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Kobayashi

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[54] SYSTEM FOR CONTROLLING FUEL SUPPLY TO AN INTERNAL COMBUSTION ENGINE

[72] Inventor: **Hisanori Kobayashi,** Kariya-shi, Japan

[73] Assignee: **Nippondenso Kabushiki Kaisha,** Showa-cho, Kariya-shi, Aichi-ken, Japan

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[51] **Int. Cl.**..**F02m 51/00**

[58] **Field of Search** ....123/32 EA, 119, 140.2, 140.3

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Primary Examiner—Laurence M. Goodridge

Attorney—Cushman, Darby & Cushman

[57] **ABSTRACT**

A system for controlling fuel supply to an internal combustion engine having a device for sensing pressure within an intake manifold of the engine. The device has bellows operable in response to variation in absolute pressure value within the intake manifold in normal operation of the engine to cause a core to move relative to an electrical coil so that electrical signals are emitted to cause the amount of fuel supply to be controlled in accordance with the state of engine operation represented by the pressure within the intake manifold. The device also has a diaphragm operable in response to variation in pressure differential of more than a predetermined value between the pressure within the intake manifold and the atmospheric pressure to displace normal operative position of the bellows relative to the coil in a direction in which the amount of fuel supply is increased, said predetermined value of the pressure differential being set to represent the state of engine operation which requires a greater output to be produced by the engine.

