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(71) Applicant: **HONDA GIKEN KOGYO KABUSHIKI KAISHA**
**Minato-ku Tokyo (JP)**

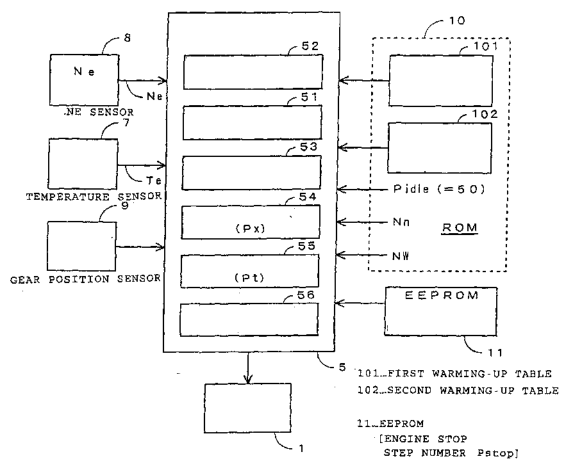
(72) Inventors:
- **Hirakata, Yoshiaki, K.K. Honda Gijutsu Kenkyusho Wako-shi, Saitama (JP)**
- **Uraki, Mamoru, K.K. Honda Gijutsu Kenkyusho Wako-shi, Saitama (JP)**
- **Ando, Hideaki, K.K. Honda Gijutsu Kenkyusho Wako-shi, Saitama (JP)**
- **Ito, Nobuhiko, K.K. Honda Gijutsu Kenkyusho Wako-shi, Saitama (JP)**

(74) Representative: **Liska, Horst, Dr.-Ing. et al**
**Weickmann & Weickmann**
**Patentanwälte**
**Postfach 86 08 20**
**81635 München (DE)**

# (54) Idling speed control apparatus for internal combustion engine

(57) To provide an idling speed control apparatus for an internal combustion engine which can perform positioning of a step motor accurately without additionally providing a battery.

The idling speed control apparatus includes storage means 11 for storing an engine stop step number Pstop, means for driving the step motor based on a target position step number Pt which represents a target position of the step motor and a present position step number Px which represents the present position of the step motor, and idling state discrimination means 52 for discriminating whether or not the idling is in a steady state. Upon starting of the engine, the engine stop step number Pstop is registered as the present position step number, and when it is discriminated that the idling is in a steady state, the present position step number is rewritten into a reference step number which is a predetermined constant and the present position step number is stored as the idling reference step number.




5...CONTROLLER
52...IDLING STATE DISCRIMINATION SECTION
51...ENGINE STARTING DISCRIMINATION SECTION
53...WARMING-UP DISCRIMINATION SECTION
54...PRESENT POSITION COUNTER (Px)
55...TARGET POSITION COUNTER (Pt)
56...MOTOR DRIVING SECTION
1...STEP MOTOR

FIG. 2

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## Description

**[0001]** This invention relates to an idling speed control apparatus for an internal combustion engine, and more particularly to an idling speed control apparatus for an internal combustion engine which regulates the intake air amount by means of a step motor to control the speed of rotation of the internal combustion engine upon idling.

**[0002]** Generally, in an idling speed control apparatus for an engine, an idling speed control valve (ISCV) is in most cases provided midway of a bypass path provided separately from an intake path in such a manner as to bypass a throttle valve. By regulating the opening of the ISCV, the intake air amount of the internal combustion engine is controlled, independently of the throttle valve, to control the idling speed.

**[0003]** The ISCV described above is driven by a step motor, and the opening thereof is controlled by supplying to the step motor a pulse signal which corresponds to the difference between the present position of an idling regulation valve which is determined by the operation step number of the step motor from a reference position and a target position which depends upon the operation condition of the engine. Such a control method as just described is known, for example, by the official gazette of Japanese Patent Laid-open No. Sho 63-42106 and so forth.

**[0004]** In the prior art described above, in order to make it possible to simply make the opening of the idling regulation valve and the operation step number of the step motor correspond to each other without using a reference position sensor such as a potentiometer or a limit switch, a fixed pulse signal is provided to the step motor to drive the idling regulation valve to its fully closed or fully open position immediately after the ignition switch is disconnected, and the operation step number of the step motor is reset in order to use the fully closed or fully open position as a reference position.

**[0005]** However, according to such an initial processing method as just described, since the step motor must be rotated to the fully open or fully closed position after the engine ignition switch is interrupted, a battery for the initial processing must further be incorporated separately from an original battery.

**[0006]** The object of the present invention resides in solution of the subject of the prior art described above and provision of an idling speed control apparatus for an internal combustion engine which can perform positioning of a step motor accurately without additionally providing a battery.

**[0007]** In order to attain the object described above, according to the present invention, an idling speed control apparatus for an internal combustion engine which includes an idling regulating valve for regulating the opening of an idling intake path and a step motor for driving the idling regulating valve to perform opening and closing movements and which controls the rotational position of the step motor to coincide with a rotational position corresponding to a target opening for the idling regulating valve is characterized in that it comprises storage means for storing an idling reference step number, means for registering, upon starting of the engine, the idling reference step number as a present position step number which represents the present position of the step motor, means for driving the step motor based on a target position step number which represents a target position of the step motor and the present position step number, idling state discrimination means for discriminating whether or not the idling is in a steady state, means for rewriting the present position step number into a reference step number which is a predetermined constant when it is discriminated that the idling is in a steady state, and means for storing the present position step number as the idling reference step number when it is discriminated that the idling is in a steady state.

