

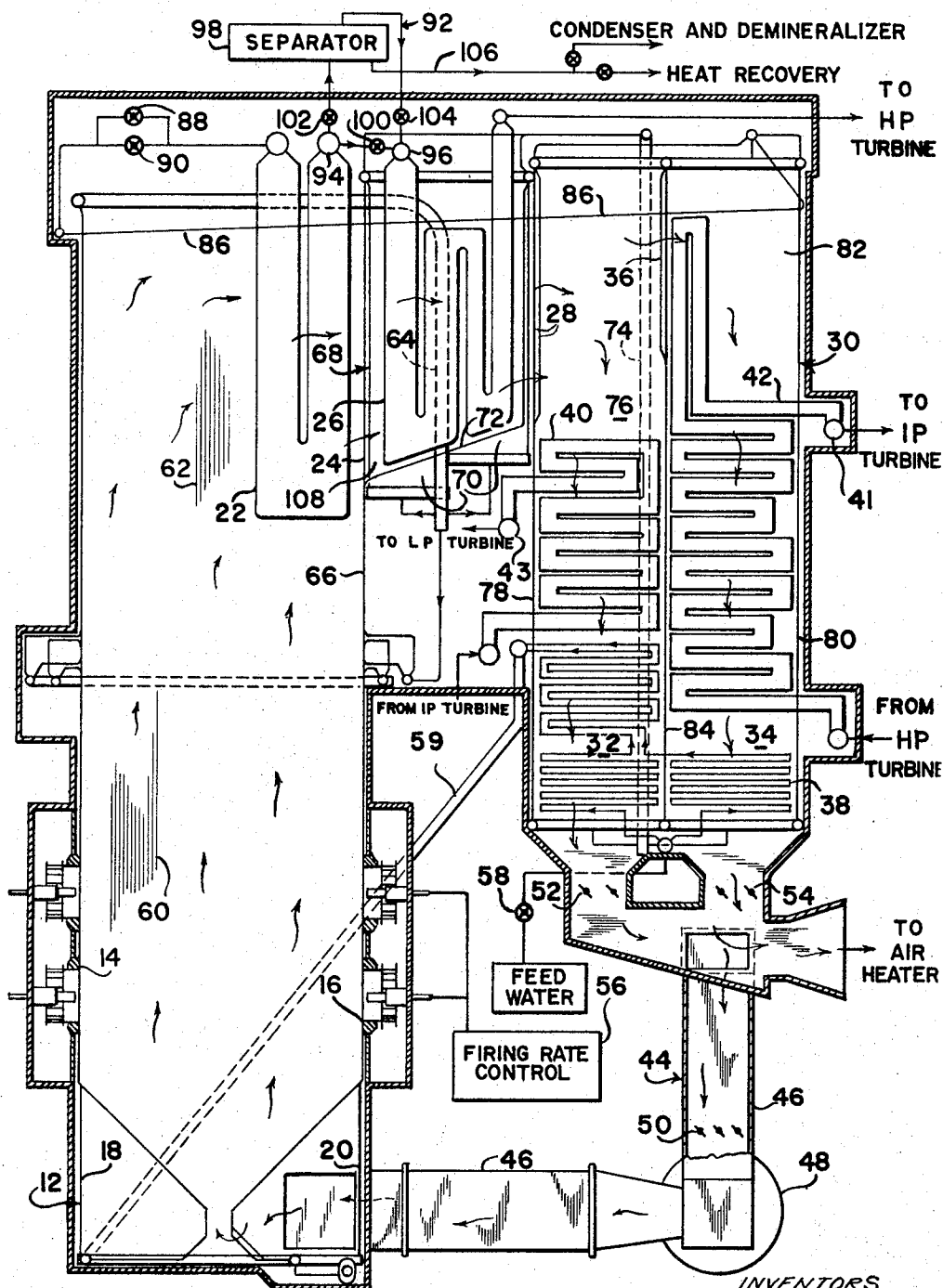
Oct. 10, 1967

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3,345,975

REHEATER AND SUPERHEATER CIRCUIT ARRANGEMENT

Filed Oct. 22, 1965



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3,345,975

REHEATER AND SUPERHEATER CIRCUIT ARRANGEMENT

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Filed Oct. 22, 1965, Ser. No. 501,169

9 Claims. (Cl. 122—406)

ABSTRACT OF THE DISCLOSURE

A forced flow once-through boiler the circuitry of which includes pendant superheater and finishing superheater sections in series flow relationship, the finishing superheater section being positioned in a convection heat transfer area of the boiler, flow bypass means for the working fluid between the pendant superheater section and the finishing superheater section bypassing the finishing superheater and turbine during start-up of the boiler, the pendant superheater being disposed with respect to the finishing superheater and relative the gas flow in front of the finishing superheater to shield the latter.

