

[54] **FUEL INJECTION APPARATUS FOR
INTERNAL COMBUSTION ENGINES**[75] Inventor: **Brian Colin Pagdin**, Sutton
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Birmingham, England[22] Filed: **Jan. 31, 1974**[21] Appl. No.: **438,354**[30] **Foreign Application Priority Data**

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[51] Int. Cl.²..... F02D 1/04; F02D 1/06

[58] Field of Search ... 123/140 MC, 140 CC, 179 L

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[57] **ABSTRACT**

A fuel injection apparatus in which the setting of a metering means is controlled by a conical cam movable axially and rotationally respectively by an evacuated bellows sensing absolute air pressure in an inlet duct of the apparatus and by the rotational output element of an addition mechanism receiving mechanical inputs from two temperature sensing elements, one sensing the temperature of the inlet air and the other sensing a further selected temperature parameter, the addition mechanism comprising two sleeves which are rotationally coupled but relatively axially slidable in response to inputs from the temperature sensing elements, one sleeve being connected to the body of the apparatus through a helical slot and pin connection, and the other sleeve being connected to an output element for rotating the bellows through a helical slot and pin connection.

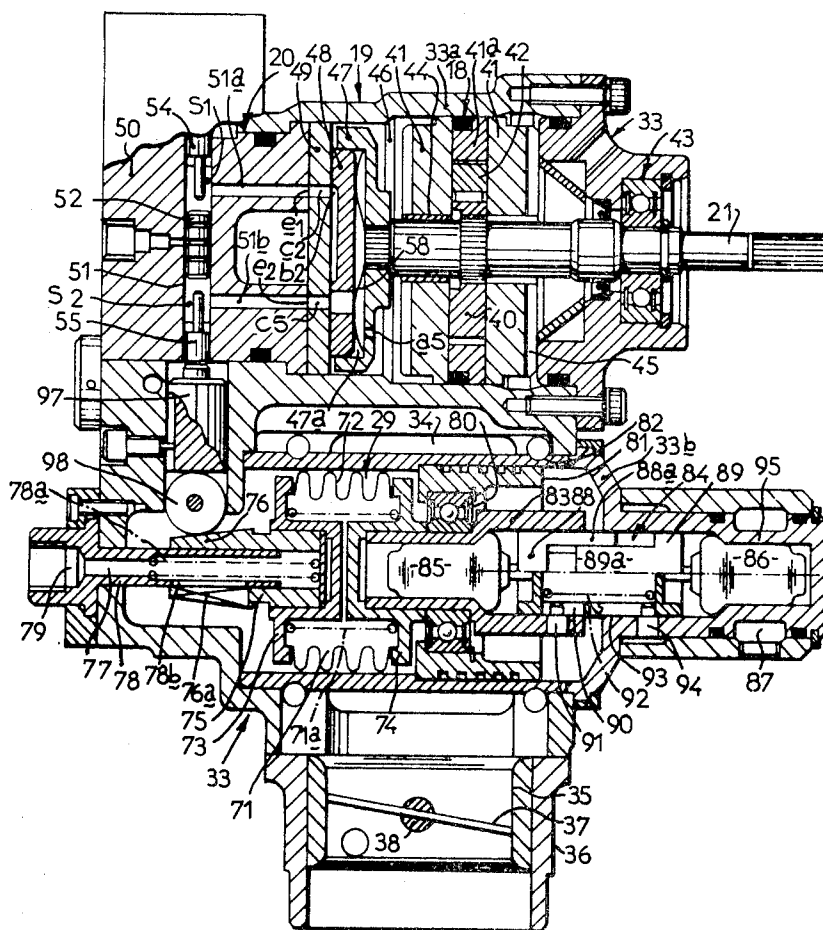
2 Claims, 5 Drawing Figures

FIG. 1.

