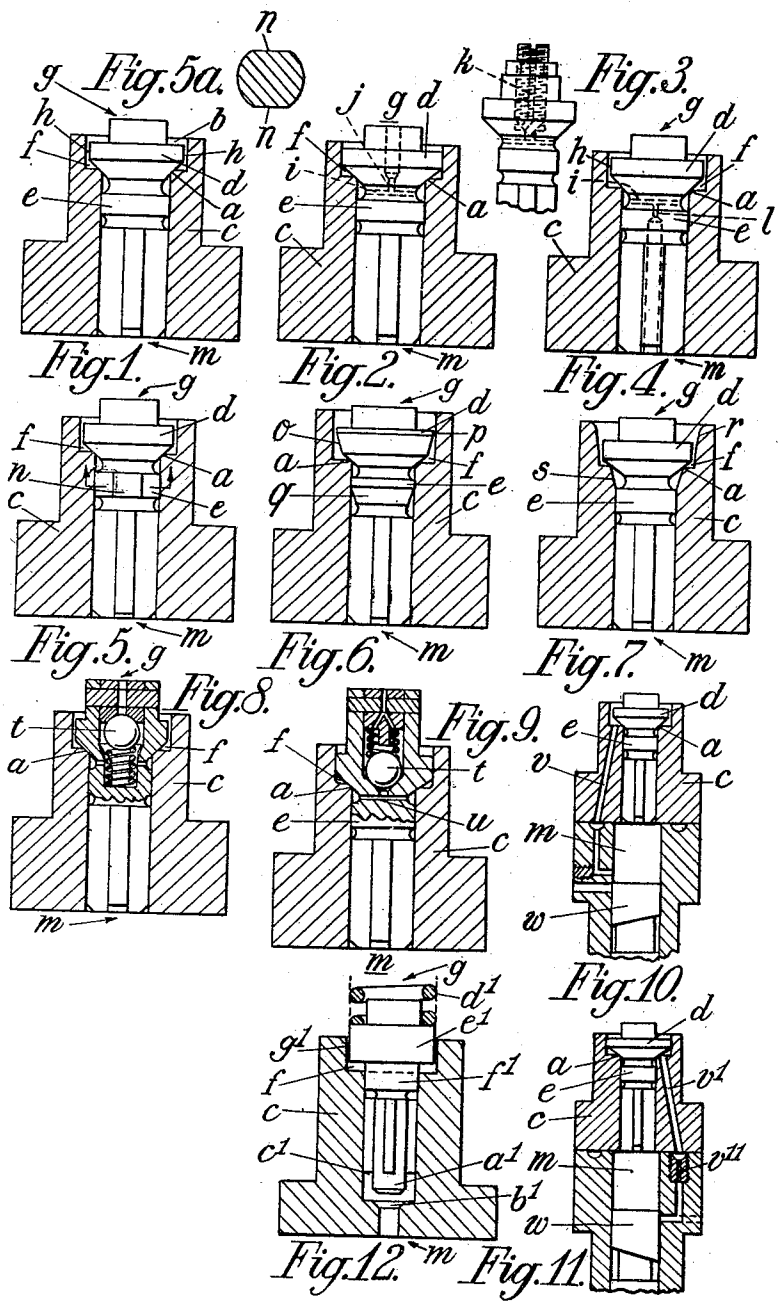
Sept. 3, 1957 W. P. MANSFIELD ET AL 2,804,825

