Dec. 11, 1945.　　J. P. VOLLRATH　　2,390,902

CONTROL SYSTEM

Filed Aug. 28, 1942　　2 Sheets-Sheet 1

FIG. I.

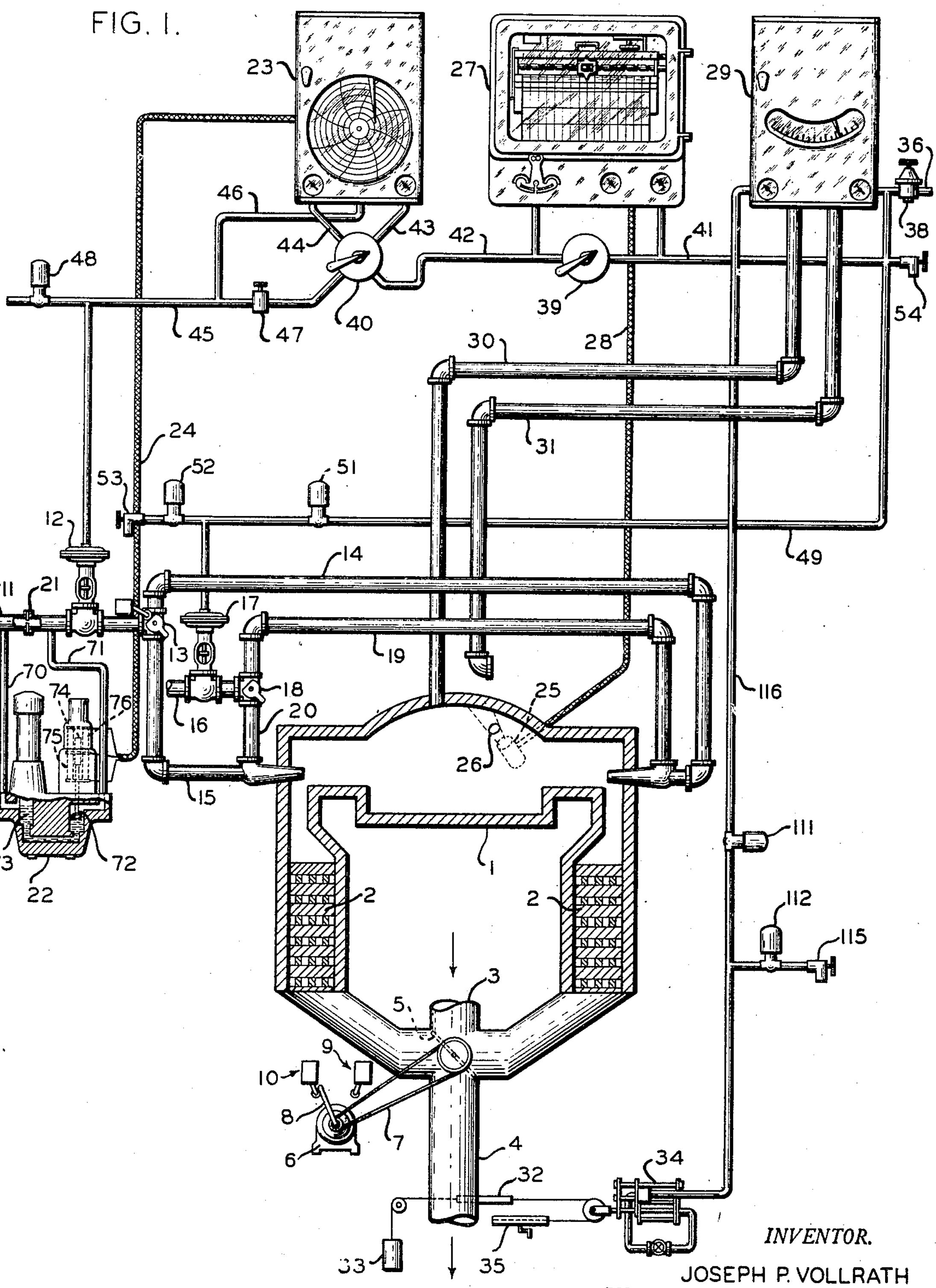

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FIG. 2.

