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W. C. TRAUTMAN ET AL

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JET ENGINE FUEL SUPPLY SYSTEM

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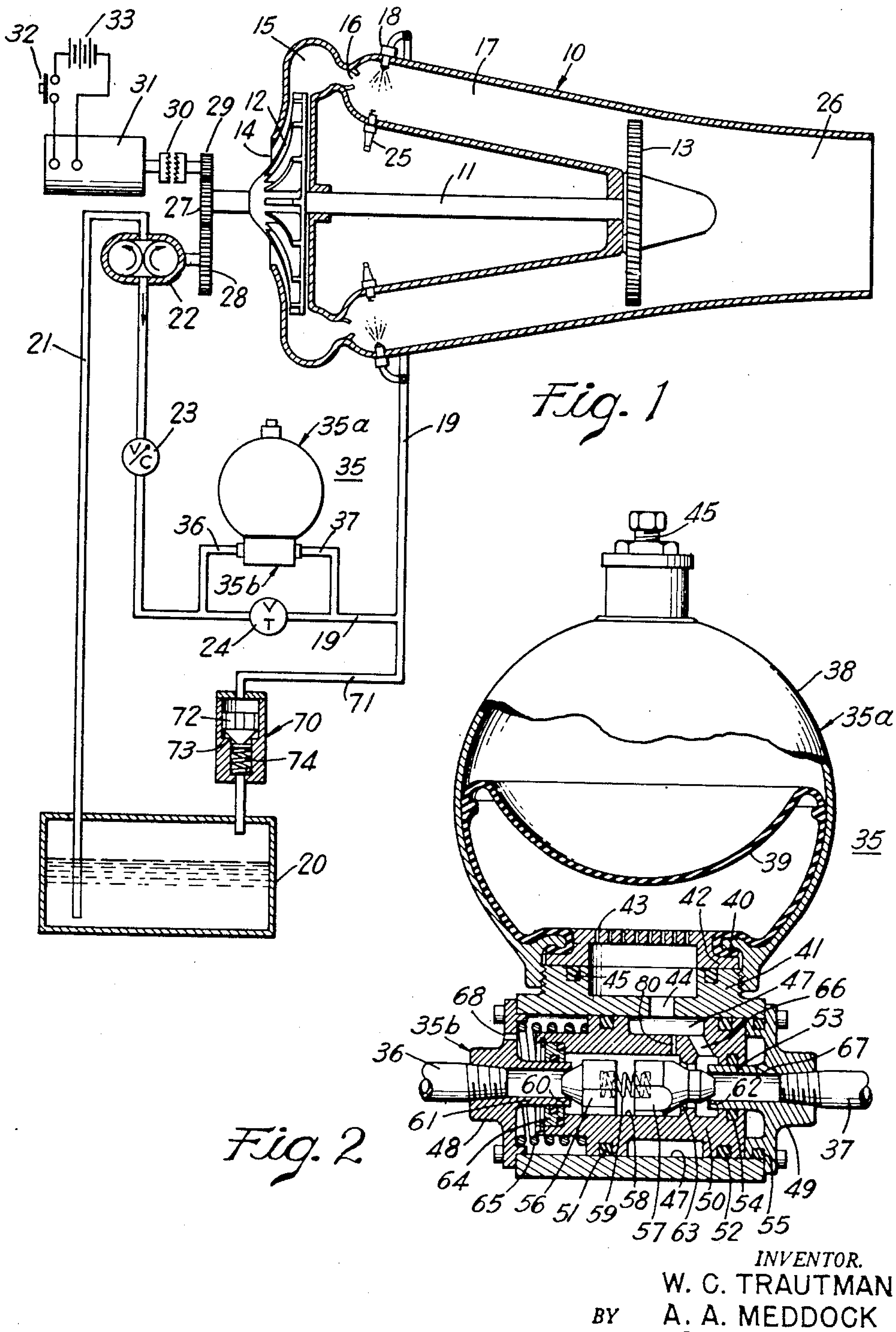


