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**Zeyns et al.**

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[54] **FUEL PRESSURE REGULATING SYSTEM FOR INTERNAL COMBUSTION ENGINES**


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[51] **Int. Cl.** ..... **F02b 33/00**

[58] **Field of Search** ..... 123/119, 139 AW, 123/140 MC, 140 VC



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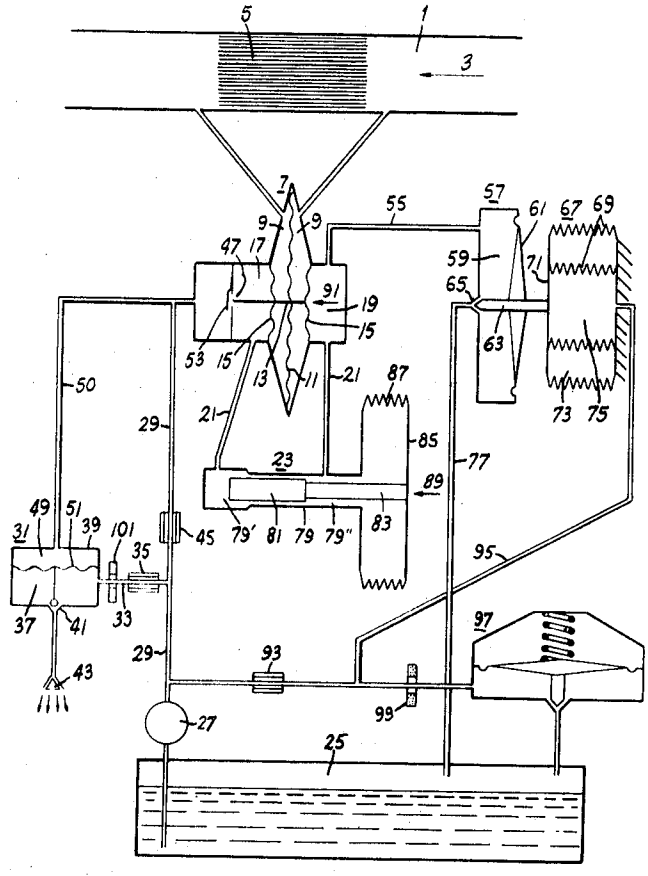
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[57] **ABSTRACT**

The invention pertains to the method for operating an internal combustion engine wherein a predetermined air-fuel mixture is maintained under all conditions of temperature and pressure. A resistance member is placed in the combustion air intake and the air pressure on each side of the resistance member is measured and sensed within a differential pressure control. The differential pressure control, by means of valves regulating the fuel pressure, causes a fluctuation in the fuel pressure dependent upon the air pressure upon opposite sides of the combustion air resistance. In addition to the fuel pressure being regulated by pressure differences occurring on opposite sides of the combustion air resistance, the fuel pressure is also regulated by means of ambient air pressure and temperature sensing valves and resistances whereby the predetermined air and fuel mixture may be maintained under all operating conditions.


