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(54) Electronic fuel injection system for internal combustion engines.

(57) An electronic fuel injection system for internal combustion engines (1) is described.

The main characteristic of this sytem lies in the fact that it comprises first means (7) for supplying the said fuel to at least one injector (5) with a supply pressure which is variable with respect to the pressure in an injection manifold (2) in dependence on a predetermined law, and second means (60) for determining variable delivery times of the said injector (5).

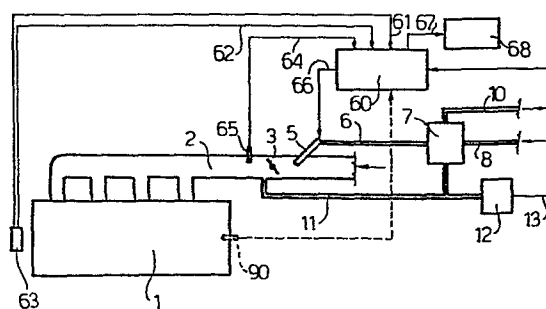


Fig.1

Electronic Fuel Injection System for Internal Combustion Engines

5 The present invention relates to an electronic fuel injection system for internal combustion engines, particularly of the type in which a single injector is used for supplying fuel to several cylinders of the engine. As is known, various synchronised electronic injection systems have been developed for supplying
10 fuel to internal combustion engines.

In the development of such systems various technical problems have been met and overcome, both in systems having a plurality of injectors, for example, one for each
15 cylinder, and in systems having a single injector for several cylinders. One problem which has arisen above all with these latter systems is that relating to the dynamics of the injector, conventionally of electro-magnetic type, which has to be able to satisfy
20 delivery requirements over the whole of the engine's range, conveniently up to 6000 revolutions per minute.

An injector of this type in fact has a delivery capacity which increases in a substantially linear manner as a
25 function of the time for which opening is controlled, but this correspondence is not always unambiguous (with consequent imprecision) for controlled times which are less than the time required for the injector to open, in that an interruption of the opening transient
30 takes place, or else if they are close to the repetition period (T_p) of operation of the injector, in this case the closing transient of the injector is in fact modified.

In these conditions the relationship between the delivery and the control time involves a significant uncertainty, consequently the range of control times usable at a given operating frequency ($F = \frac{1}{T_p}$) is
5 limited between values t_1 and t_2 to which the delivery rates $Q_{\min}$ and $Q_{\max}$ correspond.

It is to be noted that whilst t_1 is independent, in practice, of the operating frequency, being influenced
10 only by the transient opening characteristics of the injector, the value t_2 is determined by the value T_p less the time necessary to complete closure of the injector.

15 By dimensioning the injector in such a way as to have the delivery rate $Q_{\max}$ sufficient for all requirements of the engine for $T_p = 5$ ms (phase time of an engine rotating at 6000 revolutions per minute) the associated delivery rate $Q_{\min}$ defined in correspondence with the
20 time t_1 remains in general too high for strongly throttled conditions, for example, when idling.

The object of the present invention is therefore to overcome the above indicated disadvantages, obtaining
25 injectors having fuel delivery rates suitable for all operating conditions, which further provides the advantage of being able to utilise a single injector to supply several cylinders of the engine, thereby obtaining a reduction in costs of the system and in
30 maintenance.

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According to the present invention there is provided an electronic fuel injection system for internal combustion engines, characterised by the fact that it comprises first means for supplying said fuel to at least one injector with a supply pressure which is variable with respect to the pressure present in an induction manifold in dependence on a predetermined law, and second means for determining variable delivery times of the said injector.

For a better understanding of the present invention one embodiment thereof will now be described, by way of non-limitative example, with reference to the attached drawings in which:

Figure 1 is a block schematic diagram of the electronic injection system of the present invention;

Figures 2 and 3 are side views, partially in section, of two different embodiments of an element forming a component of the system of Figure 1; and

Figures 4 and 5 are explanatory diagrams relating to the system of the present invention.

With reference to Figure 1, several component elements will not be described in detail since these are already well known in the injection systems art both for single injectors and multiple injectors.

