PUBLISHED	O. POSCH	Serial No.
MAY 11, 1943.	LIQUID PUMPS	288,942
BY A. P. C.	Filed Aug. 8, 1939	4 Sheets-Sheet 1

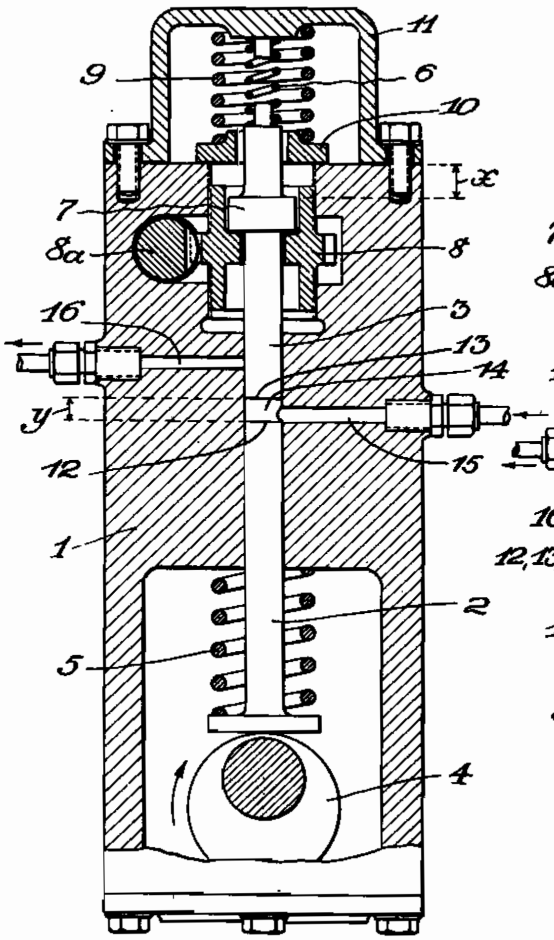

Fig. 1.

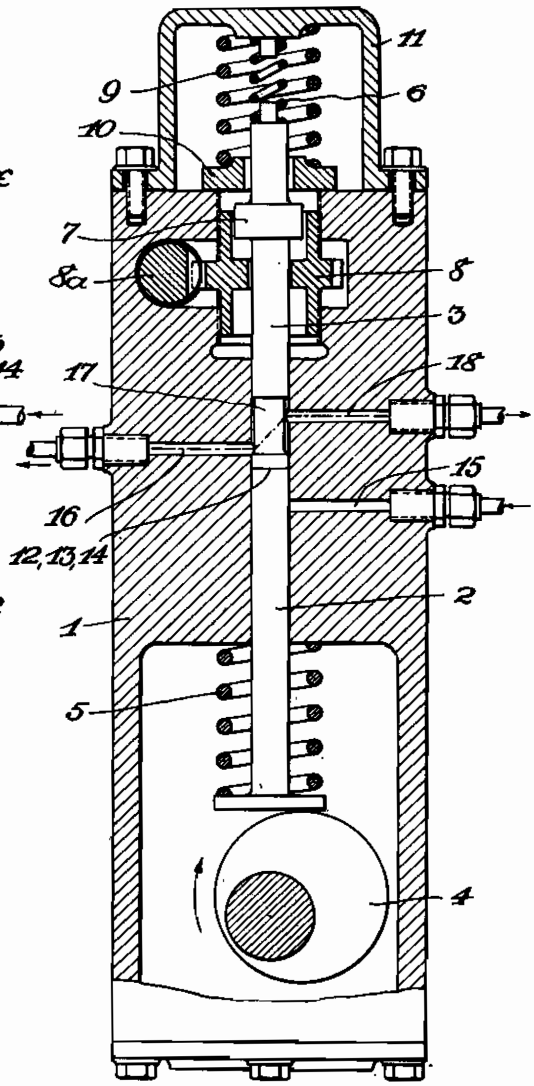

Fig. 2.

