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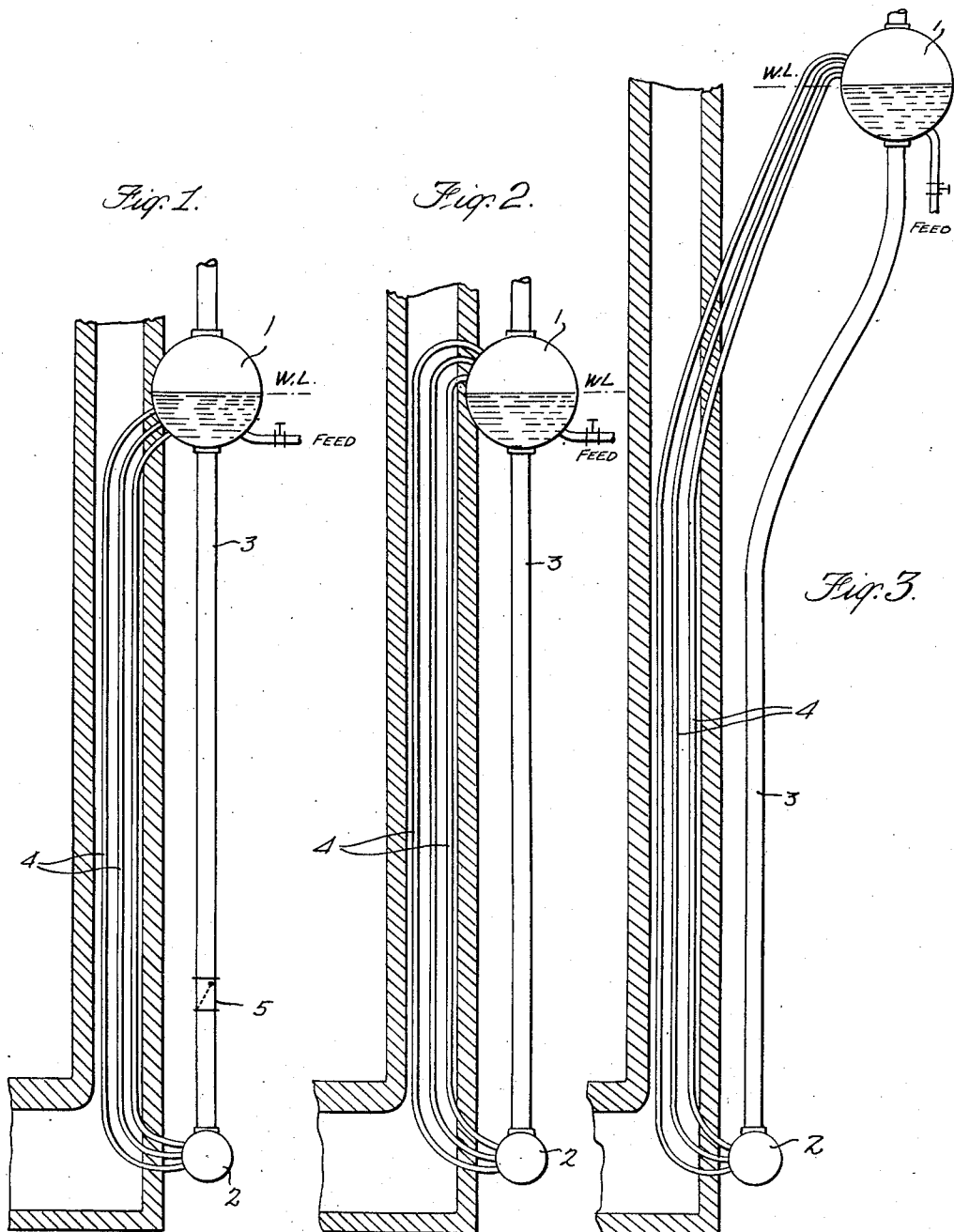
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1,827,244

GENERATION OF STEAM AND OTHER VAPORS

Filed June 16, 1926

8 Sheets-Sheet 1



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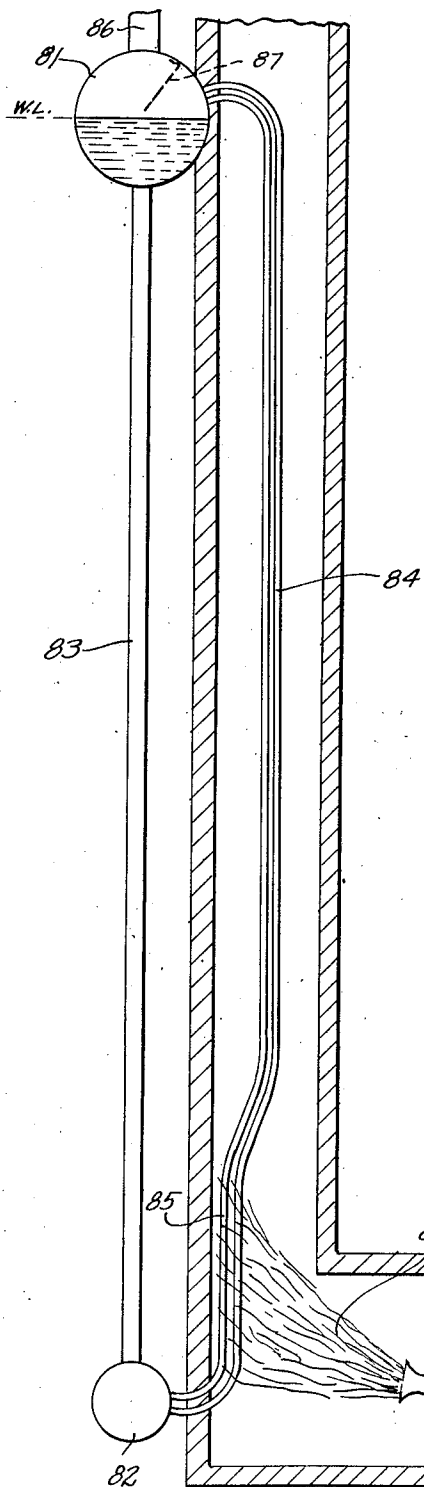


Fig. 10.

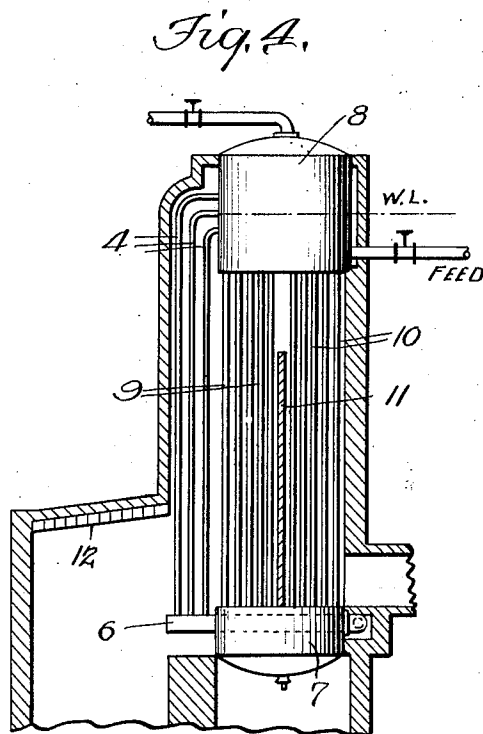


Fig. 4.

