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⑤④ **Fuel injection control method for internal combustion engines.**

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Description

The present invention relates to a fuel injection method for internal combustion engines according to the preamble of claim 1. Such a control method is known from the EP—A—106 366.

5 The Japanese Laid Open Publication No. 5841/1984 discloses a conventional acceleration adjustment in fuel injection devices of the internal combustion engine for automobiles wherein an incremental valve opening pulse for a fuel increment is generated independently of the basic valve opening pulse for causing the injectors to inject fuel normally during the normal condition. The pulse width of the incremental valve opening pulse is determined in dependence on the water temperature of an internal combustion engine.

10 However, this known acceleration adjustment in fuel injection devices has not provided fine adjustment of incremental valve opening pulse depending on the state of a running engine excepting the water temperature.

The above electronic fuel injector (MPI system) employs a vane air flow meter. Therefore, it can not abruptly increase the rate of air intake into an engine during acceleration. From this reason, a relatively rich mixture is supplied at the beginning of acceleration.

15 However, because an inherent delay exists in air intake into the engine, it has been impossible to achieve abrupt acceleration. On the rapid acceleration from idling to the fully open state under no load, the speeded up revolution time (T_0) is about 200 ms (confer Fig. 4).

Besides, a hot wire air flow meter employed in the EP—A—106 366 requires fine adjustment during acceleration, because it includes no member interrupting air intake as seen in the vane type air flow meter; hence, it causes an instantaneous flow of air into the engine.

The hot wire air flow meter which detects the volume of air is advantageous in that it allows air to be supplied to the engine more rapidly during acceleration because it has no throttle component. It does, however, have the problem of delayed fuel feed, that is, a lag in response time. This delay in fuel feed response time requires fine adjustment based on acceleration and other parameters.

25 The EP—A—106 366 describes a fuel injection control system for internal combustion engines wherein a basic fuel injector valve opening pulse is generated taking into account engine parameters. A hot-wire air-flow meter is present. An additional fuel amount is calculated in dependence on a magnitude of acceleration of the engine. The throttle-opening is fetched by interruption at 10 ms intervals. The difference of the throttle position is used to define engine acceleration and its magnitude. The additional fuel amount is injected at intervals of 10 ms after the basic injection pulse so that the additional injection pulses are generated in synchronism with the basic injection pulse.

According to Fig. 19 and claim 2 of the EP—A—106 366 additional acceleration fuel increments are (alternatively) calculated taking into account the position of the idle-switch during preacceleration condition.

35 According to the US—A—4 363 307 (especially Fig. 5, e.g. step 254) synchronous acceleration fuel injection pulses depending on the normal injection pulses are determined on the basis of the normalized variation of the intake-air flow during a predetermined time on the basis of a formula

$$40 \quad \frac{Q_{\text{new}} - Q_{\text{old}}}{Q_{\text{new}}} > K_1.$$

The object of the present invention is to provide a fuel injection control method for internal combustion engines wherein the pulse duration of an incremental fuel injection pulse can be determined in dependence on the state of a running engine excepting the water temperature and delayed fuel feed can be adjusted, acceleration matching between the state after deceleration and the state after normal operation becomes possible, speed up revolution time of acceleration from idling to the fully open state under no load can be shortened, and inadequate acceleration during rapid acceleration which is to be effected after fuel reduction for deceleration can be improved.

50 The above object is solved by the features of claim 1.

The claims 2 to 5 characterize advantageous developments thereof.

By applying the judgement of conditions for adjustment after fuel reduction for deceleration, it has become possible to match acceleration between the state after deceleration and the state after normal operation.

55 Brief description of the drawings:

Fig. 1 is a schematic diagram of an engine system embodying the present invention.

Fig. 2 is a block diagram of a relationship between input and output in the system of Fig. 1.

Fig. 3 is a graphical illustration of engine injection timing.

60 Fig. 4 is an explanatory graph of experimental results of respective speed up revolution times according to both the present invention and the prior art.

