

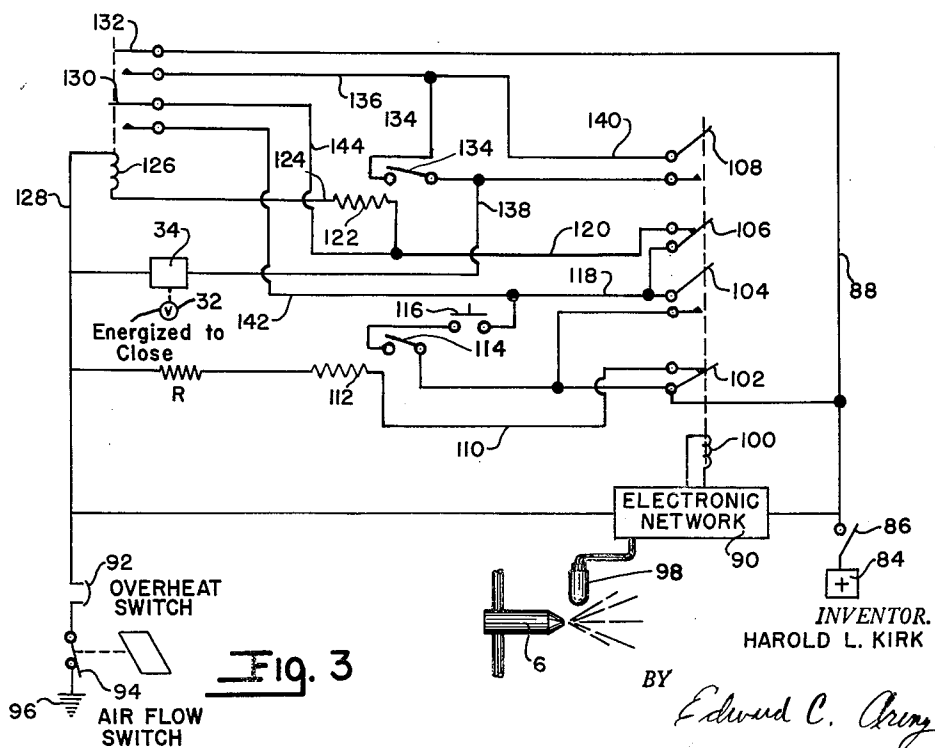
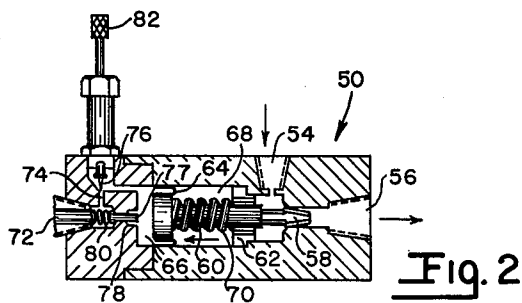
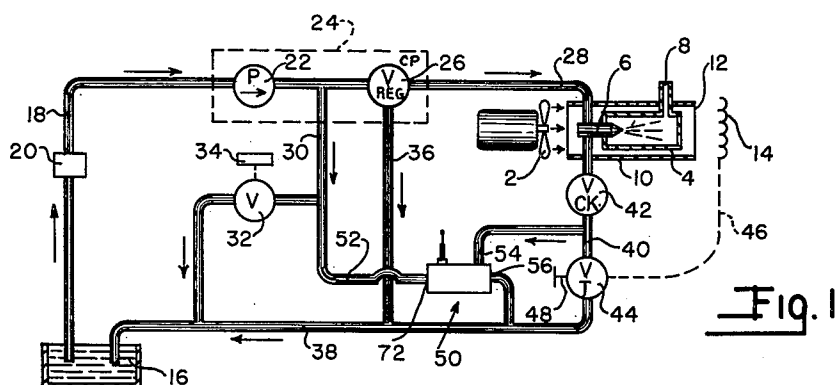
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AIR HEATER FUEL CONTROL SYSTEM

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AIR HEATER FUEL CONTROL SYSTEM

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This invention relates to a control system for space heaters employing gasoline or a similar liquid fuel.

