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## (54) Method and apparatus for determining fuel supply amount of internal combustion engine

(57) The amount of a change in the fuel injection amount that needs be made in accordance with a change in the target idle speed NETRG is corrected by the rotation speed correction factor QIPNT. When the engine friction is changed due to a change in the actual engine speed NE, the fuel injection amount is adjusted by using a friction correction factor QIPBB. The friction correction factor QIPBB is obtained independently from the other correction factors and by using a specially designed map. Therefore, all the correction factors are easily computed in accordance with changes in the target idle speed NETRG, which facilitates the development of programs for controlling fuel injection.

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## Description

**[0001]** The present invention relates to a method and an apparatus for determining fuel supply amount in an internal combustion engine. Particularly, the present invention pertains to a method and an apparatus for determining the amount of fuel supply for idling an internal combustion engine.

**[0002]** In a diesel engine for vehicle of Japanese Laid-Open Patent Publication 11-141380, the fuel injection amount is determined according to the running state of the engine during idling. Also, an integral correction factor is computed based on the difference between the actual idle speed and a target engine speed during idling (a target idle speed). The integral correction factor is used for correcting the fuel injection amount. When the engine load is increased, for example, by turning the air conditioner on, the fuel injection amount is corrected to respond to an estimated increase of the engine load. Also, since the target idle speed is increased according to an increase of the engine load, the fuel injection amount need be further changed. Therefore, a supplementary correction amount of fuel injection is computed. The supplementary correction amount is used for changing the fuel injection amount by an amount that corresponds to changes in the target idle speed. As a result, the idle speed is controlled to respond to the increased load.

**[0003]** A typical vehicle includes not only an air conditioner but also other auxiliary devices that are driven by the engine. The load applied to the engine by each auxiliary device varies according to the type of the device. The target idle speed varies according to the load applied to the engine. When the engine speed changes, the friction of the engine, that is, the load acting on the engine, changes.

**[0004]** Therefore, data used for obtaining the supplementary correction amount need be determined for each type of engine auxiliary device considering the amount of change in the fuel injection amount that corresponds to changes in the target idle speed and also changes in the engine friction, which corresponds to the actual idle speed. However, determining data for each type of engine auxiliary device considering the engine friction is extremely troublesome and thus complicates the development of programs for controlling the fuel injection control. Further, if the specifications of the engine are changed, the degree of changes applied to the supplementary correction amount is changed. Thus, every time the engine specifications are changed, data for computing the supplementary correction amount must be determined for each type of auxiliary devices through experiments. In this manner, the developments of programs are complicated, and the cost is increased.

**[0005]** In the art presented in the above publication, if the engine speed is changed abruptly, passengers feel uncomfortable. Therefore, when any of the engine auxiliary devices is turned on, the supplementary correction amount is not added to the current fuel injection amount all at once but is added to the current fuel injection amount gradually. However, such gradual change procedure requires that the supplementary correction amount and the target idle speed be gradually changed in a synchronous manner. Making a program for directly changing the supplementary correction amount in a gradual manner complicates the programs and procedures for controlling the fuel injection amount.

**[0006]** In this manner, the prior art idle speed control procedure requires complicated processes for developing programs. That is, developing the programs for computing the fuel injection amount for a required idle speed increases the costs for developing the engine.

**[0007]** Accordingly, it is an object of the present invention to provide a method and an apparatus for determining fuel injection amount of an internal combustion engine that simplify programs for computing fuel injection amount for a required idle speed, thereby reducing the costs for developing the engine.

**[0008]** To achieve the foregoing and other objectives and in accordance with the purpose of the present invention, a method for determining the amount of fuel supplied to an internal combustion engine is provided. The method includes setting a first relationship, which reflects the correlation between the engine speed and the fuel supply amount, setting a second relationship, which reflects the correlation between the engine speed and the friction created in the engine, setting a target engine speed for idling based on the load acting on the engine, and obtaining a final fuel supply amount by using the first relationship and the second relationship, the final fuel supply amount being used for operating the engine at the target engine speed.

**[0009]** The present invention also proved an apparatus for determining the amount of fuel supplied to an internal combustion engine. The apparatus includes means for storing a first relationship data and a second relationship data, means for setting a target engine speed for idling based on the load acting on the engine, and means for computing a final fuel supply amount by using the first relation ship data and the second relationship data. The first relationship data reflects the correlation between the engine speed and the fuel supply amount. The second relationship data reflects the correlation between the engine speed and the friction created in the engine. The final fuel supply amount is used for operating the engine at the target engine speed.

**[0010]** Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

**[0011]** The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Fig. 1 is a diagrammatic view illustrating a common rail type diesel engine and a control system according to a first embodiment of the present invention;

Fig. 2 is a flowchart showing a routine for controlling fuel injection amount executed by the electronic control unit shown in Fig. 1;

Fig. 3 is a graph showing a map used in the routine of Fig. 2 for computing basic injection amounts tQGOV1 and tQGOV2 based on the engine speed NE and the acceleration pedal depression degree ACCP;

Fig. 4 is a flowchart showing a routine for controlling an idle speed control (ISC) procedure executed by the electronic control unit shown in Fig. 1;

Fig. 5 is a flowchart showing a routine for computing an ISC estimation correction factor executed by the electronic control unit shown in Fig. 1;

Figs. 6(A), 6(B), and 6(C) are maps used in the routine of Fig. 5;

Figs. 7(A) and 7(B) are maps used in the routine of Fig. 5;

Fig. 8 is a flowchart showing a part of a routine for an ISC procedure executed by an ECU according to a second embodiment;

Fig. 9 is a timing chart showing one example of the procedure according to the second embodiment; and

Fig. 10 is a timing chart showing a procedure according to a modification of the second embodiment.

**[0012]** Fig. 1 is a diagrammatic view illustrating an accumulator type diesel engine (a common rail type diesel engine) 1 and its control system according to a first embodiment of the present invention. The diesel engine 1 is an internal combustion engine used in a vehicle.

**[0013]** The engine 1 has four cylinders #1, #2, #3, and #4 (only one is shown in Fig. 1). An injector 2 is located in the combustion chamber of each of the cylinders #1 to #4. Each injector 2 is connected to an electromagnetic valve. Fuel injection amount from each injector 2 into the corresponding one of the cylinders #1 to #4 is controlled by a corresponding electromagnetic valve 3.

**[0014]** Each injector 2 is connected to a pressure accumulator, which is a common rail 4 in this embodiment. While the electromagnetic valve 3 is opened, fuel in the common rail 4 is injected from each injector 2 into the corresponding cylinder #1-#4. The common rail 4 maintains a relatively high pressure that corresponds to the fuel injection pressure. To maintain such a high pressure, the common rail 4 is connected a discharge port 6a of a supply pump 6 through a supply pipe 5. A check valve 7 is located in the supply pipe 5. The check valve 7 permits fuel to be supplied from the supply pump 6 to the common rail 4 and prevents fuel from flowing from the common rail 4 to the supply pump 6.

**[0015]** The supply pump 6 is connected to a fuel tank 8 through a suction port 6b. A filter 9 is located between the fuel tank 8 and the suction port 6b. The supply pump 6 draws fuel from the fuel tank 8 through the filter 9. The supply pump 6 includes a plunger and a cam. The cam is actuated in synchronization with the engine 1 and reciprocates the plunger. The plunger increases the pressure of fuel to a required level and then sends pressurized fuel to the common rail 4.

**[0016]** A pressure control valve 10 is located in the vicinity of the discharge port 6a of the supply pump 6. The pressure control valve 10 controls the injection pressure, or the pressure of fuel supplied from the discharge port 6a to the common rail 4. When the control valve 10 is open, fuel that is not discharged from the discharge port 6a, or surplus fuel, is returned to the fuel tank 8 through a return port 6c of the supply pump 6 and a return pipe 11.

**[0017]** Each combustion chamber is connected to a common intake passage 13 and a common exhaust passage 14. Each combustion chamber is selectively connected with and disconnected from the intake passage 13 by a corresponding intake valve 31. Also, each combustion chamber is selectively connected with and disconnected from the exhaust passage 14 by a corresponding exhaust valve 32. The intake valves 31 are actuated by an intake camshaft (not shown), and the exhaust valves 32 are actuated by an exhaust camshaft (not shown). The camshafts are coupled to a crankshaft (not shown) of the engine 1 through a timing belt and rotate at half rotational speed as the crankshaft.

**[0018]** A glow plug 18 is located in each combustion chamber. Each glow plug 18 is connected to a glow relay 18a. Each glow plug 18 receives current from the corresponding glow relay 18a and glows immediately before the engine 1 is started. Atomized fuel is sprayed onto the glowing glow plug 18, which promotes ignition and combustion. In this manner, the glow plugs 18 function as an ancillary equipment for starting the engine 1.

**[0019]** The engine 1 has the following sensors for detecting the running state of the engine 1. An acceleration pedal sensor 20 is located in the vicinity of an acceleration pedal 19. The pedal sensor 20 detects the depression degree ACCP of the acceleration pedal 19. A complete closure switch 21 is arranged near the acceleration pedal sensor 20. The complete closure switch 21 is turned on when the acceleration pedal 19 is not depressed and outputs a complete closure signal.

**[0020]** An air flow sensor 22 is located in the intake passage 13. The air flow sensor 22 detects the flow rate of intake air in the intake passage 13, or the amount GN of intake air drawn into the combustion chamber. A coolant temperature sensor 24 is located in the cylinder block of the engine 1. The coolant temperature sensor 24 detects the temperature THW of coolant.

**[0021]** A fuel temperature sensor 26 is located in the return pipe 11 to detect the temperature of fuel. A fuel pressure sensor 27 is located in the common rail 4 to detect the pressure PC of fuel in the common rail 4.

**[0022]** A crank rotor (not shown) is attached to the crankshaft of the engine 1. The crank rotor has circumferential projections. A crank sensor 28 is located in the vicinity of the crank rotor. The crank sensor 28 detects the projections on the crank rotor and outputs pulse signals. A cam rotor (not shown) is attached to one of the intake camshaft and the exhaust camshaft. The cam rotor has circumferential projections. A cam sensor 29 is located in the vicinity of the cam rotor. The cam sensor 29 detects the projections on the cam rotor and outputs pulse signals. The rotation speed of the crankshaft, or the engine speed NE, and the rotation angle of the crankshaft, or the crank angle CA are computed based on the pulse signals. Also, the piston in each cylinder #1-#4 is judged to be at the top dead center (TDC) based on the pulse signals.

