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.

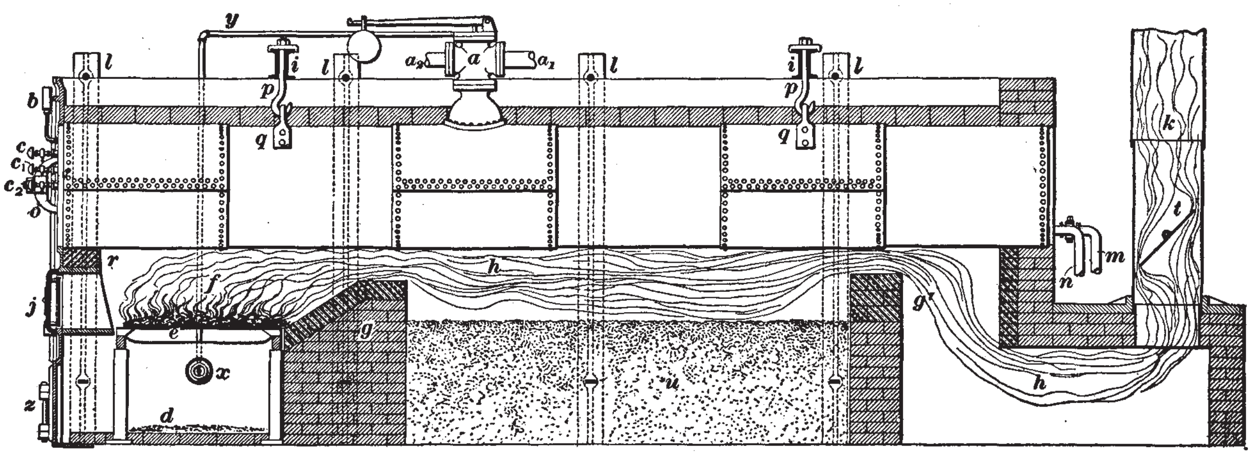


Fig. 1

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.

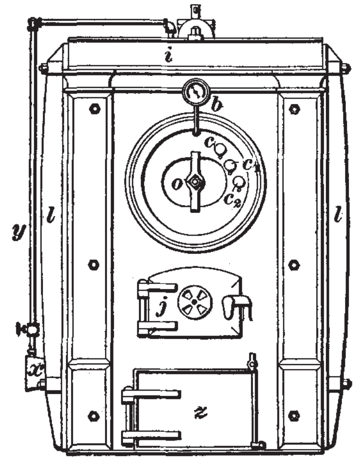


FIG. 2

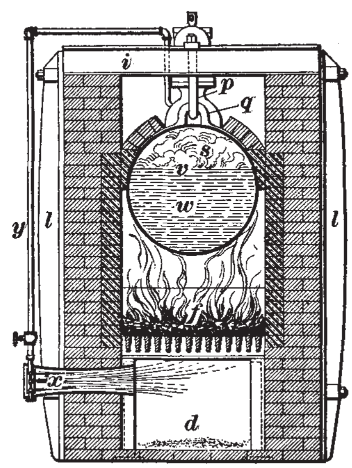


FIG. 3

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 firebrick *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

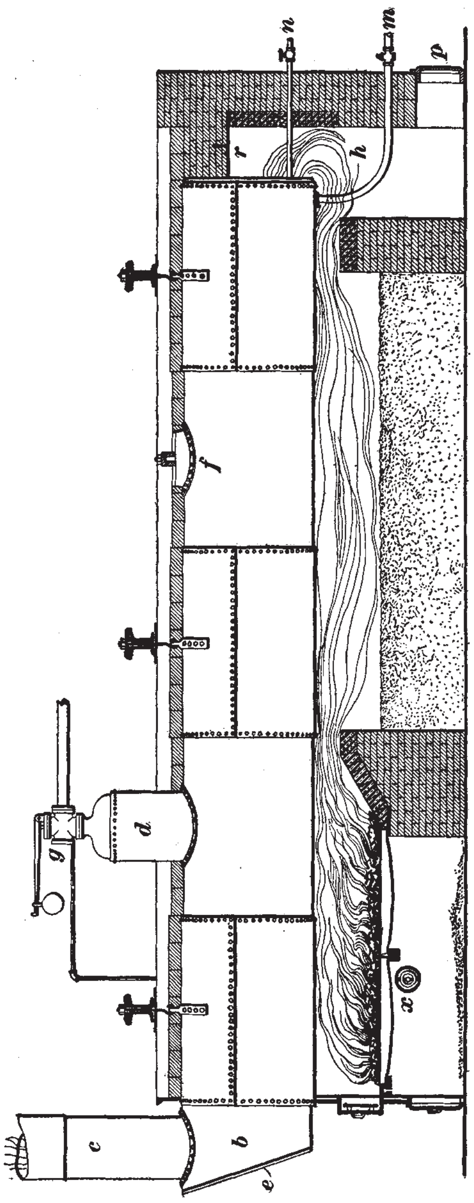


Fig. 4

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

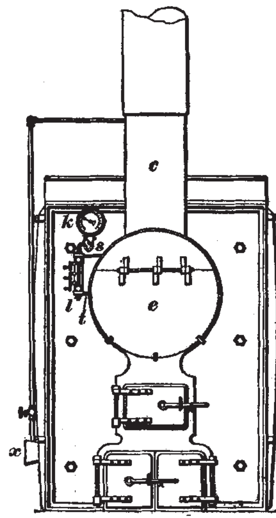


Fig. 5

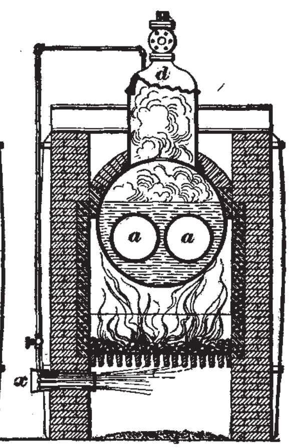


Fig. 6

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

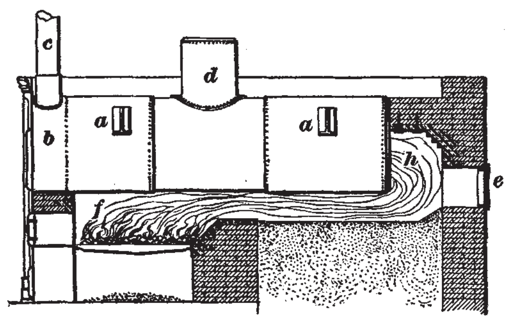


FIG. 7

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*.

