

Dec. 15, 1959

P. E. BESSIERE

2,917,034

INTERNAL COMBUSTION ENGINE FUEL INJECTION SYSTEMS

Filed Oct. 8, 1956

4 Sheets-Sheet 1

Fig.1.

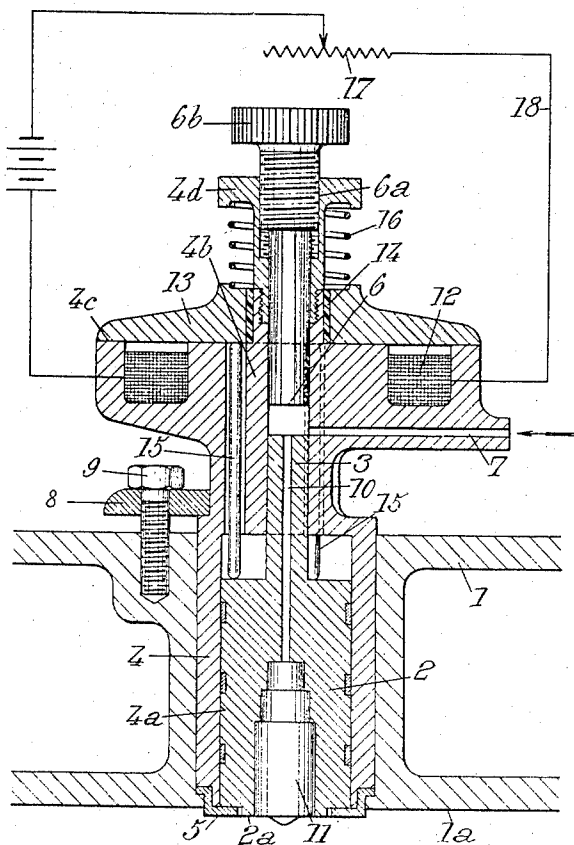
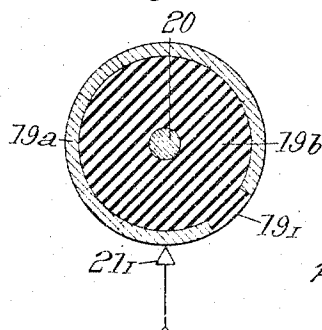


Fig. 3.



INVENTOR
Pierre Etienne Bessiere
BY
Bailey, Stephens & Luetting
ATTORNEYS

Dec. 15, 1959

P. E. BESSIERE

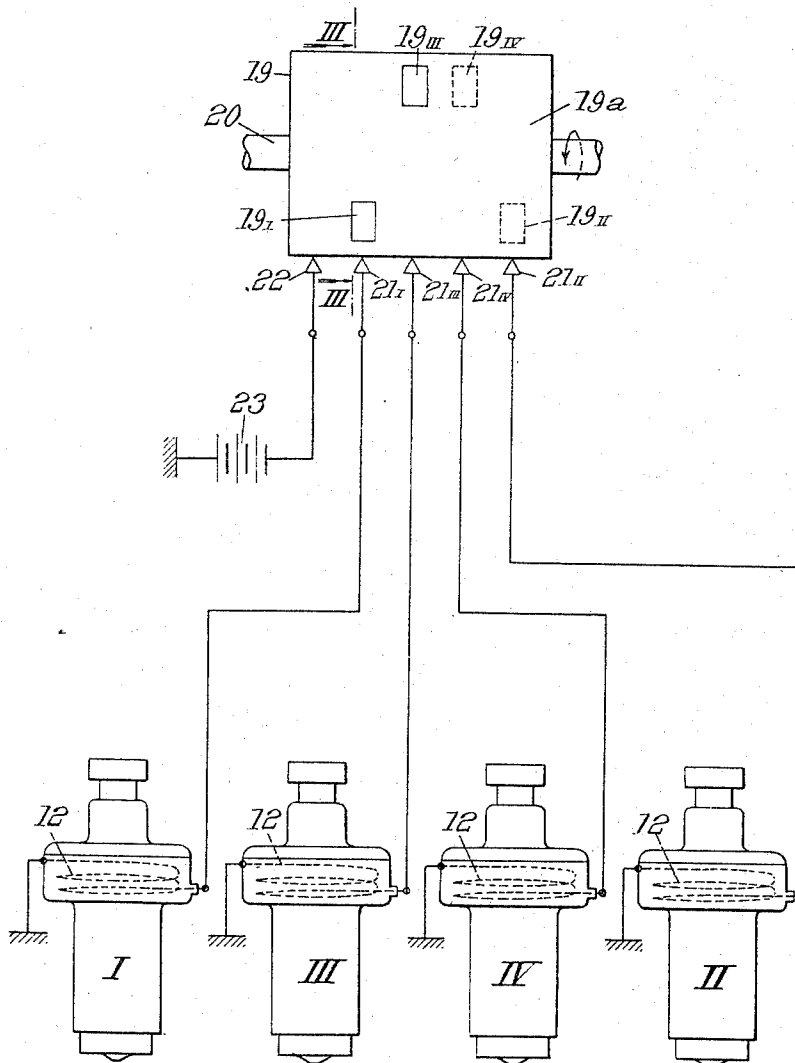
2,917,034

INTERNAL COMBUSTION ENGINE FUEL INJECTION SYSTEMS

Filed Oct. 8, 1956

4 Sheets-Sheet 2

Fig. 2.



