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J. W. WHITSON

2,798,769

LIQUID FUEL INJECTORS

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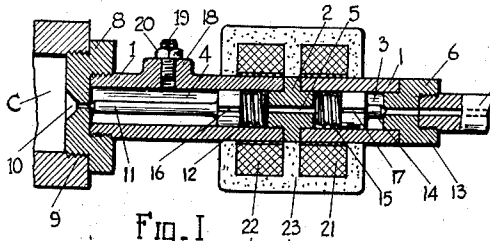


Fig. 1

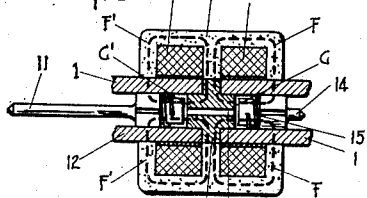


Fig. 2

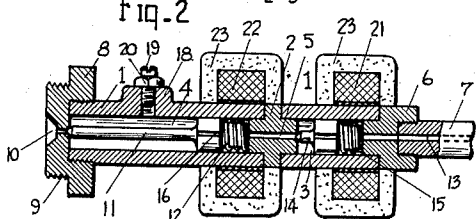


Fig. 3

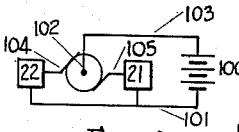


Fig. 4

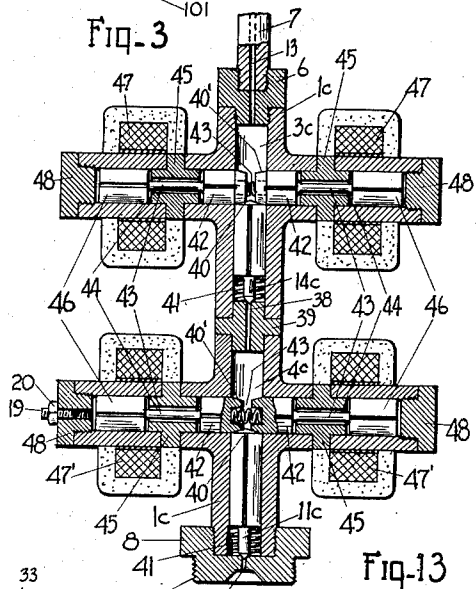


Fig. 5

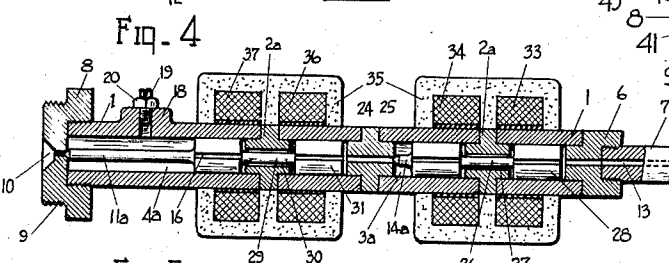


Fig. 6

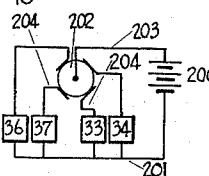


Fig. 7

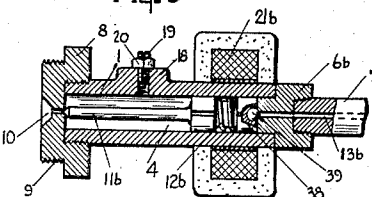


Fig. 8

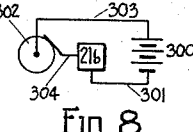


Fig. 9

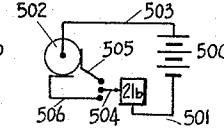


Fig. 10

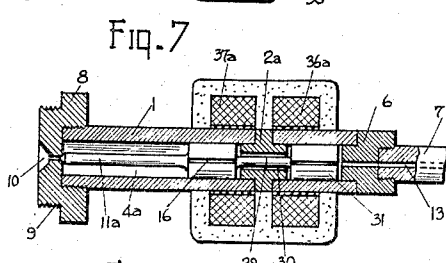


Fig. 11

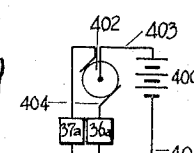


Fig. 12

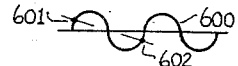


Fig. 13

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LIQUID FUEL INJECTORS

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Application September 27, 1956, Serial No. 612,398

26 Claims. (Cl. 299—107.6)

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 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 sectional view through some of the elements of the injector illustrated in Fig. 1.