Hubbard U.S. Patent 2,758,591, issued August 14, 1956 illustrates a portable space heater of the type commonly used to supply heated air to aircraft and other enclosed spaces. The present invention is directed to an improved fuel control system for a heater of this general type.

Such heaters conventionally comprise: a fuel burner-combustion chamber; a heat exchanger; blower means for supplying combustion air and ventilating air to the burner and heat exchanger respectively; fuel supply and ignition means; and means for controlling the flow of fuel in accordance with departures in sensed air temperature from a selected air temperature.

Upon starting such a heater, the means controlling fuel flow ordinarily calls for or demands full or maximum fuel flow to the burner since the sensed discharge air temperature is considerably below the desired discharge air temperature. The discharge of a maximum or relatively high rate of fuel into the burner when starting is objectionable because of thermal shock to heater structure, inefficient combustion and the possibility that a substantial quantity of fuel may be discharged into the burner without ignition thereof, and other reasons. While the effect of high initial fuel discharge may be relatively unimportant for a heater such as the commercial embodiment of the aforesaid Hubbard patent wherein the maximum rate of fuel into the burner is below 5 g.p.h., a substantial problem arises with higher capacity heaters adapted to burn fuel at a rate of 25 g.p.h. or higher.

Thus, one object of this invention is to provide a control system operable to give a relatively low fuel discharge rate or a so-called low fire start upon initiating burner combustion.

Another object is the provision of a control system operable to increase progressively the rate of fuel discharge into the burner from a low or minimum rate upon initiating burner combustion to a higher rate determined by normally controlling fuel flow control means.

Another object is the provision of such a control system including means responsive to combustion conditions in the burner for controlling fuel flow to the burner.

Still another object is the provision of a control system operative to reset itself automatically to give a low fire start upon subsequent starting after termination of fire in the burner for any reason.

Briefly, in accordance with one feature of the invention, a low fire start valve provided in parallel with a normally controlling fuel flow throttle valve is arranged to be operated progressively from a fully open position upon firing the burner, to a fully closed position as firing continues. Thus, upon firing the burner, fuel bypasses the normally controlling throttle valve and thereby renders its control of fuel flow ineffective. As the low fire start valve progressively closes in response to a continuing combustion condition, control is restored progressively to the throttle valve.

Further, the invention contemplates that the low fire start valve be controlled in response to a condition of fuel flow or pressure in a bypass line or conduit, this condition in turn being controlled by combustion conditions in the burner or other conditions related to safe heater operation.

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The invention will be explained in connection with the accompanying drawing illustrating a preferred embodiment by way of example, and wherein:

Figure 1 is a diagrammatic view of a fuel system embodying the present invention;

Figure 2 is a sectional view of a low fire start valve suitable for use in the invention; and

Figure 3 is a schematic view of an electrical circuit for controlling fuel conditions in the primary bypass line.

The combustion and air heating system is of the general type illustrated in Hubbard U.S. Patent 2,758,591, issued August 14, 1956, and as shown diagrammatically in Figure 1 comprises: forced air blower means 2 providing ventilating air and combustion air; a combustion chamber or burner 4 disposed to receive combustion air from the blower 2, and liquid fuel from jet nozzle 6, the burner also containing conventional igniting spark electrodes (not shown) adjacent the jet orifice of the nozzle; an exhaust stack 8 communicating with the combustion chamber and through which exhaust gases are passes to atmosphere; an outer jacket 10 defining a heat exchanging passageway between the combustion chamber and the outer jacket so that ventilating air may be heated in its passage therethrough; an air outlet 12 through which ventilating air is discharged into suitable conveying ducts for delivery to the served space; and, a discharge air temperature sensing element 14 preferably disposed in the path of the heated ventilating air and responsive to the differential between a selected and a sensed air temperature to control the operation of a throttle valve. It is to be understood that while a single blower means 2 is shown for providing flow of both combustion air and ventilating air, separate blowers of proper capacity may be used for each of the air flows respectively.

