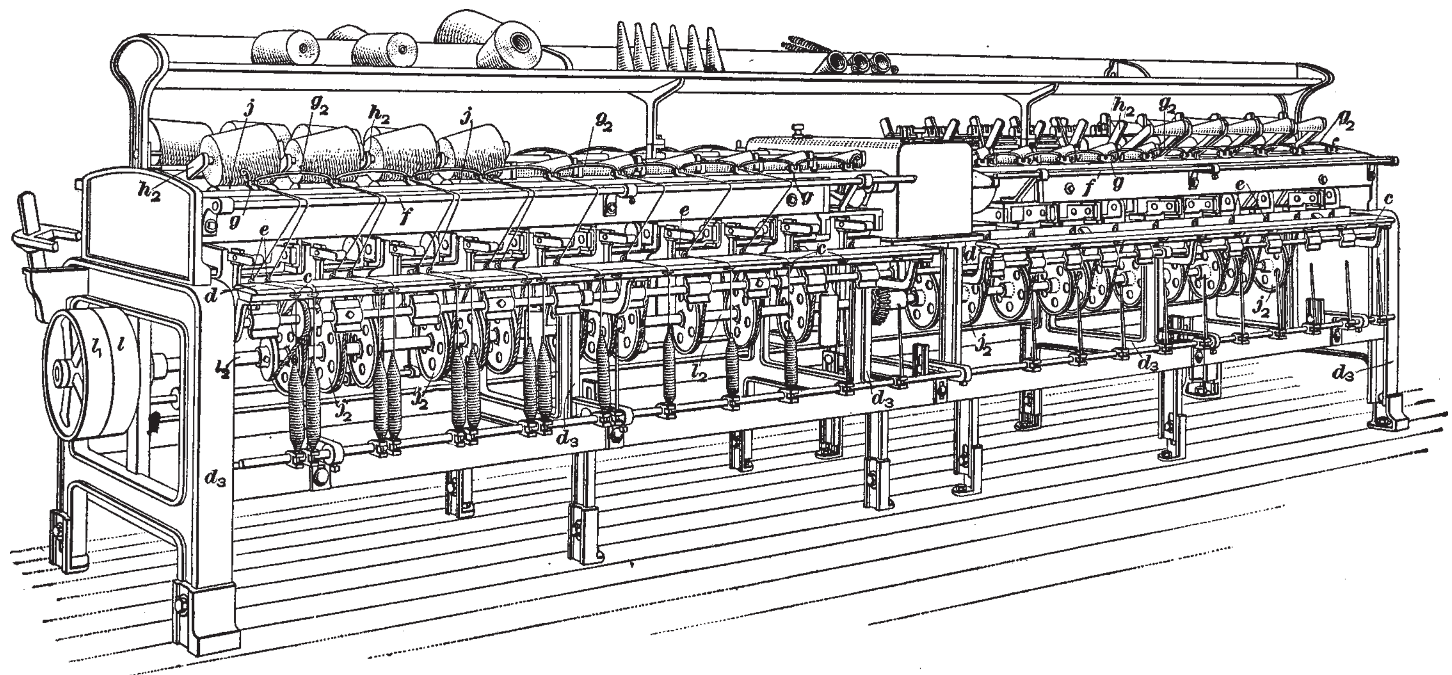
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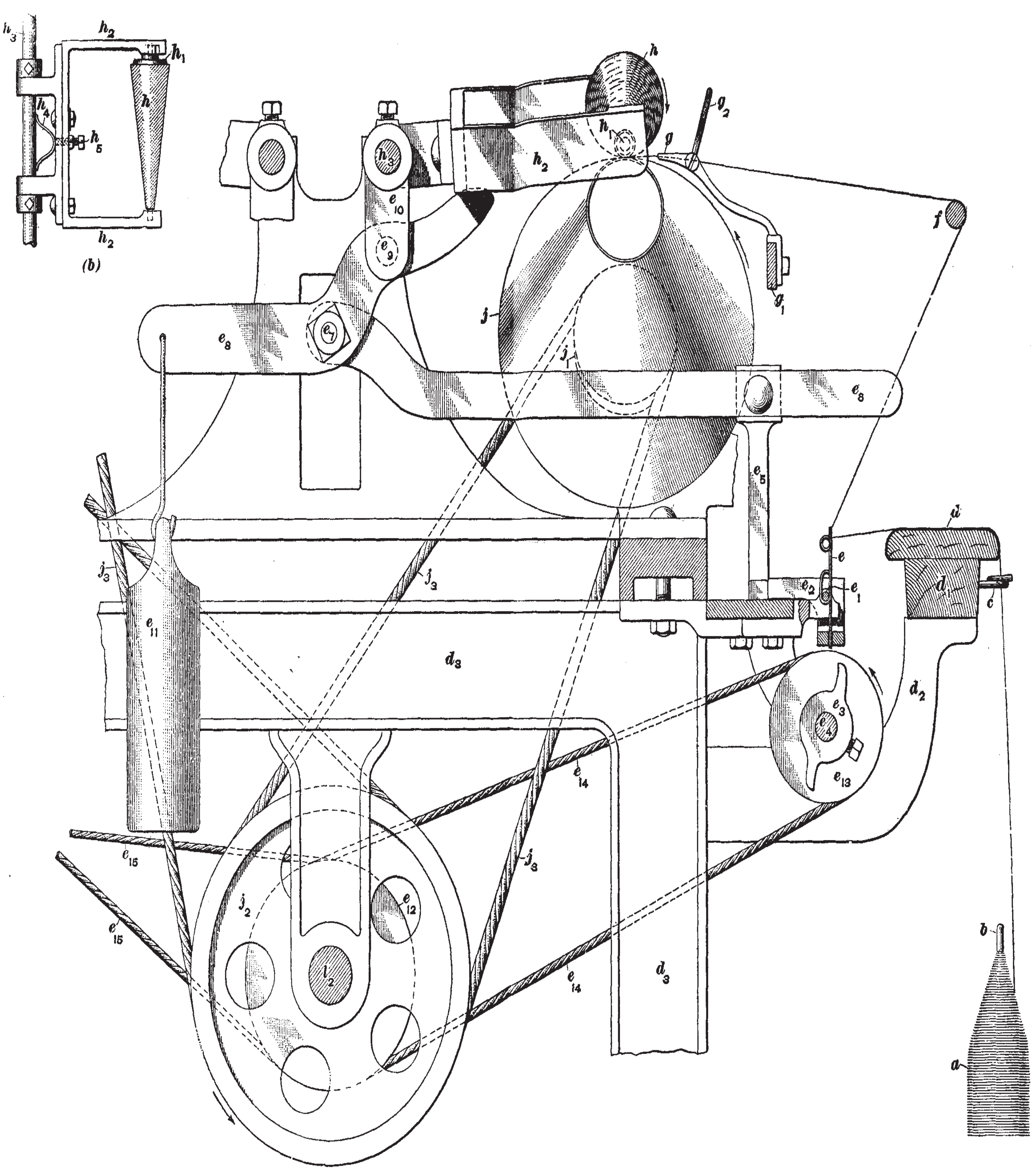
Fig. 1



a
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e
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e_4
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e_7
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e_9
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e_{15}
f
g
g_1
g_2
h
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j_3
l_2

(b)

(a)

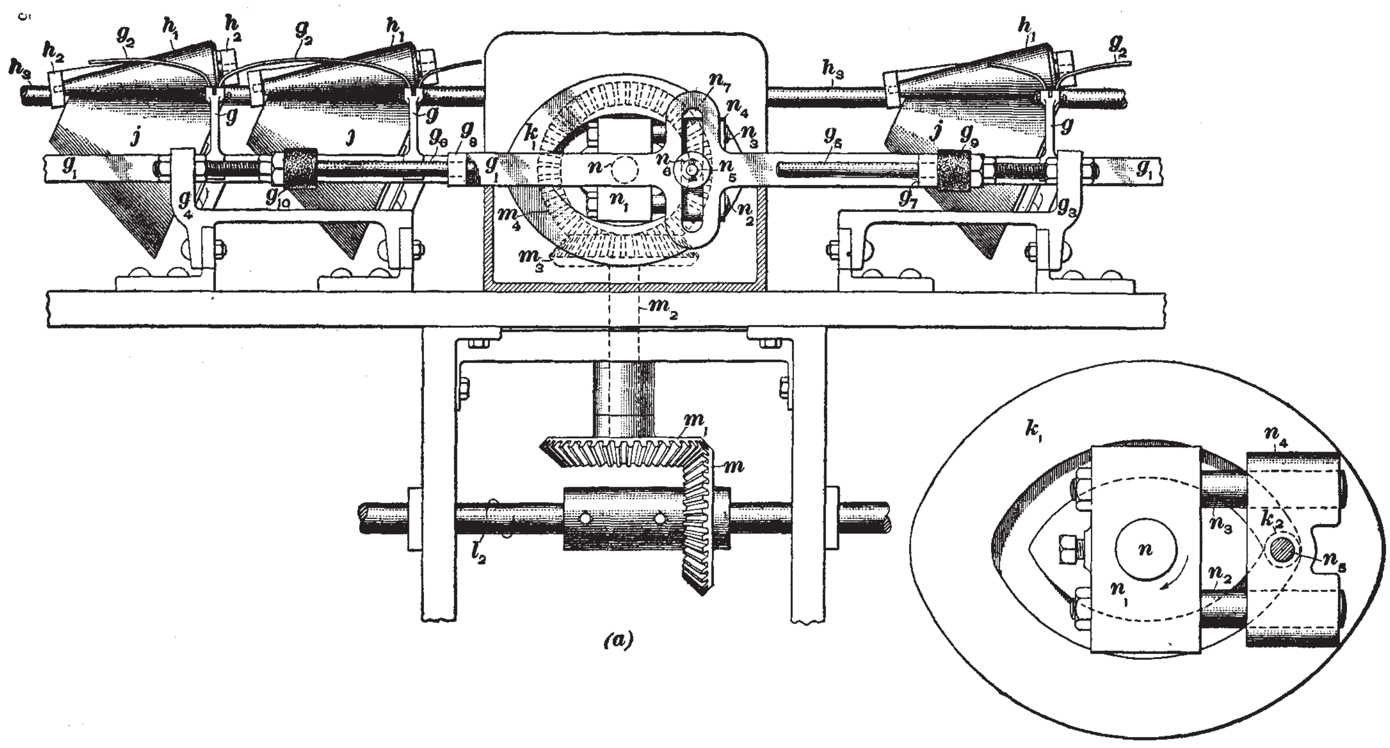

Fig. 8

mounted on a revolving spindle; the latter is known as the *Universal system.*

One form of tube winder in which the winding is performed by means of contact with a revolving drum and which possesses all the typical features of a quick-traverse cross-winding frame is shown in Fig. 1. A section through

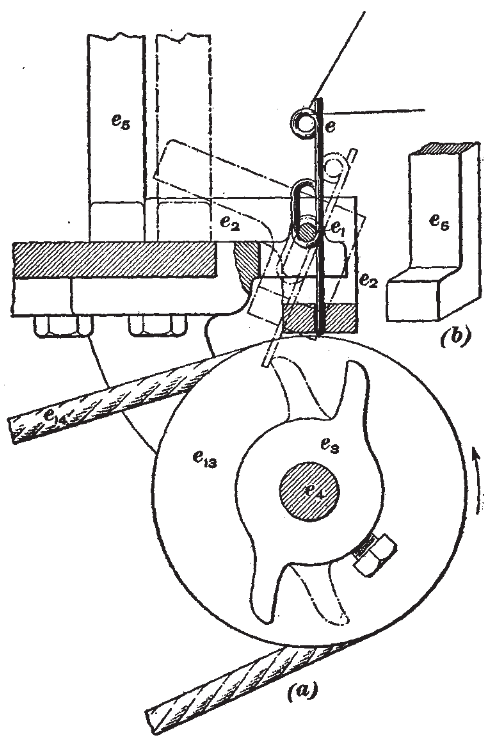

FIG. 4

a portion of the frame is shown in Fig. 2 (*a*); the mechanism for producing the traverse in Fig. 3 (*a*) and (*b*); and the stop-motion and connected parts, in Fig. 4. A plan of the driving of the drums and the knock-off dog-shafts is also shown in Fig. 6. The same reference letters apply to the same parts when represented in different figures, and in considering the construction of the machine it is advisable to refer to the parts as represented in each of the drawings in which they are shown.

