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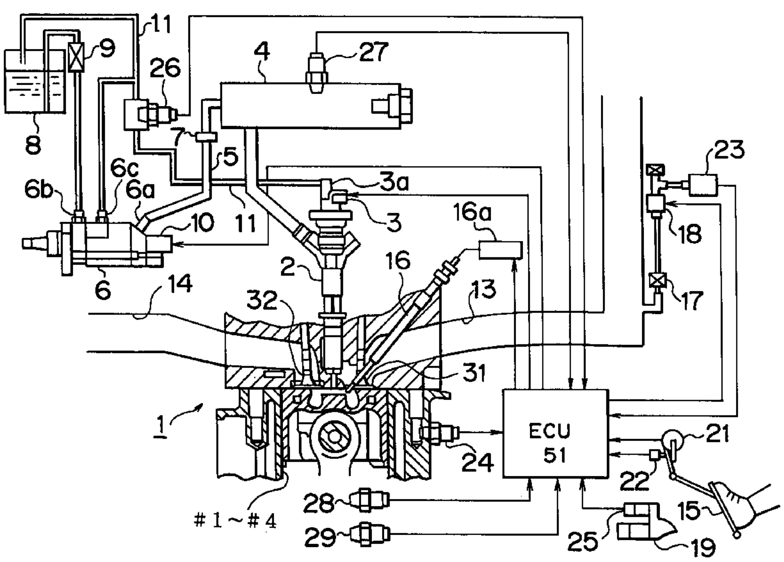
(54) Fuel injection control apparatus for an accumulator type engine

(57) A fuel injection control apparatus for an accumulator type engine (1) efficiently reduces fuel pressure in an accumulator pipe (4) if the fuel pressure exceeds a target pressure, thereby ensuring stable combustion. Injectors (2) of a diesel engine (1) are connected to a common rail (4) provided commonly for all the cylinders (#1-#4) of the engine. The common rail (4) is connected to a supply pump (6) by a supply pipe (5). Each injector (2) has a mechanism that injects fuel into the corresponding one of the cylinders (#1-#4) when an electromagnetic valve (3) provided in the injector (2) is driven, and that releases fuel to reduce the fuel pressure in the common rail (4) during an early period (ineffective injection time) after the start of the driving of the electromagnetic valve (3). An electronic control unit (51) executes an ineffective injection control during the ineffective injection control time to reduce the fuel pressure in the common rail (4), if the target injection amount is "0" and the actual fuel pressure is greater than the target fuel pressure. The ineffective injection control time is set to greater values as the fuel temperature decreases.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

1. Field of the invention

[0001] The present invention relates to a fluid injection control apparatus for an accumulator type engine, such as a diesel engine.

2. Description of the related art

[0002] An accumulator type fuel injection apparatus, known as a fuel injection apparatus for diesel engines, accumulates high-pressure fuel from a supply pump in an accumulator pipe normally termed a common rail, and injects fuel from the accumulator pipe into each cylinder of the engine by opening an injector nozzle.

[0003] In an accumulator type fuel injection apparatus disclosed in JP-A-2-191865, for example, the fuel pressure in the common rail is controlled by controlling the amount of pressurized fuel supplied from the supply pump, and a predetermined amount of fuel is injected by opening the injector for a predetermined length of time. During a fuel injecting process performed in this disclosed apparatus, a predetermined delay time occurs between the output of an on-signal to the injector and the start of actual fuel injection. That is, actual fuel injection does not occur until the delay time has been elapsed (ineffective injection time).

[0004] This fuel injection apparatus also has a direction changeover valve that is provided downstream of the common rail. If the fuel pressure inside the common rail exceeds a target pressure, the direction changeover valve is controlled, and the on-signal is outputted to the injector for a certain length of time (ineffective injection control time) within the ineffective injection time. During the ineffective injection control time, fuel is not injected from the injector but returned toward a fuel tank. The fuel pressure in the common rail is thereby quickly decreased. Therefore, this technology considerably reduces loud combustion noises resulting from injection of fuel at a pressure higher than the target pressure.

[0005] However, the time (ineffective injection time) between the output of the on-signal to the injection and the start of actual fuel injection varies depending on various conditions during engine operation, such as the viscosity of fuel, the pressure of fuel, and the like, due to the construction of the direction control valve and the like. This is because changes in fuel viscosity, fuel pressure and the like change the flowability of fuel, that is, the flow rate of fuel. For example, if the fuel viscosity is high (or the fuel temperature is low), or if the fuel pressure is low, the ineffective injection time tends to increase. Despite this fact, the ineffective injection control time is set to a fixed length of time in the related-art technology. Therefore, in the related-art technology, a case can occur where the ineffective injection time becomes considerably long due to a considerably reduced fuel flowability in accordance with the present engine operating conditions, so that the fixed ineffective injection control time becomes relatively very short. If the fuel pressure in the common rail is higher than the target fuel pressure in the aforementioned case, the reduction of the fuel pressure to the target fuel pressure requires a considerably long time, that is, a considerably great number of cycles of the ineffective injection time (including the ineffective injection control time). In the related art, therefore, there is a danger that a necessary fuel pressure reduction cannot be quickly or efficiently achieved.

SUMMARY OF THE INVENTION

[0006] The invention has been accomplished in view of the aforementioned problem of the related art. It is an object of the invention to provide a fluid injection control apparatus for an accumulator type engine wherein if the fluid pressure in an accumulator pipe exceeds a target pressure, the fluid pressure is efficiently decreased so that a stable combustion can be ensured.

[0007] The above object is achieved by the combination of features of the independent claims. In addition, the dependent claims describe further advantageous embodiments of the invention.

[0008] According to the invention, there is provided a fluid injection control apparatus for an accumulator type engine comprising: an accumulator piping for accumulating high-pressure fluid supplied from a pump; a fluid injection means driven and controlled on the basis of a balance between action and non-action of fluid pressure in the accumulator piping so as to perform fluid injection during a fluid pressure acting state and so as to refrain from performing fluid injection during a fluid pressure non-acting state; and a control valve for establishing the fluid pressure non-acting state by leaking the fluid pressure introduced into the fluid injection means, toward a low pressure side, in order to control the action and the non-action of the fluid pressure on the fluid injection means, wherein if the fluid pressure in the accumulator piping is greater than a target value, the control valve is caused to perform an operation of leaking the fluid pressure introduced into the fluid injection means toward the low pressure side at a fluid injection timing and during a period apart from the fluid injection timing, the fluid injection control apparatus further comprising: an engine operation environment detection means for detecting a state of the engine; and ineffective injection control time setting means for setting an ineffective injection control time during which the high pressure fluid injection by the fluid injection means is substantially impossible, on the basis of the state of the engine detected by the engine operation environment detection means, wherein during the ineffective injection control time, the operation of the control valve is performed.

[0009] According to a first advantageous further development, the engine operation environment detection means detects a fuel viscosity, and wherein the ineffective injection control time setting means sets the ineffective injection control time to an increased value as the fuel viscosity detected by the engine operation environment detection means increases.

[0010] According to a second advantageous further development, the engine operation environment detection means comprises a fuel temperature detection means for detecting a fuel temperature, and wherein the ineffective injection control time setting means sets the ineffective injection control time to an increased value as the fuel temperature detected by the fuel temperature detection means decreases.

[0011] According to a third advantageous further development, the engine operation environment detection means comprises a fuel pressure detection means for detecting a fuel pressure, and wherein the ineffective injection control time setting means sets the ineffective injection control time to an increased value as the fuel pressure detected by the fuel pressure detection means decreases.

[0012] According to a fourth advantageous further development, the control of causing the control valve to leak the fluid pressure introduced into the fluid injection means toward the low pressure side is performed at least when the engine state changes from a cranking state to a complete combustion state.

[0013] According to the invention, there is also provided a fuel injection control apparatus for an accumulator type engine comprising: an accumulator piping for receiving high-pressure fuel supplied from a supply pump and accumulating a high pressure fuel; a fuel injection means connected to the accumulator piping and including a mechanism being capable of injecting fuel into a cylinder of the engine when driven, and being capable of releasing fuel to reduce fuel pressure inside the accumulator piping during an early ineffective injection time after the driving of the fuel injection means is started; an engine operation environment detection means for detecting a state of the engine; an injection control means for controlling the fuel injection means so as to inject fuel from the accumulator piping into the cylinder; a target fuel pressure calculation means for calculating a target fuel pressure on the basis of result of detection by the engine operation environment detection means; and a fuel pressure reduction control means for reducing the fuel pressure in the accumulator piping by controlling fuel injection means for a predetermined ineffective injection control time when the fuel pressure actually detected by the engine operation environment detection means becomes equal to or greater than the target fuel pressure calculated by the target fuel pressure calculation means, the fuel injection control apparatus further comprising an ineffective injection control time setting means for setting the ineffective injection control time on the basis of result of detection by the engine operation environment detection means.

