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EP 0 364 147 B1

Description

This invention relates in general to a fuel injection system for an automotive type internal combustion engine. More particularly, it relates to the construction of a fuel injector in which fuel and air or other gas are premixed in a chamber in the injector prior to being discharged into the engine combustion chamber, a dwell period being provided prior to the injection so as to allow for mixing and, in the case of a liquid fuel, for evaporation of the fuel charge in contact with the gas, resulting in a premixed, rich fuel/air charge that is injected with the fuel at least partially in a gaseous state.

A fuel injector of this kind is known from US-A-1,560,025, which discloses a fuel injector assembly including a hollow body having a main fuel/gas mixing chamber open at both ends and ventable to ambient pressure so as initially to contain a gas at essentially ambient pressure, a control valve normally closing one end of the chamber as well as an outlet from the body and actuatable to an open position to permit ejection of a fuel/gas mixture from the chamber and body, a first source of fuel and a second source of gas under pressure each separably connectable to the chamber through the body, and means movable between open and closed positions for controlling admission of each of the sources to the chamber, the latter means being movable in a manner to first admit fuel to the chamber for mixing with the gas therein and after a time delay to admit the gas under pressure to the chamber to further mix the fuel and gas in the chamber and eject the mixture from the chamber body. In this injector the fuel is introduced adjacent the control valve and opening and closing of the inlets and outlet is effected mechanically by an externally actuated piston valve arranged to couple the opening and closing of respective openings.

The premixing of fuel and air or gas in an injection system is also known from other prior proposals. For example, Igashira et al, US-A-4,465,050 discloses a manifold injector system including an air pump and a fuel pump which deliver their respective fluids to an injector having a single pulsed solenoid that controls only fuel flows, air being controlled by a separate valve. The air and fuel pulses are simultaneous, however, and there is no dwell period after the fuel and air are introduced together to permit time for the fuel to evaporate before being injected into the engine.

McKay, US-A-4,554,945, shows a construction in which fuel is first introduced into a metering chamber and then air is admitted by a solenoid and air pressure to close the fuel inlet and outlet ports. However, again, there is no mixing of the air and fuel with a timed delay sufficient to permit evaporation of the fuel and further mixing prior to

injection into the engine.

Tsummura et al, US-A-4,381,077, provides an injector wherein air is introduced simultaneously with fuel and these are combined in a mixing chamber wherefrom they are displaced by a piston. While there is a mixing and a dwell period, the mixture is not displaced by engine compressed gas or air admitted to evaporate the fuel during the mixing process.

Sarich, et al, US-A-4,462,760, first fills a metering chamber with fuel and then displaces the fuel by means of pressurised gas. However, there is no dwell period for the evaporation of the fuel prior to subsequent injection into the engine.

BE-A-738,280 discloses apparatus for working materials in which the working pressure is generated by combustion of fuel in a cylinder, the fuel being first metered into an admission chamber of a mixer containing residual air under pressure from the previous cycle. An inlet valve from the mixer to the cylinder is opened, and the mixture of fuel with further air is forced into the cylinder by admitting further compressed air into the mixer. The inlet valve to the cylinder is then closed, leaving the mixing chamber containing compressed air.

It is an object of the invention to provide an improved apparatus for and method of injecting premixed fuel-air or fuel-gas mixtures into internal combustion engines.

According to the invention, in a fuel injection assembly as set forth in the preamble of claim 1 the fuel and gas sources are each connectable through the body of the injector to the end of the chamber remote from the control valve, the means for controlling the admission of fuel and gas are selectively operable and the control valve is opened by the admission of gas under pressure to the chamber to eject the mixture from the chamber and body.

These features, in combination with the separation of the admission of a metered fuel charge into the chamber of the injector and the injection of the charge into the engine by a time interval during which the fuel charge is in contact with air or gas and liquid fuel can evaporate, contribute to the injection of a premixed, rich fuel/air or fuel/gas charge in which the fuel is at least partially in the gaseous state.

According to a further embodiment of the invention an electrical control system is provided comprising driver circuits arranged to actuate the respective inlet valves for the supply of fuel and of gas/air to the injectors serving the respective combustion chambers of an engine so as to effect the supply to the injectors in a manner establishing a time interval between introduction of the fuel and discharge of the fuel/air or fuel/gas mixture into the combustion chambers.

In its process aspect the invention provides a method of supplying and discharging a fuel and gas mixture into and from an automotive type fuel injector that is biased to a closed position comprising the steps of, first, connecting a central chamber in the injector to gas at ambient pressure level, secondly, supplying the chamber with fuel at the end remote from its outlet to mix with the gas to form at least a partially combustible mixture charge, thirdly, holding the fuel/gas mixture charge in the chamber for a period sufficient to allow evaporation of the fuel and further mixing of the fuel and gas, and, fourthly, applying further gas to the chamber at a sufficient pressure level to enhance penetration of the gas into the fuel and evaporation of the fuel, the further gas being supplied at a sufficient pressure to cause a normally-closed outlet valve from the chamber to open and to effect discharge of the fuel/gas mixture charge from the injector.

The gas used to eject the mixture may be compressed air or compressed gas from an engine cylinder during its compression stroke. Subsequent to cessation of supply of the gas under pressure to the chamber and closure of the outlet valve the chamber should be vented to an ambient pressure level, and for this purpose the apparatus may include means for connecting the gas inlet to air or gas at ambient pressure.

Other features and embodiments of the invention are set forth in the sub-claims.

The invention will now be described further, by way of example, with reference to the accompanying drawings, in which :

Figure 1 is a cross-sectional schematic view of a fuel injector assembly embodying the invention, Figure 2 is a cross-sectional view taken on a plane indicated by and viewed in the direction of the arrows II-II of Figure 1,

Figure 3 is an enlarged cross-sectional view of a detail of Figure 1,

Figures 4, 5, 7 and 8 are schematic illustrations of fuel injection systems supplying both fuel and air to individual fuel injector assemblies embodying the invention; and

Figure 6 is a cross-sectional view of a gas charging assembly for use with the construction shown in Figure 1.

The invention relates generally to air or gas forced fuel injection systems for gasoline engines of the type in which electronically controlled devices, such as solenoid valves, are used as actuators for both fuel and air control. Other devices such as piezoelectric actuators can however be used instead of solenoids.

While the fuel injection system to be described is intended primarily for direct fuel injection, it is also applicable to port injection. Compressed air, or

cylinder compression gas in another embodiment, is used for fuel injection and atomisation. However, one of the main features of the system is the fact that fuel charge metering and fuel injection are separated by a time interval during which the fuel charge is in contact with air or gas and can evaporate so that when the injection is made, a premixed, rich fuel/air or fuel/gas charge is injected with the fuel at least partially in gaseous state. Important items in the system are a set of injectors, one per engine cylinder, which are usually installed directly in the cylinder head, and where cylinder compressed air is employed, a set of charging valves, also one per engine cylinder, and also usually installed directly in the cylinder head. Fuel and compressed air or gas are supplied to each injector by separate fuel and air or gas supply systems.

More specifically, Figure 1 shows a fuel injector assembly 10 that includes a shell or body 12 containing a central air/gas and fuel mixing chamber 14. The chamber extends longitudinally along the axis of the injector assembly and at its lower end is enlarged at 16 to contain a fuel injector valve 18. The valve reciprocates in a valve body 20 between open and closed positions, and has a nozzle or tip 22 seated against the body by a spring 24. Side ports 26 communicate the fuel/air mixture charge in mixing chamber 14 to the tip of the injector valve along the channel or passage 28 containing the stem of the valve.

The upper part of mixing chamber 14 is closed by a pair of normally closed, solenoid actuated poppet type valves 30 and 32. Valve 30 is a fuel control valve. It normally closes a supply passage 34 communicating with the mixing chamber 14 at one end and with a fuel supply F, as indicated, at its other end. Valve 32 is an air control valve. It normally blocks the passage of compressed air A from a passage 35 (Figure. 2) and a chamber 36 into the mixing chamber 14 through a connecting passage 38. Figure 2 further illustrates an electrical input 40 to both the fuel and air solenoids.

