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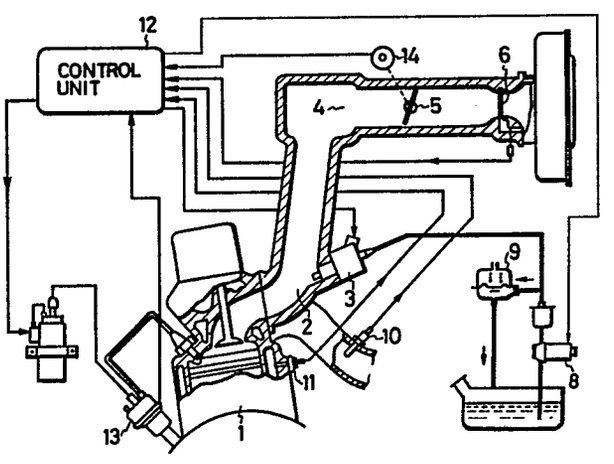
(54) Fuel injection controlling method for an internal combustion engine.

(57) In a fuel injection control method for internal combustion engines having a hot wire air flow meter (6) and a valve opening pulse for fuel increment is generated independent of a basic valve opening pulse which causes the injector (3) to inject fuel normally during the normal condition, the duration of the valve opening pulse for fuel increment is controlled dependent on at least one of parameters selected from variations in the air intake volume per unit time, a closing signal of the idle switch for the throttle valve, a signal indicating the number of revolutions of the engine etc., and independent of the duration of the basic valve opening pulse. The acceleration is determined by adjusting the fuel increment in accordance with the valve opening pulse for fuel increment. It is possible to obtain optimum acceleration by varying the adjustment depending on conditions for interrupt adjustment during acceleration. By applying the judgment of conditions for adjustment after fuel reduction for deceleration, it has become possible to acceleration matching between the state after deceleration and the state after normal operation.



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Specification

Title of the Invention:

Fuel Injection Controlling Method for An Internal Combustion Engine

Background of the Invention:

The present invention relates to a fuel injection controlling method for an internal combustion engine, and more particularly to a fuel injection controlling method for an internal combustion engine for automobiles using a hot wire air flow meter wherein the rate of fuel injection can be adjusted during acceleration.

Conventional acceleration adjustment in fuel injection devices of the internal combustion engine for automobiles has been provided the valve opening pulse generating means for the fuel increment independently of the basic valve opening pulse for causing the injectors to inject fuel normally during the normal condition, and the valve opening pulse for the fuel increment is determined the duration dependent on the water temperature of the internal combustion engine. (Japanese Patent Laid Open Publication No. 5841/1984).

However, the above acceleration adjustment in fuel injection devices has not provided fine adjustment of the

fuel increment 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.

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 (To) is about 200 ms (confer Fig. 4).

Besides, a hot wire air flow meter employed in the air flow meter 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.

Summary of the Invention:

An object of the present invention is to provide a fuel injection controlling method for an internal combustion engine wherein optimal acceleration characteristics can be obtained.

Another object of the present invention is to provide a fuel injection controlling method for an internal combustion engine wherein fuel increment depending on the state of a running engine excepting the water temperature can be adjusted.

Another object of the present invention is to provide a fuel injection controlling method for an internal combustion engine wherein delayed fuel feed can be adjusted.

Another object of the present invention is to provide a fuel injection controlling method for an internal combustion engine wherein acceleration matching between the state after deceleration and the state after normal becomes possible.

Another object of the present invention is to provide a fuel injection controlling method for an internal combustion engine wherein speed up revolution time of acceleration from idling to the fully open state under no load can be shortened.

Another object of the present invention is to provide a fuel injection controlling method for an internal combus-

tion engine wherein inadequate acceleration during rapid acceleration which is to be effected after fuel reduction for deceleration can be improved.

The present invention is to provide a fuel injection control method for internal combustion engines including the steps of: controlling the opening time of fuel injector in accordance with the control content previously programmed based on various operational parameters including air intake volume, the number of revolutions and temperature of the engine; measuring the air intake volume by a hot wire air flow meter; generating a signal of an idle switch for detecting a closed state of a throttle valve adapted to control the intake air amount; and generating a valve opening pulse for fuel increment independent of a basic valve opening pulse which causes the injector to inject fuel normally during the normal condition; and is characterized in that the duration of the valve opening pulse for a fuel increment is controlled dependent on at least one of selected from variations in the air intake volume per unit time, a closing signal for the throttle valve, a signal indicating the number of revolutions of the internal combustion engine, etc., and independent of the duration of the basic valve opening pulse.

