(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 216 531 A1

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
11.08.2010 Bulletin 2010/32

(51) Int Cl.:
F02D 41/02 *(2006.01)* ***F01N 11/00*** *(2006.01)*
F01N 3/02 *(2006.01)*

(21) Application number: **10153088.9**

(22) Date of filing: **09.02.2010**

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO SE SI SK SM TR
Designated Extension States:
AL BA RS

(30) Priority: **09.02.2009 JP 2009027312**

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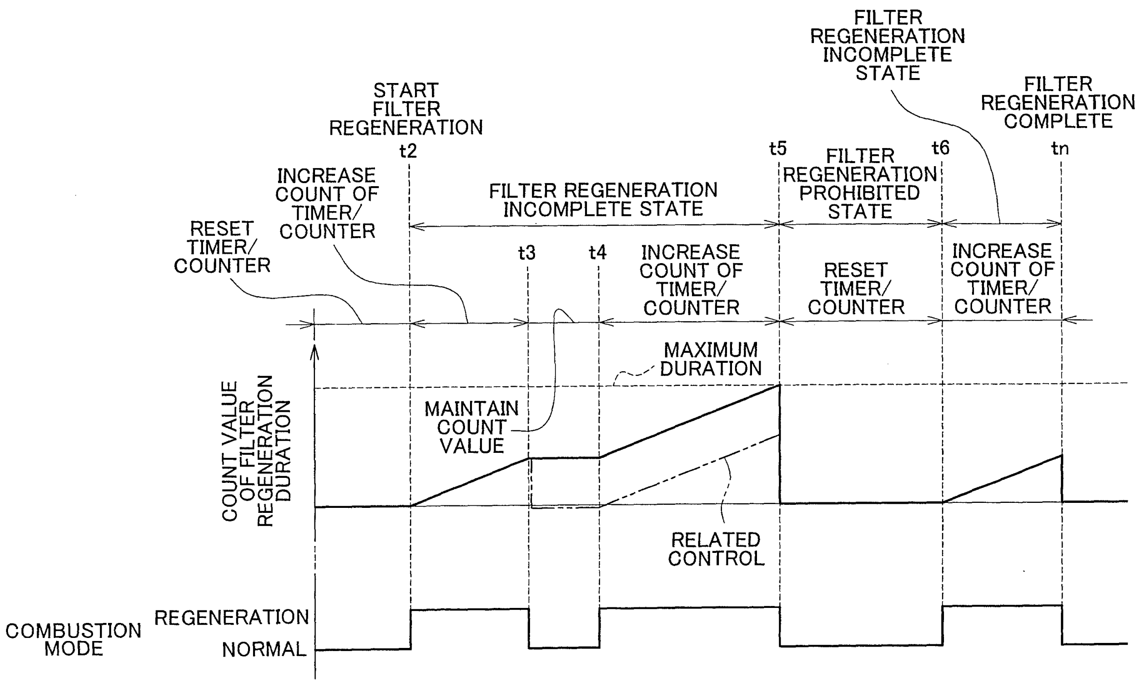
(54) **Internal combustion engine exhaust gas control apparatus**

(57) In an exhaust gas control apparatus, a period of time from after filter regeneration starts in response to a command to regenerate a filter (22) until the filter regeneration has been completed, and which is a period of time during which the filter regeneration is not prohibited, is determined to be a period of time during which the filter is in a filter regeneration incomplete state. A current duration count value is maintained when the internal combustion engine switches to a state other than a filter regenerating state while the filter is in that filter regeneration incomplete state. According to this kind of control, the counter is not reset even if the combustion mode switches to a normal combustion mode while the filter is being regenerated. Instead, the current duration count value is maintained, so the filter regeneration duration can be accurately counted. As a result, oil dilution can be reliably suppressed.

FIG. 8



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention relates to an exhaust gas control apparatus that purifies exhaust gas from an internal combustion engine (hereinafter also simply referred to as "engine"). More particularly, the invention relates to an internal combustion engine exhaust gas control apparatus that purifies exhaust gas from a diesel engine using a particulate filter.

2. Description of the Related Art

[0002] Exhaust gas that is discharged when driving an internal combustion engine such as a petrol engine or a diesel engine contains matter that is not desirable to discharge into the atmosphere as it is. In particular, exhaust gas from a diesel engine contains particulate matter (hereinafter also simply referred to as "PM") of which carbon is the main component, soot, and soluble organic fraction (SOF), and the like, all of which cause air pollution.

[0003] One known apparatus that purifies PM in exhaust gas is an exhaust gas control apparatus that reduces the amount of emissions discharged into the atmosphere by providing a particulate filter in an exhaust passage of a diesel engine and trapping PM in exhaust gas that passes through the exhaust passage. DPFs (Diesel Particulate Filters) and DPNR (Diesel Particulate-NOx Reduction system) catalysts, for example, are used as particulate filters.

[0004] When trapping PM using a particulate filter (hereinafter also simply referred to as "filter"), the filter will become clogged when a large amount of trapped PM has accumulated. When this happens, pressure loss of the exhaust gas that passes through the filter increases, which causes the exhaust gas back pressure in the engine to increase. As a result, engine output and fuel efficiency both decrease.

[0005] To solve this problem, typically when the trapped amount (i.e., accumulated amount) of PM that has been trapped by the filter reaches a predetermined amount, the filter is regenerated by oxidising (burning off) the PM on the filter by increasing the catalyst bed temperature. More specifically, the filter is regenerated, for example, by increasing the temperature of an oxidation catalyst (i.e., the exhaust gas temperature) upstream of the filter (i.e., on the upstream side of the exhaust gas flow) by additionally injecting a small amount of fuel (in a post injection) after a main fuel injection (a main injection), and then oxidising (burning off) the PM that has accumulated on the filter by executing a filter regenerating post injection (see Japanese Patent Application Publication No. 2008-202573 (JP-A-2008-202573), for example).

[0006] Incidentally, in order to burn off the PM that has accumulated on the filter by the post injection, high-temperature exhaust gas must be thermally reacted with the oxidation catalyst and passed through the filter (DPF) without performing combustion in a combustion chamber (i.e., in a cylinder) of the engine. Therefore, the injection timing of the post injection is retarded with respect to the main fuel injection. As a result, however, some of the fuel injected by the post injection flows from the piston to an oil pan, and ends up diluting the oil (i.e., dilution by the fuel mixing with the engine oil).

[0007] To solve this problem, the filter regeneration duration (i.e., the duration of the post injection) is counted by a timer/counter, and filter regeneration is prohibited for a predetermined period of time (more specifically, the period of time until the fuel that has mixed in with the engine oil has sufficiently vaporised and the oil has recovered from being diluted) when the count value reaches a maximum duration (i.e., the duration of the post injection at which the amount of fuel diluting the oil reaches the allowable limit) (hereinafter, this process may also be referred to as "regeneration prohibiting control").

[0008] In the regeneration prohibiting control described above, when filter regeneration (i.e., the regeneration combustion mode) is being executed, the count of the filter regeneration duration is increased and the timer/counter is reset with the normal combustion mode as the reset condition.

[0009] Incidentally, the combustion mode may switch from the regeneration combustion mode to the normal combustion mode even if there is a filter regeneration command. That is, even if there is a filter regeneration command, the combustion mode will switch from the regeneration combustion mode to the normal combustion mode when a PM combustion condition ceases to be satisfied due to the catalyst temperature not being high enough, for example. With typical control when the combustion mode has switched to the normal combustion mode while there is a filter regeneration command, the timer/counter is reset when the combustion mode switches to the normal combustion mode and the count value of the filter regeneration duration that has been counted thus far is canceled. As a result, the relationship between the actual amount of fuel diluting the oil and the count value of the filter regeneration duration becomes skewed (i.e., the count value of the filter regeneration duration with respect to the actual amount of fuel diluting the oil is less). If this occurs, filter regeneration will continue instead of being prohibited even if the actual amount of fuel diluting the oil exceeds the allowable limit. As result, it will no longer be possible to suppress oil dilution.

SUMMARY OF THE INVENTION

[0010] The invention therefore provides technology that makes it possible to accurately count the duration of the filter regeneration that affects the dilution of oil by fuel in an exhaust gas control apparatus which executes control to count that filter regeneration duration using a counter, and prohibit filter regeneration based on the count value of that filter regeneration duration.

[0011] One aspect of the invention relates to an exhaust gas control apparatus that is provided with a filter that is arranged in an exhaust passage of an internal combustion engine and traps particulate matter in exhaust gas, filter regeneration controlling means for performing filter regeneration that removes particulate matter that has accumulated on the filter by performing a regeneration fuel injection after a main fuel injection by controlling the injection timing of the internal combustion engine, and a counter that counts the duration of the filter regeneration. The filter regeneration controlling means determines that a period of time from after there is a command to regenerate the filter and the filter regeneration starts until the filter regeneration has been completed, and which is a period of time during which the filter regeneration is not prohibited, is a period of time during which the filter is in a filter regeneration incomplete state. The filter regeneration controlling means increases the count of the counter when the filter regeneration is being executed while the filter is in the filter regeneration incomplete state. The filter regeneration controlling means has the counter maintain the current duration count value when the internal combustion engine switches to a state other than a filter regenerating state while the filter is in the filter regeneration incomplete state.

