United States Patent

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[54] **COMBUSTION ENGINE FUEL CONTROL**
4 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** **261/23,** 261/24, 261/69, 123/119
[51] **Int. Cl.** **F02d 23/02,** F02d 9/10, F02m 7/18
[50] **Field of Search** ..... 261/23, 1, 24, 69, 1, Air-(Digest)Supercharge, 42; 123/119

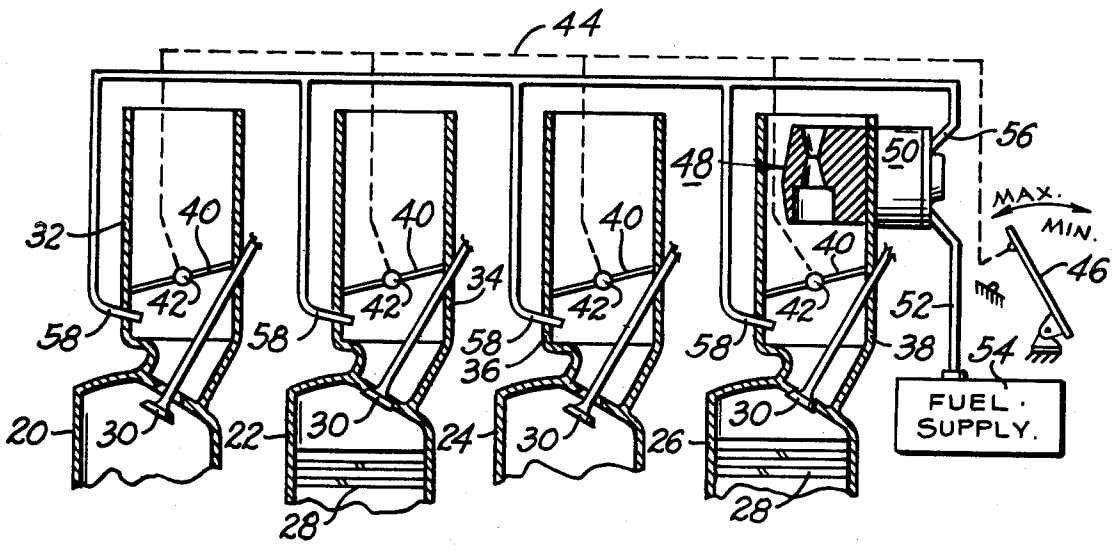
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ABSTRACT: A mass airflow sensitive fuel control for controlling fuel to a multiple cylinder internal combustion engine wherein the fuel control apparatus includes mass airflow sensing element such as a high gain venturi disposed in the air induction passage for measuring the mass airflow to a single engine cylinder and a fuel control valve actuated as a function of the venturi air pressure output for controlling fuel flow to all of the engine cylinders as a function of the mass airflow to the one engine cylinder. The air induction passage includes a plurality of air passages each having a separate airflow throttle valve therein connected to the multiple engine cylinders for supplying air thereto. The mass airflow sensing venturi is connected to one of the air passages upstream from the airflow throttle valve therein for measuring the mass airflow there through. The venturi generates an output air pressure differential which varies as a predetermined function of the mass airflow there through. A fuel metering arrangement includes a fuel conduit connecting a source of pressurized fuel with the plurality of air passages downstream from the throttle valve associated therewith. A metering restriction is located in the fuel conduit for establishing the effective flow area thereof. A fuel valve member is connected to the fuel conduit for controlling a fuel pressure differential generated across the metering restriction. A pressure differential device responsive to the air pressure differential and the fuel pressure differential is operatively connected to the valve member for actuating the same. The fuel metering arrangement establishes a flow metered fuel to all of the air passages and thus the multiple cylinders as a function of the portion of the total mass airflow in accordance with the output air pressure differential derived from the venturi. The venturi is defined by a first venturi including a first converging entrance section and a first diverging discharge section connected by a first throat section defined by a circular inner body portion and a space apart annular outer portion concentric therewith. A second venturi including a second converging entrance section and a second diverging discharge section is connected by a second throat portion formed in the inner body portion. A conduit connects the second discharge section with the first throat portion to provide a reduced back pressure against airflow through the second venturi which results in a correspondingly relatively large pressure differential between venturi impact and throat pressures derived from the second venturi for a given total mass airflow through the first and second venturi. In one embodiment, the air induction passage includes a separate air passage and airflow throttle valve for each of the multiple cylinders for conducting air to each cylinder independently of the remaining cylinders. In another embodiment, the air induction passage includes an air induction manifold common to all of the multiple cylinders and provided with an air inlet. A plurality of airflow restrictions including the mass airflow measuring venturi are arranged in parallel airflow relationship to the inlet. An air super charger is connected to the inlet downstream from the plurality of airflow restrictions for pressurizing air supplied to the manifold from the inlet.



