United States Patent

Harding

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[54] FUEL INJECTION SYSTEMS

[72] Inventor: **John Kammerer Harding,** Cheltenham, England

[73] Assignee: **Dewty Technical Developments Limited,** Brockhampton, Cheltenham, England

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[51] **Int. Cl.**.....**F02d 1/06**

[58] **Field of Search**.....123/119, 139, 139.11, 139.11 A, 123/139.17, 139.18, 140, 140.1, 140.2, 140.3

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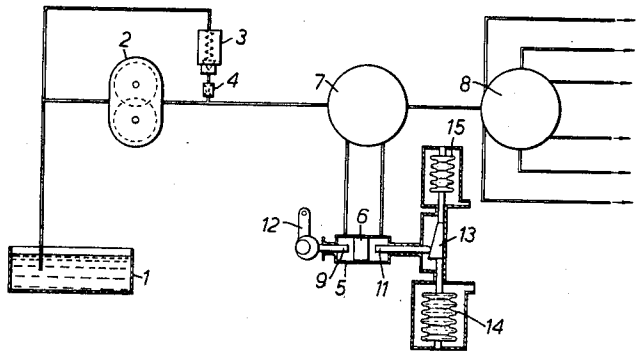
Primary Examiner—Laurence M. Goodridge

Attorney—Young & Thompson

[57] **ABSTRACT**

A fuel-injection apparatus for a multi-cylinder internal combustion engine comprising a fuel pump, a free piston mounted for reciprocation in a cylinder between stops and defining two variable-volume working spaces and a face valve adapted to be driven at a speed proportional to engine speed which includes ports for performing a commutating function comprising the successive alternate connection of one working space to the fuel pump delivery and the other working space to the engine fuel supply connection and of the one working space to the engine fuel supply connection and the other working space to the fuel pump delivery and a distributor function in which the engine fuel supply connection is connected to the injectors for the cylinders of the engine in a regularly recurring sequence.

2 Claims, 4 Drawing Figures



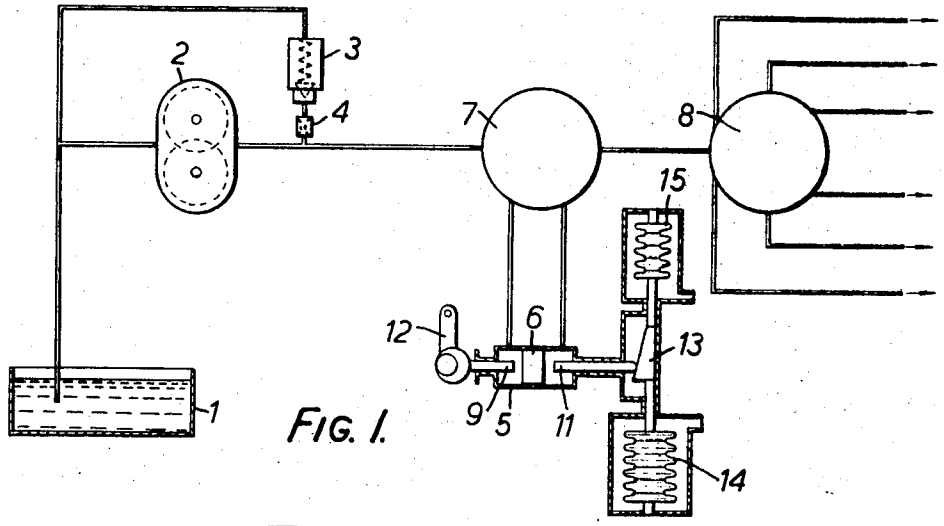


FIG. 1.

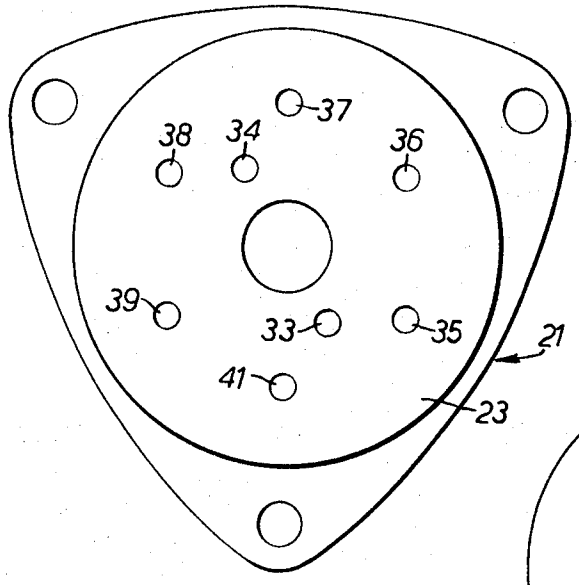


FIG. 3.