When air is employed as the mixing and pressurising gas the mixing chamber 14 will always contain air. For this purpose, the mixing chamber 14 is vented to the outside so that its residual pressure always drops after the end of injection to a low level approximately equal to atmospheric pressure. More specifically, referring to Figure 3, the air control valve 32 has an axial channel 42 extending along its length with a calibrated orifice 44 at its tip in communication with the passage 38 and chamber 14. Between injections, the channel 42 connects the mixing chamber 14 with the inside of the solenoid, which is vented to the outside through the space 46 between the top of the valve and the solenoid housing and around the valve stem and out via a passage 48 to the intake of the

air compressor or to the intake of the engine.

The solenoids in this case would be controlled by means of an electronic control system which supplies the solenoids with voltage signals of variable width and timing, the signals being fed through the connector 40 shown in Figure 2. When the fuel valve 30 opens, fuel will be metered into the mixing chamber 14. The metered fuel quantity would be determined by the duration of fuel control valve opening, size of the orifice and the supply of fuel pressure. Usually, it would be controlled by controlling the solenoid pulse width. After the introduction of the fuel into chamber 14, the fuel will stay in the air filled chamber for a substantial portion of the engine cycle. This provides a time interval in which the fuel is exposed to the air and can evaporate before the mixture is injected into the engine. It permits time for the fuel to penetrate the air in the chamber.

Therefore, when the air control valve 32 opens, a charge of compressed air fills the mixing chamber 14 to effect a further mixing and evaporation of the fuel by a penetration of the air into the fuel, and also opens the normally closed injector valve 22 to expel the premixed fuel/air charge past the valve tip. This is the fuel injection event or cycle. The timing of fuel injection can be controlled by controlling the timing of the air control solenoid pulse. Varying the compressed air pressure also can vary injection rate and fuel penetration. The injection ends when the air control solenoid or actuator is deactivated and the air control valve 32 closes.

As stated previously, after the end of injection, the mixing chamber 14 will be vented to the outside to the intake of the air compressor or to the intake of the engine through the calibrated orifice 44 in the air control valve 32 and therefrom through the vent passage 48. This once again results in the mixing chamber 14 being filled with air at ambient or atmospheric pressure level.

Figure 4 shows schematically an overall diagram of a compressed air and fuel supply arrangement for a system having three injectors 50. A fuel pump 52 draws fuel from a reservoir 54 and delivers it under pressure through a pressure regulator 56 to a common fuel supply rail 58 to which all three of the injectors 50 are connected. Any excess fuel is returned to the reservoir 54 via the line 57. At the upper part of the diagram or drawing, a compressor 60 draws atmospheric air A through an intake 62 and pumps it under pressure into a compressed air reservoir or accumulator 64. A check valve 66 on the inlet and a solenoid valve 68 on the outlet, which is open only during engine operation, maintain the air pressure in reservoir 64 when the engine is not running. During engine operation, compressed air would be discharged from the reservoir 64 through the open solenoid

valve 68 and supplied under pressure through a controllable pressure regulator 70 to a common air supply rail 72 to which all three injectors 50 are connected in parallel by connecting lines 74. Varying the air pressure in the common rail 72 will vary the fuel injection rate and fuel spray penetration, as described previously in connection with the embodiment shown in Figures 1-3. The vented air in air control valve 32 would be returned to the inlet to the compressor by the line 48.

The three injectors in this case are controlled by an electronic control system that would receive the operator's demand signal and determine the needed solenoid voltage pulse width and timing necessary to supply the engine with the required fuel quantity at the right time in the engine cycle. A voltage pulse of proper duration and timing would be sent to each solenoid and, in principle, each solenoid would require a separate driving circuit. It is possible, however, to reduce the number of driving circuits by using a single solenoid driver to drive two solenoid simultaneously. An example of such an arrangement is shown diagrammatically in Figure 5 where three solenoid drivers 80, 82, 84 are used to drive six solenoids, 1F, 2F, 3F, 1A, 2A, 3A, associated with the three injectors numbered I₁ to I₃. Each of the drivers 80, 82, 84 would drive an air control solenoid for example 1A, in one injector and a fuel control solenoid e.g., 2F in another one. Assuming the working order of the injectors to be 1-2-3, activation of driver 84 would energise solenoids 2A and 3F, resulting in injection from injector No.2 and fuel metering in injector No.3. Activation of driver 82, therefore, leads to injection from injector No. 3 and metering in injector No.1. It will be clear, therefore, that the dwell between the injection of the fuel and the opening of the air control valve is clearly provided for.

The solenoid valves would be designed so that the minimum pulse width necessary for the air controlled solenoid would never be shorter than the required fuel controlled solenoid pulse. In the arrangement just described above, the time interval between fuel metering or entering into the chamber 14 and the fuel injection event in each injector would be equal to one-third of the cycle. It is clear, however, that with a slightly different arrangement, this timed interval could be two-thirds of the cycle, for example, thus giving the fuel more time for evaporation in the mixing chamber 14. For this, the pairs of simultaneously energized solenoid actuators should be: 1A and 3F, 2A and 1F, 3A and 2F. It is clear, also, that each pair of simultaneously energized solenoids could be connected in series, rather than in parallel, as shown.

In a multicylinder engine, it is desirable to deliver equal fuel quantities to all cylinders. The fuel quantity metered by the fuel control solenoid

valve is determined by the fuel flow rate through the valve orifice and the duration of the valve opening.

$$Q = qt \quad (1)$$

where:

Q = fuel quantity in mg

q = fuel flow rate in mg/ms

t = duration of valve opening in ms

The flow rate q is a function of the orifice area and the pressure differential across the orifice. If the orifices in all solenoid valves are made with very high accuracy, their areas are equal. In a given system, the pressure differentials are also equal for all orifices. In such a system q can be considered a system constant. The duration of valve opening t is a function of the solenoid control pulse width.

$$t = t_c - t_a + t_d \quad (2)$$

where:

t = duration of valve opening in ms

t_c = solenoid control pulse in ms

t_a = valve opening delay in ms

t_d = valve closure delay in ms

From equation (2) the algorithm for control pulse is:

$$t_c = t + t_a - t_d \quad (3)$$

If the valve opening and closure delays were identical in all solenoids, equal control pulse widths in all solenoids would result in equal fuel deliveries to all cylinders. However, due to unavoidable variations in manufacturing tolerances, the values of delays t_a and t_d vary from solenoid to solenoid. As a result, equal control pulses in all solenoids produce different fuel quantities in different engine cylinders. This situation can be improved if the control pulse width t_c in each solenoid is individually tailored to achieve the required fuel delivery in spite of the solenoid-to-solenoid scatter in valve opening and closure delays. For this, the algorithm for solenoid control pulse is modified as follows:

$$t_c = t + t_s + t_x \quad (4)$$

where:

t_c = solenoid control pulse

t = required duration of valve opening

$t_s = (t_a - t_d)_{\min}$ = minimum value of net opening and closure delays which is constant

t_x = correction term

The values of t and t_c are the same for all fuel control solenoids for a given fuel quantity demand. The value of correction term t_x is, in principle,

different for each solenoid and is selected so as to assure equal fuel delivery to all cylinders. The value of the correction term t_x for each individual injector can be determined experimentally during injector bench testing and encoded on the injector in the form of a number, which can be called the injector characteristic number. The controller reads the value of the correction term t_x and for a given value of required fuel quantity Q determines the required control pulse t_c from the following algorithm:

$$t_c = Q/q + t_s + t_x$$

In many cases, the accuracy with which the control orifices in the solenoid valves are made is not high enough, and the solenoid-to-solenoid differences in orifice areas cannot be disregarded. In this case, the fuel flow rate q in equation (1) cannot be considered a system constant. It varies from injector to injector as a direct function of orifice area. In such a case, the above described single point calibration of injectors is inadequate, since the slope of injector characteristic expressed by equation (1) varies from injector to injector, and calibration for equal fuel delivery at one point cannot guarantee equal deliveries at other points. To achieve equal deliveries in all injectors at all points of the fuel flow vs. valve opening time characteristic, the equation (1) can be modified as follows:

$$Q = Kqt \quad (6)$$

where:

Q = fuel quantity in mg

q = individual injector flow rate in mg/ms

t = duration of valve opening in ms

K = correction factor

The value of the correction factor K is, in principle, different for each injector and is selected so that the product Kq is the same in all injectors. This assures equal slopes in all injector characteristics and permits subsequent single point calibration. For practical reasons, the values of K should be always larger than one (or always less than one). The value of the correction factor K for each individual injector can be determined experimentally during injector bench testing and encoded on the injector as part of the same characteristic number which contains information on the correction term t_x . The controller reads the values of both the correction term t_x and the correction factor K and, for a given value of required fuel quantity Q , determines the required control pulse t_c from the following algorithm.

$$t_c = Q/Kq + t_s + t_x \quad (7)$$

The manner in which the characteristic number is encoded should permit easy transmission of information on the number to the electronic controller. For this, the injector can be equipped with a memory device in which the value of the characteristic number is retained and can be "read" by the controller. A microchip memory would be suitable for this purpose, but, since only one number has to be stored, much simpler devices can be used.