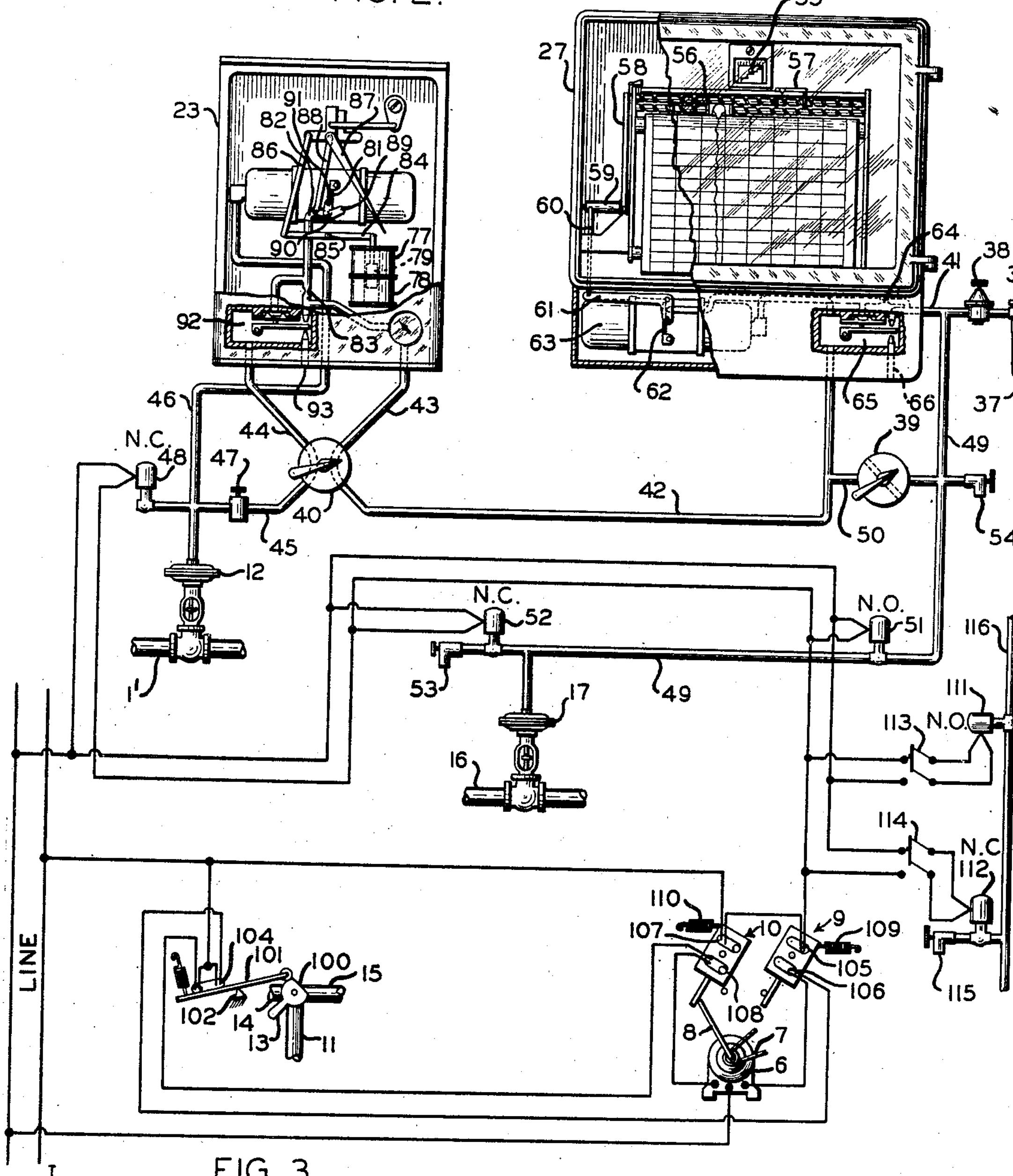
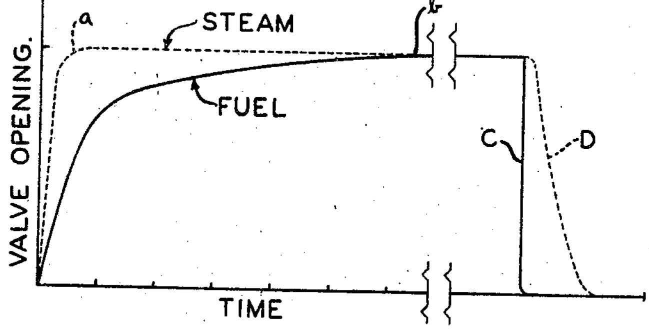


FIG. 3.



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Patented Dec. 11, 1945

2,390,902

UNITED STATES PATENT OFFICE

2,390,902

CONTROL SYSTEM

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Application August 28, 1942, Serial No. 456,531

9 Claims. (Cl. 236—15)

The present invention relates to the control of regenerative furnaces, and more particularly to a control system for controlling the supply of fuel to a regenerative furnace of the open hearth type.