**7 Claims, 2 Drawing Figures**



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SHEET 1 OF 2

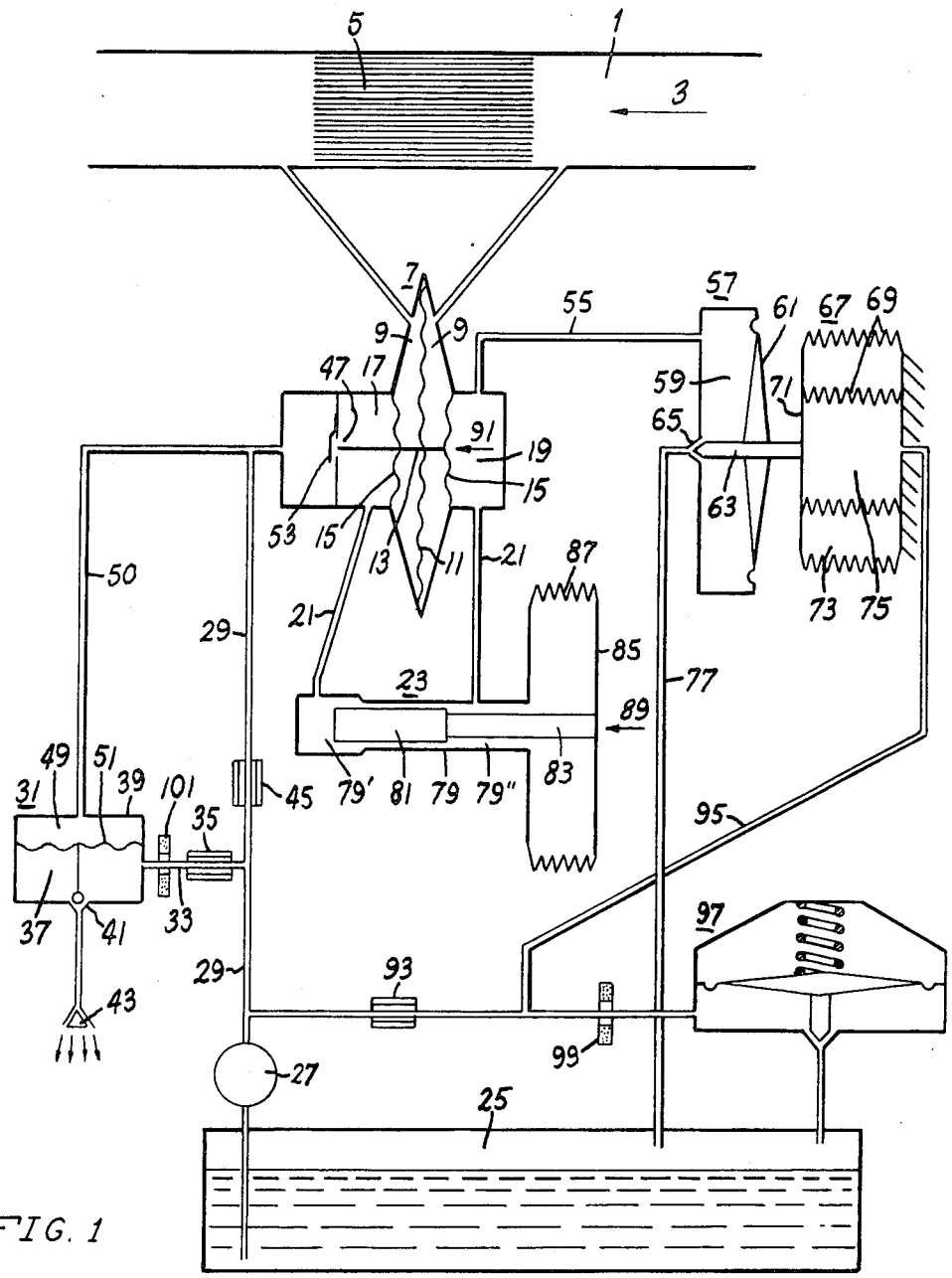



FIG. 1

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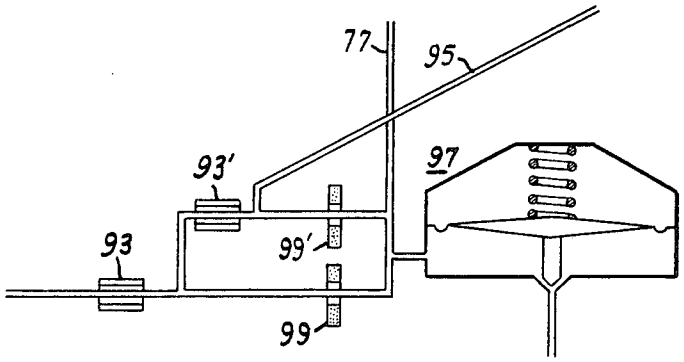



FIG. 2

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# FUEL PRESSURE REGULATING SYSTEM FOR INTERNAL COMBUSTION ENGINES

## BACKGROUND OF THE INVENTION

The invention pertains to the field of controlling the pressure for introducing fuel into an internal combustion engine in dependence upon the characteristics of the combustion air, and in dependence upon ambient temperature and pressure conditions.