Since each fuel control solenoid is usually driven by a separate power transistor driver, cylinder-to-cylinder fuel maldistribution may also be the result of differences between individual solenoid drivers. This deficiency can be corrected in the same manner as in the case of differences between solenoids. An additional correction term accounting for the deviation in the characteristic of the driver is introduced into the fuel delivery algorithm, an individual characteristic number is encoded on each driver, and the controller reads the characteristic numbers of all the drivers as well as solenoids and makes proper adjustments in control pulse widths.

The Figs. 1-5 embodiment show the use of compressed air to perform the injection of the fuel/air mixture into the engine. Fig. 6 shows a charging valve assembly in which engine gas compressed in the engine cylinders during the compression strokes is used to perform the injection of fuel for improved fuel atomization or both, instead of the compressed air in the Figs. 1-5 embodiment. More specifically, the purpose of each charging valve is to tap the pressure generated in the cylinder during the compression stroke and charge the compressed gas supply system to the predetermined maximum pressure. In the most elementary case, the compressed gas supply system would simply consist of lines connecting each charging valve with one of the injectors.

Fig. 6 shows an example of a charging valve assembly. The assembly actually includes two valves, a normally opened pressure limiting valve 90, and a normally closed check valve 92 that leads to a line 94 connecting the valve to the compressed gas supply system for the injectors. The pressure limiting valve 90 is of the poppet type having an upper land 96 sealingly secured to a spring seat 98 for a spring 100. The spring would normally maintain the valve 90 open below a predetermined cylinder compression gas pressure level. The check valve 92 could be of a known construction and operation having a spring pressed ball 102 closing the passage 104 communicating with the channel or chamber 106.

During the compression stroke, the pressure limiting valve 90 would initially be open, and as soon as the pressure in the engine cylinder ex-

ceeds the residual pressure in the compressed gas supply system, the cylinder pressure would open check valve 92 and the gas supply system would be charged by the engine compression gas to a maximum pressure determined by the preload of the spring 100. When the maximum pressure in the system is reached, the pressure force acting on the piston or land 96 of the pressure limiting valve 90 would overcome the force of the spring 100 and close valve 90. It would reopen again in the later part of the expansion stroke when the pressure force acting on the pressure limiting valve drops below the preload of the spring 100. The volume above land 96; i.e., the chamber 110 containing the spring 100, is vented to the outside through a vent 112. In some cases, this volume may have to be connected to the engine intake. It should be noted that, in principle, the charging valve can be without the pressure limiting valve 90. In that case, however, the gas supply system would be charged with hot combustion gas.

While there are several ways in which the gas forced injection system could be arranged, one is shown diagrammatically in Figure 7 for a three-cylinder engine 4. Fuel and compressed gas would be supplied to the three injectors 120, 122, and 124 associated with the respective cylinder C_1 , C_2 , C_3 by two separate system. In the fuel supply system, a fuel pump 126 would draw fuel from a reservoir 128 and deliver it under pressure via a pressure regulator 127 to a common fuel rail 130 to which all three injectors are connected, excess fuel being retrieved by a return line 129. In the compressed gas supply system, a gas line 132 from one of the charging valve assemblies 5 described in connection with Figure 6 would connect each injector with one of the charging valves. The volume of each line should be sufficient to store enough compressed gas to perform at least one fuel injection event. In a given cylinder, the injector would be connected with the charging valve installed in a cylinder preceding the given cylinder in the firing order. In an example depicted in Figure 5, the firing order of the cylinder is 1-2-3; and, thus, the charging valve in cylinder one would feed compressed gas to the injector in cylinder two, while the charging valves in cylinders two and three would feed gas to injectors in cylinders three and one, respectively. The gas vented from all the injectors would be returned to the engine intake by a line 133, as indicated.

Another example of a gas forced injection system is shown in Figure 8, which is essentially the same as that shown in the Figure 4 embodiment, except for the supply of gas to the reservoir 64'. In this case, all three injectors receive compressed gas from a common rail gas supply system, rather than air. The charging valves in all the engine

cylinders would feed compressed gas into a common compressed gas reservoir 64' from where it could be discharged through a solenoid valve 68' and a controllable gas pressure regulator 70' into the common gas supply rail 72'. The solenoid valve would be open only during engine operation and, therefore, gas pressure in the reservoir would be maintained even when the engine is not running. The system operates otherwise as described in connection with the embodiment shown in Figure 4.

A system similar to the one described above could be used also to improve fuel atomisation. Fuel injection systems in which improved fuel atomisation is achieved by injection compressed air into a stream of fuel exiting an injection nozzle are widely known and used. Their usage in reciprocating internal combustion engines is limited due to additional cost associated with the need for an air compressor. Using compressed engine gas supplied to fuel injectors in any of the manners described above permits realisation of compressed gas assisted fuel atomisation without a compressor.

Claims

1. A fuel injector assembly including a hollow body (12) having a main fuel/gas mixing chamber (14) open at both ends and ventable to ambient pressure so as initially to contain a gas at essentially ambient pressure, a control valve (18) normally closing one end of the chamber as well as an outlet (22) from the body and actuatable to an open position to permit ejection of a fuel/gas mixture from the chamber and body, a source of fuel and a source of gas under pressure each separately connectable to the chamber (14) through the body (12) and means (30, 32) movable between open and closed positions for controlling admission of fuel and gas to the chamber (14) from their respective sources, the latter means being movable in a manner to first admit fuel to the chamber for mixing with the gas therein and after a time delay to admit the gas under pressure to the chamber to further mix the fuel and gas in the chamber and eject the mixture from the chamber and body, characterised in that the fuel and gas sources are each connectable to the end of the chamber (14) remote from the control valve (18), that the means (30, 32) for controlling the admission of the fuel and gas are selectively operable, and that the control valve (18) is opened by the admission of the gas under pressure to the chamber (14) to eject the mixture from the chamber and body.
2. A fuel injector assembly according to claim 1 for injecting a slug of air mixed with partially evaporated fuel into an engine, comprising a fuel injector body (12) having an air inlet, a fuel inlet, an actuatable normally closed fuel/air outlet (22), means (42, 46, 48) connecting the air inlet to air at ambient pressure, means (30) connecting the fuel inlet to a source of fuel under pressure for admission of fuel into the body to mix with and penetrate into the ambient air in the body and partially evaporate the fuel, and means (32) for admitting air under pressure to the air inlet subsequent to admission of fuel to the body and after a time delay therebetween for further penetration of the air into the fuel and evaporation thereof and for an actuation of the valve (18) to open for ejection of the fuel/air through the outlet (22).
3. A fuel injector assembly according to claim 1 or claim 2, wherein the selectively operable means include an electromagnetically operated gas flow control valve (32) movable between open and closed positions in a gas passage (38) for controlling the flow therethrough, the passage (38) opening at one end into the chamber (14) and being connected at its other end to the source of gas under pressure, a second passage (42) connected at one end to a vent (48) at essentially an ambient pressure level and at its other end to the valve (32), the valve (32) having a restricted opening (44) therethrough permitting communication between the chamber and the second passage and vent at all times regardless of the closed position of the valve (32) to thereby vent the chamber (14) to ambient pressure level when the selectively operable valve means (30, 32) and control valve (18) are closed.
4. An assembly according to claim 1, wherein the means for admitting gas under pressure to the chamber includes means connecting compressed gas from an engine cylinder to storage means (64') for storing gases at a predetermined pressure level, and passage means containing at least one of the selectively operable valve means (32) connecting the stored gases to the chamber as a function of the operation of the valve means.
5. An assembly according to claim 4, wherein the source of gas under pressure includes a charging valve assembly (5) for charging the storage means (64') with pressurised gas from the engine cylinder, the charging valve assembly (5) including a first gas passage (106) connecting the engine cylinder containing gas under pressure to the storage means (64'), a normally open, gas pressure closed pressure

limiting valve (90) in the first gas passage (106) and movable from the open position to a closed position in response to the attainment of a predetermined pressure level in the first gas passage (106) thereagainst to limit the pressure level in the first gas passage, and check valve means (92) in the first gas passage between the storage means (64') and pressure limiting valve (90) for maintaining a predetermined pressure level in the storage means (64') for subsequent introduction into the injector mixing chamber.

