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Knapp

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[54] **FUEL INJECTION APPARATUS**

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[51] **Int. Cl.** **F02b 3/00,** F02m 39/00
[58] **Field of Search** .... 123/32 EA, 32 AE, 139 E

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[57] **ABSTRACT**

In a fuel injection apparatus, in order to maintain a constant fuel-air ratio, the position of the movable valve member of a fuel quantity distributor and metering valve is affected by an electromagnet. The intensity of the energizing current for the electromagnet is derived from a comparison between the output of a first and a second bridge circuit. The first bridge circuit contains a temperature-dependent resistance which is located in the engine suction pipe and the resistance value of which is a measure for the flow rate of air. The second bridge circuit contains a temperature-dependent resistance which is located in the distributor and metering valve and the resistance value of which is a measure for the flow rate of fuel.

7 Claims, 2 Drawing Figures

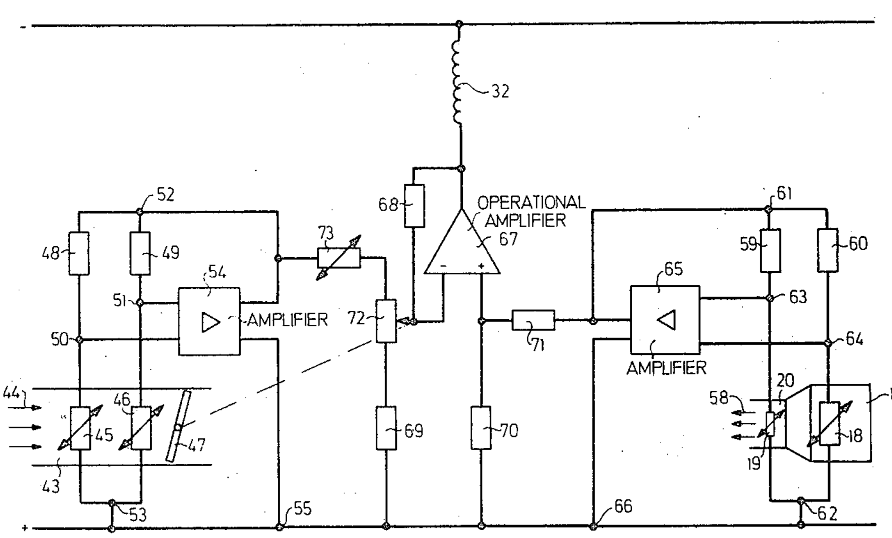
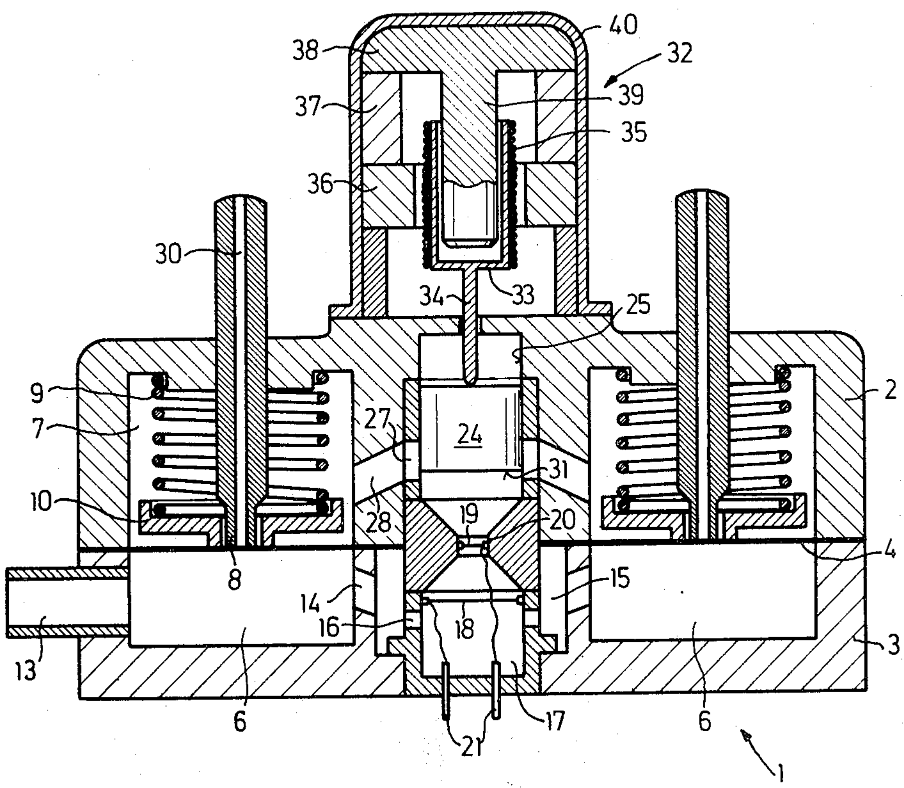


