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FORCED CIRCULATION BOILER

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Fig. 1.

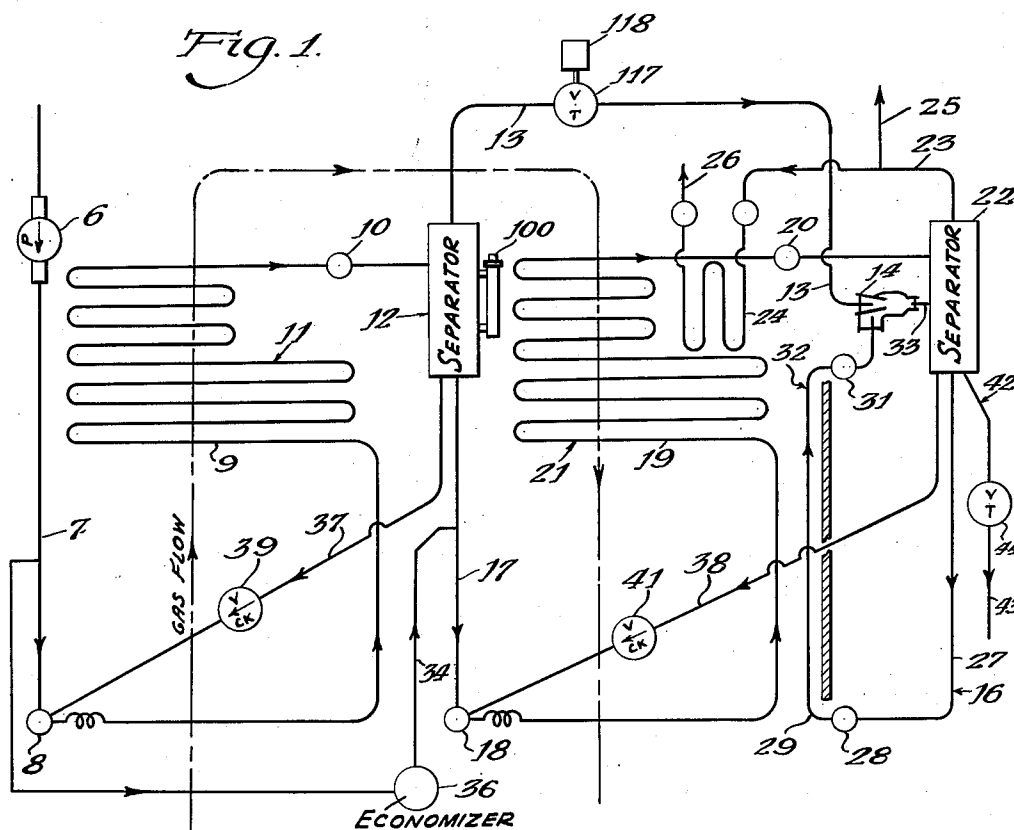
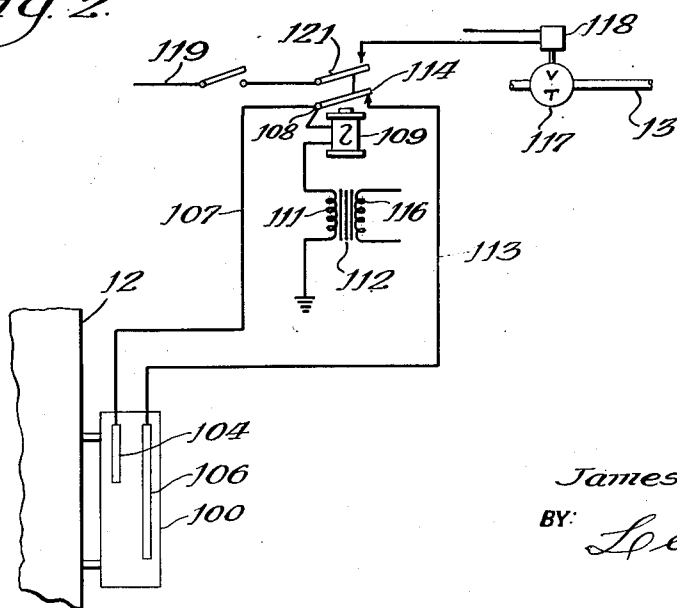


Fig. 2.