**[0008]** The opening of the idling regulation vale when idling is stable and in a steady state is determined uniquely, and even if the engine is stopped, the idling regulation valve is kept at the position. Thus, according to the characteristic described above, the rotational position of the step motor when idling is in a steady state is stored as the idling reference step number, and when the engine is started next, the rotational position of the step motor at the point of time is set to the idling reference step number stored in advance. Consequently, the relationship between the rotational position of the step motor and the operation step number which represents the present position of the step motor can be determined accurately without using a sensor.

**[0009]** According to the present invention, the following effects are achieved.

(1) Since the rotational position of the step motor when idling is in a steady state is set to a predetermined reference step number (Pidle) based on the empirical rule that the rotational position of a step motor when idling is stable and in a steady state is substantially fixed, the relationship between the present position of the step motor and the present position step number which represents the present position can be compensated for accurately without using a sensor.

(2) In a transition state in which the idling is not stable, the step number Px which represents the rotational position of the step motor at the current point of time is repetitively stored as the engine stop step number Pstop in a non-volatile fashion, and then when the engine is started next, the engine stop step number Pstop is initialized as the present position step number Px which represents the rotational position of the step motor at present. Accordingly, even if the engine is stopped in a state wherein the idling is not stable, the present position step number Px and the present position of the step motor can be made correspond accurately to each oth-

er.

[0010] FIG. 1 is a schematic sectional view showing a configuration of a principal portion of an idling speed control apparatus to which the present invention is applied.

[0011] FIG. 2 is a functional block diagram showing a configuration of a controller of FIG. 1.

[0012] FIG. 3 is a flow chart illustrating operation of the present embodiment.

[0013] FIG. 4 is a flow chart illustrating operation of the present embodiment.

[0014] FIG. 5 is a time chart illustrating operation of the present embodiment.

[0015] FIG. 6 is a diagram illustrating an example of a first warming-up table.

[0016] FIG. 7 is a diagram illustrating an example of a second warming-up table.

[0017] In the following, a preferred embodiment of the present invention is described with reference to the drawings. FIG. 1 is a schematic sectional view showing a configuration of a principal portion of an idling speed control apparatus to which the present invention is applied.

[0018] A throttle body 2 is mounted at an intermediate portion of an intake path which interconnects an air cleaner and an engine. On the throttle body 2, a throttle valve 3 which regulates the opening of the intake path is provided for pivotal motion, and also an idling intake path 4 which bypasses the throttle valve 3 is mounted. The idling intake path 4 introduces intake air for idling to the engine upon idling of the engine and an idling regulation valve 6 is mounted between the upstream side 4a and the down stream side 4b of the idling intake path 4.

[0019] The opening of the idling regulation valve 6 depends upon the rotational position of a step motor 1 which is driven with a pulse signal outputted from a controller 5. The controller 5 receives detection signals from a temperature sensor 7 which detects a cooling water temperature of the engine, an engine speed sensor 8 which detects an engine speed Ne, and a position sensor 9 which detects a gear position of a transmission, and controls the rotational position of the step motor 1.

[0020] As described in detail below, an engine stop step number Pstop which represents the rotational position of the step motor 1 upon last stopping of the engine is stored in a non-volatile EEPROM 11 which does not require backup power. Upon next starting of the engine, the controller 5 reads in the engine stop step number Pstop from the EEPROM 11, and supposes that the step number Pstop represents the rotational position of the step motor 1 at present (upon last engine stopping, that is, upon present engine starting) to start control.

[0021] FIG. 2 is a functional block diagram showing a configuration of the controller 5, and like elements to those appearing as above are denoted by like or equivalent reference characters.

[0022] In the controller 5, an engine starting discrimination section 51 discriminates whether or not the engine is started. An idling state discrimination section 52 discriminates whether or not the idling is stabilized and settled in a steady state. A warming-up discrimination section 53 discriminates whether or not the engine is in a warming-up operation state.

[0023] A present position counter 54 counts a present position step number Px which represents the rotational position of the step motor 1 at present. A target position step number Pt relating to the step motor 1 is registered into a target position counter 55. A motor driving section 56 supplies a driving pulse for forward rotation or reverse rotation to the step motor 1 so as to make the present position step number Px and the target position step number Pt coincide with each other. The driving pulse is counted by the present position counter 54 and the present position step number Px is incremented or decremented in accordance with the driving pulse.

[0024] Operation of the present embodiment is described below. FIGS. 3 and 4 are flow charts illustrating operation of the present embodiment and FIG. 5 is a time chart illustrating operation of the present embodiment.

[0025] If an ignition switch is switched on at time t1 of FIG. 5, then the idling speed control of FIG. 3 starts. At step S1, the engine starting discrimination section 51 of the controller 5 discriminates whether or not the engine is in a starting state based on the engine speed Ne detected, for example, by the Ne sensor 8. In the present embodiment, when the engine speed Ne is 700 rpm or less, it is discriminated that the engine is in a starting state. In the beginning of the process, since it is discriminated that the engine is in a starting state, the process advances to step S11.

[0026] At step S11, as described in detail below, the engine stop step number Pstop which represents the rotational position of the step motor 1 upon last stopping of the engine is read out from the EEPROM 11 by the controller 5.

[0027] At step S12, the read out engine stop step number Pstop is registered as the present position step number Px which represents the rotational position of the step motor 1 into the present position counter 54 of the controller 5.

[0028] At step S13, a warming-up step number Padd for temporarily raising the idling speed upon warming-up operation is detected based on the present cooling water temperature Te detected by the temperature sensor 7 with reference to a first warming-up table 101 of a ROM 10.

[0029] FIG. 6 is a graph showing an example of the first warming-up table in the present embodiment. The warming-up step number Padd increases as the cooling water temperature Te decreases.

[0030] At step S14, an idling reference step number Pidle (50 steps in the present embodiment) fixedly determined in advance as a reference step number upon idling is read out from the ROM 10.

