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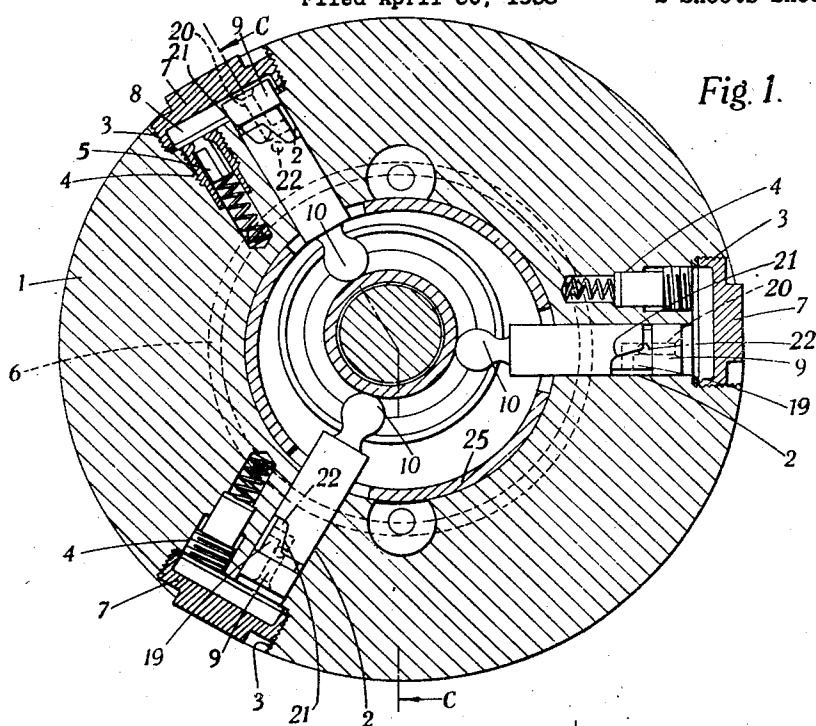
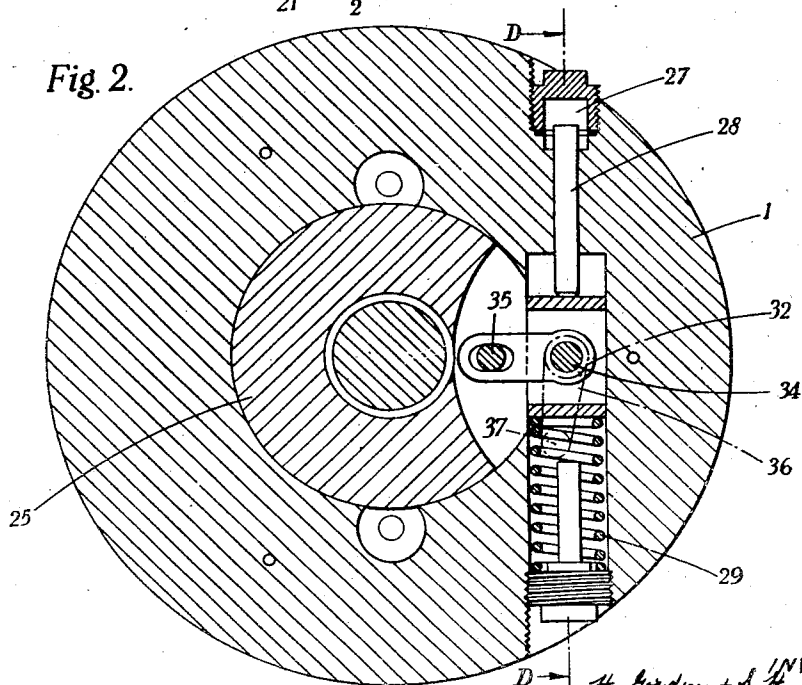
H. GORDON ET AL