Fig. 5 is a flow chart for depicting the acceleration adjusting method of the present invention.

Detailed Description of the Preferred Embodiments

65 One embodiment of the present invention will be described (in the description ΔQ_a is used as an

abbreviation of the normalized value $\Delta Q_a/Q_a$). Fig. 1 shows an engine system to which the present invention is applied. An engine 1 has intake pipes 2 which are provided with the fuel injection valves (injectors) 3 corresponding to the number of cylinders. These intake pipes 2 are brought into a single pipe at a collector 4 in the upstream side, and having a throttle valve 5 for determining the amount of intake for the engine further upstream.

An amount of intake for the engine 1 is measured by a hot wire air flow meter 6 provided still further upstream with engine rotational speed or revolutions being counted by a rotational speed sensor 13. In addition to the above, a control unit CU 12 also receives a signal 11 from engine temperature detector, an exhaust gas signal from an oxygen concentration measuring sensor 10, and a signal from an idle switch 14, etc.

Fuel is supplied to the engine 1 by opening a valve on each fuel injector 3, and the amount of fuel is measured based on valve opening time. Fuel is pressurized and regulated by a fuel pump 8 and a regulator 9.

Fig. 2 is a block diagram showing the relationship between input and output depicted in Fig. 1. With respect to the control unit CU, the left side includes sensors and the right side includes actuators.

In the control unit 12, as shown in Fig. 2 wave shaping circuits and AD-converters are arranged on the left side, an I/O LSI section for implementing therein exchange of input/output and arithmetic processing and a CPU for giving instructions to the I/O LSI section are at the center, and a circuit for driving the output actuators on the right side.

Next, injection timing, for example in a 4-cylinder, 4-cycle engine, will be measured with reference to Fig. 3. In the 4-cylinder, 4-cycle engine, fuel is usually injected one per revolution, i.e., at the timing of A and C, for all four cylinders.

The sections A and C are respectively the basic valve opening pulses for causing the injector to inject fuel normally during the normal condition.

The incremental fuel injection pulse described in the present invention is an additional fuel injection pulse shown in the section of B which is generated immediately upon detection of acceleration, so as to inject fuel at that time.

In the present invention, acceleration may be detected based on, for example, an ON $\rightarrow$ OFF signal of the idle switch 14 or a closing signal of the idle switch 14 indicating that a throttle valve 5 has been opened from an idle state, and the rate of variation ΔQ_a of the air intake volume Q_a per unit time. The magnitude of acceleration can be detected based on the normalized value $\Delta Q_a/Q_a$ of the rate of variation of the air intake volume Q_a during a predetermined time (Δt).

Table 1 shows an example of setting the incremental fuel injection pulse for a running vehicle in response to the magnitude of acceleration.

Table 1

Condition before Acceleration	Magnitude of Acceleration	Incremental fuel injection pulse duration	
		After idling	ΔQ_a
Fuel Cutdown for Deceleration	$5\% < \Delta Q_a < 37.5\%$ (Under Light Load)	9 ms	3 ms
	$\Delta Q_a > 37.5$	9 ms	9 ms (max. 4 times)
Normal (Idle Sw. Off)	$5\% < \Delta Q_a < 10\%$ (Under Light Load)	-	3 ms
	$\Delta Q_a > 10\%$	-	6 ms
Normal (Idle Sw. On)	$5\% < \Delta Q_a < 10\%$ (Under Light Load)	3 ms	3 ms
	$\Delta Q_a > 10\%$	3 ms	6 ms

By way of example, the process after acceleration is divided depending on the condition before acceleration. More specifically, after reducing fuel feed during deceleration, a large amount of fuel must be supplied to compensate for drying-up in the intake system during fuel reduction. Also after the normal condition, adjusting acceleration requires changes to correspond to the fully closed state of the throttle valve and other states thereof.

Further, acceleration is detected as a combination of the rate of variation ΔQ_a in the air intake volume per unit time and the idle switch setting. In Table 1, the legend "after idling" indicates an incremental fuel injection pulse based on detection of acceleration using the idle switch.

