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CONTROLLED BALANCE FLOW OF PARALLEL BOILER CIRCUITS

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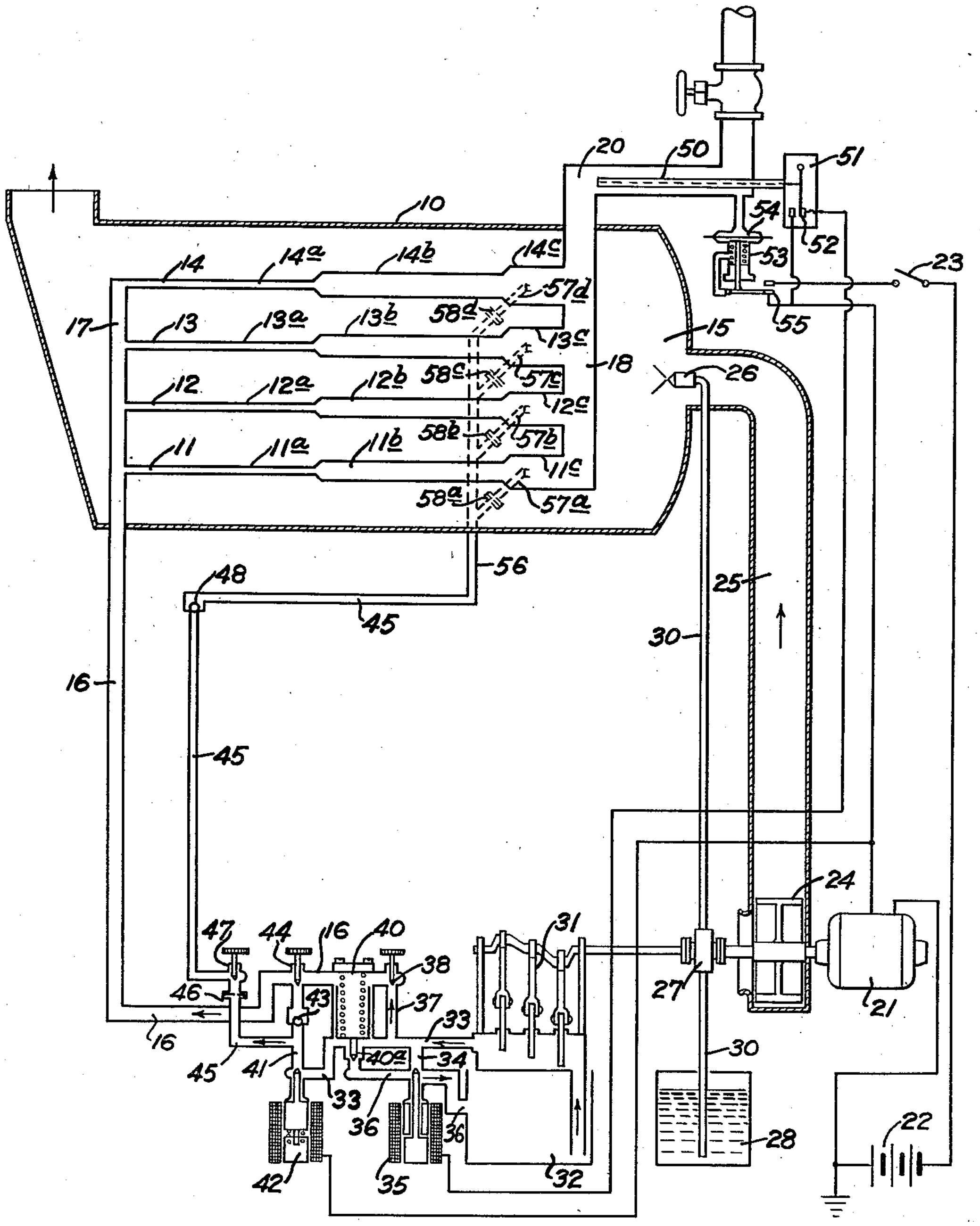

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CONTROLLED BALANCE FLOW OF PARALLEL BOILER CIRCUITS

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The present invention relates to continuous flow boilers of the once-through type characterized by the absence of headers and drums, and particularly concerns the balancing or equalizing of the flow of the operating fluid through the circuits when arranged for parallel flow.

This invention is especially concerned with boiler constructions which are free of gravitational or other similar effects.

