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[54] **ELECTROMECHANICALLY CONTROLLED FUEL INJECTION VALVE FOR INTERNAL COMBUSTION ENGINES**

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[51] **Int. Cl.²** ... **B05B 1/30;** F02M 41/16; F22B 1/02

[58] **Field of Search** ..... 123/32 AE, 32 V, 139 AT, 123/139 E; 239/585, 96

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[57] **ABSTRACT**

A fuel injection valve for use with internal combustion engines, especially Diesel engines, includes a valve needle cooperating with a valve seat to control the flow of fuel out of the valve injection orifice. The valve needle can be loaded in the closing direction of the valve by a main pressure spring exerting its force via a plunger which may be lifted by pressurized fuel. It is also loaded in the closing direction by a valve spring. A coaxial force equalizer piston opposes the hydraulic force tending to lift the valve needle from its seat. An electromagnet, when energized, exerts a valve-opening force on the force equalizer piston. The force of the main pressure spring is so great that, when pressurization of fuel ceases, it can overcome the force of the electromagnet and close the valve. An electric switch, actuated by the plunger, can control the energization of the electromagnet, alone or in combination with an electronic controller.

7 Claims, 4 Drawing Figures

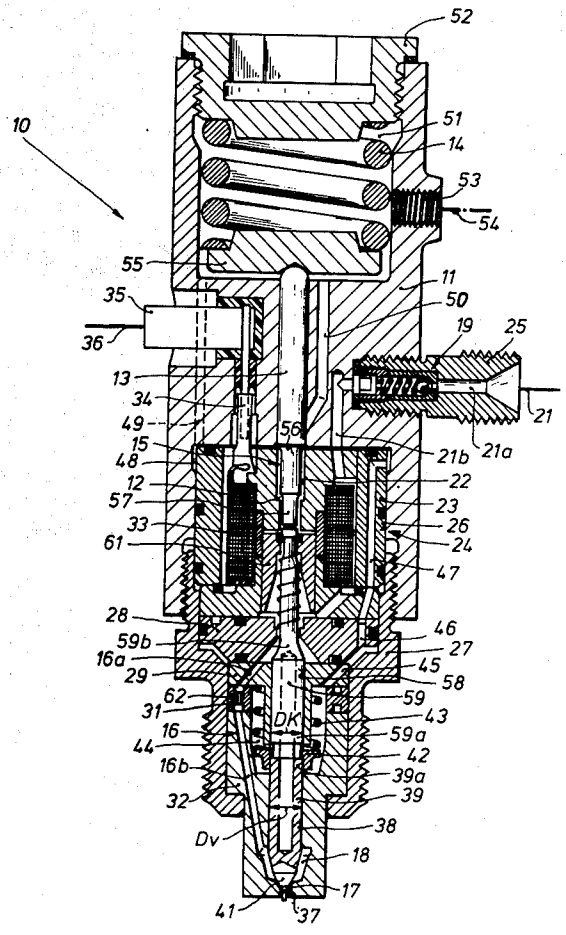


Fig.1

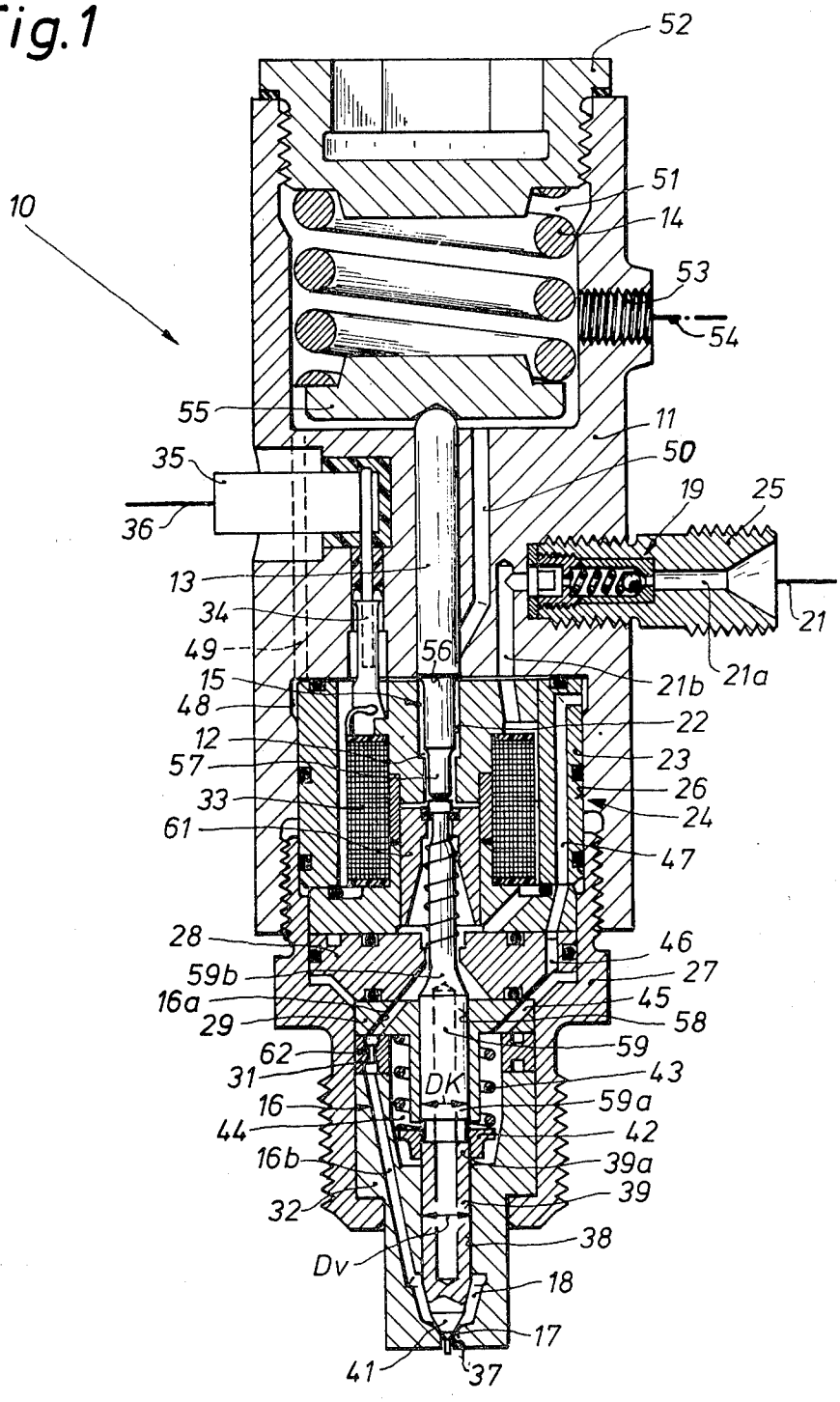
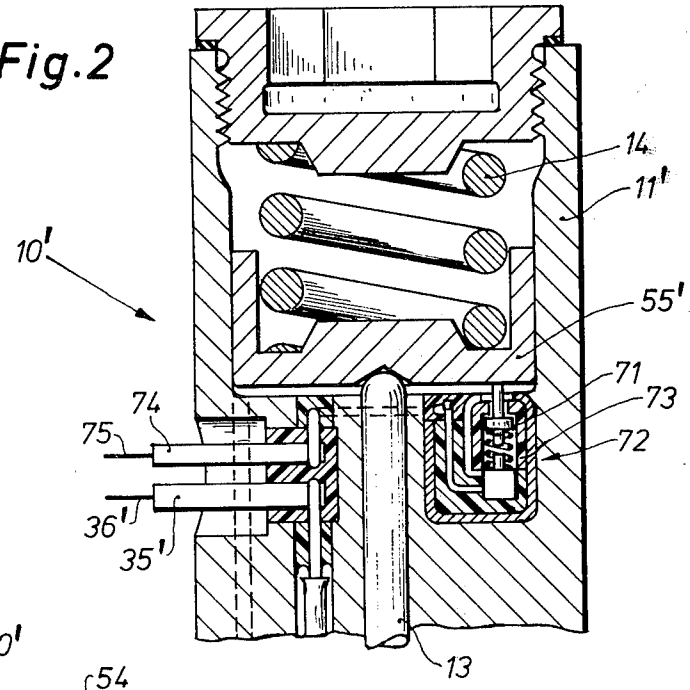

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Fig.2



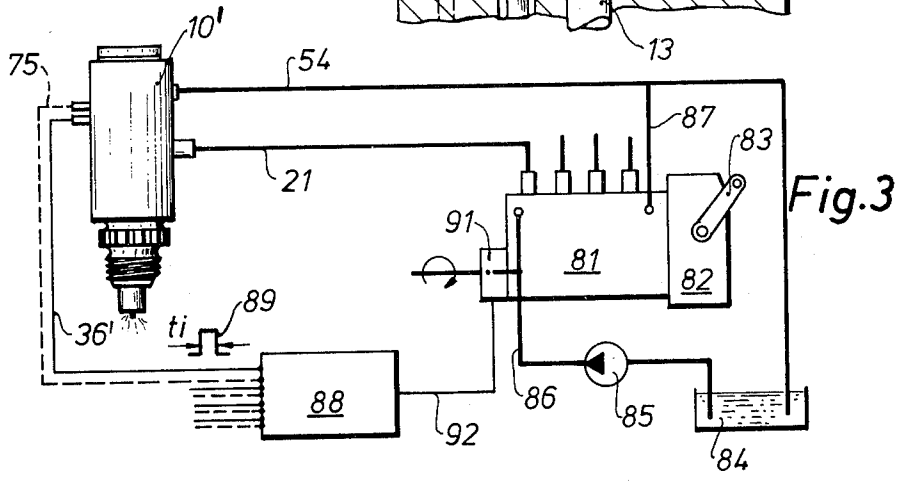
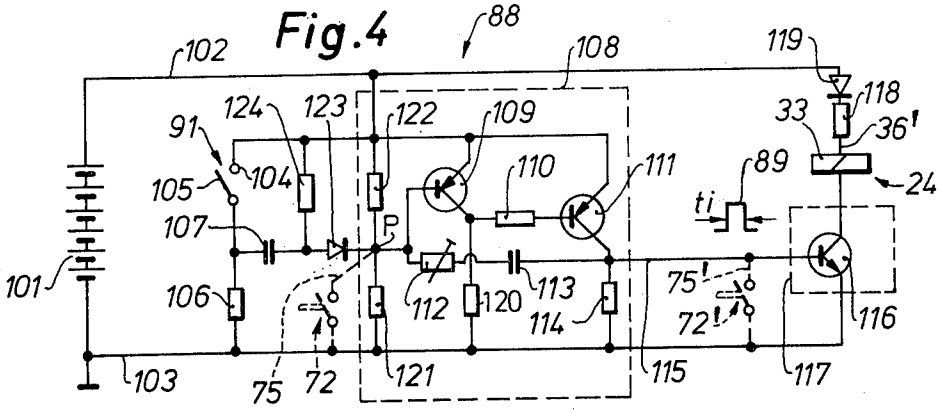


