Sept. 16, 1958 J. W. WHITSON 2,852,308

LIQUID FUEL INJECTORS

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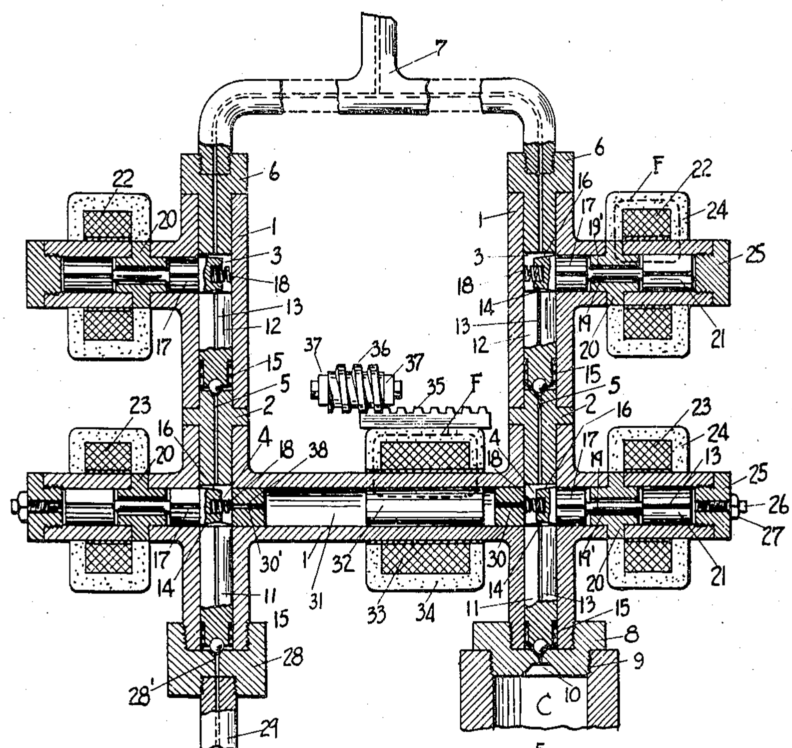

Fig. 1

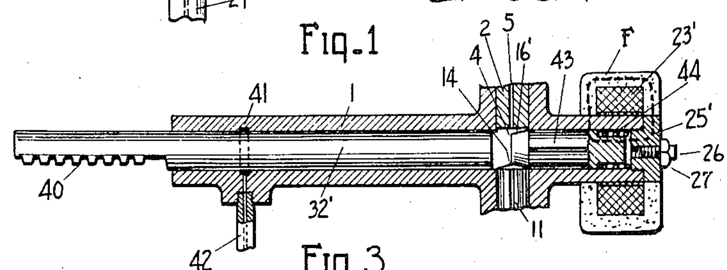

Fig. 3

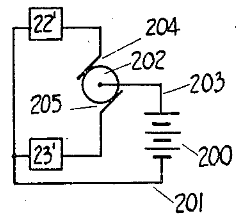

Fig. 4

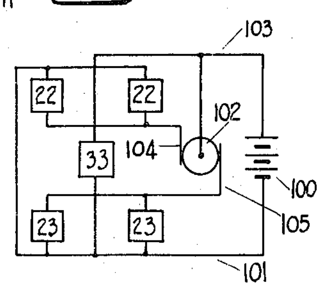

Fig. 2

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LIQUID FUEL INJECTORS

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14 Claims. (Cl. 299—107.2)

My invention relates to improvements in liquid fuel injectors which are used to introduce liquid fuel into a combustion space in which fuel is burned.

The object of the invention is to provide an injector which will introduce a metered fuel charge into a combustion space; the metering of the fuel charge being accomplished through the instrumentality of means which utilizes the phenomenon of the compressibility of liquids.

A further object is to provide means to vary the capacity of the fuel chambers of the liquid fuel injectors illustrated in my recently filed application for patent upon Liquid Fuel Injectors, Serial Number 612,398, filed September 27, 1956 and issued as Patent 2,798,769 on July 9, 1957.

A further object is to provide an injector having its mechanisms actuated through the instrumentality of magnetic attraction.

With the above mentioned and other objects in view, the invention consists in the novel construction and combination of parts hereinafter described, illustrated in the accompanying drawings, and set forth in the claims hereto appended, it being understood that various changes in form, proportion, size, location and minor details of construction within the scope of the claims may be resorted to without departing from the spirit or sacrificing any of the advantages of the invention. Referring to the drawings:

Fig. 1 is a sectional view through a liquid fuel injector.