[0012] According to this aspect, after filter regeneration starts in response to a filter regeneration command, the current count value of the filter duration is maintained even if the PM combustion condition ceases to be satisfied due to the catalyst temperature not being high enough, for example, and the combustion mode temporarily switches from the regeneration combustion mode to the normal combustion mode. As a result, the relationship between the actual amount of fuel diluting the oil and the filter regeneration duration (i.e., the duration of the post injection) will not become skewed. Accordingly, it is possible to correctly determine that the count value of the filter regeneration duration has reached the maximum duration, thus enabling oil dilution to be reliably suppressed.

[0013] In the aspect described above, the filter regeneration controlling means may reset the counter when the filter is not in the filter regeneration incomplete state.

[0014] According to this structure, in control that counts the duration of the filter regeneration that affects the dilution of the oil by fuel and prohibits filter regeneration based on the count value of that filter regeneration duration, the filter regeneration duration is able to be accurately counted, such that oil dilution can be reliably suppressed.

[0015] In the foregoing structure, the filter regeneration controlling means may establish a filter regeneration prohibited period when the count of the counter reaches a predetermined duration.

[0016] In the foregoing structure, the filter regeneration controlling means may reset the counter during the filter regeneration prohibited period.

[0017] The filter regeneration prohibited period may be established as a period of time until the fuel that is mixed in with oil that lubricates the internal combustion engine sufficiently vaporises.

[0018] In the foregoing structure, the state other than the filter regenerating state may be a state of the internal combustion engine in which the regeneration fuel injection is not performed after the main fuel injection.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The foregoing and further objects, features and advantages of the 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 block diagram schematically showing an example of a diesel engine to which the invention is applied;

FIG. 2 is a block diagram of the structure of a control system including an ECU and the like;

FIG. 3 is a view of a map for obtaining a PM generated amount pme;

FIG. 4 is a view of a map for obtaining a PM combusted amount pmc;

FIG. 5 is a timing chart showing a change in an estimated PM accumulated amount PMs that is estimated based on the engine operating state, and a change in an estimated PM accumulated amount PMd that is estimated based on differential pressure;

FIG. 6 is a flowchart illustrating a routine for counting a filter regeneration duration;

FIG. 7 is a timing chart showing the period during which the filter is in a filter regeneration incomplete state; and

FIG. 8 is a timing chart conceptually showing an example of the routine for counting the filter regeneration duration.

DETAILED DESCRIPTION OF AN EMBODIMENT

[0020] An example embodiment of the present invention will be described in greater detail below with reference to the accompanying drawings.

[0021] The general structure of a diesel engine to which the invention is applied will now be described with reference to FIG. 1.

[0022] A diesel engine 1 (hereinafter simply referred to as "engine 1") according to this example embodiment is a common rail in-cylinder direct injection four cylinder engine, for example, in which an injector (i.e., a fuel injection valve) 2 is arranged in a combustion chamber 1a of each cylinder of the engine 1, and injects fuel for combustion in the combustion chamber 1a. The injector 2 of each cylinder is connected to a common rail 11, which is in turn connected to a supply pump 10.

[0023] The supply pump 10 draws up fuel from a fuel tank and pressurises it before supplying it to the common rail 11 via a fuel line 10a. The common rail 11 functions as an accumulator that maintains (accumulates) the pressurised fuel supplied from the supply pump 10 at a predetermined pressure, and distributes this accumulated fuel to the injectors 2. Each injector 2 is an electromagnetically driven on-off valve that opens to inject (i.e., supply) fuel into the combustion chamber 1a when a predetermined voltage is applied. The opening and closing (i.e., the fuel injection quantity and the fuel injection timing) of the injectors 2 is duty-controlled by an ECU (Electronic Control Unit) 100.

[0024] An intake passage 3 and an exhaust passage 4 are connected to the engine 1. An air cleaner 9, an airflow meter 33, a compressor impeller 63 of a turbocharger 6 that will be described later, an intercooler 8, and a throttle valve 5 are arranged, in order from upstream (i.e., the portion on the upstream side of the intake air flow) to downstream in the intake passage 3. The throttle opening amount of the throttle valve 5 is adjusted by a throttle motor 51. The throttle opening amount of the throttle valve 5 is detected by a throttle opening amount sensor 41. Incidentally, the intake passage 3 branches off to each cylinder at an intake manifold 3a that is arranged downstream of the throttle valve 5.

[0025] The exhaust passage 4 is formed such that branches leading from the individual cylinders are all brought together by an exhaust manifold 4a that is connected to the combustion chamber 1a of each cylinder of the engine 1.

[0026] A CCO (an oxidation catalytic converter) 21 that purifies HC (hydrocarbons) and CO (carbon monoxide) in the exhaust gas by purifying them, and a DPF 22 that traps PM (particulate matter) are arranged in order in the exhaust passage 4. Exhaust gas generated from combustion in the combustion cylinders 1a is sent into the exhaust passage 4.

[0027] An A/F sensor 36 and a first exhaust gas temperature sensor 37 are arranged in the exhaust passage 4 upstream (on the upstream side of the exhaust gas flow) of the CCO 21. The temperature of the exhaust gas that enters the CCO 21 can be detected from the output signal of the first exhaust gas temperature sensor 37. Also, a second exhaust gas temperature sensor 38 is arranged in the exhaust passage 4 between the CCO 21 and the DPF 22. The temperature of the exhaust gas that enters the DPF 22 (i.e., the filter temperature (bed temperature)) can be detected from the output signal of the second exhaust gas temperature sensor 38. Moreover, a differential pressure sensor 39 that detects the differential pressure between the pressure upstream of the DPF 22 and the pressure downstream of the DPF 22 is also provided.

[0028] The output signals from the A/F sensor 36, the first exhaust gas temperature sensor 37, the second exhaust gas temperature sensor 38, and the differential pressure sensor 39 are input to the ECU 100.

[0029] The engine 1 is provided with a turbocharger 6. This turbocharger 6 includes a turbine wheel 62 and a compressor impeller 63 that are coupled together via a rotor shaft 61.

[0030] The compressor impeller 63 is arranged facing the inside of the intake passage 3, and the turbine wheel 62 is arranged facing the inside of the exhaust passage 4. This kind of turbocharger 6 supercharges the intake air by using the exhaust flow (i.e., exhaust pressure) on the turbine wheel 62 to rotate the compressor impeller 63. The turbocharger 6 in this example embodiment is a variable nozzle turbocharger, in which a variable nozzle vane mechanism 64 is provided on the turbine wheel 62 side, and the boost pressure of the engine 1 can be adjusted by adjusting the opening amount of this variable nozzle vane mechanism 64. Incidentally, the intake air that has been heated by the supercharging in the turbocharger 6 is forcibly cooled by the intercooler 8 arranged in the intake passage 3.

[0031] The engine 1 is also provided with an EGR system 7. This EGR system 7 is a system that circulates some of the exhaust gas that flows through the exhaust passage 4 to the intake passage 3 and lowers the combustion temperature by supplying that recirculated exhaust gas into the combustion chambers 1a of the cylinders, thereby reducing the amount of NOx that is generated. The EGR system 7 includes an EGR passage 71 that connects the intake manifold 3a with the exhaust manifold 4a. An EGR cooler 73 for cooling the EGR gas that flows (is circulated) through the EGR passage 71, and an EGR valve 72 are provided, in order from the upstream side of the EGR gas flow, in the EGR passage 71. The amount of EGR gas (i.e., the amount of recirculated exhaust gas) introduced into the intake passage 3 (i.e., the intake manifold 3a) from the exhaust passage 4 (i.e., the exhaust manifold 4a) can be adjusted by adjusting the opening amount of this EGR valve 72.

[0032] The ECU 100 includes a CPU 101, ROM 102, RAM 103, backup RAM 104, and a timer/counter 110 and the like.

[0033] Various control programmes and maps that are referenced when executing those various control programmes and the like are stored in the ROM 102. The CPU 101 performs calculations based on the various control programmes and maps stored in the ROM 102. Also, the RAM 103 is memory that temporarily stores the calculation results of the CPU 101 and data and the like that has been input from various sensors, and the backup RAM 104 is non-volatile memory that stores data and the like that is to be saved when the engine 1 is stopped. The timer/counter 110 counts (times), for example, a filter regeneration duration, which will be described later, and the control time when various controls of the engine 1 are executed.

