May 21, 1940. W. D. LA MONT 2,201,621

STEAM BOILER AND POWER PLANT REGULATION

Original Filed Nov. 13, 1933 2 Sheets-Sheet 1

Fig. 1.

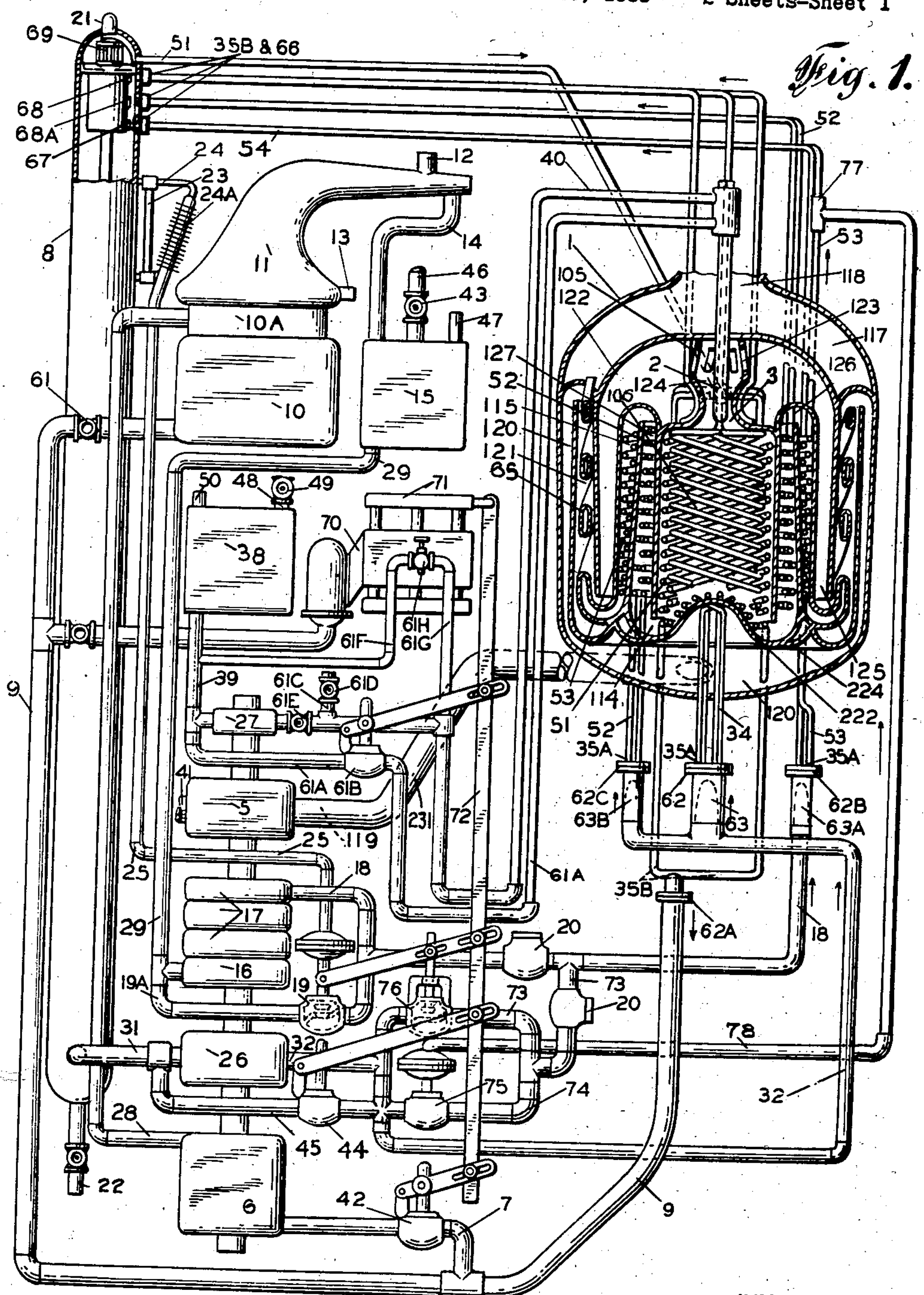

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Fig. 3.