Fig. 1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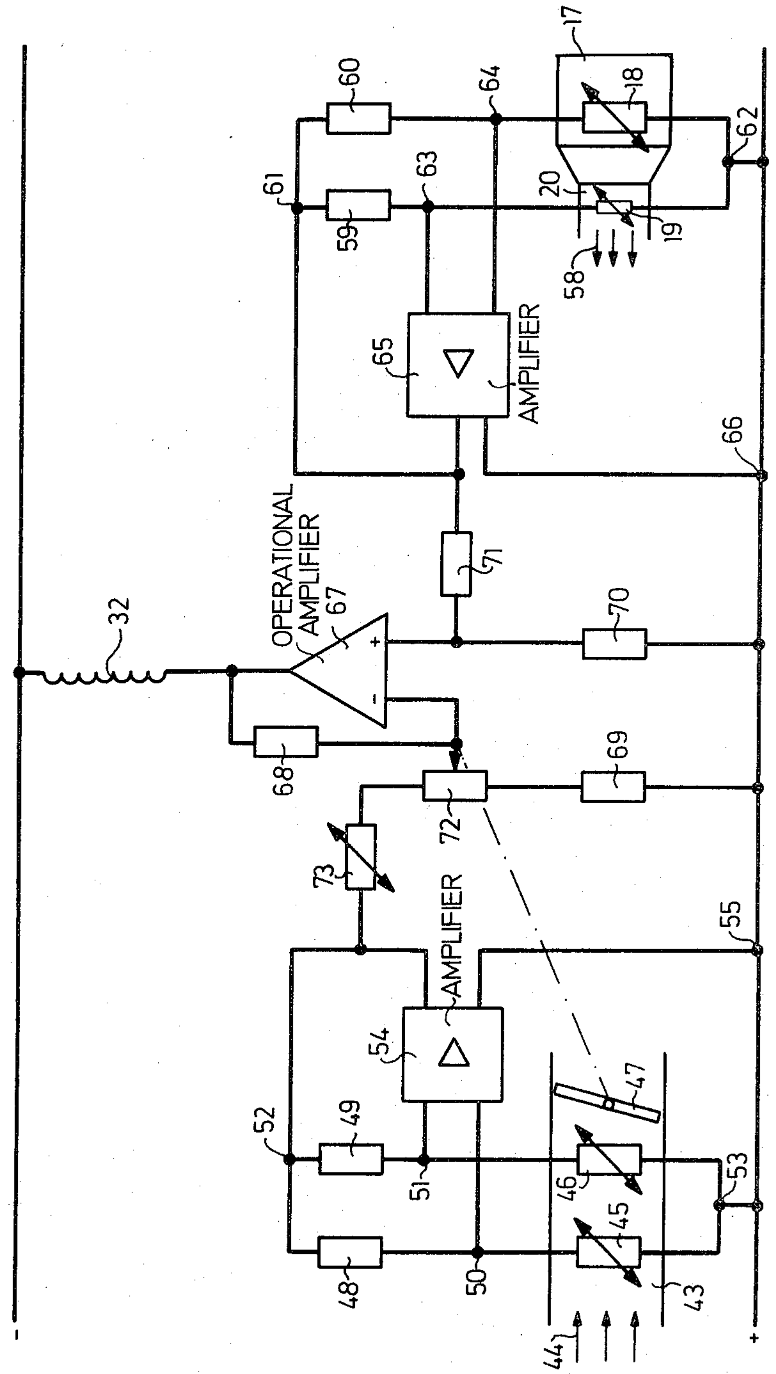
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Fig. 2

FUEL INJECTION APPARATUS

BACKGROUND OF THE INVENTION

This invention relates to a fuel injection apparatus including means for the continuous injection of fuel into the air intake tube (suction pipe) of a spark plug-ignited internal combustion engine. The fuel injection apparatus is further of the type that comprises an electric control apparatus which, as a function of engine variables, actuates the movable member of a fuel quantity distributor and metering valve situated in the fuel line for metering injection quantities in proportion with the intake air quantities. The fuel injection apparatus furthermore includes an electrically operated device for measuring the intake air quantities by means of at least one temperature-dependent resistance disposed in the intake air flow.

