United States Patent [19]

Sola

[11] **3,903,852**

[45] **Sept. 9, 1975**

[54] **FUEL INJECTION PLANT FOR INTERNAL COMBUSTION ENGINES**

[75] Inventor: **Alberto Sola**, Turin, Italy

[73] Assignee: **Fiat Societa per Azioni**, Turin, Italy

[22] Filed: **Oct. 24, 1973**

[21] Appl. No.: **409,206**

[30] **Foreign Application Priority Data**

Oct. 24, 1972	Italy	70343/72
June 14, 1973	Italy	68748/73
June 14, 1973	Italy	68749/73

[52] **U.S. Cl.** ..... **123/32 EA**; 123/140 CC; 123/140 MC

[51] **Int. Cl.** **F02d 1/04**; F02d 1/06; F02b 3/00

[58] **Field of Search** ..... 123/32 EA, 140 CC, 139 E

[56] **References Cited**

UNITED STATES PATENTS

2,687,123	8/1954	Parsons	123/139 E
3,039,988	6/1962	Trinkler	123/140 CC
3,716,035	2/1973	Adler et al.	123/32 EA
3,718,123	2/1973	Eckert et al.	123/32 EA

FOREIGN PATENTS OR APPLICATIONS

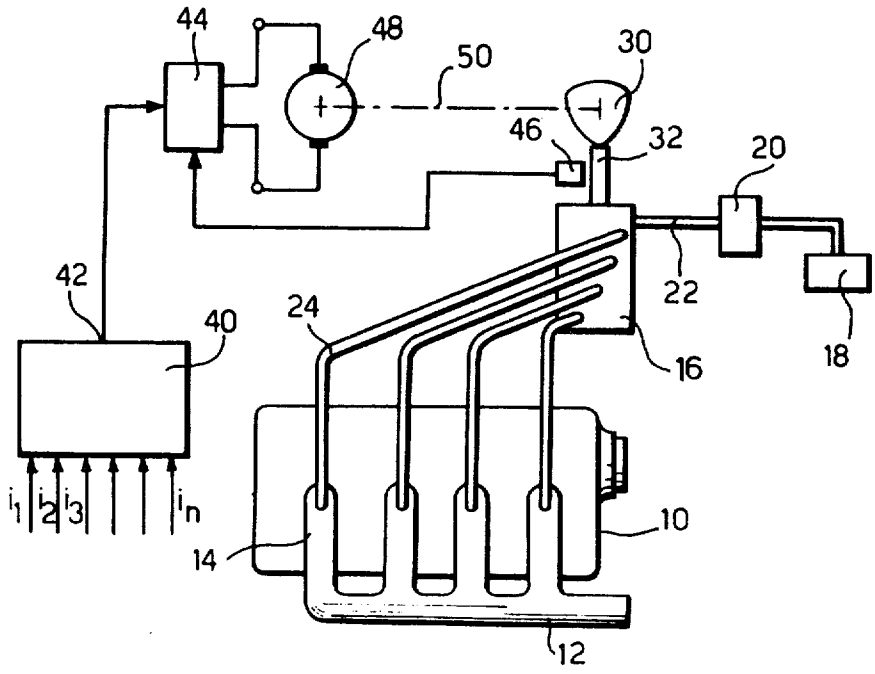
719,077	11/1954	United Kingdom	123/139
653,030	5/1951	United Kingdom	123/139

Primary Examiner—Manuel A. Antonakas
Assistant Examiner—James W. Cranson, Jr.
Attorney, Agent, or Firm—Sughrue, Rothwell, Mion, Zinn & Macpeak

[57] **ABSTRACT**

A fuel injection unit for internal combustion engines. The injection unit comprises a distributor means, sensing means, which are responsive to parameters being representative of the functioning of the engine or influencing it, transducer means converting the parameters into electric signals, an electronic control device elaborating an analogous signal on the basis of said electric signals, a means to determine the position of an adjustment means associated with the distributor means and to emit a corresponding electric signal, a comparator circuit to compare the analogous signal and the latter electric signal, and an electric motor controlled by the comparator circuit and actuating a cam element which cooperates with said adjustment means.

