United States Patent

Ishida

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[54] **FUEL SUPPLY SYSTEM FOR INTERNAL COMBUSTION ENGINES**

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Nov. 22, 1969 Japan 44/93814

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[51] **Int. Cl.** **F02d 1/04,** F02b 33/00

[58] **Field of Search** .123/119 R, 140 MC, 261, 36 A, 123/261 FL, DIG. 69

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Assistant Examiner—Ronald B. Cox
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[57] **ABSTRACT**

A fuel supply system for internal combustion engines comprising an engine rpm function control circuit for controlling fuel flow in conformity with the rpm of the engine, a manifold boosted pressure function control circuit for controlling fuel flow in conformity with the boosted pressure in the manifold, a summing impact modulator for causing fuel controlled by said two circuits to be injected, and a transverse impact modulator for supplying air in amounts such that proper proportions of air and fuel can be obtained in conformity with the boosted pressure.

5 Claims, 12 Drawing Figures

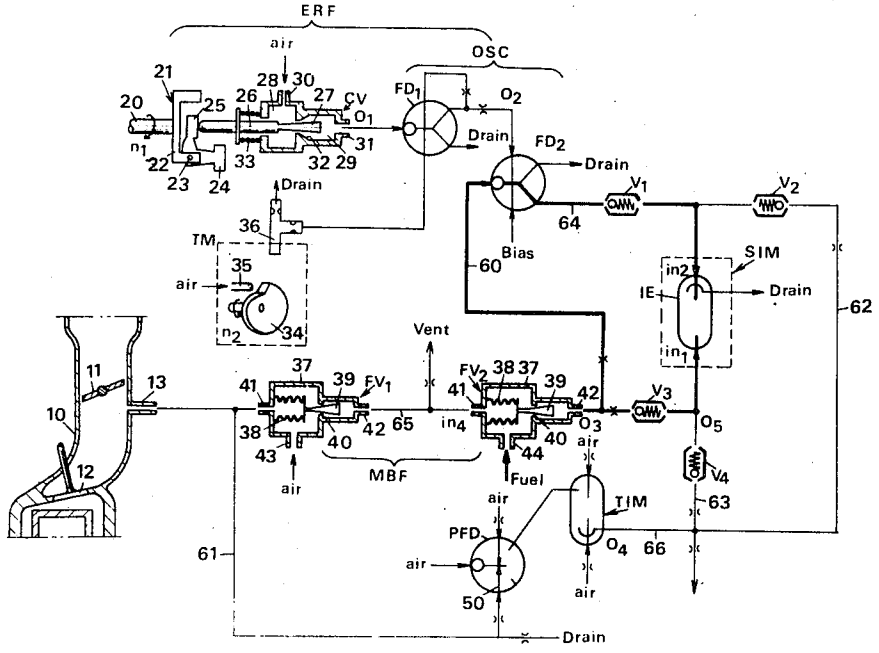


FIG. 1

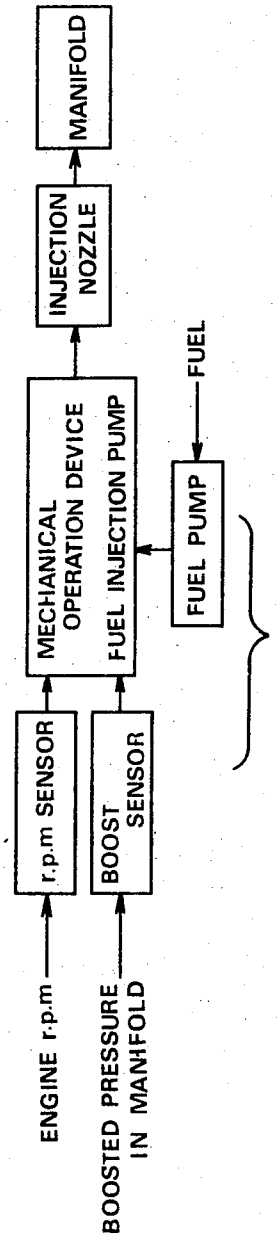
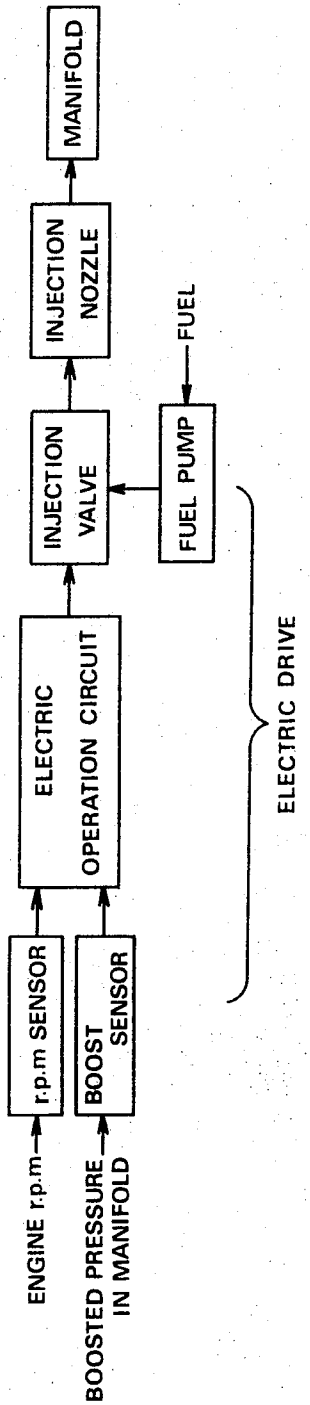


