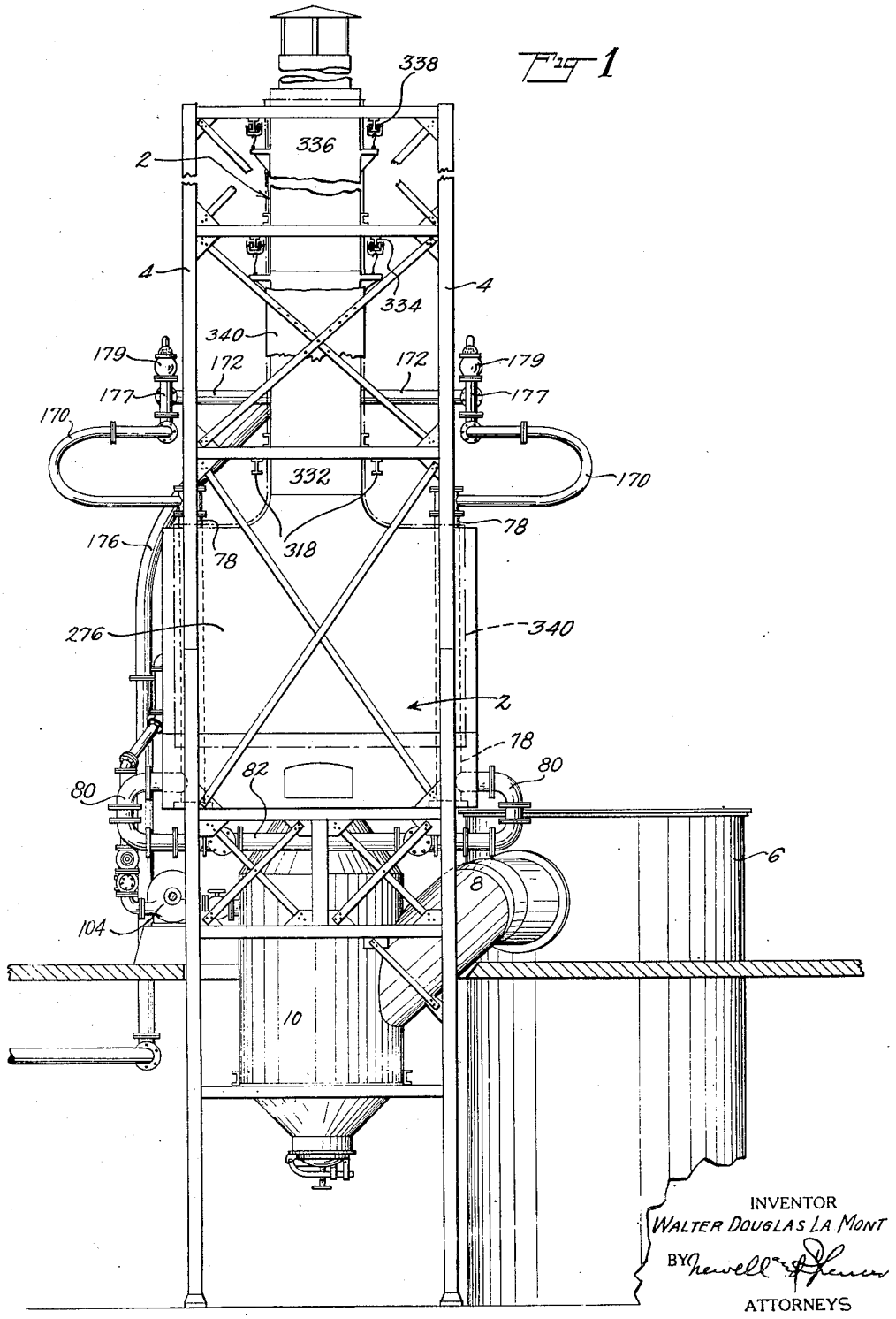
Nov. 3, 1931. W. D. LA MONT 1,830,324

STEAM GENERATOR OR THE LIKE

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STEAM GENERATOR OR THE LIKE

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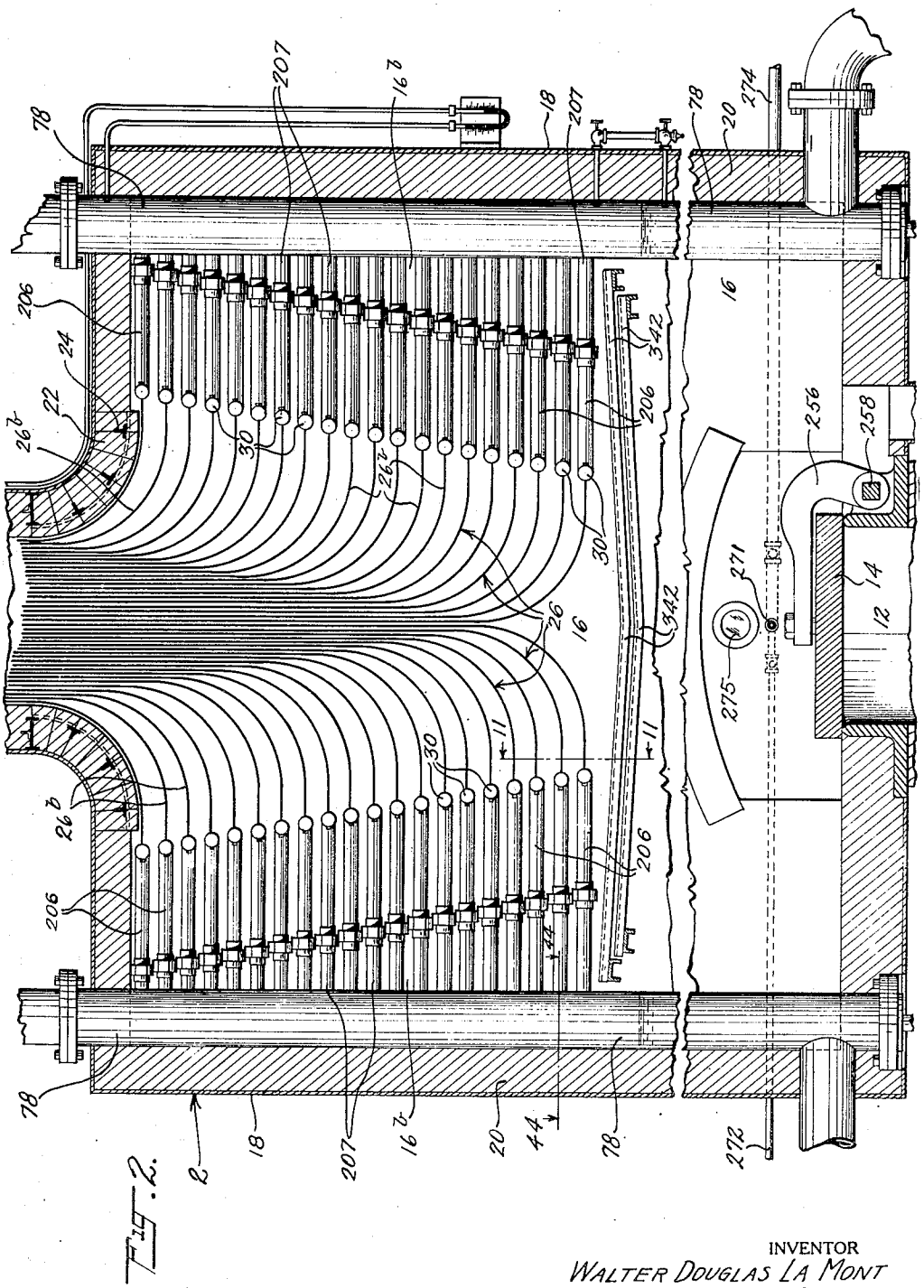


Fig. 2.

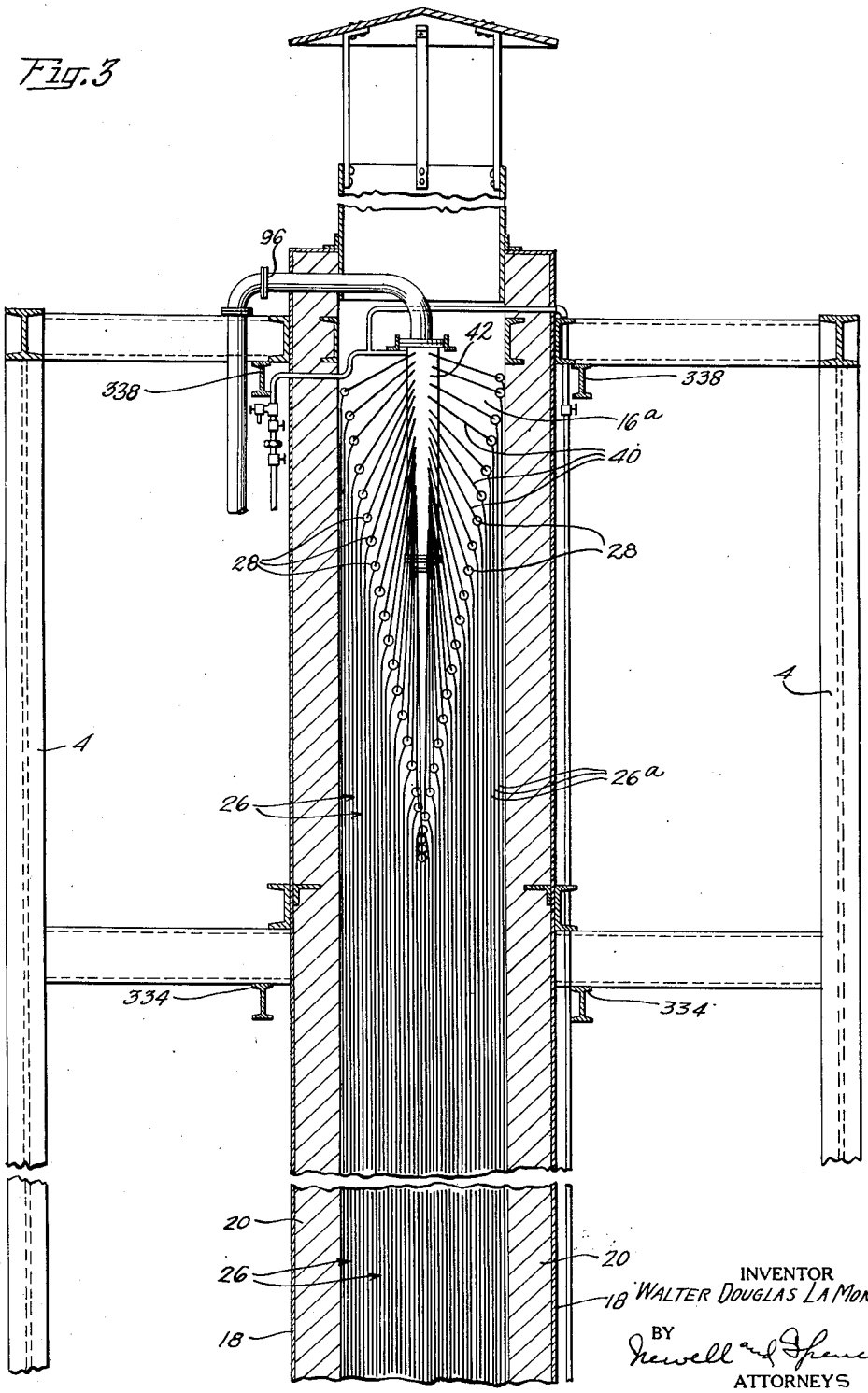
INVENTOR
WALTER DOUGLAS LA MONT
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STEAM GENERATOR OR THE LIKE

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Fig. 3



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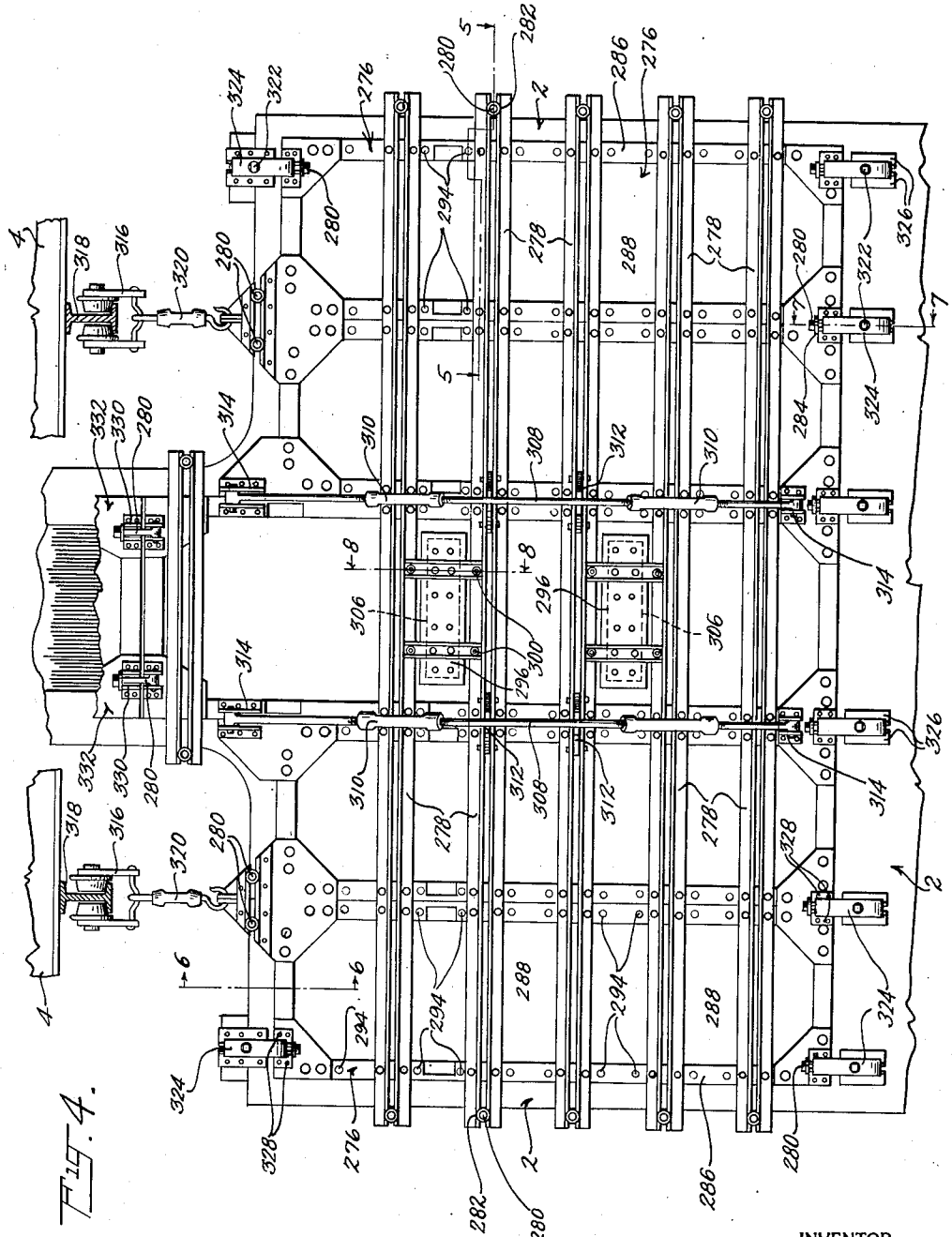


Fig. 4.

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STEAM GENERATOR OR THE LIKE

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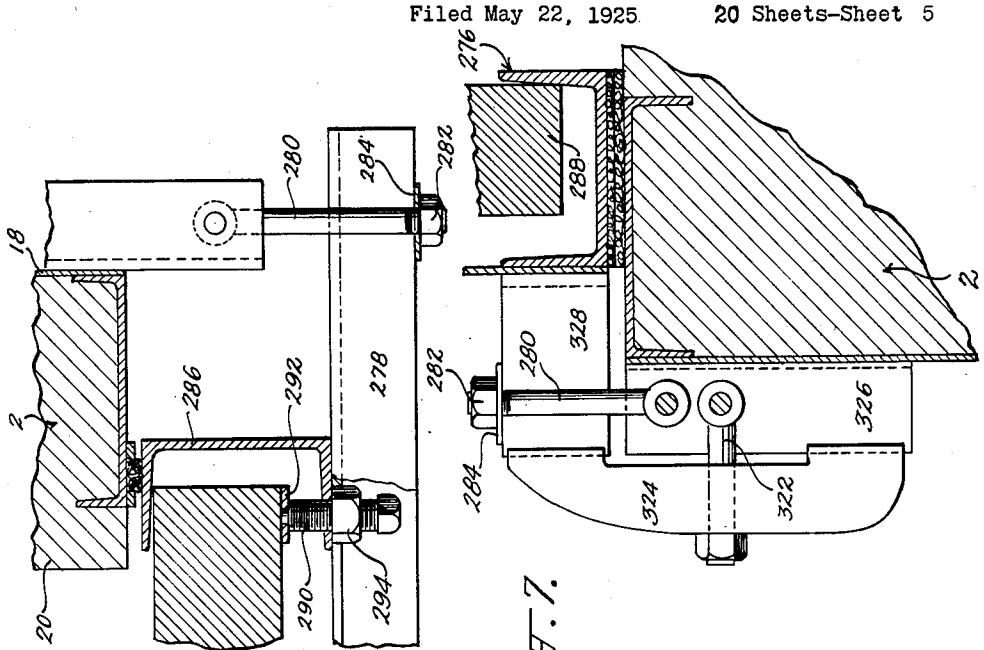


Fig. 7.

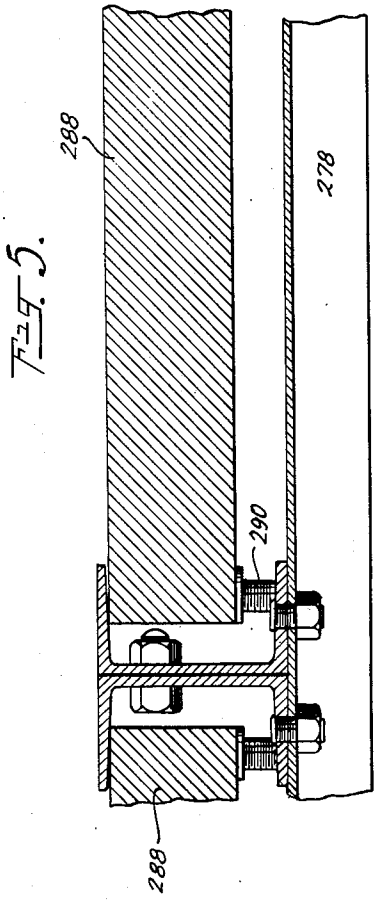


Fig. 5.