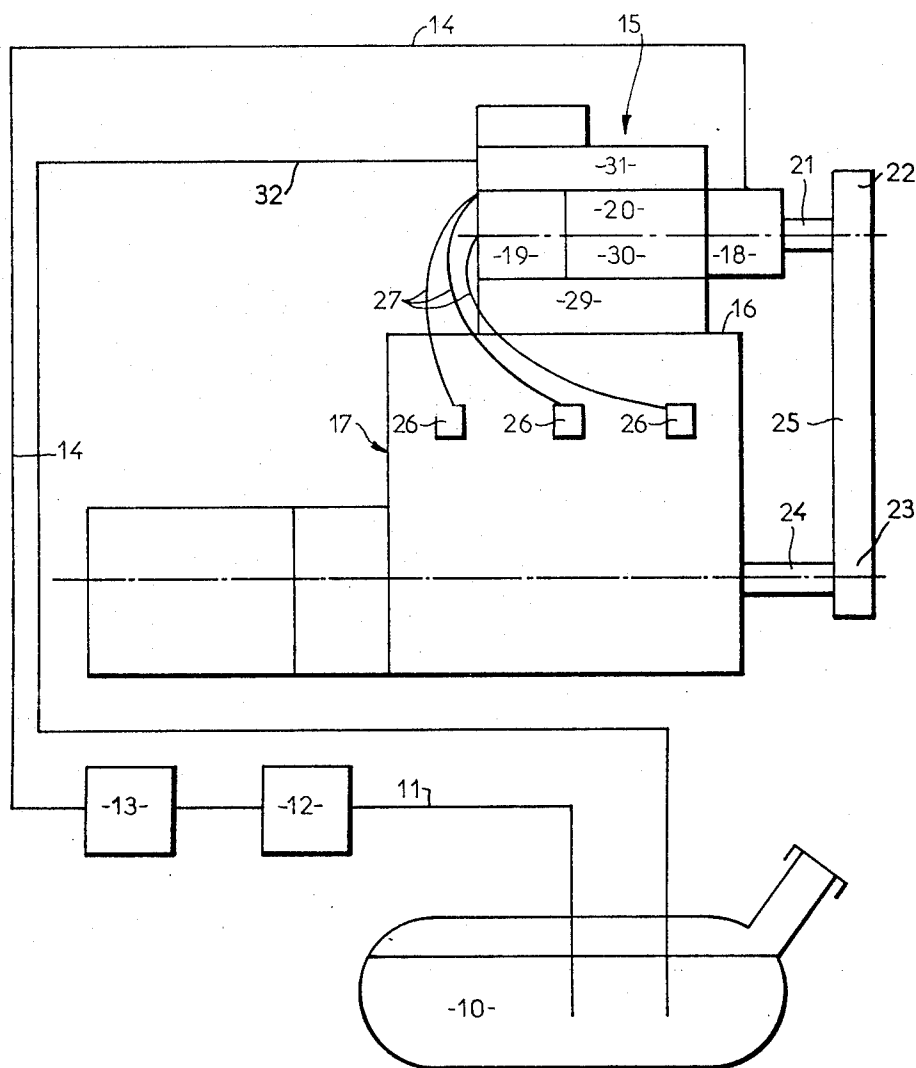


FIG. 2

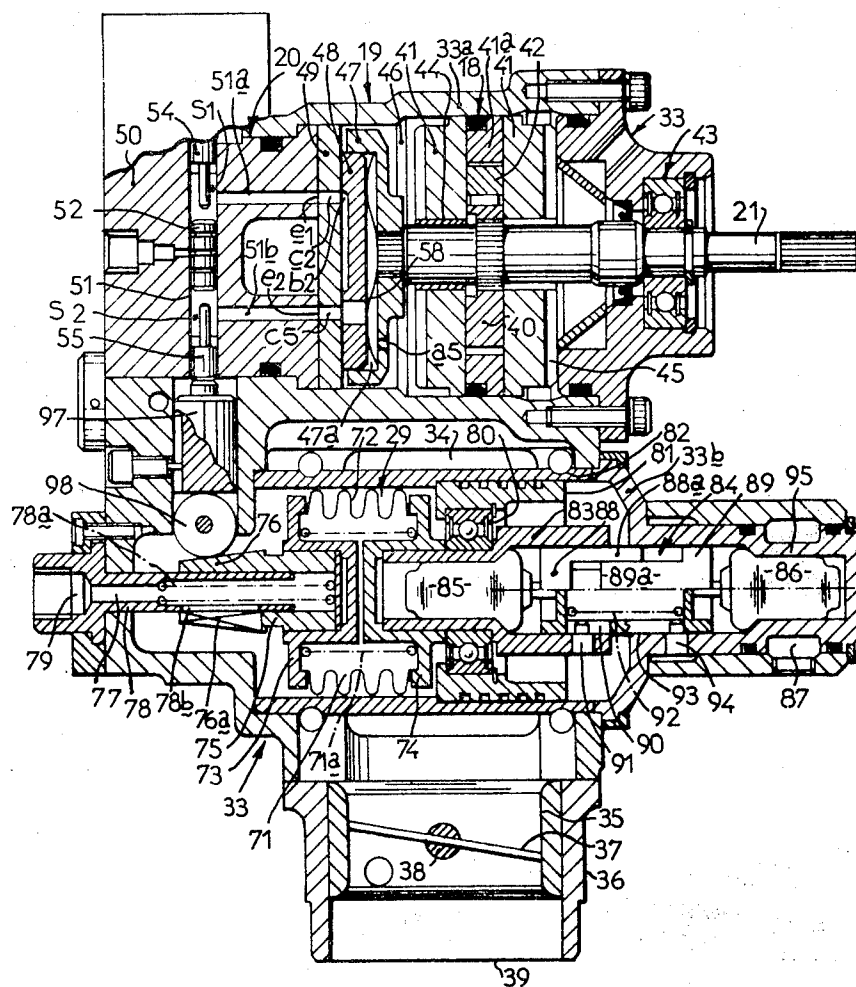