In internal combustion engines it is necessary in order to produce optimum combustion that a definite mixture ratio or proportion between the combustion air and fuel be maintained. Normally, the mixture of combustion air and fuel occurs within a carburetor basically consisting of a Venturi tube having one or more fuel jets located therein. As the air passes through the Venturi tube fuel is drawn into the tube and airstream and is evaporated and introduced into the engine cylinders. However, in spite of significant improvements in carburetor construction, the maintaining of a mixture proportion which is suitable for all operating conditions is not possible. To overcome the deficiencies of carburetors in this regard electronic fuel injection devices are known in which the supply of fuel is regulated in accordance with the operating conditions of the motor. However, such devices are complicated and expensive, and leave much to be desired toward the solution of the problem.

## SUMMARY OF THE INVENTION

The invention pertains to the method for operation of an internal combustion engine with a combustible air-fuel mixture which is of a predetermined proportional ratio under all operating conditions. In the practice of the invention the air, before mixture with the fuel, passes through a laminated and measured air resistance means which produces a reduction in air pressure in accordance with the velocity and amount of air passing therethrough. The air pressure before the resistance member, and after the resistance member is determined and measured in a pressure scale or balance member which includes a membrane separated by chambers communicating with the air pressure on each side of the air resistance member. The membrane includes a piston or control element adapted to regulate fuel flow and thereby adjust the fuel pressure in dependence upon the combustion airflow characteristics.

The combustion air resistance member consists of a large number of channels of small diameter placed within the combustion air conduit whereby the channels reduce the air turbulence, causing a pressure reduction which may be immediately measured by sensing the air pressure on each side of the resistance member. Under normal conditions the pressure difference is a measurable indication for the amount of fuel which is to be added to the air to produce the proper combustible air-fuel ratio.

The membrane of the member sensing the differential air pressure carries a piston with which a fuel regulating valve is controlled and the fuel which passes from the fuel pump to the fuel regulating valve has a pressure at least partially dependent upon the size of the valve opening determined by the membrane piston. The system includes fuel injection valves supplied with fuel immediately prior to a fuel injector.

It is the function of the invention to produce a device for the supply of an internal combustion engine with a combustible air-fuel mixture which permits an independent supply of fuel to the engine individual fuel injection valves, and in this construction each fuel injection valve functions independently from the other in which the working conditions of the engine may be varied. All injection valves utilize a common pressure which controls each injection valve separately in such a way that the desired fuel-air proportion is maintained in the air-fuel intake conduit even if the intake conduits have different air pressures. A resistance in the fuel flow system to the injection valves provides for a decreased pressure between the fuel pump of, for example, five atmospheres and the fuel pressure at the jet of, for example, two atmospheres. If the fuel regulating valve is closed, then the same pressure will be produced over the fuel resistance in the conducting of this regulating valve. The injection valve is regulated by a membrane which is connected to a valve element to regulate fuel flow, and under equal pressure conditions the injection valve may be closed. If the fuel regulating valve opens only a little and the pressure on the control side of the valve membrane decreases then the injection valve will open and fuel is introduced into the engine air-fuel intake canal, or immediately into the engine cylinder.

In the invention the combustion air differential pressure sensing device is subjected to a variable and controlled force on opposite sides of the membrane as determined by fuel pressure communicating with opposite sides of the device, such interconnection of opposite sides of the air differential sensing device as to subject the same to fuel pressure produces a hydraulic increase for varying the pressure scale or pressure differential. For instance, under certain conditions, as determined by the means for varying the pressure upon opposite sides of the combustion air sensing diaphragm a 1 to 10 ratio may be employed. However, this proportion can be increased to a ratio of 1 to 100, and the ratio is varied in proportion to pressure and temperature variations. The invention employs valves and fuel flow resistance controls sensitive to pressure and temperature variations wherein adjustments in accord with altitude and temperature may be made to modify the ratio of air and fuel in those conditions wherein a richer fuel mixture is required, such as at high altitudes, or for starting purposes. Additionally, the invention envisions the use of turbulent resistance control members in the fuel conducting conduits which particularly function under full load conditions to produce a desired rich mixture.

## BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a schematic diagram of an air and fuel circuit illustrating the invention for producing individual fuel measurement for a single combustion engine cylinder, and

FIG. 2 is a partial view of a modification in the system shown in FIG. 1.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

Combustion air for the engine flows through channel or duct 1 in the direction of the arrow 3. The duct 1 communicates with the engine cylinders in the known manner, not illustrated. Located within duct 1 is a laminated air resistance device of a measured length which consists of a large number of channels of small diame-

ter parallel to one another through which the air flows. In this laminated resistance member the combustion air is calmed and at the same time a differential air pressure will be created in front of and behind the resistance member 5 with respect to the direction of airflow. The difference in air pressure on the opposite sides of the resistance member 5 serves as the regulation value of the pressure scale or differential pressure sensing device 7. The device 7 includes two spaces or chambers 9 in communication with the duct 1, the right chamber 9 communicating with the duct 1 in front of resistance member 5, and the left chamber 9 communicating with the duct 1 at the rear of the resistance member 5. The chambers 9 are separated by a membrane 11 having a piston 13 attached thereto. The device 7 is further defined by flexible membranes 15 which are smaller than membrane 11, and are spaced from membrane 11.

The membranes 15 separate the chambers 9 from an anterior pressure chamber 17 and a posterior pressure chamber 19. The pressure chambers 17 and 19 are connected to each other through a conduit system 21 which includes a variable resistance unit 23, whose operation will be later described.

The fuel is stored in a tank or reservoir 25 and is pumped by means of a pump 27 into the fuel system which includes conduits 29. The fuel pressure in the fuel conduits 29 is approximately five atmospheres.

A plurality of injection valves 31 are connected to the fuel conduits 29, and for purpose of illustration only a single injection valve 31 is illustrated. A connecting duct 33 connects the injection valve 31 to the fuel system 29 and a laminar fuel flow resistance member 35 is located in the duct 33 to produce a fixed resistance.

The fuel may pass through the duct 33 after it has passed through the resistance 35 to the flow side 37 of a membrane chamber 39 of the injection valve 31, the chamber 39 includes an exit or outlet valve 41. Fuel passing through the valve 41 can be injected into the engine cylinder if the valve 41 is open as the valve 41 communicates with a jet 43 which may be located in the engine cylinder intake duct, or the jet 43 can be immediately associated with an engine cylinder. The pressure at the jet 43 is approximately two atmospheres.

The fuel system conduits 29 also include another fixed laminar flow resistance 45 located "behind" the duct 33, and the fuel resistance 45 is adjusted in accord with the resistance 35.

The fuel system 29 communicates with a fuel regulating valve 47 which is connected to the entrance to the anterior pressure chamber 17. As will be noted from the drawing, the control chamber 49 of the membrane chamber 39 communicates by means of conduit 50 with the fuel regulating valve 47, and thus the pressure of the fuel on the flow side 37 in the membrane chamber 39 corresponds to the pressure in the chamber 49, and when the pressures within 37 and 49 are equal the membrane 51 will maintain the valve 41 closed.

However, the pressure conditions are changed if the fuel regulating valve 47 is opened due to a flowing of the airstream in duct 1 which will produce a pressure differential in the chambers 9. In such instance the piston 13 will shift to the left and press upon the valve 47 to open this valve and also open the check valve 53. At this time the fuel will flow into anterior chamber 17 and through the resistance unit 23 to the posterior pressure chamber 19. From the pressure chamber 19 the fuel then continues through the duct 55 to an overpressure or pressure relief valve 57. The pressure relief valve 57 includes a working chamber 59 having a movable wall 61 through which the needle valve 63 extends toward its seat 65. The operation of the needle valve 63 is accomplished through a double bellows 67 which is closed on both axial ends. The rear end of the needle valve 63 is attached to the movable side walls 71 which closes both bellows 69. Space 73 between the two bellows 69 is filled with a gas, for example, air, while the inner space 75 of the inner bellows is filled with fuel. In this manner the valve 57 is operated by the bellow arrangement 67 to be sensitive to both temperature and pressure. If the ambient pressure decreases, the gas between bellows 69 expands and the needle valve 63 is shifted in the direction of its seat 65. In the event of an increase in temperature, the fuel within inner space 75 expands and also provides for the closing of the valve 57. If a pressure increase occurs, or the temperature decreases, the reverse procedure applies. The fuel which passes the relief pressure valve 57, in the embodiment of FIG. 1, flows through a duct 77 back into the fuel reservoir tank 25.