It is possible to obtain optimum acceleration by varying the adjustment depending on conditions for interrupt

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

Brief Description of the Drawings:

Fig. 1 is an engine system view for embodying the present invention.

Fig. 2 is a block diagram view showing the relationship between input and output described in Fig. 1.

Fig. 3 is an explanatory view of engine injection timing.

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

Fig. 5 is an explanatory flow chart sheet for realizing the acceleration adjusting method of the present invention.

Detailed Description of the Preferred Embodiments:

One embodiment of the present invention will be described. 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 have a throttle valve 5 for determining the amount of intake for the engine further upstream.

Such an amount of intake for the engine 1 is measured by a hot wire air flow meter 6 provided still further upstream. Engine revolutions are counted by a revolution sensor 13. In addition to the above, a control unit CU 12 also receives a signal 11 from engine temperature, 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 of the 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 a control unit CU, the left side includes sensors and the right side includes actuators.

In the control unit CU, 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 described with reference to Fig. 3. In the 4-cylinder, 4-cycle engine, fuel is usually injected once 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.

A fuel increment pulse (interrupt pulse) described in the present invention is a 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 → 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 (ΔQa) of the air intake volume Qa per unit time. The magnitude of acceleration can be detected based on the value ($\Delta Qa/Qa$) of the rate of variation of the air intake volume Qa during a predetermined time (Δt).

Table 1 shows an example of setting the fuel increment pulse (interrupt pulse) to a running vehicle in response to the magnitude of acceleration.

Table 1

Condition before Acceleration	Magnitude of Acceleration	Interrupt Pulse	
		After Idling	ΔQa
Fuel Cutdown for Deceleration	5% < ΔQa < 37.5% (Under Light Load)	9 ms	3 ms
	ΔQa ≥ 37.5	9 ms	9 ms (max. 4 times)
Normal (Idle Sw. Off)	5% < ΔQa < 10% (Under Light Load)	-	3 ms
	ΔQa ≥ 10%	-	6 ms
Normal (Idle Sw. On)	5% < ΔQa < 10% (Under Light Load)	3 ms	3 ms
	ΔQa ≥ 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 (ΔQa) in the air intake volume per unit time and the idle switch setting. In the Table 1, the "after idling" indicates an interrupt 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 (ΔQa) 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 (ΔQa) 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 (ΔQa) 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 interrupt pulse based on the rate of variation (ΔQa) 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. $5\% < \Delta Qa < 37.5\%$) and rapid acceleration ($\Delta Qa \geq 37.5\%$). For slow acceleration, an interrupt pulse of 3 ms is generated; for rapid acceleration, interrupt pulses of 9 ms are generated, (one for each detected acceleration rate).

The magnitudes of the above interrupt 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 accelera-

tion, respectively.

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

An interrupt pulse based on the rate of variation (ΔQa) in the air take volume per unit time in normal condition is set to have a 3 ms duration for slow acceleration ($5\% < \Delta Qa < 10\%$) and is set to have a 6 ms duration for rapid acceleration ($\Delta Qa \geq 10\%$) respectively, and the fuel is injected. The magnitutes of the above interrupt 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 interrupt pulse based on the idle switch may be set to a shorter duration, e.g., 3 ms, than that during deceleration. The magnitude of the above interrupt 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 with the additional interrupt 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 (ΔQa) is smaller than A1, no interrupt pulse is generated; when ΔQa is greater than A1, an interrupt pulse TA1 is issued. Note that, although inherently a decision must be made based on the inequality of $A_1' > \Delta Qa > A_1''$ so that the additional pulse may be divided into interrupt pulses TA1' (of 6 ms in Table 1) and TA1" (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 interrupt pulse TA2 (3 ms) due to the condition after idling is set and thereafter an interrupt pulse TA3, also herein inherently divided into two types - interrupt

pulses TA3', 3 ms in Table 1, and TA3", 6 ms in Table 1 - is set based on ΔQa.

The left-hand loop represents acceleration from the decelerated state. In this case, an interrupt pulse TA4 (9 ms) is issued due to the state after idling and acceleration is then determined on the basis of ΔQa. If A5 > ΔQa > A6, an interrupt pulse TA6 (3 ms) is issued and adjustment is completed therewith.

