Feb. 6, 1962 M. G. HOCUTT ET AL 3,019,598

AFTERBURNER FUEL IGNITER

Filed July 23, 1958 2 Sheets-Sheet 1

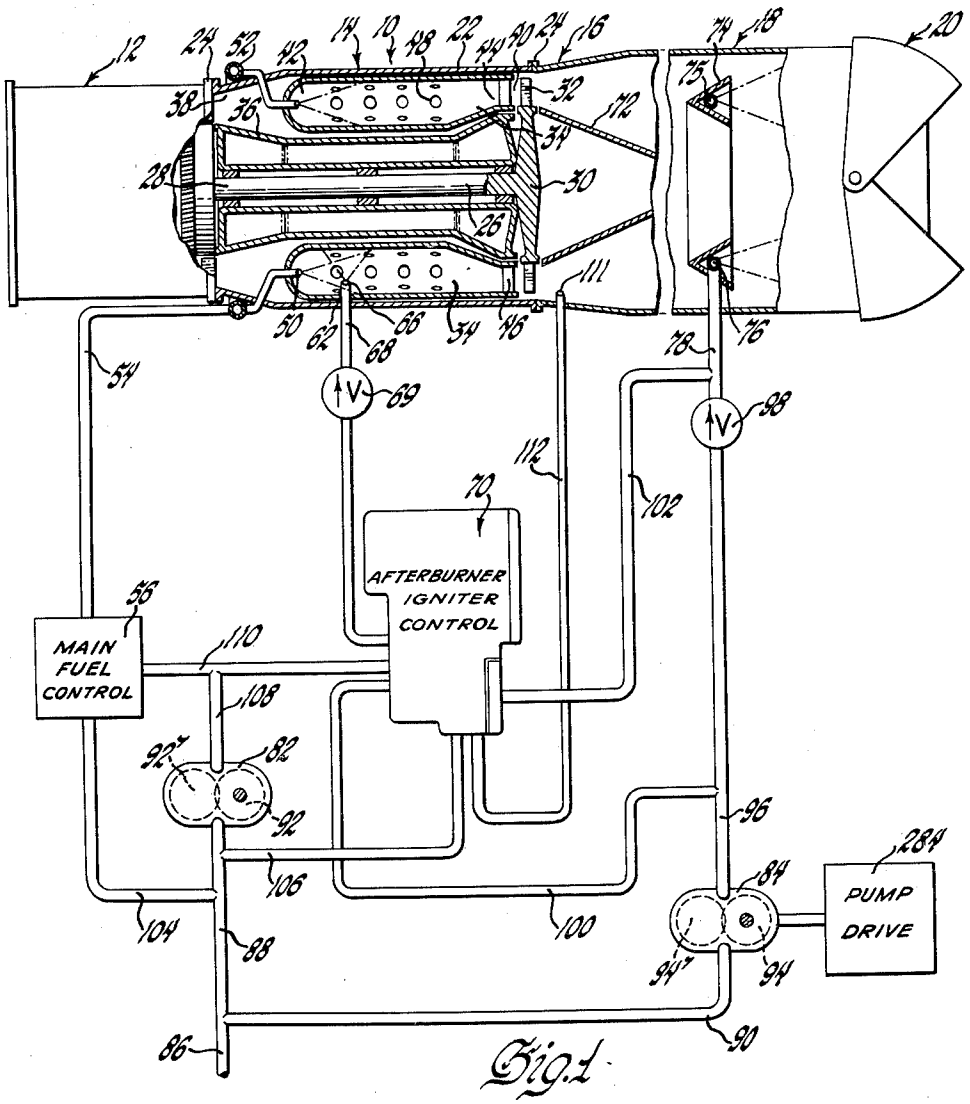


Fig. 1

INVENTORS
Morris G. Hocutt, Jr.
Carl T. McLuen
BY Paul Fitzpatrick
ATTORNEY

Feb. 6, 1962 M. G. HOCUTT ET AL 3,019,598

AFTERBURNER FUEL IGNITER

Filed July 23, 1958 2 Sheets-Sheet 2

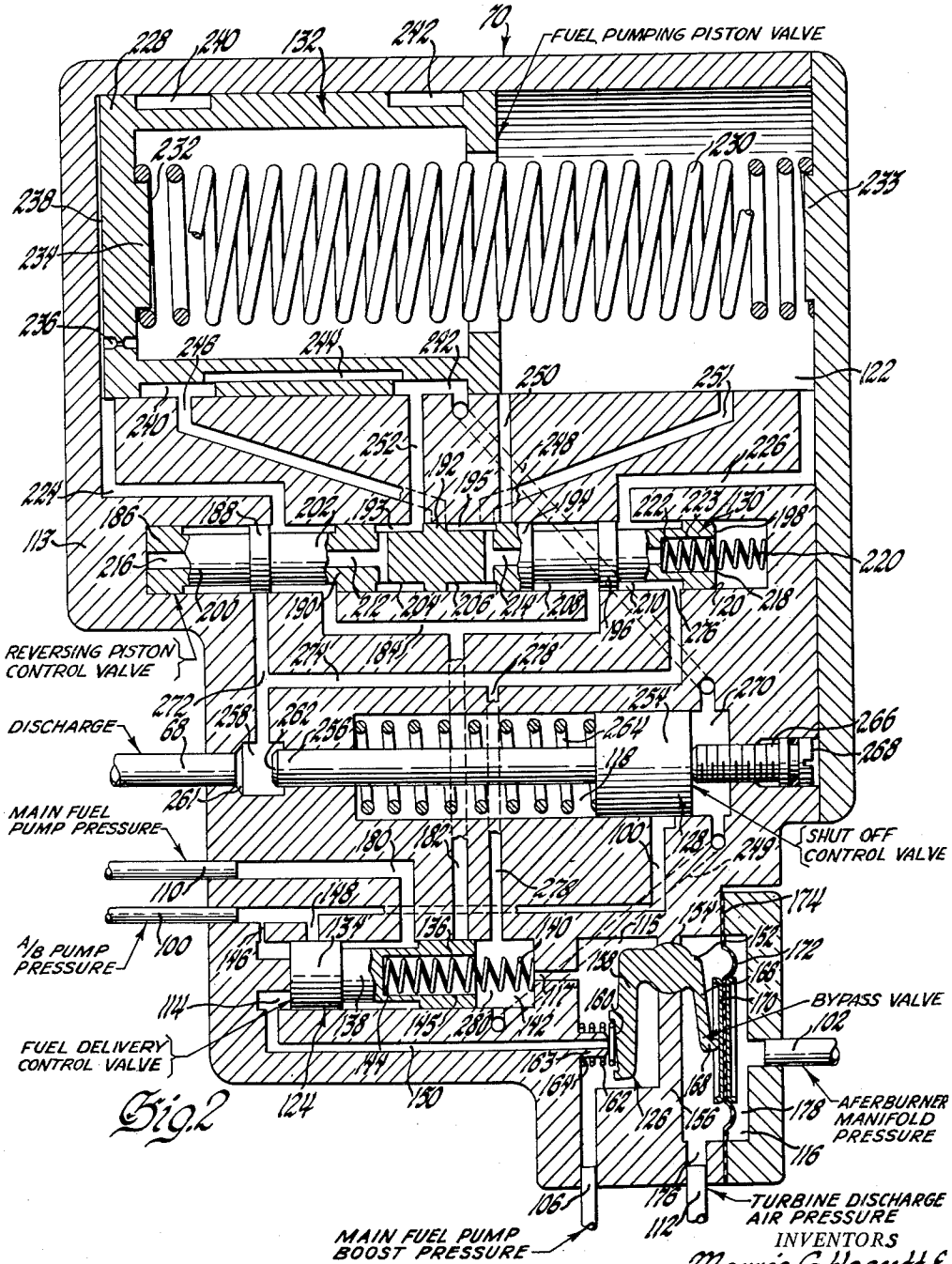


Fig. 2

INVENTORS
Morris G. Hocutt, &
Carl T. McLuen
BY
Paul Fitzpatrick
ATTORNEY

United States Patent Office

3,019,598

Patented Feb. 6, 1962

3,019,598

AFTERBURNER FUEL IGNITER

Morris G. Hocutt, San Diego, Calif., and Carl T. McLuen, Racine, Wis., assignors to General Motors Corporation, Detroit, Mich., a corporation of Delaware

Filed July 23, 1958, Ser. No. 750,348
10 Claims. (Cl. 60—35.6)

This invention relates to pre-turbine ignition of the fuel in the afterburner of a gas turbine engine

It is well known to use afterburners in connection with gas turbine engines to provide additional thrust when necessary. However, this afterburner fuel must be ignited at the proper time to provide the most efficient operation. It is generally known that only about one-third of the air present in the combustion chamber is necessary to support combustion. This invention therefore, relates to intermittently providing a charge or series of shots of fuel in the combustion chamber in addition to the regular fuel supply to momentarily provide a flame of greater intensity and of a length sufficient to extend the flame through the turbine section to ignite the fuel in the afterburner section. The igniting of the afterburner fuel in this manner poses problems. If the ignition occurs prematurely, the air-fuel mixture in the afterburner section is too lean to support combustion, whereas if the ignition is late, a dangerous start may be effected. The ignition of the afterburner fuel is further complicated by the fact that the turbine temperature must be kept below a specified maximum; therefore, the fuel injection must be such as to increase the flame intensity sufficiently to ignite the fuel and yet extend over a brief enough