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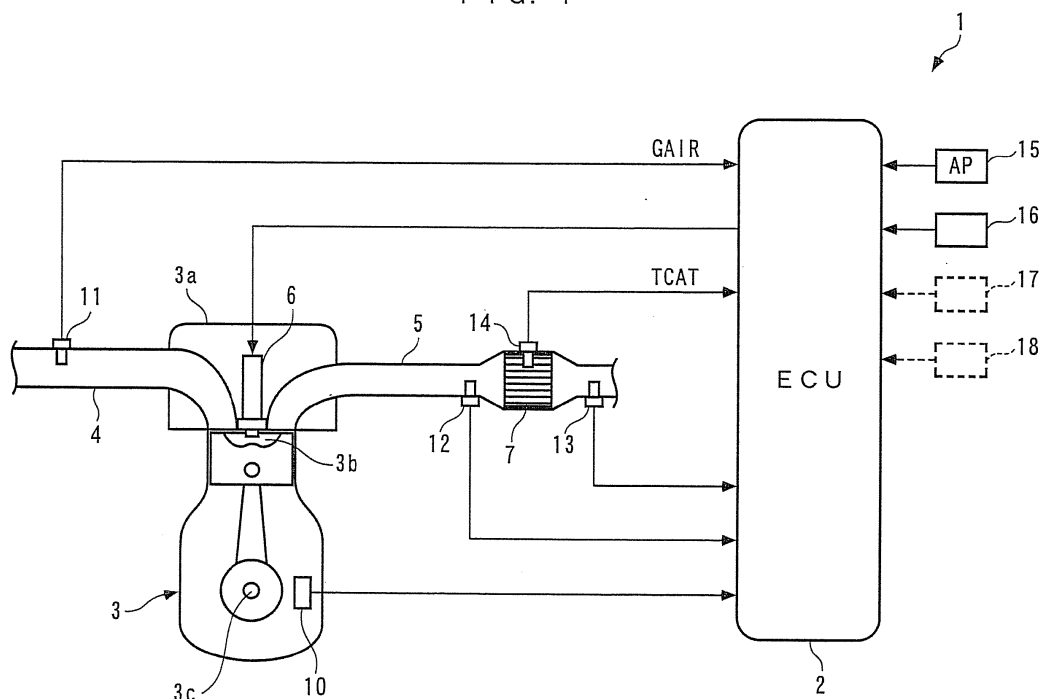
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(54) **Catalyst deterioration determination device and method**

(57) A catalyst deterioration determination device determines whether or not a catalyst which purifies exhaust gases exhausted from an internal combustion engine is deteriorated based on the capacity of the catalyst for purifying exhaust gases. If it is determined that the catalyst is deteriorated, first sulfur elimination control is

executed for eliminating sulfur content accumulated in the catalyst. Further, when the first sulfur elimination control is terminated, the deterioration determination of the catalyst is executed. Then, when it is determined by the deterioration determination that the catalyst is not deteriorated, it is determined that the fuel is high-sulfur fuel containing lots of sulfur content.

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Description**BACKGROUND OF THE INVENTION**5 **Field of the Invention**

[0001] The present invention relates to a catalyst deterioration determination device and method for determining deterioration of a catalyst that purifies exhaust gases from an internal combustion engine.

