

May 14, 1957

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2,792,259

FUEL INJECTOR FOR INTERNAL COMBUSTION ENGINES

Filed July 3, 1953

4 Sheets-Sheet 1

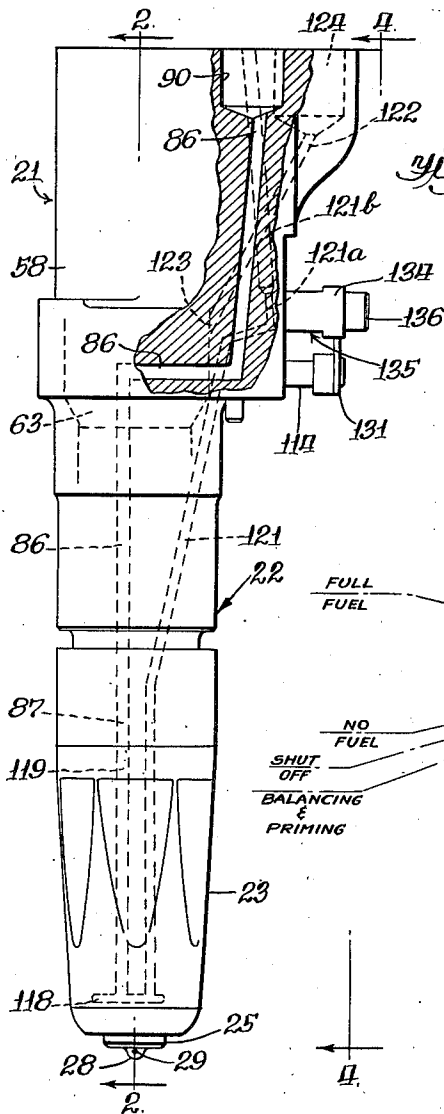


Fig. 1.

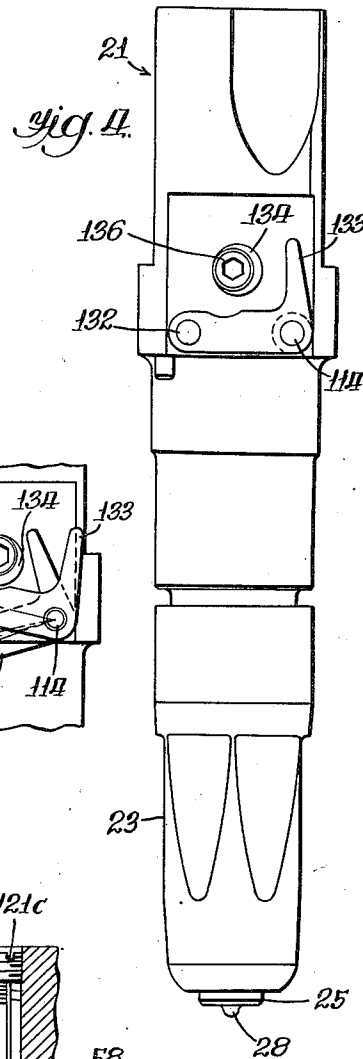


Fig. 2.

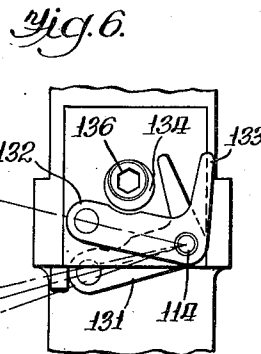


Fig. 3.

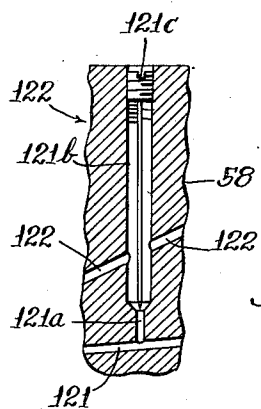


Fig. 4.

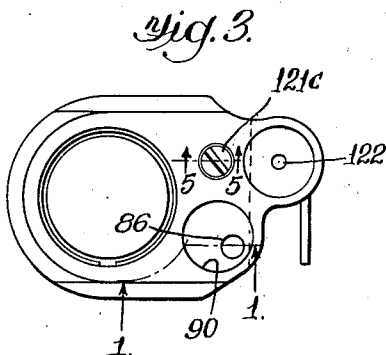


Fig. 5.

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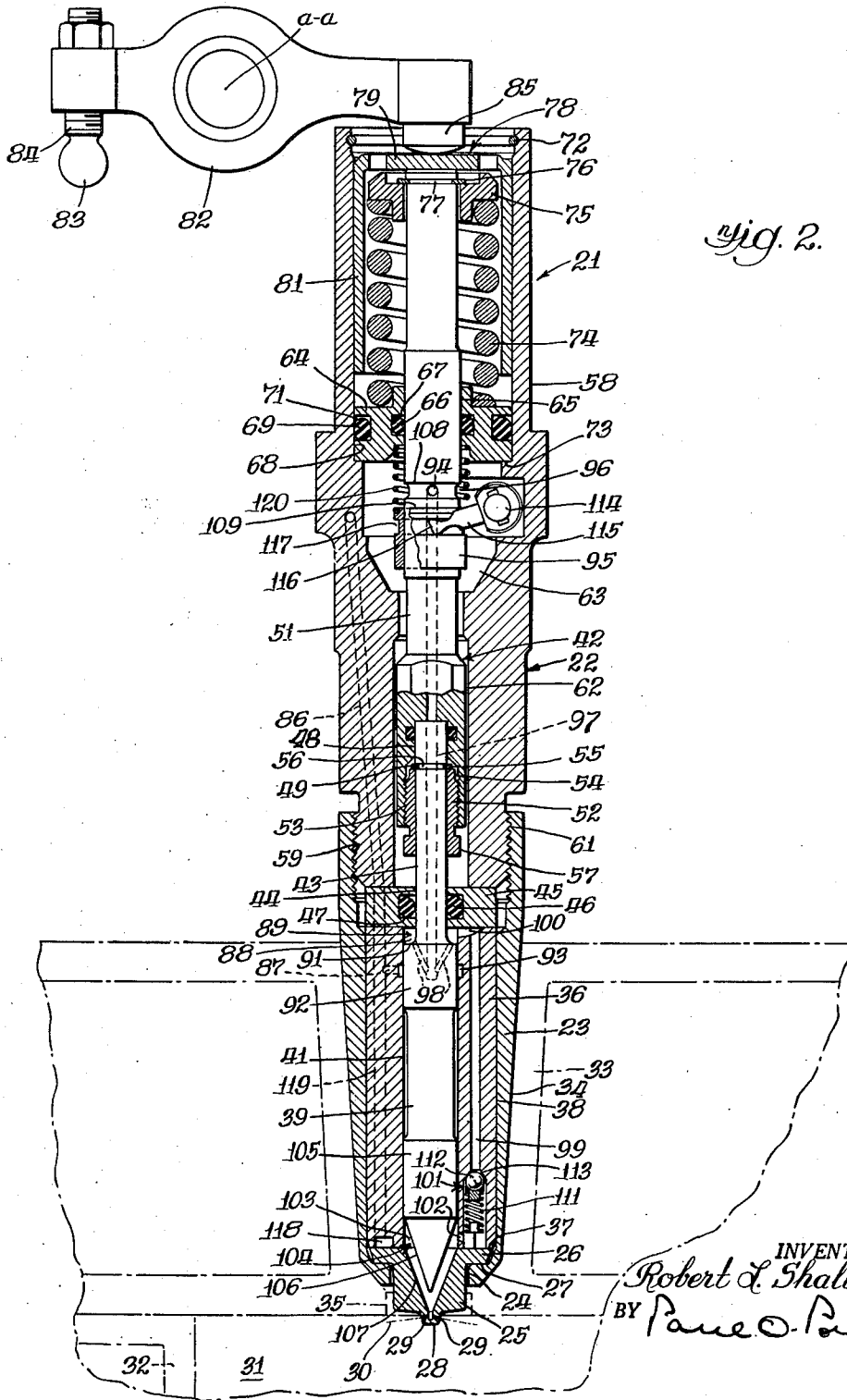
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Fig. 10.

