

May 22, 1956

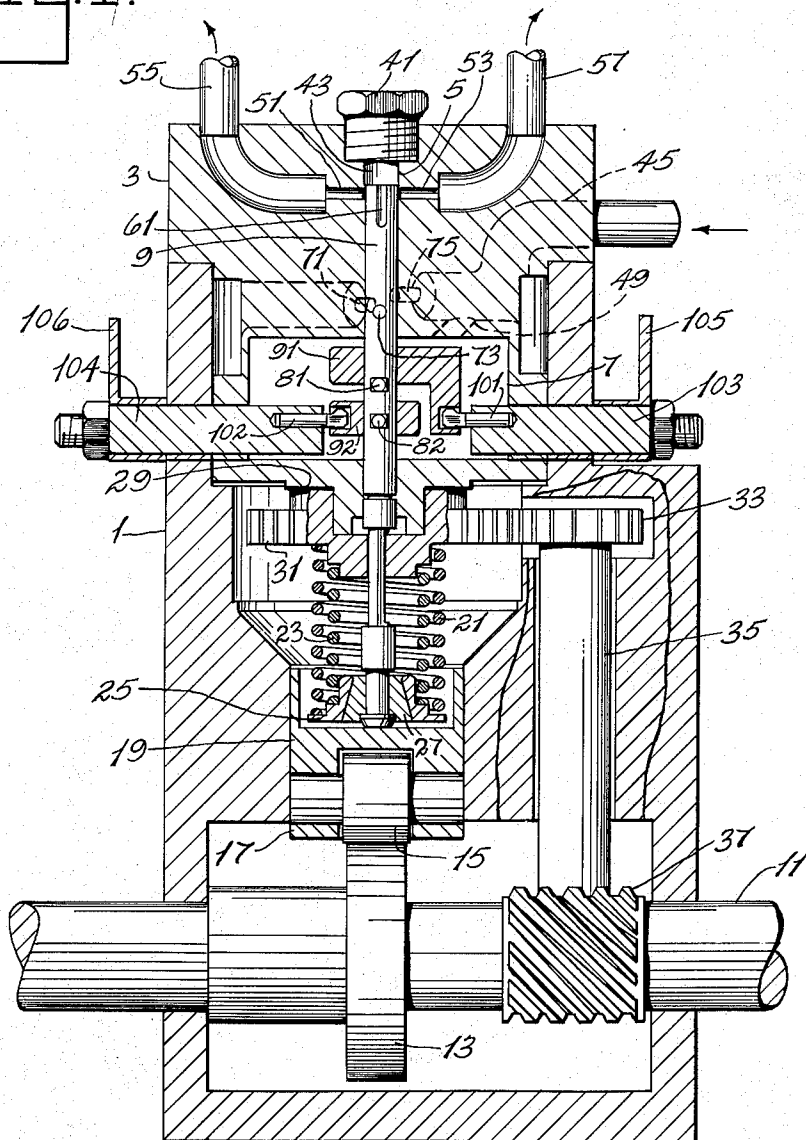
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FUEL INJECTION PUMP

2,746,443

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3 Sheets-Sheet 1

Fig. 1.



