Oct. 29, 1963 R. MICHEL 3,108,576

ONCE-THROUGH STEAM GENERATOR

Filed Feb. 24, 1959 4 Sheets-Sheet 1

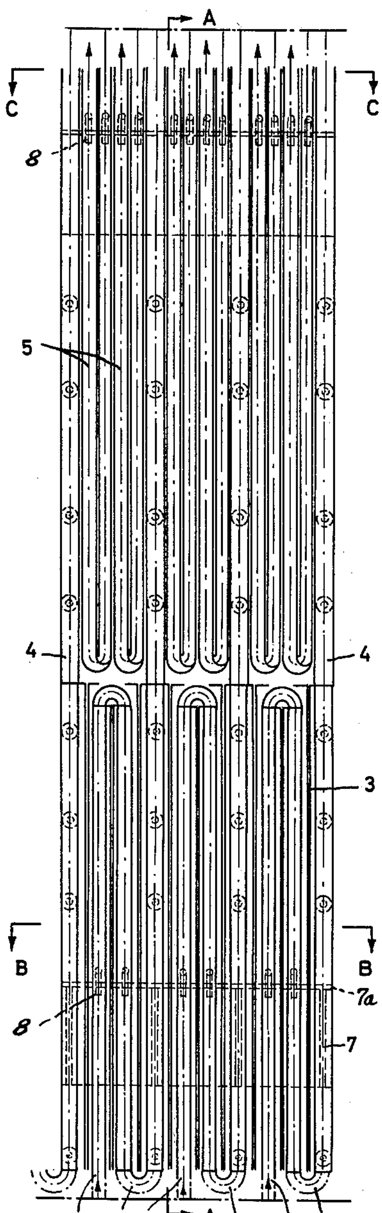

Fig.1

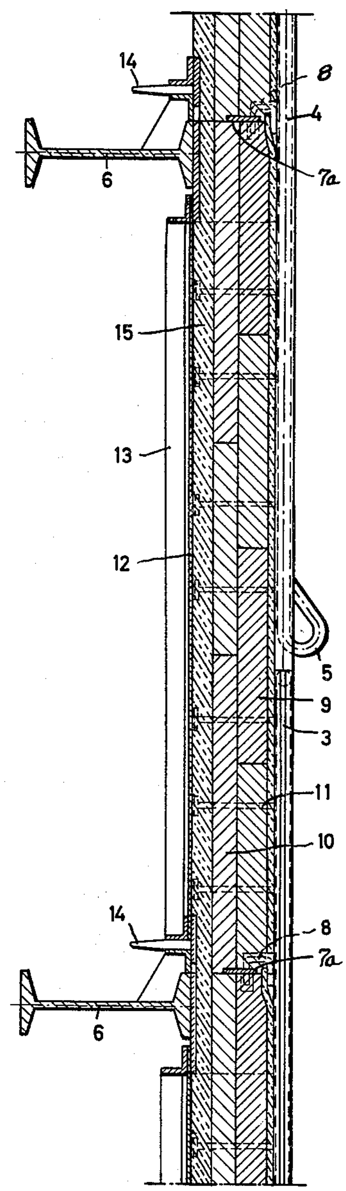

Fig.2 (A-A)