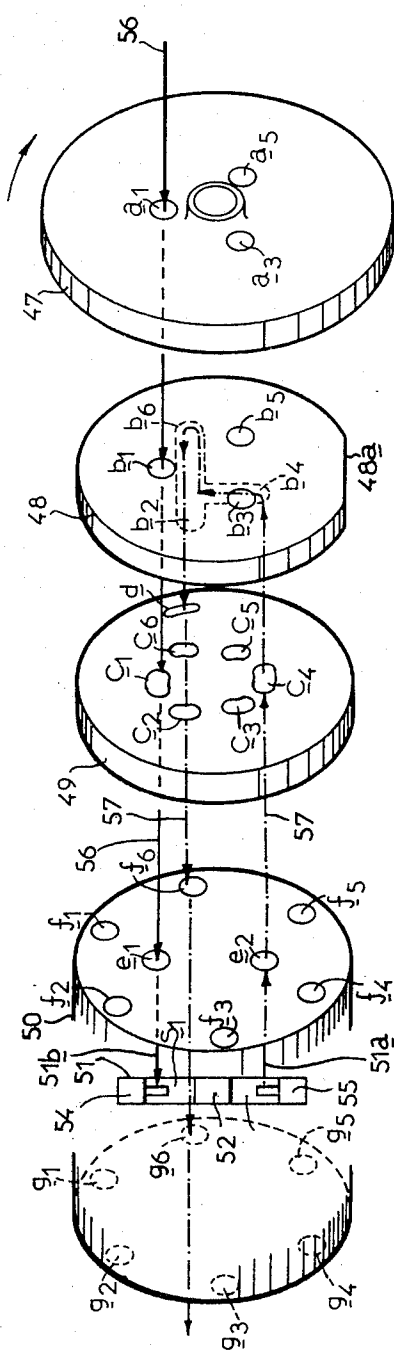
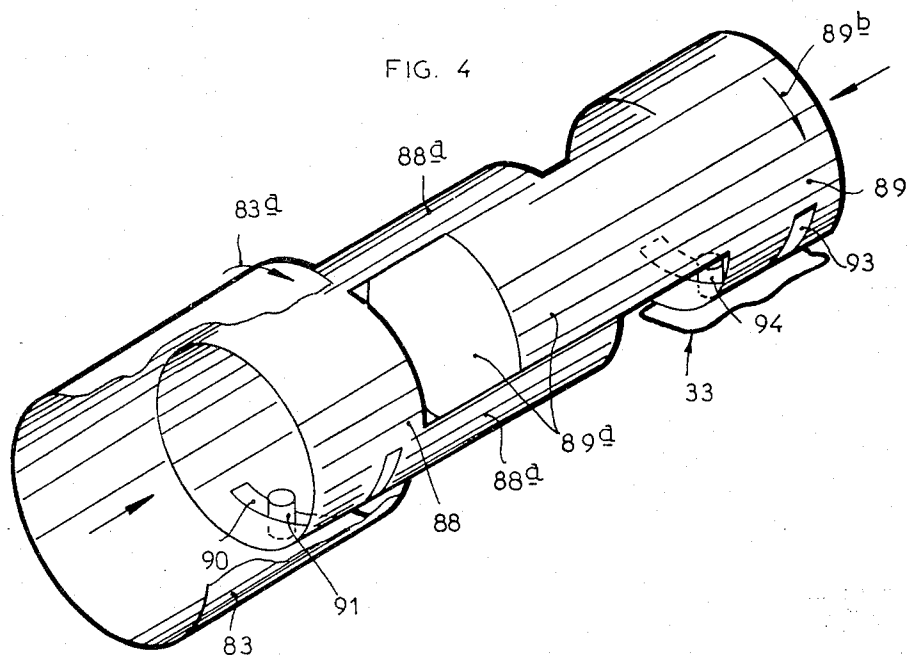
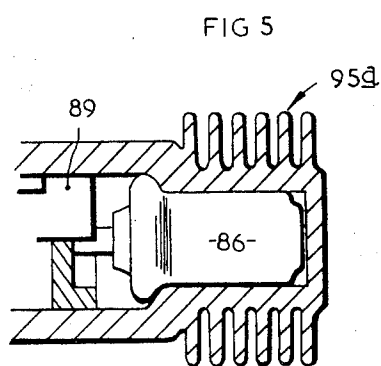