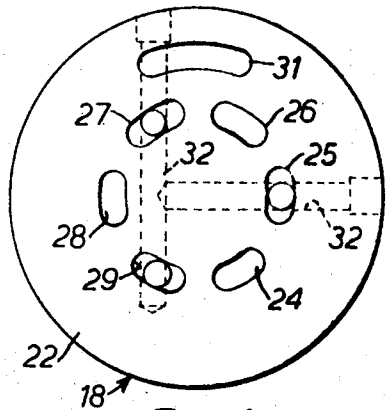


FIG. 4.

INVENTOR
JOHN KAMMERER HARDING
BY Young & Thompson
ATTORNEYS

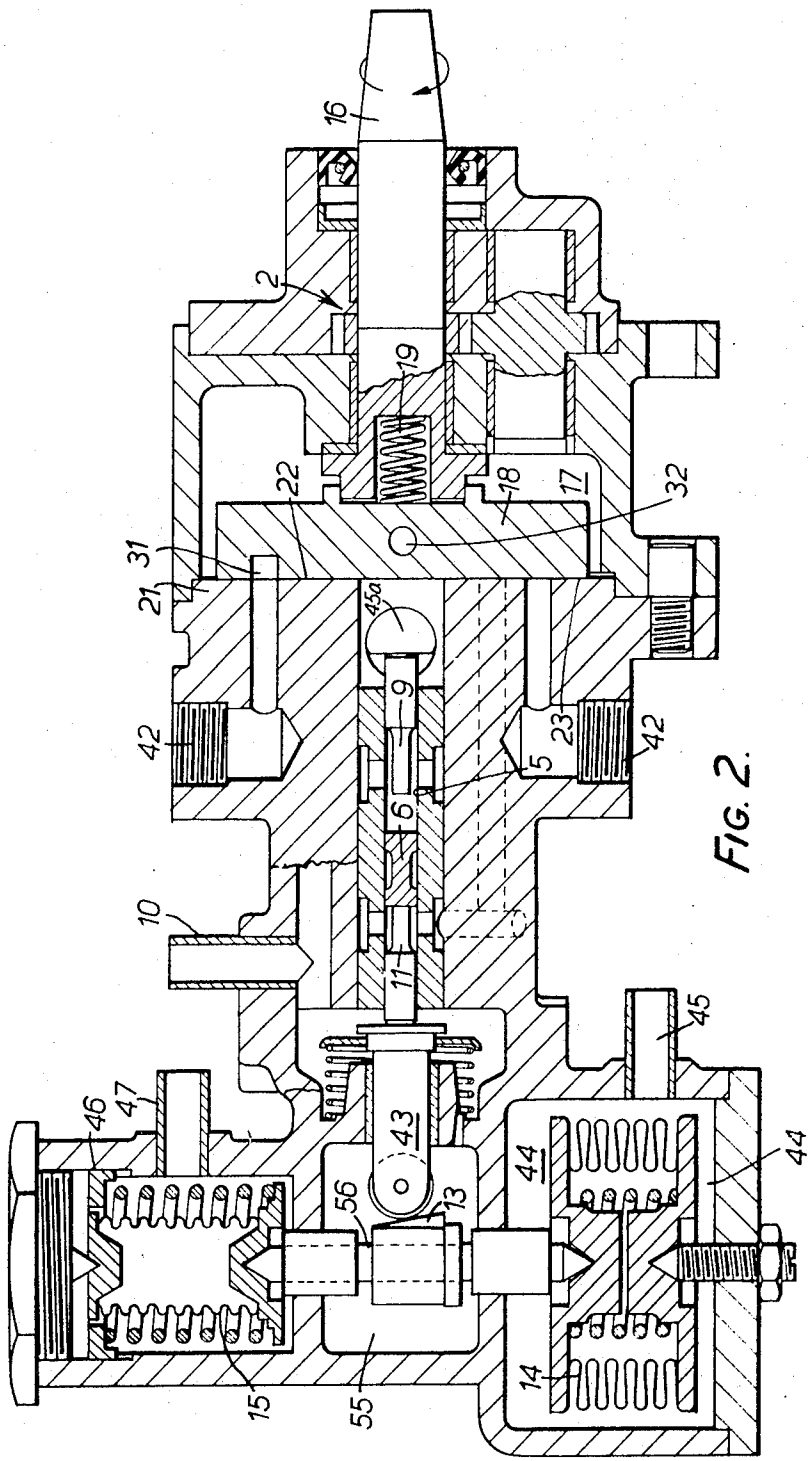


FIG. 2.

INVENTOR
JOHN KAMMERER HARDING
BY
Young & Thompson
ATTORNEYS

FUEL INJECTION SYSTEMS

This invention relates to a fuel-injection apparatus for a multi-cylinder internal combustion engine and more particularly, although not exclusively, it relates to a fuel-injection apparatus for a multi-cylinder spark-ignition internal combustion engine.

In accordance with the present invention a fuel-injection apparatus for a multi-cylinder internal combustion engine comprises a fuel pump, a free piston mounted for reciprocation in a cylinder between stops and defining two variable-volume working spaces, and a face valve adapted to be driven at a speed proportional to engine speed which includes ports for performing a commutating function comprising the successive alternate connection of one working space to the fuel pump delivery and the other working space to the engine fuel supply connection and of the one working space to the engine fuel supply connection and the other working space to the fuel pump delivery and a distributor function in which the engine fuel supply connection is connected to the injectors for the cylinders of the engine in a regularly recurring sequence.

Where the engine is a spark-ignition engine, a control mechanism is provided for the adjustment of one stop in accordance with engine manifold pressure, which pressure in turn will vary in accordance with the adjustment of the engine inlet manifold throttle.

The other stop may be manually adjustable to control the richness of the combustion mixture during starting.

Preferably also a further control mechanism is provided to vary the adjustment of the said one stop in response to exhaust back pressure.