interval to prevent the turbine temperature from exceeding the maximum. Previous to this invention, remote electrical and other timing controls were used to coordinate the igniting of the afterburner fuel with the introduction of fuel to the afterburner section. This involved additional mechanisms, therefore increasing the complexity and possibilities of failure.

This invention eliminates the above disadvantages by providing an afterburner fuel igniting control mechanism that automatically operates in response to the supply and pressure of fuel to the afterburner. A brief description of the invention will serve to clarify this.

When the afterburner operation is initiated, the pressure of the fuel in the afterburner manifold is reflected to an afterburner igniter control mechanism wherein the pressure causes a fuel inlet/by-pass valve to open and direct main pump fuel to an auxiliary pumping mechanism having an outlet connected to one of the combustion cans. The pumping mechanism is a reciprocating piston-type controlled by a reversing valve to provide a controlled charge of fuel to the combustion can upon each reciprocation of the piston. These controlled charges of fuel are supplied to the combustion can in addition to the regular fuel supply and therefore cause the flame therein to be extended through the turbine to ignite the fuel in the afterburner. Since, as stated previously, the length of time the flame is extended must be brief to prevent an excessive turbine inlet temperature rise, simultaneously with the supply of additional fuel to the combustion can, a fuel cut-off valve in the auxiliary pump fuel outlet line is progressively closed by hydraulic means which, in effect, counts the number of fuel shots discharged to the igniter nozzle. After a preset number of shots, afterburner pump pressure acts on the cut-off valve to completely close the outlet to the combustion can and thereby discontinue the additional charges of fuel thereto. The flame returns then to its normal intensity and the afterburner igniter control remains inoperative as long as the afterburner is in operation.