Fig.3

Fig.4



ELECTROMECHANICALLY CONTROLLED FUEL INJECTION VALVE FOR INTERNAL COMBUSTION ENGINES

BACKGROUND OF THE INVENTION

The invention relates to an electro-mechanically controlled fuel injection valve for internal combustion engines, especially for Diesel engines, of the type including an electro-mechanical converter, especially an electromagnet, controlling the onset of injection and further including a valve needle influenced by a valve spring and sealingly guided in a bore of a housing for the fuel injection valve. The closure element of the valve needle obturates a valve seat which controls the fluid flow through at least one nozzle orifice. The fuel injection valve further includes a fuel accumulation system whose accumulation space is connected through a pressure line to a pressure chamber located adjacent to the valve seat and it is also connected, through a check valve, to a fuel supply line through which a metering pump delivers the correct amount of fuel required for each operating cycle into the accumulation space.

The electromechanical converter used and described in the present invention for the control of the onset of injection is an electromagnet (solenoid), although other electromechanical converters may be used, e.g. piezoelectric or magnetostrictive converters.

Fuel injection valves of the type of construction described above are especially suitable for fuel injection processes employing very high injection pressures because they permit the control of the onset of injection within a wide rpm domain without necessitating expensive and mechanically highly stressed parts. In these known fuel injection valves, the electromagnet which controls the onset of injection operates a valve slide disposed in the pressure line between the fuel accumulation system and the pressure chamber of the injection nozzle. The fuel pressure acts on the shoulder of the valve needle against the force of the valve spring to open the nozzle orifice but the opening is delayed with respect to the opening control pulse because of the response delay of the electromagnet, the time taken by the valve slide to traverse its control path and because of the throttling effect at the control apertures. In addition, this delay is very dependent on manufacturing tolerances, so that the simultaneous adjustment of all the injection valves in a multicylinder, fuel-injected engine to the same setting is very difficult.

The disadvantages of indirect, i.e. hydraulic actuation of the valve needle could be obviated by direct actuation of the valve needle by the electromagnet. Such injection valves have already found use in very large numbers in gasoline injection systems. But they are not suitable for fuel injection at very high injection pressures (up to 1000 bars), because, in these known valves, actuation of the valve needle requires the electromagnet to overcome a closing force which depends both on the area of the valve seat and on the fuel pressure and may necessitate very powerful electromagnets. Such magnets would require a large space and lead to difficulties of assembly and their current consumption would be excessively high when used, for example, in motor vehicles. Furthermore, the known apparatus creates difficulties due to the time behavior of the injection process. Research conducted with a view to improving the exhaust gas characteristics in Diesel engines has shown that the characteristic time behavior of the injection process, i.e. the time of occurrence of the onset and the termination of fuel injection, greatly influences the combustion process and hence also the formation of toxic components in the exhaust gases.

OBJECT AND SUMMARY OF THE INVENTION

It is an object of the invention to provide an electromechanically controlled fuel injection valve which does not suffer from the above described disadvantages and which opens the nozzle orifices with the least possible delay and permits a rapid termination of the closing stroke. It is a further object of the invention to provide for external influence on the time behavior of the injection process.

This object is achieved, according to the invention, by equipping the fuel injection valve with a force equalizer piston, disposed coaxially with the valve needle within the valve housing and in sealing connection with a coaxial bore thereof. The electromechanical converter is provided with an actuating member which is in operative connection with the valve needle via the force equalizer piston.

One end of the force equalizer piston is pressure-relieved and the other end is acted upon by the fuel pressure prevailing in the accumulation space of the fuel accumulation system. The effective cross-sectional area of the force equalizer piston is so dimensioned that, when the valve seat is closed, the hydraulic forces acting on the valve needle in the opening and closing directions, respectively, are equal or at least approximately equal.

Finally, the forces acting on the valve needle in the closing direction can be increased by a supplemental force which is at least mediately exerted by a control plunger when it arrives in its starting position at the termination of the injection cycle.

Due to the above described combination of characteristics, the electromechanical converter requires only a very simple control circuit for the opening actuation of the valve needle. When the injection valve is closed, the hydraulic pressure acting on the valve needle is fully, or at least partially, compensated by the force equalizing piston and the termination of injection is triggered, independently of the opening control pulse, by the arrival of the control plunger in its starting position. This results in a very reliable and rapid operation even at very high injection pressures such as are required for the direct injection of fuel into Diesel engines. A particularly advantageous characteristic of the invention provides that the control plunger is coaxial with the valve needle, the force equalizing piston and the actuating member of the electro-mechanical converter, and that it is operatively coupled to the valve needle, at the very latest when it reaches its starting position, and presses the valve needle onto its valve seat. This disposition insures rapid closure of the valve because the elements of the fuel accumulation system are in mechanical contact with the valve needle at the termination of injection and since, due to the high injection pressures, they are loaded by a very great spring force.

