May 11, 1948. R. J. HOOKER 2,441,195

FUEL INJECTION CONTROL FOR FREE PISTON UNITS

Filed Jan. 16, 1945 4 Sheets-Sheet 1

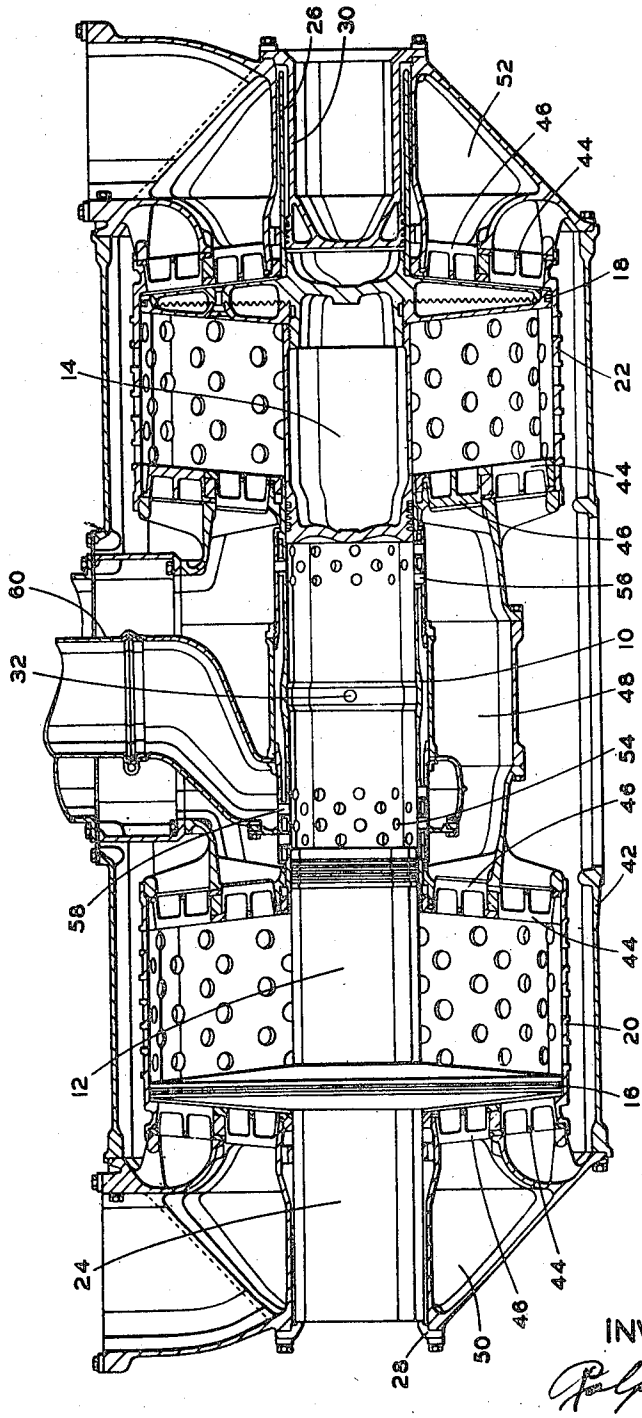


FIG. 1.

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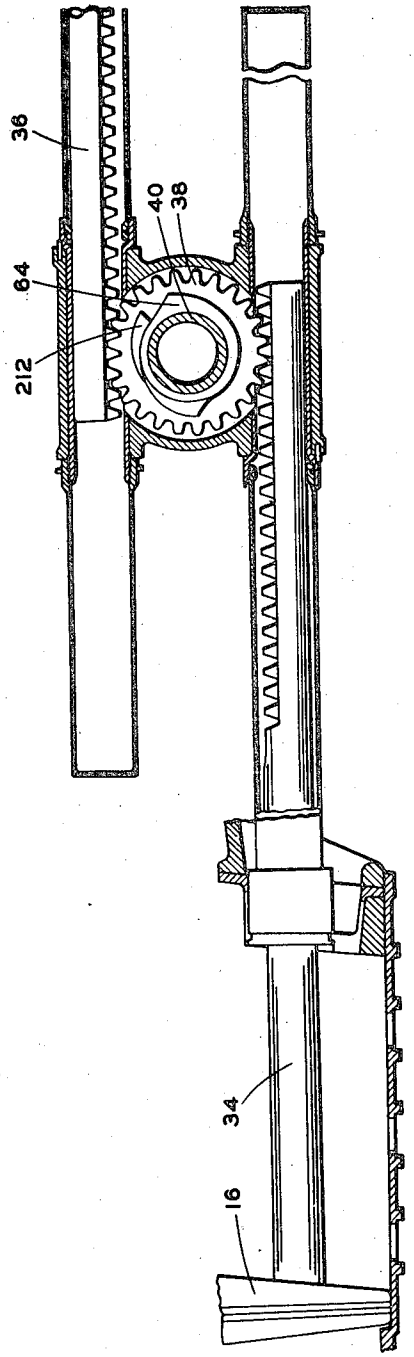


FIG. 2.