It is an object of the present invention to maintain the desired fuel flow at a constant, equal rate to both ends of the furnace irrespective of variations in fuel pressure, the injection steam pressure or temperature changes in the burner piping.

It is an object of the invention to provide a control system which will maintain a heat balance in the checker system of the furnace when the latter is reversed at periodic intervals. It is a further object of the invention to prevent entry of fuel into the furnace after reversal takes place until the waste gas dampers are completely reversed and sufficient combustion air has been supplied to the burner ports. It is a further object of the invention to eliminate flooding of the furnace with unburnt fuel immediately following a reversal operation by automatically opening the fuel valve slowly at a predetermined but adjustable rate from the time air begins to flow to the burner ports.

It is a further object of the invention to provide a control system that is instantly transferable from automatic control to manual control by means of the operation of suitable selector valves. A further object of the invention is to reduce the fuel input below that determined by the setting of the fuel controller when the temperature in the furnace reaches a predetermined maximum. This prevents damage to the furnace roof, saves fuel and shortens the heating time for the charge.

In the control system of this invention, when it is time to reverse the operation of the furnace, a suitable switch is thrown to initiate the reversing mechanism. When this takes place the fuel supply is cut off quickly and the injection steam supply is cut off at a slower rate in order to completely purge the burners. While this is occurring the combustion air dampers are reversed and upon completion of this operation, the injection steam to the opposite side of the furnace is quickly turned on and the fuel supply is turned on at a controlled rate so that when firing is resumed the initial flow of fuel will be low and will gradually increase. The combustion air dampers have limit switches on them which prevent the opening of the fuel valve until such time as these dampers are completely reversed. By having the fuel and steam cut off and opening rates positively adjusted for each end of the furnace, manual operation of the control valves will in no wise effect the speed with which the fuel is cut off and turned on. This insures that the method of starting the fuel supply will effectively prevent harmful and wasteful flooding of the furnace with unburned fuel and will admit fuel as rapidly as it can be burned. Also, the rate of fuel admission is correct for each furnace and is independent of variations caused by different operators.

The various features of novelty which characterize my invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, however, its advantages and specific objects obtained with its use, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described a preferred embodiment of the invention.

In the drawings:

Figure 1 is a schematic showing, partly in section, of an open hearth reversal control system,

Figure 2 is a view showing more in detail the manner in which the control instruments operate to control the supply of fuel and the sequence of the reversing operations, and

Figure 3 are curves showing the rate of steam and fuel supply and cut-off.

Referring to Figure 1, there is shown at 1 an open hearth furnace having checkers 2 which can be connected with a combustion air supply 3, or a stack 4 by means of a suitable damper 5. This damper is moved from the position shown to a position in which it will connect the left checker with the air supply and the right checker with the stack by means of a reversible electric motor 6 that serves to drive the damper through a transmission mechanism 7, shown herein as being a belt. As the motor 6 operates, an arm 8 attached to the shaft thereof can be used to operate switch unit 9 or switch unit 10 at the limits of operation of the motor when the damper has been properly positioned.

The fuel for the furnace is supplied through the pipe 11 past a pneumatically operated control valve 12 and an automatically or manually operated reversing valve 13 to either pipe 14 or pipe 15, depending upon whether the right or left end of the furnace is being fired. The injection steam for the fuel is supplied through a pipe 16 having in it a pneumatically controlled valve 17 and a manually or automatically operated reversing valve 18, to pipes 19 or 20 depending upon whether the right or the left end of the furnace is being fired. The control valves 12 and 17 are of the type which are closed by a spring and which are opened by means of air pressure acting on a diaphragm on the valve in opposition to the spring. The reversing valves 13 and 18 are shown herein as being separate but are preferably operated together by some suitable operating connection so that the valves will simultaneously direct fuel through pipe 14 and steam through pipe 19 or fuel through pipe 15 and steam through pipe 20. Operation of the valves 13 and 18 serves, through a mechanism to be described later, to reverse the operation of the furnace and energize the motor 6 to reverse the damper 5.

Located in the fuel supply pipe 11 is an orifice 21, the pressure across which is measured by a manometer or other flow measuring device 22. This manometer forms part of a flow controlling instrument 23 to which it is connected by a cable 24, the controller acting to adjust the valve 12 in a manner to be described in response to variations in the fuel to keep the latter constant. The temperature of the furnace is measured by means of a radiation pyrometer 25 which is directed through an opening 26 in the back wall of the furnace toward the roof thereof. This pyrometer is connected to a potentiometer type recording control instrument 27 by means of a cable 28.