[0014] According to the invention, there is also provided a fuel injection control apparatus for an accumulator type engine comprising: an accumulator piping for accumulating high-pressure fluid supplied from a pump; a fuel injection means driven and controlled on the basis of a balance between action and non-action of fluid pressure in the accumulator piping so as to perform fluid injection during a fluid pressure acting state and so as to refrain from performing fluid injection during a fluid pressure non-acting state; and a control valve for establishing the fluid pressure non-acting state by leaking the fluid pressure introduced into the fuel injection means, toward a low pressure side, in order to control the action and the non-action of the fluid pressure on the fuel injection means, wherein if the fluid pressure in the accumulator piping is greater than a target value, the control valve is caused to perform an operation of leaking the fluid pressure introduced into the fuel injection means toward the low pressure side at a fuel injection timing and during a period apart from the fuel injection timing, the fuel injection control apparatus further comprising: an engine operation environment detection means for detecting a state of the engine; and ineffective injection control time setting means for setting an ineffective injection control time during which the high pressure fuel injection by the fuel injection means is substantially impossible, on the basis of the state of the engine detected by the engine operation environment detection means, wherein during the ineffective injection control time, the operation of the control valve is performed.

(Operation)

[0015] According to the invention, high-pressure fluid is supplied from the pump to the accumulator piping, and is accumulated in the accumulator piping. By driving the fluid injection means connected to the accumulator piping, high pressure fluid is injected into the cylinder of the engine. During an early ineffective injection time after the driving of the fuel injection means is started, fluid is released so that the fluid pressure in the accumulator piping can be reduced.

[0016] Furthermore, various states of the engine can be detected by the engine operation environment detection means. Based on the result of detection by the engine operation environment detection means, the ineffective injection control time is set. Therefore, while the ineffective injection time naturally varies depending on the state of the engine, the ineffective injection control time for a pressure reduction in the accumulator piping can be set to a greatest-possible value in accordance with the state of the engine by the apparatus of the invention. Therefore, a maximum pressure reduction can be achieved in accordance with the state of the engine changing from time to time.

[0017] According to the first advantageous further development, the ineffective injection control time setting means sets the ineffective injection control time to an increased value as the fuel viscosity detected by the engine operation environment detection means increases. Normally, the actual ineffective injection time tends to increase as the fuel viscosity increases. However, the ineffective injection control time can be set to increased values substantially in accordance with increases of the ineffective injection time. Therefore, a correspondingly increased pressure reduction in the unit of time can be achieved.

[0018] In the second advantageous further development, the ineffective injection control time setting means sets the ineffective injection control time to an increased value as the fuel temperature detected by the fuel temperature detection means increases. Normally, the actual ineffective injection time tends to increase as the fuel temperature decreases. In this mode of the invention, the ineffective injection control time can be set to increased values substantially in accordance with increases of the ineffective injection time. Therefore, a correspondingly increased pressure reduction in the unit of time can be achieved.

[0019] In the third advantageous further development, the ineffective injection control time setting means sets the ineffective injection control time to an increased value as the fuel pressure detected by the fuel pressure detection means increases. Normally, the actual ineffective injection time tends to increase as the fuel pressure decreases. In this mode of the invention, the ineffective injection control time can be set to increased values substantially in accordance with increases of the ineffective injection time. Therefore, a correspondingly increased pressure reduction in the unit of time can be achieved.

[0020] In the fourth advantageous further development, the control of causing the control valve to leak the fluid pressure introduced into the fluid injection means toward the low pressure side is performed at least when the engine state changes from the cranking state to the complete combustion state. A high fluid pressure is needed during the cranking state, whereas after the transition to the complete combustion state, that is, after the starting of the diesel engine has been completed, the fluid pressure needs to be reduced. This need is reliably met by the operation of the apparatus in this mode.

[0021] According to the invention, a high-pressure fuel is supplied from the supply pump to the accumulator piping, and accumulated therein. By driving the fuel injection means connected to the accumulator piping, fuel is injected into the cylinder of the engine. During an early ineffective injection time after the driving of the fuel injection means is started, fuel is released so that the fuel pressure in the accumulator piping can be reduced.

[0022] Furthermore, various states of the engine can be detected by the engine operation environment detection means. The fuel injection means is controlled by the injection control means so as to inject fuel from the accumulator piping into the cylinder.

[0023] Further, based on the result of detection by the engine operation environment detection means, a target fuel pressure is calculated by the target fuel pressure calculation means. When the actual fuel pressure detected by the engine operation environment detection means becomes equal to or greater than the target fuel pressure calculated by the target fuel pressure calculation means, the fuel injection means is controlled by the fuel pressure reduction control means for a predetermined ineffective injection control time. By this operation, the fuel pressure in the accumulator piping is reduced.

[0024] In the invention, the ineffective injection control time is set by the ineffective injection control time setting means, on the basis of the result of detection by the engine operation environment detection means. Therefore, while the ineffective injection time naturally varies depending on the state of the engine, the ineffective injection control time for a pressure reduction in the accumulator piping can be set to a greatest-possible value in accordance with the state of the engine by the apparatus of the invention. Therefore, a maximum pressure reduction can be achieved in accordance with the state of the engine changing from time to time.

[0025] The invention does not necessarily require all the features described above. That is, the invention may also reside in a sub-combination of the described features.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] The foregoing object as well as further features and advantages of the present invention will become apparent from the following description of preferred embodiments with reference to the accompanying drawings, wherein like numerals are used to represent like elements and wherein:

Fig. 1 is a schematic illustration of the construction of a preferred embodiment of the fuel injection control apparatus for an accumulator type engine of the invention;

Fig. 2A is a sectional view of the injector shown in Fig. 1, illustrating a state wherein the solenoid of an electromagnetic valve is not excited;

Fig. 2B is a sectional view of the injector shown in Fig. 1, illustrating an ineffective injection state of the injector;

Fig. 2C is a sectional view of the injector shown in Fig. 1, illustrating an actual injection state of the injector;

Fig. 3 is a block diagram of the electric construction of an ECU;

Fig. 4 is a flowchart of an ineffective injection control time calculating routine executed by the ECU;

Fig. 5 is a map indicating the relationship of a fuel temperature correction coefficient with fuel temperature;

Fig. 6 is a map indicating the relationship of the fuel temperature correction coefficient with fuel pressure; and

Fig. 7 is a flowchart of an electromagnetic valve control routine executed by the ECU.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0027] A preferred embodiment of the present invention wherein the fuel injection control apparatus for an accumulator type engine according to the invention is embodied in a diesel engine will be described in detail hereinafter with reference to the accompanying drawings.

[0028] Fig. 1 is a schematic illustration of the construction of a fuel injection control apparatus for an accumulator type diesel engine according to the embodiment wherein the apparatus is installed in a vehicle. A diesel engine 1 has a plurality of cylinders (four cylinders #1-#4 in this embodiment). A combustion chamber of each cylinder #1-#4 is provided with an injector 2, that is, a fuel injection device. The fuel injection from each injector 2 into the corresponding one of the cylinders #1- #4 of the diesel engine 1 is controlled by turning on and off an injection control electromagnetic valve 3.

[0029] The injectors 2 are connected to a common rail 4, that is, an accumulator pipe provided commonly for all the cylinders #1-#4. Fuel from the common rail 4 is injected into the cylinders #1-#4 by the injectors 2 when the respective electromagnetic valves 3 are open. The common rail 4 needs to successively accumulate relatively high fuel pressures corresponding to the fuel injection pressure, particularly at the time of start of the engine. To this end, the common rail 4 is connected to an ejection port 6a of a supply pump 6 by a supply pipe 5. A check valve 7 is disposed in part way of the supply pipe 5. The check valve 7 allows fuel to be supplied from the supply pump 6 to the common rail 4 and restricts reverse flow of fuel from the common rail 4 to the supply pump 6.

[0030] The supply pump 6 is connected to a fuel tank 8, via an intake port 6b. A filter 9 is provided in part way of the pipe between the intake port 6b and the fuel tank 8. The supply pump 6 draws fuel from the fuel tank 8, through the filter 9. In addition, the supply pump 6 reciprocates a plunger by using a cam (not shown) that is synchronized with revolution of the diesel engine 1, in order to increase the fuel pressure to a predetermined required pressure. Then, the supply pump 6 supplies high-pressure fuel to the common rail 4.

