

May 3, 1955

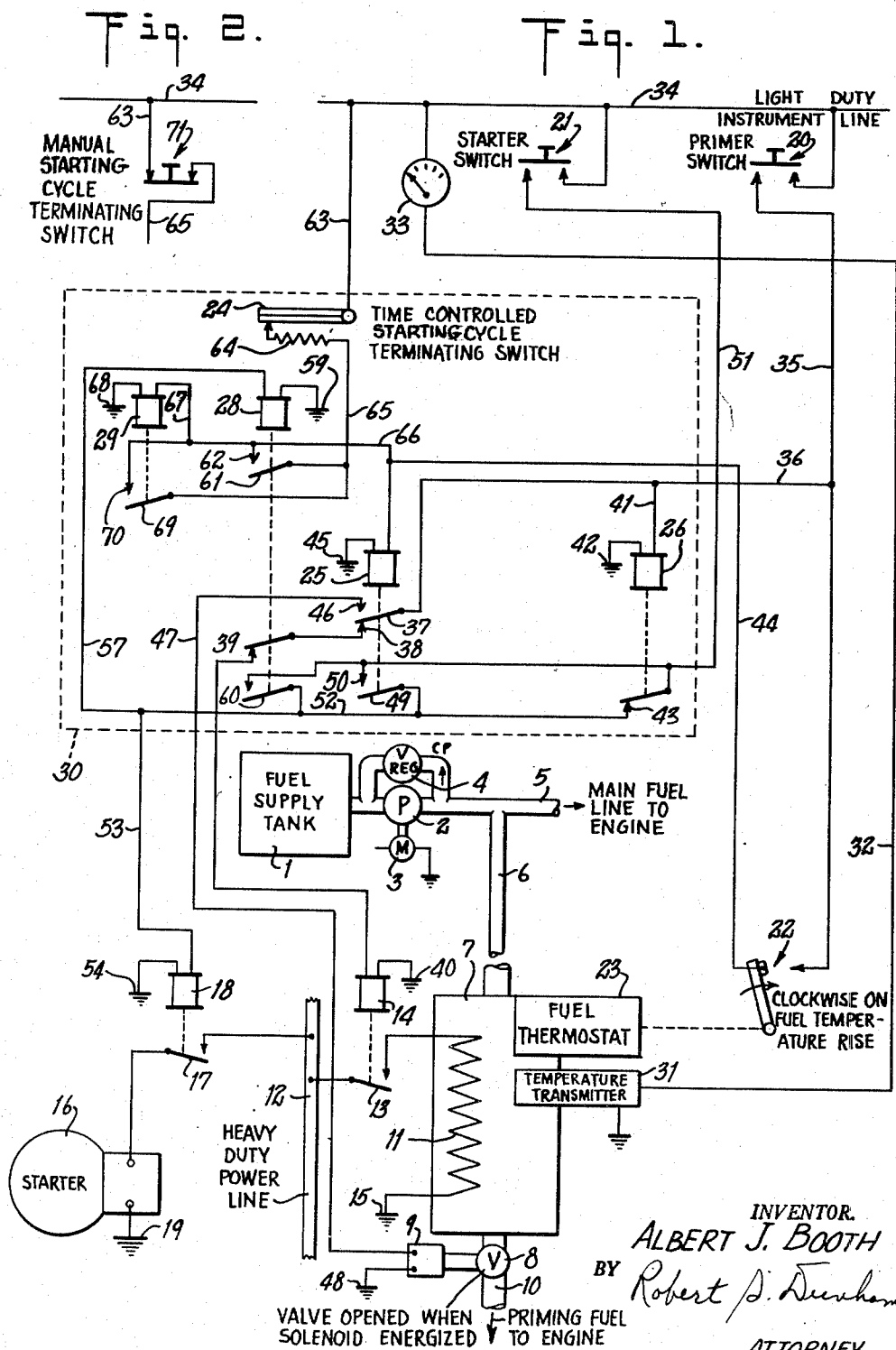
A. J. BOOTH

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STARTING CONTROL SYSTEM FOR INTERNAL COMBUSTION ENGINES

Filed Oct. 15, 1953

2 Sheets-Sheet 1



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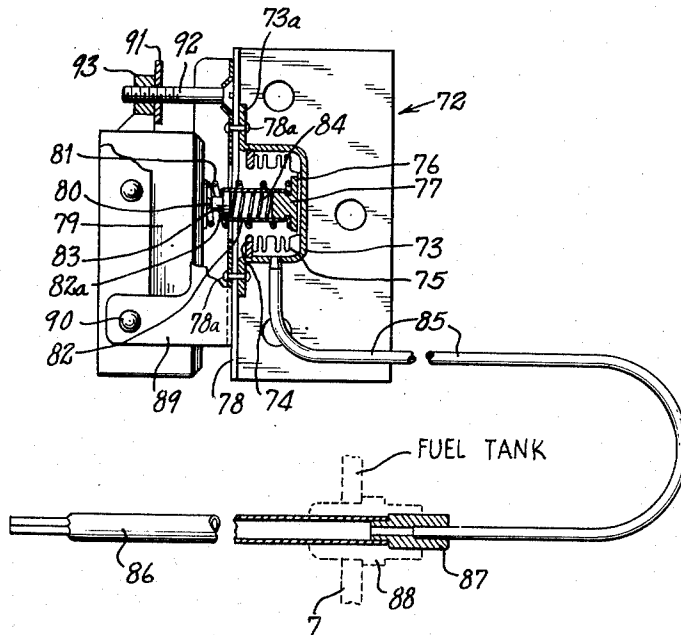
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Fig. 3.



INVENTOR.
ALBERT J. BOOTH
BY *Robert J. Dunham*
ATTORNEY

STARTING CONTROL SYSTEM FOR INTERNAL COMBUSTION ENGINES

Albert J. Booth, South Coventry, Conn., assignor to Booth Products Corporation, Flushing, N. Y., a corporation of New York

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This invention relates to starting control systems for internal combustion engines, and particularly to systems for controlling the starter and the supply of priming fuel.

The supply of fuel to internal combustion engines under running conditions is commonly controlled to maintain a constant or other desired fuel-air ratio. Under starting conditions, it is usual to supply a supplementary amount of fuel, greater than that required for a constant fuel-air ratio. This supplementary fuel is commonly termed the priming fuel, and the operation of delivering the supplementary fuel to the engine is termed priming the engine. In conventional priming systems, the supplementary fuel is forced under a positive head into the air induction system of the engine, usually through a spray nozzle. In the conventional priming systems now in common use on aircraft engines, the priming fuel supply is pumped by a boost pump driven by an electric motor, located near the fuel supply tank and provided with a spring-loaded by-pass valve to regulate the discharge pressure. The flow of priming fuel from the boost pump to the engine is usually controlled by an electromagnetic valve under the control of the pilot or some other member of the aircraft crew. This valve is usually a simple two-position valve, and is opened and closed by the operator as required during the starting of the engine.

