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[54] **STEAM GENERATOR**

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[52] **U.S. Cl.** .... **122/406 R,** 122/487

[51] **Int. Cl.** **F22d 5/00**

[58] **Field of Search** .... 122/235 R, 235 Q, 122/406 R, 487; 431/173

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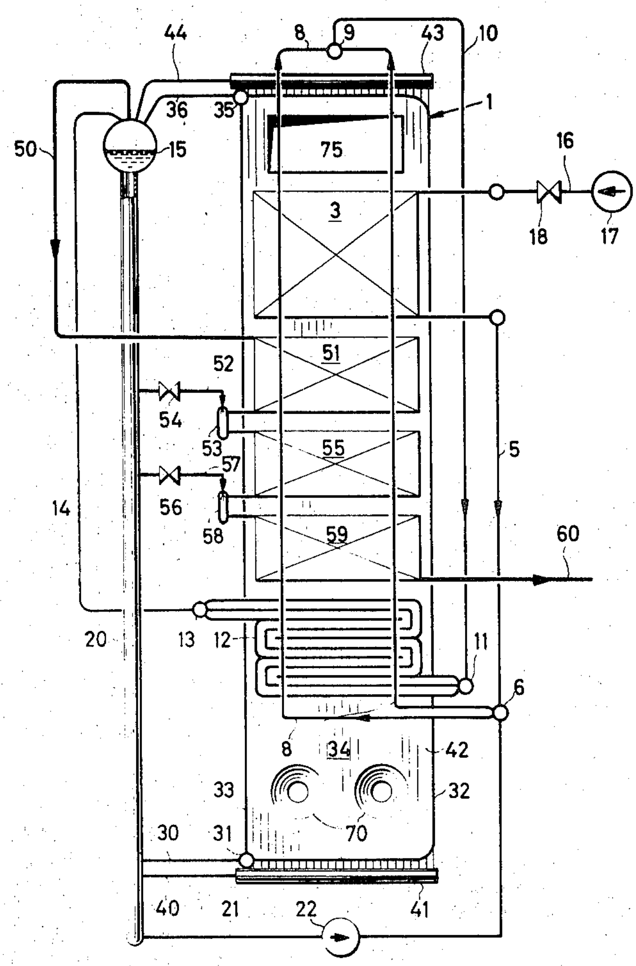
[57] **ABSTRACT**

A quantity of steam of at least 30 percent, usually 50 percent of the total is produced under forced circulation in one evaporator within the gas flue while a quantity of steam of less than 40 percent of the total is produced under natural circulation in the tube walls lining the flue. The forced circulation heating surface is disposed upstream of the natural circulation heating surface in the working medium flow.

