AUTOMATIC COMBUSTION SAFETY CONTROL SYSTEM

Filed July 7, 1931 3 Sheets-Sheet 1

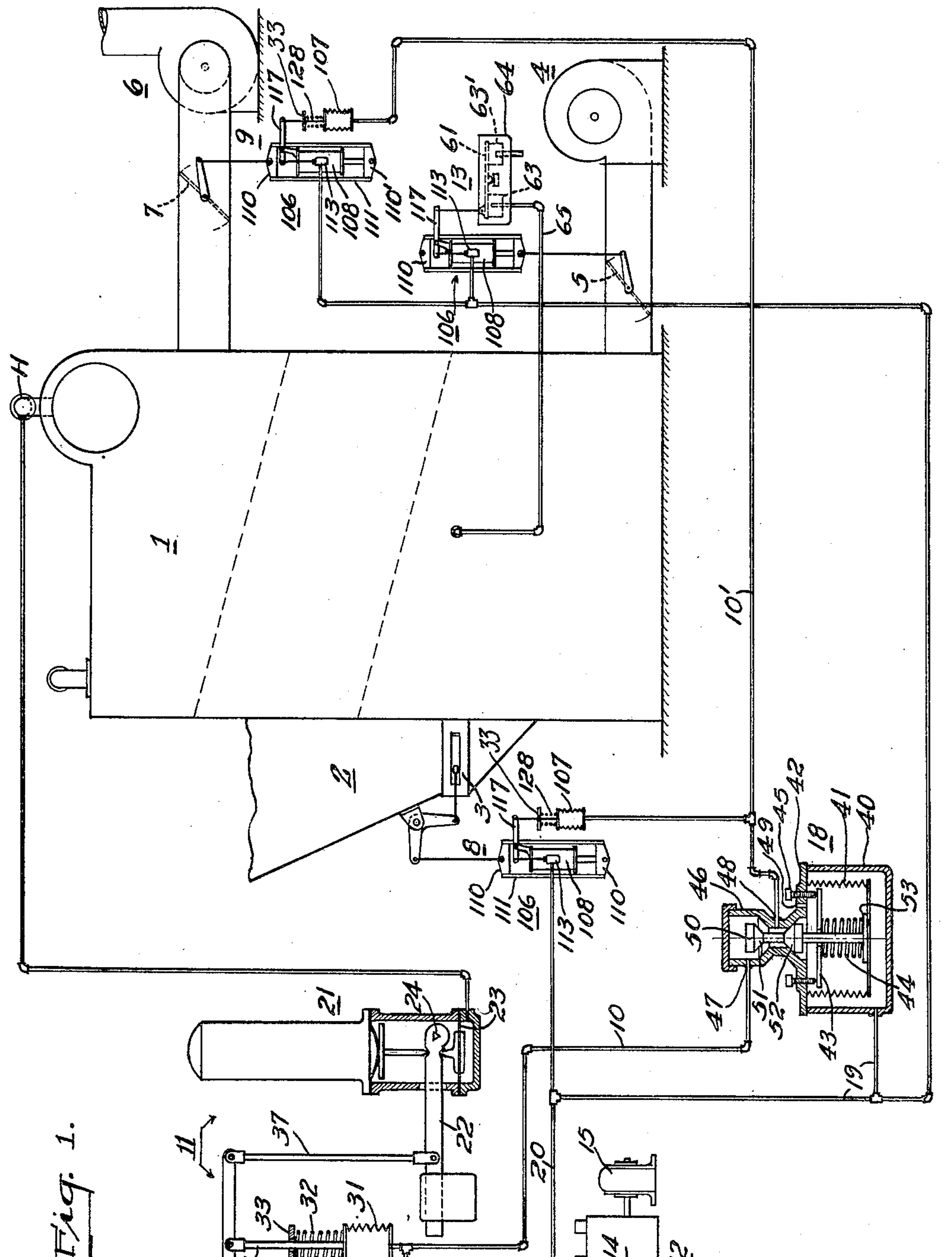

Fig. 1.

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April 25, 1933. T. A. PEEBLES 1,905,745

AUTOMATIC COMBUSTION SAFETY CONTROL SYSTEM

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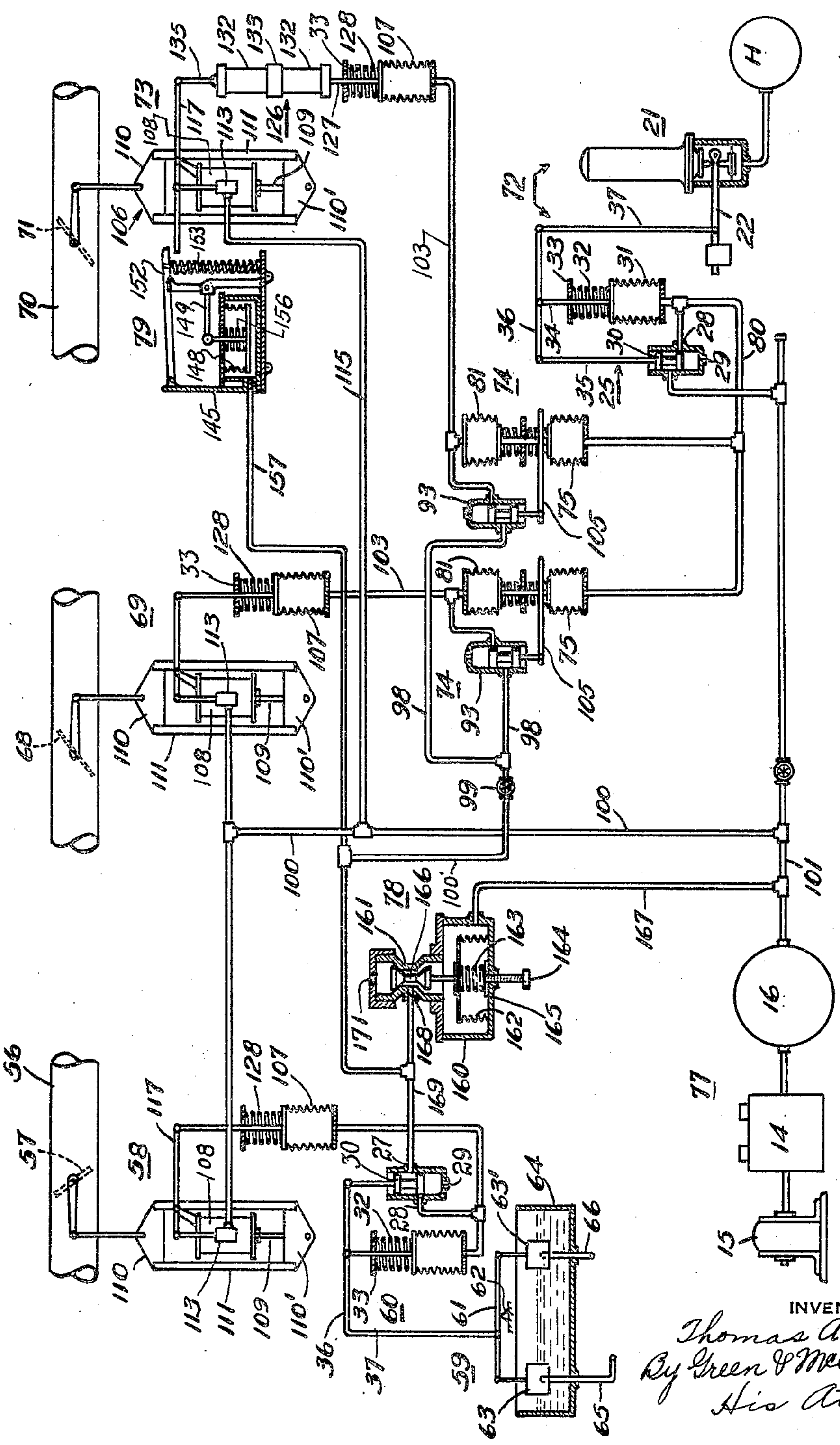

Fig. 2.