FIG. 3.





FUEL INJECTION APPARATUS FOR INTERNAL COMBUSTION ENGINES

CROSS REFERENCES TO RELATED APPLICATIONS

This invention relates to certain improvements in fuel injection apparatus for internal combustion engines as disclosed in my application Ser. No. 338,680 filed Mar. 5, 1973, now U.S. Pat. No. 3,839,998, Ser. No. 338,681 filed Mar. 5, 1973, Ser. No. 338,682 filed Mar. 5, 1973, now U.S. Pat. No. 3,791,589.

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to fuel injection apparatus (herein referred to as being of the kind specified) for an internal combustion engine, the apparatus comprising a fuel pump means for establishing flow of fuel to an outlet means connected, or adapted for connection, to one or more fuel injectors, metering means operative between the pump means and the outlet means and adapted to be driven in timed relation with the crankshaft or other rotary output member of the engine for delivering a measured quantity of fuel to the outlet means in each cycle of operation of the engine, and sensing means controlling operation of the metering means 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 a fuel injection apparatus of the kind specified intended for use in conjunction with an engine having one or more cylinders, and having ignition means for igniting the air-fuel mixture in the cylinder or cylinders by means of spark discharge. The fuel is a volatile hydrocarbon such as petrol capable of being so ignited.

In order to effect accurate control of the air to fuel ratio, more than one parameter requires to be sensed by the sensing means.

These parameters cannot always, however, conveniently be sensed by a single sensing element providing a mechanical output (either a force or a displacement, or a combination of these phenomena) for controlling operation of the metering means.

The principal object of the present invention is to provide a means for combining the outputs of a plurality of sensing elements for application to the metering means whereby the problem referred to above or analogous problems may be overcome or reduced.

SUMMARY OF THE INVENTION

According to the present invention a fuel injection apparatus of the kind specified is provided with a sensing means which comprises a plurality of sensing elements each providing a mechanical output, mechanical addition means having input elements corresponding in number to the number of said sensing elements, an output element, and means for algebraically adding displacements imparted to said input elements and applying the resultant to said output element, said sensing elements being operatively connected with respective ones of said input elements, said output element being operatively connected with said metering means.