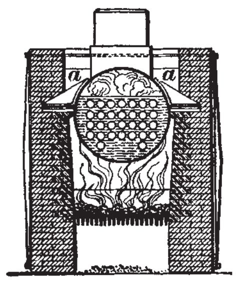


FIG. 8

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.

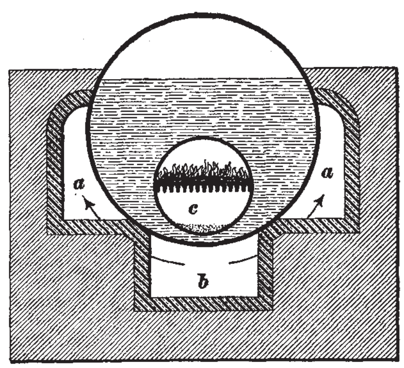


FIG. 9

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.

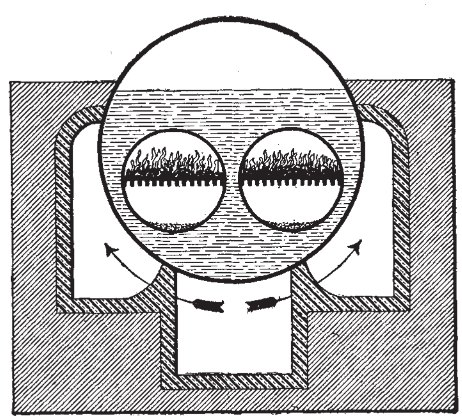


Fig. 10

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.