Therefore, it is an object of this invention to provide a control system wherein the igniting of the extra fuel in the combustion chamber is timed in accordance with the feed of fuel to the afterburner section.

It is a further object to ignite the afterburner fuel of a gas turbine engine by providing a series of controlled shots of fuel into the combustion chamber in addition to the regular fuel supply to create a flame of an intensity and length to extend through the turbine section to the afterburner section.

It is still another object of this invention to provide a control system for controlling the supply of the additional fuel to the combustion chamber consisting of a fuel pump mechanism controlled by a plurality of valves in accordance with the manifold fuel pressure in the afterburner section.

Also, it is an object of this invention to provide an afterburner fuel control system whereby the raising of the afterburner manifold pressure by feeding fuel to the afterburner section effects the operation of a valve controlled fuel pumping mechanism to deliver a controlled series of shots of fuel to the combustion chamber.

Finally, it is an object of this invention to provide a multishot fuel injector to begin operation upon the attainment of a predetermined afterburner fuel manifold pressure, the operation to be terminated by the movement of a valve by afterburner fuel pressure upon the completion of a predetermined number of shots of fuel to the combustion chamber by the multishot injector.

Other features, advantages and objects will become apparent by reference to the succeeding detailed description and to the drawings wherein:

FIGURE 1 is a diagrammatic partial cross-sectional illustration of a preferred embodiment of my invention showing a gas turbine engine together with its fuel control system, and

FIGURE 2 is an enlarged cross-sectional view of the afterburner igniter control shown in outline in FIGURE 1.

Referring now to the drawings and more particularly to FIGURE 1, there is shown therein a gas turbine engine 10 having a compressor section 12, a combustion section 14, a turbine section 16, an afterburner section 18, and a variable exhaust nozzle 20. The engine sections are shown as comprising casings 22 enclosing the sections and circumferentially joined together at their ends by means of suitable flanges 24. Suitably supported within and extending through the combustion section 14 is the engine drive shaft 26 connected at one end 28 to the compressor section and formed at its other end with a disk or rotor 30 having turbine blades 32 fixed thereto. The combustion section 14 further includes a number of annular combustion cans 34 spaced circumferentially around the drive shaft 26 and supported by suitable means (not shown) between an inner annular shroud or casing 36 surrounding the drive shaft 26 and the outer casing 22. The annular chamber formed by the inner and outer casings 36 and 22 has a divergent portion 38 at one end comprising a transition zone for the passage of air from the compressor section to the combustion section, with a convergent portion 40 at its opposite end for cooperation with the turbine section. The combustion cans 34 may be closed at one end 42 and connect at their opposite ends 44 with stationary blades 46 cooperating with the rotor blades 32 of the turbine section 16. Suitable air mixing and dilution holes 48 are provided in cans 34 to provide the proper mixture of fuel and air to support combustion in the cans and for cooling of the gas. Projecting through the closed end of the cans are fuel nozzles 50 connected by an annular conduit 52 to the main fuel supply line 54 leading from the main fuel control 56. While only two of the cans are shown in

the figure, it will be obvious that any number may be used without departing from the scope of the invention. It has been a practice to use six or more cans in the combustion section, with each of the cans having parallel connections from the fuel nozzles to the main fuel supply line such as 54.

Shown in the drawing projecting through the side wall portion 62 of one of the combustion cans 34 and casing 22 is a supplementary fuel nozzle 66 connected by a fuel conduit 68 and a check valve 69 to the afterburner igniter control 70 forming the subject of this invention. The turbine section 16 is shown having a divergent exhaust duct 72 leading to the afterburner flame holder 74 which contains the flame in the afterburner section, as is conventional. The fuel to the afterburner section is supplied through a manifold 75 having a number of nozzles 76 annularly spaced around the circumference of the flame holder 74 and connecting with a fuel pressure feed line 78.

The main fuel system includes an engine driven fuel pump 82. The afterburner fuel system includes a fuel pump 84 which is driven during afterburning by suitable mechanism indicated as a pump drive 284. Pumps 82 and 84 have a common intake line 86 from a fuel source including an aircraft boost pump (not shown) through branch lines 88 and 90. Pumps 82 and 84 may be of the conventional gear type having driving gears 92 and 94 mating with gears 92' and 94' of equal size to be driven thereby. The afterburner pump 84 supplies fuel under pressure through line 96 and a check valve 98 to the afterburner fuel supply line 78, with branch lines 100 and 102 directed to the afterburner igniter control. The fuel intake line 88 leading to main pump 82 is branched at 104 and 106, the line 104 being a return line from the main fuel control 56, with the line 106 connected to the afterburner igniter control 70 for indicating engine pump intake (aircraft boost) pressure. Main pump 82 has a delivery line 108 branched at 110 to supply fuel both to the main fuel control 56 and the afterburner igniter control 70.

Also connected to the afterburner igniter control 70 at one end is a conduit 112 having a probe 111 at its other end mounted within the engine as shown at a position to be indicative of turbine motive fluid pressure.