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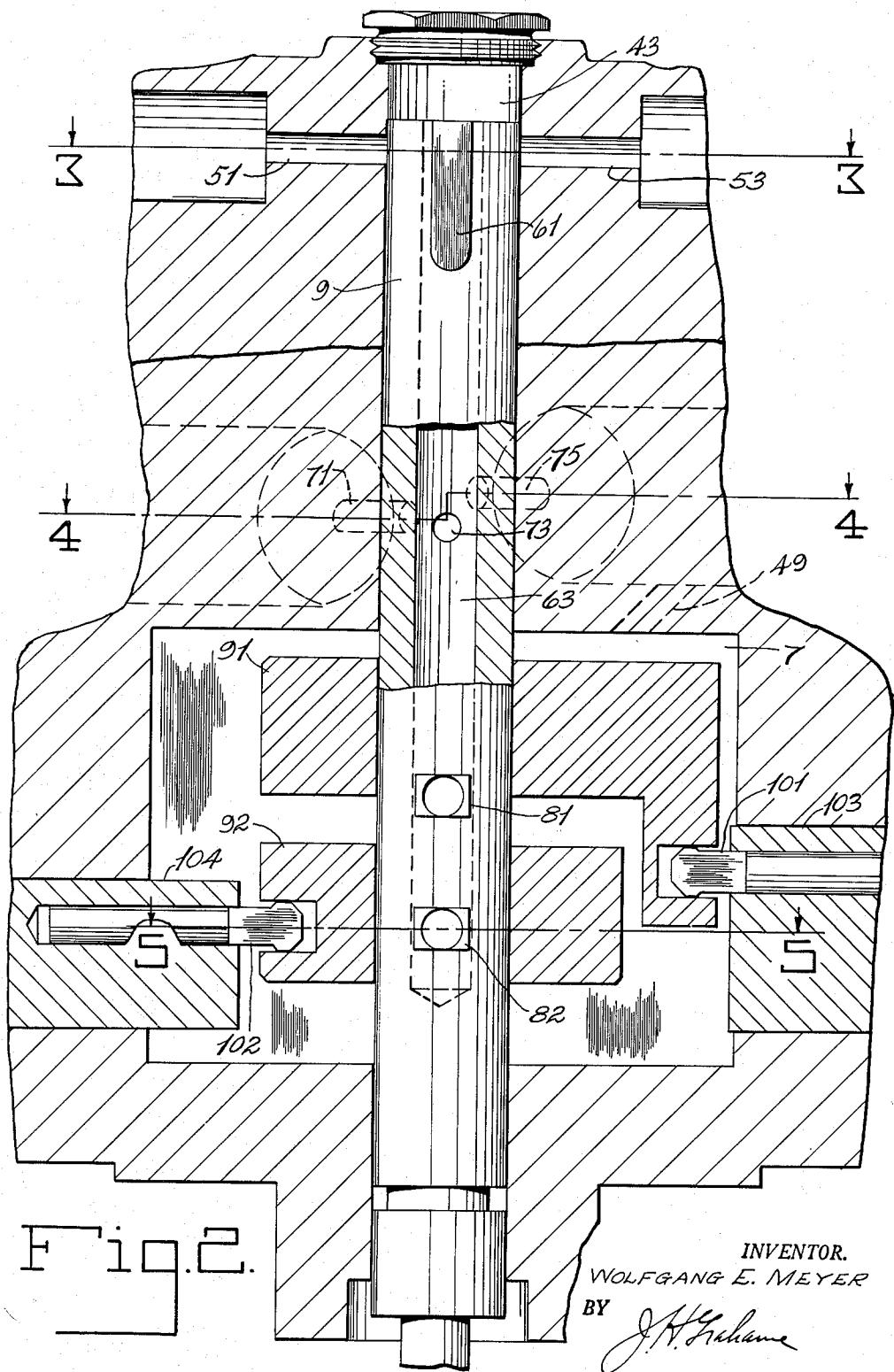
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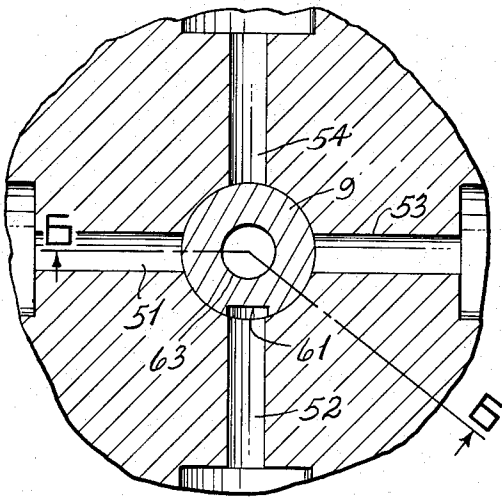