Fig. 1

Fig. 2

INVENTOR.
W. C. TRAUTMAN
A. A. MEDDOCK

BY [signature]

ATTORNEY

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## JET ENGINE FUEL SUPPLY SYSTEM

Walter C. Trautman, Los Angeles, and Alvin A. Meddock, North Hollywood, Calif., assignors to Bendix Aviation Corporation, South Bend, Ind., a corporation of Delaware

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1

This invention relates to fuel supply systems in which a liquid fuel is sprayed from atomizing jets into an air stream to create a combustible mixture and has particular application to the fuel system of a jet engine in which the fuel pump is driven by the engine.

A broad object of the invention is to insure delivery of fuel at high pressure to the jets at the time of starting to produce thorough atomization and prompt ignition of the mixture.

Another object of the invention is to provide more positive starting of jet engines.

Another object is to facilitate restarting of jet engines after a shutdown.

Still another object is to prevent flooding of jet engines at the time of starting.

Other more specific objects and features will become apparent from the detailed description to follow of a particular embodiment of the invention.

As now developed, a common form of jet engine burns kerosene or other fuel of low volatility by discharging the fuel at high pressure through atomizing jets into an air stream to form a combustible mixture which is ignited by a spark plug or other known type of igniter. Furthermore, the fuel pressure is developed by a pump which is driven from the jet engine, and the engine is started by an electric starter capable of accelerating the rotor of the engine to a speed at which it is operative.

Difficulty has been encountered in starting such engines because of the fact that fuel was frequently admitted to the jets before the engine-driven pump was rotating fast enough to develop an atomizing pressure. As a result, fuel was discharged through the jets without being atomized sufficiently to produce an ignitible mixture with the air, which fuel accumulated in liquid form within the engine until such time as the fuel pressure rose to the point where sufficient atomization was obtained to permit ignition. Thereafter, the excess fuel that had accumulated in the engine burned rapidly and abnormally, with objectionable results both with respect to the engine structure and to objects in the path of the flame discharged from the engine. Furthermore, sometimes the flooding of the engine prevented starting at all within the time the starting motor was able to operate.

The present invention overcomes the starting difficulties described by insuring that when the valve is opened to deliver fuel to the jets, the fuel will be supplied at a high pressure sufficient to produce thorough atomization of the first fuel

2

discharged, and thereby promote prompt ignition. This result is accomplished by the use of an accumulator which stores the fuel discharged by the pump during initial operation thereof at slow speed, in combination with an automatic valve that releases the stored fuel from the accumulator at high pressure to the atomizing jets when the throttle valve is opened.

In the drawing:

Fig. 1 is a schematic diagram of a jet engine in combination with a fuel supply system in accordance with the invention; and

Fig. 2 is a detailed view partly in section of the accumulator and automatic valve structure employed in the system of Fig. 1.

Referring first to Fig. 1, there is disclosed schematically a conventional form of jet engine 10 which comprises a rotor shaft 11 having an impeller 12 on one end for compressing air for combustion and having a gas turbine 13 on the other end which is driven by the discharge gases. Air enters the forward end of the engine through an opening 14, is compressed by the impeller 12, and delivered to an annular manifold 15 from which it is discharged through a plurality of orifices 16 into the forward end of an annular combustion chamber 17. As the air enters the combustion chamber through the orifices 16, it is mixed with atomized liquid fuel discharged from a plurality of jets 18, which are supplied with fuel under pressure through a pipe 19, which in turn is normally supplied with fuel under pressure from a reservoir 20, through a suction pipe 21, a pump 22, a check valve 23, and a throttle valve 24. The mixture of air and atomized fuel may be initially ignited by sparks from spark plugs 25 energized from a standard ignition circuit (not shown). The burning fuel is then discharged through the combustion chamber 17 past the gas turbine 13 and out through a discharge passage 26. For purposes of illustration, the rotor shaft 11 is shown coupled by spur gears 27 and 28 to the fuel pump 22 and is also coupled through the spur gear 27, a spur gear 29, and a clutch 30 to an electric starting motor 31.