**[0023]** A vehicle speed sensor 30 is located in the vicinity of the output shaft of a transmission (not shown). The vehicle speed sensor 30 detects the vehicle speed SPD based on the rotation speed of the output shaft.

**[0024]** The vehicle further has an air conditioner switch 34, a power steering switch 36, and an alternator control circuit 38. The air conditioner switch 34 is used for turning on and off an air conditioner, which is driven by the engine 1. The vehicle has a power steering system, which is actuated by hydraulic pressure generated by a hydraulic pump driven by the engine 1. The power steering switch 36 outputs a signal that represents whether the power steering system is functioning. The alternator control circuit 38 is located in an alternator and controls the electricity generation by the alternator through duty signal control.

**[0025]** The various control procedure of the engine 1 is executed by an electronic control unit (ECU) 40. The ECU 40 executes procedures for controlling the fuel injection amount. The ECU 40 includes a central processing unit (CPU), a read only memory (ROM) for storing various programs, maps and data, a random access memory (RAM) for temporarily storing computation results of the CPU, a backup RAM for backing up necessary data, a timer counter, an input interface, and output interface, which are connected to one another by a bus.

**[0026]** The acceleration pedal sensor 20, the air flow sensor 22, the coolant temperature sensor 34, a fuel temperature sensor 26, the fuel pressure sensor 27, the alternator control circuit 38 are connected to the input interface through a corresponding buffer, a common multiplexer, and a common analog-to-digital converter (none of which is shown), respectively. The crank sensor 28, the cam sensor 29, and the vehicle speed sensor 30 are connected to the input interface through a corresponding waveform shaping circuit (not shown), respectively. The complete closure switch 21, the air conditioner switch 34, the power steering switch 36 are directly connected to the input interface. The CPU receives signals from the sensors through the input interface.

**[0027]** The electromagnetic valve 3, the pressure control valve 10, and the glow relay 18a are connected to the output interface through a drive circuit. The CPU executes control computations based on the received signals and controls the electromagnetic valve 3, the pressure control valve 10, and the glow relay 18a.

**[0028]** A fuel injection amount control procedure, which is executed by the ECU 40, will now be described with reference to a flowchart of Fig 2. The procedure of Fig. 2 is executed in an interrupting manner at every injection. Since the engine 1 is four-cylinder type, the procedure is executed at every crank angle increments of 180°. Each step in the procedure is represented by a letter "S" accompanied by a number.

**[0029]** When the procedure is started, ECU 40 stores various information in the work area of the RAM in step S110. The stored information includes the engine speed NE detected by the NE sensor 28, the acceleration pedal depression degree ACCP detected by the acceleration pedal sensor 20, an integral correction factor QII, an idle speed control (ISC) estimated load correction factor QIPB, and an ISC estimated rotation speed correction factor QIPNT. The integral correction factor QII, the ISC estimated load correction factor QIPB, and the ISC estimated rotation speed correction factor QIPNT are computed in an ISC control procedure, which will be discussed below.

**[0030]** In step S120, the ECU 40 computes an idling basic injection amount tQGOV1 and a vehicle moving basic injection amount tQGOV2 by referring to a map shown in Fig 3. The map of Fig. 3 defines the relationship of the basic injection amounts tQGOV1, tQGOV2 with the engine speed NE and the acceleration pedal depression degree ACCP. As shown in the map of Fig. 3, the idling basic injection amount tQGOV1 is shown by broken lines and corresponds to a low speed range of the engine 1, that is, to the idling state or a state proximate to the idling state. The vehicle moving basic injection amount tQGOV2 is shown by solid lines and corresponds to a high speed range of the engine 1, that is, to a state in which the vehicle is moving.

**[0031]** In step S130, the ECU 40 adds the integral correction factor QII, the ISC estimated load correction factor QIPB, and the ISC estimated rotation speed correction factor QIPNT to the idling basic injection amount tQGOV1, and adds the ISC estimated load correction factor QIPB to the vehicle moving basic injection amount tQGOV2. The ECU 40 compares the sums and sets the greater one as a corrected injection amount QGOV. Therefore, as shown in Fig. 3, when the engine speed NE is relatively low, engine 1the corrected injection amount QGOV is mostly computed by adding values to the idling basic injection amount tQGOV1. When the engine speed is relatively high, the corrected injection amount QGOV is mostly computed by adding values to the vehicle moving basic injection amount tQGOV2.

**[0032]** In step S140, the ECU 40 computes a maximum injection amount QFULL. The maximum injection amount QFULL is the upper limit value of the amount of fuel injected into the combustion chambers, and is determined to suppress an abrupt increase of smoke from the combustion chambers and to prevent the torque from being excessive.

**[0033]** In step S150, the ECU 40 sets the smaller one of the maximum injection amount QFULL and the corrected injection amount QGOV as a final injection amount QFIN. In step S160, the ECU 40 computes an injection period TSP, which corresponds to the final injection amount QFIN. In step S170, the ECU 40 outputs the injection period TSP, and then temporarily suspends the current routine. Each electromagnetic valve 3 is controlled based on the injection period TSP. Then, the corresponding injector 2 injects fuel the amount of which corresponds to the final injection amount QFIN.

**[0034]** Fig. 4 shows a flowchart of an idle speed control (ISC) procedure. The procedure of Fig. 4 is executed in an interrupting manner at every injection.

**[0035]** When the procedure is started, ECU 40 stores various information in the work area of a RAM in step S210. The stored information includes the acceleration pedal depression degree ACCP detected by the pedal sensor 20, the on-off state of the complete closure switch 21, the coolant temperature THW detected by the coolant temperature sensor 24, the engine speed NE detected by the NE sensor 28, the vehicle speed SPD detected by the vehicle speed sensor 30, the on-off state of the air conditioner switch 34, the on-off state of the power steering switch 36, and an alternator control duty ratio DU generated by the alternator control circuit 38.

**[0036]** In step S220, the ECU 40 judges whether the engine 1 is currently idling. For example, if the acceleration pedal depression degree ACCP is 0%, the complete closure switch 21 is on, and the vehicle speed SPD is 0km/h, the ECU 40 judges that the engine 1 is idling.

**[0037]** If the engine 1 is not idling, or if the outcome of step S220 is negative, the ECU 40 temporarily suspends the current routine.

**[0038]** If the engine 1 is idling, or if the outcome of step S220 is positive, the ECU 40 proceeds to step S230. In step S230, the ECU 40 sets an idle target speed NETRG that is appropriate for the on-off state of the air conditioner, the on-off state of the power steering system, the electrical load represented by the duty ratio DU, and the coolant temperature THW. The ECU 40 determines the target idle speed NETRG based on maps and data stored in the ROM. For example, the target idle speed NETRG is set relatively high if the air conditioner is on, the power steering system is on, the electrical load is high, and the coolant temperature THW is low.

**[0039]** In step S240, the ECU 40 computes the difference NEDL between the idle target speed NETRG and the actual engine speed NE through the following formula 1.

[Formula 1]

$$NEDL \leftarrow NETRG - NE$$

**[0040]** In step S250, the ECU 40 computes an integral amount ΔQII based on the difference NEDL by referring to a map stored in the ROM. If the difference NEDL has a positive value, the integral amount ΔQII is set to a positive value, and if the difference NEDL has a negative value, the integral amount ΔQII is set a negative value.

**[0041]** In step S260, the ECU 40 adds the integral amount ΔQII of the current control cycle to an integral correction factor QII(i-1) of the fuel injection amount computed in the preceding control cycle. The ECU 40 sets the resultant as the current integral correction factor QII(i).

**[0042]** In step S270, the ECU 40 executes a procedure for an ISC estimation correction factor computation. When completing step S270, the ECU 40 temporarily suspends the current routine.

**[0043]** Fig. 5 is a flowchart showing the ISC estimation correction factor computation. In step S310 of this procedure, the ECU 40 computes the ISC estimated rotation speed correction factor QIPNT of fuel injection amount based on a function Fx of the following formula 2.

[Formula 2]

$$QIPNT \leftarrow Ax * (NETRG - NETRGbs)$$

**[0044]** Sign Ax represents the gradient of the basic injection amount tQGOV1 or tQGOV2 when the acceleration pedal depression degree ACCP is 0% in the map of Fig. 3. In other words, the value Ax represents the relationship of the basic injection amount tQGOV1 or tQGOV2 with the engine speed NE when the engine 1 receives no load. If the corrected injection amount QGOV is set based on the idling basic injection amount tQGOV1 in step S130 of Fig. 2, the value Ax that corresponds to the idling basic injection amount tQGOV1 is used in the formula 2. If the corrected injection amount QGOV is set based on the vehicle moving basic injection amount tQGOV2 in step S130 of Fig. 2, the value Ax that corresponds to the vehicle moving basic injection amount tQGOV2 is used in the formula 2. Sign NETRGbs is a referential idle speed and represents the lowest idle speed, which is used when no load is applied to the engine 1 and warming of the engine 1 is completed

**[0045]** The rotation speed correction factor QIPNT represents the amount of fuel shortage or fuel excess created due to changes of the target idle speed NETRG in the computation using the map of Fig. 3. In other words, the rotation speed correction factor QIPNT corresponds to the amount of a change in the fuel injection amount that needs be made in accordance with a change in the target idle speed NETRG.

**[0046]** In step S320, the ECU 40 computes a friction correction factor QIPBB based on the actual engine speed NE by referring to a map shown in Fig 6(A). The map of Fig. 6(A) represents the relationship between the engine speed NE and the friction generated in the engine 1. The friction in the engine 1 changes according to the engine speed NE. The friction correction factor QIPBB is used for reflecting changes of the friction according to the engine speed NE to the fuel injection amount.

**[0047]** In step S330, the ECU 40 computes a low temperature correction factor QIPBCL based on the coolant temperature THW by referring to a map shown in Fig 6 (B). The friction in the engine 1 changes according to the coolant temperature THW, which reflects the engine temperature. Specifically, when the engine 1 is cold, the friction is increased. The low temperature correction factor QIPBCL is used for reflecting changes of the friction according to the coolant temperature THW to the fuel injection amount.

