Nov. 10, 1953 H. C. MAY ET AL 2,658,462

COMBUSTION APPARATUS

Original Filed April 20, 1948

Fig. 1

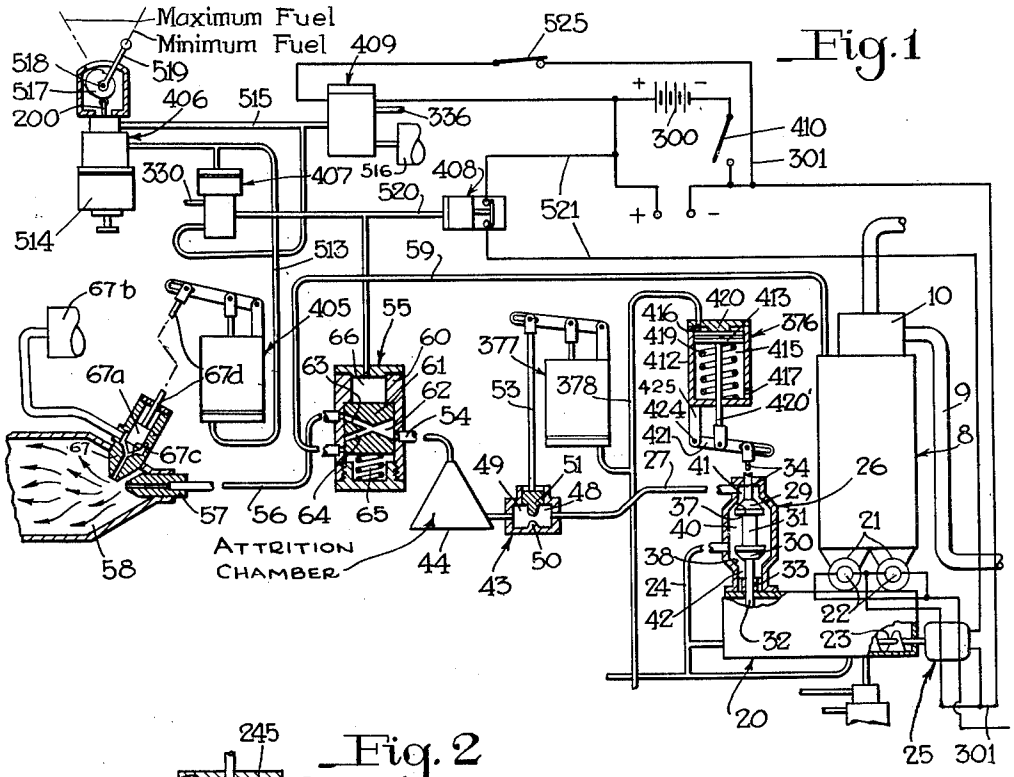


Fig. 2

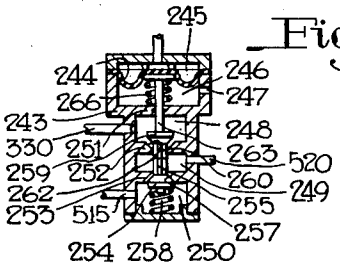


Fig. 3

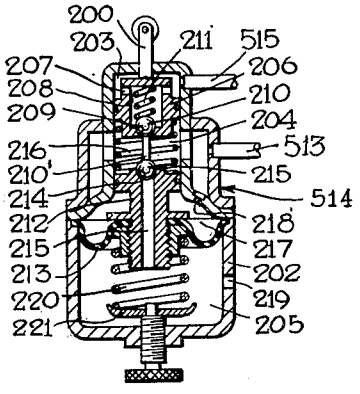
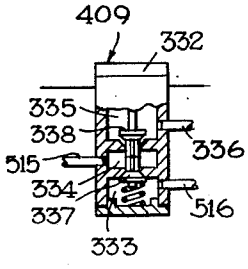


Fig. 4



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COMBUSTION APPARATUS

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2 Claims. (Cl. 110—22)

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This invention relates to combustion apparatus, and more particularly to apparatus for controlling supply of pulverized fuel and/or oil to a combustion chamber, the present invention being a division of our copending application, Serial No. 22,208, filed April 20, 1948 and now Patent No. 2,568,127.

The principal object of the invention is the provision of improved apparatus for controlling supply of pulverized coal and/or oil to a combustion chamber.

Other objects and advantages will become apparent from the following more detailed description of the invention.

In the accompanying drawing; Fig. 1 is a schematic view, partly in outline and partly in section, of control apparatus embodying the invention associated with combustion apparatus to be controlled; Fig. 2 is a vertical-sectional view of a relay valve device comprised in the control apparatus shown in Fig. 1; Fig. 3 is a vertical-sectional view of a self-lapping valve device comprised in the control apparatus shown in Fig. 1; and Fig. 4 is a similar view of a magnet valve device comprised in the control apparatus shown in Fig. 1.