Liquid fuel at pressure delivered by the pump may be arranged to act on the face valve to urge the members thereof into sealing contact one with the other.

One embodiment of the invention will now be particularly described with reference to the accompanying drawings, in which

FIG. 1 is a circuit diagram of the embodiment,

FIG. 2 is a longitudinal cross-section of the fuel-injection apparatus, and

FIGS. 3 and 4 are views of the co-operating surfaces of the face valve incorporated in FIG. 2.

Reference is made initially to FIG. 1. The apparatus is intended for use with a six-cylinder spark-ignition engine. Fuel is drawn from the fuel tank 1 by an engine-driven gear pump 2 and its delivery pressure is controlled by a relief valve 3 which passes excess fuel back to the fuel tank. A restrictor 4 in series with the relief valve 3 ensures that the delivery pressure of the pump 2 will increase with increased engine speed. The fuel delivered from the pump 2 is fed to either end of a cylinder 5 containing a free piston 6 by means of a rotary commutator valve 7. Fuel displaced from the opposite end of cylinder 5 to that fed with liquid is again fed through the rotary valve 7 to a distributor valve 8 which delivers the fuel to the injectors associated with the cylinders of the engine in a regularly recurring sequence.

The travel of the free piston 6 is limited by two stops 9 and 11. The stop 9 is manually adjustable by lever 12 to provide a rich mixture for starting. The stop 11 is restrained by a cam 13 which is moved by two evacuated bellows 14 and 15. The bellows 14 is mounted in a casing and subjected to engine inlet manifold pressure. The bellows 15 is enclosed in another casing and is subjected to engine exhaust back pressure in the engine exhaust manifold. Whilst FIG. 1 shows that both stops 9 and 11 are adjustable it is within the scope of the invention for one of the stops to be fixed and for all adjustments to be effected on the other stop.