DELIVERY VALVES FOR FUEL INJECTION PUMPS

Filed Nov. 13, 1951

2 Sheets-Sheet 1



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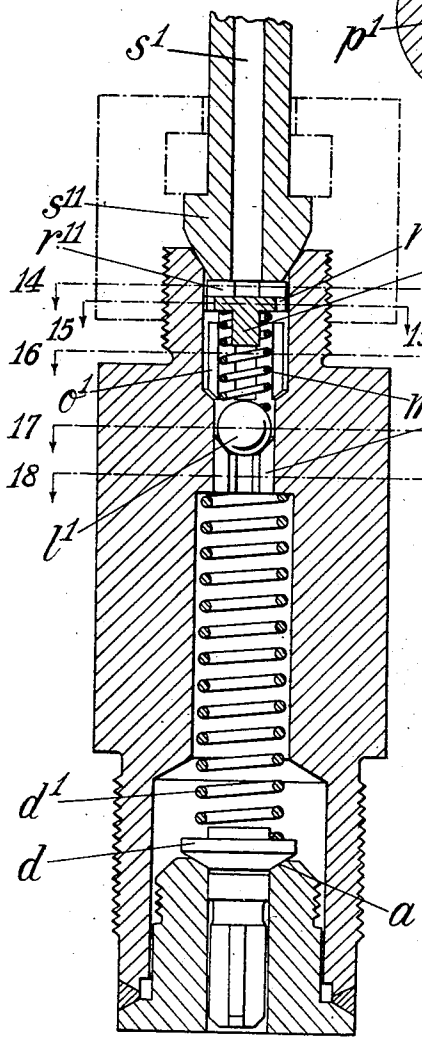


Fig. 13.

Fig. 14.

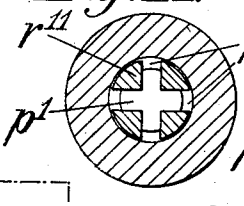


Fig. 15.

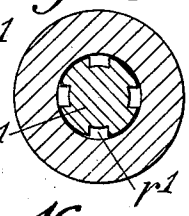
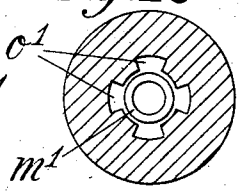


Fig. 16



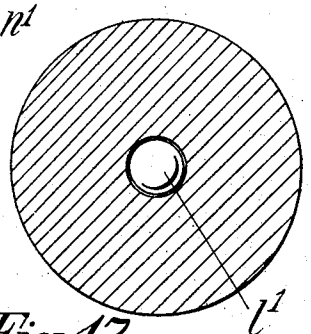


Fig. 17.

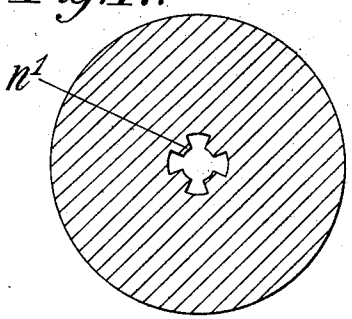


Fig. 18.

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DELIVERY VALVES FOR FUEL INJECTION PUMPS

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Application November 13, 1951, Serial No. 255,893

Claims priority, application Great Britain November 17, 1950

14 Claims. (Cl. 103—41)

This invention relates to liquid fuel injection systems, in particular to injection systems including a pump of the plunger type fitted with a delivery valve.

A common form of fuel injection system for compression ignition engines comprises a pump of the plunger type fitted with a delivery valve and a passage leading therefrom to an outlet in the engine cylinder in the form of a nozzle controlled by a spring-loaded needle valve. The end of injection is controlled by the sudden uncovering of a spill port. This action initiates a wave of rarefaction which passes via the delivery valve and pipe to the injector nozzle and causes an abrupt ending of injection.

Many arrangements of this system give satisfactory injection conditions, but with several systems that have been examined it has been found that after the pump plunger has uncovered its spill port, and the normal injection has been completed, the nozzle needle valve reopens and additional fuel is injected into the cylinder too late for efficient combustion to take place. In extreme cases a number of additional openings of the needle valve have been known to occur. Investigation has shown that the series of pressure waves in the passage which produces these additional openings of the nozzle needle valve is initiated at the delivery valve.

The main object of the present invention is to eliminate or reduce these additional pressure waves which occur after the discharge action of the pump and thus to eliminate the additional injections.

According to the present invention a liquid fuel injection system for an internal combustion engine comprises a pump of the plunger type, a fuel passage from the pump adapted to be connected to an injection nozzle, a delivery valve in said passage comprising an unloading portion which is a close sliding fit for part of its travel in part of the said passage and a head portion which on every delivery stroke of the pump moves for part of its travel through a chamber formed as part of said passage and from which it emerges to open a through way for fuel from the pump and from which, following the spilling of the pump and during the closing of the valve, together with the chamber constitutes for the latter part of its travel a dashpot in which fuel is trapped and from which it is discharged by way of a restricted passage means.