The reference numeral 1 indicates an internal combustion engine with four cylinders provided with an induction manifold 2 for these four cylinders. In the manifold 2 there is disposed a known butterfly valve 3 operated

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by the driver by means of the accelerator pedal. Upstream of the butterfly valve 3 there is disposed a known injector 5 of the electro-magnetic type which is a single injector for the several cylinders of the engine 1.

This injector 5 is supplied with fuel via a duct 6 which is connected to a pressure regulator device 7 for regulating the supply of pressure in the duct 6, and which receives fuel via a duct 8 from a supply pump (not illustrated). The fuel under pressure in excess of that sent to the duct 6 returns to the reservoir (not illustrated) by means of a duct 10.

Downstream of the butterfly valve 3, via a duct 11, the pressure in the injection manifold 2 is detected and sent to the device 7 and to a pressure sensor 12 which provides a corresponding electric output signal 13. The device 7 therefore regulates the pressure at which fuel is supplied to the ducts 6 in a manner which is variable in time, in dependence on a predetermined law, determined by the characteristics of the device 7 itself, with respect to the pressure in the induction manifold 2 which is detected by the duct 11.

Figure 2 illustrates an embodiment of the device 7 which is of substantially known structure already utilised in other systems. This device 7 includes a lower body 20 and an upper body 21 which are fixed together around a rim by means of a ring 22 folded over in such a way as to pinch the annular edge of a resilient membrane 23 which therefore defines an upper chamber 24 within the body 21 and a lower chamber 25

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within the body 20. The chamber 24 is in communication with the duct 11 via a connector tube 11'; the chamber 25 is in communication with the ducts 6 and 8 by connector tubes 6' and 8' respectively.

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In the centre of the membrane 23 there is fixed a body 28 the underside of which constitutes a seat for a plate valve 29 which cooperates with a communication orifice 30 with a connector tube 10' for the duct 10. In this plate valve 29 a helical spring 31 acts against the body 28. This body 28, on the other side of the membrane 23, carries a plate 32 against which a helical spring 33 engages, which spring at its other end engages a plate 35 which is positioned by means of an adjustment screw 36.

15

In Figure 3 there is shown a different embodiment of the device 7, which is provided with two resilient membranes 40 and 41 of different areas, which are pinched around their edges by an upper body 50 and an intermediate body 51, and by the intermediate body 51 and a lower body 52 respectively. The intermediate body 51 defines an intermediate chamber 42, whilst the upper body 50 and the lower body 52 respectively define an upper chamber 43 and a lower chamber 44. The various bodies 50, 51 and 52 are clamped by four bolts 55.

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The connector tube 11' communicates with the chamber 43, whilst the connector tubes 6' and 8' communicate with the chamber 44. On the membrane 40 there is centrally fixed a bolt 56 which at its top carries a

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5 plate 57 which carries a helical spring 58 the other end of which engages a plate 59 carried by an adjustable threaded stem 60 screwed into the body 50. On the lower end of the bolt 56 engages a plate valve 29 which closes the orifice communicating with the connector tube 10'.

10 With reference again to Figure 1, the electrical signal 13 comes from a central control unit 60 which includes a central processor unit (CPU), a read only memory (ROM), analogue-to-digital convertor units and timer units. This central control unit 60 also receives:
15 an electrical signal 61 and an electrical signal 62 from a unit 63 (of known type) which detects the number of rotations and the phase of the motor 1;
and an electrical signal 64 from a sensor 65 detecting the air temperature in the induction manifold 2.

20 The control unit 60 provides a signal 66 to the injector 5 for controlling its operation and a signal 67 to an ignition module 68 of known type, connected conveniently to the ignition coil.

25 The operation of the described electronic ignition system of the present invention is as follows.

30 The basis of the system in question is the consideration of the existence of a strict correlation between the pressure in the induction manifold 2 and the quantity of petrol necessary to reach the correct mixture strength in the combustion chamber. This

correlation depends on the air temperature and the speed of rotation of the engine, but is anyway a function which increases (normally) with the pressure in the manifold.

