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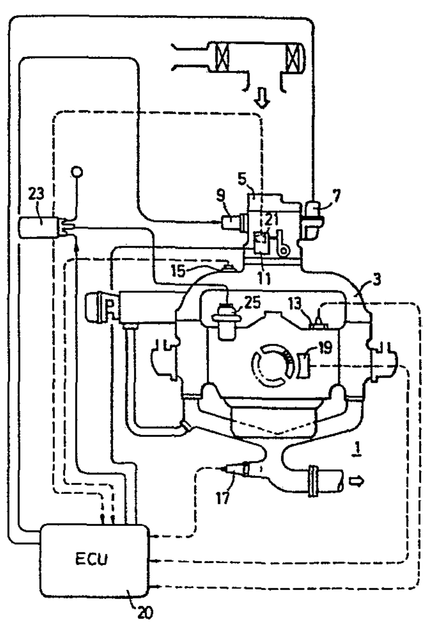
(54) **Air-fuel ratio control system for an internal combustion engine.**

(57) An air-fuel ratio control system having solenoid-actuated valves (71, 73) disposed in the fuel passage and the air bleed communicated with the fuel passage of a carburetor (5), an electric memory memorizing the data concerning the opening rates of the solenoid-actuated valves for attaining a constant air-fuel ratio through driving of these valves, in relation to the engine speed (N) and the intake vacuum (VC) of the engine, and a controller adapted to control the solenoid-actuated valves at an opening rate which is given as the product of the data read out from the electric memory and a fuel increment coefficient which differs according to the state of engine operation such as acceleration, deceleration and so forth of the engine and which varies depending on the engine temperature (TW). A correction of the air-fuel ratio is performed in accordance with the engine temperature (TW). When the engine is intentionally accelerated or decelerated during warming up of the engine, the rate of fuel supply from the carburetor (5) is changed in accordance with such a change of engine operation to always optimize the ai-fuel ratio of the mixture.

FIG. 1



EP 0 046 599 A2

Title of the Invention:

AIR-FUEL RATIO CONTROL SYSTEM FOR AN INTERNAL COMBUSTION ENGINE

Background of the Invention:

The present invention relates to a system for electrically controlling the air-fuel ratio of mixture supplied to internal combustion engines and, more particularly, to an air-fuel ratio control system adapted to make a necessary correction of air-fuel ratio during warming up of the engine.

Conventional carburetors used for automobile engines have various mechanicms for controlling the air-fuel ratio of the mixture but cannot accurately control the air-fuel ratio in response to the change in the state of operation of the engine.

Under this circumstance, Japanese Pre-examined Patent Publication No. 96350/1980 (published on May 13, 1977) discloses an electric control means combined with a carburetor to achieve a precise control of the air-fuel ratio. This system incorporates solenoid-actuated valves disposed, respectively, in the fuel passage of the carburetor and in the air bleed communicating with this fuel passage. The control of the air-fuel ratio is achieved by opening and closing these valves vibratorily at duty ratios determined by a microcomputer.

The microcomputer is equipped with a memory which stores beforehand a data concerning the duty ratios of valves for attaining a predetermined air-fuel ratio generally referred to as a "flat map". The micro-computer determines the duty ratios of the valves upon reading out the data corresponding to the instant engine speed and intake vacuum. The duty ratios are corrected by the output from an O_2 sensor disposed in the exhaust system of the engine, thereby to achieve a more precise and delicate control of the air-fuel ratio.

The O_2 sensor used in this system, however, cannot operate satisfactorily at low temperature. It is also to be pointed out that, during the warming up of the engine after a cold start, it is necessary to heat up the engine as promptly as possible without stopping the engine.

For these reasons, the conventional air-fuel control systems proposed hitherto cannot perform the precise and delicate control of the air-fuel ratio particularly during the warming up of the engine.

Summary of the Invention:

Accordingly, an object of the invention is to provide an air-fuel ratio control system which can perform a precise and delicate control of the air-fuel ratio even during warming up of the engine to suppress as much as possible the generation of noxious gas component in the exhaust emissions.

Another object of the invention is to provide an air-fuel ratio controlling system which can maintain an optimum air-fuel ratio even when the engine is operated to accelerate or decelerate during the warming up, while ensuring the normal feeling of acceleration and deceleration.

To this end, according to the invention, there is provided an air-fuel ratio controller comprising a carburetor provided with at least one solenoid-actuated valve disposed in the fuel passage or the air bleed communicating with the latter, a memory storing data concerning the duty ratio or opening rate of the vlave for obtaining a predetermined air-fuel ratio with parameters of engine speed and intake vacuum, means for detecting the state of operation of the engine such as acceleration and deceleration, and a controller adapted to read out the opening rate of the valve from the memory corresponding to the detected engine speed and intake vacuum and to control the opening ratio as the product of the read-out opening rate and fuel increment coefficient which is determined by the temperature of the engine cooling water and the state of the engine operation.

Generally, there have been used various fuel increasing means for increasing the rate of supply of fuel during warming up depending solely upon the engine temperature. However, it is not possible to obtain the optimum air-fuel ratio with these conventional means, when the engine is decelerated or accelerated during the warming up. Namely, in such a case, the amount of emission of noxious gas is increased or the feeling of acceleration or deceleration is failed.

According to the invention, the rate of supply of the fuel is adjusted without delay in response to the change of state of engine operation such as acceleration or deceleration during the warming up, to optimize the air-fuel ratio of the mixture and to make the acceleration or deceleration characteristic apprxomate that experienced after the warming up of the engine. According to the invention, the control of the air-fuel ratio during warming up of the engine is achieved by a valve for a feedback control of the air-fuel ratio after the warming up, without using a choke lever disposed at the upstream side of the carburetor, so that the construction of the carburetor can be simplified advantageously.

Brief Description of the Drawings:

Fig. 1 is a block diagram showing the whole structure of an air-fuel ratio control system in accordance with an embodiment of the invention;

Fig. 2 is a sectional view of a carburetor incorporated in the system shown in Fig. 1;

Fig. 3 is a block diagram showing the detail of a control unit incorporated in the system shown in Fig. 1;

Fig. 4 is a block diagram showing the detail of a block 203 shown in Fig. 3;

Fig. 5 is a characteristic chart showing the control effect provided by a feedback solenoid incorporated in the system shown in Fig. 1;

Fig. 6 is a dimension graph showing a flat map;

Fig. 7 is a flow chart of a program adapted to be performed by the control unit;

Fig. 8 is a graph showing the characteristic of the fuel increment coefficient in relation to temperature; and

Fig. 9 is a graph showing idling speed command.