5. **Passage of the Yarn.**—The material being wound passes from the creel, which is shown in Fig. 2 (*a*) as holding a cop, through the first wire-guide eye *c*, over and into contact with the tension board *d*, through the upper eye of the stop-motion wire *e*, around the guide rod *f*, and thence through a slot in the traverse guide *g* to the tube *h*, on which it is wound and which rests on the winding drum *j*. The arrangement for the passage of the stock is the same at each drum along both sides of the machine, for quick-traverse tube winders are constructed with the two sides of the frame alike so as to economize in floor space and the cost of construction of the machine.

6. The **creel**, shown in Fig. 1, consists of a round rod to which are setscrewed footsteps carrying skewers, or spindles, on which are mounted cops or bobbins of yarn [both cops and bobbins are shown in the creel in Fig. 1, while one of the cops is also shown at *a* in Fig. 2 (*a*)]. The creels of tube winders may be constructed to receive either cops, bobbins, cheeses, skeins, or spools, depending on the form of the yarn that is to be wound. When used also as doubler winders, the creels are so constructed as to hold a supply from two or more cops, bobbins, etc. for each drum. In Fig. 1, the first four drums are shown as being used for doubler winding, taking ends of yarn from two cops. The next two drums each take one end of yarn only from a cop, while the seventh and eighth drums each take one end of yarn from a ring-spinning bobbin with filling wind. Above the frame and supported at intervals by brackets are two slightly inclined shelves, each of which slopes toward a central vertical partition, thus forming a receptacle for the supply of yarn for the creel and also for empty and filled tubes.

7. **Driving of the Winding Drums.**—In the application of power to the tube winder two important points must receive consideration—the driving of the winding drums and the method of giving motion to the yarn-traversing apparatus.

Underneath and along the middle of the machine is a driving shaft l_2, Figs. 1 and 2 (*a*), carrying at one end a tight pulley l and a loose pulley l_1, Fig. 1. At intervals along the driving shaft are placed double-grooved band pulleys j_2, Fig. 2 (*a*), each of which drives two winding drums, one on each side of the frame, by means of a band j_3 that passes partly around the pulley j_2, then around a smaller grooved pulley j_1 attached to the drum j, again around the pulley j_2, and finally around the pulley j_1 attached to the drum j on the opposite side of the frame. The band is open on one side of the frame and crossed on the other side. In connection with this description, Fig. 6 should be referred to, as this is a top plan view of the banding of one type of a quick-traverse drum winder, which is similar to the one under description except for the mechanism for imparting the traversing motion.

8. Center Traverse Motion.—The traverse motion shown in Fig. 3 is often called the **center traverse motion,** to distinguish it from an older form of traverse motion known as the *end traverse motion*. The winding drum j, Figs. 2 (*a*) and 3, is conical, but as it is mounted so that its center arbor, or spindle, is at an angle, the portion of the drum that happens to be on the upper side is always in a horizontal position. Resting on the upper surface of the drum is a tube h mounted on a mandrel h_1, which is cone-shaped for conical-tube winding and straight for parallel-tube winding. The tube is, of course, either cone-shaped or cylindrical according to the method of winding desired. The mandrel revolves in bearings carried by the frame h_2, which can be raised by suitable mechanism and the tube thus lifted from the winding drum. The machine described is shown arranged for winding conical tubes.

Immediately in front of the winding drums is a traverse rod g_1 having a horizontal reciprocating motion and supporting the traverse guides g. In the upper part of the traverse guide is cut a small slot, through which the yarn passes to the tube when being wound. Curved pieces of wire g_2 are setscrewed to the guides g, as shown in Figs. 1, 2 (*a*), and 3, thus connecting and steadying the guides by forming bridges between them. The wires g_2 also furnish a means of guiding the yarn into the slot, so that after an end has been broken and pieced by the attendant, it is simply laid across the traverse arrangement approximately in the correct position, when it slides down the curved portion of g_2, and thus finds its way into the slot in the traverse guide. A reciprocating motion is given to the rod g_1 and consequently to the traverse guides g and to the yarn that passes through the slots in them. In Fig. 3 (*a*), the guides are shown at almost the extreme right-hand side of each mandrel; the next movement of the traverse will be toward the left-hand side, thus carrying the yarn across the face of the tube.

In ordinary forms of reciprocating motions, such as those produced by a revolving crank, the speed is greatest at the center of the traverse and gradually diminishes toward each end, and at the point where the traverse is reversed it is almost impossible to prevent a slight dwell. If such a motion were applied to the quick-traverse tube-winding machine, this dwell, although of very brief duration, would result in winding more yarn at the ends of the tubes than at the center and would thus give an uneven surface to the tube. It is the object in all tube-winding machines to reduce this dwell as much as possible by the use of a traverse motion that gives a constant speed to the traverse guides, in order to wind the yarn evenly along the face of the tube, so that in case of a parallel tube the diameter will be the same at all points, and in case of a conical tube the diameter will increase uniformly. In the frame under description the traverse is obtained as follows.

9. The shaft l_2, Fig. 3 (*a*), that carries the pulleys for driving the drums also carries at its center the bevel gear m, which drives the bevel gear m_1 on the short vertical shaft m_2. At its upper end, the vertical shaft carries a bevel gear m_3 driving another bevel gear m_4 situated on the crankshaft n, which extends horizontally across the frame above the vertical shaft m_2. At each side of the frame is a metal box that carries the mechanism for imparting a reciprocating motion to the traverse rods g_1. The shaft n extends into these boxes, a suitable portion of which forms bearings for it. The inner upright portion of each box supports a stationary cam k_1, shown in Fig. 3 (*a*) and (*b*). In Fig. 3 (*b*), the traverse rod and some of the other parts have been omitted, so that the construction of the parts that give the throw to the traverse rod may be more clearly shown. The shaft n passes through the center portion of the cam k_1 and carries a casting n_1 firmly setscrewed to it. Securely fastened to the casting n_1 are two studs n_2, n_3 that are free to slide in and out of two chambers in the casting n_4. This latter casting carries a pin, or stud, n_5 on which are situated two cam-bowls k_2, n_6. The cam-bowl k_2 is located on the inner side of the casting n_4 and runs in the course of the cam k_1, while the other bowl n_6 is located on the outside of the casting n_4 and runs in a slot n_7 in the center of the traverse rod g_1, which is enlarged in the center so as to contain the vertical slot n_7. The entire mechanism forms a crank arrangement that gives a reciprocating motion to the traverse rod g_1, the shaft n acting as a crank-shaft.

As the shaft n revolves, it carries with it the casting n_1 and the two studs that slide in the cavities in the casting n_4. Since the studs n_2, n_3 support the casting n_4, and since it carries the cam-bowl k_2, it will slide in and out on the studs n_2, n_3, according to the position of the cam-bowl k_2 in the course of the cam k_1, because the connection with the studs forces the piece n_4 to revolve around the shaft n. The length of the course in the cam k_1 governs the length of the traverse, or throw of the rod g_1 and the guides g.

As the cam-bowl k_2 travels around the course of the cam k_1 by means of the mechanism just described, the vertical position of the cam-bowl n_6 will be constantly changing in the slot n_7 and the rod will be moved first in one direction and then in the other because the piece n_4 is constantly being moved from right to left and left to right.

Each side of the framework supports two sets of brackets g_3, g_4, which serve to support the rods g_5, g_6 that steady and guide the traverse rod g_1. The traverse rod carries two lugs, or projections, g_7, g_8 that slide on the rods g_5, g_6, respectively. These rods carry rubber cushions g_9, g_{10} that can be adjusted to the required position on the rods by means of nuts. These cushions prevent jar of the traverse rod and guides carried by it, and also relieve strain on the cam-bowl k_2 and on the cam k_1 when the bowl is farthest from the center of the cam. The extreme movement of the cam-bowl k_2 in one direction is shown in Fig. 3 (*b*), while in (*a*) the positions of the various parts are shown when the cam-bowl is in this position.

The lower part of the box containing the mechanism is of solid construction and contains a supply of heavy oil, sufficiently deep to allow the casting n_4 to dip into it at each revolution. The whole of the mechanism is tightly cased in, so that the oil may be thrown over all parts of the mechanism without escaping, thus securing perfect lubrication.

10. Stop-motions are applied to tube-winding frames for two reasons. In winding single yarn, if an end broke and there were no stop-motion, the last layers of yarn wound on the tube would remain in constant contact with the winding drum and would gradually become glazed and damaged by the constant polishing effect of the drum. In case two or more ends were being wound together on one tube and one broke, if no stop-motion were applied the strand of yarn wound on the cone would contain only one end instead of two in case of 2-ply winding, two ends instead of three in case of 3-ply winding, etc. It is now customary to apply to tube winders a stop-motion so arranged that it will throw the tube out of contact with the winding drum. Such a mechanism is shown in Figs. 2 and 4.

