No. 632,708. Patented Sept. 12, 1899.

M. N. FORNEY.

FEED WATER HEATER FOR STEAM BOILERS.

(Application filed Jan. 3, 1899.)

(No Model.) 4 Sheets—Sheet 1.

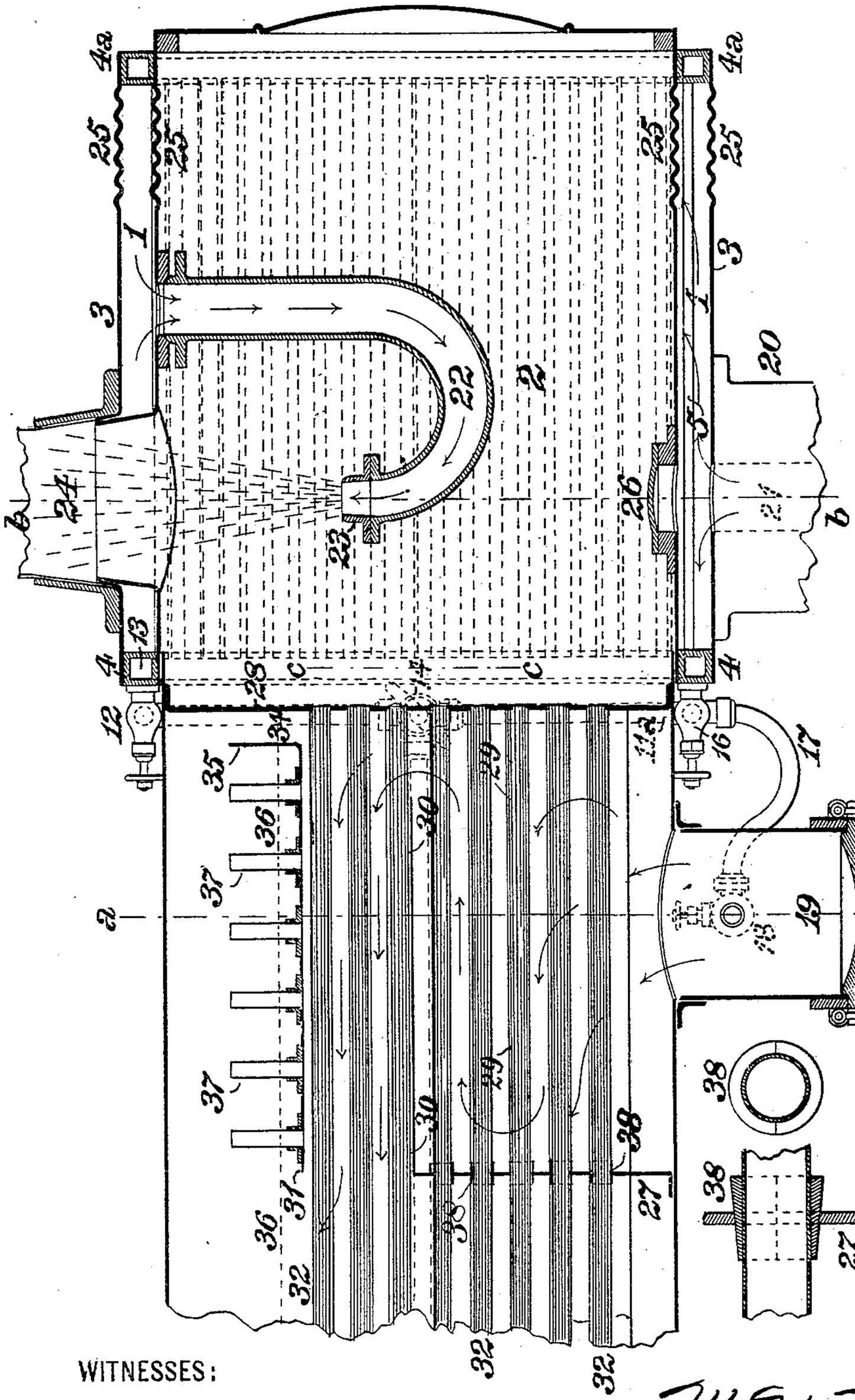

FIG. 1.

FIG. 2. FIG. 2a.

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(No Model.) 4 Sheets—Sheet 2.