The fuel system includes a tank 16 containing a supply of gasoline or a similar liquid fuel, a tank outlet line 18 having a fuel filter 20 therein and an electrically driven fuel pump 22 for drawing fuel from the tank. The direction of fuel flow is indicated by the arrows in Figure 1. The pump 22 is within a housing 24 which also includes a conventional balanced regulating type valve 26. The regulating valve 26 is adjusted to open at a predetermined pressure (e.g., 150 p.s.i.) to permit flow of fuel at that pressure into line 28 leading to nozzle 6. A primary return or bypass line 30 is connected intermediate the pump 22 and regulating valve 26 and includes a two position valve 32 operated by solenoid 34. With the pump 22 operating and the valve 32 open, all of the fuel discharged by the pump flows through the primary bypass line 30 and valve 32 back to the tank 16 since the open valve 32 prevents the build-up of sufficient fuel pressure to open regulating valve 26. It will thus be apparent that when primary bypass valve 32 is open, no fuel flows to the nozzle through nozzle supply line 28.

A secondary bypass line 36 connects the regulating valve 26 to the return line 38 so that when primary bypass valve 32 is closed, and regulating valve 26 is consequently open to pass fuel at the predetermined pressure into nozzle supply line 28, the excess fuel not required to maintain the pressure in the nozzle supply line is bypassed or returned to tank 16.

Burner nozzle 6 is of the conventional bypass type which permits an operation wherein the rate of fuel discharged into the burner through nozzle 6 is controlled by throttling fuel flow on the downstream side of the nozzle. Such a burner nozzle is illustrated and described in detail in the aforementioned Hubbard U.S. Patent 2,758,591 and includes a supply chamber into which fuel from nozzle supply line 28 flows, a combustion jet orifice through which some of the fuel escapes as a spray or jet into the burner, and a bypass chamber in the nozzle which receives the rest of the fuel. With fuel supplied

by line 28 at a constant pressure to the nozzle, part of the fuel will be discharged through the jet orifice into the burner chamber and part of it will bypass to the bypass chamber in the nozzle.

The nozzle bypass chamber is connected to nozzle return or bypass line 40 having a check valve 42 and a throttling valve 44. The check valve 42 is provided to prevent residual fuel or an unbalanced pressure between the lines 40 and 28 from causing feedback of fuel to the nozzle after the heater has been shut down. The throttle valve 44 serves in normal heater operation to throttle the nozzle bypass line 40 and thereby control the rate at which fuel is discharged through the nozzle jet orifice. As will be apparent, the more the nozzle bypass line 40 is throttled, the more fuel is discharged from the nozzle jet orifice; and conversely, the less the nozzle bypass line is throttled, the less fuel issues through the nozzle jet orifice.

The throttle valve 44 is described and claimed in U.S. Patent No. 2,505,933, issued May 2, 1950 to Clarence A. Aughey et al. and therefore will be described only briefly. It is controlled, after selection of a desired air temperature, in response to the discharge air temperature of the ventilating air sensed by element 14 positioned in the heater outlet. The temperature responsive element 14 is connected by a capillary tube 46 to the valve 44 for controlling opening and closing of the valve 44 in accordance with sensed temperature conditions at the element 14. The throttle valve may be adjusted to control fuel flow in normal heater operation to give various selected ventilating air temperatures by rotating a temperature selection knob 48, which rotation varies the compression of an internal valve spring opposing pressure in the capillary line 46. Assuming the temperature selection knob 48 has been adjusted to give a selected temperature during the normal operation of the heater, a sensed ventilating air temperature exceeding this selected temperature causes throttle valve 44 to be operated in an opening direction to decrease the fuel discharge rate into the burner. Conversely, when the sensing element 14 senses that the ventilating air temperature is below the selected value, the throttle valve 44 is operated in a closing direction to increase the fuel discharge rate into the burner.

A low fire start valve 50 is connected in a second nozzle return or bypass line, or in other words, in parallel with throttle valve 44 between nozzle bypass line 40 and return line 38. The control portion of valve 50 is placed in communication with the nozzle bypass line 30 by means of pilot pressure line 52. It will be apparent that since low fire start valve 50 is in parallel with throttle valve 44, it can be operated to exert control over the rate of fuel discharged from the nozzle jet orifice into the burner. The low fire start valve 50 is arranged to be operated to exert this control only upon starting combustion in the burner and for a short period thereafter and is controlled to be closed during normal operation of the heater so that the rate of fuel discharged from the nozzle 6 is then entirely under the control of throttle valve 44.