13 Claims, 2 Drawing Figures



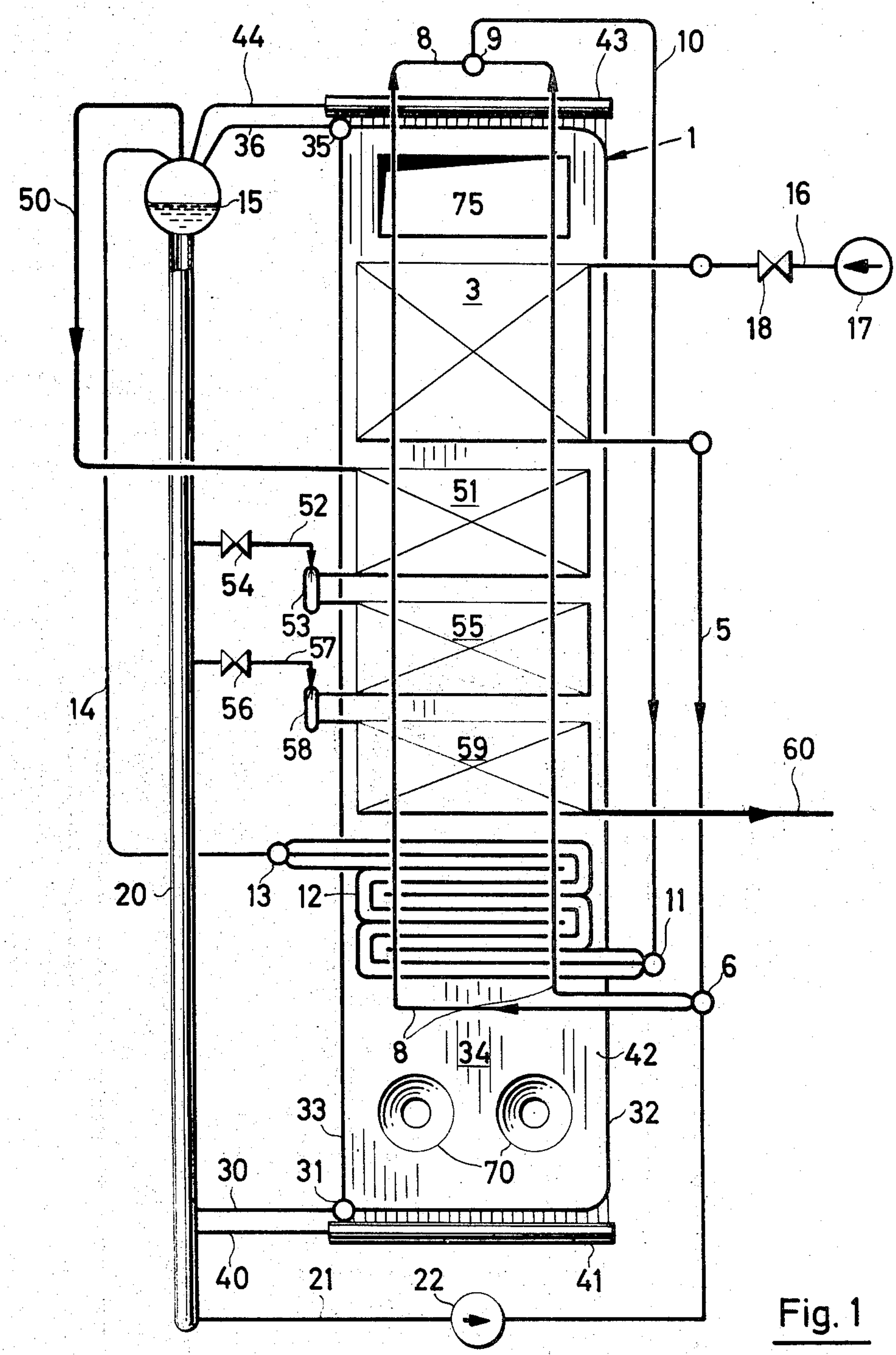

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Fig. 1

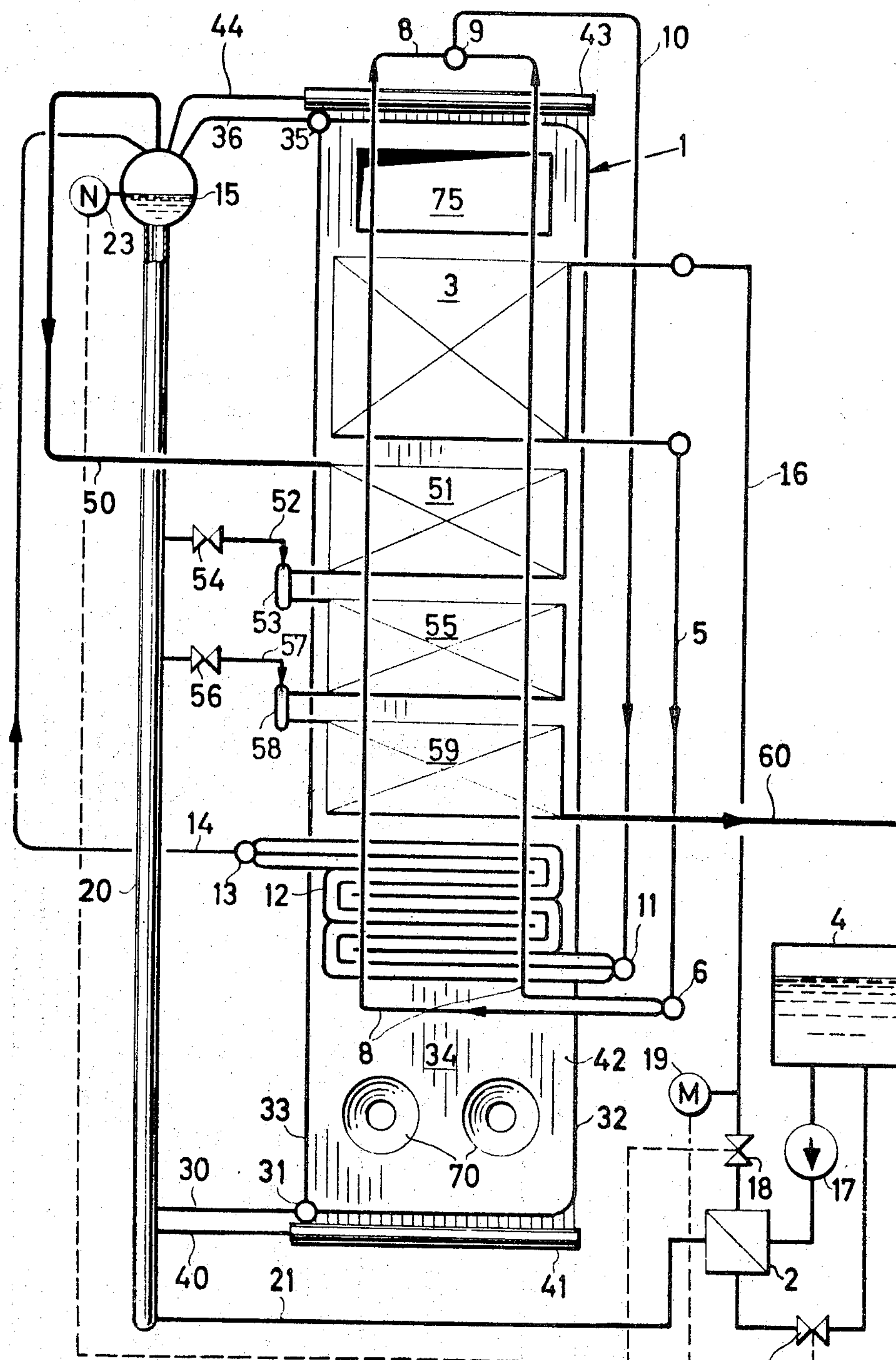
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Fig. 2

STEAM GENERATOR

This invention relates to steam generators of the kind in which all heating surfaces are situated in a hot gas pass or flue whose walls, at least in the vicinity of the hot gas inlet, are formed of vertical, coolant-carrying tubes. That is, it relates to steam generators which do not have combustion chambers with radiant heating surfaces. Such steam generators may have their own uncooled combustion chambers such as uncooled swirl-type muffle burners or may be heated by exhaust gas. The present invention consists in a steam generator of which all the heating surfaces are located in a hot gas flue the walls of which, at least in the vicinity of the hot gas inlet, are formed of vertical tubes forming a first evaporator heating surface which is arranged to be cooled by natural circulation of working medium therethrough, the hot gas flue having within it a second evaporator heating surface which is arranged to be cooled by a forced flow of working medium and through which the working medium flows before flowing through the first evaporator heating surface.

Because, in accordance with the invention, the evaporator heating surface consists of or includes a first heating surface cooled by natural circulation and a second heating surface cooled by forced flow, much of the advantage of the natural circulation principle is combined with much of the advantage of the forced through-flow principle, although the disadvantages of both principles are not fully manifested. For example, the dimensions of the steam/water drum usual in natural circulation steam generators can be made smaller, possibly to such an extent that they are of the same order of size as those of the water traps usual in forced through-flow steam generators. This makes it possible to design the steam generator for relatively high steam pressures, without making the walls of the steam/water separator too thick from the point of view of fabrication and thermal stressing. It also makes it easier to ensure that the flow of coolant through the tubes of the walls is stable whatever the load on the steam generator. Also, the steam generator can be started in approximately the same short time as a forced through-flow steam generator, since the separator, being small, contains only a small amount of water.

Preferably, the second evaporator heating surface is located between an economiser and a steam/water separator in the forced flow of working medium. This arrangement enables the steam/water separator to be made smaller than if the outlet of the economiser leads into the separator.