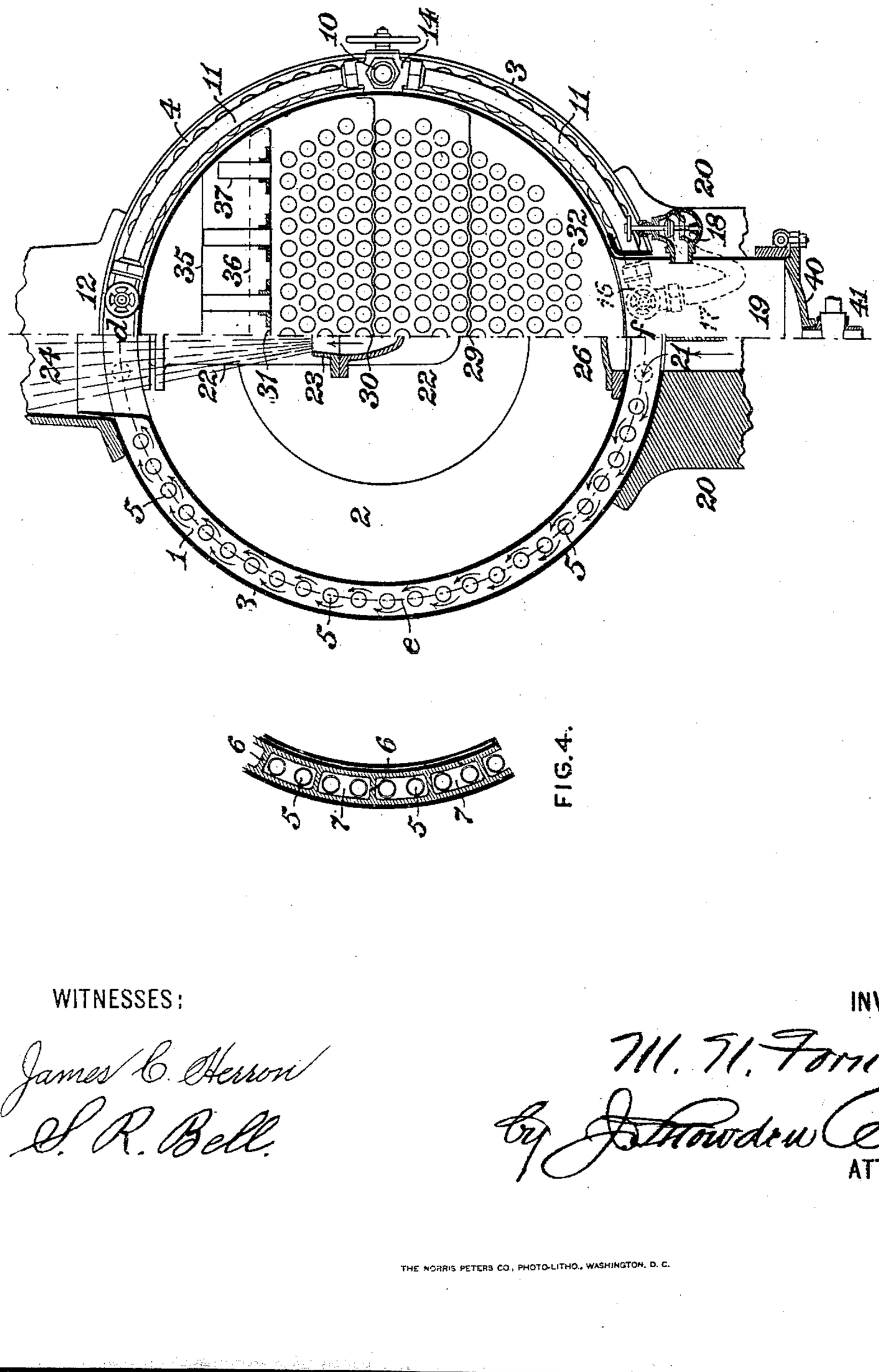

FIG. 3.

FIG. 4.

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(Application filed Jan. 3, 1899.)

(No Model.) 4 Sheets—Sheet 3.

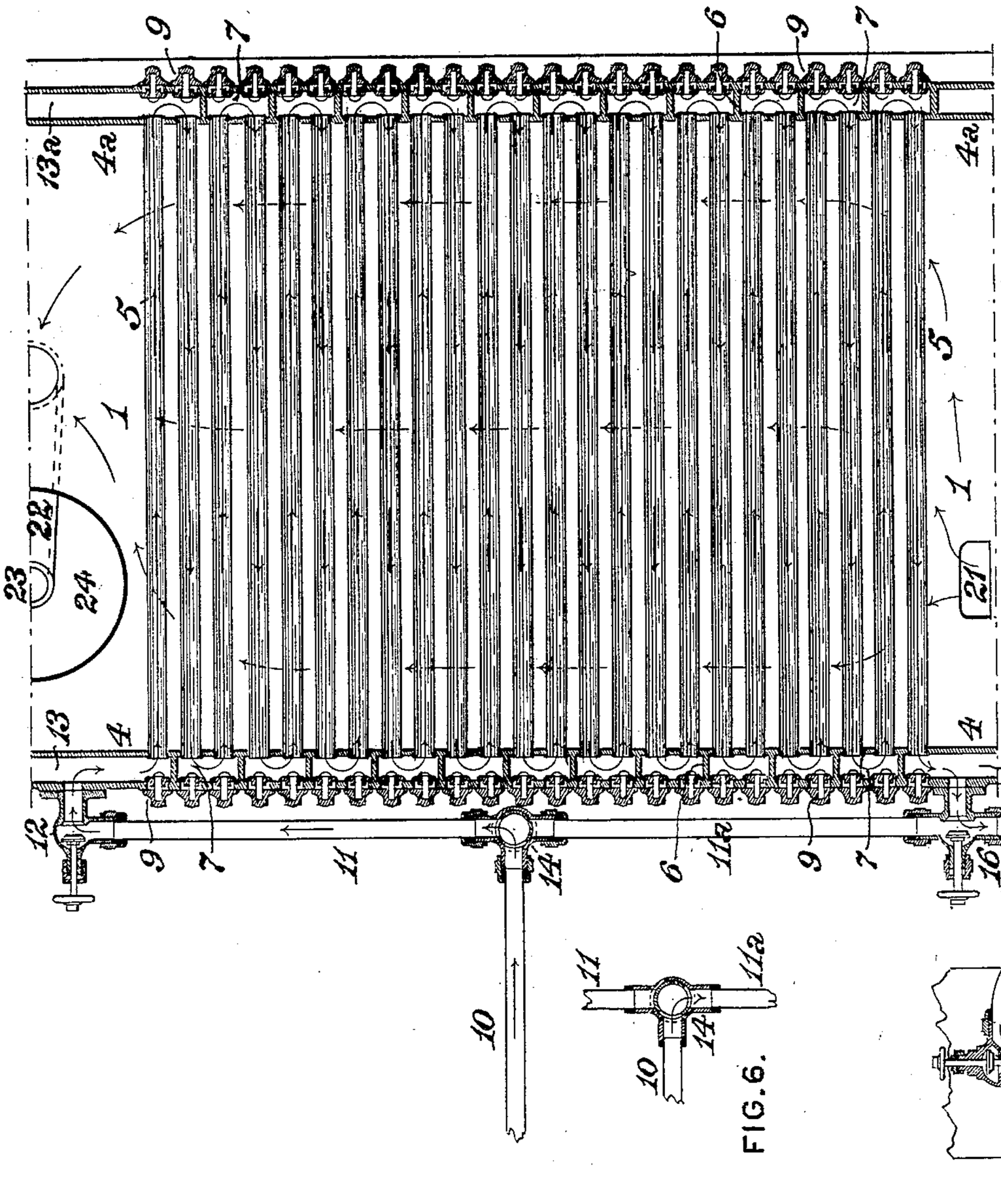

FIG. 5.