Fig. 2 is a wiring diagram illustrating the electrical control system of the injector shown in Fig. 1.

Fig. 3 is a sectional view of a modification of the injector shown in Fig. 1.

Fig. 4 is a wiring diagram illustrating the electrical control system of the injector shown in Fig. 3.

In detail the construction illustrated in the drawings comprises an outer casing 1 composed of sections of non-magnetic material which are joined together by the plug members 2 which divide the casing into the fuel chambers 3 and 4 which are connected by the openings 5 in the plugs 2.

Chambers 3 are closed at their outer ends by the caps 6 which are threaded to receive the fuel line 7 which is connected to a source of fuel supply that can be subjected to substantially constant pressure or a variable pressure as the occasion requires.

Chamber 4, at the right of Fig. 1, is closed at its outer end by the cap 8 which is threaded to receive the casing 1 and is threaded as at 9 for screwing into an opening leading into a combustion space C in which liquid fuel is to be burned.

Cap 8 has an orifice 10 in which valve 11 is seated; valves 12 are seated in the openings 5 of the plugs 2. All of the valves have grooves 13 formed therein to allow for the free passage of fuel in the chambers 3 and 4.

All of the valves have coned ends 14 and a spring 15 which tends to unseat the valve. The springs 15 cause the valves to bear against the coned shaped ends of the movable valve obstructing elements 17, each is influenced

to move away from its valve obstructing position by a spring 18.

Each of the elements 17 has a stem 19 which extends through an opening 19' in a plug 20 which is composed of magnetically attractive material; the stem 19 abuts against the movable solenoid core 21 of a solenoid coil 22 or 23 which are secured to the casing 1 and are provided with a casing 24 composed of iron impregnated plastic or other suitable magnetically attractive material.

Plugs 25 seal the chambers 3 and 4 and the plugs 25 of the chambers 4 have tapped openings for the reception of a volume adjusting screw 26 which is provided with a lock nut 27.

The above described elements are duplicated at the left of Fig. 1 except that chamber 4, at the left, is closed at its outer end by a cap 28 which is tapped to receive a fuel return line 29 which runs to a fuel tank. The cap 28 has an opening 28' in which valve 11 is seated.

The horizontal member of the casing 1, which joins the fuel chambers 4, is provided with the plugs 30 and 30' to form a chamber 31 for the reception of the piston 32 which is the movable core of the solenoid 33 which is mounted to slide on the horizontal member of the casing. A casing 34 composed of magnetically conductive material encloses the coil 33.

A gear rack 35 is mounted on the casing 34 and it engages the worm gear 36 which is journaled in the brackets 37 which can be secured to the apparatus on which the injector is mounted.

The plugs 30 and 30' each have an opening 38 which connects the chamber 31 with the chambers 4.

Fig. 2 illustrates a source of electrical energy 100 which is connected to all of the solenoid coils by wire 101 and to solenoid coil 33 and a timer 102 by wire 103; timer brush 104 is connected to solenoid coils 22 and timer brush 105 is connected to solenoid coils 23. The solenoid coils are normally maintained energized.

Operation

Solenoid coils 22 and 23 are normally energized and each attracts its movable core 21 towards the plug 20 to bear against the stem 19 of the valve obstructing element 17 to maintain the element 17 in its valve obstructing position, as illustrated in Fig. 1, to hold its valve 11 or 12 seated.

The timer 102 cycles to alternately de-energize the solenoid coils 22 and 23 so that the springs 18 can move their elements 17 from their valve obstructing positions.

Solenoid coil 33 is normally energized and serves to maintain the piston 32 centered with the solenoid coil so that when the solenoid coil is moved, through the instrumentality of the gear rack 35 and the worm gear 36, the piston will be moved in the chamber 31.

The dotted lines F indicate the path of the magnetic flux in the solenoids when they are energized.

With the chambers 4 and 31 filled to capacity with liquid fuel at normal density and with an assumed density that would be substantially equal to 3000 pounds per square inch constant pressure on the fuel in the chambers 3 and the fuel line 7 then when the timer 102 is cycled coils 22 will be de-energized and each of their springs 18 will move its valve obstructing element 17 out of its valve obstructing position so that the springs 15 will unseat their valves 12 to permit fuel to flow into each chamber 4 and raise the density of the fuel in the chambers 4 and 31 to the density of the fuel in the chambers 3; coils 22 are then energized to seat their valves 12 and seal the chambers 4, with the chambers 4 and 31 containing fuel of substantially the same density as the fuel in chambers 3.