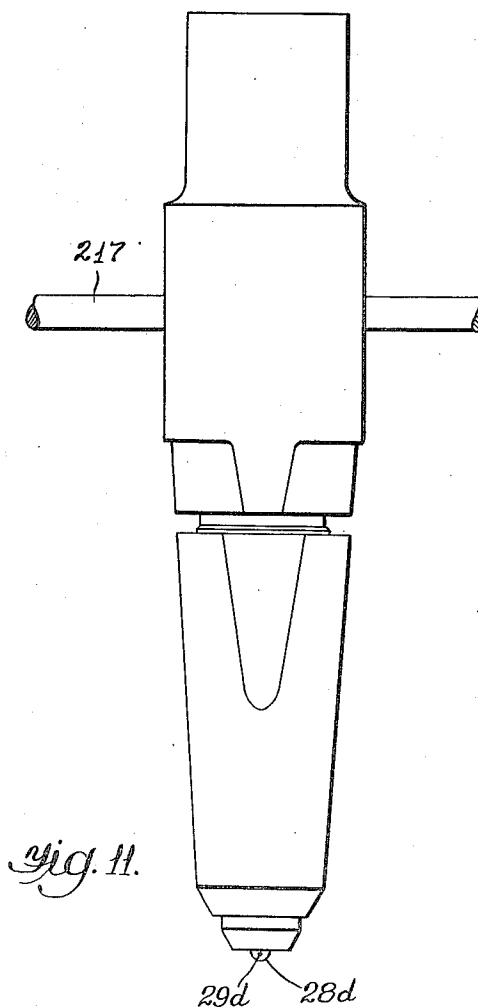
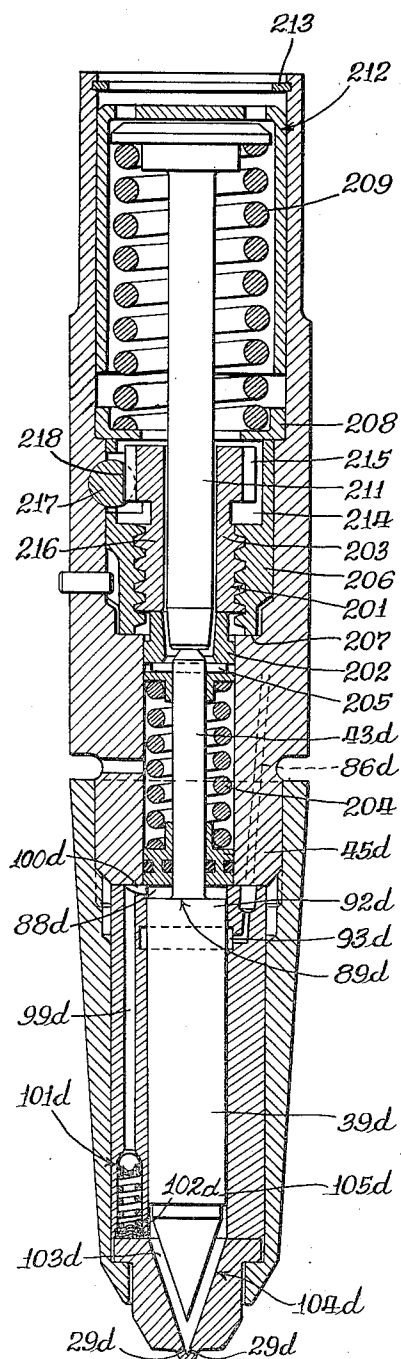


Fig. 11.

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FUEL INJECTOR FOR INTERNAL COMBUSTION ENGINES

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Application July 3, 1953, Serial No. 365,901

9 Claims. (Cl. 299—107.2)

This invention concerns liquid fuel injection nozzles for internal combustion engines and more particularly relates to such a nozzle incorporated into a unitary structure with a fuel metering pump therefor.

A principal object of this invention is the provision of a fuel metering and injection nozzle unit of simplified structure utilizing an arrangement wherein the fuel is metered at low pressure prior to being subjected to the relatively high injection pressure. Metering therefore can be accomplished during a longer time interval which is conducive to accuracy. This low pressure metering system also prolongs the useful service period of the unit since no metering surfaces of concentrated area are subjected to the erosion of rapidly flowing fuel under extremely high pressure.

A further object is the provision of an improved fuel metering and injection nozzle unit wherein the fuel pressure during metering is independent of the injection pressure, wherefore the injection pressure can be made as high as desired.

Another object is the provision of a fuel metering and injection nozzle unit settable to adapt low pressure flow of fuel therethrough to scavenge air from the fuel receiving passages and cavities thereof and thus efficiently prime the system for immediate starting of the engine with initial cranking.

Another object is the provision of a fuel metering and injection nozzle unit readily adapted for use of the fuel therein as a coolant for the nozzle tip.

Still another object is the provision of a fuel metering and injection nozzle unit having a fuel metering control conveniently accessible and readily adjustable to calibrate fuel metering whereby equal variable fuel delivery is attained for several units of a multi-combustion-chamber engine.

The above and other desirable objects inherent in and encompassed by the invention are elucidated in the ensuing specification, the appended claims and the appended drawings, wherein:

Fig. 1 is a side elevational view, with a part broken away in section approximately at the position indicated by the line 1—1 in Fig. 3, of a fuel metering and injection nozzle unit embodying a preferred form of the invention;

Fig. 2 is a vertical sectional view taken at a plane indicated by the line 2—2 in Fig. 1, and illustrating a typical installation of the unit upon a fuel-combustion chamber illustrated in dot-dash lines, and also showing an engine rocker arm operably associated with an operating stem or rod for the plunger of the unit;

Fig. 3 is a plan view looking downwardly at the upper end of the unit in Fig. 1;

Fig. 4 is a side elevational view taken at right angles to the view in Fig. 1 and in the direction indicated by the arrows associated by the line 4—4 in Fig. 1;

Fig. 5 is a fragmentary sectional view taken on the plane indicated on the line 5—5 in Fig. 3, showing detail of the intersection of a fuel exhaust passage and a coolant

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exhaust passage, and of a restricted flow capacity section in a coolant exhaust passage;

Fig. 6 is a fragmentary view showing a control arm and stop element in different positions than are illustrated in Fig. 4;

Fig. 7 is a longitudinal sectional view taken similarly to Fig. 2 through a second embodiment of the invention;

Fig. 8 is a fragmentary sectional view taken at the plane indicated at the line 8—8 in Fig. 7 to illustrate details of a control mechanism for a fuel metering element of the unit;

Fig. 9 is a longitudinal sectional view taken similarly to Figs. 2 and 7 through a third embodiment of the invention;

Fig. 10 is a longitudinal sectional view taken through a fourth embodiment of the invention;

Fig. 11 is a side elevational view of the Fig. 10 embodiment and illustrating a control rack in association with such unit; and

Fig. 12 is a fragmentary vertical sectional view of a fifth embodiment of the invention that differs from the Fig. 7 embodiment only in the metering control illustrated.

With continued reference to the drawings and particularly to Figs. 1 and 2, a fuel metering and injection nozzle unit 21 is shown having an elongated fabricated tubular body 22. An outer shell-like element 23 comprises part of the lower portion of the tubular body 22. This shell 23 has an opening 24 in its lower end. A nozzle member 25, inserted through the upper open end of the shell 23 has a flange 26 which abuts against an inner face 27 of the lower end of the shell 23 while the main portion of the nozzle member projects outwardly through the opening 24. A tip portion 28 of the nozzle element 25 contains a plurality of discharge orifices 29 adapted to spray fuel in the form of atomized jets along respectively associated median lines 30, Fig. 2, into the upper part of a combustion chamber 31 outlined by dot-dash lines. This combustion chamber comprises a typical internal combustion engine cylinder 32 closed at its upper end by a cylinder head 33, also shown in dot-dash lines. A hole 34 through the cylinder head 33 has a portion conforming to the outer periphery of the metering and injection nozzle unit shell 23 and receiving the same. The nozzle element 25 projects through a reduced diameter lower end portion 35 of the cylinder head hole 34.

A cylindrical element 36 of the elongated tubular body 22 has a flat annular lower end 37 which rests in sealed abutting relation upon the upper flat face of the nozzle element flange 26. This cylindrical element 36 is telescoped downwardly into the inner bore 38 of the shell 23 after insertion of the nozzle element 25 into such shell. The annular lower end face 37 of the cylinder 36 and the face with which it abuts upon the flange 26 are lapped to effect a high degree of smoothness of these surfaces to eliminate leakage of fluid therebetween. A pump plunger or plunger structure 39 is inserted downwardly into a plunger receiving bore 41 formed by the inner periphery of the cylindrical element 36. A fabricated stem or operating rod 42 for this plunger 39 has a stem portion 43 formed integrally with the plunger and projecting axially upwardly therefrom through a cylindrical bearing 44 of a disk-like element 45 which forms an upper end for the plunger receiving bore 41. A sealing O-ring 46 disposed within an annular groove 47 of the element 45 is compressed between the side wall of such groove and the outer periphery of the stem 43 to supplement the sealing character of the bearing 44 with the stem. The lower end face of the element 45 and the upper annular end face of the cylindrical element 36 in abutment therewith are also lapped whereby they fit together in essentially perfect conformity to prevent leakage of fluid between these abutting surfaces.

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An upper end portion of the stem 43 projects into a small diameter portion 48 of a recess 49 in the lower end of a push rod element 51 of the fabricated stem and operating rod 42. The rod 51 is connected with the stem 43 by means of an externally threaded sleeve nut 52 turned into an internally threaded portion 53 in a large diameter lower portion 54 of the recess 49. The upper end of this sleeve nut presses against a small snap ring 55 mounted within an annular groove 56 circumscribing the stem 43. A lower end portion 57 of the sleeve nut 52 has circumferentially arranged wrench-engaging facets (not shown) facilitating the turning of this nut for firmly advancing it endwise into the threaded recess 49.

An upper tubular part 58 of the elongated fabricated tubular body 22 has an exteriorly threaded lower end portion 59 turned into threaded relation with an internal threaded portion 61 of the tubular shell 23. Tubular part 58 contains an axial bore 62 for accommodating the fabricated stem and operating rod 42 for the plunger 39. An enlarged fuel-receiving spill cavity 63 constituting part of the bore 62 is closed at its upper end by an annular bearing element 64 having a bearing bore 65 in which the operating rod 51 is journaled for endwise reciprocation. Leakage of fuel from the spill cavity 63 between the bearing bore 65 and the outer periphery of the rod 51 is precluded by an O-ring 66 contained within an annular groove 67 within the bearing bore 65. Fuel leakage from the cavity 63 between the outer periphery 68 of the ring 64 and the periphery of the casing or body bore 62 is precluded by an O-ring 69 contained within an annular groove 71 formed within the outer periphery of said ring. Bearing ring 64 which is telescoped downwardly into bore 62 through the upper end of the tubular casing part 58, prior to installation of a snap ring 72, is limited in its downward motion within the tubular body or casing 22 by a shoulder 73 upon which this ring rests. Ring 64 serves as a reaction member for the lower end of an axially compressed helical spring 74. The upper end of the spring 74 presses against an annular spring seat 75 which transmits axial force from such spring to a snap ring 76 mounted within a groove 77 in the upper end of the rod 51 whereby this rod is constantly urged upwardly by the spring. A power drivable operating member in the form of a spring cup 78 has an end wall 79 resting upon the upper end of the rod 51 and has a cylindrical side wall 81 slidable axially within the upper portion of the tubular part bore 62. Abutment of the spring cup 78 with the snap ring 72 limits upward movement of the fabricated stem and operating rod 42 and the plunger 39 under the force of the axially compressed spring 74.