FIG. 6.

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FEED WATER HEATER FOR STEAM BOILERS.

(Application filed Jan. 3, 1899.)

(No Model.) 4 Sheets—Sheet 4.

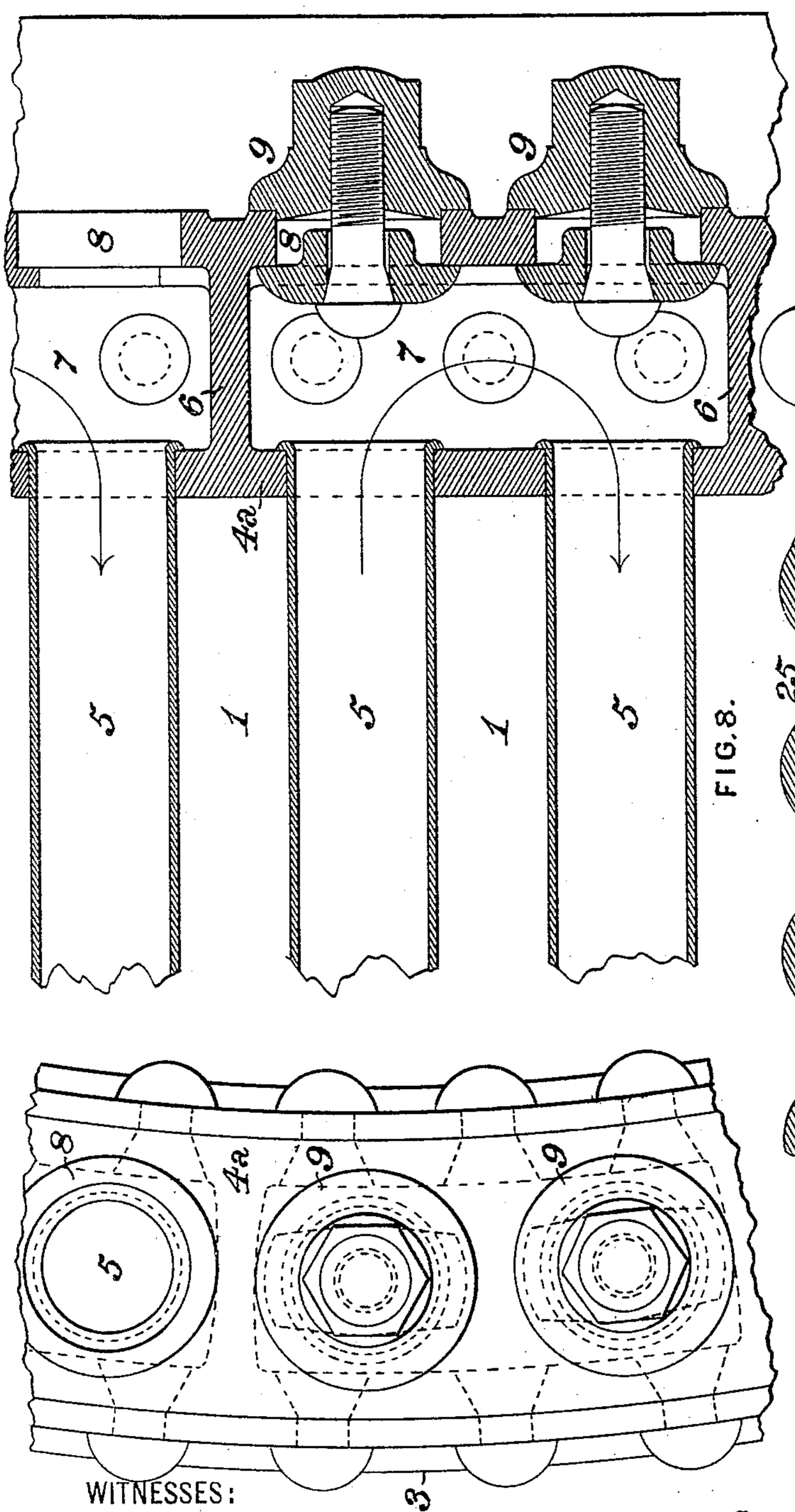

FIG. 8.