INVENTOR

Pierre Etienne Bessiere

BY

Bailey Stephens & Whitting
ATTORNEYS

Dec. 15, 1959

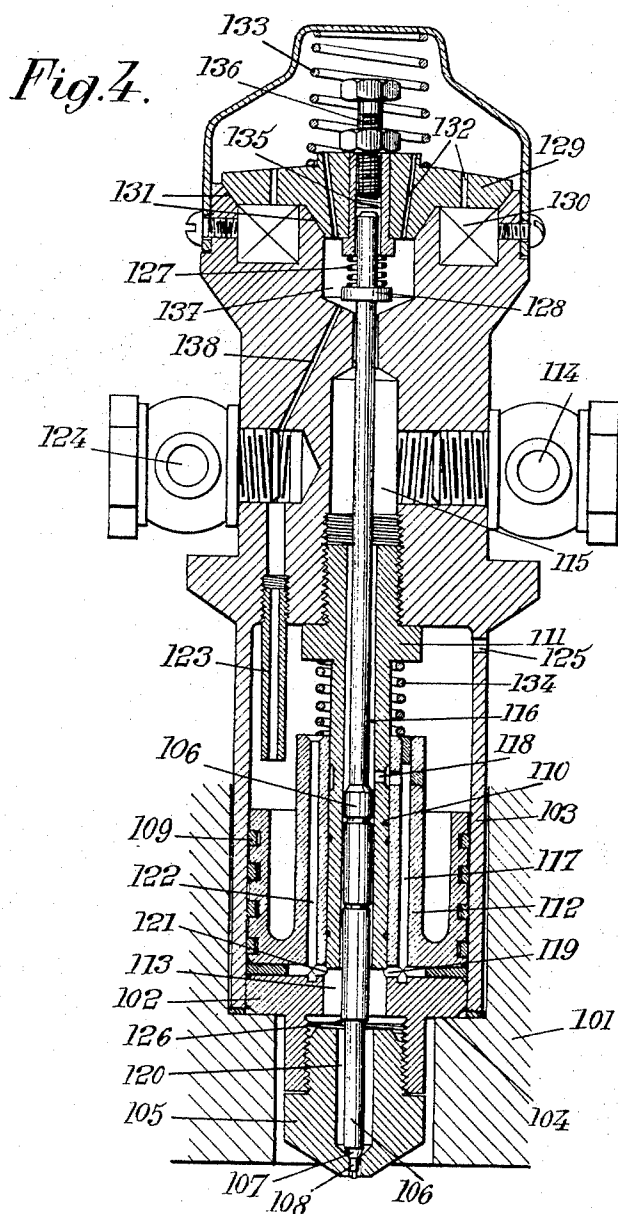
P. E. BESSIERE

2,917,034

INTERNAL COMBUSTION ENGINE FUEL INJECTION SYSTEMS

Filed Oct. 8, 1956

4 Sheets-Sheet 3



INVENTOR

Pierre Etienne Bessiere

BY

Bailey, Stephens & Hastings
ATTORNEYS

Dec. 15, 1959

P. E. BESSIERE

2,917,034

INTERNAL COMBUSTION ENGINE FUEL INJECTION SYSTEMS

Filed Oct. 8, 1956

4 Sheets-Sheet 4

Fig. 5.

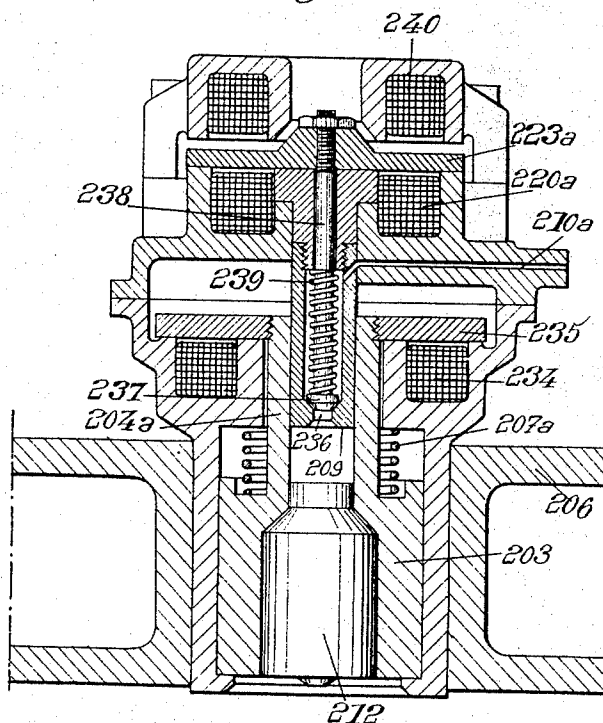


Fig. 6.

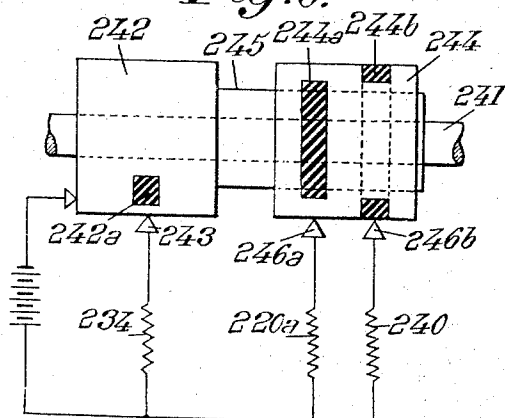
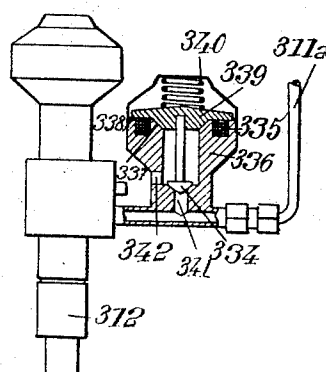


Fig. 7.



