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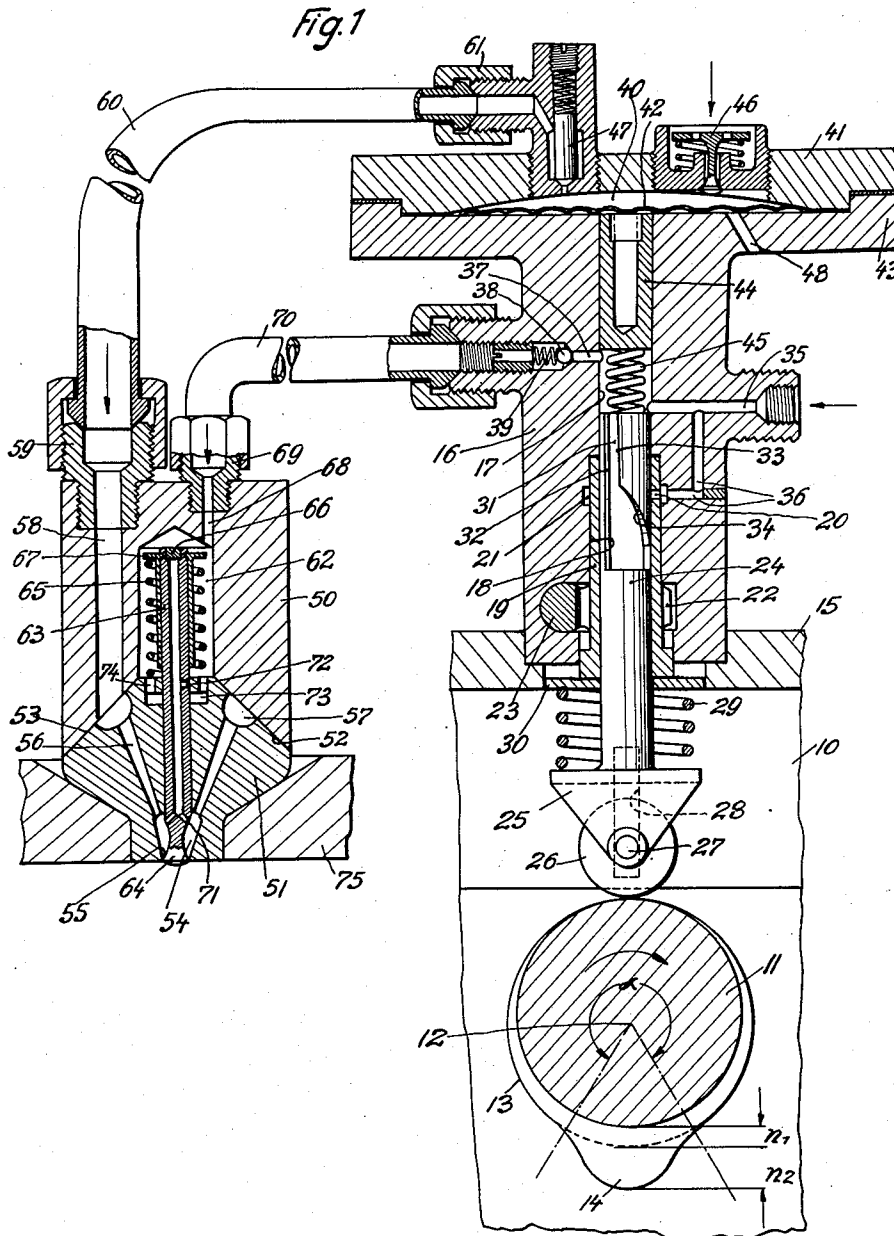
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FUEL INJECTION DEVICE FOR INTERNAL-COMBUSTION ENGINES