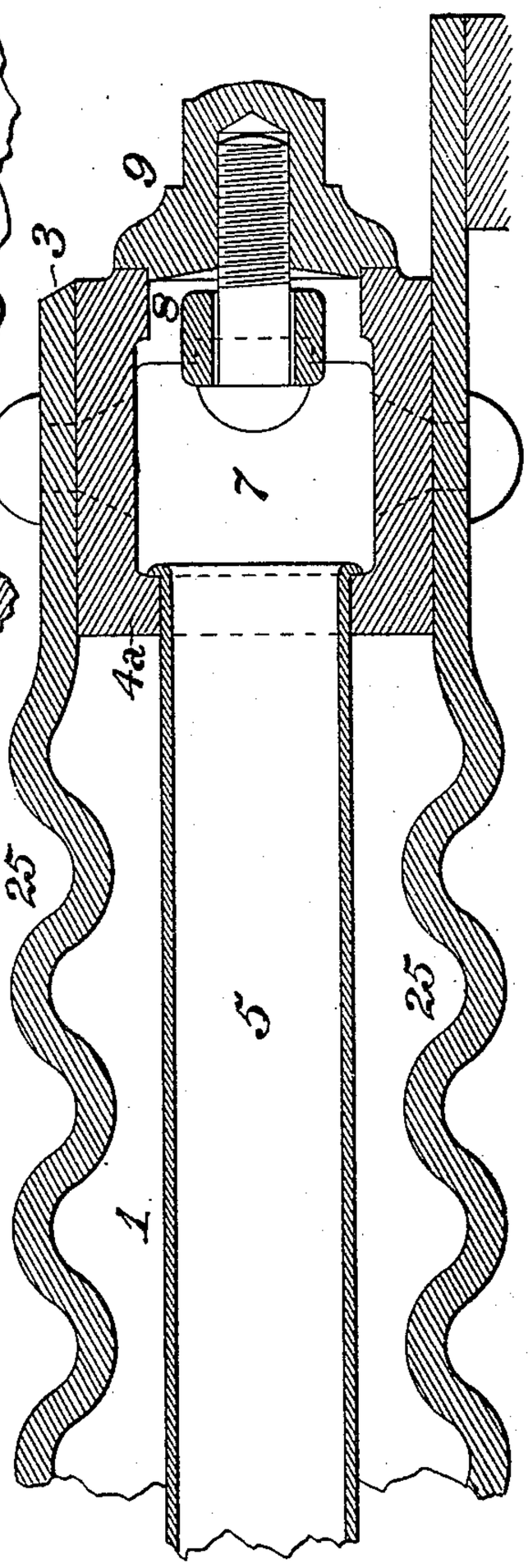

FIG. 7.

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UNITED STATES PATENT OFFICE.

MATTHIAS N. FORNEY, OF NEW YORK, N. Y.

FEED-WATER HEATER FOR STEAM-BOILERS.

SPECIFICATION forming part of Letters Patent No. 632,708, dated September 12, 1899.

Application filed January 3, 1899. Serial No. 701,084. (No model.)

To all whom it may concern:

Be it known that I, MATTHIAS N. FORNEY, of the borough of Manhattan, city and State of New York, have invented a certain new and useful Improvement in Feed-Water Heaters for Steam-Boilers, of which improvement the following is a specification.

My present invention relates more particularly to feed-water heaters for steam-boilers of the locomotive type; but it is also applicable to boilers of other forms. Its objects are to provide means whereby the exhaust-steam after it escapes from the cylinders will impart a portion of its heat to the feed-water before the feed-water enters the boiler and also means whereby a portion of the heat from the products of combustion which ordinarily escapes from the boiler-tubes and passes out of the chimney will be communicated to the feed-water after it enters the boiler; also, to provide means which will permit of a difference in the extension or contraction of the tubes in which the water is heated and of the inclosure in which they are contained; also, to provide means by which the feed-water can be shut off from the exhaust-steam heater and fed directly into the boiler in case of accident or failure of the heater.

To these ends my invention consists of certain novel devices and combinations comprising an annular space formed around the smoke-box of a steam-boiler by double peripheral plates, a series of heating-tubes disposed throughout said annular space and connected at each end to what may be termed "headers," which form the inclosed ends of the annular space and which are divided into compartments or cells, to each of which the ends of two heating-tubes are connected, openings and suitable removable covering-plates in the headers opposite the ends of the heating-tubes and communicating with the cells and the tubes, valves which are attached to the headers and to which the feed-pipe is connected, a three-way cock or valve for changing the connection of the feed-pipe to and from the heater and to and from the boiler, corrugated peripheral plates forming the sides or shell of the space containing the heating-tubes, diaphragms or plates in the front end of the boiler, which retain the feed-water when it first enters it in contact with the front ends—that is, the ends from which the smoke escapes—of the tubes and promote the circulation about them, tapered thimbles on the tubes, by which they are secured to one or more of the diaphragms, openings in the top diaphragm communicating with the steam-space to permit of the escape of any steam generated from the feed-water, and a mud-drum in connection with the heater for collecting and depositing sediment from the heated feed-water.

The improvement claimed is hereinafter fully set forth.

In the accompanying drawings, Figure 1 is a longitudinal section of the front end of a locomotive-boiler, showing the smoke-box and the front part of the boiler-shell and fire-tubes and illustrating an embodiment of my invention; Fig. 2, a longitudinal section, on an enlarged scale, through part of a tube, diaphragm, and thimble; Fig. 2ª, a transverse section through the tube shown in Fig. 2; Fig. 3, a transverse section, the right-hand half being taken on the line *a a* of Fig. 1 and the left-hand half on the line *b b* of the same figure, looking forward in each case; Fig. 4, a section on the line *c c* of Fig. 1 through the back header, showing a portion of one side; Fig. 5, a sectional view on the semicircular center line *d e f*, drawn through the centers of the heating-tubes on the left side of Fig. 3, the section being then projected on a plane; Fig. 6, a transverse section through the three-way cock when in position to shut off water from the heater; Fig. 7, an end view, on an enlarged scale, of a portion of one of the headers, the covering-plate over the upper tube being removed; Fig. 8, a longitudinal section through the ends of the tubes and header, two of the covering-plates being shown; and Fig. 9, a sectional plan showing one tube and its covering-plate and a portion of the sides of the smoke-box.

The main object of my invention is, as before stated, to utilize a portion of the heat which is carried away by the exhaust-steam and also part of that contained in the waste gases of combustion to heat the feed-water. Although the saving of fuel which can be effected by such utilization of waste heat can easily be proven theoretically and has often been shown practically, yet the use of feed-

water heaters whenever they have been tried on locomotive-engines has usually been abandoned after a comparatively short trial. Several reasons may be assigned for this, one being that the devices essayed were liable to get out of order, and thus lessen the amount of service performed by the engine in a given time. Another is that they were liable to fail at critical times while the engine is in use, and thus delay and interrupt traffic. A third reason is that their first cost and expense of maintenance was greater than the amount of saving of fuel effected by their use; a fourth, that their maintenance was troublesome. In most feed-water heaters which have heretofore been used, so far as I am aware, the source of heat which has been utilized in heating the water has been either the exhaust-steam or the escaping gases of combustion. In my improvement both or either of these sources of heat may be utilized. It may be stated, roughly, that the temperature of the exhaust-steam from a locomotive is about 240°, and as the feed-water, even when fed and heated by an injector, has a much lower temperature than this a very considerable amount of heat would be communicated to the feed-water if it was in contact for a sufficient time with one side of efficient heating-surface exposed on the other to the exhaust-steam.

