Jan. 3, 1961 H. VOGLER 2,966,896

METHOD AND APPARATUS FOR CONTROLLING THE OUTLET TEMPERATURES OF SUPERHEATERS AND REHEATERS OF A STEAM GENERATING PLANT

Filed March 10, 1959 3 Sheets-Sheet 1

Fig. 1

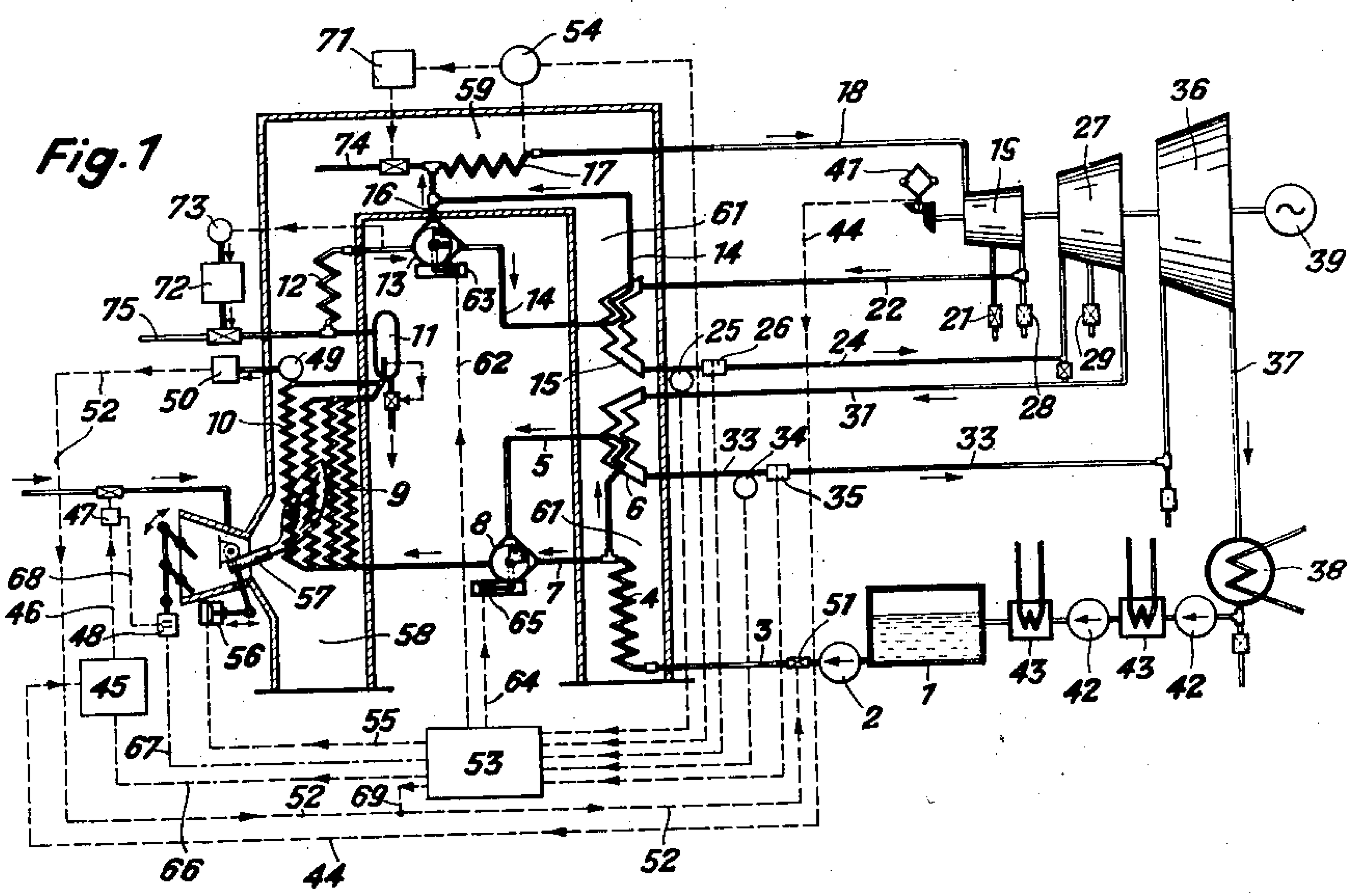
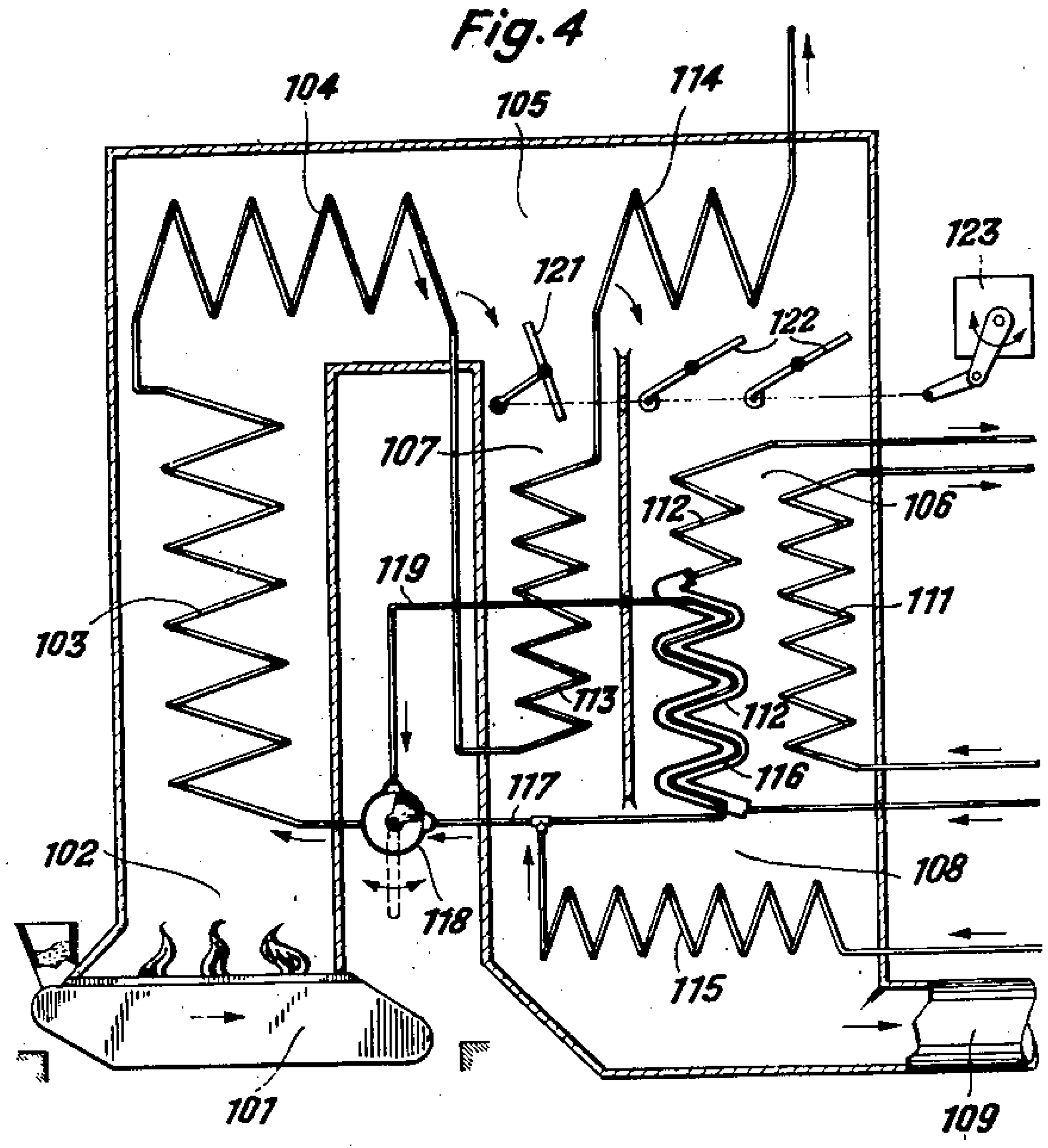