**[0048]** In step S340, the ECU 40 computes an electrical load correction factor QIPBDF based on the duty ratio DU by referring to a map shown in Fig 6(C). The vehicle includes various electricity consuming devices such as glow plugs 18 and head lights. The alternator control circuit 38 adjusts the control duty ratio DU, which is sent to the alternator, to increase the electricity generation of the alternator according to an increase of the electricity used by such devices. The electrical load correction factor QIPBDF is used for reflecting changes of the control duty ratio DU, which reflects the electricity consumption by the electricity consuming devices, to the fuel injection amount.

**[0049]** In step S350, the ECU 40 judges whether the air conditioner is operating. If the air conditioner is operating, or if the outcome of step S350 is positive, the ECU 40 proceeds to step S360. In step S360, the ECU 40 computes an air conditioner correction factor QIPBAC based on the actual engine speed NE by referring to a map of Fig. 7(A). The air conditioner correction factor QIPBAC is used for reflecting the engine load due to the operation of the air conditioner to the fuel injection amount and is adjusted according to the engine speed NE.

**[0050]** If the air conditioner is not operating, or if the outcome of step S350 is negative, the ECU 40 proceeds to step S370. In step S370, the ECU 40 sets the air conditioner correction factor QIPBAC to zero.

**[0051]** In step S380, the ECU 40 judges whether the power steering system is operating. If the power steering system is operating, or if the outcome of step S380 is positive, the ECU 40 proceeds to step S390. In step S390, the ECU 40 computes a power steering correction factor QIPBPS based on the actual engine speed NE by referring to a map of Fig. 7(B). The power steering correction factor QIPBPS is used for reflecting the engine load due to the operation of the power steering system to the fuel injection amount and is adjusted according to the engine speed NE.

**[0052]** If the power steering system is not operating, or if the outcome of step S380 is negative, the ECU 40 proceeds to step S400. In step S400, the ECU 40 sets the power steering correction factor QIPBPS to zero.

**[0053]** In step S410, the ECU 40 computes the sum of the friction correction factor QIPBB, the cool start correction factor QIPBCL, the electrical load correction factor QIPBDF, the air conditioner correction factor QIPBAC, and the power steering correction factor QIPBPS. The ECU 40 sets the resultant as the load correction factor QIPB.

**[0054]** The rotation speed correction factor QIPNT and the load correction factor QIPB are computed in the above described manner and are reflected to the corrected injection amount QGOV, which is computed in step S130 of fuel injection amount control procedure (Fig. 2). Therefore, the corrected injection amount QGOV is determined such that the engine speed NE seeks the idling target speed NETRG, which corresponds to various loads acting on the engine 1.

**[0055]** The first embodiment has the following advantages.

**[0056]** (A) The value AX, which represents the relationship between the engine speed NE and the basic injection amount tQGOV1, tQGOV2, is used for computing the rotation speed correction factor QIPNT. The rotation speed correction factor QIPNT corresponds to the amount of a change in the fuel injection amount that needs be made in accordance with a change in the target idle speed NETRG. The map of Fig. 6(A) is used for computing the friction correction factor QIPBB based on the engine speed NE. The friction correction factor QIPBB is used for reflecting changes of the engine friction according to the actual engine speed NE to the fuel injection amount. The map of Fig. 6(A) is independently stored in the ROM of the ECU 40 from the value Ax and the maps for obtaining the correction factors other than the friction correction factor QIPBB.

**[0057]** Engine auxiliary devices, or external load devices, such as the air conditioner and the power steering system are driven by the power of the engine 1 and applies load to the engine 1. The load applied to the engine 1 varies according to the type of each auxiliary device. The target idle speed NETRG is determined according to the load acting on the engine 1. The fuel injection amount is controlled such that the actual engine speed NE seeks the determined target idle speed NETRG. When the actual engine speed NE changes, the friction in the engine 1 is changed, accordingly. Therefore, the fuel injection amount need be corrected according to changes in the engine friction.

**[0058]** However, as described above, the amount of a change in the fuel injection amount that needs be made in accordance with a change in the target idle speed NETRG is corrected by the rotation speed correction factor QIPNT. Further, a change in the engine friction caused by a change in the actual engine speed NE is corrected by adjusting the fuel injection amount by using the friction correction factor QIPBB. The friction correction factor QIPBB is independently computed from the other correction factors QIPNT, QIPBCL, QIPBDF, QIPBAC, QIPBPS. Specifically, the friction correction factor QIPBB is computed by using the map of Fig. 6(A), which is specially designed for computing the fiction correction factor QIPBB. Therefore, by referring to the map of Fig. 6(A), the friction correction factor QIPBB is easily determined based only on the actual engine speed NE. Data for obtaining a fuel injection correction value that corresponds to the engine friction need not be determined for each type of engine auxiliary device. Also, the rotation speed correction factor QIPNT is easily computed based on the target idle speed NETRG by referring to the formula 2. As a result, the correction factors are easily computed according to changes in the target idle speed NETRG.

**[0059]** As described above, data for obtaining a fuel injection correction value that corresponds to the target idle speed NETRG need not be determined for each of the engine auxiliary devices. This facilitates the development of the programs for controlling the fuel injection.

**[0060]** Since the value Ax is included in the design of the program, only the map of Fig. 6(A) for computing the friction correction factor QIPBB need be obtained through experiments when the specification of the engine 1 is changed. In other words, data for computing the fuel injection correction amount need not be determined for each type of engine auxiliary device, which reduces the development costs.

**[0061]** When target idle speed NETRG is changed, the rotation speed correction factor QIPNT is automatically changed through step S310 of Fig. 5. Accordingly, the actual engine speed NE is changed, and, through step S320, the friction correction factor QIPBB is changed, accordingly. Thus, there is no need for a computation for adjusting the friction correction factor QIPBB to follow changes in the target idle speed NETRG. Accordingly, the program is simplified.

**[0062]** Therefore, the program for computing the fuel injection amount for operating the engine 1 at a required idling speed is simplified. This simplifies the development of the programs for controlling fuel injection amount. The cost of developing the engine 1 is reduced, accordingly.

**[0063]** (B) The air conditioner correction factor QIPBAC, the power steering correction factor QIPBPS, the cool start correction factor QIPBCL, and the electrical load correction factor QIPBDF are computed separately from the rotation speed correction factor QIPNT and the friction correction factor QIPBB. The correction factors QIPBAC, QIPBPS, QIPBCL, and QIPBDF are computed according to the engine speed NE, the coolant temperature THW, the duty ratio DU. Therefore, the fuel injection amount for adjusting the idle speed to correspond to the loads acting on the engine 1 is reliably computed.

**[0064]** A second embodiment of the present invention will now be described. Instead of step S230 of the ISC control procedure (Fig. 4) of the first embodiment, a procedure of Fig. 8 is executed in the second embodiment. Other structures are the same as the first embodiment.

**[0065]** If the outcome of step S220 of Fig. 4 is positive, the ECU 40 proceeds to step S510 of Fig. 8. In step S510, the ECU 40 determines a referential target idle speed tNETRG that correspond to the on-off state of the air conditioner, the on-off state of the power steering system, the electrical load represented by the duty ratio DU of the alternator control, and the coolant temperature THW.

**[0066]** In step S520, the ECU 40 judges whether the current control cycle is the first one after the engine 1 was started. If the current cycle is the first one, or if the outcome of step S520 is positive, the ECU 40 proceeds to step S530. In step S530, the ECU 40 initializes the target idle speed NETRG with the referential target idle speed tNETRG. If the current routine is not the first one, or if the outcome of step S520 is negative, the ECU 40 maintains the current target idle speed NETRG.

**[0067]** In step S540, the ECU 40 judges whether the formula 3 is satisfied.

[Formula 3]

$$NETRG + dNE < tNETRG$$

**[0068]** The sign dNE represents a gradual change margin and is determined such that a change of the engine speed NE due to an increase in the target idle speed NETRG does not disturb the passengers.

**[0069]** When the step S540 is executed for the first time, that is, when the process moves from the step S530 to step S540, the NETRG is equal to tNETRG. Thus, the formula 3 is not satisfied, and the outcome of step S540 is negative. Therefore, the ECU 40 proceeds to step S550 and judges whether the formula 4 is satisfied.

[Formula 4]

$$NETRG - dNE > tNETRG$$

**[0070]** When step S550 is executed for the first time, that is when the process moves from step S530 to step S540, NETRG is equal to tNETRG. Thus, the formula 4 is not satisfied, or the outcome of step S550 is negative. In this case, the ECU 40 proceeds to step S560. In step S560, the ECU 40 substitutes the referential target idle speed tNETRG for the target idle speed NETRG and then proceeds to step S240 of Fig 4. In subsequent steps S240 of Fig. 4 and S310 of Fig. 5, the target idle speed NETRG, which is equal to the referential target idle speed tNETRG, is used for computing the difference NEDL and the rotation speed correction factor QIPNT.

**[0071]** Next, the case when the current execution of the control cycle is a second or later time from when the engine 1 is started, that is, the case when the step S530 is not executed, will be described. If the difference between the referential target idle speed tNETRG, which is computed in step S510, and the current target idle speed NETRG is less than the gradual change margin dNE, the outcomes of steps S540 and S550 are negative. In this case, the ECU 40 proceeds to step S560. In step S560, the ECU 40 sets the referential target idle speed tNETRG, which was computed in the current cycle, as a new value of the target idle speed NETRG.

**[0072]** If, for example, the air conditioner is turned on in this state, the load acting on the engine 1 is increased. Then, the referential target idle speed tNETRG, which is computed in step S510, becomes significantly greater than the value of the referential target idle speed tNETRG that was computed in the previous control cycle, that is, than the current value of the target idle speed NETRG.

**[0073]** If the referential target idle speed tNETRG exceeds the sum of the current target idle speed NETRG and the gradual change margin dNE, the formula 3 is satisfied and the outcome of step S540 is positive. In this case, the ECU 40 proceeds to step S570 and computes the target idle speed NETRG through the following formula 5.

[Formula 5]

$$NETRG \leftarrow NETRG + dNE$$

**[0074]** That is, the target idle speed NETRG is increased by the gradual change margin dNE.

**[0075]** In subsequent steps S240, S310, the target idle speed NETRG, which is computed by adding the gradual change margin dNE to the target idle speed NETRG from the previous control cycle, is used for computing the difference NEDL and the rotation speed correction factor QIPNT.