Filed June 11, 1952

2 Sheets-Sheet 1



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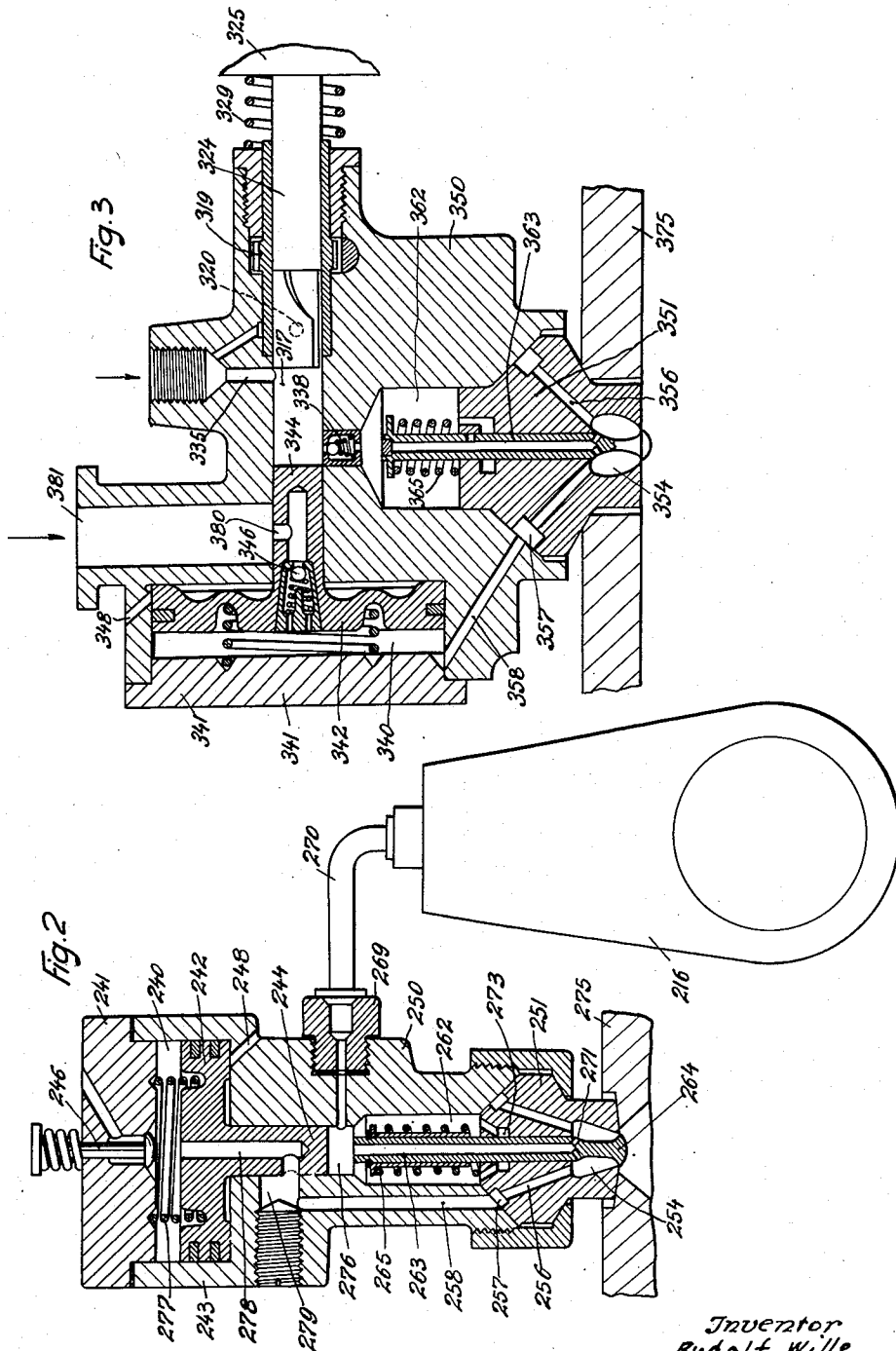
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FUEL INJECTION DEVICE FOR INTERNAL-COMBUSTION ENGINES

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24 Claims. (Cl. 299—107.2)

My invention relates to a fuel injection device for internal combustion engines and, more particularly, to a fuel injection device of the type in which the fuel is intermittently fed to a nozzle valve and injected by compressed air.