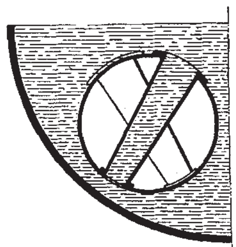


FIG. 11

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

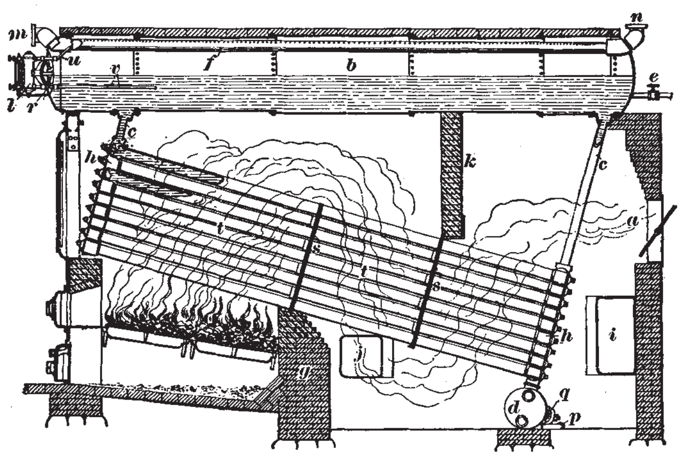


Fig. 12

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,

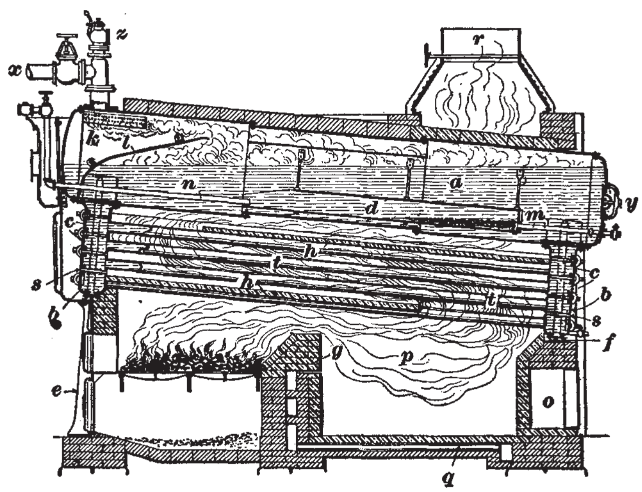


FIG. 13

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

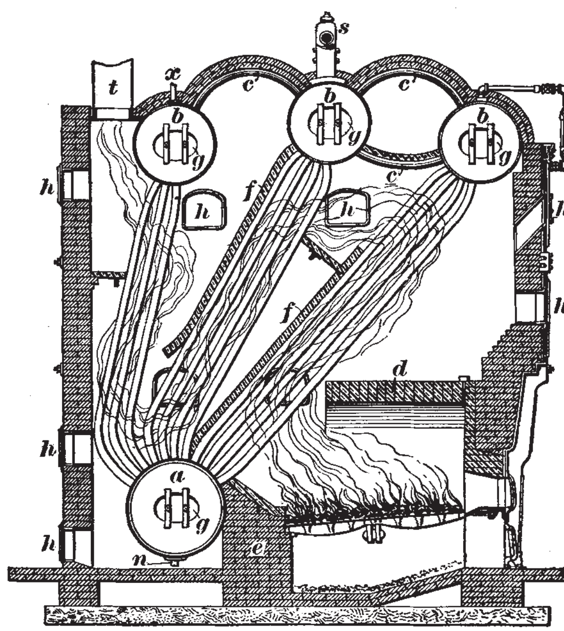


FIG. 14

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

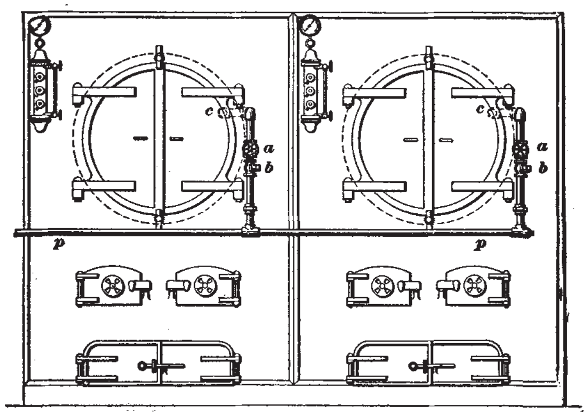


Fig. 15

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

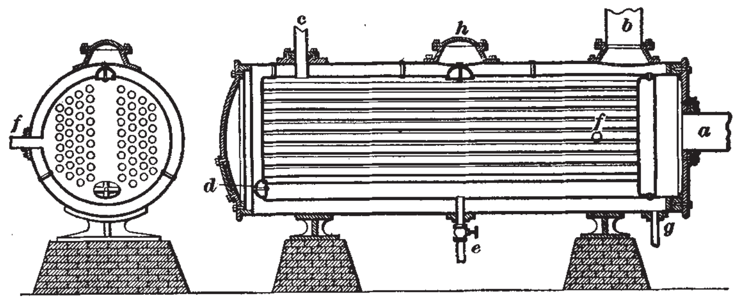


FIG. 16

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

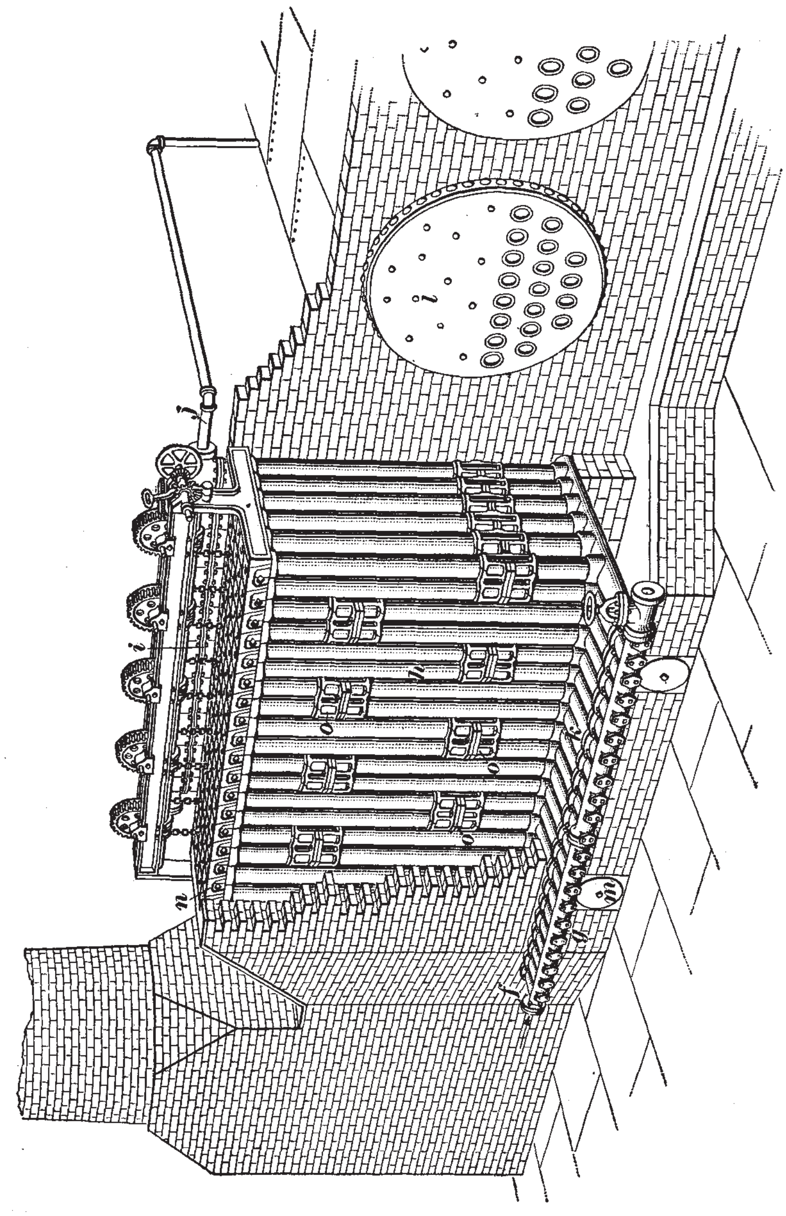


Fig. 17

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

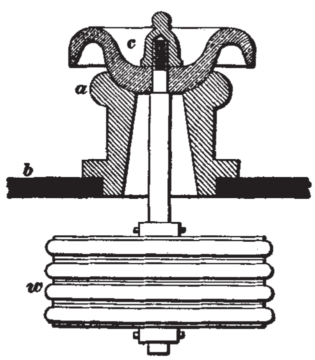


Fig. 18

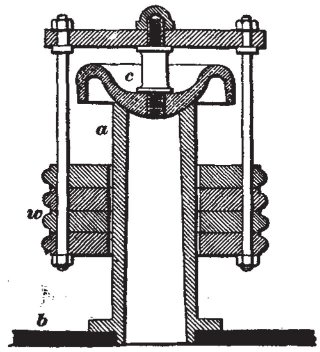


Fig. 19

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

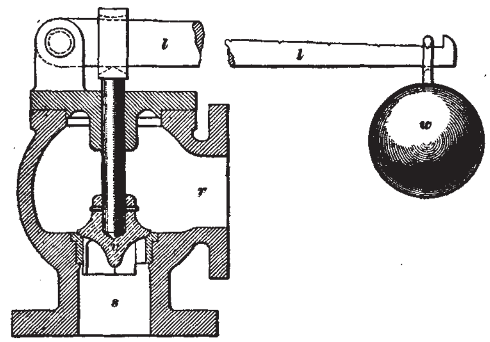


FIG. 20

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,

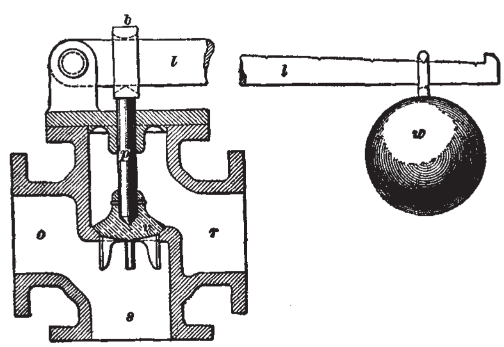


FIG. 21

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

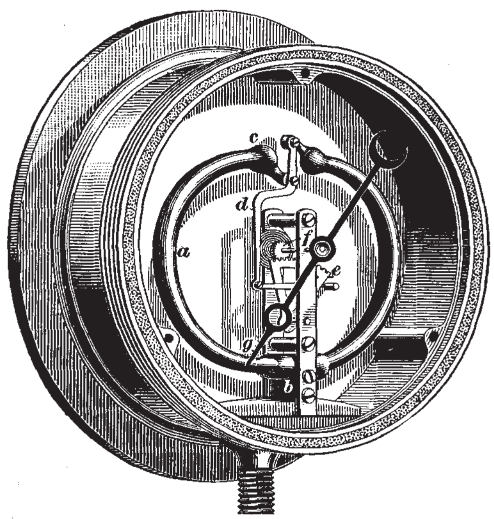


FIG. 22

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*.