The invention further consists in a liquid fuel injection system for an internal combustion engine comprising a pump of the plunger type, a delivery valve comprising a bore one end of which is connected with the chamber of the pump and the other adapted to be connected with an injection nozzle, a seating in the bore, a valve member co-operating with the seating to close the bore and having axially spaced land portions movable in substantially fluid-sealing fashion in respective sections of the bore, the dimensions of said land portions being such that in use and during the initial part of the opening stroke of the valve the pressure on the delivery side

of the valve is temporarily raised above the nozzle opening pressure and a zone of reduced pressure is established in the bore between said land portions.

In this specification the phrase "so restricted in area as to form a dashpot" is to be understood as specifying a dimension such that, under conditions of maximum output from the pump, it would not allow the fuel to pass at a rate sufficient to run the engine under load. A dimension of this magnitude will result, even under the most arduous conditions of normal operation of the valve, in ensuring that enough cushioning effect is exerted on the valve during its closing movement to dissipate kinetic or potential energy (or both) in the fuel between the valve and the injection nozzle at least to an extent such that no pressure wave is propagated in the said fuel from the valve of sufficient magnitude to cause reopening of the injection nozzle so as to produce secondary injection.

The said dimension will normally be materially smaller than would be required, say, to eliminate excessive mechanical hammering of the valve seating by the valve during normal operation of the system, and further will normally be small enough to cause, during the initial part of the valve opening travel and before it has moved far enough to allow the fuel delivered by the pump to flow into the line for the main injection, a temporary reduction in pressure within the dashpot.

This may be accompanied by a rise in pressure in the residual fuel in the line between the valve and the injection nozzle sufficient to cause injection which substantially ceases when fuel leaks back past the valve into the low pressure zone within the dashpot, to be quickly followed by the main injection as the valve begins to open fully, thus producing the effect of pilot injection.

In one form of construction in accordance with the invention the delivery valve is provided with a dash-pot arrangement such that as the valve approaches its seat, fuel is trapped in a chamber closed by some part of the valve and forced through an orifice in the form of a slot, annulus or other aperture of limited area so that the velocity of the valve is limited. In this way the kinetic energy of the fuel flowing along the passage towards the pump (as well as the kinetic energy of the valve itself) is partially dissipated and partly redistributed so that no large pressure waves are formed.

The accompanying drawings show, by way of example only, a number of embodiments of the invention in which,

Figure 1 is a longitudinal section in which the orifice is the clearance around the head of the valve,

Figure 2 is a longitudinal section in which the orifice is formed by a restricted passage through the valve communicating with the delivery side of the valve,

Figure 3 is a modification of Figure 2,

Figure 4 is a longitudinal section in which the orifice is formed by a restricted passage through the valve communicating with the pump side of the valve,

Figure 5 is a longitudinal section in which the orifices are formed by the provision of flats on the unloading portion of the valve,

Figure 5*a* is a transverse section of Fig. 5,

Figure 6 is a longitudinal section in which a part of the valve head is frusto-conical,

Figure 7 is a longitudinal section in which the bore in the valve body is bell-mouthed,

Figures 8 and 9 are longitudinal sections in which the valve is provided with a ball valve,

Figures 10 and 11 are longitudinal sections in which a passage is provided communicating through the body of the valve with the pump chamber,

Figure 12 is a longitudinal section in which the valve seating is formed on the end of the valve nearest the pump chamber,

Figure 13 is a longitudinal section including a flow restricting ball valve in the delivery passage,

Figure 14 is a transverse section on the line 14—14 of Figure 13,

Figure 15 is a transverse section on the line 15—15 of Figure 13,

Figure 16 is a transverse section on the line 16—16 of Figure 13,

Figure 17 is a transverse section on the line 17—17 of Figure 13, and

Figure 18 is a transverse section on the line 18—18 of Figure 13.

