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[54] **LIQUID FUEL PUMPING APPARATUS**
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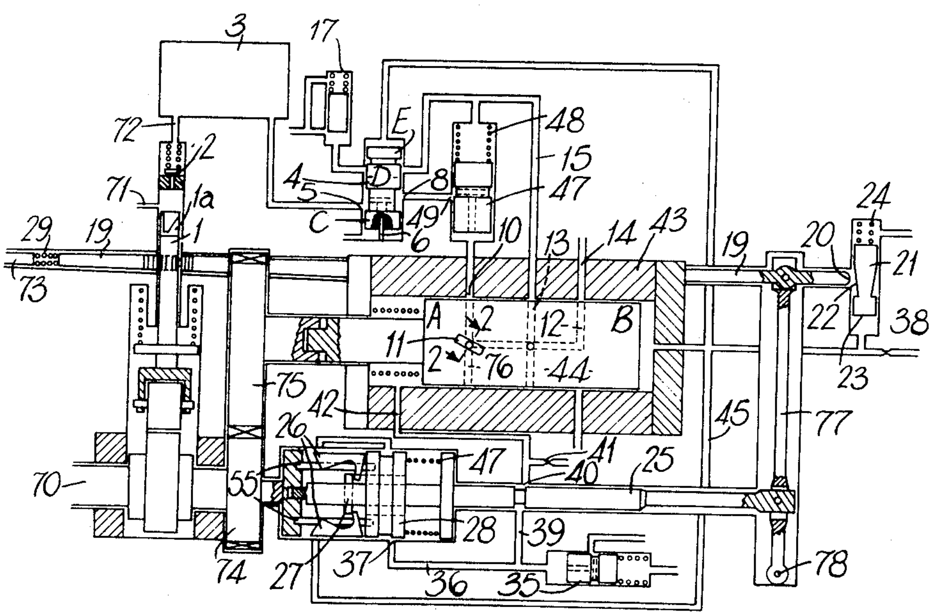
ABSTRACT: A liquid fuel pumping apparatus including an injection pump for supplying fuel to an accumulator first valve means which when opened permits fuel to flow from the accumulator to the associated engine and second valve means which closes to prevent flow of fuel to the engine when the pressure in the accumulator falls to a predetermined value.



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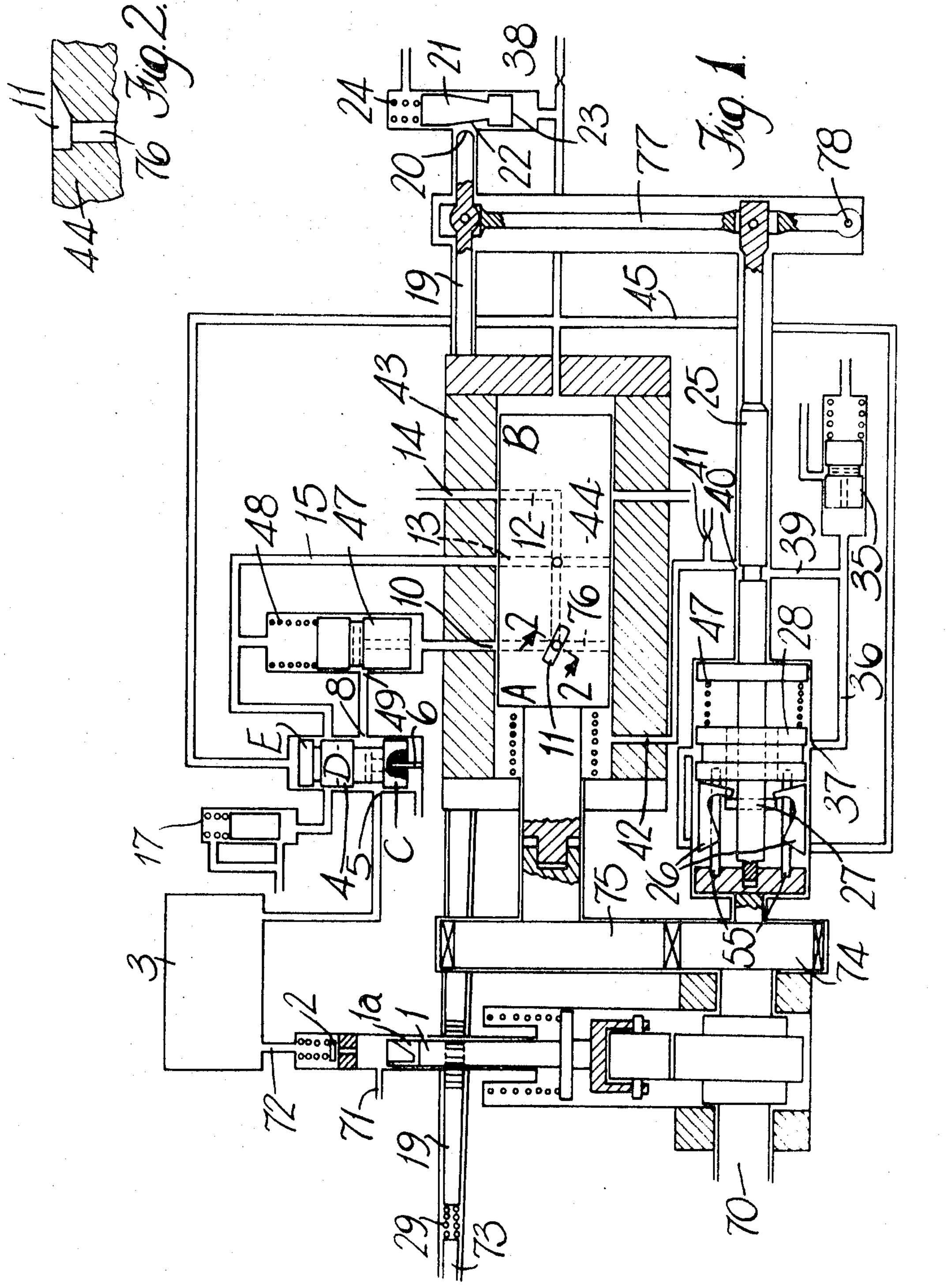