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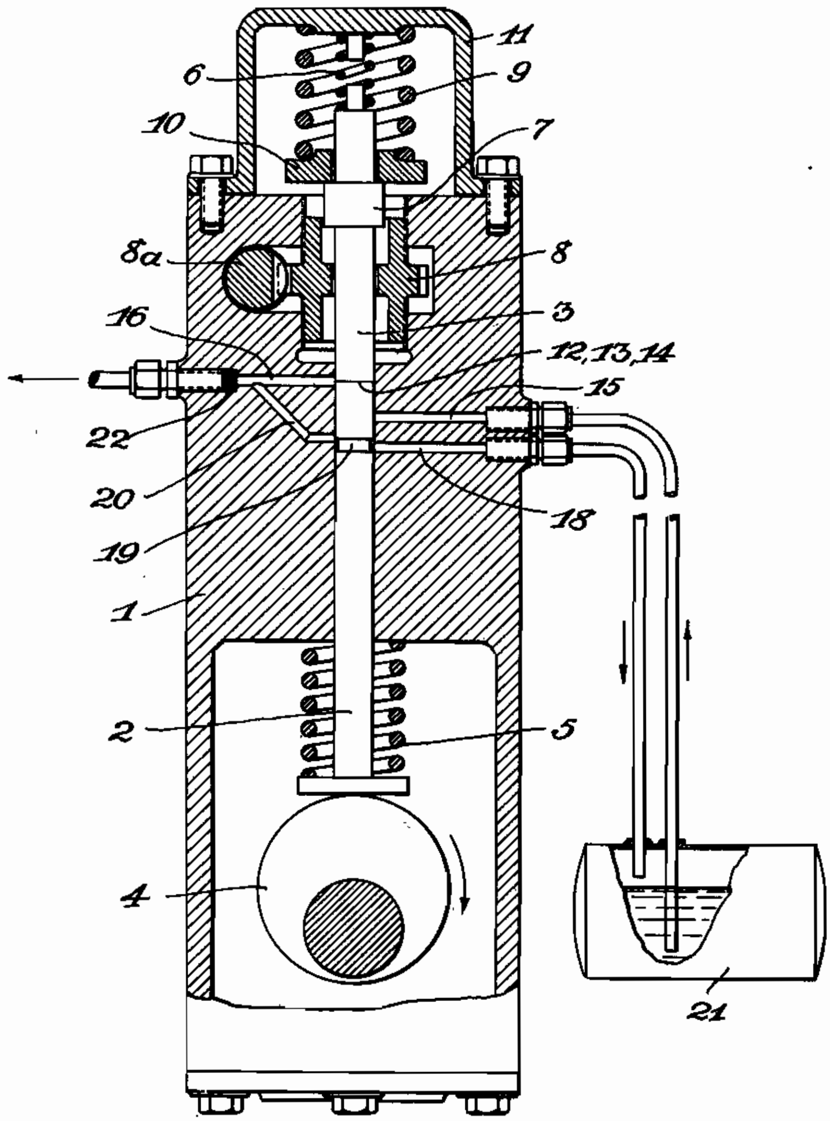

Fig. 3.