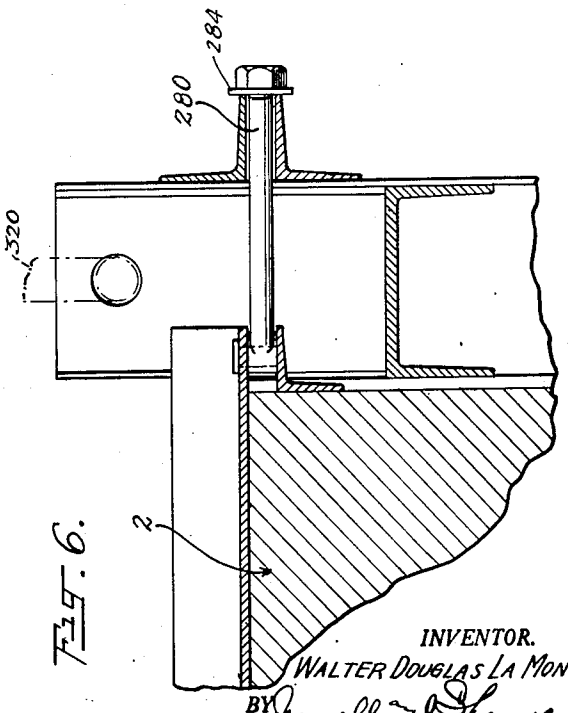


Fig. 6.

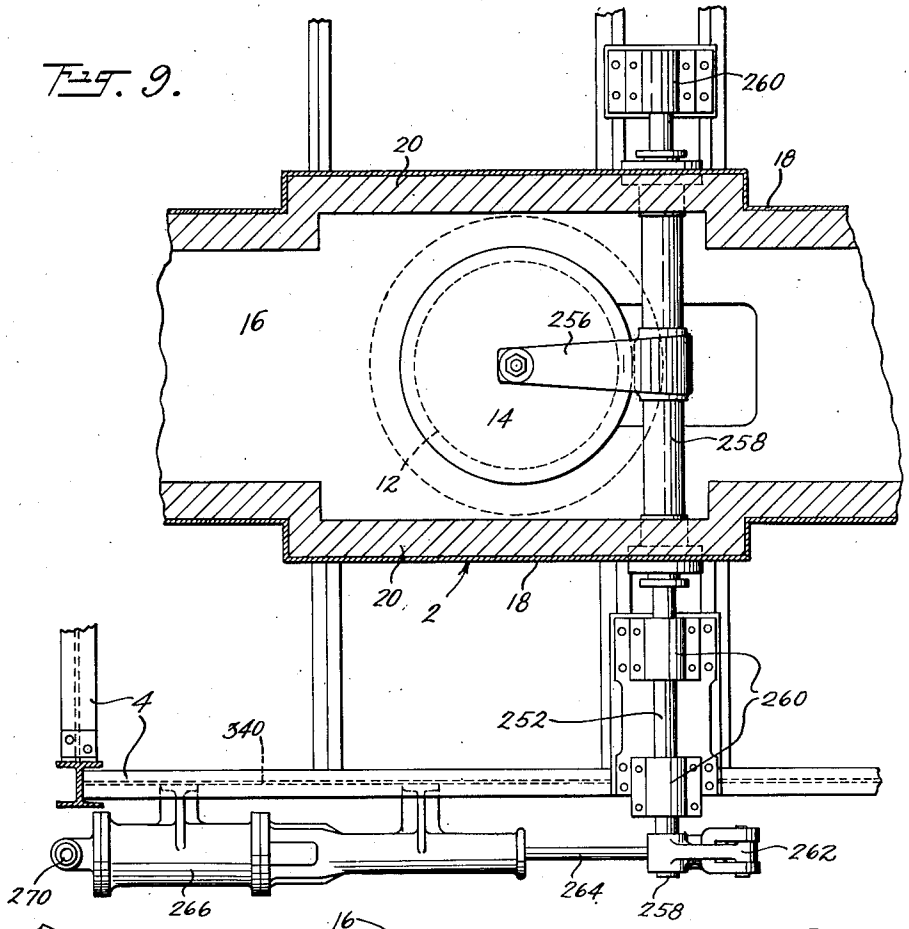
INVENTOR.
WALTER DOUGLAS LA MONT
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STEAM GENERATOR OR THE LIKE

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Fig. 9.



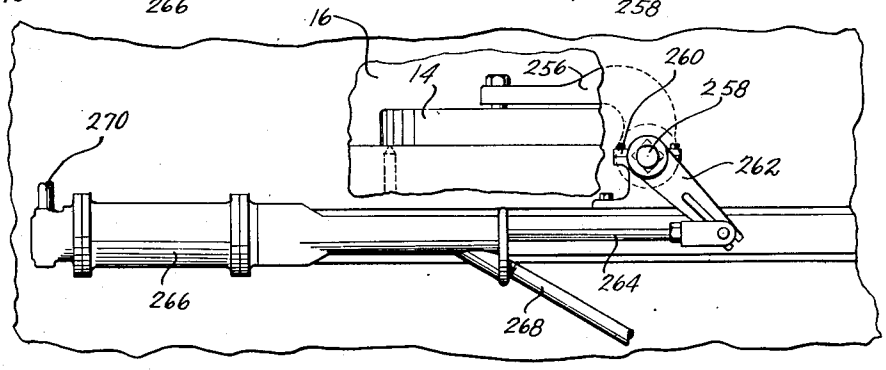


Fig. 10.

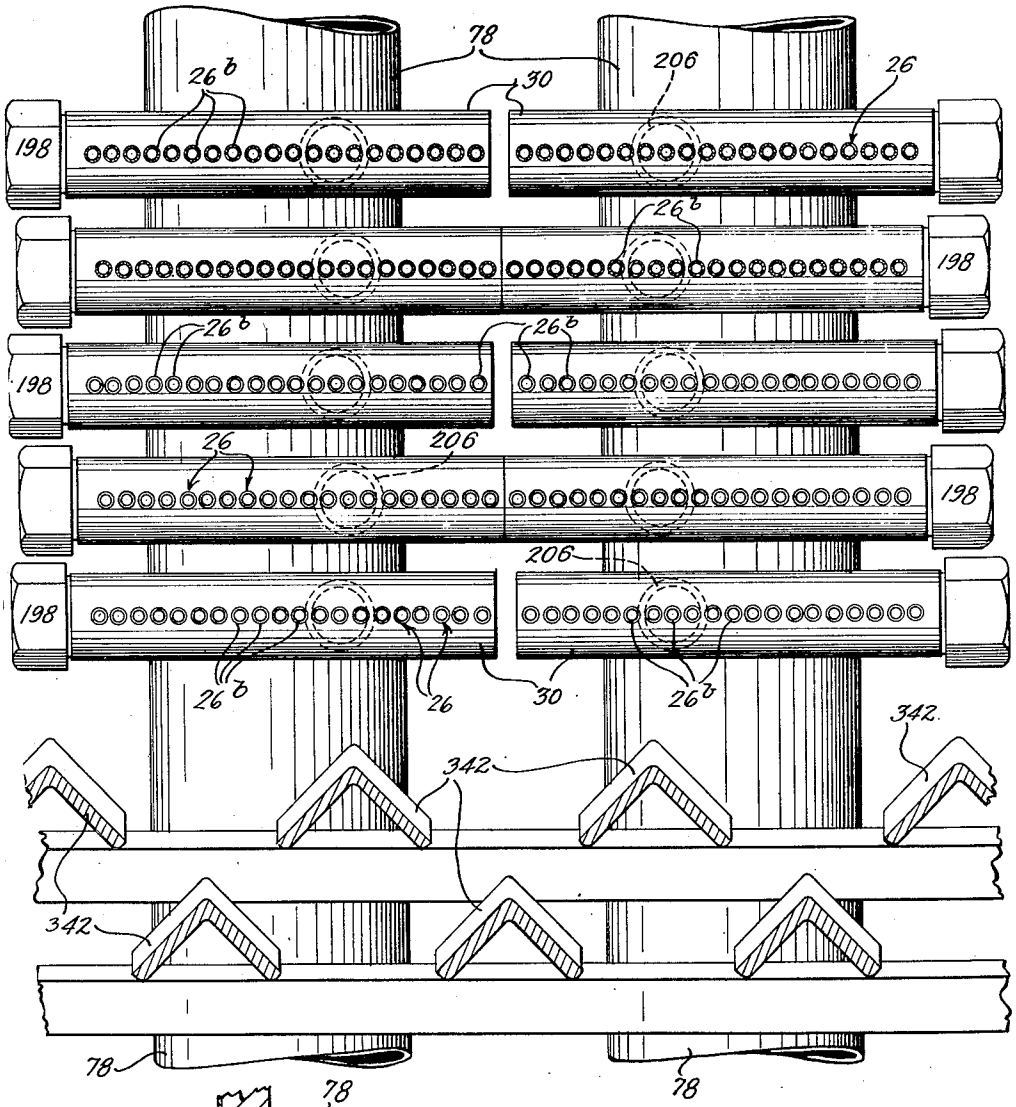
INVENTOR
WALTER DOUGLAS LA MONT
BY
Newell & Spencer
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Nov. 3, 1931. W. D. LA MONT 1,830,324

STEAM GENERATOR OR THE LIKE

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Fig. 11.



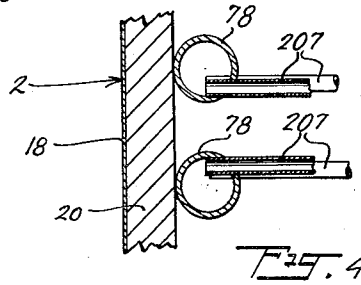


Fig. 44.

INVENTOR.
WALTER DOUGLAS LA MONT
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Fig. 12.

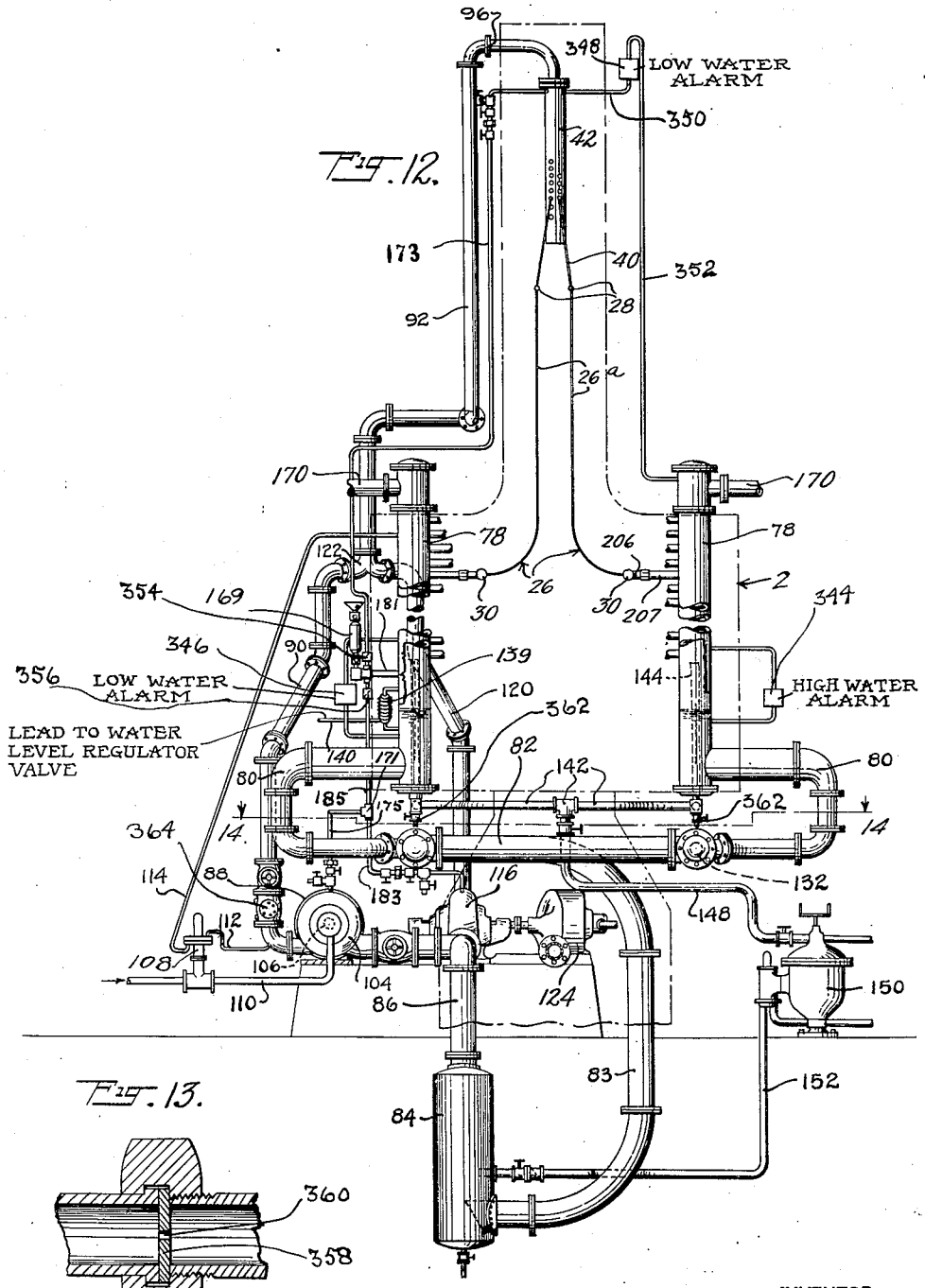


Fig. 13.

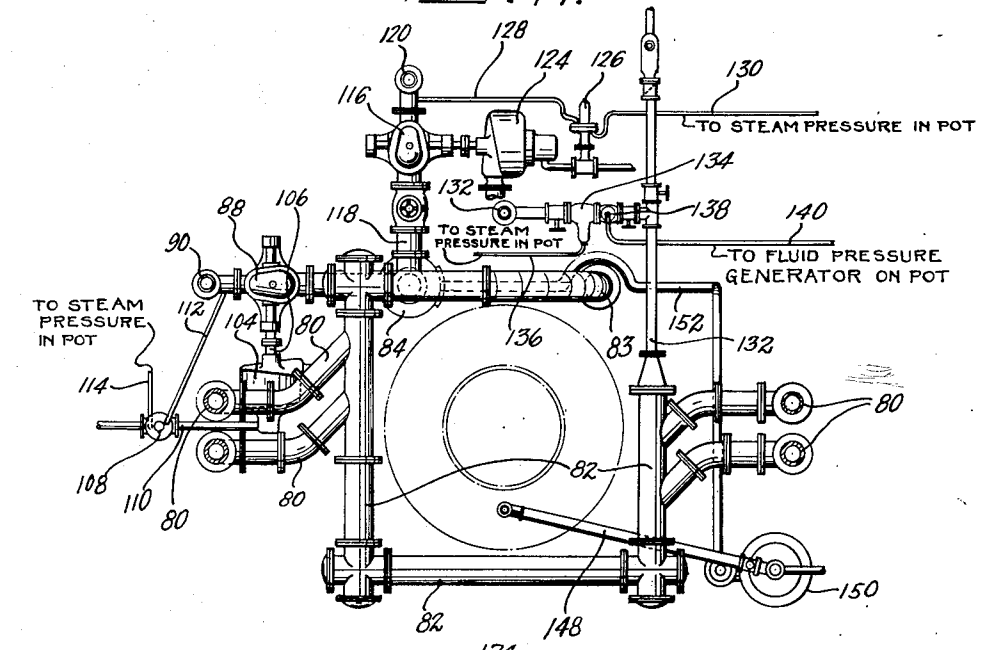
INVENTOR
WALTER DOUGLAS LA MONT
BY
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STEAM GENERATOR OR THE LIKE

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Fig. 14.



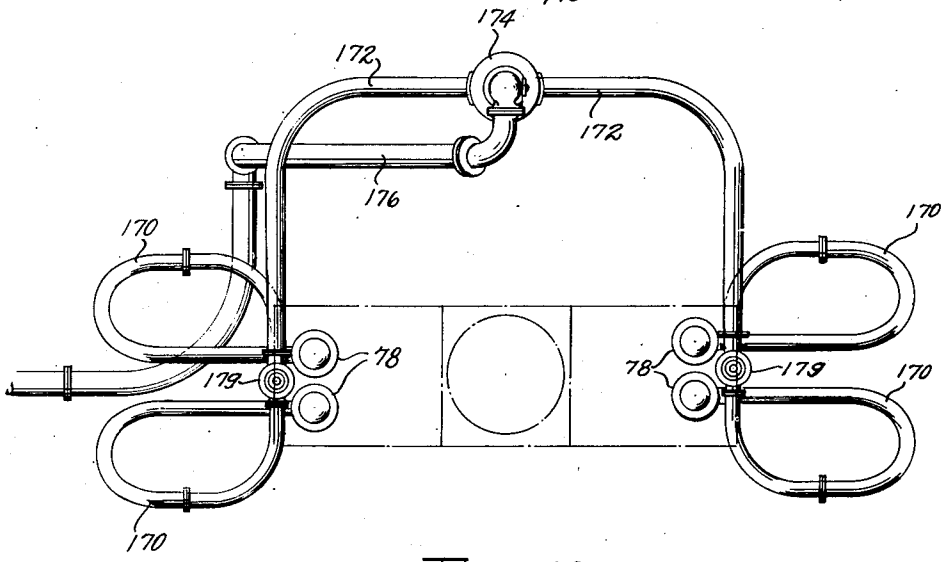


Fig. 16.

INVENTOR.
WALTER DOUGLAS LA MONT
BY Howell & Howell
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Fig. 15.

