July 27, 1943. W. L. R. EMMET 2,325,384

MERCURY BOILER

Filed May 25, 1940

Fig. 1.

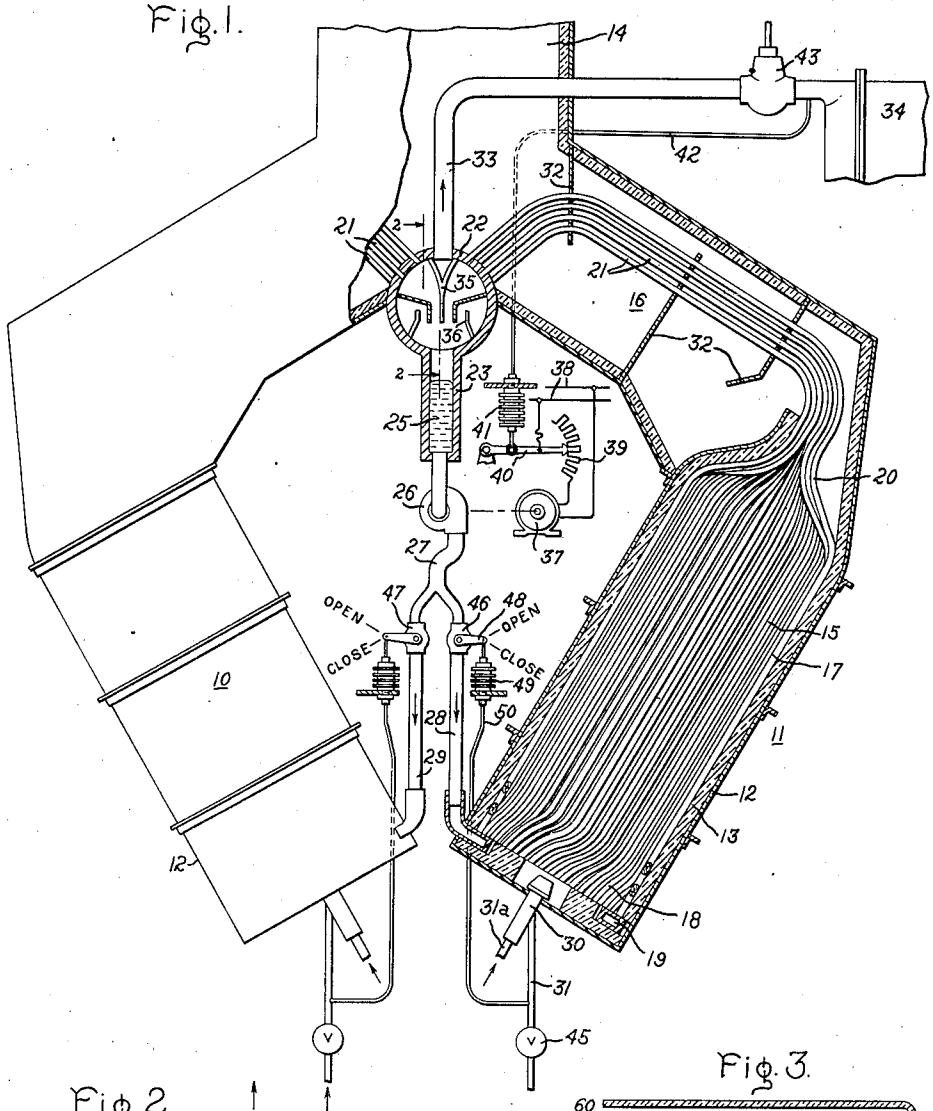


Fig. 2.

