Aug. 15, 1950 F. H. FELLOWS 2,519,240

COMBUSTION CONTROL SYSTEM

Filed April 28, 1948 2 Sheets-Sheet 1

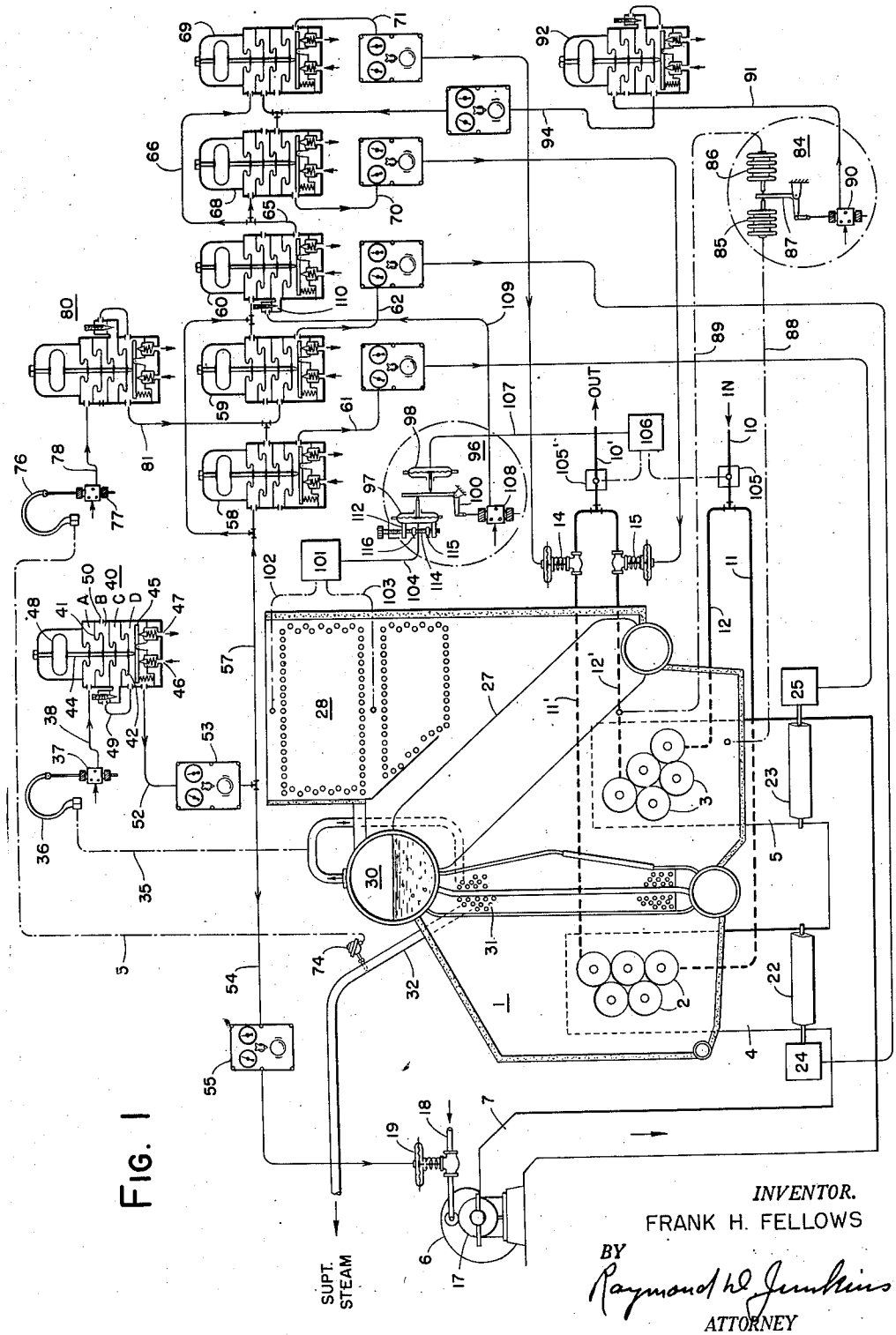


FIG. 1

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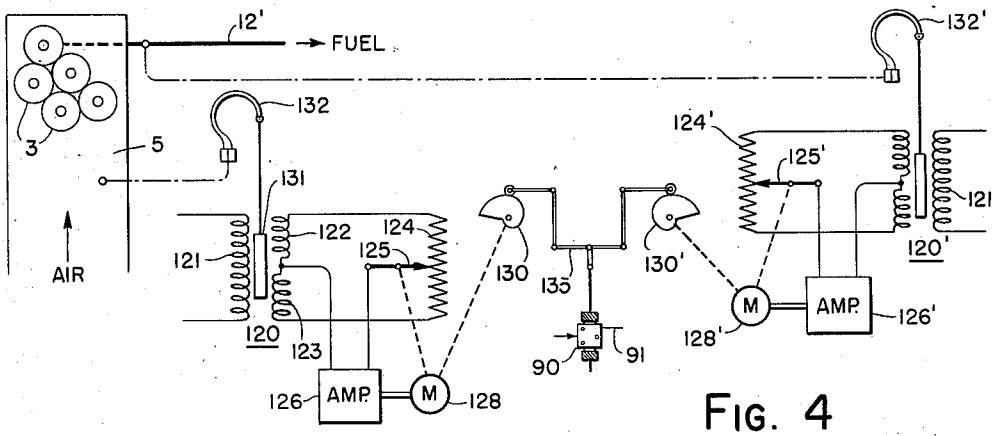


FIG. 4

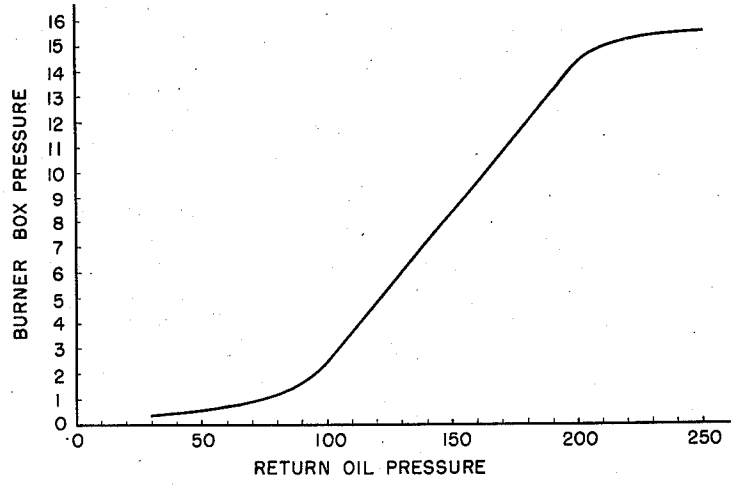


FIG. 3

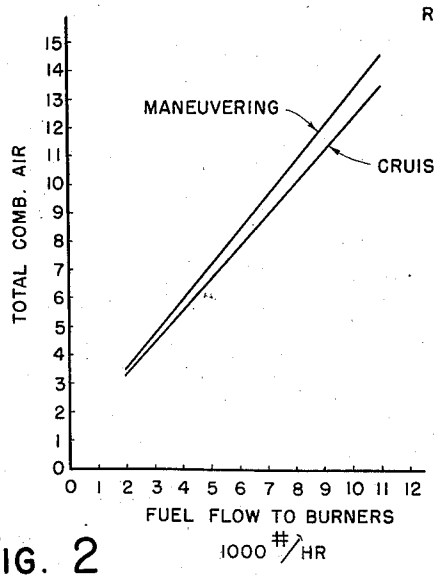


FIG. 2

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UNITED STATES PATENT OFFICE

2,519,240

COMBUSTION CONTROL SYSTEM

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Application April 28, 1948, Serial No. 23,708

10 Claims. (Cl. 236—14)

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This invention relates to systems for controlling combustion in a boiler furnace, and more particularly to systems for controlling the supply of fuel and air to burners arranged in separate generating and superheating sections of a boiler.

In some boilers, especially those of the marine type, burners are arranged in separate paths, one directing combustion gases over a steam generating section of the boiler and the other directing combustion gases over a superheating section. As the load demand on the boiler varies, it is desirable that the supply of fuel and air to the burners in each of the paths be varied so as to satisfy the demand. An increase in demand should result in an increase in the supply of fuel and air to the burners in each path, while a decrease in demand should result in a decrease in the supply to the burners in each path. It is usually desirable that the temperature of the steam discharged from the boiler be maintained at a predetermined value, and, to accomplish this, the control system may be so arranged as to increase the supply of fuel and air to the burners in one path while it decreases the supply to the burners in the other path on a change in the temperature. An increase in the temperature should result in a decrease in the supply to the burners in the path directing combustion gases to the superheating section, and an increase in the supply to the burners in the other section. A drop in the temperature should effect an opposite change in the supply to the burners. In order that the combustion efficiency may be maintained at an optimum value, there should be provided a control means for holding the ratio of the total air flow through the boiler to the total fuel supply to the burners at a constant value. This control means may be made manually adjustable so that the ratio of air flow to fluel flow is maintained at other values, if desired.

