

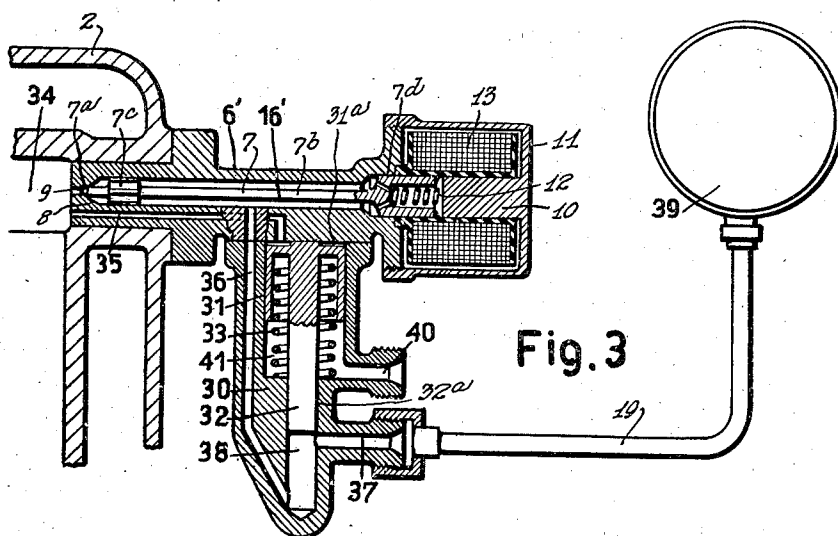
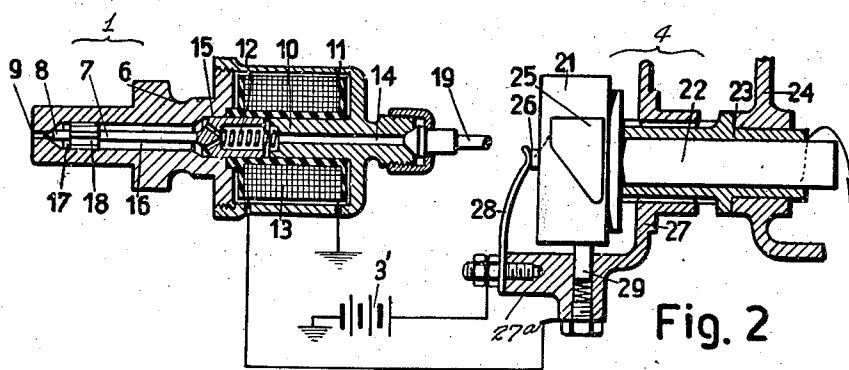
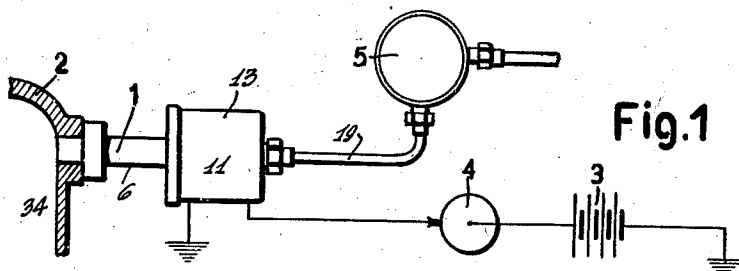
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FUEL INJECTION VALVE APPARATUS

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FUEL INJECTION VALVE APPARATUS

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Alien Property Custodian

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2 Claims. (Cl. 137-139)

The present invention is a fuel injection valve apparatus for internal combustion engines, the instant application being a division of applicant's copending application Serial No. 136,733, filed April 14, 1937.

The method of operation of the invention consists essentially in the fact that the liquid fuel is made to enter into the engine through electromagnetically controlled injecting means, within which the fuel is maintained under pressure in such a way that the difference between the pressure of the fuel and that of the chamber into which it is injected will be practically constant.