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LIQUID FUEL PUMPING APPARATUS

This invention relates to liquid fuel pumping apparatus for supplying fuel to multicylinder internal combustion engines and has for its object to provide such an apparatus in a simple and convenient form.

One example of an apparatus in accordance with the invention will now be described with reference to the accompanying drawing in which FIG. 1 shows diagrammatically the various parts of the apparatus and FIG. 2 is a section to an enlarged scale on the line 2–2 of FIG. 1.

Referring to the drawing there is provided a reciprocating plunger injection pump incorporating a spring-loaded plunger 1 which is adapted to be driven in timed relationship with the engine with which the apparatus is a associated by was way of a rotary shaft 70. Upon the shaft is mounted a cam which cooperates with a roller disposed at the adjacent end of the plunger 1 and the latter is spring-loaded in an outward direction in the usual manner. At its outermost position the plunger 1 uncovers a port 71 formed in the wall of the bore in which it is mounted and this port is connected to a source of liquid fuel under pressure. During inward movement of the plunger the port 71 is covered and fuel is displaced through an outlet 72 into an accumulator 3. For controlling the flow of fuel through the outlet 72 and for preventing the return flow of fuel from the accumulator a spring-loaded nonreturn valve 2 is provided. The plunger 1 is provided with a helical groove 1*a* in its periphery which cooperates with the port 71 to determine the quantity of fuel which is displaced by the plunger during each inward movement. A rack bar 19 is provided to control the angular setting of the plunger and this is operable through the intermediary of a coiled compression spring 29 by an operator adjustable member 73.

The shaft 70 is extended and mounts a pinion 74 with which is engaged a further pinion 75 operatively coupled to a distributor member 44 mounted within a body part 43. A tongue and groove connection is provided intermediate the distributor member and the pinion 75 and a coiled compression spring 46 is disposed to urge the distributor member in a direction away from the pinion 75.

