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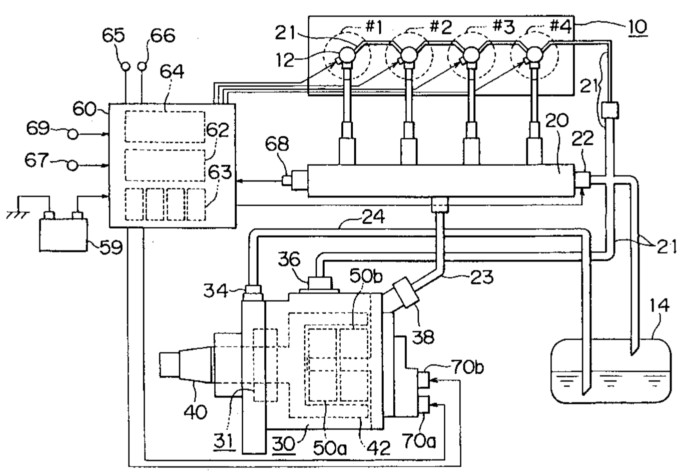
(54) Fuel pressure control apparatus

(57) The present invention proposes a fuel pressure control apparatus for a high-pressure fuel injection system which sufficiently reduces a fuel pressure in an accumulator line (20) while preventing the high-pressure fuel injection system from being adversely affected. The fuel pressure control apparatus for the high-pressure fuel injection system is equipped with an accumulator line (20) for accumulating fuel supplied from a fuel pump (30) at a high pressure and supplying the fuel to fuel injection valves (12), and with a relief valve (22) for discharging fuel in the accumulator line (20). Furthermore, the apparatus is equipped with fuel pressure control means (68) for detecting a fuel pressure in the accumulator line (20) and driving the relief valve (22) so as to reduce the fuel pressure in accordance with a pressure reduction requirement based on a comparison between the detected fuel pressure and a target pressure. A relief valve driving control means (60) controls the relief valve (22) in such a manner as to prevent the open-valve period of the relief valve from overlapping with a timing at which a fuel pressure detection means (68) detects a fuel pressure.

FIG. 1



EP 1 304 470 A2

Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a fuel pressure control apparatus according to claim 1.

2. Description of the Related Art

[0002] From JP 9 209 870 an accumulator fuel injector is known, in which pressure of fuel supplied from a fuel pump is accumulated in a common rail and ejected from an injector. To loosen fluctuation of fuel pressure in the common rail and provide stable fuel injection characteristics, a solenoid valve is provided in a fuel return passage from the common rail, in which pressure of fuel supplied by the fuel pump is accumulated to a fuel tank. The solenoid valve is controlled to be opened/closed in correspondence to a control signal to the injector. The solenoid valve is arranged on the upstream side of an orifice in a fuel return passage and is controlled together with the injector by a control circuit. That is, phase is shifted from the control pulse of the injector, the control pulse of the solenoid valve is output to the solenoid valve and thereby pressure fluctuation by the injector on a pressure side lower than a target pressure in the common rail and pressure fluctuation by the solenoid valve on a pressure side higher than the target pressure are superposed, therefore fluctuation of fuel pressure in the common rail is loosened.

[0003] From US 5,727,525 an accumulator fuel injection system for automotive vehicles is known, which includes an accumulating chamber storing therein fuel under a given pressure, a plurality of fuel injectors communicating with the accumulating chamber for injecting the fuel stored therein into engine cylinders of an engine, and a pressure regulator for regulating the pressure of fuel flowing through a drain passage from the accumulating chamber to a fuel tank. When a throttle valve is fully closed during a high-load engine operation, the fuel regulator opens the drain passage to decrease the pressure of fuel within the accumulating chamber to a target pressure level speedily. This allows an actual fuel injection pressure to follow a change in the target pressure level quickly according to an engine operating condition when the throttle valve is reopened.

[0004] In general, in an internal combustion engine equipped with an accumulator line such as a common rail, a fuel pump force-feeds high-pressure fuel to the accumulator line, and fuel injection valves connected to the accumulator line inject fuel into combustion chambers of the engine.

[0005] A fuel pressure in the accumulator line, namely, a fuel injection pressure of the fuel injection valves is controlled so as to become a pressure corresponding to an operation state of the engine. In such fuel pressure control, the amount of fuel force-fed from the fuel pump is increased, for example, when the fuel pressure in the accumulator line detected by a pressure sensor or the like is lower than a target fuel pressure set In accordance with an operation state of the engine. Conversely, the amount of fuel force-fed from the fuel pump is reduced or force-feeding of fuel is suspended when the detected fuel pressure is higher than the target fuel pressure. In this manner, the fuel pressure in the accumulator line is controlled. Due to performance of such fuel pressure control, the atomized particle size of injected fuel and the like match a combustion state of the engine.

[0006] However, in the case where the target fuel pressure decreases abruptly, for example, due to a transition of the operation state of the engine from a high-load operation state to a low-load operation state within a short length of time, even if force-feeding of fuel from the fuel pump is restricted or suspended, there needs to be a certain length of time until the fuel pressure in the accumulator line is reduced down to the target fuel pressure. In such a case, though temporarily, fuel injection is carried out based on an excessive fuel injection pressure, which leads to an increase in combustion noise resulting from excessive atomization of injected fuel.

[0007] In the light of such a problem, according to the related art as disclosed in Japanese Patent Application Laid-Open No. HEI 10-54318, a pressure regulator (a relief valve) attached to a common rail is composed of an electromagnetic valve that can be driven to be opened and closed. When the fuel pressure in the common rail is higher than a target fuel pressure, fuel is discharged from the common rail by drivingly opening the relief valve and the fuel pressure is thereby reduced. Due to performance of such a pressure reduction processing, the difference between the fuel pressure and the target fuel pressure decreases smoothly. Consequently, the increase in combustion noise resulting from fuel injection based on an excessive fuel injection pressure is suitably restricted.

[0008] However, while such a pressure reduction processing employing the relief valve is suited to securely reduce a fuel pressure, it may adversely affect fuel injection, force-feeding of fuel from the fuel pump, detection of a fuel pressure and the like. For example, if fuel injection is carried out during the pressure reduction processing, the fuel injection pressure changes drastically during fuel injection, and the amount of fuel injection and the injection rate also change accordingly. As a result, the precision of fuel injection control inevitably deteriorates.

SUMMARY OF THE INVENTION

[0009] The present invention has been made in consideration of such circumstances. It is an object of the present invention to provide a fuel pressure control apparatus and method for a high-pressure fuel injection system which is capable of securely reducing a fuel pressure in an accumulator line while preventing the high-pressure fuel injection system from being adversely affected.

[0010] According to the inventive fuel pressure control apparatus the afore-mentioned object is solved by the features of claim 1.

[0011] Improved embodiments of the inventive fuel pressure control apparatus result from subclaims 2 to 9.

[0012] According to one aspect of the present invention, there is provided a fuel pressure control apparatus for a high-pressure fuel system that is equipped with an accumulator line for supplying fuel accumulated at a high pressure to a fuel injection valve, comprising a fuel pump for pressurizing supplied fuel to a high pressure and force-feeding the fuel to the accumulator line, a relief valve for controlling discharge of fuel in the accumulator line, detection means for detecting a fuel pressure in the accumulator line, calculation means for determining a target pressure of fuel in the accumulator line, fuel pressure control means for opening the relief valve based on the detected fuel pressure and the calculated target pressure and reducing a fuel pressure in the accumulator line, and relief valve driving control means for controlling an open-valve period of the relief valve. This fuel pressure control apparatus is characterized in that the relief valve driving control means controls the relief valve in such a manner as to prevent the open-valve period of the relief valve from overlapping with a timing at which the fuel pressure detection means detects a fuel pressure.

[0013] This construction makes it possible to prevent the fuel injection amount or the injection rate from changing due to a decrease in fuel pressure in the accumulator line in response to the opening of the relief valve, and to securely reduce a fuel pressure in the accumulator line without adversely affecting the state of fuel injection.

[0014] Although this summary does not describe all the features of the present invention, it should be understood that any combination of the features stated in the dependent claims is within the scope of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015]

Fig. 1 schematically shows a structure of a high-pressure fuel injection system.

Fig. 2 is a timing chart showing a pattern of change in rail pressure, an operation state of a fuel pump and the like during steady operation.

Fig. 3 is a flowchart showing a procedure of calculating timings for driving respective adjusting valves of the fuel pump,

Fig. 4 is a flowchart showing a procedure of setting a timing for driving a relief valve.

Fig. 5 is a timing chart showing an output pattern of a conduction signal for the relief valve, an open-close state of the relief valve and the like.

Fig. 6 is a flowchart showing a control procedure in driving the relief valve.

Fig. 7 is a graph showing a pressure reduction characteristic of rail pressure when the relief valve is opened.

DESCRIPTION OF PREFERRED EMBODIMENT

[0016] An embodiment wherein the present invention is applied to a control apparatus for controlling a fuel pressure in a common rail provided for a diesel engine will be described hereinafter.

[0017] Fig. 1 schematically shows structures of a four-cylinder direct-injection diesel engine 10 according to the present embodiment (hereinafter referred to simply as "the engine") and a high-pressure fuel injection system thereof.

[0018] This high-pressure fuel injection system is equipped with injectors 12 provided so as to correspond to respective cylinders #1 through #4 of the engine 10, a common rail 20 to which the injectors 12 are connected, a fuel pump 30 for force-feeding fuel in a fuel tank 14 to the common rail 20, and an electronic control unit 60 (hereinafter referred to as "the ECU").