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UNITED STATES PATENT OFFICE

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FORCED CIRCULATION BOILER

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13 Claims. (Cl. 122-407)

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This invention relates to improvements in forced circulation boilers of the type in which water to be converted into steam is forced through boiler tubes by means of a suitable pumping apparatus and in proportion to the quantity of steam leaving the boiler.

In the operation of once-thru boilers, it has heretofore been a common practice to control the quantity of feed water entering the boiler by means operable responsive to the action of a steam-flow meter positioned in the steam outlet, and, in addition, by an auxiliary means known as a spill-over control which is operable responsive to water level within a steam drum or separator. The spillover control usually comprises a coil of small diameter pipe, known as a spill-over resistor, interposed in a water discharge line leading from the steam drum or separator, and a by-pass conduit leading around the spill-over resistor and controlled by a normally closed spill-over valve which is operable responsive to water level within the steam drum or separator.

The spill-over resistor is usually adjusted to permit passage of approximately 10% of the full load water entering a boiler when the latter is being operated at rated pressure. The spill-over valve and feed water control apparatus are both operable responsive to water level indicating means provided on the steam drum or separator. For example, when the water level rises in the steam drum above a predetermined level, the spill-over valve moves toward its open position and the feed water control acts to reduce the quantity of feed water entering the boiler; and when the water level decreases in the steam drum, the spill-over valve moves toward its closed position, and the feed water control acts to increase the quantity of feed water entering the boiler.

In the operation of a once-thru boiler during periods of increase in load, the steam-flow meter acts through the feed water control to increase the quantity of feed water in proportion to the quantity of steam leaving the boiler, plus spill-over water; while the spill-over control acts to maintain a constant water level within the steam drum or separator. It will thus be noted that a rapid increase in load produces a proportional increase in water level within the drum, and the spill-over control valve is thereby opened to by-pass water from the drum.

It has been learned that when a once-thru boiler is operated at rated pressure to produce a steam quality of 90%, a rapid increase in load

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causes the feed water input to fall a substantial amount below normal with respect to the quantity of steam being discharged from the boiler. For example, assuming the feed water input is 11% or more below normal during the period while load is being increased, the steam quality at the tube outlets will be approximately 100%; and due to heat unbalance between circuits, the steam will be superheated at the exit of some tubes and will eventually cause tube failure due to the increased metal temperatures and stresses.

There is also danger of tube failure due to scale formation, even when using the most carefully treated feed water. It is well known in this art that even the most highly soluble solids will be forced out of solution as the steam approaches the 100% quality and will be deposited as scale on the boiler tubes, particularly when forced out of solution as a mixture of different salts. At full load in a once-thru boiler with 10% spill-over, the solids are concentrated approximately ten times, and the concentration of the solids increases during overload of the boiler. In practice, the concentration of solids of any treated feed water must be maintained within a certain range; otherwise, the solids will be forced out of solution and some portion thereof will act to form scale on the tubes.

A rapid increase in load on a once-thru boiler causes an increase in water level within the steam drum or separator, unbalance between circuits, over-firing due to heat storage, over-firing due to subnormal pressure; and, as a natural result thereof causes the steam to be superheated in one or more of the circuits if the normal outlet heat condition of the steam is of high quality. While these abnormal conditions are of short duration, they do occur frequently as rapid changes in load produce pressure changes of considerable magnitude due to lack of storage space. Assuming that, during a pick-up in load, the increment of heat above that required to generate steam is 1% of the load requirements and that the new equilibrium is reached within one minute, then during that minute the total heat input might reach 160% of that required for steam generation.

It is, therefore, an object of the present invention to minimize or eliminate abnormal conditions in forced circulation boilers tending to cause tube failure due to over-concentration of solids or superheat conditions.