FIG. 2



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FIG. 3

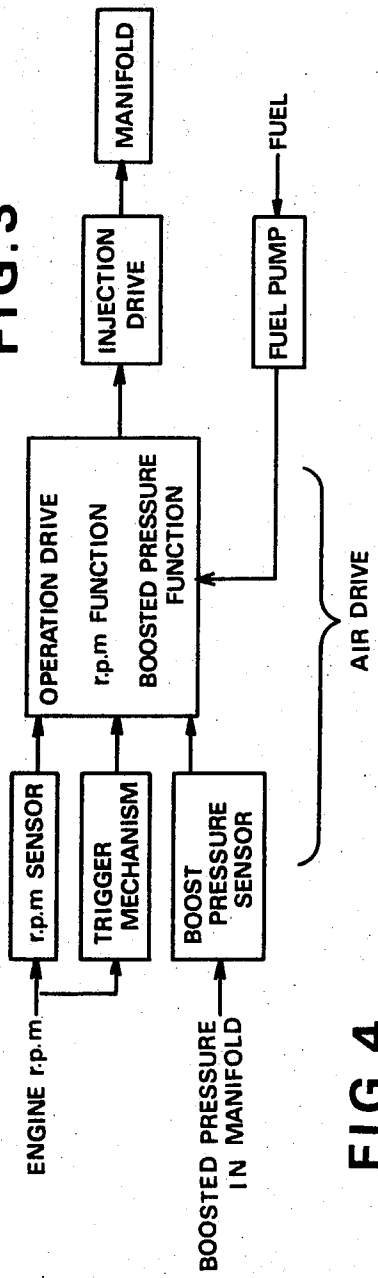
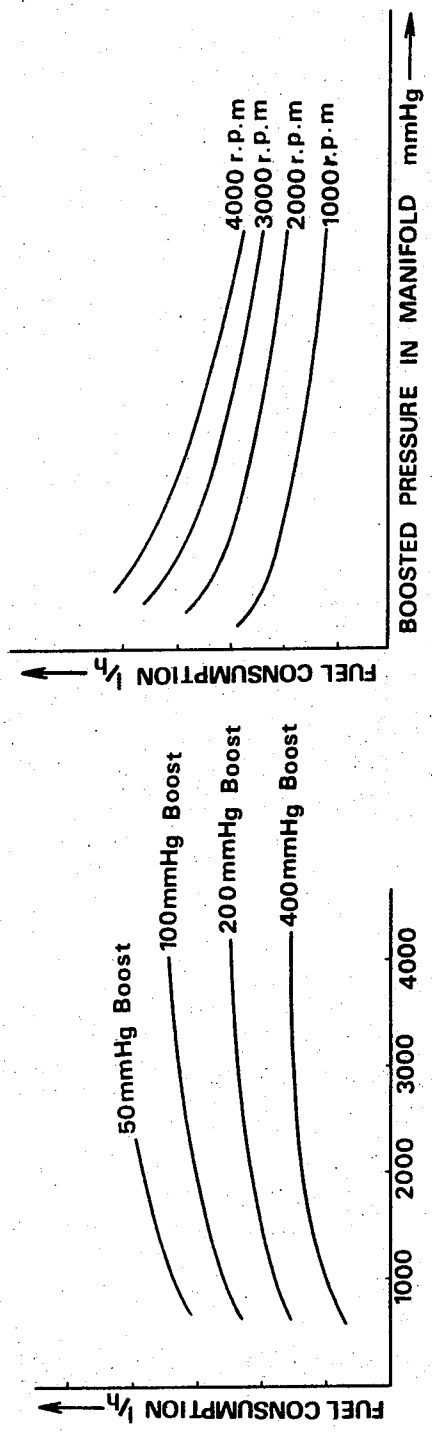