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AUTOMATIC COMBUSTION SAFETY CONTROL SYSTEM

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Fig. 3.

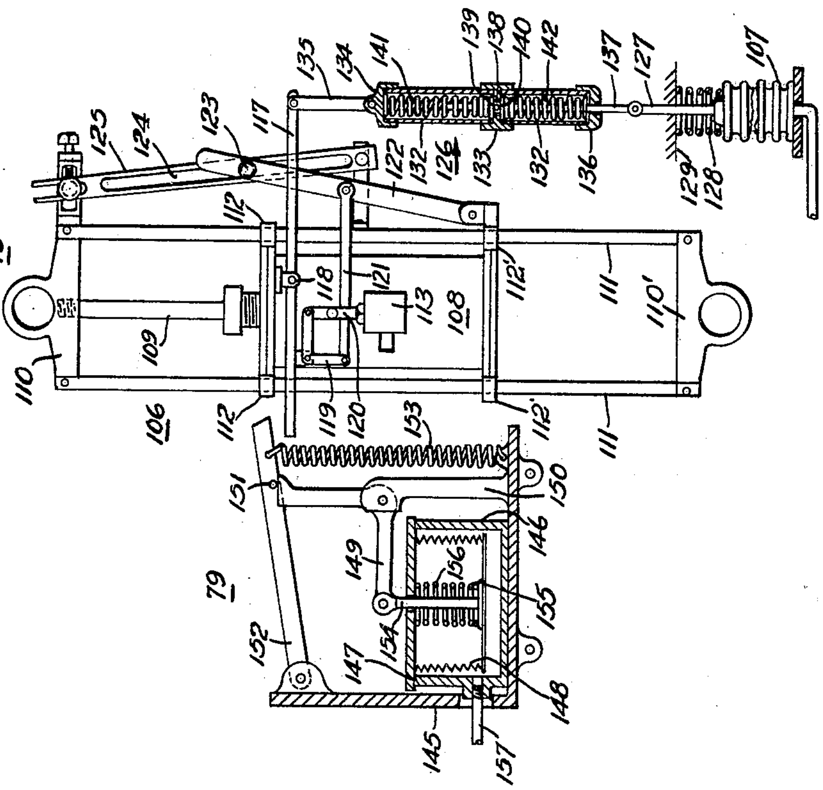
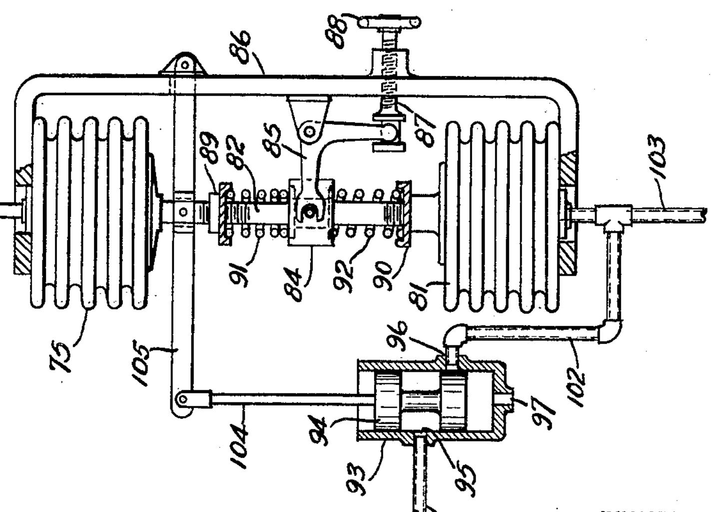


Fig. 4.



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UNITED STATES PATENT OFFICE

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AUTOMATIC COMBUSTION SAFETY CONTROL SYSTEM

Application filed July 7, 1931. Serial No. 549,178.

This invention relates to boiler furnaces having automatic combustion control systems therefor, and more particularly to safety control systems adapted to function in emergencies in such manner as to either secure continuity of boiler operation and holding of the load or to affect discontinuity of boiler operations and a dropping of the load.

Boiler furnace practice, as known to me, involves the use of control systems for automatically governing or regulating combustion in accordance with some variable, for example, the load on the boiler. The type of control selected for any particular furnace depends largely upon the type of fuel which the furnace is designed to burn.

Generally stated, the control systems employed regulate the draft and the supply of fuel in accordance with the boiler load, at the same time maintaining such relation between the draft and the fuel supplied as to insure complete and efficient combustion.

Having equipped a furnace or a battery of furnaces with automatic combustion control systems, it follows that continuity of furnace operation, under automatic control, depends primarily upon the continuity of operation of the control system.

In some cases, continuity of boiler furnace operation and the ability of the boilers to hold the load are of primary importance, this being especially so where coal is burned by the furnaces.

When coal is utilized as a fuel, the combustion control system should be so arranged that the feed of coal and the draft is turned on full, in case the control system fails, even though an excessive amount of generated steam is the result. In such a case, the furnaces may be brought back to normal operation by manual control and adjustment of the fuel and draft. By resorting to manual control, until the automatic control has been repaired and placed into operation, continuity of operation and the holding of the load may thus be attained.

Where other fuels (gas for example), dangerous to human life, are employed, the protection of human life is of prime importance while continuity of operation and the holding of the load are of secondary importance. Therefore, in case of failure of the combustion control systems, it becomes important to shut off the gas supply to the burners and to open up the drafts in order to insure that unburned gases may be forced out of the furnace to the stack. If this is done the escape of gas into the boiler rooms or other locations where men would be at work, is prevented, thus protecting human life.

In automatic combustion control systems, the control devices, relays, etc., are usually actuated by fluid under pressure, as compressed air. It, therefore, follows that if the source of compressed air fails, the control system will cease to function.

An object of this invention is, therefore, to provide for the storage of motive fluid under pressure, and to utilize such stored fluid when the pressure of the source falls to a predetermined value, to effect either increased combustion until manual control can be instituted, where solid fuels such as coal are burned, or a complete shutting down of combustion in case fuels dangerous to human life are employed.

In one case continuity of furnace operation and the holding of the load are attained, while in the other, discontinuity of furnace operation and a dropping of the load are accomplished, each for a definite purpose as set forth above.

Other objects of the invention are to provide a safety control device that shall function under predetermined conditions to perform the above operations on the combustion control elements of boiler furnaces.

Further objects not specifically mentioned above will, in part, be apparent and will, in part, be obvious from the following description taken in conjunction with the accompanying drawings in which:

Figure 1 is a diagrammatic view of a boiler furnace and an automatic combustion control system, arranged and constructed in accordance with the invention, such system being adapted to furnaces burning solid fuels such as coal;

Fig. 2 is a diagrammatic view of an automatic control system embodying the invention and adapted for use on furnaces employing gas fuels, such as are dangerous to human life if permitted to escape;

Fig. 3 is a detailed view of a fuel control regulator shown in Fig. 2 and in a slightly modified form in Fig. 1 (in the latter case the regulator is employed to control the feed of fuel and the induced draft mechanism) and a safety relay arranged to operate the regulator to a certain position in case of failure of the source of motive fluid supplied to the control system; and

Fig. 4 is a view of a compensating relay embodied in the system of Fig. 2.

Throughout the drawings and the specification, like parts are designated by like reference characters.

In Fig. 1 of the drawings, a furnace 1 is illustrated to which fuel, such as finely divided coal, is delivered from a hopper 2. The rate of fuel delivery may be controlled by a feeder 3. Feeder 3 may be of any type suitable for the purpose, as for example, the well known disc feeder.