Under extreme cold weather conditions, such as are encountered in the Arctic, a conventional priming system, such as that just described, is not effective to get an aircraft engine started in a reasonable time. It is common under such conditions to supply external heat to the engines by means of portable stoves or other heating devices, in order to get the engine up to a temperature where it can start. It has been recently proposed, as an aid to starting the engine in extreme cold, to heat the fuel in the priming system to a predetermined temperature before actuating the starter or admitting fuel to the engine. In this connection, it has also been suggested to vary the temperature to which the fuel is heated inversely with the ambient temperature.

An object of the present invention is to provide an improved priming fuel supply system. Another object is to provide such a system which is selectively adaptable under the control of the operator to various starting conditions which may be encountered.

A further object is to provide such a system which may be selectively operated either as a hot fuel system or as a conventional cold fuel system.

A further object of the invention is to provide a system of the type described which will establish a starting cycle comprising a fuel heating phase followed by a conventional priming phase.

Another object is to provide such a system in which the heating phase of the cycle may be interrupted at will and in which the priming phase of the cycle may be started immediately after such an interruption or even without any preliminary heating phase.

A further object of the invention is to provide a system of the type described in which the conventional pilot's control devices used for controlling the priming fuel valve and the starter may also be used for selection of the heating or priming phase of the starting cycle.

In the priming fuel supply system disclosed herein by way of example, the foregoing advantages are obtained by providing an improved hot fuel accumulator comprising a priming fuel tank, preferably mounted adjacent the engine and having a fuel inlet adjacent its top. Means is provided for heating the fuel in this priming fuel tank, and the heated fuel vaporizes and rises to the top of the tank. Under these conditions, the tank acts as a pressure accumulator. The tank is provided with an outlet adjacent its bottom and controlled by an electromagnetically operated priming valve.