The invention may be carried into practice in various ways but two vapor generators embodying the invention will now be described by way of example with reference to the accompanying drawings, of which:

FIGS. 1 and 2 are respectively vertical sections through the two vapor generators.

The vapor generator 1 shown in FIG. 1 consists essentially of a vertical hot gas pass or hot gas flue 34, whose boundary walls are formed of vertical tubes, and heating surfaces situated inside the flue. The heating surface 3 farthest up the flue 34 forms an economiser to which feed water is supplied by a feed pump 17 along a line 16 with a feed valve 18. Below the economiser 3 the hot gas pass 34 houses three superheater heating surfaces 51, 55 and 59 arranged in series. The superheater surface 51 is connected by a steam line 50 to the steam space of a steam/water drum 15, and a live steam line 60 leads from the superheater surface 59 to a load. Near the bottom of the flue 34 there are four swirl-type muffle burners 70, arranged in pairs opposite one another so that only two burners can be seen in FIG. 1. The heat-carrying gas flows out of the muffles of these burners into the flue 34, transferring its heat to the heating surfaces almost entirely by convection since combustion is completed inside the uncooled muffles. Closest to the outlet of the muffle burners 70 inside the flue 34 there is an evaporator heating surface 12 which consists of a plurality of tubes connected in parallel between the inlet header 11 and an outlet header 13 and which is cooled by the working medium in a forced flow. The outlet header 13 is connected by a line 14 to the steam space in the drum 15.

All four walls of the flue are formed of finned tubes welded together, the tubes in the front wall 32 being connected in parallel with those in the rear wall 33 between an inlet header 31 and an outlet header 35. Similarly, the tubes in each of the two side walls 42 are connected in parallel between an inlet header 41 and an outlet header 43. The inlet headers 31, 41 are connected by lines 30 and 40 respectively to a downcomer or gravity tube 20 leading from the drum 15, whereas the outlet headers 35, 43 are connected by lines 36 and 44 respectively to the steam space in the drum 15. The cooled flue gas leaves the flue 34 through an aperture 75 provided at the top of one of its side walls 42.

The heating surfaces 12, 59, 55, 51 and 3 are mounted on supporting tubes 8, of which the bottom ends are connected to a manifold 6 and the top ends lead into an outlet header 9 connected by a line 10 to the inlet header 11 for the evaporator heating surface 12. The manifold 6 communicates with the downcomer 20 by a line 21 containing a circulating pump 22 and with the outlet of the economiser 3 by way of a line 5.

After flowing through the economiser 3 the feed water enters the manifold 6, where it mixes with water which has been brought from the drum 15 along the line 21 by means of the circulating pump 22. The mixture of feed water and recycled water then flows along the supporting tubes 8 and through the line 10 into the evaporator heating surface 12, where partial evaporation takes place. The steam/water mixture flows along the line 14 to the drum 15, which separates the steam from the water. At the same time naturally circulating water flows along the tubes in the flue walls 32, 33 and 42, having come from the donwcomer 20 to the bottom ends of these tubes along the lines 30, 40. The steam/-water mixture formed in the tubes in the walls also passes to the drum 15, where the steam is separated. The evaporator heating surface 32, 33, 42 cooled by natural circulation and the evaporator heating surface 12 cooled by a forced flow are so designed that the latter produces at least 30 percent (preferably approximately 50 percent) and the former less than 40 percent of the total quantity of live steam produced when the steam generator is operating at normal load.

The steam separated in the drum 15 flows in succession through the three superheater surfaces 51, 55 and 59 and leaves the steam generator along the live steam line 60. In the line between the superheater surfaces 51 and 55 there is a vessel 53 and in the line between the superheater surfaces 55 and 59 there is a vessel 58. Water from the downcomer 20 is injected into these vessels through lines **52, 57.** The quantity of water injected can be adjusted by means of valves **54, 56.**

These injection devices may be arranged to produce 20 percent of the total quantity of steam generated. Alternatively, however, the valve **54** may be set at a fixed value and the valve **56** may be controlled in dependence upon the steam temperature in the live steam line **60.** Another possibility is to connect the lines **52** and **57** to the line **21** downstream of the circulating pump **22,** instead of to the downcomer **20.** This enables the valve to be made smaller and/or the atomising pressure at the inlets of the vessels **53, 58** to be raised. Ejectors may be used to add the water instead of the injection vessels.

