

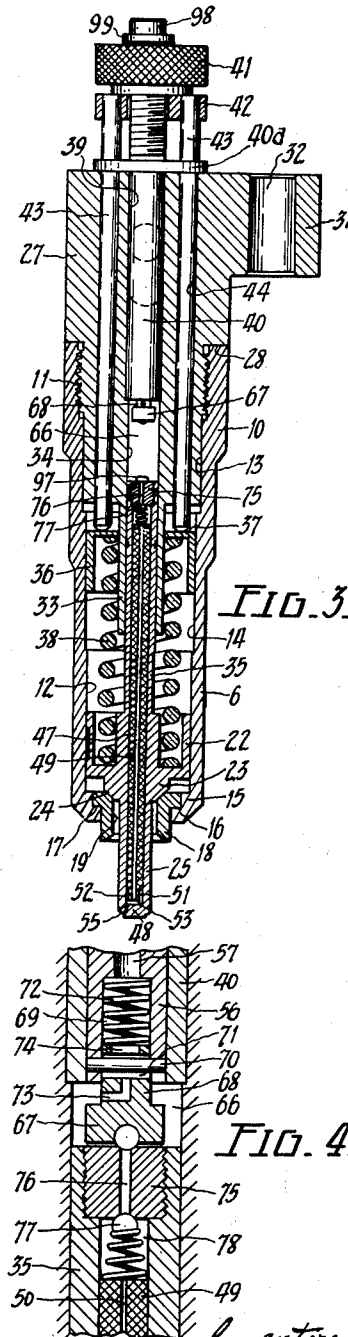
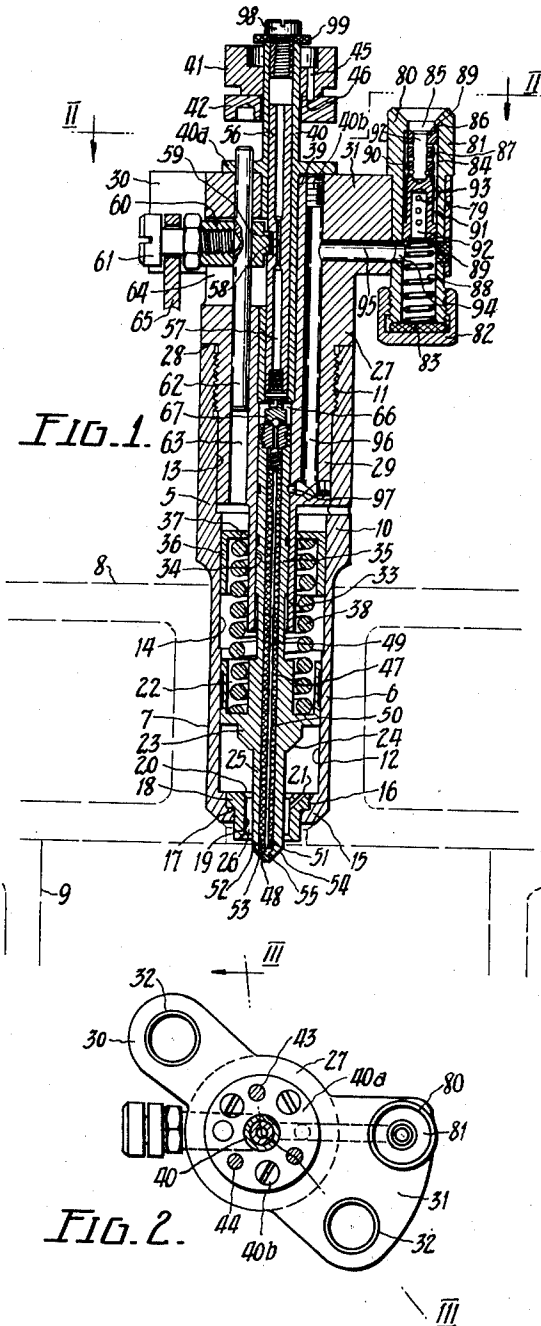
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FUEL PUMP

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## UNITED STATES PATENT OFFICE

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## FUEL PUMP

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This invention relates to "airless" or "solid" injection means or apparatus for spontaneous ignition constant pressure internal combustion engines, of the type comprising a fuel pump and motive means directly coupled with the fuel pump and operable by compression pressure in an engine cylinder to actuate the fuel pump for injecting fuel in a regulatable "solid" charge or volume into the engine cylinder.