[0031] A pressure control valve 10 is provided near the ejection port 6a of the supply pump 6. The pressure control valve 10 controls the pressure of fuel ejected (therefore, the amount of fuel ejected) from the ejection port 6a toward the common rail 4. By opening the pressure control valve 10, surplus fuel that is not ejected from the ejection port 6a is returned from the supply pump 6 to the fuel tank 8, via a return port 6c of the supply pump 6 and a return pipe 11.

[0032] An intake air channel 13 and an exhaust gas channel 14 are connected to the combustion chambers of the diesel engine 1. The intake air channel 13 is provided with a throttle valve (not shown). By operating the throttle valve, the flow of intake air to be introduced into each combustion chamber is adjusted.

[0033] A glow plug 16 is provided for each combustion chamber of the diesel engine 1. Each glow plug 16 is an engine starting assistant device that is heated to glow by supplying current through a glow relay 16a immediately before the diesel engine 1 is started. By contacting an upper portion of a spray of injected fuel, the heated glow plug 16 in each chamber promotes ignition and combustion of fuel.

[0034] The injectors 2 in this embodiment inject fuel into the cylinders #1-#4 when the electromagnetic valves 3 are driven. Furthermore, each injector 2 has a mechanism for releasing fuel therefrom so as to reduce the fuel pressure in the common rail 4 during an initial period (hereinafter, referred to as "ineffective injection time") after the driving of the corresponding electromagnetic valve 3 is started. This mechanism will be described below.

[0035] As shown in Fig. 2A, a casing 61 of each injector 2 is provided with a supply port 62 that is connected to the common rail 4 by a supply pipe 63. Therefore, fuel from the common rail 4 is introduced through the supply port 62 into a lower fuel reservoir chamber 64 formed in a lower portion of the casing 61. Nozzle pores 65 that can communicate with the lower fuel reservoir chamber 64 are formed in a lowest portion of the casing 61. The supply port 62 is also connected to an upper fuel reservoir chamber 67, via an orifice 66. A nozzle needle 68 is slidably disposed extending in the lower fuel reservoir chamber 64 and the upper fuel reservoir chamber 67.

[0036] The nozzle needle 68 has a distal end portion 69, a large-diameter portion 70, a small-diameter portion 71 and a piston portion 72 that are formed in that order from the bottom. The nozzle needle 68 is disposed so that the large-diameter portion 70 is movable up and down within an upper portion of the lower fuel reservoir chamber 64 and so that the piston portion 72 is movable up and down within a lower portion of the upper fuel reservoir chamber 67. A nozzle needle spring 73 is disposed surrounding the outer peripheral surface of the small-diameter portion 71. The spring 73 normally urges the nozzle needle 68 downwardly in Fig. 2A. Therefore, the distal end portion 69 of the nozzle needle 68 is normally in contact with a seat portion 74 of the casing 61 that is formed near the nozzle pores 65.

[0037] The upper fuel reservoir chamber 67 is connected to an electromagnetic valve housing chamber 76, via an orifice 75. The electromagnetic valve 3 is formed by a valve body 77, a solenoid 78, a valve body spring 79 and the like, which are disposed in the electromagnetic valve housing chamber 76. More specifically, the valve body 77 is disposed in a lower portion of the electromagnetic valve housing chamber 76. The valve body spring 79 is disposed in contact with the valve body 77 and a ceiling of the electromagnetic valve housing chamber 76. The spring 79 normally urges the valve body 77 downward so as to close the orifice 75, thereby shutting down the communication between the upper fuel reservoir chamber 67 and the electromagnetic valve housing chamber 76. The solenoid 78, when excited, draws the valve body 77 upward in Fig. 2A, against the urging force of the valve body spring 79. The valve body 77 has a flanged upper portion in which through-holes 77a are formed. The casing 61 has a return port 80 for releasing fuel from the electromagnetic valve housing chamber 76. Under a predetermined condition, surplus fuel is returned from the return port 80 to the fuel tank 8 through the return pipe 11. A space in which the nozzle needle spring 73 is disposed and the electromagnetic valve housing chamber 76 are connected in communication with each other by a communication channel 81. Therefore, fuel flowing in small amounts into the space containing the spring 73 gradually flows out therefrom, in small amounts, through the communication channel 81 into the electromagnetic valve housing chamber 76, and then flows through the through-holes 77a and the return port 80, toward the return pipe 11.

[0038] The operation of each injector 2 will be described. When the solenoid 78 is not excited, the valve body 77 is urged downward by the valve body spring 79, thereby shutting down the communication between the upper fuel reservoir chamber 67 and the electromagnetic valve housing chamber 76, as shown in Fig. 2A. In this condition, therefore, fuel from the supply port 62 is supplied equally to the lower fuel reservoir chamber 64 and the upper fuel reservoir chamber 67 so that pressure balance is maintained. Consequently, the nozzle needle 68 is urged downward by the nozzle needle spring 73 so that the distal end portion 69 of the nozzle needle 68 is held in contact with the seat portion 74 formed near the nozzle pores 65. In this case, therefore, fuel is not injected from the nozzle pores 65, and fuel does not quickly flow out of the upper fuel reservoir chamber 67 into the return port 80.

[0039] When the solenoid 78 is excited, the solenoid 78 draws the valve body spring 79 upward against the urging force of the valve body spring 79, so that the electromagnetic valve housing chamber 76 comes into communication with the upper fuel reservoir chamber 67. For a while, the injector 2 undergoes a transient process or state as indicated in Fig. 2B. That is, since the valve body 77 moves upward, fuel flows from the upper fuel reservoir chamber 67 into the return pipe 11 through the through-holes 77a and the return port 80. For a certain period after the start of excitation of the solenoid 78, the difference between the fuel pressure in the lower fuel reservoir chamber 64 and the fuel pressure in the upper fuel reservoir chamber 67 remains smaller than the urging force of the nozzle needle spring 73. Therefore, the nozzle needle 68 remains still, so that the distal end portion 69 remains in contact with the seat portion 74. Consequently, in this condition, fuel is not injected from the nozzle pores 65, but fuel quickly flows out of the upper fuel reservoir chamber 67 into the return pipe 11 through the return port 80. This period is the ineffective injection time.

[0040] When a considerable amount of fuel has quickly flown out of the upper fuel reservoir chamber 67 so that the difference between the fuel pressure in the lower fuel reservoir chamber 64 and the fuel pressure in the upper fuel reservoir chamber 67 exceeds the urging force of the nozzle needle spring 73, the nozzle needle 68 is moved upward as indicated in Fig. 2C, as the fuel pressure in the lower fuel reservoir chamber 64 is now sufficiently greater. Therefore, the distal end portion 69 separates from the seat portion 74, so that the lower fuel reservoir chamber 64 comes into communication with the nozzle pores 65. Thus, high-pressure fuel is injected from the nozzle pores 65.

[0041] Subsequently, the excitation of the solenoid 78 is discontinued, so that the injector 2 resumes the state as indicated in Fig. 2A, thereby completing fuel injection. If the excitation time of the solenoid 78 is less than the ineffective injection time, the transition from the state as indicated in Fig. 2B to the state as indicated in Fig. 2C does not occur. In such a case, fuel injection does not occur, but mere quick outflow of fuel from the upper fuel reservoir chamber 67 into the return pipe 11 through the return port 80 occurs.

[0042] The diesel engine 1 is equipped with various sensors for detecting conditions of the diesel engine 1. These sensors form an engine operation environment detection device. As shown in Fig. 1, an accelerator sensor 21 is provided near an accelerator pedal 15, for detecting depression ACCP of the accelerator pedal 15. Provided near the accelerator sensor 21 is a complete closure switch 22 that outputs a complete closure signal when the depression of the accelerator pedal 15 is zero.

[0043] An intake air pressure sensor 23 is connected to the intake air channel 13, with a filter 17 and a vacuum switching valve (VSV) 18 disposed therebetween. The intake air pressure sensor 23 detects pressure of intake air (intake air pressure PM) within the intake air channel 13.

[0044] A coolant temperature sensor 24 is provided in a cylinder block of the diesel engine 1, for detecting temperature of cooling water (coolant temperature THW) therein.

[0045] The diesel engine 1 also has a starter 19 for starting the engine 1. The starter 19 has a starter switch 25 that detects an operating state thereof. The starter switch 25 outputs an starter signal STA at an on-status when the ignition switch (not shown) is operated from an OFF position to a START position so that the starter 19 operates (that is, a cranking state is assumed) to start the diesel engine 1. When the starting of the diesel engine 1 is completed (a complete combustion state is assumed) and the ignition switch is returned from the START position to an ON position, the starter switch 25 outputs the starter signal STA at an off-status.