Fig. 4



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Filed March 10, 1959 3 Sheets-Sheet 2

Fig. 2

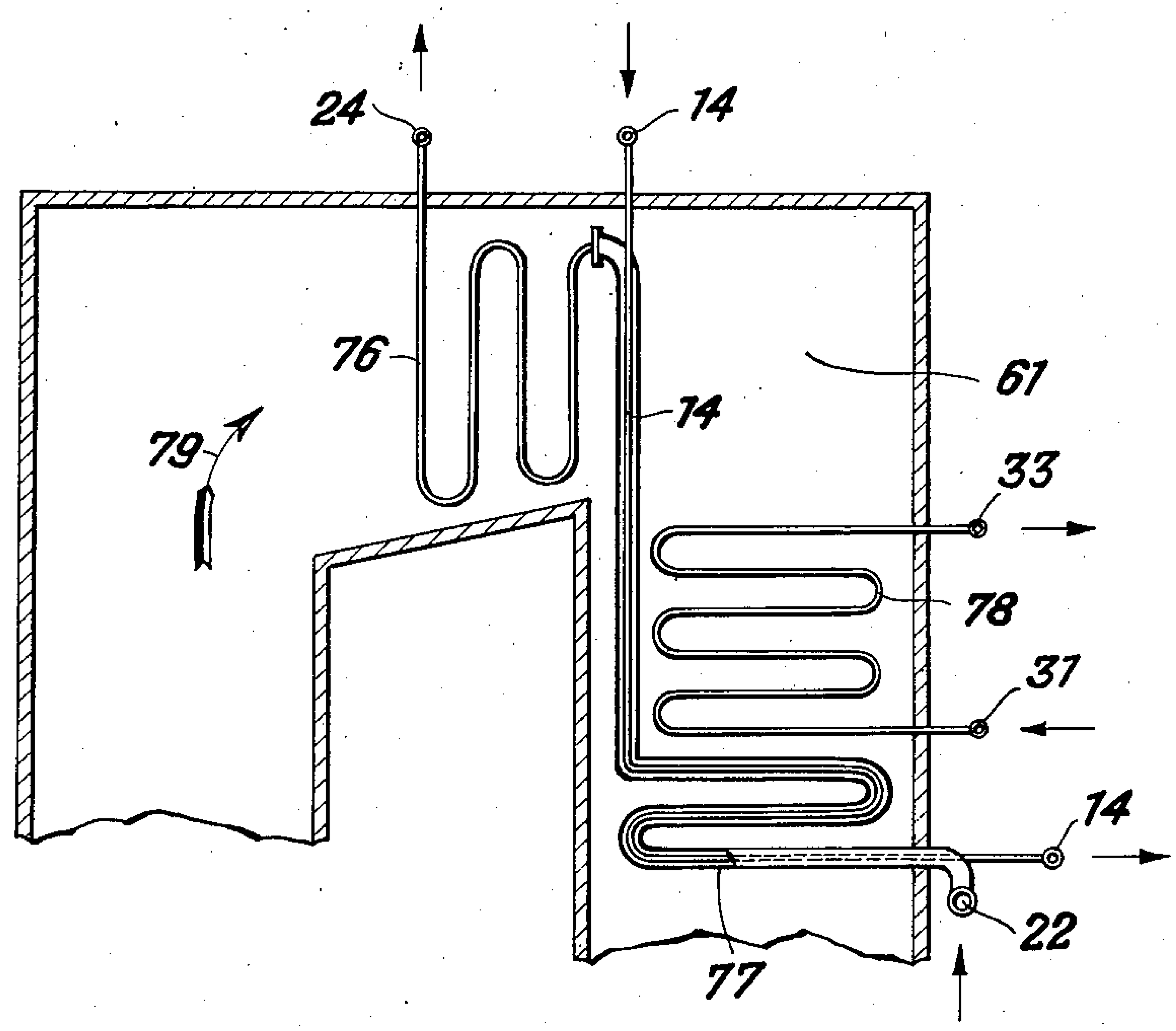
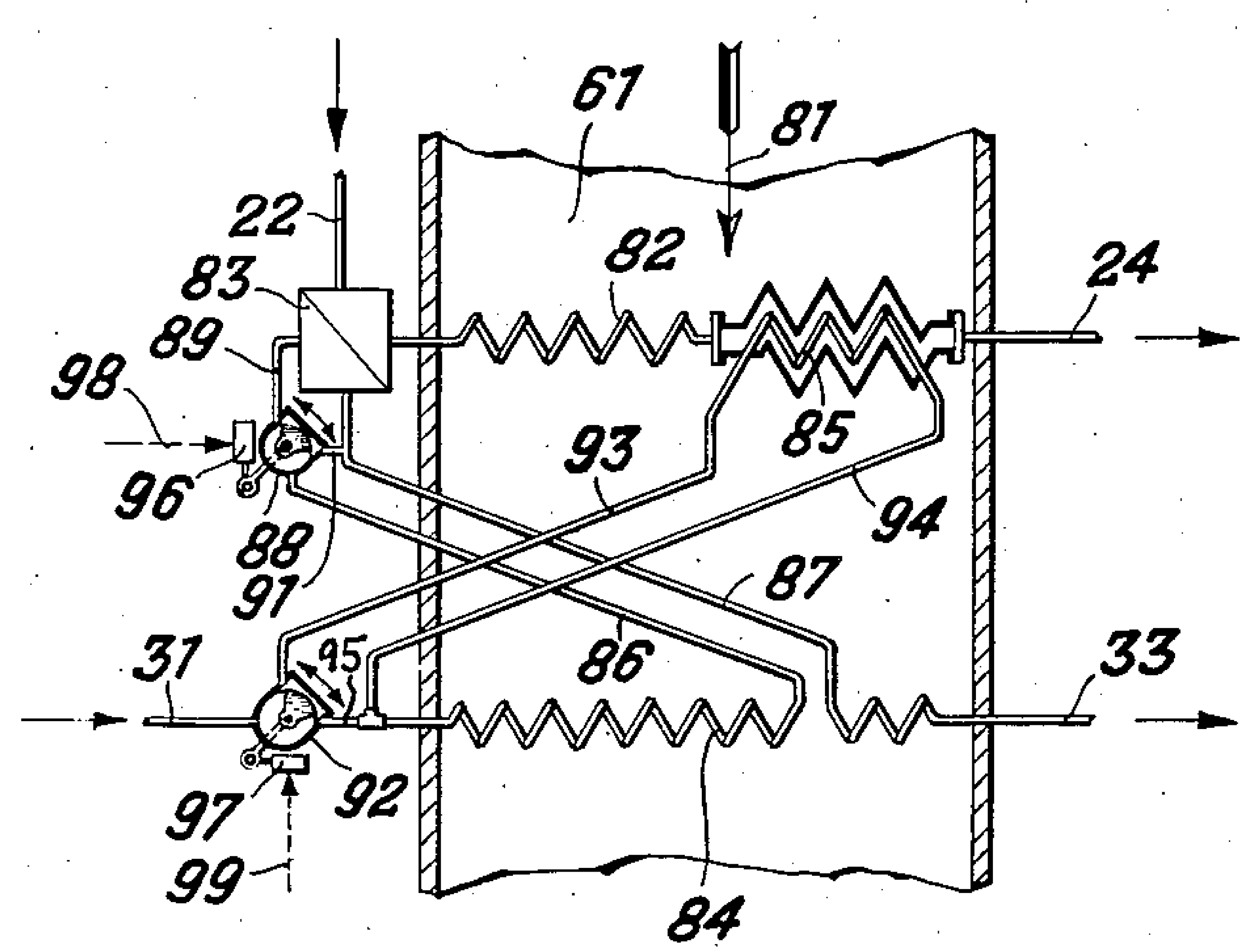