One of the sensing elements may be a temperature sensing element mounted at a position to partake of the inlet air temperature, and the other may be a further temperature sensing element subjected to one or more

temperature signals representing a further temperature parameter or parameters to be sensed.

In a preferred arrangement the addition mechanism comprises elements movable relatively to each other lengthwise of an axis, means coupling said elements to each other for rotation in unison about said axis while being free to move relatively slidably lengthwise of said axis, means for generating an increment of rotation in response to movement of each of said elements lengthwise of said axis, means for connecting one of said elements to said body and the other of said elements to said metering means whereby the algebraic sum of said increments of rotation are transmitted to said metering means.

One convenient form of sensing element which may be employed for sensing an air pressure parameter is an expansible evacuated bellows. The accuracy of the output therefrom depends upon a spring having an accurately selected rate, which spring conveniently is mounted within the bellows itself to assist expansion thereof as the magnitude of the external air pressure undergoes a reduction. Since such spring cannot readily be adjusted or exchanged when once the bellows has been adjusted, a further feature of the invention is the provision of a spring means for assisting expansion of the bellows including a spring mounted externally of the bellows. Such externally mounted spring may oppose the action of the internally mounted spring, the latter being stronger than the former but the former being capable of adjustment or exchange to achieve accurate selection of the overall spring characteristic.

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 diagrammatic view explanatory of the manner of operation of the commutating and distributing valve unit incorporated in the apparatus;

FIG. 4 is a diagrammatic view explanatory of the manner of operation of the addition mechanism for adding outputs of the two temperature sensing elements incorporated in the sensing means;

FIG. 5 is a fragmentary view in side elevation vertical cross-section showing a modification of the embodiment of FIG. 2.

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 a 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 carburettor 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 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 aluminum 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 an 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. 3 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 distribution means.

The function of ports e1, e2 in the block 50, and which are connected by passageways 51a, 51b 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 *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 will be evident from the foregoing description that the spacing 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 control means 29 is designed 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 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.

The bellows tends to be expanded by an internal spring 71*a* reacting against a spring 78*a* disposed in the spindle 78. It is required to maintain high accuracy as to the value of the ratio of axial travel of the cam to absolute pressure. Since the wall 72 of the bellows has some resilience and the spring 71*a* cannot readily be changed or adjusted once it has been inserted into the bellows, selection of the effective spring rate produced by the combination of springs 71*a*, 78*a* is achieved by selecting the latter.

The accelerator piston 81 is urged to the left by a spring 92 but is movable to the right in response to a sudden increase of pressure in the chamber 34, thereby resulting in a bodily shift of the bellows to the right. This will occur when the throttle valve is suddenly opened and will momentarily enrich the mixture by lowering the stop 55 and lengthening the stroke of the piston 52. The piston is restored gradually to its initial position as shown in FIG. 2 by leakage past the piston and through the sealed bearing, the sealing means of which is not absolutely impermeable.

The temperature sensing elements 85 and 86 may be of the wax capsule type such as are commonly employed in engine cooling systems for controlling the flow of fluid, each comprising an axially expansible chamber containing a substance, for example a wax, selected to undergo a vapour pressure change at a predetermined temperature or over a narrow range of temperatures, thereby producing marked axial expansion of the capsule. Mounting portions of the elements 85, 86 are supported respectively in the sleeve 83 and housing 95 while the end faces which constitute the output portions engage the ends of the addition mechanism.

The addition mechanism 84 serves to add algebraically when outputs of the elements 85 and 86 comprises two axially interfitted sleeves 88 and 89, each of which has two diametrically opposed slots extending over a quarter of the circumference of the sleeve leaving a pair of axially projecting part-cylindrical arms such as 88*a* and 89*a*, with the arms of one sleeve fitting axially slidably in the slots of the other sleeve so that the two sleeves are capable of relative axial movement but are in driving relation with each other rotationally.

The sleeve 88 which is displaceable axially by the temperature sensing element 85 has a helical slot 90 in which engages a radial pin 91 projecting radially inwardly of, and fixed to, the output sleeve 83.

The two sleeves 88 and 89 are urged apart by a coiled compression spring 92 so that each is kept in contact with the output portion of its respective temperature sensing element 85 and 86.

