

June 14, 1938.

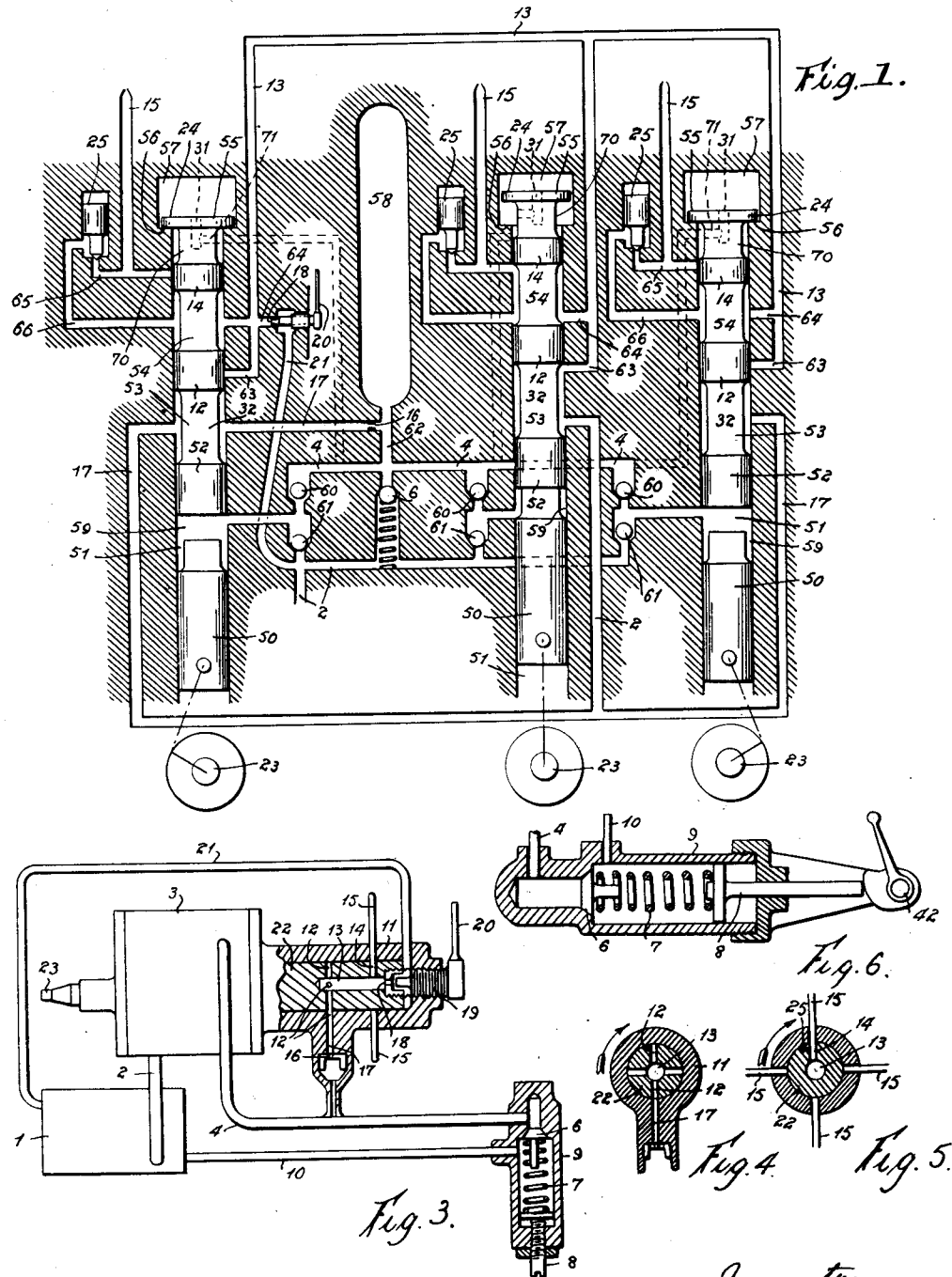
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FUEL INJECTION SYSTEM FOR INTERNAL COMBUSTION ENGINES