Endwise reciprocal motion of the fabricated stem and operating rod 42 together with the plunger 39 is accomplished jointly by the spring 74 and a rocker arm 82 rockable about a fixed axis $a-a$. Upward force imparted to the left end of the rocker arm 82 by a push rod (not shown) operated in timed relation with the crankshaft of an engine upon which the fuel metering and injection nozzle unit 21 is installed, through the spherical lower end 83 of an adjustable thrust-receiving element 84 in the left end of the rocker arm causes the right end of this arm to move downwardly and thus press a bearing element 85 thereof against the upper end 79 of the spring cup 78 to force the stem and operating rod structure 42 together with the plunger 39 downwardly while compressing the spring 74. Subsequent downward retractive movement of said push rod (not shown) enables the spring 74 to push the plunger and operating rod assembly therefor upwardly while pivoting the rocker arm 82 counterclockwise and keeping the end 79 of the spring cup 78 in contact with the rocker arm bearing member 85. Thus power from the engine operated push rod (not shown) is transmitted through the rocker arm 82 for forcing the plunger 39 downwardly and force stored within the spring 74 is effective for alternately retracting the plunger 39 upwardly.

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Liquid fuel enters the metering and injection nozzle unit 21 through a fuel inlet channel means 86 leading downwardly from a conduit coupling recess 90 in the upper end of the fabricated body 22, see Figs. 1, 2 and 3. The fuel is fed into the upper end of the inlet channel means 86 under constant relatively low pressure (25 lbs. per square inch, for example) by means of a fuel feed pump (not shown). In Figs. 1 and 2 the channel means 86 can be seen to lead downwardly through the bearing member 45 into the cylindrical member 36 of the fabricated tubular body where communication is had through a fuel inlet port 87 with a pumping chamber 88 of a metering pump 89 when the pump plunger or plunger structure 39 is at the lower end of its reciprocal movement wherefore an upper end 91 of a head-like fluid displacement portion 92 of this plunger structure is below the upper edge of an annular groove portion 93 of the fuel inlet port 87. Normally, when the plunger 39 is advanced or projected downwardly to its lower limit for expanding the metering pump chamber 88 and establishing communication between the port 87 and such chamber, a spill port 94 communicating outwardly from a side of the fabricated stem and operating rod 42 on the opposite of the bearing 44 with respect to the plunger 39 will be masked by a sleeve-like fuel metering element 95. This spill port 94 has an annular groove portion 96 circumscribing the rod portion 51 of the stem and operating rod structure 42. Spill port 94 communicates with the metering pump chamber 88 through a fuel spill passage 97 and passage laterals 98 thereof, the laterals being formed within the upper part of the plunger and said passage being formed partly within the upper portion of the plunger and partly within the fabricated stem and operating rod 42. When the sleeve-like fuel metering element masks the spill port 94 and the annulus component 96 thereof, upward or retractive movement of the plunger 39 under the force of the spring 74, after the upper end 91 of the plunger advances upwardly far enough for the head-like fluid displacement plunger portion 92 to mask the fuel inlet annulus 93, continued upward movement of the plunger forces the fuel from the chamber 88 through a port 100 into a fuel transfer passage means 99 formed in the cylindrical element 36 and downwardly through this passage 99 past a check valve 101 therein and thence through an inwardly and upwardly directed port 102 into a conical fuel delivery chamber 103 of an injection pump 104 which constitutes said chamber, the lower head-like fluid displacement portion 105 of the plunger structure 39 and a conical end 106 of the plunger which conforms to and is adapted to seat upon a conical lower end wall 107 of the delivery chamber 103. During retractive upward movement of the pump plunger 39 and consequent contraction of the metering pump chamber 88 by projection of the fluid displacement portion 92 of the plunger into said chamber for expelling of fuel through the fuel transfer passage 99 and the forcing of such fuel outwardly through the port 102, the lower fluid displacement portion 105 of the plunger will be retracting from and expanding the fuel delivery chamber 103 whereby this chamber is adapted to accommodate all of the transferred fuel without any of it leaking outward through the discharge orifices 29. In fact since the frontal area of the plunger portion 92 being projected into the chamber 88 is less than the frontal area on the conical lower end of the fluid displacement portion 105, the expansion rate of the chamber 103 exceeds the contraction rate of the chamber 88 so that a low pressure zone is formed within the chamber 103 causing suction of air from the combustion chamber 31 through the fuel discharge orifices into the chamber 103 for mixing with the fuel transferred into such fuel delivery chamber.

During the retractive upward movement of the plunger 39 fuel will continue to be transferred from the chamber 88 into the fuel delivery chamber 103 until the upper edge 108 of the spill port annulus 96 moves upwardly be-

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yond registry with the upper or fuel metering edge 109 of the fuel metering element 95. Upward movement of the plunger subsequent to such registration of the edges 108 and 109 will establish communication of the spill port 94 with the low pressure spill chamber 63 whereby the fuel instead of being transferred from the contracting chamber 88 through the transfer passage 99 will be discharged upwardly through the spill passage 97 into the spill chamber 63. Shift of discharge from the metering pump chamber 88 through the transfer passage 99 into the spill passage 97 occurs instantaneously since a spring 111 of the check valve 101 urges the ball 112 of this element against a seat 113 with sufficient force that a pressure of approximately 100 lbs. per square inch is required in this transfer passage to unseat the ball. Consequently upon the initial cracking of an annular spill space between the spill edges 108 and 109 which are of considerable peripheral extent will instantaneously provide a relatively large spill area therebetween for so diminishing the pressure in the metering pump chamber 88 and in the transfer passage 99 to enable the valve ball 112 to be promptly seated and terminate any further flow past this valve into the fluid delivery chamber 103.

The quantity of fuel transferred from the metering pump chamber 88 into the injection pump or fuel delivery chamber 103 attendant to each upstroke of the plunger is variably selectable by changing the axial position of the fuel metering element 95. When this metering element is at a higher elevation the length of the pumping stroke is correspondingly longer since it takes longer for the metering edge 108 to rise into registry with the metering edge 109 beyond which the metering element is no longer in masking relation with the spill port and groove 94-96. It follows that selective diminution of the fuel delivered into the injection pump chamber 103 is accomplished by lowering the fuel metering element 95 to correspondingly diminish the effective length of the retractive or upward metering pumping stroke of the plunger.

The axial position of the fuel metering element 95 is selectively determined by a rockable control shaft 114 which may be either manually controlled or governor controlled. This rockable shaft 114 has a yoke 115 constrained for rocking therewith. Furcations 116 of the yoke 115, one of such furcations being shown in Fig. 2, straddle the fuel metering element 95 where they project into a circumferential groove 117 thereof which adapts these furcations to impart the axial components of force to the metering element for moving this element in either direction depending upon the direction of rocking of the control shaft 114. A light spring 120 reacting between the upper end of the fuel metering element 95 and the bearing member 64 urges the element 95 downwardly and thus biases the yoke 115 and the control shaft 114 in a counterclockwise direction as viewed in Fig. 2 to eliminate back-lash between the furcations and the sides of the groove 117 and the joints of operating linkage components (not shown) connected with the control shaft 114.

Means for cooling the nozzle element 25 and other lower portions of this metering and injection nozzle unit which are subjected to the heat of combustion in the combustion chamber 31, includes a coolant-receiving cavity 118 of semicircular formation formed by a groove in the lower end of the cylindrical element 36 of the fabricated tubular body 22 and the upper end face of the nozzle element 25. Coolant in the form of fuel is constantly fed into the cavity 118 through a coolant inlet passage 119 which is a continuation of the lower end of the fuel inlet channel means 86. A coolant exhaust passage 121 shown in dotted lines in Fig. 1 leads upwardly through the tubular body 22 to a restricted flow capacity section 121a thereof. A portion 121b of the coolant exhaust passage above the restricted capacity flow passage 121a, Figs. 1-5, intersects a fuel exhaust passage 122, Fig. 1, which leads diagonally upwardly from a port 123 of communication with the spill chamber 63, shown in dotted lines in Fig. 1,

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to a conduit coupling member receiving recess 124 extending into the upper end of the tubular body or casing. A fuel exhaust conduit (not shown) attached to the tubular body 22 at the recess 124 is adapted to conduct the exhausted fuel and fuel coolant back to the aforesaid low pressure fuel supply pump (not shown). Although fuel is fed intermittently from the fuel inlet channel means 86 through the fuel inlet port 87 into the fuel metering pump 89, there is a constant flow of coolant fuel through the coolant system comprising the passage 119, cavity 118 and the coolant exhaust passage 121 at a rate determined by the capacity of the restricted flow capacity section 121a. The restricted flow capacity section 121a prevents bleeding away of the coolant fuel at a rate which would cause too great a pressure drop at the fuel inlet port 87.

In Figs. 1, 4 and 6 there is shown a control arm 131 on the outer end of the rockable control shaft 114 and with which said shaft is constrained for rocking motion. The outer end of the arm 131 contains a connecting pin receiving hole 132 to facilitate attachment of a control linkage (not shown) which would normally be governor operated but which alternatively, of course, may be manually operated. A gauge portion 133 of the arm is cooperable with an eccentric stop element 134 of a gauge sleeve 135 for obtaining a calibrated reference setting for the control arm 131 and for the pump plunger 39 and the fuel metering element 95, to facilitate installation of a plurality of the metering and injection nozzle units upon a multiple combustion chamber engine in a manner providing essentially identical fuel delivery characteristics therefor. The gauge sleeve is rotatably adjustable coaxially upon the shank of a socket-headed cap screw 136 which is threaded into a side of the tubular body 22. After swinging adjustment of the eccentric gauge 134 about the cap screw axis, this screw is turned farther into the body 22 to tightly grip the ends of the sleeve 135 between the head of this screw and said body for maintaining the adjustment.