A particularly advantageous further development of the invention provides a throttle, located in the pressure line, between the accumulation space and the pressure chamber. The restrictive effect of this throttle can change the pressure in the pressure chamber when

the valve seat is open and this effect is exploited to make the force then acting on the valve needle in the opening direction at least approximately equal to the force acting on the valve from within the same pressure chamber when the valve seat is closed. Fuel flowing through this throttle during the injection process results in a pressure drop which opposes a supplementary hydraulic force that is present when the valve is open and that acts in the opening direction of the valve. This supplementary force is due to a larger effective cross-section of the valve needle when the valve seat is open. Thus, the effective forces are compensated both dynamically as well as statically.

A still further advantageous development of the object of the invention provides that, when the control plunger reaches its starting position at the termination of the injection cycle, it actuates an electrical switch which, directly or indirectly, interrupts the current to an electromagnet serving as an electromechanical converter. Thus, no electromagnetic force opposes the closure motion of the valve needle, i.e., the closure motion is enhanced and the current requirement of the electromagnet is reduced without necessitating a complicated electrical circuit for controlling the timed switching of the electromagnet as a function of the injected fuel quantity. The invention will be better understood, as well as further objects and advantages will become more apparent, from the ensuing detailed specification of two exemplary embodiments taken in conjunction with the drawing.

BRIEF DESCRIPTION OF THE DRAWING

The drawing consists of four figures of which FIG. 1 is an axial cross-section of a first exemplary embodiment of the electromechanically controlled fuel injection valve according to the invention.

FIG. 2 is a section through the upper portion of a second exemplary embodiment of the fuel injection valve according to the invention, showing the region of the fuel accumulation system.

FIG. 3 is a schematic block diagram of a fuel injection system equipped with the fuel injection valve according to the invention.

FIG. 4 is a circuit diagram of an electronic control system for the electromagnet of the second exemplary embodiment of the fuel injection valve according to the invention and shown in FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Turning now to FIG. 1 relating to the first preferred embodiment of the object of the invention, the fuel injection valve **10** illustrated therein has a housing **11** which contains a fuel accumulation system **15** consisting substantially of an accumulation space **12**, a control plunger **13** (henceforth called plunger **13**), and a compressed pressure spring **14**. The accumulation space **12** communicates, through a pressure line **16**, consisting substantially of regions **16***a* and **16***b*, with a pressure chamber **18**, located adjacent to a valve seat **17**. The accumulation space **12** also communicates, through a fuel supply line **21** and a check valve **19**, with a fuel metering pump (see also below in reference to FIG. 3) which delivers the quantity of fuel required for each injection cycle to the accumulation space **12**.

The term accumulation space **12** is used to refer specifically to the space formed by a graduated bore **22** in the center of a multipartite housing **23** of an electromagnet **24**, because this space changes its volume, depending on the fuel quantity admitted and to the degree that the plunger **13** moves upwardly against the force of spring **14**. Precisely state, the accumulation space is formed by the entire interior volume of the fuel injection valve **10** lying between the check valve **19** and the valve seat **17**. In both exemplary embodiments, the electromagnet **24** serves as an electromechanical converter and, without going beyond the essential characteristics of the invention, the electromechanical converter could be replaced by a piezoelectric or magnetostrictive actuating mechanism.

The check valve **19** is inserted in a threaded boss **25** which is screwed into the housing **11**. The part of the fuel supply line contained within the threaded boss **25** is designated **21***a* and the part of the fuel supply line located within the housing **11** is designated **21***b*.

The housing **23** of the electromagnet **24** is inserted into a bore **26** within the housing **11** and is made pressure-tight therewith by means of a threaded bushing **27**. The threaded bushing **27** also serves to fasten an intermediate plate **28**, a guide block **29**, an intermediate ring **31** and a nozzle body **32** to the housing **11** in a pressure-tight manner. The winding **33** of the electromagnet **24** is electrically connected through plug connections **34** with two connector vanes **35** cast in the housing **11** to which a connector cable, suggested by the line **36**, may be electrically coupled. The nozzle body **32**, which includes the valve seat **17** and the pressure chamber **18** has a nozzle orifice **37**, located beneath the valve seat **17** and facing the combustion chamber (not further shown) of the internal combustion engine. The nozzle body has a guide bore **38** above the pressure chamber **18** in which a lapped-in valve needle **39** slides in fluid-tight manner. The valve needle **39** is hollow to reduce its mass and has a conical tip **41** serving as the closure member when cooperating with the valve seat **17**. The effective diameter of the valve needle in the region of the guide bore **38** is designated by D*v*. The end **39***a* of valve needle **39** remote from valve seat **17** extends beyond the guide bore **38** and forms an abutment shoulder for a spring support ring **42**, supporting a valve spring **43** whose other end rests on the guide block **29**. Thus, the closure member **41** of the valve needle **39** is pressed against the valve seat **17** and closes it. A main spring chamber **44** which surrounds the valve spring **43** and the spring support ring **42** is pressure-relieved and communicates with a space **51** containing the pressure spring **14**. This communication is established by a bore **45** within the guide block **29**, a connecting bore **46** in the intermediate plate **28**, a bore **47** within the housing **23** of the electromagnet **24**, an annular groove **48** and an axial bore **49** (shown in broken lines within the housing **11**. The space **51** containing the pressure spring **14** is closed by a threaded plug **52** which also serves as a counter bearing for the pressure spring **14**. The wall of the housing **11** is penetrated by a fuel return bore **53** to which a fuel return line **54** may be connected. The mechanical connection between the plunger **13** and the pressure spring **14** is established by a spring support plate **55**.