It is the object of the present invention to provide a fuel injection device of that type in which the air-compressing means is actuated by the pressure of the liquid fuel thus eliminating the necessity of providing separate driving means for the air pump and, at the same time, facilitating a proper timing of the air compression and the intermittent fuel feed. Further objects are to provide a simple and accurately operating fuel injection device adapted to inject clearly defined charges of liquid fuel by compressed air and adapted to be actuated by simple driving means, such as a rotary cam. Another object of my invention is to provide a fuel injection device for internal combustion engines in which the intermittent injection of the liquid fuel by compressed air is coupled with intermittent compression of such air, the injection period commencing whenever the compression of the required air charge has been completed. It is a further object of my invention to provide a fuel injection device for internal combustion engines in which compressed air is used to atomize the injected fuel fed by an intermittently operating fuel pump of the reciprocatory piston type as used for solid fuel injection in diesel engines.

Further objects of my invention will appear from the description of a number of various embodiments thereof following hereinafter which are shown in the accompanying drawings. However, it is to be understood that the detailed description of various forms of my invention serves the purpose of explanation rather than limitation of the invention. In the drawings

Fig. 1 illustrates a cam-actuated fuel-pumping and air-compressing unit associated with an injection nozzle valve, axial sections of said unit and said valve being shown;

Fig. 2 illustrates an axial section of a unit comprising an injection nozzle valve and an air pump actuated by a pulsating stream of liquid fuel, the pump producing same being shown diagrammatically; and

Fig. 3 is an axial section of a unit comprising a fuel pump, an air pump, and an injection nozzle valve.

In the housing 10 of an internal combustion engine a horizontal cam shaft 11 is mounted provided with a cam revolving about an axis 12, the profile of said cam being composed of an eccentric arc 13 embracing an angle α of about 300° and an elevation 14 extending between the ends of the arc 13, the transitional connections being rounded. It will be noted that the height of the eccentric arc 13 is designated $n1$ and that the height of the elevation 14 is designated $n2$.

On the top plate 15 of the engine housing 10 a casting 16 is mounted which constitutes the cylinder of a fuel pump of the reciprocating piston type. The casting 16 has a vertical bore 17 of smaller diameter merging into a lower co-axial bore 18 of larger diameter. The bore 18 accommodates a rotatable sleeve 19 provided with a controlling aperture 20 registering with an internal annular groove 21 in the bore 18. Moreover, the sleeve 19 has gear teeth 22 meshing with rack teeth provided on a rod 23 slidably guided in a transverse bore of casting 16 offset from the axis thereof.

The sleeve 19 has the same internal diameter as the bore 17 and both slidably accommodate a reciprocatory

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pump piston 24, the lower end of which extends out of housing 16 through an opening provided in the top plate 15 and carries a fork 25 straddling a follower roller 26 journaled on a transverse pin 27 mounted in the fork 25. The piston 24 is held against rotation relative to the casting 16 by suitable means. In the embodiment shown the ends of the pin 27 extend into vertical guiding grooves 28 provided in spaced vertical ribs of the engine housing 10 on either side of the fork 25. A helical pressure spring 29 surrounding the lower projecting end of piston 24 and bearing against the fork 25 and a washer 30 serves the dual purpose of keeping the follower 26 in engagement with the cam 11 and of urging the washer 30 inserted in the opening of top plate 15 against the projecting lower end of sleeve 19 thus securing the same against axial displacement.

The upper end of piston 24 forms a hollow sleeve provided with a longitudinal slot 31 constituting a controlling aperture co-operating with the aperture 20. While one edge 32 of the slot is straight extending parallel to the axis of the piston 24, the other edge of the slot is composed of two sections 33 and 34, the section 33 extending parallel to the axis of the piston, while the section 34 which co-operates with the aperture 20 extends helically.

When the piston 24 ascends, the edge 34 will override the opening 20 at an instant which depends on the relative angular adjustment of piston 24 and of the sleeve 19 forming part of the pump cylinder. The angular adjustment may be effected by movement of the rod 23. For this purpose the rod 23 is connected with any suitable control linkage not shown.

In Fig. 1 piston 24 is shown in its lower position uncovering a fuel inlet duct 35 opening into the cylinder bore 17 and connected to a fuel tank not shown. The duct 35 communicates with the annular groove 21 through by-pass ducts 36. Moreover, the casting 16 is provided with a fuel outlet duct 37 communicating with the bore 17 at a level above that of the inlet duct 35. The outlet duct 37 is provided with an outwardly opening check valve 38 controlled by a spring 39.