2 Claims, 3 Drawing Figures

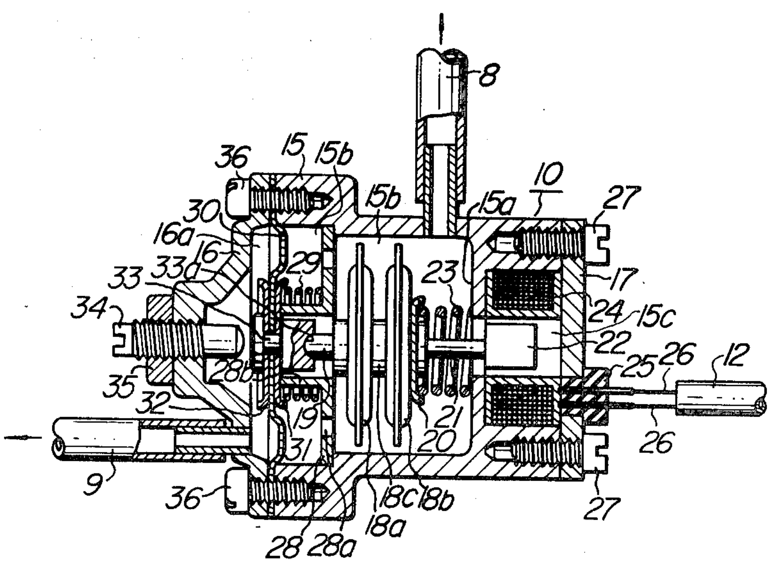

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FIG. 1

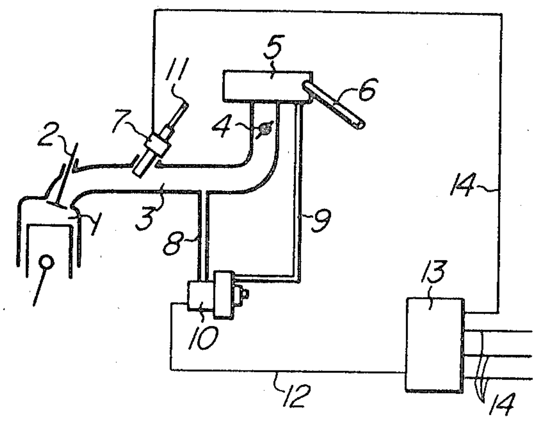


FIG. 3

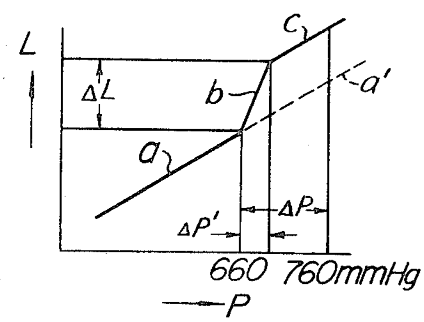
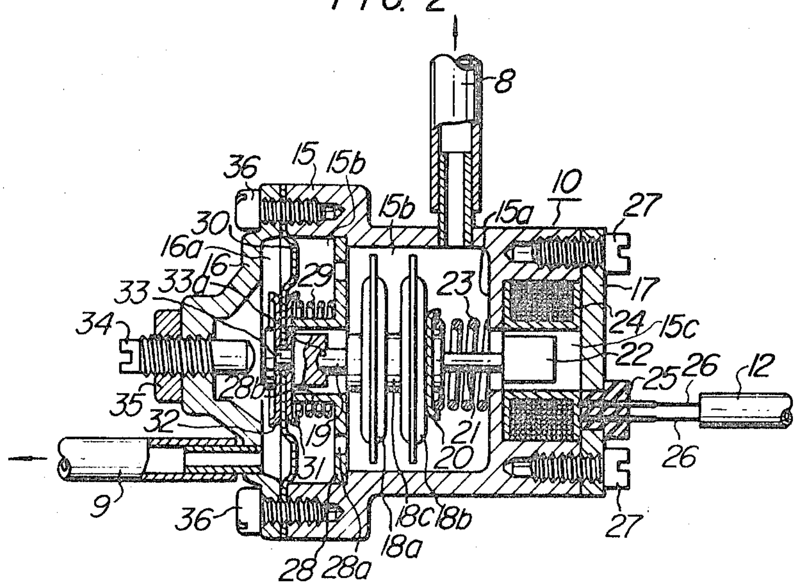


FIG. 2



INVENTOR

Hisanori Kobayashi

BY

Cushman, Darby & Cushman

ATTORNEYS

SYSTEM FOR CONTROLLING FUEL SUPPLY TO AN INTERNAL COMBUSTION ENGINE

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to a system for controlling fuel supply to an internal combustion engine and, particularly, to a device for sensing an under-pressure within an air inlet pipe of such engine to electrically actuate the fuel injection valves of the engine so that controlled amount of fuel is supplied to the combustion chambers of the engine.

In an internal combustion engine of spark-ignition type, the output of the engine is generally controlled by a throttle valve which is operable to adjust the flow of air to be taken into the engine. Thus, it is required to supply fuel of an amount appropriate for the flow of air adjusted by the throttle valve. The ratio of the air flow relative to the amount of fuel is required to be variable with the purposes of the operation of the engine. Particularly, the output characteristic of the internal combustion engine for use with a vehicle such as a motorcar is such that it is desired to supply air and fuel at a mixing ratio which would provide lean mixture when a lesser output of the engine is sufficient as is in a normal operation of the motorcar, whereas it is required to operate the engine in a manner to produce as large an output as possible rather than in a manner to obtain an economical operation of the engine when the motorcar is to be accelerated. In the internal combustion engine which employs a throttle valve, it has been found that the air flow adjusted by a throttle valve is in proportion to the absolute pressure within the air inlet pipe and the rotation of the engine. Thus, when it is required to operate such an engine at a constant mixing ratio of air flow relative to amount of fuel so as to obtain an output of a certain constant magnitude, the fuel supply system of the engine may preferably be actuated by an electrical signal in accordance with the pressure within the intake manifold of the engine. Such an electrical signal has heretofore been obtained by use of a vacuumed bellows member or members.