This invention relates to a forced flow once-through supercritical boiler, and more particularly, to the superheater, intermediate pressure reheater and low pressure reheater circuit arrangements and associated temperature controls for such a boiler.

For purposes of this application, the term "fluid" refers to the flow in the high pressure circuitry of the boiler, and "gas flow" refers to the flow on the gas side of the circuitry.

The present invention is designed primarily for use with a turbine complex which includes in the high pressure circuitry a high pressure turbine, and intermediate and low pressure turbines. With each turbine, it is necessary to maintain the temperature of the inlet steam to the turbines constant over varying loads, and for this purpose, it is customary to provide superheater circuits or surfaces for the high pressure turbine, and intermediate and low pressure reheater circuits or surfaces for the intermediate and low pressure turbines.

The boiler in operation is generally adjusted to the primary or high pressure turbine load requirements, through varying the rate of fluid flow in the high pressure circuitry and firing rate on the gas side. Although these adjustments can be made to maintain a constant superheater outlet temperature, the fluid temperatures in the boiler at the reheater outlets are considerably affected by the adjustments.

In addition, the once-through boiler by its nature requires the provision of a bypass circuit so that start-up fluid flow may bypass the turbine until proper turbine throttle steam conditions are achieved. Although the bypass generally is provided with a flash vapor-liquid separator so that steam can be obtained early in the start-up period for warming and rolling the turbines, it is not uncommon to experience in conventional units a difficulty in switching over from bypass flow back to main path flow, the nature of this difficulty being a sudden reduction of throttle steam temperature during this period.

Accordingly, it is the object of this invention to provide, in a boiler of the once-through supercritical type, an arrangement of superheater and reheater surfaces capable of more positive control of superheat and reheat temperatures over varying loads.

It is further an object of the invention to provide an

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arrangement of heating surfaces in which start-up of a once-through boiler is greatly improved from the standpoint of maintaining constant or increasing throttle steam temperature and reducing start-up time.

In accordance with the invention, the boiler comprises a radiant furnace section and a convection section in flow series, wherein the convection section comprises a horizontal passageway in communication with the upper part of the furnace section and parallel passageways between the horizontal passageway and boiler outlet. The high pressure and low pressure reheaters are disposed in the parallel passageways, and means are provided for proportioning the gas flows in the passageways for accurate control of heat input to the reheaters. The superheater sections are positioned in the boiler horizontal passageway leading from the furnace section with the primary bank of superheater tubes at the furnace outlet exposed to radiant heat in the furnace. The startup bypass connection for the boiler is positioned immediately downstream in the fluid circuitry from the primary superheater.

By disposing the primary bank of superheater tubes in a radiant high-heat absorption area of the furnace and connecting the by-pass in the flow circuit downstream of this bank, an advantage is obtained with respect to producing a greater quantity of steam earlier in the start-up cycle reducing overall start-up time. In addition, for a given burner firing rate during start-up, a higher enthalpy steady state condition is achieved so that at switch-over from bypass to main path flow, a better control is achieved over superheat steam conditions avoiding any sudden temperature reduction to the turbine.

As the location of the superheater tubes in the furnace frees the convection area passageways for disposition of the reheaters, accurate control of reheat temperatures can be achieved. This is done through fixing the temperature in one reheater by proportioning flow in the passageways and using gas recirculation to control the temperature of the other reheater.

The invention and advantages thereof will become apparent upon consideration of the following specification, with reference to the accompanying drawing in which the figure is a sectional side elevation view of a once-through boiler in accordance with the invention.

Referring to the figure, the invention includes a furnace section 12 for a forced circulation steam generating unit which has a rectangular horizontal cross-section and is vertically elongated. Burners 14 and 16 are disposed in the lower portion of the furnace setting in the front wall 18 and rear furnace wall 20, respectively. In the upper portion of the furnace, a pendant superheater 22 is located.