Filed Jan. 7, 1936

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

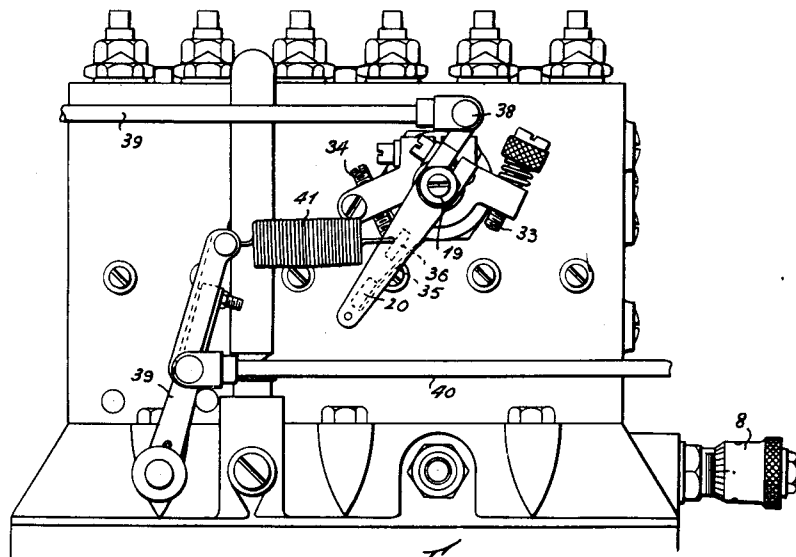


Fig. 7.

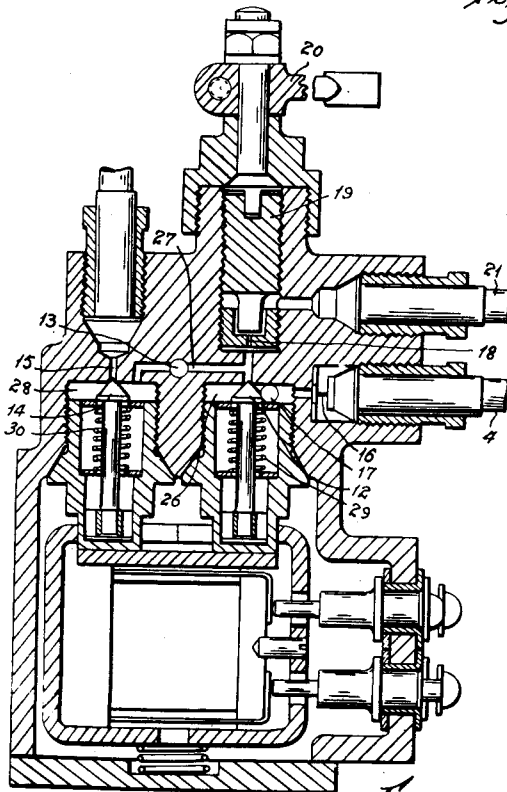


Fig. 2.

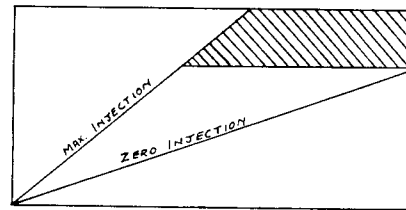


Fig. 8.

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UNITED STATES PATENT OFFICE

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FUEL INJECTION SYSTEM FOR INTERNAL COMBUSTION ENGINES

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5 Claims. (Cl. 123—138)

This invention relates to improvements in fuel injection systems for multi-cylinder internal combustion engines and in particular to injection systems of the kind wherein fuel is supplied by a feed pump or other convenient means at a substantially constant pressure sufficient to effect injection, the fuel passing by way of a selection or distributing device and through appropriate injection valves to the engine cylinders in the correct order and in timed sequence with the engine crankshaft.

In known apparatus of this kind the achievement of a uniform quantity and pressure of fuel supplied, and a uniform period of injection at each of a plurality of injection valves has been dependent upon extreme accuracy of manufacture of the apparatus.

As engine speeds increase and the quantity of fuel required at each injection decreases, it becomes increasingly difficult to obtain such equality of metering at all the injection valves as will ensure maximum power delivery by the engine and equal power delivery from the several cylinders.

The object of the present invention is an improved method and means for delivering an equal quantity of fuel to each of the several injection valves of a multi-cylinder engine and for equalizing the fuel pressure acting on each of the respective valves and the period of time during which each of the valves is subjected to the injection pressure so that the injection conditions are the same at each and every injection valve.