From a consideration of FIGURE 1, it will be seen that prior to the feeding of fuel to the afterburner, the afterburner igniter control is sensitive to a number of factors, such as main fuel pump boost (inlet) pressure through line 106, main fuel pump discharge pressure through line 110, turbine discharge pressure through line 112, afterburner manifold pressure (substantially equal to turbine discharge pressure when no fuel is supplied) through line 102, and aircraft boost pump pressure (since pump 84 is not operating) through line 100. The pressures in lines 106 and 100 will be approximately equal to each other, and the pressures in lines 102 and 112 will be approximately the same. Upon supplying fuel to the afterburner, the pressure in line 100 will be raised to afterburner delivery pump pressure, and the afterburner manifold pressure in lines 78 and 102 will also be raised.

Referring now to FIGURE 2, a cross-sectional enlarged view of the afterburner igniter control 70 is shown. The control 70 comprises a valve body 113 suitably bored at 114 for receiving a slidable main fuel delivery control valve 124; at 115 and 116 for receiving both portions of a flapper type by-pass valve 126; at 118 for receiving a slidable shut-off control valve 128; at 120 for receiving a slidable reversing piston control valve 130; and at 122 for receiving a reciprocating fuel pumping piston valve 132.

For a clearer understanding of the invention, the individual valves will be described separately at this time, with their coordinated operation being deferred until the complete operation of the system is explained.

The main fuel delivery control valve 124 is of the spool type having lands 134 and 136 connected by a neck portion 138 of reduced diameter and suitably biased toward the left-hand portion of the valve bore 114 by a compression spring 140. Spring 140 is seated at one end against a portion 142 of the bore 114 with its other end being contained within and seated against end 144 of a hollowed out portion 145 of the valve. The bore 114 is connected to the branch afterburner pump pressure line 100 by restricted and unrestricted conduits 146 and 148, respectively, for permitting the application of the afterburner pump pressure to the left end of valve land 134, and for feeding afterburner fuel under pressure through a line 150 to the flapper type valve 126.

Flapper valve 126 consists of a generally U-shaped member 152 pivotally mounted within a ball-shaped bored portion 154 of a dividing wall 156 of the valve body, wall 156 being a common wall for bores 115 and 116. The left arm 158 of the flapper valve is provided with a valve seat 160 movable with the arm to alternately open or close line 150 to thereby control the flow of afterburner fuel through line 150 into the bore 115. The flapper valve arm 158 is biased to the right to maintain line 150 open by a compression spring 162 surrounding a nipple 163 on the valve body and seated between the arm 158 and the valve body at 164. Bore 115 containing arm 158 connects with line 106 connecting with the intake side of main fuel pump 82, and also with the bore 114 of the fuel delivery valve 124 through a conduit 117.

The other arm 166 of the flapper valve 126 has an actuator or lug 168 adapted to bear against a bearing surface 170 fixed to a flexible diaphragm 172 clamped in the valve body at 174. The diaphragm 172 divides bore 116 into two pressure chambers 176 and 178, the chamber 176 communicating with and being sensitive to the turbine discharge pressure in line 112, and chamber 178 communicating with and being sensitive to afterburner manifold pressure through line 102. From a consideration of the figure, it will be seen that the force of spring 162 will move the flapper valve arm 158 to the right as long as the afterburner fuel pressure in chamber 178 is equal to or lower than the exhaust duct gas pressure in chamber 176. Thus, the afterburner fuel pump pressure in line 100, conduit 146 and line 150 will communicate with the main fuel pump intake conduit 88 (FIG. 1) through line 106. Upon an increase in afterburner manifold pressure in line 102, diaphragm 172 will be moved to the left to move the flapper valve 126 to close line 150 by the seating of seat 160 against the end of the nipple 163, thereby permitting a build-up of the afterburner fuel pump pressure in line 150 and against land 134 of the main fuel delivery control valve 124.

Valve 124 is slidable between open and closed positions, as will be defined, to control the delivery of fuel from line 110, connected to the outlet of the main fuel pump 82, to the fuel pumping piston valve 132.

The valve body is also provided with two connecting fuel conduits 180 and 182, each connecting at one end to the bore 114 of the delivery valve 124. The conduit 180 at its other end is connected to main fuel pump line 110, while conduit 182 is branched at 184 to cooperate with the reversible piston control valve 130. Land 136 of the fuel delivery control valve controls the flow of fuel between conduits 180 and 182, the closed position of the valve blocking the connection as shown, the open position being to the right of that shown and connecting the two conduits by way of the reduced neck portion 138 of the valve.

Piston control valve 130 is of the spool type and is provided with lands 186, 188, 190, 192, 194, 196 and 198, connected by neck portions of reduced diameter 200, 202, 204, 206, 208 and 210, respectively. Suitable passages 212 and 214 are drilled internally of the valve for connecting the spaces 193 and 195 between lands 190, 192 and 192, 194, respectively, with the respective ends 216 and 218 of the valve bore 120. The valve is normally biased to the left as seen in the figure by a compression spring 220 seated at one end against end 218 of the valve

bore and at the other end against a shuolder 222 of a hollowed out portion 223 of the end of the valve. The movements of lands 186, 188 and 196, 198 control the delivery of fuel to and the outlet of fuel from the piston pumping valve 132 through opposite end lines 224 and 226 to cause the piston to act as a pump and for permitting the outlet of the fuel pumped by the piston, as will appear later. The movements of lands 190, 192 and 194 control the reciprocating movement of the piston control valve 130, as will also appear later.