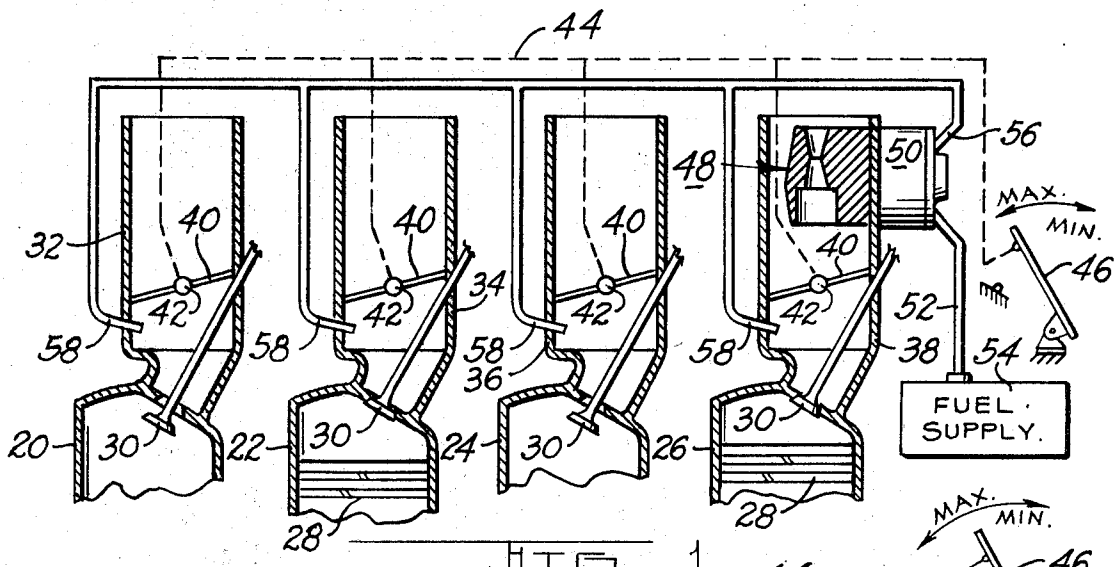


FIG. 1

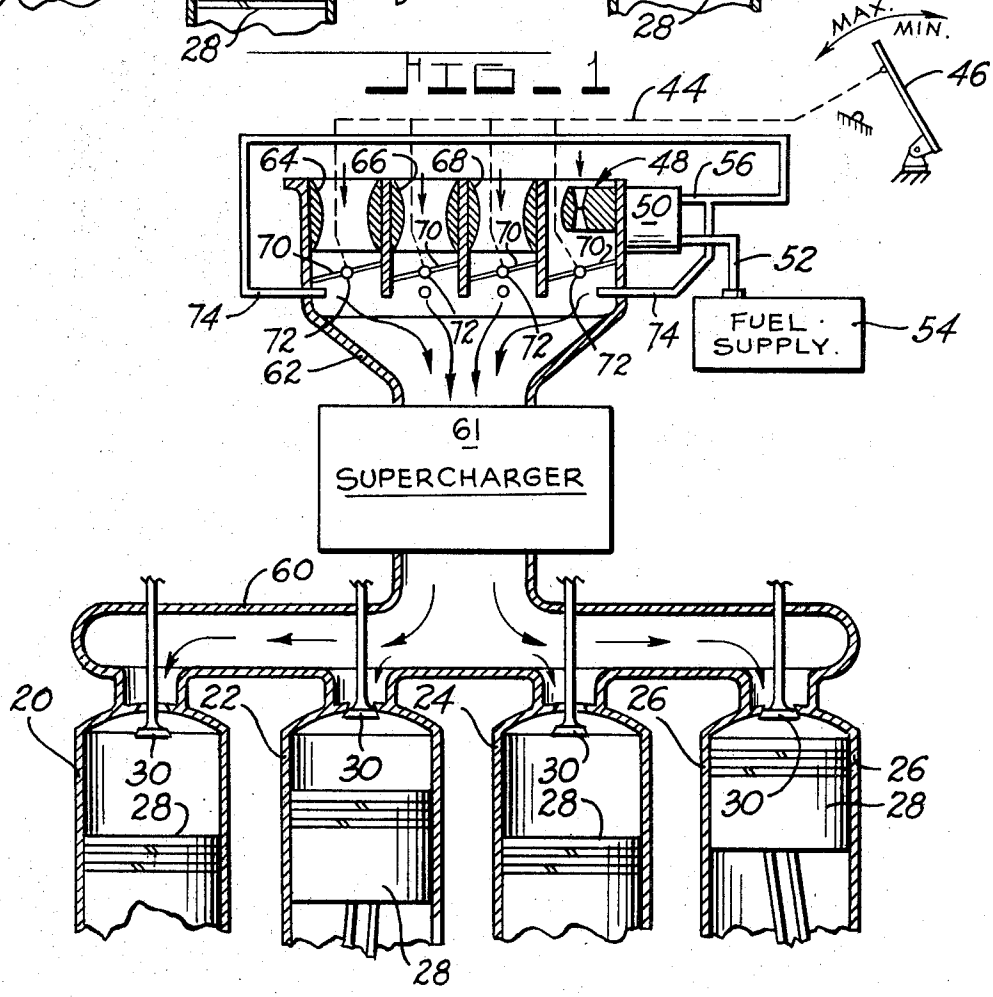


FIG. 2

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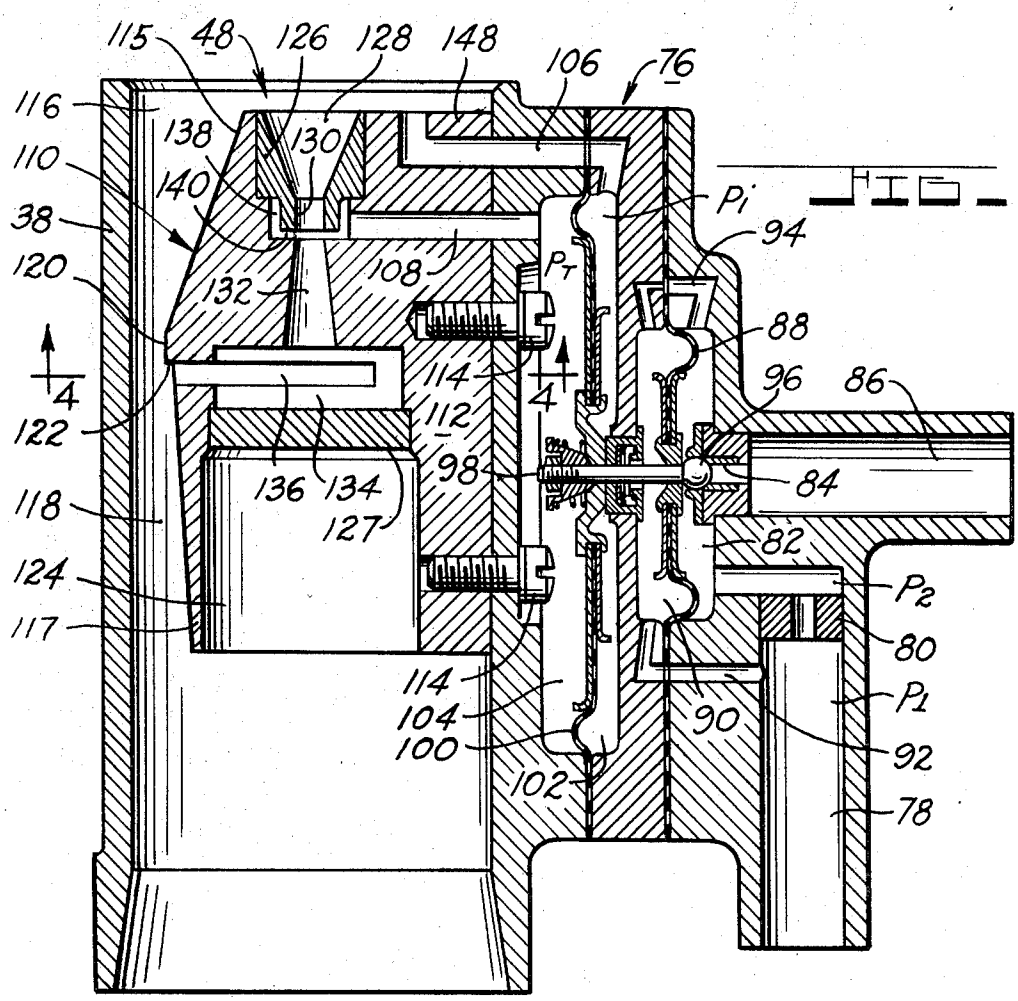


FIG. 3

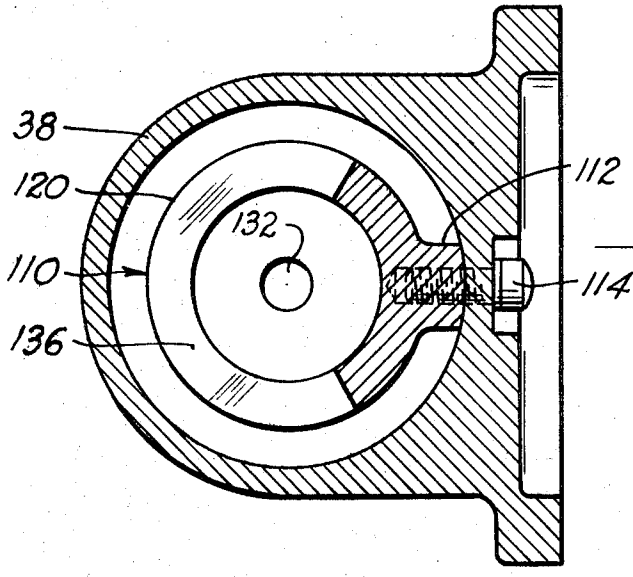


FIG. 4

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COMBUSTION ENGINE FUEL CONTROL

BACKGROUND OF THE INVENTION

The present invention relates to fuel control apparatus for multiple cylinder internal combustion engines having air fuel induction passages connected to the engine cylinders. In order to obtain maximum performance from such engines, particularly in the case of high performance naturally aspirated or supercharged engines, it is desired to provide high volumetric efficiency, i.e., each engine cylinder should receive identical charges of air and fuel having a maximum volume.