It is a further object of the invention to provide means whereby the quantity of fuel supplied may be varied at will for all injection valves in unison.

The control of the quantity of fuel injected from zero to maximum at all valves may be effected by varying the flow of fuel from the pressure supply into a distributing passage which is arranged to communicate with all the injection valves in turn and with a low or no pressure receptacle or the like through a restricted outlet or alternatively the variation may be effected by varying the restriction at the outlet. Again the variation may be achieved by varying the inlet and outlet restriction in conjunction with one another.

The arrangement is such that after an injection has taken place the pressure in the distribution passage falls and by this means dribble at the injection nozzle is prevented.

The pressure in said distribution passage must however be re-established for the next injection,

and this occurs during the time that the passage is open to the supply pressure, so that the pressure necessary to effect injection only exists during a part of the time that the passage is open to the supply pressure.

For a given time period during which fuel flows through said distribution passage, any desired maximum pressure below the supply pressure may be maintained therein for a time period which may be varied from only slightly less than the whole flow time period downwards, by the control means referred to above, and thus the injection pressure for a desired proportion of the flow period may be obtained at the injection nozzle which is in communication with the distribution passage during the said flow period.

Various embodiments of the injection system according to the present invention are illustrated in the accompanying drawings in which

Fig. 1 shows diagrammatically a pump and distribution system according to the invention for use with a three-cylinder engine, the arrangement shown being one which is well adapted to be carried out as a unitary structure,

Fig. 2 is a diagrammatic illustration of an alternative construction employing poppet type valves,

Fig. 3 is a view of still a further alternative arrangement the distributor being shown in section,

Figs. 4 and 5 are sectional views on the lines A—A and B—B of Fig. 3,

Fig. 6 shows a detail, and

Fig. 7 is a view in side elevation showing an arrangement for limiting or varying the outlet area from the distribution passage or chamber, and providing an attachment for governor control,

Fig. 8 is a graph showing the maximum and zero injection valve discharges.

The same reference numerals refer so far as is possible to corresponding parts in the various constructions illustrated.

Referring to Fig. 1, 23 represents the pump crankshaft, the cranks being shown separately for each of three pump plungers 50 for convenience in illustration. This crankshaft 23 is coupled with the engine so that the several cranks are correctly synchronized to operate the cylinders of the pump in the required order for fuel injection at the injection valves 15 of the various cylinders through their fuel supply passages.

The pump plungers 50 are arranged for reciprocating movement in passages 51 formed in a suitable body, the passages also containing piston

valves 32 each formed with three sealing portions 52, 12 and 14 and two portions 53 and 54 of reduced diameter and with an enlarged head 55 the projecting peripheral portion of which is adapted to seat upon a shoulder 56 formed at the junction of each passage 51 with an enlargement 57 formed at the upper end thereof.

The piston valves 32 are raised by the engagement of the moving plunger 50 with their lower ends and returned by the pressure of the fuel in the spaces 57 above the heads 55.

A chamber 58 is provided containing fuel at a predetermined constant high pressure, the fuel being supplied thereto by way of conduits 2 and 4, the conduit 2 being connected to any convenient source of fuel supply such as a tank not shown.

Spaces 59 in passages 51 between each plunger 50 and valve 32 are in communication with said conduit 4 and pairs of non-return valves 60, 61 are provided to permit transfer of fuel under pressure created in the spaces 59 from conduit 4 to the chamber 58 by way of outlet 62, or the introduction of fuel into space 59 from the supply pipe 2.

A spring controlled relief valve 6 is also provided between conduits 2 and 4 to permit egress of fuel from the conduit 4 to conduit 2 when the required pressure in chamber 58 is exceeded, and an adjustment may be provided to enable the pressure in chamber 58 to be determined at will.

From the chamber 58 leads a conduit 17 having branches leading to the interior of each of the passages 51 at points opposite the parts 53 of the valves of reduced diameter and at the point of juncture of passage 17 with chamber 58 is provided a feed or supply orifice 16 of selected size.

The interior of each passage 51 is also in communication with a branch of a common distributing conduit 13, each branch having two extremities 63, 64, one of which 63 is located so that it is covered and uncovered by sealing portion 12 of a valve as the latter is reciprocated while the other is at all times open opposite the portion of reduced diameter 54.