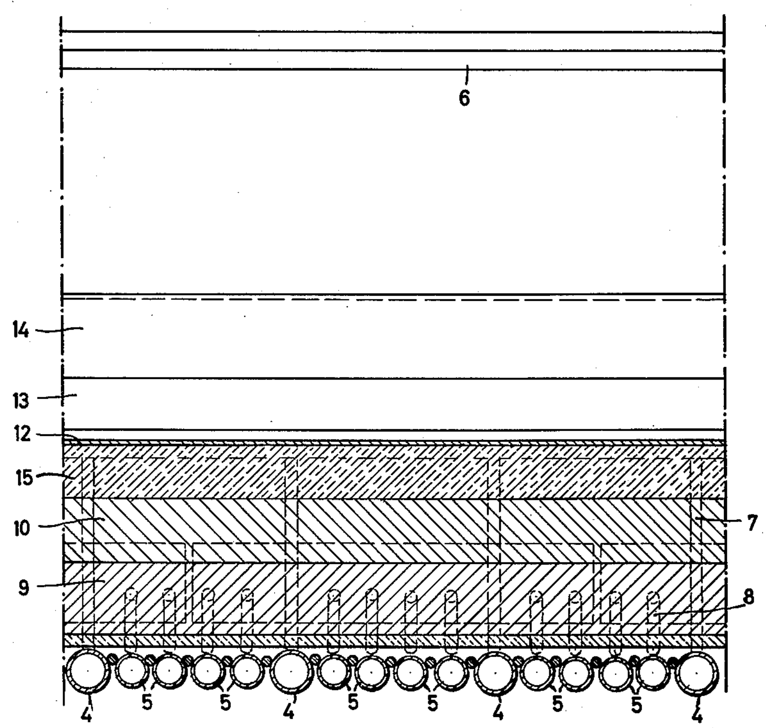

Fig.4 (C-C)

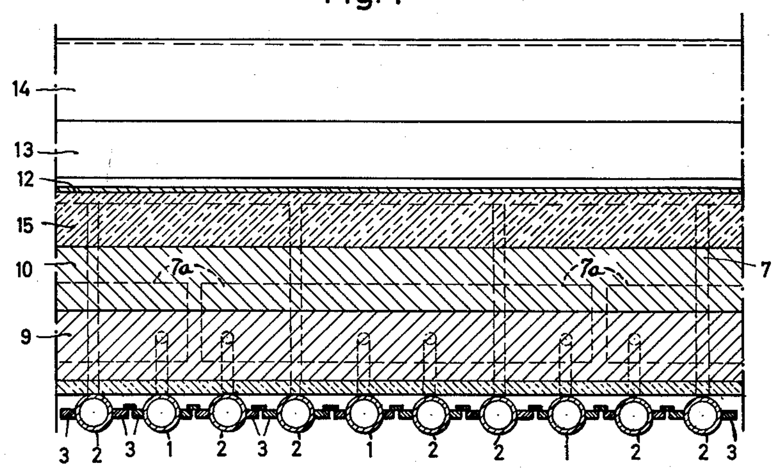

Fig.3 (B-B)