Description of the Preferred Embodiments:

Referring first to Fig. 1 showing the whole part of an air-fuel ratio control system in accordance with an embodiment of the invention, a carburetor 5 is mounted in an intake pipe 3 connected to an internal combustion engine 1. The carburetor 5 is provided with a feedback solenoid 7, fuel solenoid 9 and a throttle actuator 11 adapted to be driven by control signals derived from a control unit 20.

The control unit 20 receives signals representing the temperature TW of engine cooling water (coolant), intake vacuum VC in the intake pipe 3 and the concentration O_2 of oxygen gas in exhaust gas which are detected, respectively, by a coolant temp-rature sensor 13, vacuum sensor15 and an O_2 sensor 17. The controller 20 receives also the output from a pulse-type speed sensor 19 adapted to sense the engine speed and the output from an idling switch 21.

An ignition coil 23 generates an ignition pulse in response to an ignition control signal derived from the control unit 20. This ignition pulse is distributed to the ignition plugs of every cylinders through a distributor 25.

Fig. 2 shows the constructions of the carburetor 5 and the associated solenoid and actuator. The fuel filling a float chamber 31 is introduced from the latter into a passage 34 through a main jet 33 and a feedback main jet. When the throttle valve 50 is kept opened, a mixture consisting of the fuel in the passage 34 and a small amount of air flowing into the passage through a main air bleed 35 is atomized and delivered through a main nozzle 37. However, when the opening degree of the throttle valve 50 is small, no fuel is supplied through the main nozzle 37 but is supplied through a slow hole 41 and a bypass hole 43. Namely, the fuel in the passage 34 flows through a slow jet 38 and is mixed with the air which has passed through a slow air bleed 39 and feedback air bleed 73. The mixture is then introduced to the slow hole 41 or the bypass hole 43.

The air-fuel ratio of the mixture thus formed is adjusted by the feedback main jet and the feedback air bleed the opening rate of which is controlled by the feedback solenoid 9 which vibratorily open and close the feedback main jet and the feedback air bleed.

On the other hand, the amount of fuel supplied through the passage 45 is adjusted by means of a valve 91 which is vibratorily driven by the fuel solenoid 11. This passage is used only in the start up of the engine in which a specifically rich mixture is required.

A throttle valve 50 is operatively connected to an accelerator pedal. When the accelerator pedal is not operated, the throttle valve 50 takes the reset position due to the force exerted by a return spring which is not shown.

This reset position is such a position that a lever 51 connected to the throttle lever 50 abuts one end of a stroke shaft 53 of the throttle actuator 11, and is determined by the position of the stroke shaft 53.

The throttle actuator 11 has a motor 55 adapted to drive a gear 57 to determine the position of the stroke shaft 53 which is held by screw at the axial position of the gear 57. The stroke shaft 53 and the gear 57 are supported for a slight axial movement, and are adapted to be forced outward by a spring when the throttle valve 50 is kept opened by the operation of the accelerator pedal. In this state, an idling switch 21 incorporated in the throttle actuator takes the off state. To the contrary, as the accelerator pedal is released, the stroke shaft 53 and the gear 57 are pressed inwardly by the lever 51, so that the idling switch 21 is turned on.

As will be seen from Fig. 3, the control unit includes a microprocessor 201, read only memory 202, control logic 203, multiplexer 204 and an analog-to-digital converter 205.

The analog data such as the coolant temperature TW from the coolant temperature sensor 13, intake vacuum VC from the vacuum sensor 15 and the O_2 concentration from the O_2 sensor 17 are taken into the control logic 203 via the analog-to-digital coverter 203. Also, to the control logic 203, connected are an engine starter switch 27, ignition switch 29 and an idling switch 21, as well as a pulse-type speed sensor adapted to produce a signal representing the engine speed N.

The microprocessor 201 makes a periodical arithmetic operation for the engine control in accordance with the program stored in the read only memory 202, making use of the data taken into the control logic 203 and the data stored in the read only memory 202. The control data thus obtained through the arithmetic operation are stored in the register within the control logic 203 which produces, in accordance with the thus stored date, various signals such as drive signal PAF for the feedback solenoid 7, drive signal PF for the fuel solenoid 9, drive pulse signal PTH for the throttle actuator 11 and an ignition signal PIG. The signals PAF and PF are pulse signals having frequencies of 20 Hz. The duty ratios of these signals are determined in accordance with the data given by the microprocessor 204. The signal PTH is a negative pulse signal having a predetermined pulse width. A motor 55 of the throttle actuator 11 is driven in the forward or backward direction depending on whether this signal takes a positive or negative value. Whether this signal takes the positive or negative value, as well as the period of the pulse, is determined in accordance with the result of operation by the microprocessor 201.

Fig. 4 shows in detail the portion of the control unit 203 for producing the drive signal PAF for the feedback solenoid 7. Data DAF representing the ON duty of the feedback solenoid 7, calculated by the microprocessor 201, is stored in the register 231. On the other hand, data DP representing the period of the drive signal PAF is set in the register 233. A counter 235 counts the clock pulses and is cleared by the output from a comparator 239 at each time the counted number C coincides with the value of the data DP. A flip-flop 241 is set simultaneously with the clearing of the content of the counter 235. The flip-flop 241 is adapted to be reset at each time the counted value C counted by the counter 235 coincides with the value of the data DAF. Thus, the flip-flop 241 produces a drive signal PAF having an ON duty equal to the value represented by the data DAF, and delivers this signal to the feedback solenoid 7. In consequence, the feedback main jet 71 is opened by the feedback solenoid 7 at an opening rate equal to the value represented by DAF. Also, the opening rate of the feedback slow air bleed is equal to the inverse number to the value represented by the data DAF.