[0046] A fuel temperature sensor 26 is provided in the return pipe 11, for detecting a fuel temperature THF. In this embodiment, a parameter corresponding to a fuel viscosity is detected by using the fuel temperature sensor 26. A fuel pressure sensor 27 is provided in the common rail 4, as a fuel pressure detection device for detecting pressure of fuel (fuel pressure PC) in the common rail 4.

[0047] Furthermore, in the embodiment, an engine speed sensor 28 for detecting engine revolution speed is provided near a pulser that is provided at a crank shaft (not shown) of the diesel engine 1. Revolution of the crank shaft is transmitted to a cam shaft (not shown) for opening and closing an intake air valve 31 and an exhaust gas valve 32, by a timing belt and the like. The transmission mechanism is designed so that the cam shaft revolves at a revolution rate of 1/2 of that of the crank shaft. A G-sensor 29 is provided near a pulser that is provided at the cam shaft. In this embodiment, an engine revolution speed NE, a crank angle CA and a top dead center (TDC) of each cylinder #1-#4 are calculated on the basis of pulse signals from the sensors 28, 29.

[0048] In the embodiment, an electronic control unit (ECU) 51 for performing various controls on the diesel engine 1 is provided. The ECU 51 functions as a fuel injection device, a target fuel pressure calculating device, a fuel pressure reduction control device, and an ineffective injection control time setting device.

[0049] The electric construction of the ECU 51 will be described with reference to the block diagram of Fig. 3. The ECU 51 has a central processing unit (CPU) 52, a read-only memory (ROM) 53 in which predetermined programs, maps and the like are pre-stored, a random access memory (RAM) 54 for temporarily storing the results of calculations and operations executed by the CPU 52, a backup RAM 55 for storing pre-stored data and the like, a timer counter 56, and the like. The ECU 51 further has an input interface 57, an output interface 58 and the like. The aforementioned components 52-56 are connected to the input interface 57 and the output interface 58 by busses 59.

[0050] Each of the accelerator sensor 21, the intake air pressure sensor 23, the coolant temperature sensor 24, the fuel temperature sensor 26, the fuel pressure sensor 27, and the like is connected to the input interface 57, via a buffer, a multiplexer and an A/D converter (which are not shown). Each of the engine speed sensor 28 and the G-sensor 29 is connected to the input interface 57, via a waveform shaping circuit. The complete closure switch 22 and the starter switch 25 are directly connected to the input interface 57.

[0051] The CPU 52 reads in the signals from the sensors and the like 21-29, via the input interface 57.

[0052] Each of the electromagnetic valve 3, the pressure control valve 10 and the vacuum switching valve (VSV) 18 is connected to the output interface 58, via a driving circuit (not shown). The CPU 52 suitably controls the electromagnetic valve 3, the pressure control valve 10, the vacuum switching valve 18 and the like, based on the input values read via the input interface 57.

[0053] Among the various controls executed by the ECU 51 in this embodiment, a fuel injection control will be described. Fig. 4 is a flowchart illustrating an ineffective injection control time calculating routine executed by the ECU 51. This routine is executed to calculate an ineffective injection control time τV that is used at the time of execution of ineffective injection. The ineffective injection control time calculating routine is executed by interruption at, for example, every predetermined crank angle.

[0054] When the operation changes to this routine, the ECU 51 first determines in step 101 whether the present target injection amount QFINC calculated in another routine (electromagnetic valve control routine described below) is "0". If the present target injection amount QFINC is not "0", the ECU 51 skips the calculation of an ineffective injection control time τV, and temporarily ends this routine in order to execute a normal fuel injection control.

[0055] Conversely, if the present target injection amount QFINC is "0", the ECU 51 makes affirmative determination in step 101. In this case, it is considered that there is no need to presently inject fuel. Subsequently in step 102, the ECU 51 calculates a fuel temperature correction coefficient KTHF based on the fuel temperature THF read from the fuel temperature sensor 26. For the calculation of the fuel temperature correction coefficient KTHF, the ECU 51 refers to a map as indicated in Fig. 5. That is, if the present fuel temperature THF is low, the fuel viscosity is high, so that the fuel flowability or flow rate tends to decrease and the ineffective injection time tends to increase. In such a case, therefore, the fuel temperature correction coefficient KTHF is set to a relatively large value, as indicated in Fig. 5. If the fuel temperature THF is high, the fuel viscosity is low, so that the fuel flowability tends to increase and the ineffective injection time tends to decrease. In such a case, the fuel temperature correction coefficient KTHF is set to a relatively small value.

[0056] Subsequently in step 103, the ECU 51 calculates a fuel pressure correction coefficient KPC based on the fuel pressure PC read from the fuel pressure sensor 27. For the calculation of the fuel pressure correction coefficient KPC, the ECU 51 refers to a map as indicated in Fig. 6. That is, if the fuel pressure PC is low, the fuel flowability or flow rate tends to decrease and the ineffective injection time tends to increase. In such a case, therefore, the fuel pressure correction coefficient KPC is set to a relatively large value, as indicated in Fig. 6. If the fuel pressure PC is high, the fuel flowability tends to increase and the ineffective injection time tends to decrease. In such a case, therefore, the fuel pressure correction coefficient KPC is set to a relatively small value.

[0057] Subsequently in step 104, the ECU 51 sets a value obtained by multiplying a predetermined reference ineffective injection control time $\tau V0$ by the fuel temperature correction coefficient KTHF and the fuel pressure correction coefficient KPC presently calculated, as a final ineffective injection control time τV. Then the ECU 51 temporarily ends this routine.

[0058] By the ineffective injection control time calculating routine, therefore, the ineffective injection control time τV is set to greater values as the fuel temperature THF decreases. Moreover, the ineffective injection control time τV is set to greater values as the fuel pressure PC decreases.

[0059] Next described will the content of the control of the electromagnetic valve 3 (solenoid 78) executed by the ECU 51. Fig. 7 is a flowchart of an electromagnetic valve control routine executed by the ECU 51. This routine is executed by interruption at, for example, every predetermined crank angle.

[0060] When the operation changes to this routine, the ECU 51 first calculates a target fuel pressure PFIN in accordance with the present operating conditions (engine revolution speed, engine load and the like) in step 201.

[0061] In step 202, the ECU 51 calculates a reference injection amount QBASE based on the present engine revolution speed NE, the accelerator depression ACCP, and the like. Subsequently in step 203, the ECU 51 calculates an injection correction term QCOR in accordance with various factors, for example, the operating condition of the air conditioner, and the operating condition of the power steering, and whether or not it is at the time of cold engine start, and the like.

[0062] Subsequently in step 204, the ECU 51 calculates a target injection amount QFINC based on the reference injection amount QBASE and the injection correction term QCOR presently calculated.

[0063] In step 205, the ECU 51 reads in the actual fuel pressure PC based on the result of detection by the fuel pressure sensor 27.

[0064] Subsequently in step 206, the ECU 51 determines whether the presently calculated target injection amount QFINC is greater than "0". If the target injection amount QFINC is not greater than "0", that is, if it is "0", the operation proceeds to step 207.

[0065] In step 207, the ECU 51 determines whether the presently read actual fuel pressure PC is greater than the presently calculated target fuel pressure PFIN. If the actual fuel pressure PC is greater than the target fuel pressure PFIN, the ECU 51 makes affirmative determination in step 207, which indicates that there is a need to quickly reduce the actual fuel pressure PC. Then the operation proceeds to step 208.

[0066] In step 208, the ECU 51 sets the ineffective injection control time τV calculated in the ineffective injection control time calculating routine, as a final energization time TQFIN for the electromagnetic valve 3 (solenoid 78), in order to execute the ineffective injection control (see Fig. 2B). Then, the ECU 51 temporarily ends this routine.

[0067] Conversely, if the ECU 51 makes affirmative determination in step 206 or makes negative determination in step 207, that is, if the target injection amount QFINC is greater than "0" or if the actual fuel pressure PC is not greater than the target fuel pressure PFIN, the ECU 51 proceeds to step 209, in order to perform actual fuel injection (see Fig. 2C).