**[0031]** At step S15, a sum value [Pidle + (Padd - Pstop)] of the idling reference step number Pidle and a value obtained by subtracting the engine stop step number Pstop from the warming-up step number Padd is registered as a present target position step number Pt into the target position counter 55 of the controller 5.

**[0032]** At step S16, the present position step number Px is stored as the engine stop step number Pstop into the EEPROM 11. At step S17, the step motor 1 is controlled by the motor driving section 56 of the controller 5 so that the target position step number Pt and the present position step number Px coincide with each other.

Then, the engine is started at time t2 of FIG. 5, and when the starting of the engine is detected in step S1 described above, the process advances to step S2. At step S2, whether or not the engine is in a no-load state is discriminated based on, for example, the gear position detected by the gear position sensor 9. If the gear position is the neutral position, then it is discriminated that the engine is in a no-load state, and the process advances to step S3.

**[0033]** At step S3, whether or not the engine is in an idling state is discriminated based on, for example, the engine speed Ne and the throttle opening. If the engine speed Ne is lower than a predetermined reference speed and the throttle opening is lower than a predetermined reference opening, then it is discriminated that the engine is in an idling state, and the process advances to step S4. It is to be noted that, if any one of the discriminations in steps S2 and S3 results in the negative, then the process advances to a running mode of step S10.

**[0034]** At step S4, it is discriminated by the warming-up discrimination section 53 of the controller 5 based on, for example, the water temperature Te of cooling water whether or not the engine is in a warming-up state. In the beginning of the process, the water temperature Te is low and it is discriminated that the engine is in a warming-up state, and the process advances to step S5. At step S5, an upper limit value Nmax1 and a lower limit value Nmin1 of a target idling speed range are determined based on a second warming-up table, of which an example is shown in FIG. 7, and the water temperature Te.

**[0035]** At steps S6 and S7, it is discriminated whether or not the engine speed Ne is higher than the upper limit value Nmax1 and whether or not the engine speed Ne is lower than the lower limit value Nmin1, respectively. If the engine speed Ne reaches the upper limit value Nmax1 as at time t3 of FIG. 5, the target position step number Pt is decremented at step S8. On the contrary if the engine speed Ne drops to the lower limit value Nmin1, then the target position step number Pt is incremented at step S9. If the engine speed Ne is within the range between the upper and lower limit values, then the process advances immediately to step S16 et seq.

**[0036]** The processes described above are repeated as long as it is discriminated at step S4 that the engine is in a warming-up state, and within the period, the cooling water temperature Te rises gradually. Accordingly, also the upper limit value Nmax1 and the lower limit value Nmin1 of the target idling speed range determined at step S5 described above gradually drop, and therefore, also the engine speed Ne gradually drops as shown in FIG. 5.

**[0037]** Thereafter, if the water temperature Te exceeds the predetermined reference temperature at time t4 of FIG. 5, then since it is discriminated at the next step S4 that the engine is not in a warming-up state, the process advances to step S21 of FIG. 4.

**[0038]** At step S21, an idling stability flag Fidle is referred to. The idling stability flag Fidle is set, as hereinafter described in detail, when idling is stabilized and it is discriminated that the idling is in a steady state. Since, in the beginning of the process, the idling is in a transition state and the idling stability flag Fidle is in a reset state, the process advances to step S22. At step S22, the target rotational range for the engine speed Ne is set to a rather narrow value $\Delta$Nn.

**[0039]** At step S23, it is discriminated whether or not the engine speed Ne has converged to a value within the target rotational range $\Delta$Nn. Since, in the beginning of the process, it is discriminated that the engine speed Ne has not converged, the process advances to step S28. At step S28, the idling stability flag Fidle is reset. At step S29, it is discriminated whether or not the engine speed Ne is higher than the upper limit value to the target rotational range $\Delta$Nn. If the engine speed Ne reaches the upper limit value as at time t5 of FIG. 5, then the target position step number Pt is decremented at step S30, whereafter the process advances to step S16 et seq. On the contrary, if the engine speed Ne is lower than the upper limit value, then the target position step number Pt is incremented at step S31, whereafter the process advances to step S16 et seq.

**[0040]** At steps S16 and S17, the present position step number Px is stored as the engine stop step number Pstop into the EEPROM 11 in a similar manner as described hereinabove, and motor control for making the present position step number Px coincide with the target position step number Pt is performed.

**[0041]** Thereafter, the engine speed Ne converges to a value within the target rotational range $\Delta$Nn. When this is detected at step S23 described hereinabove, then the process advances to step S24. At step S24, the idling stability flag Fidle is referred to again, and if the idling stability flag Fidle is in a reset state, then the process advances to step S25. At step S25, the present position step number Px of the present position counter 54 and the target position step number Pt of the target position counter 55 are rewritten uniformly into the idling reference step number Pidle (= 50) irrespective of the step number at present. At step S26, the idling stability flag

Fidle is set.

**[0042]** At the following steps S16 and S17, the present position step number Px is stored as the engine stop step number Pstop into the EEPROM 11 in a similar manner as described hereinabove, and motor control for making the present position step number Px coincide with the target position step number Pt is performed.

**[0043]** In this manner, in the present embodiment, the rotational position of the step motor when idling is in a steady state is set to a predetermined reference step number (Pidle) based on the empirical rule that the absolute rotational position of a step motor when idling is stable and in a steady state is substantially fixed. Therefore, the relationship between the present position of the step motor and the present position step number which represents the present position can be compensated for accurately without using a sensor.

**[0044]** To provide an idling speed control apparatus for an internal combustion engine which can perform positioning of a step motor accurately without additionally providing a battery.

