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[54] **FUEL INJECTION APPARATUS FOR SPARK PLUG-IGNITED INTERNAL COMBUSTION ENGINES**

[75] Inventor: **Heinrich Knapp,** 725 Leonberg-silberberg, Germany

[73] Assignee: **Robert Bosch GmbH,** Stuttgart, Germany

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[51] **Int. Cl.**..**F02m 69/00**

[58] **Field of Search**.......................123/119 R, 119 F, 123/139 AW; 261/39 R, 39 C, 50 A, 50 AA, 39 E

[56] **References Cited**

UNITED STATES PATENTS

3,680,535 8/1972 Eckert et al. ....123/119 R

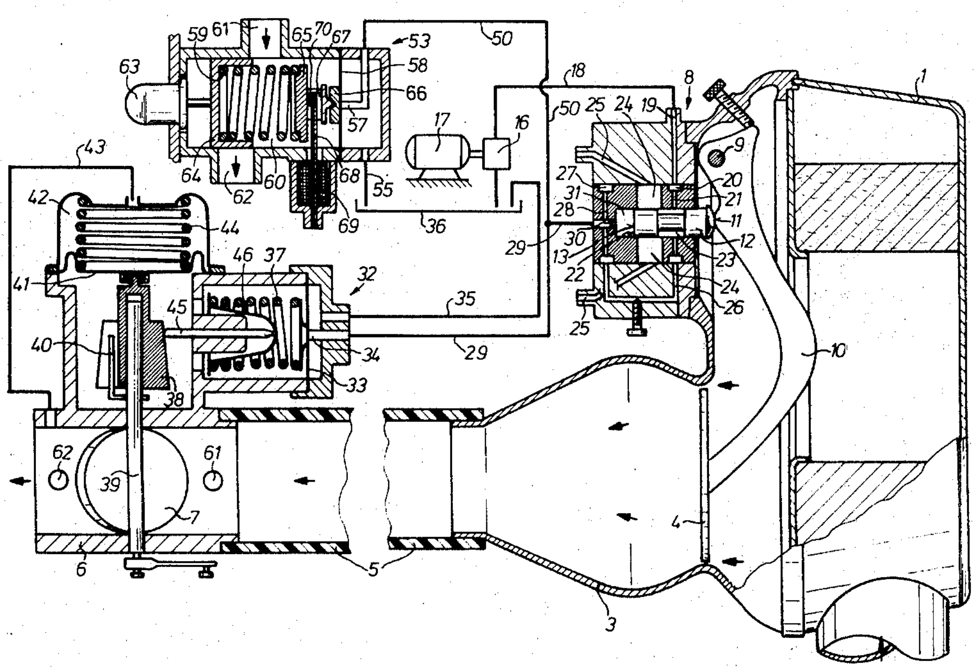
Primary Examiner—Wendell E. Burns

Attorney—Edwin E. Greigg

[57] **ABSTRACT**

In a fuel injection apparatus the air-fuel ratio is controlled by an air sensor which is deflected against a return force by the intake air and which, as a function of the extent of its deflection, controls the output of a fuel metering valve. To ensure a leaner fuel mixture subsequent to a cold engine start, there is provided a first temperature-dependent control element which is responsive to the water coolant temperature and, upon the increase of the latter, causes an increase in the bias of a spring augmenting, in turn, said return force to bring about a leaner fuel mixture and a second temperature-dependent control element which is responsive to a separate heater means and which, for a very short period subsequent to the starting of the cold engine, hinders said first temperature-dependent control element to increase said bias.