10 **Description of the Related Art**

[0002] Conventionally, there has been proposed a catalyst deterioration determination device for determining deterioration of a catalyst in Japanese Laid-Open Patent Publication (Kokai) No. 2002-195089. This catalyst is a NOx catalyst, and in this deterioration determination device, the deterioration of the NOx catalyst is determined in the following manner:
 15 First, a rate of NOx purification by the NOx catalyst is calculated based on a ratio between a required amount of reducing agent and a NOx trapping amount trapped by the NOx catalyst. The required amount of reducing agent is calculated based on the air-fuel ratio of exhaust gases in an exhaust passage downstream of the NOx catalyst, and the NOx trapping amount is calculated based on the amount of intake air, rotational speed and load on an internal combustion engine. If the calculated rate of NOx purification is less than a first predetermined value, since there is a possibility that the rate
 20 of NOx purification is lowered not by the deterioration of the NOx catalyst, but by poisoning of the NOx catalyst due to accumulation of sulfur content of fuel in the NOx catalyst, in order to check for this, a poisoning recovery control is executed for causing recovery of the NOx catalyst from the poisoned state. This poisoning recovery control is carried out by raising the temperature of the NOx catalyst higher than a predetermined temperature and then controlling the air-fuel ratio to a richer value than the stoichiometric air-fuel ratio, to thereby cause reduction (reduction-oxidation reaction)
 25 of sulfur content. Then, the rate of NOx purification is calculated again, and if the rate of purification is not less than a second predetermined value, it is judged that the rate of purification is lowered by poisoning of the NOx catalyst, and hence it is determined that the NOx catalyst is normal.

[0003] As described above, in the conventional deterioration determination device, when the rate of purification of the NOx catalyst is lowered, the poisoning recovery control is carried out to check for the cause of the lowering of the rate
 30 of purification of the NOx catalyst. Therefore, when high-sulfur fuel is used which contains lots of sulfur content, the NOx catalyst is made more liable to be poisoned, and hence the rate of purification is more liable to be lowered. Therefore, it is required to frequently perform the poisoning recovery control in which the air-fuel ratio is controlled to a richer value. As a result, more fuel is consumed, which causes degradation of fuel economy.

35 **SUMMARY OF THE INVENTION**

[0004] It is an object of the present invention to provide a catalyst deterioration determination device and method and an engine control unit which are capable of determining whether or not fuel is high-sulfur fuel containing lots of sulfur content, and properly determining whether a catalyst is deteriorated while suppressing the frequency of execution of
 40 control for recovering the catalyst from the poisoned state to the minimum.

[0005] To attain the above object, in a first aspect of the present invention, there is provided a catalyst deterioration determination device that determines deterioration of a catalyst disposed in an exhaust passage of an internal combustion engine, for purifying exhaust gases exhausted from the engine, characterized by comprising first deterioration-determining means for determining whether or not the catalyst is deteriorated based on a capacity of the catalyst for purifying
 45 exhaust gases, first sulfur elimination control-executing means for executing first sulfur elimination control for eliminating sulfur content accumulated in the catalyst, when it is determined by the first deterioration-determining means that the catalyst is deteriorated, second deterioration-determining means for determining whether or not the catalyst is deteriorated,, when the first sulfur elimination control is terminated, and high sulfur-determining means for determining that the fuel is high-sulfur fuel containing lots of sulfur content, when it is determined by the second deterioration-determining
 50 means that the catalyst is not deteriorated.

[0006] With the configuration of the catalyst deterioration determination device according to the first aspect of the present invention, the exhaust gases are purified by the catalyst provided in the exhaust passage. Further, it is determined whether or not the catalyst is deteriorated based on the capacity of the catalyst for purifying exhaust gases, and if it is determined that the catalyst is deteriorated, the first sulfur elimination control for eliminating the sulfur content accumulated
 55 in the catalyst is carried out. Thereafter, the deterioration determination of the catalyst is executed again.

[0007] If the catalyst is not deteriorated but poisoned, the sulfur content accumulated in the catalyst is eliminated by execution of the first sulfur elimination control, whereby the purification capability of the catalyst is recovered. Therefore, when it is determined that the catalyst is not deteriorated after execution of the first sulfur elimination control, the cause

of lowering of the purification capability is identified as not the deterioration of the catalyst, but poisoning of the catalyst, and it is determined that the fuel is high-sulfur fuel containing lots of sulfur content. As described above, if it is determined that the fuel is high-sulfur fuel, the first sulfur elimination control is executed on this understanding, whereby it is possible to appropriately carry out the deterioration determination of the catalyst, while suppressing the frequency of execution of the first sulfur elimination control to the minimum.