In one of the branches of distributing conduit 13 is provided an outlet or leak-off valve 18 provided with an adjustment 20 whereby the quantity of fuel flowing through said valve may be varied at will.

The outlet side of said valve 18 is in communication by way of conduit 21 with fuel inlet conduit 2.

Each passage 51 also communicates by way of a passage 65 with an injection valve 15 discharging into the corresponding cylinder (not shown), the passage 65 being located so that it is opened or closed to the passage 51 as the piston valve rises and falls.

Each passage 65 is also connected through a passage 66 containing a non-return valve 25 with the space in the corresponding passage 51 opposite the reduced portion 54 of the reciprocating valve 32. The arrangement is such that when passage 65 is closed by the portion 14 of the reciprocating valve a higher pressure may be maintained in the passage 65 to injection valve 15 than exists in the part of passage 51 opposite portion 54 of reduced diameter.

In operation as a pump plunger 50 rises fuel at high pressure is forced through the conduit 4 to pressure chamber 58, any surplus returning by way of valve 6 to conduit 2. When the plunger engages the lower end of a valve 32 to lift it and a

branch 63 of distributing conduit 13 is uncovered, fuel flows through supply orifice 16 and the appropriate quantity of fuel according to the size of supply orifice 16 is metered to the conduit 17.

Assuming the centre valve 32 in Fig. 1 to be raised, the fuel flows into the space in passage 51 surrounding the reduced portion 53 and out through branch 63 of distribution passage 13, the flow continuing for a period corresponding to a constant angular rotational period of the crankshaft. The fuel passes on partly by way of the branch 64 of the passage 13 opposite the reduced portion 54 of the piston valve and thence by way of passage 65 to the appropriate injection valve 15 and partly by continuation in distribution passage 13 to leak-off valve 18 that proportion of the fuel passing through said valve returning by way of passage 21 to the pump suction conduit 2 or to the fuel supply tank.

During such time as all the pistons 32 are in their lowered position the common distribution conduit 13 and the spaces in the passages 51 opposite reduced valve parts 54 remain in communication with the conduit 2 or fuel supply tank by way of leak-off orifice 18 and passage 21 so that the pressure therein falls. Similarly, the pressure in passages 65 to the injection nozzles is permitted to fall to a certain extent by way of non-return valve 25 in passage 66 also in communication with the space in passage 51, and by this means dribble at the injection nozzles is obviated.

As soon as a valve 32 is lifted to uncover the inlet 63 to passage 13 and the inlet to passage 65, the pressure is re-established in distribution passage 13 and the corresponding passage 65 to the injection nozzle 15 simultaneously with a fall of pressure in supply conduit 17 and the supply spaces in passages 51 opposite the reduced valve parts 53, supplied from the high pressure chamber 58 way of feed or supply orifice 16. A pressure sufficient to effect injection is built up in the distribution conduit 13 and the spaces in passages 51 opposite reduced valve parts 54 for a part of the time during which the valve is lifted this part being dependent upon the fuel supply pressure and the areas of the feed orifice 16 and the leak-off orifice 18.

Each of the plurality of injection valves 13 is therefore supplied with fuel for the same period of time from a distribution conduit 13 common to all, the pressure conditions in which are controlled from a single high pressure fuel source in conjunction with the single pair of orifices 16 and 18 and the pressure, time of injection and quantity of fuel injected will thus be the same at all the injection valves.

The return or lowering movement of the valves 32 may be effected by the pressure of fuel in spaces 57 above the enlarged heads 24 of the valves. For this purpose there is provided an annular groove 70 in the portion 14 of each valve immediately beneath the head 24 and this groove communicates by way of an aperture 71 in the valve with a central bore 31 within the valve body, the groove in turn being in communication with pressure supply conduit 4 at a point on the pump side of supply orifice 16.

Thus fuel under pressure is maintained at all times in spaces 57 so that the valves 32 are urged downwards as the pump plunger 50 recedes until the peripheries 24 of the valve heads 55 reach their seatings on shoulders 56.

In the arrangement shown in Fig. 2, poppet valves are employed in place of the piston valves of the above described embodiment.

