STEAM & HOT WATER BOILERS 1750-1930

Steam Boilers

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STEAM BOILERS
STEAM PUMPS

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TYPES OF STEAM BOILERS.

FIRE-TUBE BOILERS.

1. A **steam boiler** is an apparatus whose duty it is to generate steam for power or heating purposes.

2. A boiler consists of the following essential parts: A **furnace** in which the combustion of the fuel takes place; a **vessel** to contain the water to be evaporated; a **steam space** to contain the generated steam; a **heating surface** to transmit the heat of the furnace to the water; a **chimney** to carry away the products of combustion and to give a draft to the fire; various **attachments,** or **fittings,** to feed the boiler with water, to carry away the generated steam, to indicate the pressure of the steam, etc.

3. Boilers are built in a variety of forms to meet the varying requirements of different classes of work. They may be roughly divided into three classes: **stationary, locomotive,** and **marine boilers.**

4. The **plain cylindrical boiler** is shown in Figs. 1, 2, and 3. It consists essentially of a long cylinder called the **shell.** This shell is made of iron or steel plates riveted together as shown in Fig. 1. The ends of the cylinder are closed by flat or hemispherical plates called the **heads** of the boiler. In Fig. 2 the front head is shown carrying the fittings B, C, C_1, and C_2. In this type of boiler the heads are

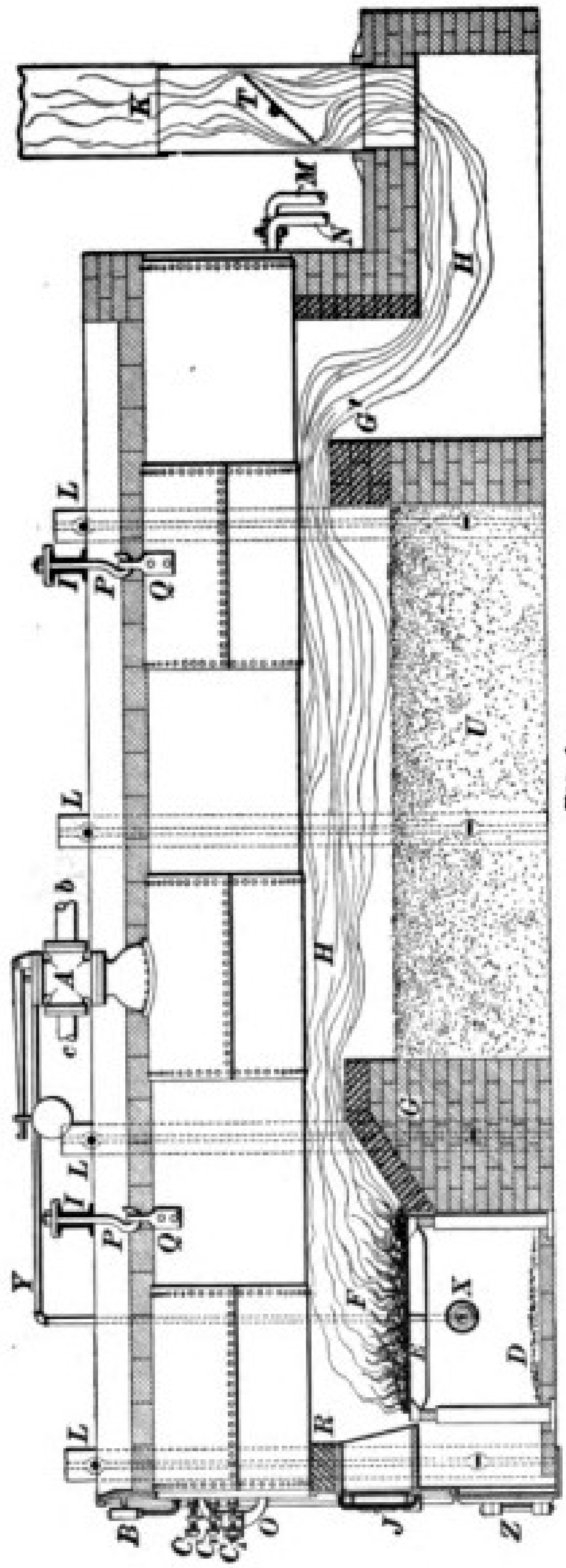

FIG. 1.

often made of thick cast iron, though wrought-iron plate may be used. The hemispherical, or dished, form of head is stronger than the flat head, and is therefore generally used for this type of boiler.

The boiler is enclosed by side walls of brick. The channel beams *I*, *I* are laid across these brick side walls, and the boiler is suspended from these beams by means of the hooks *P*, *P* and eyes *Q*, *Q* (see Figs. 1 and 3), the latter being riveted to the shell. The side walls are supported and kept from buckling by the binders, or buckstaves, *L*, *L* that are bolted together at the top and the bottom. The buckstaves are cast-iron bars of **T** section, as shown in the figure. The eyes *Q*, *Q* are placed about one-fourth 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 rear end of the shell is enclosed by the rear wall, as is shown in Fig. 1; the wall is continued back, forming the chamber *H*, into which the chimney, or stack, *K* opens. The front of the boiler, shown in Fig. 2, is of cast iron. The front end of the shell touches the firebrick lining *R*, and its weight comes upon the hooks *P*, *P*, the rear wall and firebrick lining *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 furnace door *J*

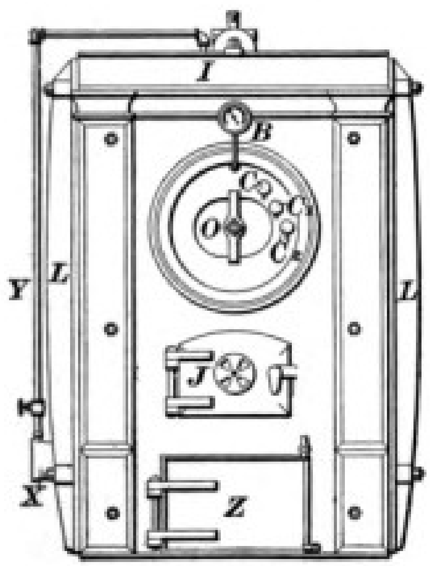

FIG. 2.

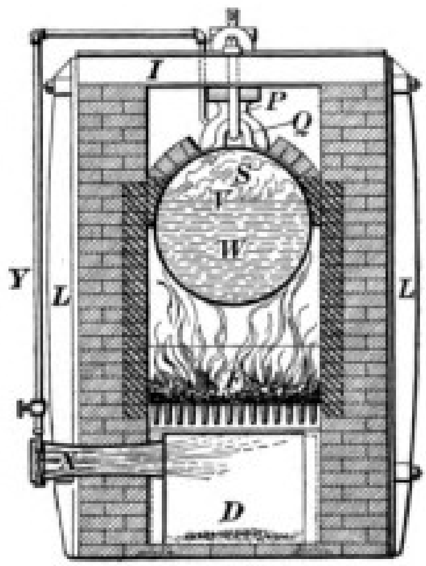

FIG. 3.

and burns upon the grate *E*, the ashes falling through the grate into the ash-pit *D*. To insure a supply of air sufficient 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 jet escapes into the ash-pit with great velocity and carries with it a quantity of air. The air thus carried in is forced through the spaces between the grate bars into the burning fuel, thus producing rapid and complete combustion.

5. Behind the furnace is built the brick wall *G*, called the **bridge.** It 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 *G'* is usually added. The gases arising from the combustion of the fuel flow over the bridges *G* and *G'* into the chamber *H* and escape through the chimney *K*. The velocity of flow of the gases, and hence the intensity of the fire, is regulated by the damper *T* that is 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 walls and rear wall, 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 this material is able to withstand a very high temperature.

It will be seen by referring to Fig. 3 that the upper portion of the boiler shell is covered with firebrick in such a manner as to prevent the hot gases coming into contact with the shell above the water-line *V*. It is a general rule in the construction and setting of fire-tube boilers that *under no circumstances should the fire-line be carried above the water-line*, for if the hot gases come in contact with the part of the boiler above the level of the water, it will become unduly heated, and thus weakened, and will be liable to rupture. In fact, a great number of boiler explosions are caused by "low water" in the boiler, in which condition the water-line is below the fire-line.