A preferred form of my invention may include relays operating in response to changes in steam pressure as a measure of load for controlling the operation of a blower or fan, the positions of dampers in separate paths including the burners, and the positions of valves in fuel lines to the burners. For varying the distribution of air to the burners with changes in temperature, there may be provided means for subjecting the damper control relays, on a change in temperature, to a varying pressure which effects their operation in a manner to open one of the dampers and to close the other

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damper. The distribution of fuel to the burners may be obtained by subjecting the fuel-valve-control relays to a pressure which varies when the ratio of air flow in one of the paths to the pressure in the fuel line to the burners in the same path varies from a predetermined value. This control pressure acts on the relays in a manner to effect an opening of the valve in one of the fuel lines, and a closing of the valve in the other line. Means measuring the ratio of the total air flow through the boiler to the total fuel supply to the burners may be provided for determining a pressure which acts on the relays controlling the fuel valves, this pressure acting on the relays to effect a simultaneous opening or closing of the valves in both lines so as to maintain a ratio resulting in smokeless combustion.

An object of my invention is to provide an improved system for controlling combustion in a boiler furnace. Another object is to provide a system for controlling the supply of fuel and air to burners in separate paths of a boiler furnace so as to satisfy the demand on the boiler and to maintain the temperature of the steam discharged at a predetermined value. Still another object is to provide a boiler control system which maintains predetermined ratios between the total air flow through the boiler and the total fuel supply to the burners, the system being adjustable manually to establish the ratio to be maintained. Yet another object is to provide a system for regulating the supply of fuel and air to burners in separate paths of a boiler furnace in direct proportion to demand, and varying the distribution of fuel and air to the burners on changes in temperature. Other objects will appear in the course of the following description.

In the accompanying drawings there is shown for purposes of illustration one form which my invention may assume in practice:

In these drawings:

Fig. 1 is a schematic diagram of a boiler having my improved control system associated therewith.

Fig. 2 shows curves between air flow through the boiler and fuel flow to the burners for different manual adjustments of a relay in the control system.

Fig. 3 shows a curve indicating the relationship between the pressures in one of the air flow paths and the pressures in one of the fuel lines.

Fig. 4 is a schematic diagram of another type of relay that is adapted for use in my control system.

Referring to Fig. 1 of the drawings, it will be noted that there is shown a boiler, generally designated 1, having burners 2 and 3 arranged in separate paths 4 and 5 to which air is supplied by a fan or blower 6 through a passage means 7. Fuel, such as oil, is supplied from a conduit 10 through branch conduits 11 and 12 to the burners 2 and 3. These burners are of the return flow type, and excess oil supplied to them from the conduit 10 is conducted through conduits 11' and 12' to a return flow pipe 10'. Arranged in the conduits 11', 12' are diaphragm controlled valves 14 and 15 which are movable to open positions on a decrease in the pressure of the control fluid supplied thereto. A closing of these valves results in an increase in the back pressure to effect an increase in the discharge of oil from the burners, and an opening of the valves reduces the oil consumption.

The fan or blower 6 is shown herein driven by a motor 17 to which operating fluid is supplied from a conduit 18 under the control of a diaphragm actuated valve 19 which is moved toward its open position when the pressure acting on the diaphragm is increased. The air supplied by the blower to the passage means 7 is distributed between the paths 4 and 5 by dampers 22 and 23 which are positioned by suitable pressure responsive devices 24 and 25. These devices operate on an increase in the pressure supplied thereto to move the dampers toward their open positions, and, on a decrease in pressure, to close the dampers.

The boiler 1 includes a steam generating section 27 arranged so that the combustion gases from the burners 3 pass over it as they move toward an uptake 28. Steam generated in the section 27 passes through a separation drum 30 to a superheating section 31 which is arranged so that the combustion gases from the burners 2 pass over it as they move to the uptake 28. The combustion gases from the burners 2 may also pass over a portion of the steam generating section, as shown. Superheated steam is discharged from the section 31 through a conduit 32 to a point of use.

For regulating the valve 19 controlling the operation of the blower 6, the valves 14 and 15 controlling the supply of oil to the burners, and the devices 24, 25 controlling the positions of the dampers, and causing the regulating actions to take place in response to changes in steam pressure as an indication of load demand, I provide a connection 35 communicating with the discharge side of the steam drum and supplying pressure to a pressure responsive device 36, such as a Bourdon tube. Connected to the device 36 is a pilot valve 37 supplying pressure through a conduit 38 to the chamber A of a standardizing relay 40. The pilot valve 37 is like that disclosed in the Johnson Patent 2,054,464 and need not be described in detail herein. It is sufficient to say that the pilot valve operates when connected as shown, to supply a pressure to the relay 40 varying inversely with the pressure supplied to the Bourdon tube.