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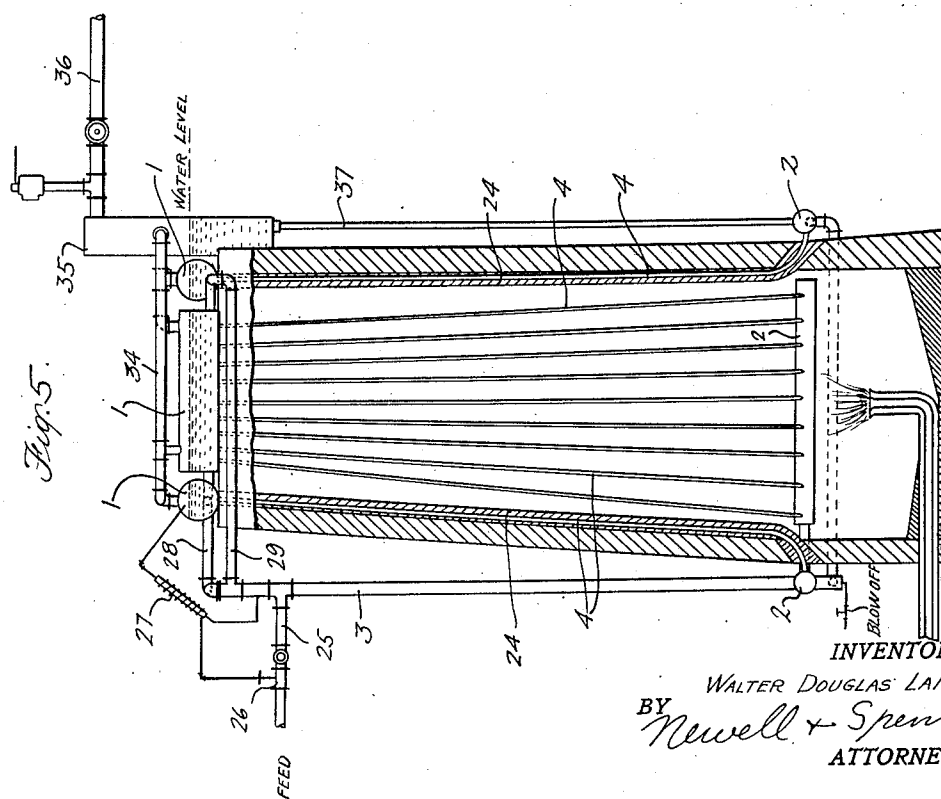
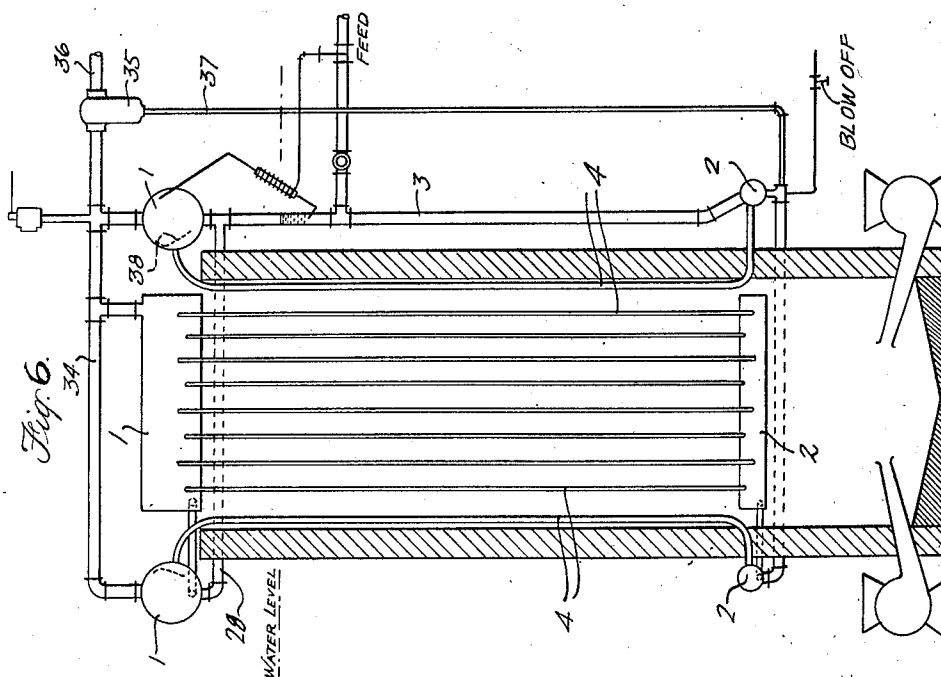
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GENERATION OF STEAM AND OTHER VAPORS

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8 Sheets-Sheet 3



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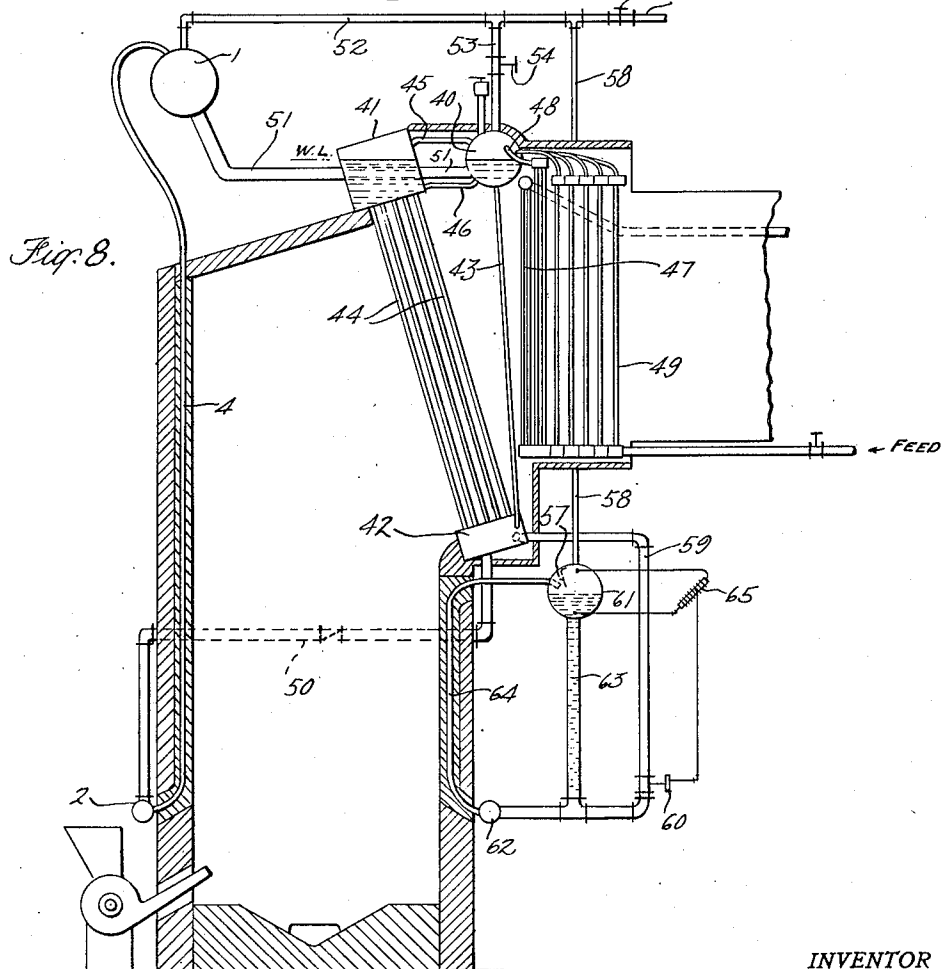
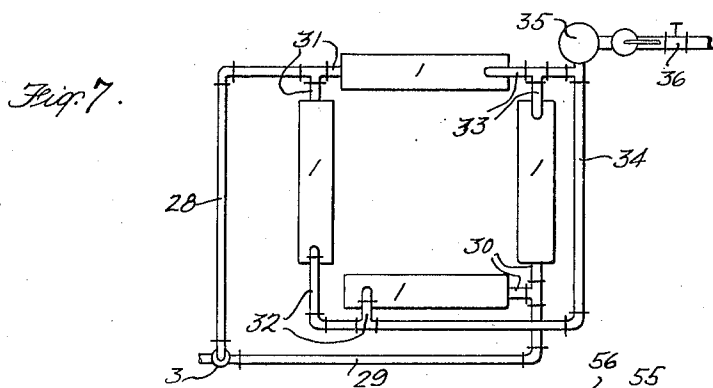
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8 Sheets-Sheet 4



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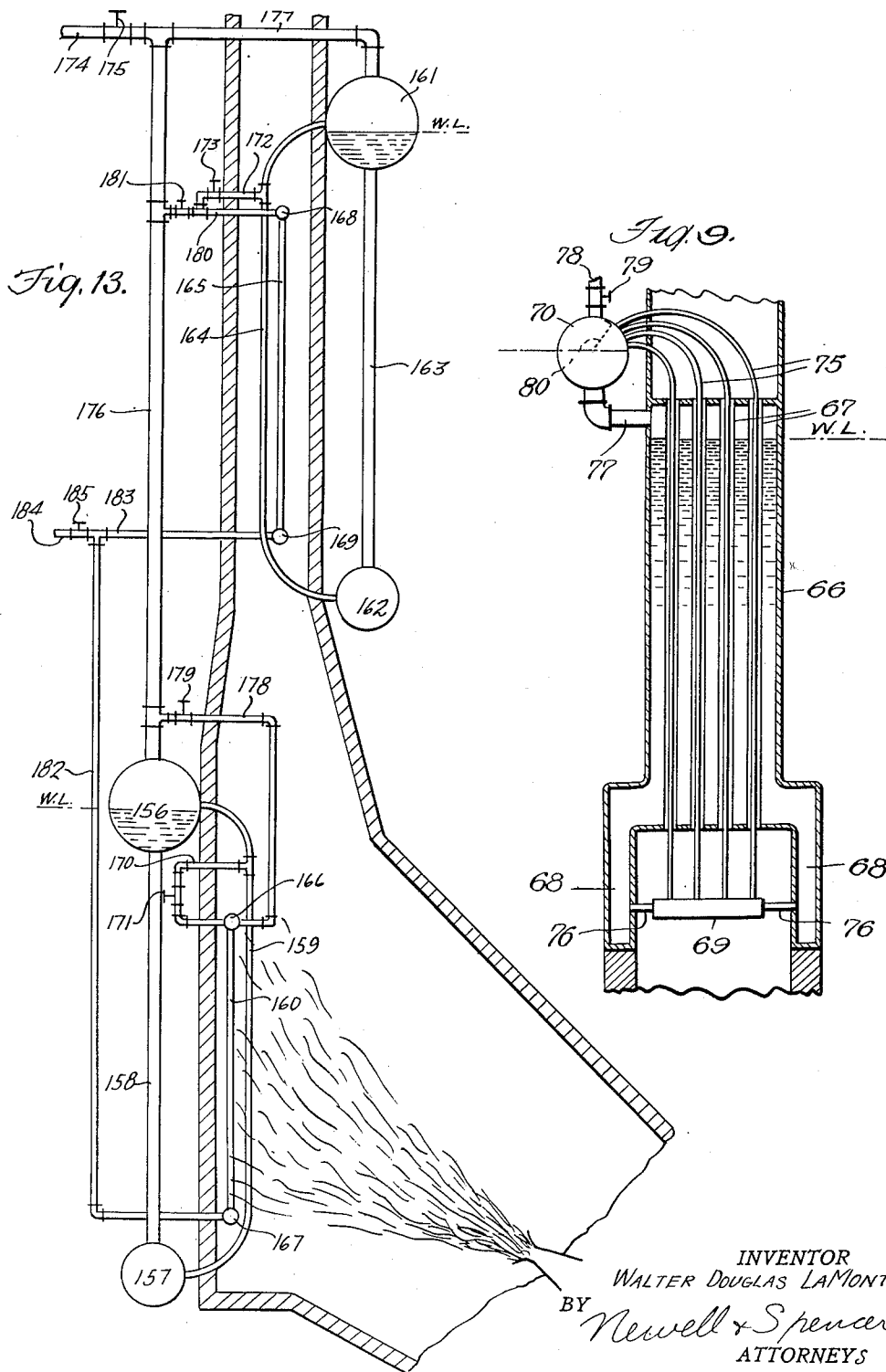
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GENERATION OF STEAM AND OTHER VAPORS