**[0076]** If the formula 3 is satisfied in the subsequent control procedure, or if the outcome of step S540 is positive, the ECU 40 proceeds to step S570 and increases the target idle speed NETRG by the gradual change margin dNE through the formula 5.

**[0077]** In this manner, the target idle speed NETRG is gradually increased until the formula 3 is not satisfied, or until the outcome of step S540 is negative. If the outcome of step S540 was positive in the previous control cycle and is negative in the current control cycle, the difference between the current target idle speed NETRG and the current referential target idle speed tNETRG is equal to or less than the gradual change margin dNE. In this case, the outcome of the subsequent step S550 is negative. Accordingly, the ECU 40 proceeds to step S560 and sets the referential target idle speed tNETRG as the target idle speed NETRG. Therefore, in the subsequent steps S240, S310, the target idle speed NETRG, which is set to the referential target idle speed tNETRG, is used for computing the difference NEDL and the rotation speed correction factor QIPNT.

**[0078]** Thereafter, the referential target idle speed tNETRG continues to be used as the target idle speed NETRG as long as the referential target idle speed tNETRG is not changed to exceed the gradual change margin dNE.

**[0079]** If the air conditioner is turned off, the formula NETRG - dNE > tNETRG is satisfied. In this case, the formula 4 is satisfied and the outcome of step S550 is positive. Therefore, the ECU 40 computes the target idle speed NETRG through the following formula 6.

[Formula 6]

$$NETRG \leftarrow NETRG - dNE$$

**[0080]** The target idle speed NETRG is decreased by the gradual change margin dNE.

**[0081]** In subsequent steps S240, S310, the target idle speed NETRG, which is computed by subtracting the gradual change margin dNE from the target idle speed NETRG from the previous control cycle, is used for computing the difference NEDL and the rotation speed correction factor QIPNT.

**[0082]** If the formula 4 is satisfied in the subsequent control cycle, or if the outcome of step S550 is positive, the ECU 40 proceeds to step S580 and decreases the target idle speed NETRG by the gradual change margin dNE through the formula 6.

**[0083]** In this manner, the target idle speed NETRG is gradually decreased until the formula 4 is not satisfied, or until the outcome of step S550 is negative. If the outcome of step S550 was positive in the previous control cycle and is negative in the current control cycle, the difference between the current target idle speed NETRG and the current referential target idle speed tNETRG is equal to or less than the gradual change margin dNE. In this case, the ECU 40 sets the referential target idle speed tNETRG as the target idle speed NETRG in step the subsequent step S560. Therefore, in the subsequent steps S240, S310, the target idle speed NETRG, which is set to the referential target idle speed tNETRG, is used for computing the difference NEDL and the rotation speed correction factor QIPNT.

**[0084]** Thereafter, the referential target idle speed tNETRG continues to be used as the target idle speed NETRG as long as the referential target idle speed tNETRG is not changed to exceed the gradual change margin dNE.

**[0085]** One example of the procedure according to the second embodiment will now be described with reference to the timing chart of Fig. 9. When the air conditioner switch 34 is turned on at time t0, the referential target idle speed tNETRG is set to a value that represents the load due to the air conditioner. However, the target idle speed NETRG is gradually increased to the referential target idle speed tNETRG in a period from time t0 to time t1. As the target idle speed NETRG is gradually changed, the rotation speed correction factor QIPNT is gradually changed. As the rotation speed correction factor QIPNT is gradually changed, the actual engine speed NE is gradually changed. As the actual engine speed NE is gradually changed, the friction correction factor QIPBB, the air conditioner correction factor QIPBAC, and the ISC estimated load correction factor QIPB are gradually changed.

**[0086]** Therefore, the friction correction factor QIPBB need not be directly controlled to be gradually changed. That is, when the target idle speed NETRG is directly controlled to change gradually, the friction correction factor QIPBB automatically follows changes in the target idle speed NETRG. Also, the actual engine speed NE is gradually changed.

**[0087]** When the air conditioner switch 34 is turned off as shown in Fig. 9 (time t2 to time t3), the control values related to the fuel injection amount control are changed in the same manner as when the air conditioner switch 34 is turned on. Also, when the power steering system is turned on or off, the control values related to the fuel injection amount control are changed in the same manner as when the air conditioner switch 34 is turned on or off.

**[0088]** In addition to the advantages of the first embodiment, the second embodiment has the following advantages.

**[0089]** (A) As shown in the ISC estimation correction factor computation procedure of Fig. 5, the rotation speed correction factor QIPNT is changed by simply changing the target idle speed NETRG. Accordingly, the actual engine speed NE is changed, and the friction correction factor QIPBB, the air conditioner correction factor QIPBAC, and the power steering correction factor QIPBPS are changed.

**[0090]** When the load acting on the engine 1 is changed, the target idle speed NETRG is gradually changed according to the engine load such that the target idle speed NETRG seeks the referential target idle speed tNETRG. Accordingly, the correction factors QIPNT, QIPBB, QIPBAC, QIPBPS are changed to correspond to the target idle speed NETRG.

**[0091]** Therefore, when changing the target idle speed NETRG, the engine speed NE is prevented from being abruptly changed, which prevents the passengers from being disturbed. Also, such a precise procedure is performed without procedures for controlling the correction factors QIPNT, QIPBB, QIPBAC, and QIPBPS according to the target idle speed NETRG. This simplifies the program and reduces the development costs.

**[0092]** It should be apparent to those skilled in the art that the present invention may be embodied in many other specific forms without departing from the spirit or scope of the invention. Particularly, it should be understood that the invention may be embodied in the following forms.

**[0093]** In the illustrated embodiment, the friction correction factor QIPBB, the air conditioner correction factor QIPBAC, and the power steering correction factor QIPBPS are computed by using the actual engine speed NE as a parameter in the maps. However, the correction factors QIPBB, QIPBAC, and QIPBPS may be computed by using the target idle speed NETRG as a parameter in the same maps. In this case, if the target idle speed NETRG is gradually changed as in the second embodiment, the values change as in the timing chart of Fig. 10.

**[0094]** In the illustrated embodiment, the accumulator type diesel engine 1 is used. However, other types of diesel engine may be used. For example, the present invention may be applied to an in-line fuel injection system and a distributor type injection system.

**[0095]** Therefore, the present examples and embodiments are to be considered as illustrative and not restrictive and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalence of the appended claims.

**[0096]** The amount of a change in the fuel injection amount that needs be made in accordance with a change in the target idle speed NETRG is corrected by the rotation speed correction factor QIPNT. When the engine friction is changed due to a change in the actual engine speed NE, the fuel injection amount is adjusted by using a friction correction factor QIPBB. The friction correction factor QIPBB is obtained independently from the other correction factors and by using a specially designed map. Therefore, all the correction factors are easily computed in accordance with changes in the target idle speed NETRG, which facilitates the development of programs for controlling fuel injection.

## Claims

1. A method for determining the amount of fuel supplied to an internal combustion engine, **characterized by**:

   setting a first relationship, which reflects the correlation between the engine speed and the fuel supply amount;
   setting a second relationship, which reflects the correlation between the engine speed and the friction created in the engine;
   setting a target engine speed for idling based on the load acting on the engine; and
   obtaining a final fuel supply amount by using the first relationship and the second relationship, the final fuel supply amount being used for operating the engine at the target engine speed.

2. The method according to claim 1, **characterized in that** the first relationship represents the correlation between the engine speed and the fuel supply amount in a state where the engine is receiving no

load.

3. The method according to claim 1, **characterized in that** the first relationship represents the correlation between the engine speed and the fuel supply amount in a state where the engine is idling and receiving no load.

4. The method according to any one of claims 1 to 3, **characterized by** obtaining a first fuel correction factor by using the first relationship and based on the difference between the current target engine speed and a referential engine speed, which is required when the engine is receiving no load, wherein the first fuel correction factor is used for computing the final fuel supply amount.

5. The method according to any one of claims 1 to 3, **characterized by** obtaining a first fuel correction factor by using the first relationship and based on the current target engine speed, wherein the first fuel correction factor is used for computing the final fuel supply amount.

6. The method according to any one of claims 1 to 5, **characterized in that** the second relationship defines the relationship between the engine speed and a second fuel correction factor, which corresponds to the engine friction, the method further comprising obtaining the second fuel correction factor based on the actual engine speed or the target engine speed and by using the second relationship, and wherein the second fuel correction factor is used for computing the final fuel supply amount.

7. The method according to any one of claims 1 to 6, **characterized by** obtaining a third fuel correction factor, which corresponds to an external load device driven by the engine, wherein the third fuel correction factor is used for computing the final fuel supply amount.

8. The method according to claim 7, **characterized in that** the third fuel correction factor is changed according to the actual engine speed or the target engine speed.

9. The method according to any one of claims 1 to 3, **characterized by**:

obtaining a basic fuel supply amount, which is required by the engine during idling;
obtaining a first fuel correction factor by using the first relationship, wherein the first fuel correction factor corresponds to the amount of a change in the fuel supply amount in accordance with a change in the target engine speed;
obtaining a second fuel correction factor by using the second relationship, the second fuel correction factor corresponding to the engine friction;
obtaining a third fuel correction factor, which corresponds to an external load device driven by the engine; and
correcting the basic fuel supply amount according to the first to third fuel correction factors, thereby obtaining the final fuel supply amount.

10. The method according to claim 9, **characterized in that** the first fuel correction factor is obtained based on the target engine speed and by using the first relationship, the second fuel correction factor is obtained based on the actual engine speed and by using the second relationship, and wherein the third fuel correction factor is changed according to the actual engine speed.

11. The method according to claim 9, **characterized in that** the first fuel correction factor is obtained based on the target engine speed and by using the first relationship, the second fuel correction factor is obtained based on the target engine speed and by using the second relationship, and wherein the third fuel correction factor is changed according to the target engine speed.

12. The method according to any one of claims 1 to 11, **characterized in that** the target engine speed is gradually changed to approach a value that is suitable for the load acting on the engine.