Description

Crushed coal particles for the equipment are stored as a source of supply of fuel such as a first storage tank 8 which is replenished by supply through a conduit 9 and a centrifugal type separator device 10 by means of a suction air stream. The separator device 10 is provided for separating the crushed coal from the conveying air, and a centrifugal type suction fan (not shown) may be provided to create suction for moving said conveying air.

From the first storage tank 8, which may be at slightly less than atmospheric pressure, the crushed coal stored therein is fed into a pressurized coal storage tank 20 which may be at a pressure of one hundred fifty pounds, for example. Coal pumps 21 are arranged to be driven by electric motors 22 for feeding the crushed coal from the storage tank 8 at low pressure into the storage tank 20 at higher pressure. Detail of the coal pumps is not shown, but said pumps may be in the form of a rotatable element having a cavity formed therein arranged to fill with coal when exposed to the tank 8 and to drop said coal upon subsequent exposure to tank 20.

Crushed coal in the pressurized coal storage tank 20 is fed by a worm feed 23 into a line 24 adapted to receive compressed air at say one hundred fifty pounds from a source (not shown).

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An electric motor 25 is provided for driving the worm feed 23.

Pulverized coal thus fed into the line 24 is conveyed by the compressed air flowing therein into a coal feed regulator device 26 which is adapted to regulate the supply of air-conveyed coal from the line 24 to a feed line 27, by-passing any excess back into the storage tank 20.

The regulator device 26 may comprise a feed valve 29 and a by-pass valve 30, both substantially in the shape of a frustrated cone or modified form of needle valve, connected one with the other by a rigid element 31. A stem 32 may be secured at one end to valve 30 and reciprocably disposed within a suitable bore in a sleeve member 33 for guiding movement of the valves. An operating stem 34 may be provided for actuating the valves 29, 30. The opposite end of stem 34 may be disposed outside the casing of device 26 for pivotal connection to an operating lever of an actuating device, as will be described in detail hereinafter. Movement of stem 34 moves valves 29 and 30 toward or away from respective valve seats 37 and 38, according to direction of such movement. As valve 29 is moved toward seat 37 by upward movement of stem 34, valve 30 is simultaneously moved away from seat 38. Line 24 opens into a supply chamber 40 intermediate the two valve seats, while feed line 27 is open to a delivery chamber 41 on the outlet side of seat 37, with a return chamber 42 on the outlet side of seat 38 opening into the top of tank 20. The air-conveyed coal supplied to chamber 40 is distributed to chambers 41 and 42 in accordance with proximity of the valves 29 and 30 to the respective seats 37 and 38, as will be appreciated.

The air-conveyed coal flowing in feed line 27 is expanded through an adjustable nozzle device 43, where the pressure drops from one hundred fifty pounds to about seventy pounds, into a conical attrition chamber 44. The compressed air which has permeated into the pores of each coal particle while passing through line 27 cannot escape rapidly enough to instantaneously attain the pressure in the attrition chamber, after passing through the nozzle device 43, and so it shatters the coal into tiny fragments. The use of a conical attrition chamber after the nozzle device 43 further reduces the size of the particles. The fineness of the product depends upon the pressure drop in the nozzle device, upon the inlet air temperature, and upon the amount of conveying air used per pound of coal. Coal of low grindability requires a higher air-to-coal ratio than coal of high grindability, so the nozzle device is

made adjustable to allow the air-to-coal ratio to be maintained at a suitable value as the coal flow varies. The conveying air to line 24 is supplied by such as a booster compressor (not shown) which may be driven by such as a variable speed turbine (not shown), whereby the pressure at the inlet to nozzle device 43 will tend to vary with speed of the booster compressor which is substantially dependent upon the amount of fuel supplied, but by adjustment of the flow area of said nozzle device the proper pressure drop therethrough may be maintained for any given amount of fuel and supply of conveying air to line 27, as will be more fully described hereinafter.

The adjustable nozzle device 43 may comprise a casing having an inlet chamber 48 to which the feed line 27 is connected, and an outlet chamber 49 connected to the attrition chamber 44. A variable area throat may be formed intermediate the chambers 48 and 49 by an element 50 fixed to the interior of the casing in the path of flow of coal and conveying air admitted to chamber 48, and by an adjustable element 51 projecting into said path of flow opposite to element 50. Adjustable element 51 may comprise a cylindrical portion slidably mounted in a suitable bore in the casing and attached to an operating rod 53 extending outwardly through the casing; the outer projecting end of rod 53 being adapted for pivotal connection to an actuator, as will be described in detail hereinafter, to position the adjustable element 51.