The top of the shell is covered by brickwork or some other non-conducting material to prevent radiation of heat. The boiler is filled with water through the feedpipe *N*, which leads to a pump or injector. When in operation, the water stands at about the level *V*, the space *S* above being occupied by the generated steam. The **safety valve** is shown at *A*. By means of this attachment the steam pressure is kept from rising above the desired point. The pipe *b* is the main steam pipe leading to the engine; the pipe *c* 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. The gauge is attached to a pipe that passes through the front head into the steam space.

The gauge-cocks C, C_1, and C_2 are placed in the front head of the shell; they 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 the cock C_1, while if steam escapes, the level must be below C_1.

The manhole *O* is simply a hole placed in the front head through which a man may enter and inspect or clean the boiler. The hole is closed by a plate and yoke.

To permit the boiler to be emptied, it is provided with a blow-off pipe *M*, through which the water or sediment may be discharged.

These boilers are made from 30 to 42 inches in diameter and from 20 to 40 feet long, though in rare instances they have been constructed with a diameter of 48 or more inches and a length of 60 or even 100 feet.

6. Plain cylindrical boilers are much used in mining districts, where fuel is very cheap; on account of their small water-heating surface, they are very uneconomical and hence are not generally used where fuel is expensive. The advantages of this boiler are: Cheapness of construction, strength, durability, and ease of access for cleaning and repairs.

7. The **flue boiler** differs from the plain cylindrical boiler in having one or more large flues running lengthwise through the boiler shell below the water-line.

Such a boiler is shown in elevation and section in Figs. 4, 5, and 6.

The flues *A*, *A* are fixed at the ends in the front and rear heads of the shell, respectively. The front end of the shell is prolonged, forming the **smokebox** *B*, into which opens the smokestack *C*. The front of the smokebox is provided with a door *E*. The boiler shell is also provided with the

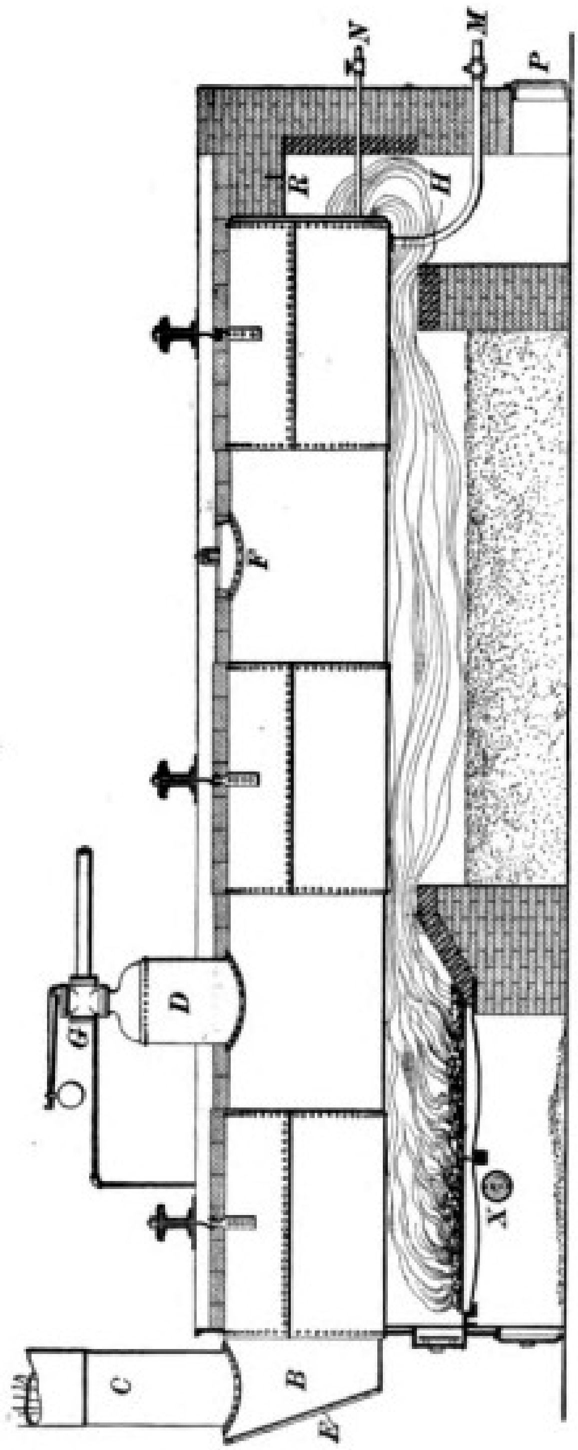

FIG. 4.

dome *D*, which forms a chamber where steam may collect and free itself from its entrained water before passing to the engine. The hot gases pass over the bridges to the chamber *H* and then back to the front end through the flues *A*, *A* into the smokebox *B*, and out through the stack *C*. It is plain that the water-heating surface is increased over that of the plain cylindrical boiler by the cylindrical surface of the flues *A*, *A*. In other particulars the description of the plain cylindrical boiler applies equally well to the flue boiler.

8. The Return-Tubular Boiler. This type of boiler is a development of the flue boiler, the two large flues of the latter being replaced by a large number of small tubes. The object of introducing the numerous tubes is to increase the heating surface of the boiler.

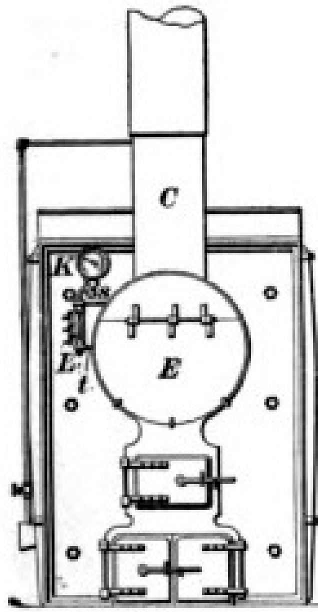

FIG. 5.

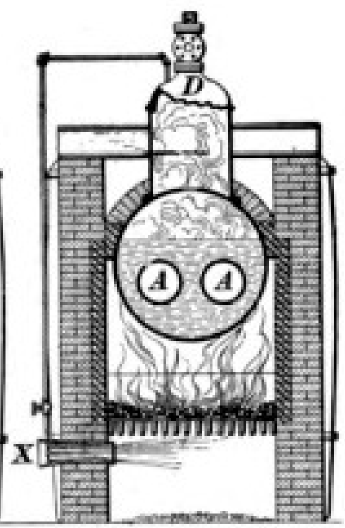

FIG. 6.

A side view of a tubular boiler is shown in Fig. 7; a cross-section through the tubes is shown in Fig. 8. The

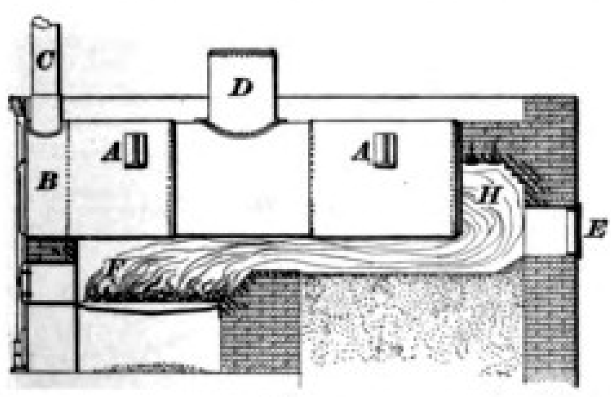

FIG. 7.

tubes extend the whole length of the shell; the ends are beaded 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*.

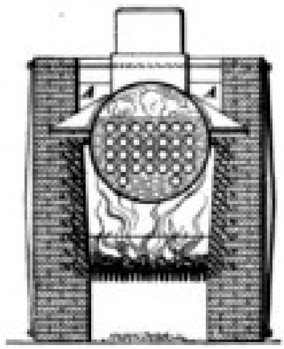

FIG. 8.

