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Gueret et al.

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[54] **ELECTROMAGNETIC INJECTORS FOR INTERNAL COMBUSTION ENGINES**

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[52] **U.S. Cl.** **239/585**
[51] **Int. Cl.** **B05b 1/30**
[58] **Field of Search** 239/585, 533; 251/139, 140, 141

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[57] **ABSTRACT**

An electromagnetic injector for reducing wear between the movable parts as provided by the spacing between the stationary and movable armatures at the end of the rising stroke of the needle valve, said spacing being obtained by a hydraulic abutment formed between said armatures by a film of fuel under pressure defining the residual gap. The fuel enters the gap through a central bore in the stationary armature and escapes over the edges of the movable armature.

11 Claims, 4 Drawing Figures

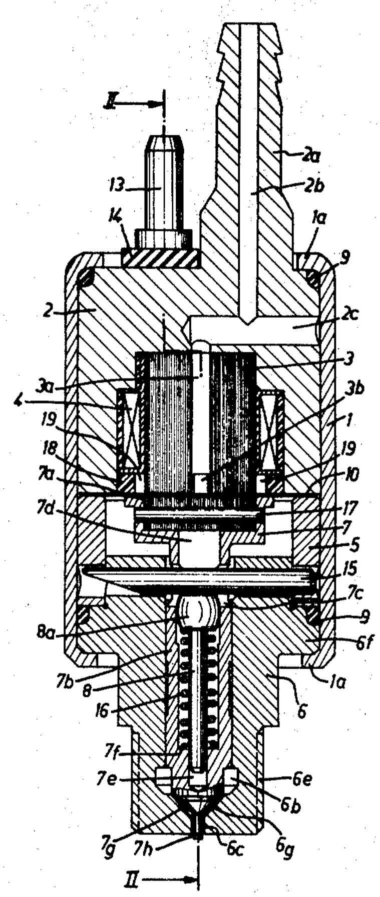
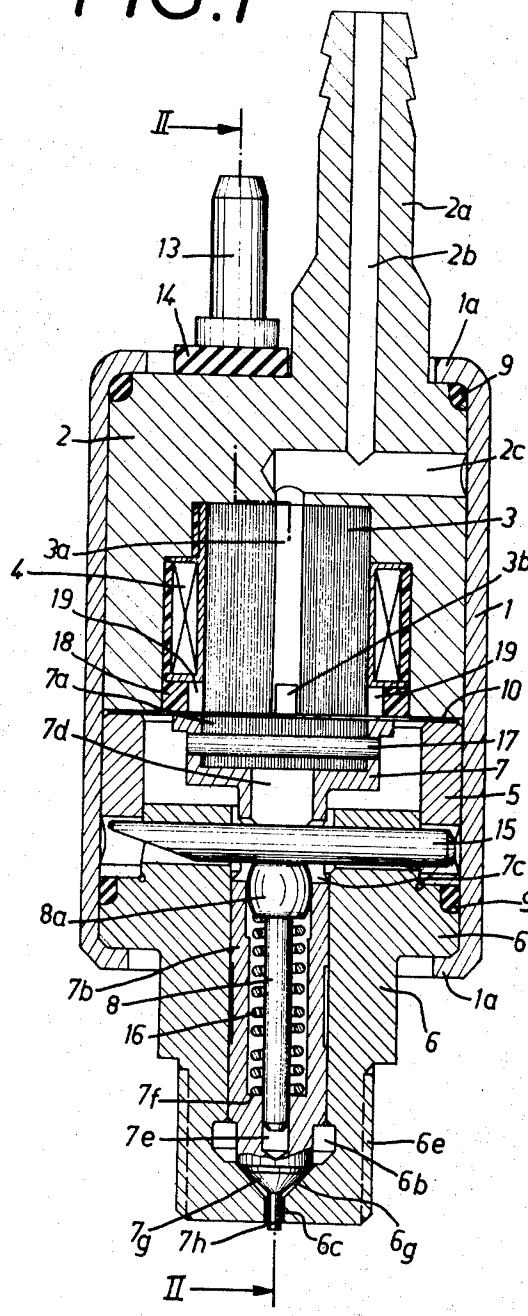