[0008] Preferably, the catalyst deterioration determination device is characterized by further comprising deterioration determination-inhibiting means for inhibiting the deterioration determination of the catalyst by the first deterioration-determining means, when it is determined by the high sulfur-determining means that the fuel is high-sulfur fuel.

[0009] In the case of high-sulfur fuel, the amount of sulfur content accumulated in the catalyst becomes larger, so that a possibility that the accuracy of the deterioration determination is lowered becomes high. According to the present invention, if it is determined that the fuel is high-sulfur fuel, the deterioration determination of the catalyst is inhibited, whereby it is possible to prevent the deterioration of the catalyst from being erroneously determined due to poisoning.

[0010] More preferably, the catalyst deterioration determination device is characterized by further comprising fuel consumption-calculating means for calculating consumption of fuel, and the deterioration determination-inhibiting means inhibits the deterioration determination, when the calculated fuel consumption reaches a first predetermined threshold.

[0011] In the case of high-sulfur fuel, as the fuel consumption increases, the sulfur content accumulated in the catalyst increases, and hence the possibility that the accuracy of the deterioration determination is lowered becomes high. According to the present invention, if it is determined that the fuel is high-sulfur fuel, when the calculated fuel consumption reaches the first predetermined threshold, the deterioration determination of the catalyst is inhibited. Therefore, when there is a high possibility that the accuracy of the deterioration determination of the catalyst is lowered by poisoning, the deterioration determination is inhibited, whereby it is possible to positively prevent the erroneous determination. Further, since execution of the deterioration determination is permitted before the fuel consumption reaches the first predetermined threshold, it is possible to carry out the deterioration determination of the catalyst as much as possible while maintaining the accuracy of the determination.

[0012] More preferably, the catalyst deterioration determination device is characterized by further comprising fuel consumption-determining means for determining whether or not the fuel which is determined as high-sulfur fuel is consumed, and deterioration determination-restarting means for restarting the deterioration determination of the catalyst by the first deterioration-determining means, when it is determined by the fuel consumption-determining means that the fuel is consumed during inhibition of the deterioration determination of the catalyst.

[0013] With the configuration of this preferred embodiment, during inhibition of the deterioration determination, when it is determined that the fuel determined as the high-sulfur fuel is consumed, the deterioration determination is restarted. This makes it possible to restart the deterioration determination in timing in which consumption of the fuel is completed, thereby making it possible to prevent the deterioration of the catalyst from being erroneous determined due to poisoning.

[0014] Further preferably, the fuel consumption-determining means determines that the fuel is consumed when the fuel consumption reaches a second predetermined threshold which is larger than the first predetermined threshold.

[0015] With the configuration of this preferred embodiment, during inhibition of the deterioration determination of the catalyst, when the fuel consumption reaches the second predetermined threshold which is larger than the first predetermined threshold, the deterioration determination of the catalyst is restarted. Therefore, by using a value which is exceeded when it is expected that the high-sulfur fuel is positively consumed as the second predetermined threshold, it is possible to restart the deterioration determination in timing in which the high-sulfur fuel is positively consumed.

[0016] Further preferably, the catalyst deterioration determination device is characterized by further comprising refueling determining means for determining whether or not refueling is performed, and the fuel consumption-determining means determines that fuel is consumed when it is determined by the refueling determining means that refueling is performed.

[0017] With the configuration of this preferred embodiment, during inhibition of the deterioration determination of the catalyst, when it is determined that refueling is performed, the deterioration determination of the catalyst is restarted. If refueling is performed, it is possible to determine that the fuel used until then has been consumed. Therefore, after refueling, it is possible to restart the deterioration determination in timing in which the high-sulfur fuel is positively consumed.

[0018] Further preferably, the first sulfur elimination control is executed prior to restarting the deterioration determination of the catalyst by the deterioration determination-restarting means.

[0019] With the configuration of this preferred embodiment, since the first sulfur elimination control is executed prior to restarting the deterioration determination of the catalyst, this makes it possible to restart the deterioration determination in a state where the catalyst has been positively recovered from poisoning, whereby it is possible to properly carry out the deterioration determination.