Fig. 3



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Filed March 10, 1959 3 Sheets-Sheet 3

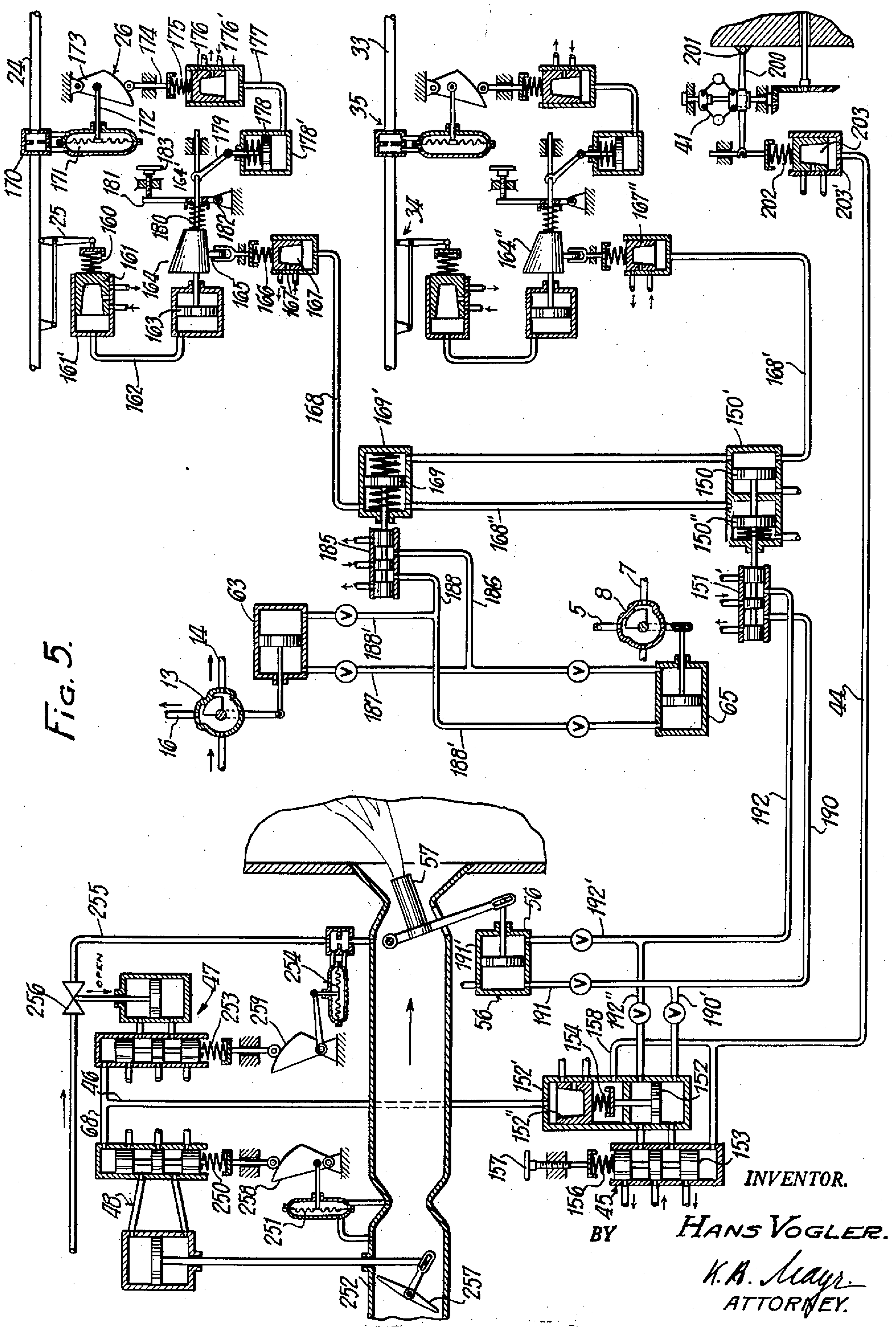

FIG. 5.

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METHOD AND APPARATUS FOR CONTROLLING THE OUTLET TEMPERATURES OF SUPERHEATERS AND REHEATERS OF A STEAM GENERATING PLANT

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8 Claims. (Cl. 122—1)

The present invention is concerned with an improved method for controlling, in a steam generating plant, the outlet temperatures of a live steam superheater and of at least two reheaters operating at different pressures and with an apparatus for practicing the invention.