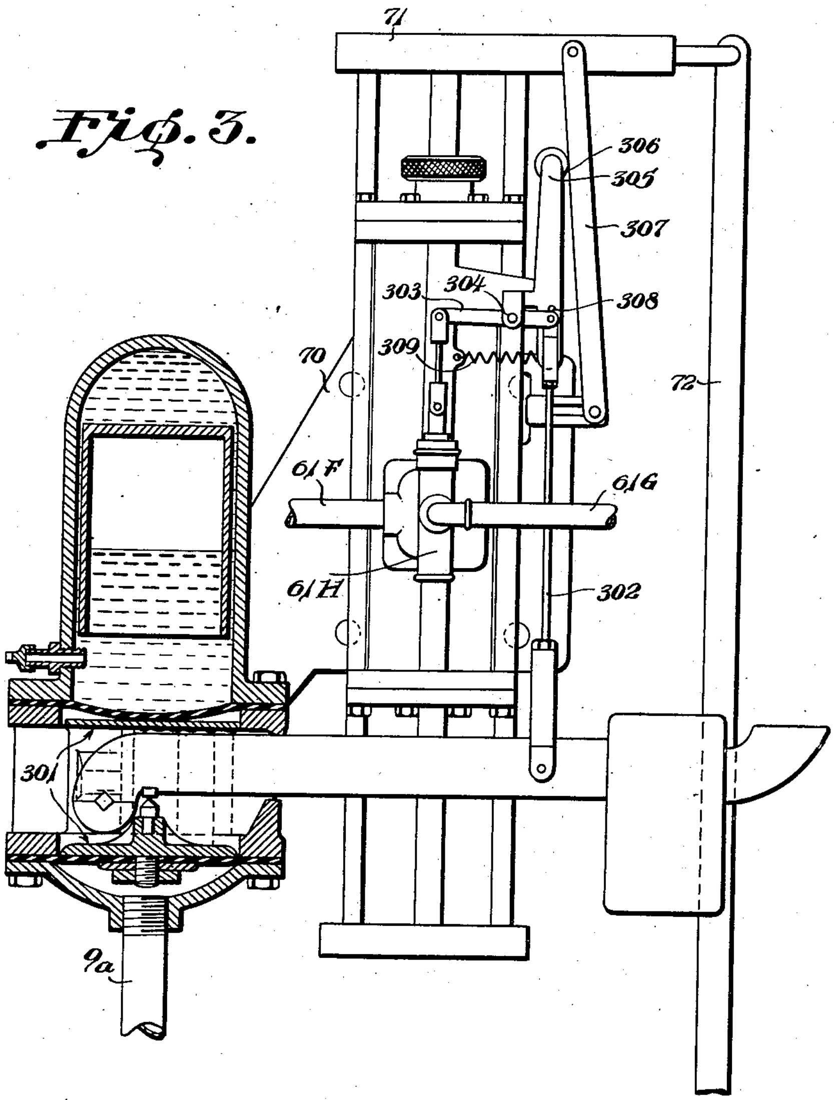
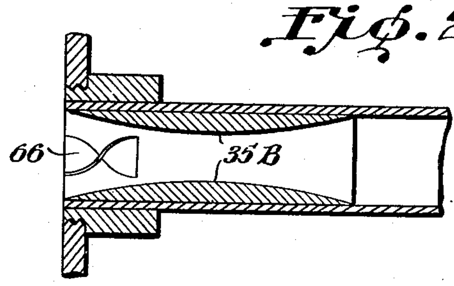


Fig. 2.



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Patented May 21, 1940 2,201,621

UNITED STATES PATENT OFFICE

2,201,621

STEAM BOILER AND POWER PLANT REGULATION

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Original application November 13, 1933, Serial No. 697,788. Divided and this application July 3, 1934, Serial No. 733,629

9 Claims. (Cl. 122—448)

This invention relates to high speed steam and power producing apparatus and high speed methods of operating the same.

It deals with supercharged steam boilers and high speed, light weight power plants using such a boiler, especially a boiler burning fluid fuels, in which all fluids; namely the fuel, the air (for supporting combustion), and the main working fluid in the tubes of the boiler, each flow at extremely high velocities in the performance of their several duties. It especially concerns steam power plant and boiler regulation and is a divisional application of my pending U. S. patent application, Serial Number 697,788, filed November 13, 1933.

It further concerns the co-ordination at all speeds, of the velocities of all flowing fluids, to insure the maximum and constant evaporation of the main working fluid in a minimum period of time.

It makes possible controlled and positive water input into each tube of the steam generator with controlled unidirectional flow or controlled non-unidirectional flow of the main working fluid in my steam generating elements as desired under conditions of high temperature radiant heat transfer at high rates of heat release.

A main object of my invention is to reduce the size, weight and cost of high speed steam generators and high speed power plants. I do this by increasing their speed of operation.

By my improved methods of operating said generators, I insure their continued performance under long sustained overload condition through many years of life up to the limit of the maximum heat load conditions for which they are designed, without destroying the steam generator, practically regardless of how rapidly combustion temperatures, or load conditions may change, or how fast fluids in all my high speed generator fluid streams may flow with my improved method of supercharging and co-ordinating their various velocities.

It is vital that the main working fluid especially, flow at least with some control of surging, or travel back and forth of steam and water in the steam generating tube at all times, under all steam making loads and speeds, substantially regardless of firebox temperatures or rates of heat release. It is also vital that a controlled quantity of water be positively put into each tube to assist with other means in controlling working fluid surging in the steam generating tube.

This present invention is particularly concerned with the improvement of high speed steam boilers, and power plants embodying the same, and methods of operating said boilers and said power plant. Where my invention and/or any of its features, applies to flash boilers or mass boilers and to high speed power plants using said flash boilers or mass boiling boilers, such improvements are well within the scope of my invention as herein described.

While my invention has been described herein as relating to steam generating apparatus is intended especially for the generation of steam from water, it will be understood that the terms "steam" and "water" as used in the specifications and claims are intended to include as equivalents, any liquids which might be handled by the novel process and/or apparatus herein described, resulting in the generation of any vapors which might be handled by, or be useful in connection with my process and/or apparatus, and it will also be understood that many of the novel features of this invention are applicable in other fields than that for which the apparatus herein specifically illustrated and described is particularly intended.

An important object of this invention is to coordinate the quantity of liquid used in forced circulation in order to obtain positive input of water into each tube in sufficient quantity to protect each tube regardless of how rapid rates of heat release are obtained in the combustion chamber, up to the maximum heat effects for which said (combustion chamber) is designed to withstand.

In order to carry out these various objects of my invention, I arrange my boiler regulation devices so that at extremely high speeds of fluid flow, my steam making elements are always protected against the possibility of their melting under high heats, said devices comprising by-passes for liquid flow around valves ordinarily actuated in response either to temperature changes or liquid level changes in my steam power plant system.

Ordinarily my master combustion control mechanism controls the flow of a fluid, the oil and air for combustion, the feed water and the circulation water going respectively to the water wall, the steam generator, and the fluid heater by, in the present instance, a common arm which actuates the valves controlling these fluids.