[0019] The common rail 20 has the function of accumulating fuel supplied from the fuel pump 30 at a predetermined pressure. A fuel injection pressure of the injectors 12 is determined based on a fuel pressure (a rail pressure) in the common rail 20.

[0020] A relief valve 22 is attached to the common rail 20. The relief valve 22 is a normal-closed electromagnetic valve that is driven to be opened through electric conduction by the ECU 60. The relief valve 22 is connected to the fuel tank 14 through a relief passage 21. If the relief valve 22 is opened, fuel in the common rail 20 is discharged into the relief passage 21 and returned to the fuel tank 14 through the relief passage 21. In this manner, the rail pressure decreases in accordance with an amount of fuel discharged from the common rail 20. The amount of decrease in rail pressure is adjusted in accordance with a length of an open-valve period of the relief valve 22.

[0021] The injectors 12 are electromagnetic valves that are driven to be opened and closed by the ECU 60. The injectors 12 inject the fuel supplied from the common rail 20 into combustion chambers (not shown) of the respective cylinders # 1 through #4. Each of the injectors 12 is also connected to the fuel tank 14 through the relief valve 21. The fuel that has leaked out into the injectors 12 is returned to the fuel tank 14 through the relief passage 21.

[0022] The ECU 60 performs control associated with a fuel force-feed amount of the fuel pump 30 and a fuel injection timing and a fuel injection amount of the injectors 12. The ECU 60 is composed of a memory 64 for storing various control programs, functional data and the like, a CPU 62 for performing various arithmetic processings, a plurality of drivers 63 for outputting a conduction signal that is produced based on a supply capability of a battery 59 to the injectors 12 and the like so as to drive them, and the like.

[0023] Further, various sensors for detecting an operation state of the engine 10, a fuel pressure in the common rail 20 and the like are connected to the ECU 60. Detection signals from those sensors are inputted to the ECU 60.

[0024] For example, a rotational speed sensor 65 is provided in the vicinity of a crank shaft (not shown) of the engine 10, and a cylinder discriminating sensor 66 is provided in the vicinity of a cam shaft (not shown). Based on detection signals inputted from those sensors 65, 66, the ECU 60 calculates a rotational speed of the crank shaft (an engine rotational speed NE) and a rotational angle of the crank shaft (a crank angle CA) respectively.

[0025] Further, an accelerator sensor 67 is provided in the vicinity of an accelerator pedal (not shown). The accelerator sensor 67 outputs a detection signal corresponding to a depression amount (an accelerator opening degree) of the accelerator pedal. The common rail 20 is provided with a fuel pressure sensor 68, which outputs a detection signal corresponding to a rail pressure (an actual fuel pressure PCR). A cylinder block (not shown) of the engine 10 is provided with a coolant temperature sensor 69, which outputs a detection signal corresponding to a temperature of engine coolant (a coolant temperature). The ECU 60 detects an accelerator opening degree, an actual fuel pressure PCR and a coolant temperature based on detection signals from the respective sensors 67 through 69.

[0026] The fuel pump 30 is composed of a drive shaft 40 rotationally driven by the crank shaft of the engine 10, a feed pump 31 operating based on rotation of the drive shaft 40, a pair of supply pumps (a first supply pump 50a and a second supply pump 50b) driven by an annular cam 42 formed on the drive shaft 40, and the like.

[0027] The feed pump 31 sucks fuel in the fuel tank 14 from an intake port 34 through an intake passage 24, and supplies the fuel to the first supply pump 50a and the second supply pump 50b at a predetermined feed pressure. Out of the fuel that has been thus sucked from the intake port 34, a surplus of fuel that is supplied to neither the first supply pump 50a nor the second supply pump 50b is returned to the fuel tank 14 through the relief passage 21. Both the first supply pump 50a and the second supply pump 50b are so-called inner cam type pumps. These pumps pressurize the fuel supplied from the feed pump 31 to a still higher pressure (e.g. 25 to 180 MPa) based on reciprocating movements of a plunger (not shown), and force-feed the pressurized fuel to the common rail 20 from a discharge port 38 through a discharge passage 23.

[0028] The fuel pump 30 is provided with a first adjusting valve 70a and a second adjusting valve 70b, which are designed to adjust fuel force-feed amounts of the supply pumps 50a, 50b respectively. Both the adjusting valves 70a, 70b are normal-closed electromagnetic valves which are driven to be opened through electric conduction by the ECU 60.

[0029] Fig. 2 is a timing chart showing timings for sucking fuel into and force-feeding fuel from the respective supply pumps 50a, 50b, a pattern of change in rail pressure during steady operation, and the like.

[0030] The respective supply pumps 50a, 50b alternately suck fuel with phases in crank angle CA (CA: Crank Angle) being offset from each other by 180°CA. Likewise, the respective supply pumps 50a, 50b alternately force-feed fuel with phases being offset from each other by 180°CA.

[0031] As indicated by (b) and (c) in Fig. 2, the first adjusting valve 70a is opened during an intake stroke of the first supply pump 50a so as to start sucking fuel, and then is closed at a predetermined timing (crank angle CA) so as to stop sucking fuel. All the fuel that has been thus sucked is pressurized in a force-feed stroke which follows the intake stroke, and is force-fed from the first supply pump 50a to the common rail 20.

[0032] In this manner, the amount of fuel force-fed from the first supply pump 50a can be adjusted by changing an open-valve period of the first adjusting valve 70a.

[0033] As indicated by arrows in (b) and (c) of Fig. 2, if the timing for closing the first adjusting valve 70a is retarded to thereby increase an open-valve period thereof, the fuel intake amount of the first supply pump 50a increases. Upon such retardation of the timing for closing the first adjusting valve 70a, the timing for starting force-feeding fuel from the first supply pump 50a is advanced by an amount equal to the amount of retardation. As a result, the fuel force-feed period is prolonged and the fuel force-feed amount of the first supply pump 50a increases.

[0034] On the contrary, if the timing for closing the first adjusting valve 70a is advanced so as to reduce an open-valve period thereof, the fuel intake amount of the first supply pump 50a decreases. Upon such advancement of the timing for closing the first adjusting valve 70a, the timing (the crank angle CA) for starting force-feeding fuel from the first supply pump 50a is retarded by an amount equal to the amount of advancement. As a result, the fuel force-feed period is shortened and the fuel force-feed amount of the first supply pump 50a decreases.

[0035] As -described above, the timing for starting force-feeding fuel from the first supply pump 50a is determined uniquely based on the timing for closing the first adjusting valve 70a.

[0036] Likewise, by advancing or retarding the timing for closing the second adjusting valve 70b, the fuel force-feed amount of the second supply pump 50b can be increased or decreased. Also, the timing (the crank angle CA) for starting force-feeding fuel from the second supply pump 50b can also be determined uniquely based on the timing for closing the second adjusting valve 70b.

[0037] The timings for opening and closing the respective adjusting valves 70a, 70b are defined using a crank angle as a unit thereof. The valve-opening timing is set as a crank angle relative to the valve-closing timing. For example, when stopping force-feeding fuel from the respective supply pumps 50a, 50b, the valve-opening timing is set to "0°CA", and the respective adjusting valves 70a, 70b are kept closed during an intake stroke. On the other hand, when setting the fuel force-feed amount to its maximum, the valve-closing timing is set to "180°CA" which corresponds to an amount of change in crank angle during the intake stroke, and the respective adjusting valves 70a, 70b are constantly kept open during the intake stroke.

[0038] Further, every time the respective supply pumps 50a, 50b suck fuel, the valve-closing timings of the respective adjusting valves 70a, 70b are set based on a rail pressure, a target fuel pressure and the like. A procedure of setting the valve-closing timings will be described hereinafter with reference to a flowchart shown in Fig. 3.

[0039] The ECU 60 carries out an adjusting valve driving timing calculation routine shown in Fig. 3 as an interruption handling at intervals of a predetermined crank angle (180°CA).

[0040] In step 110, the ECU 60 detects an actual fuel pressure based on a detection signal from the fuel pressure sensor 68. As indicated by (g) in Fig. 2, the timing for detecting the actual fuel pressure PCR, namely, the timing (the angle) for interruption of the present routine is set to a timing after termination of force-feeding of fuel from the respective supply pumps 50a, 50b (the timings when the crank angle CA reaches, for example, respective angles CAA0, CAA1, ...CAA5).

[0041] Then in step 120, the ECU 60 calculates a target fuel pressure PCRTRG based on a fuel injection amount and an engine rotational speed NE.

[0042] The target fuel pressure PCRTRG in relation to the fuel injection amount and the engine rotational speed NE is preliminarily calculated through experiments so that an atomized particle size or the like of injected fuel matches a combustion state of the engine, and is stored in the memory 64 of the ECU 60 as functional data for calculation of the target fuel pressure PCRTRG. Further, in a routine other than the present routine, the fuel injection amount is calculated based on an accelerator opening degree, an engine rotational speed NE and the like and stored in the memory 64.

[0043] In step 130, the actual fuel pressure PCR is subtracted from the target fuel pressure PCRTRG, and the resultant value is set as a difference APCR (=PCRTRG-PCR). Then in step 140, a base valve-closing angle ANGBASE is calculated based on the fuel injection amount, the actual fuel pressure PCR and the engine rotational speed NE.

[0044] The base valve-closing angle ANGBASE is determined based on a fuel force-feed amount of the fuel pump 30 that is required during steady operation thereof, namely, when the rail pressure is substantially equal to the target fuel pressure PCRTRG and the target fuel pressure PCRTRG is kept substantially constant. The relationship between the base valve-closing angle ANGBASE and the fuel injection amount and the like is stored in the memory 64 as functional data for calculation of the base valve-closing angle ANGBASE.