In all these adjustments the interrupt pulse based on ΔQa 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 ΔQa > A5, an interrupt pulse TA5 is set. The fact that the pulse TA5 has been issued is stored in memory, thus making it possible to repeat the adjustment with the interrupt pulse TA5 based on ΔQa > A5 only on the above condition.

What is Claimed is:

Claim 1.

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

- controlling the opening time of fuel injector in accordance with the control content previously programmed based on various operational parameters including air intake volume, the number of revolutions and temperature of the engine;
- measuring the air intake volume by a hot wire air flow meter;
- generating a signal of an idle switch for detecting a closed state of a throttle valve adapted to control the intake air amount; and
- generating a valve opening pulse for fuel increment independent of a basic valve opening pulse which causes the injector to inject fuel normally during the normal condition; characterized in that

the duration of said valve opening pulse for fuel increment is controlled dependent on at least one of parameters selected from variations in the air intake volume per unit time, a closing signal for the throttle valve, a signal indicating the number of revolutions of the internal combustion engine, etc., and independent of the duration of said basic valve opening pulse.

Claim 2

A fuel injection control method for internal combustion engines according to claim 1, characterized in that said valve opening pulse for fuel increment is generated immediately upon a detected acceleration so as to inject the fuel at that time.

Claim 3

A fuel injection control method for internal combustion engines according to claim 2, characterized in that the acceleration is detected based on the signal representing the closed state of the idle switch or based on the rate of variation of the air intake volume.

Claim 4

A fuel injection control method for internal combustion engines according to claim 2, characterized in that after fuel reduction for acceleration, said valve opening pulse for fuel increment is different at slow acceleration condition and at rapid acceleration condition respectively.

Claim 5

A fuel injection control method for internal combustion engines according to claim 4, characterized in that at the slow acceleration condition, the amount of injected fuel is increased by said valve opening pulse for fuel

increment generated upon the acceleration detected on the basis of the idle switch and upon the acceleration detected on the basis of the rate of variation in the air intake volume per unit time.

Claim 6.

A fuel injection control method for internal combustion engines according to claim 4, characterized in that at rapid acceleration condition, the amount of injected fuel is increased by said valve opening pulse for fuel increment generated upon the acceleration detected on the basis of the idle switch and upon the acceleration detected on the basis of the rate of variation in the air intake volume per unit time.

Claim 7.

A fuel injection control method for internal combustion engines according to claim 2, characterized in that at off condition of the idle switch in the normal condition, the fuel is increased by said valve opening pulse for fuel increment generated from the acceleration detected on the basis of the rate of variation in the air intake volume per unit.

Claim 8.

A fuel injection controlling method for an internal combustion engine according to claim 2, characterized in that on "on" condition of the idle switch in the normal condition, the fuel is increased by said valve opening pulse for a fuel increment generated from the acceleration detecting being based on the idle switch and generated from the acceleration detecting being based on the rate of variation in the air intake volume per unit time.