The starting cycle mentioned in the foregoing objects is attained by providing a master relay controlling the priming valve and the fuel heater on the priming fuel tank. When the master relay is deenergized, the conventional primer control switch controls the heater only. When the master relay is energized, the conventional primer control switch controls the priming valve and the conventional starter control switch controls the starter.

Two circuits are provided for energizing the master relay, one controlled by the primer control switch and by a thermostat responsive to the fuel temperature, and the other controlled by the starter control switch, provided the primer control switch is open. When the master relay is deenergized the system is conditioned for operation in the heating phase of the starting cycle, and when the master relay is energized, the system is conditioned for operation in the priming phase of the starting cycle. A stick relay and a stick circuit for the master relay are provided to maintain that relay energized. Suitable control devices are provided for interrupting the stick circuit.

Other objects and advantages of the invention will become apparent from a consideration of the following specification, taken together with the accompanying drawings.

In the drawings:

Fig. 1 is a wiring diagram of a starting fuel supply system embodying the invention;

Fig. 2 is a fragmentary diagram illustrating a modification of one part of the system shown in Fig. 1; and

Fig. 3 is a view, partly in section and partly in elevation, showing a fuel temperature and ambient temperature responsive mechanism for operating a switch, which mechanism may be used in the system of Fig. 1.

Referring to the drawings, there is shown diagrammatically in Fig. 1 a starter control and priming fuel supply system for an internal combustion engine. In this system, fuel flows from a supply tank 1 through a boost pump 2 driven by an electric motor 3. A pressure regulating valve 4 controls the discharge pressure of the boost pump 2. Fuel discharged by the boost pump 2 flows either to a main fuel conduit 5 or a priming fuel conduit 6 which delivers fuel to a priming fuel tank 7 through an inlet located at the top of the tank. The tank 7 has an outlet at its bottom controlled by a valve 8 and operated by a solenoid 9. The valve 8 is open when solenoid 9 is energized and closed when the solenoid is deenergized. The valve 8 controls the flow of fuel through a conduit 10 which leads to the engine through any conventional priming fuel delivery system, as for example, a discharge nozzle located in the intake manifold.

The priming fuel tank 7 is provided with a heater 11, shown as an electric heater of the resistance type, located within the tank 7.

The electrical system shown is a direct current, single line, grounded type of system. Other conventional types of power supply systems may be used with equal facility.

The heater 11 receives electrical energy through a circuit which may be traced from a heavy duty power line 12 to a switch contact 13 operated by a heater controlling relay 14, and thence through the heater 11 to a ground connection 15.

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The engine is provided with a starter 16, which may be of any conventional electrically energized type. The starter 16 is energized from the power line 12 through a circuit which may be traced from that line through a switch contact 17 operated by a starter control relay 18, and thence through the starter 16 to a ground connection 19.

The three principal controlled elements in the system are the starter 16, the heater 11, and the solenoid 9 which operates the priming valve 8.

The principal controlling elements of the system are a primer switch 20, a starter switch 21, a switch 22 operated by a thermostat diagrammatically indicated at 23 and responsive to the temperature of the fuel in the priming fuel tank 7, and a starting cycle terminating switch 24, which in the modification of the invention shown in Fig. 1 is a time-controlled switch, specifically, a switch having a bimetallic contact arm subject to heat from a resistance element 64 connected in series with the switch contacts. The switches 20 and 21 are shown as push-button switches. They may be any other equivalent type of spring-loaded manually operated switch. Both of these switches are mounted for manual actuation by the pilot or some other member of the aircraft crew.

These four controlling elements actuate the three controlled devices in various flexible sequences which may be selected by the aircraft pilot or other engine operator. This control is accomplished, in the system shown, through the intermediary of four relays, hereinafter identified as a master relay 25, a primer switch repeater relay 26, a starter repeater relay 28, and a stick relay 29. The circuits for energizing these relays and the circuits controlled by them will be described individually below as they become effective in the operation of the system.