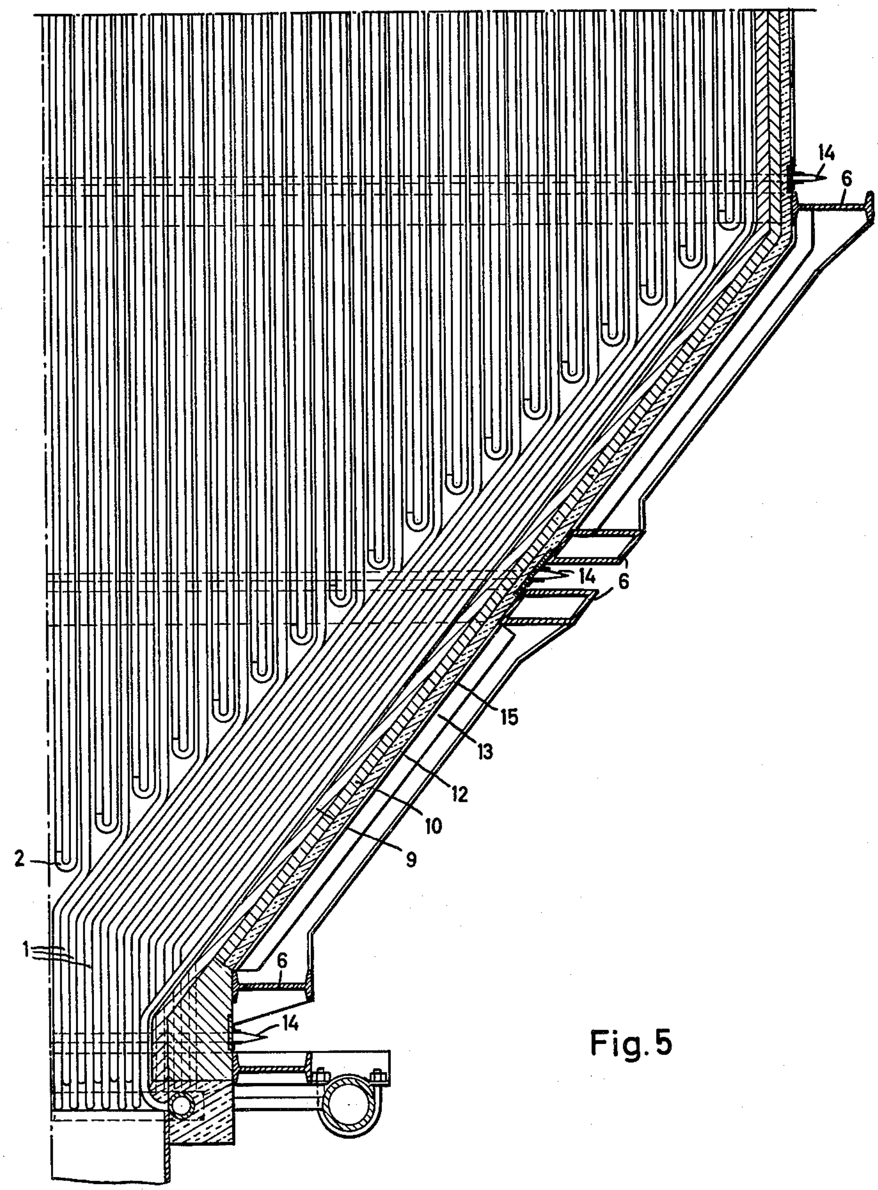

Fig. 5

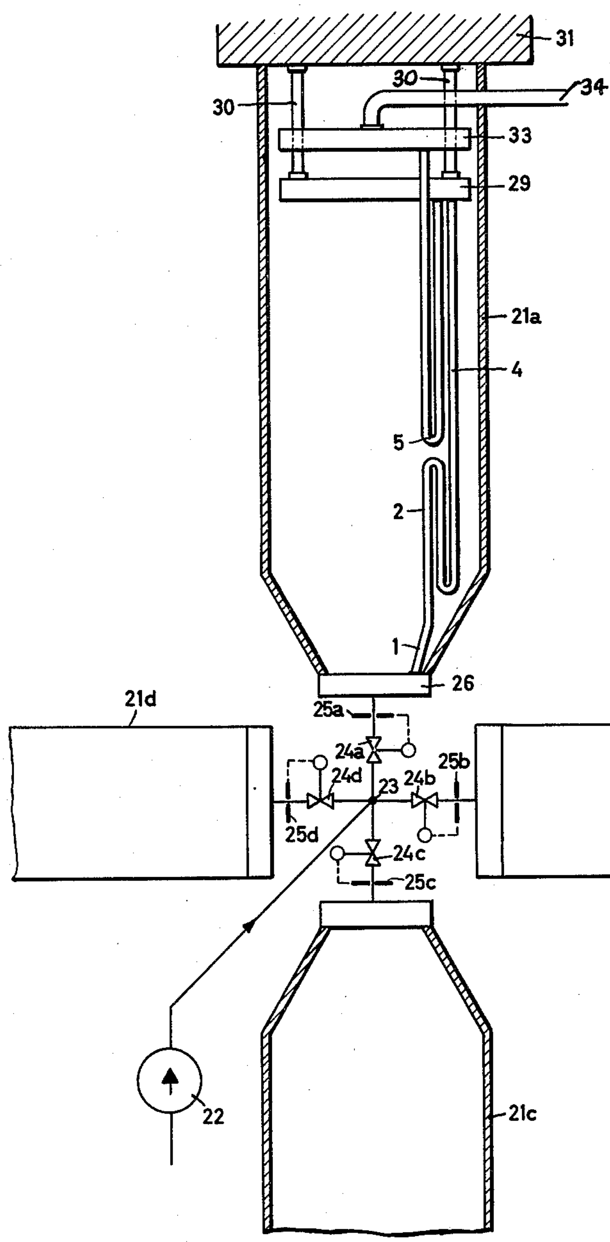
31
30
30
34
33
29
21a
4
5
2
1
26
21d
25a
24a
24d
23
24b
25b
25d
24c
25c
21b
22
21c

Fig.6

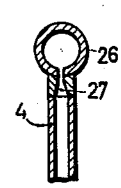
26
27
4

Fig.7

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ONCE-THROUGH STEAM GENERATOR

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13 Claims. (Cl. 122—6)

My invention relates to forced-flow boilers of the once-through type suitable for large-size steam generators, particularly in electric power plants.