The range of the mixing ratio of the air flow relative to the amount of fuel, that is, so-called "air-fuel ratio," which ratio is needed to provide a greater magnitude of the engine output, may be obtainable by use of an appropriate auxiliary means such as an electrical circuit including a switch which is operable in response to the opening of the throttle valve or a decrease in the pressure within the intake manifold of the engine to emit an electrical signal by means of which the quantity of the fuel supply is increased. Alternatively, such ratio is obtained by use of the above-mentioned vacuumed bellows members operated so as to have non-linear operative characteristic. In the former instance, it is required to employ a completely independent additional circuit for electrical signals which will inevitably complicates the fuel supply control system while, in the latter instance, the employment of the non-linear operative characteristic of the vacuumed bellows members will be encountered by a difficulty in setting the members in well adjusted condition. In addition, the system according to the latter instance will be operable with absolute pressure only, so that the system will not be suited for an engine which is adapted to be operated under decreased atmospheric pressure as is in a highland.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a device for sensing pressure within the intake manifold of an internal combustion engine to control the amount of fuel to be supplied thereto which device can eliminate such an additional electrical circuit for producing electrical signals for a larger air-fuel ratio as required in the case where a greater output of the engine is required.

It is another object of the present invention to provide a pressure sensing device of the kind specified in the preceding paragraph and which is operable also under reduced atmospheric pressure as is in a highland and which can be easily set in an adjusted condition.

It is a further object of the present invention to provide a pressure sensing device of the kind specified in the preceding paragraph and which is operable in response to change in the pressure within the intake manifold of the engine and also in response to change in pressure differential between the pressure within the intake manifold and the atmospheric pressure to produce electrical signals of linear characteristic which are adapted to be used for actuating the fuel injection valves so that the latter will operate to inject the fuel of an amount required for the condition of the engine as represented by the changes in the intake air pressure and in the pressure differential.

The above objects will be achieved by a device of the present invention which comprises means operable in response to variation in absolute pressure value within an intake manifold of an internal combustion engine to cause the amount of fuel supply to the engine to be controlled so as to provide the maximum thermal efficiency for the engine during normal operation thereof, means operable in response to variation in pressure differential of more than a predetermined value between the pressure within said intake manifold and the atmospheric pressure to mechanically shift the normally operating position of said absolute pressure variation responsive means in a direction in which the fuel supply is increased, said predetermined value of said pressure differential being set to represent the state of the engine which requires a greater output of the engine to be produced, and transducer means, such as electrical ones, for transforming the movement of said absolute pressure variation responsive means into signals to be fed to fuel supply adjusting means, such as fuel injection valves, on the engine.

The absolute pressure variation responsive means may comprise at least one axially expansible bellows member axially movably mounted within a hermetically sealed chamber defined by a housing of said sensing device. The pressure differential variation responsive means may comprise a diaphragm member extending within said housing radially thereof and partly serving to define said chamber and partly serving to define another chamber within said housing. The transducer means may comprise a core member mechanically connected to one side face of said bellows member and being axially movable thereby. The transducer means may also comprise a stationary electrical coil member mounted on the wall of said housing and extending around said core member in radially closely spaced relationship thereto.

The present invention also contemplates to provide a system for controlling fuel supply to an internal combustion engine which system includes a pressure sensing device as specified in the above.

The above and other objects and features of the present invention will be made more apparent by the following description with reference to the accompanying drawings which illustrate an embodiment of the present invention.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of an embodiment of the system for controlling fuel supply to an internal combustion engine according to the present invention;

FIG. 2 is an enlarged and detailed illustration, partly in section, of a part of the system shown in FIG. 1; and

FIG. 3 is a graphical illustration of the characteristic of the operation of the part of the system shown in FIG. 2.

DESCRIPTION OF A PREFERRED EMBODIMENT

Referring first to FIG. 1 of the drawings, there is schematically illustrated a part of an internal combustion engine including a combustion chamber 1, an air inlet valve 2 and an intake manifold 3 in which a throttle valve 4 is adjustably provided. An air cleaner 5 having an air intake pipe 6 is mounted on the intake manifold 3 at the outer end thereof. An electrically controlled fuel injection valve 7 is mounted on the intake manifold 3. The valve 7 is supplied with fuel from a fuel supply conduit 11 which leads to a supply source of the fuel such as a fuel pump (not shown).