6. An assembly according to claim 5 wherein the charging valve assembly (5) includes spring means (100) biasing the pressure limiting valve (90) to an open position, the latter valve having land means (96) thereon actuatable by the cylinder gas pressure in a direction in opposition to the force of the spring means (100) to close the pressure limiting valve (90).
7. An assembly according to claim 6, wherein the land means (96) of the pressure limiting valve (90) and the check valve (92) are in a parallel flow relationship in the first gas passage (106) whereby the check valve (92) is opened prior to closing of the pressure limiting valve (90) as soon as the residual pressure acting against the check valve from the storage means (64') is less than the charging gas pressure from the engine cylinder.
8. A fuel injection system comprising, in combination, a plurality of individually sequentially operable fuel injectors (50) according to any preceding claim, each injector having a fuel/gas mixing chamber (14) with a respective fuel inlet and gas inlet thereto and a mixture outlet therefrom normally blocked by a spring closed pressure opened valve (18), a source of fuel under pressure, a source of gas under pressure, means venting the chamber (14) to ambient pressure prior to the inlet of fuel thereto, first solenoid control means connecting the fuel source to each injector fuel inlet, second solenoid control means connecting the gas source to each injector gas inlet, and electrically operated means controlling the energisation of the solenoid means to selectively apply the fuel and gas to each injector in a manner providing a timing delay between introduction of the fuel into the injector and introduction of the gas under pressure, to permit penetration of the fuel into the gas in the chamber for evaporation of the fuel prior to ejection of the fuel/gas mixture past the valve (18) upon admission of the gas under pressure

to the chamber (14), the electrically operated means including a plurality of individual selectively energisable solenoid drivers (80, 82, 84), and circuit means each connecting each driver to at least one of the first solenoid control means for the fuel source for one injector and simultaneously to the second solenoid control means for the gas source for another of the injectors, the drivers being operated individually in sequence to establish the desired timing delay.

9. A method of supplying and discharging a fuel and gas mixture into and from an automotive type fuel injector (10) that is biased to a closed position comprising the steps of:
 - first, connecting a central chamber (14) in the injector to gas at ambient pressure level,
 - secondly, supplying the chamber with fuel at the end remote from its outlet to mix with the gas to form at least a partially combustible mixture charge,
 - thirdly, holding the fuel/gas mixture charge in the chamber for a period sufficient to allow evaporation of the fuel and further mixing of the fuel and gas, and
 - fourthly, applying further gas to the chamber at a sufficient pressure level to enhance penetration of the gas into the fuel and evaporation of the fuel and to cause a normally closed outlet valve from the chamber to open and to effect discharge of the fuel/gas mixture charge from the injector.
10. A method according to claim 9, wherein the second step includes admitting fuel under pressure to the chamber (14) in a quantity metered in accordance with engine operating parameters for penetration into the gas and evaporation of the fuel.
11. A method according to claim 9 or claim 10 including the step of.
 - fifthly, venting the chamber to an ambient pressure level subsequent to cessation of supply of the gas under pressure to the chamber and closure of the outlet valve (18)

Patentansprüche

1. Kraftstoffeinspritzvorrichtung, die einen Hohlkörper (12) mit einer Hauptmischkammer für Kraftstoff/Gas (14), die an beiden Enden offen ist und auf Umgebungsdruck entlüftet werden kann, so daß sie anfangs Gas mit im wesentli-

chen Umgebungsdruck enthält, ein Steuerventil (18), das normalerweise ein Ende der Kammer und einen Auslaß (22) vom Körper verschließt und das zu einer offenen Position hin betätigt werden kann, um das Ausströmen einer Kraftstoff-/Gas Mischung von der Kammer und dem Körper zu erlauben, eine Kraftstoffquelle und eine unter Druck stehende Gasquelle, die beide getrennt über den Körper (12) an die Kammer (14) verbunden werden können, und Mittel (30, 32) enthält, die zwischen offenen und geschlossenen Positionen bewegt werden können, um die Zufuhr von Kraftstoff und Gas von deren jeweiligen Quellen in die Kammer (14) zu steuern, wobei die letzteren Mittel auf eine Weise bewegt werden können, die es zunächst erlaubt, daß Kraftstoff der Kammer zugeführt wird, um darin mit Gas vermischt zu werden und nach einer Zeitverzögerung der Kammer unter Druck stehendes Gas zuzuführen, um Kraftstoff und Gas in der Kammer weiter zu vermischen und die Mischung von der Kammer und dem Körper auszustoßen, dadurch gekennzeichnet, daß die Kraftstoff- und Gasquellen jeweils an das vom Steuerventil (18) entfernt liegende Ende der Kammer (14) verbunden werden können, daß die Mittel (30, 32) zur Steuerung der Zufuhr von Kraftstoff und Gas selektiv betrieben werden können, und daß das Steuerventil (18) durch die Zufuhr von unter Druck stehendem Gas in die Kammer (14) geöffnet wird, um die Mischung von der Kammer und dem Körper auszuströmen.

2. Kraftstoffeinspritzvorrichtung nach Anspruch 1 zum Einspritzen eines Schalles von mit Luft vermischem, teilweise verdampftem Kraftstoff in den Motor, der einen Kraftstoffeinspritzkörper (12) mit einem Lufteinlaß, einem Kraftstoffeinlaß, einen betätigbaren, normalerweise geschlossenen Kraftstoff-/Luftauslaß (22), Mittel (42, 46, 48), die den Lufteinlaß mit Luft auf Umgebungsdruck verbinden, Mittel (30), die den Kraftstoffeinlaß mit einer unter Druck stehenden Kraftstoffquelle verbinden, die, um dem Körper Kraftstoff zuzuführen, ihn mit der Umgebungsluft im Körper zu vermischen und um in sie einzudringen und den Kraftstoff teilweise zu verdampfen, und Mittel (32) für die Zufuhr von unter Druck stehender Luft in den Lufteinlaß, nach der Zufuhr von Kraftstoff in den Körper und nach einer dazwischenliegenden Zeitverzögerung zum weiteren Eindringen der Luft in den Kraftstoff und dessen Verdampfung und zur Betätigung des Ventils, damit es sich zum Ausströmen des Kraftstoffes/der Luft durch den Auslaß (22) öffnet, enthält.

3. Kraftstoffeinspritzvorrichtung nach Anspruch 1 oder 2, wobei die selektiv betreibbaren Mittel ein elektromagnetisch betriebenes Gasströmungssteuerventil (32) enthalten, das in einem Gaskanal (38) zwischen offenen und geschlossenen Positionen bewegt werden kann, um den Fluß dahindurch zu steuern, wobei die Kanalöffnung (38) an einem Ende mit der Kammer (14) verbunden ist und ihrem anderen Ende mit der unter Druck stehenden Gasquelle verbunden ist, ein zweiter Kanal (42), der an einem Ende mit einer Entlüftungsöffnung (48) auf im wesentlichen Umgebungsdruckniveau und an seinem anderen Ende mit dem Ventil (32) verbunden ist, wobei das Ventil (32) eine verjüngte Öffnung (44) hat, durch die eine Verbindung zwischen der Kammer und dem zweiten Kanal und der Entlüftungsöffnung jederzeit möglich ist, unabhängig von der geschlossenen Position des Ventils (32), um hierdurch die Kammer (14) auf Umgebungsdruckniveau zu entlüften, wenn die selektiv betreibbaren Ventilmittel (30, 32) und das Steuerventil (18) geschlossen sind.
4. Vorrichtung nach Anspruch 1, wobei die Mittel für die Zufuhr von unter Druck stehendem Gas in die Kammer Mittel, die das Druckgas von einem Motorzylinder mit Speichermitteln (64') verbinden, um die Gase auf einem vorgegebenen Druckniveau zu speichern beinhaltet sowie Kanalmittel, die mindestens eines der selektiv betreibbaren Ventilmittel (32) enthalten, die die gespeicherten Gase je nach dem Betrieb der Ventilmittel mit der Kammer verbinden.
5. Vorrichtung nach Anspruch 4, wobei die unter Druck stehende Gasquelle eine Ladeventilvorrichtung (5) zum Laden des Speichermittels (64') mit vom Motorzylinder kommendem Druckgas, wobei die Ladeventilvorrichtung (5) einen ersten Gaskanal (106) einschließt, der den Motorzylinder, der das unter Druck stehende Gas enthält mit dem Speichermittel (64') verbindet, ein normalerweise offenes, vom Gasdruck geschlossenes Druckbegrenzungsventil (90) im ersten Gaskanal (106) und das von der offenen Position zu einer geschlossenen Position als Antwort auf das Erreichen eines vorgegebenen Druckniveaus im ersten Gaskanal (106) bewegt werden kann, um dagegen das Druckniveau im ersten Gaskanal zu begrenzen und Kontrollventilmittel (92) im ersten Gaskanal zwischen dem Speichermittel (64') und dem Druckbegrenzungsventil (90) zur Aufrechterhaltung eines vorgegebenen Druckniveaus im Speichermittel (64') zur nachfolgenden Einleitung in die Mischkammer der Ein-