The plunger **13** has an edge **56** which so cooperates with an overflow bore **50** that fuel in excess of a maximum permissible quantity can escape through the bore **50** into the space **51** and thence through the fuel return line **54** back to the fuel tank (see also FIG. 3). For ex-

ample, an excess fuel quantity, exceeding the maximum permissible amount, might be delivered into the accumulation space **12** when the predelivered fuel quantity is not actually injected because of malfunctions in the electrical circuits or at the valve needle. The end of the plunger **13** remote from the pressure spring **14** is a cylindrical stud **57**. Adjacent thereto, a force equalizer piston **59**, henceforth called equalizer piston **59**, is disposed within the bore **58** of the guide block **29** which is part of the valve housing **11**. FIG. **1** shows the plunger **13**, the equalizer piston **59** and the valve needle **39** in a position in which the force of the pressure spring **14** holds them in positive operational contact. When fuel is predelivered to the accumulation space **12**, the plunger **13** is lifted off from the end face of the equalizer piston **59**, against the force of the pressure spring **14** to an extent which corresponds to the volume of the predelivered fuel quantity. However, during this motion, the equalizer piston **59** and the valve needle **39** are still held in mutually positive operational contact due to the fuel pressure acting upon them. A downward force acts on the equalizer piston **59**, i.e., a force directed toward the valve seat **17** and an opposite force acts on the valve needle **39**, i.e., a force directed away from the valve seat **17**. These forces keep both elements in positive operational contact because the spring chamber **44** is pressure-relieved, as has already been described. The effective cross-sectional area of the equalizer piston **59**, corresponding to its diameter DK, is made equal to the effective annular area of the valve needle which is acted upon by fuel pressure in the direction of opening. This annular area is equal to the difference between the cross-sectional area of valve needle **39**, corresponding to the diameter DV and the cross-sectional area of the valve seat **17**.

Thus, the hydraulic forces acting upon the valve needle **39** in the opening and in the closing direction are equal and, after the predelivery of fuel, when the plunger **13** no longer makes contact with the equalizer **59**, the only force urging the valve needle **39** with its valve cone **41** onto the valve seat **17** is the force exerted by the valve spring **43**. Thus, an armature **61**, acting as the operating member of the electromagnet **24**, is able to attract the equalizer piston **59** and hence also the valve needle **39** when the electromagnet **24** is energized, opening the valve seat **17** and creating a communication between the pressure chamber **18** and the nozzle orifice **37**. The end **59*a*** of the equalizer piston **59** adjacent to the valve needle **39** is pressure-relieved since it extends into the spring chamber **44** which, as has already been described, communicates with the fuel return line **54**. The other end **59*b*** of the equalizer piston **59** is acted upon by the fuel pressure prevailing in the accumulation space **12** of the fuel accumulation system **15**. This end **59*b*** carries the armature **61** of the electromagnet **24**.

A throttle **62** is disposed between the two sections **16*a*** and **16*b*** of the fuel pressure channel **16**. The throttle reduces the pressure in pressure chamber **18** when the valve seat **17** is open so that the force then acting within pressure chamber **18** on the valve needle **39** in the direction of opening is made at least approximately equal to the force acting in the same direction and in the same location when the valve seat **17** is closed. The throttle **62** is a restricted bore within the intermediate ring **31** and forms the only communication between the accumulation space **12** and the pressure chamber **18**.

As previously described, the throttle **62** is so dimensioned that the pressure drop at the throttle **62** compensates for the additional force acting on the valve needle **39** in the opening direction of the valve when the valve seat **17** is open, so that the same hydraulic forces act on the valve needle **39** whether the valve is open or closed. In order to achieve a more rapid opening or closing of the valve needle **39**, it may be desirable to provide a small excess force either in the direction of opening or closing. Thus, the disposition of throttle location **62** has made possible a so-called dynamic force equalization in addition to the static force equalization performed by the equalizer piston **59**.

This dynamic force equalization is not always necessary in the present construction because the plunger **13**, loaded by the very great closing force of pressure spring **14**, mechanically presses the valve needle **39** onto its valve seat **17** via the equalizer piston **59** when the predelivered fuel quantity has been injected, so that the throttle **62** could be dispensed with. However, the throttle is necessary in a different embodiment of the invention (not shown) in which the plunger **13** does not have a mechanical connection with the valve needle **39**. Such a design would have the advantage, among others, that the fuel accumulation system **15** would not have to be disposed coaxially with the valve needle **39** and the equalizer piston **59**, but, instead, could be installed in any suitable manner. The great supplementary force exerted by the plunger **13** after it has returned to its starting position at the termination of the injection cycle as shown in FIG. **1**, is capable of pressing the valve nnedle **39** and its closure member **41** onto the valve seat **17** even when the electromagnet **24** is energized. The special advantage of this design is that the electromagnet **24** may be controlled by a controller which produces control pulses of fixed duration. Such a controller is substantially simpler and cheaper to manufacture than one which produces pulses of a particular, precisely determined duration which are required for Diesel fuel injection due to the very short injection times of the order of 1 millisecond.