Figure 1 shows one mode of carrying the invention into effect in which the delivery valve proper is of normal design (as shown at the bottom of Figure 14) but the valve seating *a* in the valve body is enclosed in a larger bore *b* above or beyond the main bore of the valve casing *c*. The stem of the valve is provided with a cylindrical unloading portion *e* which substantially seals the valve against the return of fuel from the delivery pipe to the pump as soon as the valve closes sufficiently for the said unloading portion to enter the bore of the valve. The head *d* of the valve enters the cylindrical counter bore thus trapping fuel in the chamber *f* formed between the head and the unloading portion *e* and the walls of the larger bore *b*. The fuel so trapped escapes from this chamber into the delivery passage *g* above the head of the valve by way of a narrow annulus *h* formed by a suitable clearance left between the outer periphery of the head of the valve and the wall of the cylindrical counter bore. Suitable values of dash-pot volume and length and the cross sectional area of the discharge annulus can be provided to give the required control of the velocity of the delivery valve as it approaches its seat. By making the travel of the valve head within the dash-pot less than the travel of the cylindrical unloading portion of the valve stem within the main bore, normal unloading of the system is obtained until the valve head enters its bore. During the remainder of the travel of the valve to its seat, unloading continues at a reduced rate. By making the travel of the valve head in the dash-pot greater than the travel of the cylindrical unloading portion of the valve stem in its bore, unloading at the full rate occurs during the first part of the movement of the valve head into its dash-pot. After the cylindrical portion of the valve stem enters the main bore, unloading continues at a reduced rate.

In the further embodiment of the invention shown in Figure 2, instead of using the clearance around the delivery valve head as the dash-pot discharge area, holes are drilled transversely at *i* and longitudinally at *j* through the valve placing the dash-pot chamber *f* in communication with the delivery pipe *g*. The area of these passages is such that the required damping action is obtained. For initial tests a pointed screw *k* may be used as shown in Figure 3 to make an adjustable orifice whereby the best discharge area can be arrived at.

Figure 4 shows an alternative arrangement (alternative to Figure 2) in which the longitudinal hole *l* is provided communicating with the pump chamber *m*, so that, as in Figure 2, the required damping action is obtained by arrangement of the area of the holes *i* and *l*. If desired, the discharge of fluid may be allowed from the dash-pot chamber both into the pump chamber *m* via the drilled hole *l*, and into the delivery pipe *g* via a clearance around the valve head which is less than that provided in Figure 1, so that the total area available for the discharge of fluid gives the required damping action.

As an alternative method of placing the dash-pot in restricted communication with the pump chamber, suitable flats *n* may be machined on the sides of the cylindrical unloading portion of the valve as shown in Figures 5 and cross section 5*a*. This arrangement may be used either with a valve head lapped into the dash-pot bore or with some clearance round the valve head so that, as in the previous case, some discharge occurs into the pipe and some into the pump.

If the valve head in these simple arrangements is made a close fit in the dash-pot, a higher initial rate of discharge of fuel into the pipe than normal is obtained since the movement of the valve head *d* compresses the fuel in the pipe *g* and due to the close fit of the head *d* in its bore *b*, the fuel cannot escape to the underside of the head *d* as in the normal arrangement. For the same reason a reduction of pressure occurs in the dash-pot chamber, as its volume is increasing and fuel cannot enter from the delivery pipe *g* because of the close fit of the head *d* in its bore *b*, or from the pump because of the close fit of the unloading portion *e* in its bore. When the head leaves the dash-pot there is a backward flow of fuel while the partial vacuum in the dash-pot lasts and then renewed forward movement of the fuel occurs as the pump plunger continues to rise. With a suitable nozzle release pressure, this action results in a pilot injection even when a pump cam of normal form (i. e. not two-stage) is used.

Some leakage between the valve head and the dash-pot may be permitted, i. e. a definite clearance may be provided, without losing the pilot injection effect. The back-flow of fuel when the head of the valve clears the dash-pot will then be less violent and any tendency to produce noise will be correspondingly reduced. A somewhat similar effect may be obtained by permitting some flow past the cylindrical portion of the valve which normally effects unloading as shown in Figures 5 and 5*a*.

Furthermore, a part of the cylindrical portion of the valve head nearer to the pump chamber may be of frusto-conical form as shown at *o* in Figure 6 while the portion further from the pump chamber is either a close fit in the dash-pot bore or has a small clearance as shown at *p*. After an initial movement of the valve head producing a pilot injection, the dash-pot chamber *f* will be placed into communication with the pipe less suddenly, and the back-flow of fuel will proceed more smoothly.