The shell is suspended on the side walls by the brackets *A*, *A*, which are riveted to the shell. The boiler is usually 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 figure. The safety valve would be placed on top of the dome, and the pressure gauge and gauge-cocks would be placed on the front. The manhole is either in one of the heads or on top of the shell. The feedpipe may enter the front head or the top, 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*.

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 back through the tubes to the smokebox *B*, and out of the stack *C*.

The return-tubular boiler is probably used in the United States more than any other. The details of its construction and setting will be shown later.

9. Cornish and Lancashire Boilers.—In the three forms of boilers considered so far, the furnace is placed outside 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*, and *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*, they then return beneath the boiler through the flue *B*, and finally 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.**

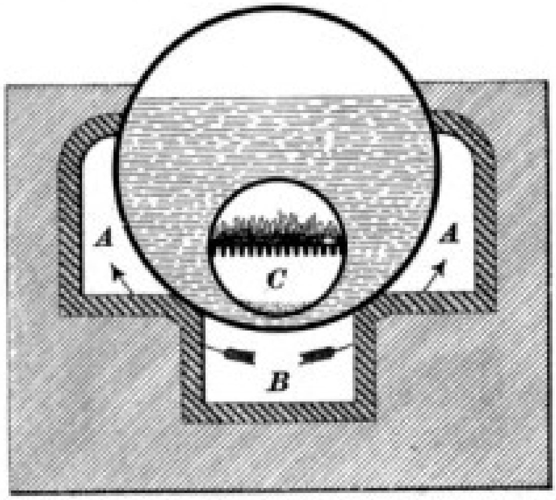

FIG. 9.

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 returned 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.

10. 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 precisely similar to that of the Cornish boiler, Fig. 9, and the split draft is formed in the same manner.

The large furnace flues of internally fired boilers, of which the Cornish and Lancashire are examples, are subjected to an external collapsing pressure equal to the pressure of the steam. The greater the diameter of the flue, the more liable it is to collapse; consequently, the Lancashire possesses an advantage over the Cornish type in this respect, since each of its two flues is necessarily of smaller diameter than the single flue of the Cornish boiler. Various measures are taken to strengthen the furnace flues of internally fired boilers. They are sometimes made corrugated; again, they are strengthened by having channel irons riveted around them. A very common method, however, is to stiffen them by transverse conical water legs, as shown in Fig. 11. The water legs not only stiffen the flue, but also provide an opportunity for the circulation of the water and split up the gases on their way through the flue, thereby providing an increased heating surface.

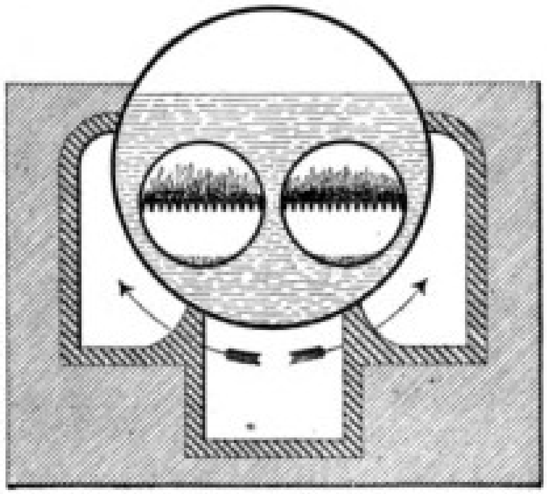

FIG. 10.

11. The **Galloway boiler** is a sort of combination of the Cornish and Lancashire types. It has two internal furnace flues fitted with grates, ashpit, etc. in the usual manner. Instead of extending through the whole length of the shell, the two flues unite just behind the bridge into one large kidney-shaped flue that 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. 10 and 11. The draft is split as previously described.

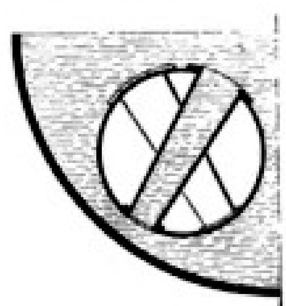

FIG. 11.

12. The Cornish, Lancashire, and Galloway boilers belong to the general class known as **internally fired** boilers. The chief objection to these three types of boilers is the liability of the internal flue to collapse and the straining actions set up by the expansion and contraction of the flue. The chief point in favor of these boilers 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.

The three types of boilers just described are extremely popular in England and on the continent of Europe, but they are little used in America.

13. The Clyde Boiler.—A stationary boiler combining the features of the Lancashire and multitubular types is shown in Fig. 12. In consists of a large cylindrical shell *a*, the ends of which are closed by the flat heads *b*, *b*. A large furnace flue *c* of the corrugated type, known technically as the **Morison suspension furnace flue,** extends clear through the boiler and is securely riveted to the two heads, which are flanged inwards for this purpose. Above and beside the furnace flue and parallel thereto and below the water-line is a nest of tubes *d* that extend from head to head. The front ends of these tubes open into a smokebox *e* that connects with the chimney or stack *f*. The flat heads are stayed by through stayrods *g*, *g* in the steam space, which prevent deflection of the heads. The remaining parts of the flat heads are supported by the tubes, which are expanded and beaded over, and by the furnace flue.

The furnace is placed within the furnace flue and, as usual, consists of the grate *h*, the ash-pit *i*, and the bridge *k*. The gases of combustion flow to the rear into the combustion chamber *l* and then pass through the tubes to the front and into the smokebox. The combustion chamber is formed by a thin cylindrical shell attached to the rear end of the

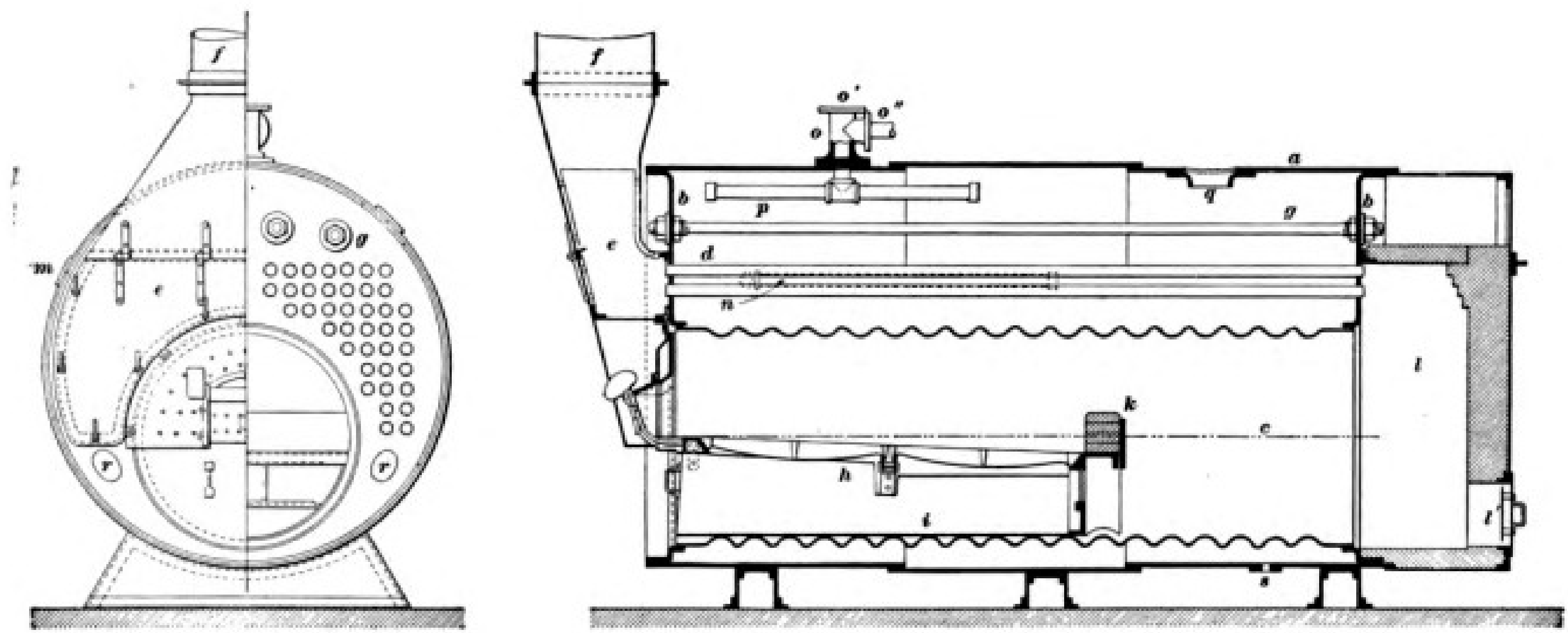

Fig. 12.

boiler, and is lined with firebrick, as shown. A door *l'* gives access to the combustion chamber for the removal of ashes and soot and for the purpose of examination and repair. This type of boiler evidently gives a very large amount of heating surface in proportion to the space it occupies.