FIG.1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2b
13
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7
5
15
7c
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16
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7g
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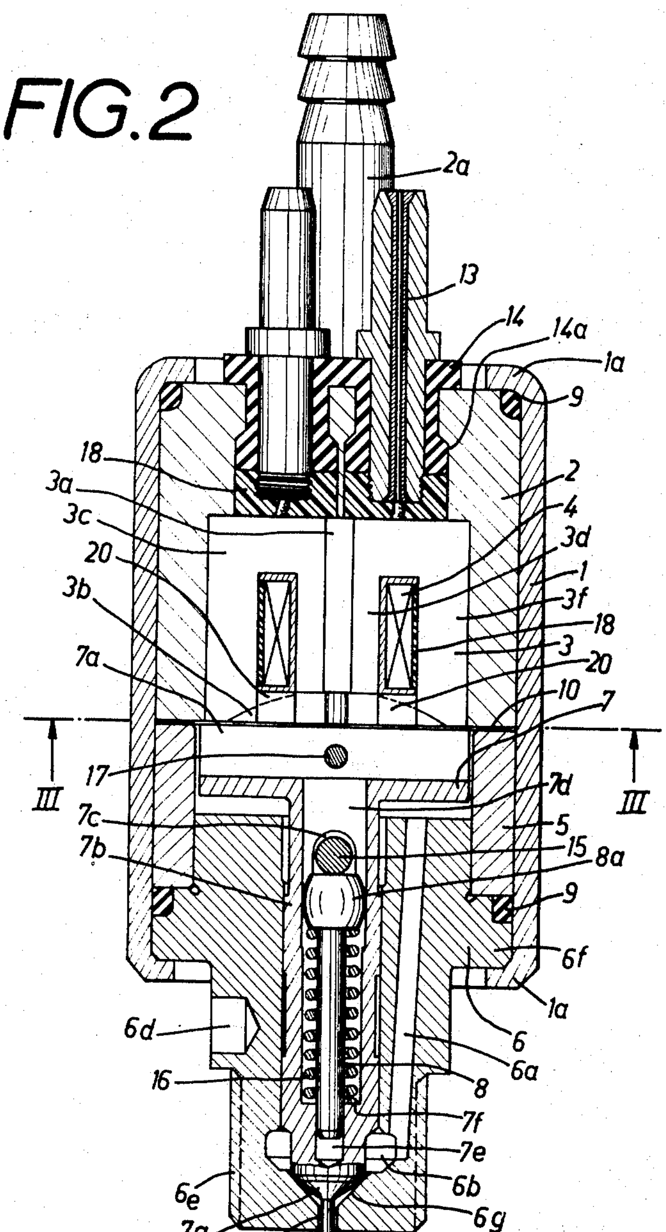
FIG.2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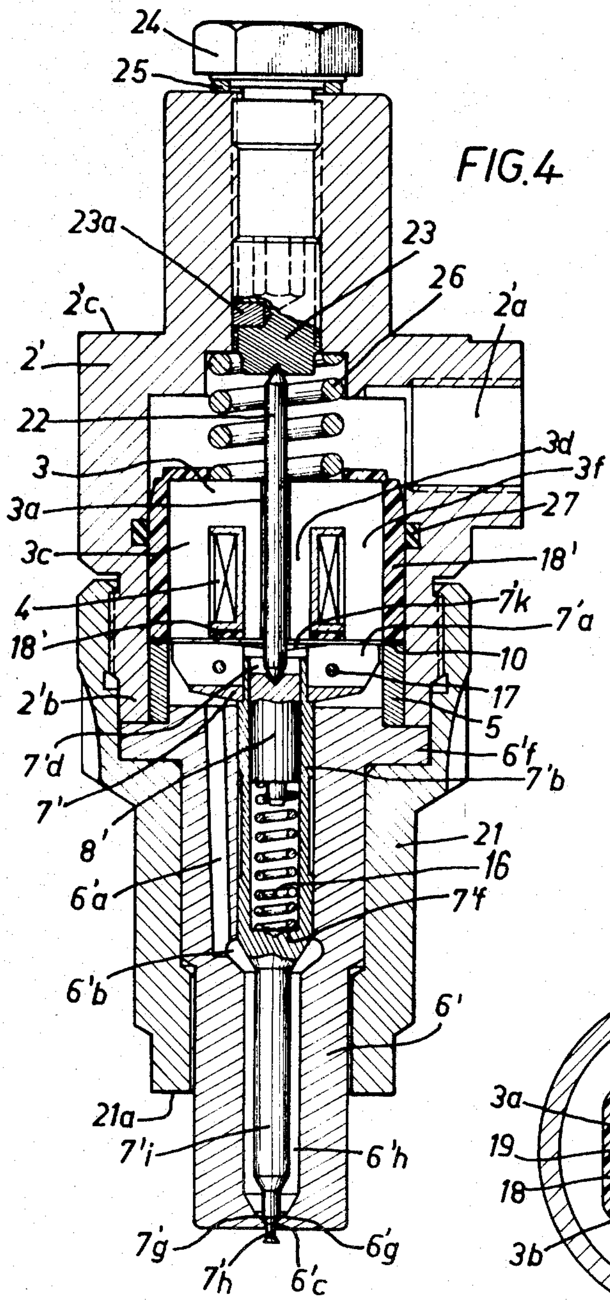
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25
23a
23
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2'c
2'a
2'
22
3d
3f
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27
3c
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7'k
7'a
18'
10
17
2'b
5
6'f
7'd
7'b
7'
8'
21
16
6'a
7'f
6'b
6'
21a
7'i
6'h
7'g
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7'h
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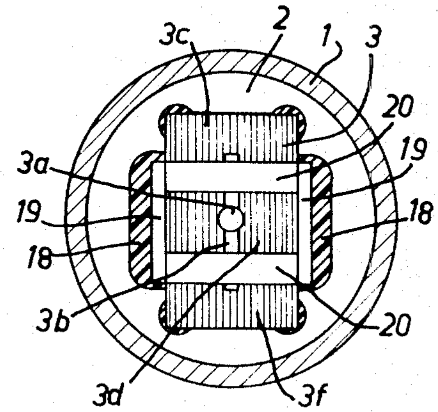
FIG. 4