It is known to arrange a steam generator in two parts through which the operating medium flows in parallel relation and to arrange two reheaters in different parts and with different heating surfaces so that the temperature of the resuperheated steam can be controlled independently in the two reheaters. By changing the load on the parts of the steam generator the heat supplied to the respective reheaters can be changed. Distribution of the heat energy to the sections of each steam generator part which sections receive heat by radiation and by convection, respectively, is effected by conventional means, for example, combustion gas bypass, combustion gas recirculation, tilting burners, and the like.

A disadvantage of the above described conventional system is that the steam generator consisting of asymmetrical parts is expensive. Furthermore, the two halves of the steam generator cannot be operated at full load at the same time because in this case there would be no control margin.

The system according to the invention avoids the disadvantage of conventional systems by exchanging and controlling, in addition to the control of the fire intensity according to the load, the exchange of heat between live steam, reheat steam, and/or feedwater for heating one and cooling the other of the heat exchanging media, and by also controlling at least two of the following: fuel supply, combustion air supply, position of the zone of maximum heat transfer, and feedwater supply.

The apparatus for practicing the method includes, in addition to a control apparatus for changing the fire intensity according to load changes, control means which regulate exchange of heat between live steam, reheat steam, and/or feedwater for heating and cooling steam and/or feedwater, and at least two of the following: fuel supply, combustion air supply, position of the zone of maximum heat transfer, and feedwater supply.

The novel features which are considered characteristic of the invention are set forth with particularity in the appended claims. The invention itself, however, and additional objects and advantages thereof will best be understood from the following description of embodiments thereof when read in connection with the accompanying drawing, in which:

Fig. 1 diagrammatically illustrates a steam power plant including a multistage turbine receiving steam from a steam generator and reheaters controlled according to the invention.

Fig. 2 is a diagrammatic illustration of an arrangement of two reheaters in a steam generator, one of the reheaters having a portion for heat exchange with superheated steam.

Fig. 3 is a diagrammatic illustration of an arrangement of two reheaters operating at different pressures and mutually exchanging heat.

Fig. 4 is a diagrammatic illustration of a modified steam generator and of reheaters combined therewith.

Fig. 5 is a part sectional diagrammatic illustration of control means for the steam generating and reheating shown in Fig. 1.

Referring more particularly to Fig. 1, numeral 1 designates a feedwater storage tank from which feedwater is delivered by a pump 2 through a pipe 3 into an economizer 4. A part of the water leaving the economizer 4 is diverted into a cooling tube 5 which extends through a reheater 6 for cooling the steam reheated therein. The balance of the water leaving the economizer 4 is conducted through a by-pass pipe 7. The cooling tube 5 is connected to the by-pass pipe 7 by means of a distributing valve 8 at the inlet of an evaporating tube section 9 of the steam generator.

The water is substantially evaporated in the evaporating section 9. Residual water is separtaed in a separator 11 from which substantially dry steam is conducted into a primary superheater 12. At the outlet of the latter a live steam distributing valve 13 is provided for distributing steam into a heating tube 14 extending through a reheater 15, and into a by-pass conduit 16. The by-pass conduit 16 as well as the heating tube 14 terminate in a secondary live steam superheater 17 wherefrom the live steam is conducted through a pipe 18 to a high pressure turbine 19.

A bleeder conduit provided with a valve 21 is connected to an intermediate stage of the high pressure turbine 19. The exhaust of the high pressure turbine flows through a pipe 22 to the first reheater 15 and therefrom through a pipe 24 provided with a temperature sensing device 25 and a steam flow measuring device 26 to the inlet of an intermediate pressure turbine 27. Steam may be withdrawn from the pipe 22 and controlled by means of a valve 28 for use by a consumer, not shown. The intermediate pressure turbine 27 is also provided with a bleeder steam connection including a valve 29.

The steam exhausting from the intermediate turbine 27 flows through a pipe 31 to a second reheater 6 whose outlet is connected by means of a pipe 33 provided with a temperature sensing device 34 and a steam flow measuring device 35 to a low pressure turbine 36. The steam expanded in the turbine 36 is conducted through a pipe 37 to a condenser 38. The multistage turbine 19, 27, 36 drives an electric generator 39. A conventional speed-responsive regulator 41 is provided for controlling the output of the plant and maintaining a constant speed on the steam turbine.

Condensate pumps 42 transport the condensate from the condenser 38 through preheaters 43 and into the feed-water storage tank 1. In the following the control system for controlling the steam temperature at the outlet of the superheater and reheaters will be described.

If the load on the steam turbine is increased, the speed regulator reports the decreasing speed of the turbo-generator through a signal conduit 44 to a controller 45 for the heat supply to the steam generator. The controller 45 is conected to a motor operator 47 by means of a signal conduit 46 and opens, by means of the motor operator 47, a fuel supply valve. The motor operator 47 is also connected to a servo motor 48 actuating air dampers for increasing combustion air supply upon increasing fuel supply. If there is a forced draft fan the servo-motor 48 actuates a speed control of the fan motor.

The evaporating section 9 of the steam generator consists of a plurality of tubes arranged in parallel relation with respect to the flow of the operating medium, which tubes are located in the combustion chamber. One of the tubes, called the control tube 10, of the evaporating section is so arranged as to produce slightly superheated steam whereas all other tubes produce saturated or slightly moist steam. Due to the increased fuel and combustion air supply the heat energy developed in the combustion chamber of the steam generator is increased, causing an increase of the steam temperature at the outlet of the control tube 10 of the evaporating section 9. This increase is measured by a temperature sensing device 49 which produces a signal which may be corrected in a device 50 and which is transmitted in a signal conductor 52 to a feed valve 51 in the pipe 3 for controlling the feedwater supply to the steam generator. If the temperature sensed by the device 49 increases, the valve 51 is opened.

Since the heat developed by the increased fuel supply is greater than the amount of heat absorbed by the increased amount of water and steam flowing through the steam generator, the temperature of the flue gases increases. This temperature increase of the combustion gases is relatively greater at greater distances from the combustion chamber so that the temperature increase at the reheaters 6 and 15 is greater than at the live steam superheater 17 whereby the temperature increase at the second reheater 6 is greater than the temperature increase of the combustion gases at the first reheater 15.

The increased temperature of the steam leaving the live steam superheater 17 caused by the increased combustion gas temperature is measured by a temperature sensing device 54 producing a signal which is conducted to a controller 53. The latter transmits a signal through a conductor 55 to a motor operator 56 adjusting the position of a tilting burner 57 whereby, in case of an increase of the load, the position of the zone of greatest heat in the combustion chamber 58 is lowered.