The relay 40 includes chambers A, B, C and D, the chambers A and B being separated by a flexible partition 41, and the chambers C and D being separated by a flexible partition 42. The chambers B and C are separated by a partition which is rigid except for a small portion at its center, as shown. A member 44 is connected to the partitions 41, 42, and is also connected to the flexible portion of the partition between the chambers

B and C. This member 44 acts on a pivoted beam 45 controlling valves which regulate the flow of pressure fluid through supply and discharge ports 46 and 47 relative to the chamber D. A manually adjustable spring 48 opposes movement of the member 44 toward the pivoted beam 45. The chambers C and D are connected in restricted communication with each other through passage means 49, and the chamber B is connected to atmosphere through a port 50. This relay mechanism is disclosed in the Gorrie Patent Re. 21,804, and it is not believed necessary that it be described further herein.

The spring 48 is adjusted to balance the pressure supplied to the chamber A when the steam pressure is at the desired value. If the steam pressure drops as a result of an increased demand, the pressure supplied to the chamber A increases and causes the beam 45 to be actuated for opening the valve at the supply port 46. The pressure in chamber D then increases to oppose the pressure increase in chamber A. This pressure increase results in a flow of fluid through the restricted connection 49 to the chamber C where it aids the pressure in chamber A to actuate the pivoted beam. It will be seen that the pressure in chamber D will continue to increase as long as the pressure in chamber A remains above the value at which it was balanced by the spring 48. If the steam pressure goes above the desired value because of a drop in demand, then the pressure in chamber A will be reduced below the value balancing the spring 48 and the beam 45 will be actuated to cause a continuing decrease in the pressure in chamber D.

The pressure in the chamber D is supplied through a conduit 52 and a selector valve 53 to a conduit 54 leading through a second selector valve 55 to the diaphragm operated valve 19. The selector valves 53 and 55 are adapted for adjustment manually either to deliver the pressure supplied to them from the relay 40, or to deliver pressure from a separate source. In normal operation, these valves will be adjusted for delivering the pressure supplied from the relay.

Connected to the discharge side of the valve 53 is another conduit 57 supplying fluid to the upper or A chambers of relays 58, 59 and 60. Each of these relays is like the relay 40 except that no communication is provided between the C and D chambers, and connections are made to the B and C chambers so that they operate in the desired manner. The D chambers of the relays 58 and 59 are connected through conduits 61 and 62 to the devices 25 and 24 positioning the air dampers. Although there are other pressure connections to the B and C chambers of the relays, as will be shortly described, it will be appreciated that the pressure supplied to the conduits 61 and 62 will vary directly with the pressure in the A chambers as long as the pressures in the B and C chambers are held constant. Assuming that the pressures in the B and C chambers remain constant, the pressures in the conduits 61 and 62 will be increased to effect an opening of the dampers when the pressure supplied to the relays 58, 59, from the relay 40 is increased by reason of an increase in demand for steam. A decrease in demand, represented by an increase in steam pressure, will result in a closing movement of both dampers.

The relay 60 has its D chamber connected by conduits 65 and 66 to the A chambers of a pair of relays 68 and 69 which are like the relay 60 except for the connections to their B and

C chambers. The D chambers of the relays 68, 69 are connected by conduits 70 and 71 to the diaphragm valves 15, 14 controlling the supply of fuel oil to the burners. The relays 60, 68 and 69 operate, as long as the pressure in their B and C chambers remains constant, to maintain pressures in their D chambers in direct proportion to the pressures in their A chambers. It will therefore be seen that the pressures supplied to the conduits 70 and 71 will be directly proportional to the pressure supplied from the relay 40 to the conduit 57. The valves 14 and 15 will then be closed equal amounts when the steam pressure drops below the desired value, and will be opened equal amounts on an increase in the steam pressure above the desired value. The closing of the valves effects an increase in the discharge of oil through the burners, and the opening of the valves reduces the oil consumption.

It is desired that the dampers and fuel valves be regulated so that the temperature of the discharged steam is maintained at a predetermined value. To accomplish this, means are provided for varying the supply of fuel and air to the burners 2 in inverse proportion to changes in temperature, and to the burners 3 in direct proportion to temperature changes. This results in a variation in the discharge of combustion gases across the superheating section 31 and the generating section 27 so that a constant temperature is maintained. The positioning of the dampers and valves is such, however, that the total air flow through the boiler, and the total fuel supply to the burners, remains constant. To obtain the above results, there is provided an element 74 subjected to the steam in the discharge line 32 and connected by a conduit 75 to a pressure responsive device 76, such as a Bourdon tube. Variations in steam temperature results in pressure changes in the conduit 75 for effecting operation of the device 76 to position a pilot valve 77 which supplies pressure through a conduit 78 to a relay 80. This relay is like the relay 40 and operates to supply a constant pressure to a conduit 81 as long as the pressure delivered by the conduit 78 is at the value obtained when the temperature is at the desired value. The connection of the conduit 78 to the pilot valve is such that an increase in temperature causes a decrease in the pressure supplied to the relay 80, and a decrease in temperature causes an increase in the pressure supplied. When the pressure in the A chamber of the relay 80 goes above the value at which the relay is balanced, an operation takes place to supply a continuously increasing pressure to the conduit 81. A drop in the pressure below this value results in a continuous decrease in the pressure supplied to the conduit 81.