Various arrangements of air induction systems and/or fuel control mechanisms have been utilized in an attempt to optimize volumetric efficiency and thus engine efficiency of multiple cylinder high performance internal combustion engines. It is a common practice in a naturally aspirated or unsupercharged engine to utilize a separate air induction pipe for each of the multiple cylinders and to provide a manually actuated air throttle valve therein as well as fuel control means for supplying fuel thereto. The fuel metering means have taken various forms including a separate fuel control for each air induction pipe or a separate fuel control connected to two or more air induction pipes for supplying fuel thereto, the latter being generally known as "multiple carburetion". The fuel control means utilized with the above mentioned arrangements take various forms including types which regulate fuel as a function of engine speed compensated by throttle actuated jets or bypasses, air manifold devices, and the like. While such prior art devices provide reasonably good air fuel distribution to each of the multiple cylinders, the devices are subject to poor load compensation such that maximum engine performance cannot be attained under all engine operating conditions such as, in the case of a vehicle, shifting from one driving gear to another or accelerating to a higher speed. Furthermore, the use of a plurality of fuel control devices increases the cost of the engine fuel system accordingly as well as increasing the complexity of the fuel system with attendant maintenance problems.

The present invention proposes a fuel control arrangement for a multiple cylinder internal combustion engine wherein a single fuel control having a high gain, low loss venturi responsive to the mass airflow consumed by a single cylinder is operative to meter fuel as a function of the measured mass airflow accurately and in equal quantity to each of the engine cylinders thereby maximizing engine efficiency and minimizing expense, complexity and maintenance of fuel control system.

It is an object of the present invention to provide a relatively simple and reliable fuel control capable of accurately controlling a flow of metered fuel to a plurality of engine cylinders as a function of mass airflow consumed by one engine cylinder.

It is another object of the present invention to provide a high gain, low loss venturi device.

Other objects and advantages of the present invention will be apparent to those skilled in the art from the following description taken with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic representation of a four cylinder, naturally aspirated, internal combustion engine and air fuel induction system therefor embodying the present invention;

FIG. 2 is a schematic representation of a four cylinder supercharged internal combustion engine and air fuel induction system therefor embodying the present invention;

FIG. 3 is a sectional view of the fuel control mechanism taken on Line 3–3 of FIG. 1;

FIG. 4 is a sectional view taken on Line 4–4 of FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, numerals 20, 22, 24 and 26 designate the cylinders of a conventional naturally aspirated four cylinder piston engine. It will be understood that the number of cylinders indicated is of no significance and the present invention may be readily adapted to use with piston engines having more or less cylinders than that shown. Each cylinder 20, 22, 24 and 26, is provided with the usual piston 28 slidable therein and cylinder inlet valve 30. Air induction pipes 32, 34, 36 and 38 are connected to supply air to cylinders 20, 22, 24 and 26, respectively, and may be of the well-known "tuned" type providing impulse charging of the air passing therethrough to the respective cylinders. A butterfly or air throttle valve 40 positioned in air flow controlling relationship in each of the pipes 32, 34, 36 and 38 is mounted on a shaft 42 suitably mounted for rotation on the associated air induction pipe. The shafts 42 are connected via conventional linkage mechanism generally indicated by 44 to a manually actuated engine control lever such as foot pedal 46 movable between minimum and maximum power request positions.

A venturi generally indicated by 48 is removably secured in position in one of the air induction pipes such as pipe 38 and provides an air pressure source which is a function of the mass airflow therethrough and thus through air induction pipe 38. A fuel meter generally indicated by 50 is suitably mounted adjacent venturi 48 and receives pressurized fuel via an inlet passage 52 from a source 54 which includes a conventional engine driven fuel pump, not shown. The fuel meter 50 is adapted to receive venturi impact and throat or static pressures P_I and P_T respectively, for fuel metering purposes as will be described hereinafter. Metered fuel is discharged from fuel meter 50 to a discharge conduit 56 which conducts fuel to a conventional air bleed fuel injection nozzle 58 connected to each of the air induction pipes 32, 34, 36 and 38 intermediate the respective inlet valve 30 and air throttle valve 40 and adapted to inject metered fuel to the air passing to the associated engine cylinder.

