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[54] REGULATOR MECHANISM FOR FUEL INJECTION APPARATUS

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[51] **Int. Cl.** **F02m 69/04**

[58] **Field of Search** .... 123/119 R, 139 AW, 123/139 BG, 140 CC; 261/50 A, 50 AA, 39 A

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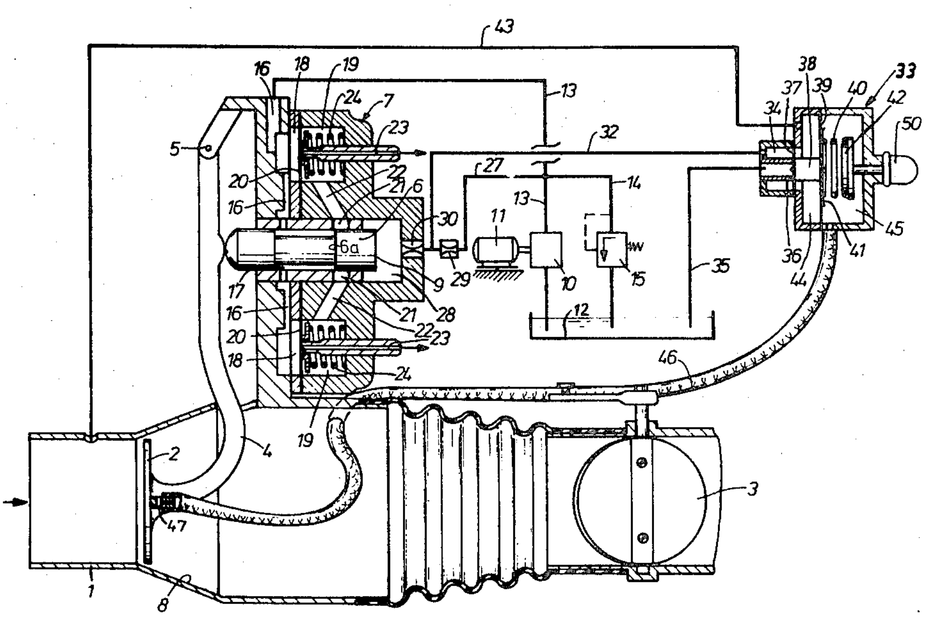
[57] **ABSTRACT**

In a fuel injection apparatus there is provided an air sensor which, as a function of the intake air quantities flowing through the suction tube causes movement of a fuel metering or control plunger. The return force exerted on the air sensor and opposing the force of the air flow is supplied by fuel pressure that is variable by a valve which is set by the interaction of the following forces: the difference between the air pressure upstream and downstream of the air sensor, the fuel tank counterpressure and a spring, the force of which is changeable as a function of engine variables.