3c
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1
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3a
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18
3b
20
3d
3f

FIG. 3

three arms forming which face the movable armature and the central arm is surrounded by the winding, while a lateral groove is provided on each side of the stationary armature so as to interconnect the recesses separating the three arms whereby a rectangle is defined by said grooves and recesses, the surface of which is such with reference to that of the movable armature that equilibrium is obtained between the hydraulic and magnetic forces, taking into account the force of the spring returning the movable armature into its starting position, a further groove being provided in the central arm so as to connect the central bore with the recesses between the three arms and consequently to further the distribution of fuel in said recesses and grooves;

The movable armature is rigid with a hollow cylindrical needle valve slidingly carried in the lower part of the injector and the conical end of which cooperates with a conical seat in said lower part while a return spring engaging the inside of said needle valve bears on the one hand against the latter and on the other hand on said lower part with the interposition of a pin extending through an elongated port in said needle valve and of a bearing member within the latter ;

the stationary armature being constituted by ferromagnetic laminae assembled so as to form a pack the three arms of which end in registry with the movable armature, the central arm being surrounded by the winding while the stationary armature is provided with a central recess defining, with reference to the total area of the cooperating surfaces of the movable and stationary armatures, an area adapted to provide equilibrium between the hydraulic and magnetic forces, account being taken of the force of the spring urging back the movable armature;

the stationary armature is glued to the upper part of the injector body which is separated from its lower part by a washer or shim defining the initial gap and also by an amagnetic tabular stay, the two parts of the injector body being held together by a tubular casing the edges of which are folded back over said upper and lower parts, whereby excessive compression of the shim and stay is cut out, the injector body being fitted in position solely through its lower part;

the stationary armature is slidingly carried inside the upper part of the injector body and is separated from the lower part by a washer or shim defining the initial gap and by an amagnetic tubular stay, the contact between the stationary armature, the shim, the tubular stay and the lower part of the injector body being ensured by a spring inserted between the stationary armature and the bottom of the upper part, while the fluidtight connection between said upper and lower parts is provided by two flat highly polished surfaces fastened together by a nut bearing on a shoulder of the lower part and screwed over a threaded section of the upper part, which section bears against said shoulder while the injector is freely fitted through its upper part and nut by means of a flange without any stressing of the magnetic circuit, the shim, the stay and the lower part.