The sleeve 89 also has a helical slot 93 in which engages a radially inwardly projecting pin 94 fixed to the body of the apparatus.

As will be evident from the diagrammatic drawing of FIG. 4, temperature sensing element 85 thus produces axial movement of sleeve 88 which is held by sleeve 89 and pin 94 against rotation, the helical slot 90 reacting against pin 91 and produces rotation of the output sleeve 83 in a clockwise direction indicated by arrow 83*a* (FIG. 4).

Expansion of temperature sensing element 86 produces axial movement of sleeve 89 which by reaction of slot 93 against pin 94 also rotates clockwise as shown by arrow 89*b* and drives sleeves 88 and 83 in the same direction of rotation.

Such rotation is transmitted through the bellows 71 to the cam 76 thereby adjusting the position of the lower stop 55 and controlling the stroke of the piston 52.

The temperature parameter applied to the element 86 may be the temperature of the cooling fluid of the engine, in which case it may conveniently be passed through the cavity 87. Alternatively, the chamber containing the cavity 87 may be omitted and the housing 95a which accommodates the temperature sensing element 86 may be finned externally to partake of the temperature of the compartment in which the engine is installed, as seen in FIG. 5.

Alternatively the temperature parameter may be derived from burning combustible constituents of the exhaust of the engine and transmitted to the element 86 either directly by mounting this to project into the combustion chamber in which such burning takes place, or transmitted as a heat signal through electrical means.

It would be possible to arrange for the element 86 to sense more than one temperature parameter.

To prevent stalling when the engine is idling in the cold condition, the hollow spindle 78 and the cam 76 may be provided with axially extending slots 78a, 76a which register or overlap with each other when the bellows and cam occupy a rotational position corresponding to a cold condition in respect of the temperature sensing element 86 thereby admitting a supply of air to chamber 34. When 86 attains a working temperature in consequence of the temperature parameter in which it is subjected, the slots move (rotationally) out of registration with each other and consequently the additional supply of air can then no longer be admitted through the interior of the spindle 78 and the slots. Such additional supply of air raises the absolute pressure in the chamber 34 (without corresponding opening of the throttle valve) and, therefore, produces axial movement of the cam to the right and lowering of the stop 55.

I claim:

1. In fuel injection apparatus for an internal combustion engine such apparatus comprising a body affording an air inlet duct, a fuel pump means for establishing flow of fuel to an outlet means, the outlet means being connected or adapted for connection to one or more fuel injectors, metering means operative between the pump and the outlet means and adapted to be driven in

timed relation with the crankshaft or other rotary output member of the engine for delivering a measured quantity of fuel to the outlet means in each cycle of operation of the engine, and sensing means for controlling operation of the metering means and sensing parameters selected to provide a proper air to fuel ratio for a range of engine loads and a range of external conditions of operation, such sensing means comprising a plurality of sensing elements each providing a mechanical output, and mechanical addition means having input elements corresponding in number to the said sensing elements, an output element, and means for algebraically adding displacements imparted to said input elements and applying the resultant to the said output element, the improvement wherein said mechanical addition means comprises:

- a. sleeves movable relatively to each other lengthwise of an axis, each sleeve having an axially extending slot slidably receiving an axially extending limb of the other sleeve for coupling said elements to each other for rotation in unison about said axis
 - b. means for generating an increment of rotation in response to movement of each of said sleeves lengthwise of said axis
 - c. means for connecting one of said sleeves to said body and the other said sleeve to said metering means whereby the algebraic sum of said increments of rotation is transmitted to said metering means
 - d. each of said sensing elements comprising a mounting part and a output part movable relatively to the mounting part lengthwise of said axis with said output part associated operatively with a respective one of said sleeves.
2. The improvement according to claim 1 wherein:
- a. The means for generating said increment of rotation in response to axial displacement of one of said sleeves comprises means for establishing a helical slot and pin connection between said sleeve and said body,
 - b. The means for generating said increment of rotation in response to axial displacement of the other of said sleeves comprises means for establishing helical slot and pin connection between said sleeve and the output element rotatable about said axis and operatively connected to said metering means.

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