It has been the practice to drain all fuel from the line 19 and the jets 18 when the engine is shut down. To this end, a drain line 71 containing a drain valve 70 is extended from the line 19 back to the reservoir 20. As shown, the valve 70 contains a poppet 72 which is normally lifted off its seat 73 by a light compression spring 74, so that whenever the pressure in the line 19 drops to a low value following the closure of the throttle 24, the spring 74 lifts the poppet off the seat 73 to permit all fuel in the line 19 and the jets 18 to drain back into the reservoir 20. However, whenever the throttle valve 24 is opened, the pressure in the lines 19 and 71 is suddenly increased to a value sufficient to seat the poppet 72 and prevent escape of fuel through the drain line when the engine is operating.

The structure so far described is conventional and its normal operation has been outlined. At the time of starting, a switch 32 in the starting circuit of the motor 31 is closed, causing the latter to engage the clutch 30 and accelerate the rotor shaft 11 and the pump 22. Initially, it has been the practice to slightly open the throttle valve 24 to permit the minimum flow from the jets 18 necessary to sustain operation of the engine, and theoretically the mixture should be ignited and the engine should start to operate as soon as the starting motor 31 has accelerated the impeller 12 to a speed at which it will deliver sufficient air for operation. Often, however, it has been found that during the initial period of operation, the pump 22 was running too slowly to build up any substantial pressure in the pipe 19, with the result that fuel was discharged at low pressure from the jets 18 for a considerable interval of time before ignition took place, this fuel accumulating in the engine so that if and when ignition did finally take place, there was sufficient accumulated fuel to cause abnormal combustion of a very rich mixture that produced excessive heat within the tail portion of the jet engine itself and caused projection of flame to a substantial distance beyond the engine, until the excess accumulated fuel had been consumed. Furthermore, the flow of fuel from the jets 18 while the pump 22 was coming up to speed prevented the fuel pressure from rising as rapidly as it would if such initial flow from the jets were prevented, and sometimes the pump was supplying insufficient pressure to produce atomization at the time the impeller 12 has reached a speed at which the engine would normally be operative. This prolonged the starting period and sometimes exhausted the starting battery 33 which drives the starting motor 31.

In accordance with the present invention the foregoing objectionable starting characteristics have been eliminated or greatly mitigated by the provision of a valve and accumulator unit 35 having an inlet connection 36 connected to the fuel line ahead of the throttle valve 24 and having an outlet connection 37 connected to the fuel line on the outlet side of the throttle valve.

Referring to Fig. 2, the unit 35 consists of an accumulator 35*a* and an automatic valve 35*b* for controlling flow between the accumulator 35*a* and the connections 36 and 37. The accumulator 35*a* comprises a shell 38 containing a bladder 39, the neck 40 of which is in sealing relation to the shell at the bottom thereof. Thus, the lower end of the shell 38 may be closed by a screw plug 41 which compresses an annular flanged member 42 against the neck 40 of the bladder. The flanged member 42 contains holes 43 through which liquid can pass into and out of the bladder through an aperture 44 in the screw plug 41. A sealing ring 45 provides a fluid seal between the screw plug 41 and the annular flanged member 42. The upper end of the shell 38 is normally filled with compressed air, a fitting 46 being provided at the upper end of the shell through which the compressed air may be injected. The bladder 39 is completely collapsed by the compressed air thereabove except when liquid is forced into the bladder under pressure.

The valve mechanism 35*b* is incorporated in the screw plug 41, the latter being shaped to provide a cylindrical bore 47 therein, opposite ends of which are closed by end plates 48 and 49, respectively, which have threaded ports for the reception of the connections 36 and 37, respectively.

There is slidably mounted within the bore 47 a piston member 50, which is sealed with respect to the bore 47 by a pair of sealing rings 51 and 52. At its right end, the piston 50 is sealed about a tubular neck 53, which extends into the piston from the closure member 49, by a sealing ring 54. The closure member 49 is sealed with respect to the bore 47 by a sealing ring 55.