It is an object of my invention to provide relatively simple and reliable means for avoiding the occurrence of detrimental stresses in the boiler structures due to temperature. Another more specific object is to suspend the entire boiler from a roof, ceiling structure or other overhead structural support means so that the boiler can freely expand downwardly at the operating temperature. Still another object is to make vertical constructions of structural steel dispensable to the greatest possible extent and to substitute for the heavy masonry work conventionally employed layers of light-weight materials which are wholly or partly heat-insulating and do not represent load-supporting elements, and thus perform merely the function of heat-insulating and sealing the boiler components toward the outside.

It is known from drum-type natural-circulation boilers to suspend the boiler from an overhead or ceiling structure. This type of design, however, meets the difficulty where once-through steam generators are concerned. The once-through type boiler cannot be suspended from a ceiling construction in the manner known for natural-circulation boilers. This is because the evaporator through tubes, the zig-zag evaporator tubes for the lower portion of the combustion chamber, and the radiation superheater tubes located above the zig-zag evaporator tubes of a once-through boiler, are subjected to considerably different respective temperatures and correspondingly different longitudinal expansions of the boiler walls. These difficulties, consequently, have heretofore made it infeasible to design a once-through steam generator of the suspended type.

It is therefore a more specific object of my invention to overcome the above-mentioned difficulties and to offer a way of mounting such a boiler with its entire system of boiler tubes in suspended relation to a ceiling structure so that the boiler can freely expand downwardly.

It is another specific object of my invention to provide means for obtaining the feed water flow velocity necessary to achieve the desired operating pressure without the need for excessively large feed water pumps.

A further specific object of my invention is to provide means for distributing the feed water flow in a once-through boiler, having evaporator tube and superheater tube strands within its firing chamber, in accordance with the operating pressure conditions of the boiler in such a manner that the cold-water flow velocity corresponding to the particular desired operating pressure for the once-through evaporator is attained.

According to one of the features of my invention, the tubes of all combustion-chamber walls are connected in parallel, and the entire firing chamber is suspended from the through-tubes of the evaporators.

According to another feature, it is preferable to have the cool feed water, entering into the boiler from below, pre-heated to boiling temperature in one or more loops ahead of the boiler tubes proper, and to have this pre-heated feed water enter into the through-tubes of the evaporator which carry the other boiler components as well as the firing chamber. The size of the evaporator

heating surface can then be so dimensioned that the evaporator tubes, extending all the way through the top and carrying the boiler structure, have at the exit a vapor content of about 75 to 80%.

According to a further feature of my invention, the pre-heater loop for the feed water preceding the evaporator tubes in the lower portion of the firing space, as well as the lower portion of the evaporator tubes, are provided on both sides with fins or vanes in order to permit reducing the number of parallel tubes and thus producing a greater speed of the cold water passing through the pre-heater loop. In the upper portion of the combustion chamber, a superheater loops of U-shape may be hung between the vertical through-tubes of the evaporator, these superheater loops being preferably connected in parallel to each other on all walls of the firing chamber. The superheater loops of U-shape can be operated as residual-evaporator loops, that is loops connected between the evaporator system and the main portion of the superheater which serve to evaporate any residual liquid remaining in the working medium.

The walls of the combustion chamber may in some cases be subjected to different amounts of heating. In order to adapt the distribution of the feed water to such differences in heating, and in accordance with a further feature of my invention, it is preferable to build orifice and valve means, also referred to herein as throttle diaphragms, with openings of the same or different diameters, into the commencing portion of all evaporator tubes within a range wherein no evaporation has as yet occurred. Since the evaporator system is of only short length and thus possesses only a slight pressure loss due to friction, very strongly effective throttle diaphragms can be used.