spritzvorrichtung beinhaltet.

6. Vorrichtung nach Anspruch 5, wobei die Ladeventilvorrichtung (5) Federmittel (100) enthält, die das Druckbegrenzungsventil (90) in einer offenen Position vorspannen, wobei das letztere Ventil darauf Flächenmittel (96) hat, die durch den Gasdruckzylinder in eine Richtung, die der Kraft der Federmittel (100) entgegengesetzt ist, betätigt werden können, um das Druckbegrenzungsventil (90) zu schließen. 5
7. Vorrichtung nach Anspruch 6, wobei die Flächenmittel (96) des Druckbegrenzungsventils (90) und des Kontrollventils (92) im ersten Gaskanal (106) ein paralleles Strömungsverhältnis haben, wodurch das Kontrollventil (92) vor dem Schließen des Druckbegrenzungsventils (90) geöffnet wird, sobald der gegen das Kontrollventil des Speichermittel (64') wirkende Restdruck kleiner ist als der vom Motorzylinder kommende Ladegasdruck. 10 15 20
8. Kraftstoffeinspritzsystem, das in Kombination, eine Vielzahl von einzeln, in Folge betreibbaren Kraftstoffeinspritzvorrichtungen (50) nach einem der vorstehenden Ansprüche enthält, wobei jede Einspritzvorrichtung eine Kraftstoff-/Luftmischkammer (14) mit einem entsprechenden dahinführenden Kraftstoffeinlaß und Gaseinlaß und einem daherausführenden Mischauslaß, der normalerweise von einem federgeöffneten, druckgeschlossenem Ventil (18) blockiert wird, eine Quelle unter Druck stehenden Kraftstoffes, eine Quelle unter Druck stehenden Gases, Mittel zum Entlüften der Kammer (14) auf Umgebungsdruck vor dem Einlaß von Kraftstoff, erste Magnetsteuermittel, die die Kraftstoffquelle mit jedem Kraftstoffeinlaß der Einspritzvorrichtungen verbinden, zweite Magnetsteuermittel, die die Gasquelle mit jedem Gaseinlaß der Einspritzvorrichtungen verbinden und elektrisch betriebene Mittel, die die Erregung der Magnetmittel steuern, um jeder Einspritzvorrichtung selektiv Kraftstoff und Gas auf eine Weise zuzuführen, in der zwischen der Einleitung von Kraftstoff in die Einspritzvorrichtung und der Einleitung des unter Druck stehenden Gases eine Zeitverzögerung geschaffen wird, um das Eindringen des Kraftstoffes in das Gas in der Kammer, zur Verdampfung des Kraftstoffes vor dem Ausströmen der Kraftstoff-/Gasmischung hinter das Ventil (18) nach der Zufuhr des unter Druck stehenden Gases in die Kammer (14) zu erlauben, wobei die elektrisch betriebenen Mittel eine Vielzahl einzeln selektiv erregbarer Magnettreiber (80, 82, 84) und Schaltmittel enthält, von denen jedes je- 25 30 35 40 45 50 55

den Treiber mit mindestens einem der ersten Magnetsteuermittel für die Kraftstoffquelle für eine Einspritzvorrichtung und gleichzeitig mit den zweiten Magnetsteuermitteln für die Gasquelle für eine andere der Einspritzvorrichtungen verbindet, wobei die Treiber einzeln in Folge betrieben werden können, um die gewünschte Zeitverzögerung herzustellen.

9. Verfahren zur Zufuhr und Entladung einer Kraftstoff-/Gasmischung in und aus einer Kraftstoffeinspritz-Vorrichtung (10) für ein Kraftfahrzeug, die in einer geschlossenen Position vorgespannt ist, das die folgenden Schritte beinhaltet:
 - erstens, eine Hauptkammer (14) in der Einspritzvorrichtung mit Gas auf Umgebungsdruckniveau zu verbinden,
 - zweitens, der Kammer an dem von ihrem Auslaß entfernt liegenden Ende Kraftstoff zur Vermischung mit Gas zuzuführen, um eine zumindest teilweise brennbare Mischungsladung zu bilden,
 - drittens, die Kraftstoff-/Gasmischung über einen zur Verdampfung des Kraftstoffes und zur weiteren Vermischung des Kraftstoffes und des Gases ausreichenden Zeitraum in der Kammer zu halten und
 - viertens, der Kammer weiteres Gas mit einem Druckniveau zuzuführen, das ausreicht, das Eindringen von Gas in den Kraftstoff und das Verdampfen des Kraftstoffes zu verstärken und ein normalerweise geschlossenes Ventil zu veranlassen, sich zu öffnen und die Entladung der Kraftstoff-/Gasmischungsladung von der Einspritzvorrichtung zu bewirken.
10. Verfahren nach Anspruch 9, bei dem der zweite Schritt die Zufuhr von unter Druck stehendem Kraftstoff in die Kammer (14) in einer Menge, die in Übereinstimmung mit den Motorbetriebskennwerten für das Eindringen in das Gas und das Verdampfen des Kraftstoffes dosiert ist, beinhaltet.
11. Verfahren nach Anspruch 9 oder Anspruch 10, das den folgenden Schritt beinhaltet:
 - fünftens, die Kammer nach dem Aufhören der Zufuhr des unter Druck stehenden Gases in die Kammer und dem Schließen des Auslaßventils (18) auf ein Umgebungsdruckniveau zu entlüften.

Revendications

1. Ensemble d'injecteur de carburant comportant un corps creux (12) ayant une chambre de

mélange principale carburant/gaz (14) ouverte à ses deux extrémités et pouvant être ouverte à la pression atmosphérique de façon à contenir initialement un gaz qui est fondamentalement à la pression atmosphérique, une soupape de commande (18) fermant normalement une première extrémité de la chambre et également un orifice de sortie (22) du corps et commandable à une position ouverte pour permettre l'éjection d'un mélange de carburant/gaz de la chambre et du corps, une source de carburant et une source de gaz sous pression chacune étant séparément raccordable à la chambre (14) par l'intermédiaire du corps (12), et des moyens (30, 32) déplaçables entre des positions ouverte et fermée pour commander l'admission du carburant et du gaz dans la chambre (14) à partir de leurs sources respectives, ces derniers moyens étant déplaçables de manière à tout d'abord admettre le carburant dans la chambre pour le mélanger avec le gaz dans celui-ci et après un certain retard à admettre le gaz sous pression dans la chambre pour le mélanger ensuite avec le carburant et le gaz dans la chambre et pour éjecter le mélange de la chambre et du corps, caractérisé en ce que les sources de carburant et de gaz sont chacune raccordables à l'extrémité de la chambre (14) opposée à la soupape de commande (18), que les moyens (30, 32) pour commander l'admission du carburant et du gaz peuvent être mis en oeuvre de manière sélective, et que la soupape de commande (18) est ouverte par l'admission du gaz sous pression dans la chambre (14) pour éjecter le mélange de la chambre et du corps.