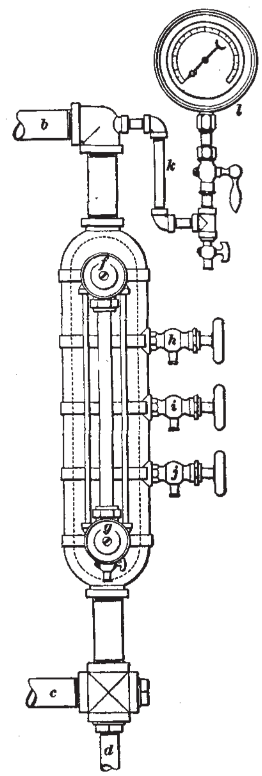


FIG. 23

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.

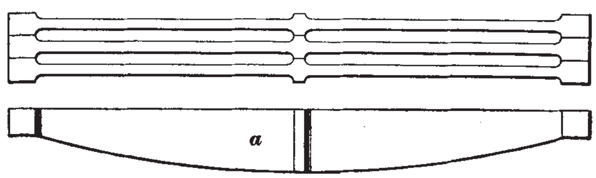


FIG. 24

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

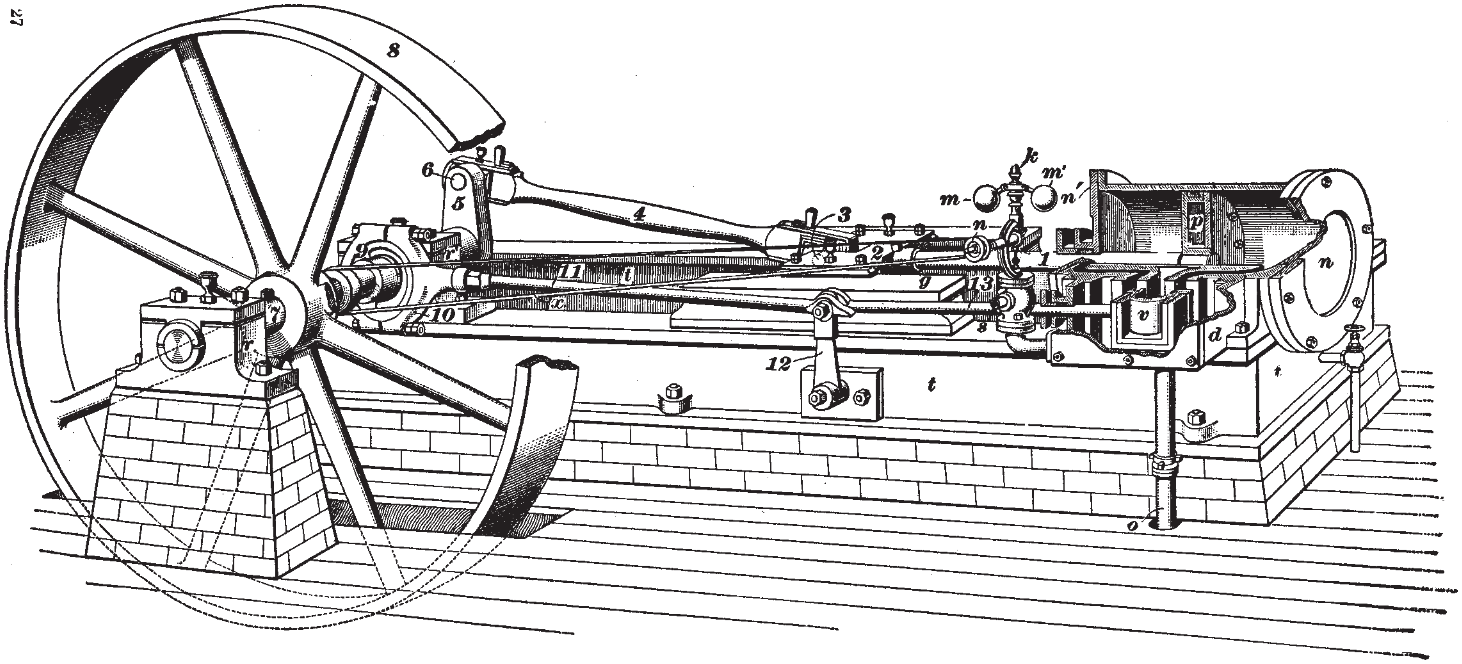


Fig. 25

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

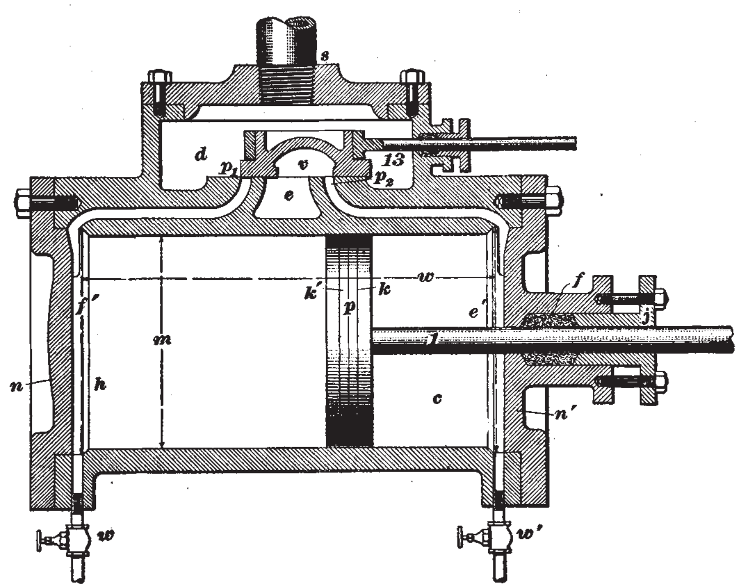


FIG. 26

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