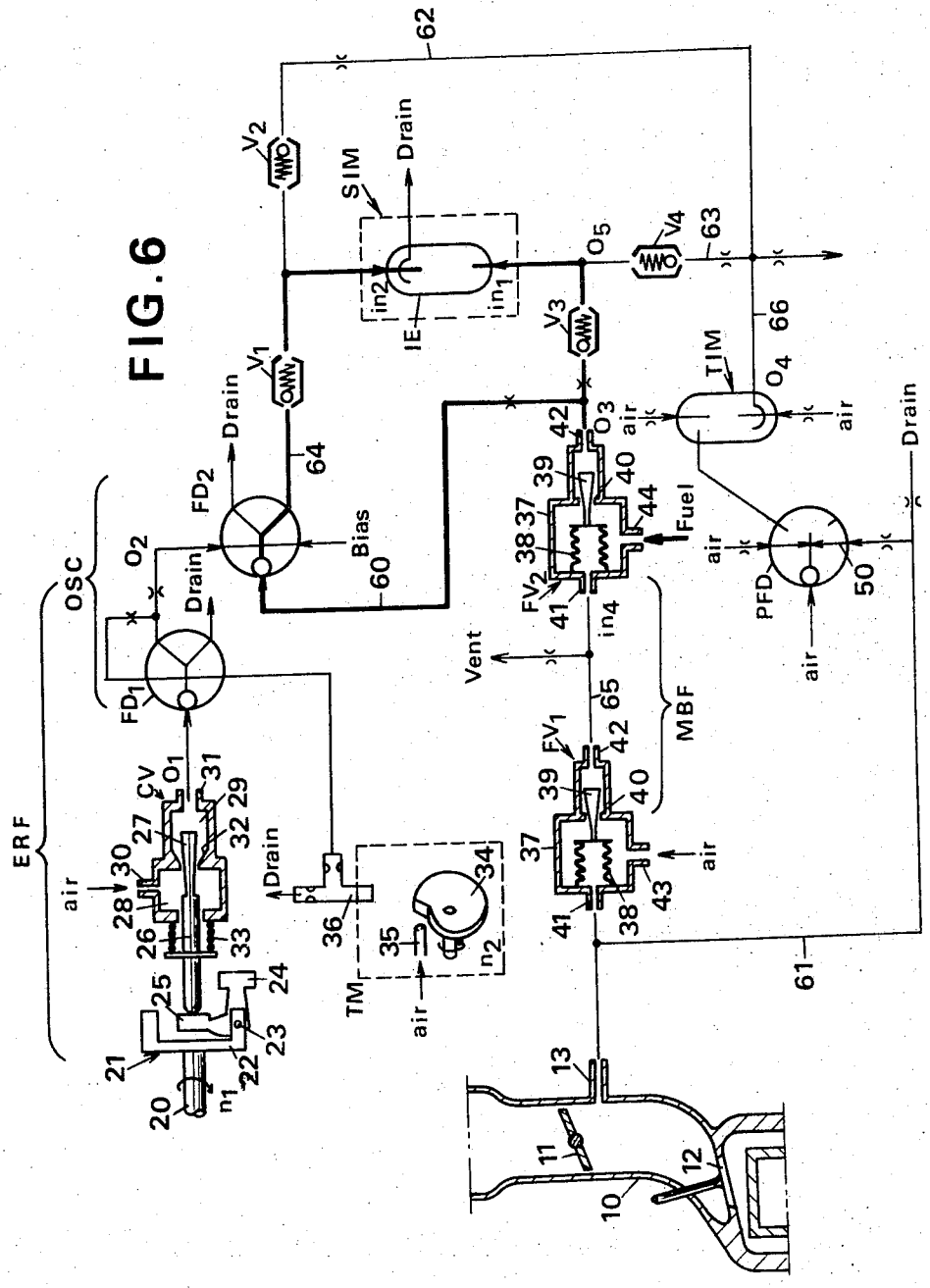
FIG. 4

FIG. 5



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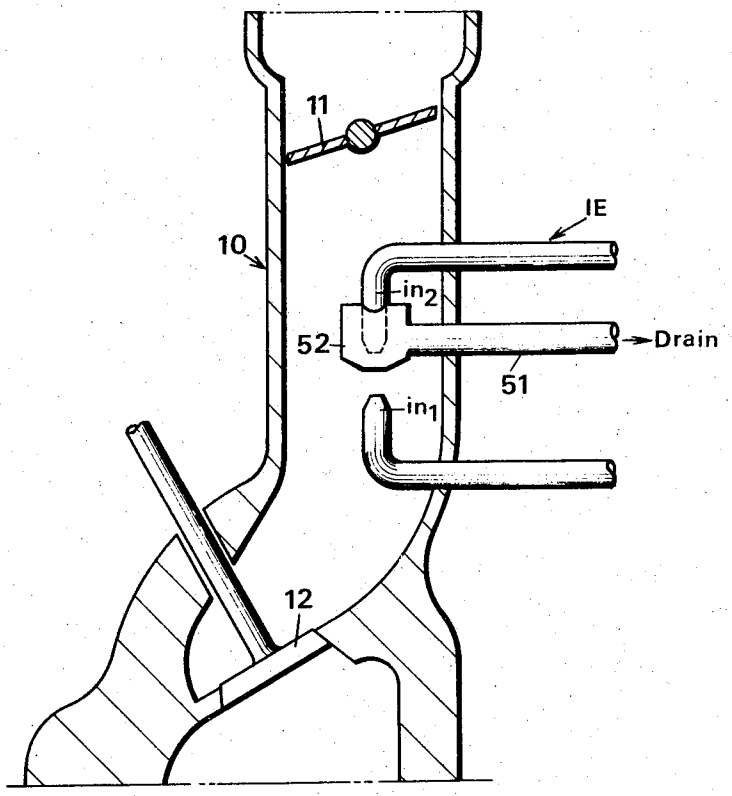
FIG. 6