Above outlet 37 the cylinder bore 17 is sealed by suitable means to be described later.

The means so far described constitute a fuel pump adapted, when operated by the rotating cam 11, to produce a pulsating stream of liquid fuel discharged through the outlet duct 37, the quantity of fuel fed on any upward stroke of piston 24 depending upon the angular adjustment of sleeve 19, since such adjustment will determine the effective portion of the piston stroke preceding the ineffective stroke portion in which the helical edge 34 of the piston uncovers the controlling aperture 20 and thus by-passes the fuel displaced by the rising piston back to the source of fuel through the ducts 36 and 35.

For the purposes of my invention I have provided means which are indirectly operable by the fuel pump through the pressure of the fuel stream and are adapted to intermittently feed compressed air to the injection nozzle. Such means, in effect, constitute an air pump now to be described including a collapsible air-compressing chamber 40 confined in the hollow of a dished cover plate 41 by a diaphragm 42. The margin of this diaphragm is clamped between a flange 43 of casting 16 and the rim of the plate 41. The diaphragm 42 may be actuated by means of a movable member which is mounted to be subjected to the pressure of the fuel stream. In the present embodiment such movable member is formed by an auxiliary piston 44 slidably mounted in the upper part of the bore 17 and held in engagement with the diaphragm by any suitable means. In the present embodiment such means comprise a comparatively weak helical spring 45 inserted between the two pistons 24 and 44. The cover 41 is provided with a spring-controlled air inlet valve 46 and with a spring-controlled outlet valve 47. Since valves of that kind are well known in the art, a detailed description thereof may be dispensed with. The flange 43 is provided with a breather port 48 which will admit atmospheric air beneath the diaphragm 42 when the same is raised by the auxiliary piston 44 under the effect of the fuel pressure. When the piston 24 descends relieving

the auxiliary piston 44 from the fluid pressure, the diaphragm 42 will return to the normal position shown by its inherent elasticity.

In the first phase of the pump operation the piston 24 will be raised a distance $n1$ by the eccentric arcuate portion 13 of the cam. This distance is so chosen that the piston 24 after having closed inlet duct 35 will raise movable member 44 and actuate the air-displacing member formed by the diaphragm 42 thus compressing the air therein and feeding it through the outlet valve 47 to the injection nozzle valve to be described later. In the second phase of the pump operation piston 24 will be further raised a distance $n2$ by the elevation 14 of the cam. During this phase of the operation the auxiliary piston 44 remains stationary in its upper position in which it presses the diaphragm 42 against the cover 41. Therefore, the pressure of the fluid confined between the two pistons 24 and 44 will be raised to a degree sufficient to open the check valve 38 and the fuel will be fed to the injection nozzle. In this manner, my combined fuel and air pumping means will accurately time the fuel injection so as to commence upon completion of the air feeding and compressing phase.

In the embodiment shown in Fig. 1 the fuel injection device comprises a housing composed of two adjoining sections 50 and 51 which have complementary conical contacting faces 52, and 53 respectively. The housing section 51 has an inwardly flaring cavity 54 constituting the injection nozzle and provided with an external conical valve seat 55. The cavity 54 communicates through a plurality of ducts 56 with an annular groove 57 provided in the conical face 52. The groove 57 registers with the lower mouth of a vertical bore 58 provided in housing section 50 and connected by a suitable nipple 59 to an air pipe 60 which leads to the outlet valve 47 of the combined fuel and air pump and is connected thereto by a suitable nipple 61. Therefore, the air pump will load the space comprising pipe 60, bore 58, groove 57, ducts 56, and cavity 54 with compressed air prior to the feed of fuel through the outlet 37.