The reason for detecting acceleration based on both the idle switch and the rate of variation ΔQ_a in the air intake volume per unit time is in that detection with the idle switch always occurs earlier than detection with the rate of variation ΔQ_a in the air intake volume per unit time. Experiments have shown that this is attributable to a delay in the intake system accompanying detection of the rate of variation ΔQ_a in the air intake volume per unit time. Though this delay is relatively short, it is still longer than that accompanying the opening of the throttle valve.

Description will now be made by referring to typical examples of the respective cases. The incremental fuel injection pulse based on the rate of variation ΔQ_a in the air intake volume per unit time after fuel cutdown for deceleration will be described.

First, after fuel reduction for deceleration, the process is divided into slow acceleration (under light load, $5\% < \Delta Q_a < 37.5\%$) and rapid acceleration ($\Delta Q_a \geq 37.5\%$). For slow acceleration, an incremental pulse width of 3 ms is generated; for rapid acceleration, an incremental pulse width of 9 ms is generated, (one for each detected acceleration rate).

The pulse widths of the above incremental fuel injection pulses are set preferably to have about 1.5~5 ms duration for slow acceleration and to have about 6~12 ms duration for rapid acceleration, respectively.

An incremental fuel injection pulse based on the idle switch is set to have, by way of example, a relatively long duration of 9 ms. The width of the above incremental fuel injection pulse after idling is set preferably to have about 6~12 ms duration.

An incremental fuel injection pulse based on the rate of variation ΔQ_a in the air take volume per unit time in normal condition is set to have 3 ms duration for slow acceleration ($5\% < \Delta Q_a < 10\%$) and is set to have a 6 ms duration for rapid acceleration ($\Delta Q_a \geq 10\%$) respectively, and the fuel is injected. The widths of these incremental fuel injection pulses are set preferably to have about 1.5~5 ms duration for slow acceleration and to have above 4~8 ms duration for rapid acceleration, respectively.

After the normal condition the idle switch is turned on, because the intake pipe does not dry as much as before, an incremental fuel injection pulse based on the idle switch may be set to a shorter duration, e.g., 3 ms, than that during deceleration. The width of this incremental fuel injection pulse is set preferably to have 1.5~5 ms duration.

Moreover, in acceleration from the state where the idle switch is turned off, i.e., the throttle valve is in an open state, better conditions exist in comparison with acceleration from a closed state of the throttle valve, in that the mixture in the intake pipe is more uniform, whereby acceleration adjustment based on the idle switch is not required.

Fig. 4 shows the experimental results obtained from application of the above-mentioned adjustment. The graph of Fig. 4 represents an example of rapid acceleration from idling to the fully open state under no load. It is evident from Fig. 4 that, as a result of adjusting the duration of the incremental fuel injection pulses during acceleration, revolution time is speeded up from T_0 of about 200 ms in the prior art to T of about 120 ms in the present invention.

Fig. 5 shows a flow chart sheet for realizing the adjustment described in connection with Table 1. First, in acceleration after the normal condition, the process flow passes the right-hand loop. When the rate of variation of the air take volume per unit time (ΔQ_a) is smaller than A_1 , no incremental fuel injection pulse is generated; when ΔQ_a is greater than A_1 , an incremental fuel injection pulse TA_1 is issued. Note that, although inherently a decision must be made based on the inequality of $A_1' > \Delta Q_a > A_1''$ so that the incremental fuel injection pulse may be divided into pulses TA_1' (of 6 ms in Table 1) and TA_1'' (of 3 ms in Table 1), this process has been omitted from the flow chart in all the following associated flow.

Next, in the central loop representing acceleration from idling, an incremental fuel injection pulse TA_2 (3 ms) due to the condition after idling is set and thereafter an incremental fuel injection pulse TA_3 , also herein inherently divided into two types of pulses TA_3' , 3 ms in Table 1, and TA_3'' , 6 ms in Table 1 — is set based on ΔQ_a .