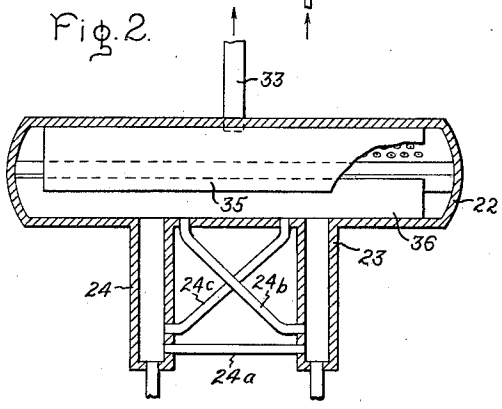
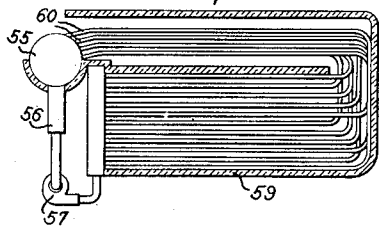


Fig. 3.



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MERCURY BOILER

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Application May 25, 1940, Serial No. 337,285

4 Claims. (Cl. 122—406)

The present invention relates to mercury boilers such as are used in power plants to produce mercury vapor for operating turbines. More particularly the invention relates to the kind of boilers and boiler arrangements as may be used wherever headroom is limited as is the case with power plants for operating locomotives and ships. To provide a path of sufficient length in the heating tubes of such boilers the tubes have to be inclined or placed horizontally whenever the headroom is limited and to prevent burning through of the heating tubes at a high rate of heat transfer the mercury is preferably forced through the tubes by pumps.

The object of my invention is to provide an improved construction and arrangement of mercury boilers of the type above specified whereby such boilers may be operated efficiently and economically.

For a consideration of what I believe to be novel and my invention, attention is directed to the following description and the claims appended thereto in connection with the accompanying drawing.

In the drawing Fig. 1 illustrates a mercury boiler arrangement embodying my invention; Fig. 2 is a section along line 2—2 of Fig. 1; and Fig. 3 illustrates a modification of a part of Fig. 1.

The arrangement of Figs. 1 and 2 comprises a plurality of boiler units 10, 11. Each unit has a casing 12 with a wall 13 of heat-resisting material. The casings 10 and 11 are joined at their upper end to a flue 14. Each casing has a lower, substantially cylindrically-shaped portion forming a combustion chamber 15 and an upper portion forming a convection chamber 16 connecting the combustion chamber 15 to the flue 14. The combustion chamber 15 has a row of heating tubes 17 lining the wall 13. Lower portions 18 of the tubes are curved along the wall 13 and have ends connected to a lower header 19. The curved portions 18 permit relative longitudinal expansion between the tubes. Upper portions 20 of the tubes are necked or curved inward and connected to a bank of heating tubes 21 located in the convection chamber 16 and having discharge ends connected to top portions of a horizontal, cylindrical drum 22. The tubes 21 of the unit 11 are connected to one side of the top portion of the drum 22 while the corresponding tubes 21 of the unit 10 are connected to the opposite side of the top portion of the drum 22. The tubes 17 in the combustion chamber, as well as the tubes 21 in the convection chamber, are inclined towards the vertical center line through the drum, and the two units 10 and 11, in particular the combustion chambers thereof, are symmetrically arranged with respect to the aforementioned vertical center line through the drum 22.

The drum 22 has at least one, in the present instance two, feed chambers 23 and 24 (Fig. 2) extending vertically downward from the bottom portion of the drum and containing mercury pools 25 during operation. The feed chambers 23, 24 are connected by an equalizing pipe 24a to equalize the liquid levels in the two chambers. In case the mercury boiler is operated with a mixture of mercury and a small amount of ingredients, such as titanium, zirconium, calcium, magnesium, and the like to assure wetting of the ferrous metal surfaces by the mercury and to prevent dissolving of the ferrous metal by mercury at high temperature, it is important to maintain the concentration of these ingredients in the mercury uniform in the different parts of the boiler. To this end the feed chambers 23, 24 are fed with mercury not only from points directly above the chambers but also from points of the drum horizontally considerably spaced from the chambers. In the present example mercury is conducted from the drum 22 to the chamber 23 by a conduit 24b connected to the chamber 23 and having an inlet considerably axially spaced from the inlet of the chamber 23. The inlet to the conduit 24b is connected to the drum 22 near the inlet of the chamber 24. Likewise, the chamber 24 is fed by a conduit 24c having an inlet portion connected to the drum near the inlet chamber 23. With this arrangement uniformity of mixture of mercury and ingredients is maintained uniform in the feed chambers 23, 24 and consequently also in the heating elements of the different units connected thereto.