Immediately behind and slightly below the tension board *d* are situated the drop, or guide, wires *e*. There is a group of these wires in front of each winding drum *j*, the number of wires in each group depending on the number of ends being wound on each tube. The framework supports a number of small swing brackets similar to e_2, there being one for each group of drop wires. These brackets swing on a pin, or stud, e_1 that also passes through the lower loop in the drop wires, thus forming a support for them and preventing their falling too far when an end breaks. The yarn passes through the upper loop, or eye, on its passage to the tube and thus holds it in the position shown in full lines in Fig. 4 (*a*). The lower end of the drop wire passes through a hole in the lower part of the bracket e_2. The inner portion of this bracket rests on a flat portion of the framework and is in contact with the lower part of the arm e_5. The construction of the lower portion of this arm is shown in Fig. 4 (*b*); at its upper end it is attached to a long lever e_6, Fig. 2 (*a*), that is fulcrumed at e_7 to the weight lever e_8. The weight lever is fulcrumed at e_9 to the pendent arm e_{10} and carries at one end, by means of a wire hook, a weight e_{11}, while the other end rests against a part of the under portion of the frame h_2. The weight e_{11} thus has a constant tendency to pull down the inner end of the lever e_8 and consequently raise the other end, together with the frame h_2, and also force outwards the lever e_6 and arm e_5. It is prevented from doing this, however, when the yarn is holding the drop wire or wires in their upright position by the pressure of the arm e_2 against e_5. The pendent arm e_{10} is setscrewed to a shaft h_3 that extends the length of the frame. There are two of these shafts, one for each side of the machine, and in addition to carrying pendent arms similar to e_{10}, they support frames similar to h_2.

When an end breaks, the swing bracket e_2 and the drop wire e, together with the arm e_5, assume the position shown in dot-and-dash lines in Fig. 4 (*a*). This is brought about by the wire e dropping because the tension of the yarn has ceased and there is nothing to hold e in position. As the wire falls, its lower end protrudes through the hole in the lower part of the swinging bracket so that it comes in contact with one of the projections of the revolving dog e_3; and as this dog continues its forward movement in the direction shown by the arrow, it carries with it the lower end of the wire and causes the bracket e_2 to turn on the stud e_1.

There is one of these dogs for each group of drop wires. When the bracket assumes the position shown in dot-and-dash lines, the inner portion is removed from direct contact with the arm e_5, thereby leaving it free to slide outwards on the framework. This allows the weight e_{11} to move downwards and carry with it the inner end of the arm e_8, raise the upper end, and force outwards the lever e_6 and arm e_5. This action of the lever e_6 raises the frame h_2 and thus lifts the tube h from contact with the drum j, so that the winding of the yarn ceases. The extreme outer portion of the lever e_6 terminates in a handle, and when starting up a tube after an end breaks or a new tube is put in place of a full one, the end is properly pieced up and the lever e_6 forced inwards by means of the handle. The lever is held in position again by means of bracket e_2, which allows the frame h_2 to be lowered into position, so that motion is imparted to the tube by means of the drum on which it rests.

11. Fig. 2 (*a*) and (*b*) shows a side view and a plan view of the frame h_2 that carries the mandrel h_1 on which the tube h is placed. The frame is composed of two main parts, which are securely bolted together and swing on the shaft h_3. It is prevented from sliding along the shaft by two collars, one on either side of the two arms that swing on the shaft h_3. The necessary friction to keep the frame from swinging too freely on the shaft is produced by means of a spring h_4 and an adjusting screw h_5. This screw passes through the frame, and when more friction is required it is turned so as to force the part of the spring that is in contact with it nearer the shaft h_3. At the outer ends of the two outward projecting arms are formed two bearings that support the mandrel.

Motion is imparted to the knock-off dog-shaft by means of two grooved pulleys e_{12}, e_{13}, Fig. 2; e_{12}, which is a double-grooved pulley, is on the main driving shaft l_2 of the machine, while e_{13}, which is a single-grooved pulley, is on the dog-shaft e_4. A similar arrangement is applied to the machine illustrated in Fig. 6. As there are two of these dog-shafts, one for each side of the machine, there are two single-grooved pulleys, as shown in Fig. 6. One of the dog-shafts is driven by an open band e_{14}, while the other is driven by a crossed band e_{15}.

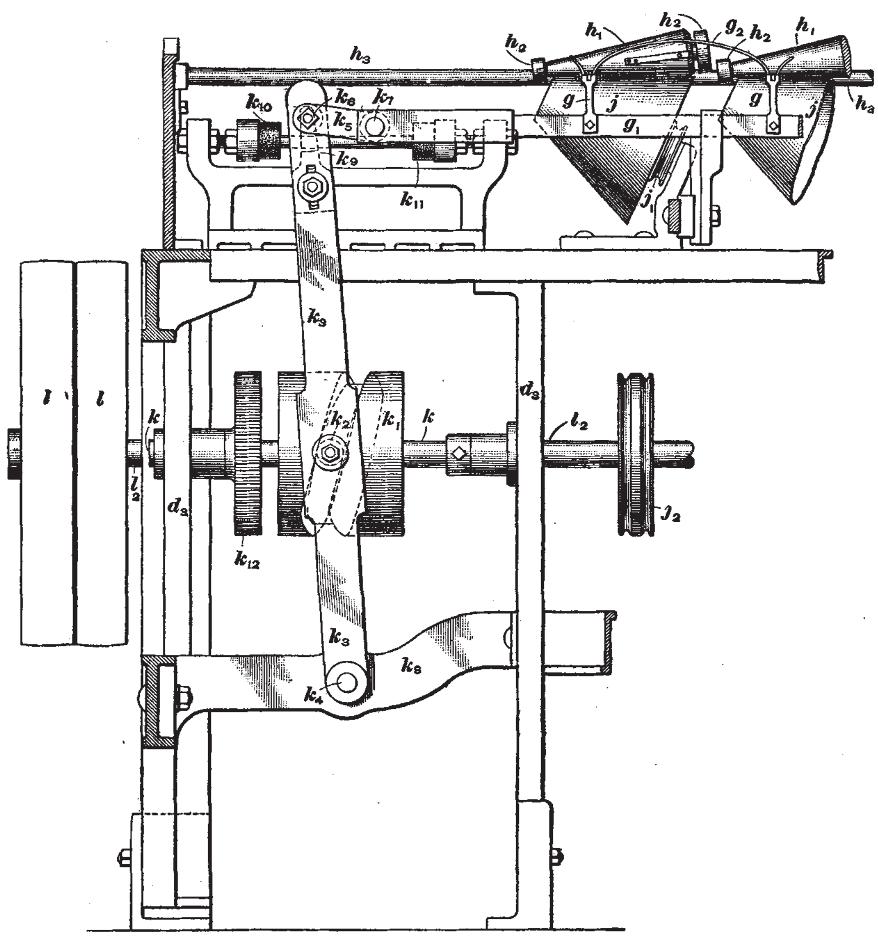

FIG. 5

12. The **end traverse motion,** Figs. 5 and 6, although an older form than that described, is largely used. The guides and guide rods are similar in both cases; the difference lies principally in the construction of the mechanism

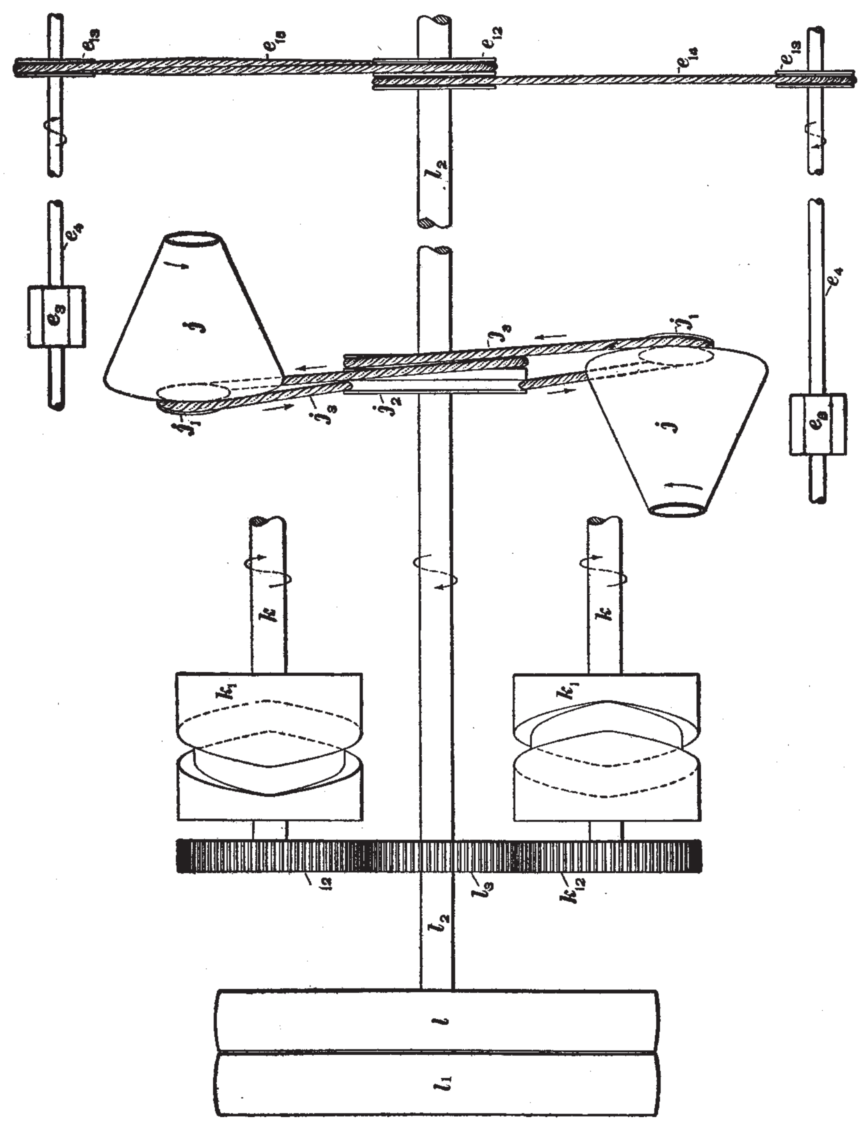

FIG. 6

that imparts a reciprocating motion to the guide rod g_1. The main shaft l_2 of the machine carries a gear l_3 that drives the gears k_{12}, k_{12}, one on each cam-shaft k. Fig. 6 is a plan view showing the method of driving the cams k_1, winding drums j, and dog-shafts e_4, while Fig. 5 is a front elevation and shows the method of driving one of the guide rods g_1, the other one on the opposite side being driven in a similar manner. The bracket k_8 extends between the two sampsons d_3 and supports the lever k_3, which is pivoted at k_4; at k_6 is attached a link k_5, which is also attached to the traverse rod g_1 at k_7. The lever k_3 is steadied at the upper end by means of an arm k_9, through which passes a small rod that carries the rubber cushions k_{10}, k_{11}. About two-thirds of the way from the top, the lever carries a stud, which in turn supports a cam-bowl k_2 that works in the course of the cam k_1. The construction of the cam, together with the other parts, is such as to give the upper end of the upright lever k_3 a reciprocating motion, which is communicated to the traverse rod g_1 by the link k_5, thereby causing the guides g to move quickly to and fro across the drums.

13. This tube winder is often spoken of as the *Broadbent winder* from the fact that it was first built by a firm of this name and is still constructed by them, although similar types of machines are now made by other builders. This name is given to it to distinguish it from the Hill & Brown winder and from the Universal winder. The Hill & Brown winder is an older form, and belongs to the drum-winder type, but the traverse of the yarn is obtained without the use of a separate traverse motion, each drum being constructed with a helical slot running along its circumference, first from one side and then to the other, through which the yarn is conducted to the tube. The Broadbent type of winder is constructed in various sizes, from 20 to 160 drums, 100 drums (50 on each side) being a common size. A machine with 100 drums occupies a space of 31 feet 10 inches by 3 feet 11 inches and requires about 1 horsepower to drive it.