Air for combustion may be supplied to the furnace by a forced draft fan 4 which is driven by a motor (not shown). A damper 5 may be utilized to regulate the pressure of the air supplied for combustion. The furnace is also provided with an induced air fan 6 for withdrawing products of combustion from the furnace chamber through the various passes, superheaters, etc. to the stack (not shown). A damper 7 may be interposed between the induced draft fan and the furnace uptake to regulate the suction induced by the fan 6. The induced draft fan may be driven by a motor (not shown).

The feeder 3 and the induced draft damper 7 are arranged for operation by pressure actuated regulators 8 and 9 of like construction.

The motive fluid, under pressure, for actuating the pressure responsive control elements of these regulators may consist of compressed air delivered thereto through a sending pipe line 10 from a master regulator 11 that responds to variations in the plant load, as for example, variations in the demand for steam upon the boiler. Master regulator operates in response to the demand for steam on the boiler and causes a varying pressure to be delivered from a source 12 of compressed air to pipe line 10. The master regulator is so arranged that when the demand for steam increases, the pressure delivered from the source 12 to the line 10 and thence to the pressure responsive elements of the induced draft fan and the coal feeder regulators, is decreased, while if the demand for steam decreases the pressure delivered from the source to these regulators is increased.

In the operation of boiler furnaces it is desirable to maintain the pressure in the furnace combustion chamber constant at some predetermined value. The pressure may be maintained substantially constant by properly adjusting the position of the forced draft damper 5. In order to so adjust forced draft damper 5 that the pressure in the furnace combustion chamber shall be maintained substantially constant, a regulator 13, which responds to the furnace chamber pressure, is provided. The regulator 13 may be of the balanced float type such as illustrated in my U. S. Letters Patent No. 1,800,400, granted April 14, 1931, and assigned to John M. Hopwood. Regulator 13 controls the operation of a pressure operated motor such as illustrated in connection with the apparatus illustrated in detail in Fig. 3 of the drawings.

Whenever the position of the induced draft damper is changed the suction pressure in the uptake of the furnace changes thereby causing a change in pressure in the furnace combustion chamber. If the chamber pressure increases, regulator 13 responds and causes the motor controlled thereby to shift forced draft damper 5 towards its closed position thereby reducing the pressure of the air delivered to the combustion chamber and restoring the pressure therein to that constant value sought to be maintained. If the pressure in the furnace chamber decreases, as a result of a change in position of the induced draft damper, regulator 13 responds and causes the fluid pressure motor to adjust forced draft damper 5 towards its open position thereby increasing the furnace chamber pressure.

The source of fluid pressure employed for operating the various regulators referred to above comprise a compressor 14, for example, an air compressor, which is driven by a motor 15, preferably an electric motor. The compressor delivers air to a storage tank 16 to which the master regulator is connected by a pipe 17.

So long as the pressure of the air supply for operating the regulators is normal, furnace 1 will operate in the usual manner and the draft mechanisms and the fuel feeder will be so controlled that the rate of combustion will vary with variations in the furnace load and the demand for steam. So much of the control system as has been describe above would in case of failure of the air supply cause a shut-down of the furnace and a dropping of the load.

Since coal, as a fuel is not inherently dangerous to human life, continuity of operation of a furnace burning coal and the holding of the load is of prime importance. Therefore, in case of failure of the source of air supply for operating the various regulators referred to above, or the fan motors, because of failure of the electric power supply, means must be provided to insure continuity of furnace operation and the holding of the load during such emergencies. Therefore, in order to prevent a shutting down of the furnace and the dropping of its load, a pressure responsive safety relay 18 is provided.

As illustrated, safety relay 18 has a pressure connection through pipes 19 and 20 with pressure line 17 leading from tank 16 to the master regulator, and with sending line 10 and receiving line 10′ to which the pressure responsive control elements of regulators 8 and 9 are connected. So long as the pressure of the air at the source is above a predetermined minimum value, the control system will be governed by the master regulator in the normal or usual manner because any pressure impulses sent out by master regulator 11 will pass through the relay; but if the pressure of the air supply source falls below this minimum value, relay 18 operates to shut off communication between the master regulator and the fuel feed and induced draft damper regulators. At the same time the pressure receiving line leading from relay 18 to the pressure elements of regulators 8 and 9, is opened to the atmosphere.

When receiving line 10′ is open to the atmosphere, pressure elements of regulators 8 and 9 are subjected to atmospheric pressure. When subjected to atmospheric pressure, the motive parts of the regulators being connected to the main pressure line will be actuated to their wide open positions whereby the maximum amount of fuel is delivered to the furnace and the maximum amount of induced draft is set up. In other words, the coal feeder will be shifted to its full open position and the induced draft damper will be adjusted to its wide open position. This is accomplished because the minimum air pressure that has caused relay 18 to operate in the manner described, is sufficient to cause these regulators to adjust the coal feed regulator and the induced draft damper to wide open position.

When the induced draft damper is open wide, the pressure in the furnace chamber will fall sharply, hence the regulator 13 will respond to such fall in pressure and actuate forced draft damper to its wide open position. The furnace will then be operating at maximum load. This may result in such rapid generation of steam that the steam blow-off valves will function, hence steam will be wasted. However, this is not so serious as a complete shut down of the boiler furnace, and a dropping of the load, would be. When the furnace is operating wide open or at maximum capacity, the coal feed and the forced and induced draft dampers may be adjusted manually until the furnace is generating the amount of steam demanded of it. Manual control of the furnace may be resorted to until the fault in the automatic control system has been rectified. The furnace will be controlled automatically as soon as the pressure at the air supply source has been increased to a value above the minimum value at which the safety relay operated to adjust the furnace for maximum steam generating capacity.

Master regulator

The master regulator 11 comprises a pressure responsive or metering device 21 which, when connected to the steam header of the furnace, measures the actual pressure of the steam. The steam pressure will vary as the load varies. Metering device of regulator 11 follows these variations and causes a weight arm 22 associated with a pressure responsive element 23 to pivot about its fulcrum or pivotal support as at 24. An increase in steam pressure causes the weight arm to turn clockwise, and a decrease in pressure causes it to turn counterclockwise.

The particular pressure metering device illustrated in the drawings is of the type shown and described in United States Letters Patent No. 1,371,243, granted to John M. Hopwood on March 15, 1921. While it is preferred to use this type of metering device other types of pressure regulators may be employed without departing from the spirit or scope of the invention.

The master regulator includes also a master sending relay 25. Sending relay 25 comprises a multi-way valve 26 having an inlet port 27 connected to the pressure line 17 leading from pressure tank 16. The valve also includes a discharge port 28 and an exhaust port 29. Communication between the inlet port and the discharge port, or between the discharge port and the exhaust port, may be established by a valve member 30 which is movably disposed within the bore of the valve body. The sending relay includes also a pressure responsive bellows 31, the interior of which is connected to discharge port 28 of the valve and to sending line 10. When expanding, the bellows operates against a compression spring 32, the tension of which may be adjusted by means of an adjustable stop 33. The adjustable stop and the spring are disposed about a vertically movable push rod 34 which is attached to the top side of the bellows.

Valve member 30 is provided with a stem 35, the upper end of which is pivotally connected to a floating lever 36. Floating lever 36 is also pivotally connected medially of its ends to the upper end of push rod 34. The opposite end of the floating lever is connected by a link 37 to the weight arm of the metering device so that as the weight arm rocks on its fulcrum, valve member 30 moves either up or down, depending upon the direction in which the weight arm moves, to thereby control the pressure in sending line 10 and receiving line 10′.