In accordance with established practice, an engine fitted with injection apparatus of the type specified, is governed by varying the volume of fuel injected. The volume of fuel injected upon each operation of the fuel may be controlled by variation of the point or position in the operative stroke of the ram or plunger at which fuel ceases to be injected or alternatively, commences to be injected.

In order to thus regulate the quantity injected, the ram may be arranged for rotation relatively to the piston of the motive means and provided with a port or groove having an inclined face or edge which registers earlier or later, according to the rotated position of the ram, with a fuel release port or the fuel supply or charging port.

Alternatively, the volume of fuel injected may be regulated by adjustably shutting off communication between the cylinder of the motive means and the engine cylinder, so that operation of the former terminates earlier or later and the volume of fuel injected is accordingly less or greater.

The volume injected may also be varied by changing the effective capacity of the fuel pump chamber, so that more or less fuel is discharged while the stroke of pump plunger remains substantially constant.

In thus controlling the volume of injection, the fuel pump may be fitted with two plungers one of which comprises a control plunger and is movable by hand or governor so as to approach or recede from the other which comprises the operative plunger and is actuated by the motive means.

Now the principal objective of this invention is the provision of injection means or apparatus of the type specified, which is of generally simplified construction and easier to assemble and dismantle than the forms hitherto developed, and is, moreover, efficient in operation, and adjustably controllable for fuel injection responsive to variations of engine load.

The facility with which the injection means or apparatus according to this invention may

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be dismantled for inspection, cleaning and repair, and readily reassembled is of material importance in the general maintenance and running of engines.

In achieving the above-stated principal objective and in the broadest concept of the invention, there is provided an injection means or apparatus of the type specified, having in the fuel pump a control plunger opposed to and separated from the operative plunger by a space comprising the fuel chamber, the operative plunger responsive to action of the motive means controlling the filling or charging with and ejection of fuel from the fuel chamber for injection, and the control plunger being adjustably movable relatively to the operative plunger to vary the volume of injection and comprise a stop variably limiting the stroke of the operative plunger.

The initial volume of fuel in the fuel chamber, i. e. the volume at the commencement of each stroke of the operative plunger, is constant, but the stroke of the latter is terminated earlier or later by engagement with the adjustable control plunger, so that the quantity of fuel displaced and injected by successive strokes of the operative plunger comprises a greater or less proportion of the constant initial volume responsive to changes of engine load.

Further objects of the invention are to provide free movement for the control plunger unopposed by pressure, so that a governor may adjust the control plunger to vary the quantity of fuel injected in response to changes of engine load, to provide means for absorbing shock upon completion of injection, and to incorporate in the motive means a device to facilitate engine starting and slow running.

In order that the control plunger may be freely moved by a governor, the former is contained in the pump bore or cylinder and is pressure-balanced i. e. the pressures upon the opposite ends are equalized by the provision of a passage interconnecting the fuel chamber at one end of the control plunger with the portion of the pump cylinder at the opposite end of said plunger.

An important function achieved by the operation of the motive piston, is the increase in clearance volume space which lowers the compression pressure, i. e. decreases the compression ratio. Such decrease in compression ratio lowers the temperature of compression below the necessary ignition temperature, but this lowering of temperature is compensated by heating of the fuel arising from sudden impact of the pump

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plunger thereon and the friction resulting from the high velocity of the fuel through the nozzle jets and through the dense compressed air.

The heating thus produced and the heat of compression raises the temperature to the ignition point, notwithstanding the reduction in compression pressure.

The injection apparatus according to the invention, may therefore be used effectively on engines of small size operating at relatively low compression pressures, and such engines are resultantly operated on a spontaneous ignition constant pressure cycle.

The invention will be better understood from the description of the exemplary practical injection apparatus illustrated in the accompanying drawings, wherein:

Fig. 1 is a longitudinal section of the injection apparatus.

Fig. 2 is a plan view on the line II—II of Fig. 1.

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

Fig. 4 is a fragmentary sectional detail on a larger scale.

In these drawings, the numeral 5 designates a cylindrical casing, of which the exterior portion, indicated by 6, is appropriately dimensioned to fit within a fuel supply aperture 7 in the combustion head 8 of a cylinder 9 of an internal combustion engine.

The cylindrical casing 5 is formed with an enlargement 10 and is axially step-bored. The bore is of maximum diameter at 11 within the enlargement 10 and of least diameter at 12 within the portion 6 with intermediate bore diameters at 13 and 14.