The low fire start valve 50 and its operation will now be explained. Referring to Figures 1 and 2 the valve is a piston operated valve which includes an inlet 54 in communication with the nozzle bypass line 40 and an outlet 56 communicating with the return line 38. Fuel flow through the valve is controlled by the position of the tapered piston valve 58 with respect to its seat. As shown in Figure 2, the valve is closed. The piston 60 is slidably mounted for movement in one direction or another in piston guide 62. A diaphragm 64 is secured to the piston head and divides the interior of the valve into a fluid chamber 66 and a spring chamber 68. Fluid pressure in chamber 66 urges the piston towards a valve-closed position. The piston is urged in the opposite direction or towards a valve-open position by an opposing compression spring 70 which engages the piston guide 62 and

piston head. With no fluid in the fluid chamber 66, and consequently no fluid pressure opposing the spring 70, the piston is moved to the left so that the valve is open.

The valve body also includes an inlet 72 to receive fluid from pilot pressure line 52 connected to the primary bypass line 30. The inlet 72 communicates with the fluid chamber 66 through metering orifice 74 which has a needle valve 76 adjustably positioned therein. A check valve 77 in the fluid chamber outlet 78 is maintained in a closed position by check spring 80 and serves to close the fluid chamber while fuel from the primary bypass line is being metered into the fluid chamber through metering orifice 74. The needle valve 76 may be adjusted to permit fuel to be metered into the fluid chamber at the proper rate by rotating a conventional adjusting screw 82.

The specific operation of the low fire start valve 50 in relation to other parts of the fuel system will now be explained. When the solenoid valve 32 in the primary bypass line is open, fuel flows freely back to the tank and the pressure in the bypass line and pilot pressure line is sufficiently low that a negligible amount of fuel is metered through the metering orifice into the fluid chamber 66. At this time, since the compression spring 70 alone controls the positioning of the piston valve, the spring 70 maintains the piston valve in an open position. However, when the solenoid valve 32 is closed, the increase in fluid pressure in the primary bypass line 30 causes fuel to flow through the pilot pressure line 52, through the metering orifice 74 at a rate determined by the position of the metering needle valve 76 and into the fluid chamber 66. As fuel is metered into the fluid chamber, the pressure in the fluid chamber increases gradually until it equals the pressure in the pilot pressure line. As this pressure increases, the force of the opposing spring 70 is overcome and the piston valve is moved progressively from an open to a closed position and fuel flow through the low fire start valve is stopped. It will be understood that when solenoid valve 32 is closed, the increased fuel pressure on the downstream side of pump 22 causes regulating valve 26 to open so that fuel flows in nozzle supply line 28.

When the solenoid valve 32 is opened, the fuel pressure in the primary bypass line and pilot pressure line immediately decreases to a value substantially below the fuel pressure in the fluid chamber 66. Thus, the fluid pressure in chamber 66 coupled with the force of compression spring 70 overcomes the force of the check spring 80 and opens the check valve 77 so that the fluid in the fluid chamber is expelled back into the pilot pressure line 52 through fluid chamber outlet 78; and the piston 60 is returned to a valve-open position. Thus, subsequent closing of the solenoid valve 32 will again result in a low fire start of the heater.

As will be apparent, when the low fire start valve 50 is opened to permit the flow of fuel from the nozzle bypass line directly therethrough to the return line 38, full control of fuel discharge into the burner by the throttling valve (which will normally be fully closed) is effectively removed. In one method of operation found desirable by some, the metering needle valve 76 is adjusted so that upon closing of the solenoid valve 32, the low fire start valve 50 will be operated from a fully open position to a fully closed position in two minutes. It will be understood that the low fire start valve is sized so that when it is fully open, the restriction to fuel flow afforded thereby will cause a rate of nozzle discharge sufficiently low to prevent undue thermal shock to combustor and heat exchanger structure and to satisfy other salient considerations.