The furnace pressure is regulated by means of a furnace pressure controller 29 that is connected with the interior of the furnace by means of a pressure line 30. This controller is also provided with a compensating line 31 which runs parallel to the line 30 and terminates adjacent the opening in the furnace through which the line 30 extends. The furnace pressure controller serves to operate a damper 32 in the stack 4 to control the pressure in the furnace. This damper is normally biased in a closing direction by a weight 33 and may be opened by a pneumatic piston 34 which is controlled by the instrument 29. A hand operated winch 35 is also used to adjust the damper 32.

Each of the instruments 23, 27, and 29 is of the air operated type, and they are supplied with air from a line 36 through a filter 37 and pressure regulator 38. The system is so set up that the fuel valve may be operated by either the fuel controller and the temperature controller or the fuel controller alone. These operations may be obtained by means of proper manipulation of a bypass valve 39 and a manual-automatic valve 40 in a manner to be set forth in detail below.

Air is supplied from the supply 36 through the filter 37 and pressure regulator 38 to a pipe 41 which leads to the instrument 27. From this instrument, air passes through pipe 42 to the valve 40 and through pipe 43 to the instrument 23. Air is modulated by this instrument in accordance with the flow of fuel and is supplied through a pipe 44 to the valve 40 and a pipe 45 to the fuel control valve 12. The modulated air is also supplied through a pipe 46 to the follow-up provisions of the control instrument that is located in casing 23. Located in the pipe 45 between the valve 40 and the valve 12 is a restriction 47 that is adjustable to vary the speed with which changes in pressure set up by the instrument 23 can be applied to the valve 12. Also in this pipe is a normally closed solenoid valve 48 that can be opened upon occasion to exhaust the air line and permit the valve 12 to close quickly. The instrument 27 can be by-passed to cut out its effect on the control of the fuel by means of air which is supplied directly from the source through pipe 49 and an equalizing connection 50, in which the valve 39 is located, to the pipe 42.

Air is supplied to the steam valve 17 by means of a continuation of the pipe 49. This pipe has in it a normally open solenoid valve 51 and a normally closed solenoid valve 52 which upon occasion can be closed and opened respectively to control the operation of the injection steam supply. Beyond valve 52 is a restriction 53 that is adjustable to vary the speed with which air can be exhausted from the line 49 when the valve 52 has been opened. There is also provided in the line 49 ahead of the valve 51 an adjustable restriction 54 that is used as a constant bleed in the air line when the mechanism is on manual control.

The instrument 27 may be a potentiometric instrument of the type shown and described in Krogh Patent, No. 2,159,971, granted May 30, 1939, and includes a motor actuated relay mechanism through which the deflection of the pointer 55 of a galvanometer connected to and responsive to the voltage of the pyrometer 25, adjusts a potentiometer recorder carriage 56 to different positions, corresponding to the different values of said voltage. The carriage 56 cooperates with a normally stationary control table 57, which may be adjustable along the path of movement of the carriage 56, and the position of which, along said path, is a measure of the normal value of the voltage to which the galvanometer of the instrument responds.

The adjustment of the carriage 56 relative to the stationary control table 57, gives up and down movements to a link 58 and thereby oscillates a rocking element 59. The latter is connected by a link 60 to an actuating lever 61 by which the flapper valve 62 of the instrument 27 is adjusted.

The instrument 27 as shown, also comprises a mechanism 63 through which an initial change in the control pressure due to the adjustment of the flapper 62, produced by a change in the position of the carriage 56, results in an immediate follow-up adjustment of the control pressure, partially neutralizing the effect of the initial change therein, and in a delayed compensating adjustment neutralizing in whole or in part, the effect on the control pressure of the follow-up adjustment.

As shown in Fig. 2, the air under pressure is supplied by the pipe 41 to the inlet side of a restricted orifice 64 to actuate the mechanism 63, and to actuate the control valve 12. The air is passed to the valve and to the mechanism 63 through a pilot valve chamber 65 which receives air from the pipe 41, and bleeds air through a vent 66, as required to maintain a pressure in the chamber 65 proportional at all times to the pressure in the nozzle 62.

For the purpose of the present invention, the only important characteristic of the instrument 27, is that it varies the pressure in the pilot valve chamber 65, in predetermined accordance with variations in the roof temperature of the furnace as measured by pyrometer 25. Further reference to the details of construction and operation illustrated and described in the above mentioned patent, is thus unnecessary.