2. Ensemble d'injecteur de carburant selon la revendication 1 pour injecter un bouchon d'air mélangé avec du carburant partiellement évaporé dans un moteur, comprenant un corps d'injecteur de carburant (12) ayant un orifice d'entrée d'air, un orifice d'entrée de carburant, un orifice de sortie d'air/carburant commandable normalement fermé (22), des moyens (42, 46, 48) raccordant l'orifice d'entrée d'air à l'air à la pression atmosphérique, un moyen (30) raccordant l'orifice d'entrée du carburant à une source de carburant sous pression pour admission du carburant dans le corps pour le mélanger avec et le faire pénétrer dans l'air ambiant dans le corps et évaporer partiellement le carburant, et un moyen (32) pour admettre l'air sous pression par l'orifice d'entrée d'air ultérieurement à l'admission du carburant dans le corps et après un certain retard entre ceux-ci pour faire pénétrer encore l'air dans le carburant et faire évaporer celui-ci et pour comman-

der la soupape (18) pour ouverture afin d'éjecter le carburant/air par l'intermédiaire de l'orifice de sortie (22).

3. Ensemble d'injecteur de carburant selon la revendication 1 ou la revendication 2, dans lequel le moyen sélectivement commandable comporte une soupape de commande d'écoulement de gaz électromagnétiquement commandée (32) déplaçable entre des positions ouverte et fermée dans un passage de gaz (38) pour commander l'écoulement dans celui-ci, le passage (38) s'ouvrant à une extrémité dans la chambre (14) et étant raccordée à son autre extrémité à la source de gaz sous pression, un second passage (42) raccordé à une extrémité à une prise d'air (48) qui est pratiquement au niveau de la pression atmosphérique et à son autre extrémité à la soupape (32), la soupape (32) ayant une ouverture limitée (44) à travers celle-ci permettant la communication entre la chambre et le second passage et la prise d'air à tous les moments sans tenir compte de la position fermée de la soupape (32) pour amener de ce fait la chambre (14) au niveau de la pression atmosphérique lorsque le moyen de soupape sélectivement commandable (30, 32) et la soupape de commande (18) sont fermés.

4. Ensemble selon la revendication 1, dans lequel le moyen pour admettre le gaz sous pression dans la chambre comporte un moyen raccordant le gaz sous pression à partir d'un cylindre de moteur à un moyen de stockage (64') pour stocker les gaz à un niveau de pression prédéterminé, et un moyen de passage contenant au moins un des moyens de soupape sélectivement commandable (32) raccordant les gaz stockés à la chambre comme une fonction de l'action de moyens de soupape.

5. Ensemble selon la revendication 4, dans lequel la source de gaz sous pression comporte un ensemble de soupape de charge (5) pour charger le moyen de stockage (64') avec le gaz sous pression provenant du cylindre moteur, l'ensemble de soupape de charge (5) comportant un premier passage de gaz (106) raccordant le cylindre moteur contenant le gaz sous pression au moyen de stockage (64'), une soupape de limitation (90) de pression normalement ouverte et fermée par la pression du gaz dans le premier passage de gaz (106) et déplaçable à partir d'une position ouverte à une position fermée en réponse à l'atteinte d'un niveau de pression prédéterminé dans le premier passage de gaz (106) par rapport à celle-

- ci pour limiter le niveau de pression dans le premier passage de gaz, et un moyen de soupape de sûreté (92) dans le premier passage de gaz situé entre le moyen de stockage (64') et la soupape de limitation de pression (90) pour maintenir un niveau de pression prédéterminé dans le moyen de stockage (64') pour introduction ultérieure dans la chambre de mélange d'injecteur.
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6. Ensemble selon la revendication 5, dans lequel l'ensemble de soupape de charge (5) comporte un moyen de ressort (100) sollicitant la soupape de limitation de pression (90) à une position ouverte, cette dernière soupape ayant des moyens d'appui (96) sur celle-ci commandable par la pression du gaz du cylindre dans une direction en opposition à la force du moyen de ressort (100) pour fermer la soupape de limitation de pression (90).
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7. Ensemble selon la revendication 6, dans lequel les moyens d'appui (96) de la soupape de limitation de pression (90) de la soupape de sécurité (92) sont en relation d'écoulement parallèle dans le premier passage de gaz (106) d'où il résulte que la soupape de sécurité (92) est ouverte avant la fermeture de la soupape de limitation de pression (90) dès que la pression résiduelle agissant contre la soupape de sûreté à partir du moyen de stockage (64') est inférieure à la pression du gaz de charge du cylindre moteur.
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8. Système d'injection de carburant comprenant, en combinaison, une pluralité d'injecteurs de carburant commandables individuellement séquentiellement (50) selon l'une quelconque des revendications précédentes, chaque injecteur comportant une chambre de mélange de carburant/gaz (14) avec un orifice d'entrée du carburant respectif, et un orifice d'entrée de gaz dans celui-ci et un orifice de sortie de mélange provenant de celui-ci normalement bloqué par une soupape ouverte par pression et fermée par ressort (18), une source de carburant sous pression, une source de gaz sous pression, un moyen plaçant la chambre (14) à la pression atmosphérique avant l'entrée du carburant dans celui-ci, un premier moyen de commande pour électro-aimant raccordant la source de carburant à chaque orifice d'entrée de carburant des injecteurs, un second moyen de commande pour électro-aimant raccordant la source de gaz à chaque orifice d'entrée du gaz des injecteurs, et des moyens mis en oeuvre électriquement commandant l'excitation du moyen d'électro-aimant pour appliquer sélectivement le carburant et le gaz à chaque injecteur de manière à procurer un certain retard entre l'introduction du carburant d'un injecteur et l'introduction du gaz sous pression, afin de permettre la pénétration du carburant dans le gaz dans la chambre pour évaporation du carburant avant éjection du mélange de carburant/gaz au-delà de la soupape (18) sur admission du gaz sous pression dans la chambre (14), le moyen mis en oeuvre électriquement comportant une pluralité de circuits d'attaque (80, 82, 84) d'électro-aimant individuels sélectivement excitables, et un moyen de circuit reliant chaque circuit d'attaque à au moins un des premiers moyens de commande pour électro-aimant pour la source de carburant d'un injecteur et simultanément au second moyen de commande pour électro-aimant pour la source de gaz d'un autre des injecteurs, les circuits d'attaque étant mis en oeuvre individuellement en séquence pour établir le retard de cadencement souhaité.
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9. Procédé pour délivrer et décharger un mélange de carburant et de gaz dans et depuis un injecteur de carburant de type automobile (10) qui est sollicité à une position fermée comprenant les étapes consistant à :
- tout d'abord, raccorder une chambre centrale (14) dans l'injecteur au gaz à un niveau de pression atmosphérique,
 - secondement, alimenter la chambre avec du carburant à l'extrémité opposée de son orifice de sortie pour mélange avec le gaz afin de former au moins une charge de mélange partiellement combustible,
 - troisièmement, conserver la charge du mélange carburant/gaz dans la chambre pendant un intervalle de temps suffisant pour permettre l'évaporation du carburant et le mélange ultérieur du carburant et du gaz, et
 - quatrièmement, appliquer ensuite du gaz à la chambre à un niveau de pression suffisant pour accroître la pénétration du gaz dans le carburant et l'évaporation du carburant et pour entraîner une soupape de sortie normalement fermée à partir de la chambre à s'ouvrir et à effectuer l'expulsion du mélange de carburant/gaz à partir de l'injecteur.
10. Procédé selon la revendication 9, dans lequel la seconde étape comporte l'étape consistant à admettre le carburant sous pression dans la chambre (14) dans une quantité calibrée en conformité avec les paramètres de fonctionne-

ment du moteur pour la pénétration dans le gaz et l'évaporation du carburant.

- 11.** Procédé selon la revendication 9 ou la revendication 10 comportant l'étape consistant à :
- cinquièmement, placer ensuite la chambre au niveau de la pression atmosphérique pour arrêter l'alimentation du gaz sous pression dans la chambre et pour fermer la soupape de sortie (18).