Connections are provided between the conduit 81 and the B and C chambers of the relays 58 and 59, respectively, as shown. The pressure in the B chamber of relay 58 opposes the pressure in its A chamber, while the pressure in the C chamber of relay 59 aids the pressure in its A chamber. The manually adjustable springs for the relays 58 and 59 may be regulated so that the pressures supplied to the conduits 61 and 62 provide the desired positioning of the dampers. When the steam temperature increases and operates the pilot valve 77 to reduce the pressure in the A chamber so as to unbalance the relay 80, the pressure in conduit 81 drops to effect an operation of the relays 58 and 59 for increasing the pressure supplied to the damper control device 25 and decreasing the pressure supplied to the damper control device 24. The damper 22 is then moved toward its closed position while the damper 23 is moved toward its open position. If the steam temperature drops below the desired value, the relays operate to effect an opening of the damper 22 and a closing of the damper 23.

With the change in the damper positions to vary the distribution of air, there must also be a corresponding change in the positions of the valves 14 and 15 for varying the distribution of fuel to the burners. For controlling the positions of the valves 14 and 15 I provide a relay 84 having bellows 85 and 86 acting against opposite sides of an arm of a bell crank 87. The bellows 85 is subjected through a conduit 88 to a pressure varying directly with the rate of air flow through the path 5, and the bellows 86 is subjected through a conduit 89 to the oil pressure in the conduit 12' as an indication of the rate of fuel supplied to the burners 3. Connected to the bell crank 87 is a pilot valve 90 supplying pressure to a conduit 91 which communicates with a relay 92 like the relays 40 and 80. This relay supplies pressure through a conduit 94 to the C chamber of the relay 68 and to the B chamber of the relay 69. An increase in the pressure in conduit 94 results in an operation of the relay 68 to increase the pressure supplied to the conduit 70, and an operation of the relay 69 to decrease the pressure supplied to the conduit 71. The conduit 91 is connected to the pilot valve 90 so that an operation of the latter by a swinging of the bell crank in a clockwise direction will result in a pressure increase in this conduit.

It will be seen that an increase in the air flow through the path 5 as a result of an increase in steam temperature will cause the bellows 85 to be subjected to an increased pressure through the conduit 88. The bell crank 87 is then swung about its pivot to actuate the pilot valve for increasing the pressure supplied to the conduit 91. This effects an operation of the relay 92 to produce a continuing increase in the pressure supplied through the conduit 94 to the relays 68 and 69, which operate in turn to increase and decrease the pressure supplied to the conduits 70 and 71, respectively, for effecting a closing of the valve 15 and an opening of the valve 14. As soon as the fuel discharge from the burners 3 has been increased in proportion to the air flow through the path 5, the pressure supplied by the conduit 89 to the bellows 86 counteracts the pressure in the bellows 85 and positions the pilot valve 90 to reduce the pressure in the conduit 91 to a point where the relay 92 is again balanced. A reduction in the air flow in the path 5 as a result of a drop in temperature causes the relays 84 and 92 to operate so as to reduce the pressure supply to the relays 68 and 69 and effect an operation of the latter to close the fuel valve 14 and open the fuel valve 15. The operations of the fuel valves effect opposite changes in the rate of fuel discharge from the burners 2 and 3, and the fuel discharge from the burners in each path is caused to vary directly in proportion to the changes in air flow resulting from changes in temperature.

For maintaining the combustion efficiency of the boiler at an optimum value, there is provided control means for additionally regulating the fuel supply valves 14 and 15 so as to main-