4 Claims, 5 Drawing Figures



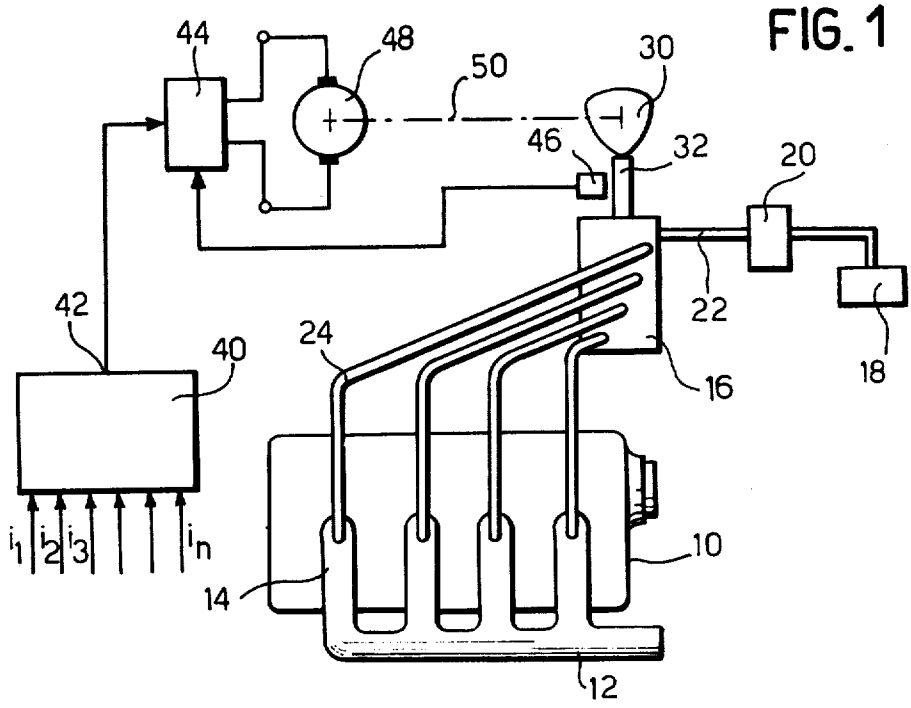

44
48
50
30
46
32
20
42
40
24
22
16
18
10
14
12
i_1 i_2 i_3 i_n

FIG. 1

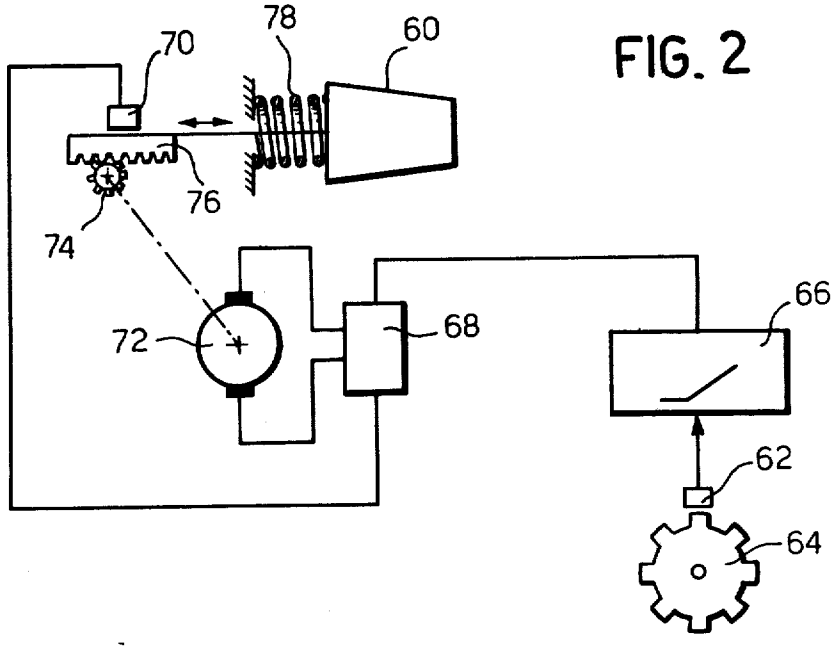

78
70
60
76
74
72
68
66
62
64

FIG. 2

FIG. 3