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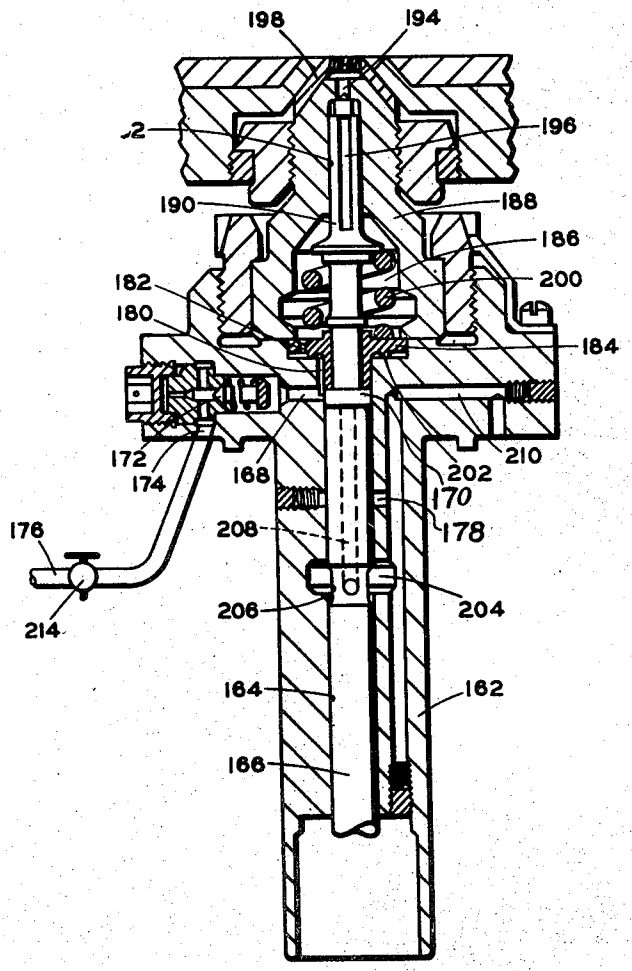


FIG. 3.