In the practice of my invention and to accomplish the end above stated an annular space or heating-chamber 1 is provided on the outside of the smoke-box 2. This space is formed by a cylindrical ring or plate of metal 3, placed outside of and at some distance from the ordinary cylindrical smoke-box ring. The ends of the annular space or heating-chamber 1 are each filled with what will be termed herein "annular headers" or "hollow rings" 4 and 4^a, to which the two plates which form the smoke-box and which inclose the annular space 1, which will be termed the "heating-chamber," are riveted. Two sets or series of horizontal tubes 5 5, which will be termed "heating-tubes," (shown by full and by dotted lines in Fig. 1,) are disposed longitudinally throughout the heating-chamber, their ends being fixed in the headers, one series being on the right side of the vertical center line $d f$ of Fig. 3 and the other on the left side thereof. The annular headers are made hollow, as shown in Figs. 1, 4, 5, 8, and 9, the internal space having partitions 6 6, Figs. 4, 5, 7, and 8, by which it is divided into separate cells or chambers 7 7. The heating-tubes 5 are connected to the header-chambers in pairs, as shown in Figs. 4, 5, and 8. Opposite to the ends of each tube the headers have circular openings or hand-holes 8 8, which are clearly shown in Figs. 7, 8, and 9, and are covered by suitable plates 9 9, secured by screws and clamps, as represented in these figures.

A feed-pipe 10, leading from the feed-pump or injector, is connected to a T branch 11 11^a, (shown clearly in Fig. 5,) the upper end of which is in turn connected by a valve 12 to the upper chamber 13 in the back annular header 4. The connection of the feed-pipe 10 with the branch 11 11^a is made by a three-way cock or valve 14, or two separate valves might be used. When the cock 14 is turned into the position represented in Fig. 5, the feed-water can flow through the pipe 10 and the valve 14 in the direction indicated by the darts and up through the pipe 11, and, if the valve 12 is open, through said valve into the chamber 13, and thence forward through the upper heating-pipes 5 5 to the upper chamber 13^a in the front annular header 4^a. From this chamber the water can flow back through the second pipe into the second chamber 7 on the left, in the back header, and thence through the third pipe to the front again, and so on, as indicated by the darts in Fig. 5, until the water is delivered into the lower chamber 15, to which the valve 16 is attached and to which the T-pipe 11^a and the delivery-pipe 17 are connected. The delivery-pipe 17 is also connected to a check-valve 18, attached to and communicating with the mud-drum 19 on the under side of the boiler. If the valve 16 is open, the water can then flow from the chamber 15 through the valve 16, the delivery-pipe 17, and the check-valve 18 into the mud-drum 19, and thence, as shown by the darts in Fig. 1, into the boiler.

The cylinder saddle-castings 20 are provided with the usual exhaust-passages 21, which, as will be seen from Figs. 1 and 3, communicate with an opening in the outer plate 3 of the annular heating-chamber 1 around the smoke-box. The escaping steam from the exhaust-passages 21 can thus flow, as shown by the darts in Figs. 1, 3, and 5, up into the annular heating-chamber 1 and there comes into contact with the heating-tubes 5 5 and imparts a portion of its heat to the water inside of them. The exhaust-pipe 22 is connected to the upper part of the annular heating-chamber and depends from the under side, as shown in Figs. 1 and 3. It is made in bent or J form, so that the escaping steam will be discharged from its nozzle 23 up the chimney 24, as indicated by the dotted lines in Figs. 1 and 3.

One of the great difficulties with feed-water heaters on locomotive and other engines is that the tubes and heating-spaces containing the water soon become obstructed with mud, sediment, or solid incrustations and deposits of various kinds. To obviate this difficulty, or rather to facilitate the removal of any obstructions and the repair or renewal of the tubes, the heating apparatus herein set forth is placed wholly on the outside of the smoke-box proper, and the tubes are thus easily accessible from the hand-holes 8 in the headers by removing the covers, which can easily be done by simply unscrewing them from the bolts which hold them. Any tube can thus be made accessible at either end and through

its entire length without disturbing any of the others, and the exposed tube and the spaces in the headers can thus be rapidly cleaned or the tube be calked, if it should leak, or be removed and renewed in case of failure from any cause.

In case the heater should fail in any way, such as by the bursting of a tube, provision is made so that the feed-water can easily be shut off from the heater and fed directly into the boiler. This may be done by closing the lower valve 16, Fig. 5, and turning the three-way cock 14 into the position shown in Fig. 6. The feed-water would then flow from the pipe 10 downward from the cock 14 through the pipe 11^a, as indicated by the dart in Fig. 6, and if the valve 16 is closed the water could not enter the heater, but would pass direct through the delivery-pipe 17 into the check-valve 18, and thence into the boiler. This change can be made in a few seconds while the engine is either running or standing still.

Another difficulty common to nearly all feed-water heaters is that the sides of the inclosing vessel and the tubes are expanded and contracted in different degrees by the differences in temperature to which they are exposed. To provide for such action, the inner and the outer shells of the annular heating-chamber are corrugated for a portion of their length, as shown at 25 25 in Figs. 1 and 9. The corrugations permit of a small amount of elongation or extension of these plates in case the tubes are expanded or contracted by heat or cold.

A manhole and cover 26, Figs. 1 and 3, is provided to give access to the heating-chamber for cleaning and also for fastening and calking the outer plate to the cylinder-castings.