The piston-valve 132 consists of a hollow piston 228 slidably moveable in a bore 122 in the valve body and normally biased to the position shown by a compression spring 230 seated at one end against the valve body, and at its other end against the underside 232 of the piston. Suitable centering bosses 233 and 234 are provided for centrally locating the spring. An orifice 236 is provided for restrictively connecting opposite sides of the piston. The piston 228 is further provided with suitable annular fuel passages 240 and 242 communicating with each other by a passage 244 to constitute a sleeve valve. The passage 240 is shown connected to the bore 120 of the piston control valve 130 by a line or conduit 246, while the annular passage 242 is connected by a conduit 248 (shown in dotted lines) to one end of the bore 118 containing the shut-off valve 128. Other suitable lines 250, 251 and 252 provide communication between the piston control valve 130 and the bore 122 containing the piston valve 132.

The shut-off control valve 128 controls the communication of fuel from the piston valve 132 and piston control valve 130 to the combustion can nozzle 66, and comprises a land 254 having a stem portion 256 of reduced diameter extending from one side of the land into a chamber 258 in the valve body. Chamber 258 is connected to the afterburner fuel igniting delivery line 68 leading to the combustion can through check valve 69 as seen in FIGURE 1. Chamber 258 is tapered or beveled at 261 and cooperates with the beveled end 262 of the stem 256 in a seal-like manner for stopping flow of fuel through line 68 upon insertion of the end 256 therein. The cut-off valve 128 is biased to the position shown in FIGURE 2 by a compression spring 264 surrounding the stem 256 and seated at one end against the valve bore 118 with the other end against the land 254. The right-hand motion of the valve by the spring 264 is limited by an adjustable screw 266 having a conventionally slotted head 268 for a suitable operating tool. The land 254 of the valve controls communication between the chamber 270, containing fuel under pressure from the piston valve passage 242 through line 248, and an extension of the afterburner fuel pump pressure line 100. The chamber 270 is also connected by a line 249 (shown dotted) with the chamber 280 of the fuel delivery control valve 124.

The shut-off control valve 128 operates to control the amount of additional fuel delivered to the combustion chamber through nozzle 66 so as to maintain the igniting flame in the combustion can just long enough to ignite the afterburner fuel; whereupon the additional fuel supply is cut off, as will appear when the general operation is described.

The control chamber 258 cooperating with the stem 256 of the shut-off valve and the fuel line 68 is connected to bore 120 of the piston control valve 130 by a line 272, the line 272 being normally blocked by the land 188 with the piston control valve 130 in the position shown. The line 272 is branched at 274 to communicate with the opposite end of piston control valve at 276 and with a branch line 278 leading to the chamber 280 beneath the land 136 of the fuel delivery control valve 124.

Operation

Referring now to both FIGURES 1 and 2, the general operation of this invention will be described. Assuming that the gas turbine engine is operating with the afterburner section 18 inoperative, the afterburner fuel pump 84 will be inoperative with the pressure in delivery line 96 and branch line 100 being approximately the same as in afterburner and main intake pump pressure lines 90, 88 and 106. The pressures in gas pressure line 112 and afterburner manifold pressure line 102 will also be approximately the same, which, without afterburning, will be low. These approximately equal pressures in lines 112 and 102 are reflected to chambers 176 and 178 of bore 116 containing arm 166 of the flapper valve 126, and therefore no movement of the arm 166 by the diaphragm 172 will take place. Spring 162 therefore pivots arms 158 and 166 of the flapper valve 126 about the pivot 154 to the position shown, uncovering afterburner pump pressure line 150 to bore 115 and to main fuel pump intake line 106. Since line 150 is open to line 106, and the pressures at this time are approximately the same, the pressure acting on land 134 of the fuel delivery valve 124 from orificed conduit 146 and afterburner fuel pump line 100 will be insufficient to move the valve to the right. Therefore, no fuel is fed from the main fuel delivery line 110 to the face 238 of piston valve 132 because land 136 of the fuel delivery control valve 124 blocks the connection between fuel connecting lines 180 and 182.

However, the fuel in line 106 at pump intake pressure will flow through bore 115, line 117, chamber 280, line 278, passage 276 past the neck portion 210 of the piston control valve 130, through line 226 and into the bore 122 housing the piston valve 132 to maintain bore 122 full of fuel. Chamber 270 of the cut-off valve 128 will also be kept filled through line 117, chamber 280, and line 249 (dotted).

The main fuel pump 82 at this time delivers fuel under pressure to the main fuel control 56 from which it is delivered through line 54 to the manifold 52 and the main fuel nozzles 50 in the combustion cans 34.