It is a further object of this invention to provide a forced circulation boiler adapted to generate steam having an average quality of ap-

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proximately 50% at circuit exit, to thus provide a substantial factor of safety to reduce tube failure due to over-concentration of solids or superheat conditions resulting from heat unbalance between circuits, over-firing due to heat storage, over-firing due to subnormal pressure, etc.

It is a further object of this invention to provide a forced circulation boiler design to provide greater stability due to its increased water storage.

It is a further object of this invention to provide a forced circulation boiler having two or more forced circulation sections arranged in series to generate and discharge steam into a steam drum or separator, together with means for automatically controlling the operation of said sections.

It is a further object of this invention to provide a forced circulation boiler embodying one or more natural circulation sections and a continuous blow-down to take the place of the spill-over apparatus heretofore employed in once-thru boilers.

This invention embodies other novel features, details of construction and arrangement of parts which are hereinafter set forth in the specification and claims and illustrated in the accompanying drawing wherein:

Fig. 1 is a schematic view illustrating a forced circulation boiler embodying features of this invention.

Fig. 2 is a wire diagram illustrating the means employed to vary the flow of steam from the primary separator to the secondary separator responsive to variations in water level within said primary separator.

Referring now to the drawing for a better understanding of this invention, the forced circulation boiler is shown as comprising a pump 6 for forcing feed water under pressure through a boiler inlet conduit 7 into a lower header 8 and thence upwardly through a group of tubes 9 employed as a primary heating section 11. Steam and water are directed from the primary heating section 11 into a top header 10 and thence into a primary separator 12.

A steam conduit 13 leads from the top of the primary separator 12 to an augment nozzle or jet 14 interposed in a natural circulation section generally indicated at 16. Water within the primary separator 12 is directed downwardly through a conduit 17 into a lower header 18 and thence upwardly through a group of tubes 19 comprising a secondary heating section 21. Steam and water leaving the secondary heating section 21 are directed into a top header 20 and thence into a secondary separator 22. Steam within the secondary separator 22 may be directed from line 23 either through an outlet line 25 to the point of use, or to a superheater 24 and thence to a point of use through a conduit 26.

Thus, the natural circulation section 16 comprises headers 28 and 31, a series of heating tubes 29, and includes an inlet line 27 and an outlet line 33. The plurality of tubes 29 lead from the lower header 28 to the upper header 31 to serve as an auxiliary heating section 32 which is designed and arranged to absorb approximately 25% of the total heat absorbed by the boiler heating sections 11, 21 and 16. The conduit 33 leads from the upper header 31 to the secondary separator 22, and therefore comprises an inlet to the separator from said header 31.

In the event the temperature of the water leav-

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ing the primary separator 12 through the conduit 17 is too high, it may flash into steam. It is, therefore, desirable to provide an auxiliary feed water inlet 34 to direct a supply of relatively cooler water from an economizer 36 to the conduit 17.

A return conduit 37 leads from the primary separator 12 downwardly to the lower header 8; and a return conduit 38 leads downwardly from the secondary separator 22 to the lower header 18. Check valves 39 and 41 are interposed in the return conduits 37 and 38, respectively, to permit a flow of water from the separators 12 and 22 to their respective lower headers 8 and 18 when the head between the separators and their respective headers becomes greater than the pressure drop through their respective heating sections 11 and 21. It will thus be noted that the boiler unit could be operated with natural circulation under very light loads. A continuous blow-down 42 comprising a conduit 43 and a blow-off valve 44 is provided for the secondary separator 22 to regulate a concentration of solids therein. The continuous blow-down 42 is also useful in placing the boiler in operation.