[0020] Preferably, the catalyst deterioration determination device is characterized by further comprising second sulfur elimination control-executing means for executing second sulfur elimination control separately from the first sulfur elimination control, for eliminating sulfur content accumulated in the catalyst in accordance with progress of operation of the

engine, and a time period over which the first sulfur elimination control is executed is longer than a time period over which the second sulfur elimination control is executed.

[0021] With the configuration of this preferred embodiment, the sulfur content accumulated in the catalyst in accordance with progress of the operation of the engine is eliminated by executing the second sulfur elimination control of an ordinary type. Further, the time period over which the first sulfur elimination control which is executed when it is determined that the catalyst is deteriorated or before the deterioration determination of the catalyst is restarted is set to be longer than a time period over which the second sulfur elimination control is executed. This causes the first sulfur elimination control to be executed for a longer time period, whereby it is possible to positively recover the catalyst from poisoning, and hence this makes it possible to more properly carry out a subsequent deterioration determination of the catalyst.

[0022] Preferably, the catalyst deterioration determination device is characterized by further comprising second sulfur elimination control-executing means for executing second sulfur elimination control separately from the first sulfur elimination control, for eliminating sulfur content accumulated in the catalyst in accordance with progress of operation of the engine, and the first and second sulfur elimination control-executing means control the exhaust gases flowing into the catalyst to a reduction atmosphere, a degree of reduction of the exhaust gases being controlled to a higher value during execution of the first sulfur elimination control, than during execution of the second sulfur elimination control.

[0023] With the configuration of this preferred embodiment, the exhaust gases flowing into the catalyst is controlled to the reduction atmosphere by executing the first and second sulfur elimination control. By this, the sulfur content accumulated in the catalyst is reduced and eliminated. Further, during execution of the first sulfur elimination control, the degree of reduction of the exhaust gases is controlled to be higher than during the execution of the second sulfur elimination control of an ordinary type. Therefore, more sulfur content accumulated in the catalyst is eliminated during the execution of the first sulfur elimination control, whereby it is possible to positively recover the catalyst from poisoning, thereby making it possible to more properly carry out a subsequent deterioration determination of the catalyst.

[0024] Preferably, the catalyst deterioration determination device is characterized by further comprising second sulfur elimination control-executing means for executing second sulfur elimination control separately from the first sulfur elimination control, for eliminating sulfur content accumulated in the catalyst in accordance with progress of operation of the engine, and temperature of the catalyst is controlled to a higher value during execution of the first sulfur elimination control, than during execution of the second sulfur elimination control.

[0025] In general, as the temperature of the catalyst is higher, the activity thereof becomes higher, and this causes the capability of eliminating sulfur content to be enhanced. According to the present invention, in the execution of the first sulfur elimination control, the temperature of the catalyst is controlled to be higher than during the execution of the ordinary second sulfur elimination control. This makes it possible to positively recover the catalyst from poisoning in a state where the catalyst is more activated, during the execution of the first sulfur elimination control, and hence it is possible to more properly carry out a subsequent deterioration determination of the catalyst.

[0026] Further preferably, the catalyst deterioration determination device is characterized by further comprising second sulfur elimination control period-setting means for setting a repetition period at which the second sulfur elimination control is executed to a short time period, when it is determined by the high sulfur-determining means that the fuel is high-sulfur fuel.

[0027] In the case of the high-sulfur fuel, the catalyst is liable to be rapidly poisoned. Therefore, with the configuration of this preferred embodiment, it is possible to recover the catalyst from poisoning in proper timing by reducing the repetition period at which the normal second sulfur elimination control is executed. This makes it possible to maintain the NOx trapping capability of the catalyst, thereby making it possible to maintain the exhaust emission characteristics.

[0028] Preferably, the catalyst is configured to trap NOx in exhaust gases under the oxidation atmosphere, and the catalyst deterioration determination device further comprises reduction control means for executing reduction control for controlling exhaust gases flowing into the catalyst to the reduction atmosphere to reduce the NOx trapped by the catalyst, and reduction control repetition period-setting means for setting a repetition period at which the reduction control is executed to a short time period, when it is determined by the high sulfur-determining means that the fuel is high-sulfur fuel.