Fig. 3

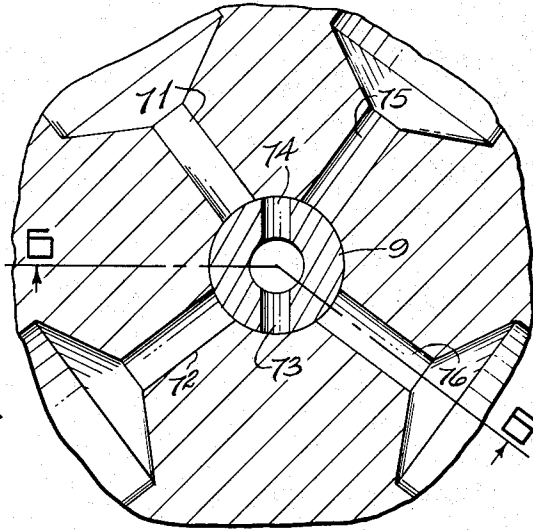


Fig. 4

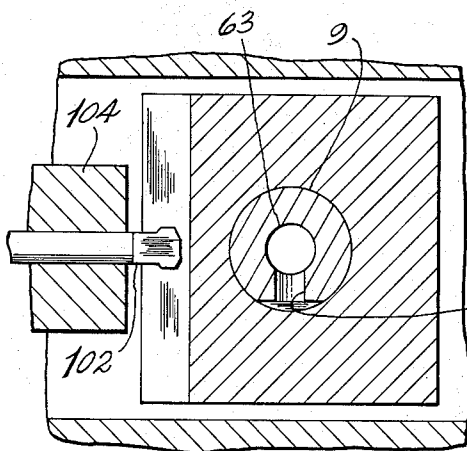


Fig. 5

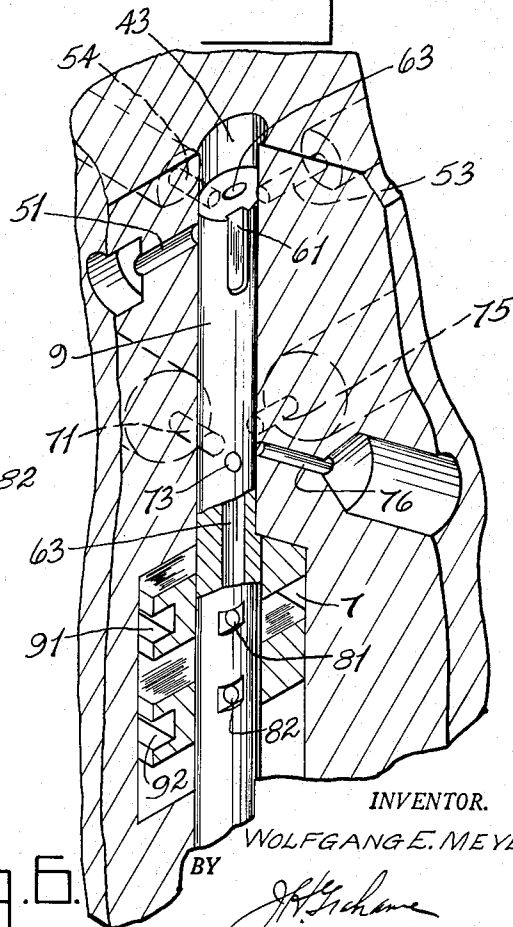


Fig. 6

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2,746,443

FUEL INJECTION PUMP

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3 Claims. (Cl. 123—139)

The present invention relates to fuel injection pumps for internal combustion engines and particularly to an improved fuel injection pump of the type wherein a single reciprocating and rotating pumping plunger serves a plurality of engine cylinders.

In the operation of fuel injection pumps of the aforesaid type with fuel pressure-actuated engine fuel injectors, particularly when highly volatile fuels are used and when the pumping frequency is high, considerable difficulty is commonly experienced in obtaining precise control of certain factors which are important to optimum engine operation and efficient combustion. Such factors as timing of the beginning and end of each fuel injection, and the quantity of fuel metered from the pump in each injection, are particularly difficult to control with precision, especially when the quantity of fuel delivered in each injection is small. This difficulty is caused basically by the compressibility of fuel in the fuel discharge path from the pump to the engine fuel injector. When this fuel discharge path has a relatively large volume in comparison with the volume of fuel discharged by the pump for each injection, the compressibility of the fuel tends to permit absorption of the fuel charge from the pump into the fuel discharge path without any corresponding displacement of fuel through the fuel injector and into the engine. This may result in actual fuel delivery to the engine of only a portion of the desired fuel charge. Also, this elasticity of the system produces an unpredictable delay between the desired beginning and ending of fuel injection, as controlled by starting and stopping of pumping in the fuel pump, and actual beginning and ending of fuel injection at the injector.

One attempt to remedy this situation which is conventional in prior art fuel injection pumps is the provision of a fuel pressure-operated delivery valve which controls egress of fuel from the pump and serves to maintain fuel pressure in the fuel discharge path from pump to injector at a level close to injection pressure during the interval between successive fuel discharges from the pump. This in effect maintains the fuel in the discharge path in a pre-compressed state and reduces its ability to absorb a fresh fuel charge delivered by the pump.

The fuel delivery valve also serves the useful purpose of isolating the fuel discharge path from the pump during the suction stroke of the pumping plunger. This prevents the rapid expansion of volume within the pumping chamber of the fuel pump from creating a vacuum in the fuel discharge path, which would tend to cause partial vaporization of fuel therein. Because fuel vapor thus created cannot easily be recondensed before the next fuel discharge from the pump, its presence severely disrupts the timing and accuracy of fuel metering. This difficulty is aggravated during pump operation at high engine speeds, and particularly so in the type of fuel pump with which the present invention is concerned, wherein a single pumping plunger serving fuel to a plurality of engine cylinders must discharge successive fuel charges

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at a rate several times the engine speed, with very little time afforded between successive fuel discharges for recondensation of any vaporized fuel in the fuel discharge path. Hence, in preventing vacuum formation in the fuel discharge path the delivery valve is particularly important.

However, use of the conventional delivery valve has the disadvantage that the valve itself requires space in which to be housed, which space further adds to the compressible volume of the fuel discharge path and increases its elasticity. Also, by immediately closing in response to the reduction in pump output pressure which is intended to terminate fuel injection, the delivery valve blocks the fuel discharge path at its pump end and provides a reflecting surface for pressure waves in the discharge path which usually accompany termination of fuel injection. The reflection of such pressure waves increases the likelihood of secondary or after-injections into the engine and thus renders more difficult precise control of timing and duration of fuel injection.