Fig. 5 shows how the air-fuel ratio is changed by the thus driven feedback solenoid 7. As will be seen from this Figure, an air-fuel ratio control of a good linearity is obtainable through the ON duty control of the feedback solenoid.

Fig. 6 illustrates a three-dimensional graph showing the ON duty of the feedback solenoid for obtaining a constant air-fuel ratio of the mixture formed by the carburetor 3, with the parameters of the engine speed N and the intake vacuum VC. This kind of chart in which the data concerning ON duty is memorized by a memory in relation to engine speed N and intake vacuum VC is generally referred to as a "flat map". This flat map is to obtain from the carburetor a constant air-fuel ratio of the mixture irrespective of change of the state of operation of the engine, as long as the engine state is steady, compensating for the mechanical setting of the carburetor.

Fig. 7 shows the flow chart of a process for effecting an air-fuel ratio control during the warming up of the engine, making use of the flat map of the type described.

This program is started at a constant period of, for example, 40 m sec, before the coolant temperature rises up to a predetermined level after the detection of the self-cranking of the engine. In the step S1, the measured values of the engine speed N and the intake vacuum VC are read and, in the subsequent step S2, ON duty data DM is read from the flat map explained in connection with Fig. 6, making use of the read data N and VC. The data read out from the flat map is referred to as "flat map value". Then, in the next step S3, the coolant temperature TW is read and, in the subsequent step S4, increment coefficients K_A, K_B, K_C and K_D are read from four tables of the read only memory 204 corresponding to the coolant temperature TW. These coefficients are set in the registers prepared beforehand. These values are set in a manner shown in Fig. 8, in relation to the engine coolant temperature TW. Namely, the increment coefficient K_A corresponds to the state during the acceleration of the engine, while K_B corresponds to the state during engine operation at a constant speed. The increment K_C corresponds to the state of warming up of the engine without any positive throttle operation, while K_D corresponds to the state of deceleration of the engine. Thus, the increment coefficient takes a greater value as the coolant temperature T_W is lower, and different coefficients have different gradients.

The steps S5,S6 and S7 are the steps for judging the state of operation of the engine. In the preceding step S4, a judgement is made as to whether the idling switch 21 is on. If the idling switch is on, the sensed engine speed N is compared in the step S5 with the command value of the engine speed N. Also, if the engine speed N is greater than a speed which is NR plus 100 R.P.M., it is judged that the engine is in the decelerating condition, and the process proceeds to a step S8. To the contrary, if the sensed speed N is lower than the speed which is the command speed NR plus 100 R.P.M., it is judged that the engine is in the warming-up without positive throttle operation, and the process proceeds to a step S9. The idling command speed NR is the speed which is the command value of the idle speed control performed by the throttle actuator 11, and is set in a manner shown in Fig. 9 in relation to the coolant temperature TW.

The proce-s proceeds to the step S7 if the idling switch S7 is detected to be off in the step S5. Then, the sensed intake vacuum VC is compared with the intake vacuum VCR sensed in the previous cycle of measurement. If the rate of change is higher than a predetermined value, it is judged that the engine is in the accelerating condition, and the process proceeds to a step S10. To the contrary, if the rate of change of the intake vacuum is below a predetermined level, it is judged that the engine is in the state of operation at a constant speed, so that the process proceeds to a step S11.

In the step S8, the increment coefficient K_D corresponding to the engine deceleration is selected, and a value which is the product of the value DM read out from the flat map and the coefficient K_D is set in the register 231. To the contrary, in the step S9, the increment coefficient K_C correspondigg to the idlign is selected, while, in the step S10, the increment coefficient K_A corresponding to the acceleration is selected. Similarly, in the step S11, the increment coefficient K_B corresponding to the constant speed operation is selected. Thus, in respective steps, the products of these coefficients and the value DM read from the flat map are set in the register 231.

The feedbalc solenoid 7 is controlled in accordance with the data DAF representing the ON duty determined by the above-described flow and stored in the register 231, thereby to control the air-fuel ratio during the warming up of the engine. Then, as the coolant temperature comes up above a predetermined temperature such as 40°C and provided that a predetermined time, e.g. 10 seconds, has passed after the start up of the engine, the program shown in Fig. 7 is no more executed and a feedback control is started making use of the output from the O_2 sensor 17. Briefly, this feedback control is to determine the ON duty DAF of the feedback solenoid in such a manner as to maintain a constant oxygen concentration in the exhaust gas. The detail of this control is disclosed in the specification of the United States Patent Serial No. 110,469.

In the embodiment described heretofore, it is possible to obtain optimum air-fuel ratio of the mixture during warming up of the engine, even when the state of the engine operation is changed by an operation of the accelerator pedal, because the ON duty of the feedback solenoid is controlled upon a suitable selection of the fuel increment coefficient corresponding to the state of the engine operation. to control the rate of fuel supply from the carburetor in accordance with the change of state of the engine operation.

The rate of change of the coolant temperature TW is generally gentle as compared with the change of state of engine operation such as acceleration or deceleration. It is, therefore, not essential that the steps S3 and S4 in the flow shown in Fig. 7, i.e. the reading of the coolant temperatyre TW and setting of the increment coefficients K_A, K_B, K_C, K_D corresponding to the coolant temperature TW in the register through reading out these coefficients from the table, be executed in each cycle of operation of the system. For instance, it is possible to arrange such that these steps are executed every 320 m sec.

In the carburetor shown in Fig. 2, both of the feedback main jet 71 and the feedback slow air bleed 73 are opened and closed by the feedback solenoid commonly. This arrangement, however, is not essential and the feedback main jet 71 and the feedback slow air bleed 73 may be controlled and actuated by independent solenoids. It is also to be understood that the present invention can be carried out by providing the solenoid-actuated valve in either one of the fuel passage of the carburetor and the air bleed connected to the fuel passage.