If anything happens to render any of my individual controls ineffective or unless, other controls are provided, in accordance with my invention, to pick up the work of the useless control and still provide each steam making element with sufficient water to prevent that particular element from being without water and in an unprotected state against the possibility of burning out, and thereby becoming useless.

To these and other objects my invention is directed, as will be more particularly pointed out in the drawings, specifications and claims forming parts of this present patent application.

In the drawings,

Fig. 1 shows a diagrammatic layout of the power plant in accordance with the present invention with a cross-sectional view of the high speed steam boiler forming a part thereof;

Fig. 2 shows a preferred form of a pressure drop device for the tube outlets; and

Fig. 3 is a side elevation of the device shown diagrammatically as numeral 70 in Fig. 1.

The high speed steam boiler 1 includes waterwall coils 34, superheater coils 51, convection steam generating coils 52, fluid heater coils 53, air preheater 121 with air passages, burner 2 and necessary pipe connections to water level cylinder 8 and to the various auxiliaries and controls. The main turbine 10 is shown with its exhaust lead 10*a* and main condenser 11.

The auxiliary turbine 6 is shown driving on one shaft the boiler circulating pump 26, condensate pump 16, feed pump 17, air supercharger 5, and oil pump 27. The connections of these auxiliaries are shown with their various control valves and by passes.

The master combustion control apparatus 70 is shown with moving arm 71 and moving control rod 72 and connections to the various control valves.

The water level regulator 24 is shown with its control element 24A control valve 19 and interconnection with control valve 76.

The thermostat control is shown with its control element 77 on the fluid heater tube 53 and its control valve 75.

The feed tank and oil tank are shown with their various connections, valves and control features. These elements are described in detail below.

The steam generator 1, has its proper casings, passages, burner, and other parts necessary for the use of my waterwall tubes 34, in combustion chamber 106, my superheater tubes 51, in combustion chamber 106, my fluid heater tubes 53, in convection gas passage 115, and my spiral cross flow air preheater with burnt gas tubes 65, and air passage 115, also my convection generating tubes 52 in tapered gas passage 127.

All piping, valves, auxiliaries and controls are shown for proper operation of my heat transfer surfaces together with the steam generator water level cylinder 8, for maintaining a water level in the system, a suction head for the circulation pump and a source of reserve power.

The main steam turbine 10, receives steam from the steam generator 1, exhausting to main condenser 11. The auxiliary turbine 6, drives on its shaft the air supercharger 5, condensate pump 16, feed pump 17, circulating pump 26, and oil pump 27.

A master combustion controller 70, operates all main controls to maintain a constant boiler pressure and to supply the boiler 1, with the necessary quantities of air, oil, feed water and circulating water for the proper operation of its heat transfer surfaces and to meet the various load demands.

The speed of the auxiliary turbine 6, is controlled by the master controller 70, to deliver the proper quantity of air.

The oil pump 27, and boiler circulating pump 26, have by-passes with control valves, operated by the master controller 70, to deliver the proper quantity of oil and circulating water as the auxiliary turbine speed is changed to meet the requirements for combustion.

The condensate pump 16, and feed pump 17, have a by-pass 19A, with control valve 19, operated by a water level regulator 24, on the water level cylinder 8, to maintain a water level in the system.

The boiler circulating pump 26, has a cross connection 73, to the feed inlet with control valve 76, operated by the master controller 70, to augment the supply of water for the fluid heater as the heat load increases.

The opening and closing of cross connection control valve 76, is modified by the opening and closing of the feed water level regulator by-pass valve 19, so that when one valve is closing the other valve is closing. This eliminates the use of unnecessary quantities of heated water for re-circulation in the fluid heater as changes in load occur.

The control valve 76, on cross connection 73, has a by-pass 74, with thermostat operated control valve 75. Thermostat control valve 75, is operated by a thermostat device 77, on the outlet end of a fluid heater tube 53. Whenever said tube 53, or the steam therein goes above the saturated temperature of the steam in the boiler thermostat element 77, opens valve 75, in bypass 74, to protect the fluid heater tubes 53.

The general operation of the power unit is as follows:

Starting with a water level in the water level cylinder 8, water is sent by the circulating pump 26, to the waterwall tubes 34, and convection generating tubes 52, of the boiler 1. Water and steam discharges from waterwall tubes 34, and convection generating tubes 52, into the water level cylinder 8, where the steam and water are separated, steam going to the superheater tubes 51, and excess water going to the water level cylinder 8, where it is picked up by the circulating pump 26, with make up feed and re-circulated in the system.

The steam in the superheater tubes 51, becomes highly superheated and passes to the main turbine 10, to main condenser, 11; also to auxiliary turbine 6, and then to main condenser 11.

Condensate from main condenser 11, goes to feed water tank 15.

Starting with the feed water in feed water tank 15, this water is picked up by condensate pump 16, and sent to feed pump 17. The feed pump 17, by means of the by-pass 19A, and control valve 19, supplies water to the fluid heater tubes 53, this supply being in accordance with the demands of the water level regulator 24, maintaining a water level in water level cylinder 8.

The circulating pump 26, by means of the bypass 74, and thermostat valve 75, actuated by the thermostat 77, on fluid heater tube 53, and by means of the cross connection 73, and control valve 76, actuated by the master combustion control 70; supply water for re-circulation in the fluid heater tubes 53, when necessary for protection and proper operation of the fluid heater tubes, independent of the water level at different load demands.

The feed water and re-circulation water in the fluid heater tube 53, together with any steam formed, is discharged into the water level cylinder 8, where the water and steam, if any, is separated. The steam going to the superheater tube 51, and the water going to the water level in water level cylinder 8, to be used for maintaining a water level, for re-circulation and for formation of more steam.