The operation of the solenoid valve 32 by solenoid 34 is controlled by the circuit shown in Figure 3 and which includes a flame responsive control circuit and certain heater safety control elements. The circuit includes a source of power 84, a power switch 86 closable to deliver power to both power line 88 and electronic network

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90 such as commercially available "Flameotrol" Model 1570-S286 made by Barber Colman Company, a thermal overheat switch 92 responsive to an excessive discharge air temperature, an air flow responsive switch 94, and, a ground connection 96. The basic purpose of this circuit is to detect fire or combustion in the burner and to control solenoid 34 in response to the detected condition. The circuit will be described briefly to explain how this is accomplished.

The flame scanner 98 which includes a lead sulphide photocell sensitive to heat is operative, when the electronic network 90 is energized by closure of switch 86, switch 92 and switch 94, and detection of flame by the scanner, to energize relay winding 100. Relay winding 100 controls switches 102, 104, 106 and 108 shown in Figure 3 in their respective positions corresponding to a de-energized winding 100. In other words, with the scanner 98 detecting no flame, and relay winding 100 consequently being in a de-energized condition, the switches 102-108 are as shown.

With no flame detected, power is delivered from line 88 through closed switch 102, and line 110 to a first time delay thermal relay resistance heater 112. Time delay relay heater 112 is preferably adjusted to delay closure of its controlled work bar switch 114 for a period of, say, 30 seconds. This time delay is so that solenoid 34 cannot be energized and thus fuel cannot be supplied to the burner until the combustion air blower has operated for 30 seconds; thus insuring that any residual explosive mixture of gas and air in the combustion chamber will be purged. When switch 114 closes after 30 seconds, power is made available at one side of normally open push-button switch 116. When switch 116 is manually closed, there occurs energization of a circuit including line 118, closed switch 106, line 120, a second time delay thermal relay resistance heater 122, line 124, relay winding 126 and line 128. When relay winding 126 is energized, its controlled switches 130 and 132 are actuated to a closed position. Warp bar switch 134, which is controlled by second time delay relay heater 122 operates from a closed to an open position within two to five seconds after second time delay relay heater 122 has been energized. Thus, when push-button switch 116 is closed and second time delay relay heater 122 and relay 126 are energized, the closure of switch 132 resulting from energization of relay 126 completes a first solenoid energizing circuit which energizes solenoid 34 by way of power line 88, closed switch 132, line 136, closed second time delay switch 134, and line 138 to the solenoid 34.

When solenoid 34 is energized, its controlled valve 32 (Figure 1) closes and fuel passes to the nozzle 6 and is discharged into the burner as explained heretofore. The fuel ignition means, which has been energized through a separate circuit, ignites the fuel issuing from nozzle 6 and flame scanner 98 immediately detects the fire in the burner. When scanner 98 detects the fire, relay winding 100 is energized by operation of electronic network 90, and switches 102-108 operate to positions opposite to those shown in Figure 3. As mentioned, from two to five seconds after second time delay relay heater 122 has been energized, it causes its controlled switch 134 to open and the first solenoid energizing circuit is thereby opened. However, assuming flame has been established, when the second time delay switch 134 operates to open the first solenoid energizing circuit, an alternate solenoid energizing circuit including switch 132, line 136, line 140, closed switch 108 (closed by energization of relay winding 100), and line 138 has been established.

The function of switch 130 is to provide an alternate path for maintaining its associated relay winding 126 energized through combustion-closed switch 104, line 142, closed switch 130 and line 144 connecting switch 130 to second time delay relay heater 122 when flame has been detected and push button switch 116 released. It will be noted that when switch 102 opens, due to establish-

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ment of flame, the first time delay relay heater 112 is de-energized so that it will have an opportunity to cool and to reset itself for providing a thirty second delay when again energized. If flame should fail after having been established, the scanner 98 will detect this, relay 100 will be de-energized, and switches 102-108 will be actuated to the positions shown in Figure 3 so that the alternate solenoid energizing circuit will be de-energized by opening of switch 108.

An overheat condition as sensed by overheat switch 92, or failure of combustion or ventilation air as detected by switch 94, will open the circuit to ground 96 and result in de-energization of the entire circuit.