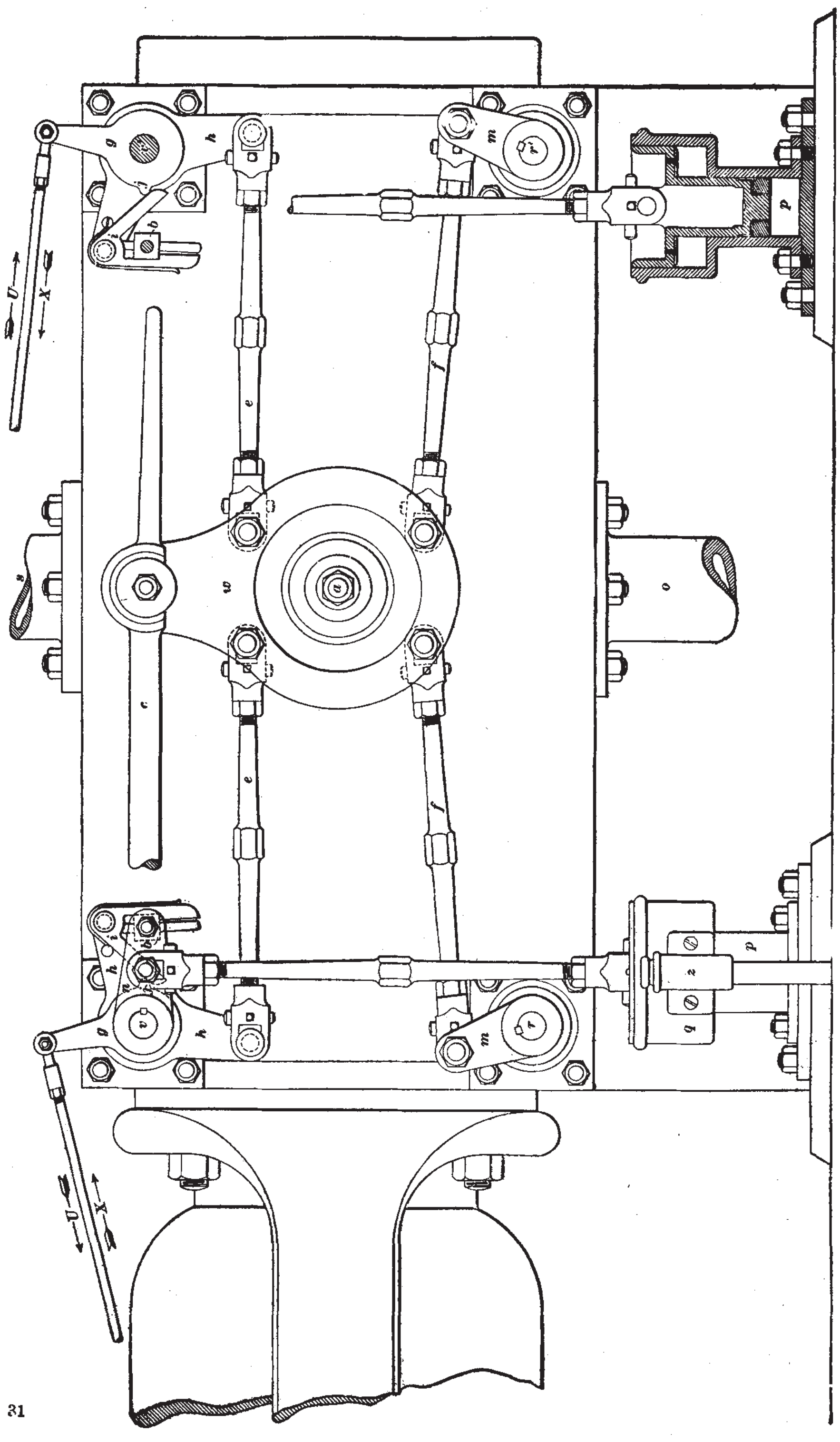


Fig. 27

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

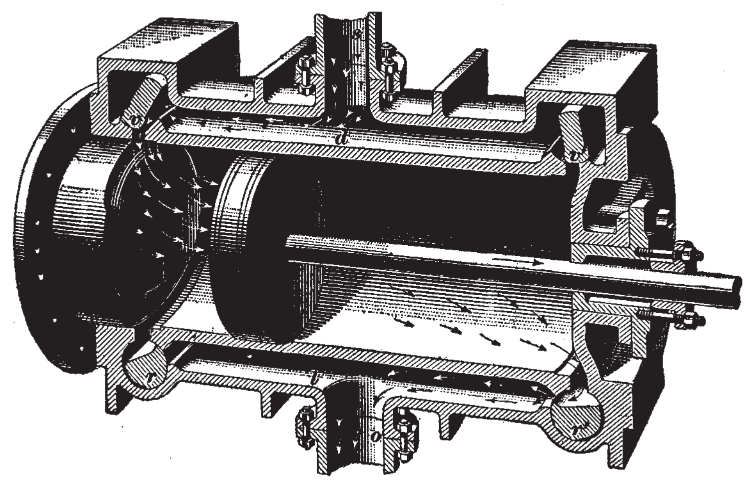


FIG. 28

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.

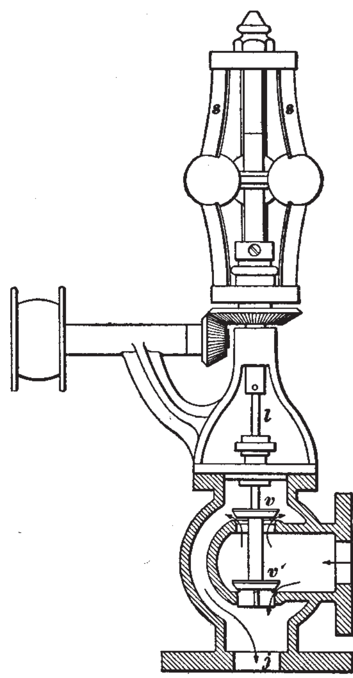


FIG. 29

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-

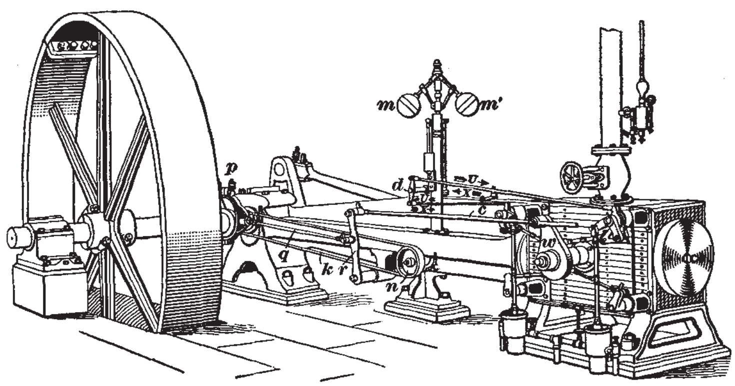


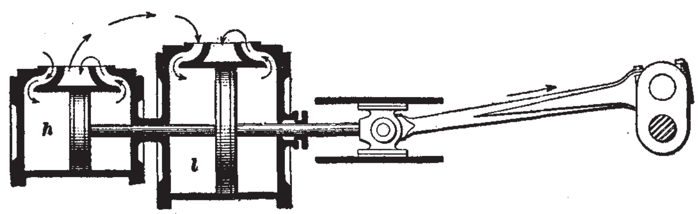
FIG. 30

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.