The present invention provides a fuel injection pump of the type in which a single reciprocating and rotating plunger serves a plurality of engine cylinders, and from which the conventional delivery valve is completely eliminated without incurring vacuum formation in the fuel discharge path. The present invention takes advantage of the characteristic plunger rotation which is normally utilized for fuel distribution in such a pump, and provides for the rotating plunger to serve in effect as a delivery valve. The plunger itself serves to isolate the fuel discharge path from the pumping chamber of the pump during the suction stroke of the plunger, and thereby prevents vacuum formation in the fuel discharge path, but does not bring about such isolation until well after the termination of fuel injection, so that any pressure waves accompanying injection termination, which might possibly be reflected in the discharge path, are effectively dissipated in the fuel supply reservoir of the pump. This utilization of the rotating plunger as an effective delivery valve not only enables the space previously required to house the conventional delivery valve to be eliminated from the discharge path volume, but at the same time permits a considerable simplification, with attendant reduction in volume, of that portion of the fuel discharge path contained within the fuel pump body. Thus, a fuel pump is provided from which the aforesaid difficulties are substantially eliminated, and which is particularly suited for precision control of fuel injection over a wide range of operating conditions.

An object of this invention therefore is to provide an improved fuel injection pump for use with internal combustion engines, in which a single plunger is reciprocated and continuously rotated for pumping and metering the fuel and for distributing it to more than one engine cylinder.

Another object is to provide a fuel injection pump of the aforesaid type in which the conventional fuel pressure-actuated delivery valve is eliminated.

Another object is to provide a fuel injection pump of the aforesaid type in which the path provided for the discharge of fuel from the pumping chamber to the engine is greatly simplified and substantially reduced in volume.

Another object is to provide a fuel pump of the aforesaid type in which vacuum formation or fuel vaporization in the fuel discharge path during the suction stroke of the pumping plunger is prevented.

Another object is to provide a fuel pump of the aforesaid type having an improved degree of precision of metering fuel.

Another object is to provide a fuel pump of the afore-

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said type, which is particularly suited for metering fuel to engines operating at relatively high speeds.

Another object is to provide a fuel injection pump of the aforesaid type in which vacuum formation in the pumping chamber during the suction stroke of the pump plunger is eliminated.

Another object is to provide a fuel injection pump of the aforesaid type in which the beginning and the end of fuel injection can be varied independently of each other.

Another object is to provide a fuel injection pump of the aforesaid type in which the entire fuel discharge path from the pump is maintained in continuous fluid fuel contact with a low pressure fuel reservoir during the termination of fuel injection pressure in said discharge path, so that pressure waves in said fuel discharge path arising from abrupt termination of fuel injection pressure are substantially damped out in said reservoir without reflection, and secondary fuel injections are thereby eliminated.

Another object is to provide an improved fuel pump of the aforesaid type having a reduced number of parts of simplified design which can be manufactured with greater ease and at reduced cost.

These and other objects and advantages of the invention will be apparent from the following description taken in connection with the accompanying drawings wherein:

Fig. 1 is a longitudinal sectional view of a pump constructed in accordance with the present invention and showing the plunger in an intermediate portion of its stroke.

Fig. 2 is an enlarged view of a portion of Fig. 1.

Fig. 3 is an enlarged sectional view of the portion of the pump shown in Fig. 2, taken on the line 3—3 of Fig. 2.

Fig. 4 is an enlarged sectional view of the portion of the pump shown in Fig. 2, taken on the line 4—4 of Fig. 2.

Fig. 5 is an enlarged sectional view of the portion of the pump shown in Fig. 2, taken on the line 5—5 of Fig. 2.

Fig. 6 is an enlarged cut-away perspective view of that portion of the pump shown in Fig. 2, the portion cut away being defined by the line 6—6 in Figs. 3 and 4.

Referring to the drawings, and particularly to Figs. 1 and 2, a single plunger fuel injection pump constructed in accordance with the present invention is shown by way of example as adapted to serve a four-cylinder engine. The pump includes a housing 1 containing a body member 3 provided with a cylindrical bore 5 which is enlarged adjacent one end to form a fuel sump 7. Slidably fitted within the bore 5 is a cylindrical pumping plunger 9 adapted for reciprocation and simultaneous rotation therein in timed relation with the engine for which the pump supplies fuel.

For reciprocating the plunger 9 within the bore 5 there is provided an engine-driven cam shaft 11 supported in housing 1 and carrying a cam 13 which cooperates with a tappet roller 15 rotatably mounted in a tappet 17. The tappet 17 is adapted to reciprocate within a bore 19 of housing 1 in coaxial alignment with the bore 5 in the body member 3. One end of plunger 9 is maintained in continuous contact with reciprocating tappet 17 by means of compression springs 21 and 23 acting against a spring retainer 25 supported from the end of the plunger by the usual split collar 27. At their other end springs 21 and 23 are restrained by a plunger rotation gear 31 which is keyed to plunger 9 intermediate its length and which is adapted to bear against a surface 29 of the body member 3 while rotating.

To enable rotation of plunger 9 simultaneously with its reciprocation in cylindrical bore 5, a pinion 33 connected in driving relation with gear 31 is driven through a shaft 35 from a helical gear 37 mounted on cam shaft 11.