The atomized coal and conveying air leaves the top of the attrition chamber 44 and, via a pipe 54, enters a by-pass control valve device 55, which, during normal running operation of the plant, connects said pipe 54 via another pipe 56 to a nozzle device 57 for introducing the fine particles of the coal from tank 8 to a combustion chamber device 58. The by-pass control valve device 55 is operative, during starting of the combustion chamber with fuel oil, as will be later described, to disconnect the pipe 56 from the pipe 54 and to connect the latter pipe to a return pipe 59 connected to the top of the first storage tank 8. Thus, during starting, any coal and/or conveying air supplied to the feed line 27 by-passes the combustion chamber device 58 and is returned to the storage tank 8 while said combustion chamber is warmed up on an oil flame, as will be pointed out.

The by-pass control valve device 55 may comprise a casing 60 in which is disposed a piston slide valve 61, or the like, having an inlet port 62, which is constantly open to the pipe 54 from the attrition chamber 44, and two separate outlet ports 63, 64 connected to port 62, may be provided for registry with pipes 56 and 59, respectively. In a first position of the valve 61, port 63 registers with pipe 56 while port 64 is blanked off, and in a second position, the port 63 is blanked off and port 64 registers with the return pipe 59. A compression spring 65 may be arranged to urge valve 61 in the direction of its first position, and by supply of fluid under pressure to a chamber 66, action of said spring may be overcome to move said valve to its second position. Upon venting of fluid under pressure from chamber 66, the spring 65 returns valve 61 to its first position, in which it is shown in the drawing.

A second nozzle device 67 is provided for introducing fuel oil to the combustion chamber device 58 for warm-up of the turbine (not shown) during starting and for supporting a pilot flame to assure combustion of coal during running operation of said turbine. Associated with nozzle device 67 is a fuel oil flow control element, such as a needle valve 67*a*, adjustable to different positions to regulate flow of fuel from a source independent of tank 8, such as a fuel oil supply tank 67*b*, through said nozzle device to the combustion chamber device 58. By advancing the needle valve 67*a* toward a seat 67*c*, the amount of fuel oil to the combustion chamber device 58 is reduced. By moving valve 67*a* away from seat 67*c*, the amount of fuel oil to chamber device 58 is increased. A stem 67*d* is provided to allow for adjustment of the needle valve 67*a*. One end of stem 67*d* is attached to the needle valve, while the opposite end is adapted to be connected to an actuator device for effecting the adjustment of said valve, as will be described hereinafter.

A fluid pressure actuator device 376 is provided for positioning the coal feed regulator device 26, and a similar fluid pressure actuator device 377 is provided for positioning the adjustable nozzle device 43. Both actuator devices 376, 377 are adjustable in accordance with variations in pressure of fluid in a control line 378 common to both devices for simultaneous positioning of devices 26 and 43.

For adjusting position of the needle valve 67*a* of nozzle device 67 to control supply of fuel oil to the combustion chamber device 58, a fluid pressure fuel oil nozzle control actuator device 405 is provided. An operator's control valve device 406 is provided for controlling supply of fluid under pressure to the actuator device 405. A relay valve device 407, responsive to pressure of fluid from the operator's control valve device 406, is operable to effect supply of fluid under pressure to the by-pass valve device 55 and to a normally closed fluid pressure switch device 408 for stopping motor 25 to prevent coal from being fed into the feed pipe 27 during warm-up with fuel oil, as will be described hereinafter. A magnet valve device 409 is provided for controlling supply of fluid under pressure to the operator's control valve device 406.

A starting switch 410 is provided for controlling supply of electric current from a source of electrical energy such as the battery 300 to the magnet valve device 409, and the various electric motors in the plant, as will be described hereinafter in detail.

The fluid pressure actuator device 376, 377, 405 may comprise a hollow cylindrical casing 412 containing a piston 413 slidably mounted therein which is subject to pressure of fluid in a chamber 415 at its one side and to pressure of fluid in a chamber 416 at its opposite side. Chamber 415 is open to a port 417 in the casing, which, in the present instance, is open to the atmosphere. A compression control spring 419 is disposed in chamber 415 and arranged to urge the piston 413 in the direction of chamber 416 toward a rest position seated against a projecting portion of an end wall 420 secured to the casing. A piston rod 420′ is attached at its one end to the piston 413 for movement therewith, and at its opposite projecting end outside the casing is pivotally connected to an operating lever 421 for positioning same. An opening in the casing accommodates the rod 420′ which is slidable therein.

The operating lever 421 is pivotally connected at its one end by a pin 424 to a projecting arm

425 attached to casing 412. The opposite end of lever 421 is provided with a slot to accommodate a pin or the like for operative connection to a device or element to be positioned.

The operating lever 421 of actuator device 376 is operatively connected to stem 34 of the coal feed regulator device 26, while lever 421 of the actuator 377, which is similar to device 376, is operatively connected to the rod 53 of the adjustable nozzle device 43. The respective chamber 416 of both actuator devices 376, 377 is connected to the control line 378 which is common to both of said devices.