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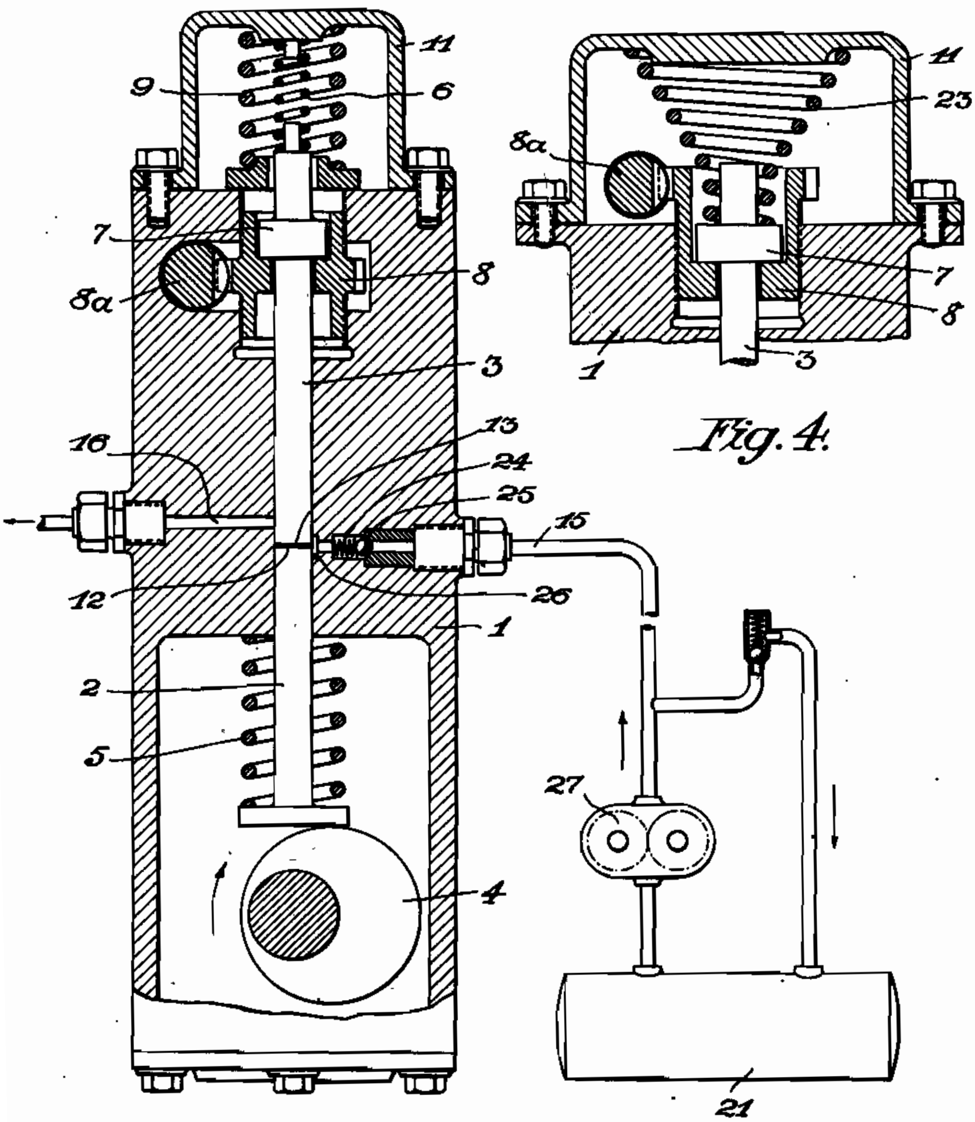

Fig. 4.

Fig. 5.

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Serial No.
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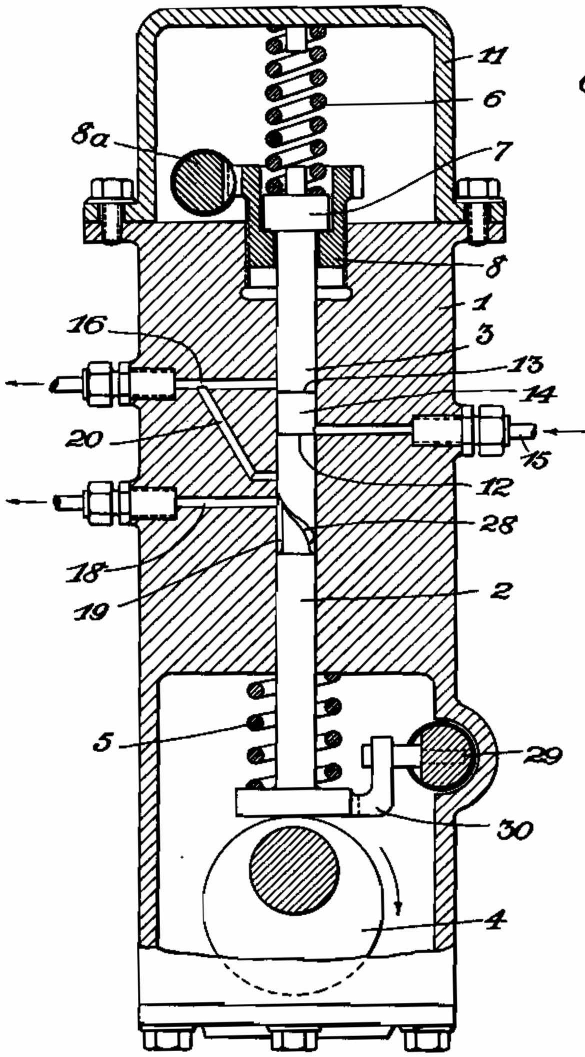

Fig. 6.

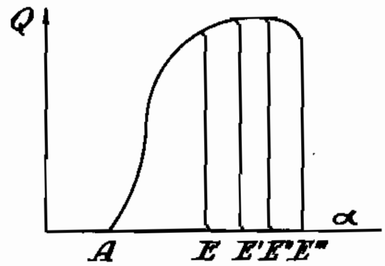

Fig. 7.