At its end remote from sump 7, the bore 5 is permanently closed during operation of the pump, as by a

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plug 41. Plunger 9 forms with cylindrical bore 5 at this permanently closed end thereof a pumping chamber 43. During operation of the pump, fuel is admitted to pumping chamber 43 for compression therein to the high pressures suitable for delivery to the conventional engine fuel injection equipment, and discharged therefrom at a selected time in the engine cycle and in accurately metered amount.

In the case of the pump shown in the drawings, which is designed to provide injection fuel to a four-cylinder engine, if the engine is of the four-stroke cycle type requiring two engine cylinder fuel injections for each engine crankshaft revolution, then cam 13 and cam shaft 11 are arranged to reciprocate plunger 9 through two complete cycles, consisting of two compression and two suction strokes, during one engine crankshaft revolution. Thus, if cam 13 is provided with two lobes, cam shaft 11 should turn at engine speed for a four-stroke cycle four cylinder engine. This could also be accomplished by providing cam 13 with four lobes and turning cam shaft 11 at one half engine speed. If the four-cylinder engine is of the two-stroke cycle type and cam shaft 11 turns at engine speed, cam 13 should have four lobes. Also, in order that the pump may deliver its entire fuel discharge during a given plunger compression stroke to but one engine cylinder, the ratio of the plunger rotating gear 31 and its driving pinion 33 should be such that plunger 9 completes one full revolution during four-pumping strokes for four-cylinder engine operation on either a two or four stroke cycle. That is, the plunger should rotate 90° from the time it leaves its bottom dead center position on a compression stroke until it returns to bottom dead center after completing its suction stroke.

Body member 3 is provided with a plurality of fuel distributor ports 51, 52, 53, 54 (only two of which are shown in Fig. 1), one for each engine cylinder, which communicate with the cylindrical bore 5 at points preferably equally spaced about a circumference in a cross-sectional plane thereof.

To each of the distributor ports 51, 52, 53, 54 is connected a fuel delivery line 55, 56, 57, 58 which conveys fuel to a particular engine cylinder fuel injection device. Distributor ports 51, 52, 53, 54 are so located along cylindrical bore 5 as to be covered by plunger 9 during the whole of its reciprocating stroke. At its pumping chamber end plunger 9 is provided with a longitudinal fuel distributor slot 61 which is of a sufficient length to intersect the plane of the distributor ports during the entire reciprocating stroke of the plunger. By this arrangement, any one of fuel distributor ports 51, 52, 53, 54 can be kept in fluid fuel contact with pumping chamber 43 during the entire length of a plunger compression or suction stroke by proper rotative orientation of plunger 9 to uncover the distributor port by distributor slot 61. Conversely, by so rotating plunger 9 that distributor slot 61 does not uncover and come into fluid contact with any of the distributor ports 51, 52, 53, 54, all of the distributor ports can be isolated from pumping chamber 43 during the whole of a plunger compression or suction stroke. In the embodiment shown, slot 61 has a width in relation to the size of ports 51, 52, etc., sufficient to uncover a distributor port during substantially 45° of rotation of plunger 9.

Body member 3 is also provided with a plurality of fuel supply ports 71, 72, 75, 76 communicating with cylindrical bore 5 at points along its length between sump 7 and distributor ports 51, 52, 53, 54. These fuel supply ports 71, 72, etc., are connected through a fuel supply passage 45, in body member 3 to any desired source of low-pressure fuel, not shown. Sump 7 is also supplied with low pressure fuel through a connection 49 in body member 3 to fuel supply passage 45. Together sump 7 and the fuel supply passage 45 provide a low pressure fuel reservoir from which the pumping chamber 43 can be charged with fuel as the pump operates.

Fuel supply ports 71, 72, etc., are located along cylindrical bore 5 sufficiently far from its closed end so that none of these ports will be uncovered by distributor slot 61 of plunger 9 during any point in the plunger suction stroke, regardless of the rotative position of the plunger.

Plunger 9 is provided also with a longitudinal fuel by-pass passage 63 which opens into pumping chamber 43, and is of sufficient length within plunger 9 to extend into that portion of the plunger surrounded by fuel sump 7. At its fuel sump end the by-pass passage 63 is connected to the fuel sump 7 through two longitudinally spaced upper and lower control ports 81, 82 in plunger 9. Control ports 81 and 82 are preferably aligned in the axial plane through the plunger which bisects the distributor slot 61, their longitudinal location and spacing preferably being such that these ports will be confined within fuel sump 7 during the entire plunger excursion.

Also provided within sump 7 are a pair of control sleeves 91, 92 which surround the plunger 9 with a close sliding fit. Control sleeves 91, 92 are slotted to receive pins 101, 102, respectively, which are eccentrically mounted on shafts 103, 104 supported in body member 3 for rotation by suitable means external to the pump, such as hand controls 105, 106, or any desired engine condition-responsive device. By this arrangement, control sleeves 91, 92 can be adjustably positioned along the plunger to cover the upper and lower control ports 81, 82, during any selected portion of the plunger compression stroke, and thereby prevent fuel flow between pumping chamber 43 and fuel sump 7. Each control sleeve 91, 92 can be manipulated independently of the other, to cover and uncover the different control ports 81, 82 at different points in the plunger excursion.