2,229,804

PUMP

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2 Sheets-Sheet 1



INVENTORS:
H. Gordon & S. H. Attwood
BY
E. F. O'Keefe
ATTORNEY

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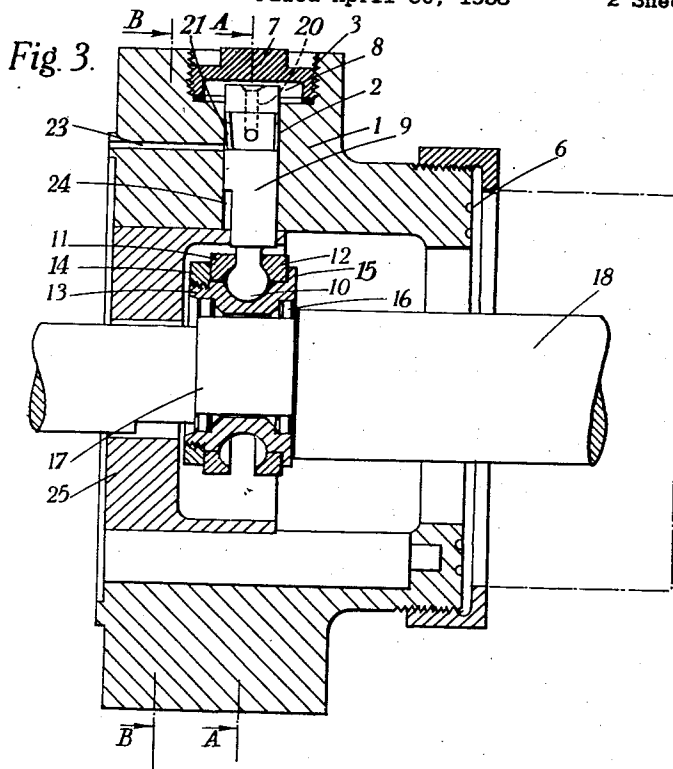
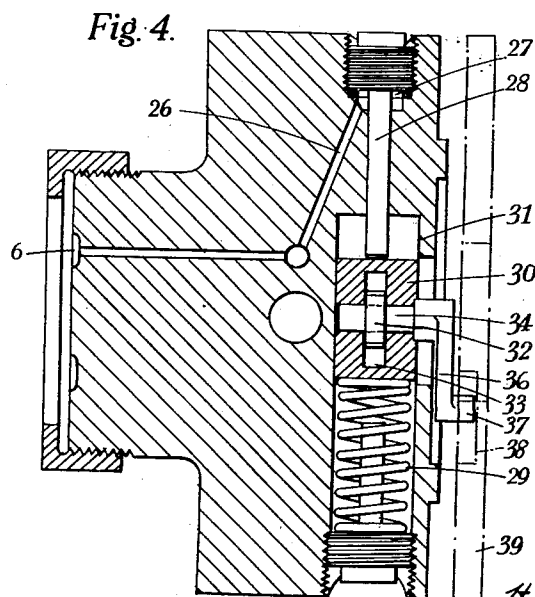
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2 Sheets-Sheet 2



INVENTORS
H. Gordon &
S. H. Ottwood
BY
E. F. Wendroth
ATTORNEY

UNITED STATES PATENT OFFICE

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PUMP

Hamilton Gordon, Weyburn, Elstead, and Stanley
Herbert Attwood, New Malden, England, as-
signors to Attwood Diesel Equipment Company
Limited, London, England, a British company

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10 Claims. (Cl. 103—41)

The present invention relates to pumps, and has for its chief object to provide an improved pump for delivering fluid at a pressure which can be varied instantly, for example, in response to changes in the speed of operation and/or the load of an engine or in response to other controlling factors.

The invention is more especially directed to the provision of an improved pump for supplying liquid fuel at injection pressure to the one or more injectors of an internal combustion engine in which the fuel is admitted to the engine cylinders from a common source at high pressure by one or more injector valves which are controlled independently of the fuel supply, that is to say, there is no inter-dependence as between the pump cycle and the cycle of operation of the injector valve or valves. Such injector valves may be controlled, for example, mechanically or hydraulically.