In both the actuator devices 376, 377, upon supply of fluid under pressure to the chamber 416 therein, the piston 413 will move in the direction of chamber 415 against action of spring 419, and through rod 420' attached to said piston, will adjust position of lever 421 according to degree of movement of the piston. Piston 413 will move in the direction of chamber 415 until the fluid pressure force on its one side balances the force of spring 419 on its opposite side, and this in turn will depend on the degree of pressure of the fluid supplied to the chamber 416. Upon subsequent reduction in pressure of fluid in the chamber 416, the piston will move in the direction of said chamber by action of spring 419 a distance dependent upon the degree of said reduction, with a resultant repositioning of the lever 421. It will thus be seen that lever 421 will be caused to assume an angular position closer to or further away from the casing of the actuator device in accord with the degree of pressure of the fluid in the chamber 416.

Variations in pressure of fluid effected via the control pipe 378 simultaneously in the respective chambers 416 in both devices 376, 377 effects simultaneous adjustment of the position of the respective levers 421. As fluid under pressure in chamber 416 in actuator device 376 is increased through consequent positioning of the operating stem 34 attached to lever 421, the valves 29 and 30 in the coal feed regulator device 26 are positioned to increase the amount of coal supplied to the feed line 27 and reduce the amount of coal returned to the tank 20. As the pressure of fluid in the chamber 416 of the actuator device 376 is decreased, through the lever 421 and stem 34 the valves 29 and 30 are positioned correspondingly to decrease the amount of coal to the feed line 27, and hence the combustion chamber 58 and return the balance to the tank 20. The amount of coal supplied to the feed line 27, is thus varied in accordance with pressure of fluid in the control line 378, increasing as pressure of fluid in said line is increased and decreasing as pressure of fluid in said line is decreased.

In similar manner, increase in pressure of fluid in the chamber 416 of device 377, through lever 421, positions rod 53 and adjustable element 51 in nozzle device 43 to increase the flow area at the throat. Decrease in pressure of fluid in chamber 416 in actuator device 377 causes adjustment of rod 53 and adjustable element 51 in nozzle device 43 to decrease the throat area of said nozzle device. An increase in coal and air supply to the fuel line 27 calls for an increased throat area in the adjustable nozzle device 43, while a decrease in coal and air in fuel lines 27 calls for a decrease in said throat area, in order to maintain the proper pressure drop through said nozzle device. For this reason, the coal feed regulator device 26 and the adjustable nozzle device 43 are positioned simultaneously in accordance with variations in pressure of fluid in the control line 378.

In the starting portion of the control apparatus for the plant, the fluid pressure actuator device 405 for adjusting position of the needle valve device 67 is similar to the actuator device 376. Device 405 is responsive to variations in pressure of fluid in a control pipe 513 connected to chamber 416 therein to adjust position of needle valve 67*a* in device 67. As pressure of fluid in chamber 416 is increased from a minimum value of ten pounds to a maximum value of sixty pounds, for example, the actuator device 405 will respond to vary position, through lever 421 and stem 67*d* of the needle valve 67*a* from a substantially closed position to a fully open position for accordingly varying the amount of fuel oil supplied from pipe 67*b* through nozzle device 67 to the combustion chamber device 58 from a minimum amount to a maximum amount. When pressure of fluid in control pipe 513 is at its minimum value, ten pounds for example, the needle valve 67*a* will be disposed a slight distance away from its seat 67*c* to allow a certain quantity of fuel oil to flow to the combustion chamber to support a pilot flame for assuring combustion of coal supplied to said chamber during running of the plant after warm-up with the oil. Graduated increase in pressure of fluid in control pipe 513 will cause graduated increase in amount of fuel oil supplied to the combustion chamber device 58 for warm-up of the plant during starting thereof. During starting, the turbine shaft is rotated by a starting motor (not shown) while the fuel oil is burned in the combustion chamber for warm-up until such as a turbine (not shown) develops sufficient power to be self-operating and is taken off the starting motor and operated on the fuel oil.

The control pipe 513 is connected to the delivery chamber 204 of a self-lapping valve portion 514 of the operator's control valve device 406.

Referring to Fig. 3, the self-lapping valve portion 514 of the operator's control valve device 406 may comprise a casing 202 having a supply chamber 203, a delivery chamber 204, and an exhaust chamber 205 therein. A supply valve seat element 206, attached to operating stem 200 for movement therewith, is adapted for reciprocable movement within the casing 202. Element 206 is open at one side to the supply chamber 203 by way of ports 207 and a cavity 208, and at its opposite side to the delivery chamber 204 by way of a supply valve seat 209. A supply valve 210 in the form of a ball may be disposed within cavity 208 for controlling communication between the supply chamber 203 and the delivery chamber 204. A bias spring 211 is disposed in the cavity 208 for urging the valve 210 toward a normally closed position on seat 209. An exhaust valve seat element 212, secured for reciprocable movement with a diaphragm 213, is open at one end to the delivery chamber 204 by way of an exhaust valve seat 214 formed therein. Valve seat element 212 extends through the diaphragm and opens into the exhaust chamber 205 by way of a central opening 215 extending from end to end. An exhaust valve 215' connected to the supply valve 210 by a pin 210' and in the form of a ball is disposed in delivery chamber 204 to cooperate with the seat 214 in element 212 for controlling communication via opening 215 between said delivery chamber and the exhaust chamber 205. A bias spring 216, disposed in the delivery chamber 204, may be interposed between seat elements

