

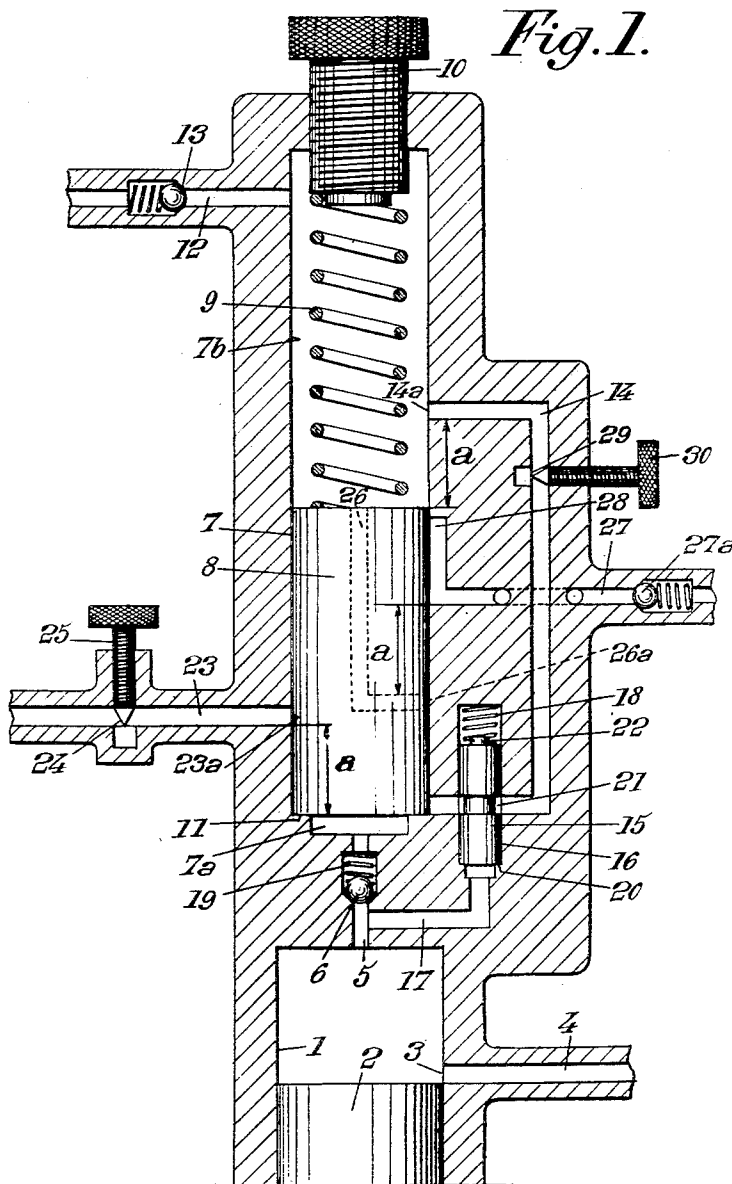
June 14, 1960 P. E. BESSIERE 2,940,398  
RECIPROCATING ACTION LIQUID PUMPS AND IN  
PARTICULAR IN FUEL INJECTION PUMPS  
Filed Dec. 3, 1957 3 Sheets-Sheet 1