The left-hand loop represents acceleration from the decelerated state. In this case, an incremental fuel injection pulse TA_4 (9 ms) is issued due to the state after idling and acceleration is then determined on the basis of ΔQ_a . If $A_5 > \Delta Q_a > A_6$, an incremental fuel injection pulse TA_6 (3 ms) is issued and adjustment is completed therewith.

In all these adjustments the incremental fuel injection pulse based on ΔQ_a is generated only once for each acceleration; therefore, tests on a running engine have revealed the problem of inadequate acceleration during rapid acceleration which is to be effected after fuel reduction for deceleration.

The present invention is to overcome this problem. Namely, when $\Delta Q_a > A_5$, an incremental fuel injection pulse TA_5 is set. The fact that the pulse TA_5 has been issued is stored in memory, thus making it possible to repeat the adjustment with the incremental fuel injection pulse TA_5 based on $\Delta Q_a > A_5$ only on the above condition.

Claims

1. A fuel injection control method for internal combustion engines, including the steps of:

— controlling the valve opening time of the fuel injector valve(s) (3) in accordance with a prestored control program based on various engine operational parameters including the intake-air volume (Q_a), the rotational speed and the temperature of the engine (1);

- measuring the intake-air volume (Q_a) by means of a hot-wire air-flow meter (6);
- generating an on- and an off-position signal of an idle switch (14) detecting the closed state of the throttle valve (5);
- detecting the state of acceleration in dependence of the throttle closed position signal;
- 5 — detecting the magnitude of acceleration on the basis of the measured intake-air volume (Q_a);
- generating a basic valve opening pulse for normal fuel injection during normal engine operation;
- and
- generating an incremental valve opening pulse for incremental fuel injection on the basis of the magnitude of acceleration, characterized in that
- 10 — the incremental valve opening pulses are generated independently of the basic valve opening pulses and start an additional fuel injection asynchronous from the basic fuel injection and are generated immediately upon detection of an acceleration state;
- the incremental valve opening pulses are generated dependent on the following preacceleration operational conditions of the engine:
- 15 a) fuel-cut for deceleration, or
- b) the off-position of the idle switch (14) under normal operating conditions, or
- c) the on-position of the idle switch (14) under idling conditions;
- and on the magnitude of acceleration of the engine; and
- the magnitude of acceleration of the engine is determined on the basis of the normalized variation
- 20 $\Delta Q_a/Q_a$ of the intake air volume (Q_a) during a predetermined time Δt .
- 2. The fuel injection control method according to claim 1, characterized in that the values of the pulse width of the incremental valve opening pulses are in the cases a) and c) at first set at predetermined values upon generation of the throttle-closed position signal and afterwards respectively determined according to the normalized variation $\Delta Q_a/Q_a$ of the intake-air volume.
- 25 3. The fuel injection control method according to claim 1 or 2, characterized in that the values of the pulse width of the incremental valve opening pulses in case b) are only determined according to the normalized variation $\Delta Q_a/Q_a$ of the intake-air volume.
- 4. The fuel injection control method according to one of claims 1 to 3, characterized in that the width of said incremental valve opening pulses which are determined by the normalized variation $\Delta Q_a/Q_a$ of the
- 30 intake-air volume is made shorter at slow acceleration conditions and made longer at rapid acceleration conditions.
- 5. The fuel injection control method according to one of claims 1 to 4, characterized in that the incremental fuel injection pulse the pulse width of which is determined on the basis of the normalized variation $\Delta Q_a/Q_a$ of the air-intake volume is generated only once for each acceleration.