As hereinbefore stated, the temperature of exhaust-steam is about 240°. If the feed-water was exposed in a heater to this temperature for an unlimited time, it would acquire the same degree of heat; but the conditions under which all boilers, and especially those used in locomotives, are worked prohibit the exposure of the water to the surfaces in the heater for more than a short time, not sufficient for the exhaust-steam on one side of the heating-surfaces to impart a temperature equal to its own to the water on the other side. For this reason it is only possible to heat feed-water with exhaust-steam to a temperature somewhat lower than that of the steam. The waste products of combustion, however, which escape from the tubes of locomotives often have temperatures as high as 800° or 1,000°. Consequently if the feed-water after being heated by exhaust-steam to a temperature somewhat below 240° (that of the steam) was then brought in contact with surfaces heated by the waste gases of combustion another increment of heat would be absorbed by the water. Many efforts have been made prior to my invention to heat feed-water by the waste products of combustion from locomotive-boilers, but they have always been abandoned for the reason that in order to provide the requisite heating-surface for the transfer of the heat from the waste gases to the feed-water more or less bulky and complicated structures had to be added to the boilers. The first cost and expense of maintenance of these was considerable, and their maintenance was often troublesome and annoying. They were all based upon the principle of bringing the waste gases in contact with feed-water-heating surfaces after they had escaped from the tubes in the boiler. Under my invention the heating of the feed-water by the waste products of combustion is effected by providing diaphragms in the boiler to keep the feed-water in contact with the portions of the tubes at and adjacent to their discharge ends, with which portions the gases come in contact after they have passed through the preliminary portions of the length of the tubes and have imparted as much heat to the surrounding water as they do in boilers of the ordinary construction. The amount of heat transmitted by any heating-surface is proportioned to the difference of the temperatures in the two sides. If then the coldest water is kept in contact with that portion of the tubes through which the gases pass last and after their temperature has been reduced, more of their heat will be transmitted to the cold water than would be if that surrounding this portion of the tubes was hotter. In other words, the difference in temperature inside and outside of the portions of the tubes adjacent to their discharge ends will be greater if the cold water is kept in contact with them than it would be if the hotter water in the boiler could circulate freely around them, and consequently the transmission of heat to the cold water will also be greater. To accomplish this end, I provide a vertical plate or diaphragm 27, Fig. 1, some distance, preferably in practice about four or five feet, back of the front tube-plate 28. This diaphragm divides the front part of the water-space of the boiler from the back part. Horizontal plates 29 and 30 are also placed between the tubes and another, 31, above them, so as to divide the space in front of the diaphragm 27 into as nearly as practicable three equal divisions. The lower horizontal plate 29 is attached to the front tube-sheet 28, but does not extend entirely back to the vertical plate 27, a space being left between it and the diaphragm 27. The intermediate horizontal plate 30 is attached to the diaphragm 27, but does not extend entirely to the tube-plate, a space being left between them. The vertical diaphragm 27 does not extend up to the water-line, but might, if desired, be made to project above it, in which case the upper plate 31 could be omitted.

For convenience of description the discharge ends of the fire-tubes may be desig-

nated as the "front" ends and tubes through which the products of combustion are conveyed as "fire-tubes."

By the means above described the portion of the boiler between the vertical diaphragm and the tube-plate is divided into three approximately equal compartments, as has been explained, and the feed-water is introduced through the check-valve 18 into the lower one, and is then in contact with the coldest part of the lower boiler-tubes. As the feed-water is forced in it rises and flows into the intermediate compartment, as indicated by the darts, and thence into the upper compartment, from which it flows into the back part of the boiler. By this means the feed-water is kept in contact with the front ends of the fire-tubes and surrounds them for a considerable period—long enough for the waste gases to transmit a part of their heat to the water. This is accomplished without adding any additional parts to the boiler excepting the plates which form the divisions in the front end; but as the pressure on each side of these plates is alike they are not subjected to any strain, and are therefore not liable to fail or get out of order.

As the temperature of the waste gases is at times very high, more or less steam may be generated in front of the diaphragm 27. To permit such steam to escape from the under side of the top plate 31, an open space 34 is left between it and the tube-plate 28. In order that the steam may escape into the space above the surface of the water and the water below the plate be retained in contact with the front ends of the boiler-tubes, a vertical division 35 is attached to the upper plate 31 and extends above the water-line, which is represented by the dotted line 36 36. With the same object in view tubes 37 37 are provided, which are connected to the plate 31 and also extend above the water-line. The water of course will not rise in the tubes above the water-line 36 36 outside of them and therefore cannot flow upward through them, but is confined below the plate until it is displaced by fresh feed-water entering below. The movement of the water in the heating-space in front of the diaphragm 27 is indicated by darts in Fig. 1.

A single vertical plate or diaphragm 27 might be used and the horizontal plates dispensed with, and in such case it would be desirable to carry it up above the water-line, so that the feed-water could not flow from the heating-space until the water in it had risen above the water-level in the rest of the boiler. Other vertical circulating-plates instead of horizontal ones might be used in combination therewith, but the construction shown in Fig. 1 is deemed the preferable one.