The feedwater enters the boiler at *m* and, passing through the internal perforated feedpipe *n*, is discharged downwards alongside the shell in small streams. The various fittings are not shown in the illustration. The steam gauge and water column would naturally be located close to the front end of the boiler; the safety valve is intended to be bolted to the outlet *o'* and the steam pipe to the outlet *o''* of the nozzle *o*. The steam is collected by the dry pipe *p*, which is perforated with numerous slots on top. The dry pipe is fairly effective in freeing the steam from any water that may be mixed with it. The manhole is at *q* and two handholes at *r*. The blow-off is attached at *s*. The boiler is entirely self-contained, i. e., it does not require any brickwork setting. It is simply bolted to three saddles that rest upon and are fastened to a suitable foundation.

A boiler of the kind just illustrated resembles the Scotch boiler used in marine work, and differs from it only in the fact that the combustion chamber is not surrounded by water. For this reason it is often called a **dry-back Scotch boiler,** although some engineers refer to it as the **Clyde** boiler, presumably because this type was originally designed in the shipyards of the Clyde, England.

14. The Locomotive, or Firebox, Boiler.—Next to the multitubular type, the firebox boiler is probably used more than any other type. It is used exclusively in railway service and also largely as a stationary boiler. A large proportion of the small portable combined engines and boilers used for agricultural purposes are of this type. The general construction is shown in Fig. 13. The shell is composed of two differently shaped parts riveted together. The front part of the shell is cylindrical; the rear part is usually of a rectangular cross-section with vertical sides or of a trapezoidal section with inclined sides; in either case the top is semicylindrical. The furnace *F* is a box of the same shape as the rear end of the shell in which it is placed. A space is left between the sides and end of the furnace and the shell; this space is filled with water, as shown at *A*, *A*. A series of tubes extends from the front sheet of the furnace, or firebox, to the front head of the shell. The shell is prolonged beyond the front head, forming a smokebox *B*, into which opens the stack *C*.

As shown in this figure, the "water legs" (as the spaces *A*, *A* are called) extend only as far as the grate, the ash-pit *D* being formed in the brick setting. In many boilers of

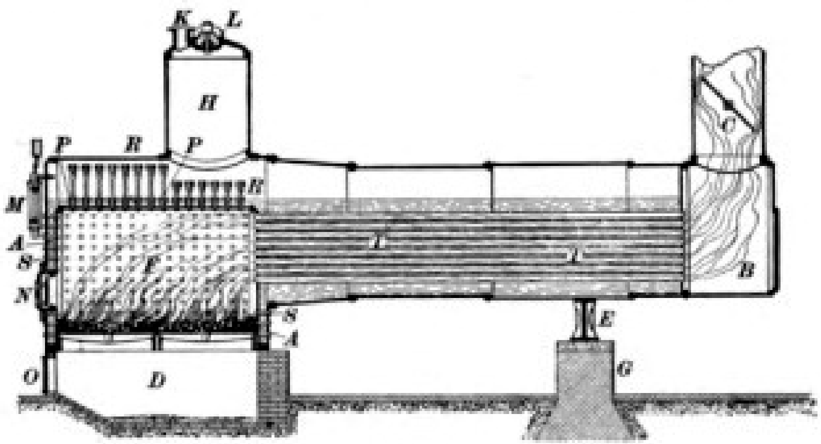

FIG. 13.

this type the water legs extend to the bottom of the ash-pit, and sometimes there is a water space below the ash-pit; that is, the furnace and ash-pit are entirely surrounded by water and no brickwork setting is required.

The boiler is supported at the front end by the cast-iron cradle *E* that rests upon the masonry foundation *G*. The rear end is supported upon a brick wall, which also forms the ash-pit. The boiler is usually provided with a dome *H*, from which is led the main steam pipe, which is bolted on at *K*. In the figure, the dome is provided with a manhole *L*. The feedwater may be introduced at any convenient point in the shell. The pressure gauge, water glass, and gauge-cocks are attached to the column *M*, which is placed in communication with the interior of the shell. The furnace and ash-pit doors are shown at *N* and *O*, respectively. The safety valve is usually attached to the dome.

Since the flat sides of the furnace and shell are liable to bulge on account of the pressure, they must be braced or stayed. This is accomplished by the staybolts *S*, *S*. The flat top of the firebox is strengthened by a series of parallel girders *P*, *P*. As an additional security, the girders are sometimes attached to the shell by the "sling stays" *R*, *R*.

The gases of combustion pass directly from the furnace through the tubes *T*, *T* to the smokebox *B* and out of the stack *C*. In locomotives, a strong draft is obtained by allowing the exhaust steam to discharge through the smokestack. The escaping steam carries along the air and the escaping gases in the smokebox *B*, thereby drawing a new supply of gases through the tubes *T*, *T* and a supply of air through the grate.

The tubes of the locomotive boiler are about 12 feet long, 2 inches in diameter, and are made of iron or steel. The tubes of stationary and portable boilers of this type are generally of larger diameter, as there is less demand for great quantities of steam.

The locomotive type of boiler evidently is self-contained.

15. The Vertical Boiler.—This type is essentially a modification of the locomotive type placed on end. A common form of vertical boiler is shown in Fig. 14. It consists of a vertical cylindrical shell, in the lower end of which is placed a firebox *F*. The lower rim of the firebox and the lower end of the shell are separated by a wrought-iron ring *k*, to which both are riveted, the rivets going through both plates and ring. The shell and firebox are also stayed together by the staybolts *a*, *a*. The space between the two is filled with water, so that the firebox is surrounded by it. The boiler shell and likewise the grate *E* rest upon a cast-iron base *D* that forms the ash-pit. A series of vertical tubes *t*, *t* extend from the top sheet of the firebox to the upper head of the shell. The tubes serve as stayrods and strengthen the flat surfaces that they connect. The upper ends of the tubes open directly into the chimney or smokestack *K*. The gases from the furnace thus pass directly through the tubes and out of the stack.

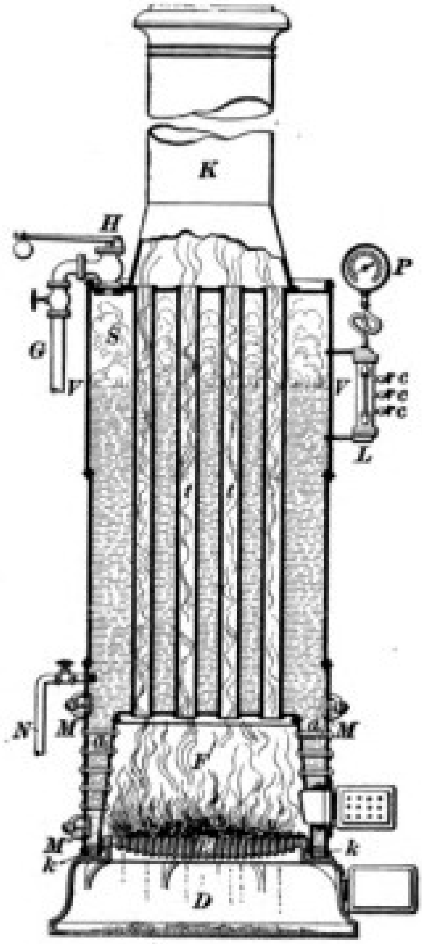

FIG. 14.