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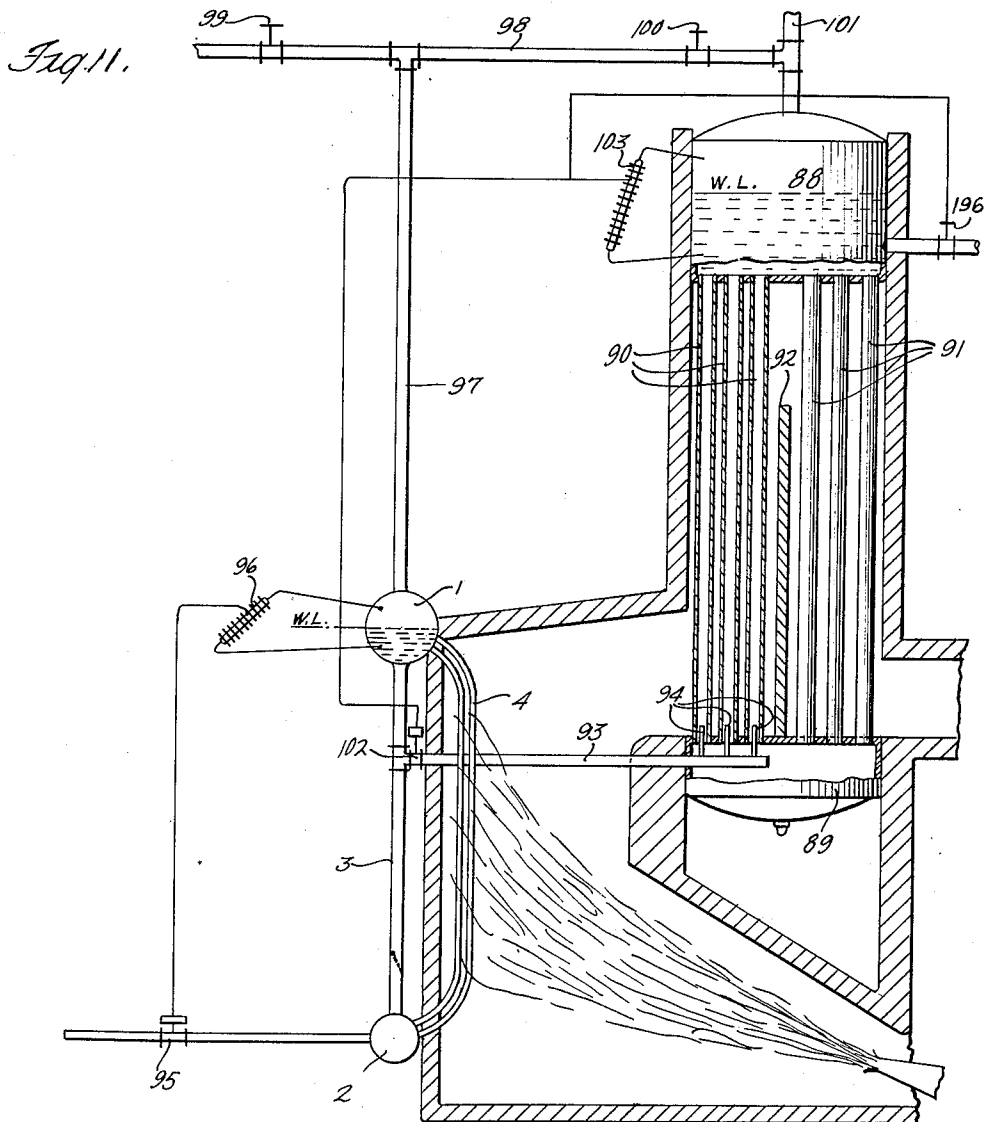
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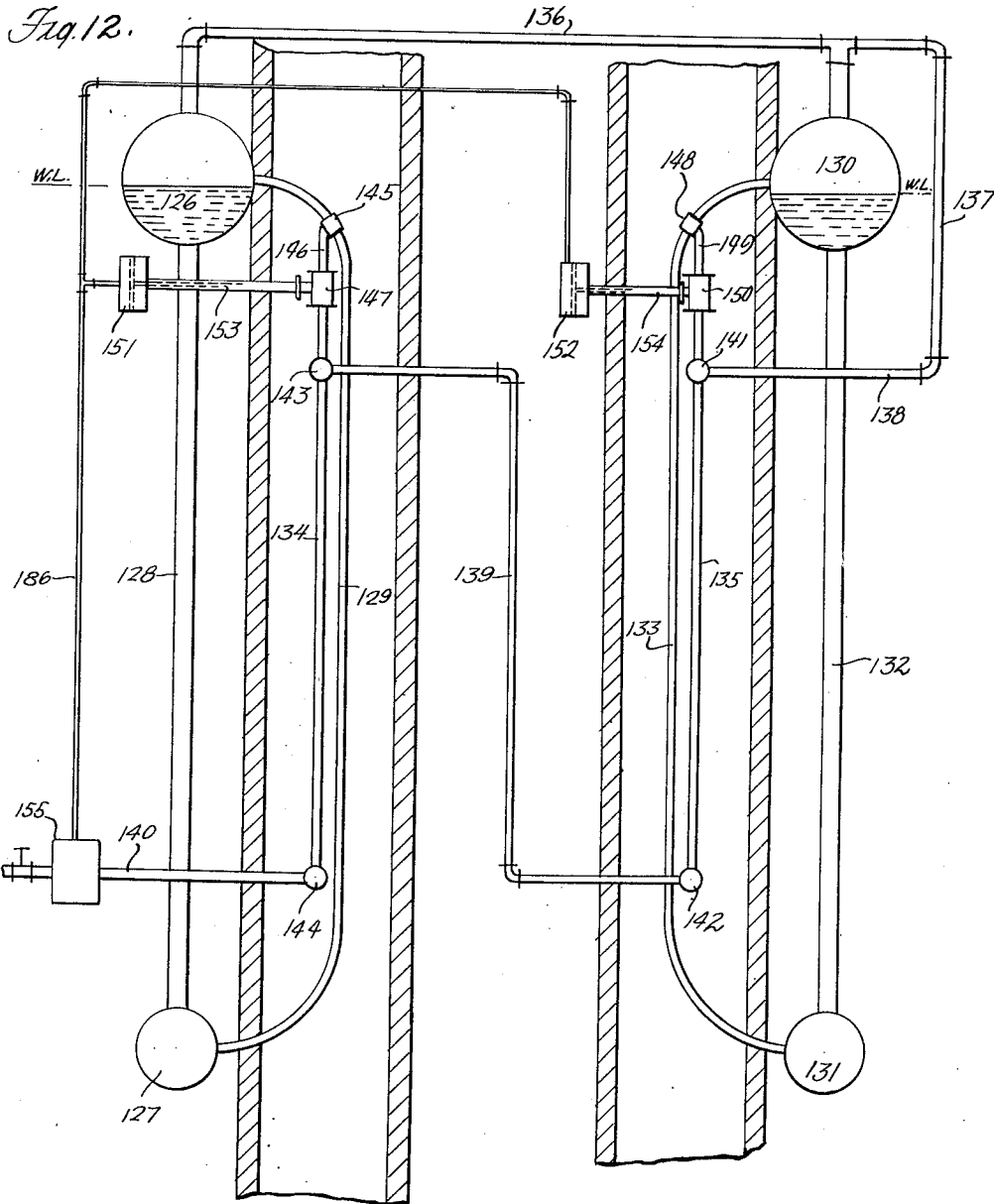
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GENERATION OF STEAM AND OTHER VAPORS