FIG. **2** is an illustration of a second exemplary embodiment of the fuel injection valve according to the invention in a partial section showing those parts which are different from those shown in FIG. **1**. Identical parts retain the same reference numerals and the sectional plane of the right half of the Figure is rotated by 120° with respect to that shown in FIG. **1**. The plunger **13** is shown here also in its starting position which it occupies at the termination of the injection cycle. A spring support plate **55′** touches a contact pin **71** belonging to an electrical switch **72** located in the valve housing **11′** of the fuel injection valve **10′**. The contact pin **71** is guided in an insulating sleeve **73** and is in electrical connection with a contact vane **74** to which a line **75** is connected. The contact pin **71** is spring-loaded and its length determines when the spring support plate **55′** touches it. The spring support plate **55′** is connected to ground through the pressure spring **14** and, when the spring support **55′** makes contact with pin **71**, the current supply to the electromagnet **24** is indirectly interrupted. The mechanism for current interruption will be described below with reference to FIG. **4**. The winding **33** of the electromagnet **24**, shown in FIG. **1** but not further shown in FIG. **2**, is connected via contact vances **35′** with connecting lines **36′**, of which

only one is shown here. Thw switch **72** shown in FIG. **2** represents only one of many possible types.

The block diagram of FIG. **3** shows the fuel injection valve **10'** and a fuel injection pump **81** serving as a fuel metering pump. The fuel injection pump **81** is a known four-cylinder serial injection pump having a mechanical centrifugal rpm governor **82** whose operating lever **83** predetermines the fuel quantity to be delivered by the injection pump **81** if it is a feed governor or whose operating lever **83** presets an rpm to be maintained. The fuel supply line **21** leading to the fuel injection valve **10'** is at the same time the so-called pressure line of the injection pump **81.** The excess leakage fuel is returned from the fuel injection valve **10'** through the fuel return line **54** to a fuel reservoir **84.** The fuel required by the fuel injection pump **81** is delivered in a known manner by a predelivery pump **85** and a delivery line **86** to the suction chamber of the fuel injection pump **81** and excess fuel is returned through a line **87** and the fuel return line **54** to the fuel reservoir **84.** An electronic controller **88** is coupled to the fuel injection valve **10'** by the connector line **36'** and is further described with reference to FIG. **4.** The electronic controller **88** is also connected to the fuel injection valve **10'** through the control line **75.** The controller **88** generates control pulses **89** which, in the case of controlling the fuel injection valve **10** according to FIG. **1,** have a constant duration *ti.*

In the embodiment represented in FIG. **3,** the pulse duration is adapted to the injected fuel quantity by the switching pulse triggered by switch **72** (see FIG. **2**) which is fed through line **75** to the controller **88.** The onset of fuel injection is initiated by an angle-of-rotation sensor **91** which is preferably mounted on the shaft of the fuel injection pump **81** and which connects through line **92** with the electronic controller **88.** In order to permit an rpm-dependent shift of the onset of injection, it is advantageous if the angle-of-rotation sensor **91** is combined with an rpm-sensor and if both respective signals are fed to the electronic controller **88.**

FIG. **4** is a schematic diagram of the electronic controller **88** which obtains its operating voltage from a starter battery **101** through a positive conductor **102** and a negative conductor **103.** The controller **88** is triggered by a signal generator embodied as an angle-of-rotation sensor **91** and coupled to the cam shaft of the injection pump **81** (see FIG. **3**). The sensor **91** is represented in FIG. **4** by a switch contact **104** and a switching element **105.** The switching element **105** is connected through a resistor **106** to the negative conductor **103** and is also connected with one of the electrodes of a differentiating capacitor **107.**

The control pulses **89** are generated in the controller **88,** here embodied as a transistorized switching system, by a monostable control multivibrator **108,** which includes a normally conducting input transistor **109** whose collector **109** is connected through a resistor **110** to the base of a normally non-conducting output transistor **111,** and further includes a timing circuit which determines the appropriate pulse duration *ti.* In the multivibrator **108,** which is to be regarded merely as an exemplary embodiment, this timing circuit consists of a resistor **112** and a capacitor **113** which are connected in series between the base of transistor **109** and the collector of transistor **111.** In addition to being coupled to the capacitor **113,** the collector of the output transistor **111** is connected through a resistor **114** with the negative conductor **103** and also, through a control line **115,** to the base of a power transistor **116** which is the essential element of a power stage **117.** The power stage **117** is preceded in a known manner, not further described, by an intermediate amplifier inserted in the control circuit **115.** One side of the winding **33** of the electromagnet **24** is connected through a resistor **118** and a diode **119** to the common positive conductor **102** and the other side of the winding is connected to the collector of the power transistor **116.** The emitter of the power transistor **116** is connected to the negative conductor **103** although other conducting elements connected to ground could replace the negative conductor.