[0068] In step 209, the ECU 51 calculates a final energization time TQFIN for the electromagnetic valve 3 (solenoid 78) based on the presently read fuel pressure PC and the presently calculated target injection amount QFINC, and sets the calculated final energization time TQFIN. For the calculation of the energization time TQFIN, the ECU 51 refers to a map (not shown) in which the energization time TQFIN is preset in relation to the fuel pressure PC and the target injection amount QFINC. After that, the ECU 51 temporarily ends this routine.

[0069] By the electromagnetic valve control routine, therefore, the ineffective injection control is performed if the target injection amount QFINC is "0" and the actual fuel pressure PC is greater than the target fuel pressure PFIN.

[0070] The advantages of this embodiment will be explained below.

[0071] In this embodiment, if the target injection amount QFINC is "0" and the actual fuel pressure PC is greater than the target fuel pressure PFIN, the ineffective injection control is performed. Therefore, the fuel pressure PC in the common rail 4 can be reduced.

[0072] For the ineffective injection control, the ECU 51 sets the ineffective injection control time τV as the final energization time TQFIN for the electromagnetic valve 3 (solenoid 78). In this embodiment, the ineffective injection control time τV is set to greater values as the fuel temperature THF decreases. Normally, if the fuel temperature THF is relatively low, the fuel viscosity is relatively high. The ineffective injection control time τV is set to greater values as the fuel pressure PC decreases. In such cases, the fuel flowability tends to decrease, and the ineffective injection time tends to increase, due to the apparatus construction. Therefore, this embodiment secures a longest-possible ineffective injection control time τV in accordance with the ineffective injection time, which changes in accordance with the engine operating conditions, due to the apparatus construction. That is, during the maximum ineffective injection control time τV, a correspondingly increased amount of fuel quickly flows out into the return pipe 11 through the return port 80. Therefore, the fuel pressure PC in the common rail 4 can be more quickly and efficiently reduced. Consequently, this embodiment substantially prevents occurrence of loud combustion noises, and stabilizes combustion condition.

[0073] The execution of this control is particularly effective when the operating state of the diesel engine 1 changes from the cranking state to the complete combustion state. A high fuel pressure is needed during the cranking state, whereas after the transition to the complete combustion state, that is, after the starting of the diesel engine 1 has been completed, the fuel pressure PC needs to be reduced. Therefore, this need is reliably and advantageously met by the aforementioned quick pressure reducing operation.

[0074] Furthermore, in the embodiment, since the injectors 2 are constructed as described above and the ineffective injection control is performed, the actual fuel pressure PC in the common rail 4 can be quickly reduced if it is higher than the target fuel pressure PFIN. Therefore, there is no need to separately provide relief valves or the like. Thus, a considerable cost increase can be prevented.

[0075] This invention is not limited to the forgoing embodiment or particular forms disclosed above. The invention may be carried out in various forms with modifications as described below, without departing from the scope of the invention defined in the appended claims.

[0076] The foregoing embodiment determines the fuel temperature correction coefficient KTHF based on the fuel temperature THF, and determines the fuel pressure correction coefficient KPC based on the fuel pressure PC. By multiplying the reference ineffective injection control time $\tau V0$ by the fuel temperature correction coefficient KTHF and the fuel pressure correction coefficient KPC, the embodiment determines the final ineffective injection control time τV. However, it is also possible to determine an ineffective injection control time τV in accordance with the fuel temperature THF and the fuel pressure PC by immediately referring to a map. Furthermore, the parameters related to the fuel viscosity may also be parameters other than the fuel temperature THF and the fuel pressure PC. For example, it is also possible to use a coolant temperature, an intake air temperature or the like or to actually detect viscosity.

[0077] The ineffective injection control time τV may also be determined on the basis of one of the present actual fuel temperature THF and the present actual fuel pressure PC. In this modification, therefore, the ineffective injection control time τV is set to greater values as the fuel temperature decreases, or as the fuel pressure PC decreases. Normally, the lower the fuel temperature THF or the fuel pressure PC, the longer the actual ineffective injection time tends to become. This modification sets the ineffective injection control time τV to greater values in accordance with the ineffective injection time having such a tendency. Therefore, the modification achieves a correspondingly increased reduction of pressure per unit time, thereby efficiently reducing the fuel pressure PC.

[0078] Although the foregoing embodiment performs the ineffective injection control when the diesel engine 1 is operating, it is also possible to perform the ineffective injection control when the diesel engine 1 is not operating. For example, when the ignition switch is off and the main relay (the power of the ECU 51) is on, it is possible to calculate an ineffective injection control time τV and perform the ineffective injection control. This modification is also able to efficiently reduce the fuel pressure PC in the common rail 4.

[0079] Although in the foregoing embodiment, the invention is applied to the diesel engine 1, the application of the invention is not limited to diesel engines. The invention may also be embodied in a gasoline engine (for example, a gasoline engine in which an accumulation type fuel injection is performed).

[0080] Although in the foregoing embodiment, the electromagnetic valve 3 is provided inside each injector 2, it is also possible to provide the electromagnetic valve 3 outside. Furthermore, it is also possible to use an injector and a direction control valve that are described in JP-A-2-191865.

[0081] In the foregoing embodiment, the ineffective injection time can be affected by various factors other than the aforementioned factors. For example, the battery voltage, the temperature of injector-driving coils, and the like may also be considered as such factors. The ineffective injection time increases as the battery voltage decreases. The ineffective injection time also increases if the injector coil temperature exceeds a predetermined range. It is also possible to set an ineffective injection time on consideration of those characteristics.

[0082] The technology in the foregoing embodiment wherein the ineffective injection control time is variably set includes to set the ineffective injection control time to "0" (that is, stopping the release of fuel) in a certain region. This setting process may be provided in a case where it is important to prevent unstable operation of the injectors due to the ineffective injection control with an extremely long or short ineffective injection time. In such a case, it becomes necessary to separately provide a relief valve. The provision of relief valves does not conflict with the invention.

[0083] As can be understood from the above description, in a fuel injection apparatus for an accumulator type engine having a reverse flow restriction device for restricting reverse flow of fuel from an accumulator pipe to a supply pump, the invention achieves an excellent advantage of substantially preventing occurrence of loud combustion noises during the transition of a high fuel pressure to a low fuel pressure in the accumulator pipe.

[0084] It should be understood that the embodiment and constructions disclosed above do not limit the claimed invention and that the discussed combination of features might not be absolutely necessary for the inventive solution.

A fuel injection control apparatus for an accumulator type engine 1 efficiently reduces fuel pressure in an accumulator pipe 4 if the fuel pressure exceeds a target pressure, thereby ensuring stable combustion. Injectors 2 of a diesel engine 1 are connected to a common rail 4 provided commonly for all the cylinders #1-#4 of the engine. The common rail 4 is connected to a supply pump 6 by a supply pipe 5. Each injector 2 has a mechanism that injects fuel into the corresponding one of the cylinders (#1-#4) when an electromagnetic valve 3 provided in the injector 2 is driven, and that releases fuel to reduce the fuel pressure in the common rail 4 during an early period (ineffective injection time) after the start of the driving of the electromagnetic valve 3. An electronic control unit 51 executes an ineffective injection control during the ineffective injection control time to reduce the fuel pressure in the common rail 4, if the target injection amount is "0" and the actual fuel pressure is greater than the target fuel pressure. The ineffective injection control time is set to greater values as the fuel temperature decreases.

Claims

1. A fluid injection control apparatus for an accumulator type engine (1) comprising:

   an accumulator piping (4) for accumulating high-pressure fluid supplied from a pump (6);
   a fluid injection means (2) driven and controlled on the basis of a difference in fluid pressure in the accumulator piping (4) so as to perform fluid injection during a higher fluid pressure state and so as to refrain from performing fluid injection during a lower fluid pressure state; and
   a control valve (77) for establishing the lower fluid pressure state by leaking the fluid introduced into the fluid injection means (2), toward a low pressure side, in order to control the level of the fluid pressure acting on the fluid injection means (2),
   wherein if the fluid pressure in the accumulator piping (4) is greater than a target value, the control valve (77) is caused to perform an operation of leaking the fluid introduced into the fluid injection means (2) toward the low pressure side at a fluid injection timing and during a period apart from the fluid injection timing,
   the fluid injection control apparatus further comprising:
   an engine operation environment detection means (26, 27) for detecting an operation environment condition of the engine (1); and
   an ineffective injection control time setting means (51) for setting an ineffective injection control time during which the high pressure fluid injection by the fluid injection means (2) is substantially impossible, on the basis of the operation environment condition of the engine (1) detected by the engine operation environment detection means (26, 27),
   wherein during the ineffective injection control time, the operation of the control valve (77) is performed.