In the vicinity of fuel supply ports 71, 72, etc., plunger 9 is additionally provided with two fuel fill ports 73, 74, connecting to the longitudinal fuel by-pass passage 63. Fill ports 73, 74 are disposed preferably on a common plunger diameter and in the plunger axial plane of control ports 81, 82 and are so arranged as to uncover and come into fluid fuel contact with fuel supply ports 71, 72, etc., during certain portions of the plunger suction stroke, as will be explained more fully hereinafter.

Operation of the pump will be described in terms of the sequence of events taking place during one complete plunger excursion, and with particular reference to Fig. 6 of the drawings, wherein is shown in enlarged schematic form the plunger 9, the ports of bore 5, and control sleeves 91 and 92. Plunger 9 begins its excursion from an initial position at bottom dead center, and with a rotative orientation at which one of the distributor ports, say 51, is just about to be uncovered by slot 61. This rotative orientation may, for reference, be termed 0° of rotation. At this point lower control port 82 is normally covered by lower control sleeve 92, while upper control port 81 is below the lower edge of upper control sleeve 91 and hence open to fuel sump 7. Also plunger fill ports 73, 74 are at this point below the vicinity of supply ports 71, 72, etc., and the rotative position of fill ports 73, 74 is therefore not as yet important in determining fluid contact with the supply ports. However, their alignment with the axial plane bisecting slot 61 places fill ports 73, 74 at this initial plunger position, rotatively between adjacent supply ports.

As the plunger begins to be lifted upward on its compression stroke by cam 13, its simultaneous rotation immediately uncovers distributor port 51 with slot 61, lower control port 82 remaining enclosed within lower control sleeve 92. At a selected point in the plunger compression stroke, as determined by the axial position of upper control sleeve 91, upper control port 81 enters upper control sleeve 91 and thereby closes off pumping chamber 43 from fluid fuel contact with fuel sump 7. The compression of plunger 9 builds fuel pressure up rapidly thereafter in pumping chamber 43 and high-

pressure fuel is displaced through distributor slot 61 and the fuel discharge path consisting of distributor port 51 and its connected fuel delivery line 55, to the appropriate fuel injection device on the engine.

As plunger 9 travels upward displacing fuel from pumping chamber 43, its motion carries fill ports 73, 74 to the vicinity of supply ports 71, 72, etc., where, if the plunger were not properly rotatively oriented, a fill port could uncover a supply port and vent the fuel pressure from pumping chamber 43 through by-pass passage 63. However, because of the alignment of ports 73, 74 with the axial plane of slot 61, and the relative angular position of supply ports 71, 72, 75, 76 and distributor ports 51, 52, 53, 54, while slot 61 remains in contact with distributor port 51 fill ports 73, 74 are carried upward between adjacent supply ports without uncovering them.

As plunger 9 ascends further on its pumping stroke, lower control port 82 emerges from lower control sleeve 92, thereby spilling high pressure fuel from pumping chamber 43 through longitudinal fuel by-pass passage 63. This immediately terminates displacement of fuel at injection pressure from pumping chamber 43. The abrupt drop in fuel pressure in pumping chamber 43 is immediately communicated, through the still maintained fluid fuel contact between chamber 43 and port 51, to the pressure actuated engine fuel injection device, and fuel injection ceases. However, since plunger slot 61 remains in contact with port 51 during and after the termination of injection, the pressure waves which are usually present in the fuel discharge path after the abrupt injection termination are allowed to travel back through the discharge path to pumping chamber 43 and thence to fuel sump 7, wherein they are effectively damped out without undesired reflection back to the engine injection device.

Plunger 9 continues to rotate while ascending, and by the time it reaches top dead center position, it has rotated a sufficient extent so that fluid fuel contact has just been broken between port 51 and distributor slot 61. Thus, when plunger 9 begins its downward or suction stroke under the influence of springs 21, 23, and as permitted by the rotation of cam 13, distributor port 51 is isolated from pumping chamber 43, and any tendency toward creation of a vacuum in the expanding volume of pumping chamber 43 is not communicated through port 51 to the fuel discharge path. The width of slot 61 in relation to the size of distributor ports 51, 52, 53, and 54 is such that, during the entire angular rotation of plunger 9 while on its suction stroke, slot 61 does not uncover the next succeeding distributor port 52, but as plunger 9 reaches bottom dead center the nearest edge of slot 61 is just about to be rotated into uncovering relationship with distributor port 52. Thus, during the whole suction stroke of plunger 9 distributor slot 61 is rotatively positioned between adjacent distributor ports, which thereby completely isolates all distributor ports 51, 52, etc., from pumping chamber 43 during the plunger suction stroke.