With changing the position of the outlet of the burner 57 the center of the heat transfer to the heating surface which is located in the combustion or radiation chamber 58 and in the flues 59 and 60 is displaced. If, for example, the outlet of the burner 57 is lowered the lower parts of the evaporating section 9 are more heated and the upper parts receive less heat than if the outlet of the burner 57 is lifted so that the center of the heat transfer to the total heating surface of the steam generator is moved towards the lower or inlet portion of the evaporating section 9. The conditions in the live steam super-heaters 12 and 17, in the reheaters 15 and 6, and in the economizer 4 are analogously changed so that the superheaters 12 and 17 are somewhat less heated and the temperature of the steam leaving the superheater 17 can be maintained at the desired value.

However, the temperature of the steam leaving the reheaters 15 and 6 is still too high.

The signals produced by the temperature sensitive devices 25 and 34 are compared in the controller 53 and a resulting signal is conducted through a conductor 62 to a motor operator 63 for the distributing valve 13. At the operating condition under consideration the flow of live steam through the heating tube 14 is decreased and the steam flow through the by-pass conduit 16 is increased. Heating of the reheater 15 by live steam is thereby so much reduced that, in spite of increased combustion gas temperature, the temperature of the medium pressure steam leaving the reheater 15 has the desired value and no further signal is produced by the device 25.

Since the medium pressure steam in pipe 24 has now the desired value, the temperature in the pipe 31 is also normal. However, the heating of the second reheater 6 by combustion gas is relatively high so that the temperature of the steam leaving the second reheater 6 is above the desired value. Therefore, a signal is produced by the device 34 and conducted to the controller 53 which emits a signal through conduit 64 to the motor operator of the distributing valve 8, increasing the flow of water through the cooling tube 5 and decreasing the flow through the by-pass conduit 7 until the temperature in the pipe 33 reaches the desired value.

The increased flow of feedwater and steam corresponds to the increased load and normal speed of the turbogenerator is restored.

Instead of adjusting the position of the burner 57 the fire intensity, i.e., the fuel and air supply may be corrected. Correction of the fuel supply is effected by a signal conducted through a conductor 66 so that the signal emitted by the controller 45 to the motor operator 47 is corrected and the fuel supply is reduced, whereupon a signal transmitted from the motor operator 47 to the servomotor 48 corrects the supply of combustion air. Alternatively, a signal may be sent from the controller 53 through a conductor 67 to the servomotor 48 for reducing the combustion air supply whereupon the motor operator 47 receives a signal from the servomotor 48 through a conductor 68 for reducing the fuel supply. In this case the heat center need not be displaced.

Alternatively, the correction of the fire intensity can be effected by the controller 53 as described in the paragraph next above whereby, however, the signals produced by the devices 25 and 34 compared in the controller 53 cause a tilting of the burner 57 and residual signals emitted by the devices 25 and 34 effect a change of heating of the reheater 15 by the heating tube 14 or a change of cooling of the reheater 6 by the cooling tube 5.

The steam for the medium pressure turbine may be heated by live steam and the steam for the low pressure turbine may be heated by live steam as well as by reheated medium pressure steam. Cooling of the low pressure steam may be effected by feedwater and cooling of the medium pressure steam may be effected by feedwater or by low pressure steam.

In order to accelerate the control operation a controller 71 responding to signals given by the device 54 which is responsive to the temperature at the outlet of the live steam superheater 17 may be provided and a controller 72 responsive to signals received from a device 73 which is responsive to the temperature of the live steam at the outlet of the first superheater portion 12 may be provided for increasing water injection through pipes 74 and 75 into the superheaters 17 and 12, respectively, if the temperatures sensed by the devices 54 and 73 are too high.

If steam is tapped from the turbine through valves 21 or 28 the amount of steam flowing through the first reheater 15 is changed. This change is reported by a flowmeter 26 in the pipe 24 to the controller 53 which, thereupon, emits a signal to the motor operator 63 for reducing the steam flow through the pipe 14 until the temperature sensed by the device 25 has the desired value. If the steam is tapped from the turbine 27 the amount of steam flowing through the reheater 6 is also reduced. This is reported by a flowmeter 35 to the controller 53 which emits a signal through conductor 64 to the motor operator 65 for reducing the amount of cooling water flowing through the pipe 5 until the temperature measured by the device 34 reaches the desired value. If steam is tapped only through the valve 29, only cooling of the reheater 6 must be reduced.

The reheaters 6 and 15 include tubes which are coaxially placed within each other. The tube 14 a portion of which is inside a portion of the reheater tube 15 serves for heating the latter. The surface of the reheater exposed to the combustion gases can therefore be reduced. A portion of the reheater 6 is cooled by a portion of the tube 5 and the heating surface of the reheater 6 which surface is exposed to the combustion gases must be increased.

The portion of the heating tube which is inside the tubular reheater 15 is preferably arranged at the inlet portion of the reheater where the temperature of the steam to be heated is low relatively to the temperature of the heating steam. The portion of the cooling tube 5 which is inside the tubular reheater 6 is preferably arranged in the outlet portion of the reheater 6. The length of the cooling tube relatively to the length of the reheater tube 6 depends on the normal operating temperatures of the combustion gas, the amounts of the low pressure steam passing through the reheater 6 and of the cooling water passing through the tube 5, and on structural conditions, for example the diameters of the coaxially arranged tubes.

The interior cooling appears to have the disadvantage of requiring an increased reheating surface. This additional surface, however, is counterbalanced by a saving of surface in the high pressure evaporator 9 or in the live steam superheaters 12 and 17.

Fig. 2 illustrates a medium pressure reheater which consists of two sections 76 and 77 which are arranged in series relation with respect to the steam flow. The section 77 is connected to the pipe 22 and the section 76 to the pipe 24 in Fig. 1. A low pressure reheater 78 connected to the pipes 31 and 33 is interposed in the combustion gas stream between the sections 76 and 77 of the first medium pressure reheater. The combustion gas flows in the direction of the arrow 79. This arrangement of the two reheaters has the advantage that if the heat center is displaced, a difference in the relative change of the combustion gas temperature heating one reheater and the temperature of the combustion gas heating the other reheater is substantially ineffective so that the control is simplified.

There are fifteen combinations of two reheaters possible whereby heating and cooling may be effected individually or jointly in one or simultaneously in both reheaters. For best results a combination is used which best fits the conditions of the plant. If both reheaters are equipped for internal cooling or heating, arrangements for changing the position of the fire, for recirculating or by-passing combustion gas and the like may in some cases be omitted. If only one of the reheaters is equipped for interior heating or cooling the outlet temperature of this reheater may be controlled by adjusting the inlet temperature of the cooling or heating agent or by adjusting the amount of cooling or heating agent passed through the reheater, while the outlet temperature of the other reheater is maintained by conventional means, for example, by tilting burners, recirculation of combustion gas, combustion gas by-pass, changing the number of burners and controlling rows of burners, water injection, individually or by a combination thereof.