Claims

1. An air-fuel ratio control system for internal combustion engine equipped with a carburetor comprising:
   a) at least one solenoid-actuated valve disposed in at least one of the fuel passage or the air bleed communicating with said fuel passage of said carburetor (5);
   b) a plurality of sensors (13, 15, 17, 19) adapted to sense at least the engine speed (N), engine temperature (TW) and the intake vacuum (VC) of said engine;
   c) an electric memory memorizing the data concerning the opening rate of said solenoid-actuated valve for maintaining a constant air-fuel ratio of mixture supplied from said carburetor (5) to said engine, said data being memorized in relation to the engine speed and the level of load;
   d) coefficient calculation means adapted to calculate a plurality of fuel increment coefficients corresponding to different states of engine operation and depending on said engine temperature (TW); and
   e) a controller adapted to read out from said electric memory the value of the opening rate of said solenoid-actuated valve corresponding to the sensed engine speed (N) and the intake vacuum (VC) and, upon judging the state of engine operation, to select one from said increment coefficients, said controller being further adapted to control the opening of said solenoid-actuated valve at an opening rate which is given as the product of the opening rate read out from said electric memory and the selected increment coefficient.

2. An air-fuel ratio control system as claimed in claim 1, wherein said solenoid actuated valve is constituted by a first valve disposed in said fuel passage (34) of said carburetor (5) and a second valve disposed in said air bleed passage (35) communicated with said carburetor (5).

3. An air-fuel ratio control system as claimed in claim 2, wherein said first and second valves are actuated by a common solenoid (7).

4. An air-fuel ratio control system as claimed in claim 1, wherein said coefficient calculating means are adapted to calculate said increment coefficient at least during the acceleration of said engine.

5. An air-fuel ratio control system for internal combustion engines comprising:

a) a carburetor (5) provided with at least one solenoid-actuated valve in the fuel passage (34) or the air bleed (35) communicating said fuel passage thereof, and with a throttle valve (50) disposed in the passage for an air-fuel mixture formed therein;

b) a plurality of sensors (13, 15, 17, 19) adapted to sense the speed (N), temperature (TW) and the intake vacuum (VC) of said engine;

c) a throttle position sensor (21) adapted to sense that said throttle valve (50) is in its reset position;

d) an actuator adapted to control the reset position of said throttle valve (50) thereby to control the engine speed (N) during warming up of said engine without any positive operation of an accelerator pedal;

e) an electric memory memorizing the data concerning the opening rate of said solenoid-actuated valve for maintaining a constant air-fuel ratio of mixture supplied from said carburetor (5) to said engine, said data being memorized in relation to the engine speed (N) and the level of load;

f) coefficient calculating means adapted to calculate a plurality of fuel increment coefficients in accordance with the engine temperature (TW) for different states of engine operation including acceleration and deceleration;

g) engine state judging means adapted to select the increment coefficient corresponding to deceleration when the engine speed is higher than a predetermined speed while said throttle valve (50) is in said reset position and to select, when said intake vacuum (VC) exceeds a predetermined level while said throttle valve (50) is not in said reset position, the increment coefficient corresponding to acceleration; and

h) a control unit adapted to read from said electric memory the opening rate of said valve corresponding to said engine speed (N) and the intake vacuum (VC), and to control said valve at an opening rate given as the product of said increment coefficient selected by said engine state judging means and said opening rate read out from said electric memory.