tain predetermined ratios between the total air flow through the boiler and the total fuel discharge from the burners. This control means includes a relay 96 having diaphragms 97 and 98 acting on opposite sides of an arm of a bell crank 100. A device 101 is subjected through conduits 102 and 103 to the pressures at spaced points in the uptake 28 and operates in response to the pressure difference between said points for establishing a pressure which is supplied through a conduit 104 to the diaphragm 97. The pressure acting on the diaphragm 97 is therefore representative of the total air passing through the boiler from the paths 4 and 5. Arranged in the fuel lines 10 and 10' are devices 105 and 105' for measuring the flow of fuel. Each of these devices may be like that disclosed in an application, Serial No. 665,108, filed April 26, 1946, for Paul S. Dickey et al., and need not be described here since it forms no part of the present invention. A device 106 is connected to the devices 105, 105' and operates to supply to a conduit 107, a pressure which is proportional to the difference between the measurements of the fuel flow. It will be appreciated then that the pressure in the conduit 107 is directly proportional to the total fuel consumption at the burners 2 and 3. The pressure in the conduit 107 is subjected on the diaphragm 98 so as to oppose the action of the diaphragm 97. Connected to the bell crank 100 is a pilot valve 108 for controlling the supply of pressure fluid through a conduit 109 and through a restricting valve 110 to the C chamber of the relay 60. The restricting valve is provided so that any sudden changes of pressure in the conduit 109 will not be applied directly to the relay 60 and effect an operation of the control means.

It will be appreciated that the pressure in the C chamber of the relay 60 aids the pressure in its A chamber for determining the pressure supplied through the conduits 65 and 66 to the relays 68 and 69, and the fuel valves 14 and 15 are positioned directly in response to the changes in pressure supplied to these relays. If the total air passing through the boiler increases for some reason, while the total fuel supply remains constant, then the pressure supplied to the diaphragm 97 increases and actuates the pilot valve 108 for increasing the pressure supplied through the conduit 109 to the relay 60. This relay operates to increase the pressure supplied to the relays 68, 69 and effect an operation of the latter to increase the pressure for closing the fuel valves 14 and 15 so that more oil is discharged from the burners. A decrease in the flow through the uptake 28 results in an operation of the relays to reduce the pressure supplied to the diaphragms operating the valves 14 and 15.

As pointed out above, the boiler 1 is adapted especially for marine service. When it is used for this service, it is necessary that the system be adjustable to vary the boiler efficiency for different types of operation. During cruising operations, it is desirable that the efficiency of combustion be maintained at a high value, one resulting in a smokeless combustion of the fuel. While maneuvering, the efficiency of operation is of less importance. In order to adjust the system for different types of operation, the diaphragm 97 is supported by a frame 112 which is adjustable by a manually operable member 114 to position the diaphragm so that it may act at different points along the arm of the bell crank 100. For cruising operation, the diaphragm is moved away from the pivot of the bell crank until the ratio of total air flow to total fuel flow is such as to give maximum efficiency. A stop 115 may be provided on the member 114 to limit the movement of the diaphragm to the point giving the optimum efficiency. For maneuvering operation, the diaphragm 97 is moved toward the pivot of the bell crank so that the ratio of the total air flow to the total fuel flow is increased. A stop 116 may be provided on the member 114 to limit the movement of the diaphragm to the point giving the desired air flow-fuel flow ratio for maneuvering operations. Fig. 2 shows the relationship of air flow to fuel flow for the different types of operation. The stops 115 and 116 may be made adjustable so that the limits of the ratios obtained may be varied as desired. An adjustment of the diaphragm 97 to points between the stops will result in operations which follow curves like those of Fig. 2 but lying between them.

The relay 84 was described above as operating in response to pressure supplied thereto for producing pressures which regulated the fuel discharge at the burners in direct proportion to the changes in air flow through the paths 4 and 5. The mechanism producing the operating pressures for this relay may not operate to vary the pressures in conduits 88 and 89 in straight line relationship with the changes in air flow and fuel consumption. For instance, the pressure in the fuel line 12' may vary in a straight line relationship with the discharge from the burners 3 through a portion of the range but fail to vary in this manner at the upper and lower limits of the range. The pressure supplied to the conduit 88 as an indication of air flow may vary in a straight line relationship throughout the full range of operation. I have shown in Fig. 3 a curve indicating the relationship between air flow pressure and return oil pressure when they vary as just mentioned. Since the relay 84 operates in response to the differential pressure supplied to the bellows 85 and 86, the pressure supplied to the conduit 91 will vary in direct proportion to these pressure differentials. It is necessary, however, that the pressure in conduit 91 vary directly with the air flow and the fuel consumption throughout the full range of operation, and, where the pressure supplied to the bellows 85 and 86 do not vary in a manner to produce this result, means must be provided to give the necessary correction.