When the load conditions are unfavorable or greater accuracy of the control is required the control of the position of the heat center based on the sum of the deviations of the outlet temperatures of both reheaters from the desired value and internal heating of one reheater based on the difference between the temperature deviations, the control system may be so supplemented that if the heat output is increased a signal corresponding to the disturbance is applied to the tilting burner whereby the latter is swung away from the respective reheater. The change of the position of the tilting burner may produce a signal affecting the fuel supply or feedwater supply whereby swinging of the burner effects a reduction of the fuel supply or an increase of the feedwater supply.

In the aforedescribed examples heating is effected by means of live steam and cooling by means of feedwater. Fig. 3 shows an arrangement in which heating and cooling is effected by exchanging heat between steam of one reheater and steam of another reheater.

Referring more particularly to Fig. 3, numeral 61 designates a flue through which combustion gas flows in the direction of the arrow 81, heating first a first reheater 82. A pipe 22 (Fig. 1) conducts medium pressure steam into an indirect heat exchanger 83 which is heated by low pressure steam taken from a second reheater 84 near the outlet thereof. The medium pressure steam flowing through the first part of the reheater 82 receives heat solely from the combustion gases whereas the second part is provided with an internal tube 85 through which low pressure steam is conducted from pipe 31 (Fig. 1) through a conduit 93 for cooling the medium pressure steam.

The reheater 84 has a first part whose outlet is connected by a pipe 86 to a distributing valve 88 to which the heat exchanger 83 is connected by a pipe 89. A by-pass pipe 91 connects the valve 88 to a return pipe 87 connecting the heat exchanger 83 to the second part of the reheater 84 which discharges into the low pressure pipe 33 (Fig. 1). Low pressure steam flow from the pipe 31 to the conduit 93 is controlled by a distributing valve 92. The medium leaving the internal pipe 85 is returned through a pipe 94 to the inlet of the reheater 84. This inlet is also connected to the valve 92 by a by-pass pipe 95.

The arrangement shown in Fig. 3 has the advantage that over-temperatures of one reheater and subnormal temperatures of the other reheater are more quickly compensated whereby the control requires relatively small heat exchange surfaces because heating of the medium pressure steam in the exchanger 83 simultaneously effects cooling of the low pressure steam. Likewise, cooling of the medium pressure steam passing along the tube 85 effects heating the low pressure steam before it enters the reheater 84.

Motor operators 96 and 97 for the distributing valves 88 and 92, respectively, receive signals through conductors 98 and 99, respectively, from a controller, for example as designated by numeral 53 in Fig. 1.

If change of location of the heat center is not possible, for example in case of a traveling grate 101, Fig. 4, the zone of maximal heat transfer can be displaced by means of a controlled combustion gas by-pass. In Fig. 4 numeral 102 designates a combustion chamber above the grate 101. An evaporating tube section 103 is placed in the combustion chamber 102, the outlet of the evaporating section 103 being connected to a live steam superheater 104 which is located in part in the radiation zone of the combustion chamber.

A flue 105 receiving hot combustion gases from the combustion chamber 102 is divided into a flue 106 and into a by-pass flue 107, both flues terminating in a chamber 108 having an outlet duct 109. A first reheater 111 and a second reheater 112 are located in the flue 106. In the by-pass flue 107 a first portion 113 of a second live steam superheater which receives steam from the first superheater 104, is located. The second part 114 of the second live steam superheater is located in the flue 105. The space 108 contains an economizer 115 whose outlet is connected to a cooling tube 116 placed within the outlet portion of the reheater 112 and is connected through a by-pass pipe 117 to a distributing valve 118 to which the inlet of the evaporating section 103 and a return pipe 119 are connected. The return pipe receives water from the tube 116.

Flow of combustion gas into the by-pass conduit 107 is controlled by a damper 121 which is connected for simultaneous inverse operation to dampers 122 controlling the flow of combustion gas through the flue 106. If the damper 121 is opened, the dampers 122 are closed so that more combustion gas flows through the by-pass 107 and less through the flue 106. Thereby the portion 113 of the second live steam superheater receives more heat whereas the second part 114 in the flue 105 and the reheaters 111 and 112 receive less heat. With this arrangement the outlet temperature of the live steam superheater 114 and of the reheater 111 may be maintained at the desired value. The valve 118 controls cooling of the second reheater 112 by controlling the amount of water flowing through the tube 116 whereby the reheat temperature of the low pressure steam is corrected.

If steam is tapped from the turbine the amount of the tapped steam instead of the amount of steam flowing through the reheaters may be used to produce a signal which acts as a disturbing signal in the controller for the internal heating or cooling of the reheaters.

Controllers 45, 50, 53, 71, 72 are constructed as proportional, integral, proportional integral, proportional differential, or proportional integral differential controllers, or as a combination thereof. Conventional apparatuses for performing the desired functions are available today.

The tube systems of the reheaters are preferably so arranged in combination with the steam generator that the heat transferred to the two reheaters remains the same after repositioning the heat center, or so that heat is supplied to the reheaters at a desired ratio. If the heat distribution to the reheaters must not be considerably changed when the heat center is relocated, the tube system of one reheater may be interspersed between the tube system of the other reheater, or one reheater may surround the other reheater, or the reheaters may be intimately combined in any other way. Parts of one or the other or of both reheaters may be interspersed or penetrate the high pressure tube system of the steam generator, or parts of the high pressure tube system may be interspersed in or penetrate the tube systems of the reheaters. The following arrangements are preferred:

(1) The second reheater is placed in the combustion gas stream between a portion of the first reheater having an internal tube and the outlet end portion of the first reheater.

(2) The second reheater is placed in the combustion gas stream upstream of the outlet end portion of the first reheater.

(3) A combination of (1) and (2).

If both reheaters are equipped for internal cooling or heating, the heating or cooling conduits may be arranged in parallel or in series with respect to the flow of the heating or cooling medium. Depending on the temperature conditions the heating or cooling conduits may be arranged downstream of or interspersed between the economizer, or they may by-pass this apparatus. In the by-pass arrangement the inlet temperature of the evaporator may be reduced.

If a heating conduit is connected to the high pressure tube system of the steam generator, it is preferably connected upstream of a live steam superheater. If two heating conduits are arranged in series, superheating between the two conduits may be advisable.