The more detailed method of operation of my power unit is as follows:

Starting

To start the boiler 1, after a shut down of the boiler and power unit, it is necessary after filling the system with water to a low water level in water level cylinder 8, to insure a supply of oil under pressure to the burner 2, to insure some degree of atomization of the oil and mixing of the air for combustion.

With a slow fire, natural air draft can be used until steam is formed to turn over the auxiliaries. In this case a hand oil pump is employed to force oil through line 61C, past opened valve 61D, to the burner, valve 61E being closed. Only a small quantity of oil is used and when ignited through burner door 212, there is sufficient air from the opening 105, through door 212, and from the air passages to carry on slow combustion until steam forms and the resulting pressure causes flow of steam under pressure from the superheater tubes 51, through the main steam line 9, through auxiliary steam line 7, past opened control valve 42, and into auxiliary turbine 6, driving auxiliary turbine 6, as it exhausts through exhaust lead 28, to exhaust lead 10A, of the main turbine to main condenser 11, to condensate line 14, to feed tank 15. Valve 61E, is then opened and valve 61D, is closed, combustion then being carried on by the auxiliaries on the shaft of turbine 6.

When electrical power is available or when a motor-generator-storage battery system is used for starting, a motor on auxiliary turbine 6, drives the auxiliaries supplying all the air, oil and water for quick starting and operation of the power unit.

However, it is within the scope of this invention to use any known method of starting the steam generator.

From the time that auxiliary turbine 6, starts driving all the auxiliaries, the operation is as follows:

Feed water

Feed water, whenever it is necessary before and during the operation of the power unit, is put into feed tank 15, from the reserve feed tanks through filling line 46, past filling line valve 43, to maintain a supply of feed water in this tank for operation of the water in the system. Vent 47, in feed tank 15, is open to the atmosphere.

Feed water is picked up by condensate pump 16 through condensate suction line 29, from feed tank 15, and delivered to the suction of the feed pump 17, through connecting passage in the casings of the two pumps, as long as the two pumps are being driven by auxiliary turbine 6, and there is water in feed tank 15.

Feed water is received from condensate pump 16, by feed pump 17, and discharged through feed pump discharge line 18, past feed stop and check valve 20, past feed water hollow cone distributor 63A, past fluid heater tube disc 62B, and into the fluid heater tubes 53; and/or the feed water from pump 17 in discharge line 18, is by-passed through by-pass line 19A, past water level regulator control valve 19, back to condensate pump suction line 29.

Water level regulator valve 19, is operated by water level regulator element 24A, through pipe line 25.

The water level regulator element 24A, is attached with the gauge glass 23, to a point above and below the water level, in water level cylinder 8.

As the water level rises and falls in water level cylinder 8, the water level regulator element 24A, through pipe lead 25, opens or closes the water level regulator valve 19, in varying degrees depending on the height of the water in the water level cylinder 8. The water level regulator by-pass valve 19, closing or decreasing its opening with a fall in the water level and opening or increasing the degree of its opening with rise in the water level.

This opening and closing of the water level regulator valve 19, opens or closes in varying degrees the by-pass line 19A, from the feed pump discharge line 18, to the condensate pump suction line 29, thereby decreasing or increasing the amount of make up feed water delivered into the fluid heater tubes 53, in accordance with the demands for maintaining a water level in the water level cylinder 8, independent of the speed of auxiliary turbine 6, driving condensate pump 16, and feed pump 17, and also independent of the requirements of the fluid heater tubes 53, for their proper protection and operation against the heat loads imposed on them. In general, the feed input into the fluid heater tubes from the action of the water level regulator valve 19, will be normally increased with increase in heat load, requiring more make up feed and thereby causing a fall in water level, but often the water level may be rising or may be at too high a level or the water level may be raised by steam bubble formation at a time of sudden increase in heat load and the water level regulator 19, may fail to close on the by-pass line 19A, or may remain open or may not move for some time from its partially opened position at the time of sudden change in heat load thereby not increasing the input of feed water into the fluid heater tubes with increase of heat load. The action of the water level regulator valve 19, is always entirely dependent on the action of the water level.

Water forced into the fluid heater tubes 53, by the feed pump 17, and the action of the water level regulator valve 19, on by-pass line 19A, passes through the fluid heater tubes 53, in the convection burnt gas heat transfer zone, passage 115, and discharges with steam, if any is formed, into water level cylinder 8, at the top, above the water level.

The feed input, as it discharges from feed pump discharge line 18, just before it enters the fluid heater tubes 53, enters and passes through the apex of the hollow feed cone distributor 63A, which smoothly spreads and directs the flow into the holes in the hollow cone leading to each tube. This action gives a minimum disruption of the flow of water to each tube and results in a more direct drive of the water into each tube. After the feed input passes the hollow cone distributor it enters a pressure drop device or Venturi shaped orifice 35A, in each tube in the design used for Fig. 1, which gives it a pressure drop delivery into the tube, which coordinated with the pressure drop device 35B, at the outlet of each fluid heater tube 53, and the quantity of water put into each tube, gives full control of the degree of compactness of the steam and water column in each tube for each heat load imposed on the tubes.

The water with steam, if any is formed, in the fluid heater tubes 53, passes through a Venturi shaped pressure drop device 35B, at the outlet end before discharging into the water level cylinder 8. This pressure drop device 35B, is used to co-ordinate with the inlet pressure drop device 35A, of the design shown in Fig. 1, and the quantity of water circulated to give full control of the compactness of the steam and water column in each tube and to insure unidirectional or controlled flow of steam and water in each tube.