5 Claims, 2 Drawing Figures



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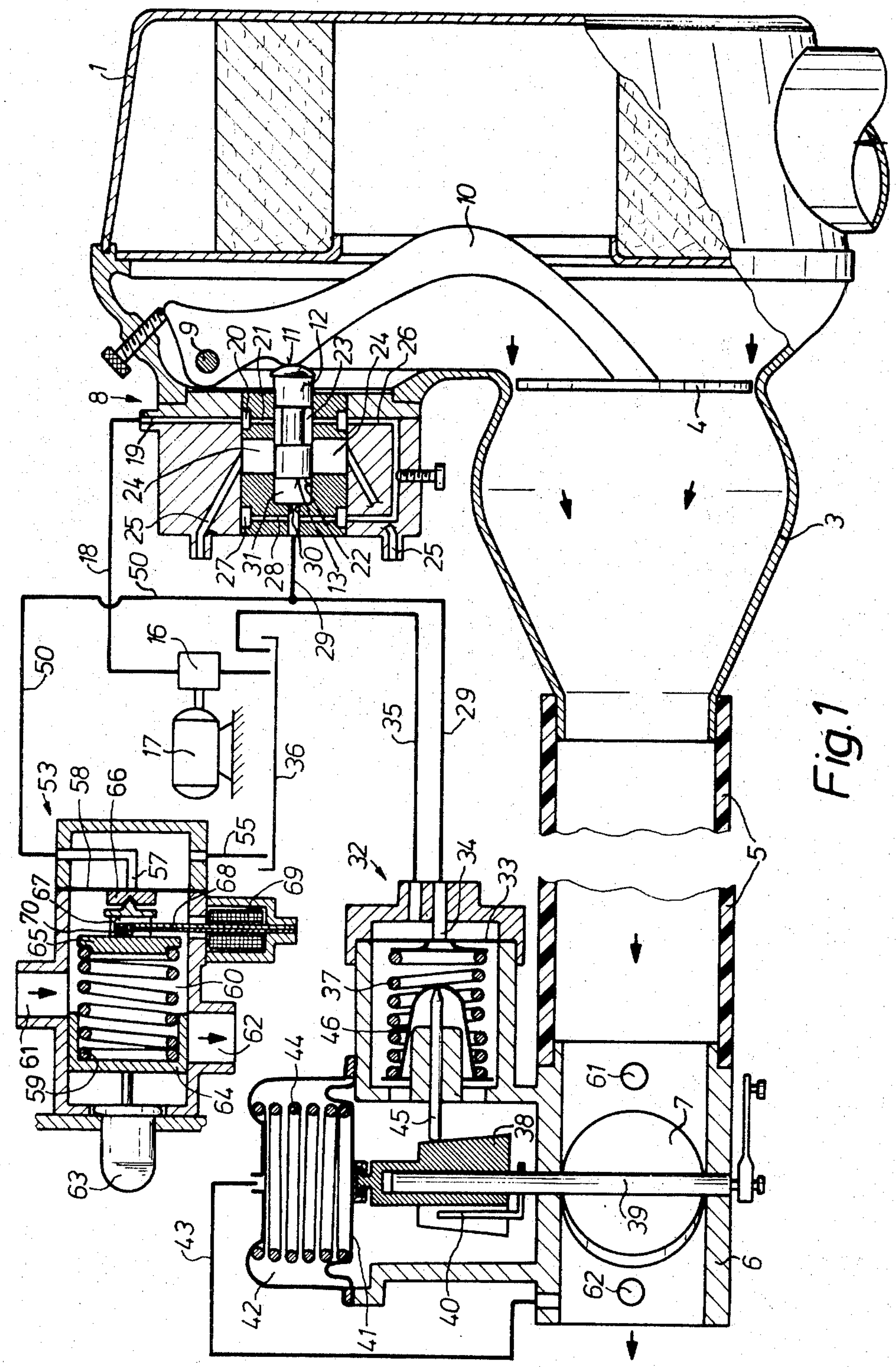