If weight arm 22 turns counter-clockwise, in response to a decrease in steam pressure, (such decrease taking place when the demand for steam increases, or when the combustion is insufficient to maintain a given steam pressure), floating lever 36 turns clockwise about its pivotal support on the push rod. When so turning, valve member 30 is moved upwardly to a position in which communication is established between the interior of the bellows 31, receiving line 10′ and the exhaust port 29, whereby a reduction in pressure is effected in the sending and receiving lines. Such reduction of pressure in receiving line 10′ causes coal feed regulator 8 and induced draft fan regulator 9 to operate and increase the amount of coal fed to the furnace and the furnace suction by opening the induced draft damper. In response to such opening of the induced draft damper, furnace pressure regulator 13 operates to open the forced draft damper to increase the air supplied, thereby reestablishing normal pressure in the furnace combustion chamber.

If the pressure in bellows 31 decreases, spring 32 causes the bellows to collapse whereby push rod is moved downwardly thereby turning floating lever 36 counter-clockwise about its pivotal connection with link 37. Such turning of floating lever 36 moves valve member 30 downwardly to that position in which communication between outlet port 28 and exhaust port 29 is shut off, thereby preventing further reduction of pressure in the sending line.

An increase of steam pressure in the steam header results in the reverse operation of the master sending relay. An increase in pressure causes weight arm to turn clockwise whereby the levers associated with the relay are caused to move in such manner that valve member 30 will be moved downwardly to the position in which pressure line 17 is connected to the outlet port 28 of the valve. The pressure in bellows 31 and the sending and receiving lines 10 and 10′ is, therefore, increased. Such increase in the receiving line pressure causes regulator 9 to shift induced draft damper 7 towards its closed position and regulator 8 to adjust coal feeder 3 to that position in which the amount of fuel delivered to the furnace is reduced. Since the furnace chamber pressure increases, when the induced draft damper is adjusted towards its closed position, regulator 13 will operate to adjust the forced draft damper towards its closed position, thereby to restore the furnace chamber pressure to normal.

Fuel feeder regulator and induced draft damper regulator will be described hereinafter in connection with a description of Fig. 2 of the drawings.

Safety relay 18 comprises a casing 40 having an inlet port to which air supply pipe 17 is connected by pipes 19 and 20. The relay includes also a pressure responsive bellows 41 which is secured to the underside of a cover 42 attached to the top of the casing. A circular plate 43 disposed within the bellows is mounted on a compression spring 44. Adjustment screws 45 threaded through the cover exert pressure on plate 43. By adjusting these screws, the pressure at which the plate bears on the spring may be adjusted to any desired value.

A valve body 46 having screw thread engagement with cover 42 is provided with inlet and outlet ports 47 and 48 and an exhaust port 49. Port 47 is connected to sending line 10 leading from the interior of bellows 31 of master sending relay, while port 48 is connected to the receiving line 10′ that serves regulators 8 and 9.

A valve plug 50 having valves 51 and 52 spaced apart is disposed within the valve body to control the flow of air from the master sending relay to the pressure elements of regulators 8 and 9. The valve plug carries an extension that extends downwardly through plate 43. The lower end of the extension, as illustrated, is provided with a head portion 53 of relatively large area that bears against the end of the bellows.

When the pressure of the air or fluid in the supply line 17 is above a predetermined minimum value, the pressure in the chamber acting on bellows 41 will be such as to hold the valve in the position shown in the drawings. If the pressure falls below this minimum value, valve member 50 will move downwardly until communication is shut off between ports 47 and 48 of the valve body. When in this position port 48 is in communication with the interior of the chamber and vent port 49 formed in the cover of the relay. The pressure in receiving line 10′ leading to the pressure elements of regulators 8 and 9 will, therefore, be reduced to atmospheric. In response to such reduction in pressure, these regulators will adjust induced draft damper to its open position and cause the fuel feeder to move to its maximum fuel delivery position.

The control system illustrated in Fig. 2 is adapted for use on furnaces in which fuels, dangerous to human life, are burned. Gas may be one of these fuels. Boilers burning gas fuel, it will be understood, may be provided with induced and forced draft mechanisms, regulators for controlling the draft mechanisms, and a regulator for controlling the amount of gas delivered to the furnace burners.

In case the control system fails, either because of some defect in the system as such, or because of failure of the electric power supply, safety relays are provided to effect immediate shutdown of the furnace. These relays are so arranged that the fuel valve regulator will be actuated to that position in which the fuel valve is closed, and the draft regulators will be operated to that position in which sufficient draft through the furnace is provided to insure that any unburned gases will be carried from the furnace to the stack, thereby avoiding the possibility of such unburned gases escaping into the boiler room or other parts of the plant in which the men are at work.

In the system illustrated in Fig. 2, air from a forced draft fan. such as shown in Fig. 1, is delivered through a conduit 56 in the furnace combustion chamber. A damper 57 is employed to so regulate the flow of air in conduit 56, that a substantially constant pressure is maintained in a furnace chamber. To obtain such regulation a regulator 58 like regulator 8 of Fig. 1 is provided to operate damper 57.

In order that regulator 58 may be operated by and in accordance with changes in the furnace combustion chamber pressure a float regulator 59 and a pressure sending relay 60 are provided. Relay 60 controls the delivery of pressure to the pressure responsive element of regulator 58 as will be explained more fully hereinafter. Since relay 60, as illustrated, is of the same construction as master relay 25 of master regulator 11, and operates in the same manner, corresponding parts are designated by the same reference characters.

Float regulator 59 comprises a lever 61 fulcrumed at 62 and inverted floats or bells 63 and 63′ mounted on opposite ends of the lever. The bells or floats are partially immersed in a liquid held in a container 64, the liquid acting as a seal whereby the pressure medium confined within the bells or floats is prevented from escaping to the atmosphere. The interior of float 63 is subjected to the furnace pressure which is communicated thereto through a pipe 65. The interior of bell or float 63′ is subjected to atmospheric pressure by means of an open ended pipe 66. Thus, as the pressure within float 63 varies, lever 61 rocks on its fulcrum, and as it rocks sending relay 60 is operated to effect the required pressure variations sent to the pressure responsive control element of regulator 58.

Float regulator 13, illustrated in Fig. 1, is essentially like regulator 59 both in structure and operation, hence corresponding parts are similarly designated.

The induced draft of the furnace may be controlled by means of a damper 68 disposed in the furnace uptake and a regulator 69. Regulators 69 and 58 are arranged to operate in response to variations in the demand for steam as measured by variations in the pressure in steam header H.

Gas fuel may be delivered to the furnace burners (not shown) through a conduit 70 in which a valve 71 is disposed for regulating the amount of gas delivered to the burners. In order that valve 71 may be adjusted to regulate the amount of fuel delivered by and in accordance with the demand for steam, hence in accordance with variations in the control pressure sent out by a master regulator 72, a regulator 73 is provided.

The control pressure impulses for initiating and governing the operation of induced draft regulator 69 and fuel valve regulator 73 are sent out by master regulator 72 like that shown in Fig. 1. This regulator is arranged to be operated by and in accordance with variations in the steam pressure in the header H. Since master regulator 72 is like master regulator 11, like parts and elements are designated by the same reference characters.

In order that regulators 69 and 73 may be adjusted independently so that their respective operating characteristics may be changed to suit particular operating requirements, compensating relays 74 are provided, such as illustrated in detail in Fig. 4.

The compensating relays are so arranged that pressures greater than, equal to, or less than the pressures sent out by master regulator 72 may be delivered to the pressure elements of regulators 69 and 73.

Generally stated, each compensating relay comprises two oppositely acting pressure responsive elements 75 and 81, the former receiving variable pressure impulses from master regulator 72 and the latter receiving pressure impulses from the main source of air or fluid pressure and deliver such to the pressure responsive control elements of regulators 69 and 73. The motive pressure for each of regulators 58, 69 and 73 is delivered thereto from air or fluid pressure supply source 77.

When normal operating conditions obtain and the control system is funtioning in its intended manner, regulators 69 and 73 control the amount of gas fuel delivered to the furnace burners, and the position of the induced draft damper, by and in accordance with variations in the plant load; while the forced draft regulator operates to so adjust the forced draft damper that a substantially constant pressure is maintained in the combustion chamber of the furnace.