FIG. 1

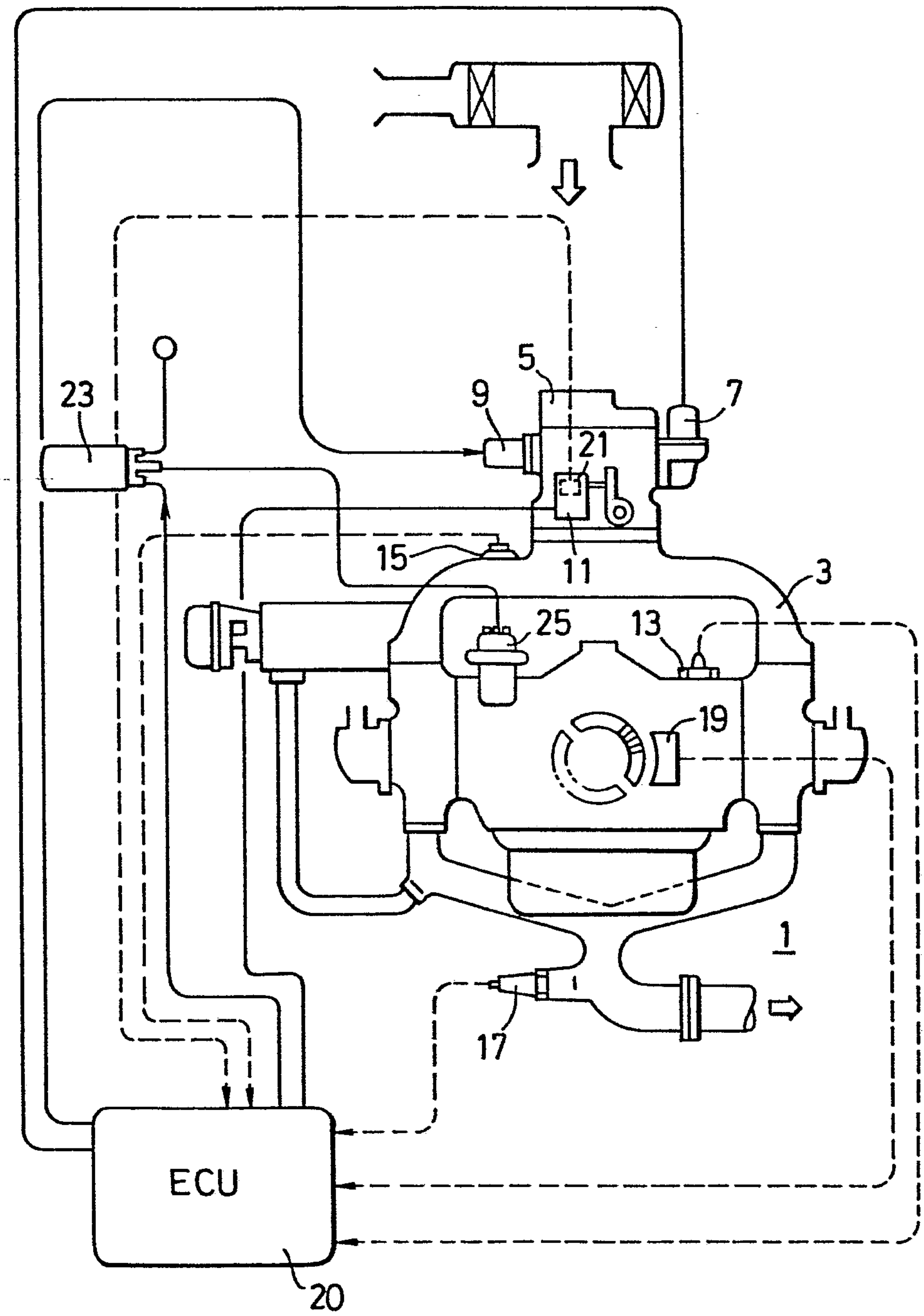


FIG. 2

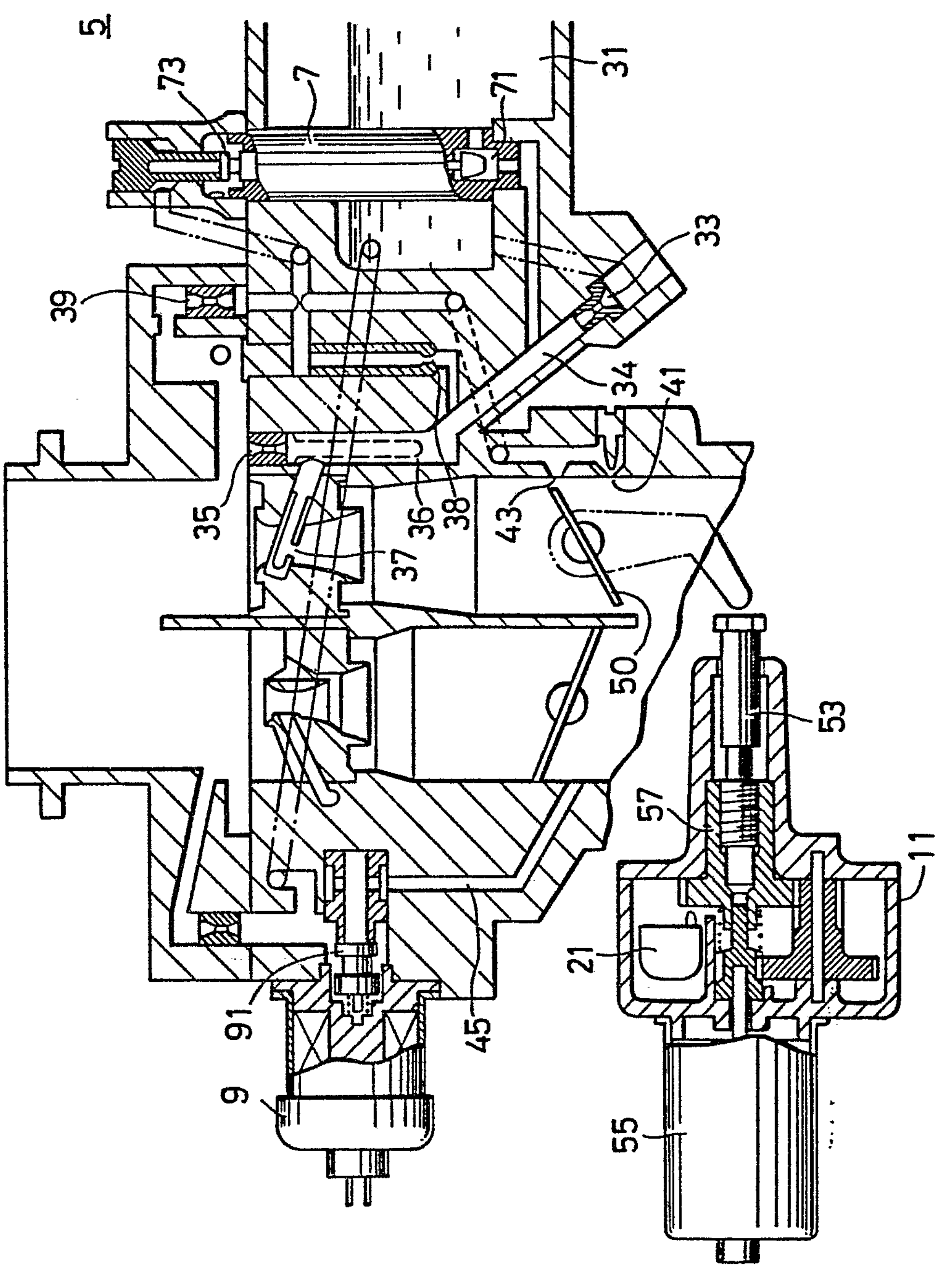


FIG. 3

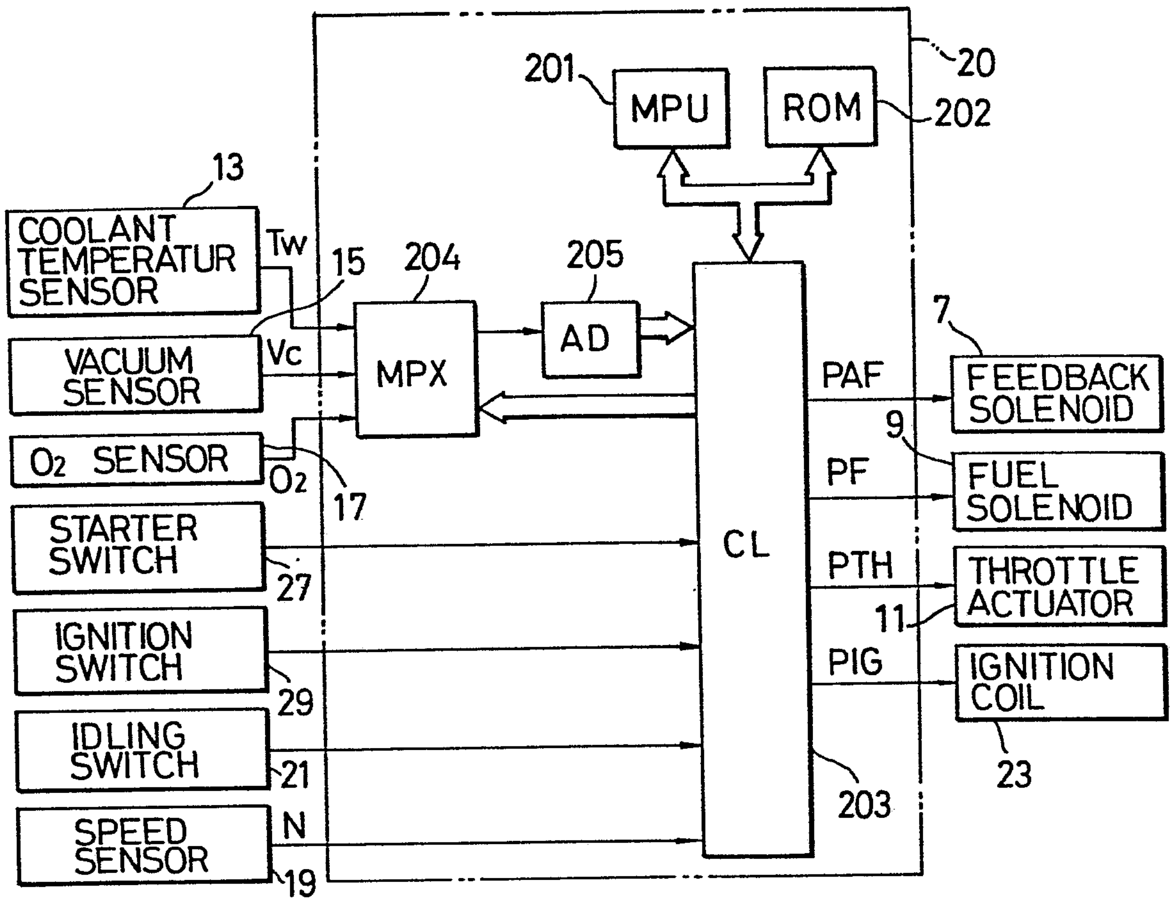

20
201
MPU
ROM
202
13
COOLANT TEMPERATUR SENSOR
Tw
15
204
205
VACUUM SENSOR
Vc
MPX
AD
O2 SENSOR
O2
17
STARTER SWITCH
27
IGNITION SWITCH
29
IDLING SWITCH
21
SPEED SENSOR