The quantity of fuel admitted to the engine per injection in such a system is dependent solely upon the effective pressure of the fuel, the area of the passage provided for the fuel past the injection valve and nozzle and the period of time during which the injection valve is open. A system of this kind is therefore quite distinct from the so-called "jerk" pump fuel injection system in which the quantity of fuel injected per stroke of the pump plunger is measured in the pump and the injection valve is automatically lifted from its seat when the delivery pressure from the pump reaches the valve and automatically closes again under spring pressure at the termination of the effective delivery of fuel from the pump cylinder.

There are two problems which arise in connection with fuel injection systems of the kind first above referred to. Firstly, to maintain the pressure of the fuel on the delivery side of the high pressure pump at a substantially constant injection pressure for any engine speed, and secondly, to enable a constant or any desired variable amount of fuel to be injected in spite of speed variations and without altering the duration of opening of the injection valve in relation to the angular displacement of the crank of the engine.

A further object of the present invention, therefore, is to provide an improved pump which will enable the pressure of fuel supplied by the pump to be maintained constant for any engine speed and which will also enable a constant or any desired variable amount of fuel to be injected in spite of variations in engine speed and without altering the duration of opening of the injector

valve in relation to the angular displacement of the crank of the engine.

In one aspect the present invention consists in a pump comprising in combination, a plurality of pump plungers, means operable positively for altering the effective but not the mechanical stroke of said plungers to vary the output of said pump, regulating means including a member responsive to the pressure of the liquid on the output side of the pump, and adjustable means operatively connecting said first mentioned means and said member whereby a predetermined delivery pressure can be selected and maintained.

Preferably the pump comprises a plurality of radially arranged cylinders in which plungers are disposed for reciprocation in relatively displaced circles by common driving means to draw liquid from a common source and to deliver it at pressure to a common receiver and a device for each plunger which is operable, for example, by relative rotation between the plunger and cylinder, to alter the effective stroke of said plunger and thereby vary the amount of liquid delivered per cycle of the plunger, the delivery from all the cylinders being controlled by a common control member.

The regulating means may conveniently comprise a regulating plunger, responsive on the one hand to the fuel pressure on the output side of the pump and on the other hand to the counter pressure of a spring, and the means for varying the output of the pump may be operated manually or automatically to vary the response of the regulating means in any desired manner. For example, when the pump is used in a fuel injection system for an internal combustion engine the regulating means may be made responsive to engine speed through speed-governor-actuated means which will vary the response of the regulating means automatically in such a manner as to increase the pressure at which the fuel is delivered by the pump with rising pump speed, or to maintain the fuel output pressure constant, or to decrease the fuel output pressure with rising pump speed over a predetermined speed range.

The speed-governor-actuated means may be arranged to vary the sensitivity of the response of the regulating means through the medium of a cam form which, when moved by the governor, serves to increase the loading, for example, by means of a compression spring, of the regulating means with rising pump speed over the desired speed range. This cam form (which may be formed on a master cam plate as described in our

co-pending Patent Application Serial No. 205,337) may also be formed so as to give a relatively high initial delivery pressure from the pump to facilitate starting the engine, and to effect a reduction of the said pressure to a predetermined lower pressure for idling of the engine and then to effect an increase of pressure with rising pump speed.

In order that the present invention may be more clearly understood and readily carried into effect reference may now be made to the accompanying drawings illustrating by way of example a pump according to the present invention for supplying liquid fuel at injection pressures for use in a fuel injection system for an internal combustion engine.

In the accompanying drawings:

Fig. 1 is a cross sectional view of the pump on the line A—A of Fig. 3,

Fig. 2 is a cross sectional view of the pump on the line B—B of Fig. 3.