The fuel capacity of the chambers 4 also includes the fuel contained in the openings 38 in the plugs 30 or 30' and the fuel capacity of the chamber 31 is the volume of the cylinder between the plugs 30 and 30′ minus the volume of the piston 32.

The piston 32 is movable to include all or any portion of the fuel contained in chamber 31 with the volume of fuel contained in either chamber 4.

With the piston positioned against the plug 30 the amount of fuel that will enter the chamber 4 at the right of Fig. 1 will approximate 1% of its fuel capacity and the amount of fuel that will enter the chamber 4 at the left of Fig. 1 will approximate 1% of the fuel capacities of the chambers 4 and 31, if it is assumed that the modulus of elasticity of the fuel approximates that of water.

Experiments show that the alteration in volume of liquids is proportional to the density, hence the relation between the changes of volume when under pressure may be expressed:

Let

v=the diminution of volume under any given pressure
V=the original volume
K=the modulus of elasticity of volume of water
p=the pressure in pounds per square inch.

Then

$$\frac{v}{V}=\frac{P}{K} \text{ or } K=\frac{pV}{v}$$

K=from 320,000 to 300,000 pounds per square inch.

Thus water is reduced in bulk or increased in density by 1% when under a pressure of 3000 pounds per square inch. This is quite apart from the stretch of the containing vessel.

When coils 23 are de-energized valves 11 will lift from their seats and substantially 1% of the fuel contained in the chamber 4, at the right of Fig. 1, will be discharged through the orifice 10 into combustion space C and substantially 1% of the fuel contained in the chamber 31 and the chamber 4, at the left of Fig. 1, will be discharged into the return line 29.

The discharge of fuel from the chambers 4 reduces the fuel remaining in them and in chamber 31 back to its normal density.

Coils 23 are then energized to seat the valves 11 and the injector is ready for another cycle.

The position of the piston 32 in chamber 31 determines the amounts of fuel that will be discharged through the orifice 10 and into return line 29; if the piston is positioned in the center of chamber 31 then equal amounts of fuel will be discharged from each of the chambers 4; with the piston against the plug 30 the minimum amount of fuel will be discharged through the orifice 10 and the maximum amount of fuel will be discharged into return line 29; with the piston against the plug 30′ the maximum amount of fuel will be discharged through the orifice 10 and the minimum amount of fuel will be discharged into return line 29.

When solenoid coil 33 is energized the piston 32 will be magnetically held to move with the coil when the worm gear 36 is turned and also magnetically held to resist movement during a time interval when the pressure against the ends of the piston differs due to a variance in the rate of fuel discharge from the chambers 4.

Moving the piston 32 serves to throttle the amount of fuel discharged through the orifice 10; this is accomplished by varying the capacity of the fuel chamber to accommodate varying amounts of fuel of substantially constant density; with the piston stationary the injector is self metering as to successive fuel charges.

In the manufacture of a series of injectors differences in volume of the fuel chambers may occur, in which event the volume adjusting screw 26 will be positioned to normalize the volume of the fuel chambers.

Figs. 3 and 4 illustrate the injector of Fig. 1 with a mechanically controlled piston 32′ instead of the magnetically controlled piston 32 illustrated in Fig. 1; also solenoid coils 22′ and 23′, which are similar to the solenoid coils 22 and 23 of Fig. 1, are illustrated as being normally de-energized.

Chambers 3 and 4 and the elements at the left of Fig. 1 have been eliminated and the piston 32′ extends from the casing 1 and has a gear rack 40 cut therein for engagement with a worm gear similar to the gear 36 of Fig. 1; rotation of the worm gear will move the piston to vary the volume of chamber 4 and throttle the discharge of fuel through the orifice 10 as described in the operation of the apparatus of Fig. 1.

The casing has a groove 41 formed therein for the collection of fuel that may have leaked past the piston 32′; a pipe 42 returns any leaked fuel to a fuel tank.

Plugs 25′ seal the chambers 3 and 4 as do the plugs 25 of Fig. 1. The plug 25′ serves as an element of the solenoid coil to attract the movable core 43. Dotted lines F indicate the path of the magnetic flux in the solenoids when they are energized.

The movable core 43 has a coned end 16′ which is maintained against the coned end 14 of the valve 11 by a spring 44 to hold the valve seated as described and illustrated in Fig. 1.

The solenoid coil 22′ and its related elements would be constructed as illustrated for coil 23′ to function to seat and unseat the valve 12 as described and illustrated in Fig. 1.

Fig. 4 illustrates a source of electrical energy 200 which is connected to solenoid coils 22′ and 23′ by wire 201 and to a timer 202 by wire 203, brush 204 of the timer is connected to coil 22′ and brush 205 is connected to coil 23′.