The rotary valve 7 and distributor valve 8 are mechanically driven from the engine and the arrangement is such that for every two complete rotations of the engine the free piston will move six times between stops 9 and 11 to displace six discrete quantities of fuel. The distributor valve 8 will direct these six discrete quantities of fuel in correct sequence to the six injectors associated with the cylinders of the engine. The inlet manifold pressure in the engine will be determined by the setting of the engine inlet manifold and also by the ambient atmospheric pressure. Principally the pressure is determined by the setting of the throttle which will then determine the movement applied from the bellows 14 to the cam 13. At the same time the exhaust back pressure acts in a contrary sense to reduce partially the movement given by bellows 14 to the cam 13. The principal function of the bellows 15 is to compensate for the characteristics of different exhaust systems which might be operative on different engines fitted with the illustrated injection system. It is normal that the injectors for the cylinders are arranged in the inlet manifold immediately adjacent to the cylinder inlet valves and the period over which the injection of fuel lasts for any injector is preferably arranged to coincide with the normal induction stroke of each engine piston in its cylinder. In the case of a four- or six-cylinder engine it can be arranged that the delivery of the gear pump 2 is continuously or almost continuously fed to one or other injector.

Reference is now made to FIGS. 2, 3, and 4 of the drawings. These drawings show in practical detail the apparatus embodying the circuit arrangement of FIG. 1. The drive shaft 16 (FIG. 2) protrudes from the right hand end of the apparatus and is driven at half engine speed by a bevel drive from the distributor shaft of the engine, or alternatively it may be driven by a toothed belt from the crank shaft or the cam shaft. Within the body of the device the drive shaft is connected to drive the gear pump 2 which is normally arranged to pump fuel at a rate of about four times the maximum rate at which the engine normally uses fuel thereby providing an adequate excess of fuel for starting. The pump 2 delivers its fuel into a chamber 17 within the device. The pump delivery pressure is controlled by a relief valve (not shown) in FIG. 2 but arranged as described in FIG. 1. The shaft extends to the valve chamber 17 where it is coupled to the rotary valve member 18 of a face valve. The rotary member is loaded by spring 19 and also by fuel pump pressure to engage the static valve face 23 formed on the static member 21. This static member is conveniently a part of a fixed casing of the apparatus. The co-operating surfaces 22 and 23 of the moving and stationary members of the face valve are shown by FIGS. 4 and 3 respectively. The rotating valve member has seven ports opening into its face 22. Six of these ports 24, 25, 26, 27, 28, and 29 lie on the same comparatively small pitch circle and are equidistantly spaced from one another. The remaining port 31 is located on a larger pitch circle. The three ports 24, 26, and 28 pass completely through the member 18 and communicate with the chamber 17. All of the four parts 25, 27, 29, and 31 extend only partially through the member 18 and are internally all connected together by means of passages 32 within the member 18. The stationary face 23 includes two diametrically opposed ports 33 and 34 on the smaller pitch circle and six equally spaced ports 35, 36, 37, 38, 39, and 41 on the larger pitch circle. The two inner ports 33 and 34 are connected by internal passages to the two ends of the metering cylinder 5. The ports 35 to 41 are individually connected to screw-threaded connections 42 in the body of the device from which pipes extend to the injectors in the engine inlet manifold adjacent to the engine inlet valves.

During rotation of the engine and of the drive shaft 16 the pump 2 will pump fuel at pressure into the valve chamber 17. The rotary valve by the co-operation of the ports 24 to 29 and 33 and 34 will feed fuel alternately to the ends of the metering cylinder 5 and will connect the liquid delivered from the metering cylinder 5 to the passage 32 and the member 18 which is then fed to the distributor portion of the valve for distribution to the injectors. The ports on the smaller pitch circle, i.e., the ports 24 to 29 and 33 and 34 together form the commutating portion of the valve and the ports 31, 35 to 41 form the distributing portion of the valve.

The bellows 14 is located in a chamber 44 connected through connection 45 to the inlet manifold of the engine, and the bellows 15 is located in a chamber 46 connected by connection 47 to the exhaust manifold of the engine. The cam 13 is located in a chamber 55 which lies in between chambers 44

and 46, this cam being on a rod 56 which interconnects the two bellows. A cam follower 43 is slidably mounted to be capable of engaging the stop 11. The cam follower 43 engages the cam 13 and the movement of the cam by the two bellows will adjust the follower and the stop 11. Any slight leakage of fuel from the end of cylinder 5 containing stop 11 may be collected and fed through the return connection 10 back to the fuel tank.

The movement of the stop 11 will be proportional to intake manifold absolute pressure less a constant multiplied by exhaust manifold absolute pressure. The correct value of this constant depends on engine design, particularly compression ratio and the exhaust pressure correction of the fuel injection apparatus can be changed by changing the effective area of the bellows 15. Small corrections can also be made by changing the diameter of the rod 56 which connects the two bellows.

