

[54] **MASS AIR FLOW MEASURING MEANS**

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417/167, 168, 177, 197

[56] **References Cited**

UNITED STATES PATENTS

1,374,491 4/1921 Coulombe 417/167
2,628,086 2/1953 Cutler.....73/213 X

846,759 3/1907 Richter 417/177
1,108,644 8/1914 Weimann.....417/177

FOREIGN PATENTS OR APPLICATIONS

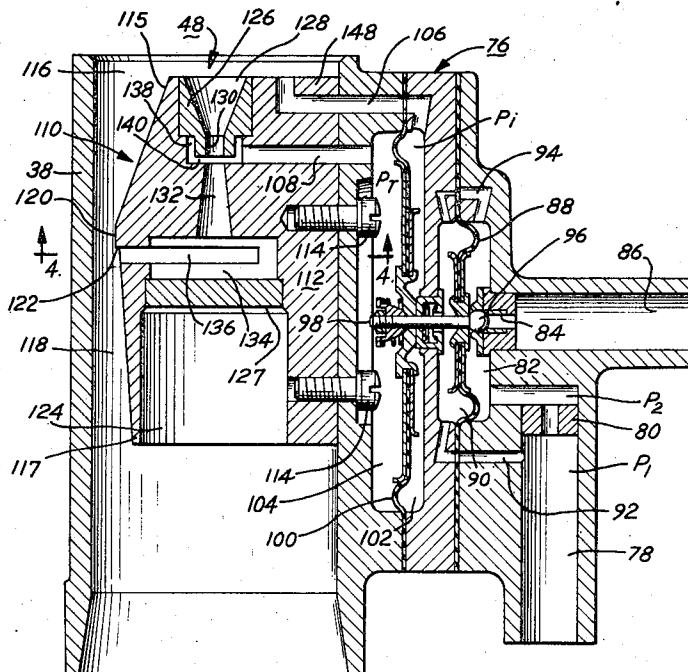
970,297 9/1958 Germany 73/213

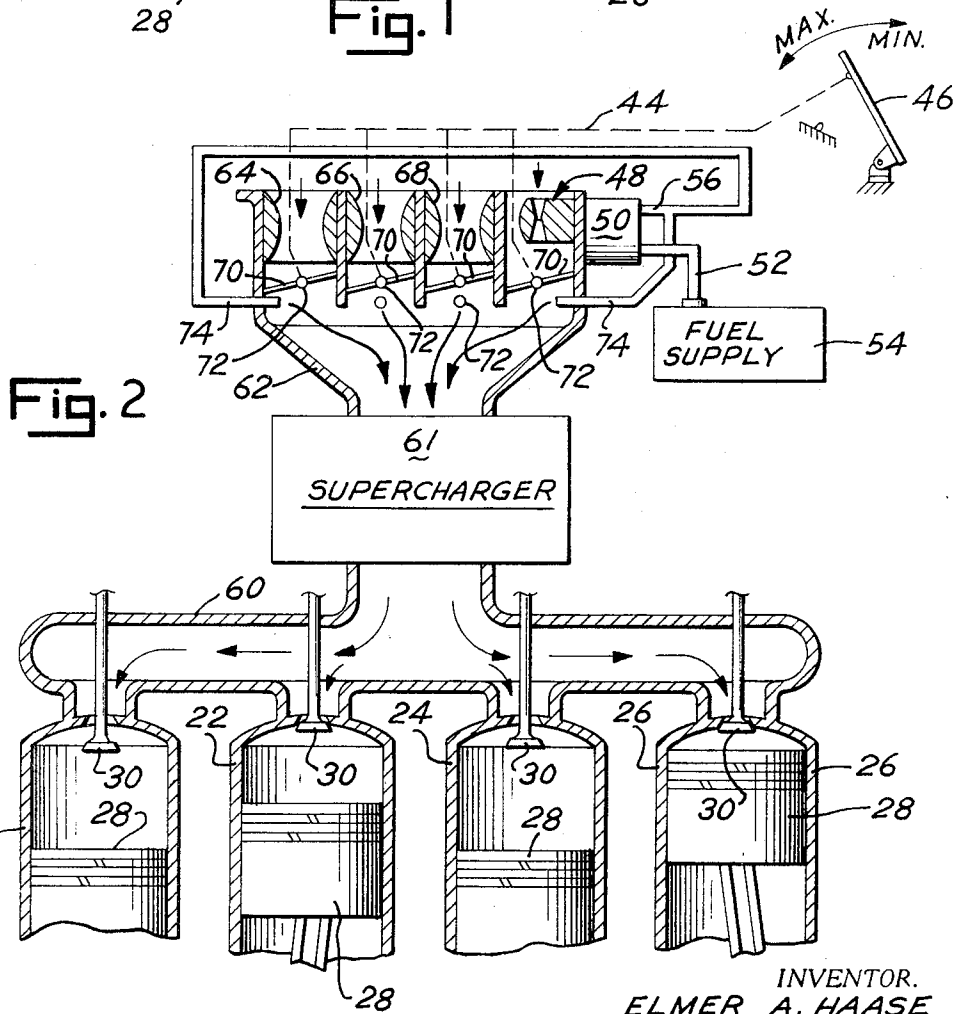
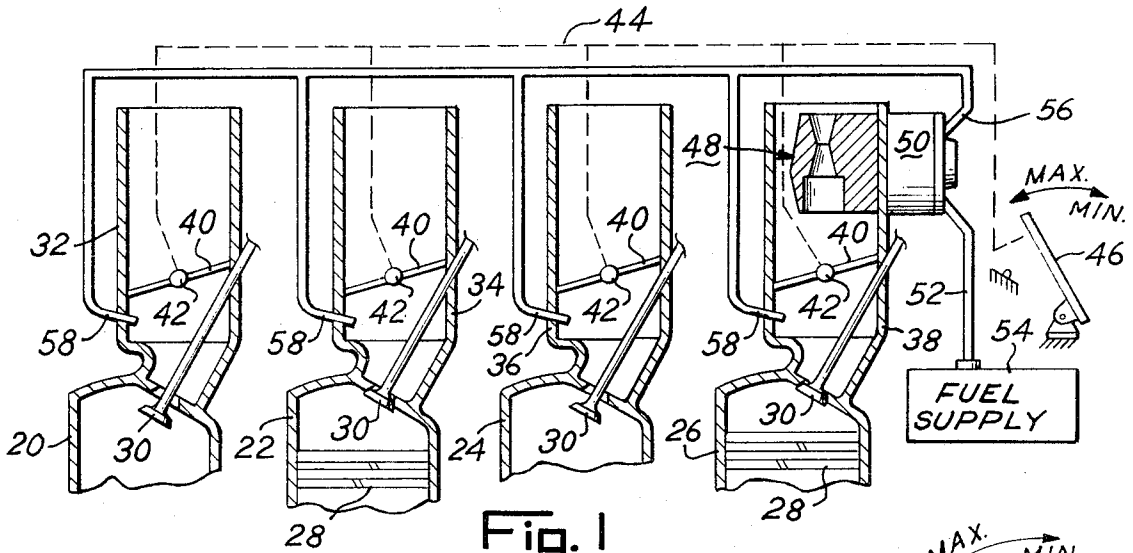
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[57] **ABSTRACT**