INVENTOR
Pierre Etienne Bessiere
BY
Bailey Stephens & Hunting
ATTORNEYS

1

2,917,034

INTERNAL COMBUSTION ENGINE FUEL
INJECTION SYSTEMS

Pierre Etienne Bessiere, Paris, France

Application October 8, 1956, Serial No. 614,527

Claims priority, application France October 13, 1955

11 Claims. (Cl. 123—139)

The present invention relates to internal combustion engines fuel injection system. A system of this kind often includes a member having a control movement which is to be started in circumstances and at times which are well determined, under the action of a fluid pressure. Such a member is for instance the piston of an injection pump and injector unit, said piston being actuated by the pressure of the gases that have been compressed inside the cylinder of the internal combustion engine, or the needle valve of the injector or a leak valve the opening of which stops injection, this needle valve or this leak valve being lifted from its seat at the desired time by the pressure of the fuel to be injected.

It has already been proposed to place such a member under control of a locking device which keeps said member in position against the action of the fluid under pressure until the control movement of said member is to take place, at which time said locking device is brought out of action.

The locking devices which have been used up to this time have not proved satisfactory. Mechanical locking devices require important forces to bring them out of action, especially when this is to be obtained practically instantaneously. Furthermore, there are serious risks of jamming. Electro-magnetic locking devices such as have been suggested up to now have the drawback that their release is not sufficiently quick. As a matter of fact, such locking devices are arranged in such manner that their winding must exert a pulling action at the time when the locking device is to be brought out of action. Now, this pulling action can take place only with a certain delay depending upon the time constant of the system which produces the magnetic force. For practical purposes this time constant is too high to permit of obtaining a satisfactory result in devices for controlling the fuel injection to an internal combustion engine.

The object of the present invention is to eliminate these drawbacks.

For this purpose, according to my invention, the locking device is constituted by a magnet and an armature cooperating with said magnet and in contact with the pole parts thereof during the locking action, one of these elements (to wit the magnet and the armature) being operatively connected with said member and the other with the part with respect to which said member is movable, whereby the attraction of said magnet on said armature temporarily prevents a control displacement of said member from taking place under the effect of said fluid pressure on said member. The member is released when the above mentioned pressure of the fluid has sufficiently increased or/and the attraction of the magnet has been sufficiently reduced to cause the action of said fluid pressure to overcome that of said attraction.

In the system according to my invention the influence of the time constant is practically negligible. This is due to the fact that the magnet, in order to release the member, is not required to supply a positive attraction effect, but must on the contrary merely release the arma-

2

ture which was previously attracted. When this release is due to the fact that the force of the fluid pressure acting in opposition to the magnetic force becomes so high that it overcomes the effect of said magnetic force, it is clear that there is no delay due to any time constant. But the effect is practically the same if the release of the member is obtained by reducing, or even eliminating, the attraction exerted by the magnet, that is to say if the energizing current of the electro-magnet is sufficiently reduced or even cut off. In this case, in order to produce the release, it is not necessary to reduce the attraction of the electro-magnet to zero. It suffices to reduce it to a given degree and once this is obtained, the armature leaves the pole piece of the magnet immediately.

Of course, this last mentioned embodiment of the invention (reduction or elimination of the energizing current) is applicable only when the magnetic force is produced by an electro-magnet. On the contrary, the first embodiment (release due to the fact that the force acting in opposition to the electro-magnetic attraction exceeds a predetermined value, without this magnetic force being reduced) is applicable both in the case of electro-magnets and of permanent magnets.

Preferred embodiments of my invention will be hereinafter described with reference to the accompanying drawings, given merely by way of example and in which:

Fig. 1 is a sectional view of a system including an injection pump and an injector, the control member which is to be held against the action of the fluid pressure being the piston of said pump, said piston being held in position by an electro-magnetic locking device according to the invention.

Fig. 2 diagrammatically illustrates the application of such a system to a four stroke internal combustion engine.

Fig. 3 is a section of the line III—III of Fig. 2.

Fig. 4 is a sectional view of another embodiment in which the member that is held by the locking device is the needle valve of an injector.

Fig. 5 shows still another embodiment in which several parts are held in position by electro-magnetic locking means.

Fig. 6 diagrammatically illustrates the means for controlling the electro-magnetic locking means of Fig. 5.

Fig. 7 shows still another embodiment of a fuel injection device including electro-magnetic locking means according to the invention.

On Fig. 1, the whole of the injection pump and of the injector is housed in the cylinder head 1 of an internal combustion engine, for instance a Diesel engine. This system includes a piston 2 hereinafter called "relay piston" and the under face 2a of which is subjected to the pressure existing inside the internal combustion engine cylinder. The relay piston 2 is integral with a pump piston 3 and these two pistons 2 and 3 are slidably fitted in a casing 4 the lower portion of which constitutes a cylinder 4a cooperating with relay piston 2, the upper part 4b of said casing 4 constituting the cylinder of the injection pump which cooperates with piston 3. The lowermost position of pistons 2 and 3 is determined by an abutment 5 against which is applied the under face 2a of piston 2 when it is in its position of rest, whereas the uppermost position of pistons 2 and 3 is determined by an abutment 6 which further constitutes the end wall of the injection pump cylinder. This abutment 6 is adjustable axially in the pump cylinder by means of screw threads 6a and of a toothed wheel 6b cooperating with a rack not shown on the drawing. In its lowermost position pump piston 3 clears the inlet opening of a feed conduit 7 which receives fuel for instance from a pump not shown.

The casing 4 is fixed in the cylinder head 1 of the internal combustion engine through suitable means, for

instance by means of a fork shaped extension 8 and bolts 9.

The inside of the fuel injection pump cylinder 4b is connected through a suitable conduit, for instance an axial passage 10 provided in pistons 3 and 4, to an injector 11 mounted inside relay piston 2 and the injection orifices of which open into the engine cylinder.