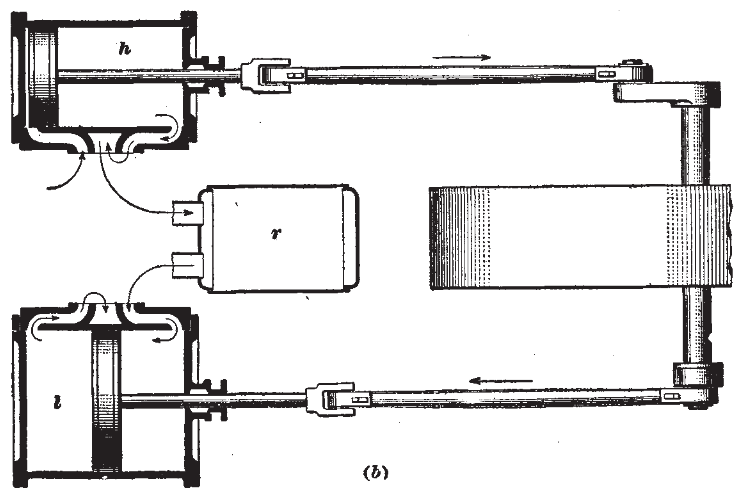
29. Condensers.—As already stated, engines may be of the non-condensing or of the condensing type. In the former, the exhaust steam from the cylinder passes directly into the atmosphere; therefore, the back pressure, or pressure against the motion of the piston, must at least equal the pressure of the 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



(a)



(b)

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.

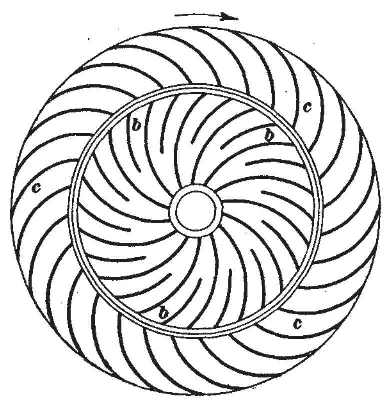


FIG. 32

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. 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.

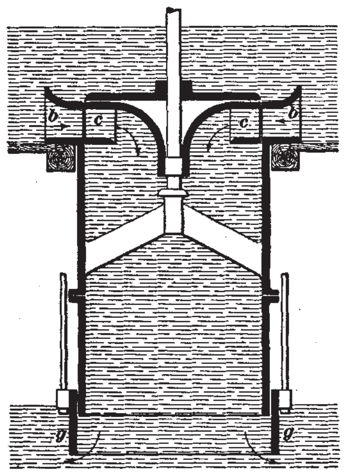


FIG. 33

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.

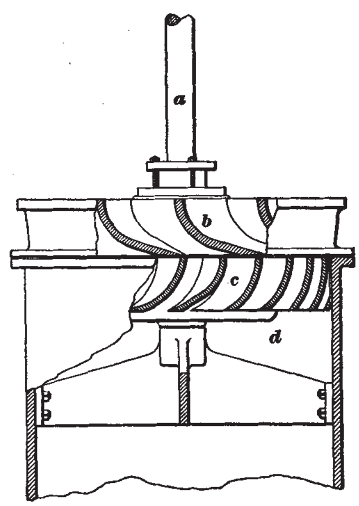


FIG. 34

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.

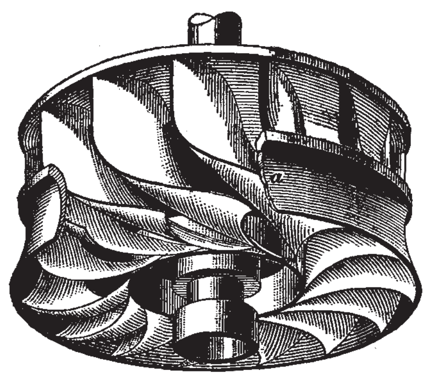


FIG. 35

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

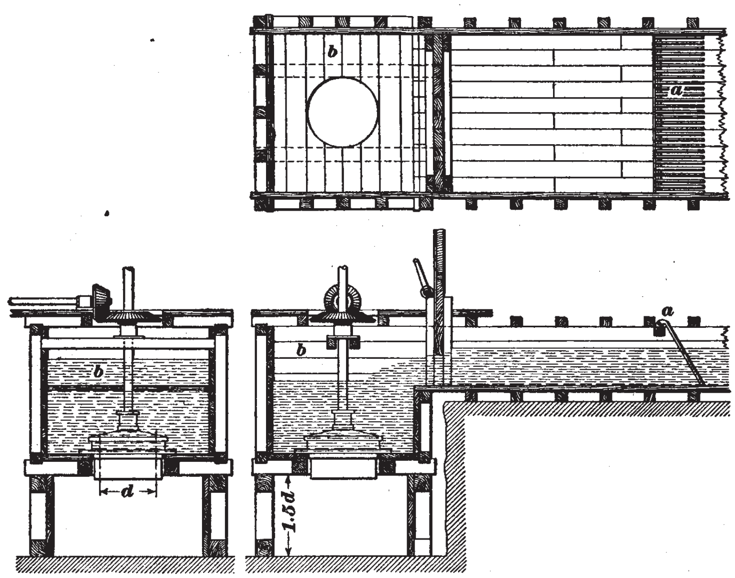


FIG. 36

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.