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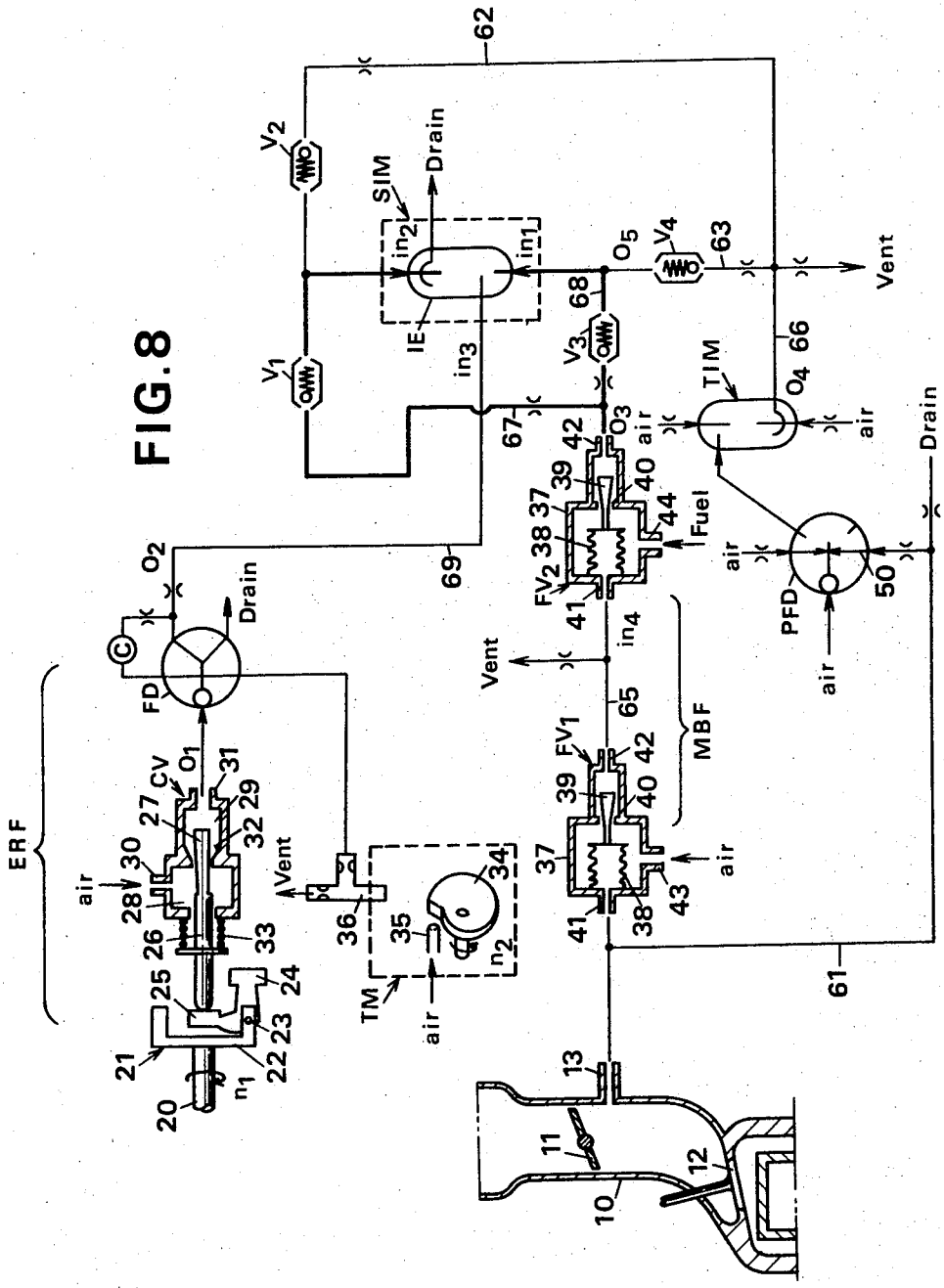
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FIG. 7



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FIG. 8



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FIG.9

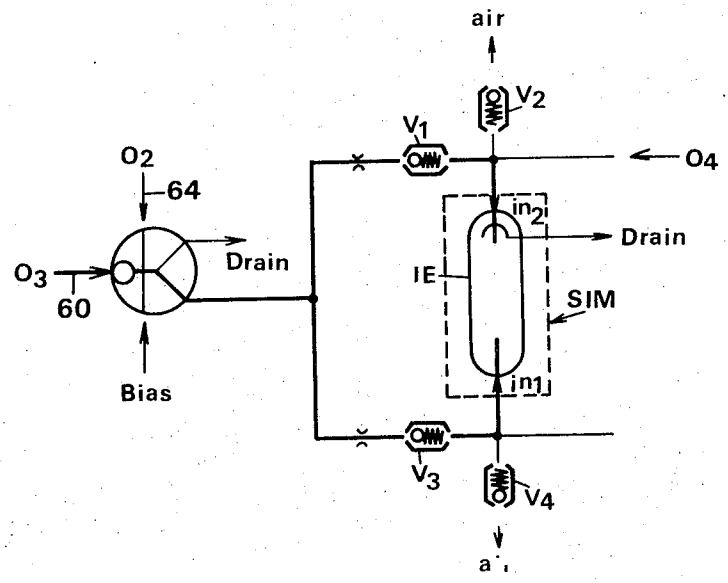
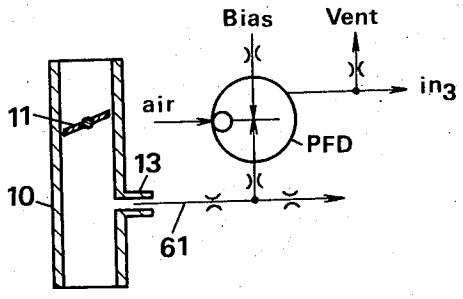


FIG.10



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FIG.11

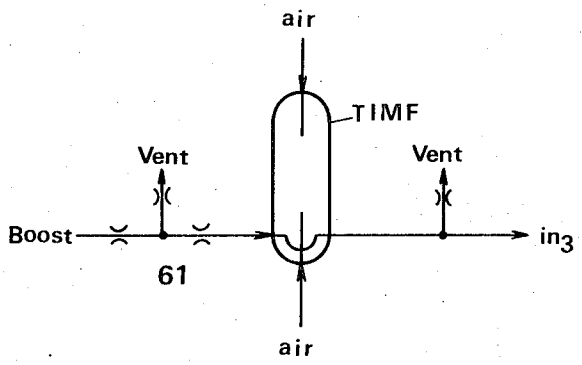
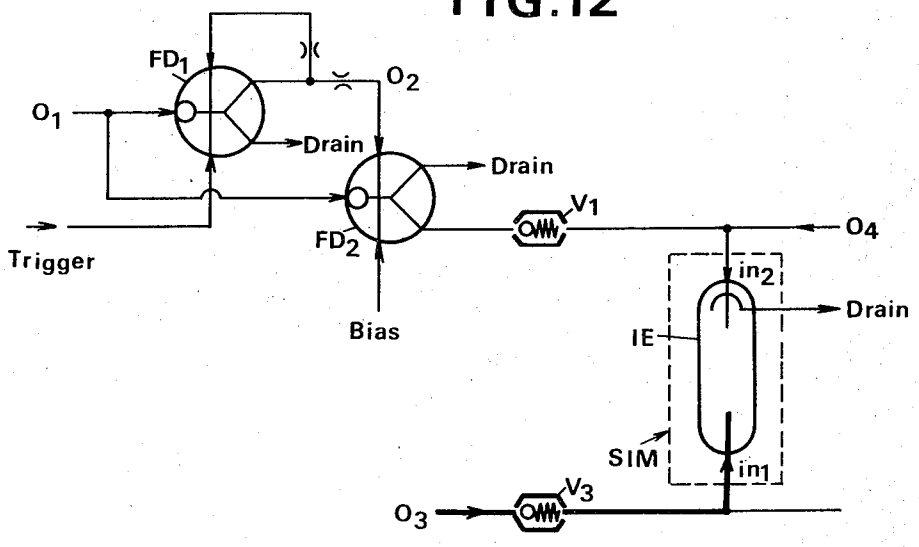