SPINDLE WINDERS

14. A tube winder of the spindle-winding type accomplishes the same purpose as the quick-traverse drum winder, but in a different manner. The revolving drum used in a drum winder is dispensed with and the yarn wound on a tube placed on a positively rotated spindle. One type of spindle winder is that known as the **Universal winder.** It is shown in Fig. 7 and consists of a single-head machine; that is, there is only one winding spindle, and consequently the machine winds only one tube at a time. A more common construction is to place several of these winding heads side by side on a standard, the number of heads usually not exceeding six, which is the most common number. Spindle winders of this type are capable of winding either parallel or conical tubes, and produce a hard, compact structure with the coils wound closely together, for which reason they are sometimes spoken of as *close-traverse* or *close-winding* machines to distinguish them from the open-traverse or open-winding type, to which drum winders belong.

As the construction of each head in a six-head machine is the same and as this construction corresponds to that of a single-head machine, only the latter type will be described. The single-head machine is shown as winding only one end, but the Universal winder can be, and frequently is, arranged to wind several ends, usually not exceeding three. A considerable portion of the mechanism is enclosed within metal covers and is so shown in Fig. 7. Fig. 8 is a front view of the machine showing the positions of the various parts during winding, while in Fig. 9, which is also a front view, the parts are shown in the positions they occupy after the machine has been automatically stopped and winding has ceased; Fig. 10 shows a side view, partly in section.

15. Passage of Yarn.—Referring to Fig. 7, the bobbin *a* is placed on a spindle in the center of the plate *b*, and the end passed upwards through the guide wire *c*. From the guide wire, the yarn passes around the tension

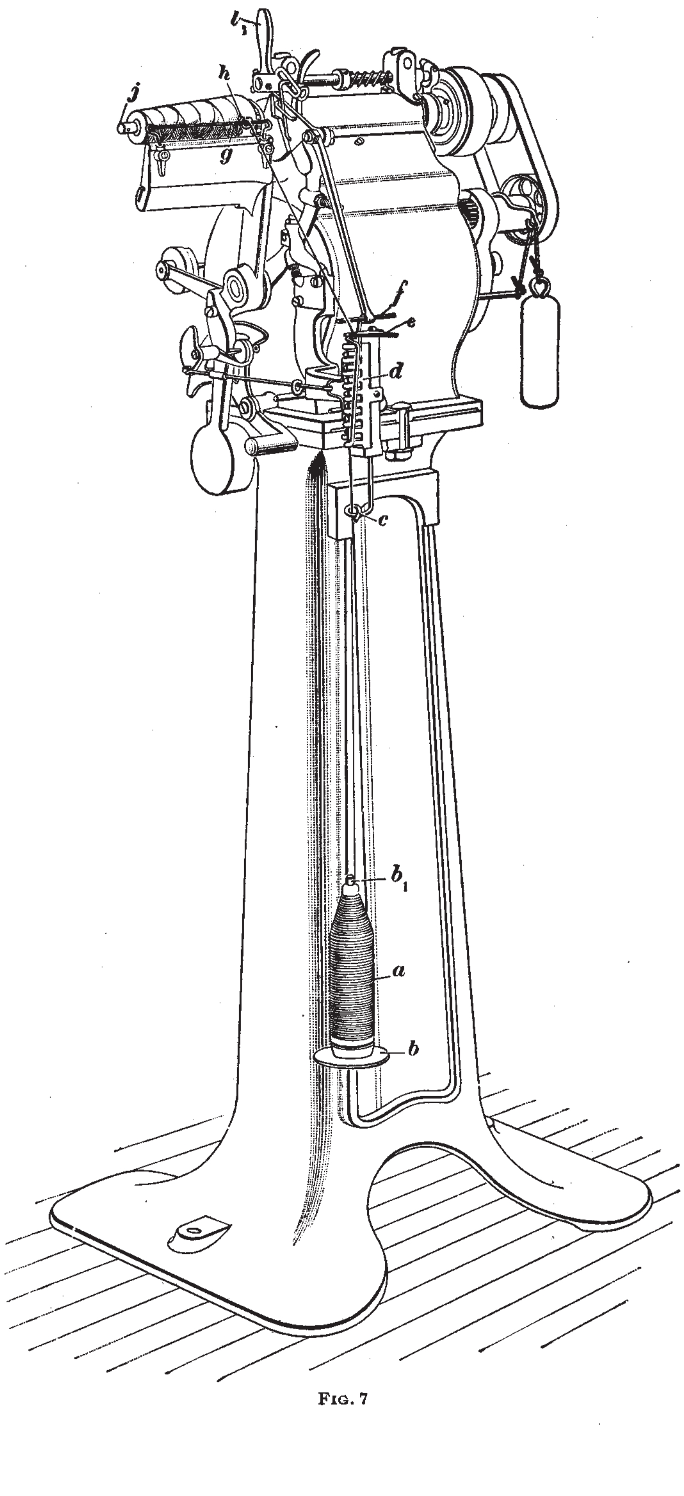

Fig. 7

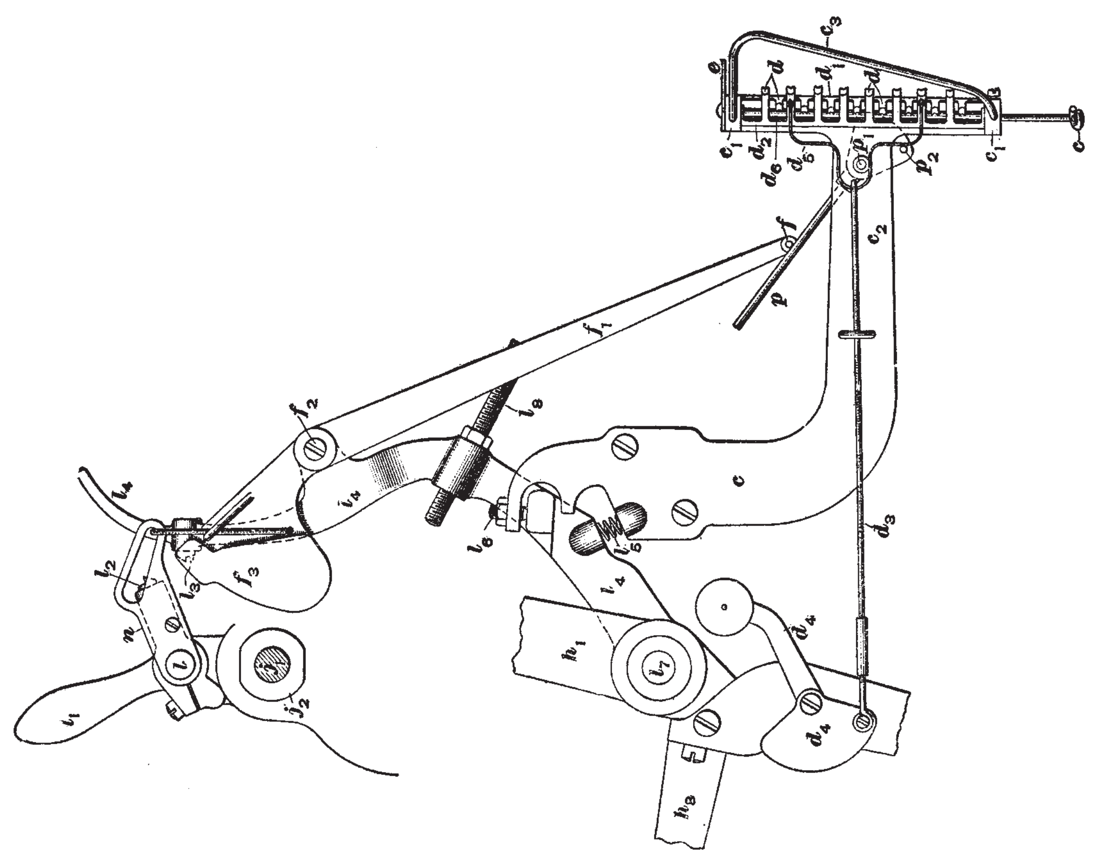

Fig. 9

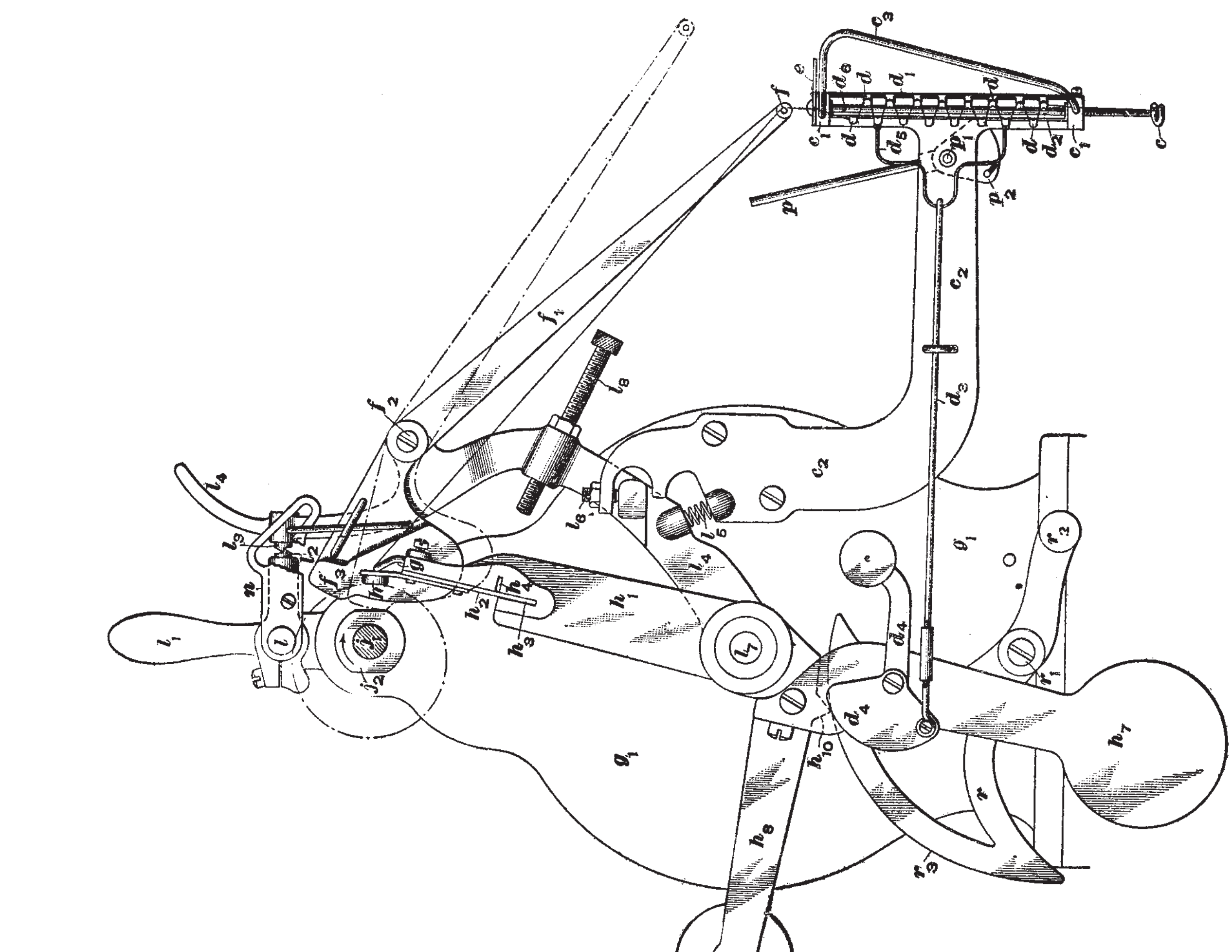

Fig. 8

Rotated 90° to fit on page.