Fig.1

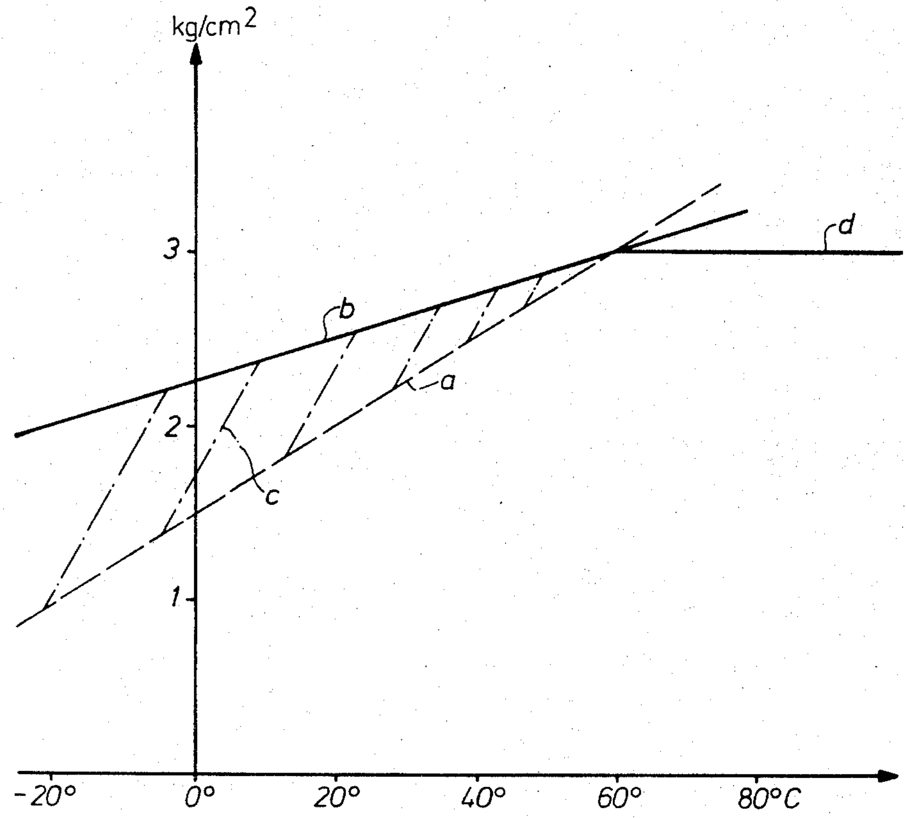

Fig.2

FUEL INJECTION APPARATUS FOR SPARK PLUG-IGNITED INTERNAL COMBUSTION ENGINES

BACKGROUND OF THE INVENTION

This invention relates to a fuel injection apparatus associated with a spark plug-ignited internal combustion engine which operates on fuel continuously injected into the air intake tube. In the latter there are serially arranged an air sensor and an arbitrarily operable butterfly valve. The air sensor is displaceable by the air flow against a constant return force to an extent proportionate to the throughgoing air quantities. The air sensor displaces the fuel rack of a fuel quantity distributor valve disposed in the fuel line for the metering of fuel quantities in proportion to the throughgoing air quantities. The aforenoted return force is derived from the pressure of a liquid which is supplied continuously and under constant pressure through a pressure conduit and which affects a control plunger operatively connected to the air sensor. The pressure of said liquid is variable by a pressure control valve which is, in turn, responsive to at least one engine variable. Besides the pressure control valve there is provided a temperature-responsive control element operating a closing member disposed in a bypass channel which circumvents the butterfly valve. Said bypass is closed after the normal operational temperatures of the internal combustion engine are reached.

In a fuel injection apparatus of the aforenoted type the difficulty is encountered that the enriching of the fuel-air mixture for the warm-up operation has to be substantially greater immediately after starting the engine than it is necessary for the subsequent engine run after a certain period. Thus, assuming for example an engine start at −20° C, the fuel mixture, by the time the engine runs at 0° C of coolant water temperature, is enriched approximately twice the extent necessary to keep the engine running immediately after starting and to ensure optimally clean exhaust gases at 0° C of coolant water temperature. The reason is the increase in fuel condensation at the cold cylinder walls which are pre-warmed by virtue of the several ignitions, whereas the coolant temperature still remains practically the same. An apparatus of the aforenoted type is described in Published German Application (DOS) 1,960,144.

OBJECT AND SUMMARY OF THE INVENTION

It is an object of the invention to provide an improved fuel injection apparatus wherein the fuel enriching for the warm-up run is improved in such a manner that for a very short period immediately subsequent to the starting of the engine, there is effected the usual fuel enriching whereupon, in a temperature-dependent manner, the extent of the enriching is gradually decreased to assume a value which ensures an optimal exhaust gas composition.

Briefly stated, according to the invention, in addition to the aforenoted temperature-responsive control element which is disposed in said bypass and which varies the bias of a spring associated with said pressure control valve, there is provided an additional, second temperature-dependent control element which, during and for a short period immediately subsequent to the starting of the engine, exerts a force opposing that of said spring.

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 taken in conjunction with the drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a longitudinal, in part schematic, sectional view of a fuel injection apparatus according to the invention and

FIG. 2 is a diagram illustrating the control pressure of the pressurized liquid as a function of temperature.