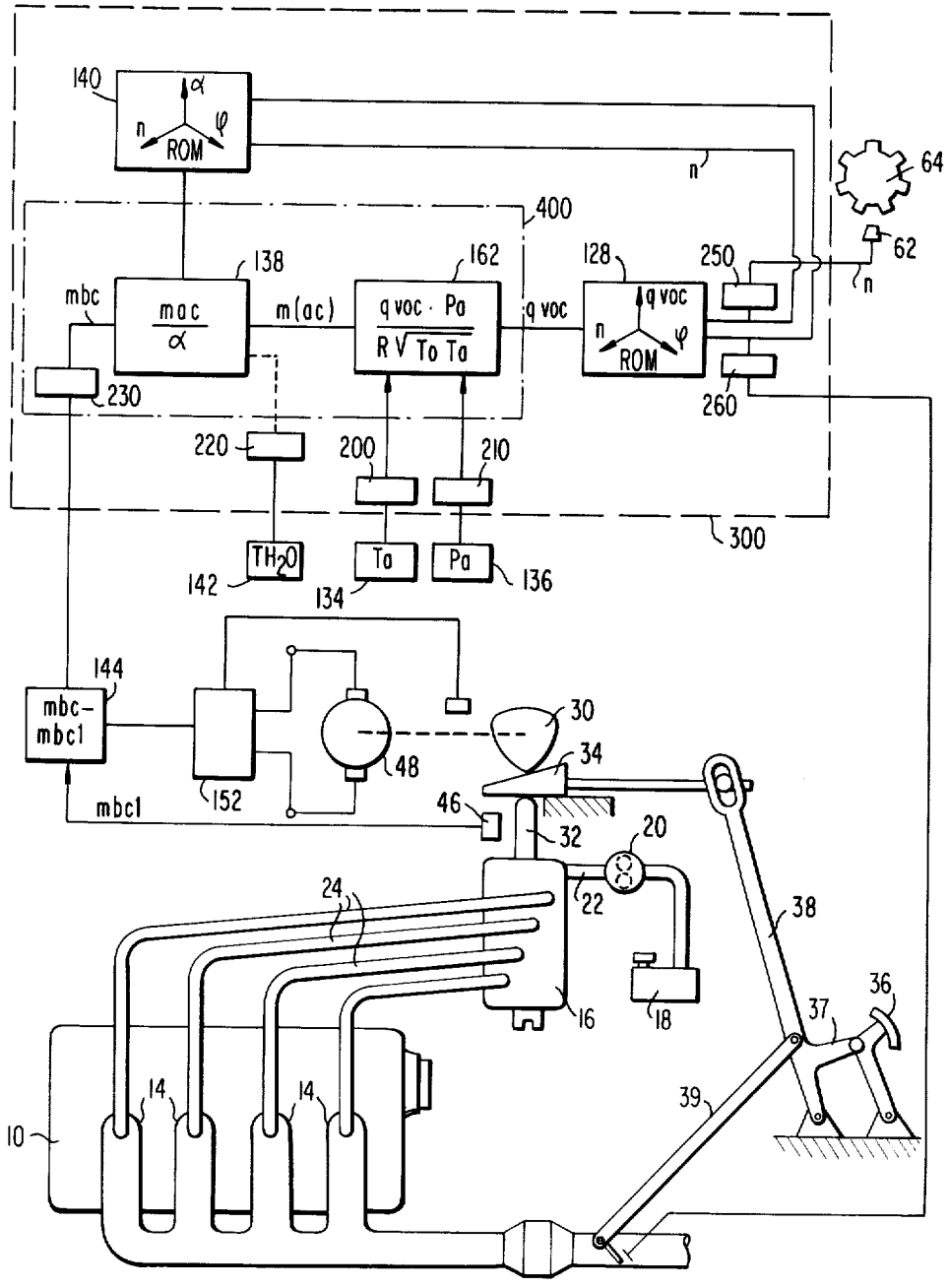

140
α
n
φ
ROM
n
64
400
62
138
162
128
250
mbc
mac / α
m(ac)
q voc · Pa / R √To Ta
q voc
q voc
n
φ
ROM
n
230
260
220
200
210
300
TH2O
Ta
Pa
142
134
136
144
mbc-mbc1
mbc1
152
48
30
34
46
32
20
24
22
38
36
37
16
18
14
14
39
10