In the housing section 50 a central cylindrical chamber 62 is provided separately from the cavity 54. An axial bore that extends through the lower housing section 51 into the cavity 54 and has a diameter substantially equaling that of the valve seat 55 slidably accommodates the hollow stem 63 of a valve member 64 which is seated on the valve seat 55 to normally close the nozzle. The hollow valve stem 63 extends into the chamber 62 and is closed at its top by a plug 66 and is surrounded by a helical spring 65. One end of the spring bears against the housing section 51 and the other end against a washer 67 suitably fixed to the upper end of the valve stem. The housing section 50 is provided with a fuel inlet 68 for the chamber 62 and with a nipple 69 connecting a fuel pipe 70 to the inlet 68. The pipe 70 is connected to the pump fuel outlet 37.

The pressure of the fuel forced by the pump through the outlet 37 past the check valve 38 and through the pipe 70 into the inlet 68 and the chamber 62, after the injection nozzle valve has been loaded with compressed air, will act on the top face of the hollow valve stem 63 and on the plug 66 and will thus depress the valve stem overcoming the force of spring 65, whereby the valve member 64 will be lifted from the seat 55.

For the purpose of admitting the liquid fuel to the nozzle cavity 54, I have provided a conduit establishing a communication between the same and the chamber 62. Such conduit includes the hollow of the stem 63, a port 71 provided at the lower end of the stem and connecting the hollow thereof with the cavity 54, another port 72 of the hollow valve stem, an annular groove 73 provided internally in the bore accommodating the valve stem, and ports 74 connecting the groove 73 with the chamber 62. In fact, the groove 73 forms part of the chamber 62. It will be noted from Fig. 1, however, that when the valve 63, 64 is in its normal closed position, the aforesaid conduit is interrupted because the port 72 is located above and out of registry with the groove 73. Just after the valve 63, 64 has been opened, however, the port 72 will register with the groove 73 and will permit the fuel fed into the chamber 62 to flow through the ports 74 and 72, through the hollow valve stem 63, and through the port 71 into the cavity 54 to be injected and atomized by the compressed air with which the injection nozzle valve had been previously loaded.

The housing composed of the sections 50 and 51 is shown as being inserted in a wall 75 which may be the wall of a cylinder of the internal combustion engine or the wall of an intake conduit thereof.

In practice, suitable means not shown are provided to firmly press the housing section 50 downwardly thus keeping the housing section 51 in position.

The operation of the fuel injection device will now be briefly recapitulated: In the position shown the fuel pump piston 24 is in its innermost position. A communication is established between the fuel inlet 35 and the cylinder space between the pistons 24 and 44 which is filled with fuel. Upon rotation of the cam 11 in the direction of the arrow, the follower 26 and the piston 24 connected therewith are first raised by the eccentric arcuate cam portion 13, whereby the inlet 35 will be first closed and the auxiliary piston 44 will be raised under the effect of the pressure of the liquid fuel enclosed between the two pistons and under the additional effect of spring 45. As a result, the air previously sucked into the collapsible air chamber 40 through the check valve 46 will be compressed and finally fed through the outlet air valve 47 into pipe 60 and the nozzle housing 50, 51. When the diaphragm 42 engages the cover plate 41 thus preventing the auxiliary piston 44 from rising any farther, the continued ascension of the pump piston 24 driven by the elevation 14 of the cam will forcibly displace the quantity of fuel enclosed between the two pistons and feed the same past the check valve 38 into the chamber 62. The pressure thus created in chamber 62 depresses the nozzle valve 63, 64 until the fuel is admitted to the cavity 54 through the hollow valve stem and will be injected into the cylinder or the intake conduit of the internal combustion engine and will be atomized by the compressed air flowing through the conduits 56 into the cavity 54.

When the piston 24 descends, the piston 44 will be forced by the atmospheric pressure acting on its top face to follow the piston 24 keeping spring 45 therebetween in compressed condition until the inlet duct 35 is uncovered. Thereupon the spring 45 will expand pushing piston 44 back into the position illustrated and sucking in fuel through the inlet duct 35. In this manner, spring 45 serves the dual purpose of keeping member 44 in engagement with the diaphragm 42 and sucking in the fuel.