The timing capacitor **113,** the resistor **112,** which is preferably adjustable for setting the pulse duration *ti* and the base of the input transistor **109** of the multivibrator **108** are all connected to the junction P of two resistors **121** and **122** which are disposed as voltage dividers between the negative conductor **103,** connected to ground, and the common positive conductor **102.** Both transistors **109** and **11** are of the pnp type and their emitters are connected to the positive conductor **102.** Whenever the angle-of-rotation sensor **91** generates a switching pulse, which, in the present example, corresponds to closing the switch **104, 105,** the multivibrator **88** is switched into its unstable state whose duration corresponds to the pulse width *ti* which, in turn, depends on the timing elements **112, 113.** In order to permit blocking the input transistor **109** at triggering time, the capacitor **107** is connected through a diode **123** to the base of the input transistor **109** and also, through a load resistor **124,** to the positive conductor **102.** As long as the switch **104, 105** is open, the differentiating capacitor **107** can charge up, and when switch **104, 105** closes, it can deliver its charge for the purpose of blocking the input transistor **109.** As soon as the input transistor **109** blocks, the output transistor **111** goes over into its conducting state. The exponentially increasing collector current within transistor **111** produces a feedback voltage in the timing elements **112,** 113, which keeps the input transistor **109** blocked beyond the closing time of switch **104, 105** until the feedback voltage falls below a value determined by the potential at point P of the voltage divider **121, 122.** When this voltage is reached, the input transistor **109** returns to its initial, conducting state. The pulse *ti* for opening the injection valves is indicated by the numeral **89** and is generated during the conducting state of the output transistor **111.**

The electromagnetically controlled fuel injection valve shown in FIG. **1** requires only a fixed pulse duration *ti* to determine the energization time of the electromagnet **24** and this time is always larger than or at least as large as the longest possible injection time. The second exemplary embodiment of the invention, shown in FIG. **2,** contains the switch **72** which, when closed, as indicated by broken lines in FIG. **4,** connects point P of the voltage divider circuit and, hence, the base of the input transistor **109** through control line **75** to the negative conductor **103.** This shortens the pulse duration *ti* and adapts it to the duration of injection which not only reduces the current consumption, but it also reduces the force required to close the injection valve **10'.**

Another possible circuit for the switch **72** is indicated in broken lines by the numeral **72'**, where it is shown connected, through a control line **75'**, to the control circuit **115** and to the base of the power transistor **116** and thus, when closed, it connects the base of this transistor to the negative conductor **103.**

The method of operation of the fuel injection pump according to the invention will now be described with the aid of the drawing. The block diagram of FIG. **3,** which is intended to be used with the secondary exemplary embodiment can also be used with the first exemplary embodiment according to FIG. **1** if the injection valve **10'** is replaced by the injection valve **10** according to FIG. **1,** and the connecting line **36'** is replaced by the connecting line **36.** The first exemplary embodiment according to FIG. **1** contains no control line **75.**

The fuel injection valve according to FIG. **1** is supplied with fuel by the fuel injection pump **81** which delivers a quantity of fuel that is precisely adapted to the operational state of the engine and is set by the centrifugal rpm-governor **82** (see FIG. **3**). The fuel is predelivered to the accumulation space **12** below the plunger **13.** During this predelivery, the plunger **13** is displaced upwardly and compresses the pressure spring **14** serving as a storage spring. The fuel pressure prevailing in the accumulation space **12,** and hence also in the pressure chamber **18,** is determined by the degree of compression of the pressure spring **14** and this pressure acts on the valve needle **39,** in both the opening and the closing directions. Now, the diameter DK of the force equalizer piston **59** is so dimensioned that the effective cross section of that piston **59** is equal to the annular cross section of the valve needle **39** which is subjected to the fuel pressure in the pressure chamber **18.** This annular cross section is defined, on the one hand, by the diameter D*v* of the valve needle **39** and, on the other hand, by the diameter of the valve seat **17.** Thus, a complete equalization of forces is achieved, i.e., the forces, due to the fuel pressure, which act on the valve needle **39** in the opening and closing directions, respectively, are equal. Intentional, small deviations from these fixed diameters can serve to produce a supplementary force for acceleration the opening or closing motion of the valve member. The electromagnet **24** needs to overcome only the force of the valve spring **43** and, since the hydraulic forces are equalized, the force of this spring **43** is relatively small. Thus, the electromagnet **24** may also be relatively small and still able to effect a rapid opening of the valve. When the controller **88** (see FIG. **4**) produces a control pulse **89,** the electromagnet **24** acts via its armature **61** and the force equalizer piston **59** to attract the valve needle **39** which is held in operative connection with the force equalizer piston **59** by fuel pressure. This motion opens the valve seat **17** and the fuel which was predelivered to the accumulation space **12** and the pressure chamber **18** can be injected through the nozzle orifice **37** into the compression chamber of the engine which is not further shown. At the termination of the injection cycle, the plunger **13** returns to its starting position as drawn in FIG. **1,** and its end **57,** under the influence of the pressure spring, again presses down on the force equalizer piston **59** and hence also on the valve needle **39,** forcing it back onto the valve seat **17,** which is thereby closed. This closure process prevents a slow closing of valve needle **39** which might result in dribbling of fuel into the combustion chamber of the engine. Since the pressure spring **14** determines the injection pressure, it is very highly precompressed and its closing force is so great that the closing motion is very rapid and is not impeded by the still-energized electromagnet **24.** This results advantageously in a very rapid closure process and makes a precise, timed control of the energization time of the electromagnet unnecessary. This latter advantage is especially significant because it is extremely difficult to produce the required switching times which, for Diesel engine injection, lie in the region from 1 to 3 milliseconds, by means of electronic control. Furthermore, the predelivery of fuel by the injection pump guarantees that, even during malfunctions of the control electronics, the injected fuel quantity will never be greater than that which has been predelivered. The force of the pressure spring **14** is so great that it is able to return the valve onto its seat **17** in spite of the additional hydraulic force acting in the opening direction which occurs due to the additional effective surface of the valve needle **39** which is subjected to fuel pressure when the valve is open.