By leaving a small amount of gas in the bellows 14 and arranging that some air flows through the bellows chamber 44 to the inlet manifold it is also possible to correct for a change in intake air temperature.

The right hand stop is adjustable by means of a rotary cam 45*a* connected to an adjustable handle (not shown). For the position shown in FIG. 2 stop 9 allows the largest movement of the free piston 6 and thus the greatest displacement of fuel which corresponds to the fuel flow required for starting the engine. For normal running the cam 45*a* is rotated to a predetermined position to urge the stop 9 inwardly into the cylinder 5 to limit the travel of the piston for normal running of the engine.

It is also within the scope of the invention that the stop 9 should be fixed in position and that cam 45*a* or the equivalent should be included within the part 43 so that all control adjustment is effected by adjustment of the stop 11.

The described fuel-injection apparatus may provide very simply for the feeding of fuel to a spark-ignition multi-cylinder internal combustion engine such that under substantially all conditions of operation the correct mixture strength may be obtained depending on the performance required from the engine which may be for example either maximum power output or alternatively maximum economy of operation. Conventional carburetor systems for supplying fuel to a spark-ignition engine cannot give an accurately constant control of mixture strength either to the individual cylinders or to the overall flow of air to the engine. Conventional fuel-injection systems overcome these defects but tend to be complicated and not to correct fully for variations in operating conditions of the engine. The described embodiment in FIG. 2 is simple and compact and can be arranged to give accurate control of mixture strength within the engine particularly by virtue of the fact that control of fuel is in accordance with the absolute values of pressure in the engine inlet manifold and in the exhaust manifold.

Whilst the described invention is particularly intended for use with a multi-cylinder spark-ignition engine it is usable with minor modifications for supplying fuel to the injectors of a compression-ignition engine. With such an engine the constancy of the mixture strength is irrelevant, but the combination of rotary face valve member and free piston metering device forms a compact fuel-injection unit usable with such an engine. Of course the injectors will operate directly into the engine cylinders and the timing of the fuel injection will be accurately controlled in accordance with normal compression-ignition practice.

I claim:

1. A fuel-injection apparatus for a multi-cylinder internal combustion engine having an intake manifold and an exhaust manifold, comprising a fuel pump, a cylinder, stops in the cylinder, a shuttle piston mounted for reciprocation in the cylinder between the stops and defining two variable-volume working spaces, adjusting means for adjustably setting the spacing between the stops, a face valve having a fixed flat face and a rotary valve member adapted to be driven at a speed proportional to engine speed and having a rotary flat face engaging said fixed flat face, the two faces including ports for performing a commutating function comprising the successive alternate connection of one working space to the fuel pump delivery and the other working space to the engine fuel supply connection and of the one working space to the engine fuel supply connection and the other working space to the fuel pump delivery to urge the piston alternately to engage each stop, and a distributor function in which the engine fuel supply connection is connected to the injectors for the cylinders of the engine in a regularly recurring sequence, whereby each injector receives a discrete quantity of fuel when connected to the fuel supply connection depending on the setting of the adjusting means, said pump delivering liquid fuel at the discharge pressure of said pump against said rotary valve member to urge the said flat surfaces into sealing contact with one another, said adjusting means comprising a pair of expansible chambers, a rod disposed between said chambers perpendicular to the direction of movement of said piston, said chambers having movable walls that act on said rod to urge said rod axially, said rod having cam means thereon for adjusting the position of one of said stops relative to said piston, means interconnecting one of said expansible chambers to the engine intake manifold and the other of said expansible chambers to the engine exhaust manifold, said movable walls acting on said rod in such a direction and said cam means being so disposed that an increase in engine intake manifold pressure moves said one stop toward said piston and an increase in engine exhaust manifold pressure moves said one stop away from said piston.

2. A fuel injection apparatus as claimed in claim 1, said movable wall of said chamber communicating with said intake manifold being a movable wall of a closed bellows which is externally exposed to the pressure of the engine intake manifold, said movable wall of the other said chamber being a piston slidable in contact with the side walls of the other said chamber and having a side that acts on said rod and that also is exposed to the exhaust manifold pressure.

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