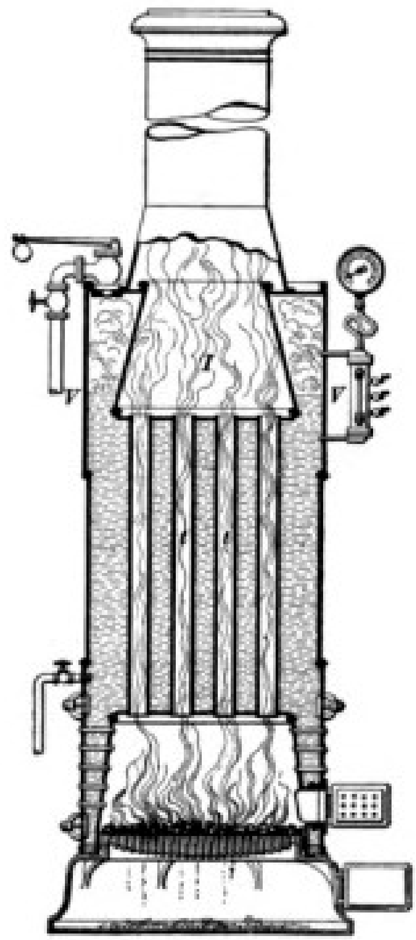

FIG. 15.

The safety valve is shown at *H*, with the main steam pipe *G* leading from it. The pressure gauge *P* and gauge-cocks *c*, *c*, *c* are attached to a column *L* that communicates in the usual manner with the interior of the shell. The construction of this type of boiler does not generally permit the use of manholes, but handholes *M*, *M* are placed in convenient positions for cleaning out mud and sediment.

16. When the tubes extend through the upper head of the boiler, as shown in Fig. 14, their upper ends pass through the steam space *S* above the water-line *V V*. This is looked upon as a bad feature, since the tubes are liable to become overheated and thus collapse when the boiler is forced.

In the form of vertical boiler shown in Fig. 15, this danger is avoided. A chamber, or smokebox, *I* extends from the upper head of the shell so that its bottom plate is always below the water-line. The upper ends of the tubes *t*, *t* are expanded into the lower plate of this chamber, and therefore the tubes are always surrounded by water from end to end. A vertical boiler constructed in this manner is said to have a **submerged head.** Aside from the submerged head, the construction of the boiler of Fig. 15 is similar to that of Fig. 14.

Vertical boilers are generally wasteful of fuel and are perhaps more liable to explosion than any other type. They are, however, self-contained, require but little floor space, and are easy to construct and repair. For these reasons the vertical type of boiler is very popular with a large class of steam users.

17. The tubular boilers so far described belong to a general class known as **fire-tube boilers,** and any boiler in which the flames and gases of combustion traverse the *inside* of the tube or flue belongs to this class.

WATER-TUBE AND SECTIONAL BOILERS.

18. Of late years, a type of boiler has come into extensive use in which the flames and gases of combustion are in contact with the *outside* of the tubes. The water is contained inside the tubes; hence, these boilers are known as **water-tube boilers.** Some of the leading types of water-tube boilers are described in the following articles.

19. The **Babcock and Wilcox water-tube boiler** is shown in Fig. 16. It consists essentially of a main horizontal drum *B* and of a series of inclined tubes *T*, *T*. (Only a single vertical row of tubes is shown by the figure, but it will be understood that each nest of tubes is composed of several vertical rows.) There are usually seven or eight of these vertical rows to each horizontal drum. The front ends of the tubes of a vertical row are all expanded into a hollow **header** *H*. The rear ends are expanded into a similar header, and the front and rear headers are placed in

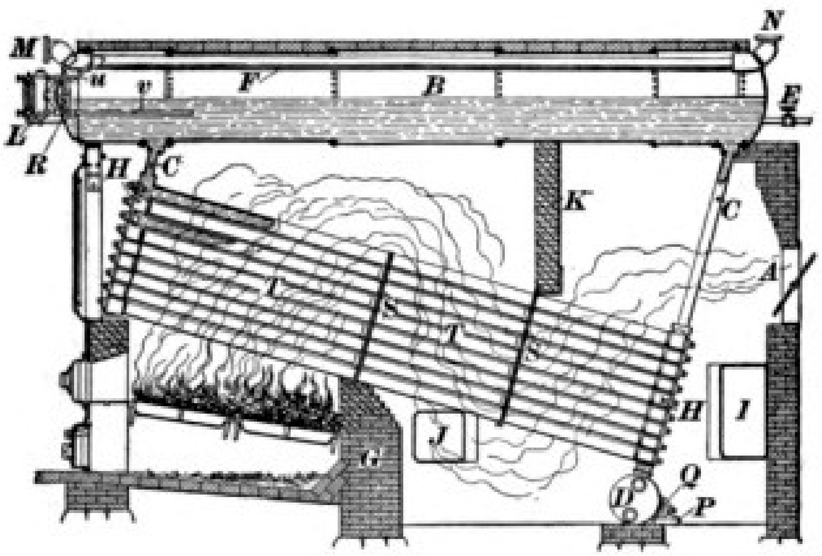

FIG. 16.

communication with the drum by tubes, or **risers**, *C* and *C*, respectively. In front of each tube, a handhole is placed in the header for the purpose of cleaning, inspecting, or removing the tubes.

The method of supporting the boiler is not shown in the figure. The usual method is to hang the boiler 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.

20. 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 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 of the 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* and *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 that communicates with the interior of the shell by the small pipes *u* and *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. This sediment may be blown out from time to time through the blow-off pipe *P*. The drum *D* is provided with a handhole *Q*. 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* and *J*.

21. 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 upon being heated, and is also partially 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. Most of the sediment sinks to the mud drum *D*, from which it is blown out from time to time.

22. The **Root water-tube boiler** is shown in Figs. 17 and 18, the latter being an end view with the brickwork removed so as to show the various drums and connections. The construction of this boiler is very similar to that of the one just described. There is a nest of inclined tubes, the ends of which are expanded into cast-iron headers. The headers are placed in communication by the **U**-shaped return

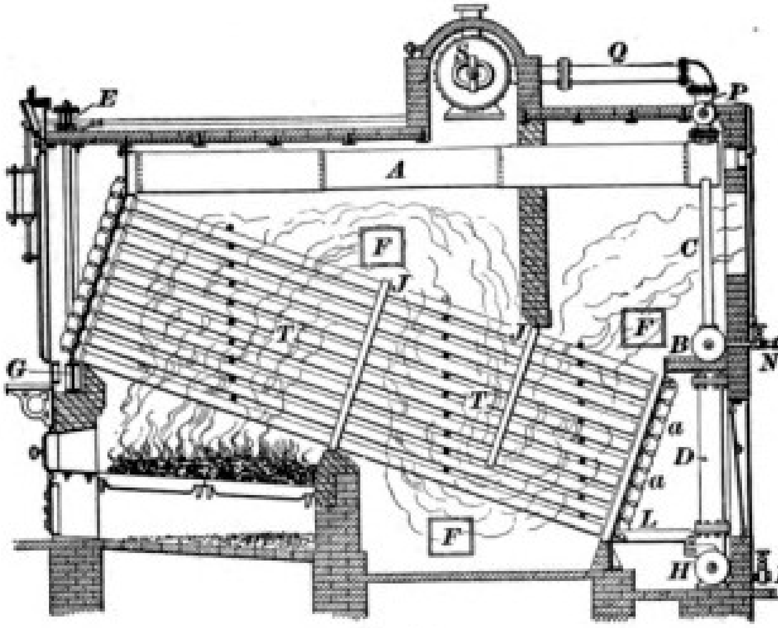

FIG. 17.

bends *a*, *a*. A continuous channel is therefore provided for the circulation of the water through the headers. There is a horizontal overhead drum *A* for each vertical section of tubes. These drums *A*, *A* are placed in communication with the transverse drum *B* by the tubes *C*, *C*. The drum *B* is in turn connected with the lower drum *H* by the two large water legs *D*, *D*. Finally the drum *H* communicates with the rear headers through the tubes *L*, *L*. There is thus an open circuit through the tubes *T*, drum *A*, tubes *C*, drum *B*, water legs *D*, drum *H*, and tubes *L*. The water-line is at about the middle of the drums *A*, *A*, and the steam arising from the surface of the water first passes into the drum *P* and then into the main steam drum *S* through the pipes *Q*, *Q*. The main steam pipe, the safety valve, and other fittings may be attached to the drum *S* at the nozzles *U*, *V*, and *W*.