In order to further the understanding of the invention, as described hereinafter, there are illustrated in the accompanying drawings :

IN FIG. 1, a sectional view of a first embodiment of the injector;

in FIG. 2, a sectional view through line II–II of FIG. 1;

in FIG. 3, a sectional view through line III—III of FIG. 2;

- in FIG. 4, a sectional view of a second embodiment of the injector.

Turning first to FIGS. 1, 2 and 3, it is apparent that the injector includes chiefly an upper part 2 and a lower part 6 which are held together b a casing 1 the edges of which are folded back and set over the upper and lowe surfaces of the upper and lower parts 2 and 6 of the injector body respectively. The upper part 2 is provided with a fuel input connection 2*a* the axial bore 2*b* of which opens into a transverse bore 2*a* which connects it with a central bore 3*a* in the stationary armature 3 of the controlling magnetic circuit. In the upper part 2 there are also fitted the electric termials 13 which are secured through the agency of rubber fluidtight means 14 including a bead 14*a* urged energetically outwardly and compressed by the terminals whereby perfect fluidtightness is obtained trough a thorough engagement against the upper part 2 (FIG. 2). The stationary armature is constituted by a lamellated magnetic block including two outer arms 3*c* and 3*f* and a central arm 3*d* surrounded by the winding 4. Said stationary armature is glued within the upper part 2 by means fo a suitable resin 18 filling in all the empty spaces. Recesses 20 are provided between the magnetic arms 3*c*, 3*d*, and 3*f* underneath the winding 4, said recesses 20 being interconnected by grooves 19 formed in the casting along the sides of the stationary armature (FIG. 2) and by grooves 3*b* cut so as to ensure a connection between the axial bore 3*a* and the empty spaces thus formed at 20. There is thus obtained a rectangle defined by the grooves 19 and the recesses 20, the size of said rectangle being selected in accordance with the pressure of the fuel. The lower part 6 of the injecto-body injector body the movable armature 7 including a lamellated magnetic blade 7*a* and a needle valve 7*b* guiding the movable armature in its cylindrical recess, the conical tip 7*g* of the needle valve cooperating with a conical seat 6*g* in the lower part 6, so as to control the injection of fuel. An amagnetic annular stay 5 is fitted over the upper end of the lower part 6 and rests on the shoulder 6*f* of the latter. The needle valve 7*b* is provided with an axial bore 7*d* housing a return spring 16 together with a rod 8 guiding said spring and ending with a part spherical head 8*a* forming an abutment for said spring; said head 8*a* is urged against a pin 15 extending through the transverse bore 7*c* in the needle valve 7*b*. The spring 16 returning the needle valve into its closing positqon is held between said head 8*a* and the inner shoulder 7*f* of the needle valve 7*b*. The lower end of the rod 8 is guided inside the terminal axial bore 7*e*. The lamellations of the blade 7*a* are glued inside the movable armature inside which they are furthermore held by the transverse pin 17. The fuel is conveyed towards the seat of the needle valve 7*b* through the eccentric bore 6*a* and the annular chamver 6*b*. The fuel is atomized through the port 6*e* which is restricted to an annular cross-section by the stud 7*h* terminating the needle valve 7*b*. The injector body is secured to the engine through its threaded section 6*a* as provided by a wrench carrying a stud engaging the lateral radial bore 6*d*. The cooperating surfaces of the stationary armature 3 fitted in the upper part 2 and of the blade 7*a* fitted in the lower part 6 are subjected after positioning of the annular stay 5, to a truing in their plane before the final assembly is made whereby the initial gap may be de-

ELECTROMAGNETIC INJECTORS FOR INTERNAL COMBUSTION ENGINES

Our invention has for its object improvements in electromagnetic injectors, chiefly those intended for injection into internal combustion engines.