206, 212 for biasing the seat element 206 in the direction of chamber 203. The diaphragm 213 is subject on one side to pressure of fluid in a diaphragm chamber 217, which pressure of fluid is that of the delivery chamber 204, the two chambers being connected one to the other by way of a choke 218. The opposite side of the diaphragm 213 is exposed to atmosphere in the exhaust chamber 205, said exhaust chamber being open to the atmosphere by way of a port 219 in the casing. A compression control spring 220 is disposed in the exhaust chamber 205, interposed between the diaphragm and an adjustable spring seat element 221, for determining the degree of deflection of said diaphragm for any given pressure condition in the delivery chamber 204. The adjustable spring seat 221 is provided to allow for changing the precompression of the control spring 220.

In operation of the self-lapping valve portion 514 of operator's control valve device 406, when operating stem 200 is moved inwardly of the casing 202 a certain distance and held there, the attached seat element 206 is moved downwardly, as viewed in the drawing, while the supply valve seat 209 formed in the end of element 206 is moved away from the supply valve 210. At this time supply valve 210 will remain stationary due to seating engagement of the attached exhaust valve 215' on seat 214 of element 212. After the supply valve seat 209 moves away from the supply valve 210, supply chamber 203 is opened to delivery chamber 204 by way of the ports 207, cavity 208 and seat 209. Fluid under pressure supplied to the supply chamber 203 from any suitable source will then flow into the delivery chamber 204 where the pressure of fluid will thus be caused to increase. Pressure of fluid in diaphragm chamber 217 will increase with that in the delivery chamber 204, the former chamber being open to the latter by way of choke 218. Pressure of fluid in diaphragm chamber 217, being greater than the atmospheric pressure in chamber 205 will deflect diaphragm 213 against action of spring 220 in the direction of the last named chamber. Deflection of diaphragm 213 will carry the exhaust valve seat element 212 with it. Bias spring 211 will cause the supply valve 210 and exhaust valve 215' to follow movement of element 212, while said exhaust valve remains seated on seat 214 in the end of said element, until said supply valve seats on seat 209 in element 206. Upon seating of the supply valve 210, the supply chamber 203 is closed to the delivery chamber 204 and further increase in pressure in the last named chamber thereby will be prevented. In absence of further increase in delivery pressure in the diaphragm chamber 217, the pressure force on its one side will balance with spring force on its opposite side and further deflection of said diaphragm will cease. The supply valve 210 and the exhaust valve 215' remain seated. If, at this time, stem 200 were moved inwardly a greater amount, element 206 would again be moved downwardly to unseat from the supply valve 210, the above described action would repeat, and an increase in pressure of fluid would be secured in the delivery chamber 204. The pressure of fluid thus obtained in the delivery chamber 204 will vary in substantial proportion to the degree of inward movement of the operating stem 200. The minimum pressure which will be held in the delivery chamber 204 will depend on the degree of precompression of the control spring 220 which may be changed by adjusting position of the spring seat element 221.

If, subsequently, the operating stem 200 is allowed to be moved outwardly of the casing by action of spring 216 to a more extended position, the supply valve 210 and attached exhaust valve 215' will be carried with it. The exhaust valve 215' is thus unseated from seat 214 in element 212 and the delivery chamber 204 thereby opened by way of opening 215 in said element to exhaust chamber 205. Delivery pressure in chamber 204 is thus caused to reduce, and such reduction, reflected in the diaphragm chamber 217, allows the control spring 220 to deflect the diaphragm 213 upwardly. Upward deflection of the diaphragm 213 carries the element 212 into engagement with the exhaust valve 215'. The delivery chamber 204 is thus closed off from the exhaust chamber 205 and further reduction in delivery pressure prevented. The diaphragm 213, therefore, ceases further deflection, and both the supply valve 210 and exhaust valve 215' remain seated. A reduced delivery pressure, determined by position of the operating stem 200, is thus secured.