At the termination of the minimum bore 12, there is an internal flange 15, which is axially bored and recessed at 16 to form a seating 17 for an externally flanged bushing 18 having an axial orifice 19 which is flared or tapered at each end, the taper indicated by 20 comprising a valve seat as presently explained.

Formed obliquely in the bushing 18 is a port or passage 21 of relatively small diameter which forms a by-pass between the interior of the engine cylinder 9 and the interior of the bore 12 of the casing 5 for a purpose hereinafter described.

Slidably fitting the minimum bore portion 12 is a piston 22 formed with a central projection or boss 23 which is tapered at 24 to form a valve for engagement with the correspondingly tapered valve seat 20, see Fig. 3.

Projecting from the boss 23 is an axial extension 25 which extends through the orifice 19 and partially closes the latter, so that an annular passage indicated by 26, is formed between the extension 25 and the interior of the bushing 18.

The annular passage 26 connects the interior of the cylinder 9 and bore 12 upon the valve 24 being displaced from the seat 20, see Fig. 1, but is closed by the valve 24 upon engagement with the seat 20 as shown in Fig. 3.

The bore 11 of the casing 5 is internally threaded to receive a correspondingly screwed closure or body member 27, the outer surface of which has the same external diameter as the enlargement 10, so that the former has a shoulder 28 which abuts upon the end of the latter.

The body member 27 has an unthreaded or plain portion 29 which fits within the bore portion 13 and thereby disposes the body member accurately in coaxial alignment with the casing 5.

Lugs 30 and 31 formed integrally with the body

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member 27 are provided with apertures 32 oppositely located at equal distances from the common axis of the casing 5 and body member, and studs or bolts (not shown) passed through the apertures 32 and fixed in the combustion head 8, firmly secure the casing 5 and body member to the latter.

Formed integrally with the body member 27 is an extension 33 which extends axially within the bore portion 14 and is internally bored at 34 to receive an axial extension 35 of the piston 22.

The extensions 33 and 35 comprise respectively the barrel and plunger of the fuel injection pump hereinafter more fully described.

Slidably fitting the bore portion 14 is a cylindrical sleeve 36 having an internal flange 37 upon which is seated one end of a helical spring 38, the opposite end of which bears upon the piston 22 and urges the valve 24 thereon into engagement with the valve seat 20 to shut off communication between the cylinder 9 and the interior of the bore 12.

Extending coaxially from the bore 34 to the end of the body member 27, is a bore 39 of somewhat greater diameter in which is fitted a liner 40 which comprises an extension of the pump barrel 33 and projects from the end of the body member and is threaded for engagement by a manually adjustable nut 41. An integral flange 40a and screws 40b secure the liner 40 to the body member 27.

In contact with the nut 41 is a collar 42 axially movable upon the liner 40 and secured to thrust rods 43 which extend through longitudinal holes 44 in the body member 27 into contact with the sleeve 36.

It will be apparent that by adjustment of the nut 41, the thrust rods 43 may be slidably moved in the holes 44 to adjust the compression or normal energising of the spring 38 to thereby vary the closing pressure of the valve 24 on the valve seat 20, and resultantly determine the compression pressure in the engine cylinder at which the valve 24 will open, as hereinafter described. Locking of the nut 41 upon adjustment, is effected by a pin 45 engageable with one or more ramp slots 46 in the collar 42.

Through the plunger 35, piston 22 and extension 25 is an axial bore 47 which terminates at the closed end 48 of the extension 25, and in the bore 47 is closely fitted a capillary tube 49 having a fine bore 50.

The end of the capillary tube 49 is reduced in diameter at 51 to form an annular space 52 and the inner side of the closed end 48 is separated from the end of the capillary tube by a space or gap indicated by 53.

The extension 25 is tapered at 54 and through this tapered part is drilled a multiple number of small spray apertures 55 through which fuel is sprayed into the engine cylinder 9, the extension 25 accordingly, comprising the fuel injection nozzle.

Slidably fitted in the liner 40 is a control plunger 56 which is reciprocal in the former and has an axial bore 57 extending between the opposite ends thereof.

In order that the control plunger 56 may be adjustably reciprocated in the liner 40, the former has at or about the mid-length, a peripheral slot 58, with which is engaged a tongue 59 on a cross-head 60 secured by screw 61 to a slide bar 62 slidably in a guide aperture 63 in the body member 27.