[0034] The CPU 101, the ROM 102, the RAM 103, the backup RAM 104, and the timer/counter 110 are all connected together, as well as to an input interface 105 and an output interface 106, via a bus 107.

[0035] Various sensors are connected to the input interface 105. Some of these sensors include an engine speed sensor 31 that detects the rotation speed of a crankshaft that is an output shaft of the engine 1, a coolant temperature sensor 32 that detects the coolant temperature of the engine (i.e., the coolant temperature), the airflow meter 33, an intake air temperature sensor 34 that is arranged in the intake manifold 3a and detects the temperature of intake air, an intake air pressure sensor 35 that is arranged in the intake manifold 3a and detects the pressure of intake air, the A/F sensor 36, the first exhaust gas temperature sensor 37, the second exhaust gas temperature sensor 38, the differential pressure sensor 39, a rail pressure sensor 40 that detects the pressure of pressurised fuel in the common rail 11, a throttle opening amount sensor 41, an accelerator operation amount sensor 42, and a vehicle speed sensor 43. Signals from these sensors are input to the ECU 100.

[0036] The injectors 2, the supply pump 10, the throttle motor 51 of the throttle valve 5, the variable nozzle vane mechanism 64 of the turbocharger 6, and the EGR valve 72 and the like are connected to the output interface 106.

[0037] The ECU 100 executes various controls of the engine 1, including opening amount control of the throttle valve 5, and fuel injection quantity and injection timing control (i.e., opening / closing control of the injectors 2) of the engine 1, based on the output signals from the various sensors described above. Furthermore, the ECU 100 executes DPF regeneration control and control for selecting a process for estimating the amount of PM (including a process for determining a filter regeneration incomplete state), which will be described later.

[0038] Control of the exhaust gas control apparatus of the invention may also be realised by a programme executed by the ECU 100 described above.

[0039] The ECU 100 estimates the amount of accumulated PM by the two processes (1) and (2) below.

[0040] (1) Process for estimating the PM amount based on the engine operating state

In this example, an estimated amount of accumulated PM (also simply referred to as the "estimated PM accumulated amount") PMs is calculated using the amount of generated PM (also simply referred to as the "PM generated amount") pme and the amount of combusted PM (also simply referred to as the "PM combusted amount) pmc.

[0041] The PM generated amount pme is the amount of PM that is discharged from all of the combustion chambers of the engine per unit of time (for example, during one control cycle of the estimating process). This PM generated amount pme is obtained referencing the map in FIG. 3 based on the engine speed NE obtained from the output signal from the engine speed sensor 31, and the fuel injection quantity Qv (a command value).

[0042] The PM combusted amount pmc is the amount of PM accumulated on the DPF 22 that is oxidised and combusted per unit of time (for example, during one control cycle of the estimating process). This PM combusted amount pmc is obtained referencing the map in FIG. 4 (a PM oxidation rate map) based on the exhaust gas temperature Theg (which corresponds to the filter temperature) obtained from the output signal of the second exhaust gas temperature sensor 38, and the intake air amount Ga obtained from the output signal of the airflow meter 33.

[0043] Then the estimated PM accumulated amount PMs is sequentially calculated (integrated) using the PM generated amount pme and the PM combusted amount pmc based on the operational expression PMs = PMs (last value) + pme - pmc. Here, the PMs (last value) when filter regeneration starts is a value that corresponds to a start-regeneration determining value Thpmss (see FIG. 5). Also, the PMs (last value) when starting the normal combustion mode after the filter regeneration has been completed (also including when starting the normal combustion mode the first time when the filter regeneration has not been executed) is an initial value of "0".

[0044] The map shown in FIG. 3 is a map of the values of the PM generated amount pme obtained through testing and calculation or the like, with the engine speed NE and the fuel injection quantity Qv as parameters. This map is stored in the ROM 102 of the ECU 100. Incidentally, in the map shown in FIG. 3, the PM generated amount pme is calculated by interpolation when the engine speed NE and the fuel injection quantity Qv are values that are between points on the map.

[0045] The map shown in FIG. 4 is a map of the values of the PM combusted amount pmc obtained through testing and calculation or the like, with the exhaust gas temperature Theg and the intake air amount Ga as parameters. This map is also stored in the ROM 102 of the ECU 100. Incidentally, in the map shown in FIG. 4, the PM combusted amount pmc is calculated by interpolation when the exhaust gas temperature Theg and the intake air amount Ga are values that are between points on the map.

[0046] (2) Process for estimating the PM amount based on the differential pressure

First, in the exhaust gas control apparatus, as more and more PM accumulates on the DPF 22, that accumulated PM impedes the flow of exhaust gas, causing the exhaust gas flow resistance to increase. As the exhaust gas flow resistance increases, so too does the differential pressure ΔP between the exhaust gas pressure upstream of the DPF 22 and the exhaust gas pressure downstream of the DPF 22 in the exhaust passage 4. The differential pressure ΔP of the exhaust gas pressures in front and in back of the DPF 22 decreases as the PM accumulated on the DPF 22 is burned off (i.e., removed) and the PM accumulated amount that is accumulated on the DPF 22 decreases. In this way, there is a correlation between the differential pressure ΔP of the exhaust gas pressures in front and in back of the DPF 22 and the PM accumulated amount that is accumulated on the DPF 22. Thus, the

PM accumulation amount of the DPF 22 can be estimated from the differential pressure ΔP.

[0047] Using this process (2), in this example embodiment, the amount of accumulated PM trapped in the DPF 22 (i.e., the estimated PM accumulated amount PMd) can be estimated referencing a map based on the differential pressure ΔP obtained from the output signal from the differential pressure sensor 39 provided in the exhaust passage 4 (i.e., the DPF 22).

[0048] Incidentally, the map used to calculate the estimated PM accumulated amount is a map of compatible values obtained through testing and calculation or the like, taking into account the correlation between the differential pressure ΔP of the exhaust gas pressures in front and in back of the DPF 22 and the PM accumulated amount described above. This map is stored in the ROM 102 of the ECU 100.

[0049] When the engine 1 is in the normal combustion mode, the ECU 100 estimates the estimated PM accumulated amount PMs and the estimated PM accumulated amount PMd by the processes described above, i.e., the process for estimating the PM amount based on the engine operating state and the process for estimating the PM amount based on the differential pressure. The estimated PM accumulated amount PMs and the estimated PM accumulated amount PMd increase over time. The ECU 100 determines whether the increasing estimated PM accumulated amount PMs has increased to a value at which a determination is made to start regeneration (also simply referred to as a "start-regeneration determining value"; this value corresponds to a limit PM accumulated amount) Thpmss, or the increasing estimated PM accumulated amount PMd has increased to a value at which a determination is made to start regeneration (also simply referred to as a "start-regeneration determining value"; this value corresponds to a limit PM accumulated amount) Thpmds (see FIG. 5). The ECU 100 determines that it is time to start regenerating the DPF 22 when the estimated PM accumulated amount PMs reaches the start-regeneration determining value Thpmss or the estimated PM accumulated amount PMd reaches the stait-regeneration determining value Thpmds.

[0050] For example, as shown in FIG. 5, if the estimated PM accumulated amount PMd reaches the start-regeneration determining value Thpmds first, the ECU 100 determines that it is time to start regenerating the DPF 22 at that time, and thus generates a command for filter regeneration. Filter regeneration then starts in response to that filter regeneration command (see FIG. 7). Incidentally, in the normal combustion mode, both of the estimated PM accumulated amounts PMs and PMd are initialised (set to "0") when the estimated PM accumulated amount PMs reaches the start-regeneration determining value Thpmss or the estimated PM accumulated amount PMd reaches the start-regeneration determining value Thpmds.

[0051] During filter regeneration, a CCO temperature-increasing fuel injection (a post injection) is executed after a main fuel injection (i.e., a main injection) that is a fuel injection performed to operate the engine (i.e., an injection of fuel into the combustion chambers 1a from the injectors 2). The fuel injected from the injectors 2 by this CCO temperature-increasing fuel injection is delivered into the exhaust passage 4 and reaches the CCO 21. When the fuel component reaches the CCO 21, an oxidation reaction takes place in the exhaust gas and on the catalyst with the components such as HC and CO and the like. This oxidation reaction generates heat which increases the temperature of the CCO 21 (i.e., the exhaust gas), which in turn causes the temperature of the DPF 22 to increase. Then after performing this kind of CCO temperature-increasing fuel injection, a DPF regeneration fuel injection is executed at a predetermined timing, which bums off the PM that has accumulated on the DPF 22, thereby reducing the amount of PM accumulated on the DPF 22.