DESCRIPTION OF THE EMBODIMENT

Turning now to FIG. 1, there is shown a fuel injection apparatus in which the intake air flows from an air filter 1 to one or more engine cylinders (not shown) through an air intake tube which comprises a portion 3 in which there is disposed an air sensor 4, a hose connection 5 and an intake tube portion 6 in which there is arranged an arbitrarily operable butterfly valve 7. The air sensor 4 is formed as a disc which is oriented normal to the direction of air flow and which is movable in the intake tube portion 3 as a substantially linear function of the air quantities flowing through the air intake tube. In case of a constant return force applied to the air sensor 4, as well as a constant air pressure prevailing upstream of the air sensor 4, the pressure between the air sensor 4 and the butterfly valve 7 remains substantially constant. The air sensor 4 directly controls a metering and fuel distributor valve 8. The motion of the air sensor 4 is transmitted to the control plunger 12 of the fuel metering valve 8 by means of a nose portion 11 of a lever 10 which is affixed to the air sensor plate 4 and which is pivotable with low friction about a shaft 9. The radial terminal face 13 of the control plunger 12 is exposed to pressurized liquid which serves as the return force for the air sensor 4.

The supply of fuel is effected by a fuel pump 16 which is driven by an electromotor 17 and which draws fuel from a fuel tank 36 forcing it through a conduit 18 to the fuel metering valve 8. From the conduit 18 the fuel is admitted to a channel 19 disposed in a housing of the fuel metering valve 8. The channel 19 merges into an annular groove 20 from which there extend ports 21 to a cylinder 22 in which the control plunger 12 is reciprocably disposed. In the latter there is provided, by virtue of two spaced lands, an annular circumferential groove 23 which is in continuous communication with the ports 21. Dependent upon the position of the control plunger 12 the annular groove 23 overlaps to a greater or lesser extent control slots 24 through which the fuel may flow from the annular groove 23 into channels 25 which, in turn, lead to the individual fuel injection valves (not shown) disposed in the air intake tube of the internal combustion engine. One part of the fuel flows from the annular groove 20 into a channel 26 and is admitted to an annular groove 27 wherefrom it flows through ports 28 into a conduit 29. The latter is in communication through a damping throttle 30 with the pressure chamber 31 (forming part of the cylinder 22) in which there is disposed the radial work face 13 of the control plunger 12.

Through the conduit 29 the fuel serving as pressurized liquid is admitted to a first pressure control valve **32** which is formed as a flat seat valve including a diaphragm **33** and a stationary valve seat **34**. The fuel flowing through the control valve **32** is returned in a depressurized condition into the fuel tank **36** through a return conduit **35**. The diaphragm **33** is loaded by a spring **37**, the bias of which is changed as a function of operational variables of the internal combustion engine. For this purpose there is provided a three-dimensional cam **38** which is rotatable as a unit with the arbitrarily adjustable butterfly valve **7** and which may be axially displaced as a function of the vacuum prevailing downstream of the butterfly valve **7** in the suction tube. The three-dimensional cam **38** is axially slidably held on the shaft **39** which is integral with the butterfly valve **7**. The rotary motion of the shaft **39** is transmitted by means of a pin **40** to the three-dimensional cam **38** which, at one frontal face, is rotatably secured to a diaphragm **41** bounding a vacuum chamber **42**. The latter is in communication by means of a conduit **43** with the air intake tube at a location downstream of the butterfly valve **7**. If the vacuum is of a sufficiently large value, the three-dimensional cam **38** is axially displaced by the diaphragm **41** against the force of a return spring **44** disposed in the vacuum chamber **42**. A follower pin **45** scans the surface of the three-dimensional cam **38** and through a spring seat disc **46**, controls the bias of the spring **37** to affect the pressure of the pressurized liquid serving as the resetting force for the air sensor **4**.

From the conduit **29** there extends a conduit **50** which is connected to a second pressure control valve **53** from which there extends a return conduit **55** to the fuel tank **36**. The pressure of the pressurized liquid serving as a return force for the air sensor **4** may be controlled as a function of temperature by means of the second pressure control valve **53**. The latter is formed as a flat seat valve having a stationary valve seat **57** and a diaphragm **58** which is loaded by a spring **59** in the closing direction of the valve **53**.

The chamber **60** accommodating the spring **59** forms one part of a bypass conduit **61, 62** circumventing the butterfly valve **7** in the suction tube. For the sake of clarity the bypass conduit itself is not shown in FIG. **1**, only its connections with the suction tube portion **6** and with the pressure control valve **53** are indicated. In chamber **60** there is disposed a plunger piston **64** which controls the flow passage section of the bypass conduit **61, 62** and which also serves as a spring seat disc for the spring **59**.