The instrument 23, which, as previously stated, regulates the air pressure supplied to the pipe 45, is responsive to the rate of fuel flow through the main 11 to the pipes 14 and 15. The instrument 23 may be of any suitable type and is made responsive to the rate of fuel flow, by means comprising the measuring orifice 21 formed in the pipe 11, and the U tube manometer 22. The latter has one leg connected by a pressure transmitting pipe 70 to the pipe 11 at the inlet side of the orifice 21, and has its other leg connected by a pressure transmitting pipe 71 to the pipe 11 at the outlet side of the orifice 21. A float 72 resting on the manometer sealing liquid 73, which may be mercury, is given rising and falling movements as a result of the sealing liquid displacement produced by increases and decreases respectively, in the rate of flow through the pipe 11.

The float 72 supports and gives movement to an armature 74 of the transmitter element of an inductance bridge of the character disclosed in the Harrison Patent No. 1,743,853. The said transmitter element comprises two end to end vertically disposed coils 75 and 76 surrounding a manometer leg portion in which the armature 74 is axially movable. The instrument 23 includes the receiver element of the inductance bridge, which comprises vertically disposed end to end coils 77 and 78, in which the core 79 is axially movable. The remote ends of the coils 77 and 78 are connected by conductors in cable 24, to the remote ends of the coils 75 and 76. The adjacent ends of the coils 77 and 78 are connected by other conductors also in cable 24 to the adjacent ends of the coils 75 and 76. The bridge is energized by an alternating current supply.

With the inductance bridge arranged and energized as described, an upward movement, for example of the transmitter armature 74 increases the impedance of the coil 76 and decreases the impedance of the coil 75. Those impedance changes result in a change in the relative current flows through the transmitter and receiver coils and thereby cause an increase of current flow through the coil 77 relative to the current flow through the coil 78, and causes the armature 79 to move upward until the resultant increase in the impedance of the coil 77 relative to the impedance of the coil 78, makes the impedance ratio of coils 77 and 78 equal to the impedance ratio of the coils 75 and 76. This reestablishes the balanced condition of the bridge. The movement given to the armature 74, and the position of the receiver armature 79 is thus dependent upon the position of the armature 74, for all values of the differential of the pressures at the opposite sides of the orifice 21.

The instrument 23 includes a flapper valve 81 and a nozzle 82, the latter being connected to the air supply pipe 43 through a restricted orifice 83. The relative adjustment of the flapper 81 and nozzle 82 is dependent upon the position of the armature 79. Changes in position of the armature 79, effect the adjustment of the flapper valve 81 through a lever 84 pivoted at 85, and from one end of which the armature 79 is suspended. The opposite end of the lever 84 is connected by a link 86 to an oscillating element which may carry an exhibiting arm 87 for indicating or recording the fuel flow. The oscillatory movements of the lever 84 effected by movements of the armature 79, give movements to the flapper 81 relative to the nozzle 82. In the commercial form of the instrument 23, shown in outline in Fig. 1, the flapper valve 81, is thus actuated through the link 84 and means through which the up and down movements of that link give up and down movements to the upper end of link 88. The lower end of the link 88 is pivotally connected to a flapper actuating lever 89, which is pivoted at 90 and provided with a pin or shoulder 91 which engages the flapper 81. The flapper is moved away from the nozzle 82 by a clockwise adjustment of the lever 89, and is spring biased for movement toward the nozzle when the lever 89 is turned counter-clockwise.

The form of air controller used is disclosed in the patent of Moore, No. 2,125,081, granted July 26, 1938, and is provided with means to automatically adjust the position of the supporting pivot 90 for the lever 89 on the initial change in the control pressure in the nozzle 82. The purpose of such adjustment of the pivot 89, is to effect a follow-up adjustment of the flapper 81 partially eliminating its previous adjustment which produced the initial control pressure change. Further reference to the follow-up adjustment mechanism is unnecessary herein, because that mechanism is now known, is in commercial use, and is fully disclosed in the above mentioned Moore patent, and also because of the fact that for the general purposes of the present invention, the pivot 90 may be stationary, and the lever 89 may be operated through a link 88 directly connecting the lever 89 to the lever 84.

The instrument 23, as shown in Fig. 2, includes a pilot valve mechanism comprising a chamber 92 and a vent 93 like the chamber 65 and vent 66, respectively, of the pilot valve mechanism of the instrument 27. The pilot valve mechanism receives air from the pipe 43 and discharges air through the vent 93 as required to maintain an air pressure in the chamber 92 in constant proportion to the pressure in the nozzle 92. The pipe 44 is connected to the chamber 92, and the pressure transmitted to the valve 11 is thus directly dependent upon the pressure in the nozzle 82, and hence upon the rate at which fuel passes through the pipe 11 to the furnace.