9 Claims, 4 Drawing Figures



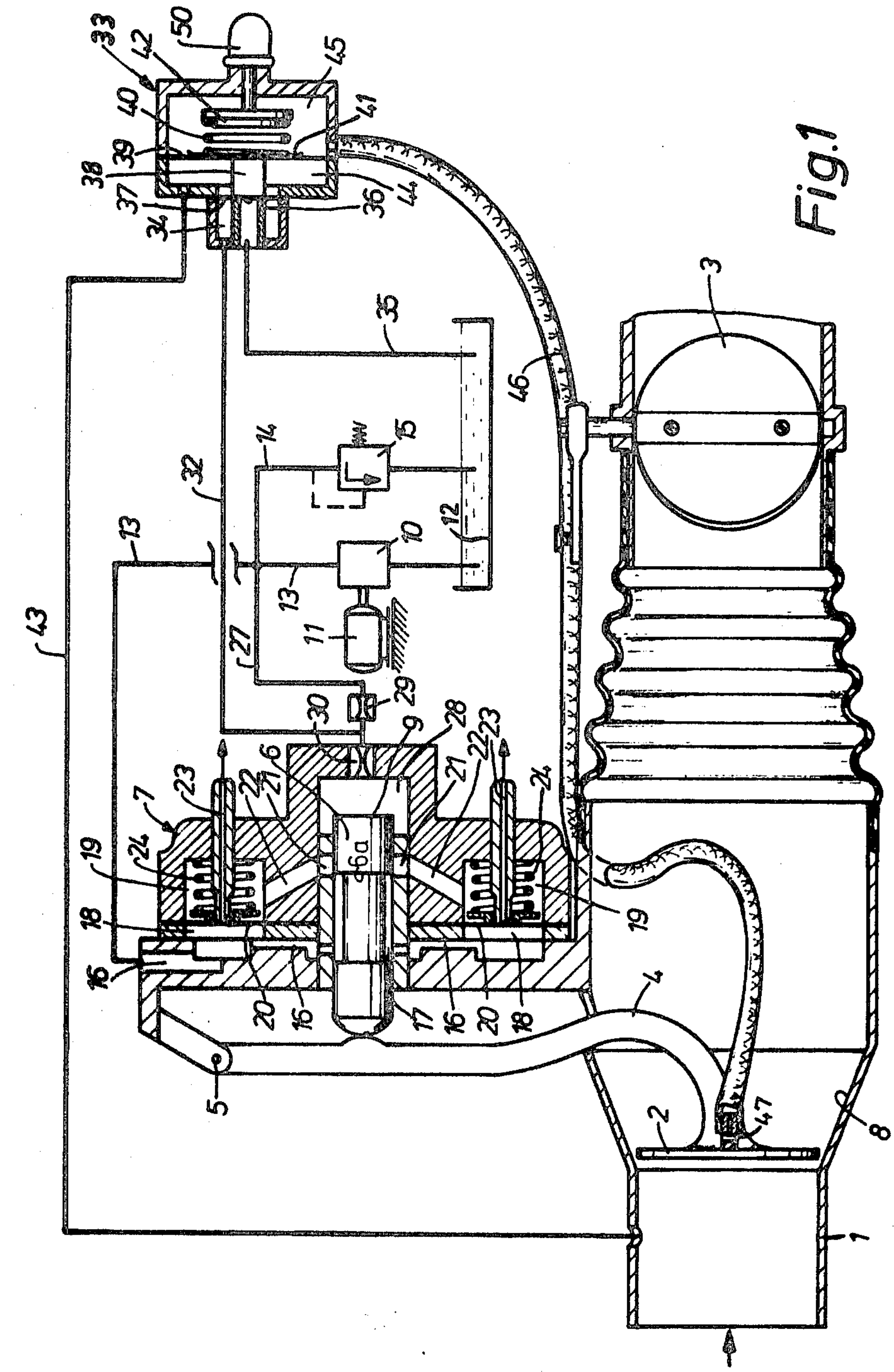


Fig.1

Fig.2

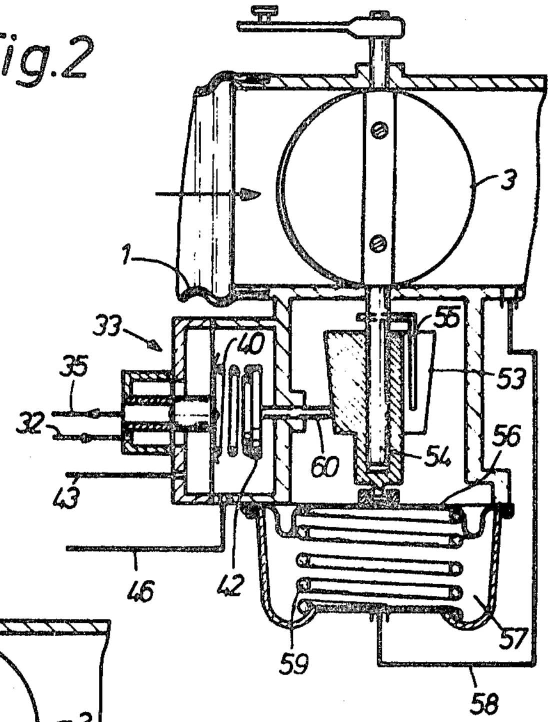


Fig.3

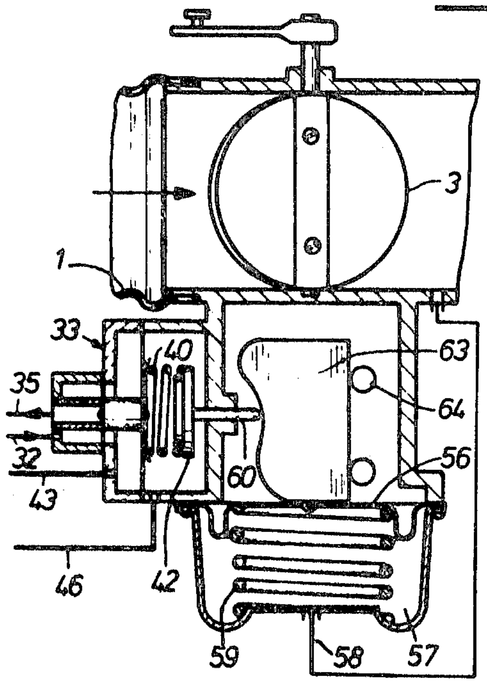
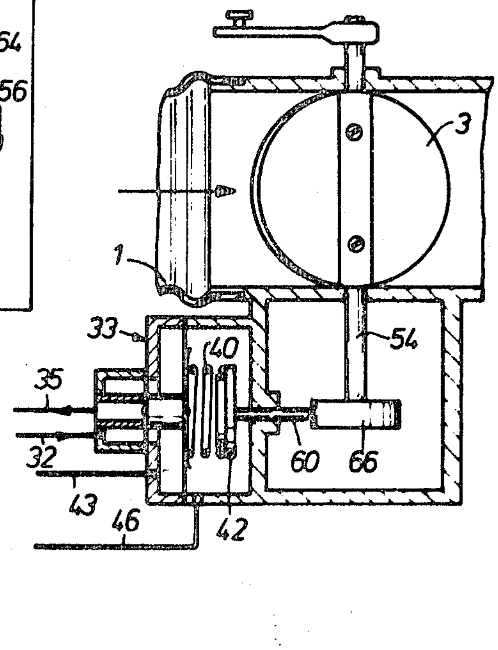


Fig.4



REGULATOR MECHANISM FOR FUEL INJECTION APPARATUS

BACKGROUND OF THE INVENTION

This invention relates to a regulator mechanism incorporated in a fuel injection apparatus which injects fuel continuously into the air intake tube of an externallly ignited internal combustion engine. The fuel injection apparatus is of the type that has, in a series arrangement, an air sensor and an arbitrarily operated butterfly valve. The sensor is moved as a function of the throughgoing air quantities against a constant resetting force generated by a pressurized liquid which continuously and normally under constant pressure actuates at least indirectly the movable member of a quantity distributor valve situated in the fuel line for the metering of fuel quantities proportionately to the air quantities.

The purpose of a fuel injection apparatus of the aforenoted type is that for any operational conditions of the internal combustion engine a favorable fuel-air mixture ratio is automatically obtained in order to ensure a total combustion of the fuel. In this manner the highest possible output of the internal combustion engine is ensured with the smallest possible fuel combustion and thus the generation of poisonous exhaust gases is avoided or at least very substantially reduced. Consequently, the fuel quantity has to be metered very accurately corresponding to the requirements of each operational condition of the internal combustion engine and the proportionality between the air quantities and fuel quantities has to be varied as a function of the engine variables, such as rpm, load and temperature.