[0045] Then in step 150, the ECU 60 calculates a final valve-closing timing (a final valve-closing angle ANGFIN) of the respective adjusting valves 70a, 70b based on a formula (1) shown below.

$$\mathrm{ANGFIN} = \mathrm{ANGBASE} + K_P \times \Delta \mathrm{PCR} \qquad (1)$$

[0046] In this formula, "$K_P \times \Delta$PCR" represents a feedback correction term and K_P represents a proportional gain. As is apparent from the formula (1), if the target fuel pressure PCRTRG is higher than the actual fuel pressure PCR (ΔPCR > 0), the final valve-closing angle ANGFIN is set to a relatively great value. On the contrary, if the target fuel pressure PCTRG is lower than the actual fuel pressure PCR (ΔPCR < 0), the final valve-closing angle ANGFIN is set to a relatively small value.

[0047] After the final valve-closing angle ANGFIN has been thus calculated, the final valve-closing angle ANGFIN is compared in steps 160 through 190 with an upper limit set value "180°CA" and with a lower limit set value "0°CA", and the final valve-closing angle ANGFIN is corrected in case of necessity. That is, if the final valve-closing angle ANGFIN is greater than "180°CA" (if the result in step 160 is YES), it is set equal to "180° CA" (step 170). If the final valve-closing angle ANGFIN is smaller than "0°CA" (if the result in step 180 is YES), it is set equal to "0°CA" (step 190). After that, the ECU 60 temporarily terminates the processings of the present routine.

[0048] Then, in a routine other than the present routine, the ECU 60 adjusts a fuel force-feed amount of the fuel pump 30 by alternately outputting a conduction signal based on the final valve-closing angle ANGFIN to the respective adjusting valves 70a, 70b through the drivers 63, and thereby controls a rail pressure.

[0049] As described above, the ECU 60 adjusts a fuel force-feed amount of the fuel pump 30 so as to control a rail pressure such that the rail pressure coincides with the target fuel pressure PCRTRG. On the other hand, for example, in the case where the target fuel pressure PCRTRG decreases abruptly and the rail pressure cannot follow the decrease in target fuel pressure PCRTRG, the ECU 60 opens the relief valve 22 for a predetermined length of time to thereby perform a processing of reducing the rail pressure (hereinafter referred to as the "pressure reduction processing").

[0050] Such a pressure reduction processing will be described hereinafter with reference to Figs. 4 through 7.

[0051] Fig. 4 is a flowchart showing the contents of a processing of "a relief valve driving timing setting routine". Fig. 5 is a timing chart showing a conduction signal outputted to the relief valve 22 from the drivers 63 of the ECU 60, an open-close state of the relief valve 22 based on the conduction signal, and the like. Fig. 6 is a flowchart showing the contents of a processing of "a relief valve driving control routine".

[0052] As indicated by (a) in Fig. 5, the conduction signal outputted to the relief valve 22 is defined based on two parameters, namely, a non-conduction time TCLOSE and a conduction time TOPEN.

[0053] With a crank angle CA after a predetermined angle a from a detection angle of the actual fuel pressure PCR (e.g. CAM, CAA2 or CAA3 shown in Fig. 5) being defined as a reference angle (CAB 1, CAB2), the non-conduction time TCLOSE represents a time from attainment of the reference angle by the crank angle CA to the start of supply of electricity to the relief valve 22. The conduction time TOPEN represents a time from the start of supply of electricity to the relief valve 22 to the stop of supply of electricity.

[0054] The relief valve 22 is opened and closed based on a conduction signal. However, timings when the relief valve 22 is opened and closed do not completely coincide with timings for starting and stopping supplying electricity to the relief valve 22, respectively. That is, the relief valve 22 is opened after the lapse of a predetermined response delay time $\Delta T1$ from the timing for starting electric conduction, and is closed after the lapse of a predetermined response delay time $\Delta T2$ from the timing for stopping electric conduction (see (b) in Fig. 5).

[0055] Taking such response delay of the relief valve 22 into account, the non-conduction time TCLOSE is set such that the crank angle CA at which the relief valve 22 is actually opened coincides with a crank angle after a predetermined angle (3 from the reference angle (CAB1, CAB2)(shown in Fig. 5 as CAC1, CAC2 and referred to hereinafter as the "actual valve-opening angle").

[0056] The actual valve-opening angle (CAC1, CAC2) is preliminarily set so as to be constantly retarded with respect to a timing for terminating fuel injection in the case where the timing for fuel injection by the injectors 12 has been changed in accordance with an operation state of the engine. Accordingly, whenever the relief valve 22 is opened, fuel injection has already been terminated.

[0057] The conduction time TOPEN is intended to set an open-valve period of the relief valve 22. The conduction time TOPEN is set based on a difference between the actual fuel pressure PCR and the target fuel pressure PCRTRG and the like in the following manner. That is, if the relief valve 22 is opened for the conduction time TOPEN, the actual fuel pressure PCR is reduced to the target fuel pressure PCRTRG.

[0058] A detailed procedure of setting the non-conduction time TCLOSE and the conduction time TOPEN will be described hereinafter with reference to Figs. 4, 5 and 7.

[0059] After "the adjusting valve driving timing calculation routine" has been terminated, the ECU 60 carries out "the relief valve driving timing setting routine" shown in Fig. 4 as an interruption handling at intervals of a predetermined crank angle (180°CA).

[0060] First in step 210, the ECU 60 determines whether or not the actual fuel pressure PCR is higher than a value (PCRTRG + $\Delta P1$) obtained by adding a predetermined value ΔPI to the target fuel pressure PCRTRG, namely, whether or not the pressure reduction processing needs to be performed.

[0061] If the pressure reduction processing is performed when the difference (PCR - PCRTRG) between the actual fuel pressure PCR and the target fuel pressure PCRTRG is not sufficiently great, the rail pressure may drop far below the target fuel pressure PCRTRG in response to the opening of the relief valve 22. In other words, there arises a concern that so-called the overshooting phenomenon might occur.

[0062] Therefore, if the difference between the actual fuel pressure PCR and the target fuel pressure PCRTRG is small enough to be able to ignore an increase in combustion noise, it is preferable to take the following countermeasure in terms of inhibition of generation of the overshooting phenomenon. That is, while restricting a fuel force-feed amount of the fuel pump 30 based on feed-back control, the rail pressure is gradually reduced by fuel injection or so-called invalid injection wherein the injectors 12 are driven within a period of invalid injection so as to discharge fuel in the common rail 20 to the relief passage 21 through the interior of the injectors 12.

[0063] From this point of view, the predetermined value $\Delta P1$ is set to a value great enough to avoid an increase in combustion noise, namely, to a value suited to inhibit generation of the overshooting phenomenon.

[0064] If it is determined in step 210 that the pressure reduction processing is unnecessary ($PCR \leq PCRTRG + \Delta P1$), the conduction time TOPEN is set to "0" in step 245. Then, the processings of the present routine are terminated temporarily.

[0065] On the other hand, if it is determined in step 210 that the pressure reduction processing is necessary ($PCR > PCRTRG + \Delta P1$), the ECU 60 calculates in step 220 a non-conduction time TCLOSE based on the response delay time $\Delta T1$ of the relief valve 22 and the engine rotational speed NE.

[0066] For example, the higher the engine rotational speed NE becomes, the shorter the time required for the crank angle CA to reach the actual open-valve angle (CAC1, CAC2) of the relief valve 22 from the reference angle (CAB1, CAB2) becomes. Hence, the nonconduction time TCLOSE is set to a relatively short length of time. The response delay time ΔT1 is preliminarily calculated through experiments or the like as a response characteristic of the relief valve 22, and is stored in the memory 64 as data for calculating the non-conduction time TCLOSE.

[0067] The respective supply pumps 50a, 50b start sucking fuel immediately after the crank angle CA has become equal to the detection angle (CAA1 through CAA3) of the actual fuel pressure PCR (see Fig. 2). However, under the condition that is affirmatively determined in step 210 (PCR > PCRTRG + ΔP1), the sucking of fuel is always terminated before the crank angle CA reaches the reference angle (CAB1, CAB2). In other words, the predetermined value API and the reference angle (CAB1, CAB2) are set so as to satisfy such a relationship.

[0068] Therefore, even if the non-conduction time TCLOSE is set to its minimum and the timing for starting supply of electricity to the relief valve 22 is set to its earliest timing in step 220, the relief valve 22 never starts being supplied with electricity during electric conduction of the respective adjusting valves 70a, 70b.

[0069] In the case of (PCR ≤ PCRTRG + ΔP1), the final valve-closing angle ANGFIN is set greater in comparison with the aforementioned case of (PCR > PCRTRG + ΔP1). Thus, even after the crank angle CA has reached the reference angle (CAB1, CAB2), the respective supply pumps 50a, 50b continue to suck fuel. However, since the pressure reduction processing is not carried out in such a case, there is no possibility that the relief valve 22 might start being supplied with electricity during electric conduction of the respective adjusting valves 70a, 70b.

[0070] Then in step 230, the ECU 60 calculates a pressure reduction rate K (>0). If the relief valve 22 is opened, fuel in the common rail 20 is discharged and the rail pressure thereby decreases. The rate at which the rail pressure decreases is not constant but changes depending on a magnitude of the rail pressure. That is, as shown in Fig. 7, the rate at which the rail pressure decreases (the gradient of an alternate short and long dash line shown in Fig. 7) tends to become lower in proportion to a decrease in rail pressure. The pressure reduction rate K, which corresponds to the rate at which the rail pressure decreases, is calculated based on the actual fuel pressure PCR. The relationship between the pressure reduction rate K and the actual fuel pressure PCR is preliminarily found out through experiments or the like, and is stored in the memory 64 as data for calculating the pressure reduction rate K.