When it is desired to operate the afterburner, the operator may, by suitable means represented by the pump drive 284, activate the afterburner pump 84 to feed afterburner fuel through line 96. As the pressure of the fuel in lines 96 and 100 increases, the afterburner manifold pressure in line 102 will also build up. With the rising manifold pressure in line 102, the diaphragm 172 in bore 116 containing a part of the flapper valve 126 is moved to the left against the action of spring 162, thereby tilting the flapper valve 126 to seat arm 158 against the end of nipple 163 and close the afterburner fuel line 150. At the same time, the increased pressure in afterburner fuel line 100 is bled through orifice 146 to act against the end land 134 of the fuel delivery control valve. As a result, lands 134 and 136 of the valve 124 move to the right as seen in FIG. 2 to connect the fuel from the main pump 82 in lines 110 and 180 to the main fuel delivery line 182, with lines 278 and 249 now being blocked by the new position of the land 136 to prevent escape of fuel from the piston bore 122 through these lines. Fuel is then fed through line 182 and around the neck portion 202 of the piston control valve 130 to fill line 224 and act on the face 236 of the piston 228. The piston 228 will then be moved to the right under pressure, forcing the fuel present in the bore 122 out through end passage 226, around neck portion 210 of the piston control valve 130, and out through lines 276 and 274 to the discharge chamber 258 leading to the combustion chamber delivery line 68. This fuel is then expelled through line 68 and nozzle 66 where it is ignited by the burning fuel already in the can from nozzles 50. The extra charge of fuel fed through nozzle 66 increases the existing flame causing it to expand. Simultaneously with the discharge of fuel to the combustion can, fuel is forced from the piston valve bore 122 through line 251 and space 195 of the piston control valve 130 into the internal bore 214 communicating with end 218 of the piston control valve bore 120 to

aid spring 220 in maintaining the control valve 130 in its position shown. The piston 132 continues to move further to the right under the pressure of fuel in line 224 until line 252 is open to the pressure of fuel acting on the face 238 of the piston, whereupon fuel is admitted to the space 193 and bore 212 leading to the end 216 of the control valve 130. The valve 130 is then forced to the right causing the fluid in the chamber at the opposite end 218 of the valve bore to be forced out through bore 214 and space 195 into lines 251, passage 242, interconnecting passage 244, passage 240 and into the passage 248 (dotted lines) leading to chamber 270 of the shut-off valve 128. After some movement of the valve, the fuel in bore 214 of the piston control valve 130 is also fed to chamber 270 of the shut-off valve by means of the space 195, line 250, passage 240 and line 248. The pressure on end 216 of the control valve 130 continues to move the valve rightwardly until land 196 is positioned to the right of the opening to end passage 226 leading to the piston bore 122. At this time, the line 246 connecting at one end to the left end of piston bore 122 is connected at its other end with the space 193 and bore 212 to cause pressure to be exerted on end land 186 to maintain the control valve 130 in its right-hand position.

The entrance of the fuel under pressure into chamber 270 of the shut-off valve 128 causes the valve land 254 and stem 256 to move slightly to the left against the force of spring 264 and the pressure of the fuel in chamber 258 on the end of the stem 256. However, not enough fuel is displaced by valve 130 to close valve 128. With the piston control valve 130 to the right, the fuel delivered through lines 182 is fed around the neck portion 208 of the piston control valve into end passage 226 to act on the right end of piston 228 to cause leftward movement of the piston. Movement of the piston to the left forces the fuel in the piston bore 122 to the left of face 238 through end passage 224, around neck portion 200 of the piston control valve 130 and into passages 272, chamber 258 and passage 68 to further cause an extension of the flame in the combustion can. Continued movement of the piston valve 132 to the left under the pressure of the fuel in line 226 connects lines 251 and 226 via bore 122, but line 251 is blocked by land 192 of valve 130. When piston 228 returns to the left end of bore 122, fluid is supplied through 250, 195 and 214 to the right end of valve 130. Valve 130 moves to the left, exhausting from end 216 through 212, 246, 240, 244, 242 and 248 (and through 252 when it opens into 242 and 248). Thus valve 128 is displaced further to the left.

This completes a cycle of piston 228 and control valve 130, and the cycle will be repeated as described until valve 128 moves far enough to the left to uncover the afterburner pump pressure line 100. The fuel under pressure from line 100 then enters the chamber 270 and is sufficient to overcome the combined forces of the spring 264 and the pressure of the fuel acting against the stem 256 of the cut-off valve to close valve 128 with a snap action, with the valve stem 256 sealingly inserted in the passage 68. Further additional injection of fuel to the combustion cans through line 68 from chamber 258 is therefore blocked.

As will be apparent, the original position of valve 130 against adjusting screw 266 determines the number of strokes of piston 228 which will occur before valve 128 closes to terminate the "hot streak" ignition.

Since the pressure of fuel from the afterburner pump in line 100 is sufficient to maintain the valve cut-off 128 in a closed position, no further fuel will be fed to the additional fuel opening 66 in the combustion chamber as long as the control 284 is operated to maintain the afterburner pump in operation and therefore pump pressure in lines 96 and 100 at its high level.

By this time, the multiple shots or charges of fuel through openings 66 in the combustion can have caused the flame to intensify sufficiently to extend rearwardly through the turbine section 16, past the transition section to ignite the fuel fed from the afterburner nozzles 76. This multiple-shot injection occurs almost continuously and simultaneously with the increase of fuel pump pressure to the afterburner nozzles, with the whole cycling series requiring but fractions of a second. Of course, it will be clear that by variably orificing the line 248, the time interval between shots of fuel as determined by the strokes of piston 132 can be controlled to limit the build up in temperature of the turbine, i.e., a definite time interval would be established between shots to permit the turbine temperature to decrease between shots instead of continuously building up as under continuous shot injection.

If the afterburner pump drive 284 is operated to idle pump 84, the pressure in line 100 will decay to pump boost pressure thereby decreasing the pressure against land 254 of the shut-off valve 128 and permitting the spring 264 to seat the land against the screw stop 266. With the decrease in pressure in afterburner manifold pressure line 102, the flapper valve 126 will move to the right to open the afterburner pump pressure line 150 to the main fuel pump boost pressure line 106, thereby connecting lines 117, 278, 276 and 226 to line 106 to maintain the piston bore 122 filled with fuel, and also connecting line 106 to lines 117 and 249 to maintain chamber 270 of the cut-off valve 128 filled. The afterburner igniter control will then be conditioned for operation again upon operation of the control 284.