The embodiment shown in Fig. 2 differs from that shown in Fig. 1 mainly by the fact that the air-compressing chamber is provided in the housing of the injection nozzle valve rather than in the housing of the fuel pump. Otherwise the design is pretty much the same and, for that reason, corresponding elements have been designated by numerals formed by addition of 200 to those used in Fig. 1. Thus, it will appear that the injection nozzle valve comprises a housing section 251 formed with a nozzle cavity 254, a housing section 250 formed with a chamber 262, a valve proper consisting of a valve member 264 and a valve stem 263, and a spring 265 surrounding same. Moreover, similar ducts and conduits are provided as described with reference to Fig. 1 so that a repetition of such descriptive matter may be dispensed with.

In this embodiment the flange 43 shown in Fig. 1 is omitted from the casting 216 of the fuel pump, and the axial cylinder bore of the same is closed at the top by the outlet check valve communicating with the pressure pipe 270.

The housing section 250, however, is provided with an axial bore 276 which merges into the chamber 262 and serves to slidably accommodate the reciprocatory movable cylindrical member 244 which corresponds to the member 44 in Fig. 1 and serves the purpose of actuating the air-displacing element which, in this embodiment, is formed by a piston 242 rather than by a diaphragm, such piston being integral with the member 244. The piston 242 is movable within a cylindrical flange 243 of the housing section 250 and is urged downwardly by a helical spring 277 inserted between the piston 242 and a cover plate 241 suitably fixed to the flange 243. The cover plate 241 is provided with an air inlet controlled by a check valve 246. Moreover, the housing section 250 is provided with a breather port 248. The air outlet of the collapsible air chamber 240 in this embodiment is formed by an axial bore 278 of the piston 242 and the member 244 integral therewith, such bore communicating with the bore 258 through ports 279. In this embodiment a check valve controlling the air outlet 278 has been omitted.

The operation is as follows: The fluid forced by the pump through the pipe 270 into the bore 276 and into the chamber 262 will be operative before opening the injection valve 263, 264 to raise the movable member 244 and the piston 242 and to thus compress the air in chamber 240. The compressed air will then fill the space comprising the bores and ports 278, 279, 258, and 256 in readiness to inject and atomize the fuel admitted into cavity 254 upon actuation of the valve 263, 264.

In the embodiment illustrated in Fig. 3 the elements corresponding to those of Fig. 1 are designated by numerals formed by the addition thereto of 300. The housing of the pump and that of the injection nozzle are consolidated. Here again the air-displacing member is formed by a piston 342 rather than by a diaphragm, such piston being integral with the movable member 344 which is slidably guided in the cylinder bore 317 of the fuel pump, such cylinder bore extending in the housing section 350 at right angles to the axis of chamber 362 and being directly connected therewith by the pump outlet controlled by check valve 338 so that a pressure pipe, such as 270 in Fig. 2, is dispensed with. The bore 358 communicating with the circular groove 357 of housing section 351 is directly connected with the collapsible air chamber 340. While in the embodiment of Fig. 2 the air inlet was provided in the cover plate 241, the cover plate 341 has no such inlet, the latter being formed by an axial bore of piston 342 and the member 344 integral therewith, such bore communicating through a port 380 with an intake conduit 381 of housing section 350 opening into the atmosphere. A check valve 346 is inserted in the piston 342 to control the admission of air through intake 381 and port 380 to chamber 340.

In the embodiments illustrated in Figs. 2 and 3, a spring, such as spring 45 in Fig. 1, may be dispensed with since the air-displacing element 242, or 342 respectively, is integral with its movable actuating member 244, or 344 respectively.

While I have described my invention by reference to three specific embodiments thereof, I wish it to be clearly understood that my invention is in no way limited to the details of such embodiments, but is capable of numerous modifications within the scope of the appended claims.

What I claim is:

1. Fuel injection device for internal combustion engines comprising an injection nozzle valve, a fuel pump adapted to produce a pulsating stream of liquid fuel, an air pump, a reciprocatory movable member adapted to actuate said air pump and mounted to be subjected to the pressure of said stream to be operable thereby, and separate conduits connecting said pumps to said injection nozzle valve.

2. Fuel injection device for internal combustion engines comprising an injection nozzle valve, pumping means adapted to produce a pulsating stream of liquid fuel, a conduit extending from said pumping means to said injection valve, a spring-controlled movable member mounted to be subjected to the pressure of said pulsating stream to be reciprocated thereby, means constituting a collapsible air chamber provided with an air inlet and co-ordinated to said movable member for actuation thereby, and a conduit connecting said collapsible air chamber to said injection nozzle.