[0071] In step 240, the ECU 60 calculates an conduction time TOPEN based on a formula (2) shown below.

$$TOPEN = K \times (PCR - PCRTRG) \qquad (2)$$

[0072] As is apparent from the aforementioned formula (2) and the reduction characteristic of the rail pressure shown in Fig. 7, if the rail pressure (the actual fuel pressure PCR) at the time of opening of the relief valve 22 is constant, the conduction time TOPEN is set longer in proportion to an increase in difference (PCR - PCRTRG) between the actual fuel pressure PCR and the target fuel pressure PCRTRG. Also, if the differential pressure (PCR - PCRTRG) is constant, the conduction time TOPEN is set longer in proportion to a decrease in rail pressure (actual fuel pressure PCR) at the time of the opening of the valve.

[0073] The respective supply pumps 50a, 50b continue to force-feed fuel immediately before the crank angle CA becomes equal to the detection angle (CAA1, CAA2, CAA3) of the actual fuel pressure PCR (see Fig. 2). The timing for starting force-feeding fuel is retarded in proportion to an increase in difference (PCR - PCRTRG) between the actual fuel pressure PCR and the target fuel pressure PCRTRG. Accordingly, when the conduction time TOPEN is set relatively long, the period for force-feeding fuel from the respective supply pumps 50a, 50b is set relatively short. Thus, the period for force-feeding fuel from the respective supply pumps 50a, 50b does not overlap with the open-valve period of the relief valve 22. In other words, the respective supply pumps 50a, 50b force-feed fuel while fuel is not being discharged by keeping the relief valve 22 open.

[0074] After having thus calculated the conduction time TOPEN, the ECU calculates in step 250 a maximum value TOPENMAX of the conduction time TOPEN based on the response delay time ΔT2 (see Fig. 5) and the engine rotational speed NE.

[0075] The maximum value TOPENMAX is the maximum value of the conduction time TOPEN under the condition that the relief valve 22 is opened before the crank angle CA reaches the detection angle (CAA1, CAA2, CAA3) of the actual fuel pressure PCR. The maximum value TOPENMAX changes in accordance with the engine rotational speed NE. That is, the maximum value TOPENMAX is set smaller in proportion to an increase in engine rotational speed NE.

[0076] In step 260, the conduction time TOPEN is compared with the aforementioned maximum value TOPENMAX. If it is determined that the conduction time TOPEN is greater than the maximum value TOPENMAX, the conduction time TOPEN is set equal to the maximum value TOPENMAX in step 270.

[0077] After the processing in step 270 has been carried out, or if it is determined that the conduction time TOPEN is equal to or smaller than the maximum value TOPENMAX, the ECU 60 temporarily terminates the processings of the present routine.

[0078] As described hitherto, the conduction time TOPEN is prevented from exceeding the maximum value TOPENMAX after termination of the routine. Therefore, whenever the actual fuel pressure PCR is detected, the relief valve 22 is closed. That is, the timing for detecting the actual fuel pressure PCR does not arise while the relief valve 22 is open.

[0079] The injectors 12 always start fuel injection after detection of the actual fuel pressure PCR. Thus, whenever fuel injection is started, the relief valve 22 is closed. As described above, the consideration of the fact that the actual open-valve angle (CAC1, CAC2) of the relief valve 22 is constantly set to a timing retarded with respect to the timing for terminating fuel injection allows one to derive a conclusion that the period for fuel injection, namely, the open-valve period of the injectors 12 does not overlap with the open-valve period of the relief valve 22 either.

[0080] Furthermore, the respective supply pumps 50a, 50b always start sucking fuel immediately after detection of the actual fuel pressure PCR, and the relief valve 22 is not supplied with electricity any more when the actual fuel pressure PCR is detected. Therefore, the respective adjusting valves 70a, 70b start being supplied with electricity after stopping supplying electricity to the relief valve 22. As described above, the consideration of the fact that the relief valve 22 does not start being supplied with electricity during electric conduction of the respective adjusting valves 70a, 70b allows one to derive a conclusion that the period of electric conduction of the adjusting valves 70a, 70b does not overlap with the period of electric conduction of the relief valve 22.

[0081] The processings in "the relief valve driving control routine" will now be described with reference to the flowchart shown in Fig. 6.

[0082] The ECU 60 carries out this routine as an interruption handling at intervals of a predetermined crank angle (180°CA). The timing (the angle) for interruption is set to the aforementioned reference angle (CAB1, CAB2).

[0083] First of all, the ECU 60 determines in step 310 whether or not the engine is out of operation. It is determined herein that the engine is out of operation if fuel injection has been stopped with an ignition switch of the engine 10 being turned "OFF" or if the engine rotational speed NE has become equal to or lower than a predetermined rotational speed.

[0084] If it is determined that the engine is not out of operation, the ECU 60 produces in step 320 a conduction signal based on the non-conduction time TCLOSE and the conduction time TOPEN, and outputs the conduction signal to the relief valve 22 through the drivers 63.

[0085] On the other hand, if it is determined in step 310 that the engine is out of operation, the relief valve 22 is supplied with electricity in step 325 so as to be kept open for a predetermined length of time. The open-valve period, which does not depend on the magnitude of rail pressure at the time of stoppage of the engine, is calculated through experiments or the like as a time which allows the rail pressure to constantly drop below the target fuel pressure at the time of start of the engine, and is stored in the memory 64. The open-valve period may be set as a constant or as a function of coolant temperature at the time of stoppage of the engine.

[0086] After having carried out the respective processings in steps 320, 325, the ECU 60 temporarily terminates the processings of the present routine.

[0087] As described above, the pressure reduction processing of the rail pressure is performed in the case where the actual fuel pressure PCR is higher than the target fuel pressure PCRTRG and the difference therebetween is greater than the predetermined value ΔPI.

[0088] As the pressure reduction processing, there is also known a method wherein the rail pressure is reduced through invalid injection by the injectors 12. However, such a method requires discharging fuel within an extremely short length of time which is called an invalid injection period. Thus, there is a limit to the amount of fuel that can be discharged from the common rail 20 at a time, and it may be impossible to secure a required amount of pressure reduction.

[0089] In this respect, according to the pressure reduction processing of the present invention, the common rail 20 is provided with the relief valve 22 and the rail pressure is reduced based on the opening of the relief valve 22. Therefore, a large amount of fuel can be discharged from the common rail 20. Accordingly, the rail pressure can be reduced smoothly and securely to a level close to the target fuel pressure, and it is possible to suitably inhibit an increase in combustion noise and the like.

[0090] In particular, according to the present embodiment, when the relief valve 22 is driven to be opened through such a pressure reduction processing, the open-valve period of the relief valve 22 is set so as not to overlap with the open-valve period of the injectors 12. Accordingly, it is possible to prevent the fuel injection amount or the injection rate from changing due to a decrease in rail pressure based on the opening of the relief valve 22. Hence, the rail pressure can be reduced without adversely affecting fuel injection.

[0091] Furthermore, since the open-valve period of the relief valve 22 is set so as not to overlap with the detection period of the actual fuel pressure PCR, even if the common rail 20 has undergone pressure pulsation at the time of discharge of fuel resulting from the opening of the relief valve 22, the pressure pulsation does not adversely affect detection of the actual fuel pressure PCR. Consequently, the actual fuel pressure can be detected with high precision. Various control amounts based on the actual fuel pressure PCR, such as the fuel injection period and the like, can also be calculated with high precision.

[0092] As described above, when setting the open-valve period of the relief valve 22 so as not to overlap with the open-valve period of the injectors 12 or the detection timing of the actual fuel pressure PCR, the open-valve period of the relief valve 22 can also be set to a sufficiently short constant length of time, preliminarily taking into account changes in open-valve period of the injectors 12 and the like. It is true that such a construction makes it possible to preliminarily set the open-valve period of the relief valve 22 so as not to overlap with the open-valve period of the injectors 12 or the like. However, even if the open-valve period of the relief valve 22 can be set longer so as to correspond to a difference between the rail pressure and the target fuel pressure, the relief valve 22 is kept open only for the constant length of time.

[0093] Unlike such a construction, according to the pressure reduction processing of the present invention, the maximum value TOPENMAX is calculated as a criterion value for determining whether or not the open-valve period of the relief valve 22 overlaps with the open-valve period of the injectors 12 or the detection timing of the actual fuel pressure PCR, and the maximum value TOPENMAX is compared with the conduction time TOPEN. Only when the conduction time TOPEN exceeds the maximum value TOPENMAX, the conduction time TOPEN is limited to the maximum value TOPENMAX.

[0094] Accordingly, the open-valve period of the relief valve 22 can be extended to its maximum as long as it does not overlap with the open-valve period of the injectors 12 or the detection timing of the actual fuel pressure PCR. Also, the rail pressure can be reduced by a suitable amount corresponding to a difference between the actual fuel pressure PCR and the target fuel pressure PCRTRG.

[0095] Furthermore, according to the pressure reduction processing of the present embodiment, the open-valve period of the relief valve 22 is set so as not to overlap with the fuel force-feed period of the respective supply pumps 50a, 50b either. That is, fuel is force-fed and discharged at separate timings.