Since the system is intended for use under extremely cold weather conditions, it is desirable to use relays which have their contacts enclosed in sealed housings, so that there will be no danger of moisture condensation on the contacts, which might cause the contacts to freeze closed. The heater control relay 14 and the starter control relay 18, both of whose contacts handle heavy currents, are best located near the devices which they control. The other four relays and the priming cycle switch 24 may be conveniently located in a single sealed housing, illustrated diagrammatically in the drawing by a dotted line 30. The use of a single sealed housing for these circuit elements permits the use of less expensive relays than is required where the relays are each provided with separate housings.

A telemetric system is provided for informing the pilot of the temperature of the fuel in the priming fuel tank 7. This system includes a transmitter 31 responsive to the temperature in the priming fuel tank 7 and connected through a wire 32 to a telemetric receiver 33 mounted on the pilot's instrument panel adjacent the primer switch 20 and starter switch 21.

Operation.—Heating and priming

The parts are shown in the drawing in their normal positions, when the system is completely deenergized. If under these conditions the pilot wishes to start the engine using hot fuel, he closes the primer switch 20, thereby completing an energizing circuit for the heater control relay 14. This circuit may be traced from a light duty power supply line 34 through switch 20, wires 35 and 36, switch contact 37 and back contact 38 of master relay 25, contact 39 of starter repeater relay 28 and thence through the winding of relay 14, to ground at 40. Energization of relay 14 closes switch contact 13 and starts the current flowing through heater 11 to raise the temperature of the fuel in the priming fuel tank 7.

Closure of the primer switch 20 also completes an energizing circuit for the primer switch repeater relay 26. This circuit may be traced from the power line 34

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through the primer switch 20, wires 35, 36 and 41, and thence through the winding of relay 26 to ground at 42. Energization of relay 26 opens its back contact 43 and prevents energization of the starter 16 while the heater 11 is energized.

The pilot continues to hold the primer switch 20 closed and the heater 11 remains energized. The temperature of the fuel in the priming tank 7 increases, eventually resulting in vaporization of part of the fuel and the building up of a body of accumulated vapor under pressure at the top of the priming fuel tank. Some of the fuel vapor passes back through the priming fuel conduit 6, which is in open communication with the fuel tank. It has been found that the conduit 6 and valve 4 do not relieve the pressure in the priming fuel tank 7 to an objectionable extent. In one case, for example, the pressure in the priming fuel tank 7 built up to about six pounds per square inch higher than the regulated pressure at the discharge side of the boost pump. It might be expected that the boost pump relief valve 4 would be effective to relieve the pressure in the priming fuel tank until it dropped to the boost pump regulated pressure. The exact cause of this pressure gradient between the priming fuel tank and the boost pump is not known, but it may be due to the existence of a considerable temperature gradient in the conduit 6 during this phase of the operation of the system.

At some time after the primer switch 20 is closed, and before the temperature of the fuel in the priming tank 7 reaches the value at which the thermostat 23 will close the switch 22, the pilot closes the starter switch 21. At this time, no circuit is completed through the starter switch. As soon thereafter as the thermostat 23 closes the switch 22, a circuit is completed for energizing the master relay 25. This circuit may be traced from the power line 34 through the primer switch 20, wire 35, switch 22, wire 44 and through the winding of relay 25 to ground at 45.

Energization of master relay 25 moves the switch arm 37 away from back contact 38 and into engagement with a front contact 46, thereby interrupting the circuit previously traced for energizing heater control relay 14 and establishing a circuit for the energization of solenoid 9. This latter circuit may be traced from power line 34 through switch 20, wires 35 and 36, switch arm 37, front contact 46 and a wire 47 to solenoid 9 and thence to ground at 48.

When the solenoid 9 is energized, valve 8 is opened, allowing fuel to discharge from the priming fuel tank 7 through the conduit 8. As the fuel discharges, the pressure is relieved slightly in the tank, and more fuel vaporizes to increase the volume of vapor in the upper part of the tank. In this way, a considerable volume of fuel can be discharged very quickly with only a small reduction in pressure. Furthermore, as explained above, the pressure in the fuel tank is actually greater than the pressure of the fuel at the discharge side of pump 2.

Energization of master relay 25 also causes switch arm 49 to engage front contact 50, thereby establishing an energizing circuit for the starter control relay 18. This circuit may be traced from power line 34 through starter switch 21, a wire 51, contacts 50 and 49, wires 52 and 53 and thence through the winding of relay 18 to ground at 54. Energization of relay 18 causes closure of contact 17, thereby initiating the energization of starter 16.