3. Fuel injection device for internal combustion engines comprising an injection nozzle valve, a pump co-ordinated thereto, said pump being of the intermittent type adapted to produce a pulsating stream of liquid fuel, means connecting said pump to said nozzle valve to conduct said stream thereto, said means including a cylinder and a spring-controlled piston movable therein and subjected to the pulsating pressure of said stream, air-compressing means operable by said piston and constituting a collapsible air chamber provided with an air inlet and an air outlet, and a conduit connecting said air outlet to said injection nozzle.

4. Fuel injection device for internal combustion engines comprising an injection nozzle valve, a fuel piston pump co-ordinated thereto and adapted to intermittently feed liquid fuel under pressure thereto, means driving said pump, means constituting a collapsible air chamber provided with an air inlet and an air outlet and including a movable element mounted to be subjected to the pressure of said fuel for actuation thereby, a conduit connecting said air outlet to said injection nozzle valve, a check valve in said conduit permitting the air compressed

in said collapsible chamber to flow into said injection nozzle valve, and a check valve co-ordinated to the outlet of said pump.

5. Fuel injection device for internal combustion engines comprising a housing forming an injection nozzle and provided with a chamber, a spring-controlled nozzle valve slidably guided in said housing to normally close the mouth of said nozzle and extending into said chamber to be operable by fluid pressure therein, means adapted to produce a pulsating stream of liquid fuel and communicating with said chamber, means forming a collapsible air-compressing chamber, a spring-controlled movable element mounted to be subjected to the pulsating pressure of said stream to be operable thereby and adapted to actuate said last mentioned means to compress the air in said collapsible chamber, and a conduit connecting said collapsible chamber to said nozzle inside of the mouth thereof.

6. Fuel injection device for internal combustion engines comprising a nozzle housing having a chamber and a separate cavity constituting the injection nozzle, an injection valve slidably guided in said housing and extending through said cavity and into said chamber and adapted to normally close the mouth of said cavity, a conduit being provided establishing a communication between said cavity and said chamber, said valve being adapted to normally close said conduit and to open same when actuated, a spring tending to keep said valve in normal position, a fuel pump connected with said housing and adapted to intermittently feed liquid fuel under pressure into said chamber to thereby actuate said valve, and means indirectly operable by said pump through the fuel pressure produced thereby and adapted to intermittently feed compressed air into said cavity.

7. The combination claimed in claim 6 in which said valve has a hollow stem slidably guided in a bore of said housing, and in which said conduit includes the hollow of said stem, the latter having an opening arranged to be normally closed by said housing and to communicate with said chamber upon actuation of said valve.

8. Fuel injection device for an internal combustion engine comprising an injection nozzle valve, a fuel pump adapted to produce a pulsating stream of liquid fuel, a collapsible chamber provided with an air inlet, a check valve in said inlet, an air-displacing member confining said chamber over a certain area, a reciprocatory piston adapted to actuate said air-displacing member, said area being a multiple of the cross-sectional area of said piston, the latter being mounted to be subjected to the pressure of said stream to be operable thereby, and separate conduits connecting said injection nozzle with said fuel pump and with said collapsible chamber.

9. The combination claimed in claim 8 in which said air-displacing member is a diaphragm.

10. The combination claimed in claim 8 in which said fuel pump comprises a housing, a bore provided therein, a fuel piston, both of said pistons being movably guided in said bore and confining between them a fuel pump chamber, said housing being provided with a fuel inlet for said chamber and with a fuel outlet communicating with one of said separate conduits, and check valves provided in the latter, said air-displacing member being mounted in said housing and said collapsible chamber being formed therein.

11. The combination claimed in claim 1 including a spring associated with said nozzle valve and tending to keep same closed contrary to the action of the pressure of said stream of liquid fuel, and a resilient element associated with said air pump and tending to restore said reciprocatory movable member upon operation by the pressure of said stream of liquid fuel, said spring and said resilient member being so correlated as to enable the pressure of said stream whenever said pressure rises to first operate said air pump and to subsequently open said nozzle valve.