FIG. 4

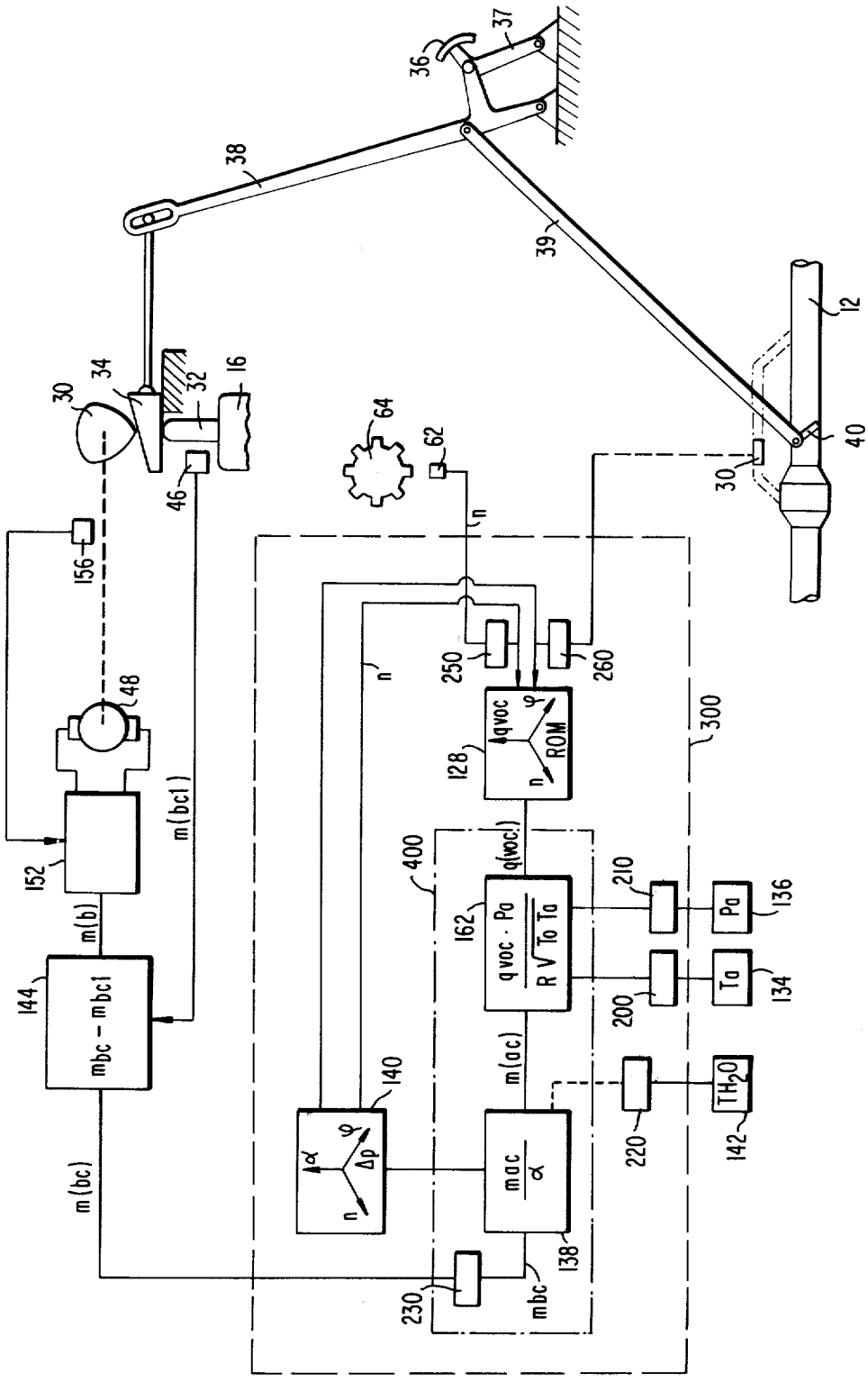
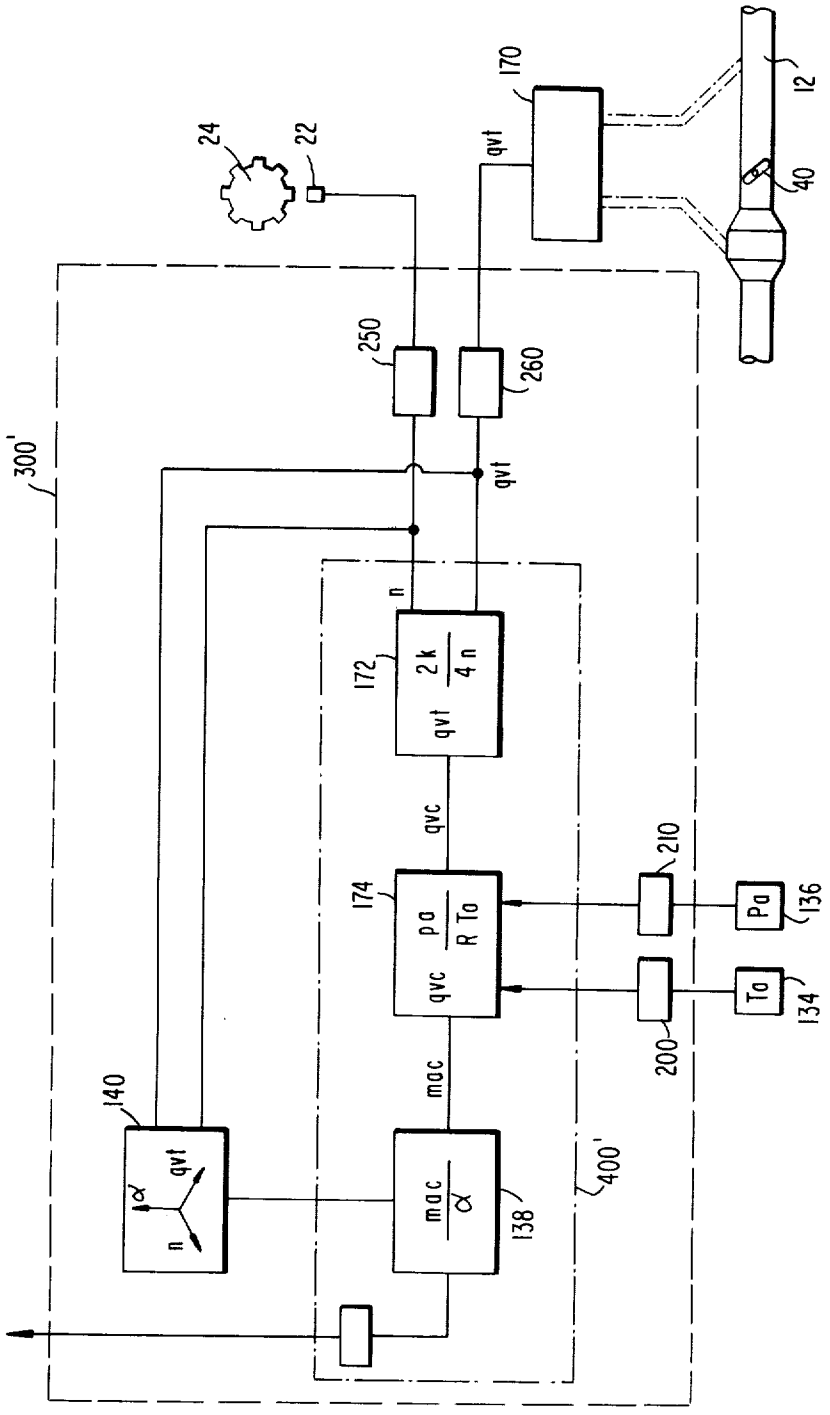