From the foregoing, it may be seen that the starter is now energized and that the priming valve 8 is open to deliver fuel to the engine. Under these conditions, the engine will start in a reasonable time, even under external temperature conditions of the order of 60° below zero Fahrenheit. Engine tests have been made, showing this time to be consistently less than thirty seconds.

When the starter controlling relay 18 is energized, a

circuit is also completed for the starter repeater relay 28. This circuit may be traced by following the circuit last traced to the wire 52, and thence along wire 57 through the winding of relay 28 to ground at 59.

Energization of starter repeater relay 28 opens its back contact 39 and closes its switch contact 61 against front contact 62. This establishes a second energizing circuit for the master relay 25 and also establishes an energizing circuit for stick relay 29. The second energizing circuit for master relay 25 may be traced from power line 34 through wire 63, priming cycle terminating switch 24, heater resistance 64 associated with switch 24, wire 65, contacts 61 and 62, wire 66, and thence through the winding of master relay 25 to ground at 45. Since the master relay 25 is already energized at this time, this circuit has no immediate effect.

Energization of relay 28 also closes its switch contact 60 which is connected in parallel with switch contact 49 of master relay 25 and back contact 43 of relay 26. The switch contact 60 has no function in the operation being presently described.

The circuit for stick relay 29 may be traced from power line 34 through wire 63, switch 24, resistance 64, wire 65, switch contact 61, front contact 62, wire 67 and thence through the winding of relay 29 to ground at 68. Energization of relay 29 closes its switch contact 69 against the front contact 70. Closure of these contacts, which are connected in parallel with contacts 61 and 62, completes stick circuits for the stick relay 29 and for the master relay 25, both of which are independent of any other relay and which may be interrupted only by the priming cycle terminating switch 24.

Once these stick circuits are established, the energization of master relay 25 is independent of the circuits which originally established that energization. Master relay 25 thereafter continues to be energized regardless of the subsequent opening of the temperature responsive switch 22 or the primer switch 20. The pilot may now utilize the primer switch 20 as a control for the solenoid 9 which operates the priming valve 8. Operation of the primer switch 20 has no effect on the system at this time other than its actuation of the valve 8. Similarly, the starter switch 21 now controls only the starter 16, and has no other effect on the system. The system has now completed its heating phase, during which heat was supplied to the fuel in the tank 7 and is now in its priming phase, in which the pilot's controls are similar in their function to that found in the conventional priming systems with which the pilot is familiar.

An engine commonly runs rather roughly when first starting, especially at low temperatures, and to get it running smoothly, the pilot may have to actuate the priming valve intermittently. He may also have to actuate the starter intermittently, but independently of the priming valve. In the system disclosed, once the priming phase of the starting cycle has been established by the energization of stick relay 29, the pilot is in full control of the priming valve and the starter and may use them as required to get the engine running smoothly.

If the engine and its accessories are in good order, the engine should start and be running smoothly within a relatively short time, for example, of the order of three minutes. The starting cycle terminating switch is set to open at the end of three minutes, so that after the engine has started and is running smoothly, the stick circuits for stick relay 29 and master relay 25 are deenergized, thereby restoring the system to its normal condition. The timing switch 24 is preferably chosen to have a resetting time much shorter than its opening time, and preferably shorter than the time required to heat the fuel to the temperature at which thermostat 23 closes switch 22. For example, the resetting time may be of the order of fifteen seconds. If the engine has not started in three minutes, the system is ready to start a new heating phase as soon as the priming phase is terminated. The system

can then shift to the priming phase at any time after the expiration of the resetting time.

Starting cycle without preliminary heating

Under some conditions, it may be desirable for the pilot to start the engine using the conventional starting cycle, without a preliminary heating of the fuel. Such an operation might be desired, for example, when starting the engine under warm temperature conditions. To secure this mode of operation, the pilot simply closes the starter switch 21 and thereafter closes the primer switch 20. Closure of starter switch 21 while the primer switch 20 remains open establishes an energizing circuit for the starter control relay 18 and energizing circuits for starter repeater relay 28.

The circuit for the starter control relay 18 may be traced from power line 34 through switch 21, wire 51, back contact 43 of relay 26, wires 52 and 53, the winding of relay 18 and thence to ground at 54. The relay 28 is energized from circuits which may be traced along the circuit last traced to the wire 52, and thence along wire 57, the winding of relay 28 and thence to ground at 59.