5

The pressure at which fuel is supplied to the injector 5 through the duct 6 is made to vary, by means of the pressure regulator device 7, in a linear manner with the pressure in the manifold 2 according to a relationship of the type

10

$$P_A = \alpha P_C + \beta \quad (1), \text{ where:}$$

P_A is the supply pressure in the duct 6

P_C is the pressure in the manifold 2 and in the duct 11;

15

α is a constant defined by the ratio between the areas of the diaphragms, is equal to 1 in the device of Figure 2 and is equal, for example, to 2 in the device of Figure 3

β is a constant defined by the characteristics of the device 7, principally by the spring 33 or 58.

20

With reference to the device of Figure 2, if the pressure in the induction manifold 2 increases the pressure in the chamber 24 increases and the useful section of the orifice 30, and therefore the return rate through the duct 10 falls so that the pressure in the supply duct 6 increases according to the relationship (1).

25

30

In a given operating condition the delivery rate of the injector 5 can be expressed, to a first approximation, as:

$$Q_1 = K \sqrt{P_A} = K \sqrt{\alpha P_C + \beta} \quad (2)$$

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where K is the fluid dynamic coefficient of the injector.

5 Considering that the ratio $\frac{Q_{\max}}{Q_{\min}}$ does not depend on the supply pressure and indicating the equivalent delivery time as t^P , we have that

$$t^P = \frac{Q}{Q_{\text{static}}} t_P \quad (3)$$

10 where Q_{static} is the delivery corresponding to the value t^P of the operating period of the injector, on the curve 70 which shows the delivery as a function of the control time (Figure 4) so that a permitted zone for the delivery is limited by the curves (Figure 5):

$$\begin{aligned} 15 \quad (a) \quad Q &= \gamma t_{\min}^P \sqrt{\alpha_{P_C} + \beta} \\ (b) \quad Q &= \gamma t_{\max}^P \sqrt{\alpha_{P_C} + \beta} \end{aligned}$$

20 By suitably dimensioning the values of the constants α , β and γ , which determine respective structural and calibration characteristics of the injector 5 and the pressure regulator 7, the permitted zone is positioned in such a manner as to include the required zone of the engine.

25 With reference to Figure 5, supposing for example that an injector has a winding of 200 turns and an opening and closure time of 0.8 m sec, it can be supposed that the injector is capable of providing a variation in delivery of from 1 to 3 (curve 72).

30 Now supposing that the motor requires a fuel supply variation per phase of from 1 to 5 when stationary (minimum consumption 0.7 l/h at 850 revolutions per

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minute, maximum consumption 25 l/h at 6000 revolutions per minute) and considering the maximum consumption at 6000 revolutions/minute (the most critical condition) we have a theoretical curve 73 and an observed curve 74. This is obtained, by positioning the curves (a) and (b) as illustrated as a function of the constants α , β and γ .

In the read only memory (ROM) of the central control unit 60 there is therefore tabulated a correspondence between input values of the signal 13 (pressure P_C in the induction manifold 2) and of the signal 61 (speed of rotation of the motor 1) which provides a binary number which determines the operating time t^P for the injector 5; this number is then corrected in a subsequent table in dependence on the signal 64 which detects the temperature of the air in the manifold 2 to provide the signal 66 adapted to the density variations of the air in the manifold 2 due to differing temperatures.

Conveniently the central control unit 60 can have programmes such as to vary the value of the signal 66 in different operating conditions, such as:

- (a) variation at idling to increase or diminish the delivery rate of fuel;
- (b) correction of acceleration;
- (c) correction to the starting (for example by detecting the value of the temperature of the water in the engine 1 by means of a sensor 90);
- (d) correction of a specific control instant of the injector 5;
- (e) deceleration correction;

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- (f) over-revolution correction;
- (g) correction of the ignition timing (signal 67).

5 With the electronic injection system of the present
invention the advantage is obtained of being able to
adapt the variation of the injector delivery, which
will be insufficient for the characteristics required
by the engine, to the requirements of the engine
itself, and this is obtained by the variation of the
10 supply pressure to the injector in dependence on a
predetermined law determined by the characteristics
of the pressure regulating device 7; this is also
obtained by the arrangement of the injector 5 up-
stream of the butterfly valve 3 and with the control
15 of the device 7 by means of the pressure in the
induction manifold 2 downstream of the butterfly valve
3.