Attempt has been made to employ parallel circulatory systems for the flow of the operating fluid in boilers and the like, but for one reason and another of numerous origins, undesirable variations of resistance to flow take place in the separate circuits which unbalance the flow and lead to various serious dangers, such as bursting of the tubes, and in any event upset control.

The circulation of operating fluid or water in tubular boilers of this type is maintained at a pressure regulated to the demands of operation. The quantity flowing through each of the circuits, which are of the same area in section, is determined by the speed of flow, and this in turn is dependent upon the resistance encountered in the flow. Since water is not compressible as is steam or a mixture of steam and water, any reliable control of the resistance or the regulation of the water supply should be primarily responsive to conditions in the liquid or water zone of the circulatory system.

It is, therefore, the object of the present invention to specifically re-apportion and proportion the heating surface so that the majority of the resistance to flow will be in the totally liquid or water zone. In placing the heating surface so that the resistance to flow is substantially in the water zone and is in the region of the coolest gases or in the region farthest from the fire, the further object of obtaining a true counterflow relationship between the heat and the operating fluid is an additional result and benefit.

It is also an object to the present invention to provide a water zone of the heating surface composed of tubing of a smaller area with respect to the other zones thereof so that the greatest resistance to flow will occur in this zone and be subject to accurate control.

In furtherance of the above, it is also an object to increase the area of the zones progressively from entrance to outlet so that resistance to flow may be likewise progressively decreased as it approaches the outlet and so insure the requisite condition that sufficient resistance to flow will be in the water zone to maintain equal flow through the parallel circuits.

Further objects are to provide a construction of maximum simplicity, economy and ease of assembly, and such further objects, advantages and capabilities as will later appear as the description progresses and as are inherently possessed by the invention itself.

The invention further resides in the combination, construction and arrangement of parts illustrated in the accompanying single sheet of drawings, and while there is shown therein a preferred diagrammatic arrangement, it is to be understood that the same is capable of modification and change and comprehends other details and constructions without departing from the spirit or the scope of the present invention.

Referring in particular to the drawing disclosing the preferred diagrammatic embodiment, there is shown in the single figure a diagrammatic representation of the complete system. The boiler casing of the system is designated as 10, and although shown as a horizontal tube type, this is not a feature of the invention as it is equally adapted to any other type of boiler including the vertical form. Inside the boiler casing 10 is located the tubing of the separate fluid circuits arranged for parallel flow in circuits or channels 11 to 14, inclusive. In the diagrammatic representation, the fluid or water zone, which is the economizer zone, 11*a* to 14*a* inclusive, is shown as having the smallest diameter, the mixed flow zone 11*b* to 14*b* inclusive, as having a larger diameter and the superheat zone 11*c* to 14*c* as having the largest diameter, so that the area increases as the flow progresses from inlet to outlet. It will also be observed that the fluid or water section of smallest area has a greater length than either of the other sections and is so positioned that it is farthest away from the firebox section 15 of the boiler. Also, it is to be noted that the length of the zone decreases as the area increases. These observations are not required conditions. All that is required is that the water zone be of sufficient length and smaller area to bring about substantially the greatest resistance to flow in this zone. Operating fluid is carried to the system by line 16 and distributed at the controlled pressure to each of the circuits 11 to 14 by the header 17. Superheated steam is taken by header 18 and thence by line 20 to accomplish whatever useful purpose is designated.

The operating drive of the control is secured by means of motor 21 connected in a circuit with an energy source or battery 22 and a master switch 23. This motor drives the blower fan 24 located in the air duct 25 which suplies air to the burner assembly 26 located at the mouth of the firebox 15.

Motor 21 also may drive the fuel pump 27 which takes fuel from the supply tank 28 and conveys it along the line 30 under pump pressure to the burner assembly 26.

The same motor 21 may also drive the water pump which always supplies more water than the boiler can evaporate and forces the supply water through the system. The flow of water from the pump 31 is directed along feed water line 33 and when the primary solenoid valve 35 is open, as it is normally, it is returned through lines 34 and 36 to the water supply tank 32. Solenoid valve 35 is normally open and when open no water is delivered to the boiler and upon being energized closes so that the water will not be diverted from the supply line. Supply line 33 also branches into line 37 when the flow in the main or primary supply line 16 is permitted and this flow is adjusted by the primary water supply valve 38. Interposed in the water supply line 16 is a compensator 40 which may be spring loaded and set for any desired pressure, as for example at 50 pounds p. s. i.