In the system illustrated, the draft and fuel regulators are designed to operate over a given control pressure range, that is, if the pressure sent out by the master regulator 72 is at a predetermined minimum value, the induced draft damper and the fuel valve will be adjusted to substantially their wide open positions, or if the pressure sent out by the master regulator is at a predetermined maximum value, the fuel valve and the induced draft damper will be actuated, by their respective regulators, to their closed positions.

As stated hereinbefore, adjustments in the induced draft damper occasion pressure variations in the furnace combustion chamber. The forced draft damper regulator responds to these pressure variations to so adjust the forced draft damper that the pressure in the combustion chamber will be maintained substantially constant. However, if the induced draft damper is actuated to its closed position, the forced draft damper will also be actuated to approximately its closed position.

It often happens that electric power lines are disrupted for a time, and during the interim, electric motors and the like will be inoperative. In the present case, failure of electric power would cause the air compressor motors and the fan motors to stop. If these motors are out of operation long enough, the control system will fail for want of air or fluid pressure. Storage tanks 16 of Figs. 1 and 2 however, would permit operation for a short time.

In case of failure of the control system, because of failure in the air supply therefor, for example, the above mentioned regulators, operating in their normal manner, would open the fuel valve and the draft dampers. When this happens gas may leak into the furnace from the gas line, but on account of the low draft conditions, the gases may not burn completely. Also the draft being low, the unburned gases may not be carried out of the furnace to the stack, hence unburned gases might escape from the furnace into the boiler room, elevator shafts or other places, where men are at work, and asphyxiate them. Not only that, the accumulation of such escaping gases may cause serious explosions and fires.

To avoid the escape of unburned fuel gas to places or locations where human life may be endangered, on account of failure in the control system, safety relays 78 and 79 are provided. Relay 78 functions when the pressure at the supply source 77 falls below a predetermined minimum value. When this relay functions, the control pressure for forced and induced draft damper regulators is shut off, whereby as the furnace chamber pressure drops, dampers 57 and 58 will be actuated towards their open positions to increase the amount of air supplied to the furnace. Safety relay 78 when it functions, also causes safety relay 79 to operate fuel valve regulator 73 to that position in which the fuel valve 71 is completely closed. With the forced and induced draft dampers open and the fuel valve closed, any unburned gases in the furnace will be carried to the stack thereby avoiding the dangers mentioned above.

When the safety relay 78 operates to affect the above mentioned operations, sufficient air under pressure is available at the source of supply to provide the necessary motive power for the regulators 58, 69 and 73 to cause them to fully perform their intended functions when the emergency arises.

With the gas supply completely shut off from the furnace burners, it will be apparent that the furnace will drop its load. However, this is of minor importance as compared to the consequences that might follow in case the furnace or furnaces were not completely shut down. When the fault in the control system or the causes contributing to the failure of the control system, has been rectified, the furnace or furnaces may be put into operation on automatic control.

Master regulator 72

Master regulator 72 is like master regulator 11 illustrated in Fig. 1, hence corresponding parts and elements are designated by the same reference characters as applied to regulator 11.

When changes in steam pressure take place in header H, metering device 21 of regulator 72 responds and operates valve 26 of the sending relay. If the pressure in the header rises, on account of a decreased demand for steam, valve plug 30 is moved downwardly to the position in which air from the air supply source 77 is transmitted to the interior of bellows 31 of the relay and a sending line 80. Sending line 80 conveys this pressure to pressure responsive elements 75 of compensating relays 74 whereby, in response to such pressure, elements 75 cause pressures to be transmitted to the pressure responsive elements of regulators 69 and 73.

If the pressure of the steam in header H falls, on account of increased demand for steam, metering device 21 operates to move valve plug 30 upwardly to that position in which pressure from the interior of bellows 31, sending line 80 and element 75 of compensating relays 74, is permitted to escape through port 29 of valve 26. Upon a reduction of the pressure within elements or bellows 75 of the compensating relays, a corresponding reduction in pressure is effected within the pressure responsive elements of regulators 69 and 73. Such reduction in pressure causes these regulators to adjust the induced draft damper 69 and fuel valve 71 towards open position, thereby increasing the furnace suction and the amount of fuel delivered to the furnace. The increased suction caused by the opening of induced draft damper 69 causes the furnace chamber pressure to fall below that predetermined value sought to be maintained constant therein. In response to such reduction in furnace chamber pressure, float regulator 59 operates to decrease the pressure in the pressure responsive element of regulator 58 whereby the forced draft damper is caused to be adjusted towards open position. Thus, the furnace chamber pressure is increased by increasing the pressure of the air delivered thereto.

If the pressure of the steam in header H rises, the opposite action takes place, hence the pressure delivered to bellows 75 of compensating relays 74 and the pressure delivered to the pressure responsive element of regulators 69 and 73 are increased. In response to such increase in pressure, the regulators adjust the dampers and the fuel valve associated therewith towards their closed positions thereby decreasing the furnace suction and the amount of fuel delivered to the furnace. When the furnace suction decreases, the pressure in the furnace chamber tends to rise. In response to such tendency float regulator 59 operates to increase the pressure delivered to the pressure responsive element of regulator 58 whereby forced draft damper 57 is adjusted towards its closed position to thereby reduce the pressure in the furnace chamber.

Compensating relays 74

Compensating relays 74, as illustrated in Fig. 2, are identical in construction, hence only one of these relays has been illustrated in detail. One of these relays is illustrated in detail in Fig. 4 of the drawings.

As illustrated in Fig. 4, relay 74 comprises pressure responsive bellows 75 and a pressure responsive bellows 81 having a push rod 82 interposed therebetween and secured to the free or expanding ends of the bellows. A collar 84 embraces rod 82, but permits the rod to move freely therethrough. A bell crank 85 pivotally mounted on frame 86 of the relay is utilized to change the position of collar 84.

In order to permit of adjusting or changing the position of collar 84 by means of bell crank 85, a screw 87 mounted on frame 86 is provided. The lower end of the bell crank operates in an annular groove formed in the inner end of the screw so that as the screw is turned into or out of frame 86, the bell crank is turned on its pivotal support. For convenience a hand wheel 88 may be utilized for turning screw 87.

Push rod 82 is provided with a flanged collar 89 disposed above collar 84, and with a similar flanged collar 90 disposed below collar 84. Between collars 89 and 84 and 84 and 90, compression springs 91 and 92 are disposed. Thus, by moving the collar 84 upwardly, spring 91 is compressed and the tension in spring 92 is released; therefore, bellows 75 will be subjected to a higher spring tension than bellows 81. Thus, it will be apparent that the pressure required to expand bellows 75 a predetermined amount must be such as will overcome the resistance of the bellows and the increased spring tension of spring 91. Thus as the spring tension in spring 91 is increased, the pressures supplied to bellows 75 must be correspondingly increased in order to obtain the same deflection of bellows 75 and movement of push rod 82, as would obtain with a lower spring tension and a lower applied pressure.

If collar 84 is moved downwardly by bell crank 85, thereby increasing the spring tension in spring 92, the spring loading on bellows 81 will be increased. Therefore the pressure applied to the interior of bellows 81 must be such as will overcome the inherent resistance of the bellows to movement as well as the resistance of spring 92. Thus, as the spring tension of spring 92 is increased, the pressure applied to the interior of bellows 91 must be correspondingly increased in order to obtain the same expansion of the bellows as would be obtained by a lower pressure and a lower spring tension.

Relay 74 also includes a multi-wave valve 93 having a valve plug 94 therein. Valve plug 94 controls communication between inlet port 95 and discharge port 96 and between discharge port 96 and exhaust port 97.