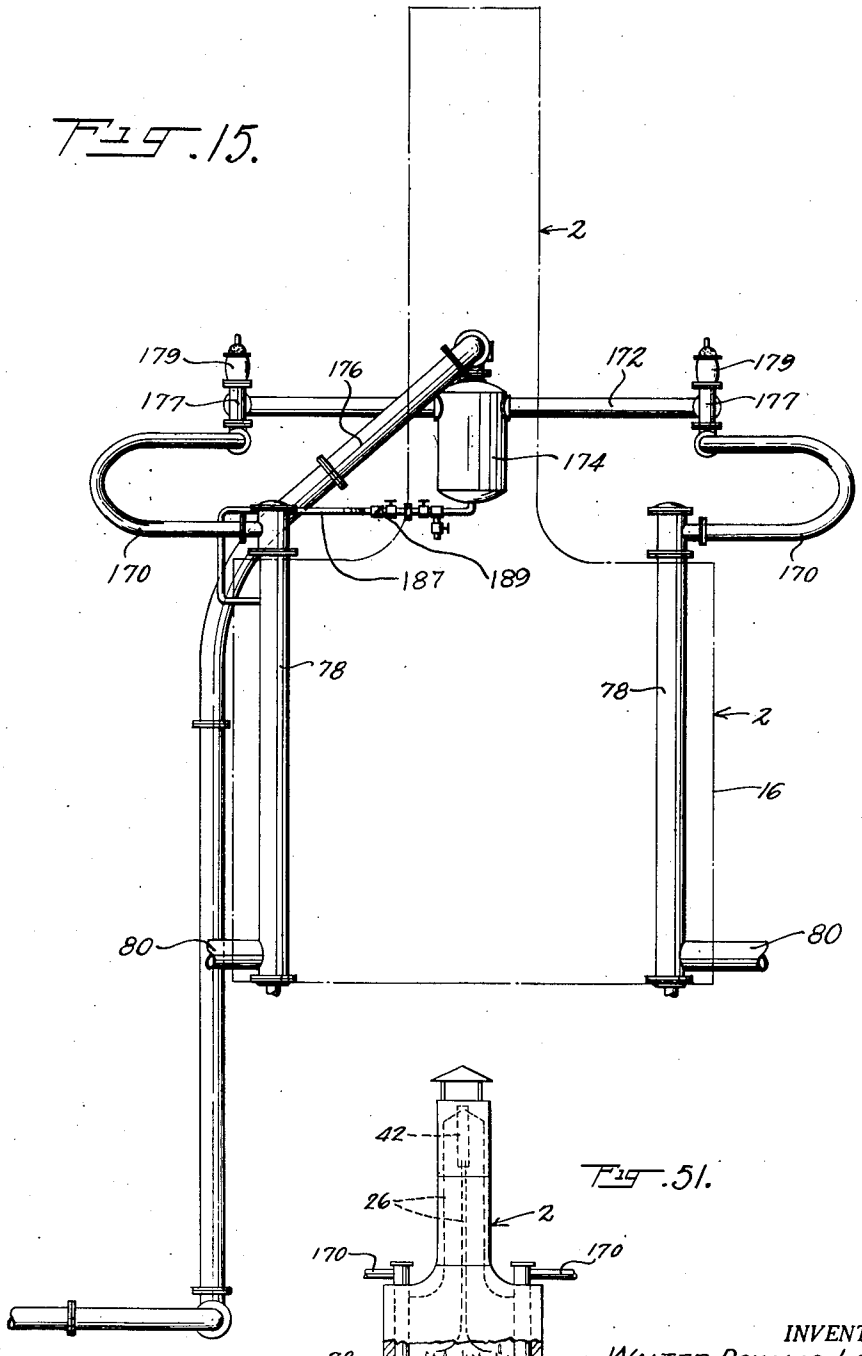


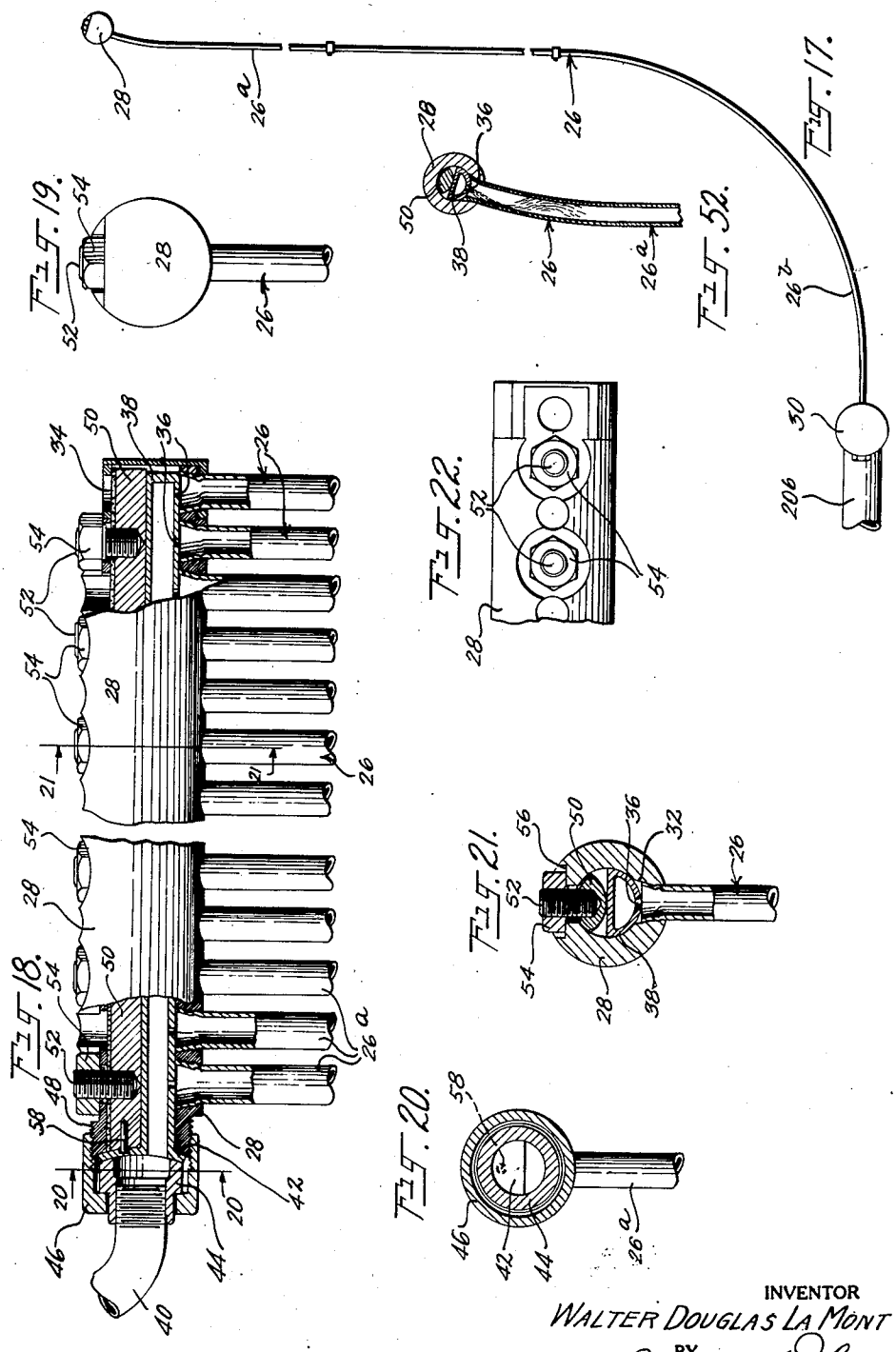
Fig. 51.

INVENTOR.
WALTER DOUGLAS LA MONT
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STEAM GENERATOR OR THE LIKE

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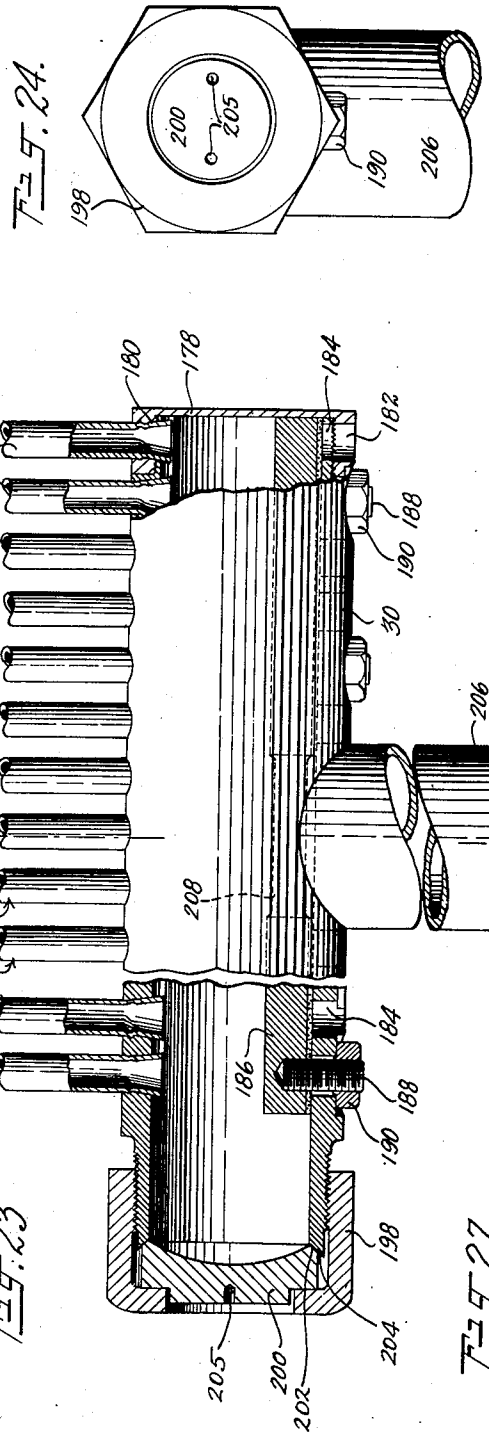


FIG. 23.

FIG. 24.

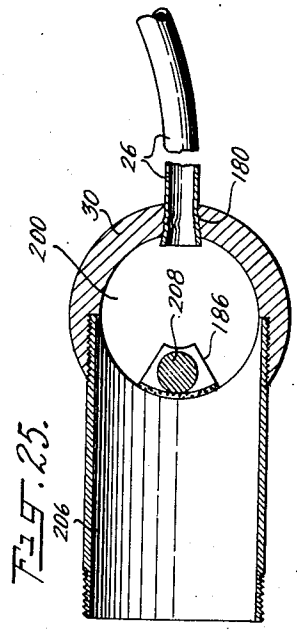


FIG. 25.

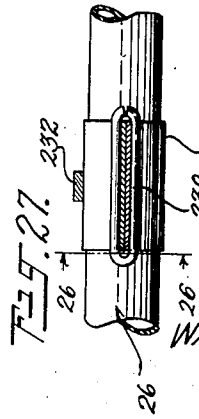


FIG. 27.

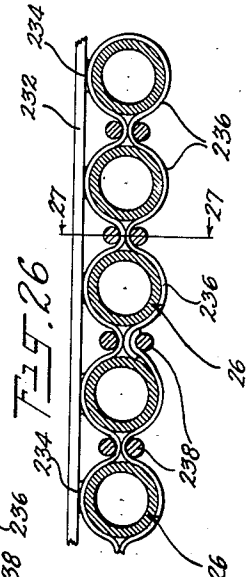


FIG. 26.

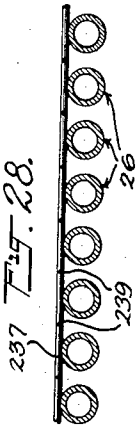


FIG. 28.

INVENTOR
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Fig. 29.

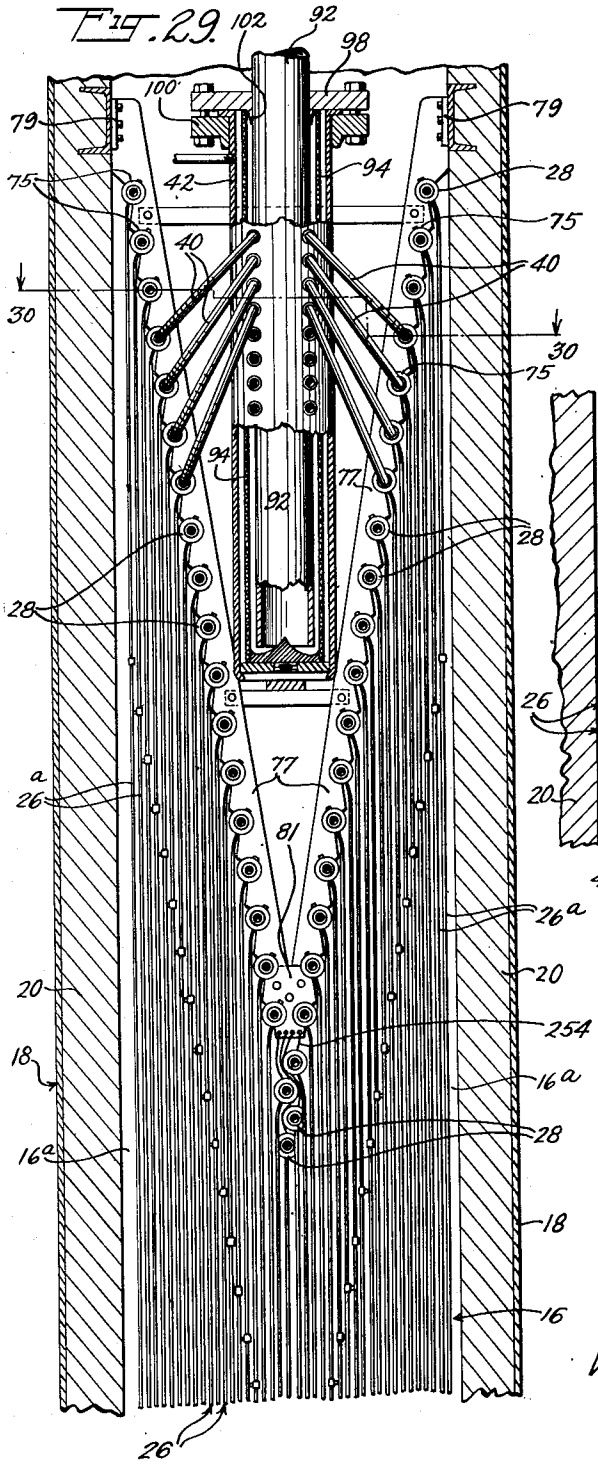
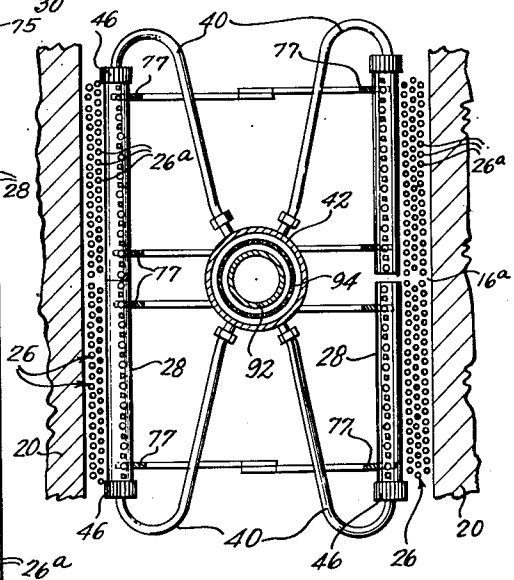


Fig. 30.



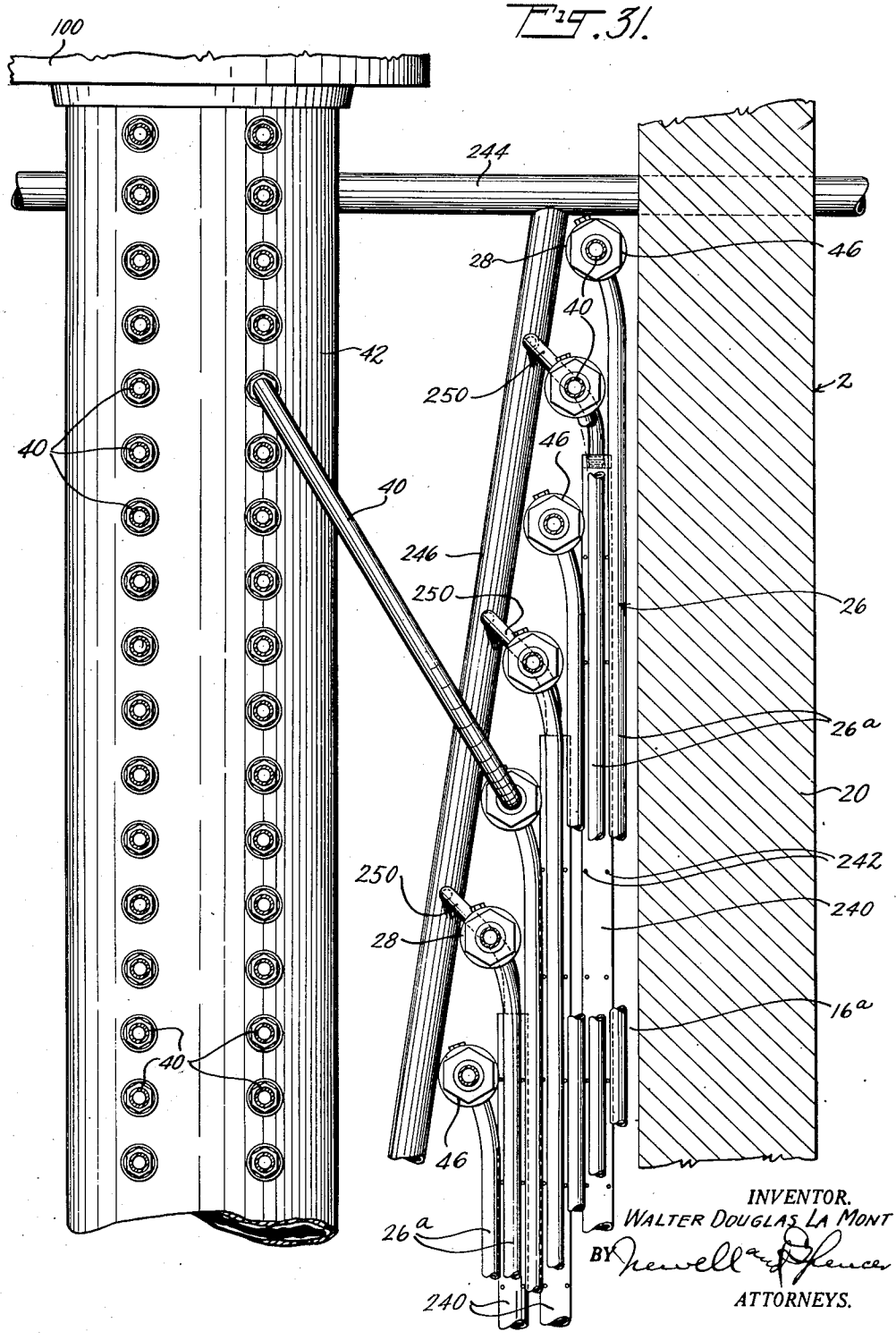
INVENTOR.
WALTER DOUGLAS LA MONT
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STEAM GENERATOR OR THE LIKE

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Fig. 31.



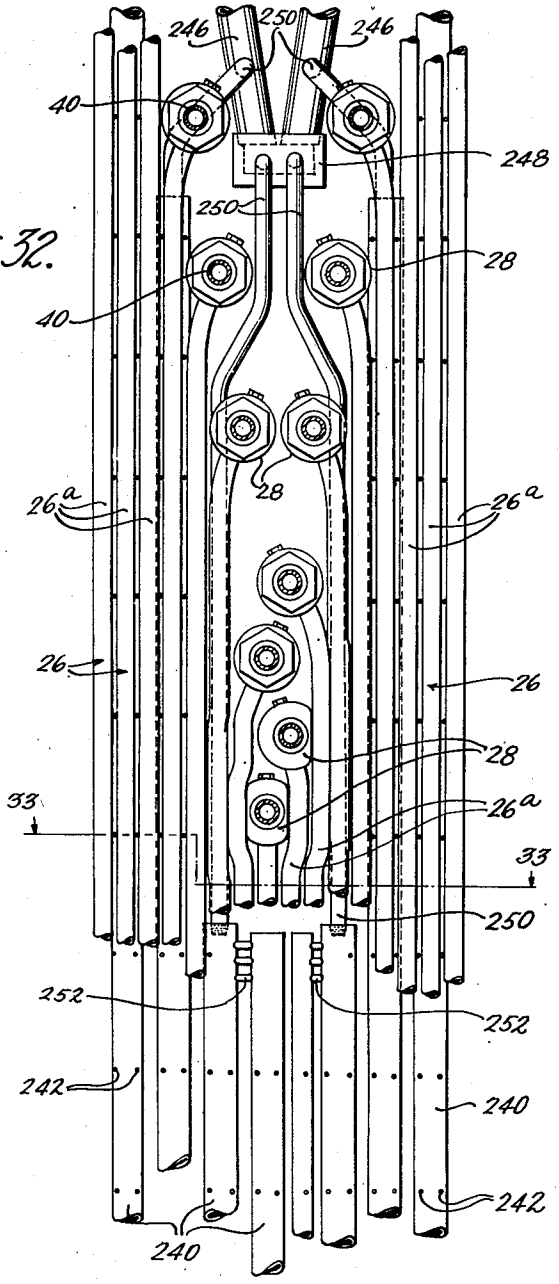
INVENTOR.
WALTER DOUGLAS LA MONT
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STEAM GENERATOR OR THE LIKE

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Fig. 32.