In a known fuel injection apparatus of the aforenoted type (such as disclosed, for example, in U.S. Pat. No. 2,937,858), the variation of the aforenoted proportionality between fuel and air is effected as a function of the engine variables by changing the return force to which the air sensor is exposed. In this structure, the sensor is exposed, on the one hand, to the force of a spring and, on the other hand, to a fuel pressure which is throttled according to the operational conditions of the internal combustion engine. The throttling of the fuel pressure is effected by a pressure control valve which is actuated by a membrane box responsive to the difference between the total pressure in the intake tube upstream and downstream of the sensor, while taking into consideration the pressure drop across the butterfly valve. The disadvantage of such an arrangement is to be regarded in the fact that, in order to obtain a sufficiently large setting force of the pressure control valve, the counterpressure in the return conduit leading to the suction side of the fuel delivery pump, is effective in the chamber which forms part of the membrane box constituted of two relatively large-area membranes and which contains the pressure control valve. The aforenoted counter-pressure has a value larger than the atmospheric pressure and, in addition, strongly fluctuates. In this manner, one membrane which is situated in the membrane box and which is exposed on the one side to the vacuum downstream of the sensor and, on the other side, to the counterpressure, is loaded in a direction opposite to the load on the other membrane which is exposed to the differential pressure between the counterpressure and the atmospheric pressure. The two membranes are rigidly connected to one another by means of a connecting member, the position of which determines the flow passage section of the pressure control valve. The opposed loads on the membranes cause, due to their rigid interconnection, a tensioning of the membranes with the result that the shifting of the pressure control valve and thus also the shifting of the sensor and the fuel metering valve no longer corresponds to the operational conditions of the internal combustion engine.