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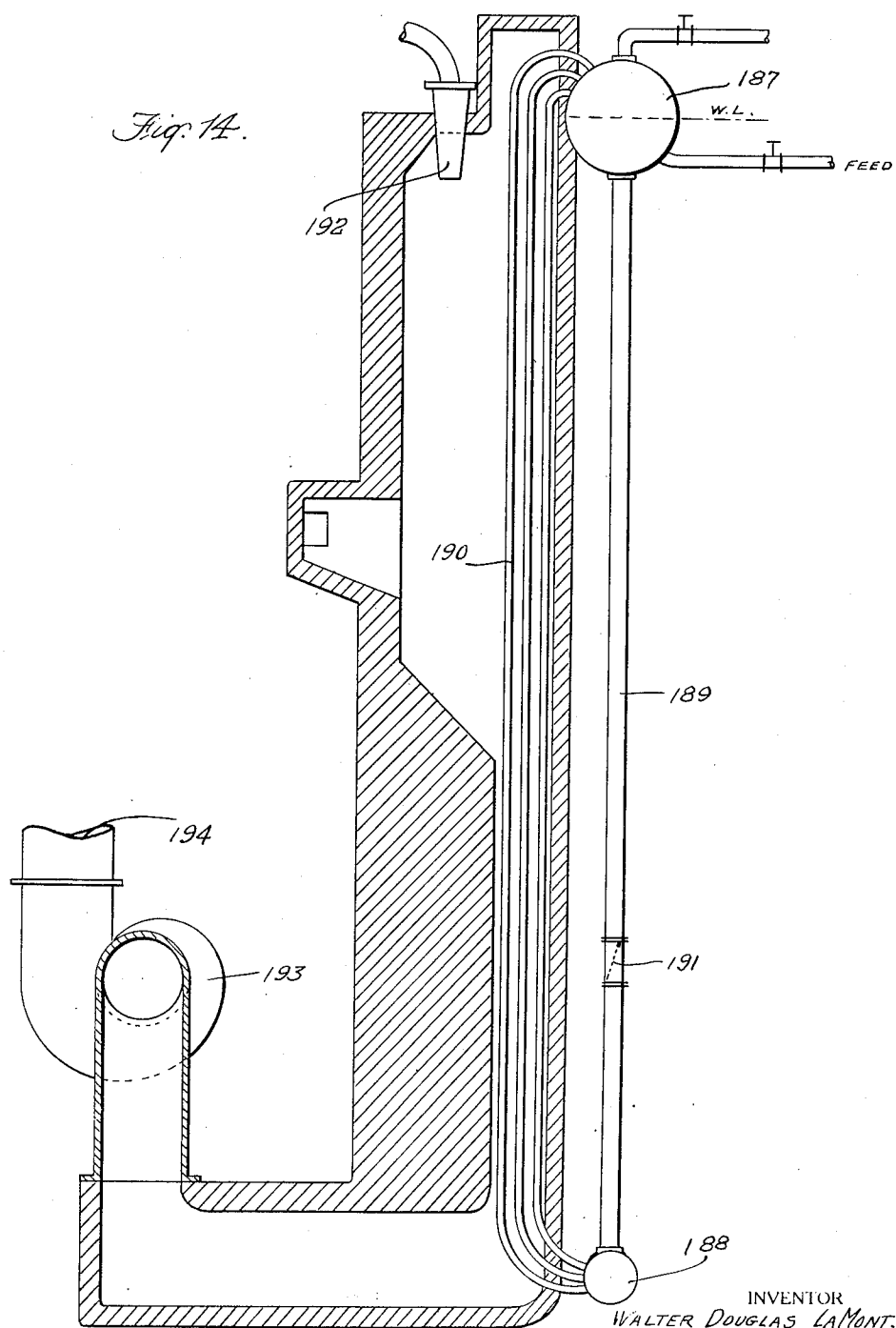
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GENERATION OF STEAM AND OTHER VAPORS

Filed June 16, 1926

8 Sheets-Sheet 8



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GENERATION OF STEAM AND OTHER VAPORS

Application filed June 16, 1928. Serial No. 116,305.

This invention relates to methods and apparatus for generating steam or other vapors and in its more specific aspects relates to methods and apparatus for generating steam in water wall boilers or similar radiant heat boilers.

In the following more detailed descriptions of the present invention methods of generating steam and apparatus for steam generation will be described but it should be understood that the invention while particularly suitable for steam generation, is not limited thereto and can be applied with suitable changes where necessary to the generation of any other vapor from a liquid and accordingly the description should not be considered as limiting the invention in any way to the generation of steam only.

A rapid circulation of water in steam generators and particularly in water wall boilers and similar radiant heat steam generators is very necessary in order to effect efficient steam generation. A rapid and thorough circulation of water can be effected by means of pumps, as described in connection with water wall boilers in my copending application, Serial No. 77,816, filed December 26, 1925.

For some installations it is desirable to eliminate pumps and other mechanically driven moving parts. This is particularly true where a suitable source of power for pumps is not available as, for example, when low pressure steam is generated which is not particularly adapted for driving small pumps, or where the suitable power is available such as electricity, but is not reliable and is subject to break-down. In most installations, of course, the possibility of failure of pumps is not serious, as a more or less constant supervision is available, but in some other installations, for example, in certain steam plants for heating buildings the boilers are fired at intervals and the supervision is not constant. It is an object, therefore, of the present invention to produce vigorous and reliable circulation without the use of pumps or other mechanical circulating devices containing moving parts.

It is one of the objects of the present invention to bring about effective circulation in steam generators and especially in water wall boilers, without the use of any pumps or other devices involving positively driven moving parts.

It is a further object of the present invention to bring about effective circulation without the use of complicated automatic or semi-automatic controls, such as water level controls and the like, or with a minimum of such controls.

According to the present invention relatively small vertical or inclined generating tubes are used and a relatively free return circulation preferably outside of the furnace or in a relatively cool zone is provided. The water in the small generating tubes is rapidly heated and the steam generated, especially at the lower portions of the generating tubes, rises rapidly, carrying with it the water in the tubes, and in the case of long tubes which are strongly heated at their lower ends, the water, which is at a pressure greater than the steam pressure in the boiler steam space, may be sufficiently superheated with respect to the steam temperature so that in rising through the tubes more steam is generated as the pressure falls and steam and water are forcibly ejected from the top of the generating tubes in spurts, the action being very similar to that of a geyser and resembling in some respects the well known coffee percolators. The water or mixture of steam and water in the generating tubes is, of course, of lower specific gravity than the water in the down-take tubes or passages which are situated in a relatively cool zone. There will, accordingly, be in most cases a considerable difference in hydraulic head due to the difference in specific gravity of the fluids in the generating tubes and the down-take tubes and circulation will be effected by this difference in specific gravity.

Another important factor in circulation consists in the velocity acquired by the rising steam bubbles and which tends to bring about very rapid circulation. In general, circulation is usually due to a number of factors, such as difference in specific gravity and

velocity effects, but the relative importance of the different factors varies greatly with the nature of the installation, and particularly with the conditions under which it is run.

5 Thus, when the boiler is steaming under light loads, the difference in specific gravity may be the most important factor in effecting circulation, whereas, when the boiler is run at higher ratings, the velocity effects become
10 more and more important and in many cases are the predominating factors influencing circulation.

It is possible to restrict the flow into the generating tubes either by throttling or by
15 a lowering of head in the down-take tubes to such an extent that a very large portion of the water in the generating tubes is turned into steam and comparatively little water is discharged from the upper portion of the
20 generating tubes. This system is satisfactory for some water wall boilers, particularly where it is not necessary to provide for any considerable steam reserve. For generators which are to be used as primary generators
25 and not as water walls in conjunction with secondary generators, I prefer to keep sufficient water in the generating tubes either by an unrestricted flow from the down-take tubes or by a sufficient head of water in the
30 down-take tubes, so that a strong geyser action takes place and a considerable amount of water is circulated through the generating tubes. In this manner fluctuations in combustion temperature and steam use can be
35 more easily taken care of than in installations where the generating tubes contain but little excess water and where there is considerable tendency to evaporate all of the water in the generating tubes when sudden increases in
40 fire take place. It should be understood, therefore, that in the preferred embodiments of the present invention, especially in those embodiments which are intended to be used as primary steam generators, I prefer to arrange
45 the units so as to assure the presence of a considerable amount of water in the generating tubes at all times and produce vigorous geyser action. In its broader aspects, however, especially in connection with
50 water wall boilers, the invention is not limited to this circulation adjustment and also includes generators and particularly water wall boilers in which the amount of water in the generating tubes is materially
55 restricted and the tubes may even operate as semi-flash generators.

The geyser action which I utilize in the preferred embodiments of the present invention may, in some cases, particularly when the
60 generator is started, become undesirably violent and may even, in some cases, tend to reverse the water flow. In order to prevent momentary reversals of water flow it is frequently desirable to provide suitable check
65 valves either in the down-take pipes them-

selves or in the connections between the down-take pipes and the generating tubes. The invention is, of course, not limited to the use of check valves but they are advantageous in many cases and constitute one of the more
70 specific features of the invention in its preferred embodiments.

The generating tubes may be connected with steam and water drums, either above or below the water level but where restricted
75 flow is used it is usually desirable to discharge the steam and water above the water level of the drum, using, if desired, suitable steam separating means. Even where strong geyser action takes place it is frequently advantageous
80 to discharge above the water level, although it is not strictly necessary in such a case since the geyser action will effect circulation even when the discharge of steam and water is considerably below the water
85 level of the upper drum and in some cases this arrangement may be desirable, although in general we prefer to discharge steam and water at or above the water level, as there is less tendency for the geyser action to set up
90 water hammers which may, in some cases, set up strains in the apparatus. A better separation of steam and water is also obtained thereby. Discharging above the water level also makes it possible to place the water and
95 steam drum at a considerable elevation above the top of the heated portion of the generating tubes and thus obtain a very large water head in the down-take pipes with a resulting rapid water circulation which is very desirable
100 in many cases, especially where the generator is intended to be operated at high ratings.