The flue gases from the combustion of, for example, oil or gas fuel, leave the furnace enclosure by passing over a furnace exit screen 24 flowing in cross-flow relationship over a finishing superheater bank 26 and through a rear screen 28. The gases then enter the convection section 30 which consists of parallel front and rear reheater passageways 32 and 34, entering into the rear reheater passageway 34 through screen 36. Located in the passageways counter to the flue gas flow are an economizer circuit 38 (disposed in part in both passageways), a low pressure reheater circuit 42 (in rear passageway 34) having an outlet header 41, and an intermediate pressure reheater circuit 40 (in front passageway 32) having an outlet header 43. The flue gases exiting the convection section flow through an air heater (not shown) to the stack (also not shown) and through a gas recirculation assembly 44 to the furnace, the gas recirculation assembly including conduits 46, a fan 48 and associated control dampers 50.

Proportioning dampers 52 and 54, respectively, are provided at the outlet ends of front and rear reheater passageways 32 and 34 for varying the proportion of flue gas flow between the reheater passageways thereby varying convection heat transfer to the reheater circuits. In this manner, the outlet steam temperature of one of the reheater circuits is controlled or fixed.

The control dampers 50 in the recirculation circuit govern the percent of flue gas recirculated to the furnace, the remainder exiting to the air heater and stack. This control varies heat absorption in the convection section by varying gas mass flow over the convection section and hence overall convection heat transfer to the convection section. In this manner, recirculation dampers 50 control the outlet steam temperature of the other reheater circuit.

The superheater outlet steam temperature is controlled by burner firing rate control 56 and/or feedwater control means generically indicated as valve 58.

The high pressure fluid flow for the generator is as follows: From the economizer circuit 38, and feedwater inlet valve 58, the fluid passes through downcomer 59 to the tubes 60 for the lower furnace circuitry. From the furnace wall tubes 60, which may define a series of upflow passes in the lower furnace section enclosure, the fluid passes upward through the tubes 62 comprising the front and side walls of the upper furnace section enclosure. The fluid exits through downcomer 64 to feed the inlet of the next pass which forms the rear wall 66 of the upper furnace enclosure and the pendant vestibule convection enclosure 68, comprising the furnace exit screen 24, rear screen 28, side walls 70 and floor wall 72. In a similar fashion, as described in the foregoing, the fluid routes through downcomer 74 and upward through the convection section pass enclosure 76, comprising front, rear and side walls, 78, 80 and 82, respectively, and division wall 84 which defines reheater flue gas passageways 32 and 34 and screen 36. From the convection section pass enclosure, the fluid flows to the roof pass 86, enclosing the upper portion of the furnace; pressure reducing station valves 88 and 90; the pendant superheater 22; and during normal operation, the finishing superheater 26 and the high pressure (HP) turbine (not shown) in that sequence. From the high pressure turbine the fluid flows upward through the intermediate pressure reheater 42 to the intermediate pressure (IP) turbine and then through the low pressure reheater 40 to the low pressure (LP) turbine (also not shown).

The superheater circuits adjacent the furnace exit, (screen 24), comprising pendant and finishing superheater banks 22 and 26, respectively, are arranged with the pendant superheater bank 22 located in front of the finishing superheater 26, receiving the hot flue gas flow before the finishing superheater 26. Superheater bank 22 is of pendant design and extends substantially across the entire cross-sectional area of the flue gas flow path adjacent the furnace exit. A start-up bypass circuit 92 is connected between the outlet header 94 of the pendant superheater and the inlet header 96 of the finishing superheater.

During start-up, the bypass circuit insures that water from the furnace and pendant superheater circuitry is not delivered to the finishing superheater and HP turbine; it further provides separated steam for the finishing superheater and HP turbine during the period of start-up when the furnace and pendant superheater circuits produce and pass a steam-water mixture to the bypass circuit.

For this purpose, the bypass circuit comprises a flash separator 98 and a stop valve 100 connected in parallel across the pendant and finishing superheater headers, 94 and 96, respectively. Separator admission valve 102 and separator exit valve 104 are located in lines leading to and from the separator, respectively. Drain line 106, bypassing the finishing superheater 26, leads from the flash separator to a condenser and demineralizer, or alternately, to the heat recovery portions of the bypass circuit (both not

shown). Details of this circuit may be seen in the United States patent application, "Once-Through Vapor Generator Start-up System," Ser. No. 281,452, filed May 20, 1963.