The apparatus comprises electromagnetically controlled injecting means and means adapted to impart to the fuel, within the injection means, such a pressure that it will pass into the engine as soon as the injection valve opens, owing to a practically constant difference of pressure.

According to the invention it will be possible to predetermine the duration of the injection and to adjust its phases within the cycle.

These and the specific characteristics of the invention will now be explained with special reference to the drawing, given merely indicatively as examples, and not limitative as to the scope of the invention.

Fig. 1 is a schematic view of a device suitable for low pressures embodying the invention.

Fig. 2 shows a practical embodiment of the invention partly in central section view; and

Fig. 3 shows in similar view an embodiment with differential piston, particularly suitable for high pressures.

As may be seen from Fig. 1, the device comprises: the electromagnetically governed injector repeated for each cylinder; the current distributor for the governing of the several injectors on the motor, and which varies in its details according to the number of injectors it has to serve; the feeding apparatus of the fuel under pressure for the several injectors, which apparatus varies according as the injection is to be at low pressure into the air feeding conduits of the motor (motors with separate ignition), or at high pressure into the compression chamber of the motor (motors with spontaneous ignition by compression).

The fuel injector 1 is placed at the most convenient point on the cylinder 2 of the motor (that is, as aforesaid, according to the cases, into the feed conduit or into the compression chamber). See Figs. 1, 2 and 3. Its nozzle 9 is normally closed by an internal valve 7 which is adapted to open it instantaneously by the attraction of a solenoid 13 when a current is supplied by the

battery 3, by means of the electric interrupter or commutator 4 which is governed by the motor, and which may close it instantaneously by means of a spring 12 when the current discontinues.

The injector is continuously fed with fuel under pressure out of a supply or manifold 5 which in the case of explosion motors may be an accumulative fuel tank under constant pressure, or, in the case of internal combustion motors may be a particular device as described hereinbelow. As the fuel, in consequence of the pressure to which it is subjected, is always ready to issue from the injector, the electromagnetic control ensures that the opening and closing of the injection valve will be instantaneous, and that the duration, variation and the timing of the phases of the injection will be of the highest precision at all speed ranges. As far as the effective pressure during the injection is concerned (that is, the difference between the absolute pressure of the liquid that is to be injected and that of the air into which it is injected), it is maintained substantially constant under the constant pressure with the apparatus of the first case (explosion motors), and will be automatically rendered constant when executed with the special apparatus in the second case (internal combustion motors).

The advantages of the described injection method are of the utmost practical importance as they permit one to suppress or to diminish to a high degree the defects of the systems at present in use: that is, they permit a considerable increase of the rate of combustion and, consequently, of the thermic efficiency and of the possible speed of the motor; a very precise dosing of the fuel, particularly in the multi-cylinder motors, and, consequently, a regular running at low consumption; a great variability of the dosage up to extraordinarily small volumes, and, therefore, a great elasticity of operation and an idle running at a rather reduced speed; a reduction of the air excess and, consequently, of the effective specific stroke volume and a reduction of weight.

In Fig. 2 the electromagnetic injector in one form is shown in detail.

Within the valve casing 6 is a cylindrical fuel chamber 16, filled at all times with fuel and which during non-injection periods is maintained closed to the combustion chamber 34, by a valve assembly 7 which slides freely in the casing 6, said assembly 7 consisting in part, of a valve stem 7^b of substantially reduced diameter and formed at its left end with a conical portion 7^a arranged to engage a valve seat 8 beyond which is the injection orifice 9.

The valve stem 7^b is arranged for limited longitudinal movement in the fuel chamber to effect the opening and closing of the valve, and for this purpose is centrally located and guided by an enlarged portion 7^c formed in the stem near the left or combustion chamber end thereof and which engages the inner surface of said cylindrical fuel chamber. The enlarged guiding portion 7^c of the valve stem is provided with a series of longitudinal grooves or liquid displacement passages 10 extending the full length of said portion so as, on the one hand to enable the fuel to flow freely past said portion, and, on the other hand, to enable the valve stem to move freely without hindrance by the fuel.