Formed in the distributor member is a delivery passage 12 which breaks out onto the periphery of the distributor member and which is arranged to register in turn and as the distributor member rotates, with a plurality of outlet ports 14 formed in the body part 43. The outlets ports in use, are connected to the fuel injection nozzle units respectively which are positioned on the engine so as to direct fuel into the combustion spaces thereof. In the particular example the engine is provided with four cylinders and in communication with the delivery passage 12 are four radially extending and equiangularly spaced feed passages 76 which break out onto the periphery of the distributor member and which are arranged to register in turn and as the distributor rotates, with a feed port 10 formed in the body part 43. Conveniently and for a purpose which will be explained later, the outer ends of the feed passages 76 are formed as helically disposed grooves 11 respectively. In addition to the feed passages 76 the delivery passage is also in communication with four radially extending and equiangularly spaced relief passages 13 and these are arranged to register in turn and as the distributor rotates, with a relief port 15 formed in the body part.

The feed port 10 and the relief port 15 communicate respectively with the opposite ends of a cylinder which contains a pilot control valve 47 and the valve is loaded in its cylinder towards the end thereof which communicates with the feed port 10, by means of a coiled compression spring 48. Intermediate the ends of the valve member 47 is formed a groove which is in communication with the end of the cylinder communicating with the feed port. For communication with the aforesaid groove there is provided in the wall of the cylinder, a port 49 and this is in communication with a port 8 which is formed in the wall of a further cylinder intermediate the ends thereof. Slidable in the further cylinder is a further valve member 4 having three lands referenced C, D and E respectively. The groove defined between the lands C and D is arranged to register with the port 8 and at the same time with a port 5 which is in communication with the accumulator 3. The ends end of the cylinder adjacent the land C is in communication with a drain and upstanding from this end of the cylinder is a post 6 slidably accommodated within a bore formed in the valve member. This bore is in communication with the groove defined between the lands D and C.

The groove defined between the lands D and E is provided for simultaneous registration with a pair of ports formed in the wall of the further cylinder one of which is in communication with the end of the cylinder accommodating the valve member 47 and remote from that end thereof which is in communication with the feed port 10. The other port is in communication with a drain by way of a constant pressure valve 17. Furthermore, the end of the further cylinder remote from the post 6 is in communication with a source of fuel under pressure, the pressure of which varies in accordance with the speed at which the apparatus is driven. The way in which this pressure is derived will be explained later in the specification, and the operation of the portion of the system thus far described will now be explained. During inward movement of the plunger 1 a predetermined quantity of fuel is delivered to the accumulator and the pressure therein rises to a value which is higher than the predetermined pressure at which the valve member 4 is moved to establish communication between the port 5 and the port 8. The valve member 4 moves as a result of the extremely high pressure within the accumulator acting upon an area equivalent to the area of the end surface of the post 6. The movement of the valve member in the aforesaid direction is opposed by the speed dependent pressure acting on the end of the valve member adjacent the land E. After the ports 5 and 8 are placed in communication with each other the distributor rotates so that port 10 and a groove 11 are in communication and then fuel flows by way of one of the feed passages 76 to the delivery passage 12 and an outlet port 14. From the outlet port 14 fuel flows to the associated nozzle unit and injection of fuel to the engine occurs. Injection of fuel continues until the pressure within the accumulator has fallen to a value such that the valve member 4 moves towards the end of its cylinder which supports the post 6. When this occurs port 8 is closed by the land D and the outlet port 14 is effectively placed in communication with the constant pressure valve 17 by way of a relief passage 13, the relief port 15 and the groove defined between the lands D and E of the valve member 4. Thus the pressure within the pipeline extending between the outlet port 14 and the associated nozzle unit is lowered to a pressure which is determined by the constant pressure valve 17. This reduction of pressure to a predetermined value ensures that at the end of the injection of fuel to the engine each pipeline contains fuel at a predetermined pressure. In addition the rapid reduction of pressure which occurs ensures that the valve members within the nozzle units close quickly. The pressure within the accumulator at the end of the injection period is the same as that which existed therein prior to the delivery of fuel by the plunger 1 and consequently the quantity of fuel which is injected to the engine is dependent upon the effective stroke of the plunger 1.

The pilot control valve 47 in conjunction with a variable restricted orifice defined by a groove 11 and the port 10 acts to control the rate of injection of fuel to the engine. In the particular example and as seen in FIG. 2 the lead portion of the grooves are shallower than the remaining portion thereof. In this manner a pressure drop will occur across the variable orifice. This pressure drop is sensed by the valve member 47 and this moves appropriately against the action of the spring 48 to restrict the flow of fuel through the port 49, and hence the initial rate of injection of fuel to the engine is controlled. After the initial injection period the grooves 11 increase in depth and the valve member 47 is moved by the action of the spring 48 so that the port 49 is not obstructed by the valve member. Hence the remaining quantity of fuel is injected to the engine at the maximum rate.