The displacement of the piston plunger **64** is effected by a first temperature-dependent control element (heat expandable regulator) **63** which, when the internal combustion engine is cold, compresses the spring **59** to a lesser extent and opens the bypass **61, 62** to a greater extent than in case of a warm engine. In this manner, under cold engine conditions more pressurized liquid flows through the valve **57, 58** and thus the pressure of the fuel working as a return force is smaller. Consequently, the injected fuel quantities are relatively increased with respect to the air quantities to obtain a richer mixture.

That terminus of the spring **59** which is remote from the control plunger **64** engages a spring seat disc **65** which exerts a force on the diaphragm **58** through an intermediate member **66**. The spring seat disc **65** has at its side remote from the spring **59** an opening **67** into which there extends one end of a bimetal spring **68**. The other end of the latter is surrounded by a heater element **69** which, together with the bimetallic spring **68**, forms a second temperature-dependent control element **68, 69**. In the shown position, prior to the operation of the internal combustion engine, a rivet **70** attached to the bimetal spring **68** is in engagement with the spring seat disc **65**.

OPERATION OF THE FUEL INJECTION APPARATUS

When the internal combustion engine is running, the pump **16** driven by the electromotor **17**, draws fuel from the fuel tank **36** and forces the same through the conduit **18** to the fuel metering valve **8**. Simultaneously, the engine draws air through the air intake tube **3, 5, 6**, as a result of which the air sensor **4** is deflected in a clockwise direction (as viewed in FIG. **1**) from its position of rest.

In response to the deflection of the air sensor **4** the lever **10**, with its integral nose **11**, displaces the control plunger **12** to the left, thus opening the control slots **24** to a greater extent. Thus, the fuel quantity passing through the metering slots **24** and admitted to the fuel injection valves (not shown) corresponds to the setting magnitude of the air sensor **4**. From the annular groove **23** of the control plunger **12**, one part of the fuel is admitted through the channel **26** into the pressure chamber **31** where it affects the frontal radial face **13** of the control plunger **12**. Other parts of the fuel flow from the channel **26** through the conduit **29** to the first pressure control valve **32** and through a conduit **50** to the second pressure control valve **53**.

The direct coupling of the air sensor **4** with the control plunger **12** results in a constant ratio between the air quantities and the fuel quantities insofar as the characteristic curves of both members are sufficiently linear (which is a desideratum by itself). The air-fuel ratio would then in this manner be maintained constant throughout the entire operational range of the internal combustion engine. It is, however, a requirement that as a function of the operational conditions of the internal combustion engine, the air-fuel ratio be richer or leaner. Such a ratio variation is effected by changing the resetting force on the air sensor **4**.

The measuring magnitudes for load and rpm of an internal combustion engine are the angular position of the butterfly valve and the vacuum in the air intake tube. Consequently, the return force is expediently varied as a function of these two magnitudes. Such variation is brought about by the change in the bias of the spring **37** of the pressure control valve **32** by shifting the spring seat disc **46**. The latter shift, in turn, is effected by the rotary and axial motions of the three-dimensional cam **38** executed, respectively, in response to the angular position of the butterfly valve **7** and the pressure in the suction tube. If for example, in a full load condition the butterfly valve **7** is in a position in which the suction tube is fully open, then a highest output, that is, a relatively rich air-fuel mixture is desired. Since the bias of the spring **37** of the first pressure control valve **32** determines the pressure of the fuel which affects the radial face **13** of the control plunger **12**, the return force affecting the air sensor **4** has to be somewhat reduced to permit the control plunger **12** to be shifted into a position in which the control slots **24** are opened to a greater extent and, accordingly, larger fuel quantities can be injected. Conversely, under partial load conditions, by virtue of a relatively higher pressure exerted on the radial face **13** of the control plunger **12**, there is obtained a relatively smaller deflection of the air sensor **4** and, as a result, the air-fuel mixture will be leaner.

When the vehicle with which the internal combustion engine is associated coasts in gear, the three-dimensional cam **38**, because of the substantial vacuum in the air intake tube, is displaced against the force of the spring **44** so that the spring **37** of the first pressure control valve **32** will be biased to a greater extent. In this manner the return force exerted on the air sensor **4** is increased so that despite the slight "air leakage quantities" that may flow through the closed butterfly valve **7**, there will be no deflection of the air sensor **4** and thus no fuel quantities will be injected.