A conduit 8 is connected at one end to the intake manifold 3 between the fuel injection valve 7 and the throttle valve 4 therein. A device 10 is connected to the conduit 8 at its other end for sensing the air pressure within the intake manifold 3 exposed to the pressure detecting device 10. The pressure detecting device 10 is opened to the atmospheric pressure preferably through a conduit 9 interconnecting the detecting device 10 and the air cleaner 5. The pressure detecting device 10 is adapted to compare the air pressure within the intake manifold 3 with the atmospheric pressure within the air cleaner 5 and provides electrical output signals which are fed through a line 12 to an adjuster 13 which in turn supplies adjusted electrical output signals through lines 14 to respective fuel injection valves 7 so that the opening and closing operations of these injection valves are electrically controlled to permit the fuel in the conduit 11 to be introduced into respective engine cylinders.

FIG. 2 illustrates, partly in section, the details of the construction of the pressure detecting device 10. As will be seen in this figure, the pressure detecting device 10 comprises a generally cylindrical housing 15 closed by a convex closure cap 16 and a flat closure plate 17 both hermetically secured to the opposite end faces of the housing 15 by means of fastening screws 36 and 27, respectively. The housing has an integral transverse partition wall 15*a* which divides the interior of the housing into two chambers 15*b* and 15*c*. Another chamber 16*a* is defined by the closure cap 16 and a diaphragm 30 having its peripheral edge hermetically fastened between the inner surface of the cap 16 and the corresponding outer end face of the housing 15. The diaphragm 30 carries on the opposite sides a pair of dish-like washers 31 and 32 which are hermetically assembled together with the diaphragm 30 by means of a central shaft 33 extending axially through these members. Thus, it will be appreciated that the diaphragm 30 also serves to partly define the chamber 15*b*.

The housing 15 is provided therein with a second transverse wall 28 formed therein with a plurality of apertures 28*a* and having outer peripheral edge in engagement with an annular shoulder formed on the inner surface of the housing. The apertured wall 28 has a central hollow tubular portion 28*b* extending axially toward the dish-like washer 31 on the diaphragm 30. The central shaft 33 has an enlarged diameter portion axially extending loosely into the tubular portion 28*b*. The enlarged diameter portion has its end face formed with a concave spherical recess 33*a* therein for the purpose which will become apparent later. A compression coil spring 29 extends around the tubular portion 28*b* between the apertured wall 28 and the dish-like washer 31 so as to resiliently bias the diaphragm 30 leftwards as viewed in FIG. 2. An adjustable stop 34 is screwed down through the wall of the closure cap 16 into chamber 16*a* and is set in a proper position by means of a check nut 35. The above-mentioned conduit 9 is connected to the closure cap 16 so that the chamber 16*a* is in communication with the interior of the air cleaner 5 by means of the conduit 9.

Within the chamber 15*b* is mounted an axial shaft 21 having an outer end extending axially outwardly through a central opening in the wall 15*a* into the chamber 15*c*. The outer end of the shaft 21 carries thereon a core 22. An electrical coil 24 is mounted in the chamber 15*c* in radially closely spaced relationship to the core 22 on the shaft 21. The coil 24 has terminals 26 hermetically extending outwardly through an electrically insulating plug 25 on the closure plate 17 and are electrically connected to the adjuster 13 by means of the line 12. The coil 24 constitutes a displacement transducer which produces an electrical signal or output voltage across its terminal 26 according to a given displacement of the core 22.