In a known fuel injection apparatus of the aforeoutlined type (as disclosed, for example, in German Pat. No. 1,109,953), for the measuring of the intake air quantities there is used a temperature-dependent resistance. The latter is disposed in the suction (air intake) system of the internal combustion engine and is heated by a heater body. Dependent upon the throughgoing air quantities, the heated resistance is cooled to different temperatures resulting in different resistance values. In this manner the momentary resistance value represents a measure for the momentary throughgoing air quantities. It is a disadvantage of a fuel injection apparatus of the aforeoutlined type that it responds only sluggishly to rapid quantity changes in the intake air, since the heat transmission from the heater body to the temperature-dependent resistance occurs with a delay. Furthermore, a number of disturbance variables are fed into the measuring circuit as error signals. These are caused partly by the oscillations in the heat output and partly by the oscillations of temperature of the intake air. As a result, the measured magnitude does not correspond accurately enough to the intake air quantities. Since, however, it is exactly the intake air quantity which serves to allocate the fuel quantity required for a perfect combustion, an accurate measured magnitude of the intake air quantities is a basic requirement for a full combustion.

OBJECT AND SUMMARY OF THE INVENTION

It is an object of the invention to provide an improved fuel injection apparatus for the aforesaid type from which the aforeoutlined disadvantages are eliminated and which, by means of automatic regulation, effects a constant air-fuel ratio.

Briefly stated, according to the invention, the injected fuel quantities metered by the fuel distributor and metering valve are measured by a temperature-dependent resistance which is located in the fuel flow and which forms a resistance in a bridge circuit. The characteristic curve of the latter has approximately the same course as that of the bridge circuit that measures the intake air quantities.

The invention will be better understood as well as further objects and advantages become more apparent from the ensuing detailed specification of a preferred, although exemplary, embodiment of the invention taken in conjunction with the drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is an axial sectional view of a fuel metering and distributor valve incorporating the invention and

FIG. 2 is a block diagram for generating a control current as a function of engine variables according to the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Turning now to FIG. **1**, in the quantity distributor and metering valve **1** between a housing **2** and a base closure **3** there is clamped taut a metal diaphragm **4**. The latter divides cavities arranged in a circular array and defined by components **2** and **3** into a plurality of chambers **6** and an equal number of chambers **7**. In each chamber pair **6, 7** the associated diaphragm portion forms a flat seat valve with a stationary valve seat **8**. Each valve seat **8** is disposed coplanar with the clamping plane of the diaphragm **4**. In each chamber pair **6, 7** there is provided a compression spring **9** which, with the interposition of a spring seat disc **10**, loads the diaphragm **4** in the direction of valve opening, so that the flat seat valve is maintained in an open position when the fuel injection apparatus is not operating. The fuel delivered continuously by a fuel pump, not shown, is admitted through an inlet nipple **13** into chambers **6** that communicate with one another through an annular channel, also not shown. From the chambers **6** the fuel is admitted through ports **14** into an annular chamber **15** which communicates with a chamber **17** by means of ports **16**. In the chamber **17** there is located a temperature-dependent resistance **18**. The terminal wires of the temperature-dependent resistance **18**, as well as those of a further temperature-dependent resistance **19** which is located in a constriction **20**, are connected to metal pins **21**. The land of a control plunger **24** which is movable in a bore **25** overlaps to a greater or lesser extent — dependent upon the position of the plunger — a plurality of control slots **27**, each of which communicates with a separate chamber **7** through separate channels **28**. From the chambers **7** the fuel is admitted through channels **30** to the individual fuel injection valves (not shown) which are disposed in the suction pipe of the engine in the vicinity of the associated engine cylinder. The diaphragm boxes each formed of a chamber pair **6, 7** ensure that independently from the extent of overlap between the control plunger **24** and the control slots **27**, that is, independently from the fuel quantities that flow to the individual fuel injection valves, the pressure drop across the fuel metering valve **24, 27** is maintained at a substantially constant value. In this manner it is ensured that the extent of displacement of the control plunger **24** is proportionate to the metered fuel quantities.