Control of the superheater enthalpy pickup is as follows:

Initially stop valve 100 and separator exit valve 104 are closed. The separator admission valve 102 is opened and water, approximately 25 to 30 percent of full load flow, is circulated in the generator via feedwater valve 58, the economizer, furnace, and convection enclosures, the roof and pendant superheater circuitry, in that sequence, through the flash separator 98 and to the condenser and demineralizer via line 106, bypassing the finishing superheater 26. The burners are placed in service and as the unit is being heated line 106 passes the water to the heat recovery system still bypassing the finishing superheaters.

At this point, it should be noted that the finishing superheater tubes with no flow therethrough are protected by limiting the flue gas temperature at the front portion 108 of the finishing superheater bank to within limits that are designed not to cause the finishing superheater tubes to become damaged. The platen superheater with its 25 to 30 percent flow is a relatively safe circuit, and because of its flue gas cooling capability and location in front of the finishing superheater bank it effectively shields the finishing superheater tubes from the hot flue gases by cooling the gases passing thereby to 1000-1200° F. With present materials for the finishing superheater, maximum furnace exit gas temperature is about 1200° F. This permits a higher burner start-up firing rate, about 15% to 20% of full load firing rate, and consequent higher furnace and pendant superheater heat absorption than heretofore achieved while maintaining the flue gas temperatures at the front portion 108 of the finishing superheater bank within design limits. The higher firing rate permits briefer start-up periods and faster build-up and attainment of higher enthalpy conditions at the outlet header 94 of the pendant superheater bank.

Warming continues and as water, and then steam-water mixtures are admitted to the flash separator 98, a level is formed in the separator. Exit valve 104 then is opened and saturated steam from the flash separator passes through the finishing superheater bank 26 to the high pressure turbine for warming and rolling the turbine.

After synchronizing the turbine and increasing the load, the fluid enthalpy increases in the pendant superheater outlet header 94 and steam of about 95 percent quality produced therein. Separator exit valve 104 is then closed and the steam required by the HP turbine is passed directly from the pendant superheater 22 to the finishing superheater 26 through valve 100, which is opened, without passing through the flash separator.

The enthalpy of the high quality steam leaving header 94 closely matches the enthalpy of saturated steam leaving the separator thereby maintaining a constant final steam temperature entering the turbine. If the enthalpy of the steam leaving header 94 was substantially lower than that leaving the separator at the time of changeover, a sudden reduction of final steam temperature would result. Because of the location of the pendant superheater 22 in a high heat absorption region, a higher steady state steam enthalpy pickup is achieved than could otherwise be possible thereby helping to raise the enthalpy of the fluid in the outlet header 94 up to the enthalpy of the saturated steam from separator 98.

From the foregoing, it is apparent that the location of the platen superheater permits a higher firing rate without exceeding flue gas temperature limits at the finishing superheater bank. Because of this, a higher enthalpy steam state condition is achieved. As a result, steam conditions, such as temperature, at switchover to main flow are more easily held constant and matched with turbine requirements at

this point in the start-up period. Also, overall start-up time is reduced.

Furthermore, positive control of intermediate and low pressure reheat steam temperatures is achieved over the load range by proportioning dampers and gas recirculation, in the manner described above.

With the present arrangement both enthalpy matching and reheater and superheater steam temperature control over the load range during the start-up period are satisfactorily achieved in a compatible design.

Although the invention has been described with respect to a specific embodiment, other variations within the spirit and scope of the invention as defined in the following claims will be apparent to those skilled in the art.

What is claimed is:

1. A forced flow once-through boiler for use with a turbine complex including high pressure and low pressure turbines, comprising

a boiler circuitry including water wall tubes defining an upright furnace section;

burner means in the lower portion of the furnace section, the furnace section including an upper exit for gas flow remote from the burner means;

a convection area in gas flow communication with the furnace upper exit;

the boiler circuitry further including a pendant superheater circuit disposed in the furnace section adjacent the furnace upper exit;

a finishing superheater circuit disposed in the convection area in series fluid flow relationship and downstream with respect to the direction of fluid flow of the pendant superheater circuit, the pendant and finishing superheater circuits being adapted to supply high pressure flow from the water wall tubes to the high pressure turbine;

further fluid flow circuitry including a start-up bypass line connected to the boiler circuitry intermediate the pendant superheater and finishing superheater wherein during start-up the fluid flow is diverted from the finishing superheater and high pressure turbine;

the pendant superheater comprising sufficient tubes adjacent the furnace upper exit to cool the flue gas at a given burner firing rate below the temperature at which damage to the finishing superheater could occur, thereby permitting maximum start-up burner input.