Fuel is supplied at high pressure through pipe 4 whence it passes by way of the feed or supply orifice 16 to a plurality of chambers 26 corresponding in number to the number of cylinders to be supplied with fuel, one only of which chambers is shown, but all of which are interconnected by a common passage 17. The outlet passage 27 from each chamber 26 is closed by a spring controlled poppet valve 12, 29. The passage 27 communicates with one of several chambers 28 corresponding in number to the number of cylinders to be supplied and all of which again are interconnected by a common distributing passage 13 which in turn is connected through one of the passages 27 and through a single outlet or leak-off orifice 18 to a pipe 21 leading to the pump suction pipe or fuel supply tank.

The outlet from each chamber 28 to the injection nozzle is also closed by a spring controlled poppet valve 14, 30 and leads to the supply pipe 15 of the corresponding injection nozzle.

The strength of the spring 30 is such that the valve 14 is held lightly on its seating when the fuel pressures are nearly equal in the corresponding passage 15 and chamber 28.

It will be understood that one unit, as shown, is provided for each injection nozzle with the exception that a single fuel supply orifice 16 and a single outlet or leak-off orifice 18 are provided common to all units.

The valves 12 and 14 may be opened and closed by electro-magnetic or other known means (not shown) the two valves of each unit being opened and closed simultaneously and maintained open for the desired constant angular rotational period of the engine crankshaft during which fuel is required to flow, the pairs of valves of each unit being held open for similar periods in the required order and in correct synchronism.

When a pair of valves 12 and 14 of one unit are opened, fuel supplied to the supply conduit 4 from a convenient constant high pressure source which is at a higher pressure than is required for injection, flows through the supply orifice 16, which meters the maximum quantity which can flow in a given time. From this feed orifice the fuel flows into the corresponding chamber 26, then past the valve 12 into passage 27 and distributing passage 13 common to all the chambers 28, and into all the chambers 28 while a part flows off through the outlet or leak-off orifice 18 to pipe 21 leading to the initial no pressure fuel supply. A valve 14 being open, the fuel from chambers 28 emerges and passes to the conduit 15 to the injection nozzle.

When all the valves 12 and 14 are closed, the chambers 28 and the common passage 13 are in communication through leak-off orifice 18 with the no-pressure fuel supply, so that the pressure in chambers 28 and distributing passage 13 falls, as does also the pressure in injection nozzle 15 by relief through valve 14, the closing spring of which, as stated above, exerts only a slight pressure.

When valves 12 and 14 are opened, the injection pressure is re-established in chambers 28 and distributing passage 13 simultaneously with a fall of pressure in the common supply passage 17 and the chambers 26 below the pressure in supply pipe 4 and the injection pressure in the said parts is maintained for a fixed period and of a magnitude which is determined in accordance with the fuel supply pressure and the areas of the feed orifice 16 and the outlet or leak-off orifice 18.

The magnitude and duration of the injection pressure at each injection nozzle is determined by the same initial supply pressure and the same orifices 16 and 18, so that the quantity and injection period at each nozzle will be the same.

In the construction according to Figs. 3 to 5, a distributing system is employed having rotary valves.

Referring to Fig. 3 a no-pressure fuel tank 1 supplies fuel to a pump 3 (shown diagrammatically) by way of a pipe.

The pump shaft 23 is coupled with, geared to or rigid with a rotating valve member 22 of the distributing system, which valve is arranged for rotation in a cylindrical casing which may be formed as an extension of the pump casing 3.

The pump shaft 23 and valve 22 are driven from the engine in a pre-arranged manner such as will afford a properly synchronized and ordered series of injections at the injection nozzles 15 in the manner yet to be described.

The pump delivers fuel at a constant high pressure as determined by a spring controlled relief valve 6 through a pipe 4 which leads on the one hand to a space formed in a boss on the distributor casing 11 and thence through a feed orifice 16 leading to a passage 17 through the casing, and on the other hand to a chamber within a housing 9 containing the above referred to relief valve 6 and thence through a return pipe 10 to the fuel supply tank 1.

An adjustable screw control member 8 is provided in housing 9 whereby the compression of spring 7 may be varied to vary the pressure at which valve 6 can open and therefore the pressure in conduit 4. While the housing 9 for the valve is shown as a structure separate from the pump and distributor, it will be understood that these parts may be combined in a single structure.

In the rotary valve 22 are formed a number of similar radial passages 12 corresponding to the number of injection nozzles (four in the example shown) uniformly distributed around the valve member 22 and all lying in the same plane as passage 17 in the casing 11 so that as the valve member 22 is rotated, the four passages 12 come into register in succession with passage 17.