The remaining structure which is necessary in order to produce proper operation of the steam and fuel valves upon the reversal of the furnace consists of switches which are used to control the various solenoid valves that have been mentioned. To this end, the valve 13 that is used to reverse the supply of fuel from one end of the furnace to the other has formed on it cam 100 that serves to position a cam follower 101 which is pivoted at 102 and normally biased into engagement with the cam by means of a spring. This follower has mounted on it a single pole, double throw switch 104 which is used to control the operation of the damper 5 by the motor 6, and, indirectly, the operation of the solenoid valves.

As this motor moves to the limits of its travel after operating the damper, switch boxes 9 and 10 are operated by the rod 8 that is carried by the motor, as has previously been described. Each of these switches boxes has in it two single pole, single throw switches. The box 9 has in it a switch 105 that is used to control the operation of the solenoid valves and has in it a switch 106 that serves as a limit switch for the motor 6. The box 10 has in it a switch 107 that serves to control the solenoid valves and a switch 108 that acts as a limit switch for the motor 6. The box 9 is biased in a clockwise direction by a spring 109 and the box 10 is biased in a counter-clockwise direction by a spring 110.

In the normal operation of the instrument the air supply comes through pipes 41 and 42 to the instrument 23, where it is modulated in accordance with the flow of the fuel to adjust the opening of the valve 12 in order to keep the fuel supply constant. If the roof temperature exceeds some predetermined amount, the pen carriage 56 will move up-scale to a point where it will engage the control carriage 57 and act through the mechanism 58 to operate the controller 63. This serves to reduce the pressure supplied through pipe 42 to the instrument 23 and therefore, to partially close the valve 12 and reduce the supply of fuel, normally the fuel is controlled entirely by the controller 23 and the controller 27 accordingly acts as a limit controller to reduce the supply of fuel when the furnace roof gets too hot. If it is desired to do away with the limit control, the valve 50 can be moved from the position shown in Figures 1 and 2 counter-clockwise to a position in which the equalizer connection 50 is open. Air will then pass through pipes 49 and 50 and valve 39 directly to the pipe 42.

If it is desired to manually control the supply of fuel to the furnace, the valve 39 will be turned to a position in which the equalizer connection 50 is open and the valve 40 will be rotated to connect pipes 42 and 45. Thereafter, the pressure applied to the fuel valve 12 can be regulated by means of the pressure regulator 38 to adjust the opening of the valve 12. During this time, the bleed restriction 54 will permit a reduction in pressure in order to permit closing of the valve. Without this restriction, pressure could only be built up in the system.

Upon reversal of the furnace, it is desired to quickly cut off the fuel supply from, for example, the right end of the furnace, reverse the damper 5, and slowly turn on the fuel on the left end. After the fuel has been turned off, from the right end, that burner must be purged in order to prevent a flare-back and there must be sufficient combustion air in the furnace before fuel is turned on at the left end. This operation is best shown by the curves in Figure 3 in which the solid line curve is that of the opening of the fuel valve and the dotted line curve is that of the opening of the steam valve. It will be seen that upon reversal, the steam valve will quickly be opened as shown by the abrupt raise of the curve from the zero point to point *a*. The fuel valve will be opened slowly as shown by the slow raise of the solid curve to point *b*. This means that the injection steam will be turned on full before the fuel is turned on so that as the fuel is turned on it will immediately begin to burn, and the furnace will not be flooded. When reversal of the furnace takes place, the fuel valve will be turned off quickly, as shown by the abrupt drop in the curve at *c* while the steam valve will be shut off more slowly as shown by the gradual drop in the curve at *d*. This means that the fuel will be turned off and the remaining steam will be used to completely purge the burners prior to the time that reversal actually takes place.

When the furnace is to be reversed, the fuel and steam valves 13 and 18 are simultaneously rotated, either manually or automatically in any known manner to direct the fuel and steam from pipes 14 and 19, respectively to pipes 15 and 20. During this operation the low portion of cam 100 on the handle of valve 13 will come under the follower 101 to permit the follower to move in a clockwise direction. The switch 104 is therefore moved so that the contacts in its left end will be opened and those in the right end will be closed. This closes a circuit through those contacts and switch 106 to energize motor 6 for rotation in a direction to reverse the valve 5 to direct combustion air from the right to the left end of the furnace and to connect the right end of the furnace with the stack. Immediately after the motor 6 begins to rotate the arm 8 will move to the right enough to permit switches 107 and 108 to close.