[0052] In this kind of filter regeneration, the ECU 100 selects the process for estimating the PM amount based on the engine operating state and estimates the estimated PM accumulated amount PMs [PMs = PMs (last value) + pme - pmc]. When this estimated PM accumulated amount PMs has decreased to a value at which it is determined that regeneration is to end (also referred to as an "end-regeneration determining value") thpmse (see FIG. 5), the ECU 100 determines that regeneration of the DPF 22 has been completed (i.e., filter regeneration complete) and filter regeneration ends. Incidentally, as described above, the initial value [PMs (last value)] of the estimated PM accumulated amount PMs during filter regeneration is a value that corresponds to the start-regeneration determining value Thpmss.

[0053] Here, in this example embodiment, filter regeneration is executed by the post injection, so oil dilution (i.e., fuel mixed into the engine oil) progresses with the injection of fuel from that post injection. Therefore, a limit is placed on the maximum duration of the filter regeneration. Once this maximum duration is reached, filter regeneration is prohibited (i.e., filter regeneration prohibited) until the fuel mixed into the oil sufficiently vaporises, even if there is still a command for filter regeneration.

[0054] More specifically, the ECU 100 counts the duration of filter regeneration using the timer/counter 110 while the filter is being regenerated (i.e., in a specific combustion mode that affects the oil dilution), and prohibits filter regeneration for a fixed period of time when a count value T_i of that filter regeneration duration reaches the maximum duration (i.e., the duration of the post injection at which the amount of fuel diluting the oil reaches the allowable limit). When the filter is in this kind of filter regeneration prohibited state, the timer/counter 110 is reset (count value $T_i = 0$), as will be described later.

[0055] Incidentally, the period for which filter regeneration is prohibited is established by obtaining, through testing and calculation or the like, the period of time during which the fuel that is mixed in with the engine oil sufficiently vaporises (i.e., the time that it takes to recover from the oil dilution well enough for filter regeneration to be able to be executed), and setting a compatible value based on the results.

[0056] Also, even when there is a filter regeneration command, the ECU 100 will switch the combustion mode of the engine 1 from the regeneration combustion mode to the normal combustion mode when the PM combustion condition ceases to be satisfied. More specifically, when the engine has been idling or the vehicle has been running at a low speed for an extended period of time, for example, the CCO 21 does not heat up so even if a post injection is executed, the filter temperature will not increase sufficiently, making it difficult to combust PM. In this case, it is determined that the PM combustion condition is not satisfied, so the ECU 100 switches the combustion mode from the regeneration combustion mode to the normal combustion mode.

[0057] In this way, even if the combustion mode is switched from the regeneration combustion mode to the normal combustion mode during filter regeneration, the timer/counter 110 is not reset if the filter is in a filter regeneration incomplete state, which will be described later. Instead, the count value of the timer/counter 110 is maintained at the current value. This will be described later.

[0058] Next, an example of control for counting the filter regeneration duration using the timer/counter 110 will be described with reference to the flowchart in FIG. 6. The routine in FIG. 6 is repeatedly executed in predetermined cycles (such as approximately every several milliseconds to every several tens of milliseconds) in the ECU 100.

[0059] In step ST101, the ECU 100 determines whether the filter regeneration has been completed (i.e., filter regeneration complete) based on the current PM accumulated amount PMs estimated according to the process for estimating the PM amount based on the engine operating state described above. If the determination is yes, the ECU 100 determines that the current PM accumulation state of the DPF 22 is a filter regeneration complete state (step ST102). If the determination in step ST101 is no (i.e., filter regeneration not complete), the process proceeds on to step ST103.

[0060] In step ST103, the ECU 100 determines whether there is no filter regeneration command and the combustion mode is the normal combustion mode. If the determination is yes, the process proceeds on to step ST108. If the determination in step ST103 is no, (i.e., if there is a filter regeneration command and the combustion mode is not the normal combustion mode), the process proceeds on to step ST104.

[0061] In step ST104, the ECU 100 determines whether the current state is a filter regeneration prohibited state. If this determination is no, the ECU 100 determines that the current state is a filter regeneration incomplete state (step ST105). If the determination in step ST104 is yes (i.e., if the current state is the filter regeneration prohibited state), the process proceeds on to step ST108.

[0062] Here, the filter regeneration incomplete state will be described with reference to FIG. 7.

[0063] First, as shown in FIG. 7, when there is a filter regeneration command at time t1, filter regeneration starts in response to that regeneration command. At time t2 when filter regeneration starts, the filter regeneration incomplete state turns on. This filter regeneration incomplete state continues as long as the filter regeneration prohibited state does not turn on. While the filter is in this filter regeneration incomplete state, the filter regeneration incomplete state will continue without turning off even if the PM combustion condition ceases to be satisfied and the combustion mode of the engine 1 switches from the regeneration combustion mode to the normal combustion mode (during the period between t3 and t4). However, the filter regeneration incomplete state turns off during the period between t5 and t6 when the filter regeneration prohibited state is on.

[0064] In this way, the filter regeneration incomplete state is a state in which there is a filter regeneration command, during a period after filter regeneration starts until filter regeneration has been completed and filter regeneration is not being prohibited.

[0065] Returning to the flowchart in FIG. 6, the counting process will now be described. In step ST106, the ECU 100 determines whether the combustion mode is a mode other than a specific combustion mode (being the combustion mode that affects oil dilution, the combustion mode for increasing the bed temperature of the CCO 21, or the filter regeneration combustion mode). If the determination in step ST106 is no (i.e., if the combustion mode is the specific combustion mode), the process proceeds on to step ST107, and the ECU 100 increases the count of the timer/counter 110 ($T_i = T_{i-1} + 1$). Then the process returns.

[0066] On the other hand, if the determination in step ST106 is yes (i.e., if the combustion mode is the normal combustion mode), the process proceeds on to step ST108. In step ST108 the ECU 100 determines whether the current state is the filter regeneration incomplete state.

[0067] If the determination in step ST108 is yes, then the current state is the filter regeneration incomplete state, so even if the combustion mode temporarily switches from the regeneration combustion mode to the normal combustion mode, there is a possibility that the combustion mode will soon return to the regeneration combustion mode. Therefore, the ECU 100 determines that the state is not one that will cause the fuel mixed into the engine oil to vaporise, and maintains the current count value T_i of the filter regeneration duration ($T_i = T_{i-1}$) (step ST109) instead of resetting the timer/counter 110. Then the process returns.

[0068] If the determination in step ST108 is no, the current state is not the filter regeneration prohibited state and the combustion mode is the normal combustion mode (either the normal combustion mode from after filter regeneration has been completed until filter regeneration starts or the normal combustion mode in the filter regeneration prohibited state), such that fuel mixed in with the engine oil will vaporise. Therefore, the ECU 100 resets the timer/counter 110 (step ST110) and initialises the count value T_i of the filter regeneration duration (i.e., $T_i = 0$). Then the process returns.

[0069] Next, the example of the counting process of the filter regeneration duration described above will be described with reference to FIG. 8.

[0070] First, until time t2 when filter regeneration starts, i.e., while the filter is in the filter regeneration complete state, the combustion mode is the normal combustion mode when the filter is not in the filter regeneration incomplete state, so the timer/counter 110 is reset.

[0071] Next, when there is a command for filter regeneration at time t2, the state of the filter in the exhaust gas control apparatus changes to the filter regeneration incomplete state and the count of the timer/counter 110 starts to be increased.

[0072] Here, if the PM combustion condition ceases to be satisfied while the filter is being regenerated, the combustion mode switches from the regeneration combustion mode to the normal combustion mode (t3). At this time, with typical control, the timer/counter 110 is reset such that count value T_i of the filter regeneration duration becomes "0" at time t3 when the combustion mode switches to the normal combustion mode. In contrast, with the control in this example, when the condition that the filter be in the filter regeneration incomplete state is satisfied, the timer/counter 110 maintains the current count value T_i of the filter regeneration duration ($T_i = T_{i-1}$), so the relationship between the actual amount of fuel diluting the oil and the filter regeneration duration (i.e., the duration of the post injection) will not become skewed. Then the timer/counter 110 starts to increase the count again at time t4 when the combustion mode returns to the regeneration combustion mode.

[0073] At time t5 when the count value T_i of the counter/timer 110 reaches the maximum duration, the ECU 100 prohibits filter regeneration for a fixed period of time (t5 to t6). The timer/counter 110 is reset while the state is the filter regeneration prohibited state. Next, the timer/counter 110 starts to increase the count due to the filter of the exhaust gas control apparatus being in the filter regeneration incomplete state at time t6 after a period of time during which the fuel that is mixed in with the engine oil sufficiently vaporises (i.e., the time that it takes to recover from the oil dilution well enough for filter regeneration to be able to be executed) has passed after time t5 when the filter regeneration prohibited state starts. Then, at time tn when regeneration of the filter of the exhaust gas control apparatus is completed, the filter regeneration incomplete state is turned off, the combustion mode switches to the normal combustion mode, and the timer/counter 110 is reset.