A further advantage of discharging the water and steam from the generating tubes
105 above the water level in the upper drum lies in the fact that by this means it is possible to place the drum in any suitable location without regard to the shape of the heating furnace. For example, in cases where a geyser
110 tube generator is to be incorporated into an existing furnace, either as a water wall or as an auxiliary generator, the furnace height available, particularly in the case of water wall installations, may not be sufficiently great
115 to provide for long geyser tubes which are necessary to bring about the best and most vigorous circulation. When the tubes discharge above the water level in the upper drum it is possible to utilize long tubes, only a
120 portion of which are subjected to heat, and the principles of the present invention may therefore be applied to many existing boiler installations without rebuilding or redesigning the furnace. The same flexibility is frequently
125 desirable even in new installations where space requirements are such as to render a tall furnace structure undesirable. It is also advantageous to discharge above the water level where a water wall embodying the
130

features of the present invention is used in connection with a secondary boiler or boilers using a common circulation. Such combinations, some of which are illustrated in the drawings, are very effective, as the advantages of the water wall boiler can be obtained without decreasing the efficiency of the secondary boiler and even with a considerable increase in efficiency in the case of series circulation which may be arranged to promote the circulation in the secondary boiler and correspondingly to increase its reliability and efficiency and it is one of the advantages of the present invention that such combined installations may be made.

In the general discussion a steam and water drum and down-take pipes have been referred to. It should be understood, of course, that the invention is not confined to installations in which a single drum or a plurality of down-take pipes are used. On the contrary, a plurality of drums may be used and a single large down-take pipe or a plurality of down-take pipes with or without headers or manifolds may be provided and in this respect the invention is capable of a large number of modifications which may be desirable in adapting the principles of the invention to any particular furnace or boiler and the proper design and placement of steam and water drums and down-take pipes will, of course, be clear to a skilled steam engineer.

It is one of the features of the present invention that the generating tubes are relatively long as compared with their diameter, as this permits effective geyser action and also promotes efficiency of heat transfer. The invention is, however, not limited to any particular length, although in general, as pointed out, above, longer tubes give better results within the limits of practical installations. In some cases, however, particularly in water wall boilers, it may be necessary to shorten the tubes for structural reasons.

The shape of the tubes may be varied within wide limits and only a few of the possible forms will be illustrated in the drawings. Thus, the tubes may be in one or more layers, closely or loosely spaced, with or without fins and the like. In the preferred embodiments of my invention, I prefer to arrange generating tubes in trays connected by headers having a somewhat similar shape to the trays of generating tubes described in my patent application No. 32,064, filed May 22, 1925, and in the more specific aspects of the invention this constitutes one of the advantageous features which reduce expense of installation and particularly make it possible to change tubes with a minimum of lost time. In its broader aspects of course, the invention is not limited to the arrangement of tubes in trays and any other suitable arrangement can be used and is included within the scope of the invention.

In the preferred modification of my invention, the steam and water from the generating tubes is discharged into a separating drum and for most purposes, particularly where the amount of water in the generating tubes is considerable and vigorous geyser action takes place, this is the most advantageous arrangement. It is, however, not the only arrangement possible and the steam and water from the generating tubes, particularly when the amount of water is restricted, may be passed into different types of steam separators such as, for example, centrifugal separators or the like, provided with drains either to a drum or directly to the down-take pipes and in some cases it may be desirable to pass the steam with the entrained water directly to superheaters to generate superheated steam. This modification is desirable in some cases where radiant heat superheaters are used or where superheaters are placed in comparatively hot zones of the furnace as the entrained water serves to protect the superheater tubes against burning out under varying loads and at the same time keeps the superheat down to lower figures which are frequently desirable. Various other combinations are possible and part only of the water and steam may be discharged directly into one or more superheaters in series or in parallel, thus effecting a superheat control particularly when the amount or proportion of the water and steam ejected from the generating tubes is variable. I do not claim in the present invention broadly the idea of controlling superheat by injecting water into the superheater tubes, this forming part of the subject matter of my co-pending application, Serial No. 83,235, filed January 23, 1926. On the contrary, this feature is claimed in the present application only in conjunction with generators embodying the main principles of the present invention. It is an added advantage of the present invention in some of its modifications, that part or all of the steam and water mixture which is forcibly ejected from the generating tubes may be used as a superheat control means.

I have described above and show for the most part in the drawings certain combinations of water wall boilers embodying the principles of the present invention with steam generators which depend on convection circulation and these combinations are particularly advantageous because they permit an increase of circulation in boilers of ordinary standard types without involving the provision of pumps or other positive circulating means which necessitate additional moving parts. The invention is, however, not limited to water wall boilers combined with secondary steam generators of the convection type and on the contrary, may be combined with secondary boilers which are provided with positive water circulation. I do not,

however, in the present application, include water walls in which the circulation is in series with boilers having positive circulation so that the positive circulation takes place through the water wall as well as the boiler, as these installations form part of the subject matter of my co-pending application, Serial No. 77,816, filed December 26, 1925, referred to above.

The invention will be described more in detail in connection with certain illustrative embodiments which are shown in the drawings. It should be understood that these specific examples of boiler installations embodying the principles of the present invention do not in any sense limit its scope and, on the contrary, they have been chosen to illustrate in a few examples, as many of the important modifications of the present invention as is possible but it will be readily apparent to the skilled steam engineer that many other modifications and combinations are possible and will be desirable in certain cases and in general the engineer designing a new installation embodying the principles of the present invention or redesigning an old installation, will adapt the present invention to the particular conditions and needs of the plant in question and the shape and placement of the generating tubes, together with the other elements of generators and water wall boilers of the present invention will be and must be largely dictated by the structural conditions of the particular installations in which the present invention is to be applied and this is particularly true with regard to water wall boilers which necessarily must conform in shape and element placement to the furnace shape and to the room available. For this reason the drawings are diagrammatic in nature and the particular forms, sizes and placement of the various apparatus elements will be determined by the steam engineer in accordance with the conditions of a particular installation and in the light of the knowledge and skill possessed by the art. It is, however, an advantage of the present invention that in many cases most or all of the apparatus elements can be constructed of standard units, which is of considerable importance where it is desired to modify existing installations in accordance with the present invention.

The vigorous circulation in the geyser tubes which is possible with the present invention, not only possesses the advantages described above, but also prevents to a large extent the formation of scale since the violent circulation appears to have a scouring action, scale being continuously removed, and, of course, being readily separated by suitable screens which may be placed at any desired point in the circulation. The somewhat high speed of the circulation and particularly the vigorous turbulence which exists in the

tubes continuously brings the water into contact with the heated metal of the generating elements and steam locking of the tubes is prevented even at very high ratings. This is very desirable in connection with generators which are operated with fuel sources of high calorific powers such as oil burners and the like.

The invention will be described in greater detail in connection with the drawings which illustrate a number of applications of the principles of the invention and in which:

Fig. 1 is a vertical cross-section through a steam generator in which the generating tubes enter the upper drum below the water level;

Fig. 2 is a similar cross-section through a generator in which the tubes enter the upper drum above the water line;

Fig. 3 is a cross-section through a modified form of generator in which the tubes are not exposed to the heated gases throughout their whole length;

Fig. 4 is a vertical section through a Wickes boiler with which a generator of the present invention has been combined in series parallel;

Figs. 5 and 6 are sections through water wall generators designed in accordance with the present invention, Fig. 5 showing a water level in the upper steam drums and Fig. 6 a water level below the steam drums;

Fig. 7 is a diagrammatic plan view of the steam headers shown in Fig. 5;

Fig. 8 illustrates water walls of the present invention combined with a single-pass water tube boiler;

Fig. 9 is a section through a steam generator of the present invention associated with a fire tube boiler;

Fig. 10 is a section through a combined generator and water wall;

Fig. 11 is a section through a Wickes boiler combined with a water wall generator according to the present invention;

Figs. 12 and 13 are vertical sections through a modified combination of generators and superheaters; and

Fig. 14 is a vertical section through the geyser tube generator in which the heating gases flow counter to the water and steam circulation.

The drawings are diagrammatic in nature and are not intended to limit the invention in any way to particular structural details which will vary with the conditions of the installation and it will be clear to a skilled steam engineer what particular structural design will be best suited to the conditions of any particular plant. It should be understood, of course, that steam generators of the present invention will be operated with the usual accessories, such as gauges, safety valves, water controls, feed controls, blow-offs and the like. In order to simplify the

illustrations, however, in many figures, these conventional accessories have been omitted, but it should be understood that in practical operation, such usual accessories as may be desirable will be used.

In the construction shown in Figs. 1 and 2, an upper steam drum 1 is connected with a lower drum or header 2 by means of one or more tubes 3 of relatively large cross-section. Generating tubes 4 of relatively small cross-section connect the two headers and pass through the furnace space. In the construction shown in Fig. 1, the generating tubes enter the upper steam drum below the water level, whereas in the construction shown in Fig. 2, they discharge above the water level. In some cases, it may be desirable to cause some of the tubes to discharge above and some below the water level.

The highly heated gases striking the lower portion of the generating tubes rapidly heat up the water in these tubes and since the water in the lower portion of the tubes is under a pressure greater than that in the upper portion of the tubes, it becomes heated without formation of steam, to a higher temperature than that which corresponds to steam at the pressure in the upper reaches of the tubes. As a result, an intermittent geyser action takes place, that is to say, the highly heated water in the lower portion of the generating tubes proceeds to rise and as the pressure drops, steam is generated which tends to carry the water up with a violent rush, discharging a mixture of steam and water into the steam drum in spurts or pulses. The steam and water is separated in the steam drum 1 and the excess water circulates downwardly through the tubes 3. In many installations, a check valve 5 (see Fig. 1), is advantageous as it prevents any tendency to backward circulation particularly when the generator first starts. The check valve is shown only in Fig. 1, but, of course, it can be applied equally to the construction shown in the other figures.