As plunger 9 descends on the first portion of its suction stroke, the fact that pumping chamber 43 is in communication with sump 7 through by-pass passage 63 and lower control port 82 prevents any vacuum formation in pumping chamber 43. Later in the plunger descent, lower control port 82 reenters lower control sleeve 92. Since the order of events is reversed from the compression stroke, upper control port 81 has not as yet emerged from upper control sleeve 91. The fluid fuel connection between pumping chamber 43 and fuel sump 7 is thereby severed. This would tend to create a vacuum in pumping chamber 43, but for the fact that the supply ports 71, 72, 75, 76 are so positioned that, at this plunger reciprocative and rotative position, at least one supply port is uncovered by a plunger fill port 73, 74. Thus, fuel is admitted to pumping chamber 43 from supply passage 45, and creation of a vac-

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uum in chamber 43 is prevented. The disposition of supply ports 71, 72, 75, 76 is thus determined by this requirement, namely that at least one supply port must be uncovered by a plunger fill port at the time when pumping chamber 43 becomes isolated from sump 7 during the plunger suction stroke. The supply and fill ports must also be of such a size as to maintain fluid fuel contact until further plunger descent permits upper control port 81 to emerge from upper control sleeve 91.

As has heretofore been stated, plunger 9 is rotated continuously in one direction and at constant speed by driving gear 31. As has also been explained, when serving a four-cylinder engine the plunger should complete one fourth of a full rotation, i. e., 90°, during the period of one complete reciprocating excursion. Since plunger 9 rotates at constant speed, the proportion of its 90° rotation which accompanies its compression stroke, relative to the proportion of its 90° rotation which accompanies its suction stroke, will be determined by the profile of the lobe of cam 13. If the cam lobe is symmetrical, for example, 45° of plunger rotation will accompany its compression stroke and 45° will accompany its suction stroke. If, however, it is desired that a larger proportion of the 90° rotation should accompany a plunger compression stroke, then the plunger will be returned on its suction stroke during a relatively small fraction of the total excursion time, with a correspondingly small amount of rotation. Thus, the shape of the cam profile is a factor which affects the disposition of fuel supply ports 71, 72, 75, 76 relative to cylindrical bore 5. Provision as here shown of a plurality of supply ports, two of which are spaced 90° about a circumference of bore 5, and the other two of which are spaced somewhat less than 90° and in a cross-sectional plane displaced slightly from the first two, and provision of two diametrically opposite fill ports 73, 74 in the plunger, permits a lengthened period of fluid contact between supply ports and fill ports during the plunger suction stroke without requiring unusually large fill or supply ports. Of course it will be understood that the shape and size of the supply ports 71, 72, 75, 76, as well as fill ports 73, 74, may be varied as desired and as necessary to maintain fluid contact therebetween during the period above described, and the relative size and shape of the ports shown in the drawing is merely exemplary of one operative arrangement.

As the plunger 9 approaches bottom dead center, and upper control port 81 emerges from the lower side of upper control sleeve 91 and reestablishes fluid contact between pumping chamber 43 and sump 7, the additional plunger descent and plunger rotation carries fill ports 73, 74 out of fluid contact with supply ports 71, 72, etc., and severs this connection between fuel source and pumping chamber 43. However, pumping chamber 43 remains connected to the low pressure fuel reservoir through upper control port 81 and sump 7 during the remainder of its suction stroke until it reaches bottom dead center. Thus, it will be seen that during the entire plunger suction stroke, pumping chamber 43 is at no time out of fluid fuel contact with a source of low pressure fuel, either through fill ports 73, 74 or through upper or lower control ports 81, 82. This completely eliminates the possibility of fuel vaporization due to vacuum formation in pumping chamber 43.

Since the four distributor ports 51, 52, 53 and 54 are spaced equally about the circumference of bore 5, operation of the pump on subsequent plunger excursions, during which fuel is distributed through the remaining ports 52, 53, and 54, is identical with the pumping cycle for port 51 previously described, and hence need not be described.

Since the relative position of upper control port 81 and upper control sleeve 91 at the start of the plunger compression stroke determines what portion of the com-

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pression stroke will be completed before upper control port 81 becomes enclosed within upper control sleeve 91 and fuel displacement from pumping chamber 43 begins, it will be appreciated that raising the upper control sleeve 91 delays the start of fuel discharge from pumping chamber 43, and lowering upper control sleeve 91 begins fuel discharge earlier. Likewise, raising lower control sleeve 92 delays uncovering of lower control port 82 and terminates fuel discharge from chamber 43 later in the plunger compression stroke, and lowering the lower control sleeve 92 terminates the fuel discharge earlier in the plunger compression stroke. Thus, varying the position of the two sleeves in unison varies the timing of fuel injection at the engine, relative to the engine crankshaft position.