It will be noted that, when piston 2 and 3 are in their lowermost position as shown by the drawing, the free space inside cylinder 4b can be filled with fuel fed to this space through conduit 7. If pistons 2 and 3, under the effect of the pressure existing in the engine cylinder and applied to the relay piston 2, are moved upwardly, the fuel enclosed in cylinder 4b after the inlet orifice of conduit 7 has been closed by piston 3, is forced through conduit 10 to injector 11 from which it is injected in a finely atomized state into the engine cylinder. The upward movement of pistons 2 and 3 is stopped when the upper face of piston 3 comes into contact with the under face of abutment 6. Thus, I obtain a sudden stopping of injection. It is also clear that the amount of fuel injected during this movement of pistons 2 and 3 depends upon the position occupied by abutment 6 in cylinder 4b. This amount can therefore be adjusted by varying this position.

In order to keep pistons 2 and 3 in their lowermost (inactive) position until fuel is to be injected into the engine cylinder, the whole of these two pistons is subjected to the action of a magnetic locking device which is made inoperative just at the time of injection.

Fig. 1 shows such a locking device made according to my invention. The metal of casing 4 advantageously is a magnetic metal having a low remanence, for instance a very mild steel. A winding 12, to be fed with electric current is mounted in the upper part of casing 4 around the axis of cylinder 4b, so that this upper portion of casing 4 constitutes an electro-magnet the pole piece of which is constituted by the upper face 4c of the casing. Preferably this surface is flat and at right angles to the axis of cylinders 4 and 4b. This electro-magnet cooperates with an armature constituted by a plate 13 also made of a magnetic material, this plate serving to exert the desired locking action on pistons 2 and 3. Advantageously plate 13 is slidable on the upper end of cylinder 4b and is thus guided in the axial direction. Preferably a sleeve 14 made of a non magnetic material surrounds plate 13 at the above mentioned upper end of cylinder 4b, this sleeve serving to prevent sticking of plate 13 in case of a remanence of the electro-magnet constituted by the upper portion of the casing 4. Finally, between the under face of plate 13 and the upper face of relay piston 2, I provide one or several rods 15 which extend through corresponding holes made in the body of casing 4. The length of these rods 15 is such that when plate 13 is attracted by the electro-magnet, relay piston 2 is maintained in its lower position, for which its under face is in contact with abutment 5.

The means for causing pistons 2 and 3 to be released at the desired time may be of different kinds. For instance such means may be responsive to a given variation of the compression pressure existing inside the internal combustion engine cylinder.

In this case the current flowing through winding 12 is substantially constant. The intensity of this current is adjusted so that the electro-magnetic force which keeps plate 13 applied against pole part 4c (and to which is added the force of a spring 16 which will be more explicitly referred to hereinafter) is overcome when the compression inside the engine cylinder, and therefore the force exerted on the under face 2a of relay piston 2, reaches a predetermined value. At this time plate 13 is unstuck from the pole face 4c by the thrust exerted on relay piston 2 and transmitted through rods 15. As soon as plate 13 has ceased to be stuck against the pole surface 4c, the magnetic force exerted by the electro-

magnet decreases very quickly since it is inversely proportional to the square of the air gap existing between plate 13 and surface 4c. Therefore, as soon as the pistons 2 and 3 have started moving upwardly, the magnetic force which up to then had kept them in their lowermost position nearly instantaneously becomes negligible so that the whole pressure of the gases acting upon the under surface 2a of piston 2 imparts an upward movement to pistons 2 and 3, practically without resistance, and achieves the injection of fuel by means of injector 11 until the upward movement of pistons 2 and 3 is stopped by abutment 6. Of course, spring 16 interposed between the upper face of plate 13 and a shoulder 4d rigid with casing 4 yieldingly opposes this movement. However, the influence of this spring is negligible because it may be made relatively weak and just sufficient to return plate 13 and pistons 2 and 3 into their lowermost position when the pressure inside the engine cylinder has decreased during the next stroke of the engine cycle.

When it is desired to adjust the injection advance, that is to say the time when injection starts, it suffices to adjust the force of the electro-magnet by adjusting the intensity of its energizing current. The more the force of the electro-magnet is reduced, the greater is the advance, since armature 13 starts lifting away from surface 4c under the effect of the compression pressure existing in the engine cylinder. Such an adjustment of the energizing current of the electro-magnet may be obtained by means of a rheostat 17 inserted in the feed circuit 18 of winding 12.

The electro-magnet which has thus just been described may be replaced by a permanent magnet. Of course in this case there is no possibility of adjusting the lead to injection, but some internal combustion engines do not need such an adjustment. Besides, it should be considered that with a system made as above described the time at which injection starts varies much less when the speed of the engine varies than in the conventional construction including an injection pump mechanically controlled and connected with the injector through relatively long pipes.

Instead of using the variation of pressure in the internal combustion engine cylinder to control the temporary interruption of the magnetic locking action exerted on pistons 2 and 3, I also have this interruption affected in accordance with the position of the driving shaft or of the camshaft of the engine. In this case such a shaft drives a switch which, for every cylinder of the engine, cuts off the current feed to the energizing winding of the electro-magnet just at the time injection is to begin and which restores current when the injection period is finished. The electro-magnet, when its energizing current is restored by said switch, may serve to return pistons 2 and 3 in their lowermost position, so that such an arrangement makes it possible to dispense with any return spring. Of course, in such an arrangement it is possible to provide means for varying the time at which injection is started.

A construction of this kind is shown by Figs. 2 and 3. The system shown by Fig. 2 includes four injection pump and injector units I, II, III and IV, each of these units being intended to cooperate with one of the cylinders of a four-cylinder engine. Each of said units may be arranged in the manner illustrated by Fig. 1. In order to control the feed of current through the windings 12 of the respective units I provide a rotary switch 19 constituted by a tubular metal drum 19a mounted on a hub 19b of insulating material, this hub being coupled with the camshaft 20 of the engine through means, for instance friction means, such that it is possible to vary the angular position of drum 19a with respect to shaft 20.