The steam generator shown in FIG. **2** does not have a separate circulating pump, since the feed pump **17** is used also to feed the recycled water. To this end a heat exchanger **2** is provided in the line **21,** the secondary side of the heat exchanger being connected into the feed water line **16.** The line **21** leads into a feed water reservoir **4** and is provided with a throttle valve **7** between the heat exchanger **2** and the feed water reservoir **4.** A flow-rate measuring element **19,** whose signal output is operatively connected to adjust the throttle valve **7,** is linked to the feed water line **16.** The feed valve **18** in the feed water line **16** is operatively connected to a water level gauge **23** connected to the drum **15.**

In the steam generator shown in FIG. **2** water from the drum **15** is also recycled through the economiser **3.** This arrangement has the advantage that during starting and during low-load operation of the steam generator a relatively large minimum quantity of water is delivered by the feed pump **17,** so that no separate circulating pump is required.

Instead of the operative connections of the valves **7** and **18** being as shown in FIG. **2,** these connections may be interchanged; that is to say, the feed valve **18** may be connected to the flow-rate measuring element **19** and the throttle valve **7** to the level gauge **23.** In another possible modification the sum of the measuring signals from the flow-rate measuring element **19** and level gauge **23** is made to act on the feed valve **18,** and the difference between these signals is made to act on the throttle valve **7,** or vice versa.

A further alternative is to supply the vessels **53, 58** with feed water instead of recycled water.

What we claim is:

1. A steam generator comprising

a plurality of walls defining a hot gas flue with a hot gas inlet and an outlet;

each said wall including a plurality of vertical tubes at leat adjacent said inlet, said tubes defining a first evaporator heating surface for passage of a working medium therethrough under natural circulation;

a second evaporator heating surface disposed within said flue for passage of the working medium therethrough under forced circulation, said second evaporator heating surface being disposed upstream of said first evaporator heating surface relative to the flow of working medium; and

means for forcing the working medium through said second evaporator heating surface.

2. A steam generator as set forth in claim **1** which further includes an economiser in said flue and a steam/-water separator in the forced flow of working medium, said second evaporator heating surface being loacted between said economiser and said separator relative to the flow of working medium.

3. A steam generator as set forth in claim **1** which further includes superheater heating surfaces in said flue and means for injecting water into a flow of superheated steam between said superheater heating surfaces.

4. A steam generator as set forth in claim **3** which further includes a steam/water separator vessel connected in common to both evaporator heating surfaces and said water injecting means is connected to said separator vessel.

5. A steam generator as set forth in claim **1** which further includes at least one swirl-type muffle burner connected to said hot gas flue to supply hot flue gas thereto through said inlet.

6. A steam generator as set forth in claim **1** which further includes at least one additional heating surface within said hot gas flue, said second evaporator heating surface being the nearest to said hot gas inlet of said heating surfaces within said hot gas flue.

7. A steam generator as set forth in claim **1** wherein said tubes of said first evaporator are welded to one another in gas-tight manner.

8. A steam generator as set forth in claim **1** which further includes means for supplying a forced through flow of feed water to said second evaporator heating surface and means for superimposing on the forced through flow a forced circulation of working medium.

9. A method of generating steam in a steam generator which comprises the steps of

heating a first part flow of working medium under natural circulation in a first evaporator heating surface to produce live steam, and

heating a second part flow of the working medium under forced circulation in a second evaporator heating surface to produce at normal load at least 30 percent of the total live steam produced in the steam generator, the second heating surface being located upstream of the first heating surface in the flow of working medium.

10. A method as set forth in claim **9** wherein approximately 50 percent of the total live steam produced in the steam generator is produced in the second evaporator heating surface.

11. A method as set forth in claim **9** wherein at normal load less than 40 percent of the live steam produced in the steam generator is produced in the first evaporator heating surface.

12. A method as set forth in claim **9** which further comprises the steps of superheating the live steam from the heating surfaces to produce superheated steam and of injecting water into the superheated steam to produce additional steam.

13. A method as set forth in claim **12** wherein said additional steam at normal load is at least 20 percent of the total live steam produced in the steam generator.

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