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FUEL INJECTION CONTROL FOR FREE PISTON UNITS

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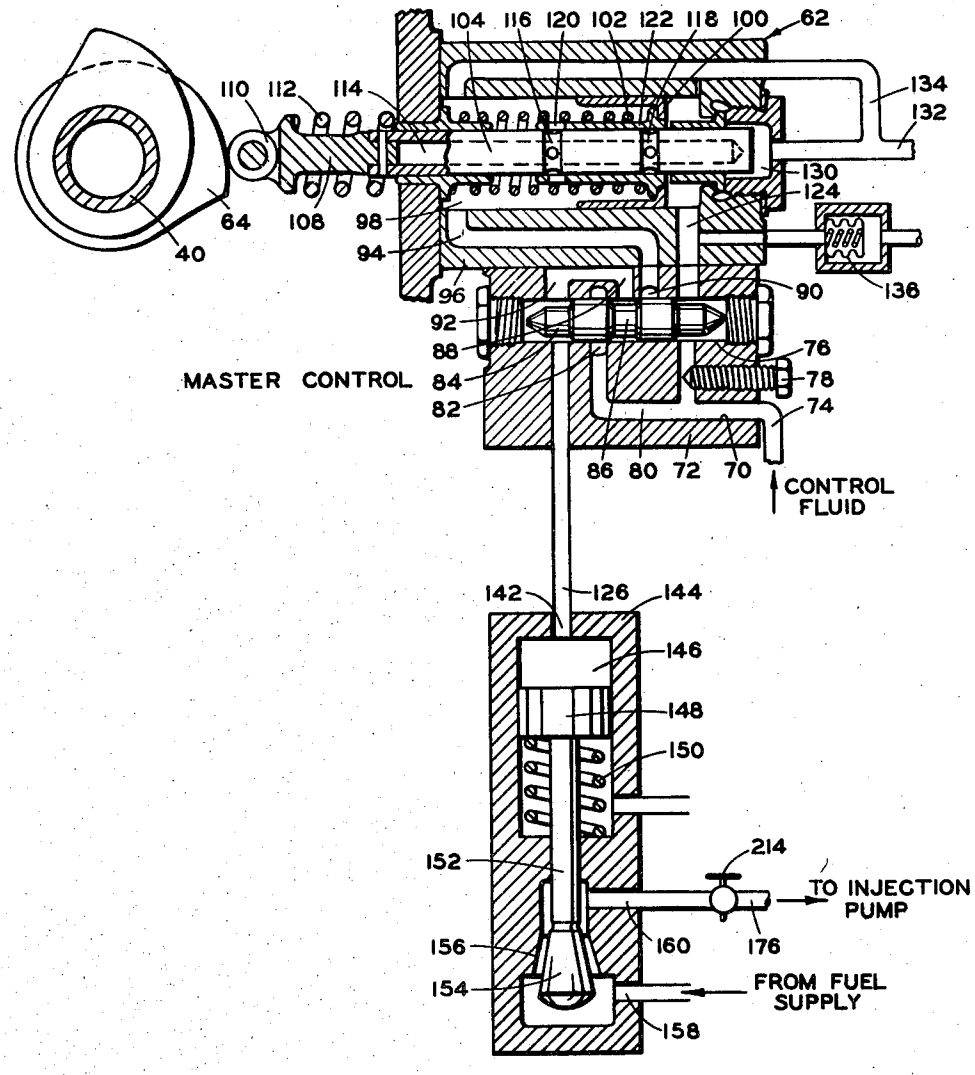


FIG. 4.

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FUEL INJECTION CONTROL FOR FREE-PISTON UNITS

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Application January 16, 1945, Serial No. 573,027

3 Claims. (Cl. 123—46)

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This invention relates to free-piston units and particularly to an injection device which will cause the unit to run more stably.

In these units the injection device is frequently actuated by piston reciprocation as by means of a cam mounted on the restraining linkage that connects the opposed pistons. If the length of the piston stroke changes the length of stroke of the pump plunger actuated by the cam is also changed. When the pump is filled through an inlet port that is covered by the plunger during a part of the stroke the filling time increases as the stroke lengthens and the filling time shortens as the stroke becomes shorter. This results in an unstable operating unit since as the plunger stroke shortens, less fuel is delivered to the engine cylinder, thereby delivering less energy to the pistons with the result that the stroke continues to shorten until the unit stalls. A feature of this invention is an injection device in which filling may occur for the entire length of the plunger stroke.

Another feature is the combination of a device of this type with a free-piston unit to cause more stable operation of the unit.

A feature of the invention is an injection pump, the filling port of which is uncovered during the entire plunger stroke so that the pump may fill as soon as the plunger begins its filling stroke. Another feature is the combination with an injection pump of this character a throttling device by which the quantity of fuel supplied to the pump may be controlled.

A feature of the invention is the use of an injection pump of this character in conjunction with an overstroke control which permits the overstroke unit to operate directly upon the fuel supply for controlling the quantity of fuel delivered to the pump. In accordance with this feature, if the plunger is moved slowly within the casing, fuel will begin to flow through the vent port with the plunger in the position at which the injection part of the cycle takes place.

Another feature of the invention is an arrangement for circulating fuel through the pump cylinder for each stroke of the plunger to assist in cooling the pump.

Other objects and advantages will be apparent from the specification and claims, and from the accompanying drawings which illustrate an embodiment of the invention.

Fig. 1 is a sectional view through the unit.

Fig. 2 is a sectional view of the restraining linkage.

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Fig. 3 is a sectional view through the injection device.

Fig. 4 shows an overstoke control in conjunction with the arrangement for throttling the fuel supply.

The unit shown includes an engine cylinder 10 having reciprocating pistons 12 and 14 to which compressor pistons 16 and 18 in cylinders 20 and 22 are integrally connected. Sleeves 24 and 26 attached to the compressor pistons complete the reciprocating piston assemblies. The sleeves in combination with stationary pistons 28 and 30 form air spring cylinders.

The piston assemblies are moved apart by the burning of fuel injected into engine cylinder 10 through one or more nozzles 32. Air compressed in the air spring cylinders on the power stroke returns the piston assemblies. The assemblies are always maintained at equal distances from the center of the engine cylinder by a linkage, which may include racks 34 and 36, Fig. 2, extending from the piston assemblies and meshing with a pinion 38 on a shaft 40.