Line 33 also carries water to the secondary supply line 41 which is controlled in its flow by secondary solenoid valve 42, which is normally closed but opens when energized in response to a rise in the outlet temperature. In the line 41 between the secondary flow control valve 44 and the secondary solenoid valve 42 is a ball check valve 43 or any other suitable check means. Line 41 branches and forms the normalizer supply line 45. In the latter line are interposed suitable control means such as orifice 46, control valve 47 and check valve 48. The normalizer supply line directs the flow to the header 56 which distributes to a plurality of jets 57*a* to 57*d*, inclusive, each with an orifice 58*a* to 58*d* for injection of water into the superheat zone.

Suitably mounted in the outlet end of the circuit are temperature and pressure responsive mechanisms. A thermometer or other heat responsive means is located within the line 20 and is so coupled with the thermostatic control 51 that upon a rise in the temperature of the superheated steam above the control point, the contact 52 will be made to close an electric circuit for energizing solenoid valve 42. Also, the pressure control mechanism 53 is positioned in this area. The diaphragm 54 may be set to any pressure desired and upon decrease in the pressure thereon the contact at 55 is made to complete an electric circuit and the control is set up to restore the proper pressure. This system is also adapted for the addition of control means to shut off the fire in case of increased temperature or pressure above desired limits.

Operation

In describing the present operation, it is assumed that upon the starting the position of the water level in each of the parallel circuits, i. e. 11, 12, 13 and 14, will or may not be the same, and that during the start-up period, the flow must be equalized and thereafter maintained within the water zone before it enters the latent heat, mixed flow, or steam and water zone. It should be noted that although the description will be made with reference to the diagrammatic drawing which shows four parallel circuits, it is to be understood that any number of parallel circuits may be employed and that the number here shown is for purposes of illustration only.

Under normal operating conditions, water is supplied to the system by closing the master switch 23 which completes the circuit to motor 21 and at the same time initiates fire in the boiler at the burner 26 by circuits and means not here shown. Water is pumped from the tank 32 along the line 33 and since the solenoid of valve 35 which is normally open has been energized by the closing of the switch 23, the return line 34 will be closed to the flow, and flow will continue, therefore, along line 37. Water is supplied at a rate which represents a deficiency, or, in other words, less water than is required by the proportion of the fire to produce a desired outlet steam condition. This rate of flow may be regulated by the primary flow control valve 38. The compensator 40 in the water feed line 16 keeps the pressure in the feed line at a constant higher pressure than the pressure at 16. For example, let it be assumed that there is a pressure in the lines 33 and 37 of 1000 pounds p. s. i. and a pressure of 950 pounds p. s. i. after the orifice of the primary control valve 38. The pressure drop, therefore, across the primary orifice or the orifice of the primary control valve 38 is 50 pounds. Also, assume that the spring in the compensator 40 exerts a pressure of 50 pounds p. s. i. If there is an increase in the pressure drop of more than 50 pounds in the orifice of valve 38, pressure builds up in line 33 and forces the piston of the compensator 40 to compress the spring opening the valve 40*a* and bleed off the additional flow and maintain the required pressure differential. This is accomplished through the valve 40*a* opening until the pressure in the line 33 equals the combined pressure of the compensator and the pressure at the valve orifice 38. In reducing this to a formula, if y equals the pressure in line 33 and x equals the pressure after the orifice of valve 38 and z equals the pressure exerted by the compensator spring or the pressure required to unseat the valve 40*a* then y equals x plus z at all times. This being true, the flow can be metered by regulating the valve 38 and the flow of water adjusted in the primary valve to any amount desired. The primary water supply then flows on through line 16 into header 17 and thence into the parallel circuits 11, 12, 13 and 14. The fact that the operating conditions call for a deficiency of water through the primary circuit results in a rise in the temperature of the superheated steam in line 20. This rise in temperature through the thermostat 51 makes contact at 52 and closes an electric circuit which energizes the solenoid of the secondary valve 42 which is normally closed. Feed water then comes in from supply line 33 to line 41, passes upwardly through ball check valve 43 and past the orifice of the secondary control valve 44, and thence into supply line 16 for a secondary supply of water to the parallel circuits. This injection of secondary water increases the flow of primary water and by means of valve 44 and its orifice, the volume of secondary water may be adequately controlled.