Inlet port 95 of the valve is connected by a pipe line 98, having a valve 99 therein, to a pipe line 100′, which is under the control of safety relay 78. Pressure line 101 is directly connected to tank 16 of fluid pressure supply source 77.

Discharge port 96 is connected by a pipe 102 to a sending line 103. Sending line 103 also communicates with the interior of bellows 81, and conveys fluid pressure impulses to the pressure responsive elements associated with regulators 69 and 73.

Valve plug 94 of the compensating relay has a valve stem 104 which is pivotally connected to one end of a lever 105. Lever 105 is pivotally connected to push rod 82 and frame 86 of the relay. Thus, as the push rod 82 moves up or down, valve plug 94 is moved up or down.

When pressure is delivered from sending relay 25 of master regulator 72, bellows 75 expands moving push rod 82 downwardly thereby causing lever 105 to turn counterclockwise and move valve plug 94 downwardly to that position in which fluid pressure flows from pipe line 98 through the valve and pipe 102 into pipe line 103 and the interior of bellows 81. The pressure so admitted to the interior of bellows 81 causes it to expand moving rod 82 upwardly. As rod 82 moves upwardly, valve plug 94 is returned to the position shown in Fig. 4, this being its neutral position. When in neutral position, port 96 of valve 93 is closed.

If the pressure in bellows 75 decreases, the opposite action takes place. Valve plug 94 is moved upwardly in this case, permitting fluid pressure from pipe line 103 and the interior of bellows 81 to escape through port 96 and exhaust port 97 to the atmosphere, thereby reducing the pressure in bellows 81, pipe line 103 and the pressure responsive elements associated with regulators 69 and 73. As soon as an equilibrium is reached between the pressures in bellows 75 and 81, valve plug 94 is returned to its neutral position.

Regulator 73 and safety relay 79

Regulator 73 embodies all the features and structural elements embodied in regulators 8, 9, 58 and 69. It also embodies the structural elements of the fluid pressure motor associated with regulator 13. Therefore, a description of regulator 73 will be sufficient for all the regulators mentioned above. Regulator 73 comprises a fluid pressure motor 106 and a pressure responsive element, such as a bellows 107, to which pressure impulses are transmitted from one of the compensating relays.

Regulator 106 comprises a cylinder 108 having a reciprocating piston therein (not shown). The piston has a piston rod 109 attached thereto upon the outer end of which is mounted a cross head 110. Depending from cross head 110 are side rods 111 that operate in guides 112 and 112′ attached to the heads of the cylinder. The lower ends of the side rods are connected by a cross head 110′.

A reversing valve 113 mounted on the cylinder is provided to admit pressure either to the top or bottom side of the piston according to which position valve 113 is operated. Pressure from the supply source for operating the piston in cylinder 108, is conveyed through pipe line 100 and pipe line 115 to valve 113, line 100 being connected to pipe 101 which is connected directly to tank 16.

Valve 113 is operated by a rocker bar 117 pivotally mounted at 118 on the cylinder, and a bell crank 119 which is pivotally mounted on the rocker bar. One leg of the bell crank is pivotally connected to stem 120 of the valve. The vertical leg of the bell crank is pivotally connected to a link 121 which in turn is pivotally connected to a bar 122 which is pivotally mounted at its lower end on the framework of cylinder 108. The upper end of bar 122 carries a pin 123 which is disposed in a slot 124 formed in an angling bar 125. Angling bar 125 is carried by one of the side rods 111.

Bar 117 is connected by means of a flexible link 126 to a vertically movable push rod 127 carried by bellows 107. Thus as bellows 107 expands and contracts, rocker bar 117 will be turned either clockwise or counter-clockwise on its pivotal support 118. Bellows 107 operates against a spring 128 disposed between the top of the bellows and a stationary support 129. Thus, the bellows will expand or contract substantially directly in proportion to the pressure applied at the interior thereof. If the pressure in bellows 107 increases, it expands moving push rod 127 and link 126 upwardly thereby turning rocker bar 117 counter-clockwise as viewed from the drawings. Counter-clockwise movement of the rocker bar results in a downward movement of bell crank 119 and valve stem 120. When valve stem 120 is moved downwardly, pressure is admitted to the underside of the piston of cylinder 108 whereby piston 109 and its cross head 110 and the side bars 111 are moved upwardly. As the side rods move upwardly angling bar 125 is also carried upwardly, thus causing bar 122 to turn clockwise upon its pivotal support. When bar 122 turns clockwise, link 121 is moved to the right as viewed from the drawings thereby turning bell crank 119 counter-clockwise. Thus valve stem 120 is moved upwardly and returned to its neutral or closed position thereby shutting off the pressure to the cylinder. Upon a further increase in pressure of bellows 107, the same action takes place and after each upward movement of piston rod 109, angling bar 125 operates to return the valve to its neutral position as aforesaid.

If the pressure in bellows 107 decreases, the opposite action takes place. Thus, rocker bar 117 will turn clockwise thereby moving valve stem 120 upwardly to the position in which pressure is admitted to the top side of the piston in cylinder 108. The piston rod 109 will then move downwardly and as it moves angling bar 125 moves downwardly turning bar 122 counter-clockwise. Counter-clockwise movement of bar 122 causes the bell crank 119 to turn clockwise whereby the valve is returned to its neutral position.

From the above description of regulator 73 it will be apparent that fluid pressure motor 106 may be caused to move its piston rod in either direction in incremental steps each time valve 113 is operated by bellows 107 and its associated mechanisms.

Regulator 73, as illustrated in Fig. 3, is arranged to operate fuel valve 71. Since it operates fuel valve 71, it may be necessary in the case of an emergency to take the control of valve 113 away from bellows 107. Such an emergency would arise when the control system fails or when the power for driving the fan motors and the compressor motor is interrupted for some reason or other. When the above mentioned emergency occurs, the pressure of the fluid at source 77 will gradually decrease.

The amount of fluid stored in tank 16 under pressure will permit operation of the control system for a period of time depending upon the capacity of the tank. As the pressure of the fluid in tank 16 decreases, the pressure delivered to bellows 107 of regulators 58, 69 and 73 will gradually decrease.

Therefore, the fluid motors of these regulators will operate to open the forced and induced draft dampers and the fuel valve 71. Thus, it will be apparent that the control system tends to open the dampers and the fuel valve at a time when the fuel valve should be closed. Therefore, when the pressure in tank 16 has been reduced to the minimum operating pressure for which the regulators are designed to operate, safety relay 78 operates. The moment that relay 78 operates safety relay 79 operates.

Relay 79 is so constructed that when it operates, rocker bar 117 is turned counter-clockwise as far as it will go thereby admitting pressure to the underside of the piston in cylinder 108. The pressure applied in this manner is maintained until piston rod 109 has moved upwardly to that position in which fuel valve 71 is completely closed.

In order to permit the turning of rocker bar 117 in this manner, a yieldable link 126 is interposed between bar 117 and bellows 107. Bar 117 is extended to the left of bell crank 119 so that it may be operated upon by safety relay 79.

Flexible link 126 comprises two cylinders 132 spaced apart at their adjacent ends and coupled together by means of a coupling 133 of substantially H shape in section. The upper end of upper cylinder 132 is closed by a cap 134 to which is attached a link 135. The upper end of link 135 is connected to the right hand end of rocker bar 117. The lowermost end of lower cylinder 132 is closed by a cap 136. Cap 136 is apertured to accommodate a rod 137 that extends upwardly through the lower cylinder and into the upper cylinder, coupling 133 being apertured as shown to permit rod 137 to move therethrough. A collar 138 is secured to rod 137.

On each side of collar 138 washers 139 and 140 are disposed. These washers are of larger diameter than collar 138 and the aperture in the cross web of coupling 133. Compression springs 141 and 142 are disposed within cylinders 132 and are held under compression by means of washers 139 and 140 and caps 134 and 136.