[0074] Incidentally, in this example embodiment, the ECU 100 may also determine whether a value obtained by multiplying one control cycle (time) of the calculation process by the count value T_i of the timer/counter 110 has reached the maximum duration. Alternatively, the ECU 100 may determine whether the count value T_i of the timer/counter 110 itself has reached a maximum count value that corresponds to the maximum duration.

[0075] As described above, the current duration count value T_i is maintained even if the PM combustion condition ceases to be satisfied due to the catalyst temperature not being high enough, for example, after filter regeneration starts in response to a filter regeneration command (i.e., while the filter is in the filter regeneration incomplete state), and the combustion mode temporarily switches from the regeneration combustion mode to the normal combustion mode. Therefore, the relationship between the actual amount of fuel diluting the oil and the count value T_i of the filter regeneration duration (i.e., the duration of the post injection) will not become skewed. As a result, the ECU 100 can correctly determine that the count value T_i of the filter regeneration duration has reached the maximum duration, so oil dilution can be reliably suppressed.

[0076] In the example embodiment described above, a DPF is used as the particulate filter, but the invention is not limited to this. For example, the invention may also be applied to an exhaust gas control apparatus that uses a DPNR catalyst.

[0077] In the example embodiment described above, an example is described in which the exhaust gas control apparatus of the invention is applied to an in-cylinder direct injection four cylinder diesel engine, but the invention is not limited to this. For example, the invention may also be applied to a diesel engine with an arbitrary number of cylinders, such as an in-cylinder direct injection six cylinder diesel engine.

[0078] Furthermore, the exhaust gas control apparatus of the example embodiment described above may also be applied to a lean-burn petrol engine in which the operating range where the engine is operated by supplying a mixture with a high air-fuel ratio (i.e., a lean atmosphere) accounts for the majority of the entire operating range. Also, the invention is not limited to being applied to an engine of a vehicle, but may also be applied to an engine used for another purpose.

[0079] While the invention has been described with reference to example embodiments thereof, it is to be understood that the invention is not limited to the described embodiments or constructions. To the contrary, the invention is intended to cover various modifications and equivalent arrangements. In addition, while the various elements of the disclosed invention are shown in various example combinations and configurations, other combinations and configurations, including more, less or only a single element, are also within the scope of the appended claims.

Claims

1. An exhaust gas control apparatus provided with a filter (22) that is arranged in an exhaust passage (4) of an internal combustion engine (1) and traps particulate matter in exhaust gas, filter regeneration controlling means (100) for performing filter regeneration that removes particulate matter (PM) that has accumulated on the filter (22) by performing a regeneration fuel injection after a main fuel injection by controlling the injection timing of the internal combustion engine (1), and a counter (110) that counts the duration of the filter regeneration, the exhaust gas control apparatus **characterised in that:**

   the filter regeneration controlling means (100) determines that a period of time from after there is a command to regenerate the filter (22) so that the filter regeneration starts until the filter regeneration has been completed, and which is a period of time during which the filter regeneration is not prohibited, is a period of time during which the filter (22) is in a filter regeneration incomplete state;
   the filter regeneration controlling means (100) increases the count of the counter (110) when the filter regeneration is being executed while the filter (22) is in the filter regeneration incomplete state; and
   the filter regeneration controlling means (100) has the counter (110) maintain the current duration count value when the internal combustion engine (1) switches to a state other than a filter regenerating state while the filter (22) is in the filter regeneration incomplete state.

2. The exhaust gas control apparatus according to claim 1, wherein the filter regeneration controlling means (100) resets the counter (110) when the filter (22) is not in the filter regeneration incomplete state.

3. The exhaust gas control apparatus according to claim 1 or 2, wherein the filter regeneration controlling means (100) establishes a filter regeneration prohibited period when the count of the counter (110) reaches a predetermined duration.

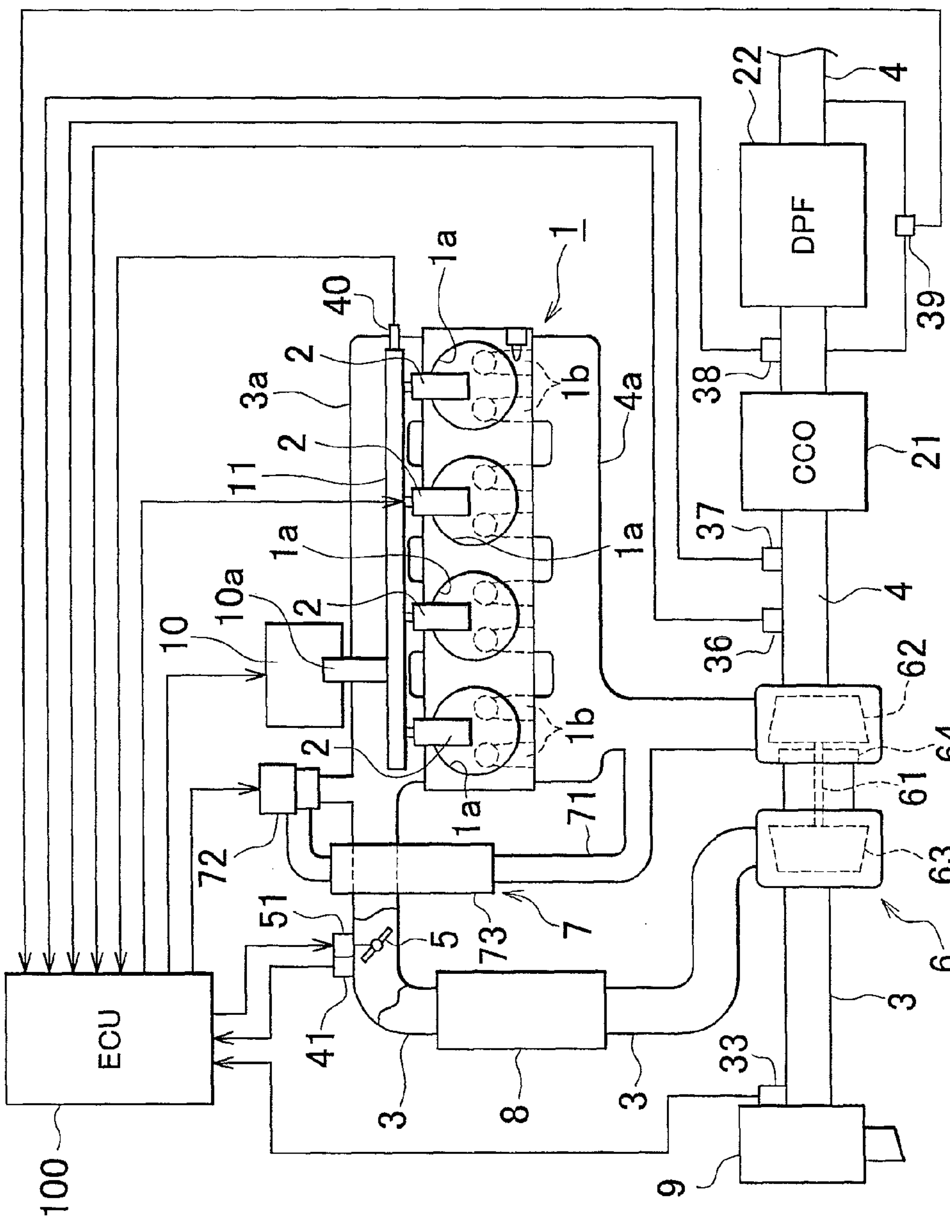
4. The exhaust gas control apparatus according to claim 3, wherein the filter regeneration controlling means (100) resets the counter (110) during the filter regeneration prohibited period.

5. The exhaust gas control apparatus according to claim 4, wherein the filter regeneration prohibited period is established as a period of time until the fuel that is mixed in with oil that lubricates the internal combustion engine (1) sufficiently vaporises.

6. The exhaust gas control apparatus according to any one of claims 1 to 5, wherein the state other than the filter regenerating state is a state of the internal combustion engine

   (1) in which the regeneration fuel injection is not performed after the main fuel injection.