The idling speed control apparatus includes storage means 11 for storing an engine stop step number Pstop, means for driving the step motor based on a target position step number Pt which represents a target position of the step motor and a present position step number Px which represents the present position of the step motor, and idling state discrimination means 52 for discriminating whether or not the idling is in a steady state. Upon starting of the engine, the engine stop step number Pstop is registered as the present position step number, and when it is discriminated that the idling is in a steady state, the present position step number is rewritten into a reference step number which is a predetermined constant and the present position step number is stored as the idling reference step number.

## Claims

1. An idling speed control apparatus for an internal combustion engine which includes an idling regulating valve (6) for regulating the opening of an idling intake path (4) and a step motor (1) for driving said idling regulating valve (6) to perform opening and closing movements and which controls the rotational position of said step motor (1) to coincide with a rotational position corresponding to a target opening for said idling regulating valve (6), **characterized in that** it comprises:

    storage means (10) for storing an idling reference step number (Pidle) ;
    idling state discrimination means (52) for discriminating whether or not the idling is in a steady state;
    means (5) for rewriting a present position step number (Px) which represents the present position of said step motor into the reference step number (Pidle) when it is discriminated that the idling is in a steady state; and
    means (5) for driving said step motor based on a target position step number (Pt) which represents a target position of said step motor (1) and the present position step number (Px).

2. An idling speed control apparatus for an internal combustion engine according to claim 1, **characterized in that** it further comprises

    storage means (11) for repetitively storing the present position step number (Px) as an engine stop step number (Pstop) in a non-volatile fashion, and

    means (5) for adopting the engine stop step number (Pstop) as the present position step number (Px) upon engine starting.

3. An idling speed control apparatus for an internal combustion engine according to claim 2, **characterized in that** said means (11) for storing the engine stop step number (Pstop) is a non-volatile memory.

4. An idling speed control apparatus for an internal combustion engine according to claim 1 or 2, **characterized in that** it comprises

    means (7) for detecting an engine temperature (Te) upon engine starting, and

    means for correcting the target position step number based on the detected engine temperature.

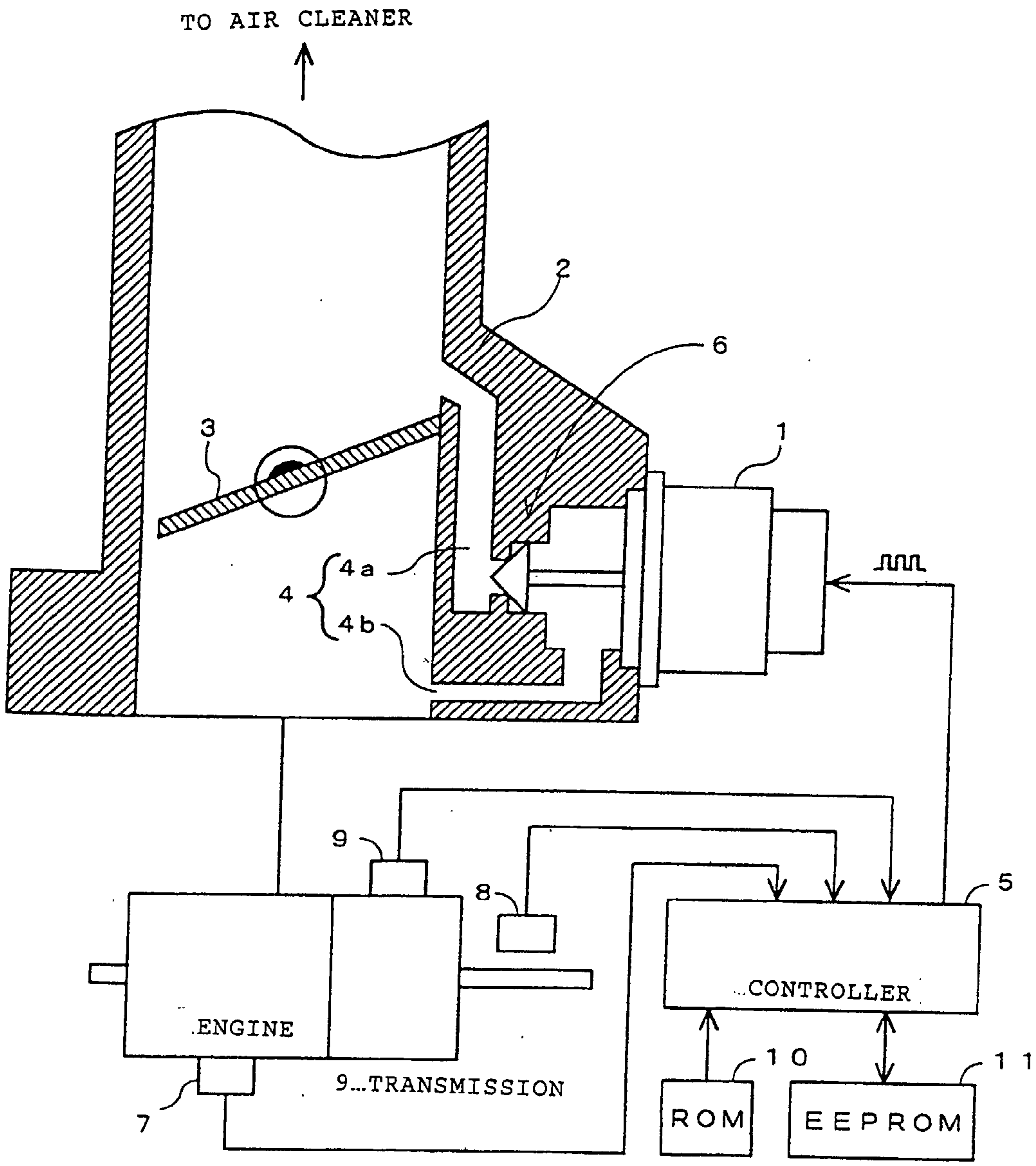
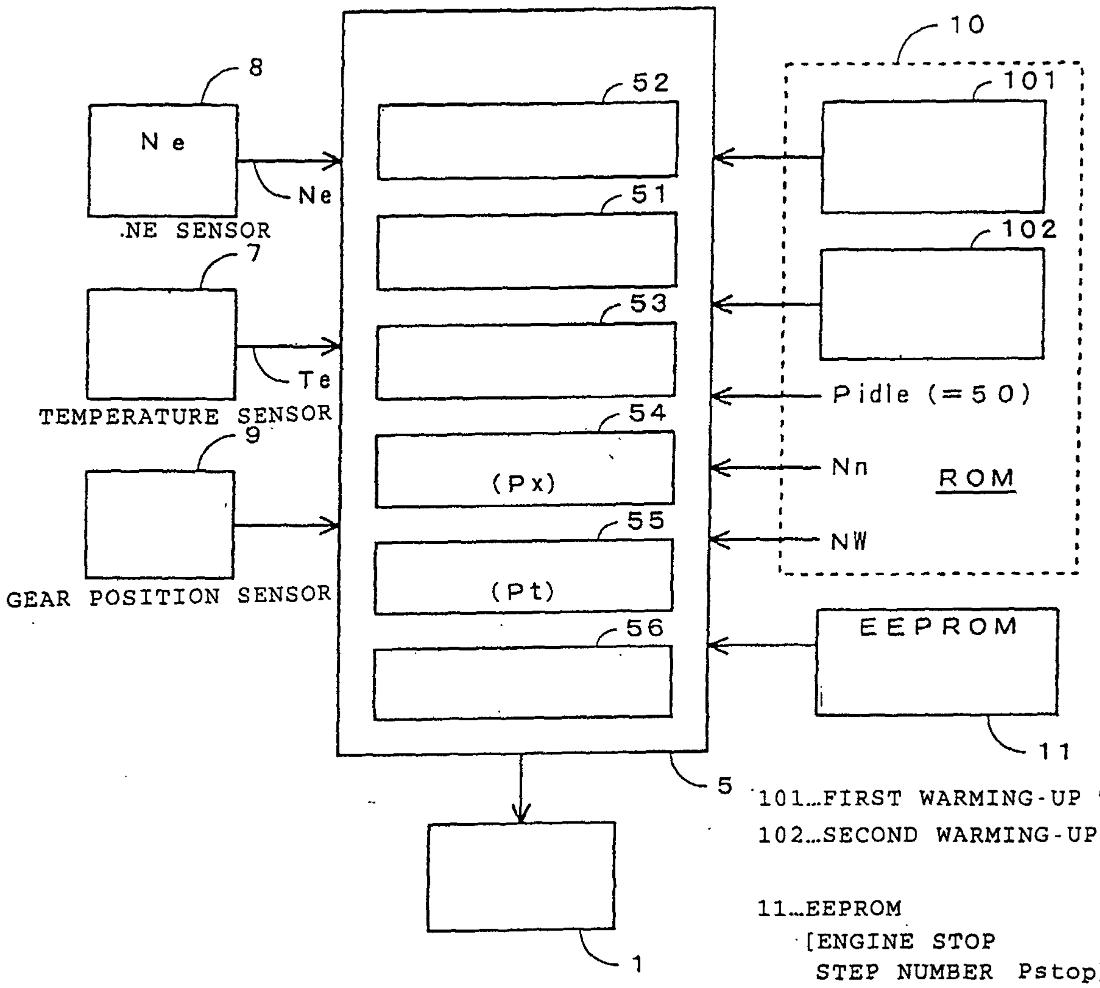