A pair of poppets 56 and 57 are slidably mounted in a longitudinal bore 58 within the piston 50, the two poppets being urged apart by a light helical compression spring 59. Poppet 56 is adapted to seal against a seat 60 at the inner end of a neck 61 projecting inwardly from the closure member 48. The poppet 57 has two sealing surfaces, one adapted to seal against a seat 62 on the inner end of the neck 53, and another one adapted to seat on a seat 63 in the piston 50.

At its left end, the piston 50 is provided with a bushing 64 which seals with the neck 61. The piston is normally urged into its right end position, as shown, by a helical spring 65 compressed between the piston and the left closure member 48.

The complete system, including the unit 35, operates as follows, when the engine is to be started:

To start the engine, the starter switch 32 is actuated while the throttle valve 24 is closed. The rotor shaft 11 gradually accelerates, and the pump 22 is, of course, simultaneously accelerated, but during this initial operation, no fuel flows to the jets 18 because the throttle valve 24 is closed.

However, the pump 22 delivers a gradually increasing flow of fuel, which flows through the connection 36 and into the bore 58 of the piston 50, past the poppet 56, the latter being closed only by its light spring 59 so that it functions as a check valve. The fuel entering the bore 58 escapes therefrom past the valve seat 63 and flows through a passage 66 into the bore 47 and thence through the aperture 44 and the holes 43 into the bladder 39, distending the latter against the pressure of the air thereabove. As the air is compressed, the pressure of the fuel within the bladder increases. Escape of fuel into the connection 37 is prevented at this stage of operation because the poppet 57 is seated against the seat 62.

By the time the starting motor 31 has accelerated the rotor shaft 11 of the jet engine to a starting speed, considerable fuel pressure has been built up in the bladder 39, and the operator then opens the throttle valve 24, whereupon fuel flows through the line 19 to the jets 18. The line 19 is initially filled with air, and at first the fuel flows through the line without building up much pressure because the air in the line readily escapes through the jets 18. However, as soon as the line 19 is filled, and the fuel starts flowing through the jets 18, the pressure in line 19 is suddenly increased because of the resistance to flow of the liquid fuel offered by the jets. This sudden rise in pressure in the line 19 is applied through the connection 37, and through a passage 67 in the end closure member 49, to the right end of the piston 50, moving it to the left. The leftward movement of the piston first closes the seat 63 against the poppet 57 thereby preventing further flow of fuel through the bore 58 past the seat 63. The final movement of the piston 50 to the left carries the poppet 57 with it, thereby opening the poppet away from the seat 62 and permitting fuel to flow from the interior of the bladder 39 through the aperture 44, the bore 47, and the passage 66 to the connection 37 and thence to the line 19.

Following initial opening of the poppet 57 off the seat 62, fuel may be supplied to the line 19 from the accumulator at a pressure higher than that delivered by the pump 22, but any reverse flow of fluid from the accumulator through line 37 and valve 24 back into the pump 22 is prevented by the check valve 23. A small vent 80 is provided between the bore 58 of the piston 50 and the annular recess 47 to permit escape of fuel displaced from the bore 58 by the neck 61 as the piston 50 moves to the left. A small leakage of fuel may occur through the vent 80 when the poppet 57 is off its seat 62 but on seat 63, and the pump is developing high pressure, but the vent 80 is so small that such leakage is inconsequential.

The net result of the operations described is that following filling of the line 19 the fuel stored under the pressure in the accumulator 35a is delivered to the line 19 at high pressure even though the pump 22 may not yet be running fast enough to maintain high pressure in the line 19. Fuel is, therefore, discharged from the jets 18 at a pressure sufficient to effect proper atomization, insuring immediate ignition of the fuel and starting of the jet engine. The latter thereupon accelerates to its normal speed, after which the fuel pump 22 is capable of maintaining full fuel pressure on the jets without the aid of the accumulator.