Operation of the first embodiment shown in (Figs. 1 through 6)

In the operation of an engine upon which the metering and injection nozzle unit 21 is installed, the rocker arm 82 will be cyclically rocked in opposite directions about the axis *a-a* thereof by a cam-operated push rod (not shown) adapted to push upwardly against the spherical end 83 of the thrust screw 84. Upward thrust of said push rod causes the arm 82 to rock clockwise for pushing the plunger 39 downwardly to seat the conical surface 106 upon the conical end wall surface 107 of the fuel delivery chamber 103. When the upwardly moved thrust rod cooperating with the spherical bearing 83 is eventually allowed to descend, the compressed spring 74 in the upper end of the unit is adapted to retractively raise the pump plunger 39 while keeping the upper end 79 of the spring cup 78 in contact with the bearing head 85 on the right end of the rocker arm 82 and thus cause the rocker arm to rock counterclockwise.

It will be assumed that fuel is being received by the unit 21 at a modest constant pressure (25 lbs. per square inch, for example) through the fuel inlet channel means 86; that the fuel metering element 95 is set in the part throttle position illustrated in Fig. 2; and that the rocker arm 82 is being rocked clockwise by power received from the engine through the aforesaid thrust rod. Fuel entering the unit through the passage 86 is blocked by the fluid displacement portion 92 of the pump plunger 39 from flowing into the metering pump chamber 88 through the port 87. However, a small quantity of this fuel can proceed downwardly through the coolant inlet passage 119 into the coolant-receiving cavity 118 for cooling the lower end of the unit and then flow upwardly from the cavity 118 through the coolant exhaust passage 121, Fig. 1, and the restricted flow capacity portion 121a

thereof, Figs. 1-5, into the fuel exhaust passage 122 for conduction back to the low pressure fuel supply pump (not shown) through the exhaust conduit (not shown) coupled into the recess 124, Fig. 1. Fuel previously introduced into the fuel delivery chamber 103 is discharged through the fuel discharge orifices 29 by the downwardly advancing plunger 39. The check valve 101 in the fuel transfer passage means 99 constitutes means preventing reverse flow of fuel under high compression in the fuel delivery chamber 103 upwardly through said transfer passage means.

The rocker arm 82 is adapted to drive the plunger 39 to a lower limit with the surface 106 seated upon the surface 107 at which time all of the fuel will have been ejected from the chamber 103 into the combustion chamber 31. While the plunger 39 is at this most advanced lower limit, the upper end 91 of the fluid displacement portion 92 of the plunger 39 will be below the upper edge of the inlet annulus 93 whereby a charge of fuel enters the pumping chamber 88 through such annulus.

The timing of the operating cycle for the metering and injection nozzle unit is so correlated with the valving and piston movement for the engine combustion chamber 31 with which it is associated that at the beginning of the air intake stroke of this combustion chamber, the push rod associated with the rocker arm 82 is allowed to gradually descend which enables the spring 74 in the upper end of the metering and injection nozzle unit to gradually raise the plunger 39. The complete upward or retractive stroke of the plunger 39 under the force of the spring 74 is accomplished by approximately the middle of the ensuing compression stroke for the associated combustion chamber 31. During the initial part of the upward movement of the plunger 39 the upper end 91 thereof approaches the upper edge of the fuel inlet annulus 93 and forces a small quantity of the fuel from the chamber 88 outwardly through the fuel inlet port 87. This back surge of fuel through the inlet port occurs because the spill port 94 and its associated annulus 96 in the fabricated stem and operating rod 42 is masked by the fuel metering element 95 and also because the constant pressure of fuel delivered into the inlet channel means 86 is less than the pressure required in the fuel transfer passage 99 to unseat the check valve ball 112. Back surge of fuel through the inlet port 87 terminates simultaneously with the upper edge 91 of the plunger 39 arriving in registry with the upper edge of the fuel inlet annulus 93. Metering of fuel commences simultaneously with continued upward retractive movement of the plunger 39 from the position of registration of the upper end 91 of the plunger with the upper end of the inlet annulus 93 and continues until the upper spill edge 108 of the spill annulus 96 reaches the upper metering edge 109 of the metering element 95. During the metering phase or period, fuel is forced from the metering pump chamber 88 through the port 100 and the fuel transfer passage 99 past the check valve 101 and through the port 102 into the fuel delivery chamber of the injection pump 104. At the end of this metering phase when the upper edge 108 of the spill annulus 96 begins to move above the upper metering edge 109 of the fuel metering element 95, the establishment of communication of the spill chamber 63 through said annulus and the port 94 with the metering pump chamber 88 through the spill passage 97 and the laterals 98 thereof, the pressure within the chamber 88 immediately diminishes below the 100 lbs. per square inch necessary to force fuel through the transfer passage 99 past the check valve 101, wherefore the remaining fuel in the chamber 88 is discharged into the spill chamber 63. From the spill chamber the fuel is exhausted back to the fuel supply pump through the fuel exhaust passage 122, Fig. 1, and the aforesaid exhaust conduit connected with the metering and injection nozzle unit at the recess 124.

During the metering phase while fuel is being pumped

from the metering pump 89 through the transfer passage 99 into the fuel delivery chamber 103 of the injection pump 104, said chamber 103 is being expanded to increase its volumetric capacity at a greater rate than the volumetric transfer of fuel thereto. This is because the frontal end area of the fluid displacement plunger portion 92 being projected into the pumping chamber 88 is exceeded by the conical frontal area 106 being retracted from the chamber 103. Consequently during this metering phase and also just prior thereto while the plunger 39 is being initially retracted from the seating relation with the conical surface 107, the pressure within the chamber 103 is exceeded by the pressure within the combustion chamber 31 wherefore there is an initial flow of hot gas from the combustion chamber through the fuel discharge orifices into the fuel delivery chamber. The gas initially introduced into the fuel delivery chamber 103 mixes with the fuel first transferred thereto through the port 102 to create a frothy status of a portion of the fuel, and this process of mixing hot gas from the combustion chamber 31 with fuel introduced into the delivery chamber 103 continues during the entire metering period. Continued upward retractive movement of the plunger 39 after termination of the metering period, continues to expand the fuel delivery chamber 103 to accommodate further introduction of air from the combustion chamber 31 thereto so that by the time the plunger 39 reaches the upper limit of its retractive motion the hot gas and fuel within the delivery chamber will have had a thorough mixing. There is a dwell for the plunger 39 at its upper limit of retractive motion during about 10° of the engine crankshaft rotation, and this dwell terminates when the crankshaft has approximately an additional 40° of rotation to reach top dead center for the piston associated with the combustion chamber 31. At the end of said dwell the push rod for the rocker arm 82 is moved up rapidly for driving the plunger 39 down sharply for injecting the air mixed fuel from the chamber 103 through the fuel discharge orifices 29 into the combustion chamber 31. This hot gas or air mixed with the fuel in the chamber 103 heats the fuel to make it more readily combustible and also conditions the fuel so that it breaks up into smaller mist-like particles more susceptible to instantaneous combustion when injected through the discharge orifices 29. Because of the presence of the air within the fuel delivery chamber 103, despite the rapid downward advancement stroke of the plunger, the initial delivery of fuel outwardly through the orifices 29 is of a relatively slow rate in comparison to what the delivery rate would be if the chamber 103 were completely filled with non-aerated liquid fuel. The pressure rise within the combustion chamber 31 attributable to the initially burned fuel is therefore modulated, thereby avoiding "diesel knock" caused by rapid burning of initially injected large amounts of fuel as is done most commonly in direct fuel injection systems for internal combustion engines. As injection proceeds the conical lower end of the plunger 39 reaches proximity with the conical lower end face 107 of the delivery chamber 103, the air mixed with fuel within this chamber is reduced into a relatively small volume and increases in pressure which causes an increase in the rate of fuel ejected through the discharge orifices 29. Because of the extremely fine particles into which this air mixed fuel forms as it is sprayed through the fuel discharge orifices the burning thereof occurs almost immediately upon entering the combustion chamber without giving rise to any period of high peak pressure within the combustion chamber. By maintaining high plunger velocity until the conical surface 106 is very close to the mating conical surface 107 substantially all of the fuel is ejected rapidly through the discharge orifices with no appreciable dribble from the outer ends of these orifices. Fuel waste and coking of fuel upon the nozzle tip 28 is thereby minimized. This completes the operating cycle for the fuel metering and injection nozzle

unit. While the plunger is at this lower advanced limit of its movement a fresh charge of fuel is admitted into the metering chamber 88 as described above, and when the plunger commences its next retractive stroke another charge of hot gas will be admitted into the fuel delivery chamber 103 through the orifices 29 for mixture with fuel pumped downwardly into such chamber through the fuel transfer passage 99 during the ensuing metering period.

It will be noted that while the plunger 39 is at the end of its downstroke a fresh fuel charge is admitted into the metering pump chamber 88 wherefore on each upstroke of the plunger a metered quantity of fuel is expelled from the metering pump 89 into the delivery chamber 103 of the injection pump 104, and then, on the ensuing downstroke of the plunger 39, this metered transferred fuel is expelled into the combustion chamber 31. The fuel metering and injection nozzle unit therefore embodies a multistage fuel pump of which a metering stage comprises the metering pump 89 and of which the second or injection stage includes the injection pump 104. The fabricated stem and operating rod structure 42 constitutes power driven means for simultaneously operating these two stages of the multi-stage pump.