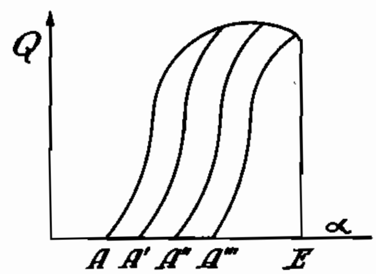

Fig. 8.

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Published May 11, 1943 **Serial No. 288,942**

ALIEN PROPERTY CUSTODIAN

LIQUID PUMPS

Oskar Posch, Stuttgart-Bad-Cannstatt, Germany; vested in the Alien Property Custodian

Application filed August 8, 1939

These improvements in liquid pumps, particularly concern fuel-injection pumps for internal combustion engines.

One object is to attain greater reliability of operation and more accurate dosage of the liquid to be delivered, particularly when fuel has to be injected in very small quantities. In this connection it is important to prevent the occurrence or collection in the pump of vapour or air bubbles which would otherwise form an elastic cushion. Such cushions when compressed and re-expanded in the cycle of piston movement, are liable to impair or even completely interrupt the pump delivery.

The invention provides a pump, wherein the delivery of fuel is performed by two co-axial pump pistons displaceable relatively to each other, one of the two pistons preferably being mechanically driven whilst the other piston is loaded by spring pressure which tends to bring the opposed ends of the two pistons into non-positive contact. Suction is effected by the movement apart of the pistons, one of the two pistons being preferably held by an abutment, and delivery is effected by the movement towards each other of the two pump pistons, and particularly under the pressure of the spring loading after the opening of the outlet passage. The opposed end surfaces of the two pump pistons enclosing the pump chamber between them are so constructed and machined that when they encounter each other at the end of the pressure stroke they bear on each other completely closely so that no harmful space remains between them.

A further object of the invention is to provide a graduated and progressive spring loading whereby the two pistons ends aforesaid are brought into non-positive contact, particularly so that the full maximum loading determining the delivery pressure commences only shortly before the opening of the pressure outlet passage whilst otherwise only a comparatively slight spring loading exists. This results in increased reliability and accuracy of operation by reason of the sparing of the pump parts and reduction of the leakage losses. Also adjustments to be performed under some circumstances upon the pump parts are facilitated.

Another object is the provision of a special relief passage giving an abrupt termination of the delivery so that dripping of the fuel at the injection nozzle, is avoided particularly when long delivery ducts are present. The relief passage is preferably controlled by one of the two pistons, for example by means of a controlling groove which is separate from the pump chamber and establishes communication between the pump outlet to the relief passage. The relief may occur before or after the termination of the pressure stroke of the positively driven pump piston. In the former case, the controlling groove is preferably arranged in the positively driven piston and in the latter case preferably in the non-positively moved piston.

In order to achieve at high speeds, a reduction of the quantity injected per stroke, as is desirable for the sake of torque constancy, provision is made for throttling the fuel flowing from the pump to the injection nozzle occurs at higher speeds. The throttling means may be adjustable, and may take the form of a changeable or adjustable throttling plate.

Yet another object is the provision of appropriate means for regulating the quantity delivered or the timing of the delivery and in particular, the termination of delivery, that is the termination of the injection period in the case of injection pumps. However the commencement of delivery and the termination of delivery may also be controllable simultaneously. The regulation of the termination of delivery is preferably performed by means of an inclined edge of a controlling groove provided in one of the two pump pistons for controlling the relief passage, the piston being rotatably adjustable for varying the control exercised by the inclined edge.

Further features and objects of the invention will appear from the following description with reference to the annexed drawings wherein:

Figure 1 is a vertical section of one form of pump in accordance with the invention,

Figures 2 and 3 illustrate modifications of Figure 1,

Figure 4 is a fragmentary view illustrating a modification of Figure 3,

Figures 5 and 6 are vertical sections of still further modifications, and

Figures 7 and 8 are diagrams illustrating pump deliveries under different controls.