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Fig. 33.

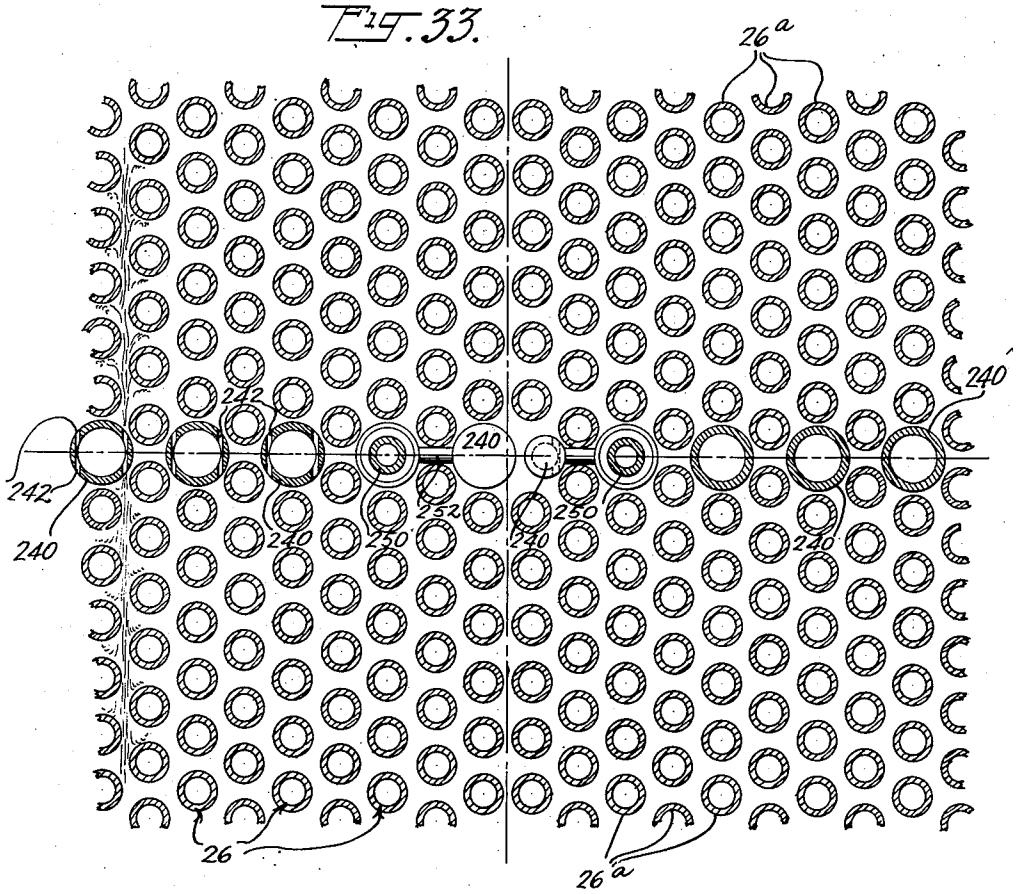
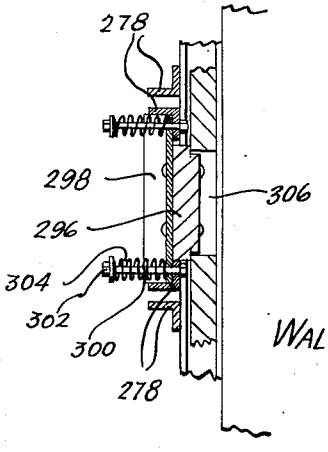


Fig. 8.



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STEAM GENERATOR OR THE LIKE

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Fig. 35.

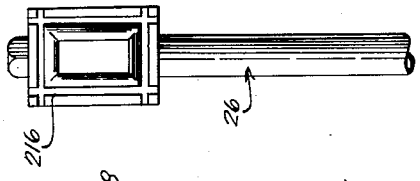


Fig. 34.

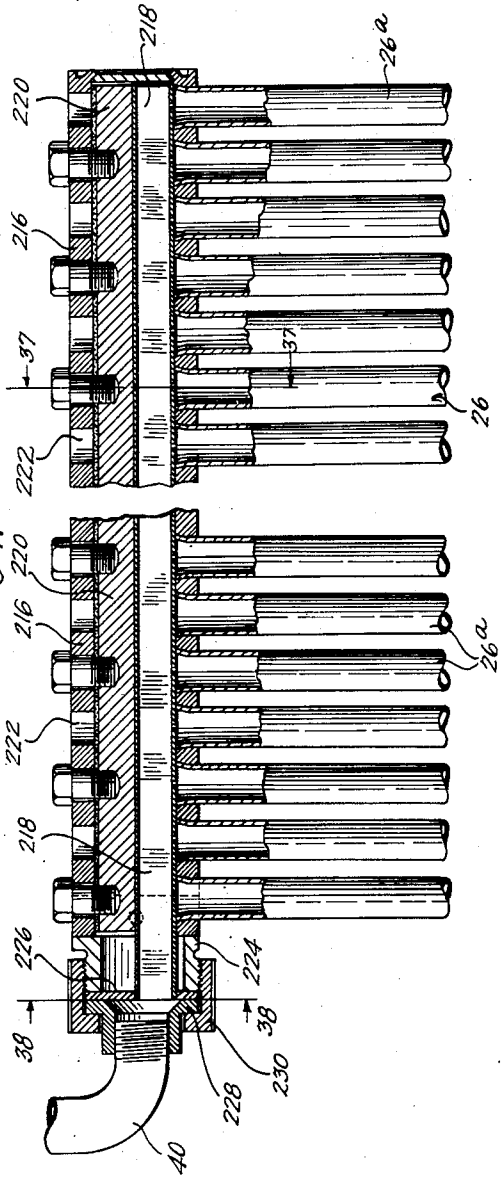


Fig. 38.

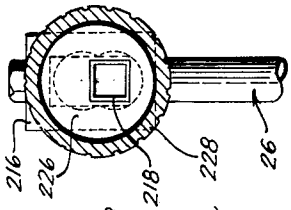


Fig. 37.

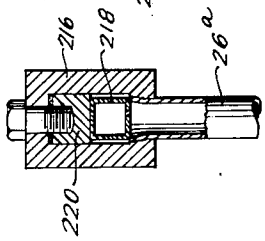
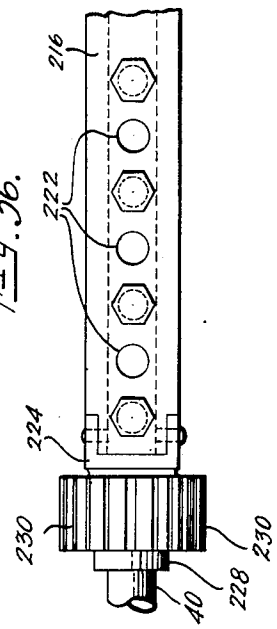


Fig. 36.



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STEAM GENERATOR OR THE LIKE

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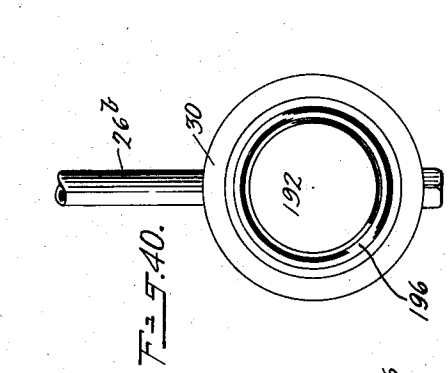


FIG. 40.

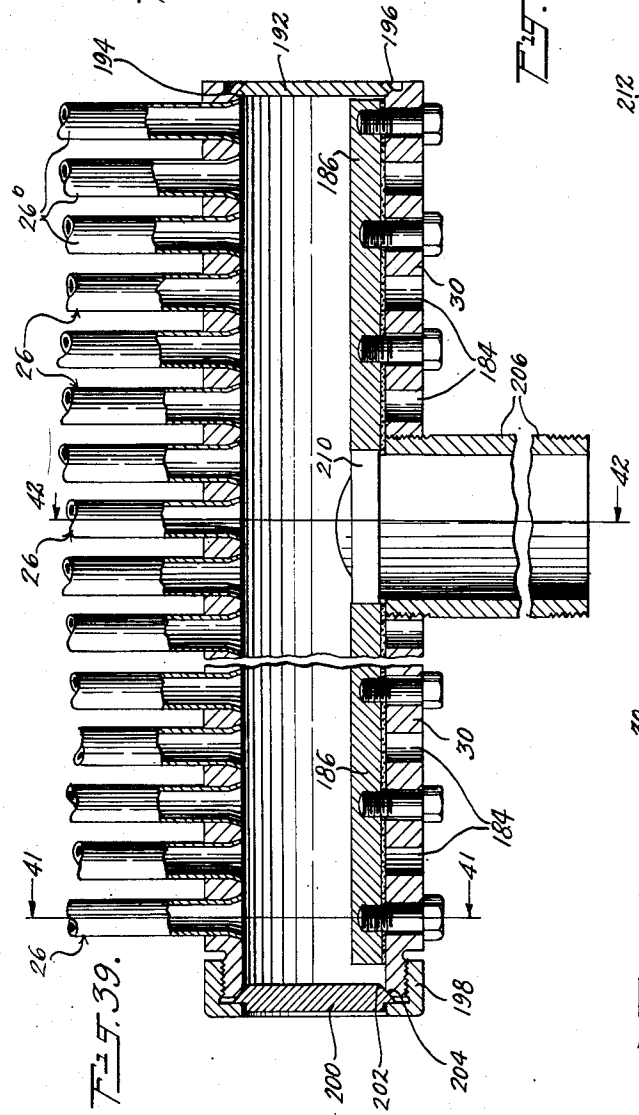


FIG. 39.

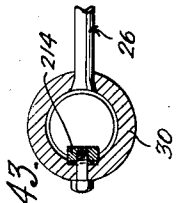


FIG. 43.

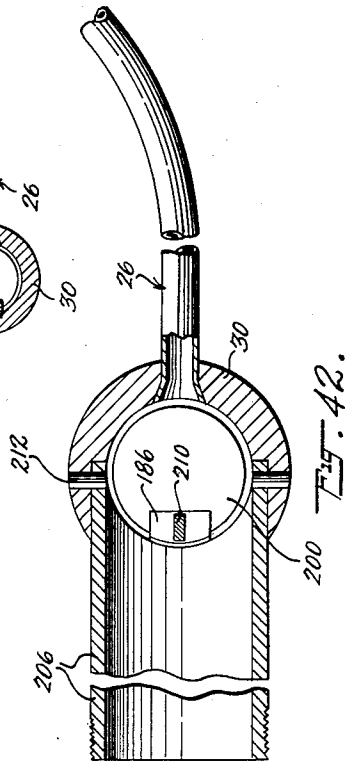


FIG. 42.

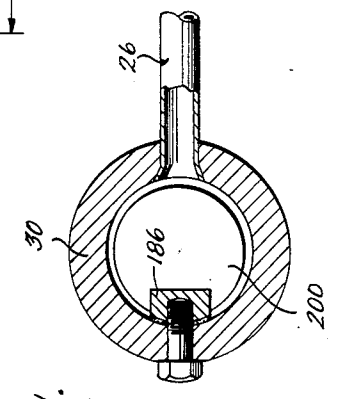


FIG. 41.

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WALTER DOUGLAS LA MONT
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STEAM GENERATOR OR THE LIKE

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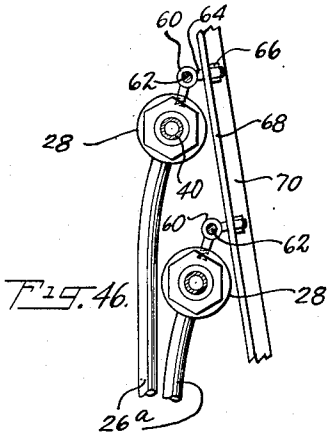


Fig. 46.

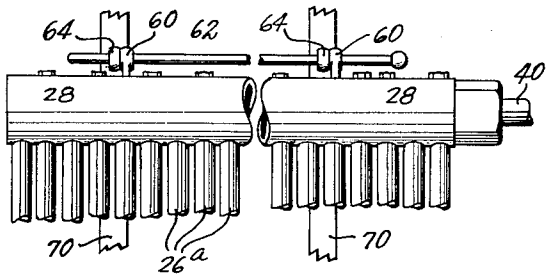


Fig. 45

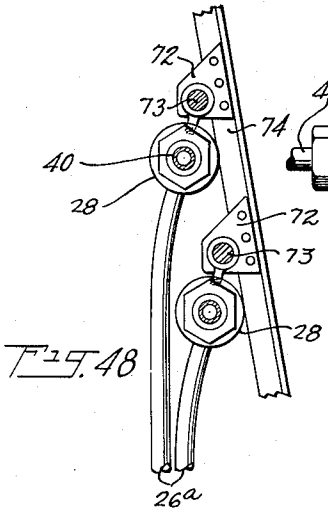


Fig. 48

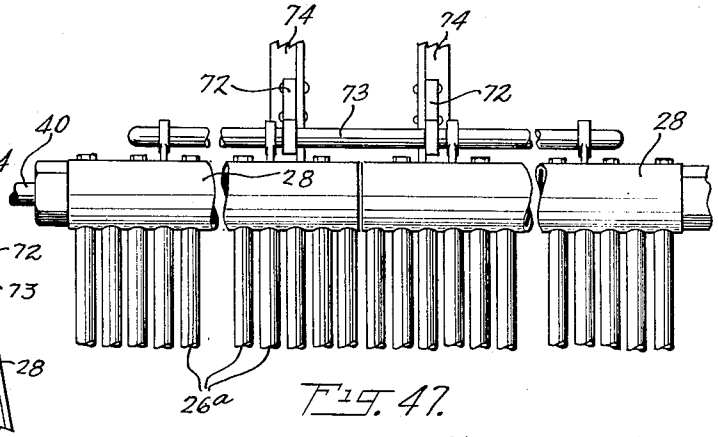


Fig. 47.

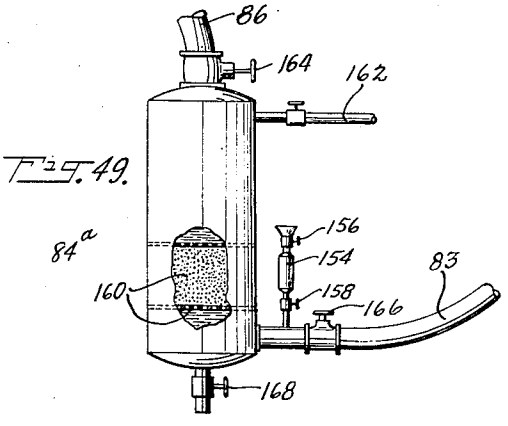


Fig. 49.

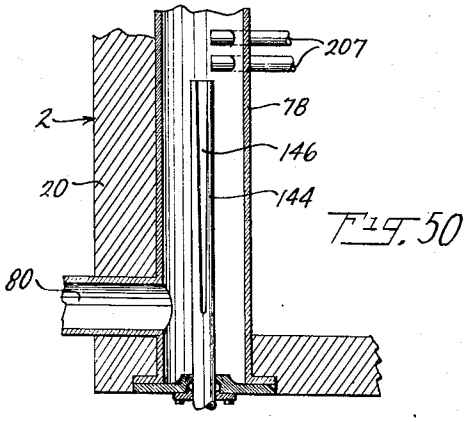


Fig. 50

INVENTOR.
WALTER DOUGLAS LA MONT
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STEAM GENERATOR OR THE LIKE

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Fig. 53

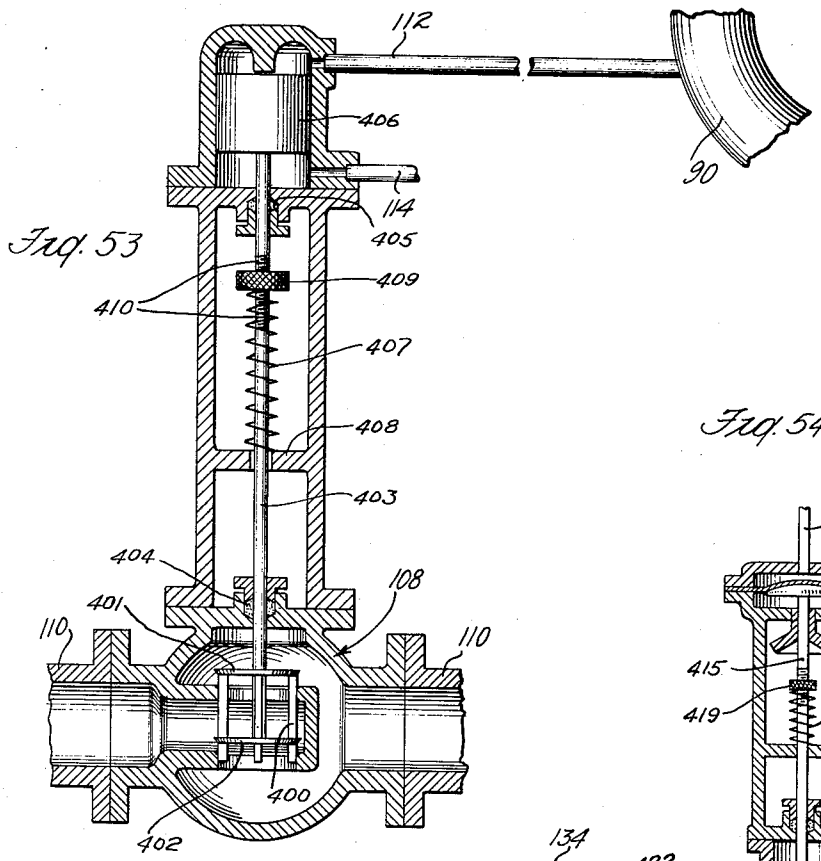
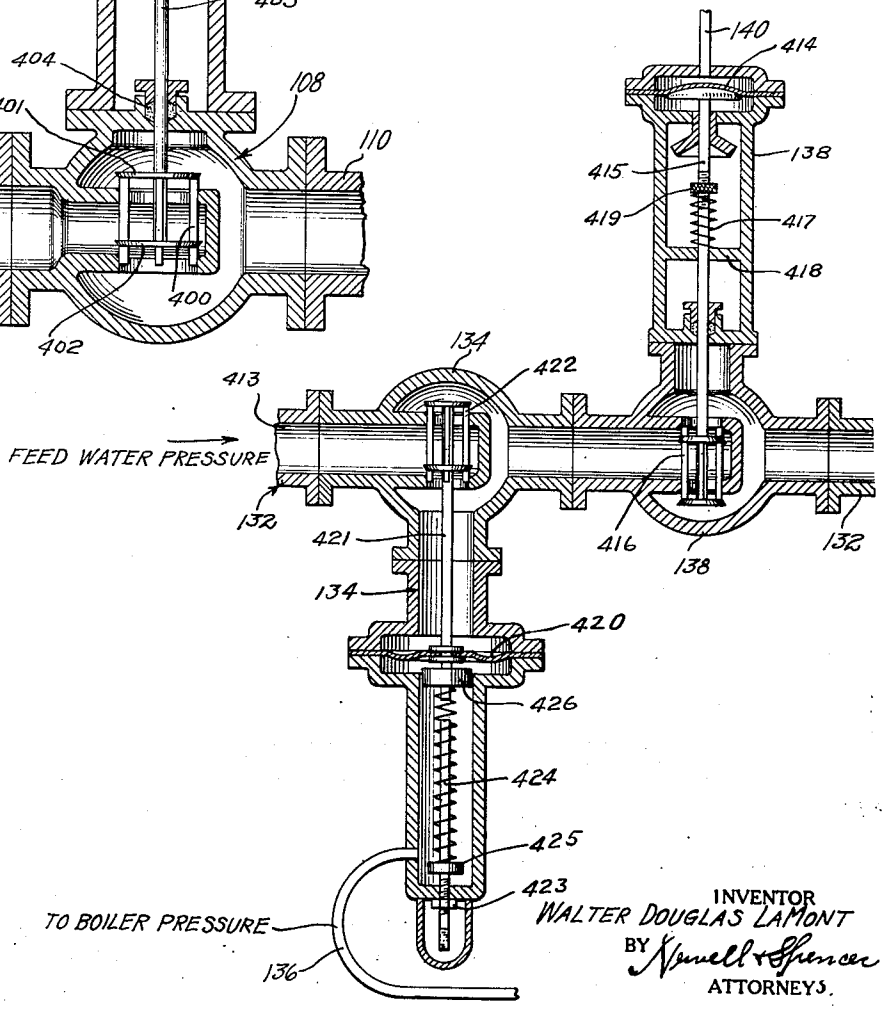


Fig. 54



INVENTOR
WALTER DOUGLAS LAMONT
BY Newell & Spencer
ATTORNEYS.