The use of a spring for the supply of the resetting force is disadvantageous in that the spring should be relatively soft and long (i.e., it should have a relatively flat spring characteristic) in order to exert a substantially constant return force which is substantially independent of the extent of compression.

OBJECT, SUMMARY AND ADVANTAGES OF THE INVENTION

It is an object of the invention to provide an improved fuel injection apparatus of the aforenoted type which responds with accuracy even to small pressure changes of the air and wherein the effect of the counterpressure on the regulator mechanism is eliminated.

Briefly stated, according to the invention, the regulator mechanism is formed as a flat seat valve and is displaced against the force of a spring as a function of the pressure difference across the sensor and upon a comprison with the pressure difference in the return circuit. The regulator mechanism has a first membrane exposed to fuel pressure and functioning as the movable member of the flat seat valve. There is further provided a second, larger membrane which is exposed to the pressure difference across the sensor and which is connected with the first membrane by means of a spacer pin.

A regulator mechanism, as outlined above, permits a substantial amplification of even the smallest changes in the pressure difference across the sensor. These changes may be caused, for example, by the friction of the sensor or the movable part of the quantity distributor valve. According to the invention, by an immediate transitory change of the resetting force the excursion of the sensor is corrected. Further, the aforeoutlined regulating mechanism not only effects a compensation of the pressure drop across the air filter, but is also insensitive to the fluctuating fuel tank counterpressure.

The invention will be better understood as well as further objects and advantages become more apparent from the ensuing detailed specification of several exemplary embodiments taken in conjunction with the drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a longitudinal sectional view illustrating, partly schematically, a fuel injection apparatus incorporating a first embodiment of the invention and

FIGS. **2, 3** and **4** are fragmentary longitudinal sections of a fuel injection apparatus showing three further embodiments of the invention.

DESCRIPTION OF THE EMBODIMENTS

Turning now to FIG. **1**, there is shown an air intake tube **1** in which fresh combustion air flows in the direction of the arrow. The air impinges on and passes around a suspended sensor **2** and an arbitrarily operated butterfly valve **3** and then flows to the cylinders of an internal combustion engine. The sensor **2** is formed as a plate arranged normal to the direction of air flow and is at its central portion secured to a pivotal lever

4 which is movable in a plane about the pivotal point 5. The sensor may also be formed as a piston displaceable normal to the direction of air flow. In either case, the sensor 2 moves in the intake tube 1 according to a predetermined manner, i.e., as an approximately linear function of the air quantities flowing through the intake tube. In case of a constant return force affecting the sensor 2 as well as a constant air pressure upstream of the sensor 2, the pressure between the sensor 2 and the butterfly valve 3 also remains constant.

The sensor 2 transmits its motion through the pivotal lever 4 directly to a control plunger 6 of a fuel metering and quantity distributor valve 7. The radial face 9 of the control plunger 6 remote from the pivotal lever 4 is exposed to a liquid of constant pressure which serves as the return or resetting force urging the sensor 2 against the force exerted thereon by the air flow in the suction of air intake tube 1.

Fuel supply is effected by means of a fuel delivery pump 10 which, driven by an electromotor 11, draws the fuel from a tank 12 and forces it through a conduit 13 to the quantity distributor valve 7. From the conduit 13 there extends a return conduit 14 in which there is disposed a pressure limiting valve 15. From the conduit 13 the fuel is admitted into a channel 16 provided in the housing of the fuel quantity distributor valve 7. The channel 16 is in continuous, unthrottled communication with each chamber 18, so that one side of the membrane 20 is continuously exposed to the fuel pressure as generated by the pump 10. The channel 16 also communicates with a circumferential annular groove 17 of the control plunger 6.