The water level within the primary separator 12 is regulated by means of a pair of electrodes 104 and 106, electrode 104 being connected in a circuit 107 leading to a switch terminal 108, thence through a relay 109 and secondary winding 111 of a transformer 112 to ground. The electrode 106 is connected in a holding circuit 113 leading through a switch 114, relay 109 and secondary winding 111 to ground. The primary winding 116 of the transformer is connected to a suitable source of current. The supply of steam passing from primary separator 12 to the secondary separator 22 through the conduit 13 is controlled by a valve 117 which is operated by means of a solenoid 118 connected to a suitable source of current through a circuit 119. A switch 121 is interposed in the circuit 119 to make or break the circuit leading to the solenoid 118 when actuated by the relay 109.

In the operation of this electric control means for regulating the water level within the primary separator 12, a surface contact between the water and the electrode 104 acts to energize the relay 109 to complete the holding circuit through the switch 114, and to open the switch 121 in the circuit leading to the solenoid 118. De-energization of the solenoid 118 acts to move the valve 117 to a partially closed position to provide a restricted passage for the passage of steam through the conduit 13, and thus increase the pressure drop between the primary and secondary separators and thus causing an increased flow of water from the primary separator 12 downwardly through the conduit 17.

When the water level within the primary separator 12 falls below the end of the electrode 106, the holding circuit 113 to the relay 109 is broken, thereby opening the switch 114 and closing the switch 121. The closing of the switch 121 causes the solenoid 118 to open the valve 117 to a full open position, if desired, to permit a substantially unrestricted flow of steam from the primary separator 12 through the conduit 13 to the secondary separator 22. While a rather simple form of control has been shown and described for operating the valve 117 between a full open position and partly open position, it is obvious that other forms of control means could be provided whereby the valve 117 could be adjusted for set-

tings intermediate a full open position and a restricted partly open position.

In the operation of the forced circulation boiler of the type shown and described to generate, for example, 20,000 pounds of steam per hour at 1500 p. s. i. in the secondary separator 22 with 50% steam quality at the exit of both forced flow sections 11 and 21 and embodying an economizer for heating the feed water to 500° F., approximately 16,410 pounds of water per hour enters the lower header 8 and passes through the primary heating section 11. The resultant mixture of steam and water is adapted to pass from the primary heating section 11 into the separator 12 at approximately 50% steam quality. The pressure in the primary separator 12 is approximately 1600 p. s. i. Approximately 8205 pounds of steam thus generated in the primary heating section 11 passes from the top of the primary separator 12 through the conduit 13 to the augment nozzle or jet 14 and thence into the secondary separator 22, while the 8205 pounds of water is discharged downwardly through the conduit 17 to the lower header 18. As the temperature of the water passing downwardly through the conduit 17 is approximately 605° F. and would flash into steam, approximately 3590 pounds of water per hour at 212° F. is directed from the economizer 36 through the conduit 34 to be mixed with the water passing from the separator 12 through the conduit 17, thus providing approximately 11,800 pounds per hour of water at approximately 500° F. for passage through the secondary heating section 21. The resultant mixture of steam and water is discharged from the secondary heating section 21 into the secondary separator 22 with 50% steam quality, and the pressure within this separator is approximately 1500 p. s. i. Steam is discharged from the secondary separator through the conduit 23 which leads either to a point of use or to a superheater 24 and thence to a point of use through the conduit 26. Approximately 5900 pounds of water per hour is directed from the secondary separator 22 into the natural circulation section 16 to be heated and converted into steam within the tubes 29 of the auxiliary heating section 32.

The pressure drop between the primary separator 12 and the secondary separator 22 is approximately 100 p. s. i., including orifices at the tube inlets. There must also be an equal pressure drop in the conduit 13 between the primary separator 12 and the secondary separator 22. This drop in pressure can be substantially controlled by means of the valve 117 and the augment nozzle or jet 14. The augment nozzle or jet 14 is adapted to utilize approximately half of the pressure drop between the primary and secondary separators to increase the circulation through the natural circulation section 16. It should also be noted that the natural circulation section 16 should be properly located to absorb approximately 25% of the total heat absorbed by the heating sections 11 and 21 and 16.

While this invention has been shown in but one form, it is obvious to those skilled in the art that it is not so limited but is susceptible of various changes and modifications without departing from the spirit and scope of the claimed invention.