The shaft 21 is connected at its inner end with a dish-like washer 20 to which is secured one end face of a first axially expansible bellows member 18*b* the other end face of which is connected through an axial member 18*c* to one end face of a second axially expansible bellows member 18*a* which in turn is secured at the other end face to a shaft 19 having a rounded outer end detachably received in the aforestated spherical recess 33*a* in the inner end face of the diaphragm shaft 33. A compression coil spring 23 extends around the shaft 21 between the housing wall 15*a* and the dish-like washer 20 so as to impart axial force to the bellows members 18*b* and 18*a* toward the diaphragm 30 or, in other words, in a direction in which these bellows members are restrained from axially expanding.

The above-mentioned conduit 8 is connected to the housing 15 so that the chamber 15*b* is in communication with the interior of the intake manifold 3 by means of the conduit 8.

In operation, the pressure within the intake manifold 3 of the engine is led through the conduit 8 to the chamber 15*b*. As the wall 28 is apertured, the pressure is exerted to one side of the diaphragm 30. On the other hand, the pressure within the air cleaner 5, which pressure is substantially equal to atmospheric pressure, is led to the chamber 16*a* through the conduit 9 and exerted to the other side of the diaphragm 30.

The fuel within the fuel conduit 11 is pressurized up to a predetermined pressure level by a fuel pump (not shown) and is arriving at the fuel injection valves 7. The adjuster 13 is supplied with signals related to the rotation of the engine by a means (not shown). At the same time, the detector 10 detects the change in the pressure within the conduit 8 and, thus within the intake manifold 3 as caused by adjustment of the position of the throttle valve 4. The detector 10 is operable to transform the pressure change into an electrical signal which is also fed to the adjuster 13 which in turn determines, in accordance with the two kinds of input signals, the period of time during which a third electrical signal is to be fed to the fuel injection valves 7 so as to cause the fuel to be injected thereby. Thus, the adjuster 13 feeds to the fuel injection valves 7 the third signal which is durable for the determined period of time. It will therefore be appreciated that the adjuster 13 controls the quantity of the fuel to be injected by the fuel injection valves 7.

Referring then to FIG. 2, a description will be made with respect to the device 10 for detecting the pressure within the intake manifold 3. For the purpose of simplifying the description, it is now assumed that the washer 31 of the diaphragm 30 is urged into abutting engagement with the end face of the tubular portion 28*b* of the apertured wall 28. The bellows members 18*a* and 18*b* are so preset as to have the illustrated positions with their inner spaces vacuumed. The bellows members are thus operable to axially expand or collapse in response to change in the pressure surrounding the bellows members within the chamber 15*b*. Since the axial member 19 is held stationary by the concave spherical bearing seat 33*a* of the diaphragm shaft 33, the bellows members 18*a* and 18*b* will axially displace the core 22 to a position in which the amount of the pressure change equilibrates with the axially biasing force of the coil spring 23 between the bellows washer 20 and the housing wall 15*a*. In other words, when the pressure within the chamber 15*b* is increased, the bellows members 18*a* and 18*b* are axially collapsed to displace the core 22 leftwards as viewed in FIG. 2 relative to the coil 24 so that the latter will emit electrical signals whereby the quantity of the fuel to be injected is increased. On the other hand, when the pressure within the chamber 15*b* is decreased, the bellows members 18*a* and 18*b* are axially expanded to shift the core 22 rightwards as viewed in FIG. 2 with respect to the coil 24, resulting in decrease in the quantity of the fuel to be passed through the fuel injection valves 7.