TO AIR CLEANER
2
6
3
1
4a
4
4b
9
8
5
CONTROLLER
ENGINE
9...TRANSMISSION
7
10
11
ROM
EEPROM

FIG. 1




101...FIRST WARMING-UP TABLE
102...SECOND WARMING-UP TABLE

11...EEPROM
[ENGINE STOP
STEP NUMBER Pstop]

5...CONTROLLER
52...IDLING STATE DISCRIMINATION SECTION
51...ENGINE STARTING DISCRIMINATION SECTION
53...WARMING-UP DISCRIMINATION SECTION
54...PRESENT POSITION COUNTER (Px)
55...TARGET POSITION COUNTER (Pt)
56...MOTOR DRIVING SECTION
1...STEP MOTOR

FIG. 2

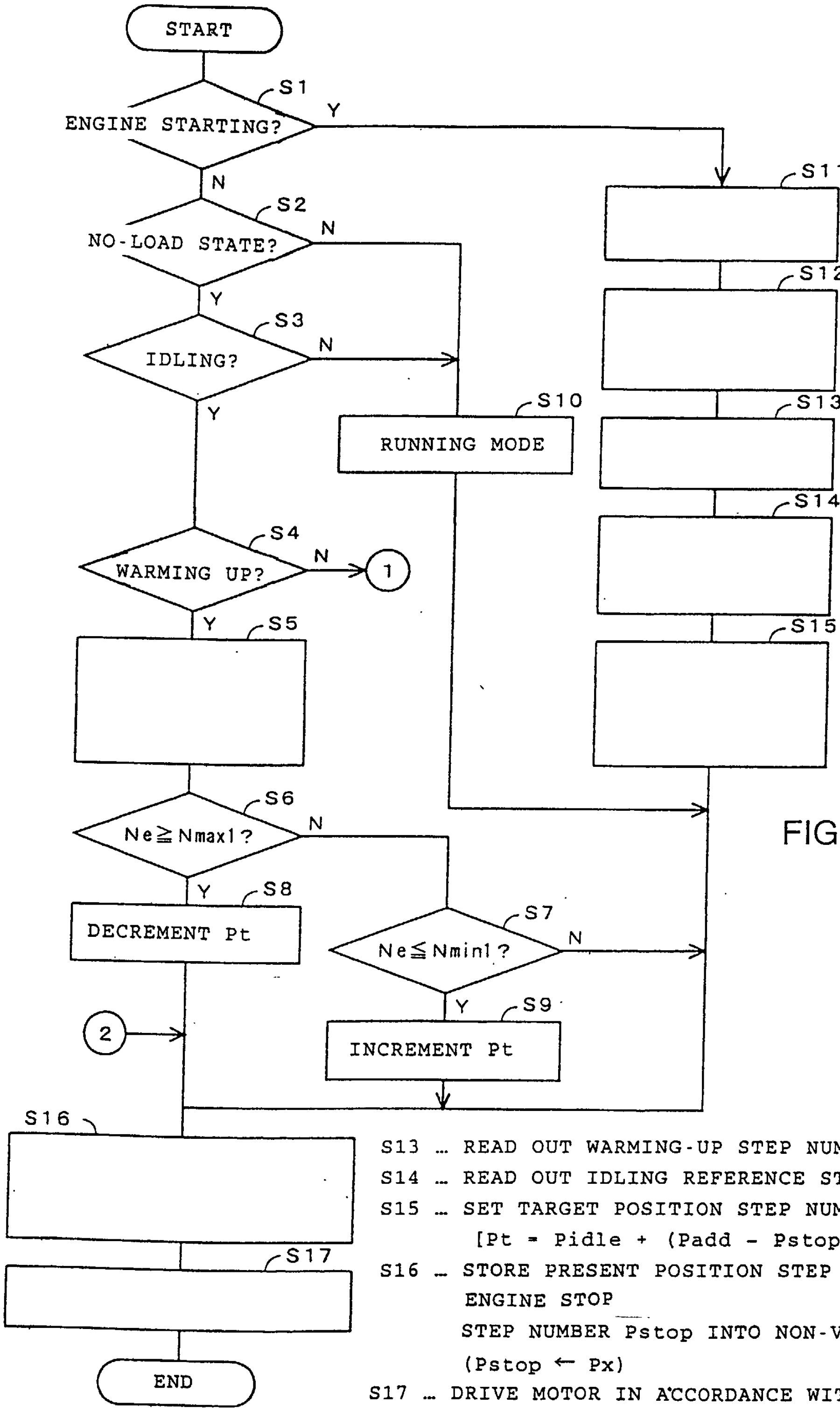



FIG. 3

S13 ... READ OUT WARMING-UP STEP NUMBER Padd
S14 ... READ OUT IDLING REFERENCE STEP NUMBER Pidle
S15 ... SET TARGET POSITION STEP NUMBER Pt
[Pt = Pidle + (Padd - Pstop)]
S16 ... STORE PRESENT POSITION STEP NUMBER Px AS ENGINE STOP STEP NUMBER Pstop INTO NON-VOLATILE MEMORY (Pstop ← Px)
S17 ... DRIVE MOTOR IN ACCORDANCE WITH Pt, Px

S5 ... SET UPPER, LOWER LIMIT VALUES (Nmax1, Nmin1) TO TARGET IDLING ROTATIONAL RANGE BASED ON WATER TEMPERATURE Te
S11 ... READ OUT ENGINE STOP STEP NUMBER Pstop
S12 ... REGISTER Pstop AS PRESENT POSITION STEP NUMBER Px (Px ← Pstop)