In removing locomotive-boiler tubes it is customary to cut off their front ends and take them out of the boiler through the opening (not shown in the drawings) for the steam-pipe in the front tube-plate 28. As it would be impossible to do this with tubes which pass through the vertical diaphragm-plate 27, they would have to be taken out through their own openings in the front tube-plate. If these tubes were made to fit accurately in the holes in the diaphragm-plate 27 and should then become incrusted with a hard deposit of lime or other substances, it would be very difficult to draw them through the holes in the diaphragm-plate. Further, if the tubes came into direct contact with the edge of the diaphragm-plate without fitting in the holes tight the jar of the locomotive would wear the tubes at this point. In order to make it possible to remove them after they become incrusted, the holes in the diaphragm-plate should be made considerably larger than the tubes. At the same time it is desirable that the boiler-tubes should be water-tight, or nearly so, where they pass through this plate, and they should also have more bearing-surface than would be provided with any ordinary thickness of plate that would be used. To meet these requirements, the holes in the diaphragm-plate are made considerably larger than the tubes and bored of taper form. A thimble 38, Figs. 1 and 2, of conical form is provided for each tube and is driven into the diaphragm-plate so as to fill the opening around the tube. If these thimbles were made in one piece or "solid," it would be essential to slide them off the whole length of the tube back of the diaphragm-plate. As this would be very difficult to do if the tubes were covered with any considerable amount of incrustation, the thimbles are made in two halves, as indicated in Figs. 2 and 2ª. When made in this way, they may be removed from the tubes as soon as the thimbles are driven out of the holes in the diaphragm-plate, and the tubes can then be withdrawn through the holes in the front tube-plate, which are made larger than the tube itself.

It is a well-known fact that water when heated will precipitate certain solid substances, such as lime, which will be held in solution when the water is cold. With the apparatus herein described the feed-water would be heated by the exhaust-steam to a temperature somewhat below 240°, and therefore if some substances are held in solution they would then be precipitated. As this process would be promoted if the water could be in a state of partial quiescence before it enters the boiler and as it is very desirable to exclude from it all substances which form incrustations, I provide a mud-drum 19 below the feed-water-heating space, into which the water which has been heated by the exhaust-steam is admitted. In this drum the water can remain partially quiescent after it enters, which permits the solid material to be precipitated in the mud-drum, from which it can readily be removed. A cover 40 is provided in the lower end of the mud-drum, which can be easily removed for cleaning it, and a blow-off cock 41 enables the contents of the mud-

drum to be blown out whenever it is desirable to do so.

In the use of the descriptive term "annular" as applied to the chamber containing the heating-tubes I do not desire or intend to limit my invention to a construction in which said chamber is of circular outline or extends uninterruptedly around its axial or middle line, as it will be seen that its form in transverse section may be varied or its continuity interrupted without departure from the spirit or operative principle of my invention.

While the construction for heating the feed-water by exhaust-steam and that for heating by the waste products of combustion are here described as operating in connection one with the other and while such a combination is considered advantageous, it is not essential that they should be combined, but either could be worked separately, and thus secure its own measure of economy.

I claim as my invention and desire to secure by Letters Patent—

1. In a steam-boiler feed-water heater, the combination of an annular heating-chamber, a system of heating-tubes in said chamber through which feed-water may be circulated, an exhaust-steam opening leading into said chamber, an exhaust-steam outlet leading out of said chamber, a feed-water-supply pipe connected with one end of the heating-tube system, and a feed-water-delivery pipe connected with the opposite end of the heating-tube system.

2. In a steam-boiler feed-water heater, the combination, of an annular heating-chamber, adapted to form the inclosure or casing of the smoke-box or uptake of a steam-boiler, a system of heating-tubes in said heating-chamber, through which feed-water may be circulated, an exhaust-steam opening leading into said chamber, an exhaust-steam outlet leading out of said chamber, a feed-water-supply pipe connected with one end of the heating-tube system, and a feed-water-delivery pipe connected with the opposite end of the heating-tube system.

3. In a steam-boiler feed-water heater, the combination of an annular heating-chamber, a system of heating-tubes in said chamber through which feed-water may be circulated, an exhaust-steam opening leading into said chamber, an exhaust-steam outlet leading out of said chamber, a feed-water-supply pipe connected with one end of the heating-tube system, a feed-water-delivery pipe connected with the opposite end of the heating-tube system, and a mud-drum adapted to be connected to the water-space of a steam-boiler and to the feed-water-delivery pipe.

4. In a steam-boiler feed-water heater, the combination of an annular heating-chamber, a system of heating-tubes through which feed-water may be circulated in said chamber, an exhaust-steam opening leading into said chamber, an exhaust-steam pipe leading out of said chamber, a feed-water-supply pipe connected with one end of the heating-tube system, a feed-water-delivery pipe connected with the opposite end of the heating-tube system, a direct boiler-supply pipe leading out of the feed-water-supply pipe, a cock or valve controlling communication between the feed-water-supply pipe and the heating-tube system, and between said supply-pipe and the direct boiler-supply pipe respectively, and a valve controlling the feed-water-delivery pipe.

5. In a steam-boiler feed-water heater, the combination of an annular heating-chamber, headers forming the ends of said chamber and divided into separate cells or compartments, heating-tubes in the heating-chamber, connected in alternate pairs to the cells of opposite headers, a feed-water-delivery pipe leading from the heating-tube system to a point of connection with a steam-boiler, a feed-water-supply pipe leading from a point of connection with a boiler-feeder to the feed-water-delivery pipe, a branch pipe connecting the feed-water-supply pipe with the heating-tube system, a valve controlling communication between the boiler-feeder connection and the heating-tube system, and a valve controlling communication between the heating-tube system and the feed-water-delivery pipe, said valves being adapted to admit feed-water to and through the heating-tube system before its entrance into the feed-water-delivery pipe, or to shut it off from the heating-tube system and admit it directly into the feed-water-delivery pipe.

6. In a steam-boiler feed-water heater, the combination of an annular heating-chamber, annular headers closing the ends of said chamber and divided into separate cells or chambers, a system of pairs of heating-tubes connecting the opposite headers, the members of each pair of tubes communicating, at one end, with a cell of one of the headers, and, at the other end, with two cells of the opposite header, an exhaust-opening leading into the heating-chamber, an exhaust-pipe leading out of said chamber, a feed-water-supply pipe connected with one end of one of the headers, and a feed-water-delivery pipe connected with the opposite end of said header.