35 Patentansprüche

1. Verfahren zur Steuerung der Kraftstoffeinspritzung für Brennkraftmaschinen, umfassend die Schritte:
- 40 — Regeln der Ventilöffnungszeit des (der) Einspritzventils (-ventile) (3) nach Maßgabe eines vorher gespeicherten Steuerprogramms auf der Basis verschiedener Motor-Betriebsparameter wie Saugluftvolumen (Q_a), Drehzahl und Temperatur des Motors (1);
- Erfassen des Saugluftvolumens (Q_a) mit einem Hitzdraht-Luftdurchflußmengenmesser (6);
- Erzeugen eines Ein- und Aus-Stellungssignals eines Leerlaufschalters (14), der den Schließzustand
- 45 der Drosselklappe (5) erfaßt;
- Erfassen des Beschleunigungszustands in Abhängigkeit vom Drosselklappenschließstellungs-Signal;
- Erfassen des Beschleunigungsbetrags auf der Basis des erfaßten Saugluftvolumens (Q_a);
- Erzeugen eines Ventilöffnungs-Grundimpulses für normale Kraftstoffeinspritzung während des
- 50 normalen Motorbetriebs; und
- Erzeugen eines Ventilöffnungs-Inkrementimpulses für inkrementelle Kraftstoffeinspritzung auf der Basis des Beschleunigungsbetrags, dadurch gekennzeichnet; daß
- die Ventilöffnungs-Inkrementimpulse unabhängig von den Ventilöffnungs-Grundimpulsen erzeugt werden und eine gegenüber der Grund-Kraftstoffeinspritzung asynchrone zusätzliche Kraftstoff-
- 55 einspritzung starten und unmittelbar nach Erfassung eines Beschleunigungszustands erzeugt werden;
- die Ventilöffnungs-Inkrementimpulse in Abhängigkeit von den folgenden Vorbeschleunigungs-Betriebsbedingungen des Motors:
- a) Kraftstoffverringerung für Verzögerung oder
- b) die Aus-Stellung des Leerlaufschalters (14) unter normalen Betriebsbedingungen oder
- 60 c) die Ein-Stellung des Leerlaufschalters (14) unter Leerlaufbedingungen;
- und dem Betrag der Motorbeschleunigung erzeugt werden; und
- der Betrag der Motorbeschleunigung bestimmt wird auf der Grundlage der normalisierten Änderung $\Delta Q_a/Q_a$ des Saugluftvolumens (Q_a) während einer vorbestimmten Zeit Δt .
2. Verfahren zur Steuerung der Kraftstoffeinspritzung nach Anspruch 1, dadurch gekennzeichnet, daß
- 65 die Werte der Impulsbreiten der Ventilöffnungs-Inkrementimpulse in den Fällen (a) und (c) zuerst auf

vorbestimmte Werte bei Erzeugung des Drosselklappenschließstellungs-Signals eingestellt und danach jeweils nach Maßgabe der normalisierten Änderung $\Delta Q_a/Q_a$ des Saugluftvolumens bestimmt werden.

3. Verfahren zur Steuerung der Kraftstoffeinspritzung nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß die Werte der Impulsbreiten der Ventilöffnungs-Inkrementimpulse im Fall (b) nur nach Maßgabe der normalisierten Änderung $\Delta Q_a/Q_a$ des Saugluftvolumens bestimmt werden.

4. Verfahren zur Steuerung der Kraftstoffeinspritzung nach einem der Ansprüche 1—3, dadurch gekennzeichnet, daß die Breite der Ventilöffnungs-Inkrementimpulse, die durch die normalisierte Änderung $\Delta Q_a/Q_a$ des Saugluftvolumens bestimmt wird, bei Langsambeschleunigungs-Bedingungen geringer und bei Schnellbeschleunigungs-Bedingungen größer gemacht wird.

5. Verfahren zur Steuerung der Kraftstoffeinspritzung nach einem der Ansprüche 1—4, dadurch gekennzeichnet, daß der Kraftstoffeinspritz-Inkrementimpuls, dessen Breite auf der Basis der normalisierten Änderung $\Delta Q_a/Q_a$ des Saugluftvolumens bestimmt wird, nur einmal für jede Beschleunigung erzeugt wird.