Although the metering pump 89 meters while pumping at approximately 100 lbs. per square inch pressure against the check valve 101 in the fuel transfer passage 99, this is a relatively low pressure compared to that developed in the delivery chamber 103 during injection. Consequently metering occurs under conditions recognized as "low pressure." Furthermore, the low pressure metering stage of the multi-stage pump is communicatively isolated from the injection stage during the development of high pressure within the injection stage wherefore any desired pressure can be developed within the injection pump stage without effecting the pressure at which metering occurs. The fact that the metering or spill edge 108 at the upper edge of the metering annulus 96 and the edge 109 at the upper end of the metering element 95 are of considerable circumferential extent to enable the fuel to spill through an annular space of large transverse area very quickly after movement of the edge 108 above the edge 109, together with the fact that the spilled fuel is at a relatively low pressure, avoids any condition where fuel at high pressure is concentrated upon a small area with rapid erosion effect.

Calibration of the metering and injection nozzle unit 21 to standardize the fuel metering and delivery characteristics thereof with respect to other such units used upon respective combustion chambers of multi-cycle combustion engines is accomplished with the aid of the rotatively adjustable gauge sleeve 135 having the eccentric gauge cam portion 134, Figs. 4 and 6. In establishing the standard setting of the control parts, the eccentric 134 is first swung away from the projection 133 of the control arm 131 to enable this control arm to be pivoted counterclockwise into a position wherein the radial center line of this arm occupies a position somewhat below that designated "Balancing and priming" in Fig. 6. This counterclockwise position for the arm 131 is merely an approximation position in which the yoke 115, Fig. 2, will have been rocked sufficiently counterclockwise to carry the upper metering edge 109 of the fuel metering element 95 lower than the spill groove 96 while the pump plunger is forced downwardly by an assembly bench jig (not shown) to seat the lower conical end thereof upon the conical surface 107 of the fuel delivery chamber 103. While the plunger 39 is so seated at its lower limit, a dial gauge for measuring linear movement of the plunger will be attached to the body or casing 22 with an actuating element thereof in abutment with the upper side of the spring cup wall 79 and the reading of this gauge set to zero. Fuel under a low pressure, the equivalent of approximately a 3 ft. head, for example, will be introduced into the inlet passage 86 of the unit, and inas-

much as the upper end 91 of the plunger 39 will then be below the inlet annulus 93 and the upper metering edge 109 of the fuel metering element is then below the spill groove 96, this fuel will flow slowly, because of the small pressure head, into the metering pump chamber 88, thence through passage laterals 98, spill passage 97, spill port 94 and spill annulus 96 into the spill cavity 63 and then upwardly through the fuel exhaust passage 122 and outwardly through a small observation tube (not shown) temporarily associated with the exhaust passage conduit coupling cavity 124. To facilitate observation of this flow, passage 121a is closed off by the conical lower end of a needle valve stem 121d depending from the screw plug 121c. While fuel is flowing through the pump and injection unit in the manner just described for spewing out of the observation tube, the plunger 39 is allowed to rise slowly under the force of the spring 74 until the upper end 91 of this plunger arrives in registry with the upper edge of the inlet annulus 93. As soon as this registration occurs spilling of fuel from the observation tube ceases and thus manifests when such registration occurs. Further upward movement of the plunger is arrested at this point and the reading on the dial indicator noted, whereupon the plunger 39 is forced downwardly a short standard distance, preferably .010", which is measured on the dial gauge. This downward movement of course carries the upper end 91 of the plunger 39 the standard .010" below the upper edge of the inlet annulus 93. The plunger will now be maintained in this position while fuel resumes its flow through the inlet passage 86 and through the unmasked inlet annulus 93 to ultimately spew from the observation tube. During this flow of fuel through the unit, the control arm 131 will be slowly rotated clockwise as viewed in Figs. 4 and 6 until the fuel metering element 95, Fig. 2, is raised for bringing its upper metering edge 109 into registry with the upper edge 108 of the spill annulus 96. The attainment of this position for the fuel metering element 95 is manifested by cessation of flow from the indicator tube. While the fuel metering element 95 is in this position the control arm 131 will be in the position designated "Balancing and priming" in Fig. 6. While the arm 131 is in this position a feeler gauge of standard thickness, $\frac{1}{32}$ ", for example, is inserted between the control arm projection 133 and the eccentric stop 134 which will be rotated counterclockwise to engage one face of the feeler gauge while the projection 133 engages the opposite face thereof. The capscrew 136 is then tightened to maintain this setting for the eccentric gauge element 134. This provides a reference from which the "Balancing and priming" position of the arm 131 can be subsequently established by use of a feeder gauge. At this time of establishment of the "Balancing and priming" position for the control arm 131, the pump plunger 39 is being held downwardly with the upper end 91 thereof .010" below the upper edge of the fuel annulus 93. Therefore, since the upper metering edge 109 of the metering element 95 is in registry with upper edge 108 of the fuel spill annulus 96 during this initial "Balancing and priming" setting, upward movement of the plunger 39 would unmask the spill annulus 96 before the plunger 39 masks the inlet annulus 93 and, since pumping of the metering pump 89 does not commence to effectively pump until the upper edge 91 of the pump plunger moves upwardly the .010" into registry with the upper edge of the inlet annulus 93, the fuel metering element can be moved upwardly to carry the metering edge 109 thereof .010" above the spill edge 108 and still establish a control setting for the unit in which no fuel will be delivered while the plunger edge 91 moves upwardly to the upper edge of the inlet annulus 93. Subsequent to such upward adjustment of the metering element 95 the upper edge 108 of the spill annulus 96 of the retracting plunger assembly will arrive in registry with the metering edge 109 of the metering element 95 to create the "spill" condition simultaneously with the start-

ing of the pumping period by the metering pump 89 and no fuel will be metered by continued upward movement of the plunger. Said .010" upward adjustment of the metering element 95 is accomplished attendant to moving the control arm 131 from the "Balancing and priming" position to the "no fuel" position in Fig. 6. Further clockwise movement of the control arm 131 into the range between the "no fuel" and the "full fuel" positions will cause corresponding upward movement of the fuel metering element 95 and the metering of fuel by the unit in a quantity correlated with the distance of movement of the arm toward the "full fuel" position. While the arm 131 is in the "full fuel" position the fuel metering element 95 will have its upper metering edge at an elevation coinciding with the highest elevation at which the upwardly moving plunger operating stem and rod assembly 42 can move the upper edge 108 of the spill annulus 96. The "shut off" position for the arm 131, Fig. 6 actually laps downwardly beyond the "no fuel" to take into account manufacturing tolerances and assure that the "no fuel" position will have been attained when the arm 131 is moved counterclockwise into this "shut off" position.

When several of the fuel metering and injection nozzle units 21 are installed upon a multi-cylinder engine each thereof which has been standardized in the setting of the fuel metering element 95 and the arm projection 133 with respect to the adjustable stop 134, will have the outer ends of the arms 131 connected with a common control linkage therefor while the feeler gauge of standard thickness, the $\frac{1}{32}$ " thickness when this is the standard used initially in standardizing the units, is inserted between the eccentric stop and the arm projection 133. Inasmuch as the fuel metering and injection units have had the "Balancing and priming" positions of their arms 131 standardized, this position of the arms is maintained during attachment of these arms to the common operating mechanism therefor of the engine wherefore after this attachment has been accomplished this operating mechanism will cause synchronous movement of the arms 131 to attain uniform fuel metering and injection characteristics for each of the units.

By using the feeler gauge between the adjustable stop element 134 and the arm projection 133 when establishing the position of this stop with reference to the "Balancing and priming" position of the arm 131, clearance is established between such arm projection and the stop for all positions of the arm 131 during operation upon an engine. Assurance is thereby had that the gauge stop 134 will not be abutted by any part of the arm to disturb the setting of this gauge stop.

Description of the Figs. 7 and 8 embodiment

Many of the parts in the Figs. 7 and 8 embodiment of this invention are readily ascertainable as corresponding to respective parts in the Figs. 1 through 6 embodiment, wherefore to expedite this disclosure such parts of the Figs. 7 and 8 embodiment are designated by the same respective reference characters as the corresponding parts of the Figs. 1 through 6 embodiment with the addition of the suffix "a," without necessarily herein reciting a description of these parts designated by the reference characters having the suffix.

In this second embodiment of the invention, Figs. 7 and 8, the fuel transfer passage 99a is formed within the pump plunger 39a instead of within the cylindrical element 36a. This fuel transfer passage 99a is an axially extension of a bore 97a which constitutes a combined fuel inlet and spill passage means within the fabricated stem and operating rod structure 42a. The conical lower end portion 106a of the plunger 39a is formed separately from the main part of such plunger and has a stem portion 141 screwed into a threaded recess 142 in the lower end of the plunger. A portion of the transfer passage 99a is formed within the conical lower end por-

tion of the plunger where such passage communicates with the fuel delivery chamber 103a through ports 102a. A check valve 101a within the transfer passage 99a comprises a ball 112a urged against a seat 113a therefor by a spring 111a of sufficient strength to require fluid pressure of approximately 100 lbs. per square inch in the upper part of the transfer passage to unseat the ball.

Liquid fuel is forced into the unit under a relatively low constant pressure, 25 lbs. per square inch, for example, through a fuel inlet channel means 86a which communicates with a combined fuel inlet and spill cavity 63a through a port 143. A short cylindrical fuel blocking element 144 of hexagonal or other suitable exterior faceted formation rests upon a shoulder 145 in the tubular body part 58a and because of the faceted outer periphery of this element 144 communication providing spaces 146 are formed between the lower end of this element and the shoulder 145 enabling fuel to flow downwardly through these spaces from the cavity 63a into a space 147 below a fuel blocking control edge 148 of the element 144.