This above-mentioned additional force acting in the opening direction is not effective, however, in the exemplary embodiment of the fuel injection valve according to FIG. **1,** because a throttle **62** is inserted between the sections **16***a* and **16***b* of the pressure line **16,** i.e. between the accumulation space **12** and the pressure chamber **18.** When the injection valve is open, this throttle reduces the fuel pressure in the pressure chamber **18** with respect to the pressure prevailing in storage space **12** so that the hydraulic force which now acts upon the entire cross-sectional area of the valve needle **39,** corresponding to the diameter D*v*, is equal to the force which had acted on the previously described annular cross section which is effective when the valve is closed. This results in a dynamic equalization of forces so that the closure of the valve needle **39** does not require additional force. In the second exemplary embodiment of FIG. **2,** the injection process is changed only in that, at the termination of the injection cycle, the plunger **13,** when returning to its starting position shown in FIG. **2,** actuates the switch **72** via the spring support plate **55'**. The switch **72** then delivers a control pulse through line **75** to the electronic controller **88,** shortening the pulse duration *ti* of the control pulse **89,** i.e., more exactly, it terminates the energization time of the electromagent **24.** The interaction of the control pulse with the electronic controller can occur in many different ways and two examples thereof have already been described with reference to FIG. **4.**

What is claim is:

1. In an electromechanically controlled fuel injection valve for internal combustion engines, especially Diesel engines, including a valve housing, an electromechanical converter, especially an electromagnet, mounted within said housing for controlling the onset of fuel injection, means forming part of the housing and defining a valve seat communicating with at least one nozzle orifice and a fuel pressure chamber located near the valve seat, a valve spring, a valve needle sealingly guided within the valve housing and loaded by the valve spring for closing off the valve seat, and a fuel accumulation system, the fuel accumulation system including means defining an accumulation space, a displaceably mounted accumulation plunger, elastically yielding means for controlling the displacement of the accumulation plunger, and a fuel supply line connected to a

fuel metering pump and to the fuel pressure chamber wherein the accumulation space communicates with the fuel supply line and with the fuel pressure chamber, the improvement comprising:

a force equalizer piston;

means defining a bore within the valve housing within which said equalizer piston is sealingly and displaceably disposed coaxially with said valve needle, and in positive operational connection therewith; and

an actuating member responsive to the energization of the electromagnet and in positive operational connection with said force equalizer piston;

whereby the accumulation plunger and the elastically yielding means are disposed with the valve housing;

whereby said valve needle and said force equalizer piston are so dimensioned that, when said valve seat is obturated, the hydraulic force acting on said valve needle tending to open said valve seat is at least approximately equal to the force acting on said valve needle tending to obturate said valve seat and

whereby the force acting on said valve needle tending to obturate said valve may be augmented by a force exerted mediately by said accumulation plunger on said valve needle.

2. An improved fuel injection valve as defined in claim **1,** wherein said accumulation plunger is disposed so that its axis is an extension of and parallel with the axes of said valve needle, said force equalizer piston, said actuating member, and is so disposed that it can establish a positive operational connection with said valve needle to urge said valve needle onto said valve seat.

3. An improved fuel injection valve as defined in claim **2,** further comprising a throttle, located between said accumulation space and said fuel pressure chamber, whereby the force acting on the valve needle tending to open said valve seat when said valve seat is obturated is rendered approximately equal to the force acting on the valve needle tending to open said valve seat when said valve seat is open.

4. An improved fuel injection valve as defined in claim **1,** further comprising a throttle, located between said accumulation space and said fuel pressure chamber, whereby the force acting on the valve needle tending to open said valve seat when said valve seat is obturated is rendered approximately equal to the force acting on the valve needle tending to open said valve seat when said valve seat is open.

5. An improved fuel injection valve as defined in claim **1,** further comprising an electric switch, disposed within the valve housing, whereby said accumulation plunger actuates said electrical switch and interrupts the current to said electromechanical converter.

6. An improved fuel injection valve as defined in claim **5,** further comprising, in combination, a controller containing at least one switching transistor for controlling the timing of the energization of said electromagnet, wherein said electric switch is connected to the base of said at least one switching transistor in said controller.

7. An improved fuel injection valve as defined in claim **5,** further comprising, in combination, a controller containing at least one power transistor connected in series with said energizing winding of said electromagnet, wherein said electric switch is connected to the base of said at least one power transistor.

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