

[54] FUEL INJECTION APPARATUS FOR INTERNAL COMBUSTION ENGINES

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[51] Int. Cl.² F02M 39/00

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[57]

ABSTRACT

A fuel injection apparatus in which a fuel metering means comprises a metering cylinder and a free metering piston therein movable between adjustable stops, and a commutating and distributing valve having stationary and rotary components having axially presented contact faces formed with commutating ports in an inner annular zone concentric with the axis and distributing ports in an outer annular zone concentric with the axis, a passageway system connecting the commutating ports between a high pressure pump and metering piston spaces on opposite sides of the metering piston, and the passageway system connecting the distributing ports between the metering cylinder spaces and a plurality of fuel outlets, leakage of fuel from one metering cylinder space to the other along the interfacial space between the metering piston and metering cylinder; and leakage of fuel between the commutating ports and the distributing ports along the interfacial space between the contacting components of the commutating and distributing valve being prevented or minimised by provision of grooves in the metering piston and in the stationary component of the commutating and distributing valve, each such groove communicating with a drain duct leading to a reservoir.

1 Claim, 7 Drawing Figures

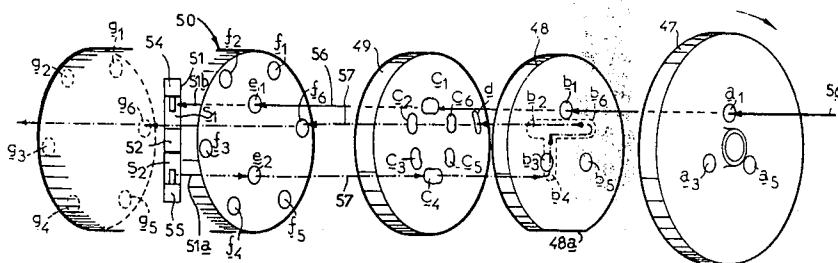


FIG. 1

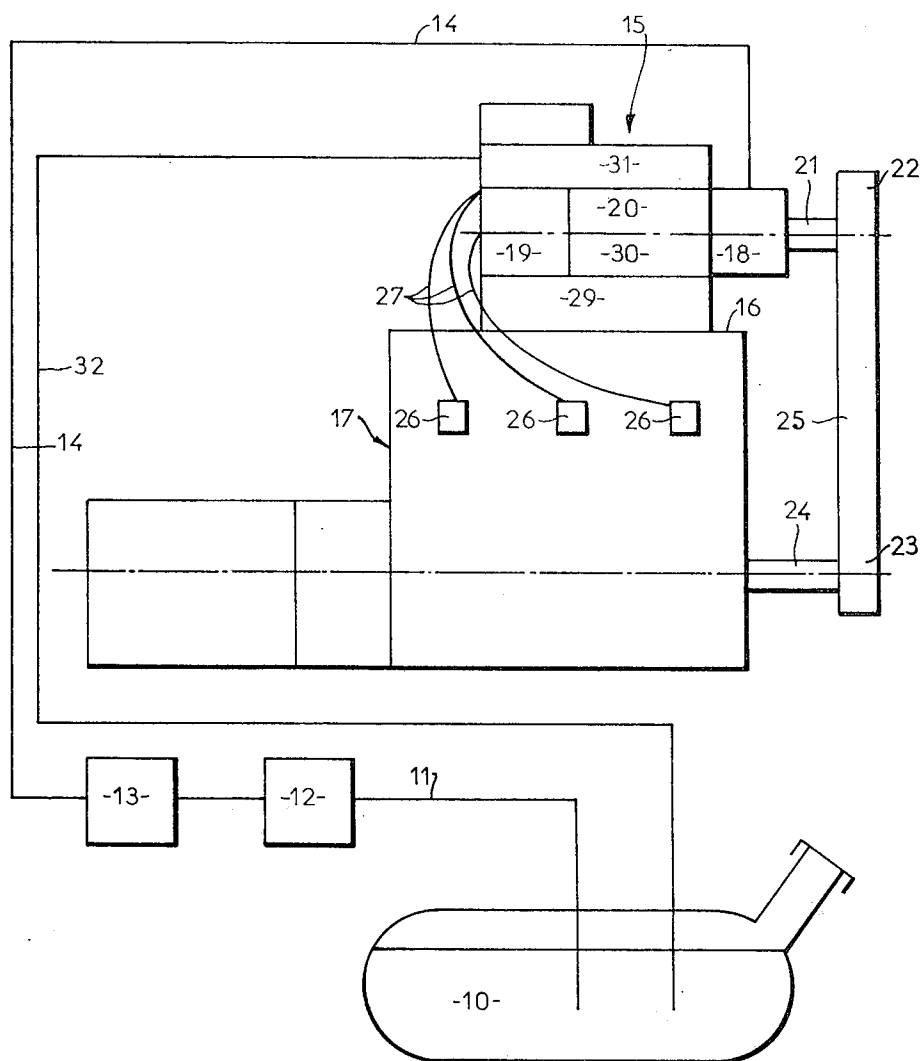
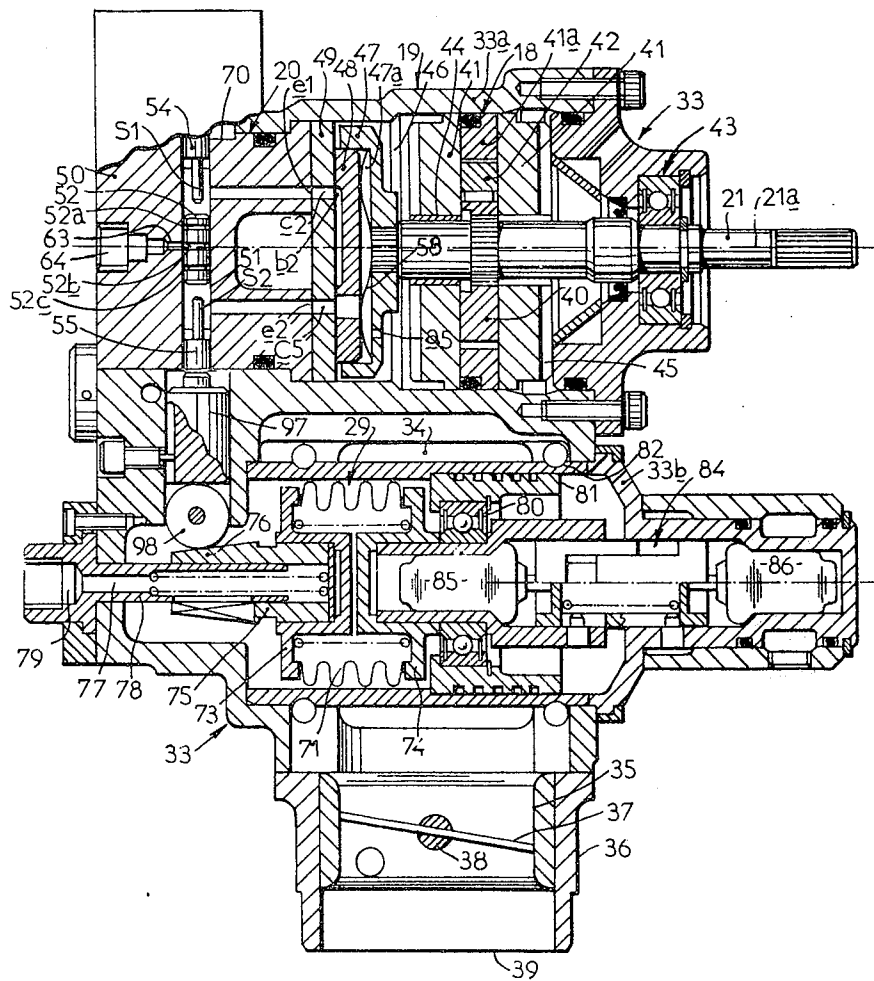
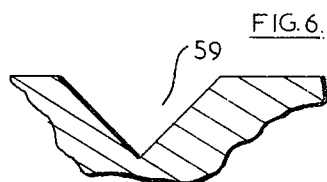
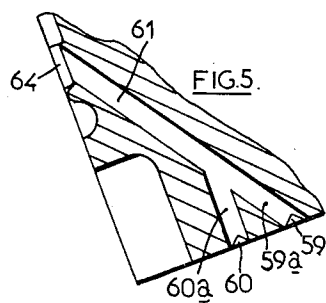
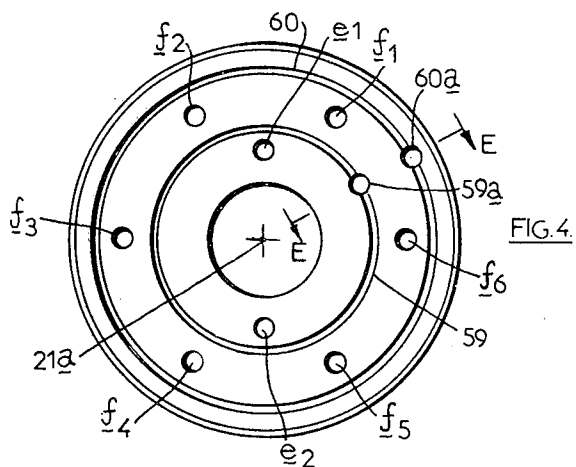
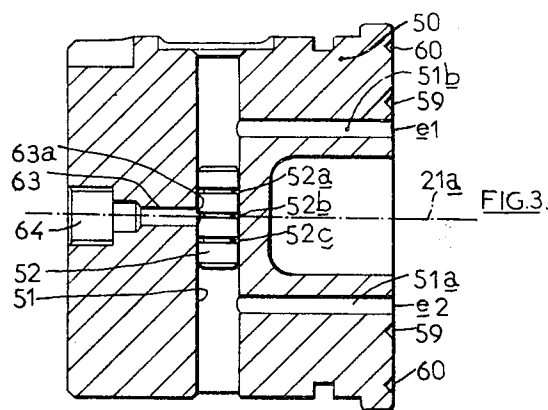
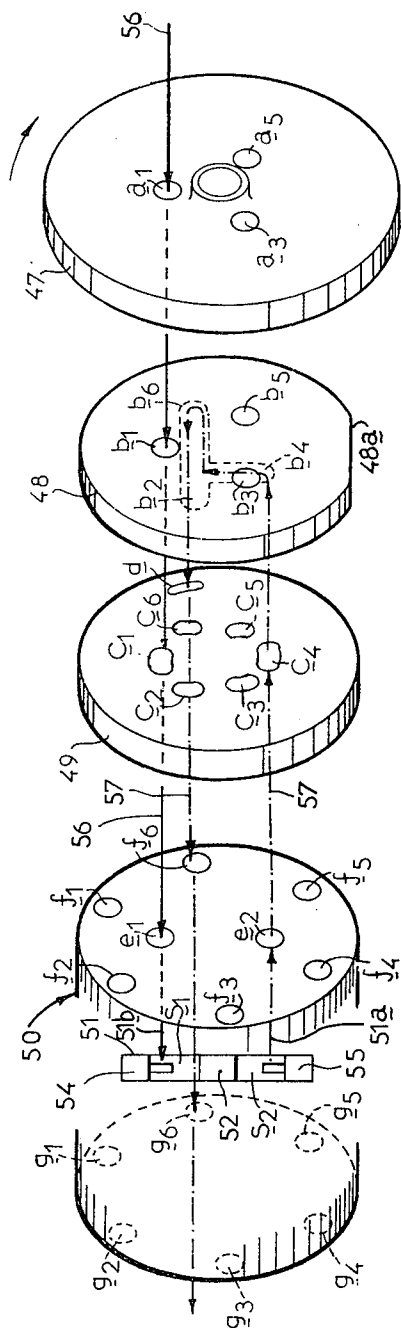