In Figure 1, two pump rams or pistons 2 and 3 acting against each other are arranged co-axially in a cylinder body 1. The pump piston 2, which is shown in its lower dead-centre position, is driven by a cam 4, designed in accordance with the desired injection law, and a return spring 5. The pump piston 3 is loaded, in the position illustrated, by a comparatively weak spring 6 which presses it by means of its collar 7 against an axially adjustable abutment 8. For example, the abutment may be adjustable by screwing it up or down in the recess in which it is inserted. A stronger spring 9 only comes in to action upon the pump piston 3 when the latter has risen by the amount x, at which moment the abutment collar 10 is lifted from the cylinder housing 1 by the collar 7 of the piston. The springs 6 and 9 abut at their upper ends against an upper part 11 which is rigidly connected to the cylinder housing 1. In the drawing, the annular abutment 8 is set so that the pump chamber 14 formed between the end surface 12 of the lower piston 2 and the end surface 13 of the upper piston 3 has an axial length y in the lower dead-centre position of the driven piston 3. The suction or inlet port 15 is then uncovered and the pressure or outlet port 16 is closed. There may be several of each of these ports. For the axial adjustment of the annular abutment 8, a displaceable rack 9a may engage teeth on the annular abutment.

The manner of operation is as follows:—

If the pump piston 2 is moved upwardly by the cam 4, then after passing over the suction passage or passages 15, it forces the quantity of fuel located in the pump chamber 14 against the end surface 13 of the pump piston 3. Up to this moment, only the opposing pressure of the spring 6 acts against the upward movement of the pump piston 3. Shortly before the pump piston 3, during its upward movement, opens the pressure passage or passages 16, the collar 7 on the pump piston 3, after a movement x thereof, comes into contact with the abutment 10 subject to the loading of the spring 9. Upon the further upward movement of the pump piston 2, the pressure of liquid in chamber 14 must rise to such an extent as to overcome the opposing pressure of the two springs 6 and 9. Thereafter, the pump piston 3 also rises further and finally opens the outlet 16, the liquid fuel then passing into the outlet 16 under the maximum pressure just reached. Such maximum pressure is determined by the force of the two springs 6 and 9 and can be varied within very wide limits by changing the springs or varying their force. Preferably, the upper dead-centre position of the pump piston 2 is so determined that its end surface 12 in this dead-centre position reaches precisely to the level of the outlet 16.

The delivery terminates when the pump piston 3 has forced into the outlet 16 the last residue of the quantity of fuel located between the end surfaces 12 and 13. In order to ensure that even the last trace of a quantity of fuel still present is actually delivered and that the pump is actually free from any harmful space, the end surfaces 12 and 13 are ground one on the other. Upon their contact at the end of the pressure stroke, therefore, vapour or air bubbles, irrespective of what proportion they may have, are forced through the outlet 16 so that the subsequent pumping action is not interfered with by the presence of such vapour or air bubbles. Consequently the use of an additional feed pump, for example, is unnecessary, as also is the provision of a de-aerating screw without which the removal of vapour or air bubbles is not possible in pump systems already known.

Upon the downward movement of the pump piston 2 after the delivery, the pump piston 3 follows the same in its downward movement under the influence of the springs 6 and 9 until finally the abutment 10 bears upon the cylinder housing 1 and, after a further movement x, the collar 7 provided on the pump piston 3 bears upon the annular abutment 8 which is adjustable as to its level but is normally fixed. During the further downward movement of the pump piston 2, the pump piston 3 can no longer follow the said movement, the end surfaces 13 and 12 separate from each other again and first of all an absolute vacuum is formed between them which is not disturbed by the presence of vapours, as every trace of fuel residues has been previously removed. When, in the course of the further downward movement, the suction passage 15 is opened by the pump piston 2, then fresh fuel flows into the pump chamber 14 under the influence of the full atmospheric pressure. As already explained, the dimension (y) of the pump chamber 14 and the quantity of fuel sucked in, are determined by the abutment 8. Thus the quantity of fuel delivered can be regulated in simple and reliable fashion by variation of the level of the abutment 8. Owing to the fact that the member controlling the pressure passage 16, namely the pump piston 3, acts after the fashion of a slide valve, it is not possible for it to partake, of harmful resonance oscillations in the pressure passage such as poppet valves, for example, are liable to suffer. This is of decisive importance particularly at very high revolution speeds (5,000 to 10,000 injections per minute). Furthermore the subject of the present invention, by reason of this arrangement, is particularly suitable for the operation of open injection nozzles.