For such applications, the fuel is injected conventionally by means of electromagnetically controlled injectors located in the vicinity and on the upstream side of the admission valve in the case of an indirect injection or else in the actual cylinder head of the engine in the case of a direct injection. Each electromagnetic injection produces then the desired mixture feeding the corresponding cylinder whenever it receives an electric control signal the duration of which is defined by electronic means, known per se, in accordance with the operative conditions of the engine. The injectors must operate at very high speeds. By way of example, it may be mentioned that the duration of injection ranges between 0.2 and 1.5 ms for Diesel engines and between 0.8 and 4 ms. for gasoline engines ithe case of injections of fuel amounts ranging between 7 and 40 cub ms.

Although it is no difficult matter to form an electric control signal in a manner satisfying the actual requirements of the engine, it is very difficult to inject an amount of fuel which is identical for all the injectors assuming the durations of the signals are the same. As a matter of fact the manufacturing allowances as to injector size lead to modifications in the movements of the needle valve of the injector, to modifications in the cross-sectional passageway afforded for the fuel and to modifications in the magnetic properties of the injector parts, so that in all cases each injector is to be subjected to gauging tests and to be adjusted by suitable means with a view to providing substantially equivalent properties for all the injectors within an accuracy of the magnitude of 1 percent.

Most of the known electromagnetic injectors used for the above purpose are of the direct action needle valve type, cooperating with a port defining the throughput, said needle valve being rigid with the movable armature of an electromagnet, which armature constituted by a foliated blade lies in registry with the stationary armature. The needle valve rises by an amount of a magnitude of 0.01 mn measured by the difference between the original and the residual gap. The cooperating surfaces of the stationary and movable armatures and also of the injector parts in which said armatures are fitted are subjected before assembly to a truing in a plane, so that the sizes of the original and residual gaps are adjusted in all known injectors by two shims inserted between the lower and upper parts and between the stationary and movable armatures respectively.

Now the amount of fuel injected depends also on the speed of response which depends in its turn for a given electromagnet power, on the cross-section of the bearing surface of the needle valve subjected to the action of the return spring since the electromagnet has to overcome during the open period the stress exerted on the needle valve by the pressure of the fuel and by said return spring. But since the force of the electromagnet depends on the sizes of the initial and residual gaps, obviously, any modification in said sizes leads to corresponding modification in the performances of an injector of the type considered.

It should be remarked that the shim inserted between the stationary and the movable armature forms an end-of-stroke abutment which results in that the speedy rising and sinking movements of the injector needle valve produce surges while the amount of liquid injected is no linear function of time and follows a particular law showing an undulating behaviour after a high speed rise at the start, with a relative maximum and a relative minimum corresponding to rebounds of the needle valve on its stops, said minimum being followed by the useful section of the curve which should be substantially linear. There exists therefore a threshold underneath which it is not possible to obtain a sufficient accuracy as far as the amount of fuel injected with prior injectors is concerned.

It should be remarked furthermore that with the known injectors of the type described, there is a certain lag for the closing of the injectors, which is ascribable to an adherence between the movable armature and the end-of-stroke shim and between the latter and the stationary armature, the liquid being completely driven out of the space separating the different parts referred to at the end of the rise of the movable armature. This lag is variable and depends on various parameters such as the surface condition of the shim, its wear, the duration of energization of the injector and the like. This leads to variations in the amounts of fuel injected.

The most serious drawback of the prior injectors described hereinabove resides however in the fact that the end-of-stroke shim cannot resist repeated shocks and is very speedily damaged which renders the injector unserviceable. Furthermore the initial gap in prior injectors may vary to a large extent, depending on the more or less energetic fastening of the injector on the engine, which fastening cannot well be accurately controlled.

Our invention has for its object to cut out the drawbacks of known injectors and it covers more particularly improvements in electromagnetic fuel injectors intended more particularly for internal combustion engines, said injectors being of the type including a stationary armature fitted in the upper part of the injector body in which are also fitted the fuel input connection and the terminals of the winding of the controlling electromagnet, said injector comprising furthermore a movable armature constituted by a ferromagnetic lammellated blade fitted in a lower part of the injector body in registry with the stationary armature, said movable armature being rigid with the injector needle valve while the cooperating surfaces of the two armatures and of the parts of the injector in which said armatures are fitted are subjected before assembly to a turning in their plane and the initial gap is defined by a shim inserted between the lower and upper parts of the injector. According to our invention, the cooperating surfaces of the stationary and movable armatures are held apart at the end of the rise of the needle valve by a film of fuel under pressure forming a hydraulic abutment, said fuel entering a central port in the stationary armature and escaping solely along the edges of the movable armature in order to reach the injection port, said hydraulic abutment defining thus the residual gap and, consequently, the rise of the needle valve, by an amount corresponding to the difference between the initial and residual gaps.