Summarizing action of the self-lapping valve portion 514 of the operator's control valve device 406, it will be seen that with the proper adjustment of spring 220 and with fluid at adequate pressure in chamber 203, the pressure of fluid in the delivery chamber 204 will vary in accordance with position of element 206 as determined by position of the attached stem 200. For example, assume that the chamber 203 is connected to a source of fluid at a pressure of sixty pounds, and it is desired to vary the delivery pressure in chamber 204 in a range between ten pounds and sixty pounds. The spring 220 may be adjusted so that with element 206 in a rest position, ten pounds will be established in delivery chamber 204, and as said element is positioned equal increments in the direction of said chamber by depression of stem 200, the pressure of fluid in said chamber is graduated in correspondingly equal increments until sixty pounds is reached. In the present example, that is, as long as the pressure of fluid in supply chamber 203 is as great as the maximum pressure desired in the delivery chamber 204, the pressure of fluid in said delivery chamber is determined by position of stem 200.

The supply chamber 203 in portion 514 of device 406 is connected to a supply pipe 515 which is adapted to be supplied with fluid under pressure via a delivery chamber in the magnet valve device 409 when energized.

Magnet valve device 409 may be of a well-known type comprising a magnet portion 332 shown in outline, and a valve portion shown substantially in cross-section. The valve portion may be provided in the usual manner with a supply chamber 333, delivery chamber 334, and an exhaust chamber 335.

A normally closed supply valve 337 disposed in chamber 333 is provided for controlling communication between the supply chamber 333 and the delivery chamber 334. A normally open release valve 338 in chamber 335 controls communication between the delivery chamber 334 and the exhaust chamber 335. A bias spring disposed in the supply chamber 333 is arranged to urge the supply valve 337 toward its closed position and at the same time urge the release valve 338 toward an open position, in which position the two valves are shown in the drawing.

In magnet valve device 409, its supply chamber

333 is connected to a source of fluid under pressure such as a reservoir 516 adapted to be charged by a compressor (not shown) to furnish fluid under pressure before the plant is started. When magnet valve device 409 is deenergized, supply pipe 515 is connected to the atmosphere via pipe 336, and when device 409 is energized, said pipe 515 is connected to reservoir 516.

The operator's control valve device 406 also comprises an operating portion for adjusting position of the stem 200 in the self-lapping valve portion 514 for effecting the variations in pressure of fluid in control pipe 513. The operating portion may be provided with a cam 517 adapted to be rotated about a fixed point 518 by an operator's handle 519. A casing may be provided secured to the self-lapping valve portion 514 to carry the cam 517 and handle 519. Handle 519 may project outwardly through a suitable slot formed in the casing. Opposite ends of the slot may define the opposite extreme limits of travel for movement of the handle 519, and these limits may represent "Minimum Fuel," in which position it is shown in the drawing, and "Maximum Fuel," respectively. The cam 517 is so shaped that by moving the handle from "Minimum Fuel" position towards "Maximum Fuel" position the self-lapping valve portion 514 is rendered responsive to effect an increase in pressure of fluid in control pipe 513 to call for more fuel oil to be supplied from nozzle device 67 to the combustion chamber device 58. Conversely, by subsequent movement of handle 519 back toward "Minimum Fuel" position, calls for a reduction in amount of fuel oil to the combustion chamber, accordingly.

Referring to Fig. 2, the relay valve device 407 may comprise a casing 243 having a diaphragm 244 disposed therein subject to pressure of fluid in a diaphragm chamber 245 on one side and to pressure of fluid in a chamber 246 on its opposite side, which latter chamber is open to the atmosphere via a port 247 in the casing. Also formed in the casing are chambers 248, 249 and 250, chamber 248 being separated from chamber 246 by a partition 251 and from chamber 249 by a partition 252. A partition 253 separates chambers 249 and 250. A valve 254 is disposed in chamber 250 for controlling communication between said chamber 250 and the chamber 249. Valve 254 may be secured to a fluted stem 255 slidably mounted in a suitable bore extending through the partition 253, a seat 257 being formed in one end of said bore to accommodate said valve. A bias spring 258 is disposed in chamber 250, arranged to urge the valve 254 in the direction of seat 257. A valve 259, similar to valve 254, may be disposed in chamber 248 for controlling communication between said chamber 248 and the chamber 249, which latter chamber may be considered to be a delivery chamber. For slidably guiding valve 259, a fluted stem 260 is provided which is slidably disposed in a suitable bore opening through partition 252. A valve seat 262 is provided, formed in partition 252 for accommodating the valve 259. Stems 255, 260 project into and meet in the chamber 249 in such a manner that action of bias spring 258 on valve 254, in urging same in the direction of its seat 257, at the same time, through said stems, urges valve 259 in a direction away from seat 262. If valve 259 is seated, valve 254 is consequently unseated. Valve 259 is operatively connected to the diaphragm 244 by means of a rod or stem 263 extending therebetween through a bore in partition 251 in which said rod is slidably disposed. A sealing ring may be provided in partition 251 for slidable sealing engagement with rod or stem 263 to prevent leakage of fluid under pressure past the stem from chamber 248 and to chamber 246. A control spring 266 in chamber 246, arranged to oppose deflection of diaphragm 244 in the direction of chamber 248 as caused by pressure of fluid in chamber 245, is provided for determining the degree of said pressure necessary for effecting operation of valves 254, 259.