Operation

Solenoid coils 22′ and 23′ are normally de-energized; the timer 202 cycles to alternately energize the coils to move their cores 43 from their valve obstructing positions.

With the chamber 4 filled to capacity with fuel at normal density and with fuel at greater than normal density in chamber 3 and fuel line 7 then when the timer is cycled coil 22′ will be energized to attract its core 43 towards the plug 25′ and out of its valve obstructing position so that valve 12 will unseat and permit fuel to flow into chamber 4 and raise the density of the fuel therein to the density of the fuel in chamber 3; coil 22′ is then de-energized and the spring 44 moves the core 43 back into its valve obstructing position to reseat the valve and seal chamber 4, with the chamber containing fuel of substantially the same density as the fuel in chamber 3.

Coil 23′ is then energized and its associated elements will function as above described for coil 22′ and valve 11 will be unseated to permit the discharge of fuel through the orifice 10 as described and illustrated in the operation of Fig. 1.

The fuel chambers 4 of the injectors illustrated in my recently filed application for patent upon Liquid Fuel Injectors Serial Number 612,398, filed Sept. 27, 1956, and issued as Patent 2,798,769 on July 9, 1957, can be equipped with the piston 32′ and its elements.

With the apparatus of Figs. 1 or 3 a pressure of 1500 pounds per square inch on the fuel supply will pass one-half of the amount of fuel into chamber 4, as compared to a pressure of 3000 pounds, 6000 pounds will pass twice as much fuel.

Thus varying the density of the fuel in combination with altering the capacity of the fuel chamber provides a two way means to throttle the fuel that will discharge through the orifice 10.

My invention provides a method for operating liquid fuel injectors which utilizes the theory of the compressibility of liquids for metering consecutive fuel charges and injecting them into a combustion space, a new discovery in this art.

Leakage of fuel when under high pressure has been a poor quality feature of fuel injectors designed to meter and inject fuel in mechanical time with an engine cycle; my injector overcomes this as its movable elements are completely sealed within the injector casing and do not require outside mechanical connections to operate them, since they are operated through the instrumentality of magnetic attraction, a new discovery in this art.

My invention provides for utilizing electro-mechanical devices to time the injection cycle, a new discovery in this art.

The drawings do not shown construction details such as removable seats for the valves, a nozzle tip for orifice **10**, etc., as would be the case in commercial designs; only the elements necessary to disclose the invention are shown so that the relationship of the common elements, of the several injectors illustrated, may be clearly seen.

While the foregoing describes the injectors as operated with liquid fuel it is to be understood that they will operate with matter in a fluid state whether liquid or gaseous.

When the term "normal density" is used it may also mean the density at atmospheric pressure.

Having described my invention above in detail I wish it to be understood clearly that many changes may be made therein without departing from the spirit of the same.

I claim:

1. The method of operating an injector having a fluid chamber comprising: sealing the chamber against the discharge of fluid; filling the chamber with fluid at normal density; unsealing the chamber for fluid to enter and increase the density of the fluid contained therein above its normal density; sealing the chamber, with the fluid contained therein at the increased density; unsealing the chamber for a portion of the fluid to discharge therefrom and reduce the fluid remaining in the chamber to normal density; then optionally cause the volume of the discharge to vary by altering the fluid capacity of the chamber.

2. The method of operating an injector having a fluid chamber comprising: sealing the chamber against the discharge of fluid; filling the chamber with fluid at normal density; unsealing the chamber for fluid to enter and increase the density of the fluid contained therein above its normal density; sealing the chamber, with the fluid contained therein at the increased density; unsealing the chamber for a portion of the fluid to discharge therefrom and reduce the fluid remaining in the chmaber to normal density; then optionally cause the volume of the discharge to vary by altering the fluid capacity of the chamber through the instrumentality of magnetic attraction.

3. The method of operating an injector having a fluid chamber comprising: sealing the chamber against the discharge of fluid; filling the chamber with fluid at above normal density, while maintaining the chamber sealed against the discharge of fluid; unsealing the chamber for a portion of the fluid to discharge therefrom and reduce the fluid remaining in the chamber to normal density; then optionally cause the volume of the discharge to vary by altering the fluid capacity of the chamber.

4. The method of operating an injector having a fluid chamber comprising: sealing the chamber against the discharge of fluid; filling the chamber with fluid at above normal density, while maintaining the chamber sealed against the discharge of fluid; unsealing the chamber for a portion of the fluid to discharge therefrom and reduce the fluid remaining in the chamber to normal density; then optionally cause the volume of the discharge to vary by altering the fluid capacity of the chamber through the instrumentality of magnet attraction.