As a further development of our inventive idea, it has been proposed in accordance with our invention that :

the stationary armature is constituted by a pack of superposed ferromagnetic laminae the ends of the fined during said assembly by means of a shim 10 inserted between the stay 5 and the upper part 2. Tore-shaped packings 9 are inserted in corresponding grooves underneath the stay and over part 2 and the casing is set in the manner already described, however with sufficient care, so as to avoid an excessive compression of the two parts of the injector body anc chiefly of the shim 10 and stay 5, an excessive compression of said shim and stay exerting a detrimential action on the size of the initial gap, and consequently on the rise of the needle valve. Now a modification of the initial gap cannot be allowed since it would modify the throughput of the injectors in an uncontrollable manner. For this reason also, the injector is secured on the egine through screwing by means of a wrench engaging the lower part of the injector body.

It should be remarked that the perpendicularity, with reference to the axis, of the trued surfaces, is not essential since parallelism between said surfaces is always obtained by the shim 10. Furthermore the movable armature is prevented from turning by the pin 15. Since these different elements are not dismantled after truing and assembly, no error can be committed as to the position of the movable armature 7 with reference to the lower part 6 and to the stay 5. It is therefore sufficient to see, during assembly, to the proper angular setting of the movable armature 7 and of its blade 7*a* with reference to the stationary armature 3, the laminae forming the blade being necessarily parallel, with an allowance however ranging between 3° and 5°.

With the arrangement described, the fuel under pressure fills all the channels 2*b*, 2*c*, 3*a*, 6*a* and 6*b* together with the recesses 20 and the grooves 19 and 3*b*.

When an electric signal is sent into the winding 4, the movable armature 7 is drawn towards the stationary armature 3, which drives the liquid fuel out of the space lying between the cooperating surfaces of the stationary and movable armatures For a predetermined width of the residual gap the magnetic forces balance the returning force exerted by the spring 16 and the pressure of the liquid on the movable armature 7, so that the latter stops at a predetermined distance from the stationary armature. Said distance equal to the residual gap depends on the area defined by the grooves 19 and 3*b* and the recesses 20 and on the fuel pressure. As a magnitude, we may mention a thickness of about 0.1m, for the initial gap defined by the shim of about 0.02 mm for the residual gap, the rise of the needle valve being therefore equal to about 0.08mm. At the end of the rise of the movable armature 7, an energetic damping is obtained as a result of the lamination of the fuel between the cooperating surfaces of the blade 7*a* and of the stationary armature 3, the fuel escaping solely over the edges of the movable armature 7 which stops at the end of its stroke where it is locked by the fuel under pressure entering through the bore 3*a*, without any contact being obtained between the stationary armature 3 and the movable armature 7. Therefore no mechanical wear is possible since there is no contact between the armatures. The wear of the conical tip 7*g* on its conical seat 6*g* is obviously very small since said tip and seat are large-sized and made of very hard material. Consequently, the throughput of fuel increases very spedily starting from the beginning of the opening of the injection port until it reaches the linear section of the curve illustrating the throughput. As already mentioned, the fuel throughput passes no longer, as in prior art, through a first maximum and a subsequent relative minimum before it reaches the linear section. Since the non-linear part of the curve is easily reproduced with injectors according to our invention, it is possible to make use even of this non-linear part for injection purposes; the gap between the cooperating surfaces of this stationary and movable armatures being filled with liquid under pressure, the injector closes, after the current is cut off in the winding 4, in a speedy and positive manner. In fact, there is no difficulty in the filling of said gap with liquid when the movable armature 7 moves away from the stationary armature 3. We may therefore state that our invention provides a hydraulic abutment or buffer playing also the part of a single-acting shock-absorber which is operative only during the opening and and is inoperative during the closing of the needle valve. This ensures an improved speedy response of the injector with an unchanging fuel output even over the non-linear section of its curve while the mechanical parts are no longer subjected to wear since they are prevented from contacting. Furthermore their assembly through an adjusted setting cuts out in practice the uncontrollable modifications of the initial gap otherwise produced in the assembly of the components.