Fig. 5 is a diagram illustrating a combination of apparatuses which are conventional, per se, to practice the method according to the invention generally illustrated in Fig. 1. Fig. 5 particularly illustrates an instrumentation of the device indicated by a box 53 in Fig. 1. The temperature sensing device 25 connected to the pipe 24 through which the steam reheated in the first reheater 15 is conducted to the medium pressure turbine 27 includes a rod made of a material having a relatively small heat expansion coefficient. One end of this rod is rigidly connected to the pipe 24, the other end of the rod being connected to a two-arm lever one end of which rests on the pipe 24 and the second end of which actuates through a spring 160 a piston 161 controlling the pressure of the pressure fluid in a cylinder 161'. This pressure is conducted through a conduit 162 to a cylinder containing a piston 163. In addition to the temperature sensing device 25 a steam flow measuring device 26 is connected to the pipe 24. This device includes an orifice plate 170 and a diaphragm dividing the space in a container 171 into two chambers which individually communicate with the pipe 24 upstream and downstream of the orifice 170. The movements of the diaphragm are transmitted through a rod 172 to a swingable cam 173 on which rests a follower roller on one end of a rod 174, the other end of the rod being connected through a spring 175 to a piston 176 which controls the pressure of a pressure fluid in a cylinder 176'. The latter communicates with the interior of a cylinder 178' through a conduit 177. A piston 178 in the cylinder 178' is movable against a spring and is connected to an arm 179 extending radially from a rod 164' axially movably carrying a cam body 164. A spring 180 is interposed between the right end of the cam body 164 and a lever 181 which is swingable on a stationary fulcrum 182 and whose position can be adjusted by manipulating a hand wheel 183. By pressing the lever 181 against the spring 180, the pressure of the latter acting on the cam body 164 which is connected to the piston 163, the set point of the control which is responsive to the temperature of the steam in the pipe 24 can be adjusted. The piston 163 which is responsive to the temperature of the steam in the pipe 24 moves the cam body 164 in the direction of the rod 164' and the piston 178 which is responsive to the amount of steam flowing through the pipe 24 rotates the cam body 164 so that the temperature value is multiplied by the quantity value and the temperature signal is increased according to the amount of the steam flowing through the pipe 24. This increased signal is produced in a cylinder 167' containing a piston 167 which is connected through a spring 166 to a roller 165 following the cam body 164. The piston 167 controls the pressure of a pressure fluid in the cylinder 167', this pressure being transmitted through a conduit 168 to a cylinder 169' containing a piston 169.

The temperature sensing device 34 and the steam quantity measuring device 35 connected to the low pressure steam pipe 33 are of the same structure as the devices 25 and 26 and are operatively interconnected in the same manner as the temperature sensing device 25 and the quantity measuring device 26 connected to the medium pressure steam pipe 24. The devices 34 and 35 actuate a cam body 164'' which controls the movements of a piston 167''. The latter produces a pressure fluid signal which is conducted through a conduit 168' to the side of the piston 169 in the cylinder 169' which is opposite to the side of the piston on which acts the pressure in the conduit 168. In the conduit 168' one of the two chambers of a cylinder 150' is interposed. One wall of this chamber is formed by a piston 150 which is axially connected to a piston 150''. The latter being reciprocatingly movable in a second chamber of the cylinder 150' to which chamber a conduit 168'', which is a continuation of the conduit 168, is connected for fluid flow. The piston 169 is connected to and actuates a pilot valve 185 which controls the flow of a pressure medium in conduits 186 and 188. The conduit 186 terminates in a conduit 187 which leads to the piston rod sides of pistons forming part of the motor operators 63 and 65. The conduit 188 is connected to a conduit 188' which connects the other sides of said pistons. Valves are interposed in the conduits 187 and 188' for restricting the flow in these conduits, if desred. As seen in Fig. 1, the motor operators 63 and 65 actuate the distributing valves 13 and 8, respectively.

The piston rod of the double piston 150, 150'' is connected to and actuates a pilot valve 151 controlling the flow of a pressure fluid in conduits 190 and 192. The conduit 190 is connected to a conduit 191 communicating with the chamber at one side of a piston in a cylinder 191' forming the motor operator 56. A conduit 192' is connected to the conduit 192 and communicates with the other side of the piston in the cylinder 191'. A conduit 190' extending from the conduit 190 terminates in the lower chamber of a cylinder 152' below a piston 152. A conduit 192'' terminates in the lower chamber of the cylinder 152' above the piston 152. Valves are provided in the conduits 190', 191, 192' and 192'' for restricting flow through these conduits, if desired. The piston 152 is connected through a spring 154 to a piston 152″ controlling the pressure of a pressure fluid in an upper chamber of the cylinder 152′. This pressure is conducted through a conduit 46 to a pilot valve forming part of the motor operator 47 for actuating a fuel supply control valve 256 in a fuel supply pipe 255 for the tilting burner 57. The conduit 46 is connected by means of a conduit 68 to a pilot valve controlling the operation of the motor operator 48 for controlling a damper 257 in a combustion air duct 252 for supplying combustion air to the tilting burner 57.

The pilot valve of the motor operator 48 is operatively connected through a spring 250 to a cam 258 whose position is controlled by a diaphragm 251 which is responsive to the difference of the pressures in the air duct 252 upstream and at a restriction thereof. Similarly, the pilot valve of the motor operator 47 is connected through a spring 253 to a cam 259 which is actuated by a diaphragm 254 which is responsive to the pressures upstream and downstream of a throttling orifice in the fuel supply pipe 255.

The turbine governor 41 actuates a lever 200 which is swingable on a stationary fulcrum 201 and whose free end is operatively connected through a spring 202 to a piston 203 controlling the pressure of a pressure fluid in a cylinder 203′. This pressure is conducted through a conduit 44 to a pilot valve 153 forming part of the controller 45. The pilot valve 153 rests against a spring 156 whose tension can be adjusted by a hand wheel 157. Manipulation of the latter adjusts the set value for the speed of the turbine 19. The pilot valve 153 controls flow from and to the lower chamber in the cylinder 152′ below and above the piston 152. A conduit 158 connected to the conduit 44 terminates in the upper chamber of the cylinder 152′ below the piston 152″. The signal arriving through the conduit 158 effects proportional control of the fuel and air supply according to the speed of the turbine, whereas the signal acting on the pilot valve 153 effects an integral control of the fuel and air supply according to the turbine speed.