20 Correspondingly the central control unit 60 determines
the operating time necessary for the injector 5 to
determine the required delivery rate, as a function
of the variability of the fuel supply pressure; the
signal 66 controlling the central control unit 60
is, in fact, determined by detection of the pressure
25 in the manifold 2.

Finally it is clear that the described and illustrated
embodiments of the electronic injection system of the
present invention can be modified and varied without
30 departing from the scope of the invention itself.

For example, the system can be applied to a plurality
of injectors to adapt their characteristics to required

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delivery variations, the strategies for correction of the signal 66 at the output of the control unit 60 can be varied, and the air temperature sensor 65 may not be present, etc.



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Claims:

1. An electronic fuel injection system for internal combustion engines (1), characterised by the fact
5 that it includes first means (7) for supplying the said fuel to at least one injector (5) at a supply pressure which is variable with respect to the pressure in an induction manifold (2) in dependence on a predetermined law of variation , and second
10 means (60) for determining variable delivery times of the said injector (5).
2. A system according to Claim 1, characterised by the fact that it includes a single injector (5) for
15 supplying fuel to a plurality of cylinders of the said engine (1).
3. A system according to Claim 2, characterised by the fact that the said injector (5) is disposed
20 up-stream of a butterfly valve (3) disposed in the said induction manifold (2) and controlled by the driver.
4. A system according to one of the preceding Claims,
25 characterised by the fact that the said first means include a device (7) for regulating the variable pressure at which the said fuel is supplied to the said injector (5), the said pressure regulator device being operable to detect the value of the pressure in the said
30 induction manifold (2) downstream of a butterfly valve (3), and controlling the value of the supply pressure to the said injector (5) according to the said pre-determined law of variation.

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5. A system according to Claim 4, characterised by the fact that the said pressure regulator device includes a device having two end chambers (24, 25); (43, 44), separated by at least one resilient membrane (23; 40, 41), the said two chambers being connected to receive, respectively, the pressure in the said induction manifold (2) and the supply pressure to the said injector (5), the said membrane acting on a member (29) restricting the flow of fuel towards a return duct (10) leading to a reservoir.

6. A system according to Claim 5, characterised by the fact that it includes a plurality (40, 41) of said resilient membranes, having different areas and delimiting intermediate chambers (42) and disposed between the said two end chambers (43, 44).

7. A system according to one of the preceding Claims, characterised by the fact that the said second means (60) include a sensor (12) sensitive to the pressure in the said induction manifold (2), a central control unit (60) receiving at least a first signal (13) from the said pressure sensor (12) and a second signal (61) from a sensor (63) sensitive to the speed of rotation of the said motor (1), the said central control unit (60) providing a control signal (66) for controlling the variable delivery times of the said injector (5).

8. A system according to Claim 7, characterised by the fact that the said central control unit (60) includes a processor unit including at least a read only memory (ROM) to provide, according to a table of predetermined correspondences, the said values of