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BY  
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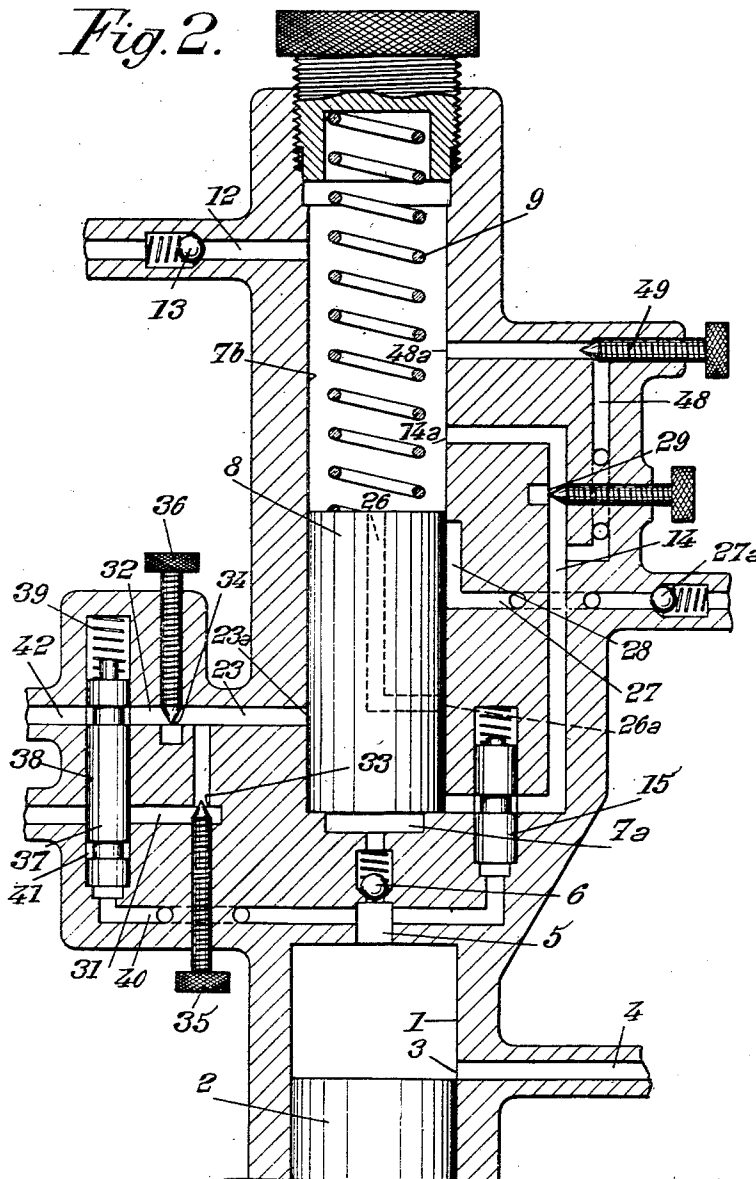
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Fig. 2.



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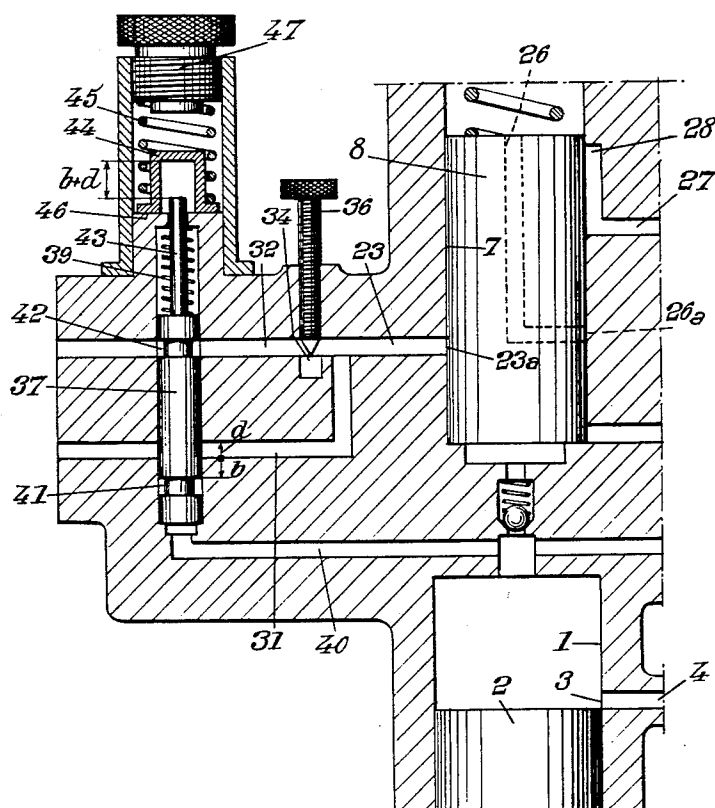
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*Fig. 3.*



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## RECIPROCATING ACTION LIQUID PUMPS AND IN PARTICULAR IN FUEL INJECTION PUMPS

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10 Claims. (Cl. 103—41)

The present invention relates to reciprocating action pumps, that is to say pumps in which the driven part (piston, diaphragm or the like) has a reciprocating movement in a fixed part to produce a chamber of varying volume for suction and delivery of the liquid. My invention is more especially but not exclusively concerned with pumps of this kind for the injection of fuel into internal combustion engines.