FIG. 1


ECU
DPF
CCO
100
1
1a
1b
2
3
3a
4
4a
5
6
7
8
9
10
10a
11
21
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33
36
37
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39
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41
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61
62
63
64
71
72
73

FIG. 2

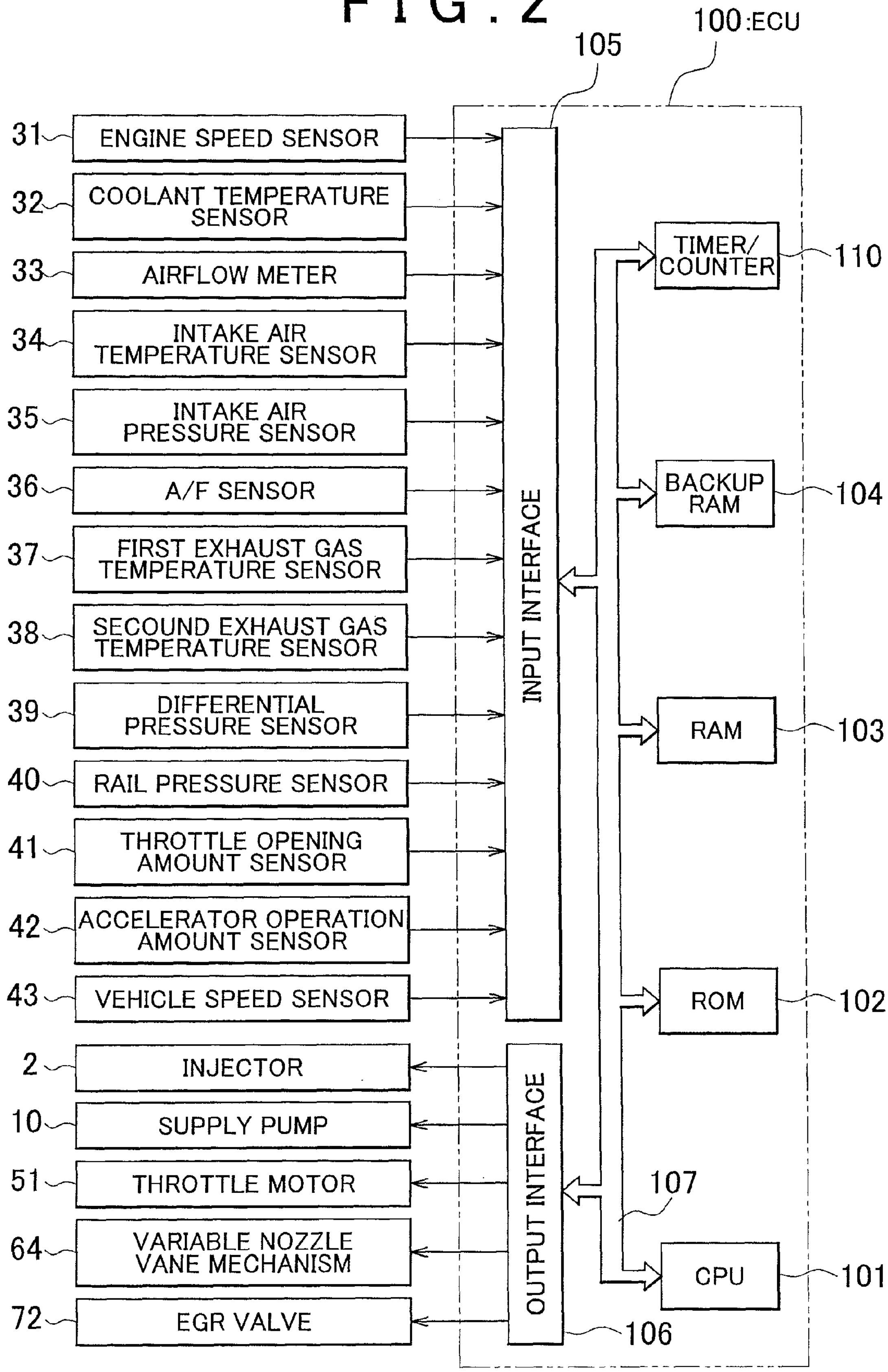

100:ECU
105
31
ENGINE SPEED SENSOR
32
COOLANT TEMPERATURE SENSOR
33
AIRFLOW METER
34
INTAKE AIR TEMPERATURE SENSOR
35
INTAKE AIR PRESSURE SENSOR
36
A/F SENSOR
37
FIRST EXHAUST GAS TEMPERATURE SENSOR
38
SECOUND EXHAUST GAS TEMPERATURE SENSOR
39
DIFFERENTIAL PRESSURE SENSOR
40
RAIL PRESSURE SENSOR
41
THROTTLE OPENING AMOUNT SENSOR
42
ACCELERATOR OPERATION AMOUNT SENSOR
43
VEHICLE SPEED SENSOR
2
INJECTOR
10
SUPPLY PUMP
51
THROTTLE MOTOR
64
VARIABLE NOZZLE VANE MECHANISM
72
EGR VALVE
INPUT INTERFACE
OUTPUT INTERFACE
TIMER/ COUNTER
110
BACKUP RAM
104
RAM
103
ROM
102
107
CPU
101
106

FIG. 3

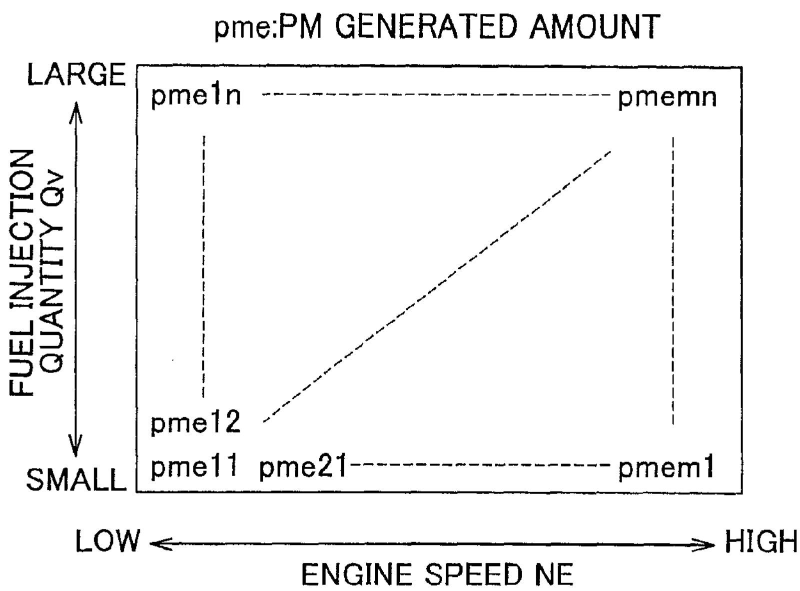
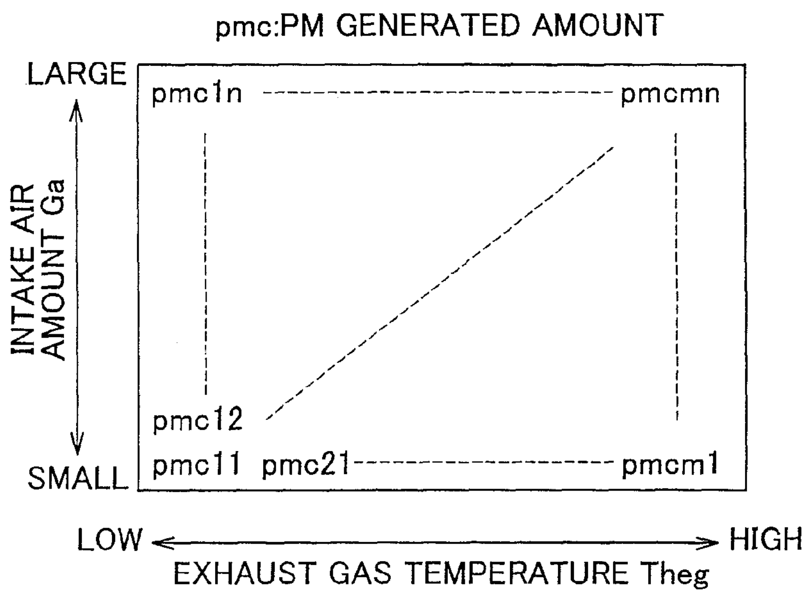

pme:PM GENERATED AMOUNT
LARGE
SMALL
FUEL INJECTION QUANTITY Qv
pme1n
pmemn
pme12
pme11
pme21
pmem1
LOW
HIGH
ENGINE SPEED NE