Fig. 3 is a wiring diagram illustrating the electrical control system for the injectors illustrated in Figs. 1 and 4.

Fig. 4 is a sectional view through a liquid fuel injector.

Fig. 5 is a sectional view through a liquid fuel injector.

Fig. 6 is a wiring diagram illustrating the electrical control system for the injector illustrated in Fig. 5.

Fig. 7 is a sectional view through a liquid fuel injector.

Fig. 8 is a wiring diagram illustrating the electrical control system for the injector illustrated in Fig. 7.

Fig. 9 is a sectional view through a liquid fuel injector.

Fig. 10 is a wiring diagram illustrating the electrical control system for the injector illustrated in Fig. 9.

Fig. 11 is a wiring diagram illustrating an electrical control system.

Fig. 12 illustrates the cycle curve of a four cycle internal combustion engine.

Fig. 13 is a sectional view through a liquid fuel injector.

In detail the construction illustrated in the drawings comprises an outer injector casing 1 as illustrated in Fig. 1 composed of two sections of non-magnetic material joined together by a plug member 2, made of magnetically conductive material; the plug 2 divides the casing into fuel chambers 3 and 4 which are connected by the opening 5 in the plug.

Chamber 3 is closed at its outer end by the plug 6 which is threaded to receive the fuel line 7 which is connected to a source of liquid fuel supply.

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

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Cap 8 has an orifice 10 in which needle valve 11 is seated by spring 12.

Plug 6 has an opening 13 therethrough in which needle valve 14 is seated by spring 15.

Needle valves 11 and 14 each have grooves 16 and 17 formed in their enlarged portions to allow for the free flow of the fuel in the chambers 3 and 4.

A boss 18 on the casing 1 has a tapped hole provided to receive the volume adjusting screw 19 which is provided with a lock nut 20.

Solenoid coils 21 and 22 are secured to the casing 1 and are provided with a casing 23 composed of iron-impregnated plastic or other suitable magnetically conductive material. The solenoid coils are connected to an electrical timer and a source of electrical energy.

Fig. 2 illustrates the functioning of the solenoids; the dotted lines F and F' indicate the path of the magnetic flux in the solenoids when they are energized. The needle valves 11 and 14 function as the movable cores of the solenoids and they are attracted to the plug 2, when the solenoids are energized, to close the gaps G and G'; the closing of the gaps serves to unseat the needle valves; the needle valves are resealed by the springs 12 and 15 when the solenoids are de-energized.

Fig. 3 illustrates a source of electrical energy 100 connected to solenoid coils 21 and 22 by wire 101 and to a timer 102 by wire 103; wires 104 and 105 connect the timer brushes to the coils 21 and 22.

Operation

With the chambers 3 and 4 of Fig. 1 filled with fuel at normal density and with an assumed density that would be equal substantially to 3000 pounds per square inch pressure on the fuel in the fuel line 7; then when the timer 102 is cycled, solenoid coil 21 will be energized to unseat needle valve 14 to permit fuel to flow into fuel chamber 3 and raise the density of the fuel in chambers 3 and 4 to the density of the fuel in fuel line 7.

The amount of fuel that will enter chamber 3 will approximate 1% of the volume of the fuel in the chambers 3 and 4 when the fuel was at normal density, assuming 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 the 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 coil 21 is de-energized needle valve 14 is resealed by the spring 15, sealing the fuel in fuel line 7 against entry into chamber 3.