During the normal operation of the jet engine, the piston 50 of the unit 35 remains in its leftmost position because the full pressure of the fuel in the connection 37 is applied to the right end of the piston, whereas the left end of the piston is exposed to atmospheric pressure by a vent 68 in the end closure member 48. Hence, open communication is maintained between the connection 37 and the bladder 39, past the seat 62, through the passage 66 and the aperture 44. In effect, the accumulator is therefore maintained floating on the line 19. The pressure of the pump 22 in the inlet connection 36 is applied to the left end of the poppet 57 and to the right end wall of the bore 58 in the piston 50, urging the poppet 57 against the seat 63 and tending to move the piston 50 to the right, but as long as the throttle valve 24 is open, this pressure is unable to overcome the pressure acting against the right end of the piston 50, which has a substantially larger area than does the bore 58 in the piston.

When the engine is to shut down, the operator closes the throttle valve 24, which quickly reduces the pressure in the line 19 and the connection 37 to a low value, permitting the spring 65 to move the piston 50 into its right end position, in which the poppet 57 closes on the seat 62 and opens off the seat 63. This prevents further escape of fuel from the bladder 39 out through the connection 37. However, the jet engine and the pump 22 will continue to coast for a period following closure of the throttle valve 24, and as long as the pump delivers fuel, it will continue to flow through the connection 36 and into the bladder 39, where it will be stored to facilitate the next start.

It will be apparent from the foregoing description that the use of the unit 35 in the system of Fig. 1 provides for the immediate supply of fluid at high pressure to the jets 18 following filling of the line 19 in response to the opening of the throttle valve 24, so that immediate atomization and ignition of the fuel results. In addition to insuring positive starting, the unit prevents the accumulation of unburned fuel in the engine prior to ignition.

Although the apparatus can be designed to function at various pressures, in an actual embodiment of the invention tested the pressures had the following values: The normal air pressure in the accumulator shell 38 when the bladder 39 was completely collapsed was between 60 and 100 p. s. i.; the pump 22 was capable of developing between 120 and 200 p. s. i. at the starting speed of the jet engine; and was capable of developing approximately 500 p. s. i. at full running speed. The spring 65 was so proportioned relative to the pressure areas of the piston 50 as to cause the piston to open the poppet 57 off the seat 62 at a pressure in the connection 37 of between 15 and 26 p. s. i.

Although during normal operation of the engine the pressure in the line 19 and in the accumulator 35a may be as high as 500 p. s. i. this pressure drops quickly to zero value following closure of the throttle valve 24, and the piston 50 is moved to the right by its spring 65 when the pressure in the connection 37 drops to about 10 p. s. i. Since the air pressure in the accumulator 35a is always at least 60 p. s. i., the bladder 39 will always be completely collapsed when the piston 50 is returned to normal position by its spring 65. However, as previously described, the engine continues to coast for some time following closure of the throttle valve 24, so that there is ample time to accumulate substantial fuel in the bladder 39, following return of the piston 50 to the right, and before the pump pressure drops appreciably.

Various departures from the exact construction described can be made without departing from the invention which is to be limited only to the extent set forth in the appended claims.

We claim:

1. A valve device of the type described comprising: a body having an inlet port, an outlet port, and an accumulator port; first, normally open, valve means for communicating said inlet port with said accumulator port, second, normally closed, valve means for communicating said accumulator port with said outlet port; and means responsive to a rise in pressure in said outlet port above a predetermined value relative to the ambient pressure for opening said second valve.

2. A valve device of the type described comprising: a body having an inlet port, an outlet port, and an accumulator port; first normally open valve means for communicating said inlet port with said accumulator port, second normally closed valve means for communicating said accumulator port with said outlet port; and means responsive to an increase of the pressure in said outlet port above a predetermined value for closing said first valve means and opening said second valve means.