Fig. 3 is a cross sectional view on the line C—C of Fig. 1, and

Fig. 4 is a cross section on the line D—D of Fig. 2.

As shown the pump comprises a main pump body 1 of annular form in which three pump cylinders 2 are bored radially so as to extend completely through the radial thickness of the body. It will be understood, however, that any desired number of pump cylinders may be formed in the pump body 1. An enlarged circular recess 3 is formed in the outer periphery of the body at the position of each pump cylinder 2 so as to embrace both the pump cylinder and a cavity 4 sunk into the body adjacent to and parallel with the cylinder. This cavity houses a spring closed delivery valve 5 for the cylinder and communicates at its inner end with a groove or high pressure conduit 6 common to all the cylinders and which may be formed in the body of the pump or in a further body secured thereto and may be connected to the inlet of mechanically or hydraulically operated fuel injection valve nozzles of an internal combustion engine. The recesses are each screw threaded and sealed by a plug 7 which may be recessed out if necessary as shown at 8 to establish communication between the cylinder 2 and the adjacent delivery valve 5. Each cylinder has a plunger 9 slidable therein and the inner end of which (that is, the end nearest the centre of the pump body) is provided with a ball head 10 and all the ball heads of the plungers are held between two laterally arranged rings 11, 12, which are recessed on their adjacent sides to receive the said heads. The rings 11, 12, are carried by an inner ring 13 and are held correctly in place between a nut 14 and a shoulder 15 on the ring 13. The ring 13 forms part of a roller bearing 16 which runs upon an eccentric 17 the shaft 18 of which is rotatable in a bearing or bearings in a side plate or plates applied to the pump body.

It will be appreciated that the ball head coupling between the plungers 9 and the eccentric 17 not only allows for the relative mutual displacement between the ball heads 10 in the holding rings 11, 12, during operation of the pump but also enables the plungers 9 to be rotated individually about their longitudinal axes. Each plunger 9 is provided with a recess 19 extending peripherally thereof at a short distance from the head of the plunger and which is connected by a passage 20 to the top of the said head and hence is in communication with the working cylinder space. This recess has a helically inclined edge

21 extending around a portion of the periphery of the plunger and which is arranged to co-act with a suction port 22 in the pump cylinder wall by overriding the said port during the strokes of the plunger in such a manner that the effective suction stroke starts as soon as the inclined edge overrides the port on the downward movement of the plunger 9 to establish communication between the port and the peripheral recess in the plunger. Similarly the effective delivery stroke of the plunger commences as soon as the inclined edge completely overrides and shuts-off the suction port 22 during the upward movement of the plunger. The suction ports 22 of the several cylinders 2 communicate by means of passage-ways 23 with a common fuel supply source.

By rotating the plunger 9 about its longitudinal axis the point in the delivery stroke of the plunger at which the inclined edge overrides the suction port 22 may be varied, hence the amount and pressure of fuel delivered per cycle of the pump plunger can be adjusted within a predetermined range by rotating the plunger. For rotating the plungers 9 in unison with one another for the purpose of regulating the amount of fuel delivered by the pump the inner end of each plunger is provided with gear teeth 24 extending around a portion of the periphery thereof, the individual teeth extending longitudinally of the plunger. A control ring 25 is rotatably mounted in the pump body and is provided with gear teeth which mesh with the teeth on the plungers so that by rotating the control ring 25 in one direction or the other all the plungers will be similarly rotated in unison and to the same extent, thus providing a device by which the amount and pressure of the liquid delivered by the individual plungers may be varied in common with one another.