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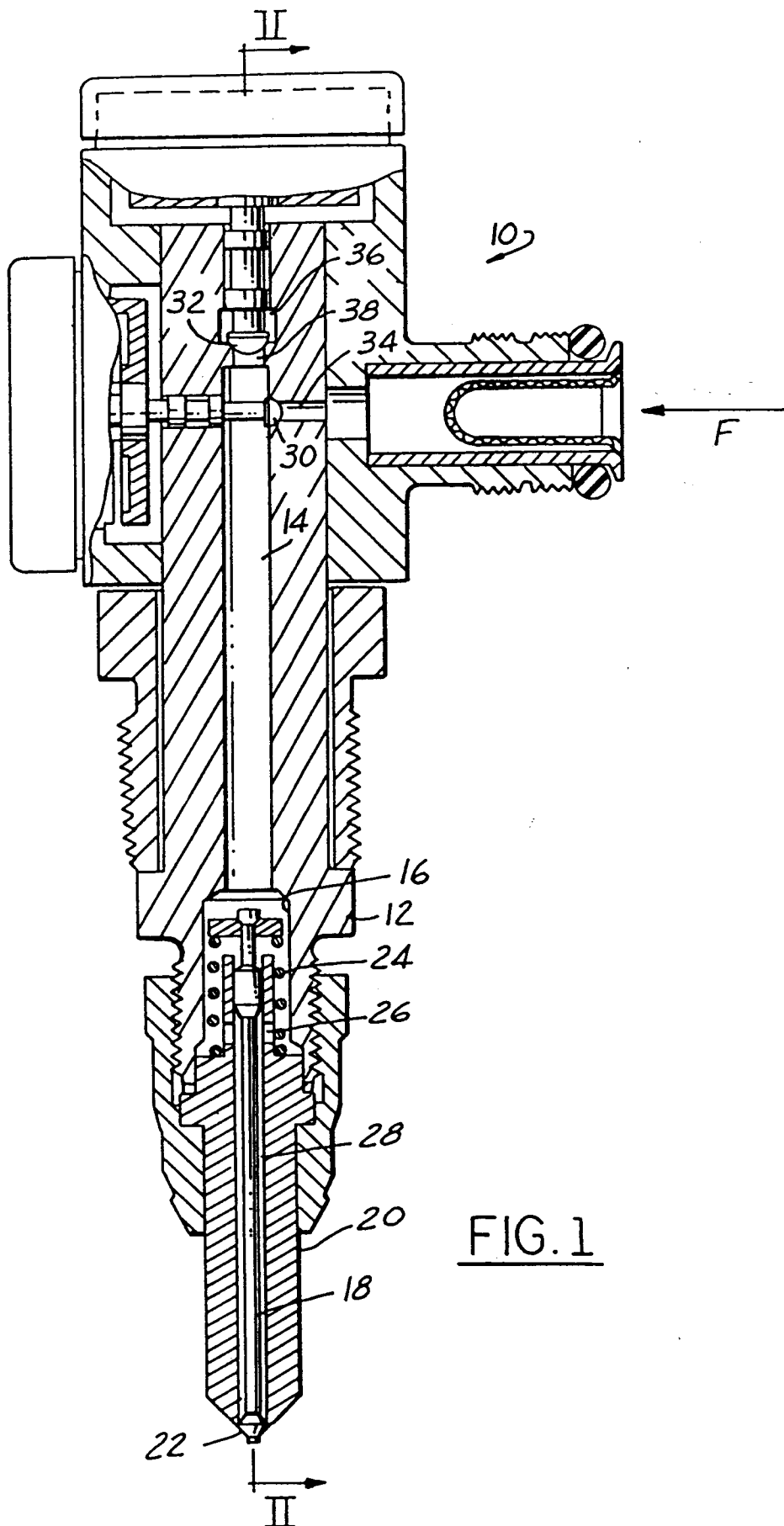
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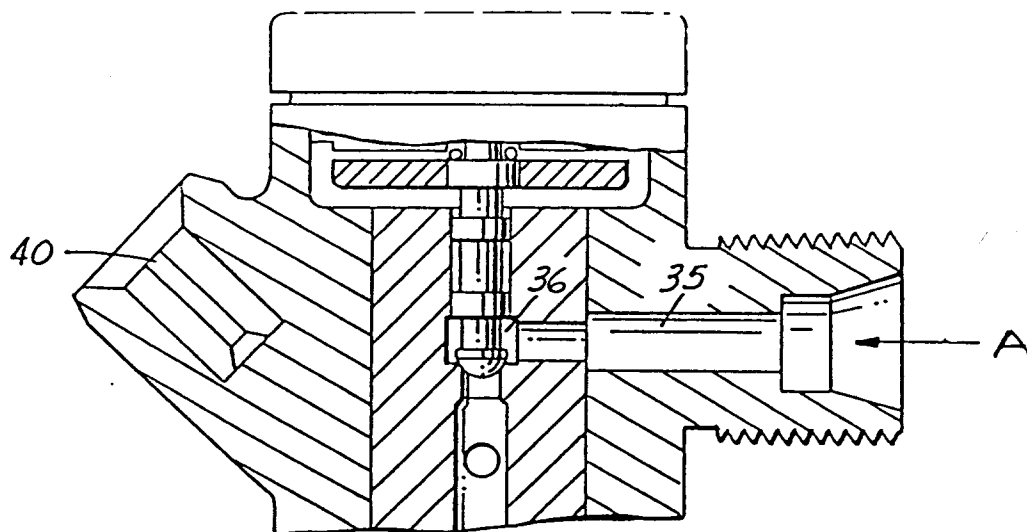