A pair of boiler units 10, 11 is fed from each feed chamber. In the present instance the feed chamber 23 is connected to the inlet of a centrifugal type circulating pump 26, which latter has an outlet conduit 27 connected by a conduit 28 to the header 19 of the unit 11 and by a conduit 29 to a corresponding header of the unit 10.

During operation, mercury is conducted through the pump 26 and the conduits 27 and 28 to the header 19, whence the mercury flows through the heating tubes 17 in the combustion chamber 15 and the tubes 21 in the convection chamber 16 to be discharged from the latter into the drum. The cold liquid level in the feed chamber 23 is near the lower portion of the convection chamber 16. Thus, during starting the heating tubes 21 in the convection chamber are empty of mercury whereas the heating tubes 17 in the combustion chamber 15 are substantially entirely filled with mercury liquid. Starting with the tubes 21 empty is permissible because of the low temperature in the convection chamber during starting operation. The provision of convection surfaces in the form of the heating tubes 21 permits a substantial increase in heat transfer surfaces without necessitating ad-

ditional mercury liquid for operating the boiler, an important advantage in mercury boilers in view of the high cost of mercury. During the starting operation the mercury liquid contained in the heating tubes in the combustion chamber expands and, as pointed out above, partly evaporates, thereby filling the tubes 21 in the convection chamber with a mixture of mercury and liquid.

Each unit has a burner 30 arranged near the bottom portion thereof and connected to a fuel supply pipe 31 and an air supply pipe 31a to effect combustion in the combustion chamber in conventional manner. The heat in the combustion chamber, especially in the lower portion thereof, is transmitted to the heating tubes in the form of radiation. A high rate of heat transfer towards the lower portions of the heating tubes is permissible because these portions are filled with mercury liquid. The heat transfer in the upper portion of the combustion chamber and especially in the convection chamber is accomplished primarily by convection. The path of the gases discharged from the combustion chamber is lengthened in the convection chamber and the gases are forced across the heating tubes 21 therein, in known manner, by the provision of a plurality of baffles 32.

The mercury on its path through the heating tubes is partly evaporated to form a mixture of liquid, and vapor discharged from the tubes 21 into the drum 22 is separated in the latter. The vapor is discharged from the drum 22 through a conduit 33 to a consumer such as a mercury turbine 34 and the liquid discharged from the tubes 21 into the drum 22 is returned to the feed chamber 25 and recirculated. The drum which constitutes a liquid vapor separating device is provided with means to effect separation of vapor and liquid in the drum 22 and to prevent the discharge of liquid into the vapor conduit 33. This means in the present instance is in the form of a plurality of baffles 35, 36 secured inside the drum to direct the mixture of liquid and vapor discharged from the tubes downward towards the feed chamber 25 and to form a circuitous path for the vapor from the discharge ends of the tubes 21 towards the inlet of the vapor conduit 33.

The circulating pump 26 which during operation forces mercury liquid through the heating tubes is driven by a power agency in the form of an electric motor 37 connected to a source of electric energy 38. The speed of the motor may be controlled by a rheostat 39. The control of the rheostat in accordance with my invention is effected by means responsive to changes in demand to load output from the boiler. To this end a control lever 40 of the rheostat is connected to a pressure-responsive device in the form of a bellows 41 subject to pressure changes of the fluid discharged from the drum 22. In cases, as in the present instance, where the turbine 34 is controlled by a throttle valve 43 the pipe 42 is connected to a point behind the throttle valve 43 as regards the direction of the flow of fluid therethrough. Obviously in arrangements in which no throttle valve is provided or such valve fully opened during operation the pipe 42 may be connected to any point between the drum and the first turbine stage.