Thus, when rocker bar 117 is turned counter-clockwise by safety relay 79, cylinders 132 of flexible link 126 will move upwardly while rod 137 remains substantially stationary. Such relative movement between the cylinders and rod 137 results in a compression of spring 142 and an elongation of spring 141. Relative movement between the cylinders and rod 137 is sufficient to permit the turning of rocker bar 117 counter-clockwise the required amount necessary to close the fuel valve.

Regulators 8, 9, the fluid pressure motor of regulator 13, and regulators 58 and 69, as illustrated, are identical to regulator 73 except that the flexible link 126 associated with regulator 73 is omitted from the aforementioned regulators. Also the extension at the left hand end of rocker bar 117 is omitted. In other respects the regulators are identical.

Safety relay 79

Safety relay 79 comprises a frame 145 on which is mounted a casing or housing 146. The upper end of the casing is closed by a cover 147, the joint between the cover and the casing being pressure tight. A bellows 148 is disposed within housing 146 and is secured to the underside of cover 147. The bellows is arranged to operate a bell crank 149 pivotally mounted on a standard 150 secured to the base of frame 145. The vertical leg of bell crank 149 engages a pin 151 attached to a trigger 152, one end of which is pivotally mounted on frame 145. The free end of trigger 152 is disposed to engage the left hand end of rocker bar 117. When the vertical leg of bell crank 149 is disengaged from pin 151 of trigger 152, the trigger is pulled downwardly by a tension spring 153. The strength of spring 153 is such that it will pull the trigger into engagement with the left hand end of rocker bar 117 with such force that the bar will turn to that position in which valve 113 is opened wide to admit pressure to the underside of the piston in cylinder 108.

The horizontal leg of bell crank 149 carries a link 154 that extends through the cover of housing 146 to the bottom of the bellows. The lower end of link 154 has a relatively large head 155 that engages the bottom of the bellows. Disposed about the link and between the underside of cover 147 and head 155 is a spring 156 that normally tends to expand the bellows and turn the bell crank 149 counter-clockwise and out of engagement with trigger pin 151.

When the pressure of the fluid, or air supply for the control system, is above the minimum value for which the regulators are designed to operate, the pressure within housing 146 will be sufficient to maintain the bell crank in the position shown in Fig. 3; that is in the position in which the trigger 152 is held away from rocker bar 117. However, the moment the pressure of the fluid at the source of supply falls below this minimum value safety relay 78 operates to exhaust the pressure from within housing 146 through a pipe line 157 to the atmosphere. Thus, when the pressure within the housing is exhausted to the atmosphere, spring 156 will expand the bellows, turn bell crank 149 out of engagement with the trigger pin, whereby the trigger is pulled downwardly by spring 153 to operate the rocker bar in the manner aforesaid.

Safety relay 78

Safety relay 78 comprises a pressure-tight housing 160 and a valve 161 mounted on the cover thereof. A bellows 162 is disposed within the housing and operates against a compression spring 163 disposed within the interior thereof. The tension of spring 163 may be adjusted by means of an adjustment screw 164, the inner end of which has a seat 165 for accommodating the spring.

Valve 161 has a double seated valve plug 166 that is operated by the bellows 162.

When the pressure of the fluid or air supply at the source 77 is above the minimum value, the interior of housing 160 will be subjected to the pressure of the source, pressure being conveyed from the source to said housing by means of a pipe 167. So long as the pressure is above the minimum value, valve plug 166 will be held in the position shown in Fig. 2. When in this position pressure may flow from the source through pipe 167 into housing 60 thence through valve port 168 to pipe line 169. Pipe line 157, through which pressure is conveyed to the interior of housing 146, of safety relay 79, is connected to pipe line 169. The control pressure served to pressure responsive elements 107 of regulators 58, 69 and 73 is also derived from pipe line 169.

When the pressure at the source 77 falls below the minimum value, spring 163 causes the bellows 162 to expand whereby valve plug 166 is moved upwardly to close off communication between the interior of housing 160 and port 168. When in this position, the pressure in lines 100′, 169, 157 and the interior of housing 146 of relay 79 is exhausted through port 168 of the valve and exhaust port 171 thereof to the atmosphere.

When relays 78 and 79 have operated, as herein described, all of the fluid under pressure stored in tank 16 will be available to operate the pistons in the cylinders of regulators 58, 69 and 73, but the pressure applied to the interior of bellows 107 of these regulators will be gradually reduced to atmospheric, unless the pressure at the source of supply is restored in the meantime. Thus, regulators 58 and 69 will tend to open the forced and induced draft dampers; but regulator 73 being under the control of relay 79 will operate in the opposite direction and close the fuel valve. Regulator 73 is operated in the opposite direction because safety relay 79 functions to take the control of valve 113 away from pressure responsive bellows 107 of said regulator 73.

While only one furnace and a control system therefor have been illustrated in the drawings, it is to be understood that the control system as illustrated in Figs. 1 and 2 may be applied to a battery of furnaces, in which each furnace of the battery delivers the steam generated thereby to a main header.

Where the control systems are applied to a battery of furnaces each furnace would be provided with regulations such as indicated at 8, 9 and 13 in Fig. 1 in case coal is the fuel supplied to the furnaces, or regulators such as illustrated at 58, 69 and 73 in Fig. 2. All of the regulators associated with each individual furnace of the battery would be controlled from a master relay such as indicated at 11 in Fig. 1 or at 72 in Fig. 2.

In the case of coal fired boiler furnaces, one relay such as indicated at 18 in Fig. 1 would cause all of the boiler furnaces to operate at maximum capacity. It will be apparent that all of the regulators for performing the same functions as regulators 8 and 9 of Fig. 1 would be connected to receiving line 10′.

If a system such as illustrated in Fig. 2 is applied to a battery of furnaces, a master regulator 72 would control each regulator such as indicated at 69 and 73 in each furnace of the battery. Also, each fuel valve regulator 73 would be controlled by a safety relay 79, all of which would be under the control of safety relay 78. Also, the forced and induced draft regulators 58 and 59 would be under the control of safety relay 78, as indicated in Fig. 2.

From the above description it will be apparent that the system illustrated in Fig. 1 is arranged to automatically regulate the combustion and draft conditions of a furnace burning solid fuel, such as coal, for example. Such a system, as illustrated in Fig. 1, upon a failure of the control system causes the furnace to operate at maximum capacity until manual control may be resorted to. Therefore, with such a system as illustrated in Fig. 1, continuity of furnace operation and a holding of the load are assured even though the automatic control system should fail.

In Fig. 2 of the drawings, the control system illustrated is adapted to automatically control combustion and draft conditions in a furnace burning fuels such as are dangerous to human life as gas, for example. When a system, such as shown in Fig. 2 is employed, but fails for some reason or other, the fuel supply is completely shut off and the draft is increased sufficiently to insure that unburned gases in the furnace combustion chamber will be carried away to the stack. With this type of system, the furnace is shut down and the load dropped until the control system has been repaired, or until the power for operating the draft fans and the compressor motors has been restored. However, in systems such as illustrated in Fig. 2, the saving of human life and the prevention of serious explosions is of more importance than the continuity of furnace operation and a holding of the load.

In both of the systems illustrated in Figs. 1 and 2, the forced draft is so controlled as to maintain a substantially constant pressure in the furnace chamber, and the delivery of fuel and the induced draft controlled by and in accordance with the demand for steam. Both systems are provided with safety devices, the one insuring continuity of furnace operation in case of failure of the control system, and the other discontinuity of furnace operation.

The control systems herein disclosed, it will be understood, illustrate how the invention may be practiced to attain the results herein set forth. Therefore, it will be apparent that various modifications and changes may be made in the systems herein disclosed without departing from the spirit and the scope of the invention.

It is desired, therefore, that only such limitations shall be placed on the invention as are imposed by the prior art and the appended claims.