Patented Nov. 3, 1931 1,830,324

UNITED STATES PATENT OFFICE

WALTER DOUGLAS LA MONT, OF NEW ROCHELLE, NEW YORK, ASSIGNOR TO LA MONT CORPORATION, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

STEAM GENERATOR OR THE LIKE

Application filed May 22, 1925, Serial No. 32,064, and in Czechoslovakia July 10, 1920.

This invention relates to steam generators and particularly to steam generating systems of the type which have a forced circulation of water therein, and to means for the regulation thereof.

The common type of boiler used for the generation of steam involves an arrangement of tubes so connected to a drum containing the water that they lie below the level of water maintained in the drum, whereby the water is caused to circulate through the heated zone only by convection currents arising from the difference in the weight of the water entering the tube and the weight of the water lightened by the steam contained therein in the tubes. The force available in such a system for moving the water into and through the tubes is very weak and uncertain.

It has, therefore, been proposed to circulate the water in a steam generator by a positively actuated pump located in a conduit connected to the tubes to form a closed circuit for fluid flow, the fluid flowing in this circuit, whether in the form of water or steam or both, being confined within the system under the conditions of evaporation therein. This arrangement has many advantages. The water may be delivered to the heat transferring surfaces in proper relation to the stetm generated so that they are kept wet and the tendency of the steam generation action to separate the water from the surface is thereby counteracted. This positive delivery, if maintained, insures increased safety, the prevention of the tubes being burned out by the intense heat of the furnace, the maintenance of high efficiency of heat transfer from the furnace fire or heated gases to the boiler water, and the continuance of operation of the steam generator.

One type of steam generator having a forced circulation of water is shown in my prior Reissue Patent No. 16,895, in which the water delivered by the pump is forced into tubes of relatively small diameter each of which has a restriction forming an orifice at the inlet end of the tube which, while limiting the quantity of water delivered to the tube to an amount which is insufficient to fill out the full internal cross section of the tube for a substantial part of its length, permits it to be delivered in an amount which exceeds the steam generating capacity of the tube. The pump is located in a return connection between the outlet ends of the generating tubes and the inlet ends and receives the excess water that has been discharged from the tubes with the steam. This water together with the new make-up feed water is delivered again to the inlet ends of the tubes. There is thus in this type of generator a definite flow of water which must be delivered between the two limits of quantity indicated, i. e. less than will fill the tube but greater than the evaporation therein and which must be continuously delivered in proper relation to the steam generated in each tube in order to insure the advantages of forced circulation as explained above. The generator of this patent, however, when the circulation is properly provided for, affords marked advantages in steam generating capacity and efficiency due to its peculiar application of forced circulation in tubes which have as a result the ability to transfer heat at high rates.

In these various forms of forced circulation generators, there has been no provision heretofore for insuring the proper circulation conditions so that, for example, if the pump should stop or should be materially reduced in speed or in its pumping capacity or if for any other reason the flow of water to or through the tubes should be decreased or stopped, there is liability of damage to the tubes or loss of efficiency occurring. This is particularly true in the case of the steam generator shown in my prior patent, in which to secure the advantages above mentioned, the water, in its passage through the tube, clings in a considerable degree to the inner surface of the tube, thereby keeping the tube surface wetted, but is restricted in quantity by the orifice so as to leave adequate space for the steam. In a boiler of this type although the water flow is in excess of the evaporation there is no storage of water in the tube. If the flow of water from the pump to the tubes should stop momentarily or be reduced to too low a quantity even for a short time, some of the tubes would not receive their proper supply of water and, becoming dry, they

would be made ineffective or, what is more serious, they would be in danger of being burned under the heat to which they are subjected.

A further problem in connection with generators of the type of my prior patent presents itself due to the small amount of water which is contained within the circulating system. This necessitates a careful control of the make-up water which is fed to the generator to replace that evaporated into steam and a proper regulation of the feeding of this water in connection with the circulation so that the circulating pump will always have water which it may deliver to the generating elements.

Other conditions of operation of steam generators of the type described present problems such as the interference with the flow of water by accumulation of air, gas or vapor in the circulating system and, again, the obtaining of proper flow to the various tubes lying in different zones of heat.

It is, therefore, the primary object of my invention so to construct and arrange a steam generator of the type which has a forced circulation of water through the generating elements that a positive circulation of water in adequate quantity to all of the generating elements will be insured at all times.

Another object is to provide such a steam generating system with regulating mechanism which is so constructed and is so coordinated in its operation with the water flow and the steam generation in the elements and which is so governed by variations in conditions in the operation of the steam generating system itself as to insure a continuance of a water flow suitable for the conditions of such steam generation.

A further object of the invention is to provide such a steam generating system with controlling mechanism so arranged that it is operated in accordance with variations in pressure in the system, and particularly any variation in the difference in pressure at two different points in the system, whereby the water flow may be rendered substantially continuous and uniform or commensurate with the variations in the steam generation.

A further object of the invention is to provide as a safety feature an auxiliary water circulating apparatus arranged to supplement, or take the place of the normally operating pump in case of failure of the pump, and further to provide regulating and control mechanism which will automatically cause the auxiliary circulating apparatus to function when the performance of the pump is inadaquate.

A still further object of the invention is to insure the opertion of the circulating apparatus and the continuity of flow by providing releasing or leak off devices which serve to vent air, gas or vapor which may accumulate in portions of the system or in the circulating apparatus itself and thereby interfere with the flow of water or prevent the circulating device from drawing the water for delivery to the tubes.

An additional object of the invention is so to relate the intake ends of the tubes to each other that the difference in level, taken in connection with the pressure produced by the pump and governed by the regulating means, provides for the proper flow of water to the various tubes or groups of tubes which are subjected to different heats, the purpose being that those tubes lying in the greater heat shall receive the greater amount of water.

In accordance with my invention, I have provided a steam generating system in which the water flow in the system is positively produced, and this is preferably accomplished by a water supplying and circulating apparatus controlled by regulating mechanism which is responsive to varying conditions in the system related to the water flow. For example, since the water circulating apparatus, such as a pump, necessarily builds up pressure or water head, which is a function of the water flow, it is therefore feasible to employ a device responsive to this pressure or a pressure differential in the system arranged to operate a control device which regulates the flow of water. These pressures or pressure differentials are not necessarily dependent upon or limited by the actual or absolute pressures existing within the system, for example, that due to the steam pressure.

To this end a rotary pump, for example, may be located in the return conduit which connects the outlet and inlet ends of the steam generating tubes, and this pump may be driven by a suitable motor, such as a steam turbine supplied with steam from a suitable source. Of the various ways which may be employed to control the flow of water delivered by this pump, one of the methods within the scope of my invention involves controlling the supply of the steam to the turbine which drives the pump. In this case the pressure responsive device may be directly connected to operate the valve in the steam supply pipe to the turbine and thereby control the speed of the pump and consequently the water flow.

As a further safety feature, I may also employ an auxiliary water circulating apparatus, such as a second pump driven from a suitable source of power, which is preferably so connected in the system that either pump may be operated or both may be used at the same time to circulate water. The regulating mechanism therefor, which may be a pressure responsive device similar to but independent of the other, is preferably so arranged that if the pump which normally

drives the water through the system fails to furnish adequate supply to the tubes, then the second pump will automatically operate to restore that supply to normal.

As the return portion of the circuit is a closed hydraulic system through which the water must continuously flow for delivery of water to the steam generating tubes, and especially in steam generators of the type disclosed in my prior patent in which relatively low pressure or head of water is utilized to deliver the water through the orifices, any interference with this circulation or flow of water or the head producing such flow by the accumulation in the circuit of air or gas or vapor naturally present in boiler waters must be prevented. I therefore provide connections from those portions of the circuit or of the circulating apparatus in which such accumulations may occur, so that the pressure produced by the water circulating apparatus may be utilized to discharge such accumulations to other portions of the circuit, such as the steam space of the generator where they may be withdrawn or condensed and thus prevented from further interference. Especial attention to this provision is necessary where long vertically arranged tubes are used involving long pipe connections, or where the structure is such that bends in the pipe are necessary, at which points, particularly the highest point in the circuit, air or gas may accumulate.

A further feature of the invention is the arrangement of the inlet ends of the tubes, especially of the type of my prior patent, at different levels relative to each other. This accomplishes in effect a placement of the inlet ends at different water head heights below a common water head, that is the different inlet ends are subjected to different pressures corresponding to these different heights. Thus the cooperation between the placement of the inlet ends of the tubes and the control of the water pressure may be utilized to deliver water to the different tubes in accordance with their placement in different heat zones and therefore in accordance with the amount of steam which they will be caused to generate. The regulating and control mechanism may be adjusted for the purposes of this type of operation so that a given pressure or water head height may be maintained.

In addition to the objects and important features of the invention hereinabove enumerated, others will appear from the following description and claims when considered in connection with the accompanying drawings, in which—

Fig. 1 is an elevation of steam generating apparatus embodying the present invention and useful in carrying out the novel method of generating steam, which constitutes a part of the invention, this apparatus being shown as associated with one of the superheaters of a gas generating plant to utilize the heat of the gases passing through said heater during the "blow" of the gas generating set;

Fig. 2 is a vertical section through the lower part of the heat chamber of the steam generator, this chamber serving as a combustion chamber when the generator is provided with its own heating apparatus as shown in Fig. 51;

Fig. 3 is a vertical section constituting substantially a continuation of the section shown in Fig. 2 through the upper part of the steam generating apparatus;

Fig. 4 is a front elevation of an explosion door preferably provided for the heat chamber of the generator;

Fig. 5 is a section on the line 5—5 of Fig. 4 showing the details of construction of one of the blow-out sections of the explosion door;

Fig. 6 is a section on the line 6—6 of Fig. 4;

Fig. 7 is a section on the line 7—7 of Fig. 4;

Fig. 8 is a section on the line 8—8 of Fig. 4;

Fig. 9 is a plan detail showing the valve between the superheater and the heat chamber of the generator, and the mechanism for operating the valve;

Fig. 10 is a detail of the valve and its operating mechanism in side elevation;

Fig. 11 is a section on the line 11—11 of Fig. 2 showing the arangement of the outlet headers and of the baffles in the heat chamber;

Fig. 12 is a detached view, in side elevation, illustrating the principal parts of the water circulating system of the generator detached from the casing;

Fig. 13 is a sectional detail illustrating the perforated reducing disk employed in the bleeding pipes associated respectively with the pump and with the manifold at the upper end of the water circulating system;

Fig. 14 is a section on the line 14—14 of Fig. 12 looking in the direction of the arrows;

Fig. 15 is an elevation of the steam collecting system separated from the remaining parts of the apparatus;

Fig. 16 is a plan view of the system shown in Fig. 15;

Fig. 17 is a side elevation of a single generating tube illustrating the curvature of this tube at its upper and lower ends and its relationship to the distributing, and collecting headers;

Fig. 18 is a sectional detail of the upper end of a bank or tray of the generating tubes showing one of the distributing headers, the way the tubes are expanded into the headers, the removable jet manifold and the openings through which the generating tubes may be cleaned;

Fig. 19 is an end view of Fig. 18 looking from the right;

Fig. 20 is a section on the line 20—20 of Fig. 18;

Fig. 21 is a section on the line 21—21 of Fig. 18;

Fig. 22 is a plan detail of the header construction shown in Fig. 18;

Fig. 23 is a sectional detail of the lower end of an assembled group, bank or tray of the generating tubes showing the construction of the collecting header;

Fig. 24 is an end elevation of the collecting header looking from the left in Fig. 23;

Fig. 25 is a section on the line 25—25 of Fig. 23;

Fig. 26 is a sectional detail illustrating the means for positioning the tubes of a tray with relation to each other, this figure being a section on the line 26—26 of Fig. 27;

Fig. 27 is a section on the line 27—27 of Fig. 26;

Fig. 28 illustrates a modified form of tube spacer combined with soot-blowing means;

Fig. 29 is an enlarged section near the upper end of the generator showing the construction and arrangement of the water distributing manifold including the screen for the prevention of the entrance of foreign matter into the generating tubes; this figure also shows the supports for and arrangement of the tube trays;

Fig. 30 is a section on the line 30—30 of Fig. 29;

Fig. 31 is a detail section near the upper end of the generator showing a portion of a soot-blowing system;

Fig. 32 is a further detail view of the form of soot-blowing system shown in Fig. 31;

Fig. 33 is a section on the line 33—33 of Fig. 32;

Fig. 34 illustrates a modified form of distributing header of rectangular cross-section;

Fig. 35 is an end view looking from the right in Fig. 34;

Fig. 36 is a plan detail of the left hand end of the construction shown in Fig. 34;

Fig. 37 is a section on the line 37—37 of Fig. 34;

Fig. 38 is a section on the line 38—38 of Fig. 34;

Fig. 39 illustrates a modified construction of the collecting header outlet;

Fig. 40 is an end view of the construction shown in Fig. 39 looking from the right;

Fig. 41 is a section on the line 41—41 of Fig. 39;

Fig. 42 is a section on the line 42—42 of Fig. 39;

Fig. 43 is a section showing a modification of the removable cover for the clean-out holes;

Fig. 44 (Sheet 7) is a sectional detail showing the means for effecting the tangential discharge into the collecting pots of the water received from the collecting headers;

Fig. 45 is a front elevation, and Fig. 46 is an end view illustrating one mode of suspending the tube trays;

Fig. 47 is a front elevation and Fig. 48 an end view of another mode of suspending the tube trays;

Fig. 49 is a broken side elevation of a modified slow point construction having associated therewith means for chemically treating and filtering the water;

Fig. 50 is a detail section of the lower end of one of the collecting pots illustrating the connection to these pots from the apparatus for chemically treating the heated water collected in the pots;

Fig. 51 is a broken diagrammatic view illustrating the mode of installing oil burners or other heating devices in the heat chamber of the generator when the generating heat is to be supplied by combustion in the chamber itself;

Fig. 52 is a sectional detail illustrating the preferred adjustment of the jet manifolds so as to direct the jets against the inner wall surfaces of the generating tubes at the upper sides of the upper bends in said tubes;

Figure 53 is a detail of the regulator 108 and Figure 54 is a detail of the feed water control valves.

As hereinabove pointed out, the steam generator herein specifically illustrated is shown as arranged to utilize the waste heat from a gas generating plant, but it will be understood, of course, that the invention is not restricted to such uses nor to any particular mode of providing heat for converting the water into steam, the illustrated application of the invention being merely one of many uses to which efficient heat exchanging apparatus of the type herein disclosed may be put.

As shown in Fig. 1 of the drawings, the steam generator has its casing 2 carried by a supporting steel frame-work 4 mounted at one side of the superheater 6 of the gas-producing plant, although if desired the casing 2 could be mounted directly on top of the superheater 6, the generator as a whole being light enough for such a mounting thereof. The connections through which the hot gases from the superheater 6 are conducted into the heat chamber of the generator comprise a pipe 8 from the superheater leading down to a dust collector 10, of any suitable construction, by which the dust is preferably separated from the gases before they enter the heat chamber of the generator, the gases then passing up through the opening 12 (Fig. 2) controlled by the valve 14 into the heat chamber 16 of the generator.

As hereinabove pointed out, the generator is adapted to be heated not only by means of hot gases produced from outside thereof, as in the illustrated embodiment, but is also adapted to be heated by its own heating plant

such, for example, as burners 17 located in the lower part of the heat chamber 16 (see Fig. 51), or by other suitable heating means, the design of the generator being particularly adapted to utilize all of the heat produced by combustion, both radiant heat and sensible heat, the path of travel of the gases in the generator being, as hereinafter pointed out, relatively long and so confined as to insure substantially complete heat absorption so that the stack temperature of the gases leaving the generator approximates the temperature of the steam in the generator.

The casing 2 of the generator may be made of any suitable construction, such, for example, as an outside covering 18 of steel provided with a lining 20 of suitable refractory material, preferably having heat insulating properties, the lower part of the heat chamber being of relatively large cross section as compared with the upper part and being preferably joined to the upper part by a curved connection having a curvature corresponding substantially to that of the generator tubes hereinafter to be described, which curved connection may be made in any suitable way as, for example, by supporting the bricks 22 of refractory material upon the T beams 24.