I provide in said metal drum 19a as many openings, respectively designated by reference numerals 19_I, 19_{II}, 19_{III} and 19_{IV}, as there are fuel injection units and

suitable brushes designated by 21_I, 21_{II}, 21_{III} and 21_{IV}, are arranged to cooperate with the drum in planes perpendicular to the axis thereof and coinciding with said apertures 19_I, 19_{II}, 19_{III} and 19_{IV}. Each of said brushes is connected with one of the windings 12 of the injection units I, II, III and IV. The metal drum 19a is electrically connected through a brush 22 with one of the terminals of a current source 23, the other terminals of this source being earthed, same as the ends of windings 12 opposed to these connected to the above mentioned brushes.

It will be well understood that when drum 19 rotates, the current passing through each of the windings 12 is cut off when the corresponding brush is located on one of the apertures provided in the metallic sleeve 19a. The time for which this current is cut off depends upon the length of these apertures. The magnetic locking device of each of the injection units is therefore made inoperative during the period for which the corresponding brush is located in front of the corresponding aperture of sleeve 19a and fuel injection takes place during this period. The relative positions of the apertures provided in sleeve 19a correspond to the times of injection in the respective cylinders of the engine. By varying the angular position of sleeve 19a with respect to shaft 20, it is possible to vary and to adjust the lead to injection in the engine cylinders.

It should be noted that the upper portion of casing 4, which constitutes a portion of the electro-magnet of the locking device, is not necessarily made of extramild steel but may be made of a magnetic material having some remanence. This remanence is not objectionable as long as the pressure force acting upon the under surface of the relay piston is, for the maximum lead to injection, substantially higher than the permanent attraction from said remanence.

Fig. 4 shows the application of an electro-magnetic device made according to my invention to the locking of the needle valve which controls the injecting and atomizing opening of an injector, this needle valve being lifted from its seat under the effect of the pressure of the liquid to be injected as soon as the attraction force of the magnetic locking device is reduced (possibly to zero).

In the embodiment shown by Fig. 4, this needle valve belongs to an injection pump and injector unit but it should be well understood that the needle valve may belong to an ordinary injector.

In the construction of Fig. 4, the injection pump and injector unit mounted in the cylinder head 101 of an internal combustion engine includes a relay piston 102 housed in a cylinder 103 so as to be slidable therein under the action of the pressure of the gases compressed inside the engine cylinder, which pressure acts upon the under face of piston 102. In its lowermost position, piston 102 rests through its periphery upon the shoulder 104, of the cylinder head. In the central portion of piston 102 there is fixed, for instance by screwing, an injection nozzle 105 the outlet opening of which is controlled by a needle valve 106, the lower end of which includes a cone 107 and an atomizing projection 108.

The general transverse section of piston 102 is annular. The outer cylindrical wall of this piston is slidable in the inner wall of cylinder 103 and packing rings 109 are interposed between these walls. The inner wall of the central bore 110 of piston 102 is slidable on the outer wall of a tubular piece 111 rigid with the body of the injection unit. The needle valve 106 extends axially through said piece 111 in which it can slide in a fluidtight fashion. In order to insure a good fluidtight contact between the central bore of piston 102 and tubular piece 111, said piston includes a skirt 112 which forms an upward extension of the central portion of the piston, bore 110 being formed in said skirt.

The free annular space 113 existing at the lower end

of the central bore 110 of piston 102 between the under face of tubular piece 111 and the upper face of injection nozzle 105 (needle valve 106 extending axially in said space) constitutes the cylinder of the fuel injection pump, the piston of this pump being constituted by the lower end of tubular piece 111.

Fuel is fed to this cylinder 113 through a connection 114 through which fuel supplied for instance by a pump (not shown) enters a chamber 115 provided inside the body of the injection device above tubular piece 111. From this chamber 115, fuel arrives through an annular passage 116 provided in the upper portion of piece 111, between the inner wall of the bore of said piece 111 and the needle valve 106, and through a conduit 117 provided in the skirt 112 of the piston, and extending parallel thereto, into the cylinder 113 of the pump when the transverse conduit 118 which provides communication between passage 116 and conduit 117 and the transverse conduit 119 which provides communication between conduit 117 and the inside of the pump cylinder 113 are open, that is to say when piston 102 is in its lowermost position illustrated by Fig. 4.

Once fuel has filled cylinder 113 and the annular conduit 120 which connects cylinder 113 with the atomizing opening of nozzle 105, the excess of fuel can for said position of piston 102, escape from cylinder 113 through opening 121 and a conduit 122 provided in the skirt 112 and which also extends parallel to the axis thereof. The excess of fuel then flows out, at a relatively high level, from conduit 122 so as to arrive into cylinder 103 above piston 102 and to be sucked out by a suitable pump not shown on the drawing through tube 123 and outlet connection 124. This suction and the provision of a vent hole 125 in the upper portion of cylinder 103 prevent the gaseous and liquid fluids which are present in cylinder 103 from having a dash-pot effect upon relay piston 102. Needle 106 is provided, at a point located inside cylinder 113 or conduit 120, with a shoulder 126. The force exerted by the liquid under pressure located in cylinder 113 upon said shoulder is balanced by the force of a spring 127 interposed between a collar 128 integral with needle valve 106 and the armature 129 of an electro-magnet which belongs to the electro-magnetic locking device. This electro-magnet is constituted by the upper end, made of a magnetic material, of the body of the injection unit, in which an energizing winding 130 is housed. The upper pole surfaces 131 of the electro-magnet thus formed cooperate with armature 129, which has a general shape of a plate provided with conduits 132 which prevent any damping as might be produced by air during the operation of the magnetic locking device.