At its opposite or right end, the valve stem is provided with another enlarged portion 7^d of magnetic material as for instance iron, this portion having a sliding fit with the solenoid and constituting an armature therefor. When the valve is closed, the rightmost end of the enlarged portion 7^d is located in slight spaced relation with a fixed core portion 10 of the solenoid and which projects inwardly from a casing, or shroud 11, housing the solenoid and screwed upon the valve casing. The portion of the armature carried by the valve stem is provided with a cylindrical recess 7^e, opened at the end, and in which there is located a spring 12 reacting between the base of said recess and the inner end of the fixed core portion 10, the spring serving to urge the valve to its closed position.

Since the solenoid shroud 11 is of magnetic material, there will be a complete path of magnetic material for the flux of the solenoid, broken only by the slight gap between the core portion carried by the casing and the armature carried by the valve stem. Liquid displacement passages 15 at the base of the recess in the armature portion 7^d permit the free flow of fuel between the valve chamber and the gap just referred to.

According to the arrangement just described, when the solenoid 13 is energized, the armature 7^d carried by the valve stem will move instantaneously (against the reaction of the spring 12) to close the gap and in doing so will effect an instantaneous and complete opening of the valve so as to allow the discharge of fuel into the combustion chamber 34. And when the solenoid is deenergized, the spring 12 will act instantaneously to move the valve to its closed position, thus cutting off the supply of fuel to the combustion chamber. Because of the liquid displacement passages 15 in the armature and the grooves or liquid displacement passages 10 in the enlarged portion 7^c near the left end of the valve stem, it will be apparent that the valve assembly is in effect floating freely in the fuel and that there is no pumping action which, on the one hand, would retard the movements of the valve to its opened or closed positions, or, on the other hand interfere with the flow of fuel to the combustion chamber 34 when the valve is opened. The quick closing is enhanced by the fuel outflow.

Of course, it will be understood that there is one electromagnetically controlled injection valve for each cylinder in the engine.

Briefly then, this part of the present improvement consists in providing for each cylinder of a multi-cylinder internal combustion engine, a liquid fuel chamber from which liquid fuel is delivered under pressure to the combustion chamber of the cylinder through a valve seat and injection nozzle, the injection of fuel through the nozzle being controlled by a valve which includes

a valve stem located in the fuel chamber and is adapted to partake of a short longitudinal movement in the chamber in its movements between its opened and closed positions. The valve stem is guided in its movements, at its valve end by a head having longitudinally disposed liquid displacement passages and at its other end by a second head likewise having liquid displacement passages, said second head constituting an armature of a solenoid which surrounds the same, the solenoid in addition having a centrally located fixed core in longitudinal alignment with the armature. The fixed core is supported by or formed integral with a shroud or casing surrounding the solenoid so that except for a slight gap existing between the armature and the fixed core when the valve stem is in a position closing the valve, the solenoid has a complete magnetic circuit of which the movable armature carried by the valve stem forms a part. The invention further contemplates the provision of means for energizing and deenergizing the solenoid periodically to regulate the timed injection of fuel into the combustion chamber. When the solenoid is energized, the armature, and consequently the valve stem on which it is mounted, is moved from valve closing position to valve opening position, the latter position being determined by the banking of the armature against the fixed solenoid core when the gap therebetween has been closed and, when the solenoid is deenergized, a spring device reacting between the armature and the fixed core restores the valve stem to valve closing position which, of course, is determined by the seating of the valve itself. The liquid displacement passageways in the stem guiding head at one end and in the armature at the other end permit the free movement of the valve assembly without interference by the liquid and also permit the free flow of liquid past the guiding head during the injection of the fuel from the fuel chamber into the combustion chamber in the engine cylinder.