After the discharging water and/or steam from each fluid heater tube has a preliminary breaking up of its steam bubbles and separation of the steam and water from the Venturi shaped pressure drop device 35B, then a further augumentation of the separation action by adding centrifugal force from both the twisted metal strips 66, at the outlet of each tube, and the still further separation and collection of the steam and water with the baffles 67, having openings for steam in them, the water separated from the steam discharges to the water level for maintaining a water level, for re-circulation in the system and for replacing steam generated, and the steam passes through the main separator 69, to the superheater tube 51.

The steam generator circulating pump 26, picks up water from the water level cylinder 8, and sends it to the waterwall tube 34, the convection generator tubes 52, and/or to the fluid heater tubes 53.

The circulating pump 26, is driven by auxiliary turbine 6, which also drives the air supercharger 5, the condensate pump 16, the feed pump 17, and the oil pump 27, the speed of the auxiliary turbine 6, being controlled by the master combustion control 70, to deliver the required amount of air for combustion, although the speed of the auxiliary turbine might be used to control the amount of oil, feed water, and/or circulating water used, and it is intended to be within the scope of this invention to use any of these control means.

The circulating pump 26, picks up the water from the water level cylinder 8, through suction lead 31, discharging it through discharge lead 32, past waterwall cone hollow distributor 63, and past convection generator cone hollow distributor 63B, which acts on the circulating water in the same way as described for the feed hollow cone distributor 63A, past waterwall tube holding disc 62, and past convection generator holding disc 62C, and into each tube, past a Venturi shaped pressure drop device 35A, at the inlet into each waterwall tube 34, and convection generator tube 52.

The pressure drop device 35A, is used in each waterwall tube 34, and in each convection steam generating tube 52, in the same manner and for the same purpose as the pressure drop device 35A, described in this invention for the fluid heater tubes.

Water and/or steam discharges from the waterwall tubes 34, and convection steam generating tubes 52, at the outlet end, past a Venturi shaped pressure drop device 35B, past a twisted metal separator strip 66, and into the water level cylinder 8. Said pressure drop devices 35B and twisted metal separator strips 66, for each individual tube acting in the same manner on the water and steam coming from the waterwall tubes 34, and convection steam generating tube 52, as described in this invention for the fluid heater tubes 53.

As the water and steam from the waterwall tubes 34, and the convection generating tubes 52, enters the water level cylinder 8, the cone shaped water spray with steam in the center, strikes baffle walls 68, and 68A similar to the baffle walls 67, described, for the fluid heater tubes. The resulting separated steam goes through the main separator 69, to the superheater 51, while the water falls to the water level where it is picked up again for re-circulation, by the circulating pump 26, with the make up feed water from the fluid heater tubes 51, where it is sent again as previously described, to the waterwall tubes 34, convection steam generating tubes 52 and/or the fluid heater tubes 53.

The discharge lead 32, of the circulating pump 26, has by-pass line 44, with control valve 44, connecting it to the circulating pump suction line 31.

The control valve 45, is operated by the moving rod 72, of the moving arm 71, of the master combustion control 70, which in turn is operated by change in boiler pressure in the following manner.

In Figure 3, the pressure responsive element consists of a double diaphragm construction counterbalanced by weights. The pressure to be controlled acts on the lower diaphragm, and the pressure of a sealed air chamber on the other. The upper diaphragm being made of phosphor bronze assumes a dished shape under the air chamber pressure and bears against the upper diaphragm plate. An increase of the controlled pressure moves the diaphragm plate 301 upwards, but in increasing force opposes this movement as the upper diaphragm is flattened against the thrust plate and a larger percentage of its area becomes effective to exert a downward force. This causes the diaphragm mechanism to move incrementally with pressure changes. An increase of the controlled pressure moves the connecting rod 302 upwards and acts through the lever 303 to move the pilot valve downward and admit motive fluid to the bottom of the operating cylinder. The crosshead moves upward carrying with it the compensater 307 which allows the roller 306 to move to the right. This roller is carried on the bellcrank 305 which is pivoted at 308 and supports the lever 303 at the pivot point 304. When the roller 306 moves to the left, the pivot 304 moves upward and raises the pilot valve to its closed position which stops the regulator after a movement dependent upon the extent of pressure change.

This arrangement gives complete flexibility of adjustment to local conditions. An increase in air chamber pressure reduces the travel of the diaphragm for a given pressure change and increases the total pressure change required to give a full stroke of the regulator. For a variable load a pressure of 20 to 30 pounds is carried in the air chamber and for steady loads this may be reduced to as low as 8 or 10 pounds, being adjusted in each case to give the relation between pressure change and regulator travel that gives the best results. As a final setting the angle of the compensator 307 may be adjusted to give the regulator the operating characteristics that best suit the load conditions.

The air chamber is pumped partially full of air through a small air valve near the base of the dome topped cylinder. The master regulator cylinder, upon the side of which, valve 67H is mounted, has a piston moving back and forth in its interior. This piston is actuated by oil under pressure, this pressure being created by pump 27 and acting through pipe-line 61G and valve 61H, returning (after it has moved the piston in the master regulator cylinder) to oil tank 38, through pipe-line 61F. The movement of the piston (not shown) in the large master regulator cylinder is transmitted through a piston rod to the moving arm or cross member 71 carrying master combustion control rod 72.

Increase in load causes a drop in boiler pressure due to a demand for more steam. A drop in boiler pressure on the lower diaphragm in Figure 3 causes the weight to fall down, pulling down arm 302. This raises the rod connected to 303, which in turn causes the opening of the bottom port in 61H sending oil under pressure to the bottom of the cylinder. This raises element 71 and the combustion control rod 72.