FIG. 2

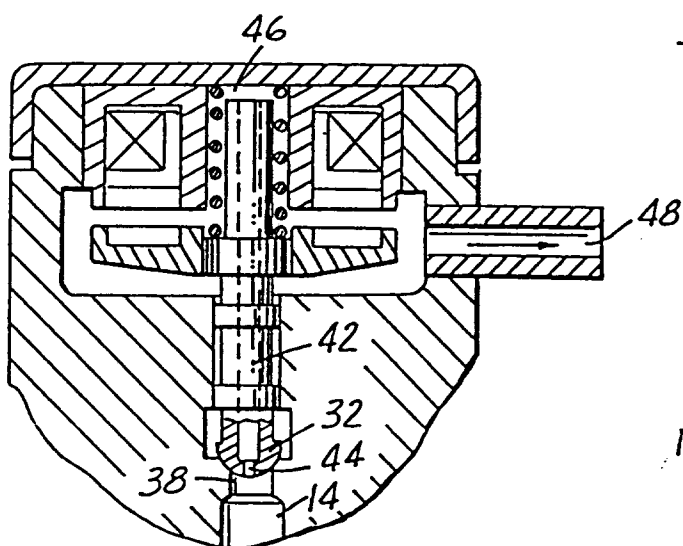


FIG. 3

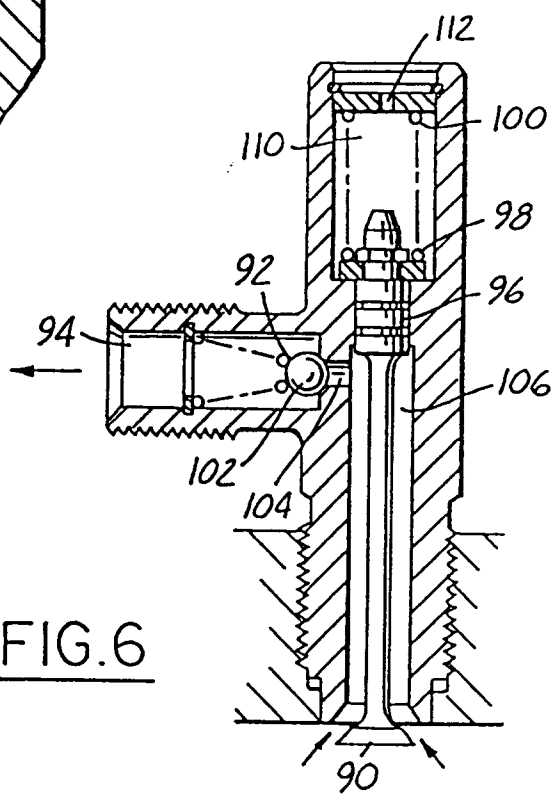


FIG. 6

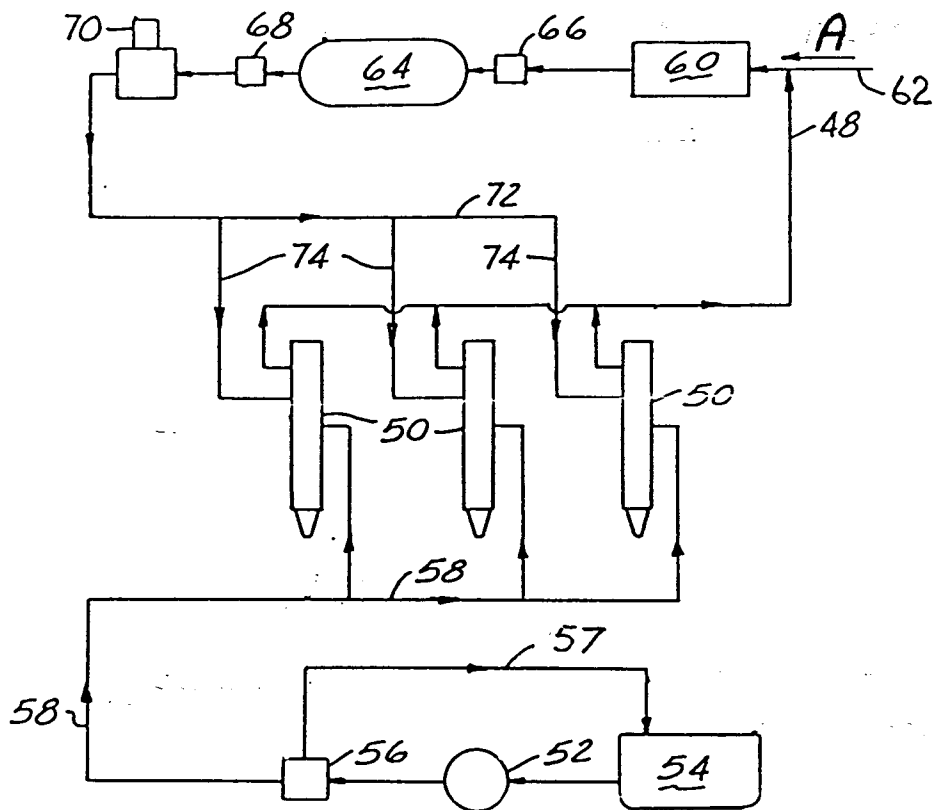
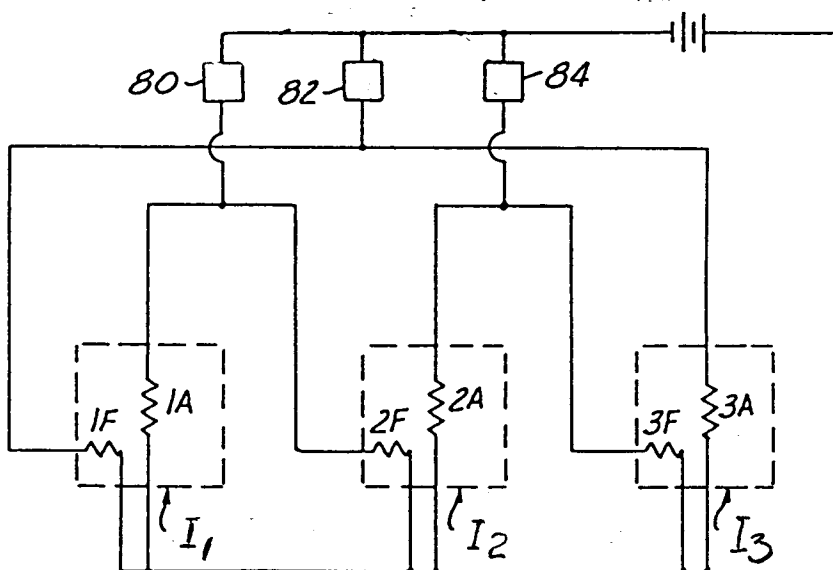


FIG.4

FIG.5



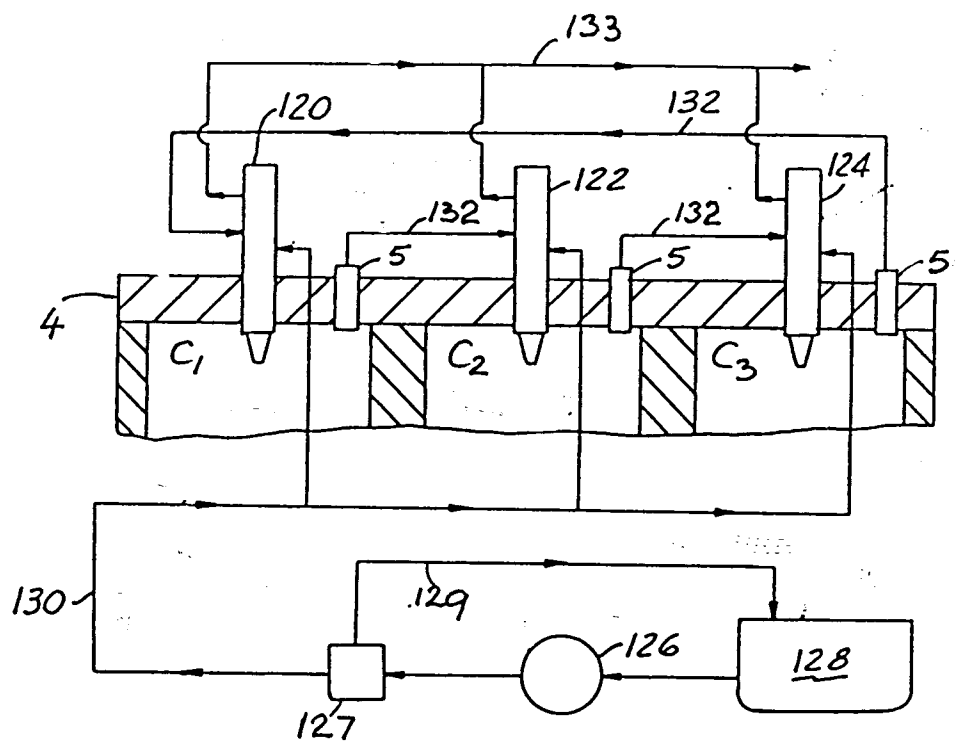


FIG. 7

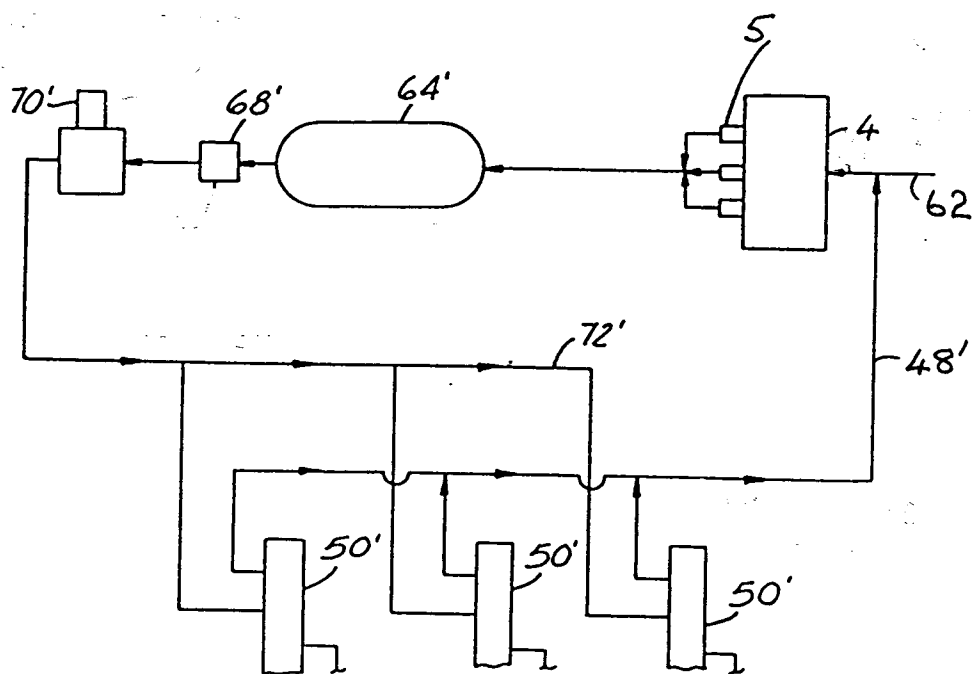


FIG. 8