As a function of the position of the control plunger 6, the control edge 6*a* bounding the annular groove 17 covers to a greater or lesser extent the control slots 21 each communicating through a channel 22 with a chamber 19 separated from the associated chamber 18 by the membrane 20. From each chamber 19 the fuel is admitted through a channel 23 to the associated individual fuel injection valve, not shown, which is situated in the air intake tube adjacent its engine cylinder. The membrane 20 serves as the movable member of flat seat valves, each being maintained in an open position by means of a spring 24 when the fuel injection apparatus is not in operation. The membrane boxes each comprising a chamber 18 and 19 ensure that independently from the extent of overlap between the annular groove 17 and the control slots 21, that is, independently from the fuel quantities admitted to the fuel injection valves, the pressure drop at each fuel metering valve 17, 21 remains substantially constant. In this manner it is ensured that the extent of displacement of the control plunger 6 and the metered fuel quantities are proportionate to one another.

During the pivotal motion of the lever 4 the sensor plate 2 is moved in a conical portion 8 of the intake tube 1, so that the periphery of the plate 2 and the wall of the conical portion 8 define an annular flow passage section which varies in proportion to the displacement of the plate 2. This precondition ensures that the control plunger 6 is displaced as a linear function of the displacement of the sensor plate 2. Consequently, the metered fuel quantities are always proportionate to the air quantities flowing through the section tube 1.

The pressurized liquid which is used as a constant resetting force affecting the control plunger 6 is fuel. For this purpose, from the conduit 13 there extends a conduit 27 communicating with a chamber 28 into which extends the control plunger 6 with its radial face 9 that is remote from the pivotal lever 4. In the conduit 27 there is arranged an advance throttle 29 by means of which the supply circuit 13 of the metering valve 7 is separated from the control pressure circuit 27, 32 of the regulator mechanism 33 to be described hereinafter. Downstream of the advance throttle 29, from the conduit 27 there extends a conduit 32 to the regulator mechanism 33 from which, in turn, there leads a return conduit 35 to the fuel tank 12. The regulator mechanism 33 corrects the setting errors caused, for example, by the friction of the control plunger 6 and the pivotal lever 4. For this purpose, the pressure in the chamber 28 (that is, the normally constant resetting force exerted on the control plunger 6 and the sensor 2) is increased or decreased in a transitory manner.

The regulator mechanism 33 is formed as a flat seat valve having a stationarily supported valve seat 36 and a movable member formed as a first membrane 37. The latter is, in the opening direction, exposed to pressurized liquid introduced into the chamber 34 through the conduit 32 and to the fuel tank counterpressure introduced through the return conduit 35. The first membrane 37 is urged into a closed position by a spring 40 exerting its force on a spacer pin 38 secured to the first membrane 37 and to a larger, second membrane 39. The spring 40 which is situated in a chamber 45 of the regulator mechanism 33, engages with one end a spring seat disc 41 which is affixed to the second membrane 39 and is, with its other end, in engagement with a spring seat disc 42. One side of the second membrane 39 bounds a chamber 44 in which prevails, by virtue of a connecting conduit 43, the air pressure in the suction tube 1 between an air filter (not shown) and the sensor plate 2. The other side of the second membrane 39 bounds the chamber 45 in which prevails, by virtue of a connecting conduit 46, the normally constant air pressure in the suction tube 1 between the sensor plate 2 and the butterfly valve 3. Thus, the second membrane 39 is exposed to a normally constant pressure difference of the air pressure upstream and downstream of the sensor plate 2. In order to ensure that the measuring error due to the air flows remains as small as possible, the sensor station 47 associated with the air conduit 46 is arranged in the intake tube 1 immediately downstream of the sensor 2. Thus, as soon as the plate 2 is, because of a frictional effect, not moved in proportion to the air quantities flowing through the air intake tube, the pressure between the sensor 2 and the butterfly valve 3 changes. This change of the constant pressure in the intake tube is transmitted through the air conduit 46 to the chamber 45 of the regulator mechanism 33. If, for example, the aforenoted pressure change is a pressure drop, then the membrane 39 is displaced against the force of the spring 40, so that an increased quantity of fuel may flow through the flat seat valve 36, 37 to the fuel tank 12. By virtue of this additional opening of the flat seat valve 36, 37, the pressure in the chamber 28 of the quantity distributor valve 7 decreases, permitting the frictional forces to be overcome. Subsequently, the pressure increases in the chamber 45 and then, by virtue of a decrease in the flow passage section of the flat seat valve 36, 37, the previous constant pressure in chamber 28 is reestablished.