The upwardly extending through-tubes of the evaporator can be mounted on horizontal steel girders by means of projections or fins passing through the insulation. As a result, the evaporator tubes will remain located in one plane and the chamber walls become stiff and resistant to bending due to the inner super-atmospheric or less-than-atmospheric pressure of the combustion chamber. The lower pre-heater loops for the feed water as well as the upper superheater loops of U-shape are preferably joined with the evaporator tubes by displaceable guide books. By virtue of such supports comprising, for example, hooks which are welded rearwardly to the evaporator tubes and in the plane of these tubes, these pre-heater and superheater loops can perform shoving or sliding motion upwardly and downwardly with changes in temperature.

The evaporator tubes, extending upwardly through the construction, can be covered on their rear side with stretchable (ductile) metal and can be covered with compressed insulating material, it being necessary to make certain that the lower per-heater loops and the upper superheater U-loops can perform the above-mentioned shoving or sliding expansion movement upwardly or downwardly in front of the insulating wall in accordance with their respectively different amounts of thermal expansion. For avoiding the use of brickwork, suitable heat-insulating materials can be used. For example, relatively strong heat-insulating panels such as those made of distomite can be placed at the outer side of the boiler wall as heat-insulation, and the inner portion of the heat-insulating wall may be formed by bats or blankets of lesser strength but increased heat-insulating effects, the latter panels being mounted in staggered relation to the outer, stronger plates. Suitable for the heat-insulation material are also the conventional bats of rock wool, slag wool, glass wool or the like, particularly for thermally insulating the boiler toward the outside. The entire insulation can be held in place by anchor piles welded to the evaporator tubes. The exterior is preferably covered by a jacket of sheet metal located between the individual horizontal supporting girders. The greater thermal expansion of the evaporator tubes relative to the exterior sheet metal jacket can be taken up by suitable expansion diaphragms. For example, such a diaphragm may be provided above each of the supporting girders and may extend about the entire firing space.

The foregoing and other objects, advantages and features of my invention, these features being set forth with particularity in the claims annexed hereto, will be apparent from and will be mentioned in, the following description in conjunction with the embodiment of a once-through steam generator according to the invention illustrated by way of example on the accompanying drawings, in which:

FIG. 1 shows a portion of a tube system mounted on one side of the firing chamber;

FIG. 2 is a cross section along the line A—A in FIG. 1;

FIG. 3 is a cross section along the line B—B in FIG. 1;

FIG. 4 is a cross section along the line C—C in FIG. 1;

FIG. 5 illustrates one of the firing-chamber sides in totality;

FIG. 6 shows schematically a layout diagram of the complete once-through boiler with emphasis on the arrangement of boiler tubes at the four boiler walls; and

FIG. 7 illustrates a modified detail of FIG. 6.

The same reference characters are used in all illustrations for the same components respectively.

Referring first to the over-all layout diagram of the entire boiler shown schematically in FIG. 6, it should be understood that the four heating surfaces denoted generally by **21***a*, **21***b*, **21***c* and **21***d*, respectively, extend along the four vertical walls of the boiler and are shown as projected into a single plane of illustration. The feed water is supplied from a pump **22** to a distribution point **23** from which it passes through respective valves **24***a*, **24***b*, **24***c*, **24***d* and respective orifice means **25***a*, **25***b*, **25***c*, **25***d* into the four heating surfaces **21***a*, **21***b*, **21***c*, **21***d* respectively along the boiler walls. For simplicity, the tube system and the mounting of the tubes is illustrated, in a somewhat simplified manner, only for the heating surface **21***a*, it being understood that the other three heating surfaces **21***b*, **21***c*, **21***d*, are provided with analogous tube systems. Connected to the feed water tube and subsequent to the diaphragm or orifice plate **25***a* is a first distributor-collector **26** from which the feed water then passes through respective throttle openings **27** (FIG. 7) into a number of parallel evaporator tubes **1**, the throttles **27** serving to secure a uniform distribution of the feed water to all parallel evaporator tubes. This uniform distribution of the feed water is accomplished in the following known manner. The diaphragms **25***a* to **25***d* serve to measure pressure differences which occur as small pressure drops resulting from the slight retardation imposed on the flow by the respective diaphragm. This drop in pressure from a point ahead of the diaphragm to a point behind the diaphragm increases with an increase in flow. The pressure difference thus determined constitutes a measure of the flow quantity. This measured value is then applied to act correctively upon the corresponding preceding valve **24***a* to **24***d* in order to increase or decrease the flow therethrough so as to secure a uniform distribution of the flow of working medium into the parallel connected paths to the four sides of the firing chamber. If the measured flow at a particular measuring diaphragm is too small and thence the pressure difference at that measuring diaphragm is below the datum value, this will cause the appertaining valve to be adjusted in an opening sense. If the measured flow is too great, the appertaining valve is adjusted in a closing sense. Suitable controllers with drives, designated symbolically by circles, are provided to operate the valves in this manner.