7. In a steam-boiler feed-water heater, the combination of an annular heating-chamber, annular headers closing the ends of said chamber and divided into separate cells or chambers, a system of pairs of heating-tubes connecting the opposite headers the members of each pair of tubes communicating, at one end, with a cell of one of the headers, and, at the other end, with two cells of the opposite header, removable plates or caps closing hand-holes in the header-cells through which the tubes may be cleaned, removed, and inserted, an exhaust-opening leading into the heating-chamber, an exhaust-pipe leading out of said chamber, a feed-water-supply

pipe connected with one end of one of the headers, and a feed-water-delivery pipe connected with the opposite end of said header.

8. The combination, with a steam-boiler, of a smoke-box or uptake having an inner and an outer shell, between which is located an annular heating-chamber, a system of heating-tubes traversing said chamber, and surrounded, in operation, by exhaust-steam, connections from said heating-tube system to the boiler and to a water-feeder, and an inlet and an outlet for the admission and escape of exhaust-steam to and from the heating-chamber.

9. The combination with a steam-boiler, of a smoke-box or uptake having a second or outside shell, between which and the inner shell an annular heating-chamber is located, a system of heating-tubes traversing said chamber and accessible and removable from the outside of the smoke-box and boiler, connections from said heating-tube system to the boiler and to a water-feeder, and an inlet and an outlet for the admission and escape of exhaust-steam to and from the heating-chamber.

10. The combination, with a steam-boiler, of an annular heating-chamber surrounding a smoke-box and having an opening for connection with a discharge flue or stack, a system of heating-tubes in said chamber, an exhaust-inlet opening leading into said chamber, an exhaust-outlet pipe leading from said chamber on the side of its axis opposite the exhaust-opening, a feed-water-supply pipe connected with one end of the heating-tube system, and a feed-water-delivery pipe connected with the opposite end of the heating-tube system.

11. The combination, with a steam-boiler, of an annular heating-chamber surrounding a smoke-box, a system of heating-tubes through which feed-water may be circulated in said chamber, an exhaust-opening leading into said chamber, an exhaust-pipe leading out of said chamber, on the side of its axis opposite the exhaust-opening, a feed-water-supply pipe connected with one end of the heating-tube system, a feed-water-delivery pipe connected to the opposite end of the heating-tube system, and a mud-drum attached to the water-space of the boiler, and to the feed-water-delivery pipe.

12. The combination, with a steam-boiler, of a smoke-box having a shell which is corrugated for a portion of its length, an exterior casing which is also corrugated for a portion of its length, annular members interposed between the smoke-box shell and exterior casing at the ends thereof and forming therewith the boundaries of an annular heating-chamber, a system of heating-tubes through which feed-water may be circulated in said chamber, an exhaust-inlet opening and an exhaust-outlet pipe leading into and out of said chamber, a pipe leading from a source of feed-water supply to one end of the heating-tube system, and a delivery-pipe leading from the opposite end of the heating-tube system to the boiler.

13. The combination, with a steam-boiler, of a feed-water-supply inlet, opening into the forward portion of the water-space, or that adjacent to the front ends of the boiler-tubes, and a transverse diaphragm interposed between the supply-pipe and the rearward portion of the water-space, said diaphragm being perforated for, and traversed by, the boiler-tubes located within its compass, and abutting against the bottom and side portions of the boiler-shell.

14. The combination, with a steam-boiler, of a feed-water-supply inlet, opening into the forward portion of the water-space, or that adjacent to the front ends of the boiler-tubes, a transverse diaphragm interposed between the supply-pipe and the rearward portion of the water-space, said diaphragm being perforated for, and traversed by, the boiler-tubes located within its compass and abutting against the bottom and side portions of the boiler-shell, and thimbles fitting around the tubes passing through the diaphragm, and within the tube-openings in the diaphragm.

15. The combination, with a steam-boiler, of a feed-water-supply inlet, opening into the portion of the water-space adjacent to the front ends of the tubes, a transverse diaphragm interposed between the supply-inlet and the rearward portion of the water-space, said diaphragm being perforated for, and traversed by, the boiler-tubes located within its compass and abutting against the bottom and side portions of the boiler-shell, and divided or two-part thimbles fitting around the tubes passing through the diaphragm and within the tube-openings in the diaphragm.

16. The combination, with a steam-boiler, of a feed-water-supply inlet, opening into the portion of the water-space adjacent to the front ends of the tubes, a transverse diaphragm interposed between the supply-inlet and the rearward portion of the water-space, and circulating-plates dividing the water-space in front of the diaphragm into compartments for the traverse of feed-water in alternately opposite directions.

17. The combination, with a steam-boiler, of a feed-water-supply inlet, opening into the portion of the water-space adjacent to the front ends of the tubes, a transverse diaphragm interposed between the supply-inlet and the rearward portion of the water-space, a horizontal circulating-plate extending forwardly from the diaphragm, and a horizontal circulating-plate extending rearwardly from the front flue-sheet.

18. The combination, with a steam-boiler, of a feed-water-supply inlet, opening into the portion of the water-space adjacent to the front ends of the tubes, a transverse diaphragm interposed between the supply-inlet and the rearward portion of the water-space, and perforated for and traversed by the boiler-

tubes, a lower horizontal circulating-plate extending forwardly from the diaphragm, an intermediate circulating-plate extending rearwardly from the front flue-sheet, and an upper horizontal circulating-plate located adjacent to the normal water-level of the boiler.

19. The combination, with a steam-boiler, of a feed-water-supply inlet, opening into the portion of the water-space adjacent to the front ends of the tubes, a transverse diaphragm interposed between the supply-inlet and the rearward portion of the water-space, and perforated for and traversed by the boiler-tubes, a lower horizontal circulating-plate extending forwardly from the diaphragm, an intermediate circulating-plate extending rearwardly from the front flue-sheet, an upper horizontal circulating-plate located adjacent to normal water-level of the boiler, and passages for the escape of steam from the under side of the upper circulating-plate to the steam-space above the water-line.

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Witnesses:
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