The crosshead 60 is accommodated and movable in a slot 64 formed in the body member 27,

and a link 65 controlled manually or by a governor is connected to the screw 61, so as to actuate the crosshead 60 and thereby move the control plunger 56 in the liner 40 in response to variations of load, as hereinafter described.

The space between the ends of the pump plunger 35 and the control plunger 56 comprises a fuel chamber 66 into which extends a cushioning block 67 carried by the control plunger 56.

The cushioning block 67 has a shank 68 which slidably fits an enlargement 69 of the axial bore 57 and is retained therein by a transverse pin 70 which extends through a slot 71 in the shank 68. Bearing upon the end of the shank 68 and seated upon the end of the enlarged bore 69 is a spring 72 which normally retains the inner end of the slot 71 in engagement with the pin 70 and the cushioning block extended from the control plunger 56. In the shank 68 are ports 73-74 whereby communication is established between the axial bore 57 and the fuel chamber 66.

The end of the pump plunger 35 is bored and threaded to receive a plug 75 having a central aperture 76 which is closable by a spring-influenced check valve 77 positioned in a passage 78 continuous with the capillary bore 50.

Extending through a vertically disposed aperture 79 in the lug 31 is a filtering device comprising a cylindrical plug 80 having a threaded head 81 to which is connected a fuel supply tube (not shown). The plug 80 projects from the opposite side of the lug 31 and is threaded to receive a removable cap 82 which by a sealing pad 83 closes a bore 84 extending through the plug to a constriction 85 forming a shoulder 86 against which a filtering sleeve 87 is normally maintained by a spring 88.

The sleeve 87 has ends 89 fitting the bore 84, and between the ends 89 there is a reduced portion 90 forming with the surrounding bore 84 an annular space 91. In the opposite ends of the sleeve 87 are axially drilled holes 92 which by small radial apertures 93 are connected with the annular space 91. In passing through the filtering sleeve 87, impurities and any contained water are extracted from the fuel and gravitate to the lower end of the plug 80 for removal upon withdrawal of the cap 82.

A hole 94 in the plug 80 is aligned with a port 95 in the lug 31 which connects with a longitudinal passage 96 in the body member 27. The passage 96 has a terminal port 97 which connects with the bore 34 of the pump barrel 33 and is opened by the plunger 35 as the valve 24 moves into contact with the valve seat 20, see Fig. 3.

Upon the terminal port 97 being thus opened, fuel from the fuel line which is maintained at a required charging pressure, passes through the sleeve valve 87 by way of the axial holes 92, radial apertures 93, annular space 91, hole 94, port 95 and passage 96 to and through the terminal port 97 into the fuel chamber 66 which is accordingly charged with liquid fuel.

Furthermore, the liquid fuel passes through the ports 73-74 in the shank 68 into and through the bore 57 and fills the portion of the liner 40 or extension of the pump barrel above the control plunger 56, the liner 40 being closed by a screw 98 and packing washer 99.

In operation, and assuming the fuel chamber 66, bore 57, and said portion of the liner 40 to be thus filled with liquid fuel, and the valve 24 to be closing the annular passage 26, the engine is initially rotated to impel the piston inwardly

into the cylinder on the compression stroke of the cycle of operations.

During the compression stroke and in accordance with the operative cycle of spontaneous ignition constant pressure engines, air is compressed in the engine cylinder, and as the pressure rises, compressed air passages through the by-pass port 21 into the cylinder 12, so that the pressure therein increases but at a relatively slow rate consequent upon the small area of the by-pass 21.

The compression pressure in rising bears upon an area of the piston 22 equivalent to the full cross-sectional area of the axial orifice 19 of the bushing 18, and as the engine piston approaches the end of the compression stroke, the compression pressure acting upon this area, together with the pressure in the cylinder 12 acting upon the annular part of the piston 22 surrounding the boss 23, is sufficient to displace the valve 24 from the seat 20 against the resistance of the spring 38.

Thereupon the compression pressure acts upon the full area of the piston 22 which together with the pump plunger 35 is rapidly moved and thrust against the spring 38 which is accordingly compressed and further energized.

In the rapid movement in the pump barrel 33, the plunger 35 firstly, closes the fuel inlet 97 and then ejects the fuel charge in the fuel chamber 66 through aperture 76 past the valve 77 into the capillary bore 50 and thence into the injection nozzle 25 from which the fuel is sprayed through the apertures 55 into the engine cylinder, wherein the fuel is spontaneously ignited and burnt in the compressed air to impart the initial impulse to the engine.