The means for varying the amount of liquid delivered per cycle by the plungers 9 of the pump may comprise any of the well known arrangements employed in connection with jerk pumps for fuel injection systems. For example, instead of or in conjunction with the arrangement above described in which the suction port co-operates with an inclined edge of a recess in the plunger, a similar arrangement could be provided in which the port is a discharge port so that when the inclined edge overrides this port on its upward movement the pressure in the working chamber of the pump cylinder is instantly relieved and the liquid for the remainder of the stroke of the plunger discharged into a relief conduit. In both the arrangements described the inclined edge could be on the wall of the pump cylinder and the port in the pump plunger. Also instead of rotating the plungers, cylinder bushes provided with teeth at the inner end thereof in lieu of the teeth on the plungers, could be coupled to the control ring so that they are rotatable instead of the plungers, the ports or recesses being then made in these cylinder bushes.

In arrangements in which the plungers are rotated to vary the amount of fuel delivered, the teeth on the plungers, which mesh with those on the control ring 25 could be provided on sleeves rotatably mounted in the pump body but not axially movable and the plungers would then be free to reciprocate in the sleeves but would be keyed thereto so as to be rotated thereby upon movement of the control ring. The control ring above described is the most convenient form of common control member for the pump cylinders and plungers but it is to be understood that any other form of coupling to a common control

member may be used as also different forms of coupling the plungers to a common drive therefor.

As shown, the groove or high pressure conduit 6 is arranged in communication by means of a conduit 26 with a cylinder 27 in which a plunger 28 operates under the influence of the delivery pressure of the pump against the counter pressure of a spring 29, the initial stress of which may be adjustable; increase of pressure in the groove or conduit 6 displaces the plunger 28 to an increased extent against the influence of the spring 29 and reduction of delivery pressure causes the plunger to be moved in the opposite direction by the spring. In view of the high pressures being dealt with, the piston surface of the plunger 28 against which the fuel pressure acts may be less than the cross sectional area of the cylinder 27, thus enabling the spring 29 to be relatively light. Furthermore, the plunger 28 is preferably connected to another larger plunger 30 which may be termed the regulating plunger operating in an enlarged bore 31.

The regulating plunger 30 is operatively connected to the control ring 25 of the pump in such a manner that with increasing displacement of the plunger 30 by the fuel pressure the pump is regulated to give a reduced output and vice versa and, other conditions remaining the same, the regulator will operate to maintain a substantially constant pressure of the fuel in the high pressure conduit or groove 6 which pressure may be predetermined as desired. As shown the operative connection between the regulating plunger 30 and the control ring 25 for the pump plungers comprises a lever 32 one end of which projects into a slot 33 in the plunger 30 and is mounted upon a shaft 34 carried by the plunger 30 whilst the other end is pivotally connected as at 35 to the annular control ring 25. An arm 36 is connected to the shaft 34 and has a pin 37 thereon which is adapted to co-act with a cam form, for example, a cam form 38 in a rotatable plate 39. The cam form may be moved to rotate the control ring 25 either manually or automatically, as for example by any suitable form of speed governor such as that described in our co-pending patent application Serial No. 205,337.

In operation the control ring 25 of the pump will be actuated both upon displacement of the cam form 38 produced by rotation of the disc 39 and also upon displacement of the regulating plunger 30, and for any particular setting of the disc 39 the regulating plunger 30 will take up a mean position under the influence of the fuel pressure acting on one side thereof and the pressure of the spring 29 acting on the other side thereof and will tend to maintain a constant delivery pressure corresponding to that setting of the disc. Subsequent rotation of the disc 39 to another position will vary the effective stroke of the pump plungers 9 to alter the delivery pressure of the pump thereby causing displacement of the regulating plunger 30 to a new mean position corresponding to the new position of the disc 39.