FIG. 2.







FUEL INJECTION APPARATUS FOR INTERNAL COMBUSTION ENGINES

CROSS REFERENCES TO RELATED APPLICATIONS

This application relates to certain improvements in fuel injection apparatus which is the subject of my prior applications Ser. No. 338,680 now U.S. Pat. No. 3,839,998 filed Mar. 5, 1973, Ser. No. 338,681 filed Mar. 5, 1973, Ser. No. 338,682 now U.S. Pat. No. 3,791,589 filed March 5, 1973.

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to fuel injection apparatus for an internal combustion engine, such apparatus incorporating metering means for determining the quantity of fuel delivered in each cycle of operation, which metering means include relatively movable parts having faces in face-to-face sliding contact with each other to define an interfacial space forming a boundary between fuel containing spaces between which the transference of fuel is required to be prevented or minimised. Such apparatus is hereinafter referred to as being of the kind specified.

One form of fuel injection apparatus of the kind specified to which the invention is particularly but not exclusively applicable comprises a fuel pump means for establishing flow of fuel from inlet means to outlet means connected, or adapted for connection, to one or more fuel injectors, metering means operative between the fuel pump means and the outlet means and including firstly a metering cylinder containing a free or shuttle metering piston movable between stops, the distance between which is adjustable to determine the quantity of fuel delivered in each stroke of the free piston, and secondly commutating valve means adapted to be driven in timed relation with the crankshaft or other rotary output member of the engine and which is operative to connect cylinder spaces on opposite sides of the metering piston respectively to the pump means and the outlet means and to reverse such connections for successive injections of fuel respectively, and sensing means controlling the distance between the stops and sensing parameters which are selected to provide a proper air to fuel ratio for a range of engine loads and a range of external conditions of operation.

The invention has been developed in relation to fuel injection apparatus of the kind specified intended for use in connection with an engine having one or more cylinders and having ignition means for igniting the air to fuel mixture in the cylinders by means of spark discharge. The fuel used in such engine is a volatile hydrocarbon such as petrol capable of being so ignited.

In cases where fuel injection apparatus of the kind specified is intended to be used in conjunction with an engine having a plurality of cylinders, the commutating valve means would also be constructed to act as a distributing valve means to effect delivery of fuel from respective outlets in the proper succession.

One of the problems encountered in a fuel injection apparatus of the kind specified is that leakage of the fuel may occur in one or more of the interfacial spaces existing in the metering means, especially having regard to the low viscosity of volatile hydro-carbon fuels,

and if this occurs the accuracy of the metering provided by the metering means, and hence the air to fuel ratio, may depart from a proper value leading to undesirable effects such as loss of power, excessive fuel consumption, atmospheric pollution, or a combination of these effects.

The object of the present invention is to minimise the risk of these undesirable effects occurring.

SUMMARY OF THE INVENTION

Broadly, in a fuel injection apparatus comprising metering means for determining the quantity of fuel delivered in each cycle of operation, which metering means includes relatively movable parts having faces in face-to-face sliding contact with each other to define an interfacial space forming a boundary between fuel containing spaces, the invention provides the improvement comprising means for preventing transference of fuel between said spaces comprising means defining a cavity in at least one of said faces, means defining a drain duct having an entrance communicating with said cavity in at least one position of said relatively movable parts, means for collecting leakage fuel from said drain duct.

Also the invention resides in the provision of a fuel injection apparatus for an internal combustion engine comprising fuel pump means for establishing flow of fuel from an inlet means to an outlet means, metering means operatively interposed between said fuel pump means and said outlet means and including a metering cylinder and a metering piston movable endwise therein between adjustable stop means to determine the quantity of fuel delivered in response to each piston stroke, commutating valve means adapted to be driven in timed relation with a crankshaft or other rotary output member of the engine and defining passageways connecting cylinder spaces in said metering cylinder at opposite sides of said metering piston respectively with said pump means and said outlet means with reversal of such connections for successive injections of fuel by said apparatus respectively, sensing means for controlling said adjustable stop means in response to sensed parameters selected to provide a proper air to fuel ratio for a range of engine loads and external conditions of operation, means for preventing leakage of fuel from one of said metering cylinder spaces to the other of said spaces comprising a cavity defined between the contacting circumferential faces of said metering cylinder and said metering piston, a drain duct communicating with said cavity, a reservoir means for collecting fuel from said drain duct.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described, by way of example, with reference to the accompanying drawings wherein:

FIG. 1 is a schematic diagram illustrating the main components of a fuel supply system of an internal combustion engine, such system incorporating one embodiment of fuel injection apparatus in accordance with the invention;

FIG. 2 is a cross-sectional view through said embodiment of fuel injection apparatus;

FIG. 3 is a view in diametral cross-section of one component of the body of the apparatus incorporating the metering cylinder;

FIG. 4 is a view in end elevation of the component shown in FIG. 3;

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FIG. 5 is a fragmentary view in cross-section on the line E—E of FIG. 4;

FIG. 6 is a fragmentary view in diametral cross-section of the component shown in FIG. 3 and on an enlarged scale;

FIG. 7 is a diagrammatic view explanatory of the manner of operation of the commutating and distributing valve unit incorporated in the apparatus.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A complete system for the supply of fuel and air to an internal combustion engine and incorporating a fuel injection apparatus is shown in FIG. 1. The system comprises a fuel tank 10 connected by a pipe 11 to the inlet of a low pressure pump 13 through the intermediary of a fuel filter 12, and thence by a pipe 14 to the inlet of the fuel injection apparatus which is indicated generally at 15.