Operation

Before the heater is started, the throttling valve 44 is adjusted by temperature selection knob 48 to control fuel flow in normal operation to give a desired temperature. An ignition switch is closed to provide an igniting spark at the jet orifice of the nozzle 6. The ignition power may suitably be provided by a magneto driven from a prime mover furnishing ventilation and combustion air. The fuel pump 22 is energized to draw fuel from the tank 16 and force it through the primary bypass line 30 and open solenoid valve 32 back to the tank. With combustion and ventilation air flowing from the prime mover operated blower, the air flow responsive switch 94 is closed. Since solenoid valve 32 is open no fuel is supplied to the burner since regulating valve 26 will not open until the pressure of fuel at its inlet is increased to at least a certain value by closure of primary bypass line.

Power switch 86 is then closed to energize first time delay relay 112. After thirty seconds, first time delay switch 114 closes and solenoid 34 is energized and valve 32 closed by closing the push-button switch 116. When solenoid valve 32 closes the primary bypass line, the increased fuel pressure at regulating valve 26 opens it and fuel flows at a predetermined pressure in nozzle line 28 to the nozzle 6. As has been explained before, the low fire start valve 50 is biased to an open position at this time by spring 70 so that a minimum or relatively low quantity of fuel is discharged into the burner and ignited. The throttle valve 44 is substantially closed at this time since the ventilating air temperature sensed by element 14 is considerably below the desired temperature. When ignition is detected by the flame scanner 98, relay 100 is energized and the switches 102-108 are operated to their alternate positions to provide the closed alternate solenoid energizing circuit when the second time delay switch 134 opens the first solenoid energizing circuit.

With solenoid valve 32 closed, the substantial fluid pressure in pilot pressure line 52 causes fuel to be metered into the fluid chamber 66 of the low fire start valve 50. This causes the piston valve to be operated progressively towards a closed position so that after approximately two minutes, the low fire start valve is closed. This progressive closing of the low fire start valve will result of course in a progressive increase in fuel discharged into the burner and a progressive restoration of fuel control to the throttle valve 44.

Assuming the heat exchanger of the heater was relatively cold when the burner was started, the ventilating air discharge temperature as sensed by element 14 will be relatively low and will progressively increase as the heat exchanger becomes warmer. As the temperature at the sensing element 14 increases, the throttle valve 44 will be operated from a fully closed position towards a position corresponding to the proper opening for the desired ventilating air temperature. Thereafter, if the ventilating air discharge temperature sensed by element 14 rises above or falls below the selected temperature due to fortuitous conditions, the throttle valve 44 will be modulated in an opening or closing direction respectively to restore the selected temperature. During this normal

operation, the low fire start valve is maintained in a closed position by the fluid pressure opposing the compressed spring in this valve.

If flame should fail in the burner, this will be detected by the scanner 98, and relay 100 will be de-energized causing operation of switches 102-108 to a position which de-energizes solenoid 34. Thus, the solenoid valve 32 and primary bypass line 30 will be opened for bypassing fuel back to the tank and terminating flow into the nozzle supply line 28. When this happens, the low fire start valve 50 will reset itself to give a low fire start when burner operation is re-initiated.

It will be seen then that, in addition to the low fire start feature, the system: prevents fuel flow to the burner until the elapse of a predetermined time after combustion air flow is initiated to insure that the burner is purged; requires that unless fire is established within a short period, such as 2-5 seconds, after fuel flow to the burner begins, fuel flow to the burner is terminated; terminates fuel flow to the burner if at any time during heater operation the fire fails, an overheat occurs or combustion or ventilating air fails; and, automatically resets itself to give a low fire start, purging and burner fuel flow termination upon restarting after fire failure or termination of heater operation.

Having described my invention, I claim:

1. A fuel control system for a fluid fuel burning air heater, comprising: a burner; a main fuel line connected to supply fuel to said burner; fuel pump means for supplying fuel to said main fuel line; a primary bypass line connected to said main fuel line; a two-position valve in said primary bypass line; switch means adapted to be closed upon the need for heat; electrical means operative in response to closure of said switch means to close said two-position valve; means including a by-pass line from said burner and a throttle valve therein for normally controlling the supply of fuel to said burner in response to a differential between a sensed air temperature produced by said burner and a selected air temperature; a valve in parallel with said throttle valve operative, when open, to remove control of fuel flow from said throttle valve; and fuel pressure responsive means operative to progressively close said parallel valve and thereby progressively restore control of fuel flow to said throttle valve in response to an increase in the fluid pressure condition in said primary bypass line corresponding to closure of said two-position valve.