13. A method for determining the amount of fuel supplied to an internal combustion engine, **characterized by**:

setting a target engine speed for idling based on the load acting on the engine;
obtaining a basic fuel supply amount for idling based on the engine speed;
obtaining a first fuel correction factor by using a first relationship, which reflects the correlation between the engine speed and the basic fuel supply amount, wherein the first fuel correction factor corresponds to the amount of a change in the fuel supply amount in accordance with a change in the target engine speed;
obtaining a second fuel correction factor by using a second relationship, which reflects the correlation between the engine speed and the friction created in the engine, the second fuel correction factor corresponding to the engine friction; and
correcting the basic fuel supply amount according to the first and second fuel correction factors, thereby obtaining a final fuel supply amount, the final fuel supply amount being

used for operating the engine at the target engine speed.

**14.** An apparatus for determining the amount of fuel supplied to an internal combustion engine, being **characterized by**:

means for storing a first relationship data, which reflects the correlation between the engine speed and the fuel supply amount, and a second relationship data, which reflects the correlation between the engine speed and the friction created in the engine;
means for setting a target engine speed for idling based on the load acting on the engine; and
means for computing a final fuel supply amount by using the first relationship data and the second relationship data, the final fuel supply amount being used for operating the engine at the target engine speed.

**15.** The apparatus according to claim 14, **characterized in that** the computing means obtains a first fuel correction factor by using the first relationship data and based on the difference between the current target engine speed and a referential engine speed, which is required when the engine is receiving no load, wherein the computing means uses the first fuel correction factor for computing the final fuel supply amount.

**16.** The apparatus according to claim 14 or 15, **characterized in that** the storing means stores the relationship between the engine speed and a second fuel correction factor, which corresponds to the engine friction, as the second relationship data, wherein the computing means obtains the second fuel correction factor based on the actual engine speed or the target engine speed and by using the second relationship data, and wherein the computing means uses the second fuel correction factor for computing the final fuel supply amount.

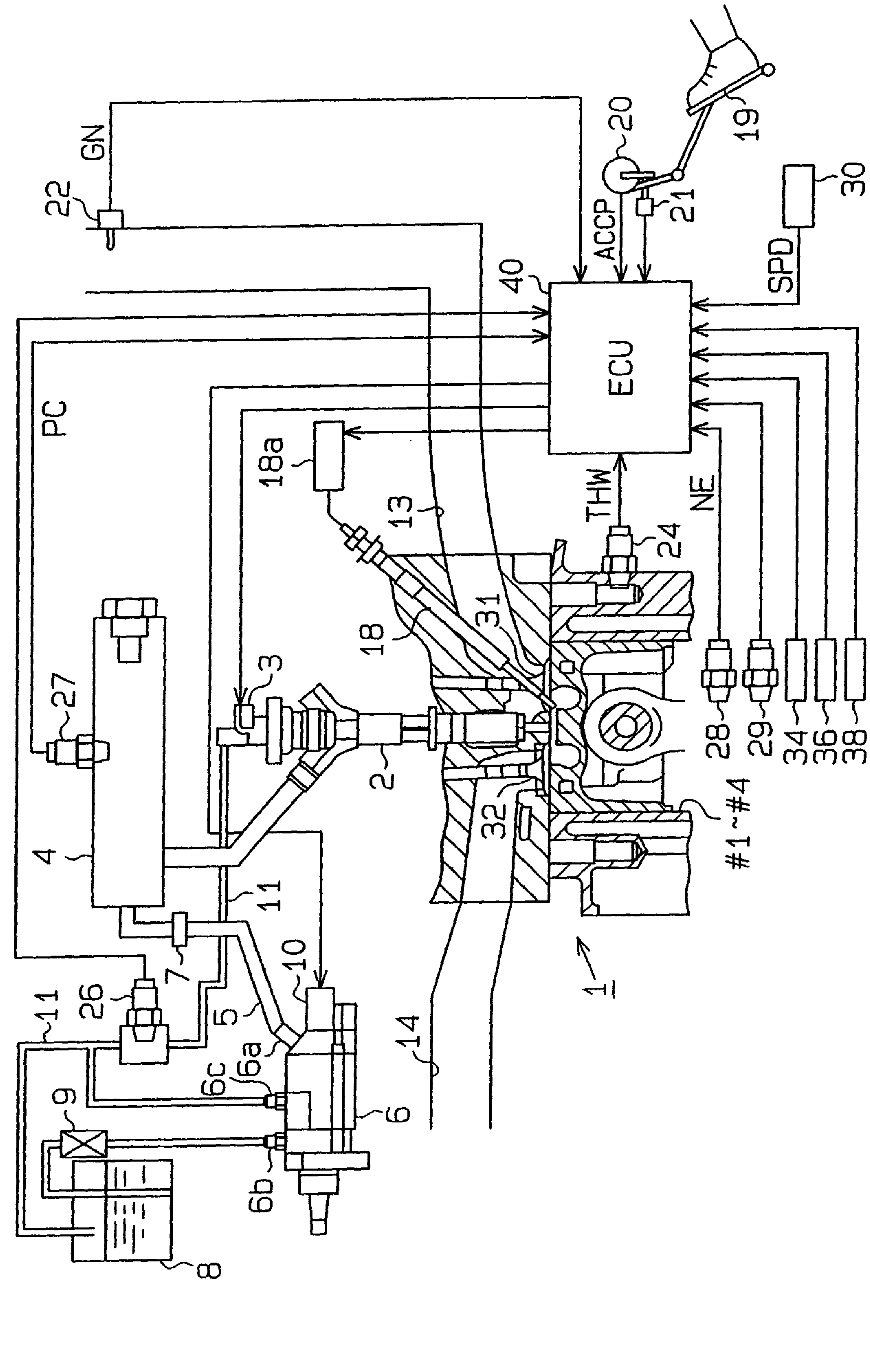
**17.** The apparatus according to any one of claims 14 to 16, **characterized in that** the computing means obtains a third fuel correction factor, which corresponds to an external load device driven by the engine, wherein the computing means uses the third fuel correction factor for computing the final fuel supply amount.

**18.** The apparatus according to claim 17, **characterized in that** the storing means stores a third relationship data, which represents the relationship between the engine speed and the third fuel correction factor, and wherein the computing means obtains the third fuel correction factor based on the actual engine speed or the target engine speed and by using the third relationship data.

**19.** The apparatus according to any one of claims 14 to 18, **characterized in that** the setting means gradually changes the target engine speed to approach a value that is suitable for the load acting on the engine.

**20.** The apparatus according to any one of claims 14 to 19, **characterized in that** the engine is a diesel engine.

Fig.1


ECU
40
PC
GN
22
ACCP
20
21
19
SPD
30
THW
NE
24
13
18a
18
31
3
27
4
2
32
28
29
34
36
38
#1~#4
11
10
7
26
5
6a
6c
6
6b
9
8
14
1

# Fig.2

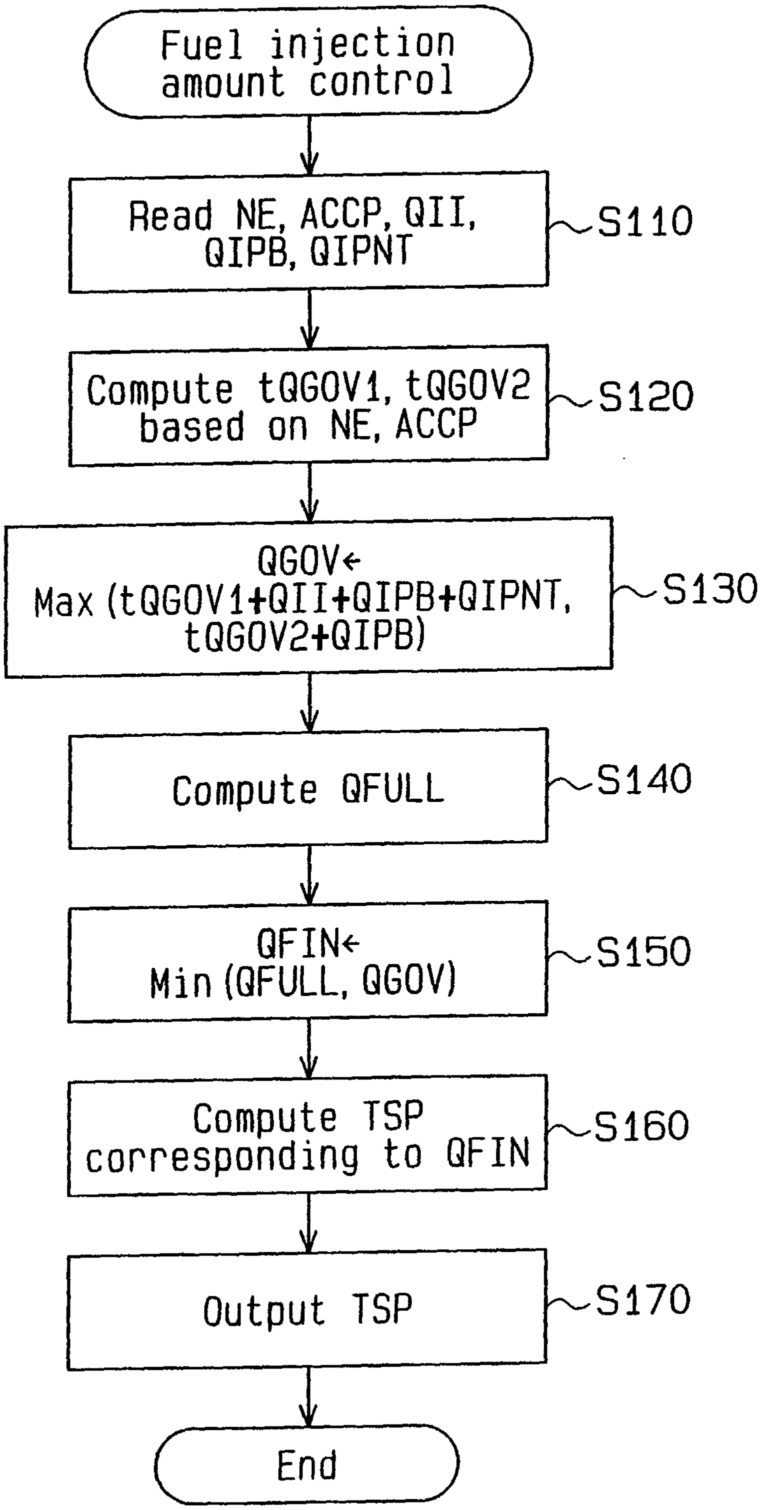

Fuel injection amount control
Read NE, ACCP, QII, QIPB, QIPNT
S110
Compute tQGOV1, tQGOV2 based on NE, ACCP
S120
QGOV←
Max (tQGOV1+QII+QIPB+QIPNT, tQGOV2+QIPB)
S130
Compute QFULL
S140
QFIN←
Min (QFULL, QGOV)
S150
Compute TSP corresponding to QFIN
S160
Output TSP
S170
End