2. The boiler of claim 1 wherein the turbine complex includes high pressure, intermediate and low pressure turbines;

the convection area comprising a horizontal passageway adjacent the furnace section exit, a convection area outlet and two parallel passages between said outlet and the horizontal passageway;

proportioning damper means associated with at least one of the parallel passages for varying the flue gas flow between the passageways;

a reheater vapor circuit disposed in each of the parallel passageways, the reheater circuits being adapted respectively for intermediate pressure and low pressure flows to the intermediate and low pressure turbines, the proportioning damper means permitting close control of heat inputs to the reheater circuits.

3. The boiler of claim 1 further including pressure reducing means upstream in the boiler circuitry of the pendant superheater to reduce the pressure of the flow from that in the boiler water wall tubes.

4. The boiler of claim 1 wherein the bypass line comprises means to separate water from steam and recycle the steam to the finishing superheater, the pendant superheater having sufficient tubes exposed to radiant furnace heat whereby at a burner firing rate of about 15% to 20% of full load firing rate, gas temperature at the furnace exit can be maintained below 1200° F. with a high pressure fluid flow rate of 25-30% of full load flow rate.

5. The generating unit of claim 1 further comprising:

means for increasing the firing rate and feedwater rate so that a steam-water mixture and then substantially dry steam is delivered to the outlet of the pendant superheater;

means for passing the steam-water mixture from the outlet of the pendant superheater into the bypass line; a separator in the bypass line for receiving the steam-water mixture and separating the steam from the steam-water mixture;

a separator exit valve for passing the separated steam into the inlet to the finishing superheater;

means for passing said substantially dry steam from the outlet of the pendant superheater into the inlet to the finishing superheater when said substantially dry steam is produced at the outlet of the pendant superheater; and

means for closing the separator exit valve when said substantially dry steam is passed to the inlet to the finishing separator for preventing the separated steam from the separator from entering the finishing superheater.

6. A forced flow once-through boiler for use with high pressure, intermediate and low pressure turbines comprising

a high pressure fluid circuitry including in flow series in a main flow path an economizer section, a vapor generating section, primary and finishing superheater sections, and intermediate and low pressure reheater sections;

the vapor generating sections defining a furnace radiant heat enclosure and a convection section enclosure in gas flow communication, the furnace enclosure having an upper exit for the gas flow, the convection enclosure including a horizontal passage adjacent the furnace exit and vertically disposed parallel passages leading from the horizontal passage;

the intermediate and low pressure reheater sections being disposed respectively in the parallel passages; gas recirculation means between the convection section enclosure downstream of the reheater sections and the furnace enclosure;

baffle means to proportion the flow between the parallel passages, and to control the recirculation of gas whereby fluid temperature for the reheater sections are controlled;

burner means in the furnace section for heating the boiler;

means for controlling the rate of flow of fluid in the high pressure circuitry of the boiler;

the primary superheater section being disposed in the furnace radiant heat enclosure adjacent the furnace exit whereby the temperature of the fluid in the section is responsive to burner firing rate and rate of fluid flow, the finishing superheater section being disposed in the horizontal passage, the primary section having sufficient surface to shield the finishing section from furnace gas temperatures and to maintain gas temperature in the passage below about 1200° F.;

the high pressure fluid circuitry including a turbine and finishing superheater bypass connected immediately downstream of the primary superheater section comprising separator means for providing a steam flow and a liquid flow during boiler start-up, and means to recycle the steam flow to the finishing superheater section.

7. The boiler of claim 6 further comprising:

means for setting the firing rate during start-up at a predetermined proportion of full load firing rate so that a steam-water mixture and then substantially dry steam is delivered to the outlet of the primary superheater section;

the primary superheater section comprising sufficient surface in the furnace enclosure whereby the steady-state enthalpy of the fluid at the outlet of the primary

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section is sufficiently high to facilitate switch-over from bypass flow to main path flow.

8. The generating unit of claim 7 wherein the primary superheater section is of the pendant type.

9. The generating unit of claim 8 wherein the convection section enclosure includes a pendant vestibule enclosure adjacent the furnace exit, the finishing superheater being disposed in the pendant vestibule enclosure, the enclosure including screen tubes between the furnace enclosure and the finishing superheater.

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