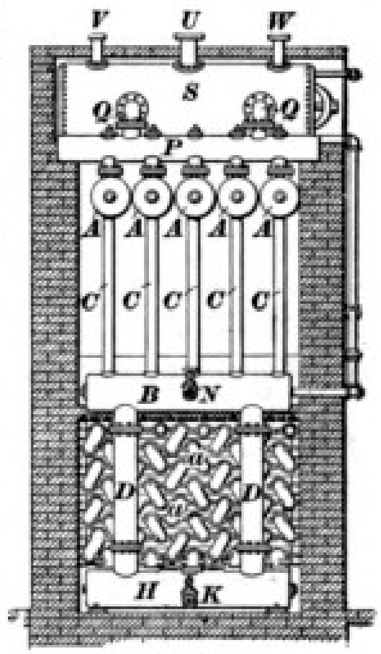

FIG. 18.

The feedwater is introduced into the drum *B* through the feed-pipe *N*. The circulation takes place in the same manner as in the boiler previously described. The drum *H* acts as the mud drum, being at the lowest point of the water circuit. The sediment may be blown out through the pipe *K*.

Access may be had to the interior of the setting through the doors *F*, *F*. The steam drum is provided with a manhole. The rear end of the boiler is supported by the brickwork foundation; the front end is supported by a beam *G* hung from the **I** beam *E*.

The arrangement of the bridge and baffle plates *J*, *J* and the course of the heated gases are precisely the same as in the Babcock and Wilcox boiler.

23. The **Heine water-tube boiler,** shown in Fig. 19, differs in many respects from those already described. It consists of a large main drum *A* that is above and parallel with the nest of tubes *T*, *T*. Both drum and tubes are inclined at an angle with the horizontal that brings the water level to about one-third the height of the drum in front and about two-thirds the height in the rear. The ends of the tubes are expanded into the large wrought-iron water legs *B*, *B*. These legs are flanged and riveted to the shell, which is cut out for about one-fourth its circumference to receive them, the opening being from 60 to 90 per cent. of the 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 (shown at *F*) that may move freely on a cast-iron plate bedded in the rear wall. These rollers allow the boiler to expand freely when heated.

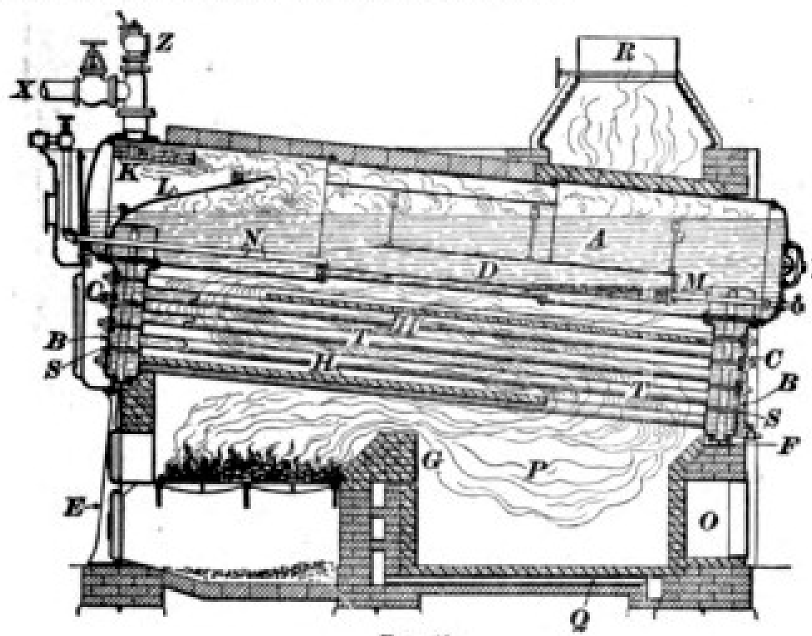

FIG. 19.

The boiler is enclosed by a brickwork setting in the usual manner. The bridge *G*, made largely of firebrick, is hollow, 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, of course, heated in passing through the bridge. In the rear wall is the arched opening *O* that is closed by a door and is further protected by a thin wall of firebrick.

When it is necessary to enter the chamber *P*, the wall may be removed 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 is useful in precipitating the impurities contained in the feedwater, which settle in the mud drum *D* and may then be blown out through the blow-off pipe *M*.

Layers of firebrick *H*, *H* are laid at intervals along the rows of tubes and act as baffle plates, forcing the furnace gases to pass back and forth around the tubes. The gases finally escape through the chimney *R* placed above the rear end of the boiler. To protect the steam space of the drum from the action of the hot gases, the drum in the vicinity of the chimney is protected by firebrick, as shown in the figure.

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 spurting 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 staybolts *S*, *S*, which are made hollow so as to give access to the outside of the tubes. In front of each tube is placed a handhole *C* that gives access to the interior of the tubes.

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*, *A*.

24. The **Stirling boiler,** shown in Fig. 20, 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 connected by 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 that 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 vertical tubes. An arch *D* is built above the furnace, and this, in

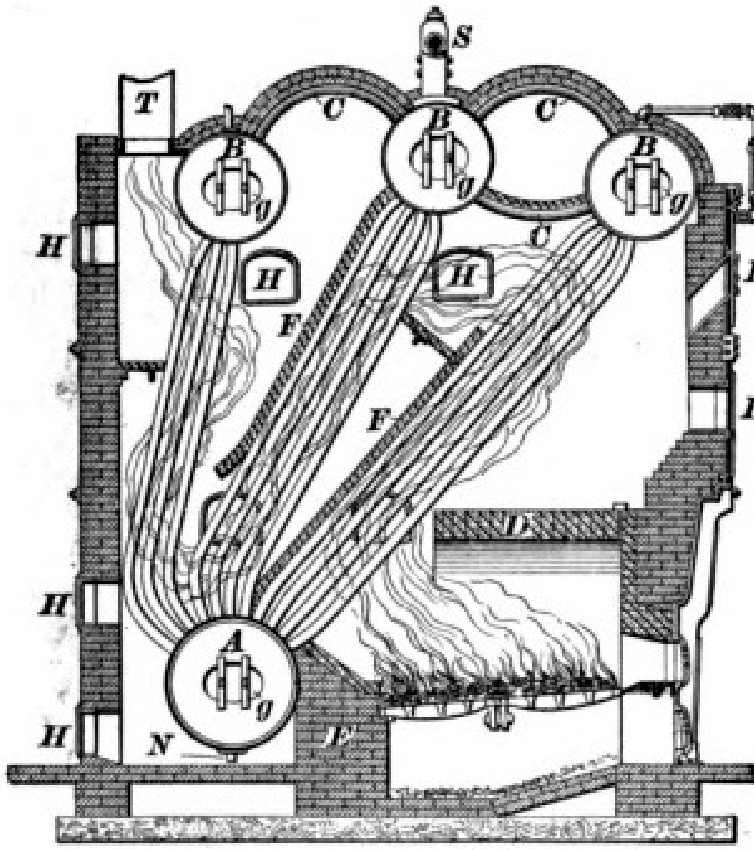

FIG. 20.

connection with the bafflers *F*, *F*, directs the course of the heated gases, causing them to pass up and down between the tubes. The arch and bafflers are made of firebrick.

The cold feedwater enters the rear upper drum and descends through the rear nest of tubes to the drum *A*, which acts as a mud drum and collects the sediment brought in by the water. A blow-off pipe *N* permits the removal of the sediment. The steam collects in the 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 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 *g*.