All the passages 12 communicate with a central bore 13 in the valve member and a further radial hole 14 is formed in the valve member 22 spaced from passage 12, and also in communication with central bore 13. In the casing 11 and also in the same plane as radial hole 14 are formed four uniformly spaced passages leading to the injection nozzles 15 shown diagrammatically in Fig. 3, with each of which radial hole 14 registers in turn as valve member 22 rotates.

In the surface of rotary valve 22 is formed a slot 25, this slot being on the trailing side of and in communication with passage 14 and in the same plane as that passage, so that as the valve rotates a passage 15 remains in communication with the interior of bore 13 for an appreciable period after communication between its corresponding passage 12 and passage 17 has been broken.

One end of the central bore 13 in valve 22 is closed while the other end is covered by a disc in which is formed a hole 18 forming the outlet or leak-off orifice from distributing passage 13. Outside this disc is mounted a plug 19, screwed into the end of casing 11 and provided with a handle 20 whereby said plug may be moved towards or away from the leak-off orifice to vary

the effective area of the fuel passage there-through.

In operation the valve member is driven in synchronism with the engine revolutions, in the direction of the arrow in Fig. 5. Fuel at high pressure flows through the pipe 4 and when one of the passages 12 comes opposite passage 17 fuel flows through feed orifice 16, the maximum quantity for a given supply pressure which can flow while a passage 12 and passage 17 are in communication being metered as determined by the pressure in the pipe 4 and space 13 and the time passages 12 and 17 are open for fuel flow.

At the same instant that communication is established between a passage 12 and passage 17, passage 14 in the valve 22 leading from space 13, comes into register with one of the passages 15 to an injection nozzle and fuel will therefore flow to the injection nozzle. At the same time a proportion will flow by way of leak-off orifice 18 to return pipe 21 back to supply tank 1 and it will readily be understood that the quantity of fuel injected and the time of injection will be dependent upon the supply pressure to the feed orifice 16 and the sizes of feed orifice 16 and leak-off orifice 18. The passages 12 all being similar to one another and passages 15 to the injection nozzles being similar to one another, fuel will flow for the same angular rotational period which period is always greater than the actual injection period.

Each injection passage 15 however remains in communication with passage 14 and space 13, after communication between the corresponding passage 12 and passage 17 has been broken, and therefore with return pipe 21 and the tank 1 by way of outlet or leak-off orifice 18, so that the fuel pressure in the passage 15 can and does fall together with that in distribution space 13 and thus dribble at the nozzles is prevented between injection periods. Pressure is re-established in space 13 and the passage 14 while the next passage 12 is in register with passage 17.

The fuel supply pressure can be varied for example by adjustment of relief valve 6 and the flow through the outlet or leak-off orifice 18 can be varied by control 20 to vary the quantity of fuel injected and the injection period, it being understood that any adjustment made will effect a variation which is the same for all injection nozzles.

Alternatively the size of the feed orifice 16 may be varied if desired.

Whilst in the above described arrangement the pump shaft 23 is coupled with, geared to or rigid with the rotating valve member 22 of the distributing system, it is to be understood that the rotating valve member 22 may be synchronously timed with regard to the engine and the pump shaft may be driven entirely independently.

Again it will be understood that the passages 12 in the rotating valve member 22 instead of being uniformly distributed around said member as described above, may be distributed other than uniformly as may be required by the engine injection intervals.

In Fig. 6 is shown an arrangement alternative to that shown in Fig. 3 whereby the fuel supply pressure may be varied, a rotatable cam 42 being provided to move a sliding plunger 8 in the housing 9 to compress or release the spring 7 controlling relief valve 6.

In the position shown the valve is held with the maximum of pressure of the spring 7 on its

seating so that flow of fuel through valve 6 is resisted and maximum pressure exerted at feed orifice 16.

In the reverse position of cam 42 the pressure on valve 6 is lowest, a greater proportion of fuel will flow past the valve 6 and a lower fuel feed pressure will be applied at feed orifice 16.

In Fig. 7 is shown a diagrammatic view of a fuel injection apparatus embodying an arrangement for controlling the fuel injection and therefore the engine by varying the area of the outlet or leak-off orifice from the distribution passage.