When the switch 107 closes, a circuit will be completed through that switch and switch 105 to energize each of the solenoid valves 48, 51 and 52.

When the solenoid valve 48 is energized, this normally closed valve is opened and air is exhausted from the pipe 45 beyond the restriction 47 so that valve 12 can close, thus quickly shutting off the supply of fuel to the furnace. When solenoid valve 51 is energized, this normally opened valve will be closed to cut off the supply of air through pipe 49 to the valve 17. At the same time, normally closed valve 52 will be opened so that air can bleed from the line 49 and valve 17 through the restriction 53 to the atmosphere. Thus the valve 17 will be closed at a rate dependent upon the speed with which air can bleed through restriction 53. Thus the fuel valve is quickly closed, and the steam valve is closed at a slower rate permitting the burner to be purged.

The valves 12 and 17 remain closed until such time as arm 8 on the motor 6 moves to a position in which switch box 9 is moved in a counterclockwise direction. This opens limit switch 106 to stop the motor 6, and at the same time opens switch 105 to deenergize the three solenoid valves. When valves 51 and 52 are deenergized, air can immediately come through line 49 to valve 17 to quickly open this valve. Upon the closure of valve 48, air can be applied to the diaphragm of valve 12 at a speed depending upon the opening of restriction 47 thereby slowly opening this valve. At this time, the furnace is firing from the opposite end, or the left end in Figure 1, at a rate depending upon the fuel controller 23. The steam has been turned on immediately and the fuel oil has been turned on slowly so that the furnace will not be flooded before combustion of the fuel starts.

During the time that the furnace is operating the furnace pressure controller 29 operates to vary the air pressure applied through a pipe 116 to the piston 34 to vary the position of the damper 33 in order to maintain the furnace pressure constant. Located in the pipe 116 is a normally open solenoid valve 111 and located in a branch of the pipe 116 is a normally closed solenoid valve 112 which will permit this pipe to bleed to the atmosphere through an adjustable restriction 115.

Depending upon the fuel that is being used and the manner in which the furnace 1 is being operated, it may be desirable to lock the damper 32 in place while the furnace is being reversed or it may be desirable to completely shut off the stack 4 during reversal since the reversing operation may cause a major disturbance in the furnace pressure. If it is desired to lock the damper 32 in place a switch 113 will be closed so that the normally open valve 111 will be energized to close at the same time the reversal takes place. In this fashion, the pressure in the lower part of pipe 116 and in cylinder 34 is maintained during the reversing operation. If, however, it is desired to completely close the damper during the reversing operation, the switch 114 will also be closed so that when valve 111 is closed the normally closed valve 112 will be open to permit air to escape from the cylinder and to permit the damper 32 to be closed by operation of the weight 33. The speed with which the damper closes will depend upon the adjustment of restriction 115.

From the above detailed description of the operation of my control system, it will be seen that I have provided a system which is adapted to control the fuel supplied to a regenerative furnace at all times during the operation of this furnace, and to reduce the supply of fuel when the temperature of the roof reaches some dangerous point. I have also provided means to quickly turn off the fuel at one side of the furnace and to slowly turn it on at the other side when a reversal operation takes place. I have also provided means to control the furnace pressure during operation of the furnace and to interlock this control with the reversing mechanism to either lock the damper in place or completely close the damper during the reversal of the furnace.

While in accordance with the provisions of the statutes, I have illustrated and described the best form of my invention now known to me, it will be apparent to those skilled in the art that changes may be made in the form of the apparatus disclosed without departing from the spirit of my invention as set forth in the appended claims, and that in some cases certain features of my invention may sometimes be used to advantage without a corresponding use of other features.

Having now described this invention, what I claim as new and desire to secure by Letters Patent is:

1. In a regenerative furnace control system in which fuel and an injection fluid are supplied alternately to each end of the furnace, a pipe line to direct fuel to the furnace ends, a pipe line to direct injection fluid to the furnace ends, a pneumatic control valve in each of said pipe lines, a valve in each of said pipe lines to direct the material therein to either end of the furnace, said latter valves being located between said pneumatic valves and the furnace whereby a single pneumatic valve in each of said fuel and injection fluid pipe lines may control the flow of material to both ends of the furnace, a supply of air to each of said pneumatic valves, electrically actuated means separately operative to control the supply of air to said pneumatic valves and means to simultaneously energize said electrically actuated means.