Energization of relay 28 closes switch contact 60 in parallel with back contact 43. This makes the circuits just traced independent of contact 43, so that the priming phase will not be interrupted by a subsequent closure of primer switch 20, even though that closure may take place before relay 25 has been energized and has picked up its contacts.

Energization of relay 28 also causes closure of switch contact 61 on the front contact 62 thereby completing the circuit for energizing master relay 25, identified above as the second circuit for that relay. The energizing circuit, previously traced, for stick relay 29 is also completed through contacts 61 and 62 and the stick circuit for master relay 25 and stick relay 29, previously traced, are thereby established. The system is now in the priming phase of its starting cycle as previously described, with the primer switch 20 controlling the solenoid 9 and the starter switch 21 controlling the starter 16.

Partial heating phase

Under some external temperature conditions, it may be desirable to heat the fuel partially, to a temperature somewhat lower than that for which the thermostat 23 is set. This may be accomplished by closing the primer switch 20 to initiate the heating phase of the cycle. The heating phase continues only so long as the primer switch is held closed. The pilot may watch the telemetric receiver 33 on his instrument panel and when the fuel in the priming tank 7 reaches the desired temperature value, he may then release the primer switch 20 to terminate the heating phase of the starting cycle and then close the starter switch 21 to begin the priming phase immediately.

Fig. 2

This figure illustrates a modification of the system of Fig. 1 in which a manually controlled starting cycle terminating switch 71 is used. The switch 71 is biased closed, and is opened by manually actuating it against its bias. This switch may be used in place of the time-controlled switch 24. Where it is so used, it is necessary for the pilot to actuate this switch after each starting cycle, in order to restore the system to its normal condition.

It may sometimes be desirable to use a manually controlled starting cycle terminating switch in series with a time-controlled terminating switch. When so connected, the pilot has the ability to interrupt the priming phase of the starting cycle at any time, without waiting for the time-controlled switch to operate.

Fig. 3

This figure illustrates a thermostatic mechanism which may be used in place of the thermostat 23 and switch 22 of Fig. 1, and which responds to both the temperature

of the fuel in the priming fuel tank 7 and to the temperature of the ambient air. The thermostat 23 of Fig. 1 responds to the fuel temperature only.

Referring to Fig. 3, there is shown a thermostat generally indicated at 72, including a cup-shaped housing 73 having a peripheral flange 73a.

A flat ring 74 is fixed, as by welding, just within the mouth of the opening of the cup-shaped housing 73. A convoluted bellows 75 of conventional construction, has one end fixed to the ring 74. The other end of the bellows 75, which extends toward the bottom of the cup-shaped housing 73, is closed, as by a plate 76. A spring retainer 77 is attached to the plate 76. The flange 73a on the housing 73 is attached, as by rivets 78a, to an angle bracket 78 mounted on a suitable support. A small unitary snap-acting switch 79, such as those sold commercially under the name "Micro-Switch," is mounted on the opposite side of the angle bracket 78. The switch 79 has an actuating button 80 which projects toward the housing 73 and is aligned with the retainer 77. A spring 81 is retained in compression between the spring retainer 77 and the housing of switch 79. This spring biases the retainer 77 to the right, or toward the position shown in the drawing, where the plate 76 abuts against the bottom of the cup-shaped housing 73. Fixed on the retainer 77 and concentric with the spring 81 is a sleeve 82 having an inwardly projecting flange 82a formed on its left-hand end to retain a switch actuating member 83 within the sleeve 82. A spring 84 is located within the sleeve 82 and biases the member 83 toward the switch 79.

The housing 73 is exposed to the temperature of the ambient air. The space between the bellows 75 and the housing 73 is connected through a tube 85 to a remotely located fuel temperature responsive bulb 86. A suitable coupling 87 connects the tube 85 and the bulb 86. A bushing 88 is provided for mounting the bulb 86 in the wall of the fuel tank 7. The bulb 86, tube 85 and the chamber defined by the bellows 75 and the housing 73 are filled with a fluid having a substantial variation of vapor pressure with temperature, for example, ethyl alcohol.

The micro-switch 79 is adjustably supported on a mounting including a bracket 89 attached by the rivets 78a to the angle bracket 78. At the lower end of the bracket 89 is mounted a pin 90, on which the body of the switch 79 is pivoted. The upper end of switch 79 carries a lug 91 apertured to receive a machine screw 92, whose head is fastened, as by welding or brazing, to the bracket 89. A nut 93 is provided, by which the position of the flange 91 along screw 92 may be adjusted. Adjustment of nut 93 determines the position of the switch actuating button 80, and hence determines the temperature at which switch 79 is actuated by thermostat 72.