Intake manifold 42, which extends around the compressor and engine cylinders, conducts air to intake valves 44 in the heads of the compressor cylinders through which air alternately enters opposite ends of these cylinders. The compressed air leaves the cylinders through discharge valves 46, also at opposite ends of the compressor cylinders and passes into a central scavenge chamber 48 and end chambers 50 and 52. These chambers may be connected by a scavenge manifold, not shown.

Compressed gas from the chambers enters engine ports 54 and 56 which are uncovered by pistons 12 and 14 at the end of the power stroke, thereby permitting air to be blown through the engine cylinder. Gas in the engine cylinders is discharged through exhaust ports 58 into exhaust manifold 60.

The location of the outer end of the piston stroke is indicated by a master control 62. This control is actuated by a cam 64 turning with the pinion 38, as shown in Fig. 2. Since this pinion is oscillated directly from the pistons, the movement of cam 64 is proportional to the piston stroke.

Fluid under pressure from a constant pressure source enters a passage 70 in a casing 72 through a conduit 74. This passage intersects a bore 76 adjacent its outer end and a throttling screw 78 controls the rate of flow into bore 76. A branch passage 80 from passage 70 connects with a port 82 in bore 76. A plunger 84 in

bore 76 has a groove 86 which connects a port 88 alternately with port 82 or a port 90. Port 88 is connected by a passage 92 to the inner end of bore 76. Port 90 is connected by a channel 94 in casing 72 and in an adjacent casing 96 to the inner end of a bore 98 in casing 96.

A piston 100 in bore 99 is moved to the right by a calibrated spring 102. A plunger 104 extends through the piston and carries on its projecting end a push rod 108. This rod has a roller 110 held against cam 64 by a spring 112. Plunger 104 has a central passage 114 connected with spaced grooves 116 and 118 in the plunger. Groove 116 aligns with openings 120 in a sleeve 122 carried by piston 100 and groove 118 is adapted to be uncovered by the end of sleeve 122 as the plunger is moved to the right by the cam as the pistons approach the outer ends of their stroke.

Fluid under pressure from the right hand end of bore 76 enters the outer end of bore 98 through a connecting channel 124, moving piston 100 against the action of spring 102. As plunger 104 is moved by cam 64 the groove 118 is uncovered by sleeve 122 to permit discharge of fluid from the right hand end of bore 98 through plunger 104 and into the inner end of bore 98 which is vented, as will appear. The pressure in the right hand end of bore 98 varies in accordance with the compression of the spring, and as the piston stroke becomes shorter, the piston 100 moves inward increasing the spring tension and increasing the pressure at the end of bore 98.

Since the change in pressure on the outer end of plunger 84 is proportional to the change in the location of the end position of the piston stroke, the pressure on the inner end of plunger 84, which balances the pressure on the outer end, must vary in the same manner. In this way the pressure in the discharge conduit 126 is proportional to the spacing of the actual end of the piston stroke from the extreme outer position of the piston, and changes in the pressure of the fluid in this conduit will be proportional to changes in the end position of the piston stroke. This pressure (and change in pressure) may indicate on a calibrated gauge (not shown) the exact position of the end of the piston stroke and may be used for actuating the fuel control means.

The outer end of plunger 104 may reciprocate in a chamber 130 connected by a conduit 132 to a sump, not shown. The inner end of bore 98 may be connected by a conduit 134 to conduit 132. It may be advantageous to reduce pressure surges in channel 124 by means of a bellows 136.

Control fluid from the outer master control may be used to cut off the supply of fuel in the event that the length of stroke becomes excessive or if the end of the actual piston stroke approaches outer dead center. As shown conduit 126 is connected to a port 142 in a casing 144 for the overstroke control. This port communicates with the end of a bore 146 in which a plunger 148 is slidable, this plunger being held in the position shown by a spring 150.

Plunger 148 has a projecting stem 152 on the end of which is a tapered plug 154 engaging a seat 156 between the fuel inlet port 158 and the fuel outlet port 160 which is connected to the injection system.