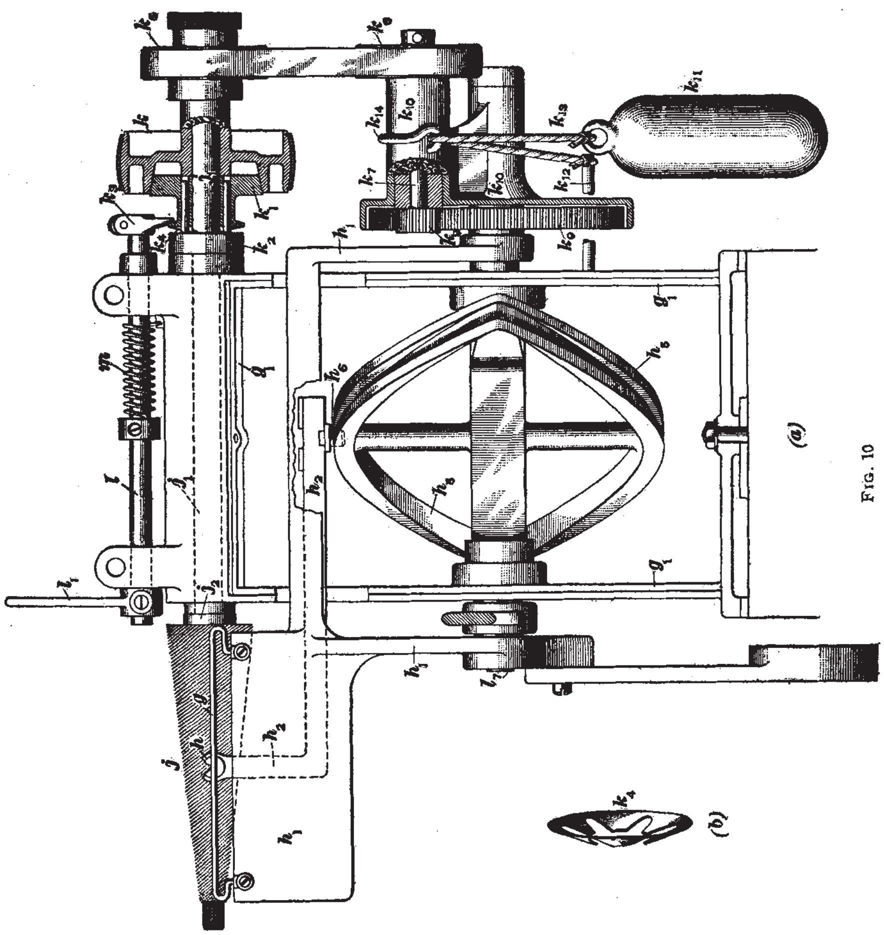

Fig. 10

fingers d, through a slot in the plate e, over the pin f, then at an angle to another guide wire g, through the traverse-guide eye h, and on to the tube or cone shell on the spindle j.

16. The **yarn holder** is a simple device for holding the bobbins, cops, etc., from which the yarn is to be wound. A spindle b_1 supported by a bracket attached to the framework carries the bobbin, which rests on a circular plate b that is passed over the spindle so as to form a flange or table around its base.

17. Yarn Guide and Tension Controller.—The yarn guide, or guide wire, c is a bent wire with a curl, or loop, at one end, as shown in Figs. 7, 8, and 9. The center of the loop of the guide wire should be directly in line with the center of the spindle in the yarn holder. This wire is supported by a bracket c_1 attached to the arm c_2. The bracket c_1 also carries the tension-finger plates d_1, d_2, and the kink, or snarl, arrester e. Each plate d_1, d_2 carries eight tension fingers d, which are curved, the face with which the yarn comes in contact being rounded, as shown in Figs. 8 and 9. The plate d_2 is pivoted at each end to a rod d_6 so that it is free to swing on the bracket c_1, while the plate d_1 is securely attached to the bracket. The swinging plate d_2 is connected by a rod d_3 and wire bracket d_5 to a quadrant weight lever d_4, which regulates the amount of tension on the yarn. The tension can be increased or decreased by putting more or less weight on the lever d_4.

The wire c_3, which is supported by the bracket c_1, serves as a guide and facilitates passing the yarn between the tension fingers when they are released and occupy the position shown in Fig. 9. The plate e, which is situated at the top of the bracket c_1 and forms a kink, or snarl, arrester, is simply a flat plate with a long, narrow slot through which the yarn passes. Any kinks, snarls, or bunches in the yarn come in contact with the under side of the plate and are thus prevented from passing forwards on to the tube.

18. The **traverse guide** h, shown more clearly in Fig. 10 (a), is carried by a flat, steel plate h_2 that works in a slot h_4, Fig. 8, in the frame h_1, which swings freely on bushings attached to the framework g_1. The plate h_2 has a number of small lugs that project into the slot h_4, which serves to guide and steady the plate during its movements to and fro. The plate is given a quick traverse motion by means of the cam h_5, Fig. 10 (*a*), and the cam-bowl h_6, which is supported by a small stud attached to the plate. The frame h_1 carries, in addition to the guide h and plate h_2, the

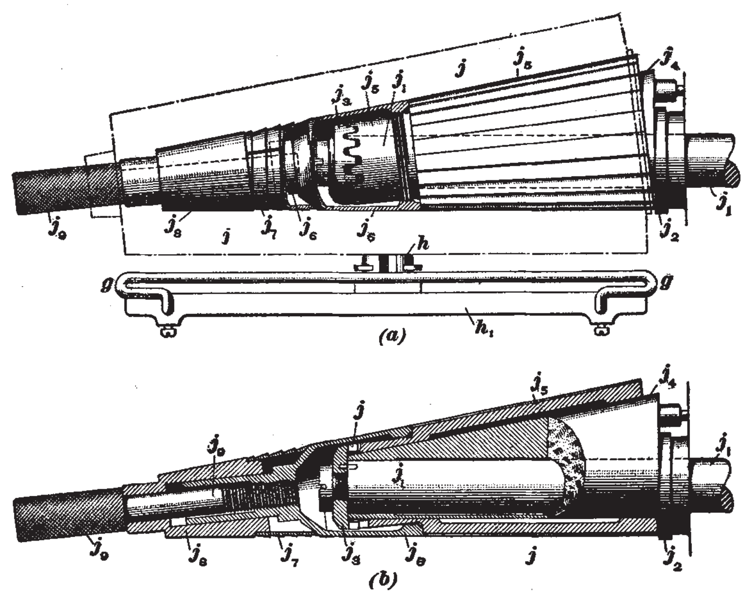

Fig. 11

guide wire g. The quick movement of the traverse guide h causes the yarn to be wound on the tube in long open spirals 2 or 3 inches apart, the next spiral being wound close to the first, the next again close to the previous, etc., thus giving the appearance and effect of a very close wind.

19. The **spindle** in the machine under consideration is for winding conical cheeses and is composed of a number of parts; a plan view partly broken away is shown in Fig. 11 (*a*) and a section in Fig. 11 (*b*). The main part j_1 of the spindle j

is a straight steel rod with a collar j_2 that comes in contact with the outside end of one of the bearings that support the spindle. There are two of these bearings carried by the framework, one at either end of the spindle. The rod j_1 carries a small gear j_3 and also a cone frustum j_4, which is so mounted that the side nearest the traverse guide *h* is always parallel to the guide. The frustum j_4 is prevented from revolving with the rod j_1 by a small pin that projects into a hole in the framework. A thin fluted conical shell j_5 that fits over the cone frustum j_4 carries teeth at its small end that mesh with those of the gear j_3 on the rod j_1. As the rod j_1 revolves, the gear j_3 turns the cone shell j_5, which is free to revolve on the frustum j_4. A cap j_6 that fits over this gearing is screwed to the cone shell and consequently revolves with it; about midway of its length the cap has a tapered shoulder so as to open the split ring j_7, which is fluted spirally. Beyond this split ring is another cap j_8, the inner end of which comes in contact with the outer end of the split ring. This cap is forced against the split ring by means of a shoulder on the screw j_9, the head of which is knurled so that it can be turned by hand; the screw passes through the cap j_8 and screws into the straight cylindrical portion of the cap j_6, thus binding the conical shell j_5 and the parts j_6, j_7, j_8 together. A paper cone tube is placed on the spindle and the screw j_9 tightened, which causes the cap j_8 to be forced inwards, thus pushing the split ring up on the shoulder of the cap j_6 and, in consequence, causing the ring to expand. The expanding of the split ring prevents the tube pulling off or getting loose until the screw j_9 is loosened, while the flutes of the conical shell j_5 prevent its turning on the spindle while in position. The position of a cone tube partly filled is shown on the spindle in dot-and-dash lines in Fig. 11 (*a*).

20. Stop-motions are applied to this frame to operate when an end breaks or runs out and when the cheese has attained the desired size. The spindle is the seat, or base, of all the stop-motions and is stopped when any one of the motions acts. The spindle is driven directly from the pulley k by means of a friction cone, shown in section in Fig. 10 (a). When the lever l_1 on the rod l is drawn up to a vertical position, as shown in Fig. 8, the friction cone is thrown in, as explained in Art. **23**, and the spindle caused to revolve. The lever l_1 carries a catch l_2, Figs. 8 and 9, that connects with the catch l_3 on the lever l_4, which is pivoted on a sleeve of the left-hand bearing of the cam-shaft and held in position by a small spiral spring l_5, the setscrew l_6 governing the extent of the upward movement of the lever. The catch l_3 coming in contact with the catch l_2 holds the lever l_1 in its upright position, as shown in Fig. 8.