The diaphragm 30 and the coil spring 29 are so arranged that the diaphragm 30 and its central shaft 33 are forced rightwards as viewed in FIG. 2 to urge the diaphragm washer 31 against the end face of the tubular portion 28*b* of the apertured wall 28 by the pressure differential between the atmospheric pressure within the chamber 16*a* and the pressure within the chamber 15*b* when the pressure differential is more than a predetermined value, for example, 100 mm. Hg. In other words, the resiliency of the diaphragm 30 is so determined that the axially rightward force of the diaphragm is greater than the axially leftward force produced by the spring 29 to thereby urge the diaphragm washer 31 against the tubular portion 28*b* (as shown in FIG. 2) when the air pressure within the chamber 15*b* acting on one side of the diaphragm 30 is less than the atmospheric pressure within the other chamber 16*a* acting on the other side of the diaphragm by more than the predetermined value, namely, 100 mm. Hg. in an embodiment of the invention. Thus, when the pressure within the intake manifold 3 is maintained within a range the maximum value of which is less than the atmospheric pressure by more than a predetermined value, for example, 100 mm. Hg., the bellows members 18*a* and 18*b* are operable to axially expand or collapse in a similar manner as that in which they are operable in a case where the diaphragm 30 should not be employed. This is a diagrammatically illustrated in FIG. 3 in which the leftward stroke of the core 22 is represented by "L" in ordinate and the pressure within the intake manifold 3 is represented by "P" in abscissa. Assuming that the atmospheric pressure is at 760 mm. Hg., the bellows members 18*a* and 18*b* operate in accordance with the pressure within the intake manifold to move the core 22 in a linear characteristic as indicated at "*a*" before the pressure within the intake manifold 3 is reached by 660 mm. Hg. (760–ΔP).

It is then assumed that the pressure within the intake manifold 3 is increased up to a value which is differentiated from the atmospheric pressure value by less than 100 mm. Hg., that is, up to a value 660 plus ΔP. Under the circumstance, the air pressures acting on both sides of the diaphragm 30 have a reduced pressure differential so that the axially leftward biassing force of the diaphragm spring 29 overcomes the axially rightward force of the diaphragm 30 as produced by the reduced pressure differential to thereby cause the diaphragm and the concave spherical bearing recess 33*a* in the diaphragm shaft 33 to be moved leftwards as viewed in FIG. 2 to a position in which an equilibrium is obtained. In addition, the increased pressure within the manifold 3 and, thus, within the chamber 15*b* will partially collapse the bellows members 18*a* and 18*b*. The leftward movement of the diaphragm 30 is combined with the collapse of the bellows members so that the core 22 is moved leftward a distance ΔL as indicated by "*b*" in FIG. 3.

When the pressure within the intake manifold 3 is increased to be equal with the atmospheric pressure, the diaphragm 30 does not have an axially rightward force produced by the pressure difference and thus is moved to a position in which the diaphragm shaft 33 is urged against the stop 34. In this position of the diaphragm assembly, the displacement or stroke "L" of the core 22 relative to the air pressure "P" within the chamber 15*b* solely depends upon the axial expansion of the bellows members 18*a* and 18*b* against the spring 23 and is of linear characteristic as indicated at "*c*" in FIG. 3. It will be appreciated that the line *a* in FIG. 3 is in parallel with the line *c* and is spaced therefrom by a distance corresponding to ΔL. When the pressure within the chamber 15*b* is decreased so sufficiently that the diaphragm assembly which has been pressed against the stop 34 will be moved rightwards, the movement of the diaphragm assembly is added to the displacement of the core 22 caused by the axial expansion of the bellows members 18*a* and 18*b*, with the result that the core 22 has an increased rightward stroke or displacement as indicated by "*b*" in FIG. 3. This increased displacement of the core 22 will be transformed by the electrical coil 24 into an electrical signal which will be fed through the terminals 26 and the line 12 to the controller 13 which in turn will be operable to control the quantity of the fuel to be fed through the fuel injection valves 7. It will be understood that, in a case where the system of the present invention is not provided with the diaphragm 30, the system will have an output characteristic represented by a dotted line *a'* when the pressure within the intake manifold 3 is more than 660 mm. Hg. The output characteristic line *c* is in parallel with the imaginary output characteristic line *a'* and is spaced or shifted therefrom a distance ΔL. The two lines *a'* and *c* are interconnected by the inclined line *b*. The degree of the inclination of the line *b* depends upon the characteristic of the spring acting on the diaphragm 30.