The chief object of my invention is to provide a pump of this kind which is better adapted to meet the requirements of practice and in particular which achieves an automatic regulation of its delivery as a function of the speed at which it is driven.

The pumps with which my invention is concerned include a reciprocating member, preferably in the form of an auxiliary piston movable in an auxiliary cylinder rigid with the fixed part of the pump, for instance the cylinder thereof which will be hereinafter called "main cylinder," said auxiliary cylinder being divided by said auxiliary piston into two chambers, to wit a first chamber connected with the main cylinder and a second chamber connected with the delivery conduit of the pump, with an outwardly opening check valve between said second chamber and said delivery conduit, said auxiliary piston being moved in one direction by the liquid delivered into said first chamber by the delivery strokes of the main piston of the pump, against the action of resilient means urging said auxiliary piston in the opposed direction.

According to my invention, said two above mentioned chambers are connected together, at least for some positions of said auxiliary piston, by a by-pass conduit, and a discharge conduit, starting from an intermediate point of the wall of the auxiliary cylinder so as to communicate with said first chamber when the auxiliary piston has moved a given distance in the first mentioned direction, is provided with means for throttling it, whereas the auxiliary piston controls means for placing a second discharge conduit in communication with the second chamber at the same time as the first discharge conduit is placed in communication with the first chamber, the orifice of said by-pass conduit into said second chamber being so located as to be closed when said two discharge conduits are in communication with said chambers respectively.

Preferred embodiments of my invention will be hereinafter described with reference to the accompanying drawings, given merely by way of example, and in which:

Fig. 1 is an axial sectional view of a fuel injection pump made according to a first embodiment of my invention.

Fig. 2 is a similar view of another embodiment of my invention.

Fig. 3 is an axial sectional view showing a modification of the means for throttling the first mentioned discharge conduit.

The pump shown by the drawings includes a main cylinder 1 cooperating with a main piston 2 driven through any suitable means such for instance as a cam (not shown); a fuel feed conduit 4 opens into a cylinder 1 at

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3, this opening 3 being cleared when piston 2 is in its lower dead center position as shown by the drawings.

The main cylinder 1 communicates, through a conduit 5 provided with a check valve 6, with the lower chamber 7a of an auxiliary cylinder 7 containing an auxiliary piston 8 which divides this cylinder 7 into two chambers 7a and 7b. A return spring 9 is interposed between the top end of cylinder 7 and auxiliary piston 8, this spring being preferably adjustable by means of a screw 10. Spring 9 urges piston 8 toward the position of rest thereof in which it is applied against a shoulder 11 provided at the lower end of cylinder 7.

A fuel delivery conduit 12 starts from the chamber 7b of cylinder 7, advantageously at a point of the cylindrical wall of said chamber located near the upper end thereof. Delivery conduit 12 is provided with a check valve 13 and leads to the injector or injectors to be fed with fuel by the pump.

Chamber 7a is connected with chamber 7b through a by-pass conduit 14 which is opened at least for some positions of auxiliary piston 8, said by-pass conduit being controlled by a slide valve 15 which closes it during the delivery (upward) stroke of main piston 2 and which opens it during the suction (downward) stroke of this piston and possibly during the time piston 2 remains stationary in its lower dead center position (as shown by the drawings). Slide valve 15 is movable in a cylinder 16 one of the ends of which communicates through a conduit 17 with the top of main cylinder 1. The other end of cylinder 16 contains a spring 18 weaker than the return spring 19 of check valve 6. This spring 18 urges slide valve 15 toward the position in which it is applied against a shoulder 20, by-pass conduit 14 being then cleared due to the fact that a groove or a recess of said slide valve 15 coincides with said conduit 14. The final position occupied by slide valve 15, when it is pushed by the pressure of the liquid supplied through conduit 17 is determined by an abutment 22 bearing against the top end of cylinder 16.