If the temperature of the medium pressure steam in the pipe 24 increases, the device 25 produces a signal of greater energy which is transmitted through the conduit 162 to the piston 163 and moves the cam body 164 to the right. The latter may also be rotated, if the steam quantity measuring device 26 indicates a change. The movements of the cam body 164 represent a multiplication of the temperature and quantity changes and produce a signal of increased pressure in the conduit 168 and an increased pressure on the left side of the piston 169. Assuming that the temperature of the low pressure steam in the pipe 33 has not changed, the piston 169 and the pilot valve 165 connected thereto will move to the right so that a pressure fluid flows through the conduits 188 and 188′ to the motor operator 63, turning the valve 13 in clockwise direction so that supply of superheated steam through the pipe 14 to the reheater 15 is reduced and a correspondingly greater amount of steam by-passes the reheater 15 through a pipe 16. This effects a reduction of the temperature of the steam in the reheater 15. Simultaneously, operating medium flows through the conduit 188′ into the motor operator 65 and turns the valve 8 in counterclockwise direction. This causes reduction of flow of feedwater which has been used for cooling the reheater 6 and an increase of feedwater flow directly to the evaporator 9 so that the cooling effect in the reheater 6 is reduced. The increased pressure signal in the conduit 168 acts also on the piston 150″ so that the double piston 150, 150″ and the pilot valve 151 connected thereto are moved to the left. This causes an increased flow of pressure medium through the conduits 192 and 192′ to the right side of the piston of the motor operator 56, moving the piston to the left and tilting the burner 57 downward so that the heat intensity received by the evaporating portion of the steam generator is increased. The increased supply of pressure fluid to the conduit 192 causes also an increased flow of pressure fluid through the conduit 192″ so that the piston 152 is moved downward. This causes a reduction of the pressure in the upper chamber of the cylinder 152′ and in the conduits 46 and 68 connected to the motor operators 47 and 48, respectively. Reduced pressure in the conduit 46 causes actuation of the fuel valve 256 in the closing direction. Reduction of the pressure in the conduit 68 causes movement of the damper 257 also in the closing direction.

The control mechanism operates analogously, if the temperature of the low pressure steam in the pipe 33 increases and the temperature of the medium pressure steam in the pipe 24 is not changed. The mechanism operates likewise, if both temperature sensing devices 25 and 34 report temperature changes and produce corresponding signals. The two temperature signals are compared in the device 169, 169′ which produces a signal corresponding to the difference of the temperatures and actuates the valves 13 and 8 and also the combustion apparatus correspondingly.

The controller 45 has a proportional-integral character and is responsive to signals corresponding to the speed of the turbine. Increasing speed causes clockwise movement of the lever 200 and reduction of the pressure signal produced in the cylinder 203′. This reduced pressure signal is conducted through the conduits 44 and 158 below the piston 152″ so that the pressure in the conduits 46 and 68 is reduced, causing throttling of the fuel and air supply. The signal arriving through the conduit 44 acts also on the pilot valve 153 and gradually reduces fuel and air supply until the pilot valve 153 is once more in equilibrium condition.

I claim:

1. An apparatus for controlling a steam generating, superheating, and reheating plant, comprising feedwater supply means, an evaporator receiving water from said supply means, a high pressure superheater receiving steam from said evaporator, a steam main receiving live steam from said superheater, a medium pressure reheater receiving steam from said high pressure superheater after the steam has been expanded, a low pressure reheater receiving steam from said medium pressure reheater after the medium pressure steam has been expanded, a firing apparatus supplying heat to said evaporator, to said high pressure superheater, and to said reheaters and including fuel supply means, air supply means, and means for changing the position of the center of the heating effect on said evaporator, high pressure superheater, and said reheaters, load responsive means operatively connected to said steam main and connected to said firing apparatus for controlling the fire intensity according to the load, a first heat exchanger for exchanging heat between the feedwater and the low pressure steam, a second heat exchanger for exchanging heat between superheated high pressure steam and medium pressure steam, first control means operatively connected to the outlet of said low pressure reheater and adapted to sense the temperature of the reheated low pressure steam and producing a corresponding control signal, second control means operatively connected to the outlet of said medium pressure reheater and adapted to sense the temperature of the reheated medium pressure steam and producing a corresponding control signal, means operatively connected to the inlet of said evaporator and to said first heat exchanger for controlling diversion of a portion of the feedwater to said first heat exchanger and operatively connected to said first control means for increasing the feedwater flow through said first heat exchanger upon rise of the temperature of the reheated low pressure steam above a predetermined level and vice versa, means operatively connected to said superheater and to said second heat exchanger for controlling diversion of superheated steam to said second heat exchanger and operatively connected to said second control means for decreasing the flow of superheated steam through said second heat ex-

changer upon an increase of the temperature of the reheated medium pressure steam above a predetermined value, and actuating means individually operatively connected to said fuel supply means, said combustion air supply means, said means for changing the position of the center of the heating effect, and said feedwater supply means; said actuating means being operatively connected to said control means for actuating the means to which said actuating means are connected according to the control signals produced by said control means.

2. An apparatus as defined in claim 1 wherein said actuating means for said fuel supply means and for said air supply means are interconnected for interdependent actuation of said fuel supply means and of said air supply means.

3. An apparatus as defined in claim 1 wherein said means for changing the position of the center of the heating effect is in the form of a tilting burner.

4. An apparatus as defined in claim 1, including a feedwater supply pipe connected to the inlet of said evaporator, said means for controlling diversion of a portion of the feedwater to said first heat exchanger including a valve interposed in said feedwater supply pipe, a conduit branching from said feedwater supply pipe upstream of said valve and being connected to said valve, said first heat exchanger being interposed in said conduit, said valve stopping flow of feedwater through said feedwater supply pipe to said evaporator and simultaneously permitting flow of feedwater through said conduit to said evaporator, and vice versa.

5. An apparatus as defined in claim 1, including a pipe interposed in the steam flow through said superheater, said means for controlling diversion of superheated steam to second second heat exchanger including a valve interposed in said pipe, a conduit connected to said valve and

terminating in said pipe downstream of said valve, said pipe extending through said second heat exchanger for transferring heat from the superheated steam to the medium pressure steam, said valve stopping flow of steam through said pipe and simultaneously permitting flow of steam through said conduit, and vice versa.

6. An apparatus according to claim 1, including a duct for the combustion gases produced by said firing apparatus, one of said reheaters comprising two sections interconnected in series relation for the flow of the steam therethrough and placed in said duct, the second of said reheaters being interposed between said sections, whereby the combustion gases consecutively pass one of said sections, the second reheater, and the second of said sections.

7. An apparatus according to claim 6 wherein said reheaters are of the tubular type, a pipe being located within at least a portion of the tubes forming one of said sections, said pipe and said portion forming one of said heat exchangers.

8. An apparatus according to claim 6 wherein said reheaters are of the tubular type, a pipe being located within the tubes forming the reheater section which is, with respect to the flow of the combustion gases, downstream of the reheater which is interposed between said sections, said pipe also extending within a portion of the reheater section which is upstream of the interposed reheater, said pipe forming the heat exchange surface of one of said heat exchangers.

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