The force of the fuel pressure to which the radial face **31** of the control plunger **24** is exposed, is counteracted by an electromagnet **32**, having a movable armature **33** provided with a pin **34** in engagement with the control plunger **24**. The sleeve-shaped armature **33** carries an externally wound solenoid **35** the energizing current of which depends in intensity from engine variables as it will be described hereinafter. The strength of the magnetic field generated about the solenoid **35** and thus the force transmitted by the pin **34** to the control plunger **24** is a function of the intensity of the energizing current. The solenoid **35** is spacedly surrounded by a stationary soft iron core 36 which is in engagement with an axially aligned annular permanent magnet 37. The latter, in turn, contacts a soft iron plate 38 which is provided with a pin 39 extending into the armature sleeve 33 through the open end thereof. The entire electromagnet assembly is closed by a sheet iron cap 40 which tightens the electromagnet assembly to the quantity distributor and metering valve 1.

Turning now to FIG. 2, there is schematically shown the air intake tube 43 in which the intake air flows in the direction of arrows 44. Within the air intake tube 43 there are located a butterfly valve 47 and, upstream thereof, two temperature-dependent resistances 45 and 46 which, together with separate fixed resistances 48 and 49 form parallel branches of a bridge circuit. Taps 50 and 51 are located between the resistances 45 and 48 and between the resistances 46 and 49, respectively. The two parallel branches are joined at junctions 52 and 53. The diagonal potential difference between the taps 50 and 51 is applied to the input of an amplifier 54. The output terminals of the latter are connected to the junctions 52 and 55, so that the output of the amplifier 54 provides the bridge circuit with operating voltage or current, as the case may be. The temperature-dependent resistance 45 is heated by the current flowing therethrough to a value at which the output voltage of the amplifier 54, that is, the diagonal potential difference in the bridge reaches a zero value or any other predetermined magnitude. At the same time, a predetermined current flows into the bridge circuit from the output of the amplifier 54. If, due to a quantity change of the intake air, the temperature of the temperature-dependent resistance 45 changes, then the diagonal potential difference in the bridge also changes. As a result, the amplifier 54 regulates the supply voltage or current for the bridge to a value for which the bridge is again in equilibrium or is detuned in a predetermined manner. The output voltage of the amplifier 54, similarly to the current flowing through the temperature-dependent resistance 45 represents a measure for the intake air quantities. The value of the temperature-dependent resistance 46 is so selected that the losses due to the branch current flowing therethrough is of such a small value that the temperature of this resistance practically does not change with the variation of the bridge voltage, but corresponds at all times to the temperature of the throughgoing intake air. The resistance value of the temperature-dependent resistance 46 is thus a measure for the momentary temperature of the intake air. The influence of temperature of the intake air on the measuring results is thus compensated in the aforedescribed manner.

According to the invention, the metered fuel too is measured by a temperature-dependent resistance. For this purpose, as also shown in FIG. 1, in the quantity distributor and metering valve 1 two temperature-dependent resistances 18 and 19 are exposed to the fuel that flows in the direction of arrow 58. The temperature-dependent resistance 19 is disposed in the constriction 20, while the temperature-dependent resistance 18 — that compensates for the fuel temperature — is located in the chamber 17. With two fixed resistances 59 and 60, the two temperature-dependent resistances 18 and 19 form parallel branches of a bridge circuit. These branches are connected at junctions 61 and 62. The diagonal voltage (potential difference) of the bridge that appears between the taps 63 and 64 is applied to the input of an amplifier 65. To the output of the latter there are connected junctions 61 and 66, so that the output voltage of the amplifier 65 provides the last-named bridge circuit with operating voltage or current, as the case may be. The value of the temperature-dependent resistance 18 is designed in such a manner that it is not warmed up by the fuel to which it is exposed. Thus, the variation of the value of the resistance 18 is solely the function of the momentary fuel temperature. The output voltage of the amplifier 65 represents, similarly to the current intensity in the temperature-dependent resistance 19, a measure for the metered fuel quantities.

The temperature-dependent resistances are preferably heater wires or heater film resistances which have a positive temperature coefficient. It is to be understood that with an appropriate design of the amplifier 54 and 65 temperature-dependent resistances of negative termperature coefficients may be used.

The constriction 20 is dimensioned in such a manner that there is obtained, in case of a variation of the metered fuel quantities of 1:30, a high flow speed which, however, does not lead to perceptible errors in the pressure difference at the fuel metering valve 24, 27 due to the pressure drop thereacross.