FIG.12



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FUEL SUPPLY SYSTEM FOR INTERNAL COMBUSTION ENGINES

This invention relates to fuel supply systems for internal combustion engines. More particularly, the invention deals with a fuel supply system for internal combustion engines which employs fluid elements in the fuel injection control circuit to ensure that fuel injection positively takes place during each suction stroke of the engine.

Heretofore, many fuel supply systems for internal combustion engines have been known wherein the valve is opened and closed by a mechanical or electric system for injecting fuel into the engine manifold through a small aperture. In a mechanical fuel supply system, the number of revolution per minute (hereinafter referred to as the rpm) of the engine, the opening of the aperture of the air valve and the internal pressure in the manifold are detected and the values obtained are applied to a mechanical operation device for actuating the injection nozzle as shown in FIG. 1. In an electric fuel supply system, the values obtained by detecting the rpm of the engine and the boosted pressure in the manifold are applied to an electric operation circuit for opening and closing the valve for injecting fuel. These systems of the prior art are not without disadvantages.

When fuel supply is controlled mechanically, it is not possible to effect injection of fuel satisfactorily irrespective of the conditions of the load. Misoperation may result from vibration and noise of external electromagnetic waves when the electric control of fuel supply is carried out.

Accordingly, an object of the present invention is to provide a fuel supply system for internal combustion engines which employs fluid elements in the fuel injection control circuit to ensure that fuel injection positively takes place during each suction stroke of the engine.

Another object of the invention is to provide a fuel supply system for internal combustion engines wherein fluid elements having no movable parts are provided in the injection nozzle portion and a part of the operation device for controlling the amount of fuel to be injected so that the fuel injected during each suction stroke of the engine may be in amounts such that correct proportions of fuel and air can be obtained.

The present invention is based on the following technical concept. Generally, the fuel flow characteristics of any reciprocating engine are represented by the factors which are the rpm of the engine and the boosted pressure in the manifold. Accordingly, fuel consumption may be indicated as the amount of fuel consumed in terms of the rpm of the engine using the boosted pressure as a parameter as shown in FIG. 4 or as the amount of fuel consumed in terms of the boosted pressure using the rpm of the engine as a parameter as shown in FIG. 5. In either case, the amount of fuel consumed covers all the operation conditions of the vehicle. From this, it naturally follows that, if a function of the rpm of the engine and a function of the boosted pressure in the manifold are prepared, then it is possible to cover fuel consumption at all the vehicle speeds under all operating conditions.

In accordance with the aforementioned concept, the rpm of the engine is converted into a pneumatic pressure in the present invention, and the pneumatic pressure detected and the boosted pressure in the manifold are applied to an operation device which is provided with fluid elements so as to operate a fuel injection device.

According to this invention, there is provided a fuel supply system for internal combustion engines which comprises an engine rpm function control circuit for controlling fuel flow in conformity with the rpm of the engine, a manifold boosted pressure function control circuit for controlling fuel flow in conformity with the boosted pressure in the manifold, a summing impact modulator for causing fuel controlled by such two circuits to be injected, and a transverse impact modulator for supplying air in amounts such that proper proportions of air and fuel can be obtained in conformity with the boosted pressure.

The fuel supply system according to this invention constructed as aforementioned has many advantages. According to the invention, the rpm of the engine, and the boosted pressure in the manifold are detected in terms of pneumatic pressures and the operation device is driven by the pneumatic pressures, so that it is possible to obtain optimum air-fuel mixtures over a wide range of vehicle speeds under all engine operation conditions. The fuel supply system according to this invention is free from the influences of vibration and noise. Besides, atomization of fuel can be effected satisfactorily.

Additional objects of this invention as well as features and advantages thereof will become evident from the description set forth hereinafter when considered in conjunction with the accompanying drawings, in which:

FIG. 1 and FIG. 2 are block diagrams of conventional fuel supply systems for internal combustion engines;

FIG. 3 is a block diagram of the fuel supply system according to this invention;

FIG. 4 is a diagrammatic representation of fuel consumption in terms of the rpm of the engine using the boosted pressure as a parameter;

FIG. 5 is a diagrammatic representation of fuel consumption in terms of the boosted pressure using the rpm of the engine as a parameter;

FIG. 6 is a schematic view showing the arrangement of various parts of one embodiment of the fuel supply system shown in FIG. 3;

FIG. 7 is a sectional view, on an enlarged scale, of the fuel injection nozzle portion of the system of FIG. 6;

FIG. 8 is a schematic view showing the arrangement of various parts of another embodiment of the fuel supply system shown in FIG. 3;

FIG. 9 is a view showing a modification of FIG. 6 in which the parts following the one shot circuit are changed;

FIG. 10 and FIG. 11 show examples in which a proportioning element and a fluid element of the collision type are used respectively in place of the pneumatic pressure control valve; and

FIG. 12 shows another modification in which engine rpm function control is effected by pneumatic pressure alone.