Feed water can be introduced at any desired point and may advantageously be introduced either into the upper steam drum or into the upper portion of the tubes 3 so that the incoming cold water increases the density of water in the tubes 3 and correspondingly increases the tendency for the hot water in the generating tubes to rise. In some cases, however, it may be desirable to introduce the feed water into the lower header or drum and the present invention is not to be considered as limited to any particular method of introducing feed water.

The construction in Fig. 3 is similar to that in Figs. 1 and 2 but only the lower portion of the generating tubes is exposed to the heat of the gases. A somewhat more violent geyser action is thereby produced due to the fact that there is a greater hydraulic head

on the water in the generating tubes and for some purposes, this construction presents many advantages. It is also possible in the construction shown in Fig. 3 to locate the drums at a considerable distance from the actual furnace structure and in some cases, this relatively smaller and shorter furnace structure is of advantage. The operation of the generator is, of course, the same as in the generator shown in Figs. 1 and 2.

The extremely rapid circulation which is effected by geyser action in the generating tubes of steam generators embodying the principles of the present invention can be utilized very effectively in promoting and increasing the circulation of many types of conventional boilers, thereby greatly enhancing their efficiency. In many cases the change can be made without any extensive rebuilding and in all cases the present invention presents the advantage that no additional moving parts are used. In the construction shown in Figs. 4, 5, 9, 11 and 13, the circulation of generators of the present invention is used to improve the circulation of ordinary boilers. The generating tubes which for convenience will be referred to hereafter as "geyser tubes" may be connected to the common type of boiler in many ways. Thus, for example, the circulation may be in series or series parallel or combinations of the two. The particular arrangement will be determined by the design of the common type boiler and will be influenced by the nature of circulation in the common boiler, by the space and shape of furnace and by other structural conditions. The invention should, therefore, in no sense be considered as limited to the combinations with the particular types of conventional boilers shown in the figures which are merely illustrative of a few of the many possible arrangements.

In Fig. 4, geyser tubes 4 are connected through a lower header 6 to the lower drum 7 of a Wickes boiler which also includes an upper drum 8, front tubes 9, rear tubes 10 and a baffle 11. The normal circulation in the Wickes boiler is usually considered to be downwardly through the tubes 10 and upwardly through the tubes 9. Accordingly, the lower header 6 of the geyser tubes is connected to the portion of the drum 7 adjacent to the discharge openings of the tubes 10, whereas the upper ends of the geyser tubes are introduced into the upper drum above the discharge of the tubes 9 and in the drawings are shown as discharging partly above, partly below and partly at the water level. The tubes may, however, be arranged to discharge all above, at or below the water level, wherever desired.

The hottest gases from the furnace passing below the arch 12, strike first the lower ends of the geyser tubes and heat up the water in these tubes to a very high temperature,

producing an intense geyser circulation, taking water from the drum below the discharge of the tubes 10 and discharging the water mixed with steam at a high rate of speed into the upper drum in the direction of the flow of water from the front to rear of the drum, greatly assisting the circulation of the Wickes boiler. Not only are highly efficient steam generation surfaces added, but the generating efficiency of the Wickes tubes themselves is actually enhanced because of the enhanced speed of circulation.

Figs. 5 and 6 illustrate water walls embodying the geyser tube circulation, Fig. 5 showing a water level in the upper drums and tubes embedded in the furnace wall, whereas Fig. 6 shows a water level below the upper drums and tubes exposed to the radiant and convection heat of the furnace. The connections between the upper drums of Fig. 5 are shown schematically in Fig. 7.

In the construction shown in Fig. 5, geyser tubes 4 are embedded in the furnace lining 24 and connect the lower headers 2 with the steam drums 1, return circulation being through the tube 3 to which is connected the feed pipe 25 provided with a valve 26 actuated by the water level control 27. Steam drums 1 are connected to the tube 3 by the pipes 28 and 29 and the T connections 30 and 31, which latter enter the drums below the water level. In a similar manner, the steam spaces are connected by means of the T connections 32 and 33 and the pipe 34 to a steam separator 35, whence the steam passes out through a steam main 36. Water carried along by the steam and separated out in the separator is returned to the lower header 2 through the pipe 37. The operation of the water wall is the same as that described in Figures 1 to 3.

In the water wall shown in Fig. 6, the water level is carried below the steam drums 1 and these latter are provided with separator baffles 38. The arrangement of steam separator 35 and return pipe 37 is similar to that shown in Fig. 5 and the operation of the water wall is the same except that the geyser action is somewhat less violent as the tubes discharge above the water and there is, therefore, less resistance to the surges in the geyser tubes than is the case where they discharge below the water level and where the mixture of steam and water discharged must displace a corresponding amount of water.

In Fig. 8, two water walls are associated with a single pass Edgemoor water tube boiler. The boiler consists in steam drum 41, lower drum 42, water feed drum 40, generating tubes 44 and feed tubes 43. The steam spaces of the drums 40 and 41 are connected by the pipe 45 and the water spaces by the pipe 46. A superheater 47 is provided connected to the steam spaces of the drum 40 by

the pipe 48 and a water preheater 49 is also provided.

The front water wall, consisting of steam drum 1, lower header 2 and embedded geyser tubes 4, is connected to the drum 42 by the feed pipe 50 and the drum 1 is connected to the water space in the drum 40 by the pipe 51. The steam spaces of the drums 1 and 40 are connected by the pipes 52 and 53, which latter is provided with a valve 54. A separate water wall steam main 55 is connected to the tube 52 and is provided with a valve 56. The circulation of the front water wall is partly in series and partly in parallel with the circulation through the Edgemoor boiler.

A rear water wall consisting of a steam drum 61, a lower header 62, geyser tubes 64, and return tube 63, forms a complete independent circuit, the steam and water discharged from the tubes 64 being separated in the drum 61 with the aid of the baffle 57 and passing out through the steam main 58 which connects with the pipe 55. Feed water is introduced from the drum 42 of the Edgemoor boiler through the pipe 59 controlled by the valve 60 which is in turn actuated by the water level control 65. The circulation through the rear water wall is, therefore, independent of the Edgemoor boiler, but feed water is taken from the latter and the amount of feed is regulated by the water level in the drum 61 which in turn varies with the amount of steam generated in the tubes 64. Thus, one of the water walls operates in series parallel with the Edgemoor boiler, whereas the other possesses an independent circuit. Steam from the two water walls can be used separately by closing the valve 54 and opening the valve 56 and steam can be passed through the superheater 47 by opening the valve 54 and closing the valve 56.

In Fig. 9, an ordinary fire tube boiler is shown consisting in a shell 66, provided with fire tubes 67 and legs 68. A geyser tube generator consisting in lower header 69, upper drum 70 and geyser tubes 75 is mounted in the fire tube boiler so that the geyser tubes pass upwardly through the fire tubes. The header 69 is connected to the legs 68 through the pipes 76 and the drum 70 is similarly connected to the steam space of the fire tube boiler by the pipe 77. A steam pipe 78 provided with a valve 79 also extends from the drum 70 in order to draw off steam. A baffle 80 is also advantageously provided in the drum 70 and aids in the separation of steam and water.

The circulation of the geyser tube generator is in series with that of the fire tube boiler and greatly improves the circulation in the latter. At the same time, the geyser tubes passing through the fire tubes decrease the hydraulic mean depth and increase the

gas velocity through the fire tubes, factors which very greatly increase the heat transfer efficiency. This modification of the present invention as is readily apparent, can be simply and easily applied to a vertical fire tube boiler without necessitating any radical rebuilding. A greatly increased steaming capacity is thereby obtained due to the additional heating surface of the geyser tubes and to the improved circulation in the fire tube boiler and the increased heat transfer from the heating gases. Vertical fire tube boilers, despite the fact that they are very economical in construction particularly in small sizes, are rather inefficient from the standpoint of steaming capacity and for many purposes are today obsolete or obsolescent. When combined with the geyser tube generator of the present invention, however, their steaming efficiency is greatly increased and in many cases, this makes it possible to utilize an old fire tube boiler which would otherwise have to be scrapped owing to its insufficient steaming capacity. It is an advantage of the present invention when combined with ordinary types of boilers that many obsolescent boilers which, however, are still in good working condition, can be redesigned and brought to a satisfactory state of efficiency with comparatively little cost by a suitable combination with geyser tube generators. Such obsolescent boilers represent a very large capital investment in many cases and the flexibility of application of the present invention which enables many of these older units to be brought to a state of efficiency satisfactory for modern conditions, is of great economic importance.

Geyser tube generators operate most efficiently with long, small diameter generating tubes and due to the fact that length of tube means increased efficiency, a very simple and effective combined generator and water wall can be built embodying the principles of the present invention. Such a combination is shown diagrammatically in Fig. 10, the steam drum 81 and the lower header 82 being connected by the circulating tube 83 and by the geyser tubes 84 which, in their lower reaches shown in the drawings at 85, act as a water wall, absorbing the radiant heat from the flame 86, and protecting the furnace wall. In their upper reaches, however, the tubes are ordinary convection heated generator tubes. The drum 81 is, of course, provided with a suitable steam pipe 86 and may advantageously be provided with a baffle 87 in a manner similar to that shown in the foregoing figures.

The lower reaches 85 of the geyser tubes are exposed to the radiant heat of the furnace and are very highly heated which promotes vigorous geyser action, since as has been pointed out in the general description of the invention, vigorous geyser action is aided by

intense heat in the lower reaches of the tubes. At the same time, the furnace wall is protected from the effects of the radiant heat and much heat which would otherwise be wasted in heating up the furnace walls and which is actually destructive in many cases, is effectively utilized in the generation of steam.