The brief injection period terminates upon engagement of the marginal edge of the aperture 76 with the cushioning block 67, whereupon the delivery of fuel into the engine cylinder ceases.

Upon injection of fuel ceasing as described, the piston 22 and plunger 35 are brought to rest without shock by the back pressure generated in the fuel remaining in the fuel chamber 66, bore 57 and the upper portion of liner 40. When the marginal edge of the aperture 76 of the outwardly rising plunger 35 engages with the cushioning block 67 the latter is impelled in an upward direction under restraint by the transverse pin 70 in the slot 71 of the shank 68, the spring 72 and the pressure of the fuel remaining in the ports 73 and 74, the bore 57 of the control plunger 56 and the upper portion of the liner 40. The back pressure of the fuel thus arising at the termination of injection and which the cushioning block 67 and its related members are designed to induce, has the effect of bringing piston 22 and plunger 35 to rest without shock, due in the applicant's belief, to the slight compressibility of the fuel, dilation of the metal parts and the increased fuel pressure which balance out the compression pressure.

In the starting of the engine as above described, and to some extent in slow running, a portion of the air undergoing compression passes through the by-pass port 21 and the compression pressure in increasing acts upon the whole area of the piston 22 which is accordingly operated earlier during the compression stroke than would be the case if the by-pass port were omitted and the compression pressure acted only upon the area of the piston equivalent to the cross-sectional area of the axial orifice 19 of the bushing 18.

Accordingly, it will be appreciated that in starting or running at much reduced speeds, the by-pass port 21 by admitting compressed air into the annular space surrounding the boss 23 obviates the factors which reduce compression pressure and arising from heat losses consequent upon the lower rate of compression, and the longer period of time for piston blow by, and leakages through inlet and exhaust valves, all of which by simultaneous action would render the operation of the motive means too late, or suspend the operation altogether, if the area below the valve 24 alone was exposed to increasing compression pressure.

As the engine accelerates, the by-pass port 21, resultant of its restricted cross-sectional area, becomes decreasingly effective until, upon the engine attaining the normal running speed the by-pass port becomes almost ineffective and the compression pressure acts only upon the area of the piston 22 equivalent to the area of the orifice 19.

The area or diameter of the by-pass port 21 whereby optimum starting and slow running are achieved is ascertained by trial.

Governing of the engine speed in response to load variations is effected by the control plunger 56 which by the link 65, screw 61 and crosshead 60 is axially moved in the liner 40 by the engine governor to vary the stroke of the pump plunger 35, so that a greater or less quantity of fuel is injected in accordance with load requirements.

The total capacity of the fuel injection pump, i. e. the volume comprised of the fuel in the chamber 66, the bore 57 of the control plunger 56 and the portion of the bore of the liner 40 above the control plunger, is constant at the commencement of each stroke of the pump plunger, notwithstanding the axial position of the control plunger 56, as it will be evident that a reduction in capacity of the fuel chamber 66 is compensated by an equal increase in capacity of the portion of the bore above the control plunger 56.

The stroke of the pump plunger 35 is limited by contact with the control plunger 56 and the latter resultant of the action of the governor in response to changes of load is positioned nearer to or further from the initial position of the former at the commencement of each stroke.

Consequently the stroke of the pump plunger 35 is varied and at each injection expels a proportionally greater or less volume of the constant total pump capacity from the fuel chamber 66.

As the pressures on the ends of control plunger 56 are balanced, as a consequence of the axial bore 57 through which fuel is free to flow in either direction, the resistance opposing the governor is slight so that sensitive governing of the engine is achieved.

Upon the piston 22 being operated during the compression stroke of the engine as described, the volume of the clearance space of the engine cylinder is increased by connection with the interior of the motive cylinder 12.

Resultantly, the compression ratio is decreased and the compression pressure is, accordingly, lowered, so that the temperature of the compressed air in the engine cylinder would be less than the minimum required for ignition, i. e. 1000° Fahrenheit, were it not for other factors which counteract the fall of temperature.

Factors which contribute to increase the temperature to the ignition point are the sudden impact of the pump plunger upon the fuel which in the applicant's belief generates heat in the

latter, and the friction arising from the high velocity of the fuel in passing through the jet orifices and through the dense compressed air, which it is believed generates heat in the fuel.

The accumulative heating effects from those causes and engine compression have been found to raise the temperature to the ignition point, so that the apparatus described herein may be used efficiently on engines of small size operating at relatively low compression pressures, both at starting and in normal running, and permits such engines to be operated on a spontaneous ignition constant pressure cycle.