Actually these two operations interact so that the output of the pump is regulated to suit any newly adjusted position of the plunger 30. The result is that when the disc 39 is coupled to a speed-responsive-governor the absolute output of the pump per injection is maintained substantially constant with increasing speed or vice versa, it being borne in mind that as the pressure increases in the high pressure conduit 6 with increasing speed of operation of the pump and

therefore of the engine, the amount of fuel discharged from the conduit 6 per injection, for a given duration of opening of each injector valve in relation to crank angle displacement of the engine, will remain unaltered because an appropriate adjustment in the pressure will have been effected to compensate for alteration in absolute period of opening of the injection valve consequent upon change of engine and pump speed. Thus, assuming a duration of opening of each injector valve corresponding to an angular displacement of 10 degrees of the engine crankshaft, an increase of 50 per cent in engine speed, for example, due to a relief of the load on the engine, will cause an approximately 50 per cent increase in the pressure of the fuel in the high pressure conduit 6 and therefore at the injector nozzle, and approximately the same amount of fuel will be injected at the higher engine speed as was injected at the lower engine speed per engine cycle.

It will be clear from the foregoing description that with a given engine speed resulting in a particular basic setting of the regulating plunger and for a given "period" of opening of the injector valve or valves in relation to the angular displacement of the engine crankshaft, the regulating means will operate to maintain substantially constant any predetermined injection pressure of the liquid fuel.

Any suitable form of intercoupling between the regulating plunger and the pump delivery pressure varying means may be utilised in lieu of that hereinbefore described.

The cam form co-operating with the pin 37 may be given any contour desired to suit particular requirements and is correlated with the load rate of the spring 29. An especially advantageous cam form intended for governor actuation in the case of fuel injection pumps is one which gives a high initial injection pressure, that is to say, the cam form is arranged to bring about a suitable displacement of the regulating plunger against its spring in the zero position to facilitate starting of the engine so that with minimum duration of opening of the injector valve in starting only a minimum quantity of fuel need be injected because as this is injected at a relatively high pressure complete atomisation results and easy starting is ensured. This avoids the disadvantage of known injection systems, particularly "jerk" pump systems, in which the effective injection pressure varies with the speed of the pump owing to the pump characteristic and is lowest when the engine is cranked over in starting, and which disadvantage resides in the fact that it is customary in order to ensure sufficient fuel being injected into the engine cylinder for starting purposes, to depress the "period" control pedal or lever which results in an unnecessarily large amount of poorly atomised fuel being injected into the engine cylinder with resultant poor starting properties due to the excess amount of fuel abstracting the heat of the compressed air, and also a smoky exhaust.

The cam form is also preferably such that when it is moved by the governor running at idling speed it brings about a displacement of the regulating plunger to a position corresponding to a reduced injection pressure suited to the idling speed of the engine and this position of the regulating plunger may be maintained by the cam form over a predetermined lower speed range before increasing the injection pressure over the higher speed range.

It is believed that the improved pump in accordance with the present invention makes it possible for the first time in a fuel injection system to maintain the quantity of fuel injected constant or variable in any desired and definitely predetermined ratio in relation to speed variations of the engine for a given angular displacement of the engine crankshaft.

It is further to be noted that the regulating means provided in accordance with the invention is not subject to the defects of those systems in which a predetermined pressure is maintained by a relief valve, namely, hunting about the predetermined pressure value and even sudden emptying of the high pressure conduit when the valve opens due to the kinetic energy developed in the fuel and the inertia of the valve, and the fact that even if a small amount of dirt becomes located between the valve and the valve seating the entire pressure regulation is disturbed and may even be made ineffective. Further, the regulating means operates satisfactorily in spite of any wear which may occur on the pump plungers because the regulating means will automatically correct the setting of the means for controlling the delivery volume in the pump to allow for any such wear.

Although in the foregoing description the pump according to the present invention has been described in connection with its use in relation to a fuel injection system for an internal combustion engine the pump can also be used in connection with such mechanisms as transmissions for automobiles, automobile braking systems, hydraulic jacks and other mechanisms.

What we claim is:

1. A pump for liquid comprising in combination, a plurality of pump plungers, means operable positively for altering the effective but not the mechanical stroke of said plungers to vary the output of said pump, regulating means including a member responsive to the pressure of the liquid on the output side of the pump, and adjustable means operatively connecting said first mentioned means and said member, whereby a predetermined delivery pressure can be selected and maintained.