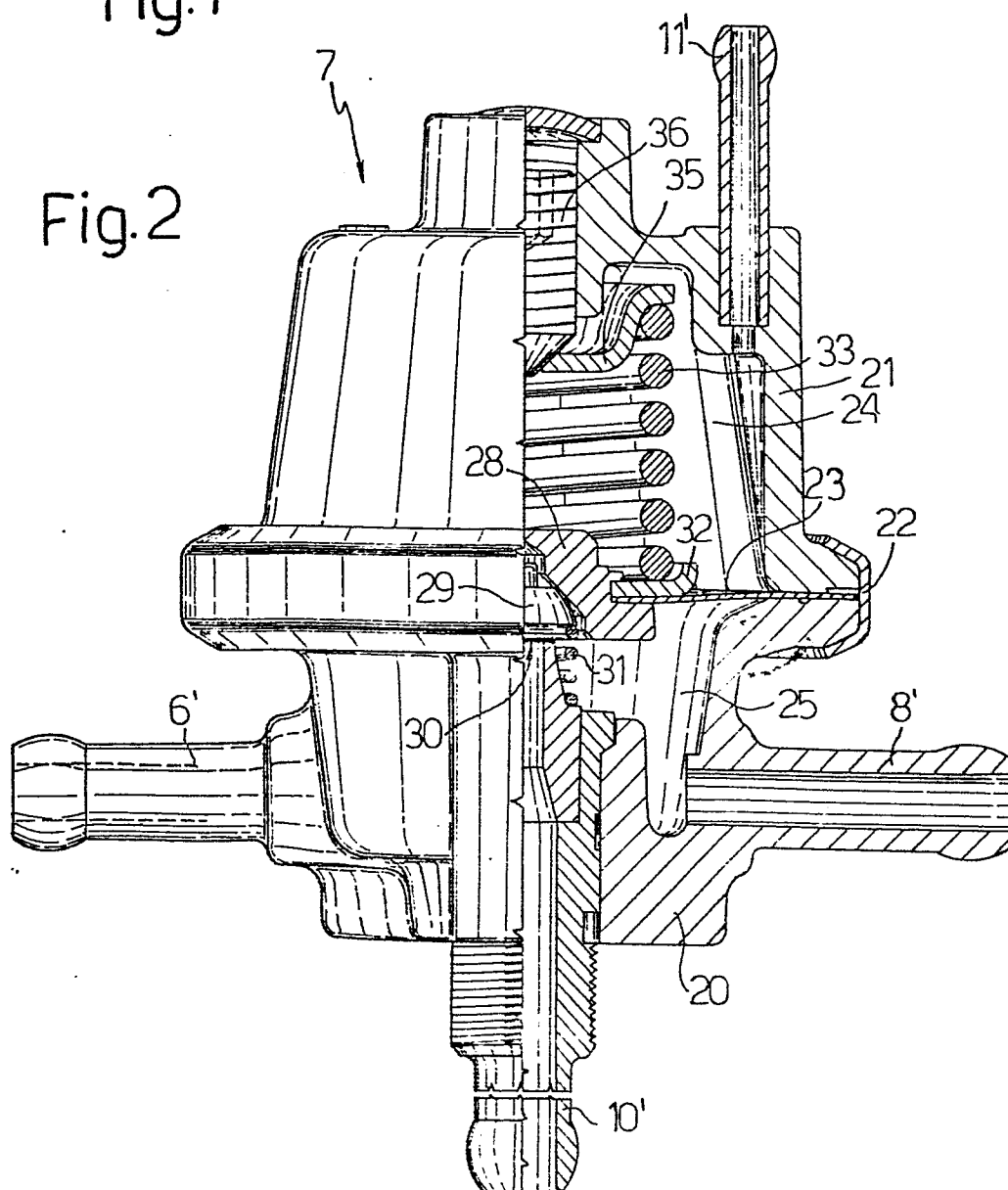
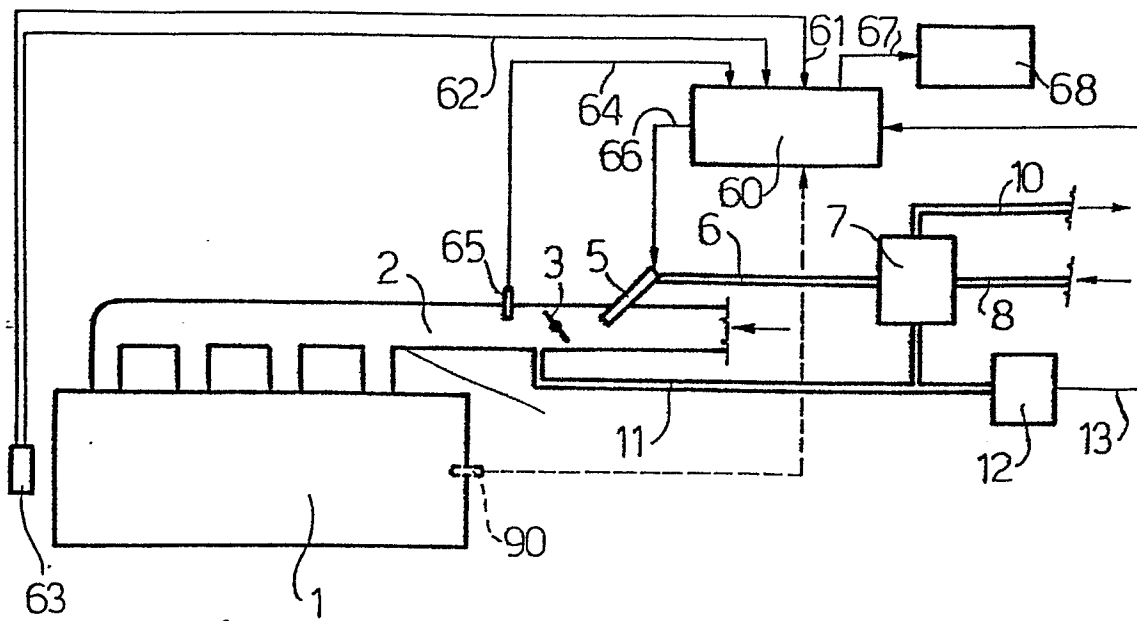
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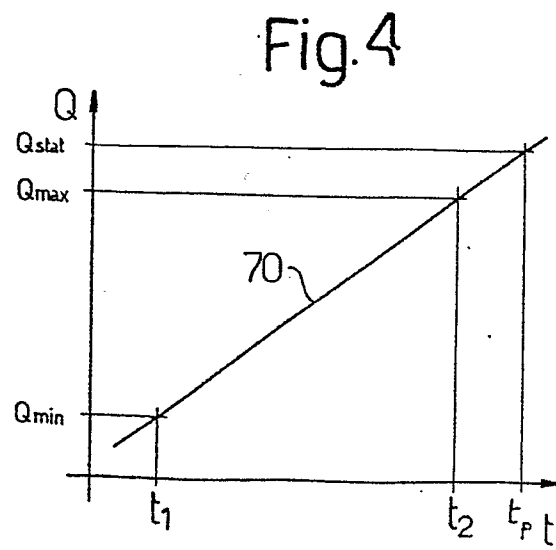