A somewhat similar effect may be obtained by leaving the valve head a close fit in the dash-pot, and by making the part *q* of the unloading portion of the valve nearer the pump chamber of frusto-conical form, the other part being either a close fit in the normal bore of the delivery valve body or having a small clearance. If this part remote from the pump chamber is made a close fit in its bore, initial movement of the delivery valve proceeds as in the simple case, but when the frusto-conical portion emerges from the bore, fluid from the pump chamber passes to the dash-pot chamber, and the velocity of the valve is reduced below the value in the simple case. Hence the dash-pot is opened less abruptly and requires less back-flow to fill it. If, in addition, some flow past the other part of the unloading portion is permitted, then the initial velocity of the valve is also reduced, and less dash-pot volume remains to be filled when the valve head clears the dash-pot.

These modifications to the delivery valve head and the unloading portions may be used in combination if desired as shown in Figure 6.

As alternatives to the use of frusto-conical portions or other suitable shaped portions on the valve head and/or unloading portion of the valve, the outer part *r* of the dash-pot bore or the main bore *s* in the valve body or both may be of frusto-conical form, bell-mouthed as shown in Figure 7, or otherwise shaped to produce similar effects.

With the simple arrangement of the dash-pot with clearance, capacity and length arranged to eliminate the pressure fluctuations tending to produce secondary injections, modifications are produced not only of the end of the injection process but also of the beginning of the process. As previously explained in connection with the commencement of the discharge process the initial rate of discharge of fuel into the pipe is greater than normal,

the flow is then reversed, and after this, discharge continues in the normal manner. When the valve is arranged for the sole purpose of suppressing a secondary injection, the area of the dash-pot discharge orifice can be made so that the initial rate of discharge into the pipe is insufficient to produce a pilot injection.

In applications where it is desirable that the commencement of the pump discharge process shall be unaffected by the dash-pot, a non-return valve may be arranged conveniently in the head of the delivery valve as shown in Figure 8, so that on the upward movement of the delivery valve, fluid can flow freely from the pipe *g* to the dash-pot chamber *f* via the non-return valve *t*. When the delivery valve closes, the non-return valve *t* is held closed by fluid pressure and discharge from the dash-pot chamber occurs only through the orifice or annulus provided for the purpose. A spring may be provided to urge the non-return valve towards its closed position.

When the dash-pot valve is used to produce pilot injection it may be desirable to make the valve head a very close fit, e. g. a lapped fit in the bore of the dash-pot. If this is done without other provision, no effective damping action at valve closure is obtained, but a compromise may be made by allowing a slight clearance round the part of the valve head remote from the pump chamber (in order that the valve may reach its seat within the time available) and in addition by providing a somewhat greater clearance (suitable for effecting the required damping) on that portion of the head nearer to the pump chamber. However the best overall effect is obtained when the conditions at the commencement of the injection process and the conditions at the end are controlled independently. For this purpose a non-return valve *t* may be arranged conveniently in the close fitting head of the delivery valve as shown in Figure 9, which is closed when the valve moves outwards but opens during the return movement so that fluid from the dash-pot flows to the pipe, via a passage *u* of suitable cross-sectional area to give the required damping, either to the pipe, or to the pump chamber.

As an alternative to the use of a non-return valve to allow free passage of fluid to the dash-pot during the outward movement of the delivery valve, the dash-pot may be placed in communication with the pump chamber as shown in Figure 10 by a passage *v* the end of which is open during the first part of pump plunger movement while the delivery valve head leaves the dash-pot and is closed by the pump plunger *w* while the pump spills and the delivery valve returns to its seat.

As an alternative to the use of a non-return valve to permit the desired discharge of fuel from the dash-pot as the delivery valve returns to its seat, a passage *v'* may be provided between the dash-pot and the pump chamber as shown in Figure 11, the end of this passage being closed by the pump plunger before commencement of the effective stroke and uncovered by the spilling edge of the plunger as the pump spills. The passage is provided with a separate insert *v''* causing the necessary restriction to give the required rate of discharge of fluid from the dash-pot.