36
37
38
39
12
40
30
34
32
16
46
64
62
n
156
48
152
m(bc1)
m(b)
144
mbc − mbc1
m(bc)
250
260
300
128
qvoc
ROM
φ
400
q(voc)
162
q voc · Po / R √To Ta
210
Pa
136
200
Ta
134
m(ac)
140
Δp
α
mac / α
220
TH2O
142
138
230
mbc

FIG. 5


170
12
24
22
qvt
40
250
260
300'
qvt
n
172
2k/4n
qvt
qvc
210
174
pa/R To
qvc
Pa
136
To
134
200
mac
140
α
qvt
n
mac/α
138
400'

FUEL INJECTION PLANT FOR INTERNAL COMBUSTION ENGINES

The invention relates to an injection unit for injecting fuel, in particular gasoline, into an internal combustion engine, with a pump means to supply the fuel to a rotary distributor means from which it is discharged intermittently to the cylinders of the internal combustion engine and which includes a fuel metering device with a freely displaceable metering plunger means, the travel of which is controlled by an adjustable stop means.

A distributor means of the type referred to above is known, for example, from British Pat. specification 653,030.

It has already been suggested in connection with distributor means of the type in question, which are usually referred to as "mechanical distributors," to control the position of the adjustable stop means mentioned in dependence on other conditions as well which are either related to the functioning of the engine or influence said functioning, such as the cooling water temperature of the engine, the engine speed, and the atmospheric pressure. Yet the solutions proposed (cf. British Pat. specification 719,077) have entailed mechanical difficulties caused by the necessity of having transducers, responsive to the various parameters, act on the adjustable stop means by way of lever arm arrangements.

It is also known, with fuel injection systems of electromagnetic structure, to employ electronic devices having a plurality of inputs, each being controlled by a respective parameter which is representative of or essential for the functioning of the internal combustion engine with fuel injection. These inputs control an internal logic circuit which is variable according to demand so as to generate an analogous signal continuously representing the interaction of such parameters and the exact evaluation of their importance with respect to the functioning of the engine. This signal is used to energize a fuel injector, consisting of an electromagnetic valve, by means of an elementary electronic circuitry, for instance, a chain comprising a voltage frequency converter, a trigger, and a monostable vibrator. The opening time of the injector and, consequently, the amount of fuel depend on the value worked out by the electronic circuit.

A serious disadvantage of this arrangement resides in the fact that, at the present time, no valves are available which would respond so fast as to assure the safe and constant supply of the exact amount of fuel in dependence on the parameters mentioned.

It is an object of the invention to provide a fuel injection unit for internal combustion engines comprising a distributor means of the type described above, in which unit all the essential parameters influencing the functioning of the engine are considered in a simple and safe manner.

It is another object of the invention to provide a fuel injection unit of the kind defined which permits a reduction of the amount of harmful exhaust gases. It is also an object of the invention to provide a fuel injection unit of the kind defined which will assure optimum engine performance.

According to one aspect of the invention an injection unit of the kind defined above is provided which comprises:

a. a plurality of sensing means which are responsive to parameters which are representative of the functioning of said internal combustion engine or influence said functioning and which are associated with corresponding transducer means converting said parameters into electric signals,

b. an electronic control device to which said signals are applied and which supplies at its output an analogous signal proportional to said parameters,

c. a comparator circuit comprising a first input to which said analogous signal is applied and a second input,

d. a d.c. electric motor controlled by said comparator circuit,

e. a cam element actuated by said d.c. electric motor and cooperating with a per se known adjustment means to control the position of said adjustable stop means,

f. a means to determine the position of said adjustment means and emit an electric signal corresponding to said position,

g. a means to supply said latter electric signal to said second input of said comparator circuit.