N
19
CL
203
PAF
PF
PTH
PIG
7
FEEDBACK SOLENOID
9
FUEL SOLENOID
THROTTLE ACTUATOR
11
IGNITION COIL
23

FIG. 4

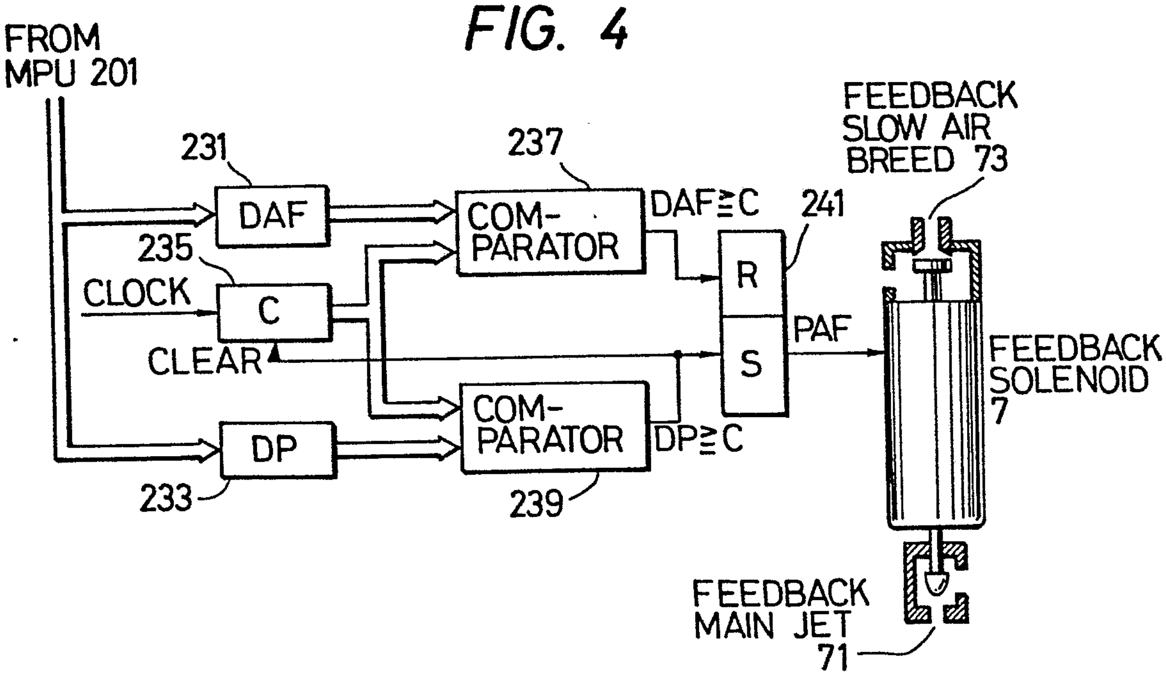

FROM MPU 201
231
DAF
237
COM-PARATOR
DAF≧C
241
235
CLOCK
C
CLEAR
R
S
PAF
DP
233
COM-PARATOR
239
DP≧C
FEEDBACK SLOW AIR BREED 73
FEEDBACK SOLENOID 7
FEEDBACK MAIN JET 71