The axial position of the fuel metering element 95a is determined by a control rockshaft 114a having a manual or governor actuated arm 131a constrained for rocking with its outer end. The inner end of the shaft 114a has a circular head 149 having an operating pin 151 mounted therein eccentrically with respect to the axis of the shaft 114a. This pin projects into a circumferential groove 117a of the metering element 95a and is thus effective for raising or lowering said element 95a when the rockshaft 114a is rocked. A spacer sleeve 152 surrounding the valve stem and operating rod structure 42a is mounted upon the lower end of the annular sealing element 64a and thus establishes an upper limit for the movement of the fuel metering element 95a. An annular clearance space 153 is provided between the spacer sleeve 152 and the valve stem and operating rod structure 42a and this clearance space communicates with the spill cavity 63a through any desired number of openings 154 in the spacer element.

Operation of the Figs. 7 and 8 embodiment

The plunger stem and operating rod structure 42a of the second embodiment is operated alternately in opposite endwise directions by a rocker arm as that designated 82 in Fig. 2 and by the spring 74a. It will be assumed that the plunger stem and operating rod 42a is being advanced downwardly under the force of rocker arm pressure applied to the upper end wall 79a of the spring cup 78a. During this rapid downward movement of the stem and rod structure 42a the pump plunger 39a is forced downwardly to expel air-entrained liquid fuel from the fuel delivery chamber 103a outwardly through the fuel discharge orifices 29a. While the conical lower end 106a of the plunger is upon or adjacent to the conical lower periphery 107a of the fuel delivery chamber, the lower edge 155 of a fuel inlet groove or annulus 156 circumscribing the plunger stem and operating rod 42a will be disposed slightly below the lower control edge 148 of the fuel blocking element 144 wherewith fuel under a constant low pressure within the space 147 is forced into the annulus 156 and through the fuel inlet port 87a into the combined fuel inlet and spill passage in 97a. At this time the fuel spill groove or annulus 96a will be masked by the fuel metering element 95a wherefore the fuel entering the passage 97a through the inlet annulus 156 and port 87a can flow only downwardly through such passage 97a and through the laterals 98a thereof into the expanded chamber 88a of the metering pump 89a.

On the ensuing upward retractive stroke of the plunger, initial contraction of the pumping chamber 88a causes a back surge of fluid upwardly through the passage 97a and outwardly through the inlet annulus 156 until the lower edge 155 of this annulus moves upwardly into registry

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with the lower annular control edge 148 of the fuel blocking element 144. When such registration occurs both the annuluses 156 and 95a will be masked respectively by the elements 144 and 95a so that continued retractive movement of the plunger develops sufficient pressure, approximately 100 lbs. per square inch, within the fuel transfer passage 99a for opening the check valve 101a and forcing fluid through the ports 102a into the fuel delivery chamber 103a. As in the case of the first embodiment the pumping rate of the fuel metering pump 89a is exceeded by that of the fuel injection pump 104a so that air or hot gas from an associated engine combustion chamber passes through the fuel discharge orifices 29a into the chamber 103a for heating and mixing with the fuel being transferred into this chamber. The transfer of fuel from chamber 88a into chamber 103a continues until the upper metering edge 108a of the spill groove 96a commences to rise above the metering edge 109a of the fuel metering element 95a. When this occurs a wide opening is suddenly formed between the edges 108a and 109a of a considerable curvilinear extent to allow rapid escape of fuel from the metering pump 89a upwardly through the passage 97a into the clearance space 153 and outwardly through the openings 154 into the spill cavity 63a. Immediately upon movement of the spill edge 108a above the fuel metering edge 109a the low pressure release thus afforded for fuel pumped by the metering pump 89a will diminish the pressure in the upper part of the fuel transfer passage 99a to result in instantaneous closing of the check valve 101a and termination of the metering period when no more fuel will be delivered into the delivery chamber 103a. Had the metering element 95a been in a lower position the spill edge 101a would have passed registration with the metering edge 109a earlier to correspondingly shorten the effective metering stroke and causes a correspondingly smaller quantity of fuel to be metered and transferred into the delivery chamber 103a. This completes the operating cycle as the plunger reaches its upward stroke limit preparatory to being again forced downwardly for ejecting air mixed fuel from the delivery chamber 103a through the fuel discharge orifices 29a.

The fact that this second species of the invention provides no coolant cavity in the lower end of the structure as in the case of the first embodiment, together with the fact that the fuel transfer passage 99a is placed within the plunger makes it possible to decrease the outside diameter of a cylindrical element 36a. As a consequence the shell or casing element 23a has a smaller outside diameter than the shell 23 of the first embodiment, thus resulting in an extremely slender unit requiring a relatively small amount of space for the mounting thereof in the head of an engine combustion chamber.

Description of the Fig. 9 embodiment

This third embodiment of the invention also has numerous elements corresponding to respective elements in the first embodiment and to expedite this disclosure these corresponding elements in the third embodiment will be designated by the same respective reference characters plus the suffix "b" in the drawing without necessarily repeating them in this description. Elements of this third embodiment corresponding to elements present only in the second embodiment, Fig. 7 and 8, will be designated by the same respective reference characters plus the letter suffix "c."

In this third embodiment an upper end portion 161 of the plunger 39b is of relatively large diameter and serves to divide a large diameter portion 162 of the plunger receiving bore 41b into a lower primary pumping chamber 163 and an upper secondary pumping chamber 164. A bearing element 45b forming the upper end wall for the chamber 164 contains a plunger stem receiving bearing 44b in which a portion of a power drivable pump operating member in the form of a plunger operating stem 42b

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projecting upwardly from the plunger 39b is in sliding sealing relation. An internal shoulder 165 of the tubular body 22b cooperates with a snap ring 166 in maintaining the bearing element 45b fixed axially of said body.

Fuel inlet ports 167 communicate inwardly through the body with the primary pumping chamber 163. These ports 167 may be connected with a fuel supply through a conventional annular coupling fitting girdling the tubular casing part 58b and having an annular delivery duct registering communicatively with such inlet ports. Communication from the pumping chamber 163 to the secondary pumping chamber 164 is had through fuel conducting passages 168 and past a check valve 169 comprising an annular wafer element 171 liftable from an upper end face 172 of the valve plunger enlargement 161 against the force of an annular spring element 173 which reacts upwardly against a snap ring 174 mounted on the plunger operating stem 42b.

Operation of the Fig. 9 embodiment of the invention

It will be assumed that fuel under a modest constant pressure is being maintained in the pumping chamber via the fuel inlet ports 167, and that a rocker arm similar to that designated 82 in Fig. 2 is being operated for forcing plunger-operating stem 42b and the plunger 39b sharply downwardly for ejecting fuel from the fuel delivery chamber 103b outwardly through the orifices 29b. During this descent of the plunger 39b the secondary pumping chamber 164 will be expanding to create a low pressure condition therein less than the pressure in the primary chamber 163 wherefore this pressure differential across the plunger end portion 161 will cause opening of the check valve 169 and the conduction of fuel from chamber 163 through the passages 168 into the secondary pumping chamber. Therefore, when the conical lower end 106b of the plunger arrives in seating relation with the conical lower end face 107b of the fuel delivery chamber 103b, secondary pumping chamber 164 will contain a charge of liquid fuel. During the ensuing upward retractive stroke of the plunger 39b under the force of the spring 74b fuel within the chamber 164 will be discharged inwardly through stem ports 175 and downwardly through the fuel transfer passage 99b past the check valve 101b and outwardly through the ports 102b into the fuel delivery chamber 103b. During this initial upward movement of the plunger 39b, the fuel discharged from the pumping chamber 164 inwardly through the ports 175 cannot flow upwardly through the spill passage 97b because the spill annulus 96b associated with the spill port 94b is masked by the sleeve-like metering element 95b. The metering period terminates with the arrival of the upper spill edge 108b of the annulus 96b in registry with the upper or metering edge 109b of the metering sleeve 95b. Further upward movement of the plunger to carry the edge 103b above the metering edge 109b enables the fuel to spill from the annulus 96b, thereby reducing the pressure in the fuel transfer passage 99b and permitting the check valve 101b to close. Thereupon no further fuel is transferred into the fuel delivery chamber 103b. Earlier termination of the fuel metering period to cause a smaller quantity of fuel to be metered and transferred into the fuel delivery chamber 103b is accomplished by lowering the metering element 95b whereby the spill edge 103b arrives in registry with the metering edge 109b after a shorter portion of the upward movement of the plunger. Fuel spilled from the spill annulus 96b enters the spill cavity 63b from which it is conducted through a drain passage 122b back to the inlet side of a supply pump (not shown) for maintaining the constant fuel pressure through the inlet ports 167 in the primary pumping chamber 163.

The metered fuel transferred through the passage 99b into the fuel delivery chamber 103b is injected through orifices 29b during the next ensuing downward advancement of the pump plunger.

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The lower portion of the unit constituting the third embodiment of this invention, that is, that portion of the unit including shell 23b and the parts embraced thereby are constructed very similarly to the parts embraced by the shell 23a of the second embodiment so that this third embodiment of the invention is also relatively slender for occupying a small space within the head of an engine cylinder. This species of the invention has the advantage over the first two embodiments that the plunger 39b and the operating stem 42b therefor are formed integrally, thus dispensing with the necessity of a joint structure such as that utilizing the coupling nut 52 and 52a respectively of the first two embodiments.

Description of Figs. 10 and 11 embodiment

Numerous elements in this embodiment of the invention correspond to elements in the first embodiment and therefore, to expedite this description, will simply be designated by the same respective reference characters with the addition of the suffix letter "d," without necessarily being referred to in this part of the description.