As will be seen from the above description, the system of the present invention is operable to control the fuel supply to the engine in such a manner that the fuel is supplied through the fuel injection valves to the combustion chambers at such a flow rate as to provide maximum thermal efficiency for the operation of the engine when the pressure differential between the pressure within the intake manifold 3 and the atmospheric pressure is more than a predetermined value ΔP, for example, 100 mm. Hg. in the instant embodiment of the invention. In addition, when the engine is in a state in which the pressure differential between the pressure within the intake manifold and the atmospheric pressure is less than the predetermined value ΔP, or in other words, when the engine is in a state in which a greater output of the engine is required as is during accelerating operation, the system of the invention is operable to control the fuel injection valves so that increased amount of fuel is allowed to pass through the valves into the combustion chambers.

With the fuel supply controlling system of the present invention, the change in fuel supply rate, that is, the change from a fuel supply rate at which the fuel is supplied to the engine so as to provide a maximum thermal efficiency for the engine as is in normal operation thereof to a fuel supply rate at which increased amount of fuel is supplied to the engine as is during accelerating operation, is achieved solely by the pressure differential between the air pressure acting on the diaphragm 30 which pressure differential serves to displace the initial positions of the bellows members 18*a* and 18*b* and the core 22 with respect to the electrical coil 24. Thus, the present invention is not required to employ an additional electrical circuit including a change-over switch which is otherwise required by conventional system of this kind for fuel supply at a greater rate so as to cause the engine to produce a greater output such as at accelerating operation. In addition, the bellows members 18*a* and 18*b* and the spring 23 of the present invention are not required to operate in non-linear characteristic even when these members alone are relied upon in performing control of the fuel supply, with a resultant advantage that the present invention can provide a fuel supply controlling system which is simple in construction and is easy to manufacture. Furthermore, since the system of the present invention utilizes the pressure differential between the atmospheric pressure and the pressure within the air inlet pipe both acting upon the diaphragm 30 to perform a change in fuel supply rate when a greater output of the engine is required as is at accelerating operation of the engine, an additional advantage is obtainable that, even if the engine is operated in an atmosphere of varied absolute value such as in a high ground, the system of the invention is not influenced by the variation in the absolute value of the atmospheric pressure and is operable to accurately increase the quantity of the fuel to be supplied to the engine at accelerating operation thereof.

I claim:

1. A device for controlling the fuel supply into an internal combustion engine, said device including a housing defining a substantially hermetically closed space therein, means within said housing sensitive to the variation in the absolute pressure value within the intake manifold of said engine, means within said housing operable in response to the pressure differential of more than a predetermined value between the pressure within said intake manifold and the atmospheric pressure so as to be displaced in one direction into mechanical connection with said absolute pressure variation sensitive means, and means for transducing the operation of said absolute pressure variation sensitive means and the displacement thereof by said pressure differential responsive means into electrical signals

which are utilized to control the fuel supply to said engine, characterized by the features that said absolute pressure variation sensitive means comprise at least one bellows member, said differential pressure responsive means including a diaphragm member dividing said closed space in said housing into two chambers one of which is in communication with the interior of said intake manifold, the other chamber being open to the atmosphere, said bellows member being disposed within said one chamber, said differential pressure responsive means also including a spring member in engagement with said diaphragm, said spring member being pre-loaded so as to resiliently displace said diaphragm member in the other direction when said pressure differential is less than said predetermined value, and that there are provided a second spring member biasing said bellows member in said the other direction to cause the same to follow the displacement of said diaphragm member in said the other direction for thereby shifting the normal operative position of said bellows member in said the other direction, and stop means for limiting the displacement of said diaphragm member and said bellows member in said the other direction.

2. A device as defined in claim **1**, in which said stop means is an adjusting screw member threadably extending through the wall of said housing into said the other chamber.

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