In relay valve device 407, diaphragm chamber 245 is connected to the control pipe 513, chamber 248 is connected to atmosphere via a pipe 330, delivery chamber 249 is connected to a control pipe 520 which is in turn connected to the pressure switch device 408, and to chamber 66 in by-pass valve device 55, while chamber 250 is connected to supply pipe 515.

When the control pipe 513, and hence the diaphragm chamber 245 in relay valve device 407, are pressurized, the diaphragm 244 is deflected in the direction of the chamber 246 so that valve 259 is seated and valve 254 unseated. With valve 259 seated, and valve 254 unseated, delivery chamber 249 is closed to chamber 248 to atmosphere and open to chamber 250.

When the control pipe 513 and the diaphragm chamber 245 of relay valve device 407 are not pressurized, the diaphragm 244 will be disposed in a rest position in which it is shown in the drawing, with valve 259 open and valve 254 closed. The delivery chamber 249 therefore is then closed to chamber 250 and open to atmosphere via chamber 248.

When pressure of fluid in control pipe 513 is increased above its minimum value a certain amount by movement of handle 519 in the control valve device 406 out of "Minimum Fuel" position, during starting of the plant, the relay valve device 407 will respond to pressure of fluid in said pipe 513 to connect the control pipe 520 to supply pipe 515 to open the switch device 408 and to move the piston slide valve 61 in by-pass valve device 55 to its second position, as previously defined for by-passing any coal and/or air supplied to the pipe 54 back into the tank 8 via pipe 59.

When handle 519 is in "Minimum Fuel" position, that is, when pressure of fluid in pipe 513 is consequently at a minimum, the relay valve device 407 will respond to such pressure to connect control pipe 520 to atmosphere via pipe 330.

The normally closed pressure switch device 408 is interposed in a wire 521 connected between one pole of battery 300 and one pole of the motor 25, the opposite pole of said motor being connected to the opposite pole of said battery by way of the wire 301 and starting switch 410.

When the switch 410 is closed, which will be the first thing to be done upon starting the plant, the terminals of battery 300 are connected to the wires 301 and 521. With the pressure switch device 408 normally closed in response to depressurization of the control pipe 520, the circuit including the closed switch 410 and wires 301, 521 is established between battery 300 and the motor 25 to operate same for feeding coal from tank 20 into the pipe 24. Upon movement of handle 519 in the control valve device 406 out of "Minimum Fuel" position, for supplying fuel oil to the combustion chamber device for warm-up, it will be seen that through consequent operation of the relay valve device 407 the control pipe 520 will become connected via device 407 to the charged

supply pipe 515 and hence become pressurized. The pressure switch device 408 will respond to such pressurization of control pipe 520 to disestablish the above defined electrical circuit to terminate operation of motor 25, thus preventing any supply of coal to the feed line 27, while the by-pass valve device 55 connects pipe 54 to pipe 59, so that while the combustion chamber device is being warmed-up on fuel oil, any coal and/or combustion air flowing in pipe 54 will be returned to tank 8.

When it is desired to operate the combustion chamber device 58 on coal, the handle 519 may be backed off toward "Minimum Fuel" position for reducing pressure of fluid in pipe control 513. When pressure of fuel in control pipe 513 reaches a certain value, the relay valve device 407 will respond to cut-off control pipe 520 from supply pipe 515 and to connect said control pipe 520 to atmosphere. The switch device 408 then returns to its normally closed position to start up the motor 25 for supplying coal to the pipe 24 in which conveying air will now be flowing, and the by-pass valve device 55 is then allowed to return to its first position to connect coal and conveying air flowing in pipe 54 to pipe 56 for supply to the combustion chamber device 58. Coal thus supplied at this time to the combustion chamber may be burned along with a relatively great amount of fuel oil from nozzle 67 to assure proper combustion of said coal. The handle 519 in control valve device 406 may then be returned to "Minimum Fuel" position for cutting supply of fuel oil down to a quantity sufficient to support a pilot flame in the combustion chamber 58. Subsequent control of supply of coal to the combustion chamber device is then effected through variation in pressure of fluid in the pipe 378 as previously described.

A normally closed switch 525 may be opened or closed to disestablish and establish the electrical circuit, including in series the battery 300, magnet valve device 409 and switch 410, to control supply of energizing current to the magnet valve device 409 accordingly. Opening switch 525 enables magnet valve device 409 to be de-energized to vent supply pipe 515 to atmosphere and thereby render the operator's control valve device 406 ineffective to operate actuator device 405, thus preventing an unintentional increase in supply of fuel oil, other than the pilot supply, to the combustion chamber device 58 by accidental movement of handle 519 in control valve device 406 during operation of the combustion chamber on coal.