Fig.3

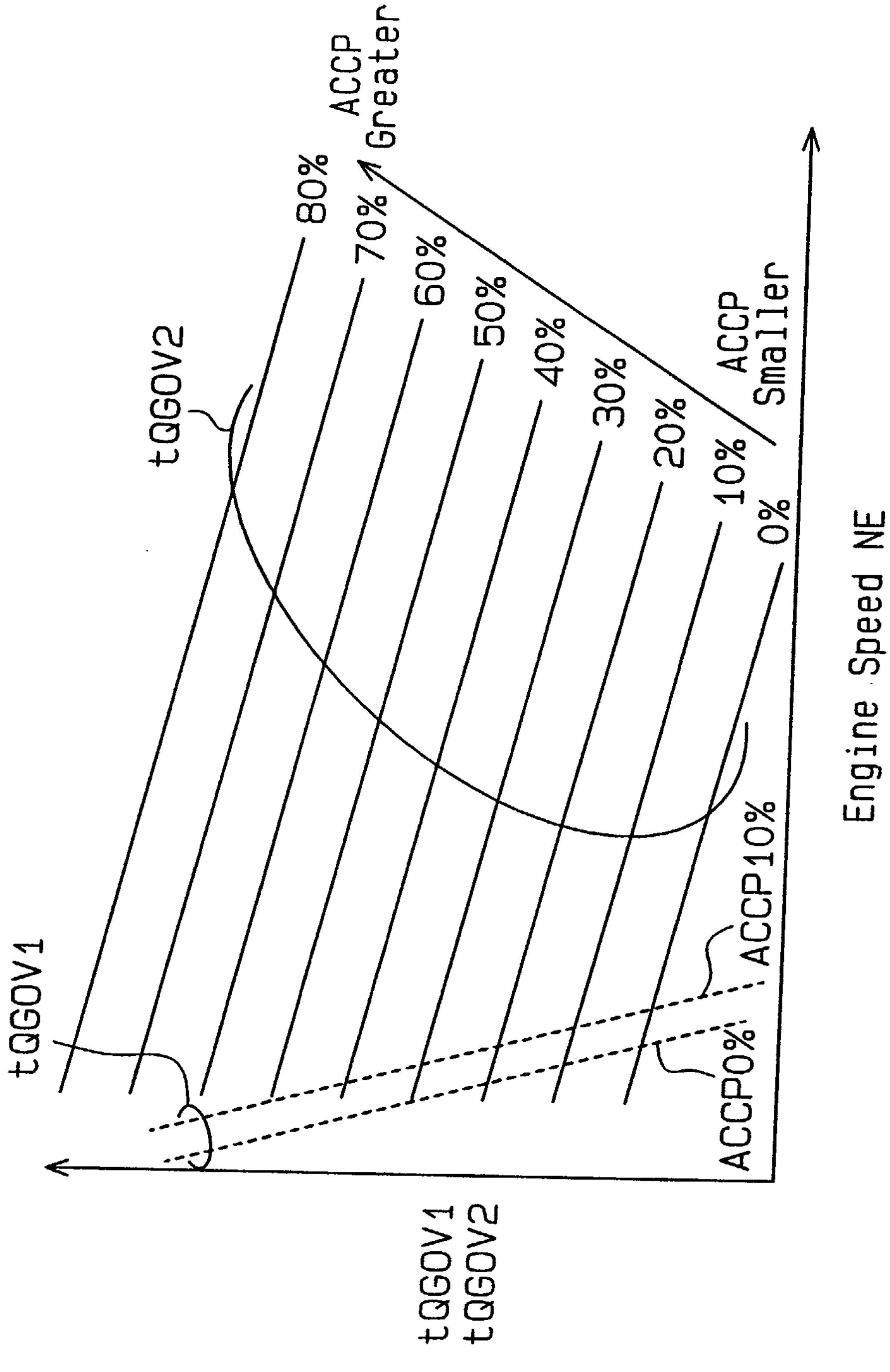
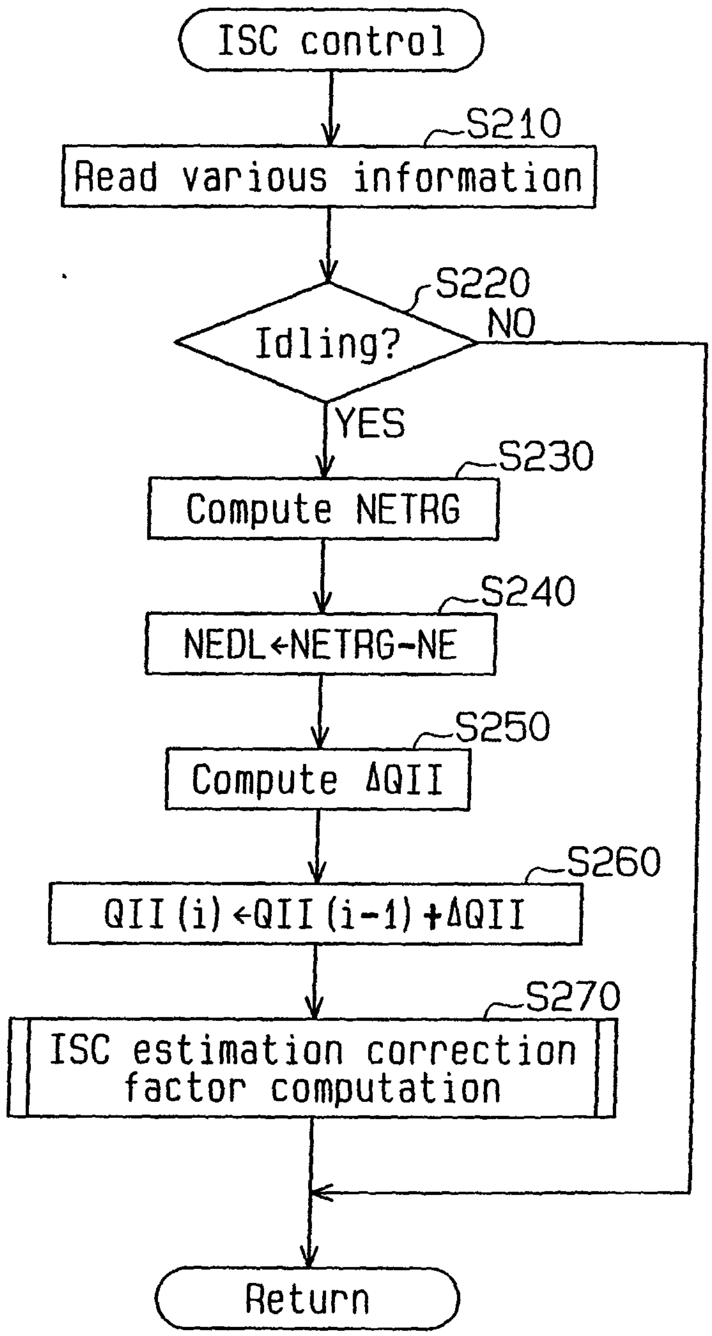

ACCP
Greater
80%
70%
60%
50%
40%
30%
20%
10%
0%
ACCP
Smaller
tQGOV2
tQGOV1
ACCP10%
ACCP0%
Engine Speed NE
tQGOV1
tQGOV2

Fig.4


ISC control
S210
Read various information
S220
Idling?
NO
YES
S230
Compute NETRG
S240
NEDL←NETRG-NE
S250
Compute ΔQII
S260
QII(i)←QII(i-1)+ΔQII
S270
ISC estimation correction factor computation
Return