The adjustable stop means is adjusted automatically, among others, in accordance with the air pressure in the suction pipe of the internal combustion engine.

In order that the invention may be clearly understood and readily carried into effect several embodiments thereof will now be described by way of example with reference to the accompanying drawings, in which like or corresponding parts are designated by like reference numerals and in which:

FIG. **1** is a diagrammatic representation of an injection unit in accordance with the invention,

FIG. **2** is a diagrammatic representation of a modified embodiment of part of the injection unit according to FIG. **1**,

FIG. **3** is a diagrammatic representation of a modified embodiment of the injection unit shown in FIG. **1**,

FIG. **4** is a diagrammatic representation of a modified embodiment of the injection unit shown in FIG. **3**,

FIG. **5** is a diagrammatic representation of a modified embodiment of part of the injection unit shown in FIG. **4**.

FIG. **1** illustrates a four-cylinder internal combustion engine **10** comprising a suction manifold **12** which is sub-divided into several conduits **14** opening into corresponding cylinders of the engine. Liquid fuel, e.g. gasoline is supplied to a mechanical distributor means **16** from a gasoline tank **18** by means of a pump **20** and a conduit **22**, and the distributor passes it on intermittently to the conduits **14** through pipes **24**. The amount of fuel supplied is controlled in per se known manner by a plunger (not shown) which is freely movable inside the distributor **16**. The stroke of this metering plunger is controlled by the position adopted by an adjustable stop means inside the distributor **16**. The position of this stop is determined by a movable adjustment member **32** operated by a cam element **30**. An electronic control device **40** comprises a plurality of inputs $i_1 \ldots i_n$, each connected to a transducer (not shown) which is responsive to a parameter influencing the engine functioning, such as the engine temperature, the exhaust gas temperature and the like. The output signal **42** of this circuit is applied in the form of an analogous signal to the first input of a comparator circuit **44**. As the analogous signal is received in a sense determined

by the importance which it is desired to assign each of the influencing parameters, it may vary from case to case. As a simple example an adding stage may be mentioned, the inputs of which are loaded by resistors which can be varied and balanced in accordance with the importance to be assigned each individual parameter. A signal received from a transducer **46** detecting the position of the movable adjustment member **32** is applied to the second input of the comparator circuit **44.** Such a comparator circuit, for instance, may be formed by a differential transformer or by a potentiometer. The output signal of the comparator circuit **44** is applied, if desired, after an amplifier stage (depending on the respective requirements), to the control circuit of a d.c. motor **48,** on the shaft **50** of which the cam element **30** is keyed. In this manner the cam element **30** is always adjusted to the desired position determined by generation of the signals by the electronic control device **40.** The transducer **46** and the comparator circuit **44** constitute a reaction or control circuit which guarantees the accurate positioning of the cam element.

It will be appreciated that the members forming the injection unit may be designed differently without causing a change of the operating principle in general. For example, the electronic control device **40** may be an analogous unit, as with the embodiment described, or it may be a digital unit followed by a digital analogous transducer.

In the embodiment shown in FIG. **2** only those parts of the injection unit are illustrated which are modified as compared to the embodiment of FIG. **1.** The cam element serving to actuate the movable adjustment member for determining the position of the adjustable stop means is indicated in general by **60.** This cam element has an outer surface which is curved in space, and it acts on the movable adjustment member (not shown) by being displaced axially as well as by rotating, as shown with the embodiment of FIG. **1.** A per se known angular speed transducer **62** cooperates with a gear **64** keyed on the shaft of the internal combustion engine (not shown). This is the transducer which supplies electric signals for the injection unit according to the invention. The signal generated by the transducer **62** and being a function of the engine speed is applied together with signals from other transducers (not shown) to an electronic control device **66.** The output signal of the electronic control device **66** is applied to the first input of a comparator circuit **68,** while the second input thereof receives a signal from a position transducer **70,** for instance, a differential transformer which continuously determines the axial position of the cam element **60.** The output signal of the comparator circuit **68,** which may be amplified, if desired, controls an electric motor **72** effecting the axial displacement of the cam element **60** through a gear **74** and a toothed rack **76** against the force of a return spring **78.**

The arrangement shown in FIG. **3** differs from that of FIG. **1** in that a further cam element **34** is interposed between the cam element **30** and the movable adjustment member **32.** This additional cam element **34** is operated directly from the accelerator pedal through a linkage system comprising several lever arms **37, 38,** 39. Through lever arm **39** the accelerator pedal acts on a throttle valve means, for example a simple flap, **40** disposed in the suction manifold **12.** By actuating the accelerator pedal **36** simultaneous control is achieved of the throttle valve **40** as well as the cam element **34** which is influenced directly. Thus a rapid increase of the amount of fuel, almost to the exact value needed for the desired engine speed, is obtained. At the same time the injection unit actuates the cam element **30** causing the movable adjustment member **32** to fully pass its course up to the exact position determined by the thermodynamic conditions of the engine. In this manner it carries out its correcting function which will be described thereafter. Should the electronic portion of the injection unit or the electric motor or any other electric connection fail to operate properly, this will in no way affect the smooth functioning of the internal combustion engine, since this is subject to direct control from the accelerator pedal **36.**