5. The method of operating an injector having a fluid chamber comprising: sealing the chamber against the discharge of fluid; filling the chamber with fluid at normal density; subjecting the fluid to a source of pressure to increase its density above normal density while maintaining the chamber sealed; unsealing the chamber for a portion of the fluid to discharge therefrom and reduce the fluid remaining in the chamber to normal density; then optionally cause the volume of the discharge to vary by altering the fluid capacity of the chamber.

6. The method of operating an injector having a fluid chamber comprising: sealing the chamber against the discharge of fluid; filling the chamber with fluid at normal density; subjecting the fluid to a source of pressure to increase its density above normal density while maintaining the chamber sealed; unsealing the chamber for a portion of the fluid to discharge therefrom and reduce the fluid remaining in the chamber to normal density; then optionally cause the volume of the discharge to vary by altering the fluid capacity of the chamber through the instrumentality of magnetic attraction.

7. The method of operating an injector having a fluid chamber comprising: sealing the chamber against the discharge of fluid; filling the chamber with fluid at normal density; subjecting the fluid to a source of pressure to increase its density above normal density; sealing the chamber and the fluid contained therein from the source of pressure; unsealing the chamber for a portion of the fluid to discharge therefrom and reduce the fluid remaining in the chamber to normal density; then optionally cause the volume of the discharge to vary by altering the fluid capacity of the chamber.

8. The method of operating an injector having a fluid chamber comprising: sealing the chamber against the discharge of fluid; filling the chamber with fluid at normal density; subjecting the fluid to a source of pressure to increase its density above normal density; sealing the chamber and the fluid contained therein from the source of pressure; unsealing the chamber for a portion of the fluid to discharge therefrom and reduce the fluid remaining in the chamber to normal density; then optionally cause the volume of the discharge to vary by altering the fluid capacity of the chamber through the instrumentality of magnetic attraction.

9. A fluid injector comprising in combination: a chamber for the containment of fluid; means to fill the chamber with fluid at above normal density; means to seal the chamber after it is filled with fluid above normal density; means to unseal the chamber, when it is filled with fluid above normal density, for a portion of the fluid above normal density to discharge from the chamber which discharge reduces the fluid remaining in the chamber to normal density and means to alter the fluid volume of the chamber.

10. A fluid injector comprising in combination: a chamber for the containment of fluid; means to fill the chamber with fluid at above normal density; means to seal the chamber after it is filled with fluid above normal density; means to unseal the chamber, when it is filled with fluid above normal density, for a portion of the fluid above normal density to discharge from the chamber which discharge reduces the fluid remaining in the chamber to normal density; means to alter the fluid volume of the chamber and means to move the last named means through the instrumentality of magnetic attraction.

11. A fluid injector comprising in combination: a sealed chamber containing fluid at normal density; means to unseal the chamber for the entry of fluid above normal density which entry increases the density of the fluid in the chamber; means to seal the chamber after the entry of fluid above normal density; means to unseal the chamber, when it is filled with fluid above normal density, for a portion of the fluid above normal density to discharge from the chamber which discharge reduces the fluid remaining in the chamber to normal density and means to alter the fluid volume of the chamber.

12. A fluid injector comprising in combination: a sealed chamber containing fluid at normal density; means to unseal the chamber for the entry of fluid above normal density which entry increases the density of the fluid in the chamber; means to seal the chamber after the entry

of fluid above normal density; means to unseal the chamber, when it is filled with fluid above normal density, for a portion of the fluid above normal density to discharge from the chamber which discharge reduces the fluid remaining in the chamber to normal density; means to alter the fluid volume of the chamber and means to move the last named means through the instrumentality of magnetic attraction.

13. A fluid injector comprising in combination: a chamber containing fluid above normal density; means to seal the chamber against the discharge of fluid above normal density; means to unseal the chamber, when it is filled with fluid above normal density, for a portion of the fluid above normal density to discharge from the chamber which discharge reduces the fluid remaining in the chamber to normal density and means to alter the fluid volume of the chamber.

14. A fluid injector comprising in combination: a chamber containing fluid above normal density; means to seal the chamber against the discharge of fluid above normal density; means to unseal the chamber, when it is filled with fluid above normal density, for a portion of the fluid above normal density to discharge from the chamber which discharge reduces the fluid remaining in the chamber to normal density; means to alter the fluid volume of the chamber and means to move the last named means through the instrumentality of magnetic attraction.

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