The evaporator tubes continue on to form a loop **2** in the lower portion of the firing chamber and then extend vertically, or generally upwardly, through the balance of the entire tube system, the upwardly extending upper or

main portion **4** of each tube extending over the greater portion of its length.

An increase in cross section of the evaporator tubes is shown in the middle of FIG. 1. After the feed water has passed through the loop **2**, it enters into the evaporator tubes **4** and flows upwardly. As shown in the middle of FIG. 1, the water enters into an enlarged cross section of the evaporator tubes **4**. The evaporator tubes **4** are secured at their tops to a second distributor-collector **29** which is suspended by means of rods **30** from the ceiling construction **31** of the boiler building. The working medium passes from the second distributor **29** into the superheater loops **5** which terminate upwardly in a third distributor-collector **33** from which the superheated steam is then supplied thru a suitable outlet pipe **34** to the turbines.

All evaporator tubes on all four sides of the firing chamber are connected in parallel. The loop **2** located in the lower portion of the chamber serves to heat the feed water up to boiling temperature so that the upwardly extending main portions **4** of the evaporator tubes have the same temperature, namely boiling temperature, from the bottom up to the top. This is a prerequisite for permitting the boiler to be suspended by means of its own tube system. The speed of the working medium in the evaporator tubes should, if possible, not drop below a given minimum value and, on the other hand, should not become excessively great. For thus obtaining the proper slow speed in these tubes, they are arranged in the lower zone of the firing chamber with a somewhat greater subdivision. The interspaces between the evaporator tubes are covered by fins **3** (FIGS. 1, 2, 3), or the like, welded on both sides to the evaporator tubes. The lower portions of the evaporator tubes each have a smaller diameter than the succeeding upper portions (see FIGS. 3 and 4). The lower pre-heater loops **2** are given a length dependent upon the operating pressure and the magnitude of the feed water temperature. That is, with higher operating pressures and higher feed water temperatures, the lower pre-heater loops **2** can be made shorter, whereas lower operating pressures and lower feed water temperatures require longer pre-heater loops.

It will be recognized that the entire boiler system is suspended by means of the upwardly extending main through-portions **4** of the evaporator tubes. Between each two of these through-tubes **4**, there are suspended two superheater loops **5** of U-shape and located in the upper portion of the firing chamber. This arrangement results in a dense covering of the heating surface with tubes and also prevents an excessive absorption of heat in the evaporator. The size of the evaporator heating surface can be so dimensioned that by the time the water-steam medium reaches the upper exit of the evaporator tubes **4** approximately 75 to 80% of the feed water has been converted to steam.

Because of their arrangement and relative dimensions, if individual evaporator tubes are supplied with water in somewhat different amounts, i.e. rate of flow, of if the individual firing-chamber walls are differently heated, i.e. to a different temperature, these different conditions make themselves felt only by producing a different water content in the medium at the exit of the individual evaporator tubes. Consequently, such differences cannot cause different temperatures in any of the respective evaporator tubes and therefore cannot result in any disturbance of the suspended system or suspending structure.