If first the effect of the second temperature-dependent control element **68, 69** is disregarded, in case of a cold engine there is obtained an enriching of the air-fuel ratio, since the heat-expandable regulator **63** of the second pressure control valve **53** causes the pressure of the fuel serving as a return force to be decreased in the chamber **31**. In this operational condition the plunger piston **64** displaced by the heat-expandable regulator **63** maintains the bypass conduit **61, 62** open. In this manner, the greater engine friction at the cold start of the engine is compensated by a correspondingly higher mixture flow rate.

The first temperature-dependent control element **63** which responds to the coolant water temperature, effects a leaner fuel mixture (by compressing the spring **59** and thus increasing the fuel pressure at the radial work face **13** of the control plunger **12**) only with a substantial delay. Since, however, already a few moments following the starting of the engine the cylinder walls, because of the preceding ignitions, have been prewarmed and thus a fuel condensation caused by the previously cold cylinder walls occurs to a decreasing degree, it is expedient to simultaneously reduce the enrichment of the air-fuel mixture to such an extent that a clean run of the engine is ensured. According to the invention, such a decrease in the fuel enriching is ensured by causing the second temperature-dependent control element **68, 69** to work against the spring **59** for a short period immediately after starting of the internal combustion engine. The heater **69** is energized by, e.g. closing its electrical circuit simultaneously with turning on the engine ignition.

Turning now to FIG. **2** there is shown the fuel pressure exerted on the control plunger **12** as a function of the coolant water temperature as controlled by the second pressure control valve **53**. In a device for the warm-up run of the engine without the second temperature-dependent control element **68, 69**, the spring **59** should be designed according to the pressure characteristic curve *a*. According to the invention, however, the spring **59** is designed to correspond to the pressure characteristic curve *b*. The cold bimetal spring **68** works against the spring **59** at the moment of starting in such a manner that the curve *a* is obtained for the engine run after starting. The heat output of the heater element **69** is determined in advance in such a manner that, dependent upon the starting temperature, the bimetal spring **68** is, after a correspondingly short time, bent away from the spring seat disc **65**. Consequently, after this occurrence the spring seat disc **65** and thus the diaphragm **58** are loaded only by the spring **59**. The transition from the curve *a* to the curve *b* occurs, dependent upon the temperature at the starting, along one of the curves *c*. At normal operating temperatures of the coolant water, the spring **59** remains biased to a constant extent according to the curve *d*.

That which is claimed is:

1. In a fuel injection apparatus serving a spark plug-ignited internal combustion engine operating on fuel continuously injected into the air intake tube thereof, said apparatus being of the type that has (a) an arbitrarily operable butterfly valve disposed in said air intake tube, (b) an air sensor disposed in said air intake tube spaced from said butterfly valve, said air sensor being displaceable by and as a function of the air quantities passing through said air intake tube, (c) a fuel quantity distributor valve for metering the fuel quantities to be injected, (d) means connecting said air sensor with said fuel quantity distributor valve to effect metering of said fuel as a function of the deflection of said air sensor, (e) means supplying a return force affecting said air sensor in opposition to the force exerted thereon by the flow of intake air, said means supplying said return force includes a control plunger operatively connected to said air sensor and cylinder means accommodating said control plunger and containing liquid under pressure exerting said return force on said control plunger, the improvement comprising

A. a pressure control valve hydraulically connected to said cylinder means for varying the pressure of said liquid in said cylinder means, said pressure control valve including a spring the bias of which affecting said pressure in said cylinder means,

B. a first temperature-responsive control element sensing the engine temperature and causing an increase in the bias of said spring as the engine temperature increases,

C. a second temperature-responsive control element opposing, when unheated, the operation of said first temperature-responsive control element, and

D. a separate heater means operatively coupled to said second temperature-responsive control element for heating the same causing discontinuance of its opposing effect on said first temperature-responsive control element.

2. An improvement as defined in claim **1**, including means to energize said separate heater means immediately after starting said engine.

3. An improvement as defined in claim **1**, said second temperature-responsive control element being formed as a bimetal spring being in engagement, when unheated, with said first-named spring and bending away therefrom when heated.

4. An improvement as defined in claim **1**, said pressure control valve being hydraulically connected to said cylinder means downstream thereof.

5. An improvement as defined in claim **1**, including

A. a bypass channel circumventing said butterfly valve and

B. means connected to said spring for varying the flow passage section of said bypass channel simultaneously with the variation of the bias of said spring.

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