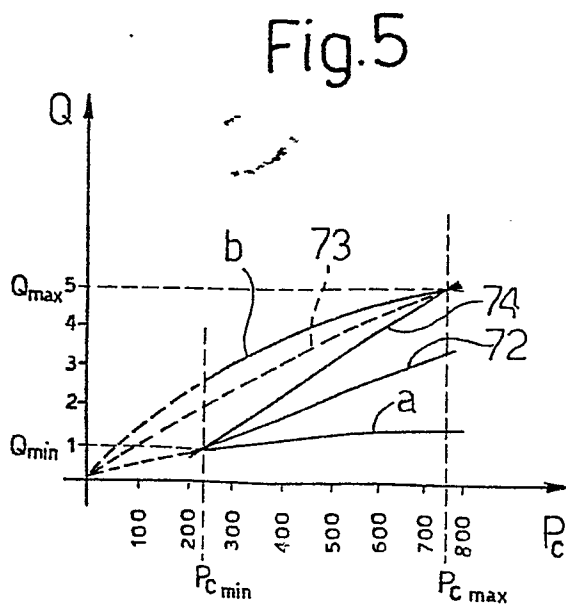
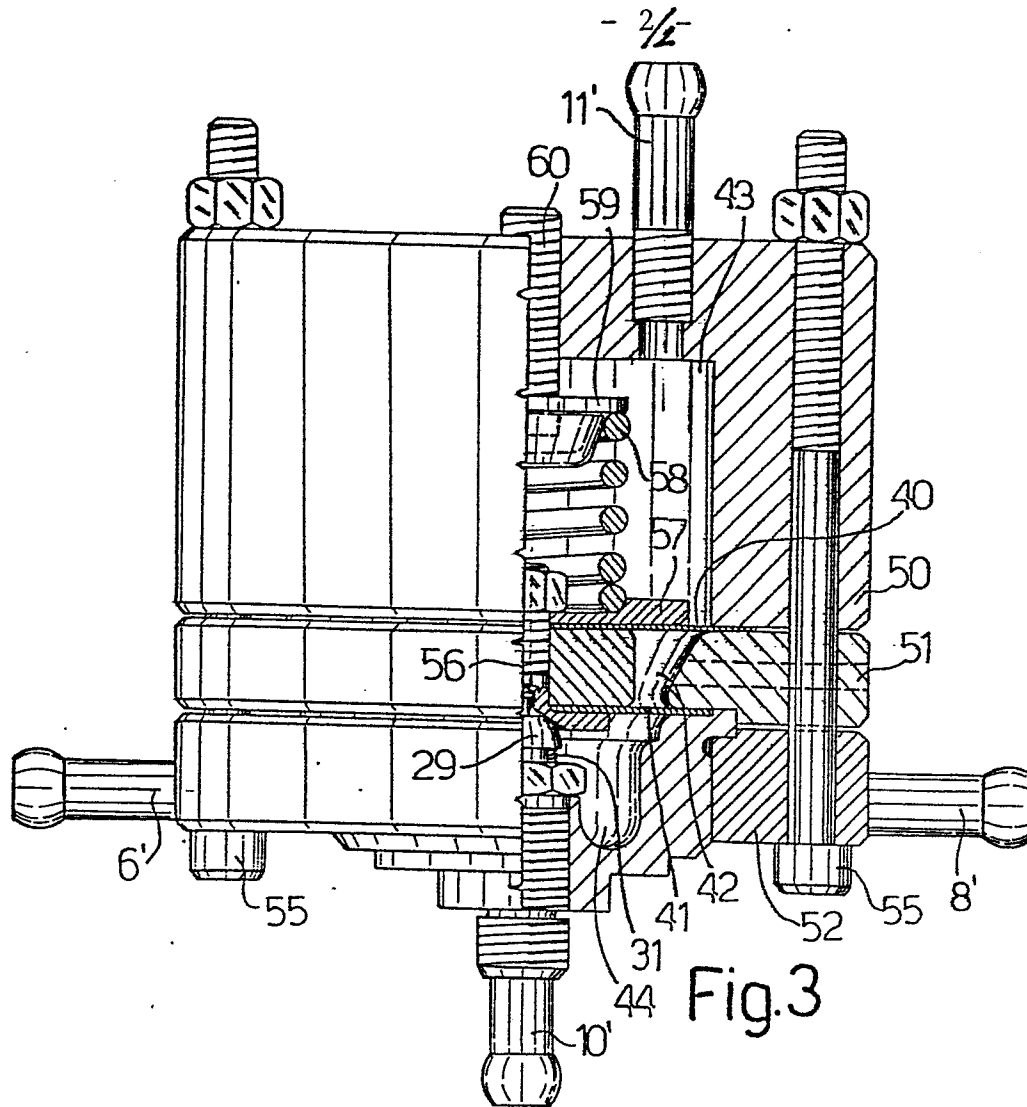
the said variable delivery times as a function of the said values of the said first and second signal.