[0096] For example, it is assumed herein that the amount of decrease in rail pressure required in the pressure reduction processing is "ΔPa" and that the amount of increase in pressure required for force-feeding fuel from the respective supply pumps 50a, 50b is "ΔPb". In this case, unless fuel is force-fed and discharged simultaneously, the final amount of change in rail pressure must be equal to (ΔPb - ΔPa). However, if fuel is force-fed and discharged simultaneously, these phenomena interfere with each other. As a result, there is no guarantee that the amount of change in rail pressure will become equal to (ΔPb -ΔPa), which adversely affects both force-feeding of fuel and discharging of fuel.

[0097] In this respect, according to the present embodiment, it is possible to avoid mutual interference between force-feeding of fuel from the respective supply pumps 50a, 50b and discharging of fuel based on the opening of the relief valve 22. Thus, the rail pressure can securely be reduced without adversely affecting force-feeding of fuel from the respective supply pumps 50a, 50b.

[0098] Furthermore, the actual open-valve period of the relief valve 22 is calculated based on a conduction signal supplied thereto and a response characteristic thereof. Therefore, the open-valve period of the relief valve 22 can be calculated with higher precision. Thus, it is possible to avoid an inconvenience which might occur when the open-valve period of the relief valve 22 overlaps with the open-valve period of the injectors 12, the detection timing of the actual fuel pressure PCR or the fuel force-feed period of the respective supply pumps 50a, 50b. In addition, the open-valve period of the relief valve 22 can be extended within a permissible range.

[0099] Further, the conduction period of the relief valve 22 is set so as not to overlap with the conduction period of the respective adjusting valves 70a, 70b. Hence, it is possible to avoid circumstances wherein the overlapping of those conduction periods disables the battery 59 from supplying a sufficient amount of electric power to the respective valves 22, 70a and 70b and thereby hampers reliable driving thereof. Accordingly, it is possible to prevent force-feeding of fuel from the respective supply pumps 50a, 50b, especially adjustment of a fuel force-feed amount thereof from being adversely affected, and to drive the relief valve 22 reliably.

[0100] Still further, according to the present embodiment, the pressure reduction processing is performed on the condition that the difference (PCR - PCRTRG) between the actual fuel pressure PCR and the target fuel pressure PCRTRG is greater than the predetermined value ΔP1. The predetermined value ΔP1 is set to a sufficiently great value as long as it does not cause an increase in combustion noise. Therefore, the pressure reduction processing is performed even in the case where the increase in combustion noise is negligible, whereby it becomes possible to avoid circumstances wherein the rail pressure drops below the target fuel pressure. As a result, it is possible to inhibit deterioration in combustion state of the engine which results from an excessive decrease in rail pressure.

[0101] In addition, according to the present embodiment, the conduction time TOPEN, namely, the open-valve period of the relief valve 22 is calculated based on the difference (PCR - PCRTRG) between the actual fuel pressure PCR and the target fuel pressure PCRTRG and the pressure reduction rate K. Therefore, unless the conduction time TOPEN is limited by the maximum value TOPENMAX, the rail pressure can be reduced precisely to the target fuel pressure PCRTRG.

[0102] Further, according to the aforementioned pressure reduction processing, if it is determined that the engine is out of operation, the relief valve 22 is opened for a predetermined length of time so as to securely reduce the rail pressure to a pressure lower than the target fuel pressure. Thus, it is possible to suitably inhibit an increase in combustion noise not only during normal operation but also at the time of restart of the engine.

[0103] Especially, the aforementioned open-valve period can be changed in accordance with a coolant temperature at the time of stoppage of the engine, whereby it becomes possible to make the rail pressure at the time of restart of the engine closer to the target fuel pressure, and to ensure further improved startability of the engine while suitably inhibiting an increase in combustion noise.

[0104] The embodiment that has been described hitherto may be subjected to the following modifications in construction.

[0105] In the aforementioned embodiment, the pressure reduction processing is performed on the condition that the difference (PCR - PCRTRG) between the actual fuel pressure PCR and the target fuel pressure PCRTRG exceeds the predetermined value ΔP1, whereby the open-valve period of the relief valve 22 is prevented from overlapping with the fuel force-feed period of the fuel pump 30. In setting those periods such that they do not overlap with each other, the following construction can also be adopted for example.

[0106] First of all, the timing (the crank angle CA) for starting force-feeding fuel from the fuel pump 30 is calculated based on the final valve-closing angle ANGFIN. Then in the processing of step 250 shown in Fig. 4, the maximum value TOPENMAX of the conduction time TOPEN is calculated based on the response delay time ΔT2 of the relief valve 22 and the engine rotational speed NE. In this case, however, the maximum value TOPENMAX is calculated under the condition that the relief valve 22 is closed prior to attainment of the timing for starting force-feeding fuel by the crank angle CA.

[0107] Then, in the processings following step 260, if the conduction TOPEN exceeds the maximum value TOPENMAX, the conduction time TOPEN is set equal to the maximum value TOPENMAX. In this manner, the conduction time TOPEN is limited to a value equal to or smaller than the maximum value TOPENMAX, whereby the fuel pump 30 always starts force-feeding fuel after the relief valve 22 has been closed.

[0108] In this construction, the open-valve period of the relief valve 22 can be extended to its maximum as long as it does not overlap with the period of force-feeding of fuel from the fuel pump 30, and the rail pressure can be reduced by a suitable amount corresponding to the difference between the actual fuel pressure PCR and the target fuel pressure PCRTRG.

[0109] In the aforementioned embodiment, the conduction time TOPEN is set based on the difference (PCR - PCRTRG) between the actual fuel pressure PCR and the target fuel pressure PCRTRG and the pressure reduction rate K. However, for example, the conduction time TOPEN may be constant and may be limited to a value that is equal to or smaller than the maximum value TOPENMAX.

[0110] In the aforementioned embodiment, the conduction time TOPEN is limited to a value that is equal to or smaller than the maximum value TOPENMAX, whereby the open-valve period of the relief valve 22 is prevented from overlapping with the detection timing of the actual fuel pressure PCR or the open-valve period of the injectors 12. However, the processing for limiting the conduction time TOPEN may be omitted. For example, the conduction time TOPEN may be set to a sufficiently small constant value, whereby the open-valve period of the relief valve 22 can be set preliminarily so as not to overlap with the detection timing of the actual fuel pressure PCR or the open-valve period of the injectors 12.

[0111] In performing the pressure reduction processing in the aforementioned embodiment, it is possible to completely stop force-feeding fuel from the fuel pump 30. In this construction, the drivers 63 can be used commonly for the respective adjusting valves 70a, 70b. As a result, the overall structure can be simplified.

[0112] In addition to the pressure reduction processing based on the opening of the relief valve 22 in the aforementioned embodiment, the pressure reduction processing for the rail pressure based on invalid injection by the injectors 12 may also be performed. In this case, these processings may be performed as follows. That is, if the difference (PCR - PCRTRG) between the actual fuel pressure PCR and the target fuel pressure PCRTRG is higher than a predetermined pressure, the pressure reduction processing based on the opening of the relief valve 22 is selected. On the other hand, if the difference (PCR -PCRTRG) is lower than the predetermined pressure, the pressure reduction processing based on invalid injection by the injectors 12 is selected.

[0113] In the aforementioned embodiment, the pressure reduction rate K is set as a function of the actual fuel pressure PCR. However, it is also possible to set the pressure reduction rate K as a constant.

[0114] In the aforementioned embodiment, in addition to the relief valve 22, the common rail 22 may be provided with a mechanical pressure regulator that opens when the rail pressure rises above a withstanding pressure of a fuel force-feed system.

[0115] In the aforementioned embodiment, the relief valve 22 is attached to the common rail 20. However, the relief valve 22 may be attached to a fuel passage that accumulates fuel at the same pressure as in the common rail 20, for example, to the discharge passage 23.

[0116] In the aforementioned embodiment, the pressure reduction processing is performed on the condition that the difference between the actual fuel pressure PCR and the target fuel pressure PCRTRG exceeds the predetermined value ΔP1. However, the pressure reduction processing may be performed, for example, on the condition that the actual fuel pressure PCR exceeds the target fuel pressure PCRTRG.

[0117] In the aforementioned embodiment, the relief valve 22 may be designed as a valve whose opening degree is adjustable. By variably setting the opening degree in accordance with the difference (PCR - PCRTRG) between the actual fuel pressure PCR and the target fuel pressure PCRTRG, the pressure reduction rate can be adjusted.

[0118] In the aforementioned embodiment, there is shown an example of a diesel engine as an internal combustion engine to which the fuel pressure control apparatus of the present invention is applied. However, the present invention can also be applied, for example, to a direct-injection gasoline engine wherein fuel is injected directly into combustion chambers.

Claims

1. A fuel pressure control apparatus for a high-pressure fuel injection system that is equipped with an accumulator line (20) for supplying fuel accumulated at a high pressure to a fuel injection valve (12), comprising:

a fuel pump (30) for pressurizing supplied fuel to a high pressure and force-feeding the fuel to the accumulator line (20);
a relief valve (22) for controlling discharge of fuel in the accumulator line (20);
detection means (68) for detecting a fuel pressure in the accumulator line (20);
calculation means (60) for determining a target pressure of fuel in the accumulator line (20);
fuel pressure control means (60) for opening the relief valve (22) based on the detected fuel pressure and the calculated target pressure and reducing a fuel pressure in the accumulator line; and
relief valve driving control means (60) for controlling an open-valve period of the relief valve (22),

wherein the relief valve driving control means (60) controls the relief valve (22) in such a manner as to prevent the open-valve period of the relief valve (22) from overlapping with a period during which the fuel injection valve (12) is open,
characterized in that
the relief valve driving control means (60) controls the relief valve (22) in such a manner as to prevent the open-valve period of the relief valve (22) from overlapping with a timing at which the fuel pressure detection means (68) detects a fuel pressure.