With the embodiment of FIG. **3** the volume amount or mass of air aspired in the suction manifold **12** of the engine is to be determined. For this purpose the engine speed is detected by a sensor or transducer **62** and by a gear as in the case of the embodiment of FIG. **2.** This gear or wheel, for instance, may be a tone wheel. Moreover, the angular position ϕ of the throttle valve **40** is determined by means of a transducer **126** which may be embodied, for example, by a differential transformer or a potentiometer. Signals corresponding to the engine speed and to the position of the throttle valve are applied through analog-digital converters, respectively **250** and **260** to a memory circuit **128** (of the type ROM, described by Carr and Mize in the book "MOS/-LSI Design and Application," McGraw-Hill Book Company) serving to process these two signals and emit a signal in dependence on the value thereof, which signal corresponds to the volume $q(\mathrm{voc})$ of the amount of air in the cycle or per stroke for each cylinder. This signal processing is necessary since it permits a change of the output value to correspond to the respective type of internal combustion engine or other requirements, such as demands of standardization. The circuit **128** forms a part of a computer **300,** which may be the minicomputer PDP11 of the Digital Equipment Corporation, including a circuit to which the signal corresponding to the valve $q(\mathrm{voc})$ is applied. The circuit **162** also receives through other analogue-digital converters **200** and **210** signals indicating the temperature Ta and the ambient pressure Pa and having been determined by transducers **134** and **136,** respectively. In the circuit **162** the signals $q(\mathrm{voc})$ and Pa are multiplied.

This multiplication product is divided by the square root of Ta and multiplied by a standardization constant $K=R\cdot\sqrt{To}$, wherein To represents a standardization temperature into which the gauge value of the memory circuit **128** has been incorporated and wherein R is a constant which is dependent on the type of engine and other factors normally occurring in this context.

Thus a signal $m(ac)$ is obtained at the output of the circuit **162,** namely

$$m(ac)=\frac{q(voc)\cdot Pa}{R\sqrt{To\cdot Ta}}$$

The signal $m(ac)$ thus corresponds to the mass of air aspired per cycle per cylinder.

Disposing of a direct metering means for the amount of air it is obvious that the signal processing stations described thus far may be disregarded.

The information corresponding to $m(ac)$ is applied to an input associated with a divider circuit **138** forming together with the circuit **162** the processing unit **400** of

the computer **300.** That input of the divider circuit **138** which is associated with the denominator receives a signal corresponding to a coefficient α which is proportional to the air-fuel ratio. Also, the coefficient α is chosen such that it is dependent on the situation prevailing in the suction manifold **12,** i.e. on the position ϕ of the throttle valve **40** (or the pressure differential) and the engine speed, by means of a second memory circuit **140** of similar structure as the memory circuit **128.**

The output of the divider circuit **138** thus provides a signal corresponding to $m(bc)$, i.e. to that mass of fuel per cycle which is needed to assure optimum functioning of the engine.

The processing of the signal $m(bc)$ in the divider circuit **138** is influenced also by the temperature of the engine cooling water TH_2Om detected by a sensor **142** which acts through an analogue digital converter **220** on a resistance parameter of the circuit arrangement.

The signal $m(bc)$ is applied through a digital analogue converter **230** to a first input of a comparator circuit **144,** the second input of which receives a signal m(bc**1**) which is proportional to the amount of fuel introduced into the conduit. This signal is determined by means of a position transducer **46** which is connected with the movable adjustment member **32** for the fuel distributor **16.**

The converters **200, 210, 220, 230, 250** and **260** may be of the 8-bit binary ADC type sold by the Teledyne Philbrick Co. Given by the type of profile of the cam element **34** there is a linear relationship between the position of the cam element **34** and the signal determined by the transducer **46,** with no change in position of the cam element **30.** The value $m(bc1)$ consequently corresponds to the amount of fuel which was introduced directly by means of the accelerator pedal. The output signal of the comparator circuit 144 is a signal $m(b)$ representing the positive or negative correction value which must be given to the position of the adjustable stop means in the distributor **16** to obtain the amount of fuel which will assure proper functioning of the engine.