By-pass conduit 14 may open into chamber 7a either below shoulder 11 or immediately above it. In this last case, auxiliary piston 8 in its position of rest closes the opening of conduit 14 into chamber 7a.

A discharge conduit 23 starts from a point of the wall of cylinder 7 located at a distance  $a$  above shoulder 11. Thus, the liquid in chamber 7a is discharged to the outside when auxiliary piston 8 has moved upwardly in cylinder 7 a distance sufficient to clear the orifice 23a of discharge conduit 23.

According to the main feature of my invention, said discharge conduit 23 is throttled at 24 by means of a throttling member 25 preferably adjustable and constituted for instance by a screw. Furthermore, auxiliary piston 8, as soon as it clears discharge conduit 23, closes the orifice 14a of conduit 14, while making it possible for the liquid present in chamber 7b to be discharged to the outside. For this purpose, the opening 14a of conduit 14 is located at a distance above the top of piston 8 equal to  $a$  when said piston is applied against shoulder 11. And, to permit discharge of the liquid from chamber 7b when orifice 23a is cleared and orifice 14a is closed, I provide in auxiliary piston 8 a conduit 26 one of the ends of which opens into the top end face of said piston 8 and the other end of which opens at 26a into the cylindrical wall of said piston, so as to be able to cooperate with a discharge conduit 27 provided in cylinder 7. Conduit 27 is provided with a check valve 27a. Said discharge conduit opens into cylinder 7 through a longitudinal groove 28, the lower end of which is located at a distance  $a$  above the opening 26a of conduit 26 when auxiliary piston 8 is applied against shoulder 11. Thus, once liquid has begun to be discharged through conduit

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27, the communication is maintained between said conduit 27 and the conduit 26 provided in piston 8.

The operation of such a pump is as follows:

When the main pump piston 2 starts moving upwardly from its lower dead center position in cylinder 1, it first closes the orifice 3 of feed conduit 4 and places the fuel in cylinder 1 under pressure. This causes slide valve 15 to move upwardly and to close by-pass conduit 14. Then the fuel delivered by piston 2 during its upward stroke moves auxiliary piston 8 in cylinder 7 until the orifice 23a of discharge conduit 23 is cleared. If discharge conduit 23 were not throttled at 24, auxiliary piston 8 would stop immediately after clearing discharge conduit 23 and it would remain stationary in this position, the excess of fuel delivered by piston 2 (which is then still moving upwardly) flowing out through conduit 23. Then, at the beginning of the downward movement of piston 2, slide valve 15 being pushed back against shoulder 20 and thus opening by-pass 14, auxiliary piston 8 would immediately close opening 23a and would move down in cylinder 7, driving the fuel present in chamber 7a through by-pass conduit 14 into chamber 7b after which, during the next upward stroke of piston 2 and therefore of auxiliary piston 8, this fuel present in chamber 7b would be delivered by said piston 8 into delivery conduit 12. No automatic regulation of the delivery would be obtained in these conditions.

The operation is much different when discharge conduit 23 is provided with throttling means such as 24. In this case, the upward movement of auxiliary piston 8 is not stopped as soon as said piston has cleared the orifice 23a of conduit 23; as said piston 8 keeps moving upwardly beyond this position, it causes the liquid present in chamber 7b to be discharged through conduit 26 and 27, the orifice 14a of by-pass conduit 14 being then closed. The height to which auxiliary piston 8 will thus move upwardly depends upon the speed at which the piston 2 of the pump is being driven, that is to say upon the speed of the engine supplied with fuel by the injection pump. This is due to the fact that the presence of throttling means at 24 in discharge conduit 23 maintains a pressure in chamber 7a practically until piston 2 has reached the top of its upward movement, whereas the pressure in chamber 7b is the atmospheric pressure due to the cooperation of conduits 26 and 27.