As hereinabove pointed out, the steam generator of the present invention operates upon the principle of my copending application hereinabove identified and comprises a plurality of relatively long approximately upright tubes, of relatively small diameter and gage, into the upper ends of which tubes the water is forced in the form of jets so directed against the walls of the tubes as to insure the formation of films thereon, the water being continuously forced into the tubes in such quantity as to maintain films upon the inner walls thereof throughout a substantial portion of the lengths of the tubes. This arrangement leaves the centers of the tubes free and unobstructed so that steam generated by the heat conducted through the walls of the tubes into the water films upon the inside thereof may readily break through the surface tension of the film and escape to the free open space of the center, traveling down the tubes and out of their lower ends together with any water which remains unevaporated on arrival at said lower ends. In the illustrated embodiment of the invention, these generating tubes 26 comprise relatively long, substantially vertical upper portions 26*a* and relatively short curved lower portions 26*b*, the curved portions 26*b* being located in the lower or larger part 16*b* of the heat chamber, 16 whereas the upright or vertical portions 26*a* are in the smaller part 16*a* of the heat chamber 16. These tubes 26, which are preferably comparatively long, say each about 25 feet long in a generator adapted for the purposes of that herein shown, are, as above stated, of relatively small diameter, say 5/8" outside diameter and 1/2" inside diameter, thereby having a wall thickness of 1/16th of an inch, and are made of any suitable material, for example, seamless drawn steel.

Each of the tubes 26 is connected at one end to a distributing header 28 and at its other end to a collecting header 30, the tubes, for convenience in assembling and for permanence of construction, being preferably expanded into openings in these headers at their ends, as shown in Figs. 18 and 23 of the drawings. The distributing header 28, which is illustrated in detail in Fig. 18, is drilled with openings 32 to receive the upper ends of the tubes 26, these openings as shown being countersunk upon the inside of the headers so that the ends of the tubes may be expanded into the openings and thus locked in the headers. The expanding may be effected by a tool inserted through an opening 34 in the opposite side of the header, the opening 34 being directly opposed to the opening 32. These openings 34, as hereinafter pointed out, are useful not only in assembling the tubes 26 in the headers 28, but also to provide for the insertion of a cleaning tool into the tubes to remove scale or other possible accumulations upon the insides of the tubes, although for the most part the tubes are self-cleaning.

As hereinabove pointed out, the water distributed to the tubes 26 through the associated header 28 is projected into the tubes in the form of jets which strike the inner walls of the tubes, there being preferably a single jet for each tube. These jets are preferably produced by jet openings 36 in a jet manifold 38 which is removably held within the header 28, the manifold being so located in the header 28 that the jet openings 36 are directed slightly toward the inner walls of the tubes. This may be done, as in the illustrated construction, when the jet openings are all in one line along the side of the manifold 38, by moving the manifold about the axis of the header 28 so as to direct all of the jets toward corresponding sides of the inner walls of the tubes 26. For the greatest effectiveness in wetting the inner surface of the tube and insuring the starting and maintenance of a film over the whole surface thereof, the jet is preferably directed into the tube so that it strikes the upper side of the curve adjacent to the upper end of the tube, as shown in Fig. 52.

The jet manifold 38, in the embodiment shown in Figs. 18 and 21, is in the form of a tube, semi-circular in cross section, which fits the inner wall curvature of the header 28, the jet manifold 38 being held in the header by any suitable means, such as a pipe union providing a connection between the jet manifold and one of the pipes 40 from the water

manifold 42. The end of the header 28 is preferably concave to nest with a correspondingly shaped flange on the jet manifold 38. One member 44 of the pipe coupling is threaded on to the pipe 40 and the rotatable member 46 of the pipe coupling is adapted to be screwed on to a threaded part 48 on the header 28.

To cover the openings 34 in the header 28 and also to provide means for maintaining the location of the jet manifold 38, a gasket bar or strip 50, of substantially segmental cross section so that its curved face fits snugly against the inner surface of the header, is provided, this strip 50 being tapped to receive screws 52 by which it may be held tightly against the inner surface of the header 28 and thus close the openings 34, nuts 54 on the screws 52 being adapted to bear against flat surfaces 56 on the header 28 and thus draw the gasket bar or strip 50 tightly against the inner wall of the tube 28. The correct or desired angular position of the jet openings 36 having been determined, adjustment of the jet manifold, when replaced after removal for cleaning the tubes or other purposes, can be avoided by providing locating means, as, for example, a locating pin 58 projecting from the end of the strip 50 and engaging a recess in the flange 42 on the manifold.

Each of the headers 28 is utilized to effect the support of the bank or tray of tubes of which it constitutes a part, and to secure compactness, as well as to bring the tubes as closely together as possible in order to absorb substantially all of the heat from the passing gases, the trays of tubes are suspended in the manner shown in the drawings, so that the header of one tray is above and only slightly offset from the header of the next tray in toward the center of the boiler or generator, the upper ends of the tubes being slightly bent toward the middle line of the boiler to facilitate such location of the banks or trays of tubes. Any suitable means may be provided for supporting the upper headers 28 in order to support the banks or trays of tubes thereby, such means being preferably constructed and arranged for ready detachment in order to permit the removal of one or more of the banks or trays.

In Figs. 45 and 46 is shown a construction in which two or more of the screws 52 are replaced by screw eyes 60 through which may extend a rod 62 engaging corresponding screw eyes 64 fastened by nuts 66 to the flanges 68 of angle members 70 constituting part of the supporting framework of the boiler. In Fig. 48 the screw eyes 64 are replaced by brackets 72 riveted or bolted to parts of the frame structure corresponding to parts 70.

In the form of support shown in Figs. 45 and 46, it is intended that the rod 62 be withdrawn from the screw eyes when removing the tray from the casing, and that it be again threaded through the screw eyes when the tray has been replaced. In the form of support shown in Fig. 48, however, the brackets 72 are so located that the rods 73 supported thereby require no support beyond the screw eyes on the headers 28 and therefore the trays may be removed from the casing by simply sliding them off the rods 73.

Still another form of support which facilitates the ready removal of the trays from the generator housing or casing, is that illustrated in Fig. 29 of the drawings. This comprises a series of sockets 75 formed in a supporting bracket 77, this bracket, as shown, being arranged as a V-like structure connected at 79 to the casing of the generator and having its two arms connected by plates 81 at the apex of the V. The sockets or seats 75 in the bracket 77 are so arranged that by disconnecting the pipe 40 at one end of the tray, the tray may be moved edgewise out of its supporting sockets.

As above pointed out, each of the headers 28 is connected by pipe 40 to the vertically arranged water manifold 42, the uppermost headers 28 being connected by pipes leading to the uppermost discharge opening of the manifold 42, and the lowermost headers 28 being connected by pipes 40 to the lowermost discharge openings of the manifold 42, one of the purposes of this arrangement being to vary the water head and therefore the amount of water supplied to the respective banks of tubes proportionately to the varying demands made upon the water supply by reason of the variations in the heat intensity at different parts of the generator. It will be seen that the lowermost headers 28 suspend their banks or trays of tubes in such manner that their lower curved ends, as shown in Fig. 2 of the drawings, are located lower down than any of the other tubes in the heat chamber 16 and thereby receive the first heat from the gases. It will also be noted that these banks or trays are nearest the center of the path of travel of the heat through the generator and therefore receive the most intense heat, so that the generation of steam in these tubes is greater than in the outermost and uppermost banks or trays, with the result that it is desirable that a greater water supply be provided for these innermost banks or trays of tubes in order to insure maintenance of the water film upon the insides thereof. This is accomplished, it will be noted, by the convenient and compact arrangement which gives the greatest water head in the manifold 42 to the innermost and lowermost extending tubes and the least water head to the outermost and uppermost tubes.

The manifold 42 receives a continuous supply of water which, after the generator has started, is made up partly of water which has

passed through the generating tubes and has not been evaporated into steam, and partly of water from outside the circulating system introduced into the circulating system of the generator to replace that which has been turned into steam. The feed water from outside the circulating system of the generator may of course consist either wholly or partly of condensed steam that has performed its useful service.

The collected water from the tubes is received in the collecting headers 30 and is then conducted through outlets 206 and pipes 207 to collecting pots 78 of which there are preferably a plurality arranged to facilitate the initial separation of water and steam from different parts of the generator. From the collecting pots 78 lead conduits 80. The conduits 80 from the collecting pots on one side are connected to a common 82 which passes around the four sides of the generator and upon its side opposite that on which the first two conduits 80 are connected to it, the other two conduits 80 from the other two collecting pots 78 join it and it then passes along the fourth side of the generator into the "slow point" 84. From the "slow point" 84, a pipe 86 leads to a pump 88 by which the water from the "slow point" is again elevated through pipes 90 and 92 to the manifold 42.

The discharge end of the pipe 92 is preferably carried down into the manifold 42 (Fig. 29) to substantially the lower end thereof, and to prevent foreign matter from entering the pipes 40 leading to the headers 28 and to the jet manifolds, with the possibility of clogging the openings 36 in the jet manifold 38, a screen 94 is preferably interposed between the pipe 92 and the wall of the manifold 42 through which the water discharges into the pipes 40, which screen, as shown, is cylindrical in form and preferably extends throughout the length of the manifold 42.

To prevent the formation of scale or other solids which might interfere with the operation of the jet manifolds, the manifold 42, the tubes 40, the jet manifold 38 and all connections between these, in fact all parts through which the water travels after it passes through the screen 94 and until it is discharged through the jet openings 36, are preferably formed of non-corrodible metal, so that the water which has been freed from foreign substances as it passes through the screen 94 will not collect other foreign substances by reason of its action on the metal of the passages through which it travels to the jet openings 36.

For convenience in assembling and removing the parts for cleaning, the screen 94 is removably mounted in the manifold 42 and the section of the pipe 92 which enters the manifold is removable to permit the withdrawal of the screen for cleaning, being provided with a clamp-joint 96 (Fig. 3) permitting its disconnection from the rest of the pipe 92. The cover 98 of the manifold 42 is clamped to a ring 100 on the manifold and is provided with a centering lip or rib 102 about the pipe 92, which serves to center the screen 94 in the chamber of the manifold 42.

The pump 88 (Fig. 12), herein shown as of the rotary type, is driven from a motor 104 connected by a shaft 106 to said pump. The motor may be of any suitable type permitting ready control of its speed to meet varying demands, the motor herein shown being a steam turbine to which the supply of steam may be varied in accordance with the variable demand made upon the pump. In the illustrated construction, the steam for the motor is preferably taken from a source of steam supply outside the present generator, and the control of the steam supply to the motor is preferably effected by means of a fluid pressure regulator which depends for its action on a predetermined differential between the steam pressure and the water pressure. In the illustrated construction the pump governor or regulator 108 which operates to control the supply of steam coming from a suitable source through the pipe 110 to the motor 104, has a connection through a pipe 112 to the discharge end of the pump 88 or to the conduit 90 and has another connection through a pipe 114 to the steam pressure in one of the pots 78 whereby the differential between the steam pressure in the pots 78 and the water pressure in the water supply pipe 90 acts to control, through the governor or regulator 108, the speed of operation of the motor 104 and therefore of the pump 88. The governor or regulator 108 may be one of the standard commercial regulators and in itself does not constitute a part of the present invention. A check valve 364 prevents counterflow through the pipe 90 when the pump 88 is not operating.

In Figure 53 the regulator 108 is shown in enlarged detail. Here the pipe 110 is shown at that portion only which includes the control valve. This valve is indicated by the reference character 400 and has a valve disc 401 and a valve disc 402, the valve being controlled by a stem 403 passing through stuffing boxes 404 and 405, the upper end of the stem carrying a piston 406. Referring also to Figure 12, as well as to Figure 53, it will be noted that the connection 112 leads from the water supply pipe 90 to a portion of the valve casing above the piston 406. On the other hand, the steam pressure from the pot acts upon the under side of the piston through the connections 114. The amount of steam which is supplied to the turbine 104 will depend upon the amount to which the valve 400 is open. The valve is urged away from its seat by a spring 407 surrounding the stem 403, the spring being confined between a partition 408 in the cas-

ing and an adjustable nut 409 which may be moved up and down on the threaded portion 410 of the stem 403. The adjustment will be such as to maintain the valve at a certain definite opening and therefore supply the pump with enough steam to give it a velocity to maintain the desired pressure in the supply pipe 90.

The pressure in said pipe 90 must be such as to overcome the friction in the pipe as well as the friction in the several headers and manifolds, including the losses due to pressure drops through the jet orifices, and therefore such pressure would normally be in excess of that in the pot 78 to which the pipe 114 is connected. The spring 407 is therefore set to balance this desired pressure differential, and under normal operation any decrease in this differential will allow the spring to open the valve and deliver more steam to the turbine, thus speeding up the pump and so increasing the discharge pressure of the pump, with a consequent restoration of the differential. Such a fall in differential may be caused by a reduction in the pressure of the steam supply to the turbine or may be due to wear of the pump parts, causing reduced water flow.

Conversely if there is an increase in the differential due to overspeeding of the pump or, on the other hand, sudden withdrawal of the steam from the pot 78, this increase will act against the spring 407 by increasing the pressure difference acting upon the piston 406, thus closing the valve and reducing the speed of the turbine. There is then avoided a delivery of too great an amount of water and possible flooding of the generating elements.

To provide for failure or break down of the main circulating pump and also as a possible reserve to meet extraordinary demands upon the generator, there is preferably provided an auxiliary or reserve pump 116 which has its intake pipe 118 connected to the pipe 86 leading from the "slow point" 84 and has its discharge pipe 120 connected to the pipe or conduit 90 at 122. The pump 116, like the pump 88, is herein shown as driven by a steam turbine 124 from the same source of steam supply as that to the motor turbine 104. The pump 116 preferably operates only when the differential between the steam and water pressures is less than a certain amount The governor 126, which controls the speed of the turbine 124, has a connection through a pipe 128 (Fig. 14) to the discharge pipe 120, and a connection through a pipe 130 to the steam pressure in one of the pots 78, and, as above suggested, the governor is so set that a differential between the steam and water pressure less than that furnished by the pump 88 when running at its proper delivering capacity, but of course high enough to insure protection of the boiler, in case of breakdown or failure of the main pump, will cause the turbine 124 and its attached pump to start. In other words, the pump 116 is merely an auxiliary or reserve pump and operates only when the main pump breaks down or when the demand upon the generator is greater than can be supplied by the pump 88 alone. The pipe 120 is preferably provided with a check valve (not shown) similar to the valve 364 in pipe 90.

The governor or control valve 126 may be of the same type and operate in the same manner as the valve described in connection with the main pump 88 but arranged to operate independently of the latter valve, so that a failure or improper operation of either the main pump or its control valve will cause the control valve for the auxiliary pump to operate the same and restore the required flow.

The feed water supply means for the generator, which delivers water to replace that which has been converted into steam, is arranged to deliver the water to such part of the water circulation that the cold water from outside the generator is mixed with hot water that has just come through the generating tubes, thereby effecting a substantial precipitation of the minerals and other foreign substances which may be in solution in the feed water before this water is delivered to the generating tubes. To insure such a precipitation and also to insure a separation of the precipitates from the water before delivery to the generating tubes, the feed water is preferably introduced into the water circulation at a point between the discharge end of the generating tubes and the "slow point".

As herein shown, the feed water is introduced into the water circulation system of the generator at one end of the collecting common 82 which receives the water separated from the steam in the pots 78. As above pointed out, this common extends substantially along the four sides of the generator before discharging into the "slow point" 84, this common being preferably outside the heat or combustion chamber of the generator, as shown in Fig. 1 of the drawings. The pots 78 are preferably in the chamber 16, there being one at each corner of the lower part 16b of the chamber in the illustrated construction.

The feed water, which may be from any suitable source of supply and under suitable pressure, comes through a pipe 132 (Fig. 14), and passes through a pressure regulator 134 of known construction controlled by the steam pressure in one of the pots 78 through pipe 136. This varies the feed-water pressure in accordance with variations in the steam pressure in the generator. Preferably the control of the entrance of the feed water into the generator is effected by a valve device 138 governed by a regulator 139 (Fig. 12) controlled by the water level in one of the pots

78 and operatively connected to the valve device 138 through pipe 140, this regulator being of a standard type such as are now on the market for use with ordinary boilers to maintain a predetermined water level in the boiler, the regulator being governed in its operation by the water level and operating through any suitable fluid in the pipe 140, such, for example, as water. In this manner feed water, in quantity to replace the water in the generator which has been converted into steam, is introduced into the generator and the water level in the pots 78 is maintained at a predetermined point.

In Figure 54 there is shown in detail the control devices for the feed water. The pipe 140 is shown as entering the top of the chamber of the valve device 138 and the fluid which enters through 140 acts upon a diaphragm 414 to which is connected a stem 415 carrying at its lower portion a double-disced valve 416, the valve stem passing through suitable stuffing boxes as is customary in these devices.

A spring 417 confined between a partition 418 of the casing and an adjustable nut 419 normally tends to move the valve towards seating position, while the pressure entering through 140 tends to open the valve. The feed water is supplied at 413 and might be led directly to the valve device 138, but for the purpose of insuring a more uniform feed of water under varying conditions of boiler operation it is customary in practice to introduce the regulator 134. This comprises a casing which near its central portion supports a diaphragm 420, the under side of which is acted upon by the boiler pressure entering the casing through the pipe 136. A stem 421 passes through the diaphragm and at its upper end carries a double-disced valve 422. Below the diaphragm the stem carries a disc 426 to which one end of a spring 424 is attached. The stem is in two parts and its lower part carries a disc 425 to which the lower end of the spring is attached. The lower part of the stem is threaded and engages a threaded hole in the casing. A lock nut 423 holds the stem in adjusted position; such adjustment being made by rotating the stem whose lowermost end is flattened for this purpose. The purpose of this regulator is to maintain a definite pressure within the chamber above the diaphragm 420 and between the two valves 422 and 416, the pressure in this chamber being maintained at some predetermined amount and sufficiently high to cause feed water entering at 413 to flow through the valve 416 when such valve is opened under control of the regulator 139, Fig. 12. The feed water is allowed to pass through the valve 422 only when the pressure in the said chamber falls below a predetermined amount, it being understood of course that the pressure of the feed water at the entrance 413 of the pipe 132 is sufficiently high to overcome the boiler pressure. The pressure which the spring 424 exerts on the diaphragm 420 is equal to the difference between the boiler pressure entering through the tube 136 and the pressure in the chamber, which latter pressure also exerts a pressure on top of the diaphragm 420. Thus it will be seen that the valve 422 is intermittently opened according to the pressure conditions in the boiler and will always maintain a sufficient pressure behind the valve 416 to cause feed water to enter through said valve against the boiler pressure on the other side of the valve when said valve is opened, which opening is always controlled by the fluid pressure from the pipe 140, as described above.

As above suggested, one of the advantages of introducing the feed water into the receiving end of the collecting common 82 for the pots 78 is that by mixing the incoming cold water with the water that has just passed through the generating tubes and is heated to a relatively high temperature, the salts in solution in the incoming water tend to separate from the water and are carried along with the water to the "slow point" 84, where they have an opportunity to settle from the water before it is picked up by the pump and returned to the upper ends of the tubes. A further and fully as important an advantage of the introduction of the feed water at the point just described, is the heating of the feed water before it is introduced into the generating tubes, thus obtaining the results obtained by the various feed water heaters designed for use with ordinary boilers.