In another arrangement in accordance with the invention an additional cylindrical portion is provided above the unloading portion and below the valve seat, this additional portion (and the part of the valve body in which it works) being of larger diameter than the unloading portion, so that a dash-pot chamber is formed between the two. Since the diameter of the unloading portions is normally equal to the inner diameter of the valve seat, this arrangement necessitates the use of either a larger diameter of the valve seat or a smaller diameter unloading portion and guide, or a small change in both dimensions. A dash-pot discharge passage of suitable area is provided by one or more of the means previously described to pass the fluid from the dash-pot to either the pipe or the pump chamber. Again the dash-pot may be formed round the end of the valve nearest the pump chamber, passages being provided round the outside of the dash-pot for the passage of fluid from the pump. Such arrangements may incorporate the various features described in connection with a dash-pot situated around the valve head.

In another arrangement in accordance with the invention, the valve seating face is formed on the end *a'* of the valve nearest the pump chamber as shown in Figure 12, and the seat *b'* is formed at the end of a bore of reduced diameter communicating directly with the guide bore *c'* in the valve body. In addition to carrying the valve spring *d'*, the valve head *e'* serves only to close one side of the dash-pot formed between the head, the surrounding wall and an unloading cylindrical portion *f'* below the valve head. Suitable discharge area from the dash-pot is provided by way of the annulus *g'* or as previously described.

In a still further embodiment in accordance with the invention the energy can be dissipated and redistributed and the valve be caused to return to its seating at reduced velocity by including a ball valve-like restriction in the delivery passage between the delivery valve and the injector as shown in Figures 13 to 18. The ball *l'* is held by the spring *m'* against the four projections *n'* shown in Figure 18 which arrangement allows a restricted passage for the return of fluid by way of the clearance between the ball and the wall of the bore containing the same as shown in Figure 17, thus preventing the valve from returning so rapidly to the seating as would be the case if this restriction was not present. When the pump discharges, the ball is carried upwards by the flow of the fluid into the space above where free flow is allowed by the axial grooves *o'* shown in Figure 16.

The upper abutment for the spring *m'* is provided by the flanges on the member *p'* the lower end of which prevents the ball from travelling too far up the passage. Axial and radial grooves *r'* and *r''* shown in Figures 14 and 15 allow of the passage of the fuel to the bore *s'* in the delivery pipe *s''*. When the pump spills and the fluid flow is reversed the ball enters the reduced bore and returns to its seating *n'*. Depending upon the length of the reduced bore, this movement of the ball to its seat effects first part of the unloading of the pipe without restriction of the flow which may be an important and valuable feature of the system. Thereafter the restriction of the fluid flow prevents the delivery valve from returning with too great a velocity to its seating.

The invention is not restricted to the use of a ball valve as in the last described embodiment, as other forms of valve-like means may be provided for the same purpose. These valve means may be incorporated at any point in the system on the injector side of the pump chamber, but the most effective position will be adjacent to the pump chamber so that the greater part of the return flow of fluid has to pass the valve-like means.

Details for carrying the invention into effect may be varied without departing from the scope of the invention.

We claim:

1. A liquid fuel injection system for an internal combustion engine comprising a pump of the plunger type for supplying fuel to an injection nozzle, means forming a fuel passage between the pump and the injection nozzle having a relatively larger passage portion connected to a smaller passage portion nearer the pump plunger, a delivery valve in said passage comprising an unloading portion formed and arranged with a close sliding fit in said smaller passage portion for part of its travel and operable beyond said smaller passage portion for another part of its travel and a head portion spaced from and connected to said unloading portion, said head portion being formed and arranged to have a small clearance fit in said relatively larger passage portion during every delivery stroke of the pump for part of its travel and operable beyond said larger passage portion in the fuel

passage whereby a throughway for fuel from the pump to the nozzle is opened, said spacing of said head portion from the plunger side of said unloading portion of said valve being at least equal to the length of said larger passage portion whereby during the closing of the valve following the spilling of the pump said unloading valve portion substantially seals said smaller passage portion toward the pump and forms a dashpot with said head portion in said fuel passage during the closing of said valve after said head portion enters said larger passage portion in which fuel is trapped and from which it is discharged by way of a restricted passage.

2. System as claimed in claim 1 in which the restricted passage means comprises bore means formed in the valve and communicating between the space between said head and unloading portions and the passage at one end of the valve.

3. System as claimed in claim 2 in which the bore means communicates between the space between said head and unloading portions and the pump side of the valve.