It is known that the presence of throttling means in a conduit creates a pressure drop which is proportional to a power greater than 1 of the speed. The ratio

$$\frac{\text{speed of auxiliary piston 8}}{\text{speed of piston 2}}$$

therefore increases constantly during the upward stroke of piston 2 when the speed of said piston increases and the distance travelled over by piston 8 therefore increases for a given stroke of piston 2 when the speed of this piston increases. Consequently the height of which piston 8 will move above opening 23a will be the greater as the speed of piston 2 is higher.

During its upward movement above the level of orifice 23a, auxiliary piston 7 discharges into the fuel tank through conduits 26 and 27 an amount of fuel proportional to the height reached above said opening 23a. When the auxiliary piston moves down as a result of the downward movement of piston 2, the auxiliary piston first creates a corresponding vacuum in chamber 7b. Furthermore, during its downward movement, auxiliary piston 8 discharges the liquid present in chamber 7a through discharge conduit 23 until the opening 23a of this conduit is closed and the opening 14a of by-pass conduit 14 is opened. If the speed of piston 2 (and consequently that of the engine supplied with fuel by the pump) is lower than a limit speed which will be hereinafter referred to, the auxiliary piston, after it has closed opening 23a and opened opening 14a, drops suddenly onto shoulder 11 while delivering an amount of fuel corre-

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sponding to a displacement  $a$  through by-pass conduit 14 into chamber 7b. This amount of fuel must first fill up the vacuum formed above piston 8 in chamber 7b, the importance of this vacuum depending upon the length of the movements of piston 8 beyond the position thereof in which it cleared the orifice of discharge conduit 23 and it is only the difference between the piston displacement corresponding to distance  $a$  and the volume corresponding to this vacuum that is truly delivered through delivery conduit 12 toward the injector or injectors.

It follows that this amount of fuel is the smaller as the speed of piston 2 is higher (and piston 8 has moved higher in cylinder 7).

The delivery rate of the pump is therefore automatically regulated in accordance with the speed of piston 2.

Furthermore, for speeds of the pump above a value corresponding to the limit speed of the engine (i.e. the speed which must not be exceeded by the engine) the pump ceases to deliver fuel. This is due to the fact that when piston 8 moves down from its highest position to the position where it closes orifice 23a and opens orifice 14a, the speed of said auxiliary piston is braked by the provision of throttling means at 24. If, due to an increase of the speed of piston 2, the time taken by the auxiliary piston to move through said first portion of its downward stroke becomes equal to the time elapsing between the beginning of the suction (downward) stroke of piston 2 and the beginning of its next delivery (upward) stroke, the fresh stream of fuel delivered by piston 2 prevents auxiliary piston 8 from effecting the second portion of its downward stroke. Now, this second portion of the downward stroke of piston 8 is that during which it moves, after closing opening 23a, onto shoulder 11. Therefore the auxiliary piston starts back on its next upward stroke without having been able to deliver fuel through by-pass conduit 14 to chamber 7b. The pump shown by Fig. 1, even if it includes only the elements which have been above described, ensures an automatic regulation of the delivery and also a limit speed beyond which there is no delivery of fuel.

In order further to improve the automatic regulation effect, it is advantageous to vary the length of the second portion of the downward stroke of auxiliary piston 8 as a function of the speed of the pump piston 2. This result may be obtained by making use of the so-called "liquid abutment" phenomenon described in my U.S. patent application Ser. No. 673,343 for "Improvements in reciprocating liquid pumps, and in particular in fuel injection pumps."

For this purpose, I provide means for throttling by-pass conduit 14 at 29, such means being for instance constituted by a screw 30. With this arrangement the downward movement of auxiliary piston 8, after opening 23a has been closed and opening 14a opened, is still braked by the throttling at 29. Consequently the length of the second portion of the downward stroke of auxiliary piston 8 is made shorter and the amount of fuel delivered by the auxiliary piston 8 from chamber 7a to chamber 7b is the more reduced as the speed of piston 2 increases above a given value that is to say above the speed for which auxiliary piston 8 due to the throttling of by-pass conduit 14 at 29 can no longer reach shoulder 11.