When the yarn is passing from the holder to the tube, the lever f_1 pivoted at f_2 is held in the position shown by the full lines in Fig. 8 by the yarn passing over the pin f, which prevents the heavier end f_3 falling. When, however, an end breaks or runs out, the end f_3 falls until its face comes in contact with the collar j_2. When this action first takes place, a notch on the face of f_3 bears against that portion of the collar j_2 that is concentric with the rod j_1. As the collar continues to revolve, a flat face on it comes in contact with the face of the upper portion of f_3, thus allowing f_3 to fall still farther until it occupies the position shown by the dot-and-dash lines in Fig. 8. Then, as the spindle continues its revolution, the increase in size of the collar will force the lever f_1 to the right, bringing with it the knock-off lever l_4, which swings on its center l_7, compressing the spring l_5, and disconnecting the two catches l_3, l_2. This allows the spring m on the rod l, Fig. 10 (a), to turn the rod a portion of a revolution, which causes the friction cone to be thrown out, thus stopping the spindle.

Attached to, and swinging with, the lever l_1 is an arm n, Figs. 8 and 9, that has a slot at its outer end connected with the upper end of the lever f_1 by means of a short wire rod. When the two catches unlock and the spring m forces the lever l_1 to the left, looking at the front of the machine, the outer portion of the arm n will be raised, which will lift the upper end of the lever f_1 and cause the lever to turn on its center f_2. The lower end of f_1, being depressed by this action, comes in contact with the upper end of a lever p centered at p_1. The lower end of this lever carries a pin, or stud, p_2, which comes in contact with the wire bracket d_5 attached to the swinging tension plate d_2 and also to the rod d_3 through which the tension is regulated; this forces the wire bracket to the right and opens the tension fingers, so that the yarn can be readily passed between them and pieced to the end on the cheese. When the end is pieced up and the lever l_1 drawn toward the right and locked, the lower end of the lever f_1 rises and assumes the position shown in full lines in Fig. 8. This figure shows the various parts of the stop-motion in the positions they occupy during winding, while Fig. 9 shows the positions of the various parts after the stop-motion has acted and stopped the head. After the machine has knocked off and the lever l_1 occupies the position shown in Fig. 9, the spring l_6 expands and forces up the lever l_4 into position, so that the catch l_3 will lock with the catch l_2 when the lever l_1 is drawn to the right in order to throw in the friction cone and start the machine.

21. The stop-motion that operates when the cheese has attained the desired size is as follows: The lever l_4, Figs. 8 and 9, carries an adjusting screw l_8, which can be turned so as to project through the lever to a greater or less extent, in order to regulate the size of the cheese to be made. The traverse guide h rests against the surface of the cheese, as shown in Figs. 8 and 11 (a). As the cheese increases in size, the traverse guide h and frame h_1, Fig. 8, are gradually forced from the center of the spindle until the cheese has become so large that the frame h_1 is forced against the end of the adjusting screw l_8. A continued increase in the size of the cheese will force the screw l_8 and, consequently, the lever l_4 to the right and unlock the catches l_3, l_2, thus stopping the head.

22. The frame h_1 is counterbalanced by the weight arm h_7, while the arm h_8 carries a stud at its outer end on which weights h_9 are placed, so that the frame h_1 will be held in proper position and exert a slight pressure on the cheese while it is being wound.

The quadrant r, Fig. 8, is used when piecing up a broken end. Pulling the upper end of the frame h_1 to the right, so as to raise the arm h_8 and weight h_9, removes the pressure of the projection h_{10} on the curved surface of the quadrant and allows the latter to swing on its center r_1; as the handle r_2 is heavier than the curved portion r_3, it swings down and raises the curved portion, which is eccentric in its relation to the center r_1, the upper part being nearer the center than the lower part. Consequently, when the upper portion of the frame swings on its center, the quadrant turns so that its curved face is always in close contact with the projection h_{10}. When the pressure has been removed from the upper portion of the frame h_1, the projection h_{10} is allowed to press on the curved surface of the quadrant and thus hold the frame in any desired position. By this means the frame h_1 can be drawn back out of the way to facilitate piecing, after which it can be moved forwards to its proper position by simply raising the handle of the quadrant.

23. Method of Driving.—The main driving pulley of the frame is shown at k, Fig. 10 (a). This pulley is loose on the shaft j_1, but its inner surface is conical to fit a cone k_1 attached to the shaft j_1 by means of two pins firmly fixed in the collar k_2 attached to the shaft. When the lever l_1 is drawn forwards and locked in position, the dog k_3 on the rod l, by reason of its shape, releases the cone k_1 and allows the diaphragm spring k_4 to force it to the right until its conical surface is firmly in contact with the surface of the conical cut-out of the pulley k. This spring is shown in section in position in Fig. 10 (a), while a perspective view is given in Fig. 10 (b). The pulley k is crowned and is about 4 inches in diameter.

The traverse cam h_5 is driven from the spindle shaft j_1 in the following manner: Attached to the spindle shaft j_1 is a pulley k_5 that drives the pulley k_6 by means of a short belt.

The pulley k_6 is on a short shaft k_7, the opposite end of which carries a small spur gear k_8 of 20 teeth, which in turn drives a large spur gear k_9 of 120 teeth. The gear k_9 is attached to the cam-shaft and thus imparts motion to the cam h_5. As the casting k_{10} forming a casing for the gears k_8, k_9 and a support for the short shaft k_7 swings on the cam-shaft, some means must be adopted to give the necessary tension to the belt on the pulleys k_5, k_6, in order that the cam-shaft may be driven properly. This is accomplished by having the weight k_{11} connected to a rod, or pin, k_{12} by a cord, or band, k_{13} that passes over the hook k_{14} attached to the casting k_{10}. The pulleys k_5, k_6 are each about 3 inches in diameter.

24. Spindle-winding machines are not usually operated singly, as shown in Fig. 7, but in groups of six heads, spoken of as a *gang* of six spindles. The floor space occupied by a six-head machine is 4 feet 8 inches by 1 foot 8 inches.

MANAGEMENT

25. The points connected with the proper operation of a room of tube winders are numerous and require careful attention. The instructions given by buyers of the yarn should always be carefully followed. These relate principally to the numbers of the yarn and sizes of tubes or cones. The room should be so operated that each number or kind of yarn is kept separate, and thus the possibility of mixing different kinds or qualities avoided, both before the yarn arrives at the machine and at the winder.

Winders are usually constructed to make tubes with a maximum traverse of 6 inches, although occasionally frames are made for 8-inch traverse. Those made for 6-inch traverse can be changed to 5-inch, 4-inch, or even a smaller traverse; the change is usually made by changing the cam, but on some makes of machines, especially those with the traverse motion at the end, a slight adjustment of about 1 inch can be made by changing the leverage of the lever k_3,

Fig. 5, by moving the connection at k_6 downwards or upwards as required.

Buyers do not often specify the length of traverse; for ordinary knitting yarn, when not specified, a $5\frac{1}{2}$-inch traverse is used in case of cones. When yarn is to be wound on cones, the diameter of the cone at its larger end is generally given by the buyer as a guide, usually 7 or $7\frac{1}{2}$ inches. Sometimes as small a diameter as $5\frac{1}{2}$ or 6 inches is required, but very seldom. The attendant should be instructed to remove the cones when they attain the desired size and he should be watched to see that this is done. Parallel tubes are often made with a $5\frac{1}{2}$-inch traverse and a $4\frac{1}{2}$-inch diameter. These dimensions are for ordinary cotton yarns, and of course are varied for other materials and for special purposes. When making parallel tubes, the end of the yarn last wound on should always be tied so as to avoid its raveling off; it is better to do this on cones also, although this is not always done.

26. Among the points that require attention in the operation of the machine are cleanliness and satisfactory oiling. The newer makes of quick-traverse drum winders are so constructed that the traverse motion is self-oiling, while in the Universal winder the spindle is self-oiling, thus avoiding the necessity of constant attention to these quickly revolving parts. There are, however, on the quick-traverse drum winder a number of other parts that do not revolve so quickly but that require oiling twice a week or oftener. Oiling should be carefully performed, since in case of an excess of oil or oil getting on to parts of the machine with which the yarn comes in contact, the yarn will be stained. For the same reason winders should be kept carefully cleaned, so as to avoid the possibility of lint and dirt passing forwards with the yarn.

The rapid reciprocating motion of the traverse rods of drum winders creates considerable jar and vibration, and although this is counteracted by the strong construction of the machines and of the traverse motions, as well as by rubber cushions so placed as to destroy as much as possible of the jar, there is a tendency for parts to work loose and adjustments to become slack. The machines should be carefully and periodically examined for such defects, and all wear taken up promptly and loose parts tightened. If such defects are attended to at once, it prevents additional wear and enables the machine to be run with much less vibration.

The full tubes from each machine should be occasionally examined to make sure that the yarn does not overrun at the ends, which produces what are called *cobwebs* or *dropped ends* and makes it difficult to unwind the yarn at the next process, often causing breakage there. In some cases this is caused by faulty construction of the machines and is then difficult to remedy, but more frequently it is on account of parts working loose and wearing, which consequently allow the ends to run over the ends of the tube. A careful study should be made of the best relation between the speed of traverse and the length of the yarn wound. Some classes of yarn, especially smooth, or polished, yarn or ply yarn, require a quicker traverse in proportion to the amount of yarn wound than ordinary yarns or single yarns.

In case of winding more than one end on a tube, the stop-motion should be kept in perfect order so as to act promptly in case an end breaks; otherwise the strand of yarn will pass to the tube with one end short of the required number. When an end breaks it should be carefully tied to the other end with a small knot. In case of winding two ends to one tube, the single broken end should be tied to the other single end and not made into a bunch knot. The tension on the yarn should also be carefully adjusted so that the same amount will be applied to every end. This is of special importance in case of winding several ends together where the object is to wind exactly the same length of each end on the tube. Should there be less tension on one end than another, a slightly different length of yarn would pass from one cop or bobbin than from the others, thus tending to make corkscrewed yarn at the twisting process.

In the case of the Universal winder, care should be taken to have the friction cone fit the conical shell properly, in order to obtain a positive and even drive when it is necessary to revolve the spindle, and also so that it will be out of contact with the shell when it is necessary to stop the spindle. When the friction cone is out, the driving pulley should revolve freely on its shaft without imparting motion to any other part of the machine.

Before shipping the tubes or cheeses, they should be separately wrapped in paper and packed in wooden cases, which are also lined with paper. These cases are of different sizes according to the requirements of buyers, but a common weight of case with open-wound tubes or cones such as are made on the quick-traverse drum winders is 250 pounds, although sometimes large cases are used with a capacity of 400 pounds. A greater weight of yarn wound on a close-winding spindle winder can be packed in a case and runs as high as 350 pounds for the ordinary sized case. The attendants are usually women, who are paid so much per 100 pounds, a slightly higher rate being paid for winding from ring bobbins than from cops.

27. The production of the various machines depends on the counts and quality of the yarn and the number of ends that are being run, as well as the form into which it is being wound. These factors affect the speed at which it is possible to run the machine, but for all ordinary purposes a well-constructed quick-traverse drum winder can be operated so as to wind 140 or 150 yards per minute, and the net production after allowing for breakages and stoppages for various purposes should be in excess of 100 yards per minute for each drum or spindle.

The makers of spindle winders claim that the production per spindle is approximately three times that of a drum of a quick-traverse drum winder.