I claim as my invention:

1. In a forced circulation once-through boiler, a primary heating section, means operable to directly and continuously supply feed water under

pressure to said primary heating section, a primary separator to receive steam and water from said primary heating section, a water conduit leading from said primary separator, a secondary heating section connected to said water conduit to receive water under pressure from said primary separator, a secondary separator to receive steam and water from said secondary heating section, a natural circulation type heating section having inlet and outlet conduits connected to said secondary separator, and means to adjust the pressure drop between said primary separator and said secondary separator.

2. In a forced circulation one-through boiler, a primary heating section, means operable to directly and continuously supply feed water under pressure to said primary heating section, a primary separator to receive steam and water from said primary heating section, a water conduit leading from said primary separator, a secondary heating section connected to said water conduit to receive water under pressure from said primary separator, a secondary separator to receive steam and water from said secondary heating section, a natural circulation type heating section having inlet and outlet conduits connected to said secondary separator, a steam conduit leading from said primary separator to the outlet conduit of said natural circulation type heating section, and means to vary the pressure drop through said steam conduit responsive to variations in water level within said primary separator.

3. In a forced circulation once-through boiler, a primary heating section, means operable to directly and continuously supply feed water under pressure to said primary heating section, a primary separator to receive steam and water from said primary heating section, a water conduit leading from said primary separator, a secondary heating section connected to said water conduit to receive water under pressure from said primary separator, a secondary separator to receive steam and water from said secondary heating section, a natural circulation type heating section having inlet and outlet conduits connected to said secondary separator, a steam conduit leading from said primary separator to the outlet conduit of said natural circulation type heating section, a valve interposed in said steam conduit, and means to move said valve toward its open or closed positions responsive to variations in water level within said primary separator.

4. In a forced circulation once-through boiler, a primary heating section, means operable to directly and continuously supply feed water under pressure to said primary heating section, a primary separator to receive steam and water from said primary heating section, a water conduit leading from said primary separator, a secondary heating section connected to said water conduit to receive water under pressure from said primary separator, a secondary separator to receive steam and water from said secondary heating section, a natural circulation type heating section having inlet and outlet conduits connected to said secondary separator, and a valve controlled steam conduit leading from said primary separator to the outlet conduit of said natural circulation type heating section.

5. In a forced circulation once-through boiler, a primary heating section, means operable to directly and continuously supply feed water under pressure to said primary heating section, a primary separator to receive steam and water from

said primary heating section, a water conduit leading from said primary separator, a secondary heating section connected to said water conduit to receive water under pressure from said primary separator, a secondary separator to receive steam and water from said secondary heating section, a natural circulation type heating section having inlet and outlet conduits connected to said secondary separator, a valve controlled steam conduit leading from said primary separator to the outlet conduit of said natural circulation type heating section, and an augment nozzle provided in the outlet conduit of said natural circulation type heating section to receive steam from said steam conduit.

6. In a forced circulation once-through boiler, a primary heating section, means operable to directly and continuously supply feed water under pressure to said primary heating section, a primary separator to receive steam and water from said primary heating section, a water conduit leading from said primary separator, a secondary heating section connected to said water conduit to receive water under pressure from said primary separator, a secondary separator to receive steam and water from said secondary heating section, a natural circulation type heating section having inlet and outlet conduits connected to said secondary separator, a valve controlled steam conduit leading from said primary separator to the outlet conduit of said natural circulation type heating section, an augment nozzle provided in the outlet conduit of said natural circulation type heating section to receive steam from said steam conduit, and means to supply relatively cool feed water under pressure to said secondary heating section.