FIG. 4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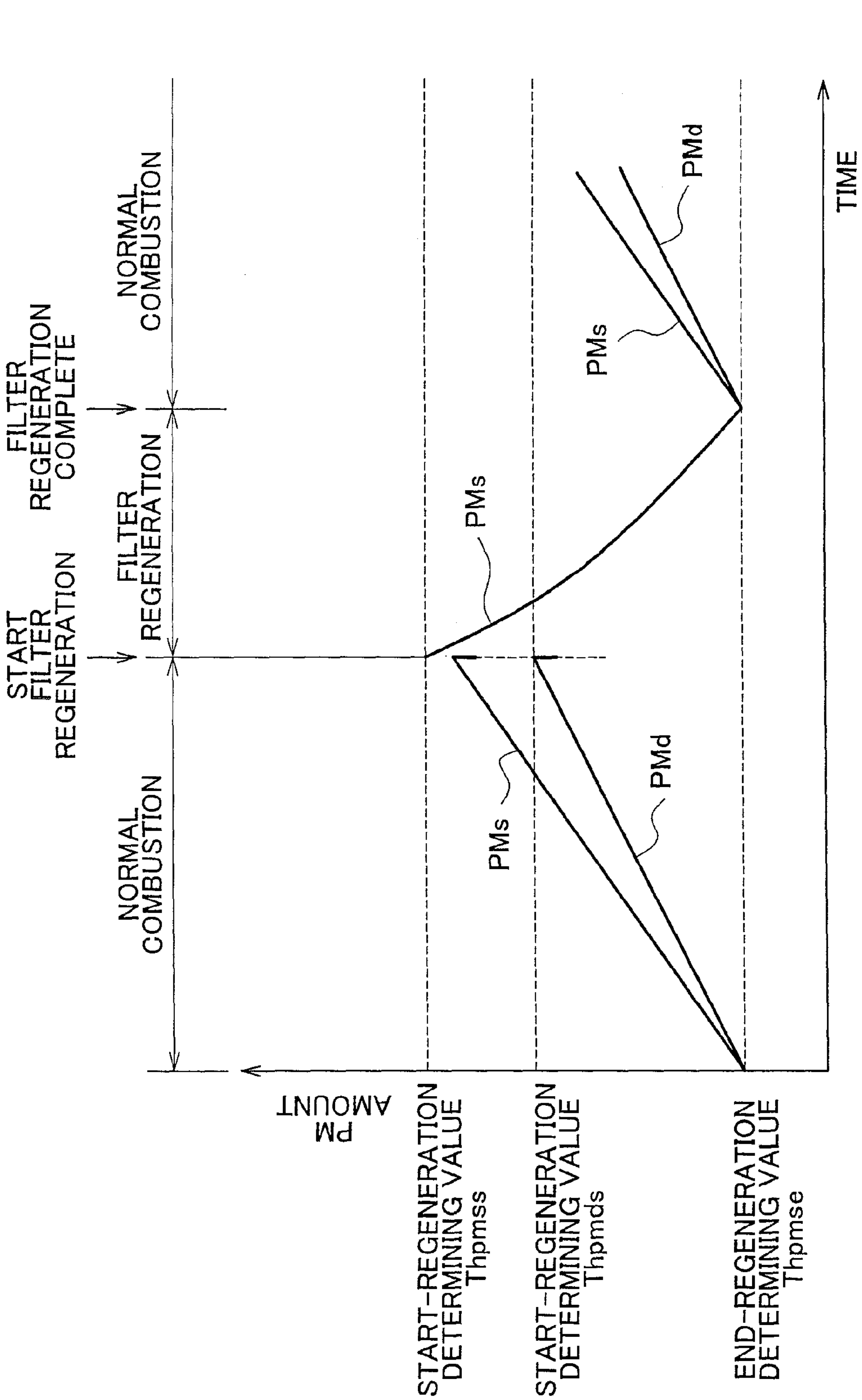
SMALL
INTAKE AIR AMOUNT Ga
pmc1n
pmcmn
pmc12
pmc11
pmc21
pmcm1
LOW
HIGH
EXHAUST GAS TEMPERATURE Theg

FIG. 5


START FILTER REGENERATION
FILTER REGENERATION COMPLETE
NORMAL COMBUSTION
FILTER REGENERATION
NORMAL COMBUSTION
PMs
PMd
PMs
PMs
PMd
PM AMOUNT
TIME
START-REGENERATION DETERMINING VALUE Thpmss
START-REGENERATION DETERMINING VALUE Thpmds
END-REGENERATION DETERMINING VALUE Thpmse

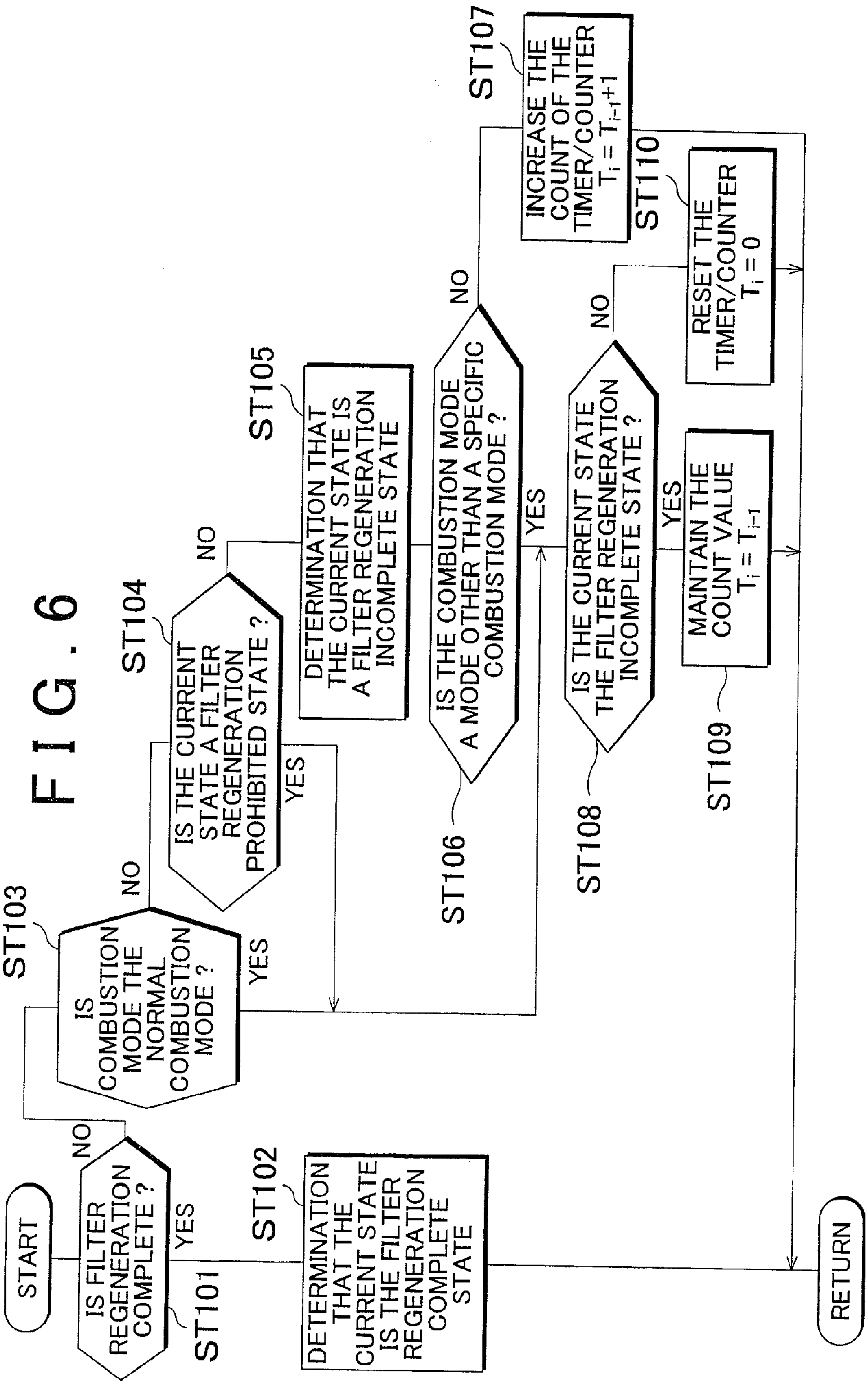

START
ST101
IS FILTER REGENERATION COMPLETE ?
YES
NO
ST102
DETERMINATION THAT THE CURRENT STATE IS THE FILTER REGENERATION COMPLETE STATE
ST103
IS COMBUSTION MODE THE NORMAL COMBUSTION MODE ?
ST104
IS THE CURRENT STATE A FILTER REGENERATION PROHIBITED STATE ?
ST105
DETERMINATION THAT THE CURRENT STATE IS A FILTER REGENERATION INCOMPLETE STATE
ST106
IS THE COMBUSTION MODE A MODE OTHER THAN A SPECIFIC COMBUSTION MODE ?
ST107
INCREASE THE COUNT OF THE TIMER/COUNTER $T_i = T_{i-1}+1$
ST108
IS THE CURRENT STATE THE FILTER REGENERATION INCOMPLETE STATE ?
ST109
MAINTAIN THE COUNT VALUE $T_i = T_{i-1}$
ST110
RESET THE TIMER/COUNTER $T_i = 0$
RETURN