25. The **Hazelton** or **porcupine boiler,** shown in Fig. 21, is a vertical water-tube boiler of peculiar form. As shown in the figure, it consists of an upright cylinder *A*, into which are expanded a large number of radial tubes *B*, *B*, whose outer ends are closed, while the inner ends open into the cylinder *A*. The boiler is enclosed in a circular brickwork wall, on top of which is placed the chimney *H*, which is provided with a damper for regulating the draft. Below the tubes the wall is lined with firebrick and projects inwards, forming the furnace *E*. There are several fire-doors spaced equidistant around the circumference, one of which is shown at *K*. The grate *G* forms a ring between the central cylinder and the external brick wall. The space below the grate serves as the ash-pit. The water is

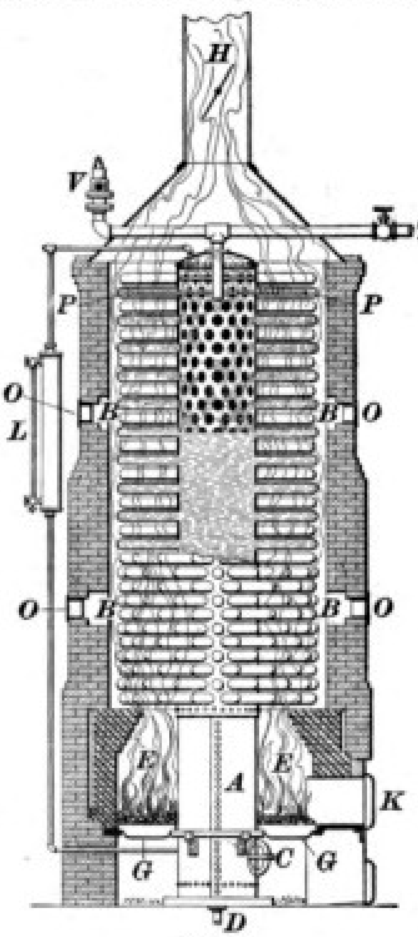

FIG. 21.

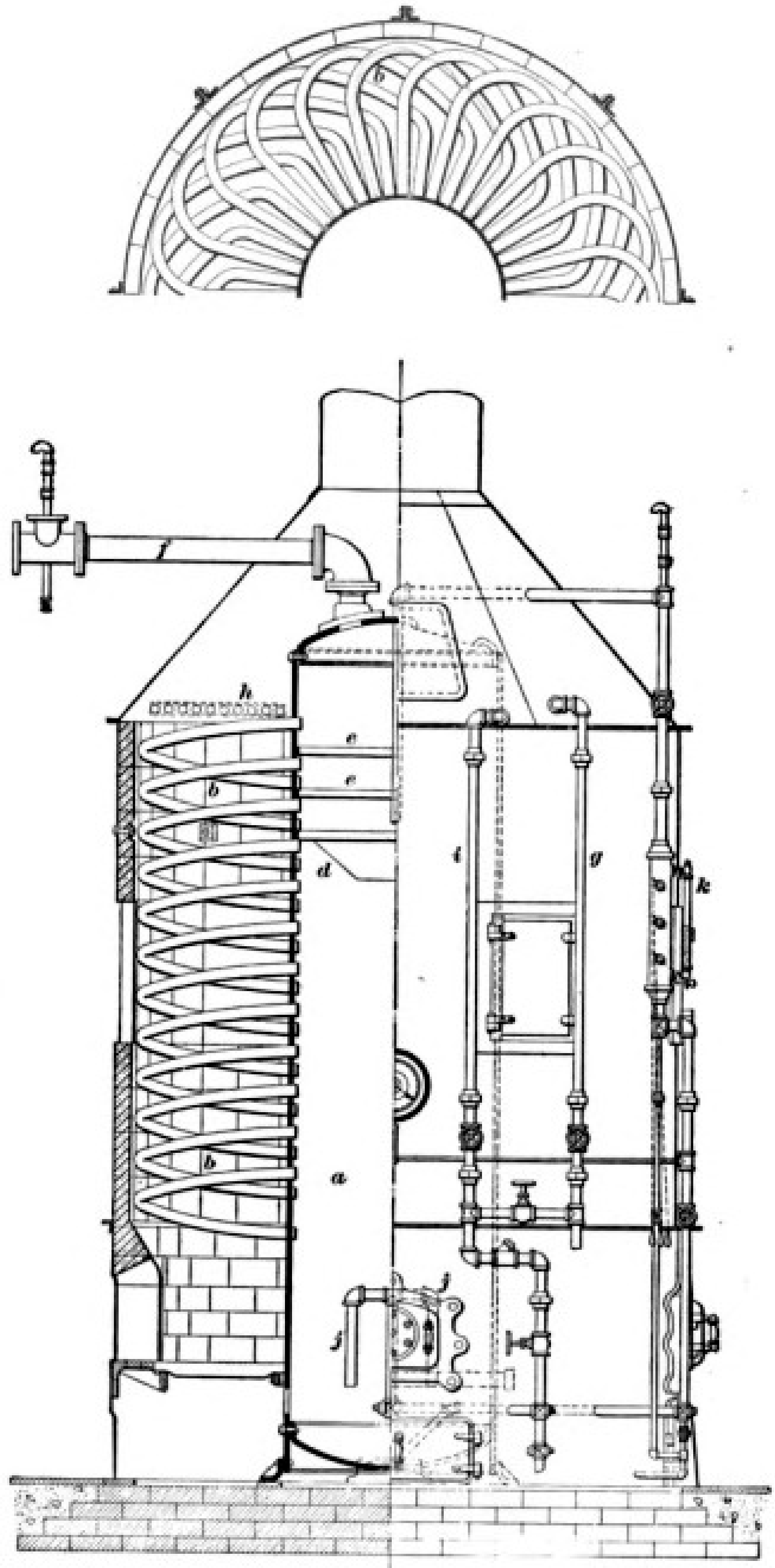

FIG. 22.

contained in the cylinder and tubes. The sediment naturally collects in the bottom of the cylinder and is blown out through the pipe *D* or removed through the manhole *C*. The steam is collected in the perforated dry pipe *P* and led to the main steam pipe *T*. The safety valve is shown at *V* and the water column at *L*. The openings *O*, *O* are left in the wall so that the interior may be inspected.

The heated gases pass from the furnace *E* between the tubes *B*, *B*, and by the time they have reached the chimney, the heat has been mostly absorbed by the water in the tubes.

This boiler does not require to be suspended in any way; the whole weight rests upon the foundation, which may be built in the ground.

26. The **Morrin "Climax"** boiler, shown in Fig. 22, is a water-tube boiler that somewhat resembles the porcupine boiler, and differs from it chiefly in that instead of radial tubes the standpipe or main shell *a* is fitted with a large number of loop-like tubes *b*, *b*, the ends of which are expanded into the shell. The furnace is circular, as in the porcupine boiler, and in order to give free access to the fire, four furnace doors are provided. A deflector plate *d* is fitted to the shell a little above the water level, which tends to throw back any water carried up by the steam. The upper portion of the central shell is divided by a series of diaphragms *e*, *e* into a series of superheating chambers, through which the steam is compelled to circulate successively by the connecting loop-like tubes. The steam thus becomes thoroughly dried and somewhat superheated before it enters the main steam pipe *f*. The feedwater coming from the pump is discharged through the delivery pipe *g* into a spiral feed-coil *h* resting on top of the tubes, where it is heated to a high temperature. It leaves the coil through the pipe *i* and passes downwards, finally being discharged into the bottom of the shell through the internal feedpipes *j*, *j*. The water column *k* is connected to the top and bottom of the central shell. The safety valve is attached to a **T** placed in the main steam pipe close to the boiler.