In Fig. 4 I have shown a relay which may be used in place of the relay 84 to regulate the pressure in the conduit 91 so that it varies in the desired manner with changes in air flow and fuel consumption. This relay includes a transmitter 120 having an energized primary winding 121 and a pair of bucking secondary windings 122 and 123 connected across a slidewire 124. A contact 125 on the slidewire and the adjacent ends of the secondary windings are connected to an amplifier and control device 126 which effects operation of a motor 128 in one direction or the other depending upon the phase of the voltage supplied thereto. The motor is connected to the contact 125 for rebalancing the system, and it is connected to a cam 130 for rotating the latter. Arranged between the primary and secondary windings is a movable core 131 connected to a pressure device 132 responsive to the pressure in the path 5. A similar system is provided for positioning a cam 130' in response to pressures in the fuel line 12'. The parts of the latter

system corresponding to those of the system described have been given corresponding primed numbers. Each of the motor control systems is like that disclosed in the Hornfeck Patent 2,406,221. The cams 130 and 130' are connected as shown through a linkage mechanism 135 for actuating the pilot valve 90.

When the pressure in the path 5 changes, the device 132 operates to change the position of the core 131 and effect opposite changes in the voltages induced in the secondary windings. This products an unbalance in the circuit so that a voltage is applied to the amplifier at a phase depending upon the direction of unbalance. The motor 128 is then energized to operate and position the contact 125 in a direction to rebalance the circuit. The cam 130 is positioned at the same time by the motor for varying the adjustment of the pilot valve 90. The system responsive to the pressure in the fuel line operates in the same manner to position the cam 130'. Both of the motors are operated in direct proportion to the pressure changes in the air path and the fuel line. If these pressure changes are not directly proportional to the changes in the rates of flow, then the cams are shaped so that the pilot valve 90 is actuated to vary the pressure in the conduit 91 in direct proportion to changes in flow.

While I have described certain embodiments which my invention may assume in practice, it will be evident that they may be modified in many ways without departing from the spirit or scope of the invention.

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

1. A combustion control system for a boiler having burners arranged in separate air flow paths comprising, in combination, means for supplying air to said separate paths, dampers arranged in said paths for regulating the distribution of air from said air supply means to said paths, separate passage means for conducting fuel relative to said burners, valve means for regulating the supply of fuel from said passage means to said burners in each of said paths, control means responsive to boiler steam pressure operating said air supply means and said dampers and said valve means to vary the supply of air and fuel to the burners in inverse proportion to the changes in steam pressure, control means responsive to the boiler steam temperature operating to position the damper in one of said paths in direct proportion to changes in steam temperature and to position the damper in the other of said paths in inverse proportion to the changes in steam temperature, second control means responsive to the ratio of the air flow and the fuel supply rate to one of said paths operating to position said valve means to vary the fuel supply to the burners in the path in which said ratio is measured in direct proportion to changes in the ratio and to vary the fuel supplied to the burners in the other of said paths in inverse proportion to changes in said ratio, and third control means responsive to the ratio of the total air flow through the boiler to the total fuel supplied to the burners operating to position said valve means for varying the fuel supplied to the burners in each of said paths in direct proportion to changes in the ratio.

2. A combustion control system for a boiler having burners arranged in separate passages directing combustion gases respectively to steam generating and superheating sections comprising, in combination, means for supplying fuel and air to said boiler in inverse proportion to boiler steam pressure, means for varying the distribution of air from said supply means to said passages in response to discharge steam temperature, said last mentioned means varying the air flow in one of said passages in direct proportion to changes in temperature and varying the flow in the other of said passages in inverse proportion to changes in temperature, and means for varying the distribution of fuel from said supply means to the burners in the separate passages in response to changes in the ratio of air flow to fuel flow to the burners in one of said passages, said last mentioned means operating to maintain a predetermined ratio of air flow to fuel flow to the burners in each of said passages constant.

3. The system of claim 2 in which said means for varying the distribution of air operates to supply air to the one of said passages directing combustion gases to the steam generating section in direct proportion to changes in temperature and to the other of said passages in inverse proportion to changes in temperature.

4. A combustion control system for a boiler having burners arranged in separate passages directing combustion gases respectively to steam generating and superheating sections comprising, in combination, an air supply passage common to said separate passages, means for delivering air to said supply passage in inverse proportion to boiler steam pressure, dampers arranged in said separate passages for regulating the flow of air therethrough from said supply passage, means responsive to steam pressure and operating to position said dampers in direct proportion to pressure changes, means responsive to steam temperature and operating on a temperature change to open one of said dampers and to close the other of said dampers proportional amounts, separate passage means for conducting fuel to said burners, valve means arranged in each of said passage means for controlling the flow of fuel therethrough, means for positioning said valve means in both of said passage means directly in response to changes in steam pressure, and means responsive to the ratio of air flow to fuel flow past the burners in one of said paths for positioning said valve means, said last mentioned means operating to position one of said valve means directly in proportion to changes in the ratio and to position the other of said valve means in inverse proportion to changes in the ratio.