The injection system, as shown in Fig. 3, has a casing 162 having a bore 164 in which a plunger 166 reciprocates. The bore has an inlet port 168 located beyond the end of the plunger so that it is open during the entire plunger stroke to the

space 170 at the head of the plunger. A check valve 172 prevents escape of fluid from port 168 and allows fuel to enter the space 170 through an inlet passage 174 connected by a conduit 176 to the outlet port 160 of the over-stroke valve. A discharge port 178 in the bore 164 is adapted to be covered by the plunger during the pumping stroke. After port 178 is covered fuel is pumped through grooves 180 and passages 182 in a cuff 184 to a chamber 186 located in a nozzle 188. A needle 190 is guided by a bore 192 in the nozzle body and is adapted to close a discharge port 194 for the chamber. The needle has a groove 196 by which fuel may flow past the needle to the discharge port. A nozzle tip 198 controls the pattern of the fuel discharge into the engine cylinder.

A spring 200 normally holds the cuff in such a position that a flange 202 on the cuff prevents flow of fuel out of the chamber and into space 170. This spring also normally holds the needle 190 in a position to close the port 194.

As the plunger moves upwardly on the pumping stroke the pressure of the fuel in space 170 moves the cuff 184 upward to permit fuel to enter the accumulator chamber 186. Fuel accumulates in the chamber until a spill port 204 in the casing communicates with an annular groove 206 in the plunger, thereby venting the space 170 through a passage 208 in the plunger. When this occurs, the drop in pressure in space 170 permits the pressure within the chamber to force needle 190 down so that fuel may discharge through groove 196 and passage 194 into the engine cylinder.

At the completion of the pumping stroke of the plunger the plunger moves down for the filling stroke and fuel enters the space 170 past check valve 172. While the plunger is in the position shown and during the first part of the downward movement of the plunger until the groove 206 no longer communicates with port 204 fuel under pressure may flow through passage 208 and discharge through the port 204 and a communicating passage 210. With the injection device installed in the free-piston unit the point at which injection takes place may be accurately checked by slowly moving the plunger 166 down until fuel stops discharging from the open end of passage 210. This indicates the position of the plunger at the time the pump begins the injection part of its cycle so that the exact timing with respect to the pistons of the unit may be checked. The timing may be checked on the pumping stroke in a similar way.

It will be understood that the injection plunger may be reciprocated from a cam 212 which, as shown in Fig. 2, is arranged to turn with the pinion 38 of the restraining linkage.

The fuel quantity may be adjusted by a throttle in the supply conduit 176. This may be done either by a manually operated valve 214 or by means of the overstroke control of Fig. 4 which, as will be apparent, throttles the flow of fuel and thereby controls the quantity of fuel entering the space 170. By the use of the overstroke control above described, in conjunction with the injection system in which the filling port has a check valve and is always open to the pump bore, a very stable operation of the unit may be obtained.

It is to be understood that the invention is not limited to the specific embodiment herein illustrated and described, but may be used in other ways without departure from its spirit as defined by the following claims.

I claim:

1. In a fuel injection system for free-piston

units, each unit including opposed reciprocating pistons having variable strokes, a linkage connecting said pistons, and actuating means on said linkage for the fuel injection system, said system including a pump having a casing with a bore, a plunger reciprocating in the bore and having a variable stroke, a filling port connecting with said bore at a point beyond the end of the plunger at the extreme end of its stroke, a connection to said port, a check valve in said connection, and a throttle valve controllable by a change in the end position of the piston stroke for adjusting the flow of fuel to said port.

2. In a fuel injection system for free-piston units, each unit including opposed reciprocating pistons having variable strokes, a linkage connecting said pistons, and actuating means on said linkage for the fuel injection system, said system including a pump having a casing with a bore, a plunger reciprocating in the bore and having a variable stroke, a filling port connecting with said bore at a point beyond the end of the plunger at the extreme end of its stroke, a connection to said port, a check valve in said connection, a throttle valve for controlling the flow of fuel to said port, and means responsive to a change in the end position of the piston stroke for adjusting the throttle valve.

3. A device of the class described, a free-piston unit including engine and compressor cylinders, piston assemblies in said cylinders, and a linkage

connecting said assemblies, in combination with an injection device for the unit actuated in response to reciprocation of said pistons, said device including a plunger connected to and actuated by said linkage, a casing having a bore in which the plunger reciprocates, and a filling port communicating with said bore at a point beyond the extreme end of the stroke of the plunger so that the bore may fill during the entire plunger stroke, a discharge port adapted to be uncovered by the plunger during its reciprocation, a check valve for controlling the flow of fuel from said inlet port, and a throttle valve for adjusting the flow to said inlet port.

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