Embodiments of this invention will now be explained with reference to the accompanying drawings. FIG. 6 shows a first embodiment of the fuel supply system ac-

cording to this invention which comprises an engine rpm function control circuit ERF, manifold boosted pressure function control circuit MBF, summing impact modulator SIM for causing fuel to be injected in conformity with the outputs of the two aforementioned circuits, and a transverse impact modulator TIM for supplying air in amounts such that correct proportions of air and fuel can be obtained in conformity with the boosted pressure.

The engine rpm function control circuit ERF detects the number of revolution per minute of a rotary shaft **20** connected to the engine crank shaft and the like and controls fuel flow in accordance with the rpm of the engine. The manifold boosted pressure function control circuit MBF controls fluid flow in terms of the boosted pressure in a manifold **10** using the boosted pressure as an input. The manifold **10** is provided with a throttle valve **11** on the opening side and an inlet valve **12** on the engine side, and a boosted pressure detection aperture **13** is formed in the wall of the manifold **10** in a position below the throttle valve **11**. The summing impact modulator SIM is attached to the manifold **10** in the form of an injection element IE.

ENGINE RPM FUNCTION CONTROL CIRCUIT

This circuit ERF comprises a governor **21**, pneumatic pressure control valve CV, one shot circuit OSC and trigger means TM.

A fly-weight **24** which is brought to an upright position while the rotary shaft **20** rotates is pivotally supported by a pin **23** attached to a part of a disc **22**. The fly-weight **24** includes an arm **25** which is adapted to engage a forward end of a valve stem **26** of the control valve CV.

The valve stem **26** extends through the interior of a casing of the control valve CV which is divided into two chambers **28** and **29** by a valve seat **32** cooperating with a needle **27** attached to a rear end of the valve stem **26**. An air supply port **30** is formed in the wall of one chamber **28** and an air exhaust port **31** is formed in the wall of the other chamber **29**. The valve stem **26** extending through the valve casing is normally urged by the biasing force of a spring **33** to move in a direction such that the forward end of the valve stem **26** is brought into engagement with an end surface of the arm **25** and the needle **27** is seated at the valve seat **32**.

If the valve stem **26** moves to the right in FIG. **6** against the biasing force of the spring **33**, the aperture of the control valve CV will be successively increased in cross-sectional area. Accordingly, a discharged air flow 0_1 proportional to the rpm of the engine is supplied to the one shot circuit OSC.

The one shot circuit OSC comprises two fluid elements FD_1 and FD_2 which have no movable parts. The output 0_1 of the control valve CV is applied to the one shot circuit OSC as an input thereto and the deflected output 0_2 of the first stage fluid element FD_1 is introduced into a control port of the second stage fluid element FD_2 whose output is applied through a check valve V_1 to an injection port in_2 of the summing impact modulator SIM subsequently to be described.

Signals from trigger means TM are introduced into the first stage fluid element FD_1. The trigger means TM comprises a cam disc **34** formed with a planar surface which is inclined with respect to the direction of rotation of the cam disc, an air jet supply duct **35** through which an air jet stream is supplied to impinge on the inclined planar surface, and an output duct **36** through which one impulse output signal is provided for each revolution of the cam disc **34**.

The number of revolution n_2 of the cam disc **34** can be expressed as follows:

$$n_2 = \tfrac{1}{2} kn_1 \ldots . \text{ In the case of four cycle engines.}$$

$$= kn_1 \ldots \text{ In the case of two cycle engines.}$$

where n_1 is the number of revolution of the governor **21** and $n_1 = k_1 n_e$, n_e being the number of revolution of the engine crank shaft and k_1 being the constant. Thus, as the cam disc rotates, trigger signals of a definite cycle are applied to the first stage fluid element FD_1 as a basis for engine rpm function control.

A fuel supply controlled by the manifold boosted pressure function control circuit MBF is delivered to a main injection port of the second stage fluid element FD_2, and the periodical output 0_2 of the first stage fluid element FD_1 is applied to the second stage fluid element FD_2 which produces a deflected output.

MANIFOLD BOOSTED PRESSURE FUNCTION CONTROL CIRCUIT

This circuit MBF comprises a pneumatic pressure control valve FV_1 and fuel flow control valve FV_2 connected in series with each other.

The pneumatic pressure control valve FV_1 and fuel control valve FV_2 each includes a valve casing **37** in which a bellows **38** and a needle **39** cooperating with a valve seat **40** are mounted. The valve casing **37** is formed on the wall on the bellows side with an input port **41** and on the wall on the needle side with an output port **42**. An air supply port **43** is formed in a side wall of the first stage valve FV_1 and a fuel supply port **44** is formed in a side wall of the second stage valve FV_2.

The pneumatic pressure supplied through the detection aperture **13** of the manifold **10** is introduced into the input port **41** of the first stage valve FV_1 to actuate the bellows **38** and produce an output which is applied to the input port **41** of the second stage valve FV_2. An output 0_3 of the second stage valve FV_2 is applied to an injection port in_1 of the summing impact modulator SIM.