The increase of the vacuum in chamber 7b when the speed of the piston pump increases is therefore accompanied by a reduction of the amount of fuel delivered by the auxiliary piston into said chamber 7b. A particularly efficient self regulation is thus obtained.

Fineness of this self regulation is determined by the following factors:

If  $t_1$  is the time taken by the auxiliary piston to move down from its highest position to the position in which it closes opening 23a and opens opening 14a and if  $t_2$  is the time elapsing between the passage of the auxiliary piston in the last mentioned position and the stopping thereof by the "liquid abutment," I obtain for the total

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time  $t$  of the downward movement of the auxiliary piston the relation  $t=t_1+t_2$ .

Furthermore, I designate by  $T$  the time elapsing between the beginning of the downward stroke of piston 2 and the beginning of the next upward stroke of this piston. For the limit speed, the corresponding value of  $T$ , called  $T_p$ , becomes equal to  $t_1$ .

If for the speed of piston 2 for which the "liquid abutment" just starts being formed, time  $t_1$  is for instance equal to  $4t_2$ , the limit speed is reached when  $T$  passes from the value it had just when the "liquid abutment" starts being formed to the value  $T+1/5T$ . Therefore injection will be wholly stopped for a variation of the speed equal to 20%. As a matter of fact, limitation of the speed takes place before injection is wholly stopped because injection of a minimum amount of fuel is necessary to overcome the friction forces created in the engine. Therefore, the fineness of regulation will be smaller than 20%, being for instance equal or even lower than 15% and this regulation will be an all speeds regulation. It is possible to adjust the fineness of regulation at a predetermined value even when the engine is running by varying either the cross section at the throttled portion of the conduit or the force of spring 9. In order to obtain a constant fineness, the simplest way is to act upon screw 10 in order to vary the force of spring 9 instead of moving the throttling screws 25 and 30 the adjustment of which must then be inter-related, which is more difficult to obtain.

In the construction illustrated by Fig. 1, the same throttled passage 24 serves both to create the pressure in chamber 7a which causes auxiliary piston 8 to move above the position in which it clears orifice 23a and to brake the flow of fuel discharged by said piston 8 when it moves down toward the position in which it closes orifice 23a. However, in some cases it is preferable to provide different throttled passages acting respectively during the upward movement of piston 8 and during its downward movement. For this purpose, I might of course provide means operative in accordance with the movements of the auxiliary piston 8 to act upon an element the position of which determines the cross section of the throttled passage.

However, it seems more advantageous to use the arrangement illustrated by Fig. 2 according to which discharge conduit 23 is divided into two branches 31 and 32 each of which is throttled at 33 and 34 respectively, preferably in an adjustable manner, for instance by means of screws 35 and 36 respectively. These two branches 31 and 32 of the discharge conduit are controlled by slide valve 37 movable in a cylinder 38, under the action, in one direction of the pressure existing in the main pump cylinder 1 when its piston 2 is moving upwardly and, in the other direction of a return spring 39. Thus, the lower end of cylinder 38 is connected by a conduit 40 with the top of cylinder 1. Slide valve 37 is provided with two grooves 41 and 42 positioned in such manner that, in one of the positions of the slide valve, which is given thereto when piston 2 is moving upwardly, branch 31 is opened and branch 32 is closed, whereas in the other position of slide valve 37 (as shown by the drawings) branch 32 is opened and branch 31 is closed.

According to a modification which is not shown by the drawings, the two slide valves 37 and 15 might be combined into a single one.

The pump shown by Fig. 2 further includes a conduit 48 one of the ends of which is connected with by-pass conduit 14 at a point thereof located between slide valve 15 and the throttled passage 29, the other end of said conduit 48 opening into cylinder 7 at a point 48a located above orifice 14a. This conduit 48 may be either opened or closed by means of a needle valve 49 which may also serve to throttle it more or less. During normal operation of the pump, conduit 48 is closed by needle valve 49. On the contrary, when conduit 48 is opened, it permits

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of obtaining, in particular during the engine starting period, an increased fuel delivery the volume of which may be at most equal to that of a cylinder having the same diameter as cylinder 7 and of a height equal to the distance between the level of orifice 14a and that of orifice 48a.