If cut-off valve 128 closes with piston 228 at the right end of bore 122, spring 230 will return piston 228 to the left end of its stroke, displacing fuel through orifice 236. This will permit spring 220 to return control valve 130 to its left or normal position. The bleed through orifice 236 in normal cycling of the piston 228 is inconsequential.

From the foregoing it will be seen that this invention provides an afterburner fuel ignition system eliminating the use of complicated electrical timing devices while igniting the afterburner fuel by increasing the fuel charge to the combustion chamber. This increase in fuel charge causes an extension of the flame therein through the turbine and transition sections to the afterburner section. Thus, a very efficient and simplified fuel ignition control is provided.

We claim:

1. A fuel injection means comprising a housing, a plurality of fuel inlets and an outlet in said housing, said inlets each having a fuel under pressure therein, and fuel pumping means in said housing for pumping the fuel in one of said inlets through said outlet, means including conduit means connecting the fuel in said one inlet to said pumping means and connecting said pumping means and said outlet, movable closure means for closing said outlet, said closure means being movable by the pressure of fuel thereon from another of said inlets to close said outlet and terminate the fuel injection upon the pumping of a predetermnied quantity of fuel.

2. A multi-shot fuel injection system for a turbomachine having a main fuel combustion chamber and an afterburner chamber therein, main and afterburner sources of fuel under pressure, first conduit means connecting the fuel from said afterburner source to said afterburner chamber, second conduit means connecting the fuel from said main source to said main combustion chamber in a plurality of paths, and fuel flow control means in one of said paths, said control means including a fuel pump having a fuel inlet connected to said main source and an outlet connected to said combustion chamber, movable fuel flow blocking means normally blocking said inlet, other conduit means connecting the fuel from said afterburner source to said blocking means to act thereon, said blocking means being movable in response to the pressure of afterburner fuel thereon to

unblock said inlet providing substantially continuous injection of said fuel by said pump into said combustion chamber, and means movable into said outlet to block said outlet and terminate said injection upon the pumping of a predetermined quantity of fuel.

3. A fuel injection means comprising a housing, a plurality of fuel inlets and an outlet in said housing, said inlets each having a fuel under pressure therein, and means in said housing for pumping the fuel in one of said inlets through said outlet, said means including a reciprocating fuel pumping means reciprocated by the pressure of fuel delivered thereto alternately at opposite ends thereof, conduit means connecting the fuel from said one inlet to said pumping means and from said pumping means to said outlet, and movable valve means in said conduit means for controlling the delivery of fuel to said pumping means, said valve means having an open position and a normally closed position and movable to said open position in response to the pressure of fuel acting thereon from another of said inlets to effect reciprocation of said pumping means injecting a substantially continuous supply of fuel into said outlet.

4. A fuel injection means comprising a housing, a plurality of fuel inlets and an outlet in said housing, said inlets each having a fuel under pressure therein, and means in said housing for pumping the fuel in one of said inlets through said outlet, said means including a reciprocating fuel pumping means reciprocated by the pressure of fuel delivered thereto alternately at opposite ends thereof, conduit means connecting the fuel from said one inlet to said pumping means and from said pumping means to said outlet, and movable valve means in said conduit means for controlling the delivery of fuel to said pumping means, said valve means having an open position and a normally closed position and movable to said open position in response to the pressure of fuel acting thereon from another of said inlets to effect reciprocation of said pumping means injecting a substantially continuous supply of fuel into said outlet, and means movable into said outlet to block said outlet and terminate the injection of fuel thereinto upon the pumping of a predetermined quantity of fuel.

5. A fuel injection means comprising a housing, a plurality of fuel inlets and an outlet in said housing, said inlets each having a fuel under pressure therein, and means in said housing for pumping the fuel in one of said inlets through said outlet, said means including a reciprocating fuel pumping means reciprocated by the pressure of fuel delivered thereto alternately at opposite ends thereof, conduit means connecting the fuel from said one inlet to said pumping means and from said pumping means to said outlet, first movable valve means of the reversing type in said conduit means for controlling the distribution of fuel to and from opposite ends of said pumping means, and second valve means in said conduit means having an open position and a normally closed position and movable to said open position in response to the pressure of fuel acting thereon from another of said inlets to deliver fuel to said first valve means to effect reciprocation of said pumping means injecting a substantially continuous supply of fuel into said outlet.

6. A fuel injection system comprising a housing, a plurality of fuel inlets each having a fuel under pressure therein and an outlet in said housing, and means in said housing for intermittently injecting fuel through said outlet from one of said inlets, said means comprising a reciprocating fuel pump, first conduits connecting one of said fuel inlets and opposite ends of said pump for reciprocating the same, first reciprocating valve means in said first conduits controlling the supply of fuel to and the exhaust of fuel from opposite ends of said pump, and second movable valve means cooperating with said outlet for controlling the discharge of fuel therethrough, second conduits connecting at times another of said fuel inlets and said second valve means to act thereon and move said second valve means, means connecting the fuel from said pump to one end of said second valve means to act thereon, and third conduits connecting said outlet and said first conduits, said second valve means having an initial and a final movement for closing said fuel outlet, reciprocation of said pump by the pressure of fuel in said one inlet moving said second valve means through its initial closing position, the pressure of the fuel in said other inlet providing the final outlet closing movement of said second valve means preventing further injection of fuel through said outlet from said pump.