With the actuating of the secondary control solenoid valve 42, secondary feed water is likewise supplied to the normalizer line 45, which passes through orifice 46 to the normalizer control valve 47 through line 45 to header 56 where the normalizer portion of the secondary water is injected by means of injectors 57*a* to 57*d* through orifices 58*a* to 58*d* into the superheat zone 11c to 14c. The orifice 46 in the normalizer circuit is proportioned so that if valve 47 should be wide open the volume would be limited so as not to inhibit the temperature rise in header 18 and line 20 and so prevent the requisite supply of secondary water to the system, and consequent undesirable temperature rise before the point of normalizer injection 57a to 57d.

Thus secondary water is supplied not only through the addition of water to the primary flow but also through the normalizer by injections into the tubing nearest the boiler outlet. This supply of secondary water, including the normalizer flow, is proportioned so that it supplies the deficiency of the primary flow and meets the operating requirements. The effect of injecting secondary water near the boiler outlet is to secure rapid response in the operating outlet thermostat in order that this thermostat may be given advance information of the rise of feed water in the heating circuits; otherwise, the boiler may go into flood condition.

It will be understood that any circuit 11, 12, 13 or 14, which has the least water in liquid form will have the least resistance to flow and that water when supplied at the pressure controlled by the compensator in relation to the values fixed in the formula, will tend to flow into this circuit as the path of least resistance. This, however, is only true where the greatest or the majority of the resistance to flow is maintained in the water zone 11a to 14a. Several features particularly combine to insure such allocation of flow. The length of the tubing prolongs the water zone until equalizing can be accomplished; the progressive increase in area of the sections successively handicaps them as zones of resistance; and the disposition of the water zone in the coolest portion of the boiler insures that the zone will keep the operating fluid in liquid condition.

Control can only be effected in the economizer or water and latent heat or mixed flow zones, and cannot be attained in a circuit so proportioned that the majority of resistance to flow in each circuit would be in the steam zone or 11c to 14c. If this latter condition were the case, it would then follow that the circuit which had the most steam would likewise have the most resistance to flow, and consequently the circuit having the least water would offer the path of greatest resistance. Accordingly, water entering the boiler system would choose some other circuit where the resistance to flow would be less, bringing about a condition which might result in water squirting from one of the circuits while highly superheated steam would issue from the circuit or circuits which had tended to starve. Obviously, control of the system would be impossible because of the variations in temperature of the several circuits, and damage would result to those circuits where there was insufficient water.

It is also of importance to note that the flow control here disclosed and described accomplishes likewise a controlled counterflow with the portions of greatest heat transference nearest the burner and portions of lowest heat transference farthest from the burner with the appropriate intermediate gradations.

I claim:

1. In a vapor generator of the once through type, a plurality of circuits within the generator arranged for unbroken parallel flow and for receiving pressure liquid at the inlet and delivering vapor at the outlet, said circuits each being arranged in zones, each successive zone being of increased cross-sectional area from inlet to outlet, said zones substantially corresponding to the liquid zone, the mixed liquid and vapor zone and the superheat zone.

2. In a vapor generator of the once through type, a plurality of circuits within the generator arranged for continuous parallel flow and for receiving pressure liquid at the inlet and delivering vapor at the outlet, said circuits each being arranged in zones corresponding to the liquid zone, the mixed liquid and vapor zone and the superheat zone, each successive zone being of increased cross-sectional area from inlet to outlet, and the length of the zone varying inversely with the area.

3. In a steam generator of the once through type, including a plurality of circuits arranged for uninterrupted parallel flow of water where pressure water at an operating deficiency is received at the inlet and superheated steam is delivered at the outlet, each circuit having a liquid zone, a mixed liquid and vapor zone and a superheat zone progressively increasing in cross-sectional area from zone to zone, the liquid zone being smallest, the mixed liquid and vapor zone being larger and the superheat zone being the largest in area, and combined pressure drop and flow equalizing means for injecting secondary water to supply the operating deficiency into the system and normalizer water into the superheat zone.

4. In a vapor generator of the once through type, a plurality of circuits within the generator arranged for uninterrupted parallel flow and for receiving pressure liquid at the inlet and delivering vapor at the outlet, said circuits being arranged in a plurality of the zones wherein the pressure drop decreases from zone to zone and wherein said zones substantially approximate the liquid zone, the mixed liquid and vapor zone and the vapor zone.