In this form of the invention fuel enters the chamber 88d of a fuel metering pump 89d through a fuel inlet passage 86d and an inlet annulus 93d which is adapted to communicate with the chamber 88d when the plunger 39d is at the lower limit of its movement. On the ensuing retractive upward movement of the plunger the fluid displacement portion 92d thereof at its upper end masks the annulus 93d and thereby forces fluid from the pumping chamber 88d through the outlet port 100d and then downwardly through the fuel transfer passage 99d past a check valve 101d into the fuel delivery chamber 103d. Here again the pumping rate of the metering pump 89d is exceeded by that of the injection pump 104d wherefor as the fuel displacement lower portion 105d of the plunger 39d rises the fuel delivered into the chamber 103d will be supplemented by hot gas from the associated combustion chamber (not shown) entering the chamber 103d through the injection orifices 29d, for the purpose and with the effect explained in connection with the first embodiment above.

The ending of the metering period in this embodiment employs a mechanical stop means 201 instead of the spill port system in the first three embodiments. The metering pump 89d commences the effective part of its metering stroke upon the movement of the upper end thereof into complete masking relation with the inlet annulus or port 93d and will continue until the upper end of a tubular stem guide 202 upon the plunger stem 43d abuts against an axially adjustable element 203 of the adjustable stop means 201. A helical spring 204 reacts between the plunger-stem-receiving bearing 45d and said stem guide 202, which is secured to the stem 43d by a pin 205, for retracting the plunger 39d upwardly.

The unit body non-rotatively carries an internally threaded sleeve nut 206 which is constrained against axial movement between a shoulder 207 and a seating element 208 for a spring 209 which urges a power drivable pump operating rod or member 211 upwardly at all times. A spring cup 212 telescoped over the upper end of the spring 209 is abutable against a snap ring 213 for limiting upward movement of the rod 211. A recess 214 in the upper end of the non-rotatable nut 206 contains a gear 21 having a threaded stem portion 216 meshed with the threads of the nut 206. A rack 217 has a toothed section 218 meshed with the teeth of the gear 215 wherefore endwise movement of the rack will cause rotation of the gear whereby the latter will be caused to advance or retract axially within the fixed nut 206 dependently on the direction of the endwise motion of the rack. Manual or governor control of the rack 217 will therefore govern the axial position of the threaded stem 216 of which the lower end is abutable by the sleeve guide 202 on the upper end of the plunger stem 43d to selectively determine the amount of fuel delivered by the metering pump

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89d during the metering phase of the operation of this unit.

Upon the sleeve guide 202 abutting against the lower end of the threaded stem 216 to determine the amount of metered fuel, the power drivable pump operating member 211 can continue to retract upwardly under force of the spring 209 until the upper end of the spring cup 212 abuts the snap ring 213. In commencing the injection phase of the unit, force from an engine rocker arm, or the like, is imparted downwardly to the upper end of the spring cup 212 and thence to the power drivable member 211 which is thus forced downwardly to carry its lower end into abutting relation with the upper end of the plunger stem 43d to forcibly advance the plunger 39d downwardly and thus operate the injection pump 104d for injecting the fuel and air outwardly through the orifices 29d. Following this injection stroke of the plunger 39d, the driving force for the power drivable member 211 will be relieved and this member allowed to rise under the force of the spring 209 whereupon the plunger 39d will be allowed to rise under the force of the spring 204 for metering and transferring a quantity of the fuel that had entered the chamber 88d through the port 100d while the plunger was in its lowermost position, through the transfer passage 99d into the fuel delivery chamber 103d preparatory to this metered transferred fuel being ejected through the orifices 39d when the plunger 39d is next forced downwardly.

Description of Fig. 12 embodiment

This species of the invention is primarily a modification of the second species of the invention shown in Figs. 7 and 8 and therefore also includes elements corresponding to the first species shown in Figs. 1 through 6.

To expedite this description those elements shown in Fig. 12 corresponding to elements in the first species will simply be designated by the same respective reference characters with the addition of the suffix letter "e" whereas elements respectively corresponding to elements present only in the second species will be designated by the same respective reference characters with the addition of the suffix letter "f," without these elements necessarily being referred to in this part of the specification.

The Fig. 12 species differs from the Fig. 7 species in the respect of omitting the fuel blocking element 144, the fuel inlet port 87a and the fuel inlet annulus 156 associated with said port, and by utilizing the port 94e and the associated annulus 96e for both a fuel inlet and a fuel spill means. The lower edge 109f of the metering element 95e then becomes the metering edge of this element 95e instead of the upper edge thereof being the metering edge as in the Fig. 7 species. The plunger push rod 51e is illustrated at the upper or retracted limit of its reciprocal movement wherefore the plunger (not shown) at the lower end of this unit will be retracted in the manner illustrated with respect to the plunger 39a in Fig. 7. Therefore, when the push rod 51e is forced downwardly the fuel that had been transferred into the fuel delivery chamber in this species of the invention will be forced into the engine combustion chamber associated therewith. This downward movement of the push rod 51e carries the spill annulus 96e downwardly so that the lower edge thereof will be below the metering edge 109f whereupon the port 94e is communicative with the combined fuel inlet and spill chamber 63e whereby the fuel fed inwardly to this chamber through the port 143f can displace the fuel inwardly through the port 94e and downwardly through the combined fuel inlet and spill passage 97e into the metering pump chamber. During retractive upward movement of the push rod 51e, fuel in the pumping chamber will be forced upwardly through the spill passage 97e and outwardly through the spill port 94e until the lower edge of the spill annulus 96e moves upwardly into registry

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with the metering edge 109f. When this occurs the fuel displaced from the pumping chamber will necessarily flow through the transfer passage into the fuel delivery chamber in an amount correlated with the vertical adjustment of the metering element 95e. In this species of the invention spill of the fuel occurs immediately preceding the metering portion of the retractive movement of the plunger instead of at the end of the metering portion of such retractive movement. The vertical position of the metering element 95e is controlled by the control shaft 114f and the pin 151f eccentrically mounted thereon as in the instance of the Fig. 7 species.

Having thus described the several embodiments of the invention with the view of fully, clearly and concisely illustrating the same, I claim:

1. In a fuel metering and injection nozzle unit, a body containing a plunger-receiving bore, a plunger-stem-receiving bearing of less diameter than said bore and extending axially from one end of such bore, a plunger axially reciprocal in said bore and dividing the same into a fuel pumping chamber within the one end thereof and into a fuel delivery chamber within the opposite end thereof, fuel discharge orifice means communicative outwardly from the delivery chamber, a plunger-operating stem of less diameter than the plunger and projecting endwise therefrom through said bearing with which such stem is in sliding sealing relation, said stem being endwise movable to alternately effect endwise advancement of the plunger toward the delivery chamber end of the bore and retraction toward the pumping chamber end of the bore, a side wall of the bore in the fuel pumping chamber containing a fuel inlet port exposed by the advanced plunger for admitting fuel into such pumping chamber, fuel transfer passage means communicative between said chambers, a fuel spill port communicating outwardly through a side portion of said stem on the opposite side of said bearing from the plunger, a spill passage extending communicatively from the spill port axially through the stem into communication with the pumping chamber, a metering element in masking relation with the spill port and having a metering edge past which the stem can move the spill port during retractive movement of the plunger and stem, said plunger being sequentially operable during retraction to sealingly mask the fuel inlet port and thereafter displace fuel from the pumping chamber through the transfer passage into the expanding fuel delivery chamber until the stage in such retraction when the spill port arrives at said metering edge, said metering element being adjustable axially of the stem to vary the time when the spill port arrives at the metering edge and thus selectively vary the amount of fuel transferred into the delivery chamber during plunger retraction, means preventing return flow of the metered and transferred fuel from the delivery chamber through the transfer passage, and the plunger being operable during its ensuing advancement to expel the metered and transferred fuel from the delivery chamber through the discharge orifice.

2. In a fuel metering and injection nozzle unit, an elongated tubular body having a fuel delivery chamber adjacent an end thereof and a fuel discharge orifice communicative between such chamber outwardly through said end of the body, a plunger projectable axially within the tubular body into said chamber to expel fuel therefrom through said orifice and alternately retractable for expanding the chamber, and a metering pump within said body and spaced endwise thereof on the opposite side of said chamber from the discharge orifice, said pump having a fuel inlet including inlet channel means within said body and also having a fuel outlet communicative with said chamber and being operable by said plunger to displace a metered quantity of fuel through such outlet into the expanding chamber during retraction of the plunger preparatory to expulsion of the displaced metered fuel through the discharge orifice during the suc-

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ceeding projection of the plunger, said body also having a coolant-receiving cavity within a portion of said end thereof, a coolant passage extending lengthwise within said body in intercommunicative relation between the fuel inlet channel and said coolant cavity for conducting coolant fluid in the form of a portion of the fuel from the inlet channel into the coolant cavity, and a coolant exhaust passage extending axially in said body from the coolant cavity for conducting cooling fuel therefrom as it is displaced by fuel forced thereinto from the fuel inlet channel.