In Fig. 7, 19 represents the spindle of the plug illustrated in Fig. 3 as being movable towards and away from the outlet or leak-off orifice 18 to vary the area of the flow passage therethrough. On the spindle is fixedly mounted the control arm 20 bearing a projecting lug 36 and on said arm 20 is also mounted a stiff leaf spring 35, the free end of which is normally spaced from lug 36.

On the side of the apparatus is mounted a fixed two-armed bracket in the arms of which are mounted stop screws 33 and 34 to limit the movements of lever or arm 20.

In the position shown the arm is in a position where lug 36 is against stop screw 34 and the leak-off orifice is closed to the maximum extent for the shown setting of screw 34 and maximum injection is achieved. Increase or decrease of the maximum injection can be achieved by adjustment of the screw 34.

The screw 33, which is provided with a friction retaining device such as a spring, is set so that when the arm 20 and spindle 19 are in the appropriate position for idling, the spring 35 is engaged with the end of the screw 33.

The arrangement is such that the arm 20 can be moved further in the counter-clockwise direction against spring 35 forcing the spring 35 against the lug 36 to still further open the leak-off orifice 18 and thereby stop the engine.

A rod 39 may be connected with the arm 20 as shown at 38 and with a suitable form of engine driven governor device (not shown), so that the lever 20 is automatically adjusted to counteract variations in engine speed.

A further control rod 40 may be provided connected with lever 20 through a further lever 39 and a spring 41 to permit manual control or foot control.

The quantity of fuel injected for a given setting of the outlet or leak-off orifice 18 or for a given range of settings as controlled by lever 20 may also be varied by adjustment of the fuel pressure on the supply orifice 16, an external adjustment 8, Fig. 7, being provided for this purpose.

By this means a quantity of fuel can be supplied to the distribution system which will ensure the achievement of the required pressure conditions for a given opening pressure of the injection valves and the required quantity of injection.

As stated above, after injection the pressure in the distributing system may be arranged to fall, the extent of the fall being determined by the provision of adjustable relief valves or it may even be permitted to fall to the pressure existing in the suction line, and this fall in pressure is instrumental in preventing dribble at the injection nozzles.

On opening a valve from the distributing system pressure will rise in the passages leading fuel to the appropriate injection nozzle and the rate of pressure rise, and the duration of injection

tion pressure will be determined by the relative sizes of the supply and outlet or leak-off orifices, and it will readily be seen that by adjustment of these orifices either separately or in conjunction

5 with one another, the proportion of the flow period during which pressure sufficient to effect injection exists and therefore also the quantity of fuel injected can be varied.

It is well known that the weight of air taken 10 into the cylinders of an engine per cycle decreases with the increase of engine speed. Under such conditions the quantity of fuel injected should also be decreased and by the arrangement described above this will be effected automatically 15 as engine speed increases, because of the decrease in the total flow time in the distribution passage 13 for each injection.

It is also sometimes desirable to provide non-uniform variations of fuel supply with changes 20 in engine speed according to the characteristics of the engine and this may be done with the apparatus according to the present invention by adjustment of the fuel supply pressure, for example by means of the relief valve 6 between the 25 pressure and suction sides of the pump.

The fuel container 53 according to Fig. 1 may also be utilized as an air pressure vessel if desired.

The curves indicated in the diagram of Fig. 8 30 show the maximum and zero injection valve discharges with an arrangement using injection valves of the kind which open at a predetermined pressure. The curves represent injection when injection and leak-off discharges take place into 35 the same pressure, which may be atmospheric. The abscissae represent a fixed angular portion of the engine crank rotation and the ordinates, pressure, the maximum injection quantity being shown by the shaded area. The lengths of the 40 horizontal lines represent the period of fuel flow through the distributing system in terms of engine crank degrees for each injection and the vertical height from the bottom of the diagram to the top horizontal line represents the maximum injection pressure, while that to the intermediate horizontal line represents the injection 45 valve opening pressure.

The diagonal lines represent the rate of pressure rise in the distributor, zero injection discharge occurring when the maximum pressure 50 built up in the distribution passage does not exceed the injection valve closing pressure.

It is to be understood that these curves represent maximum injection discharge at maximum 55 engine speed and load, and zero injection discharge. Variations of engine speed and load can be compensated for on the injection of adjusting, for example, the area of the outlet orifice from the passage, such adjustments being effected 60 manually, or if desired by a governing device controlled by the engine speed.