In Fig. 10, two tubes only have been shown for the sake of clearness, but it should be understood that in an actual generator, a very large number of tubes will be used in order to abstract a maximum of heat from the gases. It should also be understood that there is no sharp dividing line between the portion of the tubes acting as water walls and those acting as ordinary generating tubes heated by convection. As a matter of fact, even in their lowest reaches, the tubes are heated to a certain extent by convection and as they extend up through the furnace pass and are bent out to fill the pass, they are more and more heated by convection and less and less by radiant heat, but there usually is no sudden line of demarcation, although in some installations it may be desirable to provide for rather sudden bends, making for a more definite line of demarcation. The particular arrangement of the tubes will, of course, be controlled by the conditions encountered in any given installation and various aids to effective screening such as fins on the lower reaches of the tubes and the like may be employed. In fact, tube structures, which have proven advantageous in conventional types of water walls, may be applied for the most part to geyser tubes of the present invention with such modifications as may be necessary. Obviously, also, the water wall tubes may be partly or wholly embedded in the furnace wall or two layers of tubes may be provided, one embedded and the other directly exposed to the fire, or both embedded, or both directly exposed to the flame. Other modifications may also be utilized.

Fig. 11 illustrates a somewhat different application of the geyser principles of the present invention. In the generators which have been illustrated hitherto, the production of water at a temperature higher than that corresponding to the boiling point under steam pressure conditions in the generator has been effected by applying intense heat to the bottom of small generating tubes under a considerable hydraulic head. In other words, the geyser has been formed by heat, water and pressure conditions in the generator itself. For many purposes and particularly where a new unit is to be constructed, this constitutes the most efficient and economical design. It is not, however, the only method whereby geyser action can be brought about and the essential conditions of the highly heated water volume at the bottom of generating tubes can be brought about

by introducing water at high temperature and under high pressure into the bottom of these generating tubes from an external source. This is of great importance in connection with certain conventional type boilers which show a rather poor steaming capacity owing to sluggish circulation, large tubes and the like. One modification of this idea is shown in Fig. 11 in connection with a Wickes boiler, a type of boiler which is not highly efficient from the standpoint of steam capacity per square foot of heating surface and which can be very easily redesigned to produce a vigorous and effective geyser circulation.

In the drawings, the Wickes boiler with the conventional upper drum 88, lower drum 89, front tubes 90, rear tubes 91 and baffle 92, is connected to a geyser tube generator having a steam drum 1, lower header 2, circulating tube 3 and geyser tubes 4, by means of a pipe 93 connecting to the pipe 3 of the geyser tube generator, and extending into the drum 89 and provided with nozzles 94 discharging into the tubes 90. The auxiliary geyser tube generator, which of course, can be of very much smaller size than the Wickes boiler, is shown as a radiant heat water wall. This is a very effective method of mounting the generator with certain furnace structures, but of course, any other arrangement can be provided or the geyser tube generator may be separately fired.

The geyser tube generator is operated at a steam pressure which may be slightly or greatly in excess of that in the Wickes boiler plus the hydraulic head between the drums 88 and 89. The water in the geyser tube generator is discharged into the steam drum 1 at a higher temperature and under a higher pressure than is the water at the bottom of the tubes 90 in the Wickes boiler. Accordingly, water will flow through the pipe 93 and will be ejected through the nozzles 94 in the form of jets. A reduction of pressure takes place in passing through the nozzles 94 and a corresponding formation of steam results since the temperature of the water is above the boiling point at the reduced pressure. The powerful jet of water and particularly the immediately resulting generation of steam causes a vigorous geyser action to take place in the tubes 90 and a very rapid and vigorous circulation takes place throughout the Wickes boiler, resulting in a largely increased steaming capacity.

The feed to the auxiliary generator is determined by the adjustment of the feed valve 95 which is controlled by the water level control 96. A steam pipe 97 extends from the steam drum 1 to the steam line 98 provided with valves 99 and 100 and connecting beyond the valve 100 with a steam line from the Wickes boiler 101. If it is desired to utilize the high pressure steam from the auxiliary generator separately, the valve 100 is

closed, and the valve 99 is opened. Where, however, the auxiliary generator operates at a pressure only slightly above that of the main Wickes boiler, it may be desired to mix the steam from this generator with the steam from the Wickes boiler and this can be effected by shutting the valve 99 and by opening the valve 100, the opening of the valve being just sufficient to cause a pressure drop or throttling effect to take place, the drop being great enough to equal the difference in pressure between the auxiliary generator and the Wickes boiler.

The amount of water which is introduced through the pipe 93 should be sufficient to cause vigorous geyser action in the Wickes boiler and need not be greater than this amount, although, if desired, it may be largely increased up to the amount represented by the steam taken off from the Wickes boiler. This naturally constitutes an upper limit to the amount of water which can be fed in. A suitable regulation of feed can be effected by operation of a valve 102 in the pipe 93 and controlled by the water level control 103 on the Wickes boiler, thus preventing the introduction of an amount of water in excess of that evaporated in the Wickes boiler. Manual control of the valve 102 can, of course, be utilized. Additional feed can be introduced into the Wickes boiler through the feed pipe illustrated which is controlled by the valve 196. This additional feed is necessary when the amount of water introduced from the geyser tube generator into the Wickes boiler is less than the amount of steam evaporated in the latter. The valve 196 may be controlled manually or it may be hooked up to the water level control 103 as shown. By providing valve 196 with a dash pot of ordinary construction it will open in any desired relation with the opening of the valve 102. Thus, for example, the control may be arranged so that valve 196 will not begin to open until valve 192 has been fully opened or any other suitable regulation which will determine the proportion of hot water from the geyser tube generator and cold feed water introduced into the Wickes boiler may be utilized.

The geyser action of the present invention can be very effectively combined with a control of superheat which is of considerable importance where a very even superheat temperature is required and which may also be utilized in order to protect superheaters in very hot zones of the furnace. Two modifications of this method of superheat control are shown in Figs. 12 and 13.

In the construction shown in Fig. 12 two geyser tube generators are illustrated with steam drums 126 and 130, lower headers 127 and 131, return circulation pipes 128 and 132 and geyser tubes 129 and 133. A superheater is associated with each generator, the super-

heater tubes being placed parallel and adjacent to the geyser tubes. The superheater associated with geyser tubes 133 is provided with an upper header 141, a lower header 142 and superheater tubes 135. Similarly the superheater associated with geyser tubes 129 is provided with an upper header 143, a lower header 144 and superheater tubes 134, the lower header 144 of this latter superheater being connected to the superheated steam main 140. A pipe 139 joins the lower header 142 to upper header 143. A pipe 136 connects the steam spaces of the drums 126 and 130 and pipes 137 and 138 convey the steam from both generators to the upper header 141 of the superheater associated with the geyser tubes 133. Thence, the steam passes down through the superheater tubes 135 into the lower header 142, then through the pipe 139 into the upper header 143 of the other superheater, down through the second set of superheating tubes 134 into the lower header 144 and thence out through the superheated steam main 140 which main is provided with a thermostat 155.

T connections 145 are placed in some or all of the geyser tubes 129 and steam and water pass through the tube 146 and valve 147 into the superheater header 143. A similar set of T's 148 are mounted in the geyser tubes 133 and are connected to the header 141 by the pipe 149 and valve 150. The valves 147 and 150 are respectively operated by the diaphragm chambers 151 and 152 through the rods 153 and 154. The thermostat 155 connects with the diaphragm chambers 151 and 152 through the pipe 186.

In operation, saturated steam at substantially the same pressure is generated in the two geyser tube generators and passes in series through the superheaters, first through the tubes 135 and then through the tubes 134, being superheated and passing off through the superheated steam main 140. When the temperature of the superheated steam rises too high, the thermostat 155 actuates the diaphragms 151 and 152 and opens the valves 147 and 150, permitting a portion of the mixture of saturated steam and water in the geyser tubes 129 and 133 to flow into the superheaters, thus cooling down the superheated steam and preventing burning out of the superheaters. The openings of the valves 147 and 150 can, of course, be varied so that the proportion of saturated steam and water entering the superheater tubes 134 and 135 may be the same or different, depending on the safety requirements for the different superheaters and on the extent of heating surfaces and other factors.

The generators in Fig. 12 are shown as separate from each other, but this is in no sense essential to the invention, and on the contrary, the hot gases may advantageously in many cases be caused to circulate in paral-

lel through the generators and the proportion of heat on the different generators can be varied. Thus, for example, a more vigorous heating of the tubes 134 is desirable in some cases in order to produce high superheats, as the hottest gases then come in contact with the steam which has already been superheated or dried in its passage through the superheater tubes 135 of the first superheater and a continued adequate heat head is provided which results in effective heat transfer.

The introduction of water into the superheaters and the parallel placement of generating tubes and superheating tubes are not claimed broadly in this application, but form a part of the subject matter of my application Serial No. 83,235, filed January 23, 1926. In the present application, these features are claimed only in combination with geyser tube generators which form the broad subject matter of the present invention.

In Fig. 13 two geyser tube generators and associated superheaters are shown arranged for series circulation of heating gases. The lower geyser tube generator consisting in steam drum 156, lower header 157, circulating tubes 158, geyser tubes 159 and superheater tubes 160, is placed in the lower portion of the furnace and contacts with the heating gases directly from the source of combustion. This generator and superheater may, therefore, be operated in part at least by radiant heat.