The insensitivity of the regulator mechanism 33 to the tank counterpressure is ensured by virtue of the large area ratio A_{39}/A_{36} which is approximately 1,500. A_{39} designates the area of the second membrane 39 which is exposed to the pressure difference of the air across the sensor 2, while A_{36} designates that portion of the first membrane 37 which is exposed to the counterpressure in the return conduit 35.

The force of the spring 40 of the regulator mechanism 33 is variable by means of the shiftable spring seat disc 42. The displacement of the latter is effected by means of a temperature-responsive member 50 which is, for example, a heat-expandable regulator. By virtue of the latter the spring 40 is compressed to a lesser extent when the engine is cold than when it is hot. In this manner, the flat seat valve 36, 37 is opened to a greater extent when the engine is cold and thus the resetting pressure in the chamber 28 of the quantity distributor valve 7 is smaller and the injected fuel quantities are larger in relation to the air quantities than when the engine is hot.

The liquid pressure is applied to the chamber 28 through a dampening throttle 30. The latter effects a substantially temperature-independent dampening of the motion of sensor plate 2 since the dampening liquid is fuel, the viscosity of which varies very little as the temperature changes. This dampening is necessary for limiting an over-shot of sensor 2 during acceleration to control the travelling behavior of the vehicle and to limit the effect of the suction thrusts of the engine.

Turning now to FIG. 2, in the embodiment shown therein the bias of the spring 40 is variable by means of magnitudes which, in turn, are a function of engine variables other than the engine temperature. In this embodiment, a three-dimensional cam 53 which is rotatable in unison with the butterfly valve 3 and which is displaceable in an axial direction as a function of the vacuum prevailing downstream of the butterfly valve 3, exerts a force on the spring seat disc 42 associated with the spring 40. The three-dimensional cam 53 is axially displaceably secured on the shaft 54 of the butterfly valve 3. The rotary motion of the shaft 54 is transmitted to the three-dimensional cam 53 by means of a coupling member 55. The three-dimensional cam 53 is at one end rotatably secured to a membrane 56 of a vacuum chamber 57. The latter is connected by means of a conduit 58 with a location in the suction tube which is downstream of the butterfly valve 3. In case of sufficient pressure, the three-dimensional cam 53 is axially displaced by means of the membrane 56 against the force of a resetting spring 59. The three-dimensional cam 53 is in contact with a follower pin 60, the setting motion of which is transmitted through the spring seat disc 42 to the spring 40. The bias of the latter, as explained earlier, determines the pressure of the resetting force applied to the sensor 2.

Magnitudes characterizing the load and rpm are the angular position of the butterfly valve 3 and the vacuum in the suction tube. Consequently, the return force exerted on the control plunger 6 is expediently varied by these magnitudes. Accordingly, the force of the spring 40 is varied as a function of the position of the butterfly valve 3 and the magnitude of the pressure in the suction tube by a corresponding rotation or, respectively, an axial shift of the three-dimentional cam 53. If, for example, in case of full load conditions the butterfly valve 3 is in a position in which the suction tube

1 is fully open, then a highest output and thus a relatively rich mixture is desired. Since the bias of the spring 40 of the regulator mechanism 33 determines the pressure of the fuel in the chamber 28, the return force affecting the sensor 2 has to be slightly decreased so that the control plunger 6 can be shifted into a position in which the control slots 21 are opened to a greater extent and thus correspondingly larger fuel quantities are injected. Conversely, in operational conditions under partial load, by means of a relatively higher pressure on the radial face 9 of the control plunger 6, a relatively smaller excursion of the sensor member 2 takes place and, as a result, the air-fuel mixture will be leaner.