Referring to FIG. 2, the four cylinder engine of FIG. 1 is shown with a modified air fuel induction system adapted to provide engine supercharging. To that end, a common induction manifold 60 communicates with all of the engine cylinders 20, 22, 24, and 26 via respective inlet valves 30. The manifold 60 is connected to the outlet of a conventional engine driven supercharger 61 which receives an air fuel mixture from an air inlet casing 62 containing three dummy venturis 64, 66 and 68 as well as venturi 48 arranged in parallel air flow relationship. A butterfly or air throttle valve 70 mounted downstream of each of the venturis 48, 64, 66 and 68 is carried on a shaft 72 rotatably secured to casing 62. The shafts 72 are suitably connected via linkage mechanism 44 to movable foot pedal 46. A fuel injection nozzle 74 suitably connected to casing 62 downstream from each of the venturis 48, 64, 66 and 68 and associated air throttle valves 70 is connected to fuel discharge conduit 56 and adapted to inject metered fuel to the airflow associated therewith.

Referring to FIG. 3, the venturi 48 and fuel meter 50 are shown in cross-sectional detail. The fuel meter 50 may be of the conventional fuel pressure regulating type which meters fuel on the basis of mass airflow and reference is made to U.S. Pat. No. 3,140,324 issued Jul. 7, 1964, in the name of Elmer A. Haase for details of one such type of fuel metering device. In general, the fuel meter 50 includes a multipart casing 76 defining a fuel conduit connecting inlet conduit 52 with discharge conduit 56 which fuel conduit includes a passage 78 containing a fixed area fuel metering orifice 80, a fuel chamber 82 downstream of orifice 80 and provided with a variable area outlet orifice 84, and outlet passage 86. A fuel diaphragm 88 suitably secured at its radially outermost portion to casing 76 separates chamber 82 from a second fuel chamber 90. Chamber 90 is vented via a passage 92 to passage 78 at unmetered fuel pressure P_1 and to chamber 82 via a restricted passage 94 which results in diaphragm 88 being exposed to unmetered fuel pressure P_1 in chamber 90 and metered fuel pressure P_2 in chamber 82 and thus the pressure differential across metering orifice 80. The variable area outlet orifice 84 is controlled by a valve member 96 having a stem 98 secured to fuel diaphragm 88 and an air diaphragm 100. The

air diaphragm **100** separates two air chambers **102** and **104** and is suitably secured at its radially outermost portion to casing **76** so as to respond to the differential between venturi impact air pressure P_i and throat or static pressure P_T in chambers **102** and **104**, respectively. The chamber **102** is connected via passage **106** to receive venturi impact air pressure P_i and chamber **104** is connected via passage **108** to receive venturi throat pressure P_T.

The venturi **48** is particularly adapted for use with the fuel meter **50** but it is obvious that the high gain and low loss characteristics thereof lend it to use in other flow systems where such venturi features are advantageous. Referring to FIGS. **3** and **4**, the venturi **48** includes a secondary venturi portion defined by air induction pipe **38** and an inner generally circular body member **110** concentric therewith and provided with a strut portion **112** drilled and threaded to accommodate one or more bolts **114** which secure body member **110** to pipe **38**. The body member **110** is provided with a diverging portion **115** which together with pipe **38** defines a converging entrance section **116** and a converging portion **117** which together with pipe **38** defines a converging discharge section **118** which entrance and discharge sections are joined by a throat section **120**. The throat section **120** is stepped to form a shoulder **122**. A primary venturi portion is defined by a stepped axial bore **124** in body member **110** which bore is adapted to receive an insert **126** and a plug **127** suitably secured in bore **124** as by press fits. The insert **126** is provided with a converging entrance section **128** and a throat section **130** which are aligned with a diverging discharge section **132** defined by bore **124**. The diverging discharge section **132** terminates in an enlarged diameter chamber **134** to which the discharge section **132** exhausts and from which air passes to throat section **120** via arcuate slot **136** extending radially through the wall of body member **110** into communication with throat section **120** at the downstream side of shoulder **122**. The insert **126** is suitably dimensioned diametrically and axially to provide a spaced relationship between the insert **126** and adjacent walls of bore **124** thereby defining an annulus **138** and an annulus **140** which provide fluid communication between throat section **130** and passage **108** leading to air chamber **104**.