5. A combustion control system for a boiler having burners arranged in separate passages directing combustion gases respectively to steam generating and superheating sections comprising, in combination, an air supply passage common to said separate passages, means for delivering air to said supply passage and operating in response to changes in a fluid pressure for varying the amount of air supplied, dampers arranged in said separate passages, means responsive to fluid pressures for positioning said dampers, separate fuel passages for said burners, pressure responsive valve means for controlling the flow of fuel through said fuel passages, means for determining a first fluid pressure in response to changes in boiler steam pressures, means for determining a second fluid pressure in response to changes in discharge steam temperature, means for determining a third fluid pressure proportional to the ratio of air flow to fuel discharge at the burners in one of said separate passages, means for determining a fourth fluid pressure proportional to the ratio of total air flow through the boiler to

total fuel supply to the burners, means for subjecting said air delivering means to said first fluid pressure, relays operating in response to changes in said first and second fluid pressure for determining pressures controlling said damper positioning means, a relay operating in response to said first and fourth fluid pressures for determining a fifth fluid pressure, and relays operating in response to said third and fifth fluid pressures for determining pressures controlling said valve means.

6. A combustion control system for a boiler having burners arranged in separate passages directing combustion gases respectively to steam generating and superheating sections comprising, in combination, an air supply passage common to said separate passages, means for delivering air to said supply passage and operating in response to changes in a fluid pressure for varying the amount of air supplied, dampers arranged in said separate passages, means responsive to fluid pressures for positioning said dampers, separate fuel passages for said burners, pressure responsive valve means for controlling the flow of fuel through said fuel passages, means for determining a first fluid pressure in response to changes in boiler steam pressures, means for determining a second fluid pressure in response to changes in discharge steam temperature, means for determining a third fluid pressure proportional to the ratio of air flow to fuel discharge at the burners in one of said separate passages, means for determining a fourth fluid pressure proportional to the ratio of total air flow through the boiler to total fuel supplied to the burners, means for subjecting said air delivering means to said first fluid pressure, relays subjected to said first and second fluid pressures for determining pressures controlling said damper positioning means, one of said relays operating in response to the total of said fluid pressures and the other operating in response to the difference of said fluid pressures, a relay subjected to said first and fourth fluid pressures and operating in response to the total of such pressures for determining a fifth fluid pressure, and relays subjected to said third and fifth fluid pressures for determining pressures controlling said valve means, one of said last mentioned relays operating in response to the total of said third and fifth fluid pressures and the other operating in response to the difference of such pressures.

7. The system of claim 6 in which said means determining the fourth fluid pressure is manually adjustable to vary the value of the pressure determined by changes in the ratio of fuel flow to air flow.

8. The system of claim 6 in which the one of said first mentioned relays operating in response to the total of the fluid pressures controls the position of the damper in the passage directing combustion gases to the superheating section, and the one of said last mentioned relays operating in response to the total of said third and fifth fluid pressures controls the operation of the valve means regulating the supply of fuel to the burners in the passage directing combustion gases to the generating section.

9. A combustion control system for a boiler having burners arranged in separate passages directing combustion gases respectively to steam generating and superheating sections comprising, in combination, an air supply passage common to said separate passages, means for delivering air to said supply passage in response to changes in a control pressure, dampers arranged in said separate passages, means responsive to fluid pressures for positioning said dampers, separate fuel passages for said burners, pressure responsive valve means for controlling the flow of fuel through said fuel passages, means for determining a first fluid pressure in response to changes in boiler steam pressure, means for determining a second fluid pressure in response to changes in discharge steam temperature, means for determining a third fluid pressure proportional to the ratio of air flow to fuel discharge at the burners in one of said separate passages, means for subjecting said air delivering means to said first fluid pressure, a relay operating in response to the difference between said first and second fluid pressures for determining a pressure controlling the means positioning the damper in the one of said passages directing combustion gases to the generating section, a relay operating in response to the total of said first and second fluid pressures for determining a pressure controlling the other of said damper positioning means, a relay operating in response to the total of said second and third fluid pressures for determining a pressure controlling the one of said valve means regulating fuel supply to the burners in the passage directing combustion gases to the generating section, and a relay operating in response to the difference between said second and third fluid pressures for determining a pressure controlling the valve means in the other of said fuel passages.

10. The system of claim 9 in which said damper positioning means operate to open said dampers on an increase in the pressure supplied thereto, and said valve means operate to increase the supply of fuel to the burners on an increase in the pressure supplied thereto.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,806,970	Gibson	May 26, 1931
1,975,104	Junkins	Oct. 2, 1934
2,124,215	Stillman	July 19, 1938
2,143,820	Payn	Jan. 10, 1939
2,223,658	Bailey	Dec. 3, 1940
2,405,573	Frisch	Aug. 13, 1946

FOREIGN PATENTS

Number	Country	Date
528,269	Great Britain	Oct. 25, 1940