4. System as claimed in claim 2 in which the bore means communicates between the space between said head and unloading portions and the delivery side of the valve.

5. System as claimed in claim 4 in which there is provided a non-return valve in the bore means to prevent the flow of liquid therethrough as the valve opens.

6. System as claimed in claim 1 in which the inner periphery of the part of the passage in which the head portion of the valve travels is frusto-conical whereby upon opening of the valve the dashpot is placed gradually in communication with the delivery side of the valve.

7. A system as claimed in claim 1 in which the unloading portion is coaxial with the valve head and on the pump side thereof, that part of the passage in which the unloading portion works opening directly in said larger passage portion.

8. A system as claimed in claim 1 in which the length of travel of said valve head portion within said larger passage portion is less than the length of travel of said unloading portion in said smaller passage portion.

9. A system as claimed in claim 1 in which the restricted passage is constituted by the radial clearance between the outer periphery of said head portion of said valve and the inner periphery of said larger passage portion.

10. A system as claimed in claim 9 in which a frusto-conical portion is provided adjacent the peripheral edge of said head portion of the valve whereby upon opening of the valve the dashpot is placed gradually in communication with the delivery side of the valve.

11. System as claimed in claim 9 in which there is provided bore means in the valve between the space between said head and unloading portions and the delivery side of the valve and a non-return valve in said bore means to prevent the flow of liquid therethrough as the valve closes while allowing unrestricted flow from the delivery side of the valve to the dashpot as the valve opens.

12. A liquid fuel injection system for an internal combustion engine comprising a pump of the plunger type for supplying fuel to an injection nozzle, a delivery valve between the pump and nozzle comprising a bore one end of which is connected with the pump and the other with the nozzle, a valve seat in the bore, a valve member cooperating with said seat to close the bore and having axially spaced land portions movable in substantially fluid-sealing fashion in respective sections of the bore, the dimensions of said land portions and the axial spacing thereof being such that during the initial part of the opening stroke of the valve the pressure in the connection with the nozzle is temporarily raised above the nozzle opening pressure and a zone of reduced pressure is established in the bore between said land portions until said valve member land adjacent to the nozzle passes from fluid-sealing relation with its respective section of the bore.

13. A liquid fuel injection system for an internal combustion engine comprising a pump of the plunger type for supplying fuel to an injection nozzle, means forming a fuel passage between the pump and the injection nozzle, a fuel passage member in the fuel passage having a relatively larger passage portion connected to a smaller passage portion nearer the pump, a delivery valve in said passage member comprising an unloading portion formed and arranged with a close sliding fit in said smaller passage portion for part of its travel and operable beyond said smaller passage portion for another part of its travel and a head portion spaced from and connected to said unloading portion, said head portion being formed and arranged to have a small clearance fit in said relatively larger passage portion during every delivery stroke of the pump for part of its travel and operable beyond said larger passage portion in the fuel passage whereby a throughway for fuel from the pump to the nozzle is opened, said spacing of said head portion from the plunger side of said unloading portion of said valve being substantially greater than the length of said larger passage portion whereby during the closing of the valve following the spilling of the pump said unloading valve portion first substantially seals said smaller passage portion toward the pump and subsequently said head portion enters said larger passage portion, and means forming a dashpot in which fuel is trapped and from which it is discharged by way of a restricted passage including said unloading and head portions of said valve and said fuel passage member during the closing of said valve after said head portion enters said larger portion of said fuel passage member.

14. Liquid fuel injection system having an internal combustion engine comprising a pump of the plunger type, a fuel passage from the pump adapted to be connected to a nozzle, a delivery valve in said passage comprising an unloading portion which is a close sliding fit for part of its travel in part of the said passage and a head portion which, on every delivery stroke of the pump, moves for part of its travel through a chamber formed as part of said passage and from which is emerges to open a throughway for fuel from the pump and which, following the spilling of the pump and during the closing of the valve, together with the chamber constitutes for the latter part of its travel a dash-pot in which fuel is trapped and from which it is discharged by way of a restricted passage means, the unloading portion having a frusto-conical portion at the pump end thereof, whereby, upon opening of the valve the dash-pot chamber is placed gradually in communication with the pump chamber.

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