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

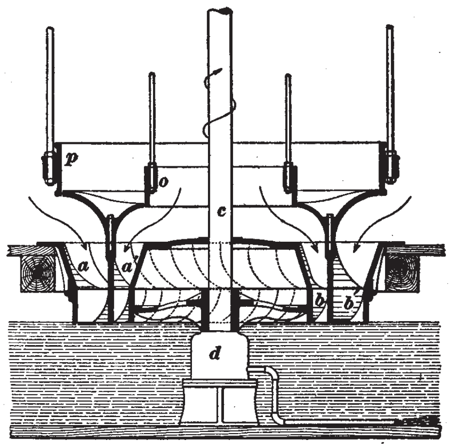


FIG. 37

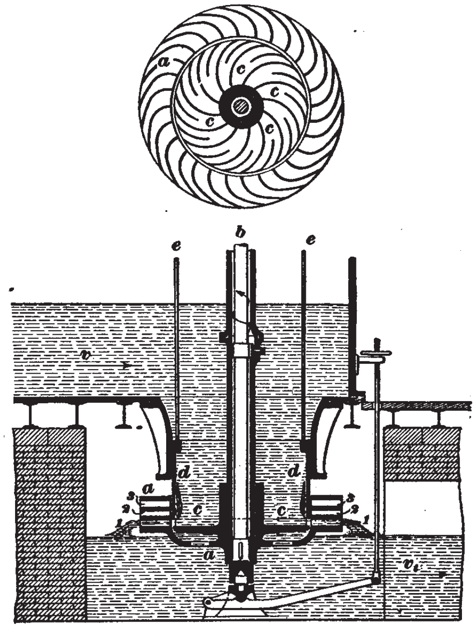


FIG. 38

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.

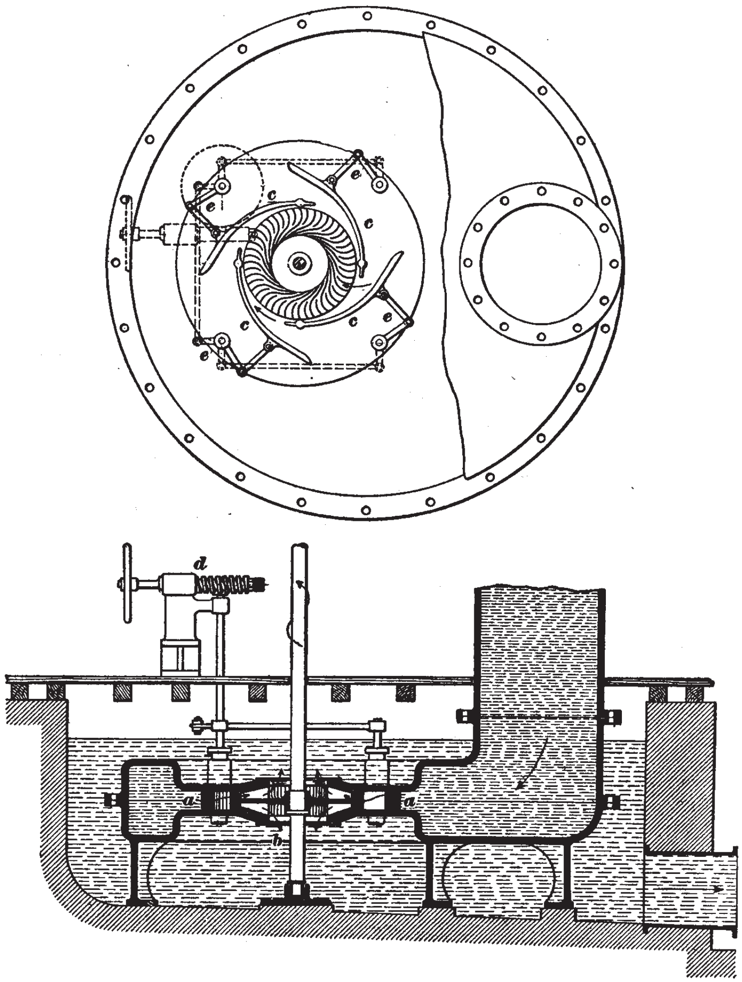


FIG. 39

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.

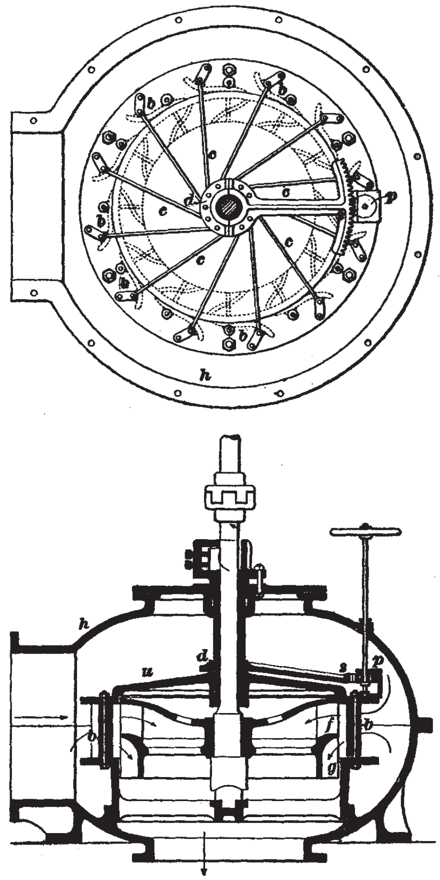


Fig. 40

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.