The fuel injection apparatus 15 is mounted directly on the inlet manifold 16 of an internal combustion engine 17, the latter being illustrated by way of example as having six cylinders in "V" formation.

The fuel injection apparatus comprises the following main units or sub-assemblies, namely a high pressure pump 18, the inlet of which is connected to the fuel pipe 14, a metering means which includes a commutating and distributing valve unit 19, and metering unit 20. The high pressure pump 18 and the commutating and distributing valve unit 19 are driven at half crankshaft speed by an input shaft 21 through the intermediary of toothed pulleys 22, 23 respectively on the shaft 21 and on a driven shaft 24 of the engine, such pulleys being engaged by an internally toothed belt 25.

Fuel at high pressure from the outlet of the pump 18 is fed through commutating ports of a commutating and distributing valve means 19 to the metering unit 20 and then back to the distributing ports of the valve means 19, passing thereafter to injectors 26 through respective pipe 27 connected to outlets fed from the valve means 19 so that the injectors receive fuel in the required sequence. Only three injectors are seen in FIG. 1, these being mounted in openings in the inlet manifold 16 of the engine 17.

The fuel injection apparatus further comprises a sensing or control means 29 for controlling operation of the metering unit 20 to determine the ratio of air to fuel supplied to the engine. The fuel injection apparatus 15 has an air flow duct through which air can flow to the inlet manifold 16 under the control of a manually operated valve such as a butterfly valve. The term "manually" is of course to be deemed to include foot operation.

The fuel injection apparatus also includes a carburetor start device 30 and a blow-off valve 31 through which excess fuel delivered from the high pressure pump 18 is returned to the tank by way of the pipe 32.

FIG. 2 illustrates one constructional form of fuel injection apparatus as above described in which the main units or sub-assemblies already referred to are designated by reference numerals corresponding to those already applied to FIG. 1.

The body 33 of the fuel injection apparatus comprises an upper part 33a affording an elongated chamber in which is accommodated the high pressure pump 18, the commutating and distributing valve means 19 and the metering unit or assembly 20. The lower part 33b of the body which may be formed integrally with

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the upper part is of generally rectangular box-shape form and affords a chamber 34 which communicates with the passageway 35 in a sleeve-like throttle valve fitting 36 containing a manually controlled butterfly valve plate 37 fixed on a rotatable spindle 38.

The chamber 34 is open at three sides, namely the front and rear sides as seen in FIG. 2 and the lower side, and the fitting 36 can be attached to any of these sides, one remaining opening being closed by a plate and the other connected over the inlet aperture of the inlet manifold of the engine. This arrangement permits of some variation in the manner of mounting the apparatus on any given engine so as best to suit the throttle linkage and to make the best use of the space in the engine compartment for the accommodation of such ancillary parts as an air filter.

The chamber 34 which thus forms part of an air inlet duct extending from the air inlet 39 to the open side of the chamber 34 serves to accommodate the main components of the control means 29 for sensing the parameters of absolute pressure of the inlet air and temperature thereof to control operation of the metering means 20, 19. The parts 33a and 33b of the body may be formed as castings of a light alloy such as an aluminium alloy.

The high pressure pump 18 is of the rotary vane type and comprises a rotor 40 mounted between stator plates 41 spaced apart by a ring 41a having a plurality of radial vanes 42 made of carbon. The rotor is fixed on the drive shaft 21 which is rotatably mounted in a ball bearing 43 at one end and in a bearing 44 on one of the stator plates 41 at its other end. Fuel such as petrol is admitted through the inlet (not shown) to the space 45 and passes through an opening in the adjacent stator plate 41 and after pumping is delivered from an opening (not shown) in the left-hand stator plate 41 so that a supply of fuel under high pressure exists in the space 46.

Before referring to the detailed construction of the metering means, that is the metering piston and cylinder unit or assembly 20 and the commutating and distributing valve means 19, it is convenient to refer to FIG. 7 which illustrates diagrammatically the general arrangement and manner of operation of the metering means.