During operation, an increased load output of the turbine 34 is accomplished by opening of the throttle valve 43. This causes an increase in pressure ahead of the first turbine stage whereby the bellows 41 of the pressure-responsive device is expanded and effects adjustment of the rheostat 39 to increase the speed of the motor 37 and accordingly the speed of the circulating pump 26. With the increased circulation of mercury thus effected, the level of evaporation in the heating tubes 17 is raised. The increased relative amount of liquid contained in the heating tubes and the raised level of evaporation permits increased rate of heat transfer to the tubes without endangering their safety. For example, during low load condition of the boiler the circulating pump 26 may be operated at a speed just sufficient to maintain the heating tubes 17 filled with mercury liquid to a height of about one-third of the total height of the tubes 17. At no-load the boiler may be operated with the pump 26 at standstill, that is, purely by gravity feed. During high load condition the pump 26 may be operated at a speed sufficient to maintain the tubes 17 in the combustion chamber filled to a height of the order of two-thirds of their height in the combustion chamber. Thus, in accordance with my invention, I provide means whereby the level of evaporation in the combustion chamber is automatically controlled in response to changes in demand for load output. With increasing load output the level of evaporation is raised and, vice-versa, with decreasing demand for load output the level of evaporation is lowered.

The fuel supply line 31 of each unit includes a valve 45 to control the supply of fuel to the burners 30. The circulation of mercury through the heating tubes in accordance with my invention may also be controlled in response to changes of the supply of fuel to the combustion chambers. To this end I have shown in the present instance valves 46 and 47 in the down-conduits 28 and 29 respectively. Each valve has an arm 48 connected to a pressure-responsive device in the form of a bellows 49 communicating through a tube 50 with the fuel line 31. With this arrangement an increase in pressure in the fuel line 31 due to increased supply of fuel causes expansion of the bellows 49, which latter thereupon moves the valve 46 towards opening position, thus increasing the circulation of mercury through the heating tubes.

The valves 46 and 47 in addition serve to equalize or adjust the supply of mercury to the several units 10, 11. Also, the valves 46—47 in the down-conduits permit disconnection of any of the units during operation of the other unit or units. In this manner the individual units of the boiler may be operated at maximum efficiency. During low load condition one or more units may be completely disconnected and upon increase in load demand these units may be successively put in operation within a short period of time.

The modification shown in Fig. 3 comprises a drum or liquid vapor separating device 55 corresponding to the drum 22 of Fig. 1 with a feed chamber 56 connected by conduit means including a circulating pump 57 to a header 58. The latter is located at one end of a horizontally disposed combustion chamber which is lined with heating tubes 59 connected at one end to the header 58 and at the other end to a bank of convection tubes 60 discharging into the drum 55. The tubes 59, 60 correspond to the tubes 17, 21 respectively of Fig. 1. In the present arrangement both heating tubes 59, 60 are horizontally disposed, that is, inclined by an angle of 90°

towards the vertical center line through the drum 55. Thus they assume minimum headroom and render the boiler especially adaptable for locomotives. Otherwise the boiler may be arranged similarly to that described above in connection with Figs. 1 and 2.

With a boiler of the type shown in Fig. 3 installed in a locomotive with only about ten feet of headroom available, it will always be desirable and advantageous to use forced circulation of the liquid mercury through the boiler tubes. Forced circulation affords possibilities highly desirable in a locomotive, namely capacity for temporary or even long continued overload and equalization of temperatures and stresses.

In mercury boilers of this type the back pressure at the point where the mercury enters the tube is governed by two factors, the quantity of vapor made, and the quantity of liquid that is swept through the tube by the escaping vapor. The act of accelerating this liquid involves very considerable energy, so that the more liquid enters the tube, the more pressure in mercury vapor will be needed to impel it. By using a pump to increase the circulation of liquid, the safe load on the boiler could be greatly increased without danger of overheating any of the tubes. The reason for this is that the mercury liquid after entering the tube must rise to a certain level, that is, to the boiling point, before it can begin to form vapor. With forced circulation a large quantity of liquid, say fifty or sixty times the feed, must pass through and fill several feet of tube before ebullition can begin. Experiments have shown that tubes filled with mercury in motion and below the boiling point will receive heat at a very high rate, much more than can possibly be delivered by radiation in such a combustion chamber, and the part of the tubes so filled is that at the entrance where the burners are situated and the heat is a maximum.