2. A fluid injection control apparatus according to claim 1, wherein the engine operation environment detection means (26, 27) detects at least one of characteristics of the high pressure fluid and/or an operation environment condition of the fluid injection means (2).

3. A fluid injection control apparatus according to claim 2, wherein the high pressure fluid is fuel to be injected into the engine.

4. A fluid injection control apparatus according to claim 3, wherein the engine operation environment detection means (26) detects a fuel viscosity, and the ineffective injection control time setting means (51) sets the ineffective injection control time to an increased value as the fuel viscosity detected by the engine operation environment detection means (26) increases.

5. A fluid injection control apparatus according to claim 4, wherein the engine operation environment detection means comprises a fuel temperature detection means (26) for detecting a fuel temperature, and the ineffective injection control time setting means (51) sets the ineffective injection control time to an increased value as the fuel temperature detected by the fuel temperature detection means (26) decreases.

6. A fluid injection control apparatus according to any of claims 1 to 5, wherein the engine operation environment detection means comprises a fuel pressure detection means (27) for detecting a fuel pressure, and the ineffective injection control time setting means (51) sets the ineffective injection control time to an increased value as the fuel pressure detected by the fuel pressure detection means (27) decreases.

7. A fluid injection control apparatus according to any of claims 1 to 6, wherein the control of causing the control valve (77) to leak the fluid introduced into the fluid injection means (2) toward the low pressure side is performed at least when the engine state changes from a cranking state to a complete combustion state.

8. A fuel injection control apparatus for an accumulator type engine comprising:

   an accumulator piping (4) for receiving high-pressure fuel supplied from a supply pump (6) and accumulating a high pressure fuel;

a fuel injection means (2) connected to the accumulator piping (4) and including a mechanism being capable of injecting fuel into a cylinder (#1-#4) of the engine when driven, and being capable of releasing fuel to reduce fuel pressure inside the accumulator piping (4) during an early ineffective injection time after the driving of the fuel injection means (2) is started;

an engine operation environment detection means (26) for detecting an operation environment condition of the engine (1);

an injection control means for controlling the fuel injection means (2) so as to inject fuel from the accumulator piping (4) into the cylinder;

a target fuel pressure calculation means for calculating a target fuel pressure on the basis of result of detection by the engine operation environment detection means (26); and

a fuel pressure reduction control means for reducing the fuel pressure in the accumulator piping (4) by controlling the fuel injection means (2) for a predetermined ineffective injection control time when the fuel pressure actually detected by the engine operation environment detection means (26) becomes equal to or greater than the target fuel pressure calculated by the target fuel pressure calculation means,

the fuel injection control apparatus further comprising an ineffective injection control time setting means (51) for setting the ineffective injection control time on the basis of result of detection by the engine operation environment detection means (26).

9. A fuel injection control apparatus according to claim 8, wherein the engine operation environment detection means (26, 27) detects at least one of characteristics of the fuel and/or an operation environment condition of the fuel injection means (2).

10. A fuel injection control apparatus for an accumulator type engine (1) comprising:

an accumulator piping (4) for accumulating high-pressure fluid supplied from a pump (6);

a fuel injection means (2) driven and controlled on the basis of a difference in fluid pressure in the accumulator piping (4) so as to perform fuel injection during a higher fluid pressure state and so as to refrain from performing fuel injection during a lower fluid pressure state; and

a control valve (77) for establishing the lower fluid pressure state by leaking the fluid introduced into the fuel injection means (2), toward a low pressure side, in order to control the level of the fluid pressure acting on the fuel injection means (2),

wherein if the fluid pressure in the accumulator piping (4) is greater than a target value, the control valve (77) is caused to perform an operation of leaking the fluid introduced into the fuel injection means (2) toward the low pressure side at a fuel injection timing and during a period apart from the fuel injection timing,

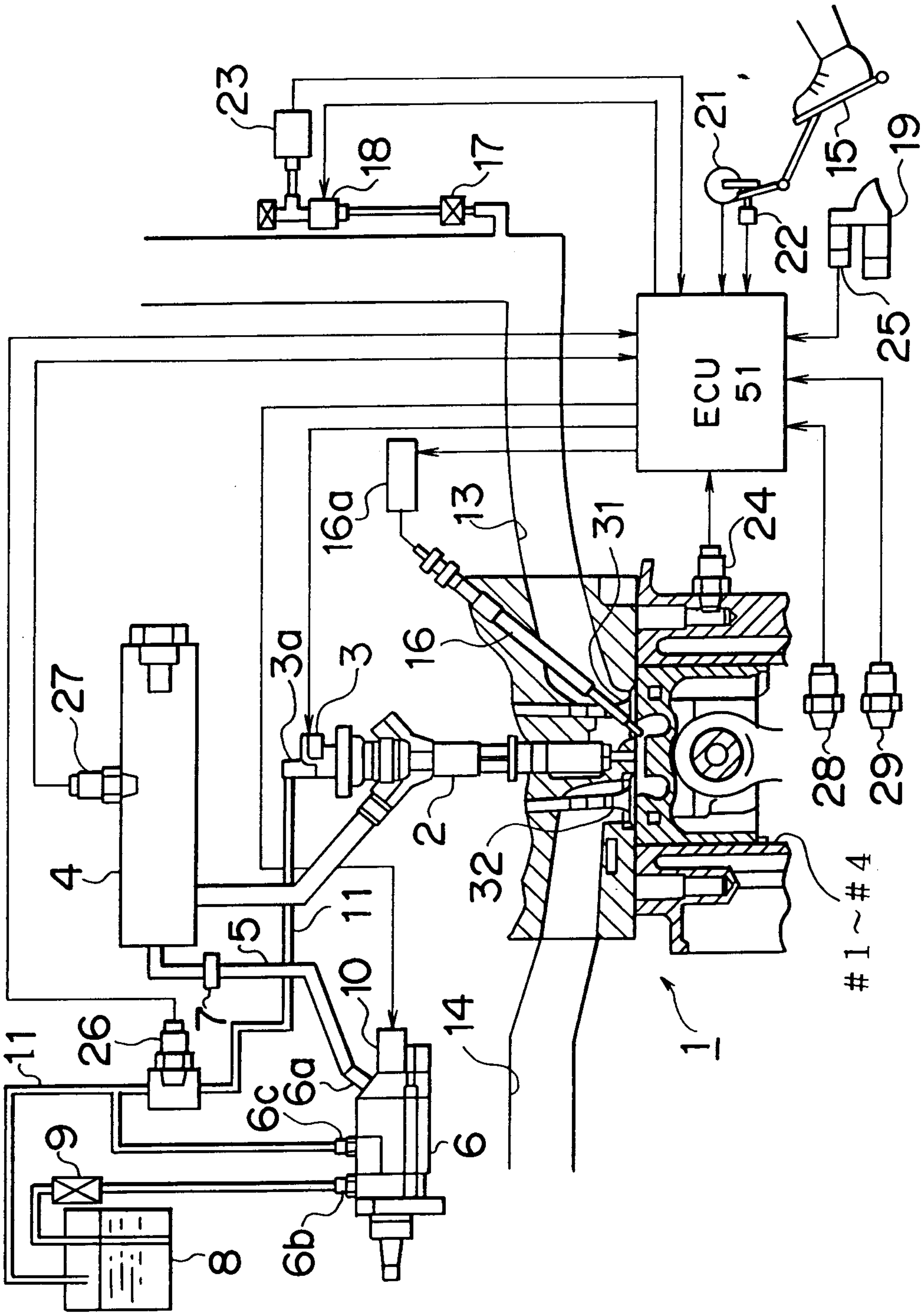
the fuel injection control apparatus further comprising:

an engine operation environment detection means (26, 27) for detecting an operation environment condition of the engine (1); and

an ineffective injection control time setting means (51) for setting an ineffective injection control time during which the high pressure fuel injection by the fuel injection means (2) is substantially impossible, on the basis of the operation environment condition of the engine (1) detected by the engine operation environment detection means (26, 27),

wherein during the ineffective injection control time, the operation of the control valve (77) is performed.