FIG. 4 illustrates a modified injector intended more particularly for incorporation with a Diesel engine. The injector body includes as precedingly an upper part 2′ housing the stationary armature 3 which in the present case is embedded within a sheath of molded resin 18′ and is adapted to slide within said upper part 2′ while it is urged against the stay 5 by a spring 26. A tore-shaped packing 27 surrounds the stationary armature so as to prevent any fuel from passing round the latter end to constrain it to pass exclusively through the central bore 3*a*. The winding 4 is also glued inside the stationary armature 3 and all empty spaces are filled with the same resin as the sheath 18′. The upper part 2′ rests on a shoulder 6′*f* of the lower part 6′ and is held fast over said shoulder by the nut 21 so that said shoulder 6′*f* is clamped between the operative surface of the nut 21 and the cylindrical outwardly threaded extension 2′*b* of the upper part 2′. The movable armature 7′ includes a blade 7′*a* and a needle valve constituted by a cylindrical guiding tube 7′*b* and its solid extension 7′*i* terminating with a frustoconical fluidtight seating section 7′*g* and a stud 7′*h*. Within the axial bore 7′*d* of the needle valve, there is inserted a return spring 16 held between the lower end 7′*f* of the tube 7′*b* and a small piston 8′ slidingly carried inside the latter and controlled by an adjusting screw 23 through the intermediate spindle 22. Said screw 23 serves thus for the adjustment of the preliminary stressing of the spring 16 and it is locked automatically by the superpolyamidic or the like stud 23*a* engaging the thread of said screws. The housing provided for the screw 23 is rendered fluidtight by a bolt 24 engaging a packing 25. The fuel enters the injection port 6′c through the connection 2′*a*, the bore 3′*a* in the stationary armature, the lateral bore 6′*a* in the lower part 6′, the annular channel 6′*b* and the annular channel 6′*h* surrounding the needle valve, the frustoconical seating section 7′*g* of the latter cooperates with a correspondingly shaped seat 6′*g* in the lower part 6.

As in the case illustrated in FIGS. 1 to 3, the lamellated magnetic blade 7′*a* is glued on the movable armature 7′ and is furthermore secured thereto for improved safety by transverse pins 17. The stay 5 is fitted over the lower part 6' and the shim 7 is inserted between said stay 5 and the stationary armature 3, so as to define the initial gap in the magnetic circuit. In order to ensure an uniform distribution of fuel over the blade, a groove 7'k is cut in the latter. Since the pressure in a Diesel engine is far higher than in the case of engines provided with a controlled ignition, it is not necessary to have such a large surface to be subjected to the full pressure of the fuel.

The stationary armature 3 shows therefore no recess or groove and the movable armature is provided merely with its axial bore 7'd and with the samll groove 7'k of a breadth of 2mm extending very slightly beyond the periphery of the bore 7'd. The shim 10 defining the initial gap is given in the case of a Diesel engine a thickness of say 0.15 mm. The residual gap defined by the pressure of the liquid fuel and the balance between the magnetic forces and the return spring is larger than in the preceding case by reason of the larger throughput and is of a magnitude of 0.4 mm.

It should be remarked that the injector according to FIG. 4 is fitted on the cylinder head of a Diesel engine with the lower bearing surface 21a of the nut engaging a cooperating surface of the cylinder head while a strap engages the upper surface 2'e of the upper part 2' so as to hold the elements together.