Solenoid coil 22 is next energized to unseat needle valve 11 and permit the release of substantially 1% of the fuel through the orifice 10 which drops the density back to normal on the fuel remaining in the fuel chambers.

When coil 22 is de-energized needle valve 11 is resealed by the spring 12 and the injector is ready for another cycle.

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Thus the injector is self-metering as to successive fuel charges and can be throttled by varying the pressure on the fuel in the fuel supply line.

A pressure of 1500 pounds per square inch on the fuel will pass one half of the amount of fuel into chamber 3, as compared to a pressure of 3000 pounds, 6000 pounds will pass twice as much fuel.

In the manufacture of a series of injectors differences in the volumes of the fuel chambers 3 and 4 may occur, in which event the volume adjusting screw 19 will be positioned to normalize the volume of the fuel chambers.

Fig. 4 illustrates an injector with its fuel chamber 3 having an open connection to the fuel line 7 and with the position of the needle valve 14 reversed from that illustrated in Figure 1 so as to seat in the opening 5 of plug 2 to seal chamber 4 from chamber 3 and from the fuel supply.

Solenoid coil 21 is moved so that plug 6 which is made of magnetically attractive material serves as an element of the solenoid to attract and unseat the needle valve 14 when coil 21 is energized.

Operation

With chamber 4 of Fig. 4 filled with fuel at normal density and with fuel of greater density in chamber 3 then, when coil 21 is energized, needle valve 14 will be attracted to plug 6 and unseat to permit fuel to flow into chamber 4 and raise the density of the fuel therein to the density of the fuel in chamber 3; when coil 21 is de-energized needle valve 14 will be reseated; solenoid coil 22 is next energized and the action then follows that is described for the operation of the injector illustrated in Fig. 1.

Fig. 5 illustrates an injector which is also provided with solenoids to control the seating of its needle valves.

Casing 1 is divided into two fuel chambers 3a and 4a by plug 24 which has an opening 25 therethrough in one end of which is seated needle valve 14a which has a stem 26 that extends through the opening 27 in plug 2a which is similar to plug 2 of Fig. 1; a movable solenoid core 28 bears against the stem 26 to maintain needle valve 14a seated when coil 33 is energized.

Needle valve 11a is similar to needle valve 11 of Fig. 1 and has a stem 29 which extends through the opening 30 in plug 2a which is similar to plug 2 of Fig. 1; a movable solenoid coil 31 bears against the stem 29 to maintain the needle valve 11a seated when coil 36 is energized.

Needle valve 14a is closed and opened by the solenoid coils 33 and 34 which are provided with a casing 35 composed of magnetically conductive material. Solenoid coils 36 and 37 serve to close and open the needle valve 11a.

Fig. 6 illustrates a source of electrical energy 200 connected to solenoid coils 33, 34, 36 and 37 by wire 201 and to a timer 202 by wire 203, wires 204 connect the timer brushes to the solenoids.

The timer will cycle to energize coil 33 to maintain needle valve 14a seated; to energize coil 34 to unseat needle valve 14a; to energize coil 36 to maintain needle valve 11a seated; and to energize coil 37 to unseat needle valve 11a.

Operation

With the chamber 4a of Fig. 5 filled with fuel at normal density and with chamber 3a supplied with fuel of a greater density and with the timer 202 positioned to energize coils 33 and 36, then a cycle of the timer will first de-energize coil 33 and energize coil 34 to unseat needle valve 14a to permit fuel to enter chamber 4a to increase the density of the fuel in chamber 4a to equal the density of the fuel in chamber 3a, coil 34 is then de-energized and coil 33 is energized to seat needle valve 14a and seal the fuel chamber 4a; next coil 36 is de-energized and coil 37 is energized to unseat needle valve 11a and permit the discharge of fuel through the orifice 10; coil 37 is then de-energized and coil 36 is energized to unseat needle valve 11a, completing a cycle of the timer.