OPERATION

Referring to FIG. **1**, it will be assumed that the engine is operating at a selected power output corresponding to the position of lever **46**. Air passes through induction pipes **32, 34, 36** and **38** and associated butterfly valves **40** and mixes with metered fuel injected thereto via associated nozzles **58**. The resulting air fuel mixture is aspirated through inlet valves **30** into cylinders **20, 22, 24** and **26** by the reciprocating pistons in timed relationship in the conventional manner of a four-cycle internal combustion engine.

A maximum volume air fuel mixture depends upon minimizing airflow restrictions in the air induction pipes **32, 34, 36** and **38**. To that end, the air induction pipes **32, 34** and **36** are free of air flow restrictions other than the required butterfly or air throttle valves **40**. As mentioned heretofore, prior art metering devices which require separate fuel metering devices for each engine cylinder induction pipe or a separate fuel metering device for each two or more engine cylinders include one or more venturis or similar air flow measuring devices to provide an air pressure input for metering purposes so that the metered fuel may be controlled as a function of mass airflow.

The venturi **48** is designed to provide high gain and low flow loss characteristics which minimize airflow losses through induction pipe **38**. It has been found that the flow loss through venturi **48** will not exceed approximately one percent which results in substantially no adverse effect on the air distributed to cylinder **26**.

The major portion of the airflow through induction pipe **38** passes through the secondary portion of venturi **48** which has a relatively large throat area compared to that of the primary venturi portion. The air passing through the secondary venturi section **116** is increased in velocity to a maximum at throat section **120** where the resulting throat or static pressure is reduced accordingly thereby establishing a relatively low back pressure at slot **136** and chamber **134** connected thereto. The relatively low air pressure in chamber **134** to which the primary venturi discharge section **132** exhausts provides an air pressure differential boost across the primary venturi which results in a corresponding increased high velocity flow through throat section **120** and reduced throat or static air pressure P_T at throat section **136**. The reduced throat pressure P_T results in a corresponding high output pressure differential $P_i - P_T$ and thus gain for any given airflow through venturi **48**. Since the pressure differential $P_i - P_T$ varies as a function of airflow through throat portion **136** which, in turn, varies as a function of the throat or static pressure at throat section **120** of the secondary venturi portion, it is apparent that the pressure differential $P_i - P_T$ varies as a function of the total air flow through venturi **48** to the engine cylinder **26**.

The venturi pressure differential $P_i - P_T$ is transmitted to air diaphragm **100** via chambers **102** and **104** thereby generating a corresponding force on stem **98** which tends to pull valve **96** away from orifice **84**. The fuel pressure P_2 downstream of metering orifice **80** varies depending upon the effective flow area of orifice **84** in response to the position of valve **96** and acts against fuel diaphragm **88** in opposition to unmetered fuel pressure P_1 upstream from metering orifice **80**. The resulting $P_1 - P_2$ fuel pressure differential acting against diaphragm **88** produced a against stem **98** equal and opposite to the force derived from air diaphragm **100** thereby regulating the fuel pressure differential $P_1 - P_2$ as a function of the air pressure differential $P_i - P_T$ or mass airflow through venturi **48** to establish a corresponding fuel to air ratio. Since the metering orifice **80** has a fixed area, metered fuel flow therethrough varies as a function of the fuel pressure differential $P_1 - P_2$ thereacross which, as a result of the above-mentioned relationship renders metered fuel flow a function of mass air flow to cylinder **26**. The flow of metered fuel passes to discharge conduit **56** which communicates the fuel to each fuel nozzle **58** associated with engine cylinders **20, 22, 24** and **26**. It will be recognized that the fuel meter **50** may be suitably calibrated to meter any desired flow of fuel as a function of the mass airflow to cylinder **26** so that the total fuel requirement of the four engine cylinders **20, 22, 24** and **26** is readily established. Furthermore, the mass airflow and thus fuel flow consumed by engine cylinder **26** is equivalent to each of the remaining engine cylinders **20, 22** and **24** so that fuel flow to each engine cylinder metered on the basis of mass airflow to one engine cylinder provides a simple, accurate and inexpensive fuel control arrangement.