I claim:

1. A distributor for injecting liquid fuel into 65 the cylinders of a multi-cylinder internal combustion engine comprising a low pressure liquid fuel supply, a high pressure fuel reservoir, an injection nozzle for each of the cylinders, chambers corresponding in number to each of the cylinders, passages connecting the low pressure liquid 70 fuel supply and high pressure reservoir with said chambers, and means within said chambers to transfer the fuel from the low pressure supply to the high pressure reservoir, additional passages connecting said high pressure reservoir 75 with each of said chambers, and means within

the chambers for controlling the flow of fuel from the high pressure reservoir to the nozzles, the first named means moving the second named means into injection position, said second named means being urged out of injection position by 5 the pressure existent in the high pressure reservoir.

2. A distributor for injecting liquid fuel into 10 the cylinders of a multi-cylinder internal combustion engine comprising a low pressure liquid fuel supply, a high pressure fuel reservoir, an injection nozzle for each of the cylinders, chambers corresponding in number to the cylinders, 15 conduits connecting the low pressure liquid fuel supply and high pressure reservoir with said chambers, and means within said chambers to transfer the fuel from the low pressure supply to the high pressure reservoir, additional conduits connecting said high pressure reservoir with 20 each of said chambers, passages connecting said chambers with said nozzles and means for controlling the flow of fuel through the last named passages from said chambers to said nozzles, the 25 first named means moving the second named means into injection position, said second named means being urged out of injection position by the pressure existent in the high pressure reservoir and a restricted outlet connecting the last named passages with the low pressure supply.

3. A distributor for injecting liquid fuel into 30 the cylinders of a multi-cylinder internal combustion engine comprising a low pressure liquid fuel supply, a high pressure fuel reservoir, an injection nozzle for each of the cylinders, chambers corresponding in number to the cylinders, 35 conduits connecting the low pressure liquid fuel supply and high pressure reservoir with said chambers, reciprocating pistons within said chambers to transfer the fuel from the low pressure supply to the high pressure reservoir, additional conduits connecting said high pressure 40 reservoir with each of said chambers and piston valves within the chambers for controlling the flow of fuel from the high pressure reservoir to said nozzles, the reciprocating pistons moving the 45 piston valves into injection position, the piston valves being urged out of injection position by the pressure existent in the high pressure reservoir.

4. A distributor for injecting liquid fuel into 50 the cylinders of a multi-cylinder internal combustion engine comprising a low pressure liquid fuel supply, a high pressure fuel reservoir, an injection nozzle for each of the cylinders, chambers corresponding in number to the cylinders, 55 conduits connecting the low pressure liquid fuel supply and high pressure reservoir with said chambers, and reciprocating pistons within said chambers to transfer the fuel from the low pressure supply to the high pressure reservoir, additional conduits connecting said high pressure 60 reservoir with each of said chambers, passages connecting said chambers with said nozzles and piston valves for controlling the flow of fuel through the last named passages from said chambers 65 to said nozzles, the reciprocating piston moving the piston valves into injection position, said piston valves being urged out of injection position by the pressure existent in the high pressure reservoir and a restricted outlet connecting the last named passages with the low 70 pressure supply.

5. Apparatus for injecting liquid fuel into the cylinders of a multi-cylinder internal combustion engine, comprising a low pressure liquid fuel 75

supply, a high pressure fuel space, an injection
nozzle for each of the cylinders of the engine,
means for transferring fuel from the low pres-
sure fuel supply to the high pressure fuel space
5 and for maintaining in said high pressure space
a substantially constant pressure exceeding the
maximum required injection pressure, a fuel pas-
sage adapted to distribute fuel intermittently to
all the injection nozzles in turn, said fuel dis-
10 tributing passage being at all times in communi-
cation with the source of low pressure fuel supply
through an orifice of limited and variable area,
a supply passage for conducting fuel from the
high pressure fuel space to said fuel distributing

passage, valve means for putting said supply pas-
sage intermittently into communication with the
said distributing passage and simultaneously put-
ting said distributing passage into communica-
tion with an injection nozzle each for a constant 5
angular period of engine rotation exceeding the
maximum angular period of injection required,
and means for establishing communication be-
tween the injection nozzle last supplied and the
low pressure fuel supply during the intervals be- 10
tween injections.

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