Revendications

1. Procédé de commande de l'injection de carburant, pour des moteurs à combustion interne, incluant les étapes consistant à:

— commander la durée d'ouverture de la ou des soupapes d'injection de carburant (3) conformément à un programme de commande préalablement mémorisé, basé sur différents paramètres de fonctionnement du moteur incluant le volume d'air d'admission (Q_a), la vitesse de rotation et la température du moteur (1);

— mesurer le volume d'air d'admission (Q_a) au moyen d'un débitmètre d'air à fil chaud (6);

— produire un signal de position fermée et de position ouverte d'un interrupteur de ralenti (14) détectant l'état fermé du papillon des gaz (5);

— détecter l'état d'accélération en fonction du signal de position fermée du papillon des gaz;

— détecter l'amplitude de l'accélération sur la base du volume d'air d'admission mesuré (Q_a);

— produire une impulsion de base d'ouverture des soupapes pour l'injection normale de carburant pendant le fonctionnement normal du moteur; et

— produire une impulsion incrémentale d'ouverture des soupapes pour une injection incrémentale de carburant sur la base de l'amplitude de l'accélération, caractérisé en ce que

— les impulsions incrémentales d'ouverture des soupapes sont produites indépendamment des impulsions de base d'ouverture des soupapes et déclenchent une injection additionnelle de carburant d'une manière asynchrone par rapport à l'injection de base du carburant et sont produites immédiatement

lors de la détection d'un état d'accélération;

— les impulsions incrémentales d'ouverture des soupapes sont produites en fonction des conditions suivantes de fonctionnement en pré-accélération du moteur:

a) coupure d'envoi du carburant pour la décélération, ou

b) la position d'ouverture de l'interrupteur de ralenti (14) dans les conditions normales de fonctionnement, ou

c) la position de fermeture de l'interrupteur de ralenti (14) dans des conditions de ralenti;

et en fonction de l'amplitude de l'accélération du moteur; et

— l'amplitude de l'accélération du moteur est déterminée sur la base de la variation normalisée $\Delta Q_a/Q_a$ du volume d'air d'admission (Q_a) pendant un intervalle de temps Δt prédéterminé.

2. Procédé de commande d'injection de carburant selon la revendication 1, caractérisé en ce que les valeurs de la durée des impulsions incrémentales d'ouverture des soupapes sont, dans les cas a) et c), réglées tout d'abord à des valeurs déterminées lors de la production du signal de position fermée du papillon des gaz et ensuite sont déterminées respectivement en fonction de la variation normalisée $\Delta Q_a/Q_a$ du volume d'air d'admission.

3. Procédé de commande d'injection de carburant selon la revendication 1 ou 2, caractérisé en ce que les valeurs de la durée des impulsions incrémentales d'ouverture des soupapes dans le cas b) sont déterminées uniquement en fonction de la variation normalisée $\Delta Q_a/Q_a$ du volume d'air d'admission.

4. Procédé de commande d'injection de carburant selon l'une des revendications 1 à 3, caractérisé en ce que la durée desdites impulsions incrémentales d'ouverture des soupapes, qui sont déterminées par la variation normalisée $\Delta Q_a/Q_a$ du volume d'air d'admission, est réglée à une valeur plus faible dans des conditions de faible accélération et est réglée à une valeur plus longue dans des conditions de forte accélération.

5. Procédé de commande d'injection de carburant selon l'une des revendications 1 à 4, caractérisé en ce que l'impulsion incrémentale d'injection de carburant, dont la durée est déterminée sur la base de la variation normalisée $\Delta Q_a/Q_a$ du volume d'air d'admission, est produite uniquement une fois lors de chaque accélération.