Referring to FIG. **2**, the mass airflow through venturi **48** constitutes a portion of the total mass airflow through inlet casing **62** to induction manifold **60** common to cylinders **20, 22, 24** and **26**. The dummy venturis **64, 66** and **68** are calibrated as necessary to equalize the mass airflow therethrough and venturi **48** in a conventional manner to establish the same fuel metering function as heretofore described with regard to FIG. **1**. The four parallel air fuel mixture charges established by the dummy venturis **64, 66, 68** and **48** with associated separate fuel nozzles **74** merge to form a composite air fuel mixture which, in passing through supercharger **61**, is further mixed and discharged to induction manifold **60** to provide a well distributed air fuel mixture to the engine cylinders **20, 22, 24** and **26**.

Existing multiple cylinder internal combustion engines with conventional air induction systems may be easily and quickly modified to accommodate the above described invention as will be recognized by those persons skilled in the art.

It will also be recognized by those persons skilled in the art that various changes and modifications in the above described structure may be made without departing from the scope of Applicant's invention as defined by the following claims.

I claim:

1. Fuel supply apparatus for an internal combustion engine having multiple cylinders comprising:

air induction means including a plurality of air passages each having a separate air flow throttle valve therein operatively connected to the multiple cylinders for supplying air thereto;

mass airflow sensing means including a venturi operatively connected to one of said air passages upstream from said airflow throttle valve therein for measuring the mass airflow therethrough and thus a portion of the total mass air through all of said air passages to the multiple cylinders;

said venturi generating an output air pressure differential which varies as a predetermined function of the mass airflow therethrough;

fuel metering means including a fuel conduit connecting a source of pressurized fuel with said plurality of air passages downstream from said throttle valves associated therewith, a metering restriction in said fuel conduit for establishing the effective flow area thereof, valve means operatively connected to said fuel conduit for controlling a fuel pressure differential generated across said metering restriction and pressure differential responsive means responsive to said output air pressure differential and said fuel pressure differential operatively connected to said valve means for actuating the same;

said fuel metering means establishing a flow of metered fuel to all of said air passages and thus the multiple cylinders as a function of said portion of the total mass airflow in accordance with the output air pressure differential derived from said venturi;

said venturi being defined by a first venturi means including a first converging entrance section and a first diverging discharge section connected by a first throat section defined by a circular inner body portion and a spaced apart annular outer portion concentric therewith, second venturi means including a second converging entrance section and a second diverging discharge section connected by a second throat portion formed in said inner body portion, and conduit means connecting said second discharge section with said first throat portion to provide a reduced back pressure against airflow through said second venturi means which results in a correspondingly relatively large pressure differential between venturi impact and throat pressures derived from said second venturi means for a given total mass airflow through said first and second venturi means.

2. Fuel supply apparatus as claimed in claim 1 wherein: said air induction means includes a separate air passage and associated airflow throttle valve for each of the multiple cylinders for conducting air to each cylinder independently of the remaining cylinders.

3. Fuel supply apparatus as claimed in claim 1 wherein:

said air induction means includes an air induction manifold common to all of the multiple cylinders and provided with an air inlet;

a plurality of airflow restrictions including said mass airflow measuring means arranged in parallel airflow relationship in said inlet; and

air supercharging means operatively connected to said inlet downstream from said plurality of airflow restrictions for pressurizing air supplied to said manifold from said inlet.

4. Fuel supply apparatus as claimed in claim 1 wherein: said fuel conduit includes a plurality of fuel injection nozzles downstream from said metering restriction and each of which is connected to an associated one of said plurality of air passages for injecting metered fuel to the airflow passing therethrough.