# Fig.5

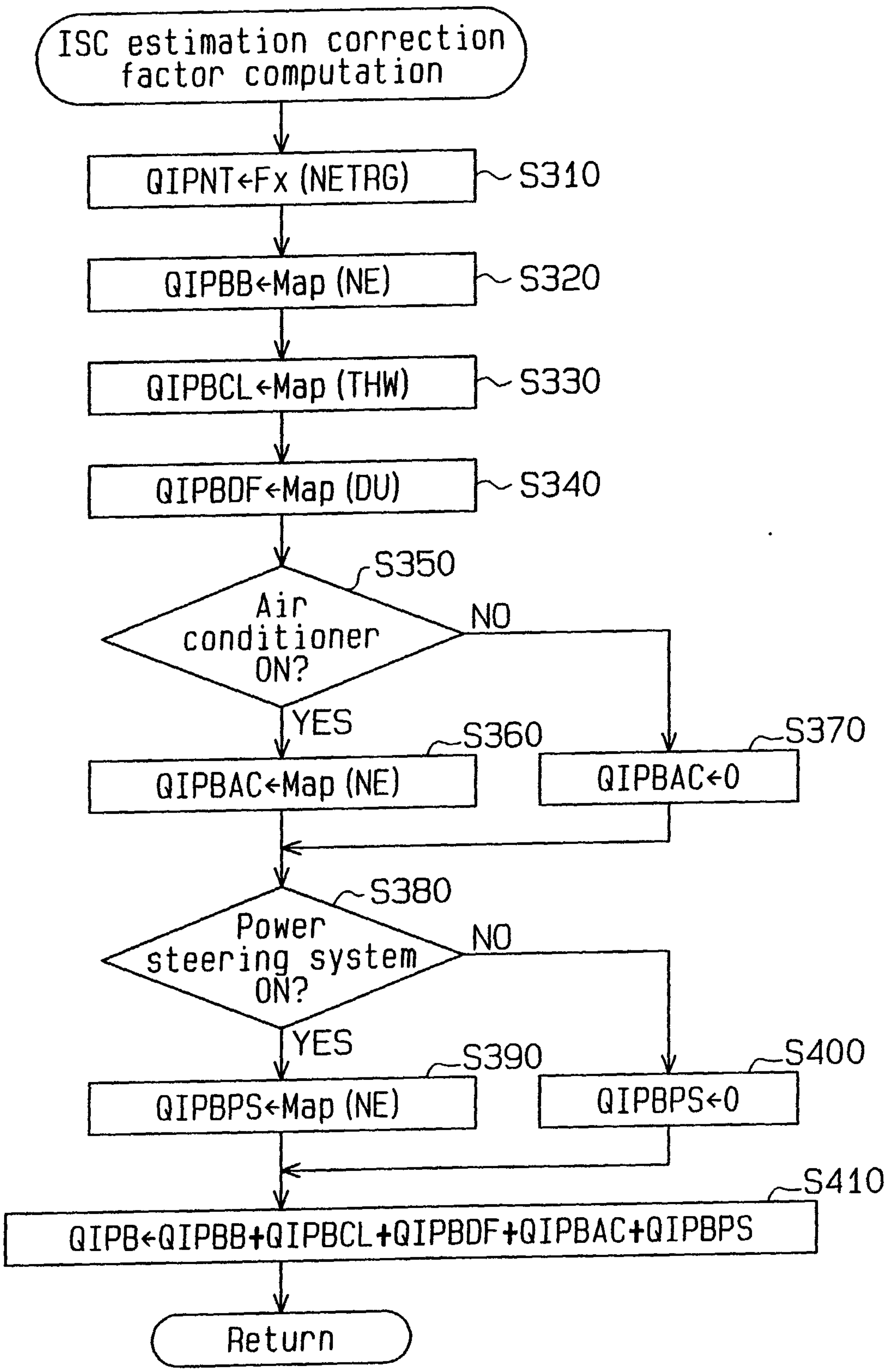

ISC estimation correction factor computation
QIPNT←Fx (NETRG)
S310
QIPBB←Map (NE)
S320
QIPBCL←Map (THW)
S330
QIPBDF←Map (DU)
S340
S350
Air conditioner ON?
NO
YES
S360
QIPBAC←Map (NE)
S370
QIPBAC←0
S380
Power steering system ON?
NO
YES
S390
QIPBPS←Map (NE)
S400
QIPBPS←0
S410
QIPB←QIPBB+QIPBCL+QIPBDF+QIPBAC+QIPBPS
Return

Fig.6(A)

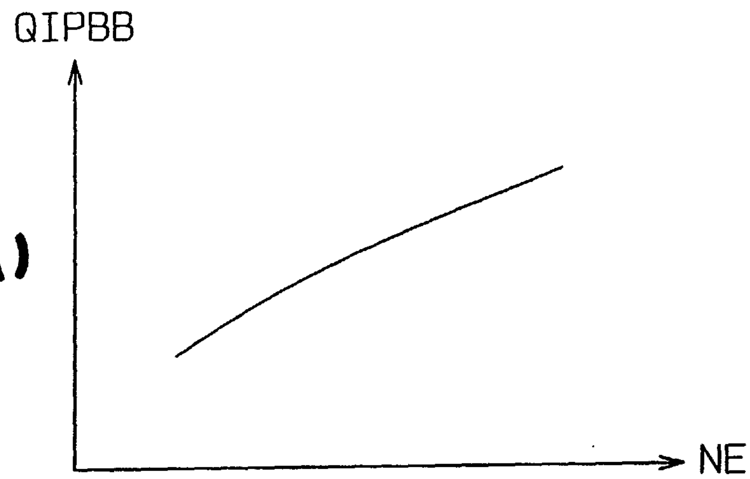



Fig.6(B)

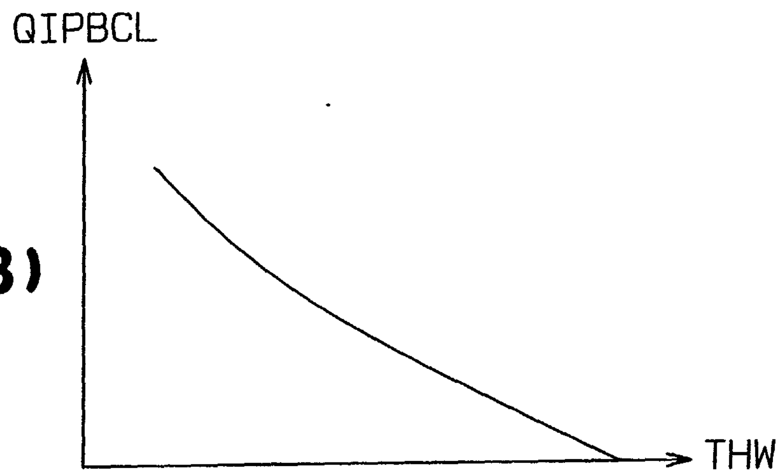



Fig.6(C)

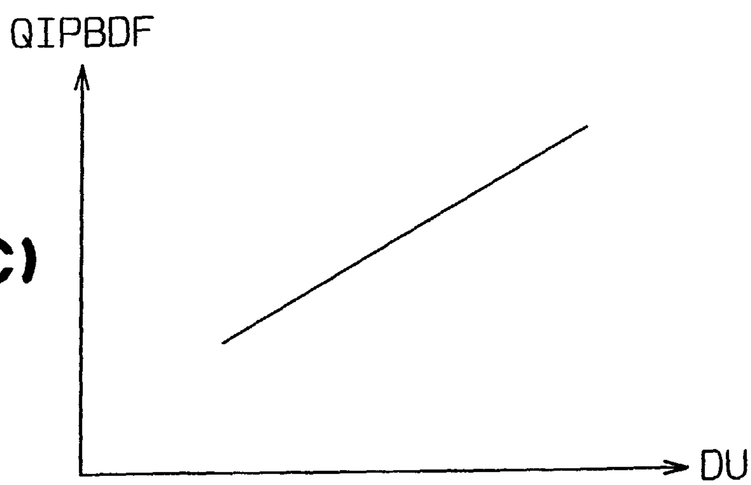


Fig.7(A)

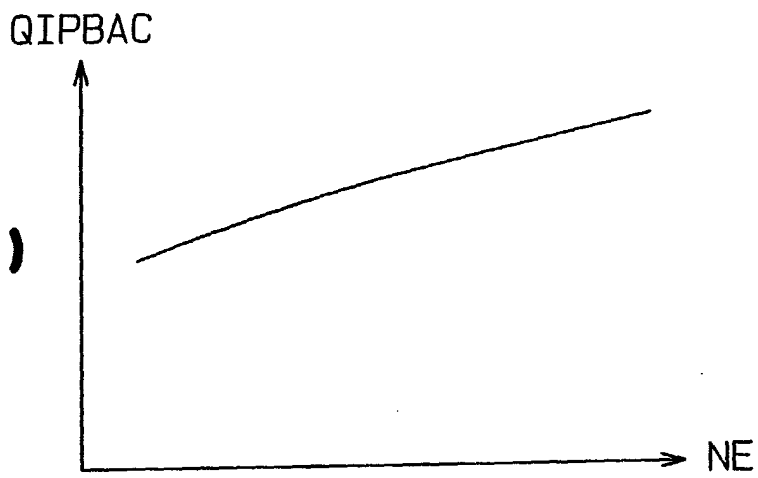



Fig.7(B)