The second stage valve FV_2 varies the aperture formed between the valve seat **40** and needle **39** as the bellows **38** expands and contracts in conformity with the magnitude of the outputs of the first stage valve FV_1 so as to control fuel flow therethrough after the fuel is supplied through the fuel supply port **44**.

Part of the output O_3 of the second stage valve FV_2 is passed through a branch line **60** to a main injection port of the second stage fluid element FD_2 of the one shot circuit referred to above.

TRANSVERSE IMPACT MODULATOR

This circuit TIM is intended to supply air in amounts such that proper proportions of air and fuel in proportion to the boosted pressure can be provided.

A line **61** branching from the line connecting the boosted pressure detection aperture **13** to the first stage valve FV_1 referred to above is connected to a

control port **50** of a proportioning element PFD. The output of the proportioning element PFD is transmitted to the modulator circuit TIM whose output is supplied through a check valve V_2 mounted on a line **62** to the injection port in_2 of the summing impact modulator SIM together with the output of the second stage fluid element FD_2 supplied through a check valve V_1. Part of the output of the modulator circuit TIM is passed through a check valve V_4 on a line **63** and supplied to the injection port in_1 of the summing impact modulator SIM together with the output of the second stage valve FV_2 which is passed through a check valve V_3.

SUMMING IMPACT MODULATOR

This circuit SIM is provided with a drain in addition to the injection ports in_1 and in_2 referred to above. The circuit SIM is formed into an injection element IE to be built in the manifold **10** as shown in FIG. **7**. It will be seen that the injection ports in_1 and in_2 have apertures which are juxtaposed to each other with a small clearance being interposed therebetween, and that a cover **52** is provided around the injection port in_2 to which a drain **51** is connected.

OPERATION OF THE SYSTEM

The operation of the fuel supply system according to this invention will now be explained. In FIG. **6**, the governor **21** rotates at a rate proportionate to the rate of revolution of the engine and actuates the fly weight **24** for regulating the pneumatic pressure control valve CV.

The output of the control valve CV is supplied to the one shot circuit OSC as its input while the one shot circuit is triggered by pulse-like pneumatic pressure signals from the trigger means TM.

The cam disc **34** for producing trigger signals produces one trigger pulse for each one complete revolution. Therefore, the cam disc is set such that it rotates at a number of revolution which is one half the number of revolution of the crank shaft of four-cycle engines and at the same number of rotation as the crank shaft of two-cycle engines.

The output cycle of the one shot circuit OSC is increased as its supply pressure increases. The output characteristics of the engine rpm function control circuit ERF comprising the governor **21**, pneumatic pressure control valve CV, one shot circuit OSC and trigger means TM are such that by selecting a suitable shape for the needle **27** of the control valve CV it is possible to draw curves of fuel consumption as shown in FIG. **4**. An engine rpm function can be obtained in this way.

On the other hand, the boosted pressure in the manifold is led to the pneumatic pressure control valve FV_1 including the bellows and needle. The needle **39** of the pneumatic pressure control valve FV_1 is set such that the output of the control valve FV_1 is reduced in value when the absolute value of the boosted pressure is increased, and increased when the absolute value of the boosted pressure is reduced. The pneumatic pressure regulated in this way is supplied to the fuel flow control valve FV_2 to which fuel is supplied. The fuel flow control valve FV_2 is constructed such that by selecting a suitable shape for the needle **39** it is possible to draw curves of fuel consumption as shown in FIG. **5**. A manifold boosted pressure function can be obtained in this way.

Thus, the engine rpm function and manifold boosted pressure function are produced, and part of the output of the fuel flow control valve FV_2 is transmitted to the one shot circuit OSC as a supply of power.

Part of the output of the fuel control valve FV_2 is transmitted through the check valve V_3 to the summing impact modulator SIM provided in the manifold **10** as a supply of power thereto. In FIG. **6**, this supply of power is shown as being in the form of a steady current and not being pulse-like. On the other hand, the output of the one shot circuit OSC is transmitted through the check valve V_1 to the summing impact modulator SIM as a supply thereto. The supply of power passed through the check valve V_1 is set to enter the summing impact modulator from the side on which its output port is provided. Accordingly, the supply of power to the injection port in_2 shown in FIGS. **6** and **7** is in pulse form. The check valve V_1 is an element which is intended to prevent reverse flow of pneumatic pressure to the one shot circuit which might otherwise be caused by the supply of power delivered in the form of a steady stream to the injection port in_1 when there is no output of second stage fuel element FD_2. Because of this arrangement, the injection port in_1 does not constitute a so-called impact surface when no pressure is applied to the injection port in_2 and fuel is drained away through the output port of the summing impact modulator SIM. The fuel is returned to a fuel tank or fuel pump (not shown).

It will thus be seen that the summing impact modulator SIM provided in the manifold **10** constitutes an impact surface by the output of the one shot circuit OSC for injecting fuel into the manifold **10**. The interval of time in which fuel injection takes place may vary depending on the rpm of the engine and the pressure under which fuel is injected may vary depending on the boosted pressure. The interval of time in which fuel injection takes place can be freely selected by suitably setting the cam disc **34** of the trigger means TM.

The lines **64** and **65** can be constructed such that, when the absolute value of the boosted pressure in the manifold exceeds a certain level, there is no output of the fuel flow control valve FV_2. At the same time, air is supplied to the summing impact modulator SIM in the manifold **10** in the form of a steady current and not in pulse form.