The signal $m(b)$ is applied to a second comparator circuit **152,** the second input of which receives a signal determined by a position transducer **156** and being proportional to the prevailing position of the cam element **30.**

The output signal of the comparator circuit **152** controls the electric motor **48,** if desired, after an amplification stage. The cam element **30** is mounted on the shaft of said electric motor. If desired, the elements **152** and **156** may be dispensed with. The embodiment shown in FIG. **4** differs from that of FIG. **1** in that additional information corresponding to the angular position **4** of the throttle valve **40** and obtained by measuring the pressure differential ΔP in the suction manifold **12** by means of a pressure difference transducer **130,** are furnished through a further analogue-digital converter **470** to the circuits **128** and **140.**

FIG. **5** shows a modified embodiment of that part of the arrangement of FIG. **4** which serves to determine the amount or mass of air aspired. With this modified embodiment a measuring device **170** of known structure for determining the total volume supplies an information $q(vt)$ which is applied through an analogue-digital converter **280** to a signal processing circuit **172** likewise receiving an information n which cprresponds to the engine speed. In the circuit **172** the following operation is carried out:

$$q(vt)\ \frac{2K}{4n} = q(vc)$$

wherein K is a constant of the injection unit and $q(vc)$ is the volume amount of air aspired per cycle per cylinder. The output signal of the circuit **172** is applied to a second signal processing circuit **174** which also receives information concerning the pressures and ambient temperatures Pa and Ta, respectively, by means of transducers **136** and **134,** and analogue-digital converters **200** and **210** respectively. In the circuit **174** the following operation is carried out:

$$q(vc)\ \frac{Pa}{RTa} = m(ac)$$

wherein R is a constant and $m(ac)$ represents the mass of air aspired. The signal $m(ac)$ is subsequently applied to a circuit block **138** identical to the block **138** shown in FIG. **4.** The circuits **172, 174** and **138** form the processing unit **400'** of a computer **300',** which may be of the above-mentioned PDP11 type.

The term "proportional" as used in the present specification and particularly in the claims in connection with signals is to be understood as embracing any predetermined relationship between any value and a corresponding signal, the exact proportional relationship, however, being preferred.

This invention may be embodied in other forms without departing from the spirit or essential chracteristics thereof. The present embodiments are, therefore, to be considered as in all respects illustrative and not restrictive, the scope of the invention being indicated by the appended claims, and all changes which come within the meaning and range of equivalency are intended to be embraced therein.

Having thus described the invention, what we claim is:

1. An injection unit for injecting fuel, in particular gasoline, into an internal combustion engine, with a pump means to supply the fuel to a rotary distributor means from which it is discharged intermittenly to the cylinders of the internal combustion engine and which includes a fuel metering device with a freely displaceable metering plunger means, the travel of which is controlled by an adjustable stop means, and with means to adjust said adjustable stop means, comprising:

a. a plurality of sensing means which are responsive to parameters which are representative of the functioning of said internal combustion engine or influence said functions;

b. transducer means associated with corresponding sensing means for converting said parameters into electric signals;

c. an electronic control device electrically connected to said transducer means to which said signals are applied and which supplies at its output analogous signal proportional to said parameters;

d. a comparator circuit having a first input to which said analogous signal is applied, a second input, and an output;

e. a d.c. electric motor electrically connected to the comparator circuit output and controlled by said comparator circuit;

f. a first cam element mechanically connected to and actuated by said d.c. electric motor and located adjacent to said means to adjust said adjustable stop;

g. a second cam element interposed between and engaging said first cam element and said means to adjust said adjustable stop means;

h. mechanical means connecting said second cam element with an accelerator pedal such that said cam is moved in proportion to the pedal movement; and

i. means connected to the second input of the comparator circuit to determine the position of said means to adjust the adjustable stop means and emit an electric signal corresponding to said position.

2. An injection unit as claimed in claim **1** further comprising:

a. a first comparator circuit;

b. a second comparator circuit, having a first input connected to an output of said first comparator circuit, a second input and an output connected to said d.c. motor;

c. a divider circuit having an output connected to said first comparator circuit, and first and second inputs;

d. means connected to a first input of said divider circuit to generate a signal proportional to the mass of air in the suction manifold per engine cycle and per cylinder;

e. means connected to a second input of said divider circuit to generate a signal proportional to the air fuel ratio;

f. first transducer means connected to an input of said first comparator circuit to generate a signal responsive to the position of the second cam element; and

g. second transducer means connected to the second input of said second comparator circuit to generate a signal responsive to the position of said first cam element.

3. An injection unit as claimed in claim **2**, wherein said means emitting a signal proportional to the mass of air aspired comprises a memory circuit, to the inputs of which signals are applied which correspond to the position of a throttle valve means and to the engine speed, and a signal processing circuit which receives the signal supplied by said memory circuit and further signals proportional to other values.

4. An injection unit as claimed in claim **2**, wherein said means serving to detect the mass of air comprises a measuring device for the total volume amount of air aspired, which device controls a first signal processing circuit generating a signal proportional to the volume amount of air per cycle and per cylinder and a second signal processing circuit receiving said signal emitted by said first signal processing circuit and signals proportional to the values of pressure and ambient temperature.

* * * * *