7. A fuel injector for a turbomachine comprising a housing, a plurality of inlet ports therein each having a fuel under pressure therein, a fuel outlet port, and means controlling the delivery of fuel from one of said inlet ports to said outlet port, said means comprising a reciprocating pump, means connecting the fuel in one of said inlet ports alternately to opposite ends of said pump for reciprocating said pump by the force of the fuel pressure thereon, said means also connecting said outlet port and said pump, each reciprocation of said pump supplying fuel to said outlet port, and valve means being movable into said outlet port for closing the same, conduit means at times connecting the fuel from said pump to said valve means for acting on and moving said valve means upon each reciprocation of said pump by the force of fuel pressure thereon, and second conduit means at times connecting a portion of said valve means and the fuel under pressure from another of said inlet ports to move said second valve means in response to the force of fuel pressure thereon, reciprocation of said pump injecting fuel from said one inlet port through said outlet port and against said valve means to move the same, said valve means being movable into said outlet port by the pressure of the fuel in said other inlet port after a predetermined number of reciprocations of said pump.

8. A fuel injector comprising a housing, a plurality of inlets in said housing each containing a fuel under pressure, a fuel outlet, and fuel reciprocating pumping means for delivering fuel from one of said inlets to said outlet, said outlet having a movable valve cooperating therewith, said valve having a progressive movement to close said outlet, means connecting the fuel in said one inlet alternately to opposite ends of said pumping means for reciprocating the same and connecting said pumping means and said valve, conduit means connecting the fuel under pressure in another of said fuel inlets to said valve upon a predetermined movement of said valve, further conduit means connecting said pumping means and said outlet, initial reciprocation of said pumping means effecting simultaneously injection of the fuel from said one inlet through said outlet and from said pumping means to said valve to progressively move said valve towards a position closing said outlet, further reciprocation of said pumping means effecting movement of said valve to said predetermined position to be acted upon by the pressure of the fuel in the other inlet to move said valve to close said outlet.

9. A fuel injection means comprising a housing, a plurality of fuel inlets and an outlet in said housing, said inlets each having a fuel under pressure therein, and fuel pumping means in said housing for pumping the fuel in one of said inlets through said outlet, means including conduit means connecting the fuel in said one inlet to said pumping means and connecting said pumping means and said outlet, closure means progressively moveable for closing said outlet, other conduit means connecting said pumping means and said closure means, said closure means being movable in response to the pressure of fuel from said pumping means towards a position closing said outlet, further conduit means connecting the fuel in another of said inlets to said closure means to act thereon, said closure means being movable in response to the pressure of fuel from said other inlet to fully close said outlet, the closing of said outlet by the progressively moving

closure means predetermining the quantity of fuel to be passed from said one inlet through said outlet.

10. An afterburner fuel igniting system for use in a turbomachine having a combustion section, a turbine section and an afterburner section, first and second sources of fuel under pressure, first and second conduit means connecting said first and second sources respectively to said combustion and afterburner sections respectively, said first conduit means having a plurality of paths delivering fuel to said combustion section, and means in one of said paths controlling the delivery of fuel therethrough, said means including a reciprocating fuel pumping means reciprocated by the pressure of fuel delivered thereto alternately at opposite ends thereof, the reciprocation of said pumping means delivering fuel to said combustion chamber through said one path, a reciprocating valve means in said one path controlling the supply and exhaust of fuel to and from said pumping means, conduit means connecting the fuel in said one path and said valve means to reciprocate said valve means by the pressure of said fuel in said one path, said valve means and pumping means together constituting a repeating fuel discharge means, a movable valve also in said one path having an open and closed position and movable to an open position in response to the pressure of fuel thereon from said second source to connect the fuel from said first source to said reciprocating valve means, and movable to a closed position blocking the connection, other conduit means connecting said afterburner section and second source and said movable valve for moving said valve to its open position in response to a predetermined pressure of the fuel from said second source, and other movable valve means in said one path between said pumping means and said combustion section for blocking the flow of fuel therebetween, further conduit means connecting said pumping means and said other valve means and said second source and said other valve means, said other valve means being movable to a blocking position in response to the pressures of fuel from said pumping means and said second source, the movement of said movable valve to its open position in response to the pressure of fuel from said second source effecting operation of said repeating fuel discharge means to deliver fuel to said combustion chamber through said one path in addition to the fuel delivered thereto through said other paths, said delivery continuing until said other valve means is moved to a blocking position, the burning of the fuel in said combustion section from said other paths igniting the additional fuel delivered thereto from said one path whereupon the flame resulting therefrom is caused to extend through said turbine section to ignite the fuel in said afterburner section.

References Cited in the file of this patent

UNITED STATES PATENTS

1,624,139	Kettering	Apr. 12, 1927
2,496,756	Seborg	Feb. 7, 1950
2,520,434	Robson	Aug. 29, 1950
2,640,316	Neal	June 2, 1953
2,736,166	Mock	Feb. 28, 1956
2,780,055	Bristol	Feb. 5, 1957
2,829,489	Meyer	Apr. 8, 1958
2,867,083	McCombs	Jan. 6, 1959
2,886,280	Lord et al.	May 12, 1959
2,899,798	Borders et al.	Aug. 18, 1959

FOREIGN PATENTS

690,168	Great Britain	Apr. 15, 1953