Of course, instead of using such a conduit 48, I may apply to the pump according to my invention other equivalent arrangements such as that described in my above mentioned prior patent application.

According to another embodiment of the invention, to improve the self regulation effect, some throttled portions of the conduit instead of being fixed although adjustable (see Figs. 1 and 2) undergo a modification of their cross section in order to produce a variation of the pressure drop. For this purpose, and concerning the discharge branch conduits 31 and 32, it seems particularly advantageous to make use of a delayed movement of slide valve 37 in order to produce a gradual closing of the conduits controlled by said slide valve.

In the modification illustrated by Fig. 3, this gradual closing achieved by said valve 37 is applied only to branch conduit 31 so that this branch conduit does not require the provision of throttling means such as shown at 33 on Fig. 2. But branch conduit 32 keeps the fixed but adjustable means 36 for throttling it at 34.

In order to obtain a gradual closing of branch conduit 31 by the mutual action of the cooperating surfaces of this branch conduit and of the groove 31 of said valve 37, I provide this slide valve with a rod 43 adapted to come into contact with a cap 44 applied by a spring 45 against a shoulder 46 after slide valve 37 has moved under the action of the fuel compressed in pump cylinder 1 a distance " $b+d$ " ( $d$  being equal to the height of branch conduit 31) just sufficient to bring the upper wall of groove 41 to the level of the upper wall of conduit 31 so that said conduit is then wholly opened. When slide valve 37 is moved upwardly beyond this position, the passage is more and more throttled as a function, on the one hand of the pressure existing in cylinder 1 and conduit 40 and, on the other hand of the compression of spring 45.

If the cooperating portions of groove 41 and conduit 31 are suitably chosen, it is possible to obtain any desired values for the variations of the pressure drop due to the throttling of the passage. Thus, the pressure drop may increase as a power of the speed greater than the second power. It is for instance easy to reach the fourth power. Instead of braking the upward movement of slide valve 37 by means of a spring such as 45 the force of which may be adjusted by means of a screw 37, I may use a liquid which would be discharged by cap 44, acting as a piston, through a restricted passage.

The present invention may be applied to pumps of the kind illustrated by Figs. 5 to 7 of my above mentioned prior application, where the upward movement of the auxiliary piston does not serve to drive into the delivery conduit the fuel that has been metered by the auxiliary piston but the movement of said piston serves merely for self regulation and speed limiting purposes.

What I claim is:

1. A reciprocating action liquid pump which comprises, in combination, means forming a variable volume space, said means including a fixed part and a part movable with respect to said fixed part to vary the volume of said space, an auxiliary cylinder located in fixed position with respect to said fixed part, a passage connecting one end of said auxiliary cylinder with the said variable volume space, valve means in said passage arranged to be closed during the periods where said variable volume is increasing an auxiliary piston reciprocable in said auxiliary cylinder, said auxiliary cylinder being divided by said auxiliary piston into two chambers, to wit a first chamber located at said above mentioned end of said auxiliary cylinder and a second chamber located at the other end of said auxiliary cylinder, a liquid delivery conduit lead-

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ing from said second chamber a check valve in said delivery conduit arranged to prevent liquid from flowing back from said delivery conduit to said second chamber, spring means interposed between said auxiliary cylinder and said auxiliary piston for exerting on said auxiliary piston a return force opposed to that exerted on said auxiliary piston by the liquid pressure from said variable volume space during the periods where said variable volume is decreasing, a by-pass conduit leading from said first chamber to said second chamber, valve means in said by-pass conduit operative to close said by-pass conduit during a portion of every reciprocation of said movable part, a first discharge conduit leading to the outside from a point of the cylindrical wall of said auxiliary cylinder, whereby said first chamber is placed in communication with said discharge conduit when said auxiliary piston has moved a given distance in said auxiliary cylinder away from said first mentioned end thereof, means in said discharge conduit for throttling thereof, a second discharge conduit mounted in fixed position with respect to said auxiliary cylinder, means operative by said auxiliary piston to place said second chamber in communication with said second discharge conduit as soon as said first chamber is placed in communication with said first discharge conduit, the point where said by-pass conduit opens into said second chamber being located in the wall of said auxiliary cylinder at a place such that it is closed when both of said chambers are placed in communication with said discharge conduits, respectively.