The stepwise increase of the spring loading of the pump piston 3 by the additional cutting in of the further spring 9 shortly before the opening of the pressure passage 16 has the following advantages: Firstly the full spring pressure which is necessary for the attainment of the maximum delivery pressure never bears upon the abutment 8 and creates no difficulty in the adjustment of such abutment. Furthermore, the leakage loss between the pump pistons and the cylinder is reduced to a minimum by the stepwise increase of the pressure, because a low liquid pressure corresponding to the weak spring 6 obtains in the fuel in the pump chamber 14 over the largest part of the pump stroke. Only at the last instant does the liquid pressure rise to its maximum value so that the harmful effect of the leakage loss cannot develop to the extent known in other pump systems in the short period only which thereafter remains.

In Figures 2–6, similar or corresponding parts are indicated by the same reference numerals as in Figure 1.

In Figure 2, the pump is illustrated in the first part of the downward stroke of the two pistons and is essentially the same as that in Fig. 1. It differs in respect of the upper pump piston 3 which is provided with a constriction passage or relief groove 17 which, after the piston 3 has executed a short portion of the downward stroke, establishes communication between the outlet 16 and a relief passage 18. The latter preferably leads back to the fuel tank, so that the fuel present in excess in the delivery (such excess being due to the elasticity of the injection ducts and the compressibility of the fuel) can pass back into the tank for example by the shortest path. This arrangement gives instant relief in the outlet 16.

In Fig. 3, wherein the pump pistons are shown in the upper dead-centre, another mode of relief is illustrated. There is provided on the lower piston 2, at a point which does not come into contact with the suction passage 15 in the upward stroke, (that is a point distant from the end surface 12 of the lower piston 2 by more than the depth of stroke,) a constriction 19 which opens the relief-connection passage 20 shortly before the upper dead-centre position of the lower piston 2. The constriction 19 then connects the pressure passage 16 to the relief passage 18 leading back to the fuel tank 21, whereby there is instantaneous relief of pressure in the outlet 16. This mode of relief, in comparison with that illustrated in Fig. 2, has the advantage that the relief and, consequently, the termination of injection take place shortly before the upper dead-centre position of the lower piston 2. Thus that part of the injection is cut out which, owing to the already de-celerated piston movement, would otherwise result in a lingering injection which might cause dripping at the injection nozzle.

Furthermore, as illustrated in Fig. 3, a throttling plate 22, preferably changeable, is provided in the pressure passage 16 beyond the branching point of the passage 20. Its manner of operation is as follows:

During delivery, the fuel is forced to pass through the narrow bore in the small nozzle plate 22, since the relief-connection passage 20 is still closed by the pump piston 2. At low revolution speeds, there is sufficient time available for the whole of the fuel charge to penetrate through the narrow bore in the nozzle plate 22. Shortly before the upper dead-centre position of the pump piston 2, the throat-like constriction 19 opens the relief-connection passage 20, whereby an instantaneous relief of pressure in the outlet 10 takes place. At high revolution speeds, on the other hand, the time does not suffice for the flow through the nozzle plate 22 and residual fuel remains between the end surfaces 12 and 13 of the two pistons. By the subsequent relief action, however, the fuel situated between the end surfaces 12 and 13 is completely discharged under the pressure of the springs 6 and 9 through the relief-connection passage 20, the constriction 19 and the relief passage 18 until the end surfaces 12, 13 bear on each other closely and without any intervening space.

The throttling plate 22 may also be advantageously employed in a form of construction in accordance with Fig. 2 wherein the relief passage is controlled by the upper spring-loaded piston 3 and the delivery continues beyond the upper dead centre of the driven lower piston 2.

Fig. 4, illustrates a loading spring 23 which may be substituted for the springs 8 and 9 in any one of the preceding examples. The spring 23 has a spring characteristic which is obtained by reason of the fact that it has different coil diameters. By this means, fluttering phenomena, such as occur with cylindrical springs for example, are suppressed since the parts of the volute spring 23 vibrating with different natural frequencies interfere with each other in the development of oscillations. The employment of progressive springs, such as 23, enables the abutment 10 illustrated in Figs. 1 to 3 to be dispensed with. This is desirable because it gives rise to the production of noise owing to its hammering mode of operation.