FIG. 5

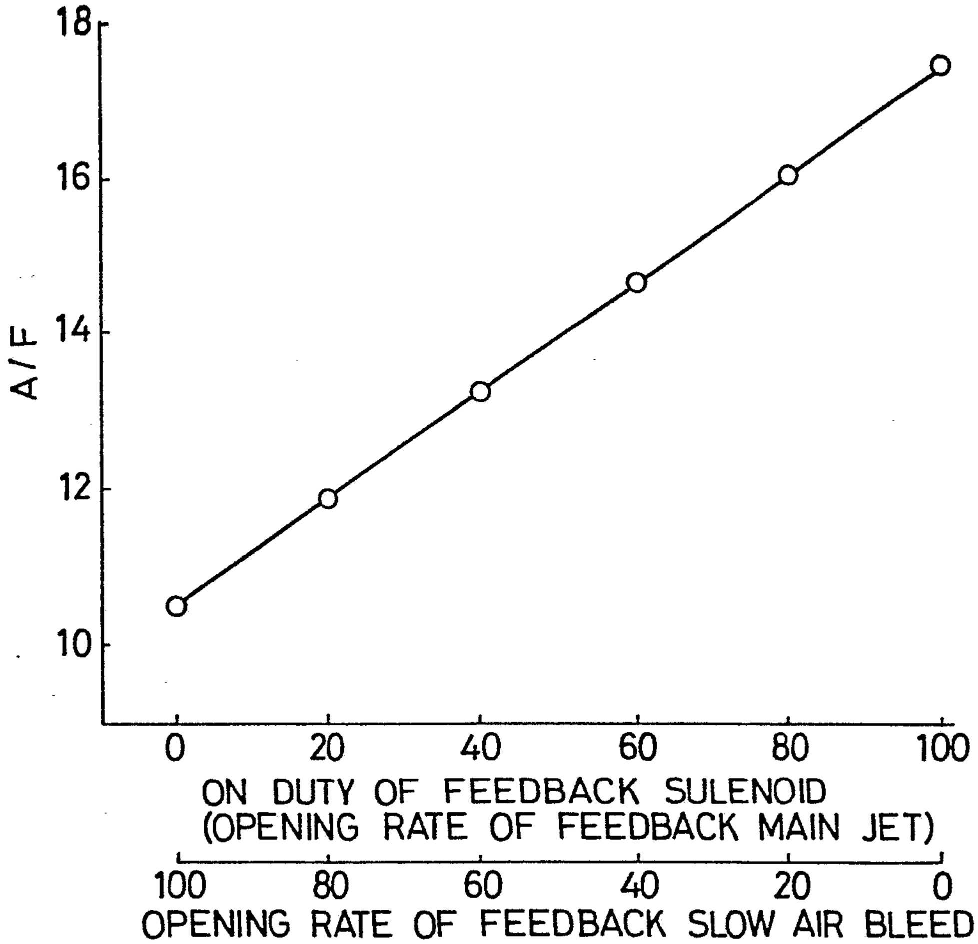

18
16
14
12
10
A / F
0
20
40
60
80
100
ON DUTY OF FEEDBACK SULENOID
(OPENING RATE OF FEEDBACK MAIN JET)
100
80
60
40
20
0
OPENING RATE OF FEEDBACK SLOW AIR BLEED

FIG. 6

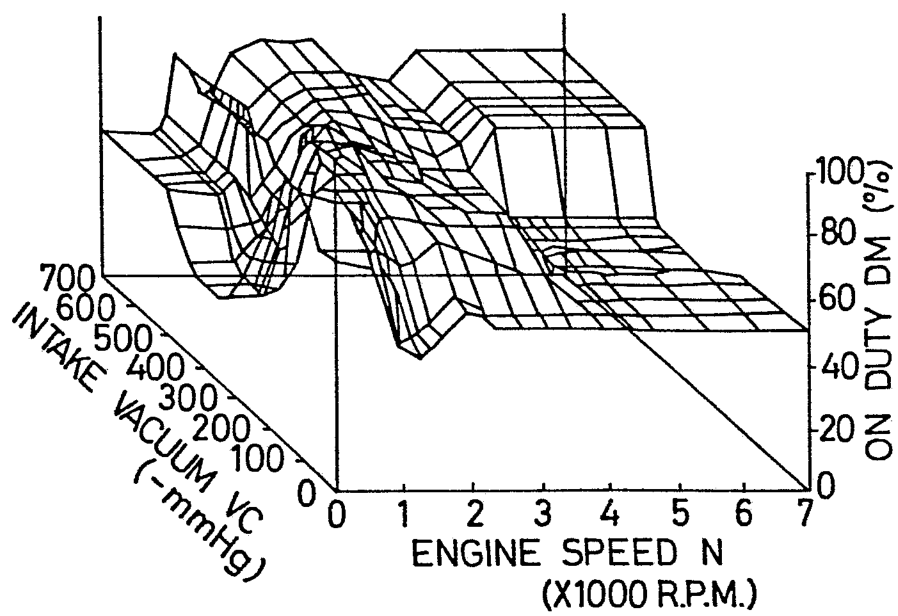

700
600
500
400
300
200
100
0
INTAKE VACUUM VC
(-mmHg)
0
1
2
3
4
5
6
7
ENGINE SPEED N
(X1000 R.P.M.)
100
80
60
40
20
0
ON DUTY DM (%)