2. The fuel pressure control apparatus according to claim 1, **characterized in that** the relief valve driving control means (60) prevents the open-valve period of the relief valve (22) from overlapping with the detection timing of the fuel pressure by the detection means (68) by setting the open-valve period of the relief valve (22) short.

3. The fuel pressure control apparatus according to claim 1, **characterized in that** the relief valve driving control means (60) sets the open-valve period of the relief valve (22) based on a difference between the detected fuel pressure (PCR) and the calculated target fuel pressure (PCRTRG).

4. The fuel pressure control apparatus according to claim 3, **characterized in that** the relief valve driving control means (60) opens the relief valve (22) when the detected fuel pressure (PCR) is by a predetermined pressure (API) higher than the calculated target pressure (PCRTRG).

5. The fuel pressure control apparatus according to claim 1, **characterized in that** the relief valve driving control means (60) outputs a valve-opening signal of the relief valve (22) in such a manner that a valve-opening timing of the relief valve (22) is constantly retarded than a termination of fuel injection of the fuel injection valve (12).

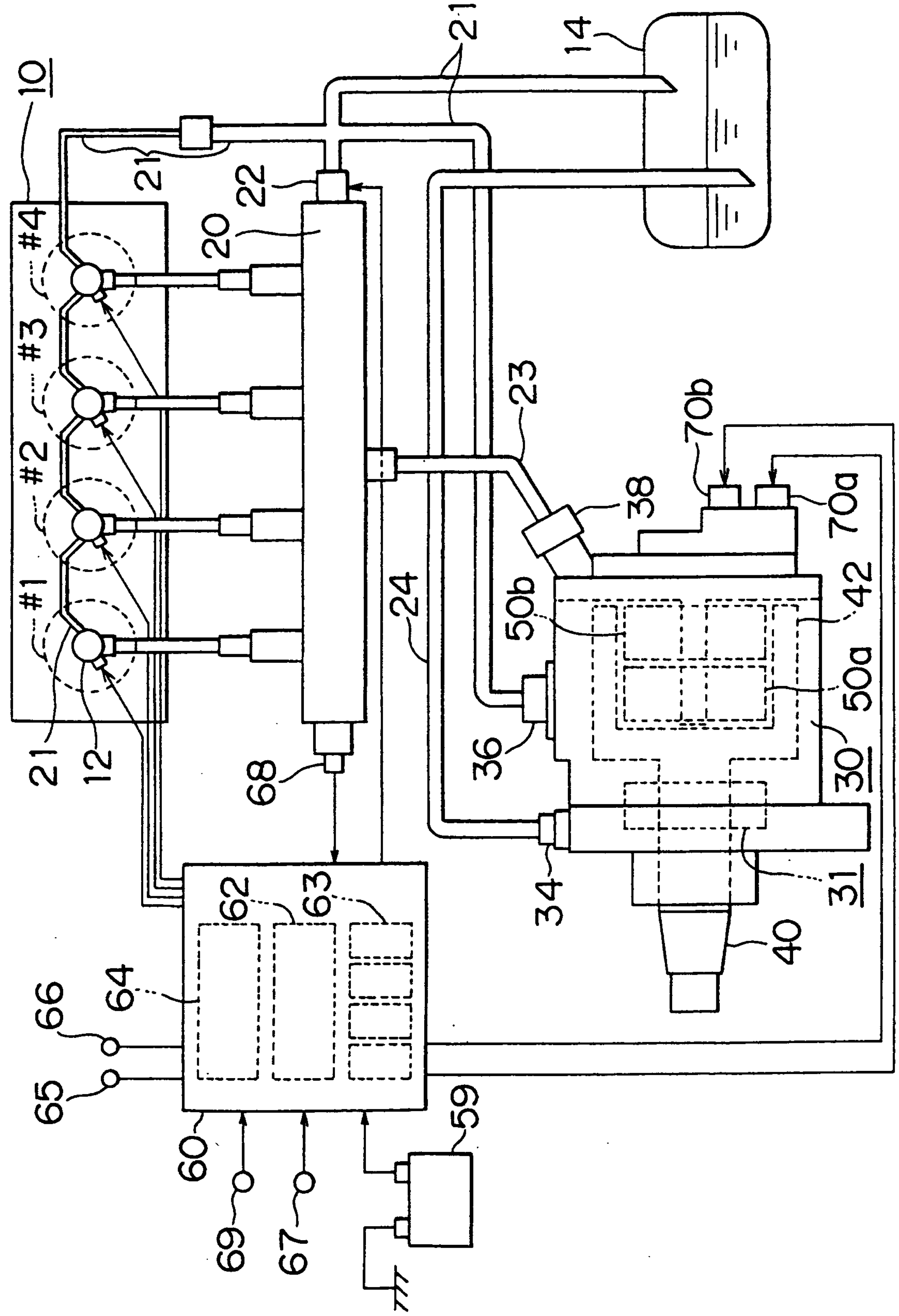
6. The fuel pressure control apparatus according to claim 1, **characterized in that** the electronic control unit (60) calculates a maximum open-valve period (TOPENMAX) of the relief valve (22) based on a response delay time (ΔT2) and an engine rotational speed (NE).

7. The fuel pressure control apparatus according to claim 6, **characterized in that** the maximum open-valve period (TOPENMAX) is shorter as the engine rotational speed (NE) is higher.

8. The fuel pressure control apparatus according to claim 3, **characterized in that** the relief valve driving control means (60) sets the open-valve period of the relief valve (22) based on a decreasing speed of the relief valve (22) and a differential pressure (PCR-PCRTRG) between the detected fuel pressure (PCR) and the calculated target fuel pressure (PCRTRG).

9. The fuel pressure control apparatus according to claim 1, **characterized in that** the relief valve driving control means (60) outputs a valve-opening signal and a valve-closing signal of the relief valve (22) based on a response delay time (ΔT2) of the relief valve (22).