Turning now to the embodiment illustrated in FIG. 3, the bias of the spring 40 of the regulator mechanism 33 is varied by a cam plate 63 which is displaced only by the pressure prevailing in the suction tube downstream of the butterfly valve 3. For this purpose the cam plate 63 is supported on rollers 64. The setting motion is again transmitted to the spring seat disc 42 by means of the follower pin 60 which is in engagement with the cam plate 63. Thus, in this embodiment, the butterfly valve 3 is in no way connected with the mechanism that affects the bias of spring 40. Thus, the change of the bias on the spring 40 and consequently the change of the return or resetting force on the sensor 2 occurs in an rpm and load dependent manner.

Turning now to the embodiment shown in FIG. 4, the follower pin 60 is displaced by a cam disc 66 which is affixed to the shaft 54 of the butterfly valve 3, so that when the latter is adjusted by means of rotating the shaft 54, the pin 60 is shifted by the cam disc 66. In this manner there is effected only a load-dependent change of the resetting force exerted on the sensor 2.

What is claimed is:

1. A regulator mechanism for a fuel injection apparatus supplying fuel to an internal combustion engine having an air intake tube provided with an arbitrarily operable butterfly valve, said fuel injection apparatus being of the type that has (a) an air sensor disposed in said air intake tube in series with said butterfly valve and displaceable by the air flow in said intake tube to an extent proportionate to the throughgoing air quantities, (b) a fuel metering and distributor valve including a control plunger connected to said air sensor to be displaced thereby for the metering of fuel quantities in proportion to the air quantities passing through said intake tube, (c) means for applying a normally constant return force to said air sensor, said return force opposing the force of air flow exerted on said air sensor, said return force being exerted by pressurized fuel, said means incuding a chamber containing said pressurized fuel, comprising

A. a conduit communicating with said chamber for discharging pressurized fuel from said chamber,

B. a flat seat valve controlling the flow passage section of said conduit, said flat seat valve having

1. a stationary flat valve seat,
2. a relatively small movable membrane cooperating with said valve seat to vary the flow passage section thereof for throttling to a greater or lesser extent the discharge of pressurized fuel from said chamber through said conduit,

C. means for applying the fuel pressure in said conduit to one side of said relatively small membrane,

D. a relatively large membrane spaced from said relatively small membrane,

E. rigid means connecting the two membranes to one another for transmitting forces from one membrane to the other,

F. means for applying the air pressure prevailing in said intake tube upstream of said sensor to one side of said relatively large membrane,

G. means for applying the air pressure prevailing in said intake tube downstream of said sensor to the other side of said relatively large membrane and

H. a spring urging said relatively small membrane into a closed position towards said valve seat.

2. A regulator mechanism as defined in claim 1, wherein said air sensor is formed as a plate situated in said intake tube normal to the direction of air flow, said means defined in (G) includes a pressure pickup or sensor station disposed on said plate at the downstream side thereof.

3. A regulator mechanism as defined in claim 1, including means for varying the force of said spring exerted on said relatively small membrane, said last-named means being responsive to at least one engine variable.

4. A regulator mechanism as defined in claim 3, wherein said last-named means includes a component displaced as a function of the engine temperature.

5. A regulator mechanism as defined in claim 3, wherein said last-named means includes a device connected to said butterfly valve, said device being displaced as a function of said butterfly valve.

6. A regulator mechanism as defined in claim 3, wherein said last-named means includes a device dis-

placed as a function of the air pressure in said intake tube down-stream of said butterfly valve.

7. A regulator mechanism as defined in claim 5, wherein said device includes

A. a cam disc connected to said butterfly valve and rotated therewith in unison and

B. a follower in engagement with said cam disc and in contact with said spring.

8. A regulator mechanism as defined in claim 6, wherein said device includes

A. a cam plate,

B. means for linearly displacing said cam plate as a function of the air pressure in said intake tube down-stream of said butterfly valve and

C. a follower in engagement with said cam plate and in contact with said spring.

9. A regulator mechanism as defined in claim 3, wherein said last-named means includes

A. a three-dimensional cam,

B. means for rotatably and axially displaceably supporting said three-dimensional cam,

C. means connecting said three-dimensional cam to said butterfly valve for rotating said three-dimensional cam in unison with said butterfly valve,

D. means for axially displacing said three-dimensional cam as a function of the air pressure in said intake tube downstream of said butterfly valve and

E. a follower in engagement with said three-dimensional cam and in contact with said spring.

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