By introducing the feed water at the receiving end of the collecting common, it travels along with the heated water throughout the whole length of this common, first becomes substantially thoroughly mixed with the water received from the first two pots discharging into the common, and then receives a further accretion of heat from the water discharged from the remaining two pots as it passes their discharge conduits 80, thereby being raised to a temperature to effect precipitation of its mineral content just before being conducted to the "slow point" 84 through the pipe 83.

By varying the water level in the pots 78, which may be done by adjustment of the regulator 139 in a well known manner, the temperature of the water delivered to the generating tubes 26 may be controlled, this variation of the water level resulting in a variation in the total heat units in the water discharged from the pots in o the common 82 and thereby either increasing or decreasing the amount of heat imparted to the incoming feed water.

In order further to insure separation from the water delivered to the generating tubes of minerals or other foreign substances con-

tained in the water, there may also be connected to the water circulation system of the boiler apparatus for chemically treating a portion of the collected heated water before this water passes to the slow point 84 in the circulation. The apparatus itself for chemically treating the water constitutes no part of the present invention and may be of standard commercial construction. Its particular application to the generator of the present invention and the advantages obtained by its arrangement in the positively defined water circulation of the generator of the present invention are, however, novel features of the present invention.

In the illustrated embodiment of the invention, a certain proportion of the water in each of the collecting pots 78 is sucked out of these pots through the bottom thereof, taken to a chemical treating apparatus which, as above suggested, may be of standard commercial construction, where it is chemically treated and the precipitates removed by filtering or otherwise and the water is then carried to the slow point 84. The construction and arrangement for this chemical treatment in the illustrated embodiment of the invention are particularly shown in Figs. 12 and 50 of the drawings and comprise collecting pipes 142 branching to intake ends 144 extending up into the pots 78 through the bottoms thereof and preferably above the normal water levels in the pots, the intake ends 144 each having a V-shaped slot 146 in one or more sides thereof, with the widest part of the V at the top, the purpose of this being to suck the greatest amount of water into the collecting pipes 142 from the surface of the water in the pots 78, this being the point where the water is hottest and also being the point in the collected water where the precipitating action or the tendency to precipitation is most marked. Thus by sucking water in greater volume from the upper surface of that in the pots, a greater proportion of water needing chemical treatment is received into the collecting pipes 142, and this water being the hottest is also most readily susceptible to chemical treatment.

The water drawn off through the collecting pipes 142 is taken through a common pipe 148 to any suitable chemical treating apparatus 150, such, for example, as the apparatus known under the commercial name of "Hagan Deconcentrator", where it may be treated with soda ash, or other suitable precipitating reagent, and then after passing through a filter to remove the precipitates, conducted through another pipe 152 to the "slow point" 84, preferably being received in the "slow point" 84 at a point slightly above the discharge end of the pipe 83 which connects the common 82 to the "slow point" 84. This water, after passing through the chemical treating apparatus and the filter, will ordinarily contain in solution some of the precipitating reagent and thus, as it is received in the "slow point" 84, it will tend to facilitate the precipitation and separation from the water therein of any minerals or other foreign matters contained therein.

In the form of the invention shown in Fig. 49, the water delivered to the slow point through the connecting pipe 83, is delivered, as in the other form of the invention hereinabove described, at the lower end of the slow point, but may receive a charge of chemical before entering the slow point, so that when its movement is retarded as it passes through the slow point, the chemically charged water will precipitate whatever foreign matter it contains. The chemical may be introduced through a charging device 154 having two valves 156 and 158, permitting the charging of the device 154 when the upper valve 156 is open and the lower valve 158 closed, and its discharge when the upper valve is closed and the lower open.

This modified slow point, designated as 84*a* in Fig. 49, is preferably provided with filtering means 160 between the point at which it receives water from the connecting pipe 83 and the point where the water is taken out of it through the pipe 86, this filter serving to separate from the water any precipitates which tend to travel with it, and the whole arrangement being designed to be blown out occasionally by steam or other fluid entering the slow point through the pipe 162, valves 164 and 166 being provided respectively in the pipes 86 and 83 to close these when the clean-out valve 168 is open.

The chemical for treating the water may also be introduced, as shown in Fig. 12 of the drawings, into one of the pots 78 and preferably, as shown in this figure, into the last one of the pots discharging into the common 82, the charging device 169 shown in Fig. 12 being connected to the pot through a pipe 173 with which are also connected the air leak pipe 173 from the upper end of the water manifold 42, and the steam leak pipes 175 and 183 through a common pipe 185, the T 171 being connected to the pot through a short pipe 181.

In Fig. 15 is shown a side elevation, and in Fig. 16 a plan view of the steam collecting system of the generator. As hereinabove suggested, the steam and water collected in the collecting headers 30 are discharged into the pots 78 in a direction substantially tangential to the inner wall or inner surface of each pot 78, the steam and water passing from the headers 30 through outlets 206 coupled to inlets 207 extending tangentially through the walls of the pots 78 (see Fig. 44 of the drawings), so that the mixed steam and water is projected against the inner wall and tends to travel around the cylindrical inner surface of the pot, this action by reason of the greater

gravity of the water tending to effect a centrifugal separation of the steam and water whereby the steam is displaced toward the center of the pot while the water travels down the inner wall of the pot. The steam displaced toward the center is free to pass up and out of the top of the pot, the upper end of each pot being connected to a steam pipe 170 which in turn is connected to a common steam pipe 172 for the two pots on one side of the generator. Thus the steam collected from the four pots 78 is conducted through the pipes 172 to a steam separator 174 where any entrained water is finally taken from the steam before it passes to the main steam pipe 176 by which it is conducted to the point at which it is to be used.

The connection between the pipes 170 and the common steam pipe 172 preferably comprises a T 177, as shown in Fig. 15, on which is located a safety valve 179, there being, as shown, two safety valves, one for each of the T's 177.

As shown in Fig. 11 of the drawings, the collecting headers 30 are so located that the tubes of one tray are positioned opposite the spaces between the tubes for the adjacent trays and to insure substantial uniformity of spacing of the tubes throughout the upper portions of the generator, these headers are preferably arranged as shown in Fig. 11, so that alternate pairs of headers abut at their ends while the other pairs are spaced sufficiently to locate the tubes of their trays opposite the spaces between the tubes of those trays of which the headers abut. There will, of course, be a corresponding arrangement of the upper headers, (see Fig. 30). Preferably the tubes of one tray will be so located opposite the spaces between the tubes of adjacent trays that each tube will be substantially the same distance from each of the tubes which define the space to which it is opposed as said tubes are from each other.

To facilitate such intimate location of the tubes, the abutting ends of the headers are preferably so constructed as to permit the location of tubes very near these ends, as shown particularly in Figs. 18, 23, 34 and 39 of the drawings. In the construction shown in Fig. 23, the end of the header 30 which is adapted to be located adjacent to or to abut the end of the associated header is made in the form of a cap 178 adapted to be screwed upon the threaded shouldered end of the header 30, this cap having formed therein an opening 180, which opening is adapted, when the cap is in position on the header, to register with the corresponding opening in the header, so as to permit that tube 26, which is to be located adjacent to this end of the header, to be expanded into this opening, thus locking the cap in position at the same time that the tube is locked in position. There is preferably also provided an opening 182 opposite the opening 180 in the cap, which opening 182 will register with one of the openings 184 in the header and permit the introduction of an expanding tool for expanding the tube end 26. The openings 182 and 184 serve also, when the segment strip or gasket bar 186 is removed, to permit the introduction of a cleaning tool for cleaning out the tube 26, the segment strip 186 serving substantially the same purpose as the segment strip or gasket bar 50 hereinabove described, used to close the openings in the upper header, and being similarly secured in position by screws 188 and nuts 190. The cap 178 is preferably also brazed or welded on the header to secure tightness and permanency of the construction.

In the modified form of construction of the header shown in Fig. 39, there is provided, in place of the cap 178 shown in Fig. 23, a disk 192 adapted to seat against a shoulder 194 extending about the inner wall of the header 30, which disk 192 is adapted to be clamped in position by turning over the lip 196 of a channel formed at the end of the header 30. Both in the form shown in Fig. 23 and in the form shown in Fig. 39, the other end of the header is closed by an annular threaded member 198 having an inturned flange adapted to engage and clamp in position a closure 200 having a conical valve-like bearing surface 202 adapted to engage a correspondingly shaped seat 204. Spanner sockets 205 permit oscillation of the disk in its seat to grind it to a tight fit. The closure 200 is made readily removable to permit the segment strip or gasket bar 186 to be withdrawn when it is desired to have access to the tubes 26 through the openings 184.

From an examination of Fig. 25 of the drawings, it will be noted that the segment strip 186, at the point where it crosses the opening into the outlet 206 from the collecting header (which outlet, in Fig. 25, is shown as screwed into the header), is reduced in cross section to avoid interference with the passage of the steam and water, the cross section 208 of the segment at this point being shown as circular. In the modified form of the header construction shown in Fig. 42, the cross section of the reduced part of the segment is rectangular, as shown at 210, and the outlet 206 is shown as fastened in the header by pins 212. In Fig. 43 a further modification of the header construction is shown in which, instead of the segmental strip 186 for closing the openings into the header, the header has its inner wall provided with a flattened portion or groove adjacent these openings, so that a strip 214 having a flat bearing surface may be used to close the openings.

Although the headers thus far described, both the upper heads 28 in which the jet

manifolds are located and the lower headers 30, are shown as of cylindrical construction or circular cross section, it will be obvious that the invention is not restricted to the particular cross-sectional contour of the headers, and in fact some advantages may be obtained by using other cross-sectional contours, such, for example, as the header of rectangular cross section shown in Figs. 34 to 38, inclusive. In these figures is illustrated a modified upper header construction in which the rectangular header 216 has associated therewith a rectangular jet manifold 218, the rectangular construction permitting the use of a rectangular strip 220 to close the openings 222 which provide for the cleaning out of the tubes 26 and for expanding their ends into the tube-receiving openings in the opposite side of the header. To facilitate connection of one of the pipes 40 to the rectangular header, there is preferably attached to its end one part 224 of a union similar to that employed to the form of header shown in Fig. 18, except that the flange 226 connected to the jet manifold 218 engages a flat seating surface at the end of the part 224, and that there is therefore a corresponding flat surface on the pipe-engaging part 228 of the union. The rotatable member 230 of the pipe coupling or union corresponds substantially to the rotatable member 46 of the union hereinabove described.

Because of the relatively great length and the relatively small cross section of the tubes 26, these tubes in one practical embodiment of the invention being twenty-five feet long, of an outside diameter of five-eighths of an inch, and an inside diameter of one-half inch and spaced apart about one-quarter of an inch, it is usually advisable to provide means for insuring uniform spacing of the tubes so as to expose the whole outer surface of each tube to the heated gases, thereby insuring substantially uniform transfer of heat to the inner surfaces of the tubes. Various means may be provided for this purpose: In Fig. 26 are shown means for insuring permanent uniform spacing of the tubes comprising a rod 232 extending along one side of the bank or tray of tubes and preferably spot welded at a point opposite each tube to a metal strip 236 bent about the tubes as shown in Fig. 26, the opposite portions of the strip 236 being forced together between the tubes and preferably locked in position by clips or staples 238 which straddle the two portions of the strip or strips 236 and thus form definitely spaced loops in which the tubes are held against lateral displacement in the plane of the bank or tray. It will be noted that the rod 232 also tends to prevent relative displacement of the tubes out of the plane of the bank or tray. In Fig. 28 the rod-positioning means 237 is shown without the other form of positioning means and is welded directly to the tubes.

The provision made for cleaning out the insides of the generator tubes in the present construction has been described hereinabove. Provision is preferably also made for blowing off or otherwise cleaning off the soot or other matter which may accumulate upon the outsides of the tubes. For example, the spacing rod 237 may be hollow as shown in Fig. 28, provided with jet openings 239 and connected to a steam or air supply to blow the soot from the tubes 26. In another illustrated embodiment of the invention, the soot blowing or cleaning means comprises, as particularly shown in Figs. 31, 32 and 33, a series of vertically arranged jet pipes 240 having jet openings 242 in their sides so arranged and directed, as shown in Fig. 33, that steam or air or other cleaning fluid forced through these pipes will pass over the outsides of the tubes 26 and tend to blow accumulations of soot or other foreign matter from the outside surfaces of these tubes. As shown in Fig. 33, there is preferably a row of these jet tubes arranged at such intervals in a median plane across the generator that a jet will be projected over each side of each of the tubes 26, thus insuring effective cleaning of the outer surfaces of the tubes.

In Figs. 31 and 32 is illustrated particularly the mode of conducting the steam or air to the jet tubes 240, there being provided at the upper end of the generator a main steam or air pipe 244 from any suitable source of supply with branches 246 leading downwardly therefrom toward each other and toward the center of the generator and substantially meeting at their lower ends where they discharge into a common box, loop or T 248 from which lead some of the connections 250 to the jet tubes 240 nearest the center of the generator. Connections 250 also lead from the branches 246 to the jet tubes associated with the generator tubes which are located farther from the center. Those jet tubes which are located in the center of the generator, instead of being directly connected by connections 250 to the source of steam or air supply, are preferably connected by branch connections 252 from the adjacent jet tubes, these connections not only serving to provide the innermost jet tubes with steam or other fluid, but also to support them.

In this connection, it is to be noted that the innermost banks or trays of tubes, instead of being suspended from brackets as those further from the center are shown as suspended in Figs. 45 to 48, or instead of being seated in sockets in brackets 77 as those shown in Fig. 29 are seated, are necessarily provided with other means of support because of the closeness of the quarters in which they are located, one form of support being that illustrated in Fig. 29 in which these trays are sus-

pended by flexible suspending means 254, such, for example, as wires, which may be connected to the plates 81 at the lower ends of the brackets 77.

As hereinabove suggested, one of the aims of the invention is the provision of means for assuring the safety of the apparatus when the apparatus is employed for utilizing the waste heat from gas-making plants, and to prevent injury to the apparatus by accidental explosions of unburned combustible constituents of the waste gases or even explosions due to leakage from the gas generator during the run of the gas-making plant into the heat chamber of the steam generating apparatus.

As hereinabove described, the valve 14 (Fig. 2) which controls the entrance of gas into the heat chamber of the apparatus, whether heated products of combustion for heating the tubes of the apparatus, or the gas generated during the run of the gas-making plant, is located between the heat chamber 16 of the generating apparatus and the superheater 6 of the gas-making plant, or specifically between the heat chamber 16 and the dust collector 10, which is interposed between the superheater and the generator, this valve 14 being an ordinary clapper valve, as shown particularly in Figs. 2, 9 and 10, and being mounted upon an arm 256 attached to a rock shaft 258 carried in bearing supports 260. The rock shaft 258 extends to the outside of the casing 2 of the generator and at its outer end has attached thereto an arm 262 to which is connected a piston rod 264 of a valve operating pneumatic or hydraulic apparatus 266 for effecting the opening and closing of the valve. Tubes 268 and 270 communicate with the cylinder of the apparatus 266 on opposite sides of the piston therein for effecting the movements of the piston in the desired directions. The piston may be operated through any suitable fluid, such as air, oil, water, etc. from a point remote therefrom.

It has heretofore been customary to place the valve of waste heat apparatus employed with gas-making plants in the stack of the apparatus and to fill the heat chamber of the apparatus with some inert non-combustible substance such as steam during the run of the gas-making plant, to avoid the danger of explosions. This, of course, has the drawback that it cools off the heat-absorbing surfaces of the waste heat apparatus and thereby wastes a substantial part of the heat intended to be conserved. To avoid this waste in the apparatus of the present invention, the valve 14, as above set forth, is placed between the waste heat apparatus and the super-heater of the gas-making plant, and to prevent explosion from gas that might possibly leak past the valve during the run of the gas-making set and also to avoid explosions of combustible gases that may pass into the heat chamber during the blow of the gas-making set, due to incomplete combustion, provision is made for burning these gases immediately as they enter the heat chamber 16 of the waste heat apparatus. In the illustrated embodiment of the invention, this provision consists in the location of an inextinguishable pilot light 271 adjacent to the opening 12 into the heat chamber, which pilot light comprises a Bunsen burner fed by gas entering through a pipe 272 and supplied with air coming in through a pipe 274, the air supply being greater than that required to burn the gas fed to the burner 271, whereby an excess of air is provided for igniting any combustible gases which enter through the opening 12. This ignition and consumption of these combustible gases as they enter the heat chamber 16 prevents the accumulation thereof in the heat chamber in explosive quantities sufficient to do any damage. The pilot light may be viewed through a glazed sight opening 275.

Further to insure the safety of the apparatus in the event of the possible accumulation of explosive mixtures in dangerous quantities in the heat chamber 16, the apparatus is preferably also provided with explosion relief valves and explosion doors, which permit the pressure of a possible explosion to be relieved without danger to the more important parts of the apparatus. The construction of the relief valves and explosion doors is particularly illustrated in Figs. 4 to 8 inclusive. The explosion doors, which are preferably a part of the removable side walls of the casing 2 and which can be opened to permit the removal of the trays of tubes for inspection, repair or replacement, are herein shown as arranged on opposite sides of the heat chamber. The doors over the lower part 16b of the heat chamber will be particularly described. As shown particularly in Fig. 4 of the drawings, the explosion door 276 comprises a steel framework, including spaced transverse bars of angle iron 278, and vertical channel bars 286. The transverse bars 278 extend beyond the adjacent sides of the casing 2 and are adapted to receive between them locking bolts 280 hinged to the sides of the casing and provided with nuts 282 and washers 284 which engage the opposed outwardly projecting flanges of the angle bars 278, the bolts 280 projecting through the slots formed by these flanges and serving to lock the door 276 in its closed position.

The vertical channel bars 286 are adapted to receive between them blocks or sections 288 of refractory material or at least material of low heat conductivity and relatively high heat resistance. These blocks or sections 288 are preferably frangible at relatively low pressure, for example 2 pounds per square inch, and are so mounted between the channel bars 286 as to be readily replaceable in case of breakage. As shown particularly in Fig. 5 of the drawings, the blocks 288 are clamped

in position in the panel frames provided therefor in the frame structure of the door 276 by clamping screws 290, threaded through one channel side of the bars 286, these screws having swiveled to their ends clamping plates 292. Lock nuts 294 serve to lock the screws 290 in their adjusted clamping position.

As shown in Fig. 5, the blocks or sections 288 are somewhat narrower than the space between the channel bars in which their edges are seated, so that they can readily be put in position between the channel bars when it is necessary to renew or replace them. Moreover, having only a small margin of their edges supported by the frame structure, they yield more readily to the force of any explosion, and thus prevent injury to other parts of the waste heat structure.