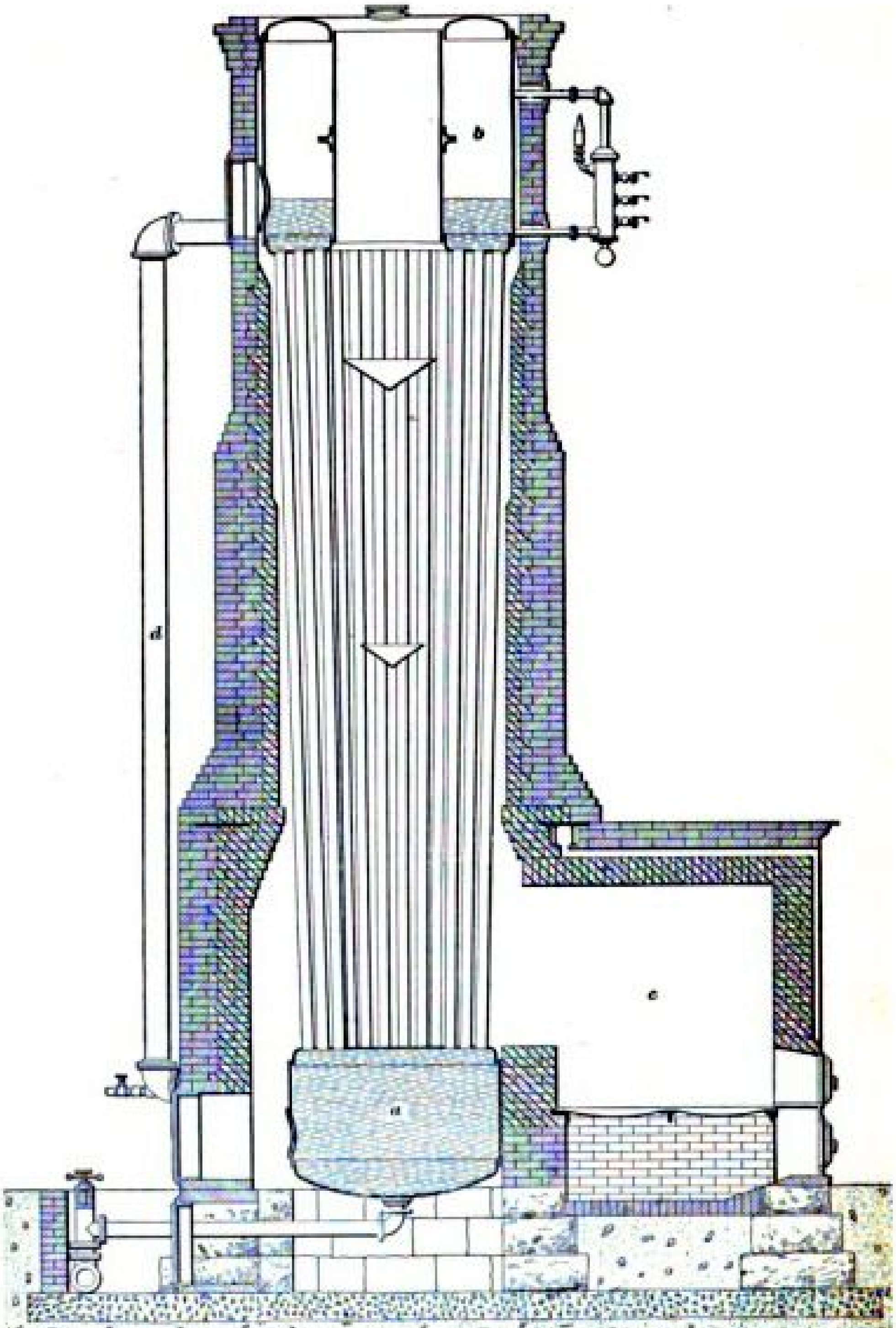

FIG. 21.

27. The **Cahall** boiler may aptly be called a **vertical** water-tube boiler. As a reference to Fig. 23 will show, it consists of a cylindrical mud drum *a* and steam drum *b*, which are connected by nearly vertical tubes. The furnace *c* is placed to one side of the boiler, and the gases of combustion surround the tubes and finally pass through a central passage in the steam drum to the smokestack. The steam becomes slightly superheated in this steam drum, through coming in contact with the surface of the central passage, which is kept at a fairly high temperature by the escaping gases. The steam drum and mud drum are connected by an external circulating pipe *d* that enters the steam drum some distance below the water-line. The feedwater enters the mud drum and, becoming highly heated, rises through the vertical tubes to the steam drum, where the steam bubbles are liberated. Some of the water in the lower part of the steam drum flows continually into the circulating pipe, and since this pipe is not exposed to the heat of the fire, the density of the water in it is much greater than the density of the water in the vertical boiler tubes. In consequence, the water is continually flowing downwards and a rapid circulation is promoted.

28. The **Harrison safety boiler,** shown in Fig. 24, is a sectional safety boiler, but not of the water-tube type. It is composed of hollow cast-iron or steel sections *A*, *A*, called **units,** that are accurately faced and bolted together. Each section is composed of two or more approximately spherical vessels, and the sections are bolted together in a zigzag manner, as shown in the figure, so as to form a solid slab. Each bolt runs from top to bottom through all the units, as shown at *C*. There are several of these vertical slabs of sections suspended side by side from the girders *B*, *B*.

The boiler is enclosed by a brickwork setting that is lined with firebrick. The top of the boiler is likewise covered with firebrick to prevent radiation. The wall is pierced with the openings *D*, *D* for the purpose of inspecting the interior. The bridge *G* and bafflers *H*, *H* direct the hot gases back and forth between the sections.

The feedwater enters the boiler at its lowest point through the feedpipe *N*. The steam pipe is bolted on at the flange *J*. The water column *L*, placed in front at the height of the water level, is connected by pipes with the steam and water spaces, respectively.

The chimney flue is placed at the rear near the floor; the draft is regulated by the damper *T*.

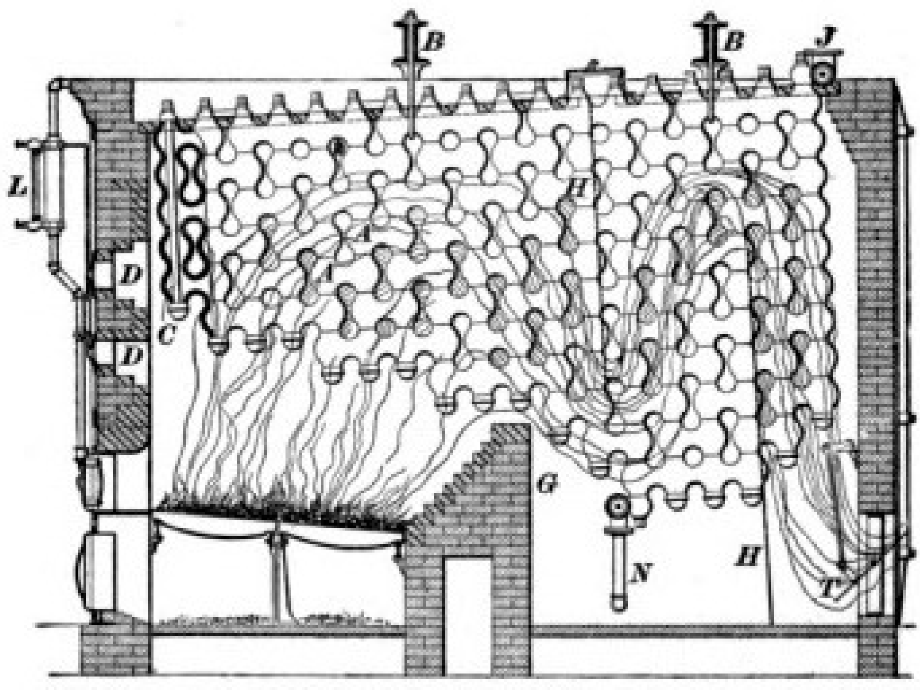

FIG. 24.

The boiler is essentially a safety boiler. If the steam pressure becomes excessive, the bolts *C* will elongate a little and allow steam to escape through the joints. Even if the pressure should be sufficient to burst a unit, there would be no disastrous explosion, and it would be only necessary to replace the unit.