By controlling the input to the one shot circuit OSC by suitably reducing the boosted pressure, the output of OSC can be made to be in inverse proportion to the absolute value of the boosted pressure. The output of the transverse impact modulator TIM is supplied to the summing impact modulator SIM in the manifold **10** through the check valve V_2. By selecting a suitable spring for the check valve V_2, it is possible to supply air to the summing impact modulator SIM when the absolute value of the boosted pressure exceeds a certain level. It will thus be seen that, when the vehicle is coasting, air injection takes place simultaneously as the supply of fuel is cut, thereby preventing contamination of atmosphere by the exhaust of incompletely combusted fuel.

In mechanical fuel injection systems of the prior art, the mechanical operation device, injection nozzle and the like require high precision machining. Yet, it is not possible to effect fuel injection in an ideal manner by conventional systems when fuel flow is low in rate, such

as when the engine is idling. In some cases, the stability of engine operation is lower than that of carbureter.

Electric systems of the prior art are disadvantageous in that misoperation of operation circuit may result from vibration, abnormal engine temperatures and electromagnetic wave noise. In electric systems, the injection nozzle portion requires no less high precision machining than in mechanical systems.

In the present invention, ordinary (not precise) machine finishes of the parts are tolerated, and the parts are impervious to the influences of vibration, heat, electromagnetic wave and the like. The mechanism of cutting of fuel when the vehicle is coasting is very much simpler in the fuel supply system of this invention than in the conventional fuel supply system using a carbureter. This invention makes it possible to provide correct proportions of fuel and air by utilizing an engine rpm function of normal operation and a manifold boosted pressure function in combination with each other.

FIG. **8** shows another embodiment of the invention in which the summing impact modulator SIM serving as an injection element in the embodiment shown in FIG. **6** is replaced by the transverse impact modulator TIM. The operation of this modulator is similar to that of the modulator of FIG. **6** except for the operation of the injection element. When the transverse impact modulator TIM is used as an injection element, a supply of fuel or the output 0_3 of the fuel control valve FV_2 is passed through lines **67** and **68** and applied to the injection ports in_2 and in_1 while the output of the one shot circuit OSC is passed through a line **69** and applied to an injection port in_3 (which corresponds to the inlet port of the transverse impact modulator TIM shown in FIG. **6**), so that fuel injection may take place as the flow of fuel to the injection port in_1 is disturbed.

FIG. **9** shows a modification of the embodiment shown in FIG. **6** in which the one shot circuit OSC and the mechanisms that follow it are changed. In this modification, valves V_1, V_2, V_3 and V_4 are set such that fuel is caused to flow to the injection ports in_1 and in_2 of the summing impact modulator SIM only when fuel injection takes place and air is drawn by suction when fuel injection does not take place.

In the modification shown in FIG. **10**, the pneumatic pressure control valve FV_1 of the embodiment shown in FIG. **6** is replaced by a proportioning element PFD. The boosted pressure in the manifold is suitably reduced and led to one control port of the proportioning element PFD whose output is supplied to the inlet in_4 of the fuel control valve FV_2. This arrangement permits to replace the needle and bellows by an element having no movable parts.

FIG. **11** shows a modification in which the air pressure control valve FV_1 of the embodiment shown in FIG. **6** is replaced by the transverse impact modulator TIM instead of the proportioning element.

FIG. **12** shows a modification in which fuel of boosted pressure function is supplied only to the supply port in_1 of the summing impact modulator SIM while the engine rpm function is operated by air, and pneumatic signals are supplied to the supply port in_2 of the modulator SIM, so that an impact surface of fuel and air can be formed in the manifold.

From the foregoing description, it will be appreciated that according to the present invention injection of fuel is controlled not by mechanical means but by the collision between fuel and fuel or fuel and air. This arrangement is effective to bring about atomization of fuel in a satisfactory manner and thereby increase efficiency of combustion of fuel, making it possible to economize on fuel and reduce the amount of noxious materials in the exhausts. The use of the fluid elements permits to reduce production cost of the fuel supply system according to this invention as compared with fuel injection systems of the prior art. Besides, the fuel supply system according to this invention operates positively and is reliable in performance.

What I claim is:

1. A fuel supply system for internal combustion engines comprising an engine rpm function control circuit for controlling fuel flow in conformity with the rpm of the engine, a manifold boosted pressure function control circuit for controlling fuel flow in conformity with the boosted pressure in the manifold, a summing impact modulator for causing fuel controlled by said two circuits to be injected, and a transverse impact modulator for supplying air in amounts such that proper proportions of air and fuel can be obtained in conformity with the boosted pressure.

2. A fuel supply system as defined in claim **1** in which said engine rpm function control circuit comprises a governor responding to the rpm of the engine, a pneumatic pressure control valve, a trigger mechanism, one shot circuit, and trigger means.

3. A fuel supply system as defined in claim **1** in which said manifold boosted pressure function control circuit comprises a pneumatic pressure control valve and a fuel flow control valve connected in series with each other.

4. A fuel supply system as defined in claim **1** in which said summing impact modulator has two injection ports and a drain.

5. A fuel supply system for an internal combustion engine having a crankshaft and an intake manifold with a pressure detection aperture, comprising:

an engine rpm function control circuit including a governor responsive to the engine crankshaft, an air pressure control valve responsive to the governor, and a one-shot circuit responsive to air pressure from the air pressure control valve;

a manifold boosted pressure function control circuit including an air pressure control valve responsive to pressure from the detection aperture in the intake manifold, and a fuel flow control valve connected in series with said pressure control valve;

a boosted pressure detection circuit including a proportioning element connected to a line bypassed from the boosted pressure detection circuit and a transverse impact modulator connected to the output side of said proportioning element; and

a summing impact modulator injection element including a fuel injection port and a fuel-air injection port for connecting an output of the one-shot circuit and the boosted pressure detection circuit.

* * * * *