Summary

From the foregoing description, it will be apparent that, according to one interpretation of the invention, the reservoir 516 may be considered to be a source of fluid under pressure, the battery 300 may be considered to be a source of electrical energy. The fuel oil tank 67*b* may be considered to be a source of fuel oil, and the tanks 8 and/or 20 may be considered to be the source of pulverized coal. Since the source of fuel oil 67*b* and the source of pulverized coal 8 are independent and there is one of each source, and since both are sources of fuel, same may be considered to be two independent sources of fuel. Since the pipe 24, regulator device 26, feed line 27, device 43, chamber 44, pipe 54, valve device 55 and pipe 56 act to convey coal to the nozzle device 57, same may be considered to be fuel conveying means to convey fuel to one of said

nozzle devices. The worm feed 23 driven by motor 25 may be considered to be motor operated feeder means for feeding fuel from one of said sources of fuel to the conveying means 24, 26, 27, etc. The control pipe 513 might be considered to be a first control pipe to distinguish over the control pipe 520, which latter might be referred to as a second control pipe. The actuator device 405 including valve 67*a* associated with nozzle device 67 might be referred to as fuel flow regulating means for regulating flow of fuel from the other of said sources of fuel 67*b* through the other nozzle device 67, between a maximum and a minimum amount in response to variation in pressure of fluid in said first control pipe 513 between a maximum and a minimum pressure, respectively. The operator's control valve device 406 might be referred to as an operator's control valve device employing fluid under pressure from the supply pipe 515 to effect the variation in pressure of fluid in the first control pipe 513. The pressure switch device 408 might be referred to as a pressure switch device responsive to establishment and disestablishment of pressure in the second control pipe 520 to disestablish and establish, respectively, an electrical circuit 521, 301, 410 between the source of electrical energy 300 and the motor operated feeder means 23, 25. The relay valve device 407 may be referred to as relay valve means responsive to pressure of fluid in the first control pipe 513 at or above the minimum pressure to connect the second control pipe 520 either to atmosphere or to the supply pipe 515, respectively. The magnet valve device 409 might be referred to as magnet valve means energizable and de-energizable to establish connection between the supply pipe 515 and either the source of fluid under pressure 516 or atmosphere via 336, respectively, and the switch 525 may be referred to as switch means operable to establish and disestablish electrical circuit between the source of electrical energy 300 and the magnet valve means 409.

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

1. In combination with a source of fluid under pressure, a source of electrical energy, a combustion chamber device, two independent sources of fuel, and two nozzle devices for introducing fuel into said combustion chamber device from said two sources of fuel, respectively, fuel conveying means for conveying fuel to one of said nozzle devices, motor operated feeder means for feeding fuel from one of said sources of fuel to said conveying means, a first control pipe, fuel flow regulating means for regulating flow of fuel from the other of said sources of fuel through the other nozzle device, between a maximum amount and a minimum amount in response to variation in pressure of fluid in said first control pipe between a maximum pressure and a minimum pressure, respectively, a fluid pressure supply pipe, an operator's control valve device employing fluid under pressure from said supply pipe to effect said variation in pressure of fluid in said first control pipe, a second control pipe, a pressure switch device responsive to pressurization and depressurization of said second control pipe to disestablish and establish, respectively, an electrical circuit between said source of electrical energy and said motor operated feeder means, relay valve means responsive to pressure of fluid in said first control pipe at or above said minimum pressure

to connect said second control pipe either to atmosphere or to said supply pipe, respectively, magnet valve means energizable and de-energizable to establish connection between said supply pipe and either said source of fluid under pressure or atmosphere, respectively, and switch means operable to establish and disestablish electrical circuit between said source of electrical energy and said magnet valve means to control energization thereof.

2. In combination with a fluid pressure supply pipe, a source of electrical energy, a combustion chamber device, two independent sources of fuel, and two nozzle devices for introducing fuel into said combustion chamber device from said two fuel sources, respectively, by-pass valve means having a chamber and being responsive to release or supply of fluid under pressure to and from said chamber to establish a fuel supply communication between one of said sources of fuel and the respective one of said nozzles or to by-pass said supply communication, respectively, a control pipe, fuel flow regulating means for regulating flow of fuel from the other of said fuel sources to the respective other of said nozzle devices between a maximum amount and a minimum amount in response to variation in pressure of fluid in said control pipe between a maximum

pressure and a minimum pressure respectively, a fluid pressure supply pipe, an operator's control valve device employing fluid under pressure from said supply pipe to effect said variation in pressure of fluid in said control pipe, relay valve means responsive to pressure of fluid in said control pipe at or above said minimum pressure to connect said chamber either to atmosphere or to said supply pipe, respectively, magnet valve means energizable and de-energizable to establish connection between said supply pipe and either said source of fluid under pressure or atmosphere, respectively, and switch means operable to establish and disestablish electrical circuit between said source of electrical energy and said magnet valve means.

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