The outlet voltages of the amplifiers 54 and 65 are compared in an operational amplifier 67. The latter readjusts the metered injection quantities in the distributor and metering valve 1 through the electromagnet 32 until balance is achieved. A resistance 68 serves as a feedback coupling. The resistances 69, 70 and 71 form a voltage divider. In order to permit the feeding of correcting signals into the circuit, the equilibrium may be detuned — for example, for a λ-correction — by means of a potentiometer 72 which is connected with the butterfly valve 47 and/or, for a warm run correction, by means of a temperature-dependent resistance 73 which is exposed to the flow of engine coolant. The air amount λ is so defined that it assumes the value of 1.0 in the stoichiometrical air-fuel mixture. The air amount λ is the mass ratio of air to fuel. In a lean mixture the air amount is larger than 1.0, in a rich mixture it is smaller than 1.0.

In order to maintain a drift of the zero point of the measuring bridge circuits at the smallest possible value, the two bridge circuits are supplied by the same voltage source.

The resistances of the two bridge circuits are chosen in such a manner that the characteristic curves of the bridge circuits have an approximately coinciding course. By means of comparing the two output voltages of the amplifiers 54 and 65 and by means of reducing the difference to zero, there is obtained a constant air-fuel ratio over the entire range of air flow. The fuel injection apparatus incorporating the above-described invention thus has the advantage that the feedback of the measured magnitude of the fuel quantities is effected by means of a measured magnitude of the same type and without the aid of mechanical components, wear prone potentiometers or inductive transducers.

It is seen that in the system described hereinbefore the temperature-dependent resistances are heated by control currents and form part of two separate, closed control circuits. The latter readjust the electric current flowing through the associated temperature-dependent resistance in such a manner that these resistances are maintained at a constant temperature. The two control currents, or the two voltages proportionate thereto are a measure for the air and fuel flow rates.

What is claimed is:

1. In a fuel injection apparatus serving a spark plug-ignited internal combustion engine operating on fuel continuously injected into the suction tube of the engine, said engine having a butterfly valve disposed in said suction tube, said apparatus being of the known type that has (a) a fuel metering valve disposed in the fuel line and having a movable valve member, (b) an electric control apparatus affecting the position of said movable valve member for metering, as a function of engine variables, fuel quantities adapted to the intake air quantities, (c) first electrically operating means for measuring the intake air quantities, (d) a first bridge circuit forming part of said first electrically operating means, (e) a first temperature-dependent resistance exposed to the flow of intake air and forming part of said first bridge circuit, the resistance value of said first temperature-dependent resistance being the function of the flow rate of intake air, the improvement comprising

A. a second electrically operating means for measuring the metered fuel quantities,

B. a second bridge circuit forming part of said second electrically operating means, said second bridge circuit having a characteristic curve of approximately the same course as that of said first bridge circuit,

C. a second temperature-dependent resistance exposed to the flow of the metered fuel and forming part of said second bridge circuit, the resistance value of said second temperature-dependent resistance being the function of the flow rate of the metered fuel,

D. comparator means connected to said first and second electrically operating means for comparing their output signals and

E. means coupled to the output of said comparator means and to said movable valve member for adjusting the position of the latter as a function of the output signals of said comparator means.

2. An improvement as defined in claim **1,** wherein said first and second electrically operating means constitute closed, separate first and second regulator circuits, respectively, each regulator circuit including current regulator means for so readjusting the electric current flowing through said temperature-dependent resistances as to maintain the latter at approximately constant temperatures, whereby the intensity of current flowing through said first and second regulator circuits represents a measure for the flow rate of air and fuel, respectively.

3. An improvement as defined in claim **2,** including an operational amplifier constituting said comparator means and an electromagnet forming part of said means coupled to the output of said comparator means, the intensity of the magnetic field of said electromagnet being variable as a function of the output signals of said operational amplifier.

4. An improvement as defined in claim **2,** each regulator circuit includes a separate amplifier, the input of which is connected to the diagonal junctions of its associated bridge circuit.

5. An improvement as defined in claim **4,** wherein said current regulator means includes means connecting the output of said amplifier to its associated bridge circuit.

6. An improvement as defined in claim **2,** including a potentiometer and means varying said potentiometer as a function of the position of said butterfly valve, said potentiometer forming part of said first regulator circuit for detuning the electric current flowing therethrough to effect a λ-correction.

7. An improvement as defined in claim **2,** including an additional temperature-dependent resistance exposed to the temperature of the engine coolant and forming part of said first regulator circuit for detuning the electric current flowing therethrough to effect a correction for the warm run of the engine.

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