2. A fuel control system for a fluid fuel burning air heater, comprising: a burner having a jet fuel nozzle; a nozzle supply line connected to supply fuel to said nozzle; pump means for supplying fuel to said supply line; a nozzle bypass line for bypassing fuel not discharged from said nozzle into said burner; a discharge air temperature responsive throttle valve in said nozzle bypass line operative to normally control nozzle discharge in response to differentials between a selected air temperature and a sensed discharge air temperature produced by said burner; a primary bypass line connected to said supply line; a valve in said primary bypass line operative when open to bypass fuel and prevent flow in said nozzle supply line, and when closed to prevent fuel flow in said primary bypass line; means for closing said primary bypass line valve upon the need for heat; a valve in parallel with said throttling valve in said nozzle bypass line; and means responsive to the fuel flow condition in said primary bypass line for operating said parallel valve from an open position progressively to a closed position in response to a change from a full flow condition to a no-flow condition in said primary bypass line.

3. The system of claim 2 including: means biasing said parallel valve towards an open position.

4. The system of claim 2 wherein: said primary bypass line valve is a solenoid operated valve biased to an open position; and initiating circuit means including first switch means adapted to be closed upon the need for heat

are provided for energizing said solenoid operated valve to operate it to a closed position to terminate fuel flow in said primary bypass line when combustion is to be initiated.

5. The system of claim 4 including: solenoid holding circuit means including second switch means adapted to be held closed to maintain said solenoid energized in response to a combustion condition in said burner; means responsive after an initial time delay to a non-combustion condition in said burner for opening said second switch means and de-energizing said solenoid operated valve whereby a full flow condition is restored in said primary bypass line.

6. The system of claim 5 including: overheat switch means in said circuit means for de-energizing said solenoid operated valve in response to a sensed overheat condition.

7. The system of claim 6 including: air flow responsive switch means for de-energizing said solenoid operated valve in response to a sensed air flow below a predetermined safe value.

8. In a fuel control system for a fluid fuel burner: a fuel burner; fuel supply means including a fuel pump, a burner supply line, and a regulating valve intermediate said pump and said burner supply line adapted to open when the fuel pressure on the upstream side of said regulating valve equals or exceeds a predetermined value; fuel return line means including a first burner fuel return line having a burner-produced air temperature responsive throttle valve for normally controlling fuel discharge into said burner, a second burner fuel return line in parallel with said first burner fuel return line and having an openly-biased low fire start valve therein, and a primary fuel return line connected intermediate said pump and said regulating valve and having a two-position openly-biased valve therein; switch means adapted to be closed upon the need for heat; electrical means operative in response to closure of said switch means to close said two-position valve; and means for operating said low fire start valve progressively from an open to a closed position in response to closure of said primary fuel return line valve causing an increase in fuel pressure on the upstream side of said regulating valve to a value equaling or exceeding said predetermined value.

9. In a fuel control system as specified in claim 8: means responsive to combustion in said burner for maintaining said primary fuel return line valve closed by maintaining said electrical means energized while combustion continues, and for opening said primary fuel return line valve by de-energizing said electrical means when combustion ceases.

10. A fuel control system as specified in claim 8 wherein: said low fire start valve operating means includes a pilot pressure line connecting the upstream side of said primary fuel return line valve with said low fire start valve; and said low fire start valve includes a fluid pressure chamber having a restricted inlet adapted to receive fluid at a metered rate through said pilot pressure line whereby, upon an abrupt increase in fluid pressure in said pilot pressure line, the fluid pressure in said fluid pressure chamber increases at a relatively slower rate.

11. A fuel control system as specified in claim 10 wherein: said low fire start valve fluid pressure chamber includes a normally closed fluid relief outlet operative, in response to opening of said primary return line valve and a consequent abruptly decreased pressure in said pilot pressure line, to open for exhausting the fluid in said fluid chamber.

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