The interrupter 4 which is arranged to control the passage of the current in each solenoid is shown, as an example, in Fig. 2 for the case of a single cylinder motor. A drum 21 made of an insulating material turns with a shaft 22 rotating within the bearing 23 which is fixed on the casing of the engine 24, the said shaft being moved by the engine at the engine speed when it is a two stroke motor, and with half speed in the instance of a four stroke motor. On the cylindrical surface of the drum 21 a metal lamina or contact plate 25 having a trapezoidal tile form is attached and stands in electric communication with a central button or contact 26 which is fixed on the drum 21. A muff or sleeve 27 made of an insulating material may slide longitudinally on the bearing 23 and its extension 27^a supports two brushes; one of them, 28, is in constant contact with the button 26 and the other one 29, is in constant contact with the cylindrical surface of the drum 21. To these two brushes lead the conductors of each of the electric circuits in which the solenoid 13 of each injector and the battery 3' are comprised. When the motor is in rotation, and with it also the interrupter, the duration of the injection is obviously equal to the duration of the contact between the trapezoidal lamina 25 and the brush 29; if the drum of the interrupter rotates in the direction of the arrow, thus displacing axially the muff 27, the duration of the contact (and consequently that of the injection) varies, with the adjusting displacement

of the muff, as regards the beginning of injection, while the end will be maintained uniform.

In the instance of multi-cylinder motors, the electric interrupter which controls the passage of the current in the several injectors is analogous to that just described, differing only by its having as many equidistant brushes, similar to brush 29, as there are cylinders, each of these brushes being electrically connected to one of the solenoids; and as the trapezoidal lamina is a single one only, the duration of the injection and its adjustments are identical for all cylinders.

In the instance of injection at low pressure into the intake air conduits (with two stroke as well as four stroke engines), the fuel-feeding apparatus may be constituted of a tank, in which the fuel is stored at constant pressure by means of any self-regulating diaphragm pump or of another known type whatever; or this apparatus, in certain cases—as, for instance, when liquid acetylene is used—may be constituted by the common steel bottles provided with any pressure reducer whatever, preferably maintaining constant the absolute pressure of the air in the conduit and of the fuel in the injector, and thus, also the effective injection-pressure.

In the instance of injection at high pressure (internal combustion motors), instead, the fuel-feeding apparatus should constitute a special device, both because it has to supply a constant injection pressure when the pressure of the air in the compression chamber is variable, and because it is not easy to store the fuel under high pressures. Therefore, it is necessary that, by means of this apparatus, the absolute injection pressure shall be of exactly increasing extent in relation to that of the absolute pressure which is extant in the compression chamber, so that, consequently, also the difference between them may remain constant, or at least not decrease during the piston stroke.

This result is obtained, for each injector, by means of a differential pressure-responsive device or piston, which is automatically driven by the gas pressure, acting upon the large-diameter surface, that is extant in the compression chamber and which piston, for its part, with the small-diameter surface, applies pressure upon the fuel which is contained in the injector.

The whole of such an arrangement is shown in Fig. 3 in which the fuel-feeding apparatus is shown as a unitary part of the injector, in order to eliminate external pipings under pressure. The electromagnetic injector is like that already described with exception of the entrance of the fuel. At side of the injector casing 6' a pump casing 30 is fixed having connecting large and small recesses 31^a and 32^a within which plays a double piston having large and small diameters at its ends 31 and 32. A restoring spring 33 pushes this piston constantly upward or in the direction of the larger diameter; at this side the piston recess 31^a is in constant gas communication with the compression chamber 34 of the motor, and this by means of the passage 35; and at the side of the minor diameter, the recess 32^a is in constant communication with the annular chamber 16' of the injector, and this by means of the passage 36. A port 37 which at the end of the stroke is uncovered by the small piston 32, puts the fuel chamber 38 below the piston 32 into communication with the pipe 19 and fuel tank 39 and a constantly open air hole or vent 40 serves for the discharge, back into the same tank 39 or

to another place, the leakage losses which take place from the two pistons within the chamber 41 below the piston 31. The areas of the two pistons 31 and 32 stand with one another in proportion equal to the proportion which it is desired to obtain between the absolute pressure of the fuel and that of ignition.