In Fig. 5, there is an inlet valve 25 loaded by a spring 24 in the suction passage 15. The inflowing fuel is placed under pressure by a pump 27 in front of the inlet and constructed in any desired manner, so that the fuel is supplied into the pump chamber under pressure. The inlet valve is thus constructed as a non-return valve to permit flow into the pump chamber but not in the reverse direction. In order to give light fuels no opportunity to vaporize, the mouth 26 of the suction passage is made sufficiently wide and is so arranged that the end surfaces 12 and 13 of the pump pistons 2 and 3 separate opposite this mouth at the commencement of the suction stroke, that is when the collar 7 rests upon the abutment 8. By this means, any formation of vacuum is avoided and the fuel flowing in under pressure passes into the pump chamber, unseating the valve 25 (for example a ball or disc valve) against the loading of the spring 24. During the subsequent upward movement of the pump piston 2, the inlet valve 25 closes and prevents a return flow of the fuel into the suction passage, whereby any pulsatory liquid movement which might give rise to local bubble formation is avoided.

The employment of a feed pump 27 is primarily useful for very light fuels. Owing to the fact that the suction or inlet passage is subjected to pressure, the boiling or vaporising point of the liquid therein also rises. It is then possible to set the pump for a maximum delivery pressure which is made so high that the temperatures occurring in operation lie below the boiling temperature of the fuel subjected to the pressure in question so that formation of vapour in the suction passage is prevented. The operation of the pump is thereby further improved. Preferably, when a feed pump is employed, the inlet valve 25 is also provided in order to prevent a pulsatory liquid movement in the passage 15. However, in some cases, the inlet valve may also be dispensed with for reason of simplicity.

In Fig. 6, the controlling groove 19 is provided with an inclined controlling edge 28. Furthermore, the pump piston 2 can be turned about its axis through a certain angle, for example by a displaceable rod which engages by means of a pin in a fork 30 on the piston. Upon upward movement of the piston 2, the fuel situated in the pump chamber 3 is delivered under pressure, after opening of the outlet 16, until the inclined controlling edge 28, is cut in the pressure piston 2 passes over the relief passage 20. Thereupon an abrupt relief of the pressure in the pump chamber and in the outlet 16 takes place. The manner of operation of an inclined controlling edge such as 28 is known. By turning the pressure piston 2, the time of the commencement of the relief may be influenced at will and consequently the delivery can be interrupted earlier or later. The commencement of delivery may then remain unaltered. By this means, a gradual and stepless variation of the quantities delivered and injected is made possible.

However, if desired, the commencement of injection may be regulated as well as the termination of injection. For this purpose, for example, use is made of the axially adjustable abutment 8 which serves, in the previously described manner, for the limitation of the movement of the piston 3 and by adjustment of which the time at which the outlet 16 is connected to the pump chamber 14 is determined.

Since the quantity of fuel entering at 15 is dependent upon the limitation of the stroke of the controlling piston 3 in its downward movement, it is possible to regulate the quantity of fuel delivered to the injection nozzles of an internal combustion engine both by rotatably adjusting the piston 2 and also by adjusting the level of the abutment 8, the termination of injection being varied in the former case and the commencement of injection in the latter case.

These two regulating possibilities are illustrated in the diagrams according to Figs. 7 and 8 in which the quantity Q delivered is plotted against the crank angle or the time α. In Figure 7, A, indicates the commencement of injection and E, E^{I}, E^{II}, E^{III} the termination of injection for different adjustments.

In Figure 8, A, A^{I}, A^{II}, A^{III}, indicate different commencements of the injection for several adjustments and E indicates the abrupt termination thereof.

In injection-type internal combustion engines with widely varying revolution speed, it is desirable to be able to vary the injection timing as desired. By the simultaneous use of the two modes of regulation described above, it is possible to shift the injection period as desired, without thereby varying the quantity injected, this is accomplished by adjusting both the commencement of injection and also the termination of injection to an earlier or later time. However, the commencement of injection and the termination of injection may be varied differently, or only the one or the other may be varied at one time, it being possible also to suit the time of injection to the loading for the time being.

For common adjustment of the abutment 8 and piston 2 by means of the regulating rods 8A and 28 thereof, these latter may be coupled together. In some cases, the adjustability of the abutment 8 may be dispensed with. Furthermore, a spring 6 in every case may be replaced by a spring 23, or by two springs 8 and 9, or by other suitable resilient means. Finally, a throttling plate 22 or similar throttling device may be arranged in the pressure passage, for example, of any of the constructions.

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