When 72 is raised, valve 42, which is constructed similarly to valve 76, opens, thereby speeding up auxiliary turbine 6 which operates to send more air to the combustion chamber. Valve 45 in the by-pass line of the circulating pump, as well as valve 61B in the by-pass line of the fuel pump, are formed with reversed seats so that an upward movement of member 72 effectuates a closing of these valves rather than an opening thereof as in the case of valves 42 and 76. Thus when valve 45 closes, it cuts off the by-pass circuit around the circulating pump and serves to send more circulating water to the economizer and steam generating tubes. Also, valve 76 opens, sending more water to the economizer. Valve 61B operates similarly to valve 45 and by cutting off the by-pass circuit functions to send more oil to the burner.

The reverse sequence of operations and control of the valves takes place with a decrease in load, and with an increase in pressure in steam conduit 9.

Since the master combustion control rod 72, moves with change in heat load demand, its movement can be used to operate the by-pass line 44, of the circulating pump 26, opening said valve 45, when load demands decrease, and closing said valve 45, when load demands increase, thereby varying the quantity of water available for circulation in the waterwall tubes 34, and/or the fluid heater tubes 53, to any amount desired for any given heat load and setting of the valve.

The discharge lead 32, of the circulating pump 26, has a cross connected line 73, connecting to the discharge lead 18, of the feed pump 17, between the feed stop and check valve 20, of line 18, and the fluid heater tubes 53.

This cross connecting line 73, has a control valve 76, and a check valve 20, also a by-pass line 74, around valve 76, with a thermostatic operated valve 75.

When the valve or valves of the cross connecting line 73, are open, the circulating pump 26, delivers water positively into each fluid heater tube 53, for circulation and re-circulation in any quantity desired, at any time, independent of the water level in water level cylinder 8.

Thermostatic valve 75, in by-pass line 74, is opened or closed by the action of a thermostat device 77, on fluid heater tubes 53. When the tubes of the fluid heater have insufficient water said thermostatic device becomes heated, as the steam formed within the tubes becomes superheated, causing the thermostat element 77, to open control valve 75, on by-pass line 74, on cross connecting line 73, opening cross connecting line 73, and thereby discharging circulating water from circulating pump 26, into the fluid heater tubes 53.

Thermostat element 77, is set to cause the opening of valve 75, at any time the temperature in the fluid heater tubes goes above that of the temperature of saturated steam, at the designed working pressure of the boiler.

The action of the thermostat element 77, and valve 75, is independent of the water level and also independent of the heat load except indirectly, when lack of water with the heat load might cause rise in temperature in the fluid heater above that at the temperature of the saturated steam.

Control valve 76, is operated by the master combustion control arm 71, moving rod 72, with change in heat load. This rod 72, is connected to the lever valve 76, from a lever point over on the water level regulator valve stem of water level regulator valve 19. The connecting arm between rod 72, valve 76, and the lever point on valve stem 19, together with the location of both valves 19, and 76, are so arranged at the different heat load settings, that if the water level regulator valve stem is in the open position, the rod 72, will have opened valve 76, but if the water level valve closes it will close valve 76, or close it to any degree desired, as made with the valve and arm setting.

When valve 76, is open, cross connection 73, is open, thereby discharging circulating water from circulating pump 26, into the fluid heater in any quantity desired.

The cross connection 73, with its valves and controls is mainly for the purpose of supplying water to the fluid heater in any desired quantity for coordination with the pressure drop devices in the tubes to protect said tubes and insure their proper operation, at any time, only when and if, the supply of feed water coming into the fluid heater is insufficient to accomplish this purpose due to the water level condition and action of the water level regulation valve on the feed line.

Steam

The saturated steam from the waterwall tubes 34, convection generating tubes 52, and/or the fluid heater tubes 53, passing through the main separator 69, and into the superheater tubes inlet ends 51, at the top of the water level cylinder 8, as previously described; becomes highly superheated as it passes through the superheater tubing 51.

At the outlet of each superheater tube 51, I place a Venturi shaped pressure drop device 35B, adjusted to insure proper distribution of steam flow in each tube and compactness of the steam column in the coiled tubes 51.

In order to maintain a fairly constant final steam temperature with variable heat loads superheater tubes 51, are equipped, as previously described in co-pending application 6,938,714 of October 16, 1933, with a thermostat control on superheater tube 51, with regulator, which raises or lowers the superheater coil with change in final steam temperatures, so that the position of the superheater coils 51, relative to the waterwall coils 34, is changed from in the rear of the waterwall tubes 34, but with full radiant heat, acting on the superheater coils 51, to a position of the superheater coils 51, directly behind the waterwall coils 34, with practically no radiant heat acting on the coils 51, the heat transfer being mainly by convection action.

As a result during the operation of my power unit at various loads the superheater coils 51, are being automatically raised and lowered to meet the heat conditions of various loads and maintain a fairly uniform final temperature.

The highly superheated steam discharges from the outlet ends of the superheated tubes 51, past the superheater tube holding disc 62A, into main steam line 9, where a second safety valve is generally located, (not shown).

The superheated steam in main steam line 9, passes through main throttle stop valve 61, to main steam turbine 10, exhausting through exhaust lead 10A, to main condenser 11, where it is cooled and condensed back to water by cooling water entering inlet 12, and leaving by exit 13, in main condenser 11.

The superheated steam from main steam line 9, also passes through auxiliary steam line 7, past auxiliary control valve 42, to auxiliary turbine 6, which drives all of the main auxiliaries. The exhaust steam from auxiliary turbine 6, passes through auxiliary turbine exhaust line 28, to main exhaust line 10A, to main condenser 11, where it is condensed with the exhaust steam from main turbine 10. The condensate then passes through line 14, to feedtank 15, where it mixes with any feed water from the reserve feed tanks, put into the feed tank 15, through filling line 46, past valve 43. The resulting water mixture then passes through condensate suction line 29, of condensate pump 16, to pass through the system as previously described.