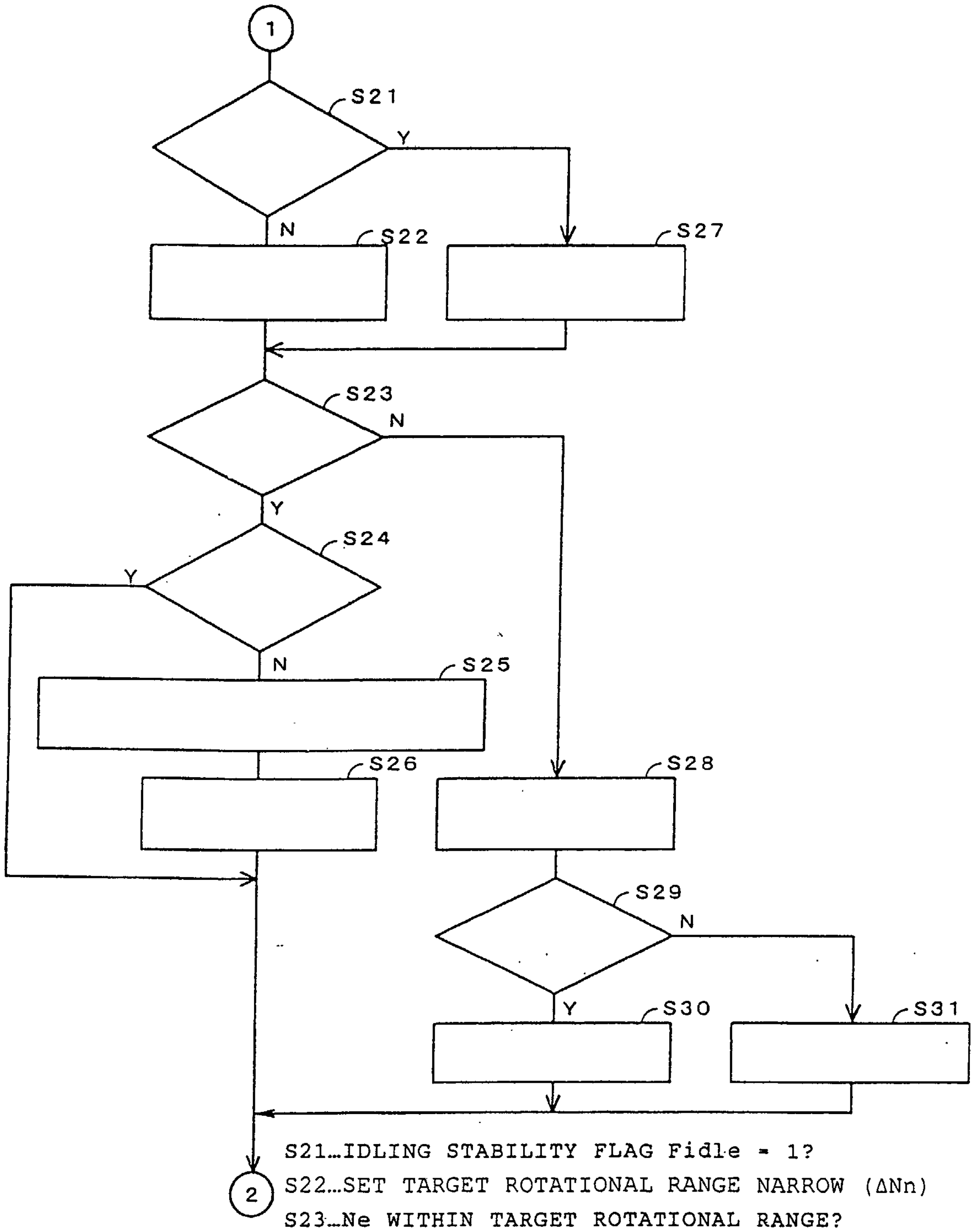



FIG. 4

S21...IDLING STABILITY FLAG Fidle = 1?
S22...SET TARGET ROTATIONAL RANGE NARROW (ΔNn)
S23...Ne WITHIN TARGET ROTATIONAL RANGE?
S24...IDLING STABILITY FLAG Fidle = 1?
S25...PRESENT POSITION STEP NUMBER Px ↘
Pidle (= 50)
TARGET POSITION STEP NUMBER Pt ↙
S26...SET IDLING STABILITY FLAG Fidle
S27...SET TARGET ROTATIONAL RANGE WIDE (ΔNw)
S28...RESET IDLING STABILITY FLAG Fidle
S29...Ne EXCESSIVELY HIGH?
S30...DECREMENT Pt
S31...INCREMENT Pt

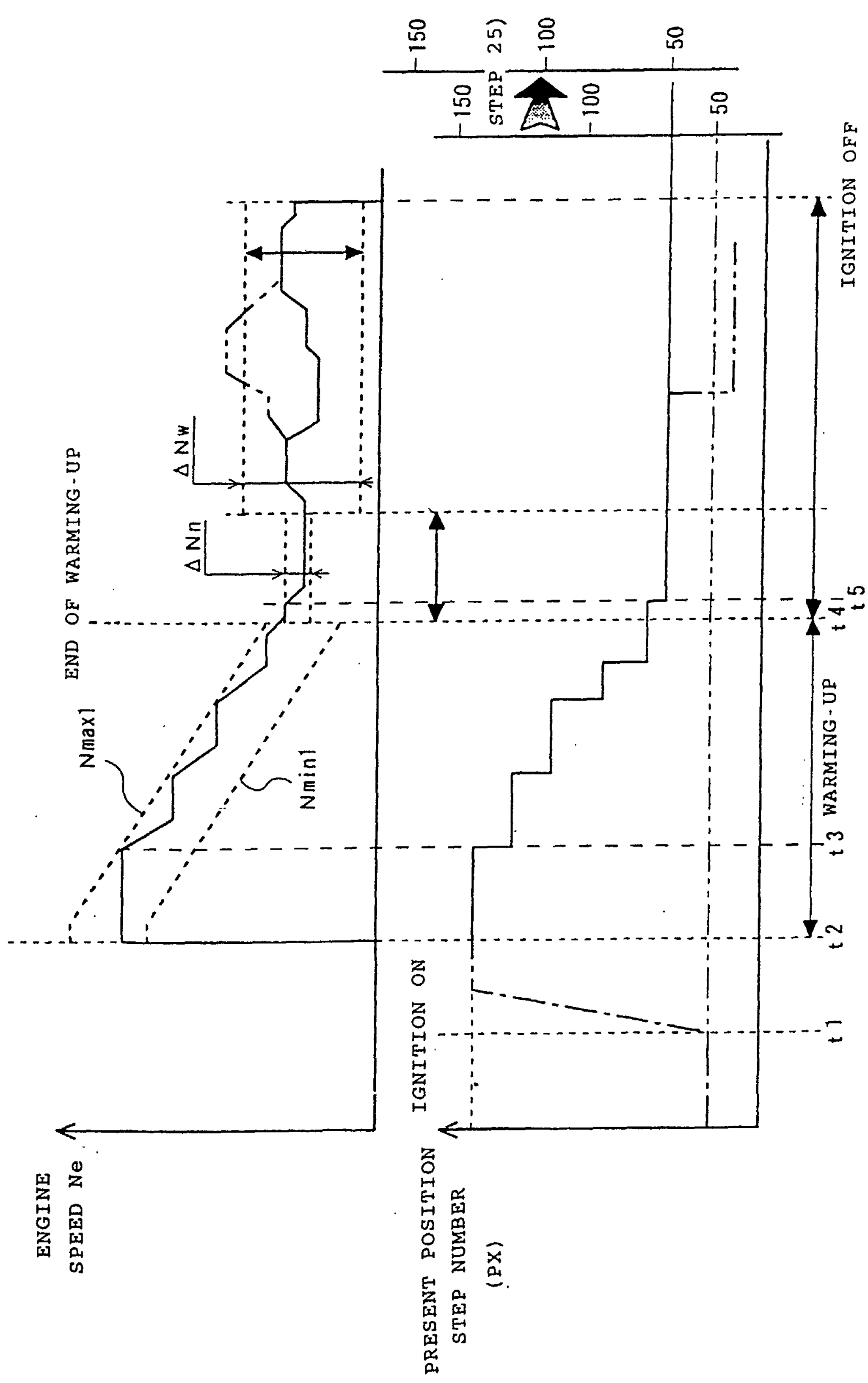

ENGINE SPEED Ne
PRESENT POSITION STEP NUMBER (PX)
IGNITION ON
IGNITION OFF
WARMING-UP
END OF WARMING-UP
Nmax1
Nmin1
ΔNn
ΔNw
STEP 25)
150
100
50
t1
t2
t3
t4
t5