As long as armature 129 is applied against the electro-magnet 130—131 by the whole attraction force of said electro-magnet, the strength of spring 127 is sufficient to keep the lower cone 107 of needle valve 106 in contact with its seat in nozzle 105, despite the action of the fuel pressure in cylinder 113 upon the shoulder 126 of said needle valve and this for the highest values of said pressure in cylinder 113. On the other hand, the force of attraction of the electro-magnet is then higher as the force tending to move armature 129 upwardly.

On the contrary, as soon as the attraction force of the electro-magnet is reduced through suitable control means to a value below that of the force urging armature 129 upwardly, said armature is unstuck from the electro-magnet and needle valve 106 moves upwardly with respect to nozzle 105 under the effect of the pressure of the liquid upon shoulder 126. The reduction of the attraction force on the electro-magnet is obtained for instance by cutting off or reducing the energizing current.

Such control means may be constituted by a switch analogous, for instance, to that illustrated by Fig. 2, and by a driving shaft of the engine, the angular position of

7

this rotating switch being adjustable so as to permit of varying the lead to injection.

Return springs 133 and 134 are provided to return the armature 129 of the magnetic locking device and the relay piston 102 toward their positions shown on Fig. 4.

A central aperture 135 provided in armature 129 and normally closed by a screw 136 permits of having reach to the upper end of the needle valve which is slidable in this aperture. It should be noted that the upper end of the needle valve must never come into contact with this screw.

If, due to some leaks, some amount of fuel penetrates into space 137, located in the upper part of the body of the injection unit, in which are housed spring 127 and collar 128, this amount of liquid will be also evacuated through a connection 124 by the provision of a conduit 138 which connects spaces 127 with said connection.

The operation of the device which has just been described is as follows.

When relay piston 102, nozzle 105 and needle valve 106 are in their lowermost positions as indicated by the drawing, which are the positions they occupy for instance in a four-stroke engine during the suction stroke, the fuel arriving through feed connection 114 fills the pump cylinder 113 and the excess of fuel, after reaching conduits operating cylinder 103 through conduit 122, is evacuated by suction through conduits 123 and 124.

In view of the fact that an excess of fuel is fed to cylinder 113, there is produced, every time fuel is fed to this cylinder, a stream of liquid which is in contact with needle valve 106 and the relay piston 102 and which serves to cool these parts.

At the beginning of the next stroke of the engine piston (compression stroke in the case of a four-stroke engine) the whole of elements 102, 105 and 106 moves slightly in the upper direction so as to close cylinder 113 while slightly compressing spring 127. This movement is stopped when the openings 119 and 121 of cylinder 113 are closed. Then comes a time when, through suitable control means, the attraction force of electro-magnet 130, 131 is reduced, possibly to zero, whereby armature 129 is unstuck from said electro-magnet under the action of spring 127. This magnetic locking action having then ceased the liquid under pressure in cylinder 113 acts upon the shoulder 126 of needle valve 106 to lift said needle valve with respect to nozzle 105 and thus opens the outlet opening of said nozzle. Piston 102 is then moved upwardly by the pressure of the gases in the engine cylinder and causes the liquid contained in cylinder 113 to be ejected through nozzle 105 into the engine cylinder. The upward movement of the relay piston 102 stops when the upper face of nozzle member 105 comes into contact with the lower end of tubular piece 111.

When, at the end of the next stroke of the engine, the exhaust valve of said engine cylinder opens, the pressure in said cylinder drops to a value sufficiently low to enable return springs 133 and 134 and the electromagnet, which is now once more energized, to return all the parts (piston 102, nozzle 105, needle valve 106 and armature 129) into the respective positions illustrated by Fig. 4. Then, fuel fed from connection 114 will be able to reach the cylinder 113, from which the excess of fuel will flow out through aperture 121 and conduit 122 to be evacuated through conduits 123 and 124. The above described cycle of operations is now repeated.

Concerning the adjustment of the fuel flow rate, various means (not shown by Fig. 4), may be used, for instance analogous to those shown on Fig. 1. Such means are mentioned merely by way of example.

It should be noted that, in the system illustrated by Fig. 4, there is provided a double locking of the relay piston 102, to wit a hydraulic locking when the apertures 119 and 121 are closed by the lower end of tubular piece 111 and an electro-magnetic locking exerted on

8

needle valve 106, the fact of making this electro-magnetic locking inoperative also making the hydraulic locking inoperative.

Owing to this arrangement the magnetic locking device has to support only a small portion of the force acting upon the relay piston 102. For instance, if the maximum force acting upon this piston averages 100 kilograms, the attraction force of the magnetic locking device 129, 130 need not be higher than about 2 kilograms.

Thus it is possible to reduce the mass of the parts and, in particular, of armature 129 so that the time of response of the magnetic locking device is much shorter and the locking device works at a high speed.

I may also use a magnetic locking device according to the invention to keep in the closed position a valve and, in particular, an exhaust or leak valve, opening of this valve taking place as soon as the force of attraction of the magnetic locking device is reduced (possibly to zero) or as soon as a force acting upon said valve in opposition to the attraction of the locking device magnet increases to a value above that of said attraction.

Fig. 5 shows a system including an injection pump and injector unit mounted in the cylinder head 206 of an internal combustion engine, the rate of feed of this injection system being adjustable by means of a leak valve which is kept closed for a portion of the discharge stroke of the pump by means of an electro-magnetic locking device.