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FIG. 1

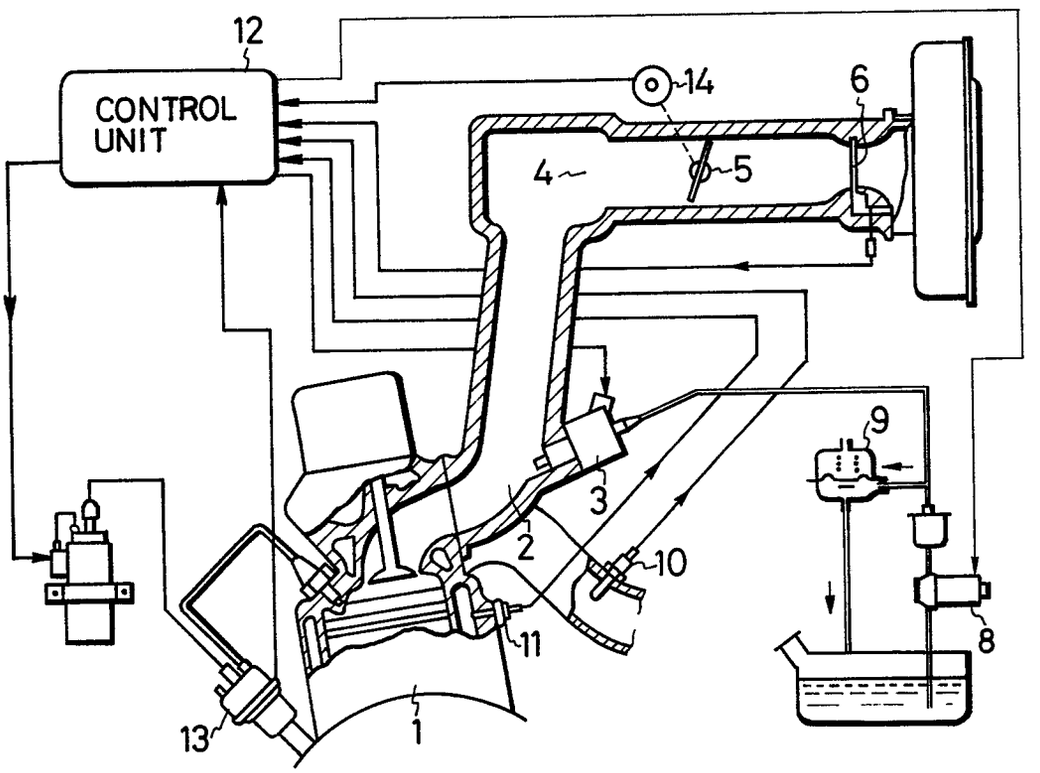

FIG. 2

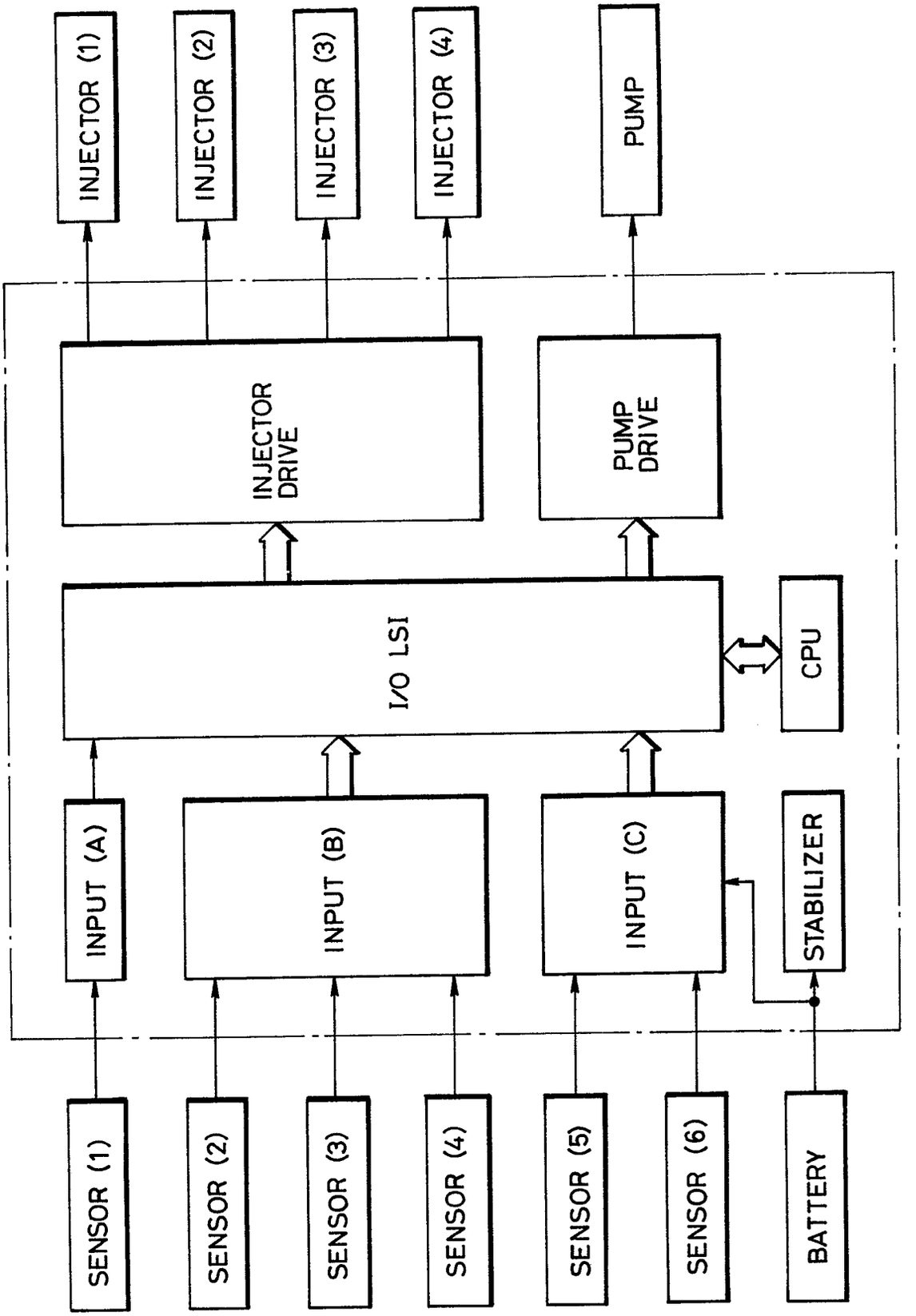
INJECTOR (1)
INJECTOR (2)
INJECTOR (3)
INJECTOR (4)
PUMP
INJECTOR DRIVE
PUMP DRIVE
I/O LSI
CPU
INPUT (A)
INPUT (B)
INPUT (C)
STABILIZER
SENSOR (1)
SENSOR (2)
SENSOR (3)
SENSOR (4)
SENSOR (5)
SENSOR (6)
BATTERY