An additional control is represented by the resistance unit 23. The resistance unit 23 consists of a differential cylinder 79 which has a large diameter at 79' and a small diameter at 79''. Within the differential cylinder 79 a piston 81 is located which may be shifted. Grooves are defined in the outer wall of the piston 81 and in the inner wall of the cylinder 79, and the resistance of fuel passage through the unit 23 is affected by the position of the piston 81 in the cylinder 79. The more the piston 81 is shifted to the left the lesser the resistance to fuel flow past the piston. The more the piston is shifted to the right the higher the resistance to fuel flow. The piston 81 is connected to a plate 85 of bellows 87 and the bellows will be filled with fuel. The plate 85 is connected to the piston 81 by piston rod 83. Thus, if the outer or ambient air pressure changes the bellows 87 will change its shape and shift the piston 81 accordingly.

The additional force exerted upon the piston 81 is indicated by the arrow 89. This additional force may result in a multiplied correction of the pressure in the conduit 50. In addition to this correction, there is also an additional force provided which is indicated by the arrow 91 as occurs within the posterior pressure chamber 19, which influences the position of the piston 13. Thus, the force 91 constitutes an additive correction to the pressure occurring in conduit 50, and control chamber 49.

A fuel pressure conduit branches off from the conduit 29 adjacent the pump 27 prior to the injector valves 31 and a resistance member 93 is placed within this conduit. In communication with this passage is a branch conduit 95 which leads to the inner space 75 of the double bellows 67. In further communication with the conduit 95 is an additional relief pressure valve 97 having a turbulent resistance member 99 placed intermediate the valve 97 and the conduit 95. The addition of the turbulent resistance member 99 in front of the relief pressure valve 97 has the function of increasing the pressure in the fuel conduit 95 to the inner space of the double bellows 67 if the fuel viscosity becomes small, and to decrease the pressure if the fuel viscosity becomes greater. With a change in fuel viscosity the

turbulent resistance **99** does not change and the desired regulation can be achieved. Similar devices may be added in series or parallel to produce similar results of uniformity. For example, the arrangement shown in FIG. **2** can produce a considerable correction for stabilizing the system. In FIG. **2** the conduit branching from conduit **29** to resistance **93** has associated therewith the turbulent resistance member **99** and the relief pressure valve **97.** Between the resistance **93** and **99** a conduit branches off which extends over the resistance **93** and **99** also to the relief pressure valve **97.** Between the resistance **93'** and **99'** the conduit **95** branches off which leads to the inner space **75** of the double bellows **67.** It will be noted that the duct **77** communicates with the valve **97** in this instance.

An additional turbulent resistance member **101** is preferably located on the entry side of the injection valve **31,** associated with the connecting duct **33.** This turbulent resistance member **101** has the function of producing a desired flow load rich mixture. According to need it may be placed in line with resistance **35** as illustrated, or it may also be located in the duct with the fuel resistance member **45** in order to produce the desired rich mixture under full load.

FIG. **1** illustrates the principle of the device from the practical standpoint and the individually represented constructions of the components may be varied. From a practical standpoint the individually illustrated components may take several forms which present certain technical advantages.