The upper generator having a steam drum 161, lower header 162, circulating pipe 163, geyser tubes 164 and superheater tubes 65 is arranged in the stack and contacts with heating gases which have already passed over the generating and superheating tubes of the lower generator. The superheaters are, of course, provided with the usual headers 166 and 167 for the tubes 160 and headers 168 and 169 for the tubes 165. A pipe 170 provided with a valve 171, permits introduction of a mixture of steam and water from the geyser tubes 159 into the superheater header 166 and a similar pipe 172 provided with a valve 173 permits introduction of steam and water from the geyser tubes 164 into the superheater header 168. The steam spaces of the drums 156 and 161 are connected to a common saturated steam main 174 provided with a valve 175 by means of the pipes 176 and 177. A pipe 178 provided with a valve 179 leads from the pipe 176 to the superheater header 166 associated with the lower generator and a similar pipe 180 provided with a valve 181 connects the pipe 176 to the superheater header 168 and also forms part of the passageway through which steam and water can be introduced into the header from the geyser tubes 164. The lower superheater headers 167 and 169 are connected to pipes 182 and 183, respectively, which pipes unite

to form the superheated steam main 184 provided with a valve 185.

In operation, saturated steam is generated in both of the generators and part or all of it can be used as such by an opening or closing of the valve 175. In the usual case, however, where it is desired to superheat the steam, the valve 175 is closed and the valves 179 and 181 are opened, causing the steam to pass in parallel through the two superheaters. By a suitable operation of the valves 179 and 181, the proportion of the steam passing through different superheaters may be varied, which provides for a control of the superheat such as is described in my co-pending application, Serial No. 83,235, referred to above. Where a still further control of superheat is desired, and particularly where it is advisable to protect the superheater tubes, water and steam from the geyser tubes can be introduced into the superheater tubes through the pipes 170 and 172 by a suitable opening of the valves 171 and 173. The amount of introduction can be so varied as to produce superheated steam of the same temperature in both superheaters. This will necessitate, of course, in most cases, the introduction of more water into the superheater tubes 160 than is necessary in the case of the tubes 165 owing to the fact that the former are situated in a very much hotter zone and in the embodiment illustrated in Fig. 13 are also exposed to a considerable amount of radiant heat, although being somewhat shielded by the generating tubes 159. It is by no means necessary, however, to generate superheated steam of the same quality in both superheaters and, on the contrary, superheated steam of varying temperatures and quantities can be produced in the different superheaters and by mixing in the superheated steam main 184 superheated steam of the desired quantity and temperature can be produced.

When the generators are first started, it may be necessary to protect the superheater tubes and particularly the superheater tubes 160 which are exposed to the full heat of the flame. In order to protect these tubes, the valve 171 may be opened, the valve 185 closed and the valve 181 opened. The water passing through the pipe 170 is transformed into saturated steam in the superheater tubes 160, thus protecting them from burning out and the saturated steam thus produced passes upwardly through the pipes 182 and 183 and up through the superheater tubes 165 where it is superheated and finally joins the saturated steam pipe 176. If it is desired to produce saturated steam only or steam having but slight superheat, this same arrangement can be utilized so that the superheated steam passing from the pipe 180 mixes with the saturated steam in the pipe 176 and joining the saturated steam in the pipe 177, passes out through the saturated steam main 174, the

valve 175, of course, having been opened. By this means, the high steaming capacity of the superheater tubes 160 can be utilized and the superheat imparted to this portion of the steam by the superheater tubes 165 can be effectively used to dry the saturated steam generated and assure good quality.

The broad idea of controlling the temperature of the superheated steam by passing saturated steam in parallel through two superheaters situated in different heat zones and regulating the proportions of steam passing through the different superheaters is not claimed broadly in the present application but forms part of the subject matter of my co-pending application, Serial No. 83,235. In the present application, this feature is claimed only in combination with the particular method of injecting water and with the geyser tube generators of the present invention.

Figs. 12 and 13 illustrate series or parallel arrangements of superheaters with manual or automatic control of water injection. Obviously, either method of control can be associated with either arrangement and series or parallel arrangement of superheaters can be associated with series or parallel flow of the heating gases over the generating tubes and superheaters or with independently fired generators. Other combinations are possible and will be utilized by those skilled in the art wherever the conditions of individual installations render it desirable.

In Figs. 12 and 13, the only steam passing through the superheaters is that generated in the geyser tube generators themselves. The advantages of superheat regulation by injection of the mixture of steam and water from geyser tubes is, however, not confined to superheaters in which all of the steam is taken from the geyser tube generators themselves. On the contrary, where geyser tube generators are associated with other sources of steam the superheaters may be fed from these other steam sources alone or may take steam, both from the other sources and from the geyser tube generators, the temperature in each case being controlled by suitable injection of water and steam from the geyser tube generators, as shown in Figures 12 and 13.

Fig. 14 illustrates a modified geyser tube generator with a reverse flow of heating gases. The generator consists in an upper drum 187, lower drum 188, downtake tube 189 and geyser tubes 190. A check valve 191 may advantageously be placed in the down-take tube. Heating gases enter the top of the furnace structure, for example, from a powdered coal burner 192 and flow downwardly over the geyser tubes 190 and then upwardly into a stack 194, the draft of which may advantageously be augmented by the blower 193. Other sources of hot gases may be used instead of a powdered coal burner such as, for

example, an oil burner, or gases from any other source may be utilized. The circulation in the generator is the same as in the ordinary modification but a considerably greater heat absorption can be obtained as the heating gases flow counter to the water and steam in the geyser tubes, so that the hottest gases come in contact with the hot steam or water and the cooled gases, striking the bottom portions of the tubes, come in contact with relatively cooler water. As it is necessary to superheat the water in the lower reaches of the geyser tubes care must be taken to provide for a vigorous circulation, as otherwise there is danger that the upper reaches of the tubes may be burnt out before geyser action takes place. The same reason makes it desirable to use relatively small tubes containing comparatively small amounts of water in their lower reaches, so that a comparatively short heating period is sufficient to superheat the water and geyser action sets in almost at once.

What is claimed as new is:

1. Apparatus for the generation of steam and other vapors comprising in combination relatively long generating tubes exposed to heat throughout their lower reaches at least, and means including a conduit for providing a path of unrestricted return flow and for maintaining a water level in the generator so located as continuously to provide a head of water above said lower reaches at such a height that the water within the tubes in said lower reaches is subjected to pressure considerably above that corresponding to the temperature of the steam generated and discharged from the tubes, the amount of water maintained in the tubes, the proportions of the tubes in relation to the capacity of said conduit and their relation to the heat source being such that a relatively high velocity is produced therein and the reduction in pressure of the water as it rises in the tubes causes vigorous geyser action therein.

2. An apparatus according to claim 1 in which generating tubes are unheated for a considerable proportion of their length in their upper reaches, in which upper portions the reduction of pressure is principally effective to produce the water circulating geyser action.

3. Apparatus for generating steam according to claim 1 in which the generating tubes are exposed to radiant heat.

4. A steam generator comprising a steam generating tube of relatively small diameter arranged with one end at a relatively great distance above the other end, a chamber adjacent the upper end of the tube for separating from the steam any water discharged from the tube therewith and a conduit of relatively large diameter as compared with the diameter of the generating tube and connecting the chamber with the lower end of

the generating tube and constructed to provide a free return flow to said lower end of the water separated in the chamber, whereby the water within the lower reaches of the tube is subjected to a pressure sufficiently in excess of the steam pressure in the chamber to cause it to be superheated above the temperature of the steam so that in said lower reaches of the tube ebullition is repressed and in the upper reaches violent geyser action is brought about for discharging any excess water into the chamber and an effective circulation in the system is produced.

5. Steam generator according to claim 4 in which the superheating of the water in the lower reaches of the tube is effected by subjecting these lower reaches to the intense heat of radiation of the source of heat in a furnace while subjecting the upper reaches to the normal gas temperature.

6. Steam generator according to claim 4 in which the steam generating tubes are arranged as a water wall adjacent the side walls of a furnace of great height relative to its cross section.

7. A steam generator comprising a steam generating tube of relatively small diameter and relatively long length arranged with one end above the other, a chamber connected to the upper end of the tube for separating from the steam generated in the tube any water discharged from the tube therewith, a return conduit of relatively large diameter as compared with the diameter of the tube providing a path for free flow therethrough and connecting the water space of the chamber with the lower end of the tube, said chamber being located at such a height in consideration of the length of the tube and its diameter that in the steam generating process the water in the lower portion thereof is subjected to a pressure sufficiently in excess of the steam pressure in the chamber to cause the water to become heated appreciably above the temperature of the steam, whereby in the lower portion of the tube ebullition is repressed and in the upper portion of the tube violent geyser action is brought about for discharging any excess water into the chamber and producing an effective circulation in the system.

8. A process of generating steam in a tube having one end higher than the other which consists in heating the water contained in the lower reaches of the tube to a temperature in excess of the temperature of the steam to be generated, maintaining a water column above said lower reaches so as to produce a pressure on the water therein sufficient to repress ebullition, causing the water to move upwardly with high velocity in the tube while reducing the pressure thereon whereby violent ebullition takes place in the upper reaches and causes any excess water to be discharged with the steam from the upper end of the tube,

separating the steam and water so discharged,
and returning the excess water to the lower
reaches of the tube by delivering it to the
volume of water contained in the water
column.

Signed at New York, New York, this 15th
day of June, 1926.

WALTER DOUGLAS LA MONT.

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