3. A valve device of the type described comprising: a body having a cylinder, an inlet port, an outlet port, and an accumulator port; piston

means reciprocal in said cylinder and exposed to ambient pressure at one end and to pressure in said outlet port at the other end; passage means in said body including a first valve seat for intercommunicating said outlet and accumulator ports; a poppet valve normally closing said first seat; a second valve seat in said piston means; means defining a passage from said inlet port through said second seat to said accumulator port; the arrangement of said piston means and poppet being such that movement of said piston means in response to pressure in said outlet port closes said second seat on said poppet and carries the poppet clear of said first seat.

4. A valve device as described in claim 3 including a second poppet valve seating against said inlet port, and spring means urging said second poppet against said inlet port for permitting fluid flow from said inlet port into said body while preventing return flow through said inlet port.

5. A valve device of the type described comprising: a body defining a cylinder having an inlet port in one end thereof, an outlet port in the other end thereof, and an accumulator port in the side wall thereof; a hollow piston reciprocal in said cylinder and sealing with said inlet and outlet ports, and with the side wall of said cylinder on opposite sides of said accumulator port, passage means communicating one end of said piston with said outlet port; passage means communicating the other end of said piston with the atmosphere; a valve seat within said piston, a poppet valve within said piston, spring means urging said piston into one end position against the force of the pressure existent in the outlet port; a poppet valve within said piston and spring means urging it into sealing relation with said outlet port when said piston is in said one end position; a valve seat in said piston in spaced relation to said poppet valve when said piston is in said one end position and said poppet is seated against said outlet port, said piston and outlet port defining a chamber between said outlet port and said seat in said piston normally communicated through said seat in said piston with said inlet port; said outlet port and said seat in said piston being so positioned relative to said poppet valve that movement of said piston out of said one end position by pressure in said outlet port first engages the seat in said piston against said poppet to prevent flow of fluid from said inlet port through said seat in the piston, and thereafter carries said poppet clear of said outlet port to communicate said outlet port with said accumulator port.

6. A valve device as described in claim 5 including an additional poppet within said hollow piston positioned back to back with respect to said one poppet and adapted to seat against said inlet port, said spring means being interposed between said two poppets for urging them apart.

7. In a fuel system for a combustion engine including a fuel-atomizing jet, a fuel pump driven by the engine, a fuel line connecting the pump to the jet, a throttle valve in the fuel line, and means for normally draining fuel from that portion of the fuel line between the throttle valve and said jets when substantially no pressure exists in the fuel line on the jet side of the throttle valve; an accumulator; means normally connecting said accumulator to said line on the pump side of said throttle valve; and means responsive to a rise in pressure in said fuel line on the jet side of said throttle valve above a predetermined value for connecting said accumulator to said fuel line on the jet side of said throttle valve.

8. A system as described in claim 7 including means responsive to said rise in pressure in said fuel line on the jet side of said throttle valve above said predetermined value for substantially preventing flow of fuel from that portion of the fuel line on the pump side of said throttle valve into said accumulator.

9. A system as described in claim 7 including check valve means for permitting flow of fluid from that portion of said fuel line on the pump side of said throttle valve into said accumulator while preventing reverse flow.

10. A system as described in claim 7 including means responsive to said rise in pressure in said fuel line on the jet side of said throttle valve above said predetermined value for substantially preventing flow of fuel from that portion of the fuel line on the pump side of said throttle valve into said accumulator, and check valve means for at all times preventing reverse flow from said accumulator into said fuel line on the pump side of said throttle valve.

11. A system as described in claim 7 including means responsive to said rise in pressure in said fuel line on the jet side of said throttle valve above said predetermined value for substantially preventing flow of fuel from that portion of the fuel line on the pump side of said throttle valve into said accumulator, check valve means for at all times preventing reverse flow from said accumulator into said fuel line on the pump side of said throttle valve, and check valve means in said fuel line adjacent said pump permitting fluid flow from the pump into the line while preventing reverse flow from said line back into the pump.

WALTER C. TRAUTMAN.
ALVIN A. MEDDOCK.

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