As described above with reference to FIG. 6, a uniform distribution of the feed water into the respective parallel-connected groups of evaporator tubes, on the respective heating surfaces **21***a* to **21***d*, can be given greater uniformity by providing the above-described orifice and valve means **25***a* to **25***d* and **24***a* to **24***d* in the starting portion of each parallel tube group. The respective throttling action of these orifice and valve means can be adapted to any different heating of the firing-chamber walls. Since the evaporator system is relatively short and hence possesses only slight frictional pressure losses, very strongly active orifice and valve means can be used.

As shown in FIGS. 2, 3 and 5, horizontal I-beam or channel girders **6** are provided, which hold the evaporator tubes together. Welded to each evaporator tube **4**, in vertically spaced relation to each other, are fins or webs **7**. The other side of these webs is welded to the horizontal girders **6**, or otherwise attached thereto, for example by screw bolts. Fixedly attached to vertical webs **7** and hooks **8** are horizontal interconnecting members *7a*, as shown in FIGS. 1, 2 and 3. As a result, the evaporator tubes of any one group on a respective firing-chamber wall will remain held within a single plane, and the firing-chamber walls are accordingly made stiff and resistant to bending under the effect of the interior positive or negative pressure of the firing chamber relative to the ambient atmosphere. The lower pre-heater loops **2** as well as the upper U-shaped superheater loops **5** are held in the plane of the evaporator tubes **4** by means of hooks **8** which are welded to the rear side of the respective loops **2**, **5**, and hook through plate 7A (as shown in FIG. 2). The loops therefore can perform the necessary upward and downward shoving or sliding motion with changes in temperature.

For avoiding the use of a heavy lining of the firing chamber such as masonry or brickwork, the walls of the chamber are insulated toward the outside by relatively strong light-weight heat-insulating panels or plates **9** made of a compressed refractory ceramic or fiber insulation material of diatomite material. Located behind and in staggered relation to the plate **9** are insulation plates **10**, made of a mechanically weaker but better heat-insulating material than that of panels **9**. Suitable for panels **10** are ordinary heat-insulating bats available commercially. The exterior layer **15** of the heat-insulation is formed by bats or blankets of spun mineral-wool fiber, such as slag-wool bats or rock-wool bats. The entire insulation is held in position by anchor irons **11** welded to the evaporator tubes **4**. The firing-chamber walls are covered toward the outside by a sheet metal shell **12** with reinforcing ribs **13** welded thereto. The sheet metal members are located between the individual horizontal girders **6**. The greater thermal expansion of the evaporator tubes relative to the sheet metal shell **12** is compensated for by means of diaphragms **14** which are located above each girder **6** and extend around the entire firing space.

The U-shaped superheater loops **5** located in the upper portion of the firing chamber between each two evaporator tubes prevent an excessive heat supply to the evaporator.

A boiler of the type according to the invention avoids the need for intermediate collectors and thus reduces such source of pressure losses. Furthermore this type of design involves an extremely small expenditure with respect to structural steel and insulation required, thus resulting in greatly reduced installation cost of the boiler plant.

It will be obvious to those skilled in the art, upon a study of this disclosure, that this invention permits of various modifications and alterations with respect to the individual boiler and insulation components and arrangements disclosed, and hence can be embodied in forced-flow or once-through boiler equipment other than as particularly illustrated and described herein, without departing from the essential features of the invention and within the spirit and scope of the claims annexed hereto.

I claim:

1. A once-through type forced-flow steam generator of suspended-type construction, comprising working medium supply means, a tube system and a firing chamber having walls on which the tubes of said system are mounted, said tube system including evaporator tubes each connected with said medium supply means and arranged in parallel for traversal from below upwardly by the working medium to be evaporated, suspension means joined with said evaporator tubes for supporting the latter and said firing chamber from above, each of said evaporator tubes having a first portion adapted to carry working medium from said medium supply means prior to evaporation, said first tube portion forming at least one loop having an intermediate downwardly traversed tube length, said one loop being located in and extending over only the lower portion of said firing chamber, the upper portions of said evaporator tubes being straight and parallel, a plurality of superheater tubes each forming a U-shaped looped portion in the upper portion of said firing chamber, each of said superheater tubes being suspended from said suspension means and located between the upper portions of adjacent ones of said evaporator tubes.