FIG. 1


ECU
51
1
2
3
3a
4
5
6
6a
6b
6c
7
8
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10
11
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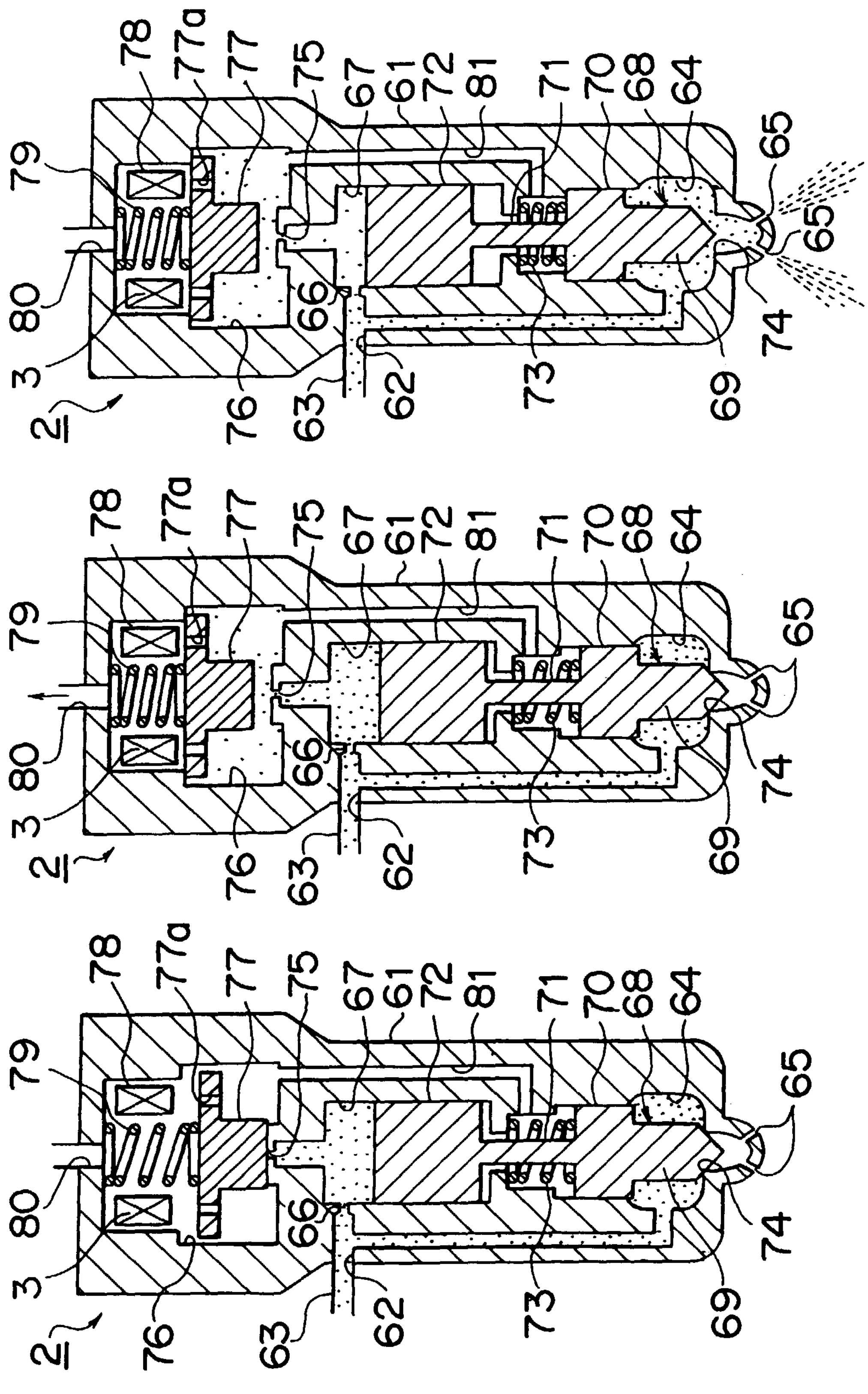


FIG. 2A FIG. 2B FIG. 2C

FIG. 3

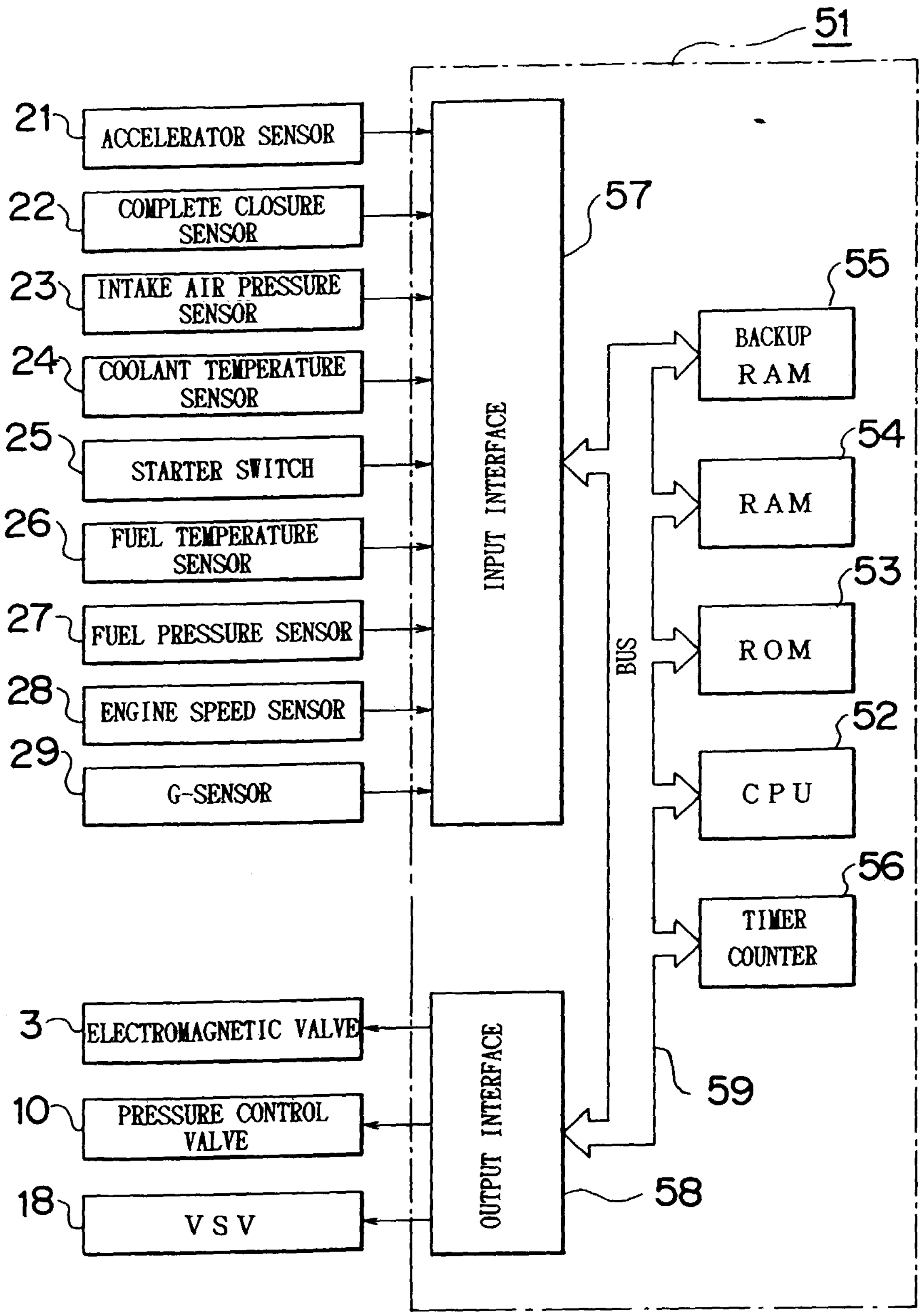

51
21
ACCELERATOR SENSOR
22
COMPLETE CLOSURE SENSOR
23
INTAKE AIR PRESSURE SENSOR
24
COOLANT TEMPERATURE SENSOR
25
STARTER SWITCH
26
FUEL TEMPERATURE SENSOR
27
FUEL PRESSURE SENSOR
28
ENGINE SPEED SENSOR
29
G-SENSOR
57
INPUT INTERFACE
55
BACKUP RAM
54
RAM
53
ROM
52
CPU
56
TIMER COUNTER
BUS
3
ELECTROMAGNETIC VALVE
10
PRESSURE CONTROL VALVE
18
VSV
OUTPUT INTERFACE
59
58