5. In a vapor generator of the once through type, a plurality of circuits within the generator arranged for parallel flow and for receiving pressure liquid at the inlet and delivering vapor at the outlet, said circuits being arranged in a plurality of the zones wherein the pressure drop decreases from zone to zone and the resistance to flow is substantially maintained in the liquid zone and wherein said zones substantially approximate the liquid zone, the mixed liquid and vapor zone and the vapor zone, means for supplying primary liquid to the system at an operating deficiency and means operative in response to temperature and pressure at the outlet for supplying secondary liquid to meet the deficiency.

6. In a vapor generator of the once through type, a plurality of circuits within the generator arranged for parallel flow and for receiving pressure liquid at the inlet and delivering vapor at the outlet, said circuits being arranged in a plurality of the zones wherein the pressure drop decreases from zone to zone substantially maintaining the greatest resistance to flow in the liquid zone and wherein said zones substantially approximate the liquid zone, the mixed liquid and vapor zone and the vapor zone, means for supplying primary liquid to the system at an operating deficiency and means operative in response to temperature and pressure at the outlet for supplying secondary liquid to meet the deficiency both to the inlet end and to the vapor zone, said supply means for the vapor zone being restricted so that if wholly open the volume of liquid sup-

plied would not inhibit a temperature rise in the flow thereafter.

7. In a vapor generator of the once through type, a plurality of circuits within the generator arranged for parallel flow and for receiving pressure liquid at the inlet and delivering vapor at the outlet, said circuits being arranged in zones corresponding to the liquid zone, the mixed liquid and vapor zone and the vapor zone, means for maintaining substantially the greatest resistance to flow in the liquid zone, means for supplying the primary pressure liquid at an operating deficiency and means responsive to the temperature and pressure of the vapor at the outlet for supplying secondary liquid to meet the deficiency.

8. In a vapor generator of the once through type, a plurality of circuits within the generator arranged for parallel flow and for receiving pressure liquid at the inlet and delivering vapor at the outlet, said circuits being arranged in zones corresponding to the liquid zone, the mixed liquid and vapor zone and the vapor zone, means for maintaining substantially the greatest resistance to flow in the liquid zone, means for supplying the primary pressure liquid at an operating deficiency and means responsive to the temperature and pressure of the vapor at the outlet for supplying secondary liquid to meet the deficiency, said means supplying secondary liquid both to the inlet and to the vapor zone.

9. A method of operating a steam generator having a plurality of circuits arranged therein for parallel flow receiving water at one end and heated to deliver superheated steam at the other, which comprises the maintenance of the greatest resistance to flow within the totally water zone and increasing the cross-sectional areas of the mixed flow and superheat zones to prevent resistance to flow.

10. A method of operating a steam generator having a plurality of circuits arranged therein for continuous parallel flow receiving water at one end and heated to deliver superheated steam at the other to balance or equalize the flow in the various circuits, which comprises the reducing of the cross-sectional area of flow in the water zone in order that the greatest resistance to flow will occur in this zone where the pressure is constant.

11. A method of operating a vapor generator having a plurality of circuits arranged therein for uninterrupted parallel flow receiving liquid at one end and heated to deliver vapor at the other for controlling the balance or equalization of the flow in the varying circuits, which comprises the maintenance of the greatest resistance to flow within the liquid zone and decreasing the pressure drop from zone to zone to prevent resistance to flow.

12. A method of operating a vapor generator having a plurality of circuits arranged therein for parallel flow receiving liquid at one end and heated to deliver vapor at the other to balance or equalize the flow in the various circuits, which comprises the maintenance of the greatest resistance to flow within the totally liquid zone, decreasing the pressure drop from zone to zone to prevent resistance to flow, supplying primary liquid at an operating deficiency and supplying secondary liquid to satisfy the deficiency in response to the temperature and pressure of the vapor at the delivery end.

13. A method of balancing or equalizing the flow of operating liquid in a steam generator having a plurality of uninterrupted parallel circuits therein comprising the steps of maintaining the greatest resistance to flow in the circuits within the totally liquid zone in said circuits and within the said generator.

14. A method of balancing or equalizing the flow of operating liquid in a vapor generator having therein a plurality of uninterrupted parallel circuits comprising the steps of maintaining the greastest resistance to flow within the totally liquid zone in said circuits within said generator and maintaining the totally liquid zone in the region of the coolest gases farthest from the fire.

15. A method of balancing or equalizing the flow of operating liquid in a vapor generator having therein a plurality of uninterrupted parallel circuits comprising the steps of maintaining the greatest resistance to flow within the totally liquid zone in said circuits within said generator and maintaining true counter-flow relationship between the operating liquid and the heat.

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