What I claim as new and desire to secure by Letters Patent is:

1. The combination with a boiler furnace having means for automatically controlling the draft and fuel supply in accordance with the demand for steam, of means responsive to a predetermined condition approaching failure in the automatic control means arranged to so adjust the draft and supply of fuel in advance of actual failure as to cause said furnace to be adjusted for maximum capacity operation when the failure occurs.

2. The combination with a boiler furnace having forced and induced draft mechanisms, fuel delivery mechanism, pressure actuated regulators for controlling the draft and the rate of fuel delivery, said regulators being disposed to operate between two extreme positions, and a source of supply of fluid under pressure for operating said regulators, of means responsive to a predetermined condition approaching failure of the fluid pressure source for causing said regulators to move to one of said extreme positions, before failure of the supply source has been completed.

3. The combination with a boiler furnace having forced and induced draft mechanisms, fuel delivery mechanism, pressure actuated regulators for controlling the draft and the rate of fuel delivery, said regulators being disposed to operate between two extreme positions, and a source of supply of fluid under pressure for operating said regulators, of means for causing said regulators to move to one of said extreme positions in response to the pressure of the fluid pressure supply source falling below a predetermined minimum value, and approaching failure, but before the failure has reduced the pressure of the source below a value which would be insufficient to operate the regulators to said extreme position.

4. In a control system, the combination with a reversing motive element operated by fluid under pressure, a source of supply of fluid under pressure, a pressure responsive element arranged to control the direction of application of fluid pressure to said motive element, said pressure responsive element being disposed to cause said motive element to operate between two extreme positions, means responsive to a condition to be controlled for transmitting variable pressure impulses from said source to said pressure responsive element, and means operable upon said pressure responsive element to effect operation of said motive means in one direction only to one of said positions in response to the pressure of said source decreasing below a predetermined minimum value, approaching failure.

5. In combination, a regulator having a movable element actuatable by fluid under pressure, a source of supply of fluid pressure, a reversing valve having two maximum open positions and a closed position, said valve controlling the direction and application of pressure from said source to said movable element, a pressure responsive element for operating said valve, means for transmitting variable pressures from said source to said pressure responsive element in accordance with a condition to be controlled, and means for shutting off pressure impulses to said pressure responsive element in response to the pressure of the source falling below a predetermined minimum value and approaching failure, thereby to effect operation of said reversing valve to one of its wide open positions, so that the movable element of the regulator will be actuated to an extreme position, as determined by the position of the reversing valve, before the pressure of the fluid supply source has been reduced to an inoperative value.

6. In combination, a regulator having a movable element actuatable by fluid under pressure, a source of supply of fluid under pressure, a reversing valve having two maximum open positions and a closed position, said valve controlling the direction and application of pressure from said source to said movable element, a pressure responsive element for operating said valve, means for transmitting variable pressures from said source to said pressure responsive element in accordance with a condition to be controlled, and means for shutting off the supply of pressure to said pressure responsive element and exhausting the pressure fluid therefrom in response to the pressure of the source being reduced to a predetermined minimum value approaching failure thereby to effect operation of said reversing valve to one of its maximum open positions, and thereby cause the movable element of the regulator to be actuated to one of its extreme positions before the pressure of the supply source is reduced to an inoperative value.

7. In combination, a regulator having a movable element actuatable by pressure, a source of fluid pressure, a reversing valve having at least two positions of maximum opening arranged to control the direction and application of pressure from the source to said movable element, a pressure responsive

element for actuating said valve, and means for actuating said valve to one of said maximum positions independently of the action of the pressure responsive element, the moment the pressure of said source falls below a predetermined minimum value.

8. In combination, a regulator having a movable element actuatable by pressure, a source of fluid pressure, a reversing valve having at least two positions of maximum opening arranged to control the direction and application of pressure from the source to said movable element, a pressure responsive element for actuating said valve, and means for actuating said valve to reverse the direction of movement of said movable element the moment the pressure at the source falls below a predetermined value.

9. In combination, a regulator having a member arranged to move under the influence of pressure, a source of pressure supply, a reversing valve disposed to control the application of pressure from said source to said member to control its direction of motion, means for operating said valve in accordance with a condition to be controlled and means disposed to operate said valve so as to cause said member to move in a direction opposite to that in which it normally tends to move, in response to the pressure of the source falling below a predetermined value.

10. In combination, a regulator having a member arranged to move under the influence of pressure, a source of pressure supply, a reversing valve disposed to control the application of pressure from said source to said member to control its direction of motion, means for operating said valve in accordance with a condition to be controlled, a trigger positioned to operate said valve in one direction only, and means rendering said trigger ineffective while the pressure of the source is above a predetermined value, but effective to operate the valve when the pressure falls below said value.

11. The combination with a furnace having draft and fuel regulators said regulators being disposed to operate between two extreme positions, means for controlling said regulators in accordance with a variable entering into the operation of said furnace and a source of power for operating said regulators, of means responsive to a predetermined condition approaching failure in said source of power arranged to cause said regulator controlling means to actuate at least some of said regulators to one of their extreme positions.

12. In a control system, the combination with a motive device having an element adapted for movement in either direction under the action of fluid pressure and requiring pressure above a predetermined minimum value to actuate the movable member to the end of its stroke in either direction, under load, a source of supply of fluid pressure, pressure actuated means for controlling the pressure delivered by the source to said movable member and its direction of travel, means responsive to a variable condition for transmitting variable pressures to said pressure actuated means, and means responsive to the pressure of the source for rendering said responsive means inoperative and causing the pressure actuated means to admit fuel pressure to the movable member and cause it to travel to the end of its stroke in one direction the moment the pressure of the source falls below said predetermined minimum value.

13. In combination, a source of supply of a compressible fluid under pressure, a cylinder having a piston working therein, valve mechanism for controlling the admission of fluid to the cylinder from the source and the direction of movement of the piston, pressure actuated means for operating the valve mechanism, a master regulator adapted to normally vary the pressure in said pressure actuated means from a predetermined minimum value to a value substantially equal to the pressure at the source, and means responsive to the pressure of the source decreasing to a predetermined minimum value for rendering the master regulator inoperative with respect to said pressure actuated valve operating means and adjusting the pressure acting thereon to such a value that the valve will be shifted to a position such as will cause the piston to travel to the end of its stroke in one direction before the pressure acting thereon becomes too low.

14. In a control system, the combination with a motive device having an element adapted for forward and reverse movements between two extreme positions, a source of motive power for said element, said element requiring available power above a predetermined minimum value to actuate the same to the end of its travel, in either direction, under load, a master regulator for controlling the supply of power from the source to said motive element and its direction of movement, and means responsive to partial failure of the motive power for rendering the master regulator inoperative, with respect to the motive device, and causing such degree of power to be applied to said movable element that it will move to one of its extreme positions before the available motive power from the source decreases below said minimum value.

15. In a control system, the combination with a reversing motor adapted to actuate a load between predetermined limits of travel in either direction, a source of motive power for the motor, a master regulator for controlling the supply of power to the motor and its direction of operation, and means responsive to approaching failure of the source of motive power for rendering the master

regulator inoperative with respect to the motor and causing such degree of power to be applied to the motor that the load will be actuated to one of its limiting positions before the supply of power has decreased below a value sufficient to enable the motor to actuate the load to said position.

In testimony whereof, I have hereunto subscribed my name this 18th day of June, 1931.

THOMAS A. PEEBLES.

CERTIFICATE OF CORRECTION.

Patent No. 1,905,745. April 25, 1933.

THOMAS A. PEEBLES.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, line 41, for "air" read "draft"; page 12, line 75, claim 12, for "fuel" read "full"; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 23rd day of May, A. D. 1933.

M. J. Moore.
Acting Commissioner of Patents.

(Seal)