2. In a regenerative furnace control system in which fuel and a fuel injection medium are supplied alternately to each end of the furnace, a pipe line to supply fuel to both ends of the furnace, a reversing valve to direct fuel through said pipe line to one end or the other of the furnace, a pneumatic control valve located in said pipe line on the supply side of said reversing valve, a supply of air under pressure to operate said pneumatic valve, means to restrict the flow of air to said pneumatic valve whereby said pneumatic valve may not be opened faster than some predetermined rate, and means operative to quickly exhaust the air supplied to said pneumatic valve whereby said pneumatic valve may close quickly, the arrangement being such that the fuel on either end of the furnace may be turned on slowly and turned off quickly by operation of the same pneumatic valve, depending upon the position of said reversing valve.

3. In a regenerative furnace reversing system the combination of fuel supply lines to the opposite ends of the furnace, a pneumatic valve to control the supply of fuel, a supply of air for said valve, electrically operated means to control the supply of air to said valve, a pipe line to supply an injection medium to ends of the furnace, a second pneumatic valve in said pipe line to control the supply of injection medium, other electrically operated means to control the supply of air to said second pneumatic valve, an air supply duct for the ends of said furnace, a damper in said supply duct to direct combustion air to one end or the other of said furnace, a motor to operate said damper, means to operate said motor and means operated by said motor to actuate said electrically operated means to close both of said pneumatic valves while said motor is running.

4. In a regenerative furnace reversing system, the combination of fuel and injection medium supply lines, a pneumatic valve in each of said supply lines, a supply of air for each valve operative to open the same when applied to the valve, electrical means to control the application of air to each of said valves, an air supply duct for said furnace, a damper means in said duct, said damper means serving to reverse the supply of combustion air to said furnace, a motor to operate said damper means, and means operated by said motor to actuate said electrical means in a manner to relieve the supply of air to said valves while said motor is running whereby said valves will close when said damper means is being operated.

5. In a regenerative furnace control system, the combination of means to supply air to either end of the furnace, a stack to be connected to either end of the furnace, damper means operative to connect said means and stack to opposite ends of the furnace, means to measure the pressure in the furnace, a second damper in said stack to regulate the pressure of the furnace, means operated by said furnace pressure measuring means to adjust said second damper, means to reverse the furnace and mechanism operated by said last means to close said second damper while the furnace is being reversed.

6. In a regenerative furnace control system, means to supply combustion air to either end of the furnace, a stack adapted to be connected to either end of the furnace, damper means movable from a first position in which the combustion air is directed to one end of the furnace and the stack is connected to the other end to a second position in which the combustion air is directed to the second end and the stack is connected to the first end, means to measure the furnace pressure, means to regulate the furnace pressure operated by said measuring means, a motor to drive said damper means from its first position to its second position and mechanism operated by said motor to lock said regulating means in place while said motor is operating.

7. In a regenerative furnace reversing system, the combination of fuel and injection medium supply lines, a pneumatic valve in each of said supply lines, a supply of air for each valve and adapted to open the same when applied to each valve, electrical means to control the application of air to each of said valves, a damper to control the pressure in the furnace, a supply of air to control the operation of said damper, additional electrical means to control the application of air to said damper, reversing means to reverse the supply of combustion air to the furnace, a motor to operate said reversing means, and means oper-

ated by said motor to actuate each of said electrical means while said motor is running.

8. In a regenerative furnace control system, the combination of means to supply fuel, an injection medium and air to each end of the furnace, a stack to be connected to either end of the furnace, air operated valve means to control individually the supply of fuel and injection medium to the furnace, reversing means operative to connect the supply of air to either end of the furnace, an air operated damper to regulate the furnace pressure, motor means to operate said reversing means, and mechanism controlled by said motor to control the supply of air to said valves and damper during the time that said motor is running to reverse the furnace.

9. In a regenerative furnace reversing system having pipes to supply fuel to each end of the furnace, pipes to supply an injection medium to each end of the furnace, and having an air duct to supply combustion air to each end of the furnace, a valve in each of the pipes to supply fuel and injection medium to the furnace ends to direct the fuel and injection medium to one or the other of the furnace ends, a pneumatic valve in each pipe upstream from said previously mentioned valves, said pneumatic valves being opened by the application of air thereto, electrical means to control the application of air to said pneumatic valves, a damper in the air duct to direct the combustion air to one end or the other of the furnace, motor means to operate said damper, means operated upon operation of said first mentioned valves to reverse the fuel and injection medium to the furnace to start said motor means operating to operate said damper, and means operated by said motor means to energize said electrical means during the time said motor means is operating to relieve the air pressure in said pneumatic valves.

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