Fuel

The feed oil tank 38, is filled when necessary from the reserve fuel tanks through filling line 48, past stop valve 49. Vent 50, connects the fuel oil tank 38, with the atmosphere.

The fuel oil pump 27, picks up fuel oil from fuel oil tank 38, through fuel oil pump suction line 39, discharging it to the burner 2, through discharge line 40.

Fuel oil under pressure from the fuel oil pump 27, issues from the burner, in a finely divided or atomized spray, where it mixes with the air, and after ignition keeps continually forming the gases of combustion in combustion chamber 106, at a rate of heat release proportional to the amount of air and oil mixture made available in the combustion chamber by input from the fuel oil pump 27, with its controls and the air supercharger 5, with its controls.

The fuel oil pump discharge line 40, has a lead 61G, going to the control valve 61H, on the master combustion control 70, for power operation of its moving arm 71, and motion of its valve operating rod 72.

Oil passing through control valve 61H, on master combustion control 70, discharges through line 61F, to the suction line 39, of oil pump 27.

The fuel oil burner has a centrifugal atomizing chamber with by-pass opening at its rear through which oil from the fuel oil pump, not issuing from the burner opening into the combustion chamber is by-passed back to the suction of the fuel oil pump suction line 39.

The fuel oil by-pass line 61A, has a lever control valve 61B, which controls the quantity of oil sent to the burner.

A lead pipe 61C is provided for using starting oil under hand pressure when starting combustion in the boiler fitted with a stop valve 61D therein. When oil is supplied from this source, a stop valve 61E is provided to shut off the oil pump supply.

The master combustion control, 70, through its moving arm 71, and moving rod 72, operates the fuel oil by-pass lever valve 61B, so that if the boiler pressure is lowered from load demand the rod 72 moves, closing the by-pass valve 61B, and increasing the oil output of the burner. If the boiler pressure is raised from decrease in load demand, the master combustion rod 72 is moved so that the by-pass valve 61B is opened, decreasing the pressure in the centrifugal chamber of the burner and the input of oil into the combustion chamber. In this manner a sufficient quantity of oil is automatically forced in the combustion chamber in proportion to the load demands maintaining a fairly constant boiler pressure throughout the system, at all load conditions.

Air

The air supercharger 5, driven by auxiliary turbine 6, picks up air from the atmosphere through its suction inlet 41, and by high speed rotation with centrifugal action compresses and drives the air throughout the boiler air and gas passage system with the combustion gases against any pressure drop conditions occurring in the system.

The air leaves the air supercharger 5, through the supercharger air discharge line 119, which enters the circular air entrance dome passage 120, tangentially, giving the entering air a whirling motion in said passage.

Air from the circular air entrance dome passage still whirling, enters through and into the stream lined air passages 121, of the tapered spiral cross flow air preheater. The air, as it is forced at high velocity into said air preheater air passage 121, past the spiral tapered air preheater burnt gas tubes 65, meets with more resistance to cross flow than to spiral flow along the tapered spiral coiled air preheater burnt gas tubes 65, which result in a combination of spiral flow and cross flow of the air in its air passages 121, giving spiral cross flow of the air along the heat transfer surfaces. The spiral tubes 65, of the air preheater are wound around the circular tapered fluid heater outer casing 225, so that the air continues to have the same whirling motion in the air preheater air passages as it had when leaving the circular entrance dome chamber.

Air leaving the tapered spiral cross flow air preheater air passages 121, still whirling in the original direction, enters the circular air inlet passage 125, and then the circular air inlet burner chamber 122, to the burner guide vanes at the burner entrance 123.

The burner guide vanes augment the whirling of the air, leaving the circular air inlet chamber 122, without change of direction of the whirl, guiding the air into the burner throat passage 124, and on into the combustion chamber 106, where it mixes with the atomized fuel oil from the burner to form the combustion gases. The ports 105 in the burner entrance wall are used for purposes of inspection and ignition when starting combustion.

Combustion gases

The combustion gases formed in the combustion chamber 106, from the mixed and ignited oil and air, are driven at high velocity throughout the burnt gas passages of the steam generator 1, by the oncoming air from the air supercharger 5.

The main part of the combustion gases in the combustion chamber 106, striking the bulbous central position of the combustion chamber outlet end wall 223, are dispersed toward the depressed and curved turn 224, of the combustion chamber outlet end wall 222, near the circumference and thereby guided smoothly into the combustion chamber circular burnt gas passage 114, and then into the convection generating spiral tapered burnt gas passage 127. As the combustion gases pass down the sides of the spiral coiled waterwall tubes 34, and superheater tubes 51, in the combustion chamber 106, these tubes tend to whirl in the same direction it had when leaving the throat 124, and this air with the combustion gases, continues to whirl as it enters the convection generating spiral tapered burnt gas passage 127.

Since the spiralled convection generating coils 53, in the spiral tapered convection generating passage 127, are coiled in the opposite direction to the waterwall coiled tubes 34, and superheater coiled tubes 51, in the combustion chamber 106, the combustion gases continue to whirl in the same direction they had when leaving the combustion chamber, as they travel through the convection generating passage 127, the circular outlet convection generating passage 126, and into the spiral tapered fluid heater passage 115.

Since the fluid heater tubes 53 are coiled in the opposite direction to the convection steam generating tubes 52, the gases continue to whirl in the same direction while passing through the fluid heater tapered spiral cross flow passage 115, as they whirled when passing through the convection steam generating gas passage 127.

The combustion gases travelling through the spiral tapered fluid heater passage 115, at high velocity, strike the coiled fluid heater tubes 53, meeting with more resistance to cross flow than spiral flow and resulting in a combination of spiral flow along the fluid heater tubes 53, and cross flow across them, giving spiral cross flow of the gases on the heat transfer surfaces.