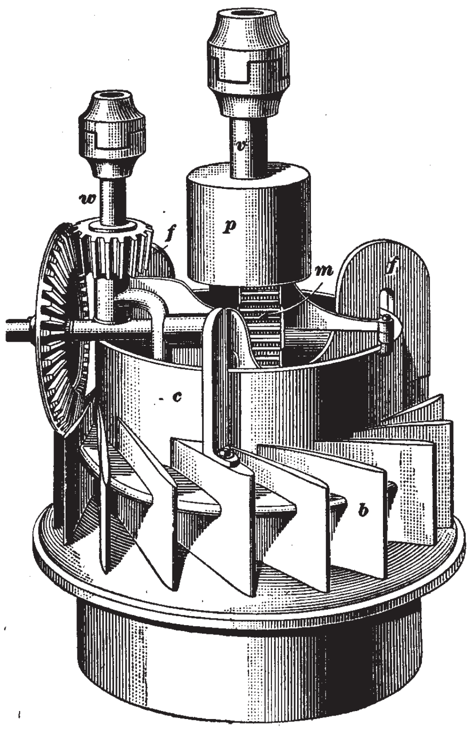


FIG. 41

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

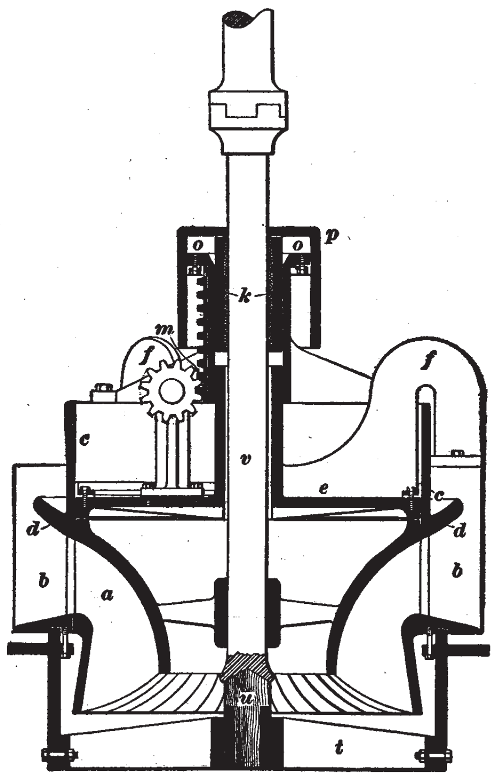


FIG. 42

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

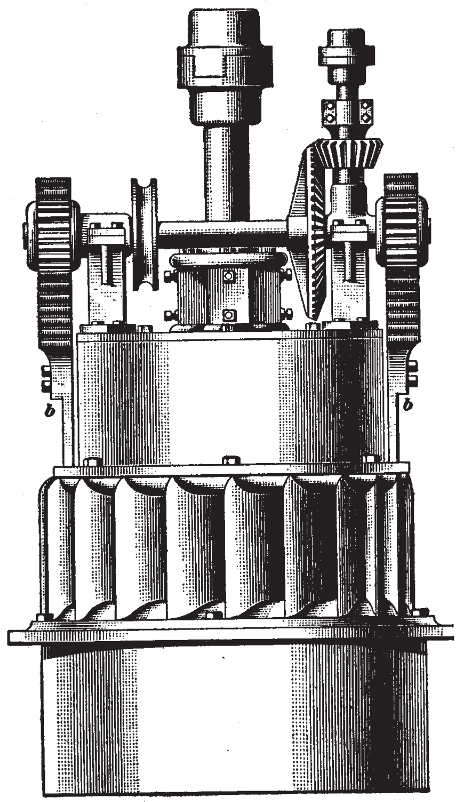


FIG. 43

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

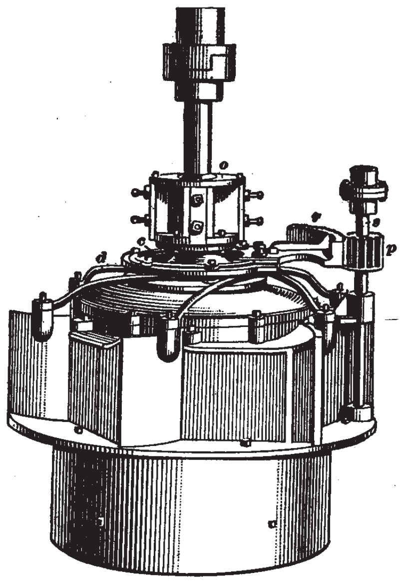


FIG. 44

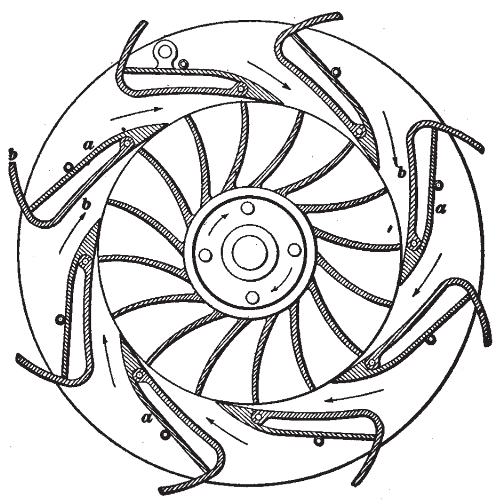


FIG. 45

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

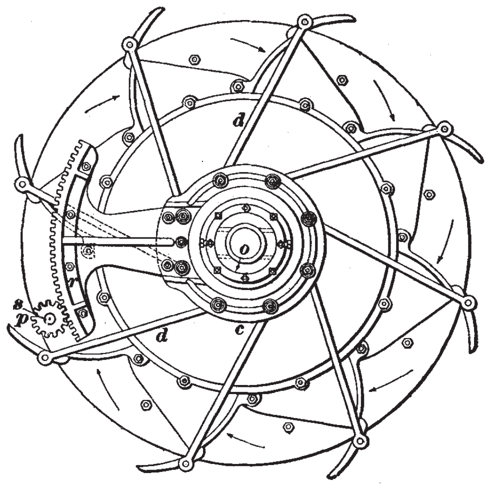


FIG. 46

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.

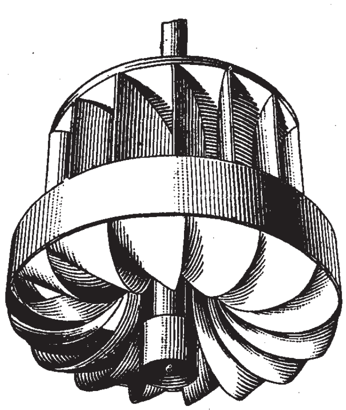


FIG. 47

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 $1\frac{1}{4}$ 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 $\frac{1}{8}$ 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.

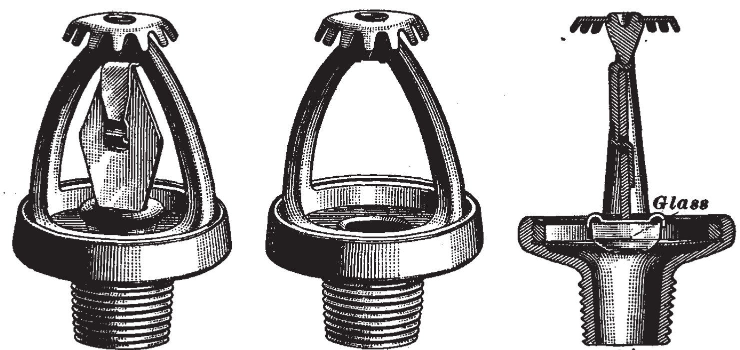
The risers run vertically from the main supply pipe to the roof of the mill, passing through each floor and supplying the sprinklers in each story with water. Insurance requirements call for this riser to be of sufficient size to supply all the sprinkler heads on any floor in each section. Formerly it 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 tim-



(a) (b) (c)

FIG. 48

bers, 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.

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 $\frac{1}{2}$-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
$\frac{3}{4}$	1
1	2
$1\frac{1}{4}$	3
$1\frac{1}{2}$	5
2	10
$2\frac{1}{2}$	20
3	36
$3\frac{1}{2}$	55
4	80
$4\frac{1}{2}$	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.