3. In a fuel metering and injection nozzle unit, an elongated body containing a plunger-receiving bore, a plunger-stem-receiving bearing of less diameter than said bore and extending axially from one end of such bore, a plunger axially reciprocal in said upper bore and dividing the same into a fuel pumping chamber within the one end thereof and into a fuel delivery chamber within the opposite lower end thereof, said body having a fuel inlet channel and fuel exhaust passage, fuel discharge orifice means communicative outwardly from the delivery chamber through such opposite end of the body, a plunger-operating stem of less diameter than the plunger and projecting endwise therefrom through said bearing with which such stem is in sliding sealing relation, said stem being endwise movable to alternately effect endwise advancement of the plunger toward the delivery chamber end of the bore and retraction toward the pumping chamber end of the bore, the fuel pumping chamber containing a fuel inlet port communicating with such chamber from the fuel inlet channel and exposed by the advanced plunger for admitting fuel into such pumping chamber, fuel transfer passage means communicative between said chambers, a fuel spill port communicating outwardly through a side portion of said stem with the fuel exhaust passage and on the opposite side of said bearing from the plunger, a spill passage extending communicatively from the spill port axially through the stem into communication with the pumping chamber, a metering element in masking relation with the spill port and having a metering edge past which the stem can move the spill port during retractive movement of the plunger and stem, said plunger being sequentially operable during retraction to sealingly mask the fuel inlet port and thereafter displace fuel from the pumping chamber through the transfer passage into the expanding fuel delivery chamber until the stage in such retraction when the spill port arrives at said metering edge, said metering element being adjustable axially of the stem to vary the time when the spill port arrives at the masking edge and thus selectively vary the amount of fuel transferred into the delivery chamber during plunger retraction, means preventing return flow of the metered and transferred fuel from the delivery chamber through the transfer passage, the plunger being operable during its ensuing advancement to expel the metered and transferred fuel from the delivery chamber through the discharge orifice means, said body containing a coolant fluid-receiving cavity in non-communicating embracing relation with said bore adjacent the end of the body containing the fuel discharge orifice, a coolant inlet channel extending axially within the body communicatively between the fuel inlet channel and the coolant cavity for conducting coolant in the form of fuel into the coolant cavity, a coolant outlet passage extending axially within said body communicatively between the coolant cavity and said fuel exhaust channel, said coolant cavity and the coolant inlet and outlet passages therefor constituting a coolant circuit, and at least one of said coolant circuit passages having a restricted flow capacity preventing inordinate pressure diminution of the fuel in the fuel inlet channel.

4. In a fuel metering and injection unit, a tubular body containing a plunger receiving bore and having a plunger-stem-receiving bearing at an end of said bore, a plunger reciprocally mounted in said bore and dividing the same

into a fuel pumping chamber at the one end and a fuel delivery chamber at the opposite end, said body having a fuel inlet port communicative with the pumping chamber in spaced relation from the one end of the bore in position to be unmasked by an end of the plunger when it is axially advanced into the fuel delivery chamber, a fuel transfer passage communicative between said chambers, said plunger being operable during axial retractive movement thereof to mask the inlet port and contract the pumping chamber for expelling fuel therefrom through the transfer passage into the fuel delivery chamber, discharge orifice means through which the transferred fuel is ejectable from the fuel delivery chamber during an ensuing advance of the plunger, a valve stem and operating rod structure projecting axially from said end of the plunger through the said bearing and reciprocal for alternately imparting the advancement and retractive movements to the plunger, a spill port communicating outwardly through a side section of the stem and rod structure on the opposite end of said bearing from the plunger, a spill passage communicative through the stem and rod structure from the pumping chamber to said spill port, a fuel metering element adjustable axially of the stem and rod structure and adapted to mask the spill port during a portion of the retractive movement of the plunger until said port is retracted beyond a metering edge of such element, means for determining the position of the metering element axially of the stem and rod structure comprising a control arm operably connected with said metering element incident to the rocking of said arm about an axis thereof, and a standardizing gauge element adjustably mounted on said body adjacently to said arm to establish a reference position of said gauge element from which a predetermined standardizing pivotal position of the arm is determinable.

5. In a fuel metering and injection nozzle unit, a body containing a plunger-receiving bore, a plunger-stem-receiving bearing of less diameter than said bore and extending axially from one end of such bore, a plunger axially reciprocal in said bore and dividing the same into a fuel pumping chamber within the one end thereof and into a fuel delivery chamber within the opposite end thereof, fuel discharge orifice means communicative outwardly from the delivery chamber, a plunger-operating stem of less diameter than the plunger and projecting endwise therefrom through said bearing with which such stem is in sliding sealing relation, said stem being endwise movable to alternately effect endwise advancement of the plunger toward the delivery chamber end of the bore and retraction toward the pumping chamber end of the bore, a side wall of the bore in the fuel pumping chamber containing a fuel inlet port exposed by the advanced plunger for admitting fuel into such pumping chamber, fuel transfer passage means communicative between said chambers, a fuel spill port communicating outwardly through a side portion of said stem on the opposite side of said bearing from the plunger, a spill passage extending communicatively from the spill port axially through the stem into communication with the pumping chamber, a metering element having a metering edge and cooperable with the spill port to mask such port for preventing discharge of fuel from the spill passage while the port is upon one side of the metering edge axially of said stem and to unmask the port and thus facilitate discharge of the fuel therefrom when the port registers with or is upon the other side of said metering edge, said metering element being adjustable axially of the stem to vary the portion of the plunger traction stroke during which the spill port is masked by said metering element, and said plunger being sequentially operable during retraction to sealingly mask the fuel inlet port and thereafter displace fuel from the pumping chamber through the transfer passage into the expanding fuel delivery chamber during masking of the spill port by the metering element, and means preventing return flow of the metered and transferred fuel

from the delivery chamber through the transfer passage, and the plunger being operable during the ensuing advancement thereof to expel the metered and transferred fuel from the delivery chamber through the discharge orifice means.

6. In a combined fuel metering and injection nozzle unit, a body containing a bore with fuel pumping and delivery chambers spaced apart axially therein, a plunger-stem-receiving bearing of less diameter than the portion of said bore having the pumping chamber and extending axially of the bore from such chamber, fuel discharge orifice means communicating outwardly from the fuel delivery chamber, a plunger axially reciprocal in said bore and constituting a partition separating said chambers from one another, a plunger-operating stem of less diameter than the plunger and projecting axially therefrom through the pumping chamber and through said bearing with which such a stem is in sliding sealing relation, said stem being endwise movable to alternately effect endwise advancement of the plunger into the delivery chamber and retraction thereof into the pumping chamber, fuel transfer passage means disposed communicatively between the chambers, valve means operable to prevent reverse flow of fuel through the transfer passage means from the delivery chamber to the pumping chamber, a combination fuel inlet and spill port within a side portion of the stem beyond the opposite end of said bearing with reference to the plunger, fuel inlet and spill passage means extending communicatively from said port axially through the stem into communication with the pumping chamber, a metering element having a metering edge past which said port is movable into masking registry with the metering element during plunger and stem retraction, said port being movable into and beyond registry with the metering edge out of said masking relation during advancement of the plunger and stem to facilitate ingress or egress of fuel through said port during such unmasked relation, the unmasked port being adapted to receive fuel for delivery through the inlet and spill passage into the pumping chamber during the expansion of this chamber pursuant to plunger advancement, said port being adapted for the expulsion of fuel from the pumping chamber and inlet and spill passage during ensuing retraction of the plunger until the port is retracted into masking relation with the control element whereupon during continued retraction of the plunger the fuel from the pumping chamber is forced through the transfer passage into the expanding fuel delivery chamber, said metering element being adjustable axially of the stem to vary the time when the port retracts past the metering edge into masked relation with such element to thus selectively vary the length of the pumping period and the quantity of fuel transferred into the delivery chamber during plunger retraction, and the plunger being operable during its ensuing advancement to expel the metered and transferred fuel from the delivery chamber through the discharge orifice means.

7. The combination set forth in claim 6, wherein the fuel transfer passage comprises an extended portion of the fuel inlet and spill passage into said plunger.

8. In a fuel metering and injection nozzle unit, a body containing a plunger-receiving bore, a plunger-stem-receiving bearing of less diameter than said bore and extending axially from one end of such bore, a plunger axially reciprocal in said bore and dividing the same into a fuel pumping chamber within the one end thereof and into a fuel delivery chamber within the opposite end thereof, fuel discharge orifice means communicative outwardly from the delivery chamber, a plunger-operating stem of less diameter than the plunger and projecting endwise therefrom through said bearing with which such stem is in sliding sealing relation, said stem being endwise movable to alternately effect endwise advancement of the plunger toward the delivery chamber end of the bore and retraction toward the pumping chamber end of the bore, fuel supply means communicative with the pump-

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ing chamber to supply such fuel thereto while the plunger is advanced and operable to terminate such communication attendant to completion of an initial portion of retraction of the plunger, fuel transfer passage means communicative between said chambers, a fuel spill port communicating outwardly through a side portion of said stem on the opposite side of said bearing from the plunger, a spill passage extending communicatively from the spill port axially through the stem into communication with the pumping chamber, a metering element adapted to mask the spill port during further retraction of the plunger and having a metering edge past which the stem can move the spill port during such further plunger retraction, whereby fuel is displaced by the plunger from the pumping chamber through the transfer passage into the expanding fuel delivery chamber until the stage in such further retraction when the spill port arrives at said metering edge, said metering element being adjustable axially of the stem to vary the time when the spill port arrives at the metering edge and thus selectively vary the amount of fuel transferred into the delivery chamber during plunger retraction, means preventing return flow of the metered and transferred fuel from the delivery chamber through the transfer passage, and the plunger being operable during its ensuing advancement to expel the metered and transferred fuel from the delivery chamber through the discharge orifice means.

9. In a fuel metering and injection nozzle unit, a body containing a plunger-receiving bore, a plunger-stem-receiving bearing of less diameter than said bore and extending axially from one end of such bore, a plunger axially reciprocal in said bore and dividing the same into a

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fuel pumping chamber within the one end thereof and into a fuel delivery chamber within the opposite end thereof, fuel discharge orifice means communicative outwardly from the delivery chamber, a plunger-operating stem of less diameter than the plunger and projecting endwise therefrom through said bearing with which such stem is in sliding sealing relation, said stem being endwise movable to alternately effect endwise advancement of the plunger toward the delivery chamber end of the bore and retraction toward the pumping chamber end of the bore, fuel supply means communicative with the pumping chamber to supply such fuel thereto while the plunger is advanced and operable to terminate such communication attendant to completion of an initial portion of retraction of the plunger, one-way fuel transfer passage means operable to conduct fuel under pressure from the pumping chamber into the fuel delivery chamber during further retraction of the plunger, and means including means cooperable with a portion of the plunger stem on the opposite side of said bearing from the plunger to terminate the pumping of fuel from the pumping chamber into the transfer passage attendant to execution of selectively variable amounts of plunger retraction.

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