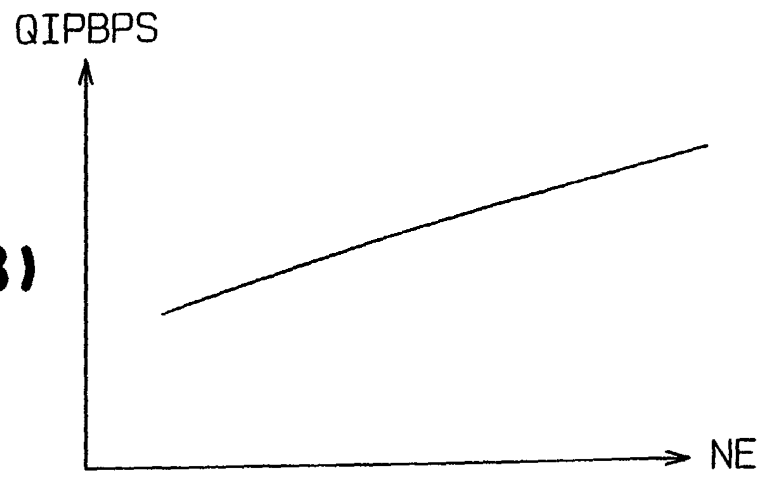


Fig.8

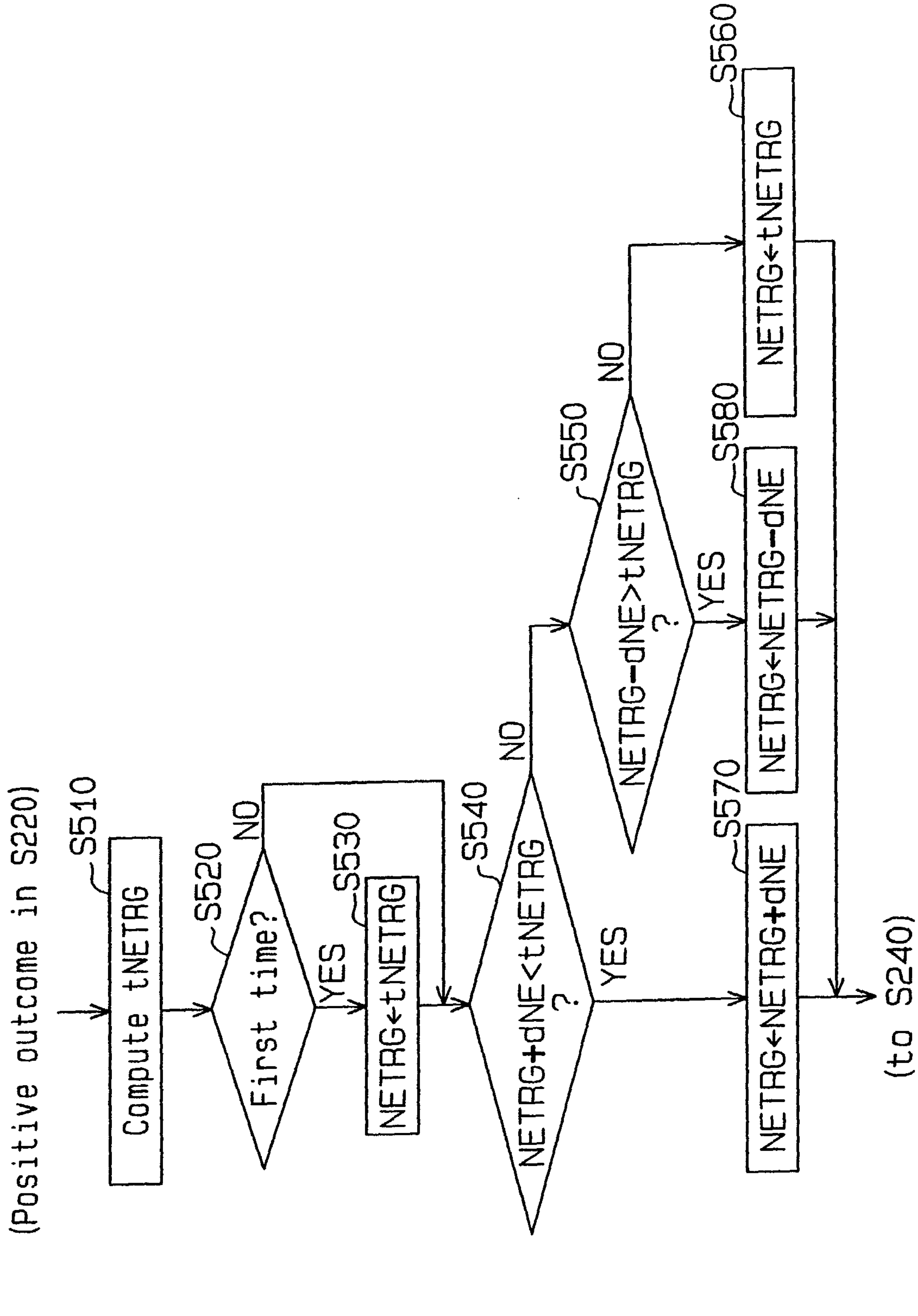
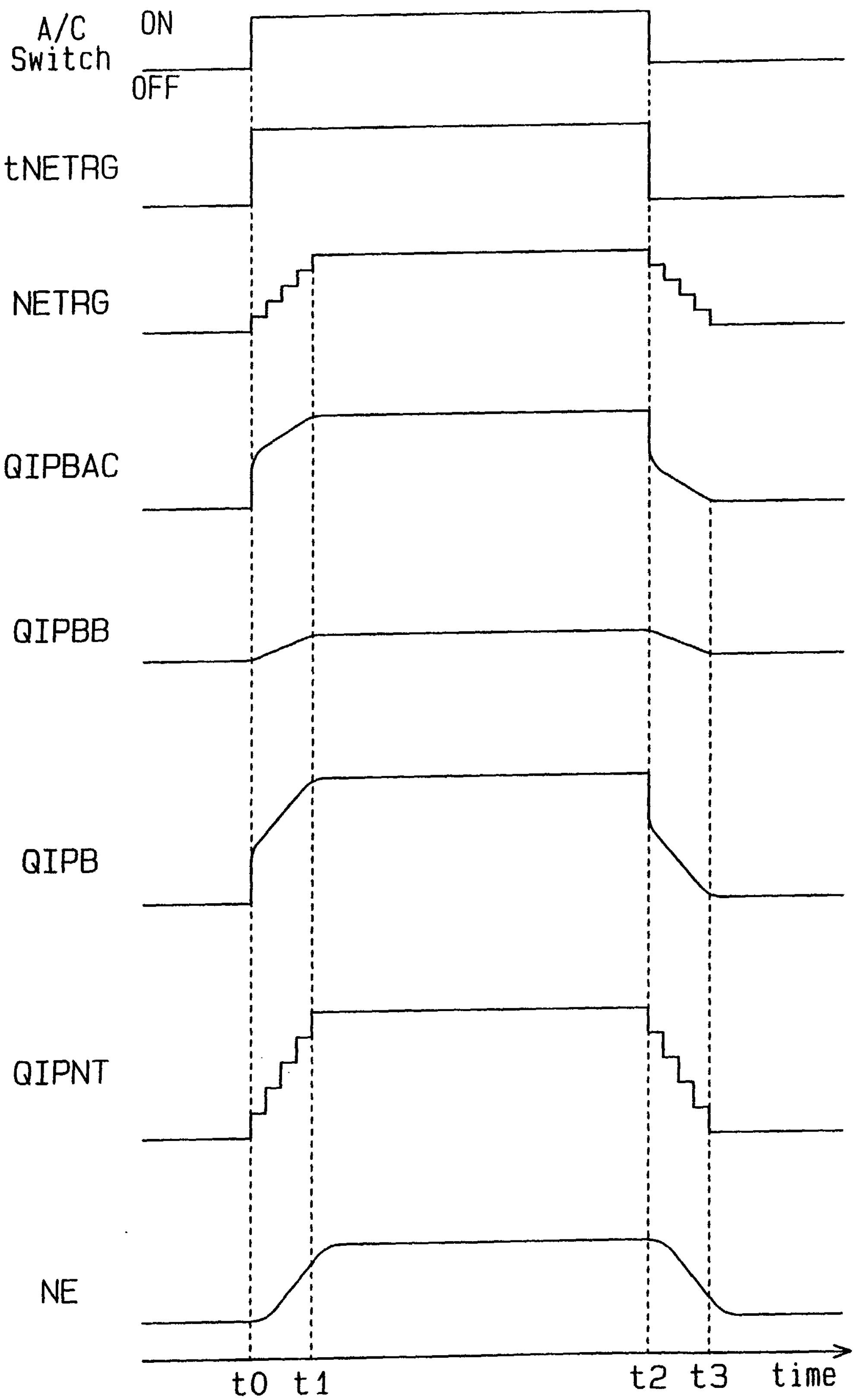
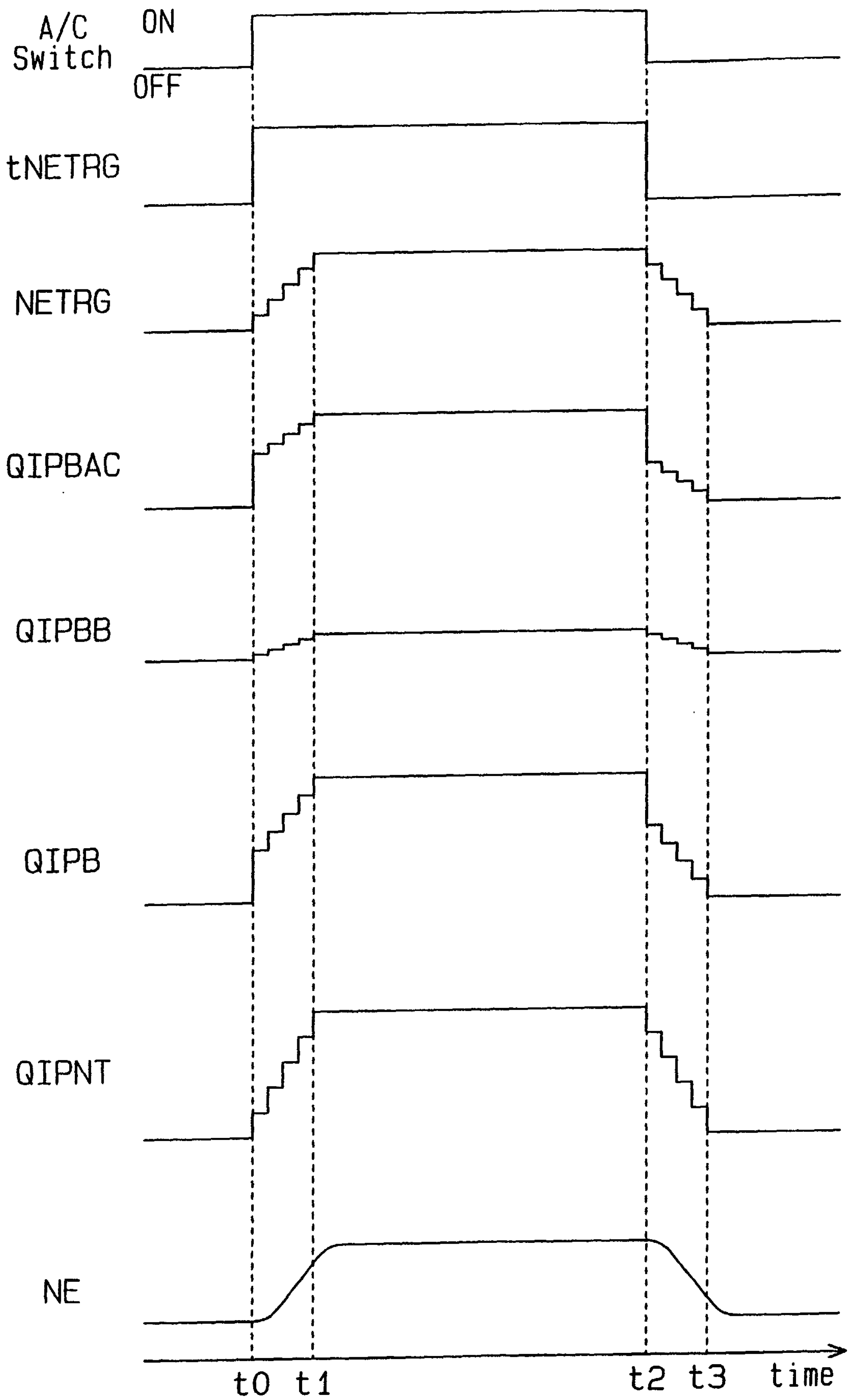

(Positive outcome in S220)
S510
Compute tNETRG
S520
First time?
YES
NO
S530
NETRG←tNETRG
S540
NETRG+dNE<tNETRG ?
YES
NO
S550
NETRG−dNE>tNETRG ?
YES
NO
S560
NETRG←tNETRG
S570
NETRG←NETRG+dNE
S580
NETRG←NETRG−dNE
(to S240)

Fig.9


A/C Switch
ON
OFF
tNETRG
NETRG
QIPBAC
QIPBB
QIPB
QIPNT
NE
t0
t1
t2
t3
time

# Fig.10


A/C Switch
ON
OFF
tNETRG
NETRG
QIPBAC
QIPBB
QIPB
QIPNT
NE
t0
t1
t2
t3
time