Views are shown in Fig. 12 of the various styles of conical and parallel tubes. The conical tubes are shown at (*a*) and (*b*), (*a*) being an open-wind tube such as is made on a quick-traverse drum winder, and (*b*), a close-wind tube as produced on a spindle winder. A parallel tube with an open wind is shown at (*c*) and one with a close wind at (*d*). These are all shown built up on paper tubes. A spool with

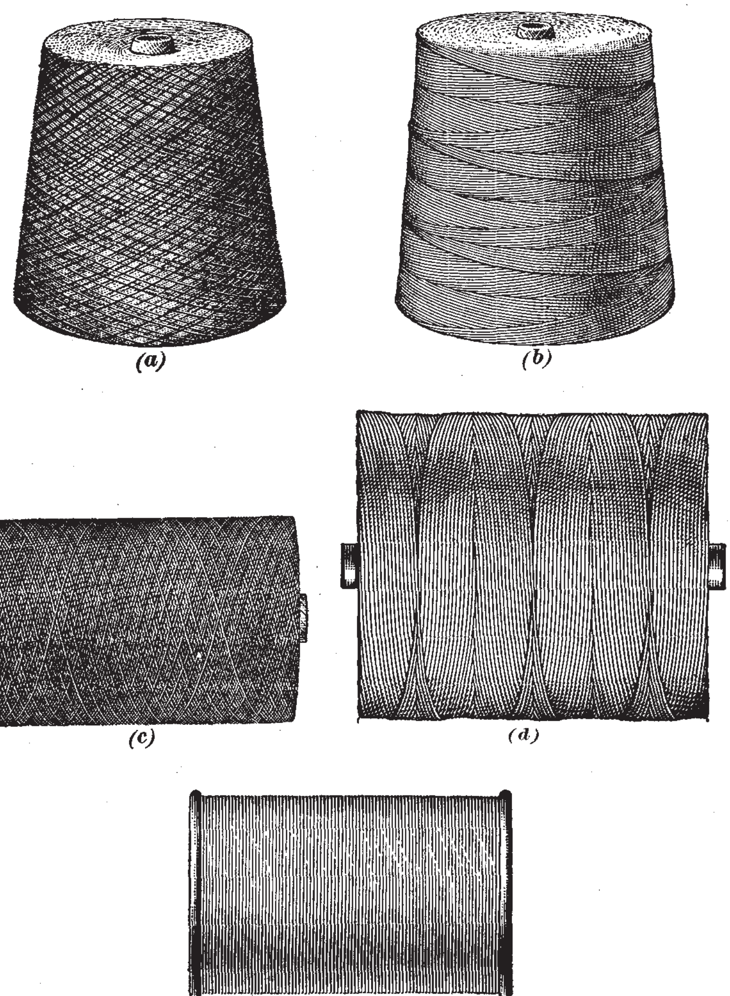
(a) (b) (c) (d) (e)

Fig. 12

double heads, such as made on the slow-traverse drum winder, is shown at (*e*).

BACK WINDING FOR WEAVING YARNS

28. **Back winding** is the term applied to the rewinding of skeined yarns in suitable form for the purpose for which they are intended. Another name for this is *skein winding*. Skeined yarns for weaving may be rewound for use either as filling or as warp, although back winding for filling yarns is much more common than for warp yarns.

29. **Pirn Winder.**—The back winding of filling yarn is performed on a **pirn,** or **quill, winding machine** so constructed as to hold the skein on a rice, or swift, constructed of wood with a number of pairs of rods, radiating in different directions, inserted in the center hub, and tied together at their ends. The hubs contain two pins, each of which rests in a suitable bearing. The skein of yarn is stretched over the ends of the rods in a suitable position for unwinding and the end passed to a bobbin placed on a horizontal or vertical spindle, being given a short traverse that builds it up in the form shown in Fig. 13 (*b*). The empty bobbin is shown in section at (*a*). Such bobbins are called *quills*, *pirns*, or *shuttle bobbins*.

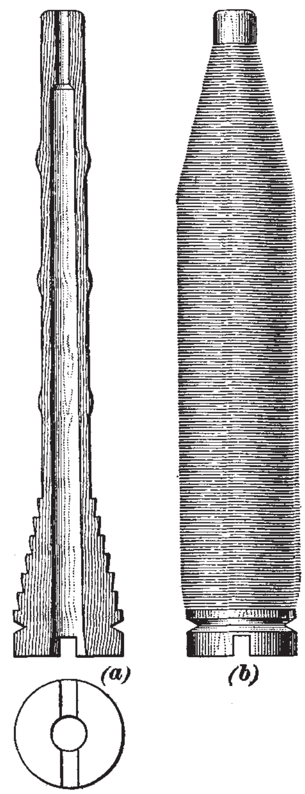

FIG. 13

30. The **slow-traverse drum winder** is the machine used for backwinding skeined yarn that has been bleached, dyed, mercerized, or otherwise treated, on to double-headed spools, Fig. 12 (*e*), for warping purposes. The skein of yarn is held in the same way as in pirn winding. Motion is imparted to the spool by its resting on a revolving drum of suitable width to fit between the heads of the spool, and a traverse corresponding to the distance between the heads is given to the yarn. This traverse is comparatively slow so as to build up the yarn in a succession of even layers until the spool is filled, and the name slow-traverse winding is therefore given to this process to distinguish it from quick-traverse winding, which forms tubes of yarn built up on a paper or wooden tube without heads.

31. Miscellaneous Winding Machines. — Various other types of winders are used for special purposes in various branches of the textile trade. The number of varieties and the many different styles of construction prevent a detailed description of each, but most of the machines consist merely of a framework for holding in a suitable position the yarn to be unwound and some mechanism for driving the part of the machine that carries the framework on which the yarn is to be wound. One form of such machines is that known as the cop winder, in which the yarn is wound on to a cop to be used in the shuttle of the loom or of a sewing or embroidery machine. Winders are also made to take yarn from imperfectly wound cops, bobbins, or quills, and rewind it in perfect form, thus avoiding the loss that would result if the yarn were cut off and sold as waste.

The construction of the machines is usually of the simplest and their operation and management do not involve any special knowledge beyond that of applying the ordinary methods of cleaning, oiling, and economical operating by reducing the possibilities of making waste, and keeping the machinery in proper repair and running order.

Perhaps the most important matter to look out for in many cases is to have the machinery so oiled and cleaned as to prevent the possibility of black oil coming in contact with the yarn as it passes through the machine.

A SERIES OF QUESTIONS

RELATING TO THE SUBJECTS
TREATED OF IN THIS VOLUME.

It will be noticed that the questions contained in the following pages are divided into sections corresponding to the sections of the text of the preceding pages, so that each section has a headline that is the same as the headline of the section to which the questions refer. No attempt should be made to answer any of the questions until the corresponding part of the text has been carefully studied.

YARNS

(PART 1)

EXAMINATION QUESTIONS

(1) How would you distinguish between sea-island cotton yarn and Egyptian cotton yarn?

(2) In what direction is the twist usually inserted in ply yarn as compared with that of the single yarn from which it is made?

(3) Give a definition of a warp.

(4) Name three kinds of tubes for cops.

(5) Name some of the characteristics required in knitting yarns.

(6) What is ramie yarn?

(7) What are the characteristics and chief features of: (*a*) warp yarn as made from cotton? (*b*) filling yarn?

(8) (*a*) What is a chain? (*b*) Describe a linked chain. (*c*) Describe a balled chain.

(9) State what is meant by the word yarn.

(10) What yarns are spun in the United States of America from foreign cottons?

(11) What is the difference between an ordinary ply yarn and a cable yarn?

(12) Is filling yarn ever put up in chain form?

(13) Describe the difference between a ring-spinning-frame bobbin intended for warp wind and one intended for filling wind.

(14) What is the difference between the two kinds of yarn made from flax known as line and tow?

(15) (*a*) What is the difference between the through tube used for spinning cops and the parallel tube used for winding yarn? (*b*) Of what material is each made?

(16) What is the difference, in construction, between a yarn made by a roll-drawing series of processes and yarn made by a condensing and a mule-spinning process?

(17) When a geographical name is applied to cotton yarn, does it refer to the country in which the yarn is spun or to the country where the cotton of which the yarn is made has been grown?

(18) Name a representative yarn made from each of the following: (*a*) animal fiber; (*b*) mineral fiber; (*c*) vegetable fiber.

(19) What is the difference between what are commercially known as carded cotton yarns and combed cotton yarns?

(20) (*a*) What is the name of the machine where two or more ends of yarn are twisted together? (*b*) What is the name of the machine where two or more ends of yarn are laid together without twisting?

(21) What is a cone of cotton yarn?

(22) Name and briefly describe, mentioning their different characteristics, three kinds of cotton yarn produced on different spinning machines.

(23) What is meant by the expression ply yarn?

(24) Describe the structure of a cop and give the usual dimensions of warp and filling cops of cotton yarn.

(25) In case of a ply yarn being composed of three ends of 40s yarn, how would it be designated: (*a*) in America? (*b*) in England?

YARNS

(PART 2)

EXAMINATION QUESTIONS

(1) What is meant by prepared worsted yarns?

(2) What is a ready means of determining the difference between yarn made from cultivated silk and from wild silk?

(3) What are meant by the terms half white, three-quarters white, and full white, and are these terms usually applied to yarns of animal, vegetable, or mineral origin?

(4) How would you distinguish between a bouclé and a bourette yarn?

(5) How would you distinguish yarn made of raw-stock mixes of different colors from self-colored yarns?

(6) (*a*) In what form does woolen yarn generally leave the mule? (*b*) Is filling yarn ready for the shuttle of the loom when in this form?

(7) How is a mock twist made in single cotton yarns?

(8) What is the difference between a woolen and a worsted yarn?

(9) Describe a spool in the sense in which the word is used in connection with woolen warp yarns.

(10) Name and define the varieties of silk produced by different degrees of scouring or boiling off.

(11) What is asbestos, and what quality makes it especially useful for certain purposes?

(12) What class of yarns is often weighted in connection with the dyeing process?

(13) (*a*) What is a flake yarn? (*b*) Mention and briefly describe two different kinds of flake yarn.

(14) Define: (*a*) woolen merino yarn; (*b*) shoddy yarn.

(15) What is meant by a silk single?

(16) What is the meaning of such expressions as $\frac{1}{4}$-blood, $\frac{1}{2}$-blood, etc., when used in connection with yarns?

(17) From what material are mercerized yarns made?

(18) When a woolen merino yarn is spoken of as 60–40 what does it mean?

(19) Describe a knickerbocker yarn.

(20) Define: (*a*) printed yarns; (*b*) polished yarns; (*c*) gassed yarns.

(21) On what system of spinning are the majority of worsted yarns made?

(22) Explain the meaning of the word twist as applied to a certain variety, or varieties, of cotton, woolen, and worsted yarn in America.

(23) From what animal is mohair obtained and what are the principal uses of mohair yarns?

(24) Define the terms: (*a*) warp-dyed, (*b*) cop-dyed, and (*c*) skein-dyed, as applied to yarns.