FIG. 1


10
21
14
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22
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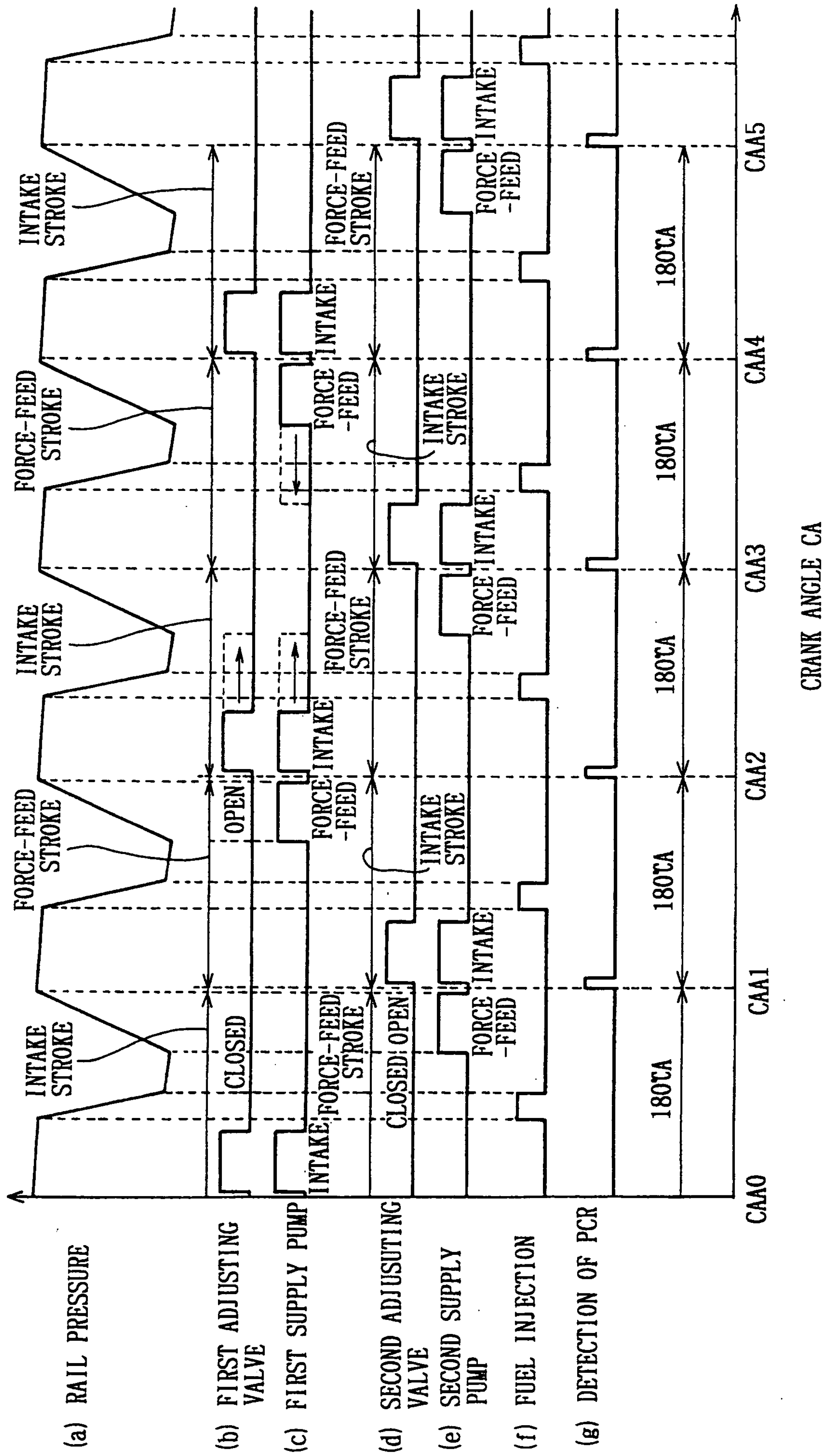
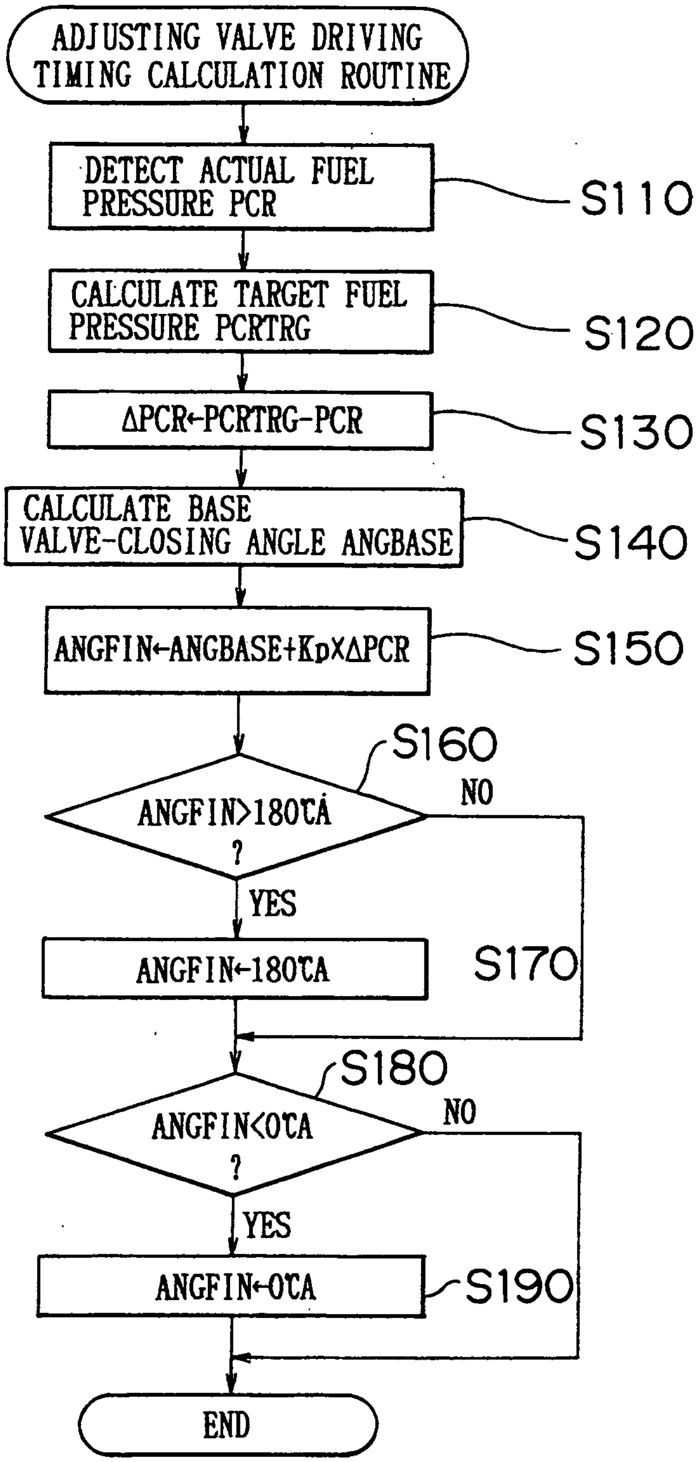
#1
#2
#3
#4
21
12
23
24
38
70b
70a
42
50b
50a
30
31
36
34
40
68
60
62
63
64
65
66
67
69
59

FIG. 2


(a) RAIL PRESSURE
(b) FIRST ADJUSTING VALVE
(c) FIRST SUPPLY PUMP
(d) SECOND ADJUSUTING VALVE
(e) SECOND SUPPLY PUMP
(f) FUEL INJECTION
(g) DETECTION OF PCR
INTAKE STROKE
FORCE-FEED STROKE
INTAKE STROKE
FORCE-FEED STROKE
INTAKE STROKE
CLOSED
OPEN
INTAKE
FORCE-FEED STROKE
FORCE -FEED
INTAKE
FORCE-FEED STROKE
FORCE -FEED
INTAKE
FORCE-FEED STROKE
CLOSED
OPEN
INTAKE STROKE
INTAKE STROKE
FORCE -FEED
INTAKE
FORCE -FEED
INTAKE
FORCE -FEED
INTAKE
180℃A
180℃A
180℃A
180℃A
180℃A
CAA0
CAA1
CAA2
CAA3
CAA4
CAA5
CRANK ANGLE CA

F I G. 3


ADJUSTING VALVE DRIVING TIMING CALCULATION ROUTINE
DETECT ACTUAL FUEL PRESSURE PCR
S110
CALCULATE TARGET FUEL PRESSURE PCRTRG
S120
ΔPCR←PCRTRG-PCR
S130
CALCULATE BASE VALVE-CLOSING ANGLE ANGBASE
S140
ANGFIN←ANGBASE+Kp×ΔPCR
S150
S160
ANGFIN>180℃A ?
NO
YES
ANGFIN←180℃A
S170
S180
ANGFIN<0℃A ?
NO
YES
ANGFIN←0℃A
S190
END

F I G. 4

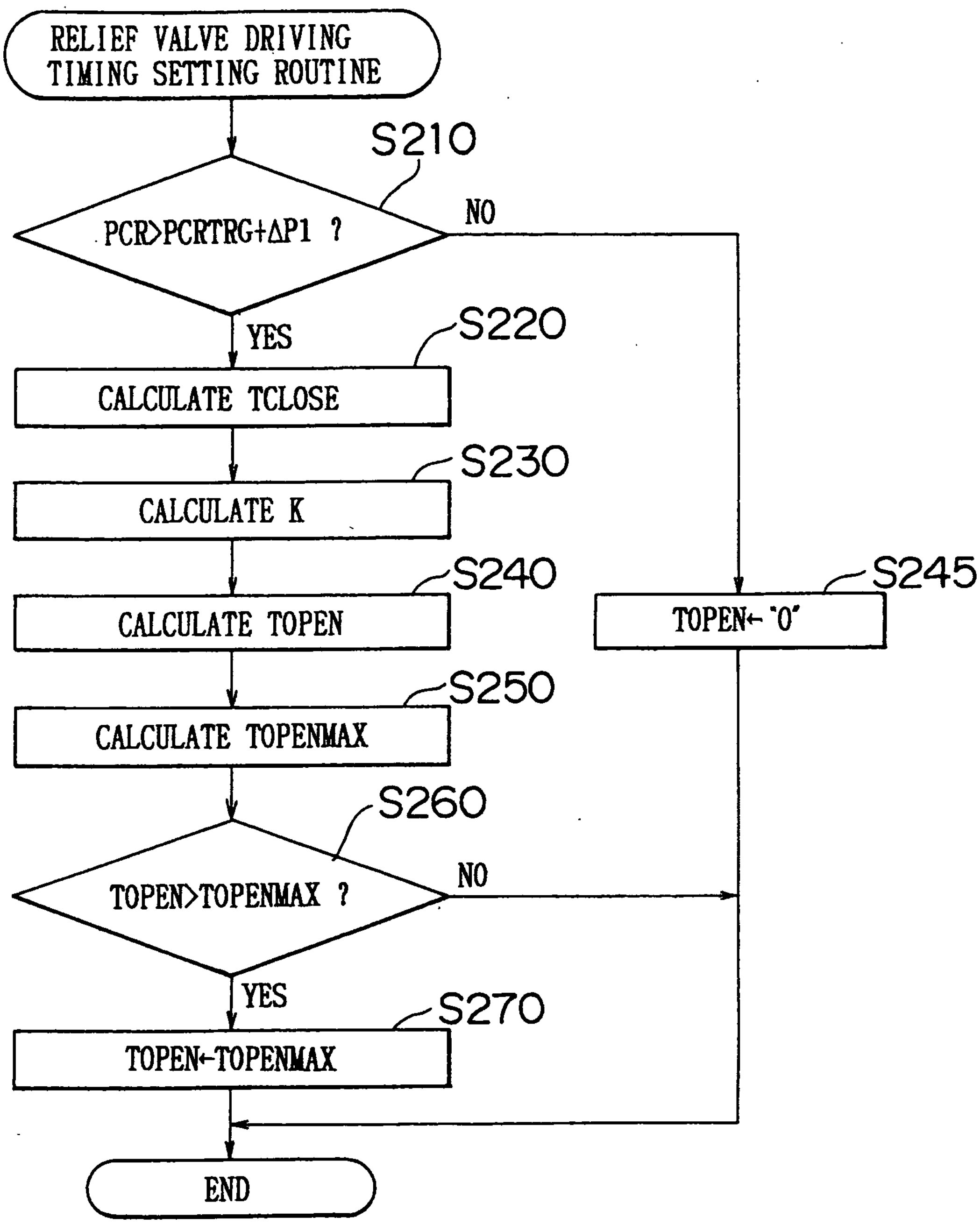

RELIEF VALVE DRIVING
TIMING SETTING ROUTINE
S210
PCR>PCRTRG+ΔP1 ?
NO
YES
S220
CALCULATE TCLOSE
S230
CALCULATE K
S240
CALCULATE TOPEN
S245
TOPEN← "0"
S250
CALCULATE TOPENMAX
S260
TOPEN>TOPENMAX ?
NO
YES
S270
TOPEN←TOPENMAX
END