7. In a forced circulation once-through boiler, a primary heating section, means operable to directly and continuously supply feed water under pressure to said primary heating section, a primary separator to receive steam and water from said primary heating section, a water conduit leading from said primary separator, a secondary heating section connected to said water conduit to receive water under pressure from said primary separator, a secondary separator to receive steam and water from said secondary heating section, a natural circulation type heating section having inlet and outlet conduits connected to said secondary separator, a valve controlled steam conduit leading from said primary separator to the outlet conduit of said natural circulation type heating section, an augment nozzle provided in the outlet conduit of said natural circulation type heating section to receive steam from said steam conduit, means to supply relatively cool feed water under pressure to said secondary heating section, a water return conduit leading down from each separator to the feed water inlet end of its respective heating section, and a check valve interposed in each of said water return conduits.

8. In a forced circulation once-through boiler, a primary heating section, means operable to directly and continuously supply feed water under pressure to said primary heating section, a primary separator to receive steam and water from said primary heating section, a water conduit leading from said primary separator, a secondary heating section connected to said water conduit to receive water under pressure from said primary separator, a secondary separator to receive steam and water from said secondary heating section, a natural circulation type heating section

tion having inlet and outlet conduits connected to said secondary separator, a steam conduit leading from said primary separator to the outlet conduit of said natural circulation type heating section, means to vary the flow of steam through said steam conduit responsive to variations in water level within said primary separator, and an augment nozzle provided at the juncture of said steam conduit and the outlet conduit of said natural circulation type heating section.

9. In a forced circulation once-through boiler, a primary heating section, means operable to directly and continuously supply feed water under pressure to said primary heating section, a primary separator to receive steam and water from said primary heating section, a water conduit leading from said primary separator, a secondary heating section connected to said water conduit to receive water under pressure from said primary separator, a secondary separator to receive steam and water from said secondary heating section, a natural circulation type heating section having inlet and outlet conduits connected to said secondary separator, a steam conduit leading from said primary separator to the outlet conduit of said natural circulation type heating section, means to vary the flow of steam through said steam conduit responsive to variations in water level within said primary separator, an augment nozzle provided at the juncture of said steam conduit and the outlet conduit of said natural circulation type heating section, and means to supply relatively cool feed water under pressure to said secondary heating section.

10. In a forced circulation once-through boiler, a primary heating section, means operable to directly and continuously supply feed water under pressure to said primary heating section, a primary separator to receive steam and water from said primary heating section, a water conduit leading from said primary separator, a secondary heating section connected to said water conduit to receive water under pressure from said primary separator, a secondary separator to receive steam and water from said secondary heating section, a natural circulation type heating section having inlet and outlet conduits connected to said secondary separator, a steam conduit leading from said primary separator to the outlet conduit of said natural circulation type heating section, means to vary the flow of steam through said steam conduit responsive to variations in water level within said primary separator, an augment nozzle provided at the juncture of said steam conduit and the outlet conduit of said natural circulation type heating section, means to supply relatively cool feed water under pressure to said secondary heating section, a water return conduit leading down from each separator to the feed water inlet end of its respective heating section, and a check valve interposed in each of said water return conduits.

11. In a forced circulation boiler, a primary heating section interconnected with a primary separator, a secondary heating section interconnected with a secondary separator, and a natural circulation type heating section having inlet and outlet conduits, an augment nozzle to supply steam from said primary separator to said inlet conduit and means to vary the pressure drop between said primary and secondary separators, said means controlling steam flow in said nozzle.

12. In a forced circulation boiler, a primary heating section interconnected with a primary separator, a secondary heating section intercon-

ected with a secondary separator, and a natural circulation type heating section having inlet and outlet conduits, an augment nozzle to supply steam from said primary separator to said inlet conduit and means responsive to variations in water level in said primary separator, to vary the pressure drop between said primary and secondary separators, said means controlling steam flow in said nozzle.

13. In a forced circulation boiler, a primary heating section interconnected with a primary separator, a secondary heating section interconnected with a secondary separator, said primary separator having a steam line to said secondary heating section, and a natural circulation type heating section having inlet and outlet conduits, an augment nozzle to supply steam from said primary separator to said inlet conduit and means in said steam line responsive to variations in water level in said primary separator to vary the pressure drop between said primary and secondary separators, said means controlling steam flow to said nozzle and said means controlling fluid flow through said primary separator outlet.

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