A mass air flow sensitive fuel control for controlling fuel to a multiple cylinder internal combustion engine wherein the fuel control apparatus includes mass air flow sensing means such as a high gain venturi disposed in the air induction passage for measuring the mass air flow 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 air flow to the one engine cylinder.

5 Claims, 4 Drawing Figures





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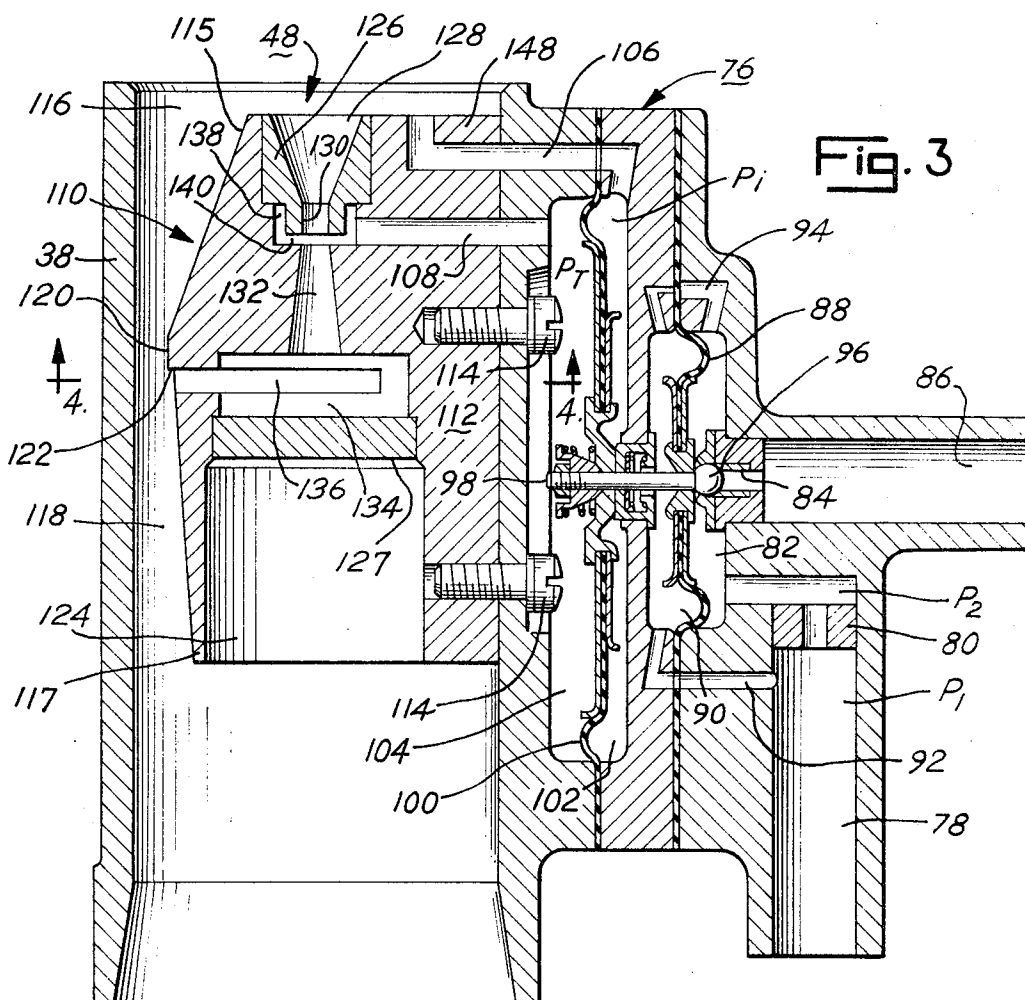