(25) (*a*) What is bourette silk yarn? (*b*) Give a definition of another kind of yarn called bourette.

CLOTH ROOMS

(PART 1)

EXAMINATION QUESTIONS

(1) Explain briefly the operation of the sewing-and-rolling machine.

(2) Explain how a full roll of cloth is removed from the calender-rolling head shown in Fig. 15.

(3) Make a sketch showing the arrangement of a ledger blade and revolver when they are on the under side of the cloth, and describe the method of setting with reference to the same.

(4) Under what condition is a portable sewing machine advantageous?

(5) Explain the mechanism by means of which the rotary motion of the revolvers is checked when a seam is passing through the shearing-and-brushing machine.

(6) (*a*) What is the object of the cloth rests i_4, Fig. 7? (*b*) Explain how they are raised when a seam passes through the machine.

(7) Explain fully the precautions that are taken to prevent cloth from being lost or mislaid during transit from the weave room to the cloth room.

(8) Explain the object and construction of the bar g_7, Fig. 7.

(9) Why is it desirable to attach a number of pieces of cloth together before passing them through certain machines?

(10) Describe the method of imparting a traversing motion to the revolvers of the shearing-and-brushing machine.

(11) Why is good lighting an important factor in the cloth room?

(12) Describe the passage of the cloth through the shearing-and-brushing machine shown in Fig. 7.

(13) What are the objects of the shearing-and-brushing machine?

(14) What are the objects of the front guide frame through which the cloth passes before it enters the shearing-and-brushing machine?

(15) What can be said of the location of the cloth room with reference to the conveyance of the cloth from the weave room?

CLOTH ROOMS

(PART 2)

EXAMINATION QUESTIONS

(1) State several methods of inspecting cloth.

(2) What are the objects of the trimming-and-inspecting machine?

(3) (*a*) What types of presses are used for baling cloth intended for domestic shipment? (*b*) What type is most commonly used?

(4) Name some of the principal faults to be noticed when inspecting cloth.

(5) Explain how the table t, Fig. 5, is kept in contact with the jaws t_1, t_2 when it is not lowered positively by the cams.

(6) Why is it not a good practice only partly to cover a bale of cloth with burlap?

(7) Describe the passage of the cloth through the trimming-and-inspecting machine.

(8) Referring to Fig. 5, explain how the cams depress the table t.

(9) (*a*) What type of press is used for baling cloth for ocean shipment? (*b*) Why is this type used?

(10) What is the object of stamping cloth?

(11) State the object of the mechanism shown in Fig. 6 and also the number of teeth that the gear moves in registering 40 folds.

(12) State how rolls of cloth are prepared for shipment.

(13) In a folder, what would be the effect of: (*a*) too much tension on the cloth? (*b*) too little tension?

(14) How is the table *t*, Fig. 5, lowered when a cut of cloth is to be removed from the folder?

(15) If a folder operates at the rate of 70 yards per minute, how many hours will be required to fold 10,000 yards of cloth, making an allowance of 40 per cent. for stoppages, etc.? Ans. 3.968 hr.

MILL ENGINEERING

(PART 1)

EXAMINATION QUESTIONS

(1) State some of the natural and artificial advantages that should be taken into consideration in locating a mill.

(2) What is the object of footings?

(3) What proportions of sand, stone, and cement are suitable for the concrete footings of a moderately high mill?

(4) Describe, briefly, how foundations are supported when the soil is marshy.

(5) State the requisite qualities of good building bricks.

(6) Discuss, briefly, the character of the following soils: (*a*) rock; (*b*) gravel; (*c*) clay; (*d*) quicksand.

(7) How should footings partly on rock and partly on gravel be built?

(8) What is the danger in uneven settlements of a mill foundation?

(9) (*a*) How are stone foundation walls bonded? (*b*) Why should the joints in a stone foundation wall be carefully broken?

(10) What precaution should be taken in laying brick in hot weather?

(11) (*a*) What is meant by Flemish bond? (*b*) What is meant by running bond?

(12) (*a*) How thick should be the bed of mortar between the bricks in a wall? (*b*) What is a good proportion of lime and sand for lime mortar?

(13) Describe how the floors are constructed and supported in a mill built on the slow-burning principle.

(14) (*a*) What is a stretcher brick? (*b*) What is a header brick?

(15) What is a monitor and what are its chief objects?

(16) (*a*) Describe an automatic fire-door and state its purpose. (*b*) Why are iron fire-doors unsuitable?

(17) What is meant by bond in brickwork?

(18) What can be said of stairways in mill structures?

(19) What are fire-walls and what is their object?

(20) What is meant by the term slow-burning construction?

(21) What is the object of shoeing piles?

(22) Discuss the relative advantages of iron and wooden columns.

(23) (*a*) Why should a hole be bored through a wooden column? (*b*) Should this hole be bored from one or both ends? Explain.

(24) Describe the construction of a gravel roof.

(25) Why should the outside doors of a mill open outwards?

MILL ENGINEERING

(PART 2)

EXAMINATION QUESTIONS

(1) (*a*) What are the two general methods of developing motive power in textile mills? (*b*) Of these two systems, which is in more general use?

(2) Make a sketch of a return tubular boiler, and describe the principles involved in its construction and the passage of the flame and gases with reference to the sketch.

(3) What is meant: (*a*) by an internally fired boiler? (*b*) by an externally fired boiler?

(4) What is meant: (*a*) by a fire-tube boiler? (*b*) by a water-tube boiler?

(5) What is a bridge in a boiler setting and what is its object?

(6) State some of the advantages of the water-tube boiler.

(7) Make a sketch, similar to Fig. 26, of the cylinder of a simple slide-valve engine, and explain its action with reference to the sketch.

(8) How does the Corliss engine differ from the plain slide-valve engine?

(9) What is: (*a*) a non-condensing engine? (*b*) a condensing engine? (*c*) the advantage of the condenser to an engine?

(10) (*a*) How does a compound engine differ from a simple engine? (*b*) Explain the difference between a tandem and a cross-compound engine.

(11) What is meant by: (*a*) a register-gate turbine? (*b*) a cylinder-gate turbine?

(12) What is meant: (*a*) by a direct-heating system? (*b*) by an indirect system?

(13) Name some of the advantages and disadvantages of using exhaust steam for heating purposes.

(14) Why is the exhaust-steam system of heating impossible with a condensing engine?

(15) Why does an exhaust-steam system of heating require larger heating pipes than a system employing live steam?

(16) Describe the indirect system of heating a mill and state some of its advantages.

(17) What is meant by the fan system of ventilation?

(18) (*a*) What is the best method of lighting a mill? (*b*) Discuss briefly this system.

(19) (*a*) What is a sprinkler? (*b*) Describe its action.

(20) Give a brief description of the methods you would employ for fire-protection and prevention in a textile mill.

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.

REELING AND BALING

EXAMINATION QUESTIONS

(1) Define: (*a*) double reeling; (*b*) slack-reeled yarn; (*c*) 7-lea reeling; (*d*) 5-ounce skein.

(2) What is the reason for adopting a doffing device on a reel?

(3) (*a*) How many revolutions of a 54-inch swift would be necessary to reel 1 hank of cotton yarn in 1 skein? (*b*) How many revolutions of a 72-inch swift to reel 1 hank of worsted?

Ans. { (*a*) 560 rev. (*b*) 280 rev. }

(4) What is meant by banding skeins?

(5) Find the number of pounds of yarn delivered per spindle per day of 10 hours when reeling 18s yarn in 54-inch skeins, the swift making 120 revolutions per minute, assuming that 50 per cent. of time is lost. Ans. 3.571 lb.

(6) Explain the method of holding the arms of the swift in position for reeling, as shown in Fig. 1.

(7) Explain how a reel making 60-inch skeins would be adjusted if it were desired to make 54-inch skeins.

(8) Explain the American method of obtaining any desired weight of skeins. Does this give absolutely accurate results?

(9) Define: (*a*) live spindle; (*b*) skein; (*c*) swift; (*d*) reeling.

(10) (*a*) What are the objects of reeling yarn? (*b*) Is reeled yarn more frequently intended for warp or for filling?

(11) Is it possible to wind from both warp- and filling-wind ring-spinning bobbins with a reel fitted with spindles similar to those in Figs. 1 and 2? If so, what change is necessary in the creel when changing from warp wind to filling wind? Describe the passage of the yarn from the bobbin to the swift in each case.

(12) What is the length of a reel with 40 spindles and a $3\frac{1}{4}$-inch gauge? Ans. 13 ft. 1 in.

(13) Explain, fully, one method of baling skeined yarn for the market by using a press similar in construction to the one shown in Fig. 11. Refer to the materials used for covering and the relative positions of such materials with regard to the yarn.

(14) How many skeins of cotton yarn are required for a 10-pound bundle of 25s yarn, each skein containing 5 hanks?

(15) State, briefly: (*a*) the object of tying reeled yarn; (*b*) three methods of tying yarn.

(16) What are important points in the management of reels?

WINDING

EXAMINATION QUESTIONS

(1) (*a*) Explain how a reciprocating motion is imparted to the guide rod g_1, Fig. 3, by means of its connections with the shaft l_2. (*b*) What is the object of this reciprocating motion?

(2) Explain, fully, how the cone of yarn is removed from contact with the winding drum when the end breaks, referring to Fig. 2.

(3) Explain the meaning of the following expressions as used in connection with winding: (*a*) quick-traverse winding; (*b*) cross-winding; (*c*) drum winding; (*d*) slow-traverse drum winding; (*e*) quick-traverse drum winding; (*f*) spindle winding; (*g*) cone winding.

(4) Explain how the length of the traverse of the tube winder shown in Fig. 5 could be slightly reduced.

(5) What machine is used to place skeined yarn in a suitable form for use in the shuttle of a loom?

(6) Summarize the reasons for the increasing use of the tube-winding machine for cotton yarns.

(7) State, briefly, the important points of difference in the construction of the spindle and the drum winders on the quick-traverse principle.

(8) Explain, briefly, how the spindle of a spindle winder is caused to stop winding under the following conditions: (*a*) when an end breaks; (*b*) when the cone or tube becomes sufficiently large.

(9) When the tension of the yarn being wound on a spindle winder is insufficient, how can it be increased to the proper amount?

(10) State how cheeses of yarn are packed for shipment.

(11) What are the common dimensions of conical tubes of knitting yarn?

(12) What faults should be avoided in winding conical tubes?

(13) (*a*) For what class of work are the slow-traverse drum winders used? (*b*) In what form and by what means is the yarn wound?

(14) (*a*) State, fully, the objects of applying stop-motions to drum winders. (*b*) Does the entire machine stop when an end breaks, in case two ends are passing to each tube, on a machine of the type shown in Fig. 1?

(15) Explain, fully, how the traverse guide of the spindle winder shown in Fig. 7 is caused to move to and fro in order to guide the yarn on the tube in the required manner.

(16) Explain, clearly, the object of the kink, or snarl, arresters used on spindle winders.

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