— produire une impulsion incrémentale d'ouverture des soupapes pour une injection incrémentale de carburant sur la base de l'amplitude de l'accélération, caractérisé en ce que

FIG. 1

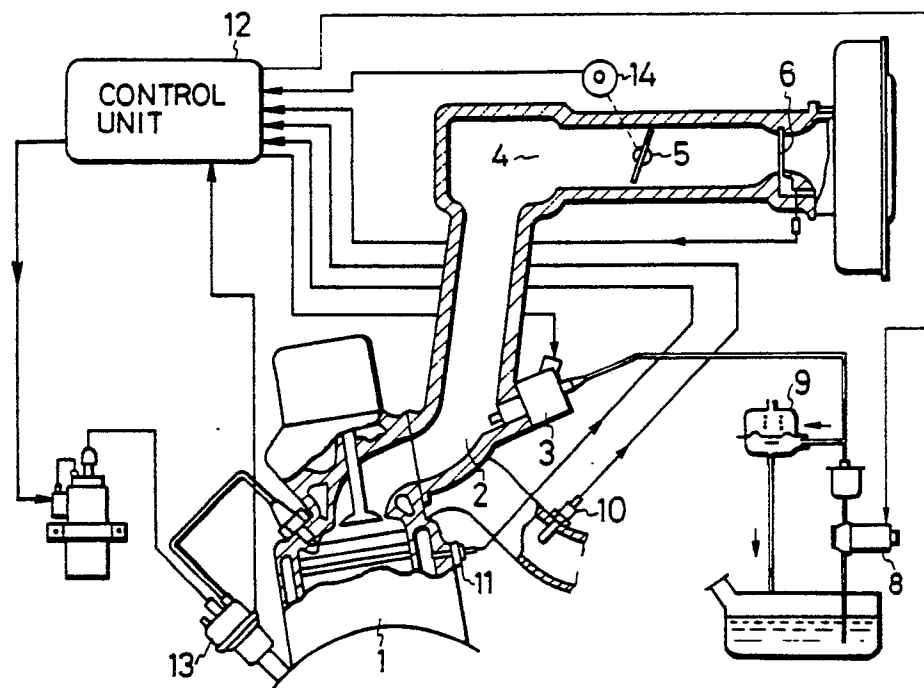


FIG. 2

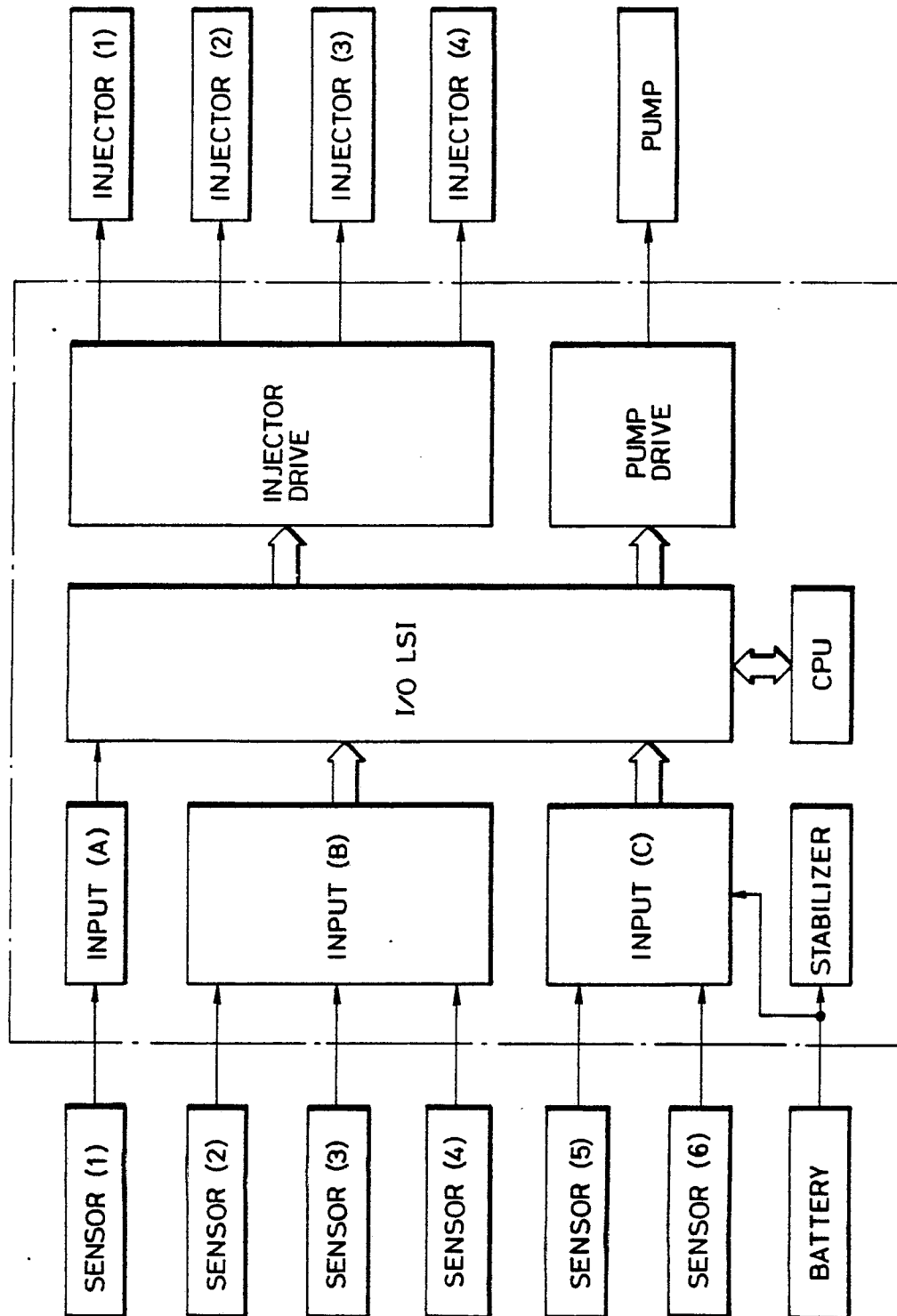


FIG. 3

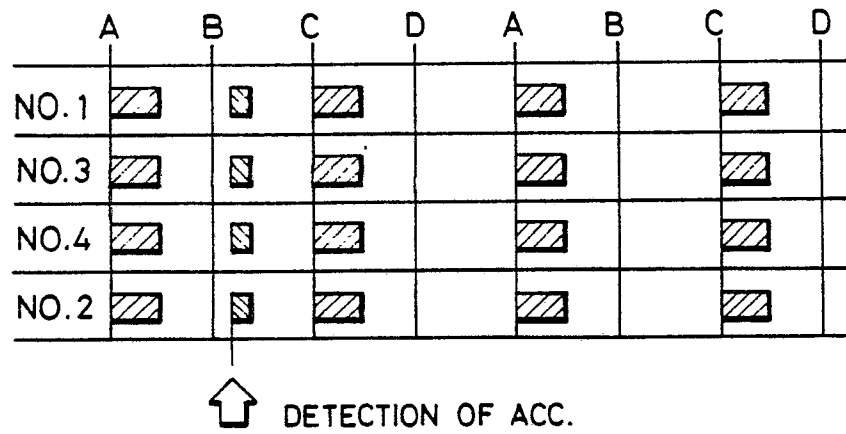


FIG. 4

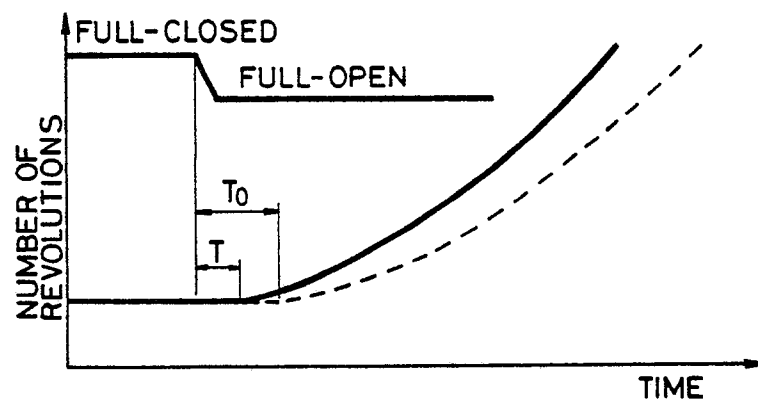


FIG. 5