In the fuel injection system of Fig. 5, there is a relay piston 203 rigid, as in the arrangement of Fig. 4, with the side wall 204a of the pump cylinder, whereas the piston 209 of said pump is stationary. The time at which relay piston 203 is allowed to start moving upwardly is determined, as in the arrangement of Fig. 1, by armature 235 ceasing to be stuck by the electro-magnet the winding of which is shown at 234, said armature 235 being rigid with the whole of parts 293 and 204a and spring 207a acting merely as a resilient return element. In this construction, the electro-magnet ceases to keep armature 235 stuck thereon as a result of a reduction of the energizing of said electro-magnet. The feed of fuel to cylinder 204a during the suction displacement of parts 203—204a is effected through an opening 236 provided in the end wall of the fixed piston 209 and controlled by a valve 237. The same opening 236 serves also to permit a possible excess of fuel enclosed in cylinder 204a to escape without being fed to injector 212 fixed in relay piston 203. In order to enable valve 237 to act in this way as a leak valve which determines the end of the injection action, this valve 237 is subjected not only to the pressure existing inside cylinder 203 and which tends to open said valve, but also to the action of a force acting in the opposed direction and tending to keep the valve 237 closed, this last mentioned force being that of an electro-magnet constituting another locking device according to the invention and the winding of which is shown at 220a. This electro-magnet cooperates with an armature 223a connected through a rod 238 with valve 237. An opposing spring 239 also tends to keep valve 237 applied against its seat.

The feed of fresh fuel to cylinder 204a and the escape of any excess of fuel from cylinder 204a as the result of the opening of valve 237, take place through a conduit 210a.

In order to keep valve 237 open during the period necessary to permit the feed of fresh fuel to cylinder 204a, I provide a third electro-magnet 240 which also cooperates with armature 223a and is disposed on the opposed side thereof from electro-magnet 220a.

The three electro-magnets 220a, 234 and 240 may be controlled by means of a device such as shown by Fig. 6. Shaft 241 is driven by the internal combustion engine at a suitable speed. A rotating switch 242 is mounted on said shaft and driven by it through suitable means, for

instance friction means, so that its angular position with respect to shaft 241 is adjustable. This switch is in the form of a drum, the external cylindrical surface of which is metallic with the exception of an area 242a made of an insulating material. A brush 243 is sliding on said external surface of drum 242 in the transverse plane where said area 242a is located and this brush is inserted in the circuit of the control winding of electro-magnet 234. Consequently, this electro-magnet 234 is energized and keeps relay piston 203 and cylinder 204a in their lowermost position (Fig. 5) as long as brush 243 is not in contact with area 242a. As soon as this area comes under brush 243, the energizing current of electro-magnet 234 is cut off and relay piston 203a and cylinder 204a, now released, move upwardly under the effect of the pressure existing in the engine cylinder and cause fuel to be forced toward injector 212. By varying the angular position of drum 242 with respect to shaft 241, it is possible to adjust the lead to injection.

A second switch drum 244 is mounted on a sleeve 245 turning together with drum 242. Drum 244 is driven through friction means by sleeve 245, but its angular position with respect to said sleeve, and consequently with respect to drum 242, can be modified in order to adjust the flow-rate of the injection pump. On drum 244, I provide in two juxtaposed planes two areas 244a and 244b made of an insulating material. To cooperate with the portions of the drum carrying these areas 244a and 244b, I provide two respective brushes 246a and 246b, the first one being inserted in the circuit of electro-magnet 220a and the second in the circuit of electro-magnet 240. The feed circuit of electro-magnet 220a is closed as long as brush 246a is bearing upon the metallic surface of drum 244, but is cut off when said brush 246a comes into contact with the insulating material of the area 244a. At this time valve 237, and also armature 223a which is rigid therewith, are pushed upwardly by the pressure of the fuel present in cylinder 204a until armature 223a is applied against electro-magnet 240. Since when the energizing current of electro-magnet 220a was cut off the energizing circuit of electro-magnet 240 was closed, this last mentioned electro-magnet keeps armature 223a and valve 237 in their uppermost position during the whole of the period for which brush 246b is in contact with the metallic surface of drum 244, that is to say for a time sufficient to permit the feed of fresh fuel into cylinder 204a. When brush 246b again comes into contact with the insulating area 244b, electro-magnet 244 releases armature 223 and this armature, same as valve 237, are returned by spring 239 into lowermost position, for which valve 237 is closed and armature 223 applied against the pole elements of electro-magnet 220a which has just been reenergized. The time at which electro-magnet 220a ceases to be energized and, consequently, fuel ceases to be fed toward injector 212, is adjustable by modifying the angular position of drum 244 with respect to drum 242.

Fig. 6 relates to the case of a single engine cylinder. Of course, in the case of a multi-cylinder engine, each cylinder being provided with a fuel injection unit such as shown by Fig. 5, each of the drums carries a number of insulating zones corresponding to the number of cylinders of the engine, these areas being offset in accordance with the angular offsetting in the operations of the respective cylinders of the engine.

It should be well understood that the magnetic locking devices according to my invention are applicable to any system for the injection of fuel and their application is not limited in any way to such systems including an injection pump and injector unit the relay piston of which is actuated by the pressure existing during the compression stroke in the engine cylinder.

Fig. 7 shows an injector 312 on the feed conduit 311a of which is mounted a valve 334 controlling an escape orifice the opening of which immediately stops injection

through the injector. As a matter of fact, the needle of the injector is lifted from its seat by the pressure of the fuel discharged by the injection pump (not shown on Fig. 7); but it immediately drops onto its seat thus stopping injection, when due to the opening of valve 334 the fuel pressure immediately drops to a low value.

Valve 334 is held upon its seat against the pressure of fuel entering through 311a by an electro-magnet constituted by a winding 335 mounted on a support of a magnetic material 336 which forms two concentric circular portions 337, 338, cooperating with an armature 339 which is subjected to the attraction of a return spring 340. As long as an energizing current of given intensity is flowing through winding 335, valve 334 closes the escape or leak orifice 341, but as soon as the current through the winding 335 is reduced or cut off, valve 334 opens and permits fuel to escape through this orifice 341 and a second orifice 342 located downstream of valve 334.