FIG. 6

FIG. 7

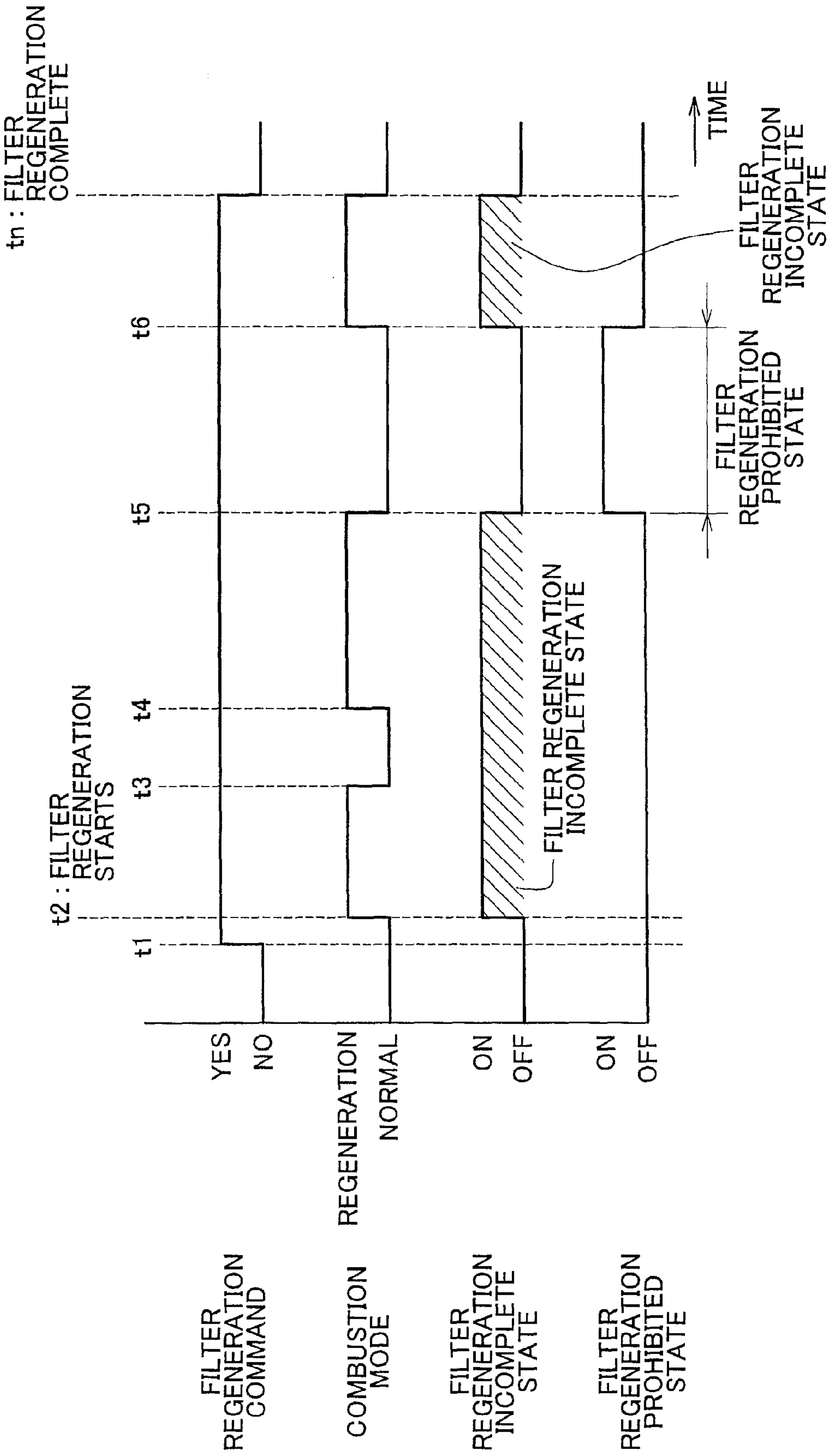
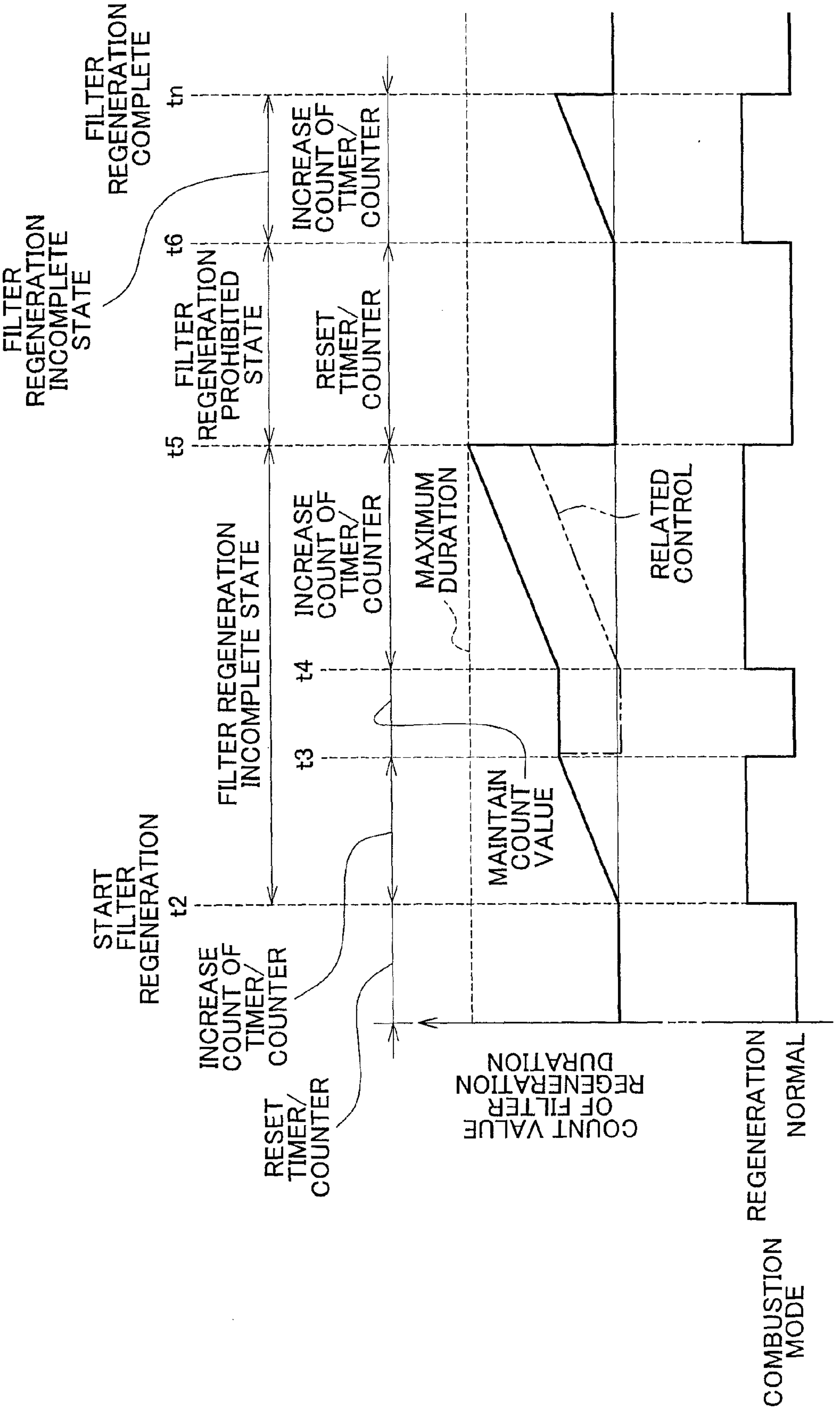

FILTER REGENERATION COMMAND
COMBUSTION MODE
FILTER REGENERATION INCOMPLETE STATE
FILTER REGENERATION PROHIBITED STATE
YES
NO
REGENERATION
NORMAL
ON
OFF
ON
OFF
t1
t2 : FILTER REGENERATION STARTS
t3
t4
t5
t6
tn : FILTER REGENERATION COMPLETE
FILTER REGENERATION INCOMPLETE STATE
FILTER REGENERATION PROHIBITED STATE
FILTER REGENERATION INCOMPLETE STATE
TIME

FIG. 8


START FILTER REGENERATION
t2
FILTER REGENERATION INCOMPLETE STATE
FILTER REGENERATION INCOMPLETE STATE
t3
t4
t5
FILTER REGENERATION PROHIBITED STATE
t6
FILTER REGENERATION COMPLETE
tn
INCREASE COUNT OF TIMER/ COUNTER
RESET TIMER/ COUNTER
INCREASE COUNT OF TIMER/ COUNTER
RESET TIMER/ COUNTER
INCREASE COUNT OF TIMER/ COUNTER
MAXIMUM DURATION
MAINTAIN COUNT VALUE
RELATED CONTROL
COUNT VALUE OF FILTER REGENERATION DURATION
COMBUSTION MODE
REGENERATION
NORMAL

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EUROPEAN SEARCH REPORT

Application Number
EP 10 15 3088

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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1

Place of search	Date of completion of the search	Examiner
Munich	9 April 2010	Calabrese, Nunziante

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& : member of the same patent family, corresponding document

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09-04-2010

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