The combustion gases leaving the spiral cross flow tapered fluid heater passage 115, are guided by the streamlined entrance into the spiral tapered air preheater burnt gas tubes 65, travelling in counterflow to the air on the other side of said tubes 65, in the air preheater air passages 121, to the stack gas passages 117.

The gases leaving the stack gas passage 117, enter the streamlined entrance 118, into stack and leave the Venturi shaped stack exit to the atmosphere.

I claim:

1. In a steam power plant, a boiler of the forced recirculation type having steam generating tubes with working fluid regulating orifices in said tubes, a burner in said boiler, a turbine receiving steam from said boiler, a fuel pump, an air pump, a feed water pump, and a circulating water pump driven by said turbine, said fuel pump connected to said burner and the other pumps connected to said boiler, a steam throttle controlling steam flow through said turbine, a steam and water separating chamber connected to said boiler and circulating water pump for supplying the separated water to said circulating pump, by-pass conduits bridged across the inputs and outputs of said fuel pump, feed water pump and circulating water pump, valves in each of said by-pass conduits, and a combustion control device arranged to control all of said valves.

2. In a steam power plant, a boiler of the forced recirculation type including steam generating tubes and feed water preheater tubes therein, a burner in said boiler, a turbine operated by the steam delivered from said boiler, a fuel pump, a feed water pump, and a circulating water pump driven by said turbine, said fuel pump connected to said burner, said feed water pump connected to said preheater tubes to pump feed water into said preheater tubes, a steam and water separator connected to said boiler and circulating pump for supplying the separated water to said circulating pump, conduits bridged across the output and input of each of said pumps, valves in said bridging conduits, and a combustion control device arranged to control said valves.

3. In a steam power plant, a boiler of the forced recirculation type including steam generating tubes and feed water preheater tubes therein, regulating pressure-drop devices in at least the steam generating tubes controlling fluid flow therethrough, a burner in said boiler, a steam turbine operated by the steam delivered from said boiler, a fuel pump, an air pump, a feed water pump, and a circulating water pump driven by said turbine, said fuel pump connected to said burner, said air pump connected to said boiler adapted to supply air to the burner of the boiler in conjunction with the fuel delivered thereto by said fuel pump, and said feed water pump connected to said feed water preheater tubes adapted to pump feed water into said preheater tubes, a steam and water separator connected to said boiler and circulating pump for supplying the separated water to said circulating pump, by-pass conduits associated with said fuel pump, feed water pump and circulating water pump, and a combustion control device responsive to the output of the boiler and the heat demands made thereupon for controlling the flow of media supplied by said pumps.

4. In a steam power plant, a boiler of the forced recirculation type including steam generating tubes and feed water preheater tubes therein, a burner in said boiler, a steam turbine operated by the steam delivered from said boiler, a fuel pump, an air pump, a feed water pump and a circulating water pump driven by said turbine, said fuel pump connected to said burner, said air pump connected to said boiler adapted to supply air to the burner of the boiler in conjunction with the fuel delivered thereto by said fuel pump, and said feed water pump connected to said feed water preheater tubes adapted to pump feed water into said preheater tubes, a steam and water separator connected to said boiler and circulating pump for supplying the separated water to said circulating pump, by-pass conduits associated with said fuel pump, feed water pump and circulating water pump, a combustion control device responsive to the output of the boiler and the heat demands made thereupon for controlling the flow of the media supplied by said pumps, and means for modifying the control exercised by said combustion control device.

5. The combination set forth in claim 2 wherein an air pump for supplying air to the burner of the boiler is also driven by said turbine.

6. The combination set forth in claim 2 wherein is provided additional control means for said valves.

7. The combination set forth in claim 2 wherein is provided additional devices responsive to the conditions of the fluids in the steam gener-

ator for controlling at least one of said valves in said bridging conduits.

8. In a steam power plant, a boiler of the forced recirculation type including steam generating tubes and feed water preheater tubes therein, regulating pressure-drop devices in at least the steam generating tubes controlling fluid flow therethrough, a burner in said boiler, a steam turbine operated by the steam delivered from said boiler, a fuel pump, an air pump, a feed water pump and a circulating water pump driven by said turbine, said fuel pump connected to said burner, said air pump connected to said boiler adapted to supply air to the burner of the boiler in conjunction with the fuel delivered thereto by said fuel pump and said feed water pump connected to said feed water preheater tubes adapted to pump feed water into said preheater tubes, a steam and water separator connected to said boiler and circulating pump for supplying the separated water to said circulating pump, conduits bridged across the inputs and outputs of said fuel pump, feed water pump and circulating water pump, valves in said bridging conduits, and a combustion control device arranged to control said valves in response to the output of the boiler and the heat demands made thereupon by controlling the flow of the media supplied by said pumps.

9. In a steam power plant, a boiler of the forced recirculation type including steam generating tubes and feed water preheater tubes therein, a burner in said boiler, a steam turbine operated by the steam delivered from said boiler, a fuel pump, an air pump, a feed water pump and a circulating water pump driven by said turbine, said fuel pump connected to said burner, said air pump connected to said boiler adapted to supply air to the burner of the boiler in conjunction with the fuel delivered thereto by said fuel pump and said feed water pump connected to said feed water preheater tubes adapted to pump feed water into said preheater tubes, a steam and water separator connected to said boiler and circulating pump for supplying the separated water to said circulating pump, conduits bridged across the outputs of said fuel pump, feed water pump and circulating water pump, valves in said bridging conduits, a combustion control device arranged to control said valves in response to the output of the boiler and the heat demands made thereupon by controlling the flow of the media supplied by said pumps, and means for modifying the control exercised by said combustion control device.

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