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Fig. 7 illustrates an injector similar to the injector illustrated in Fig. 1 except that the fuel chamber 3 and its elements are not included. Plug 6b is similar to plug 6 of Fig. 1. The portion of the needle valve 11b which serves as the movable core of solenoid coil 21b has been shortened to provide space for the check valve 38 which also serves as part of the movable core of the solenoid. The check valve contains a ball 39 which seats in the opening 13b to seal chamber 4 against entry of fuel from fuel line 7 when coil 21b is energized. The coil 21b is encased in magnetically conductive material.

Fig. 8 illustrates a source of electrical energy 300 connected to the solenoid coil 21b by wire 301 and to a timer 302 by wire 303; the timer is connected to coil 21b by wire 304.

Operation

With fuel chamber 4 of Fig. 7 containing fuel under pressure from fuel line 7, then when the timer 302 cycles to energize coil 21b, check valve 38 will be attracted by plug 6b and seat ball 39 tightly in the opening 13b to seal off the fuel in chamber 4 from the fuel supply in line 7; needle valve 11b will be attracted against check valve 38 unseating the needle valve to permit the discharge of fuel through the orifice 10; when coil 21b is de-energized spring 12b will reseal the needle valve and de-energizing coil 21b will also release the check valve so that fuel can enter chamber 4 from fuel line 7, completing the cycle of the timer.

The pressure of spring 12b against the needle valve 11b delays its unseating until after the check valve has sealed the opening 13b.

Fig. 9 illustrates an injector similar to that illustrated in Fig. 5 except that the fuel chamber 3a and its elements are not included and plug 6 serves to close fuel chamber 4a. Fuel chamber 4a and its elements are similar to those illustrated in Fig. 5 and function in a like manner.

Fig. 10 illustrates a source of electrical energy 400 connected to coils 36a and 37a by wire 401 and to a timer 402 by wire 403, wires 404 connect the timer brushes to the coils.

Operation

While the fuel line 7 connected to a metering fuel pump that delivers fuel under pressure into fuel line 7 and thence into fuel chamber 4a and with the timer 402 positioned to energize coil 36a then a cycle of the timer will first de-energize coil 36a and energize coil 37a to unseat needle valve 11a to permit fuel to discharge through the orifice 10; the volume of the discharge will be as determined by the fuel pump, and the cycling of the fuel pump and the timer can be coordinated so that the fuel will be under substantial pressure at the time of discharge; coil 37a will be de-energized and coil 36a energized to reseal the needle valve 11a, preparing the injector for another cycle.

Any of the injectors illustrated can be used to inject fuel into an internal combustion engine to operate the engine in either the Otto or Diesel cycles.

The same injector can also be used to inject fuel in either the Otto or Diesel cycles in the same engine so that an engine using a vaporizing fuel may have fuel injected during the intake stroke in the Otto cycle to warm up the engine and then when the engine is warm it may be switched to inject fuel during the compression stroke in the Diesel cycle.

The engine can operate in the Otto cycle for maximum power output at full throttle and then be switched to the Diesel cycle for maximum economy when operating at less than full throttle; this feature can be utilized in aircraft engines; the Otto cycle providing the maximum power necessary to get the plain airborne and the Diesel cycle providing economical power to cruise the plane when it is airborne.

Fig. 11 illustrates how a timer can be arranged to operate the injector of Fig. 7 in either the Otto or Diesel cycles.

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A source of electrical energy 500 is connected to coil 21b by wire 501 and to a timer 502 by wire 503, a switch 504 serves to connect coil 21b to either of the timer brushes 505 or 506.

In a four cycle engine the timer will operate at one half of the engine speed, then, with the switch 504 closing the circuit of brush 505, the injector will cycle to inject fuel during the intake stroke of the engine and when the switch closes the circuit of brush 506 the injector will cycle to inject fuel during the compression stroke of the engine in accordance with the diagram of Fig. 12 in which line 600 represents the cycle curve of a four cycle internal combustion engine and 601 represents the point at which injection starts during the intake stroke in the Otto cycle and 602 represents the point at which injection starts during the compression stroke in the Diesel cycle.