It should be remarked furthermore that the actual structure of the injector prevents any interference in the adjustment of the initial and in the residual gap of the clamping stresses exerted by the fitting of the injector on the cylinder head, which stresses are considerable by reason of the very high combustion pressures in Diesel engines. As a matter of fact, said stresses are transmitted by the extension 2'b of the upper part 2 to the shoulder 6'f of the lower part and thence directly to the bearing surface of the nut 21. Consequently, neither the stationary armature 3 nor the shim 10, nor the stay 5, nor even the lower part 6' are submitted to the clamping stresses and therefore no deformation is to be feared and no undesired compression of the shim 10 and of the stay 5 can appear, so that no uncontrollable modifications in the initial or residual gap can appear during the clamping operation. Our improved injector shows thus accurate, always reproducible features which cannot be affected by subsequent assembling or the like operations or by wear and the gauging of the injectors if required may be restricted to slight corrections of the characteristic data, as provided for instance by individual modifications of the signals controlling the different injectors or else by acting on the adjusting screw 23, so as to modify the preliminary stressing of the spring urging the needle valve back.

What we claim is:

1. An electromagnetic fuel injector comprising an injector body having first and second parts, stationary electromagnetically responsive armature means located in one part of said body and movable electromagnetically responsive armature means located in the other part of said body, means for mounting the stationary armature means with respect to movable armature means with opposing surfaces of both said armature means in an electromagnetically active relationship with a predetermined gap therebetween, needle valve means in said other part of said body, means for coupling said needle valve means to said movable armature means to move the former as the latter moves, electrical terminals in said body for supplying electrical energy to said stationary armature means to produce electromagnetic lines of force and thereby cause said movable armature means and said valve means to move, said body formed with a fuel input connection in one part thereof and an exit port at said other part thereof adjacent said needle valve which is opened and closed by the movement of said needle valve, and means for directing the flow of fuel from the input connection to the exit port, said directing means passing the fuel through the cooperating surfaces of the stationary and movable armature means and forming a hydraulic film to prevent the contact of the opposing surfaces of said two armature means when in their closest position produced by the electromagnetic lines of force.

2. An electromagnetic fuel injector as in claim 1 wherein said stationary armature means comprises a plurality of spaced arms having surfaces which face the movable armature, said arms separated by spaces formed in said one part of said body through which the fuel flows, said means for directing the fuel to form said hydraulic film comprised at least in part by said spaces.

3. An electromagnetic fuel injector as in claim 2 wherein there are three arms on the stationary armature which are generally parallel to each other, said spaces formed as a respective groove separating a pair of arms, said body also formed with recesses connecting the ends of said grooves to form a rectangular shape, said means for directing including said rectangular shape, the area of said rectangular shape with reference to the cross section of the movable armature producing equilibrium between the hydraulic and magnetic forces of the injector when the opposing faces of the two armature means are at their closest position.

4. An electromagentic fuel injector as in claim 3 further comprising means for supplying a mechanical biasing force to said movable armature means, the cross section of said rectangular shape also being such to produce equilibrium to overcome the force provided by said biasing means.

5. An electromagnetic injector as in claim 1 wherein said needle valve has an internal bore and its outer surface slidingly engages said other part of the injector body and terminates with a seat which closes said exit port, a transverse pin passing through a hole in the wall of the needle valve, a return spring located in the bore in the needle valve held between one end of the bore and said pin, and a bearing member between said spring and said transverse pin.

6. An electromagnetic fuel injector as in claim 2 wherein said movable armature means is also formed with an axial opening which is part of said means for directing the fuel to form the hydraulic film.

7. An electromagnetic injector as in claim 1 wherein said one part of said injector body is separated from said other part by a shim defining the maximum between said opposing faces of said armature means and by a magnetic annular stay, a tubular casing for holding said two parts together the edges of which are folded back over said parts of said body to prevent excessive compression of the shim and stay.

8. An electromagnetic injector as in claim 7 further comprising means on said other part of said body for attaching the injector to an engine.

9. An electromagnetic injector as in claim 7 wherein the stationary armature means is mounted within a bore of said one body part, spring means acting be-

tween said stationary armature means and said one part of said body for producing contact between said stationary armature means, the shim, the stay and said other part of the body.

10. An electromagnetic fuel injector as in claim **7** further comprising a flange formed on the one of said parts of said body and a threaded section on the other of said parts, and a nut engaging said flange and said threaded section to produce a fluid tight connection.

11. An electromagnetic fuel injector as in claim **10** further comprising a strap engaging said nut for mounting said injector to an engine.

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