The energizing current of winding 335 may be controlled through any suitable means. Advantageously I make use of a rotating switch analogous to that of Fig. 6.

The exact time at which the energizing current through windings 335 is reduced or cut off and, consequently, the amount of fuel injected through the injector, may be modified by an angular displacement of the switch, which displacement may be effected either manually or automatically, for instance by means of a conventional speed regulating system.

What I claim is:

1. In an internal combustion engine having a cylinder head and a rotating shaft, a fuel injection system which comprises, in combination, a fuel injector mounted in said engine, means for controlling the operation of said fuel injector, said means including a part fixed with respect to said cylinder head and a member movable with respect to said part, means for transmitting to said member a force proportional to a variable fluid pressure developed in said engine during the operation thereof, a locking device for temporarily opposing a control displacement of said member relatively to said part under the effect of said pressure, said locking device including two elements, to wit an electro-magnet and an armature cooperating with said magnet, one of said two elements being operatively connected with said member and the other with said part so that the attraction of said magnet on said armature temporarily prevents said control displacement of said member from taking place under the effect of said fluid pressure on said member, said two elements being in contact with each other as long as said locking device is operative, said electro-magnet including an energizing winding, a source of current and a switch coupled with said engine shaft and arranged to vary the current supplied to said winding for different portions of the cycle of operation of said engine.

2. A fuel injection system according to claim 1 in which the pole parts of said magnet consist of concentric annular surfaces and the armature consists of a plate concentric with said annular surfaces and movable axially with respect thereto, this plate having an area such that it can simultaneously cover said concentric annular surfaces.

3. A fuel injection system according to claim 1 in which said armature is provided with apertures for the flow of air therethrough.

4. In an internal combustion engine having a cylinder head, a fuel injection system which comprises, in combination, a fuel injector mounted in said engine, means for controlling the operation of said fuel injector, said means including a part fixed with respect to said cylinder head and a needle valve movable with respect to said part, means for transmitting to said needle valve a force proportional to a variable fluid pressure developed in said engine during the operation thereof, and a locking device for temporarily opposing a control displacement of said needle valve relatively to said part under the

effect of said pressure, said device including two elements, to wit a magnet and an armature cooperating with said magnet, one of said two elements being operatively connected with said needle valve and the other with said part so that the attraction of said magnet on said armature temporarily prevents said control displacement of said needle valve from taking place under the effect of said fluid pressure on said needle valve, said two elements being in contact with each other as long as said locking device is operative.

5. In an internal combustion engine having a cylinder head, a fuel injection system which comprises, in combination, a fuel injector mounted in said engine, means for controlling the operation of said fuel injector, said means including two parts movable with respect to each other to form between them a variable volume chamber having only one outlet orifice, said chamber being filled with liquid, this liquid constituting hydraulic locking means which prevent said parts from moving toward each other as long as said outlet orifice is closed by said member, and a valve member movable with respect to one of said parts, capable of closing said orifice, means for transmitting to said member, to urge it to open said orifice, a force proportional to a variable fluid pressure developed in said engine during the operation thereof, and a locking device for temporarily opposing an orifice opening displacement of said member relatively to said last mentioned part under the effect of said pressure, said device including two elements, to wit a magnet and an armature cooperating with said magnet, one of said two elements being operatively connected with said member and the other with said last mentioned part so that the attraction of said magnet on said armature temporarily prevents said displacement of said member from taking place under the effect of said fluid pressure on said member, said two elements being in contact with each other as long as said locking device is operative.

6. A fuel injection system for an internal combustion engine having a cylinder which comprises, in combination, a fuel injector for feeding fuel to said cylinder, means to feed fuel under pressure to said injector, means for subjecting the fuel fed to said injector to a pressure proportional to the pressure developed in said cylinder during the operation of said engine, means for controlling the operation of said fuel injector, said latter means including a part having an opening thereto and a member movable with respect to said part to open and close said opening, means for transmitting to said member a

force proportional to the fuel pressure in said injector and acting on said member in the opening direction, and a locking device for temporarily opposing the displacement of said member relatively to said part in opening direction under the effect of said fuel pressure, said device including two elements, to wit a magnet and an armature cooperating with said magnet, one of said two elements being operatively connected with said member and the other with said part so that the attraction of said magnet on said armature temporarily prevents the opening displacement of said member from taking place under the effect of said fuel pressure on said member, said two elements being in contact with each other as long as said locking device is operative.

7. A fuel injection system according to claim 6 in which said magnet is an electromagnet.

8. A fuel injection system according to claim 6 in which said magnet is an electromagnet surrounding said member and said armature has the form of a plate the plane of which is normal to the axis of said member, its area being such as to cover said electromagnet.

9. A fuel injection system according to claim 6 in which said part and said member constitute a fuel leak controlling valve.

10. A fuel injection system according to claim 1 in which the core of said electro-magnet has its two poles on the same side of the winding of said electro-magnet and located in surfaces transverse to the direction of movement of said member with respect to said piece and said armature has its face turned toward said poles shaped to correspond to said surfaces so that when said armature is attracted by said electro-magnet it comes to fit against both of said poles simultaneously, thereby instantaneously closing the magnetic circuit formed by said core and said armature.

11. A fuel injector according to claim 10 in which said surfaces are both located in a plane perpendicular to the direction of movement of said member with respect to said piece.

References Cited in the file of this patent

UNITED STATES PATENTS

2,332,909	Fuscaldo	Oct. 26, 1943
2,499,706	Ward	Mar. 7, 1950
2,630,761	Mashinter	Mar. 10, 1953
2,703,562	Seubert	Mar. 8, 1955