2. A forced-flow steam generator according to claim 1, the mutually adjacent parallel tubes forming said first portions being slightly spaced from each other to form interstices therebetween, and only said first portions of said evaporator tubes being provided externally with projecting fins extending from both sides of the tubes into said interstices for providing greater heat transfer and forming a substantially continuous heating surface lining the lower portion of said firing chamber, whereby the number of parallel tubes necessary is reduced and the flowing speed of the working medium in the tubes is increased.

3. A steam generator according to claim 1, all of said superheater loops being connected in parallel on each wall of the firing chamber.

4. A steam generator according to claim 1, including throttle diaphragms disposed between said working-medium supply means and said evaporator tubes within a range of the latter where no evaporation has occurred, and so dimensioned as to adapt the comparative distribution of said medium therein to differences in heating of the respective tubes.

5. A forced-flow steam generator according to claim 1, the evaporator tubes on all said firing chamber walls being through-tubes all connected in parallel and extending in an upward direction throughout their length and covering at least a major portion of the height of said firing chamber, the upwardly-extending portion of said evaporator tubes subsequent to said looped portions being so dimensioned and arranged in relation to said firing chamber that the working medium in said evaporator tubes at said outlet end thereof has a steam content of approximately 75% to 80%.

6. A forced-flow steam generator according to claim 1, the evaporator tube groups on all of the respective firing chamber walls each comprising through-tubes, all evaporator tubes of the group on a respective wall being connected in parallel and covering at least a major portion of the height of said firing chamber, orifice and valve means connected between said working-medium supply means and each group of evaporator tubes, said orifice and valve means being so dimensioned that the rate of distribution of said working medium into each group of said evaporator tubes on a respective firing chamber wall is controlled thereby in accordance with differences in heat distribution and temperature between the various firing chamber walls.

7. A forced-flow steam generator according to claim 1, the evaporator tube groups on each of respective firing chamber walls each comprising through-tubes, all groups being connected in parallel and extending in an upward direction throughout their respective lengths and covering at least a major portion of the height of said firing chamber, suspension means forming a load-supporting element for said firing chamber, guiding hook means joining said first portions of said evaporator tubes and said U-shaped looped portions of said superheater tubes at a location such that each of said tube portions can perform the necessary upward and downward shoving motion in

accordance with tube expension due to variations in the operating temperature.

8. A forced-flow steam generator according to claim 1, each wall of said firing chamber having mounted thereon a first distributor-collector connected to said supply means and connecting said evaporator tubes in common, a second distributor-collector forming part of said suspension means and connecting the upper portions of said evaporator tubes in common, and a third distributor-collector forming another part of said suspension means and connecting respective outlets of said superheater tubes in common.

9. A forced-flow steam generator according to claim 1, the walls of said firing chamber each comprising an insulating wall having panels of compressed light-weight insulating material, and fastening means guidingly joining said insulating material to said evaporator tubes at a tube location such as to support said insulation panels and to permit at the operating temperature a shoving expansion motion of said first portions of said evaporator tubes and of said looped portions of said superheater tubes with respect to said insulating wall, said panels of insulating material including a plurality of layers of plates disposed in staggered relationship to each other.

10. A forced-flow steam generator according to claim 8, said superheater tubes as a group being connected mutually in parallel, and said group of superheater tubes being connected in series with said evaporator tubes.

11. A forced-flow steam generator according to claim 8, said looped portions of U-shape in said superheater tubes being connected to said second distributor collector subsequent to said evaporator tubes and adapted to

evaporate any residual liquid remaining in the working medium passing therethrough.

12. A forced-flow steam generator according to claim 9, further defined in that said insulating material of said insulation wall includes an exterior layer of sheet metal forming a shell covering the outside of said insulation wall.

13. A forced-flow steam generator as set forth in claim 12, and including at least one expansion diaphragm membrane extending horizontally around the entire generator, mounted on said exterior sheet-metal shell thereof and so dimensioned as to permit different amounts of longitudinal expansion between said evaporator tube system and said sheet-metal shell.

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