Although the improved injection apparatus has been described with particular reference to constant pressure engines operating on relatively heavy fuels, such as diesel oil, it will be appreciated that the apparatus may be utilized with like advantages for constant volume engines operating on light and volatile liquid fuels or spirits, such as petrol, benzine, alcohol, kerosene and the like.

In order to overcome the lubrication difficulties apt to be encountered in injection apparatus when such light fuels are used, the liner 40 may be made of material having self-lubricating characteristics such as a suitable plastic, oil or graphite impregnated metals, powdered metals, or the like, and operative parts such as the pump plunger and barrel, and the control plunger may be sleeved or lined with such materials.

I claim:

1. In a pressure operated liquid injection apparatus, a pump cylinder, a plunger reciprocable in the pump cylinder, an axially adjustable stop member in the pump cylinder to variably limit the stroke of the plunger, an axially disposed discharge duct in the plunger, means for hydraulically balancing the stop member against liquid pressure, and valvular means carried by the stop member to engage the plunger and obturate the axially disposed discharge duct.

2. In a pressure operated liquid injection apparatus, a pump cylinder, a pump plunger reciprocable in the cylinder, an axially adjustable control plunger in the pump cylinder to variably limit the stroke of the pump plunger, an axial discharge duct in the pump plunger, means for equalizing the liquid pressures on opposite ends of the control plunger, and a valve carried by the control plunger to engage the pump plunger and obturate the axial discharge duct.

3. In a pressure operated liquid injection apparatus, a pump cylinder, a pump plunger in the cylinder, a control plunger in the cylinder opposed to and axially adjustable to limit the stroke of the pump plunger, an axial discharge duct in the pump plunger, a pressure equalizing duct extending longitudinally through the control plunger to hydraulically balance the liquid pressures on the opposite ends of said plunger, and a valvular member resiliently mounted on the control plunger to engage the pump plunger and obturate the axial discharge duct.

4. In a pressure operated liquid injection apparatus, a pump cylinder, a power cylinder in coaxial alignment with the pump cylinder, a piston in the power cylinder operable by increasing fluid pressure in said cylinder, a plunger in the pump cylinder operatively connected with the piston, a control plunger in the pump cylinder opposed to the pump plunger, means for axially adjusting the control plunger to variably limit the stroke of the pump plunger and piston, a longitudinal discharge duct in the control plunger, and a valve

resiliently mounted on the control plunger to engage the pump plunger and obturate the longitudinal discharge duct.

5. A pressure operated liquid injection apparatus comprising a pump cylinder, a power cylinder, a piston in the power cylinder operable by increasing fluid pressure in said cylinder, a plunger in the pump cylinder operatively connected with the piston, an admission port in the end of the power cylinder closable by a portion of the piston having a primary area exposed to the increasing fluid pressure through said port, a secondary area of the piston to which the fluid pressure is additionally applied upon initial movement of the piston responsive to action of the increasing fluid pressure on the primary area, a chamber between the secondary area of the piston and the end of the cylinder, and a by-pass through which the fluid is fed at reduced rate to the chamber to effect a gradual increase of pressure on the secondary area simultaneously with the direct increase of pressure on the primary area through the admission port.

6. A pressure operated liquid injection apparatus, comprising a pump cylinder, a power cylinder in coaxial alignment with the pump cylinder, a piston in the power cylinder operable by increasing fluid pressure in said cylinder, a plunger in the pump cylinder operatively connected with the piston, an admission port for fluid under increasing pressure in the end of the power cylinder, an extension of the piston, a valve seating disposed about the admission port, a valve on the extension of the piston engageable with the seating, an annular chamber disposed about said extension, resilient means urging said valve upon the seating and opposing operative stroke move-

ment of the piston and plunger, a control plunger in the pump cylinder opposed to the pump plunger, means for axially adjusting the control plunger to variably limit the operative stroke of the plunger and piston, a longitudinal discharge duct for liquid extending axially through the plunger, the piston and said extension of the piston, a pressure equalizing duct extending axially through the pump plunger, means for equalizing the liquid pressures on opposite ends of the control plunger, and valvular means carried by the control plunger to engage the pump plunger and obturate the longitudinal discharge duct.

7. A pressure operated liquid injection apparatus as claimed in claim 6, wherein the fluid under increasing pressure is applied through the admission port directly to a primary area of the piston and through a by-pass port at reduced rate into the annular chamber to act at a diminished pressure upon a secondary area of the piston.

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