Fig. 3

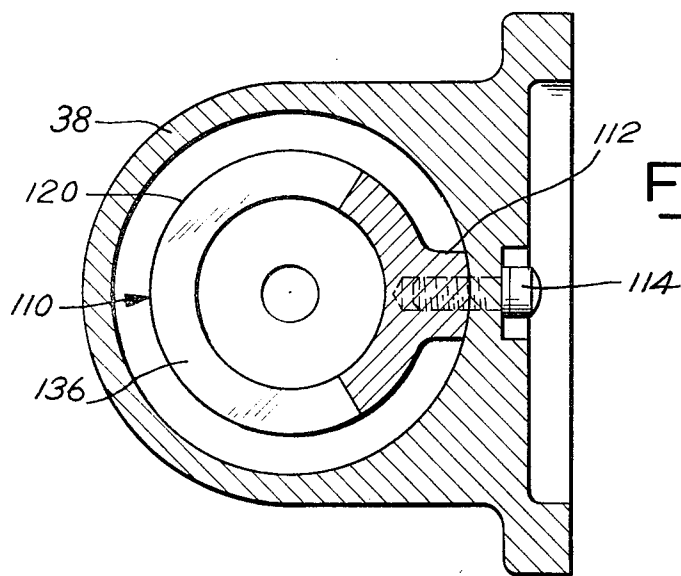


Fig. 4

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MASS AIR FLOW MEASURING MEANS

This application is a division of application Ser. No. 673,815 filed Oct. 9, 1967, now U.S. Pat. No. 3,549,132.

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 by-passes, 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 air flow consumed by a single cylinder is operative to meter fuel as a function of the measured mass air flow 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 air flow 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 presesent 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 air flow 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_1 and P_7 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 air flow 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 air flow and reference is made to U.S. Pat. No. 3,140,324 issued July 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 multi-part 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 ex-

posed 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 diverging portion 117 which together with pipe 38 defines a diverging 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 air flow 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 air flow.

The venturi 48 is designed to provide high gain and low flow loss characteristics which minimize air flow losses through induction pipe 38. It has been found that the flow loss through

venturi 48 will not exceed approximately 1 percent which results in substantially no adverse effect on the air distributed to cylinder 26.

The major portion of the air flow 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 130 and corresponding reduced throat or static air pressure P_T at throat section 138. The reduced throat pressure P_T results in a corresponding high output pressure differential $P_i - P_T$ and thus gain for any given air flow through venturi 48. Since the pressure differential $P_i - P_T$ varies as a function of air flow 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 produces a force 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 air flow 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 air flow 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 air flow 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 air flow to one engine cylinder provides a simple, accurate and inexpensive fuel control arrangement.

Referring to FIG. 2, the mass air flow through venturi 48 constitutes a portion of the total mass air flow 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 air flow 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.

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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. Mass air flow measuring means comprising:

first venturi means including a first converging entrance section and a first diverging discharge section connected by a first throat section defined by a generally 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;

conduit means connecting said second discharge section with said first throat portion to thereby provide a reduced back pressure against the air flow through said second venturi which, in turn, results in a correspondingly relatively large pressure differential between venturi impact and throat air pressures derived from said second venturi means for a given total mass air flow through said first and second venturi means;

pressure responsive means responsive to said air pressure differential and operative to produce an output signal representative thereof and thus mass air flow through said

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first and second venturi means.

2. Mass air flow measuring means as claimed in claim 1 wherein:

said first section is provided with a circumferentially extending stepped portion; and

said conduit means includes a slot formed in said circular inner body and extending radially therethrough to communicate said second discharge section with said first throat section on the downstream side of said stepped portion.

3. Mass air flow measuring means as claimed in claim 2 wherein:

said slot is arcuate and substantially coextensive with said stepped portion.

4. Mass air flow measuring means as claimed in claim 1 wherein:

said inner body portion is provided with a radially extending strut portion adapted to bear against said annular outer portion and secured thereto by fastening means.

5. Mass air flow measuring means as claimed in claim 1 wherein:

said first throat section is substantially annular; and said second throat portion is circular and concentric with said first throat portion.

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