FIG. 7

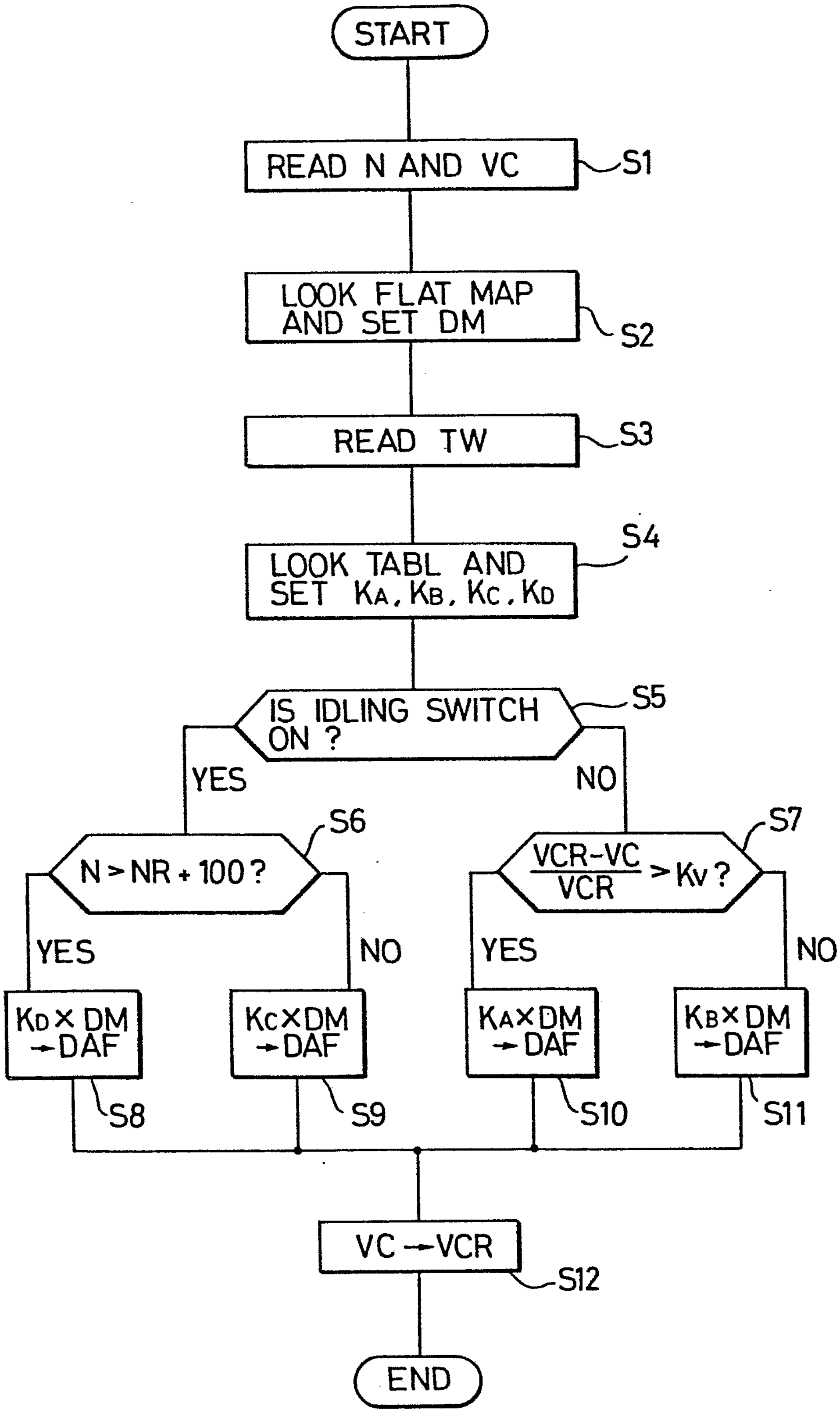

START
READ N AND VC
S1
LOOK FLAT MAP AND SET DM
S2
READ TW
S3
LOOK TABL AND SET KA, KB, KC, KD
S4
IS IDLING SWITCH ON ?
S5
YES
NO
N > NR + 100 ?
S6
(VCR−VC)/VCR > Kv ?
S7
YES
NO
YES
NO
KD × DM → DAF
S8
KC × DM → DAF
S9
KA × DM → DAF
S10
KB × DM → DAF
S11
VC → VCR
S12
END

FIG. 8

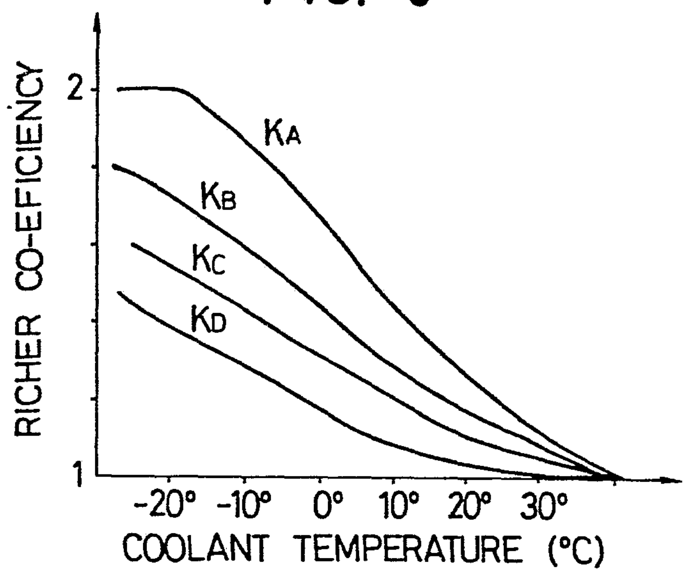
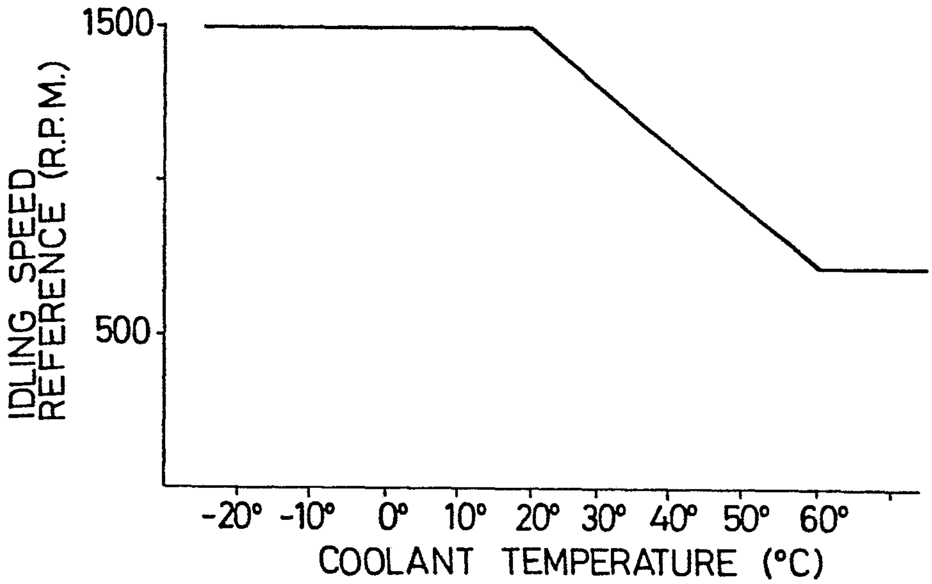

RICHER CO-EFICIENCY
2
1
KA
KB
KC
KD
-20° -10° 0° 10° 20° 30°
COOLANT TEMPERATURE (°C)

FIG. 9


IDLING SPEED REFERENCE (R.P.M.)
1500
500
-20° -10° 0° 10° 20° 30° 40° 50° 60°
COOLANT TEMPERATURE (°C)