The purpose of the frangible sections or blocks 288 is to take care of the more serious explosions, provision being preferably also made for taking care of small explosions by the relief valves hereinabove referred to. In the illustrated embodiment of the invention, these relief valves are preferably provided in the explosion doors 276, and may comprise blocks 296 of heat-resisting or refractory material carried upon short channel bars 298 supported in any suitable manner for easy opening movement. As herein shown the bars 298 are guided upon studs 300 atttached to the angle bars 278, these studs being provided with heads 302 between which and the channel bars 298 are springs 304 which tend to force the blocks 296 into tight seating relation to the relief opening 306 in the explosion door, these blocks 296, as above suggested, constituting valves closing the openings 306.

To prevent buckling of the framework of the explosion door 276 by the heat, the door is preferably provided with truss rods 308, including turn buckles 310 and bearing against brace plates or struts 312 extending outwardly from the door 276 and clamped between the flanges of the angle bars 278, the truss rods being hinged at their ends between angle plates 314 mounted upon the framework of the door. The door 276 as a whole is suspended from hangers 316 arranged to travel on tracks 318 to permit the bodily movement of the door toward and away from the casing 2 when it is desired to get access to the interior of the casing, as, for example, to remove or replace the trays of generating tubes 26.

In Fig. 6 of the drawing is illustrated the manner in which the locking bolts 280 operate to lock that part of the door framework to which the hangers 316 are connected through the swivel hooks 320. In Fig. 7 is shown another modified locking arrangement used at the lower end of the door, the action of the hinged locking bolt 280 in this view being supplemented by that of a second locking bolt 322 which engages a clamp member 324 bearing at one end against the spaced angle plates 326 between which the bolt 322 is hinged, and at its other end bearing against the spaced angle plates 328 carried by the door 276 and which are engaged by the washer 284 of the locking bolt 280.

At its extreme upper end the door 276 carries a pair of locking bolts 280 which engage angle plates 330 at the lower end of a second door 332 covering a portion of the narrower upper part 16*a* of the heat chamber 16, this door being constructed in a manner similar to the door 276 and being suspended to travel outward on tracks 334 (Fig. 1) when it is desired to obtain access to the interior of the casing 2, a third door 336 being similarly constructed and arranged to travel on the tracks 338 so that the entire side of the casing 2 may be opened. These doors are not illustrated in detail in the drawings, but are preferably of construction similar to that of the door 276.

To prevent any accidental explosion which may blow out sections 288 of the explosion door from injuring workmen or attendants, the supporting framework 4 of the generator is preferably provided opposite each door with a protecting screen or shield 340 (Figs. 1 and 9) against which any flying pieces from the sections 288 may strike.

It will be noted that the construction of the casing 2 with the reduced cross section of the upper end and the close positioning of the tubes 26 in this part of the casing insures a comparatively complete absorption of the heat from the gases passing over the tubes, whether of products of combustion or of gases in the burning or incandescent stage, and that the enlarged lower part of the casing not only facilitates the convenient arrangement of the necessarily larger parts required to take care of the collection and separation of the steam and water issuing from the lower ends of the generating tubes, but also provides ample space for locating heating elements when this lower part of the casing is to be used as a combustion chamber. Moreover, the increased spacing of the tubes 26 at their lower ends facilitates the more even distribution of the heated gases over the tubes as these gases travel into the upper parts of the generator where the tubes are more compactly arranged, the tubes being of such length that not only do they absorb substantially all of the radiant heat of the gases, particularly when the combustion takes place in the heat chamber of the generator itself, but they effectively absorb substantially all of the sensible heat before the gases pass to the stack.

To facilitate the distribution of the heat in the tubes and also to protect the tubes from abrasion from particles carried into the heat chamber in the gases, baffles 342 may be pro-

vided in the lower part 16b of the heat chamber.

In order further to insure safety of the apparatus in connection with its operation, alarms are preferably provided to indicate high and low water in the collecting pots and also to indicate low water in the water distributing manifold 42. The high water alarm is shown at 344 in Fig. 12 of the drawings, being preferably connected to the first pot 78 that discharges into the common 82, this being the pot nearest to the point where the feed water from the pipe 132 enters the common 82, and the low water alarm 346 being preferably located upon the last pot 78 in the line of discharge into the common 82. The alarms 344 and 346 may be either local alarms or connected to some central board in well known manner.

The low water alarm for the distributing manifold 42 is shown at 348 and may be of standard construction, operating, for example, upon a differential between the water pressure communicated thereto through the pipe 350, and the steam pressure communicated thereto through the pipe 352, this alarm serving also to vent the air from the manifold 42 whenever the water pressure falls low enough, due to accumulation of air, to open the communication between the water pipe 350 and the steam pipe 352 through the alarm 348.

As above suggested, this low water alarm is of standard construction and may comprise a whistle connected with the steam pipe 352 closed by a float in the chamber 348 when this chamber is sufficiently filled with water as it will be when the water level is at the proper height. If the water level falls below the proper height the float opens the whistle, which is operated by steam from the line 352, and gives the alarm.

To prevent counter-flow through the air leak 173 and the steam leak common 183, check valves 354 and 356 are preferably provided. There are also preferably provided in these pipes perforated disks or diaphragms 358 which, by reason of the smallness of their orifices 360 provide for the gradual escape or "bleeding" of air, steam or water and do not permit any sudden pressure changes.

From the steam separator or "dry pipe" 174 a leak back 187 (as shown in Fig. 15) to one of the pots 78 is provided to drain back any water separated from the steam in said separator and this leak back is also preferably provided with a check valve 189 and with one of the choke disks 358 having a reducing orifice 360 (see Fig. 13).

In addition to the blow-down 168 preferably provided at the lower end of the slow point 84 to permit blowing out of the water circuit, blow-downs 362 are preferably also provided at the lower end of each of the pots 78.

As hereinabove pointed out, the lower ends 26b of the generating tubes 26 are laterally bent in easy curves to meet the headers 30, this lateral bending of the lower ends of the tubes permitting a greater spreading of the tubes as they enter the lower part 16b of the heat chamber 16 and also permitting the use of headers 30 of the larger cross section required to handle effectively the steam and water discharged from the lower ends of the tubes. This spreading of the lower ends also permits the convenient arrangement of these headers, as shown particularly in Fig. 2 of the drawings. Moreover, the spreading permits the hot gases, whether from combustion in the chamber or introduced from outside thereof, to pass readily over the lower ends of the tubes and also permits spreading of the gas by the tubes substantially uniformly across the cross sectional area of the reduced upper part of the heat chamber as they pass into it and thus insure a more even distribution of the heat over all of the generating tubes.

It will be seen that the close positioning of the tubes and their substantially upright arrangement not only facilitates the uniform distribution of the gases over the tubes, but insures the absorption of substantially all the available heat of the gases before they pass to the stack. As hereinabove pointed out in a practical embodiment of the invention, these tubes of 5/8" outer diameter are arranged with a spacing apart of only a quarter of an inch, which insures substantially direct contact of all parts of the heated gases within one or more of the tubes.

It will be noted that in the novel apparatus of the present invention, there is obtained, in addition to the marked economy in space and weight resulting from the design of the apparatus, the economy in operation due to the preliminary heating of the water. Not only is the feed water heated by its mixture with water that has passed through the generating tubes and that has not been converted into steam, but the passage of water through the generating tubes effects a preliminary heating of the water by which the advantages obtained by so-called "economizers" are obtained in this apparatus. The water which travels through the tubes without being converted into steam receives a preliminary heating which facilitates its ready conversion into steam on its return to the tubes. Although this economizing action in the present embodiment of the invention is intended to be distributed substantially uniformly throughout the generating tubes, it is of course not essential that such uniform distribution be effected, but a selective distribution of the various functions of the ap-

paratus among the various tubes may be made.

Although the invention has been described herein as embodied in apparatus intended particularly for a generation of steam from water, it will be understood that the terms "steam" and "water" as used in the specification and claims are intended to include as equivalents any vapors for the generation of which the present invention might be used, or any liquids which might be handled by the novel process of the present invention, or by the novel apparatus herein described, and it will also be understood that many of the novel features of the invention are applicable in other fields than that for which the apparatus herein specifically illustrated and described is particularly intended.

What I claim as new is:

1. A steam generating system comprising a steam generating element exposed to heat, a conduit forming therewith a closed circuit for fluid flow, means for positively circulating water in said circuit and delivering it to the element, and means responsive to variations in a force caused by the fluid flow which serves to control said circulation so as to effect the delivery of an adequate amount of water to said element.

2. A steam generating system comprising a set of steam generating tubes exposed to heat, a conduit forming therewith a closed circuit for fluid flow, means for positively circulating water in said circuit and delivering it to the tubes in quantity sufficient for their evaporating capacity, mechanism effective to control the water flow to said tubes and means responsive to a variation in a pressure differential related to the fluid flow in said system which serves to cause said mechanism to maintain an adequate flow of water to the tubes.

3. A steam generating system comprising a steam generating tube, a pump connected to cause water to flow to one end of the tube, a conduit connecting the other end of the tube to the pump so as to return thereto any unvaporized water, a device controlling the operation of the pump, and means responsive to a variation in a pressure differential within the system related to the water flow which cooperates with said device to maintain a predetermined flow producing pressure at the inlet end of said tube.

4. A steam generating system comprising a set of steam generating tubes exposed to heat, a conduit forming a water circuit therewith, means including a pump in said conduit which in normal operation circulates water under a predetermined pressure to said tubes, a control device connected to said pump for controlling the rate of flow of water, and a device responsive to a variation in a pressure differential between two parts of the system which actuates the control devices and serves to maintain a constant flow of water to the tubes under said predetermined pressure.

5. A steam generator, comprising steam generating tubes, and a conduit forming a return circuit therewith, means at the inlet ends of said tubes providing a flow of water therethrough in quantity less than will fill the cross sectional area of the tubes but in excess of the vaporizing capacity thereof, a pump arranged to produce a continuous circulation of water through said circuit in said excess quantity, and means responsive to variations in a force varying with the quantity of water flowing in a portion of the circuit for controlling the operation of the pump to constantly maintain a predetermined excess flow producing water head at the inlet ends of said tubes.

6. A steam generating system comprising a set of steam generating tubes, inlet and outlet headers therefor, the inlet header providing restricting orifices for distributing water to the tubes in quantity insufficient to fill the cross sectional area of each tube but greater than its evaporating capacity, a conduit connected to the headers and forming a closed circuit for fluid flow, a pump in the conduit for positively circulating the water in the circuit, and means responsive to a variation in the difference between the pressures at opposite sides of an orifice producing flow therethrough, said means controlling said pump and causing it to maintain said flow producing pressure.

7. A steam generating system comprising a plurality of steam generating tubes, a conduit forming therewith a closed circuit for fluid flow means in said circuit for positively circulating water therein, means responsive to variations in a force caused by the fluid flow in the circuit for maintaining a flow of not less than a predetermined minimum quantity of water through said circuit, and automatically ac uated mechanism for maintaining a predetermined amount of water in the circuit.

8. A steam generating system comprising a set of steam generating tubes exposed to heat, inlet and outlet headers therefor, the inlet header being arranged to distribute water to the tubes in quantity insufficient to fill the cross sectional area of each tube but greater than its evaporating capacity, a conduit connecting the headers and forming a closed circuit for fluid flow, a pump in said conduit for forcing water through the system, means for delivering feed water to the system, means for regulating the supply of water to the system, and means including mechanism responsive to variations in a force varying with the variations in the fluid flow through the circuit for controlling the amount of water delivered by the pump to the tubes.

9. In a steam generator, a positively defined water circuit, including steam generating elements, means for positively circulating

the water in the circuit, means responsive to a pressure differential in the circuit for maintaining a predetermined water head to said generating elements, and means for automatically maintaining a predetermined volume of water in the circuit.

10. In a steam generator, a positively defined water circuit including steam generating elements and a return connection between the discharge and the receiving ends of said elements having a reservoir into which steam and excess water are discharged, means in said return connection for maintaining a continuous circulation of water through the circuit, means at the receiving ends of the generating elements for restricting the inflow of water to a quantity less than sufficient to fill the elements but greater than the generating capacity thereof, means responsive to a pressure differential in the circuit for governing said circulating means so as to maintain a predetermined water head to said generating elements, and means for so automatically governing the quantity of water in said circuit as to maintain a substantially constant water level in said reservoir.

11. In a steam generator, a positively defined closed water circuit comprising steam generating tubes along the walls of which the water to be converted into steam travels in the form of an adherent film, a pot into which the steam and excess water are received and in which the steam and water are separated, a conduit leading from said pot through which the water must pass in its travel to the receiving ends of the tubes, a pump in said conduit to effect the positive flow of the water towards the receiving ends of said tubes, and a by-pass from that point in the circuit where air accumulates to the steam zone of the pot for venting air or other gas released from the water.

12. In a steam generator, a positively defined circuit for the water therein including steam generating elements adapted to be exposed to heat for generating steam, a return connecting the discharge and receiving ends of said elements, means for positively circulating the water in the circuit and a vent for air or the like at a point near the receiving ends of the elements to prevent accumulation of air or the like from interfering with the free entrance of water to the elements.

13. A steam generator comprising a set of steam generating tubes exposed to heat, a conduit forming therewith a closed circuit for fluid flow, a pump connected to said conduit for normally maintaining a circulation of water in said circuit, a second pump, normally inoperative, also connected to said circuit to produce water circulation therein, and means responsive to a variation in a force varying with variations in the fluid flow in the circuit for governing the operation of the second pump.

14. In a steam generator, a positively defined circuit for a continuously circulating water system, a pump in said circuit for normally maintaining said continuous circulation, a normally inoperative auxiliary pump in said circuit, and means operated by a predetermined fall in pressure in said continuously circulating system for causing operation of the auxiliary pump.

15. In a steam generator, a positively defined circuit for a continuously circulating water system, a pump in said circuit for maintaining continuous circulation, an auxiliary pump arranged to circulate water in said circuit, and means governed by a predetermined fall in pressure in said system for automatically starting said auxiliary pump, said pressure-governed means serving to stop the auxiliary pump upon building up of the pressure in the system to a predetermined point.

16. In a steam generating plant, a heat chamber, means for supplying heat thereto, a plurality of water pots in said heat chamber having communication with each other, and a plurality of steam generating elements mounted in the heat chamber and discharging in groups into said water pots.

17. In a steam generating plant, a heat chamber, means for supplying heat thereto, a plurality of groups of steam generating elements in said heat chamber, a corresponding plurality of water pots in said heat chamber into which the respective groups of steam generating elements discharge, and a common collecting means for collecting the water from said pots.

18. In a steam generating plant, a heat chamber, means for supplying heat thereto, a plurality of groups of steam generating elements in said heat chamber, a corresponding plurality of water pots in said heat chamber into which the respective groups of steam generating elements discharge, a common collecting means for collecting the water from said pots, and return means from said common collecting means to said generating elements, said return means being located outside of said heat chamber.

19. In a steam generating plant, a heat chamber having a reduced upper portion of considerable vertical extent, a plurality of supporting bars extending substantially lengthwise of said reduced upper portion and inclined to the vertical, and a plurality of steam generating elements removably suspended in said upper portion from said bars and extending to a point within the larger lower part of the heat chamber.

20. In a heat exchanging apparatus, a plurality of sets of heat exchanging tubes, an inlet and an outlet header for each set, each

of which is of greater diameter than the distance between the centers of adjacent tubes, and a heat chamber in which said tubes run lengthwise thereof, the inlet headers being arranged in stepped parallelism to permit the tubes of successive sets to be connected thereto in close proximity to each other.

21. In a heat exchanging apparatus, a plurality of sets of heat exchanging tubes, an inlet and an outlet header for each set, a heat chamber in which said tubes run lengthwise thereof, the inlet headers being arranged in stepped parallelism, the tubes being bent near their point of attachment to the headers to permit the tubes of successive sets to be brought into greater proximity to each other.

22. In a steam generator, a water manifold, steam generating elements, connections of non-scaling material between said manifold and said elements, a closed water circuit of which said elements and manifold form a part and including means for circulating water in the circuit supplying it through said manifold to said elements in quantity greater than the evaporating capacity of said elements, jet orifices associated with said elements to limit the supply of water thereto to a quantity less than sufficient to fill them, whereby steam and water rapidly circulate through the elements exerting a scouring action thereon, and means for straining said water before its discharge from said manifold to free it from any scale or other matters that might clog said jet orifices.

23. In a steam generator, a positively defined water circuit including the steam generating elements, means for supplying water to said elements in excess of the quantity that can be evaporated in passing therethrough and effecting a re-circulation of the unevaporated water, and means for removing foreign substances from said excess water before reintroduction thereof into the generating elements.

24. A steam generator according to claim 23, in which feed water is introduced into the closed circuit to replace that vaporized in the generating elements, and mixed with the excess water from the elements before treatment of the excess water whereby the mixture is subjected to this treatment.

25. A steam generator according to claim 23, in which the closed circuit includes an enlarged portion in which the water is so retarded as to permit precipitation of foreign substances in the water.

26. In a steam generator, a positively defined closed water circuit, including the steam generating elements and a common return for the water collected from said generating elements, means in said circuit for effecting a positive flow of the water therethrough in quantity in excess of the steam generated in said elements, and means also located in said circuit for effecting a precipitation or removal of foreign substances in the water.

27. In a steam generator, a positively defined water circuit, including the steam generating elements, and a common return for the water collected from said generating elements, a pump in said common return for effecting a positive flow of the water in said return to the receiving ends of said generating elements in quantity in excess of the steam generated in the elements, means for introducing water into said return to replace that vaporized in said elements, and means in said common return for effecting a precipitation or removal of foreign substances in the mixture of feed water and heated water.

28. Steam generator comprising a steam generating tube, a pump, connections between the pump and the tube forming a water flow circuit, means for causing the pump to produce a flow of water to the tube through said connections, and means responsive to variations in a force caused by said flow and effective to control the rate of said flow and to automatically maintain said rate in excess of a predetermined minimum amount.

29. A steam generating system comprising steam generating elements exposed to heat, a conduit for delivery of water to said elements and for collecting water discharged therefrom, thereby forming a complete water circuit, means for delivering water through said circuit to said elements, means for controlling the operation of said water delivery means which is responsive to variations in a force caused by the water flow and varying with the amount of water delivery, auxiliary water delivery means also arranged to deliver water through the circuit, and means independent of the first mentioned control means and responsive to variations in a force caused by the water flow and varying with the amount of water delivered through the circuit for so controlling the auxiliary water delivery means as to supplement the first delivery means and maintain the delivery of a predetermined minimum quantity of water to the elements.

30. A steam generator comprising a set of steam generating tubes, a conduit forming therewith a closed water circuit, a pump connected to said circuit for normally maintaining a circulation of water in said circuit, means responsive to variations in the difference in pressure at the discharge of the pump and at another point in the circuit for governing the operation of the pump to produce a predetermined delivery of the water by said pump, an auxiliary pump of sufficient capacity to maintain the circulation of water also connected to the circuit, and auxiliary governing means, also responsive to a variation in a difference in pressure in the circuit,

but independent of the first mentioned governor for governing the operation of the second pump to produce a predetermined delivery of water by said second pump.

Signed at New York, N. Y., this 21st day of May, 1925.

WALTER DOUGLAS LA MONT.