12. Fuel injection device for internal combustion engines comprising an injection nozzle valve, a fuel pump including a reciprocatory piston adapted to produce a pulsating stream of liquid fuel, an air pump, a reciprocatory movable member co-ordinated to and adapted to actuate said air pump and mounted to be subjected to the pressure of said stream to be operable thereby, resilient motion-transmitting means interposed between said piston and said movable member and adapted to assist said stream in the operation of said movable member, and

separate conduits connecting said pumps to said injection nozzle.

13. Fuel injection device for internal combustion engines comprising an injection nozzle valve, a fuel pump having a reciprocatory piston adapted to produce a pulsating stream of liquid fuel, an air pump, a reciprocatory movable member adapted to actuate said air pump and mounted to be subjected to the pressure of said stream to be operable thereby, separate conduits connecting said pumps to said injection nozzle valve, and a rotary cam adapted to actuate said piston, the profile of said cam being composed of a circular arc eccentric with respect to the axis and extending through about 300° and of an elevation between the ends of said arc, the height of said eccentric arc corresponding to the air pump actuating portion of the stroke of said piston, and the height of said elevation corresponding to the fuel-injecting portion of the stroke of said piston.

14. The combination claimed in claim 1 in which said fuel pump comprises a cylinder having a fuel inlet, a fuel outlet and a by-pass conduit establishing a communication therebetween, a cam-actuated reciprocatory piston slidably guided in said cylinder, said cylinder and said piston being provided with co-operating apertures forming part of said by-pass conduit and adapted to be controlled by relative rotation of said piston and said cylinder, and fuel-controlling means adapted to effect relative angular adjustment of said piston and said cylinder.

15. The combination claimed in claim 1 in which said fuel pump and said air pump have a common housing.

16. The combination claimed in claim 1 in which said injection nozzle valve and said air pump have a common housing.

17. The combination claimed in claim 1 in which said injection nozzle valve, said fuel pump and said air pump have a common housing.

18. The combination claimed in claim 1 in which said injection nozzle valve, said fuel pump and said air pump have a common housing, said housing being composed of at least two adjoining sections having complementary conical contacting faces, one of said sections constituting a fuel pump cylinder and the other one of said sections constituting the housing of said injection nozzle valve.

19. The combination claimed in claim 1 in which said air pump is provided with an air inlet check valve and with an air outlet check valve.

20. The combination claimed in claim 1 in which said injection nozzle valve comprises a housing provided with a fuel inlet and constituting an injection nozzle formed

with an external valve seat, a valve member slidably guided in said housing and normally seated on said valve seat and adapted to be opened by the pressure of the liquid fuel fed to said inlet, a spring co-ordinated to said valve member and said housing and tending to normally keep said valve closed, and means co-operating with said valve member and adapted to control the communication between said inlet and said nozzle and to admit the fuel to said nozzle after said valve has been opened by the pressure of said fuel.

21. The combination claimed in claim 1 in which said air pump includes a collapsible chamber, and in which one of said separate conduits constitutes an unobstructed communication between said collapsible chamber and said injection nozzle valve.

22. Fuel injection device for internal combustion engines comprising air pump means, engine-driven fuel pump means for pressurizing the fuel, means responsive to pressurization of said fuel for pressurizing the air by said air pump means, and means responsive to further pressurization of said fuel for simultaneously injecting pressurized air and pressurized fuel into said engine.

23. Fuel injection device for internal combustion engines comprising an air pump, a fuel pump driven by the engine for pressurizing the fuel, means responsive to initial pressurization of said fuel for actuating said air pump to pressurize the air, and means responsive only to further pressurization of said fuel for simultaneously injecting the pressurized air and pressurized fuel into the engine.

24. Fuel injection device for internal combustion engines comprising normally closed injection means, an air pump, a fuel pump driven by the engine for pressurizing the fuel, means responsive to initial pressurization of said fuel for compressing the air by said air pump and means responsive to further pressurization of said fuel for opening said normally closed injection means to simultaneously inject said pressurized air and fuel.

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