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

Fig. 13 illustrates an injector which is a modification of those previously illustrated. The injector comprises a cruciform casing 1c enclosing two fuel chambers 3c and 4c which have functions similar to those of chambers 3 and 4 of Fig. 4; needle valves 11c and 14c seat in orifice 10 and opening 38 of plug 39 respectively and the upper ends of the needle valves are cone-shaped as at 40 and each needle valve has a spring 41 which tends to unseat the valve and causes the valve to bear against the cone-shaped ends 40' of the movable elements 42 which are influenced to move away from each other by the springs 43; each of the elements 42 has a stem 43 which extends through the opening 44 in a plug 45 and abuts against the movable cores 46 of the solenoid coils 47 and 47' which are similar to the solenoid coils described herein; plugs 48 seal the chambers 3c and 4c, and chamber 3c is also sealed by plug 6 into which fuel line 7 is threaded. The casing 1c is made of non-magnetic material; the other parts are made of magnetically attractive materials.

Operation

With the chamber 4c filled with fuel at normal density and with fuel of greater density in chamber 3c and with the coils 47 and 47' energized the needle valves 11c and 14c will be maintained seated sealing chamber 3c from chamber 4c and chamber 4c against the discharge of fuel through orifice 10; when coils 47 are de-energized the spring 43 will force the movable elements 42 apart and the spring 41 will unseat the needle valve 14c to permit fuel to flow into chamber 4c and raise the density of the fuel therein to the density of the fuel in chamber 3c; coils 47 are then energized to seat valve 14c and seal chamber 4c; coils 47' are then de-energized to unseat needle valve 11c (as described for needle valve 14c) for fuel to discharge through orifice 10 and reduce the fuel remaining in the chamber 4c to normal density; coils 47' are then energized to seat needle valve 11c.

The springs 43 may be omitted and the elements 42 moved with the solenoids arranged like those of Figs. 4, 5, and 9. With high density fuel the springs 41 may be omitted as the high density fuel will tend to unseat the needle valves when the elements 42 are moved from their obstructing positions.

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 the 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.

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The drawings do not show construction details such as removable seats for the needle 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 above 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; then unsealing the chamber for a portion of the fluid to discharge therefrom and reduce the fluid remaining in the chamber to normal density.

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, through the instrumentality of magnetic attraction, 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; then unsealing the chamber, through the instrumentality of magnetic attraction, for a portion of the fluid to discharge therefrom and reduce the fluid remaining in the chamber to normal density.

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

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

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 above normal density, while maintaining the chamber sealed against the discharge of the fluid; then unsealing the chamber for a portion of the fluid to discharge therefrom and reduce the fluid remaining in the chamber to normal density.

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 above normal density, while maintaining the chamber sealed

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to increase its density above normal density; then unsealing the chamber, through the instrumentality of magnetic attraction, for a portion of the fluid to discharge therefrom and reduce the remaining fluid in the chamber to normal density.

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

15 16. A fluid injector comprising in combination: a chamber for the containment of fluid; means to fill the chamber with fluid 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
20 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 move the sealing and unsealing means through the instrumentality of magnetic attraction.
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17. A fluid injector comprising in combination: a chamber for the containment of fluid; means to fill the chamber with fluid 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 move the unsealing means through the instrumentality of magnetic attraction.

18. A fluid injector comprising in combination: a chamber for the containment of fluid; means to fill the chamber with fluid 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 move the sealing means through the instrumentality of magnetic attraction.

19. 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 and 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.

20. A fluid chamber 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 move the sealing and unsealing means through the instrumentality of magnetic attraction.

21. A fluid chamber 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 move the unsealing means through the instrumentality of magnetic attraction.

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

23. 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, and 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.

24. 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 move the sealing and unsealing means through the instrumentality of magnetic attraction.

25. 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 above normal density fluid to discharge from the chamber which discharge reduces the fluid remaining in the chamber to normal density, and means to move the unsealing means through the instrumentality of magnetic attraction.

26. 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 move the sealing means through the instrumentality of magnetic attraction.

No references cited.