5 9. A system according to Claim 8, characterised by the fact that the said central control unit (60) further receives a third signal (62) from a sensor (63) sensitive to the phase of the said engine (1).

10 10. A system according to Claim 9, characterised by the fact that the said central control unit (60) also receives a fourth signal (64) from a sensor (65) sensitive to the temperature of the air in the said induction manifold (2), and a fifth signal from a
15 sensor (90) sensitive to the temperature of the cooling water of the engine (1).


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EUROPEAN SEARCH REPORT

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Application number

EP 83 10 8744

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
X	US-A-4 292 945 (KIESLING) * Column 4, line 46 - column 5, line 43; figures 1,2 *	1	F 02 M 69/00 F 02 M 51/02
A	GB-A-1 115 562 (HUBER) * Page 2, lines 18-102; figures 1,3 *	1,2,7	
A	GB-A-2 059 503 (NIPPONDENSO) * Page 1, line 84 - page 2, line 49; figure 1 *	1,2,7	
X	FR-A-2 051 385 (PETROL INJECTION) * Page 3, line 24 - page 16, line 20; figures 1A,1B *	1,2	
X	DE-A-2 928 454 (MITSUBISHI) * Page 11, line 6 - page 17, line 10; figure 1 *	1,4,5,7,8,9,10	TECHNICAL FIELDS SEARCHED (Int. Cl. ³) F 02 M
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 08-12-1983	Examiner SCHMID R.
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