The flame and gas content of such a combustion chamber is highly opaque to radiant heat transmission, so that the high rates of heat delivery occur only near the burners where the tubes will be filled with mercury liquid which has not yet reached the boiling point, and thus affords sure protection from overheating.

For the reasons here stated, the use of forced circulation in combination with elongated combustion chambers having heating surface on their walls constitutes an important feature, not only for locomotives where height is not available for gravity circulation, but for other cases where overload capacity in limited spaces is desirable as, for example, in certain types of ships.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. Mercury boiler arrangement comprising a drum having axially spaced feed chambers, a plurality of pairs of combusion chambers, the combustion chambers of each pair being symmetrically arranged with regard to and inclined towards the vertical center line of the drum, heating tubes disposed within the combustion chambers, means for conducting mercury liquid from each feed chamber to the heating tubes of one pair of chambers, and conduit means connecting the discharge ends of the tubes of a pair of chambers to opposite top portions of the drum.

2. Mercury boiler arrangement comprising a horizontally disposed cylindrical drum, a plurality of pairs of spaced heating units having discharge ends for connection to separate portions of the drum with the units of each pair located on opposite sides of the drum, each unit comprising a casing having a lower portion forming a combustion chamber and an upper portion forming a convection chamber, a header located near the lower end of the casing, a plurality of heating tubes located in the chambers with inlet ends connected to the header and outlet ends connected to a top portion of the drum, means for conducting mercury from the drum to the headers of each pair of heating units comprising a feed chamber connected to the bottom of the drum, a circulating pump having an inlet connected to the feed chamber and separate valved conduits connecting the outlet of the pump to the headers of the pair of heating units, and means to effect uniform distribution of mercury comprising a conduit connecting each feed chamber to another feed chamber and another conduit connecting each feed chamber to a portion of the drum spaced from the connection between such feed chamber and the drum.

3. Mercury boiler arrangement comprising a horizontally disposed cylindrical drum, a plurality of spaced feed chambers connected to the bottom of the drum, a plurality of pairs of spaced heating units with the units of each pair located on opposite sides of the drum, each unit comprising a casing having a lower portion forming a combustion chamber and an upper portion forming a convection chamber, a header located near the lower end of the casing, a plurality of heating tubes located in the chambers with inlet ends connected to the header and outlet ends connected to a top portion of the drum, separate means for conducting mercury from the drum to the headers of each pair of heating units comprising one of the feed chambers, a circulating pump having an inlet connected to the feed chamber and conduits connecting the outlet of the pump to the headers of the pair of heating units, and means to effect uniform distribution of mercury comprising a conduit connecting each feed chamber to another feed chamber.

4. Mercury boiler arrangement comprising a horizontally disposed cylindrical drum, a plurality of axially spaced feed chambers connected to the drum, a plurality of pairs of spaced heating units with the units of each pair located on opposite sides of the drum, each unit comprising a casing having a lower portion forming a combustion chamber and an upper portion forming a convection chamber, a header located near the lower end of the casing, a plurality of heating tubes located in the chambers with the inlet ends connected to the header and outlet ends connected to a top portion of the drum, means for conducting mercury from the drum to the headers of each pair of heating units comprising one of the feed chambers, a circulating pump having an inlet connected to the feed chamber and separate conduits connecting the outlet of the pump to the headers of the pair of heating units, and means to effect uniform distribution of mercury comprising a conduit connecting each feed chamber to a portion of the drum spaced from the connection between such feed chamber and the drum.

WILLIAM L. R. EMMET.