Also, it should be recognized that since the two control sleeves 91 and 92 can be moved independently, the distance between them may be varied. Thus, simultaneously raising upper control sleeve 91 and lowering lower control sleeve 92 delays the beginning of fuel discharge from pumping chamber 43, and also hastens its termination, thereby shortening the effective pumping stroke of the plunger. Conversely, bringing the two control sleeves 91 and 92 closer together lengthens the period in the plunger compression stroke during which fuel discharge takes place from pumping chamber 43. As an extreme example of this latter condition, upper and lower control sleeves 91 and 92 may be brought together until they are in contact and form one continuous enclosure about the control ports. In this case, there will be no by-pass connection through passage 63 between pumping chamber 43 and fuel sump 7 during any portion of the plunger compression stroke. When the control sleeves 91 and 92 are in this specialized position therefor, the plunger delivers fuel to a fuel delivery line during its entire compression stroke, thus effectively expelling air from the pumping chamber 43 and the delivery line. Since the connection between the pumping chamber and the delivery line is broken, when the plunger reaches its topmost position, and the delivery line thereafter remains isolated until the plunger completes a full rotation, fuel once pumped into this particular fuel delivery line has no opportunity to return to the fuel sump. This arrangement therefore progressively expels air from the various delivery lines, and enables effective priming of the pump.

Thus, there has been shown and described an internal combustion engine fuel injection pump from which the conventional delivery valve has been completely eliminated, enabling a substantial reduction in volume of the fuel delivery path between pump and engine without incurring vacuum formation and fuel vaporization in the discharge path or pumping chamber even during high speed operation and with volatile fuels. Pumps constructed in accordance with the present invention are moreover characterized by greatly simplified internal fuel flow passages as well as provision for simple and effective control of the beginning and termination of effective pumping, thereby providing a pump which is less expensive to manufacture, and which enables precision control of fuel injection over a wide range of operating conditions.

Obviously many modifications and variations of the invention, as hereinbefore set forth, may be made without departing from the spirit and scope thereof, and therefore only such limitations should be imposed as are indicated in the appended claims.

I claim:

1. In an internal combustion engine fuel injection pump of the type wherein a single plunger is employed for pumping and metering fuel and distributing it to a plurality of engine cylinders, a body having a bore therein closed at one end and enlarged at the other end to form a fuel sump, a plunger adapted to reciprocate and rotate in said bore and forming at the closed end of said

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bore a pumping chamber, means for reciprocating and simultaneously continuously rotating said plunger in said bore, said fuel sump enclosing a portion of said plunger during the whole of said reciprocation thereof, a fuel passage in said plunger communicating with said pumping chamber, a plurality of control port means in said portion of said plunger enclosed within said fuel sump connected to said fuel passage and adapted to by-pass fuel from said pumping chamber to said sump during a plunger compression stroke, a first and a second movable means in said sump for isolating said control port means from said sump during a selected portion of said plunger compression stroke respectively to produce injection fuel pressure in said pumping chamber and to release said injection fuel pressure, a plurality of fuel distributing ports communicating with said bore at points equally spaced around a circumference of said plunger and located between said pump and said pumping chamber, a fuel distributing slot in said plunger adapted to connect one of said fuel distributing ports to said pumping chamber during a plunger compression stroke and to isolate said distributing ports from said pumping chamber during a plunger suction stroke, fuel supply ports communicating with said bore and located between said fuel distributing ports and said fuel sump, and supply ports in said plunger connected to said plunger passage and adapted to overlap said fuel supply ports to admit fuel to said pumping chamber during the portion of said plunger suction stroke when said plurality of control port means are otherwise isolated from said fuel sump.

2. A valveless fuel injection pump comprising, in combination, a low pressure fuel reservoir, a high-pressure pumping chamber, a fuel delivery line, a pump plunger, means connecting said high-pressure pumping chamber to said fuel delivery line during the initial portion of the compression stroke of said plunger while at the same time maintaining said high-pressure pumping chamber connected to said low pressure fuel reservoir,

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individual means on the continued compression stroke of said plunger first operatively disconnecting said low pressure fuel reservoir from said high-pressure pumping chamber to initiate high-pressure fuel supply to said delivery line, and then reconnecting said low pressure fuel reservoir with said high pressure pumping chamber to terminate high-pressure fuel supply to said delivery line respectively, said last mentioned means then maintaining connection of said delivery line and high-pressure pumping chamber with said low pressure fuel reservoir during the completion of said plunger compression stroke to damp out pressure waves in said system, means independently varying the timing of the initiation and termination of high-pressure fuel supply to said delivery line during the plunger compression stroke, and means during the entire succeeding plunger suction stroke disconnecting said fuel delivery line from said high-pressure pumping chamber while maintaining connection of said high-pressure chamber with said low pressure fuel reservoir to prevent vacuum formation and vaporization of fuel in said high-pressure pumping chamber.

3. A fuel injection pump according to claim 2, wherein the said pump plunger simultaneously reciprocates and rotates to control high-pressure fuel supply in sequence to a plurality of fuel delivery lines, each supplied from said high-pressure pumping chamber.

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