In the case of a four stroke motor the operation may be as follows: during the suction stroke of the motor, the differential piston 31—32 remains at the stroke-end, pushed by the spring 33 and sucked by the depression within the chamber 34; during the compression stroke the increasing pressure in the chamber 34 overcomes the spring 33, the shifting piston 31—32 advances and drives a bit of the fuel through port 37 back to the tank 39, and from the moment in which the piston 32 covers the hole 37, a pressure is established in 38—36—16' the value of which at any instant stands to that existing in the chamber 34 in the same proportion as that which exists between the areas of the large and small pistons 31 and 32. At the predetermined moment, the interrupter which is governed by the motor (analogous to that already described) makes the injector valve electromagnetically open, and the injection begins under fuel pressure; the absolute pressure of the fuel increases automatically as that in the chamber 34, and thus the injection itself takes place at an effective constant pressure; the injection ends abruptly with the discontinuation of the current. The pump piston 31—32 remains still where it was left at this moment, until the end of the discharge of the motor; when the pressure in the cylinder 34 is ceasing, the piston is pushed back by the spring 33 and soon uncovers the hole 37, thus causing a connection to the chamber 38 which is fed again with fuel for the next cycle.

Consequently, the required injection pressure is applied upon the fuel well in advance of the opening of the injector and only terminates well after its closing so that there is abundant latitude for the altering of the period of injection, with assurance of full pressure throughout the period.

In a two stroke motor the working is absolutely analogous.

The automatic pump at constant effective pressure as above described presents no piping subjected to elevated pressures, neither valves nor mechanical controls.

The wear of the piston 31—32 maintains a slight clearance which has no effect on the precision of the injection, as the timing depends only upon the electric control of the injector while any leakages are compensated by the increase of displacement of the small piston 32. The clearance permits the piston to be restored by the spring.

Although there have been described several variations of structure and application, it will be understood that the invention is not intended to be limited to these forms; as there could be devised many others, utilizing the novel principles and thus embodying the present invention.

What I claim and desire to secure by United States Letters Patent is:

1. In an apparatus of the kind described, having a liquid fuel chamber, a retractible valve for controlling the delivery of fuel therefrom, a spring normally urging said valve toward closed position, a valve stem extending from said valve and carrying an armature head, means guiding the stem for longitudinal movement, the valve

stem having a short movement between its closed and open positions, and a magnet coil surrounding said armature head and being adapted to be periodically energized to actuate said head and stem against the resistance of said spring to control the timed opening and closing of said valve; said apparatus characterized in that the valve stem and armature head are bodily immersed to swim in the liquid fuel in said chamber and have liquid displacement passages adjacent both ends of the valve stem permitting substantially unimpeded longitudinal stem movement within the liquid, between closed and open positions, so that by the energizing or deenergizing of the coil the stem and valve are moved instantaneously from one position to the other swimmingly within the liquid, and without change of chamber volume, for fuel delivery; and characterized further in that the magnet coil is enclosed by iron parts including an end portion presenting a fixed central iron core in alignment with said armature head which acts as a movable core and another end portion formed and arranged to guide the armature head with which the head is in sliding engagement at all times, whereby there is provided a substantially complete magnetic circuit except for the slight gap between

the movable and fixed cores when the valve is closed.

2. An electromagnetically actuated valve means, the same having a magnet coil arranged to attract a movable iron core which is connected to the valve thereby to open it; characterized in that the movable core is located inside the coil, which is encased in an iron housing presenting at one end a second iron core located within the coil in alignment with the movable core and, at the other end, being formed and arranged to guide the movable iron core which is in sliding engagement therewith at all times so as to present a complete magnetic circuit without appreciable air gap other than between the two cores, whereby the movable core which is connected to the valve stem is, during the opening motion thereof, constantly under the influence of the magnetic flux in said circuit, and forms a closing armature for such flux; and characterized further in that the parts moving with the valve stem are formed with channels adjacent both ends of the valve stem which allow the free swimming motion thereof within the liquid fuel without altering the volume of the chamber.

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