The remaining portion of the system will now be described and this portion of the system is mainly concerned with obtaining a load responsive pressure and a speed responsive pressure, these two pressures being applied to effect control of various elements of the system.

Also provided is an extended shaft **25** which is supported for relative angular movement in the pinion **74** at its end adjacent thereto, and which at its other end is connected to a lever **77** so that axial movement of the shaft **25** will impart angular movement to the lever **77** about an axis **78**. The end of the lever **77** remote from its pivot point **78** is coupled to the rack bar **19** with the result that movement of the rack bar to effect angular adjustment of the plunger **1** will impart axial movement to the shaft **25** and vice versa.

An extension of the pinion **74** carries cage members **55** rotatable with the pinion and these support centrifugally operable weights **26** each of which is in the form of a bellcrank lever. The weights pivot about an edge located against a valve member **28** slidable axially relative to the shaft **25** and the toes of the weights bear upon a pin **27** secured to the shaft **25**. The valve member **28** is biased by a coiled compression spring **47** against the action of the weights **26**. The arrangement is such that as the weights move outwardly the valve member **28** will move against the action of the spring **47** and in addition the shaft **25** will be moved axially in the direction to effect compression of the spring **29** which is located intermediate the rack bar **19** and the operator adjustable member **73**. The valve member **28** is provided with a peripheral groove which is in constant communication with a pipeline **45**. The pipeline communicates with the end of the further cylinder which contains the valve member **4**, remote from the post **6**. The land of the valve member **28** adjacent the spring **47** controls the effective size of a port **37** and this port is in communication by way of a pipeline **36**, with the outlet of a constant pressure valve **35**. This valve controls the flow of liquid from a source to the pipeline **36** so that the pressure therein remains constant. The setting of the valve member **28** is dependent upon the force exerted by the governor weights **26** and therefore the effective size of the port **37** is dependent upon the speed at which the apparatus is driven. Hence the pressure in the pipe **45** is also dependent upon the speed at which the apparatus is driven and for ensuring a flow of fuel through the port **37** the pipeline **45** is connected to a drain by way of a restricted orifice **38**. The pipeline **45** is additionally in communication with a chamber defined by the end of the distributor member **44** and the adjacent end of the body part **43** so that the pressure acting on the distributor member will move same in opposition to the action of a coiled compression spring **46** acting between the other end of the distributor member and the adjacent body part. Thus the axial setting of the distributor member within the body part varies in accordance with the speed at which the apparatus is driven. By virtue of the helical disposition of the grooves **11**, the timing of injection of fuel is also dependent upon the speed at which the apparatus is driven.

In order to control the maximum quantity of fuel which can be supplied to the engine in accordance with the speed at which it is driven, a torque control piston **21** is provided having a shaped periphery and against which an end **20** of the rack bar **19** is arranged to bear. The torque control piston is subjected on one side, to the pressure pertaining in the pipeline **45** and this pressure moves the piston **21** in opposition to the action of a coiled compression spring **24**. As the speed at which the apparatus is driven increases the torque control piston moves to modify the range of movement of the rack bar **19**. If so desired but not as shown, the torque control piston may be shaped to provide an excess of fuel for starting purposes. The combination of the spring **29** and the governor weights **25** define a mechanical governor to control the setting of the plunger **1** and thereby to effect a control of the speed of operation of the apparatus for any given setting of the operator adjustable member **73**.

It is desirable to be able to vary the timing of the injection of fuel in accordance with the load on the engine. The axial setting of the shaft **25** is representative of the quantity of fuel which is being supplied to the engine and hence the actual load on the engine and at one point the shaft **25** is grooved and this groove is in communication with the outlet of the constant pressure valve **35** by way of a passage **39**. A portion of the shaft **25** controls the effective size of a port **40** which communicates with the end of the distributor member adjacent the spring **46**. A bleed orifice **41** is provided downstream of the port **40** to ensure a flow of fuel through the port **40** so that the effective size of the port controls the pressure applied to the distributor member. It will be noted that the load-dependent pressure derived from the port **40** opposes the action of the speed-dependent pressure derived from the port **37**.