What is claimed is:

**1.** In a fuel injection system for controlling the injected fuel quantities as a function of the flow rate of combustible air flowing through the air intake duct of an internal combustion engine served by said fuel injection system, the improvement comprising in combination

A. a fuel injector valve having
   1. a first chamber,
   2. a second chamber,
   3. movable diaphragm means separating said first chamber from said second chamber,
   4. valved outlet nozzle means connected with said first chamber and operated by said diaphragm,

B. a fuel reservoir,

C. a fuel pump in communication with said reservoir and having a pressure outlet,

D. a first conduit connecting said pressure outlet of said fuel pump with said first chamber of said fuel injector valve,

E. a first flow resistance located in said first conduit to effect a pressure drop of the fuel flowing from said fuel pump into said first chamber of said fuel injector valve,

F. a regulating valve having
   1. an inlet,
   2. an outlet,
   3. means for determining the position of said regulating valve as a function of the pressure in said air intake duct,

G. a second conduit connecting said pressure outlet of said fuel pump with the inlet of said regulating valve,

H. a second flow resistance located in said second conduit to effect a pressure drop of the fuel flowing from said fuel pump through said regulating valve,

I. a third conduit connecting said second chamber of said fuel injector valve with the inlet of said regulating valve for effecting a pressure variation in said second chamber of said fuel injector valve as a function of the flow rate of fuel through said second conduit across said regulating valve, the pressure in said second chamber of said fuel injector valve being reproduced in said first chamber thereof by said movable diaphragm means for determining the pressure drop across said first flow resistance, the last-named pressure drop determining the fuel quantities injected through said outlet nozzle means, the pressure drops across said first and second flow resistances being of equal magnitude and

J. a fourth conduit connecting said outlet of said regulating valve with said fuel reservoir to effect return of the fuel flowing through said second conduit across said regulating valve.

**2.** An improvement as defined in claim **1,** wherein said means for determining the position of said regulating valve as a function of the pressure in said air intake duct includes

A. an airflow resistance member within said air intake duct for effecting a pressure drop of the air flow thereacross,

B. air differential pressure sensing means having
   1. a first air chamber,
   2. a second air chamber,
   3. a movable main membrane separating the first air chamber from the second air chamber,
   4. first channel means maintaining communication between the first air chamber of said air differential pressure sensing means and a location of said duct upstream of said airflow resistance member,
   5. second channel means maintaining communication between the second air chamber of said air differential pressure sensing means and a location of said duct downstream of said airflow resistance member and

C. means connecting said regulating valve to said main membrane for causing said regulating valve to assume a position as a function of the position of said main membrane; the position of said main membrane being a function of the pressure difference in said first and second air chambers of said air differential pressure sensing means.

**3.** An improvement as defined in claim **1,** said first and second flow resistances including means for effecting a laminar flow of the fuel passing therethrough.

**4.** An improvement as defined in claim **1,** including an ambient pressure sensing valve and a temperature and fuel pressure sensing valve connected in series in said fourth conduit for additionally controlling the flow through said regulating valve.

**5.** An improvement as defined in claim **1,** including a third flow resistance located in said first conduit between the first chamber of said fuel injector valve and said first flow resistance, said third flow resistance including means for effecting a turbulent flow of the fuel passing therethrough.

**6.** An improvement as defined in claim **2,** including

A. a first additional movable membrane forming part of said air differential pressure sensing means and disposed at one side of said main membrane spaced therefrom, said first additional membrane defining

a portion of the first air chamber of said air differential pressure sensing means,

B. a first fuel receiving chamber at least partially defined by said first additional movable membrane,

C. a second additional movable membrane forming part of said air differential pressure sensing means and disposed at the other side of said main membrane spaced therefrom, said second additional membrane defining a portion of the second air chamber of said air differential pressure sensing means,

D. a second fuel receiving chamber at least partially defined by said second additional movable membrane, said regulating valve communicating with said second fuel receiving chamber,

E. a conduit portion maintaining communication between said first and second fuel receiving chambers, said conduit portion forming part of said fourth conduit and

F. an ambient air pressure-controlled variable fuel flow resistance means located in said conduit portion for controlling the fuel flow between said first and second fuel receiving chambers.

**7.** An improvement as defined in claim **6,** including means connecting said regulating valve to said first additional movable membrane for affecting the position of said regulating valve as a function of the pressure in said first fuel receiving chamber.

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