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FIG. 3

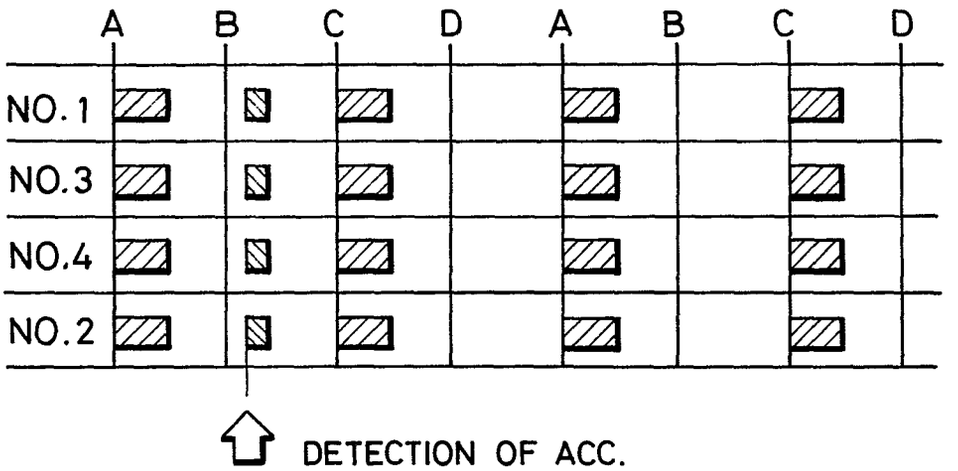

FIG. 4

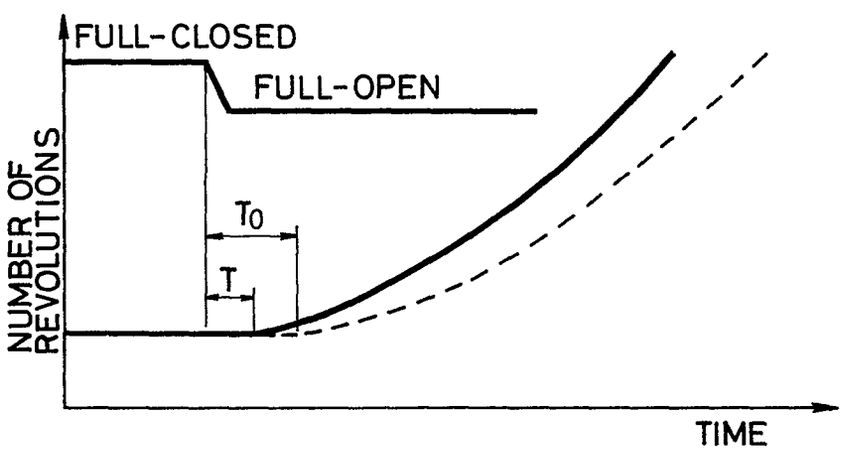

FIG. 5