FIG. 5

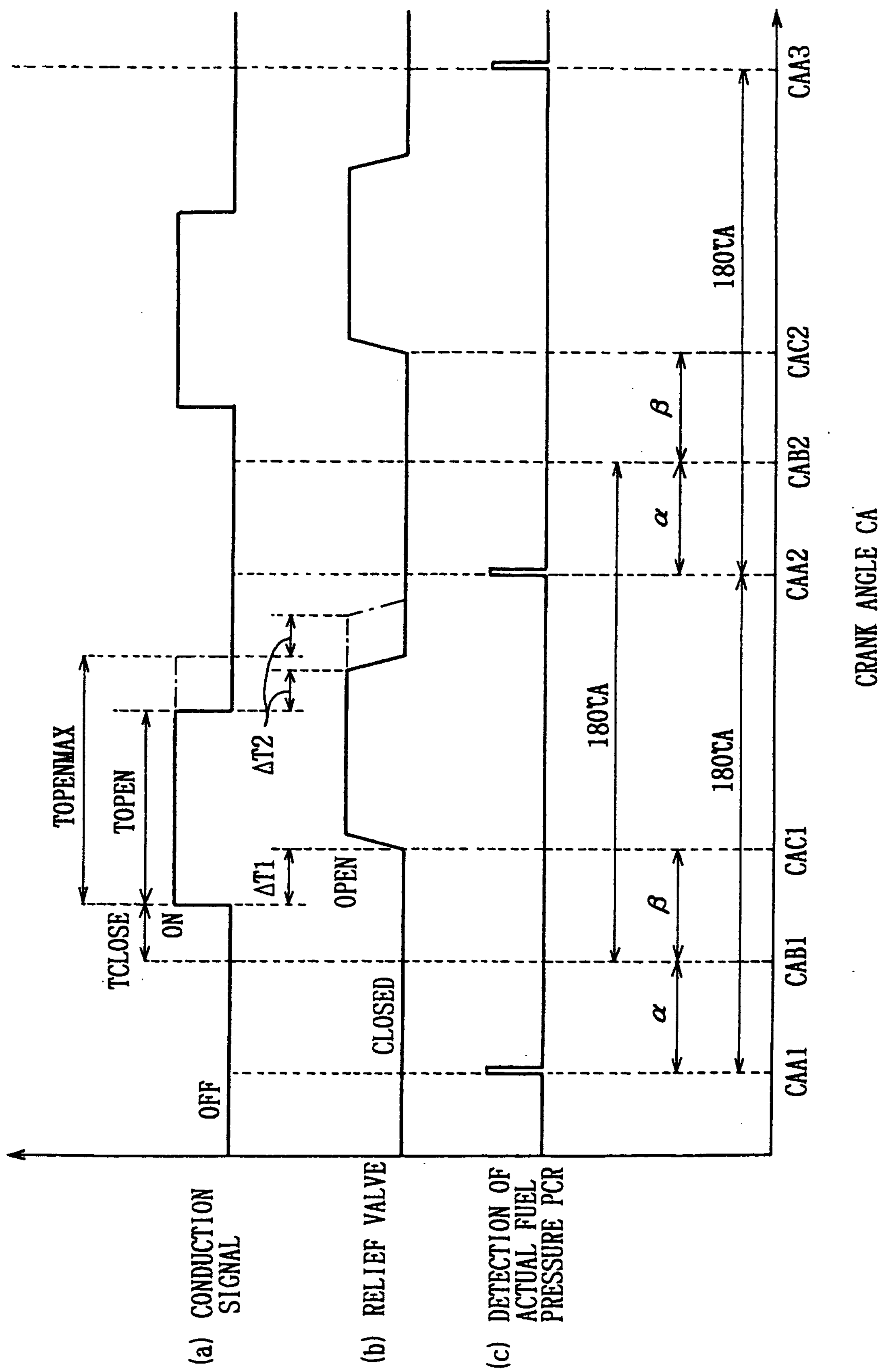

(a) CONDUCTION SIGNAL
(b) RELIEF VALVE
(c) DETECTION OF ACTUAL FUEL PRESSURE PCR
OFF
ON
TCLOSE
TOPEN
TOPENMAX
ΔT1
ΔT2
CLOSED
OPEN
α
β
180℃A
CAA1
CAB1
CAC1
CAA2
CAB2
CAC2
CAA3
CRANK ANGLE CA

FIG. 6

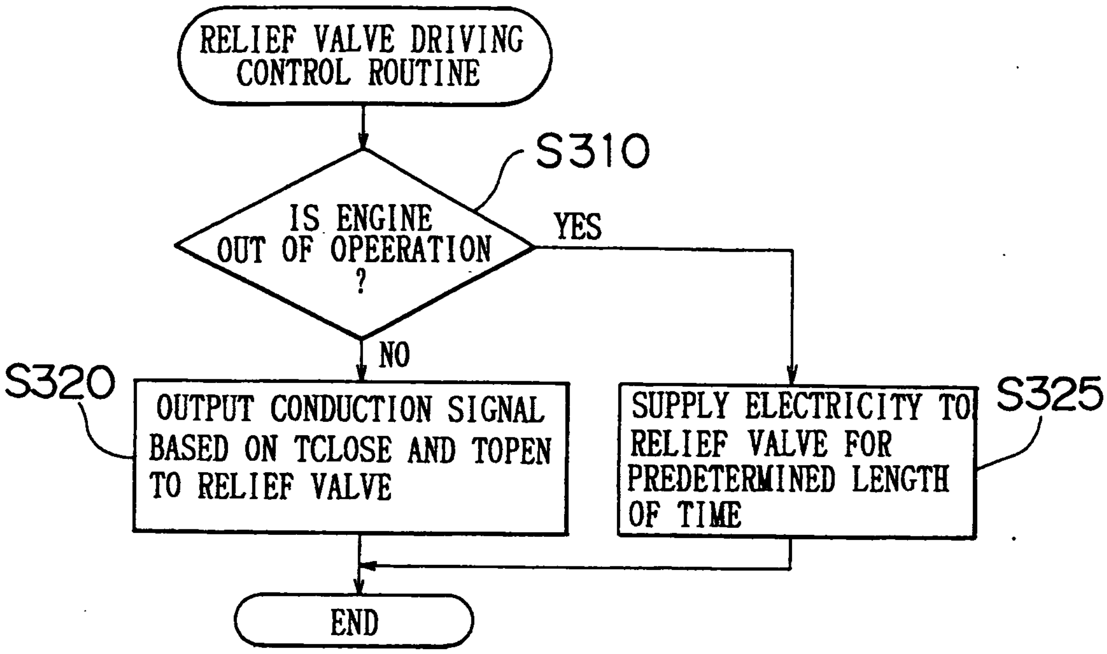
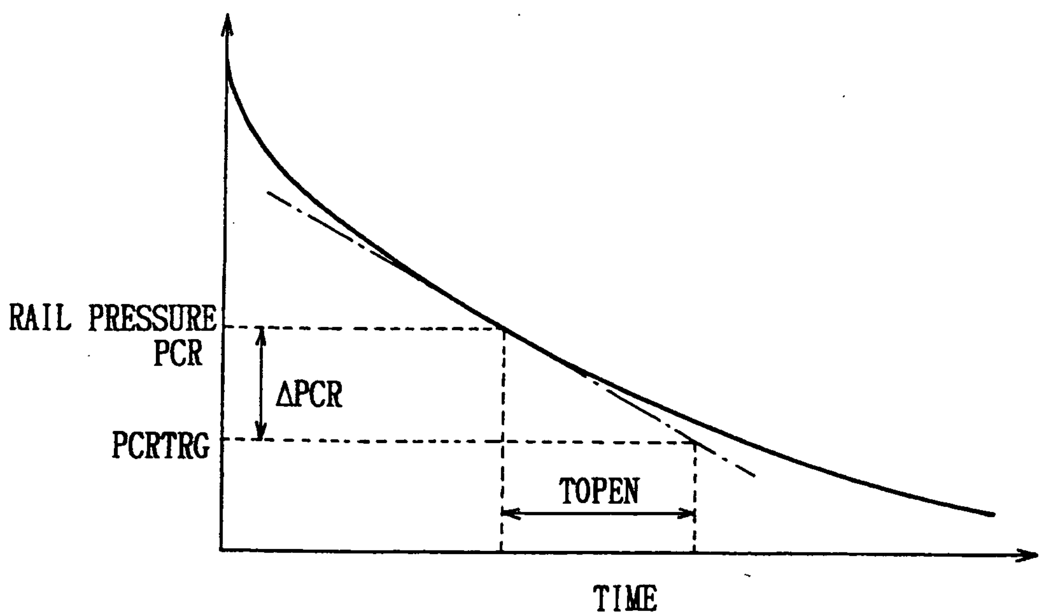

RELIEF VALVE DRIVING CONTROL ROUTINE
S310
IS ENGINE OUT OF OPEERATION ?
YES
NO
S320
OUTPUT CONDUCTION SIGNAL BASED ON TCLOSE AND TOPEN TO RELIEF VALVE
SUPPLY ELECTRICITY TO RELIEF VALVE FOR PREDETERMINED LENGTH OF TIME
S325
END

FIG. 7


RAIL PRESSURE PCR
ΔPCR
PCRTRG
TOPEN
TIME