FIG. 4

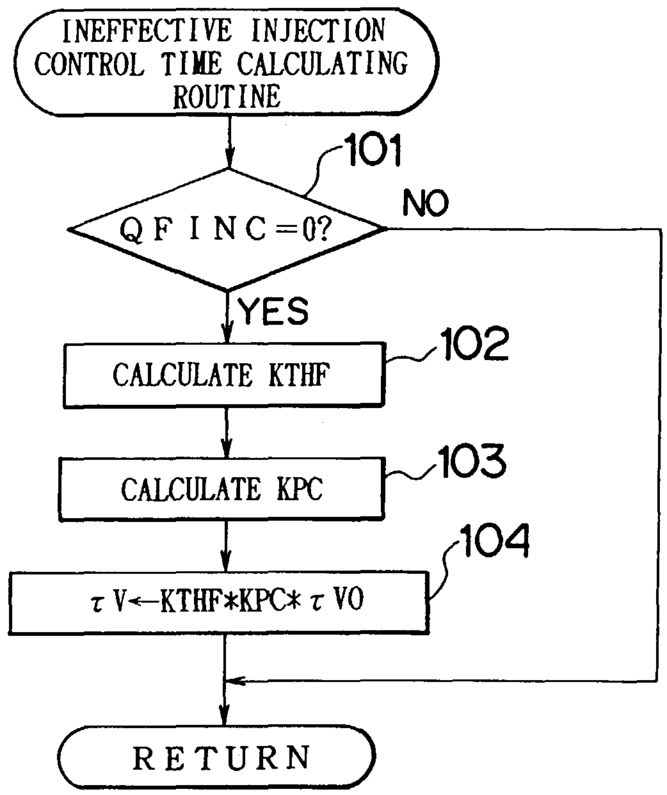

INEFFECTIVE INJECTION CONTROL TIME CALCULATING ROUTINE
101
QFINC=0?
NO
YES
CALCULATE KTHF
102
CALCULATE KPC
103
τV←KTHF*KPC*τV0
104
RETURN

FIG. 5

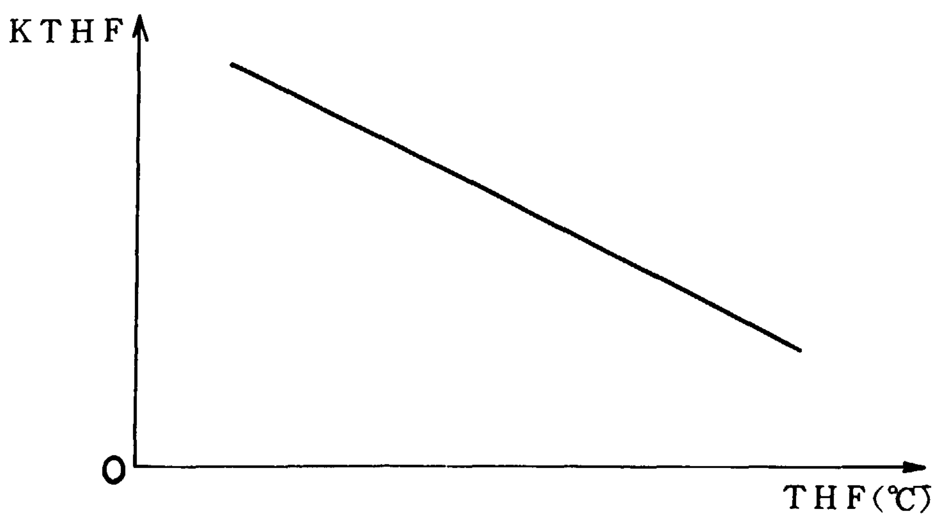

KTHF
0
THF(℃)

FIG. 6

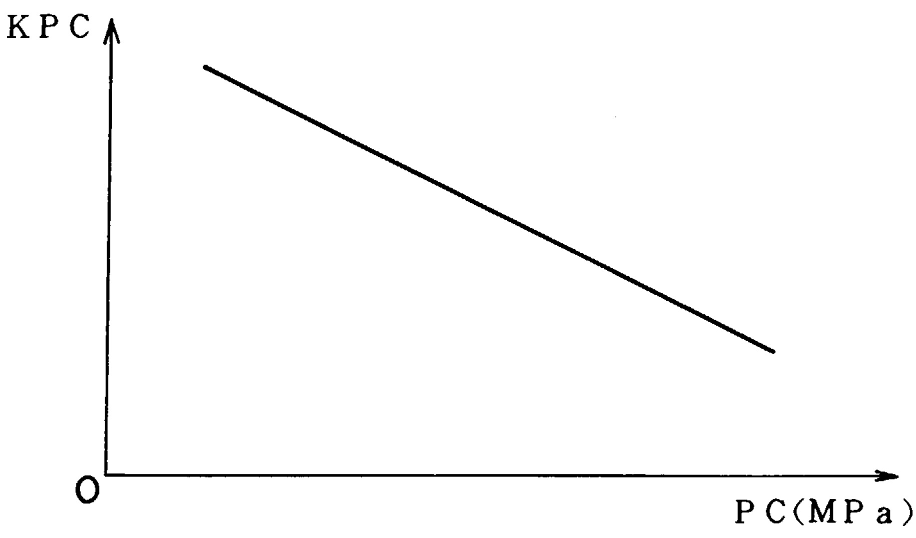
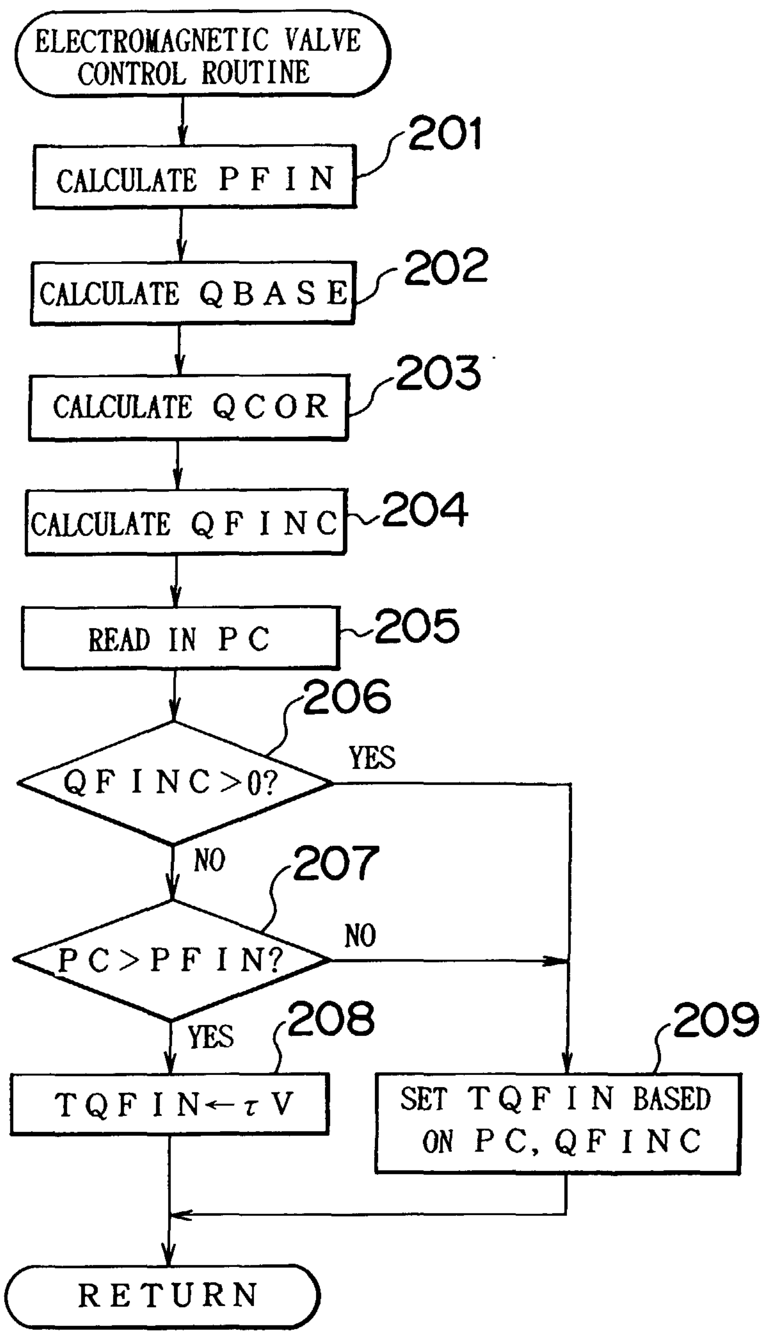


FIG. 7


ELECTROMAGNETIC VALVE CONTROL ROUTINE
CALCULATE PFIN
201
CALCULATE QBASE
202
CALCULATE QCOR
203
CALCULATE QFINC
204
READ IN PC
205
QFINC>0?
206
YES
NO
PC>PFIN?
207
NO
YES
TQFIN←τV
208
SET TQFIN BASED ON PC, QFINC
209
RETURN