The commutating and distributing valve means comprises a rotary assembly which includes a rotary carrier 47 fixed to the driving shaft 21 (FIG. 2) and affording a shallow cylindrical recess 47a (FIG. 2) for receiving a rotary valve plate 48, to which is attached a larger diameter rotary valve plate 49. The plate 48 has a flat face 48a at one side engaging a flat face in the carrier 47 to ensure positive drive from the latter to the plates 48, 49 which are cemented or otherwise secured together face-to-face.

The rotary valve plate 49 is maintained by a spring 58 (FIG. 2) in pressure contact with the opposed face of the metering cylinder block 50 in which the metering cylinder 51 extends transversely to the axis of rotation of the rotary valve plates.

The cylinder 51 contains a free or shuttle piston 52 which is movable between stops 54 and 55. The metering cylinder block has outlets g1 to g6 for connection to respective pipes 27 leading to the injectors 26 (FIG. 1), these outlets being connected by way of passageways extending axially through the block with ports f1 to f6 respectively, these ports being traversed in succession by a port d in the rotary valve plate 49 thereby acting as

a distributing means.

The function of ports *e1*, *e2* in the block 50, and which are connected by passageways 51*a*, 51*b* to the cylinder spaces *S1*, *S2* above and below the piston 52 respectively is to operate in combination with ports *c1* to *c6* in plate 49 and with ports *b1*, *b3*, *b5* in plate 48 together with a T-shaped surface passageway formed in the left-hand face but not extending through the thickness of the plate 48, and having branches *b2*, *b4*, *b6*, as a commutating means to produce one stroke of the piston 52 from its upper limit to its lower limit or vice versa for each traversing of a port *f1* to *f6* by the port *d*, and thereby deliver a measured quantity of fuel (dependent upon the length of the stroke of the piston 52) to the outlet *g1* to *g6* concerned.

The full line arrows 56 illustrate the flow of fuel into the upper cylinder space *s1* of cylinder 51 during the down stroke of the piston 52 which is effective to expel fuel as shown by the broken line arrows 57 from the lower cylinder space *s2* and deliver it from the outlet *g6*.

It will be evident that fuel from the high pressure pump traverses the ports *a1*, *b1*, *c1*, *e1* to reach cylinder space *s1*. Fuel from the cylinder space *s2* traverses the ports *e2*, *c4*, limb *b4*, limb *b6*, port *d*, *f6* and outlet *g6*. When the driving shaft has rotated through a further 60° (corresponding to an engine crankshaft rotation of 120°), fuel from the high pressure pump will traverse ports *a5*, *b5*, *c5* (then in the lowermost position), *e2* to reach cylinder space *s2*. Fuel in cylinder space *s1* will be delivered through port *e1*, *c2*, limb *b2* (then in the topmost position), limb *b6*, port *d*, *f5* and outlet *g5*. This position is shown in FIG. 2. Similarly, after the next 60° of rotation, another fluid flow path will be established causing movement of the piston 52 in the opposite direction and delivering a measured quantity of fuel from the next outlet *g4* and so on.

The spring 58 (FIG. 2) reacting between the inner or bottom face of the recess 47*a* in the carrier plate 47 and the smaller diameter rotary plate 48 urges the plates 48, 49 into contact with the ported face of the metering cylinder block 50. At least the plate 49 is made of a material which provides good sealing properties with respect to the face of the cylinder block 50 and of a material which will have a suitably long service life. In practice both plates 48, 49 may be made of carbon, whereas the block 50 may be made of steel.

It is important to reduce leakage in the interfacial space between the ported face of the cylinder block 50 and the opposing face of the plate 49 (such space being of minute axial dimensions) because such leakage can result in some of the measured quantity of fuel intended to be delivered to a particular port *f1* to *f6* reaching another one of these ports.

To minimise this leakage the ported face of the valve block 50 is formed with cavities in the form of grooves as seen more particularly in FIGS. 3 to 6. These grooves are connected by way of drain passageways to an outlet 64 through which any leakage of fluid can drain back to a reservoir such as the tank 10. For example, the pipe 32 shown in FIG. 1 may be used for this purpose.

It will be noted from FIG. 4 that two grooves are provided, these being concentric with the axis 21*a* of the shaft 21. One such groove 59 lies between the two annular zones occupied by ports *e1*, *e2* and ports *f1* to *f6* respectively, while the other groove 60 lies out-

wardly of the annular zone occupied by the ports *f1* to *f6*.