The volume of the space defined by bellows 75 and housing 73 is so related to the characteristics of the enclosed fluid and the characteristics of the spring 81 that the parts have the positions shown when the fuel and the ambient temperature are both below a temperature in the neighborhood of 30-40° above zero Fahrenheit. If either the fuel or the ambient temperature increases above that value, the fluid in the thermostat expands, contracting the bellows. The nut 93 is adjusted so that when the fuel and the ambient temperature are at a selected value, e. g., in the neighborhood of 50° above zero Fahrenheit, the bellows will actuate the switch 79. It may be observed that an increase in fuel temperature tends to actuate the switch and that an increase in ambient temperature also tends to actuate the switch in the same sense. The fuel temperature and ambient temperature therefore work together. Consequently, an increase in ambient temperature will tend to decrease the temperature of the fuel at which the switch 79 is actuated.

When the thermostatic mechanism of Fig. 3 is substituted for thermostat 23 and switch 22 in the system of Fig. 1, the operation is similar to that previously described, except that the termination of the heating phase

of the starting cycle is dependent not only on the fuel temperature but on the ambient temperature. The relationship is such that the fuel temperature required to terminate the heating phase of the starting cycle is decreased as the ambient temperature increases.

While I have shown and described certain presently preferred embodiments of my invention, other embodiments will occur to those skilled in the art, and I therefore intend my invention to be limited only by the appended claims.

I claim:

1. A starting fuel supply system for an internal combustion engine, comprising a fuel supply tank, an electric motor-driven boost pump adjacent said tank, a priming fuel tank spaced from the boost pump and adjacent the engine and having an inlet adjacent the top thereof, an elongated conduit extending between said boost pump and said priming fuel tank and in free fluid communication with said inlet for conveying fuel thereto, means for heating the fuel in said priming fuel tank, said fuel being effective when heated sufficiently to vaporize and rise to the top of said tank, said tank and conduit cooperating when partially filled with vaporized fuel to act as a pressure accumulator, said priming fuel tank having an outlet adjacent its bottom, a priming valve controlling said outlet, conduit means communicating with said outlet and effective to deliver fuel discharged therefrom to said engine, an engine starter, a manual starter control device, a manual primer control device, means effective upon initial actuation of said primer control device to operate said heating means, means responsive to the temperature of the fuel in the priming fuel tank, means including said temperature responsive means and said starter control device for actuating the starter when the fuel in said priming fuel tank reaches a predetermined temperature, and means including said temperature responsive means and said primer control device for opening the priming valve when the fuel in said priming fuel tank reaches said predetermined temperature.

2. A starting fuel supply system for an internal combustion engine, comprising a priming fuel tank having an outlet in fluid communication with the engine, means for heating the fuel in said priming fuel tank, a priming valve controlling said outlet, an engine starter, a manual starter control device, a manual primer control device, means responsive to the temperature of the fuel in the priming fuel tank, means effective upon initial operation of said primer control device to initiate a starting cycle comprising a first heating phase during which said heating means is actuated while said priming valve remains closed and said starter is inactive, and means including said temperature responsive means and effective when the fuel in the priming fuel tank reaches a predetermined temperature to terminate said heating phase and initiate a second priming phase of said starting cycle during which the starter may be selectively and intermittently operated by actuation of the starter control device.

3. A starting fuel supply system for an internal combustion engine, comprising a priming fuel tank having an outlet in fluid communication with the engine, means for heating the fuel in said priming fuel tank, a priming valve controlling said outlet, an engine starter, a manual starter control device movable between off and on positions, a manual primer control device movable between off and on positions, means responsive to the temperature of the fuel in the priming fuel tank, means effective upon initial operation of said primer control device to its on position to initiate a starting cycle comprising a first heating phase during which said heating means is actuated while said priming valve remains closed and said starter is inactive, and means including said temperature responsive means and effective when the fuel in the priming fuel tank reaches a predetermined temperature to terminate said heating phase and initiate a second priming phase of said starting cycle during which the priming valve may be selectively opened and closed by operation of the primer control device respectively to its on and off posi-