2. A reciprocating action liquid pump which comprises, in combination, a main cylinder, a main piston reciprocable in said cylinder to form therewith a variable volume space, an auxiliary cylinder fixed with respect to said main cylinder, a passage connecting one end of said auxiliary cylinder with the end of said main cylinder where is located said variable volume space, an auxiliary piston reciprocable in said auxiliary cylinder, valve means in said passage arranged to be closed during the strokes of said main piston which produce an increase of said variable volume space, said auxiliary cylinder being divided by said auxiliary piston into two chambers, to wit, a first chamber located at said above mentioned end of said auxiliary cylinder and a second chamber located at the other end of said auxiliary cylinder, a liquid delivery conduit leading from said second chamber, a check valve in said delivery conduit arranged to prevent liquid from flowing back from said delivery conduit to said second chamber, spring means interposed between said auxiliary cylinder and said auxiliary piston for exerting on said auxiliary piston a return force opposed to that exerted on said auxiliary piston by the liquid pressure from said main cylinder during the delivery stroke of said main piston, a by-pass conduit leading from said first chamber to said second chamber, valve means in said by-pass conduit operative to close said by-pass conduit during a portion of every reciprocation of said main piston, a first discharge conduit leading to the outside from a point of the cylindrical wall of said auxiliary cylinder, whereby said first chamber is placed in communication with said discharge conduit when said auxiliary piston has moved a given distance in said auxiliary cylinder away from said first mentioned end thereof, means in said discharge conduit for throttling thereof, a second discharge conduit mounted in fixed position with respect to said auxiliary cylinder, means operative by said auxiliary piston to place said second chamber in communication with said second discharge conduit as soon as said first chamber is placed in communication with said first discharge conduit, the

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point where said by-pass conduit opens into said second chamber being located in the wall of said auxiliary cylinder at a place such that it is closed when both of said chambers are placed in communication with said discharge conduits, respectively.

3. A pump according to claim 2 in which the wall of said auxiliary cylinder is provided with a groove in communication with the second discharge conduit, said groove extending, in the direction of the axis of said auxiliary cylinder, from the opening of said second discharge conduit and in the first mentioned direction of movement of said auxiliary piston to a distance such that said second discharge conduit remains in communication with said second chamber for all positions of said auxiliary piston such that said first discharge conduit is in communication with said first chamber and said second chamber is out of communication with said by-pass conduit.

4. A pump according to claim 3 in which said means for placing the second discharge conduit in communication with the second chamber consists of a conduit extending through said auxiliary piston.

5. A pump according to claim 2 further comprising means in said by-pass conduit for throttling thereof.

6. A pump according to claim 2 in which said first discharge conduit comprises two branches, said throttling means including a throttling member located in each of said branches, said two throttling members being arranged to have different throttling effects respectively, and valve means in said branches operative by pressure variations in said main cylinder to open one of said branches and close the other when said auxiliary piston is moving in one direction, and inversely.

7. A pump according to claim 2 further including a supplementary conduit extending between said by-pass conduit and a point of the second chamber located between the opening of said by-pass conduit into said second chamber and said delivery conduit, with throttling means in said supplementary conduit.

8. A pump according to claim 2 in which said throttling means is automatically variable during the movement of said auxiliary piston in one direction.

9. A pump according to claim 6 in which at least one of said throttling members is automatically movable during the movement of said auxiliary piston in one direction.

10. A pump according to claim 2 further including a slide valve movably mounted across said first discharge conduit to be able to control the flow of liquid there-through, resilient means interposed between said discharge conduit and said slide valve for urging said valve toward a position with respect to said discharge conduit where said discharge conduit is closed by said slide valve and means operative in response to increases of the liquid pressure in said main cylinder for moving said slide valve against the action of said resilient means to first open said discharge conduit and subsequently close it gradually to produce a gradual throttling thereof.

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