The drain passageway leading from the groove 59 is indicated at 59*a* and that leading from the groove 60 at 60*a*, these join each other to form a common drain passageway 61 having an outlet 64 which may be connected by a pipe 32 to a reservoir such as tank 10.

Both grooves 59, 60 may be of identical dimensions in cross-section and may be V shaped as seen more particularly in FIG. 6 illustrating the groove 59.

A further interfacial space across which it is important to prevent leakage is that defined by the outer surface of the piston 52 and the inner surface of the cylinder 51.

Leakage of fluid in this interspace would allow fuel to be transferred from space *s1* to space *s2* and vice versa and would thus interfere with the accuracy of the measured quantity delivered in each stroke of the piston.

Accordingly the surface of the piston is formed with at least one, and preferably a series, of longitudinally spaced circumferentially extending grooves as indicated at 52*a*, 52*b*, 52*c*. These are traversed past the entrance 63*a* to a drain passageway 63 extending to the outlet 64.

The establishment of a low pressure zone in the locality of each of the grooves 59, 60, 52*a* to 52*c* prevents any liquid leaking from a high pressure space reacting to a lower pressure space and interfering with the quantitative accuracy of the fuel contained in a low pressure space. Any leakage of fuel takes place from the high pressure space to the drain duct and reservoir. Since, in general, the high pressure space is connected to the source of high pressure fuel delivered by the pump, the leakage to the drain duct and reservoir will be made good and the quantitative accuracy of the fuel contained in the high pressure space will not be diminished.

It will be evident from the foregoing description that the space between the upper and lower stops 54 and 55 determines the stroke of the piston 52 and hence the quantity of fuel delivered in each stroke. The lower stop 55 is positionally controlled by the control means 29.

This means is designated to sense the parameter of absolute pressure of air in part of the inlet duct, i.e. the chamber 34, the temperature of the air in this chamber and other temperature parameters as hereinafter referred to. The control means comprises an axially expansible and contractable bellows 71 which is evacuated internally. The bellows comprises a corrugated flexible side wall and rigid end plates 73, 74, the former of which is fixed to the bush portion 75 of a cam element 76. The cam element 76 is of generally frusto-conical form with its frusto-conical face eccentric to the axis 77 about which the cam element can rotate. The cam element is mounted for this purpose on a hollow spindle 78 which is open internally to the atmosphere of an inlet 79.

The other end plate 74 of the bellows is mounted rotatably through a sealed bearing 80 in the interior of an accelerator piston 81 movable axially in cylinder 82.

The end plate 74 is axially and rotationally fixed on a sleeve 83, such sleeve 83 forming the output element of an adding mechanism indicated generally at 84 which serves to add the parameters of temperature sensed by a sensing element 85 in respect of the air in the chamber 34 and temperature sensed by an element 86, this

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latter being the temperature applied to the element 86 from means disposed in an annular chamber 87.

It will be evident that owing to the configuration of the cam 76, the position of the lower stop 55 which is adjusted through the intermediary of a tappet 97 having a roller 98 bearing on the cam is varied, both in response to axial movement of the cam and rotation of the cam, the former occurring in response to pressure variations sensed by the bellows, and the latter by rotation produced by either the temperature sensing element 85 or the temperature element 86, or both in combination.

I claim:

1. In fuel injection apparatus for an internal combustion engine, such apparatus incorporating metering means for determining the quantity of fuel delivered in each cycle of operation, which metering means includes a metering piston and a metering cylinder having faces in face-to-face sliding contact with each other, and commutating valve means having stationary and rotary components of which the latter is adapted to be driven in timed relation with the crankshaft or other

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rotary output member of the engine, and which are in combination operative to define connections between cylinder spaces in said metering cylinder on opposite sides of said metering piston respectively to a pump means for said fuel and an outlet means with reversal of such connections for successive injections of fuel, the improvement being the provision of means for preventing transference of fuel between opposite sides of said metering piston, comprising:

- a. At least one groove formed in the circumferential face of same metering piston,
- b. Means defining a drain duct extending through a body portion of said metering cylinder,
- c. Said drain duct having an entrance positioned intermediate the limits of travel of said groove resulting from reciprocation of said metering piston, whereby in each stroke of the latter said groove moves past said entrance,
- d. Means for collecting leakage fuel from said drain duct.

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