By the arrangement described the period during which inward movement is imparted to the plunger **1** by the cam mounted on the shaft **70** is longer than the period of plunger movement of a conventional system. The effect of this lengthening of the period of inward movement of the plunger **1** is to reduce the shock loading applied to the shaft **70** whilst at the same time maintaining the normal pressure at which fuel is delivered to the engine.

We claim:

1. A liquid pumping apparatus for supplying fuel to a compression ignition engine and comprising in combination, an accumulator for storing liquid fuel under pressure, an injection pump operable to deliver a metered quantity of fuel under pressure to the accumulator prior the to the delivery of fuel to the engine, a conduit extending from said accumulator to an outlet which outlet in use, is connected to a fuel nozzle disposed to direct fuel into a combustion space of the engine, first valve means operable in timed relationship with the engine and arranged when open, to permit flow of fuel through said conduit, second valve means in series with said first valve means, said second valve means being responsive to the pressure of fuel in the accumulator and arranged to open to permit flow of fuel through said conduit when the pressure of fuel in the accumulator is above a predetermined value and to prevent flow through said conduit when the pressure in the accumulator falls to said predetermined value, and means whereby the quantity of fuel delivered by the injection pump can be adjusted, the arrangement being such that before the injection pump supplies fuel to the accumulator the pressure therein will be at said predetermined value a but after the supply of fuel the pressure will be at a higher value depending on the volume of fuel supplied by the injection pump, said first valve means following the supply of fuel by the injection pump being opened to permit flow of fuel through the conduit to the outlet, the flow of fuel through the conduit being halted by the closure of said second valve means when the pressure of fuel in the accumulator has fallen to said predetermined value, the volume of fuel flowing through to the outlet being equal to the volume of fuel supplied by the injection pump.

2. A pumping apparatus as claimed in claim **1** in which said second valve means is positioned intermediate the accumulator and said first valve means, said second valve means when in the closed position acting to maintain the portion of the conduit downstream of the second valve means at a second predetermined pressure lower than said first mentioned predetermined pressure.

3. A pumping apparatus as claimed in claim **2** in which said first valve means constitutes a variable restricted orifice across which a varying pressure drop is developed during flow of fuel through the conduit, third valve means being provided and which is responsive to said pressure drop, said third valve means acting to control the rate of flow of fuel through said conduit in accordance with the magnitude of said pressure drop.

4. A pumping apparatus as claimed in claim **3** including a rotary distributor member mounted within a body part, said first valve means being constituted by a port and a groove formed in the body part and the distributor member respectively, there being formed in the distributor member and axial passage communicating with said groove and with a delivery passage, the delivery passage being positioned to register with an outlet in the body part.

5. An apparatus as claimed in claim 4 in which a plurality of said grooves and said outlets are provided whereby the apparatus can be used to supply fuel to the cylinders of a multicylinder engine.

6. An apparatus as claimed in claim 5 including supply means for supplying fluid under pressure and at a pressure which varies in accordance with the speed at which the apparatus is driven said second valve means comprising a spool movable within a cylinder an area at one end of the spool being exposed to said fluid pressure and a smaller area at the other end of the spool being subjected to the pressure within the accumulator, a pair of grooves defined on the spool, one of said grooves being in constant communication with the interior of the accumulator, and forming in conjunction with a port in the wall of the cylinder, part of said conduit, said port being uncovered to said one groove when the pressure within the accumulator is such as to move the spool against the action of said fluid pressure, the other groove serving to place a further pair of ports in the wall of the cylinder in communication with each other when the spool is moved against the action of the pressure in the accumulator, one of said ports being in communication with said passage of the distributor member.

7. An apparatus as claimed in claim 6 in which the other of said pair of ports communicates with a drain by way of a constant pressure valve.

8. An apparatus as claimed in claim 7 in which said grooves on the distributor member are of varying depth whereby the restriction imposed by the variable orifice depends upon the extent of registration of the groove and port.

9. An apparatus as claimed in claim 7 in which said grooves are helically disposed, and the distributor member is axially adjustable to determine the timing of delivery of fuel to the engine.