FIG. 5

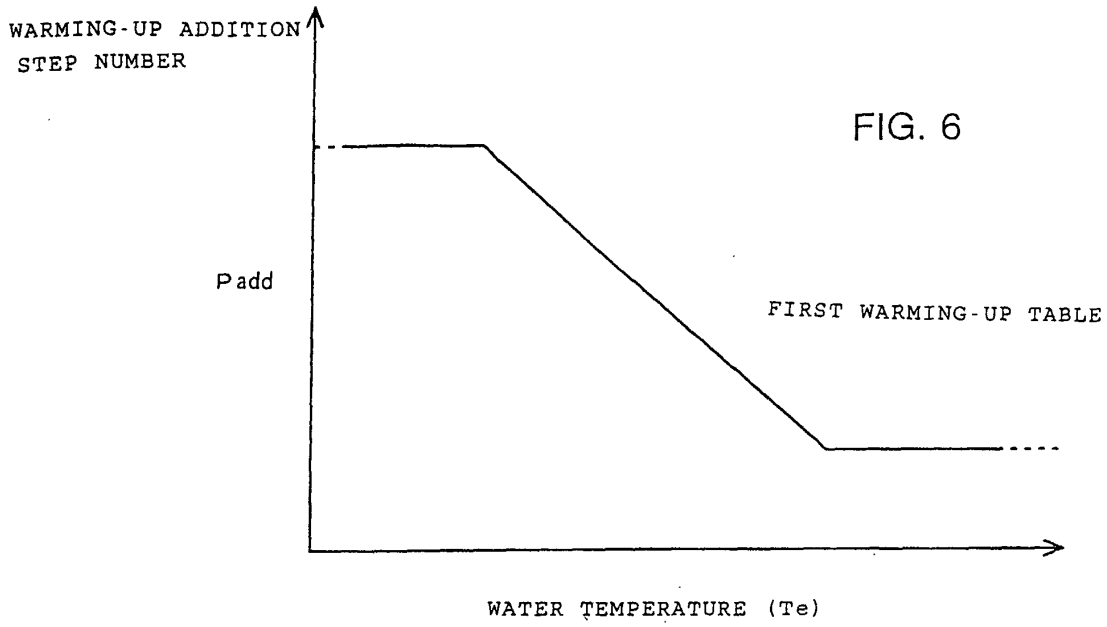

WARMING-UP ADDITION
STEP NUMBER
Padd
FIRST WARMING-UP TABLE
WATER TEMPERATURE (Te)

FIG. 6

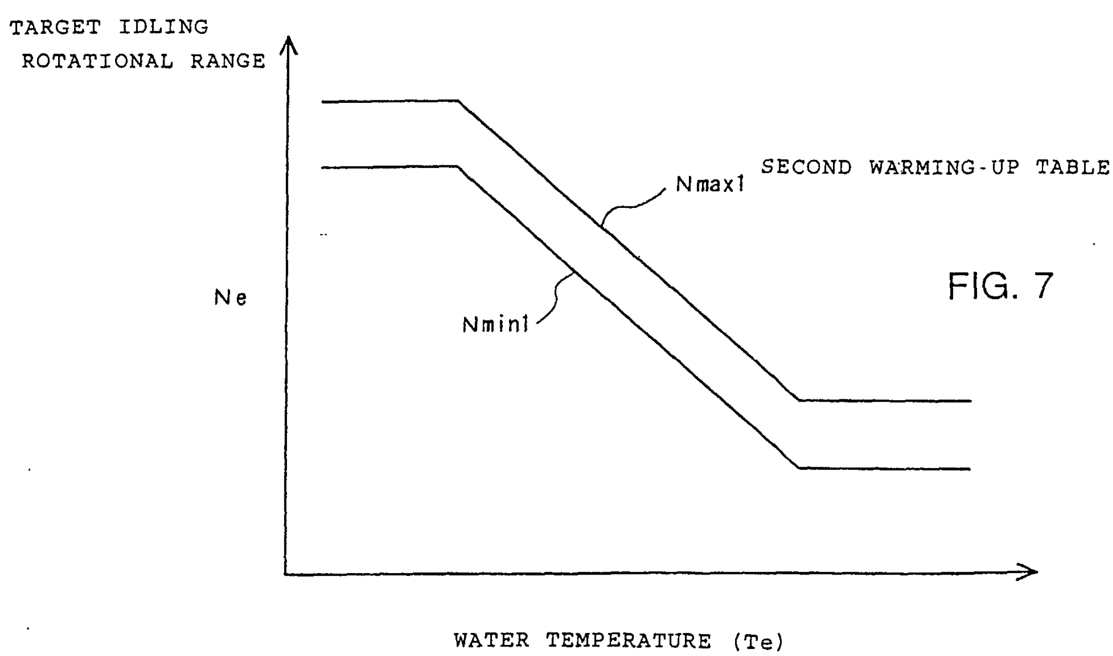

TARGET IDLING
ROTATIONAL RANGE
Ne
Nmax1
Nmin1
SECOND WARMING-UP TABLE
WATER TEMPERATURE (Te)

FIG. 7