2. A pump for liquid according to claim 1 in which the means for positively varying the output of the pump is adjustable manually in addition to operation by the regulating means.

3. A pump for liquid according to claim 1 in which the means for positively varying the output of the pump is adjustable automatically in addition to operation by the regulating means.

4. A pump for liquid comprising a plurality of pump plungers, a common receiver to which liquid is pumped continuously by said plungers, means operable positively for altering the effective but not the mechanical stroke of said plungers to vary the output of the pump, regulating means including a member responsive to the pressure of the liquid on the output side of the pump, and means operatively connecting said first mentioned means and said member, in combination with cam means for adjusting the basic setting of the regulating means to alter the output pressure.

5. A pump for liquid comprising a plurality of radially disposed cylinders, plungers arranged in said cylinders, common driving means for reciprocating said plungers in relatively displaced cycles, means for altering the effective but not the mechanical strokes of said plungers to vary

the amount of liquid delivered per plunger cycle for each plunger, and a common control member operative upon said last mentioned means for controlling the delivery from all the cylinders.

6. A pump for liquid comprising a plurality of radially disposed cylinders, plungers arranged in said cylinders, common driving means for reciprocating said plungers in relatively displaced cycles, means for altering the effective but not the mechanical strokes of said plungers to vary the amount of liquid delivered per plunger cycle for each plunger, a common receiver to which liquid is pumped continuously by said plungers, a common control member operative upon said last-mentioned means, regulating means including a member responsive to the pressure of the liquid on the output side of the pump and means operatively connecting said regulating means and said common control member, whereby a predetermined delivery pressure can be selected and maintained.

7. A pump for liquid comprising a plurality of radially disposed cylinders, plungers arranged in said cylinders, common driving means for reciprocating said plungers in relatively displaced cycles, an element rotatably adjustable about each cylinder axis for altering the effective stroke of the respective plunger to vary the amount of liquid delivered per plunger cycle, a common receiver to which liquid is pumped continuously by said plungers, a common control member rotatable about the axis of the pump driving shaft and coupled to all said elements, regulating means including a member responsive to the pressure of said liquid on the output side of the pump and means operatively connecting said regulating means and said common control member, whereby a predetermined delivery pressure can be selected and maintained.

8. A pump for liquid comprising in combination, a plurality of pump plungers, a common receiver to which liquid is pumped continuously by said plungers, means operable positively for altering the effective but not the mechanical strokes of said plungers to vary the output of the pump, a regulating plunger, means for subjecting said regulating plunger on one side to the pressure of liquid on the output side of the pump, a spring acting on the other side of said plunger in the opposite direction to said liquid pressure, and means operatively connecting said regulating plunger and said output varying means, whereby a predetermined delivery pressure can be selected and maintained.

9. A pump for liquid comprising in combination, a plurality of pump plungers, a common receiver to which liquid is pumped continuously by said plungers, means operable positively for altering the effective but not the mechanical strokes of said plungers to vary the output of the pump, a regulating plunger, means for subjecting said regulating plunger on one side to the pressure of liquid on the output side of the pump, a spring acting on the other side of said plunger in the opposite direction to said liquid pressure, and a bell crank lever pivotally mounted on said regulating plunger, said lever being connected at one end to said output varying means and being operable at the other end to vary the response of the regulating plunger to variations in the liquid delivery pressure.

10. A pump for liquid comprising in combination, a plurality of pump plungers, a common receiver to which liquid is pumped continuously by said plungers, means operable positively for

altering the effective but not the mechanical strokes of said plungers to vary the output of the pump, regulating means including a member responsive to the pressure of the liquid on the output side of the pump, means operatively connecting said output varying means and said

member, and cam means for adjusting the basic setting of the regulating means to alter the output pressure.

HAMILTON GORDON.
STANLEY HERBERT ATTWOOD.