[0029] With the configuration of this preferred embodiment, the NOx in exhaust gases is trapped by the catalyst under the oxidation atmosphere, and the trapped NOx is reduced by executing the reduction control which controls the exhaust gases flowing into the catalyst to the reduction atmosphere. In the case of the high-sulfur fuel, since the amount of the sulfur content accumulated in the catalyst becomes larger, the catalyst more rapidly becomes saturated. According to the present invention, when it is determined that the fuel is high-sulfur fuel, a repetition period at which the reduction control is executed is reduced, whereby it is possible to execute the reduction control in proper timing before the catalyst becomes saturated. This makes it possible to suppress flowing of NOx through the catalyst due to saturation of the catalyst, thereby making it possible to maintain the exhaust emission characteristics.

[0030] To attain the above object, in a second aspect of the present invention, there is provided a method of determining deterioration of a catalyst disposed in an exhaust passage of an internal combustion engine, for purifying exhaust gases exhausted from the engine, characterized by executing first deterioration determination for determining whether or not

the catalyst is deteriorated based on a capacity of the catalyst for purifying exhaust gases, executing first sulfur elimination control for eliminating sulfur content accumulated in the catalyst, when it is determined the first deterioration determination that the catalyst is deteriorated, executing second deterioration determination for determining whether or not the catalyst is deteriorated, when the first sulfur elimination control is terminated, and determining that the fuel is high-sulfur fuel containing lots of sulfur content, when it is determined by the second deterioration determination that the catalyst is not deteriorated.

[0031] With the configuration of the method according to the second aspect of the present invention, it is possible to obtain the same advantageous effects as provided by the first aspect of the present invention.

[0032] Preferably, the method is further characterized by inhibiting the first deterioration determination of the catalyst, when it is determined that the fuel is high-sulfur fuel.

[0033] More preferably, the method is further characterized by calculating consumption of fuel, and the inhibiting includes inhibiting the first deterioration determination, when the calculated fuel consumption reaches a first predetermined threshold.

[0034] More preferably, the method is further characterized by determining whether or not the fuel which is determined as high-sulfur fuel is consumed; and restarting the first deterioration determination, when it is determined by the fuel consumption determining that the fuel is consumed during inhibition of the deterioration determination of the catalyst.

[0035] Further preferably, the method is **characterized in that** the fuel consumption determining includes determining that the fuel is consumed when the fuel consumption reaches a second predetermined threshold which is larger than the first predetermined threshold.

[0036] Further preferably, the method is further characterized by determining whether or not refueling is performed, and the fuel consumption determining includes determining that fuel is consumed when it is determined by the refueling determining that refueling is performed.

[0037] Further preferably, the method is **characterized in that** the first sulfur elimination control is executed prior to restarting the first deterioration determination of the catalyst.

[0038] Preferably, the method is further characterized by executing second sulfur elimination control separately from the first sulfur elimination control, for eliminating sulfur content accumulated in the catalyst in accordance with progress of operation of the engine, and a time period over which the first sulfur elimination control is executed is longer than a time period over which the second sulfur elimination control is executed.

[0039] Preferably, the method is further characterized by executing second sulfur elimination control separately from the first sulfur elimination control, for eliminating sulfur content accumulated in the catalyst in accordance with progress of operation of the engine, and the first and second sulfur elimination controls control the exhaust gases flowing into the catalyst to a reduction atmosphere, a degree of reduction of the exhaust gases being controlled to a higher value during execution of the first sulfur elimination control, than during execution of the second sulfur elimination control.

[0040] Preferably, the method is further characterized by executing second sulfur elimination control separately from the first sulfur elimination control, for eliminating sulfur content accumulated in the catalyst in accordance with progress of operation of the engine, and temperature of the catalyst is controlled to a higher value during execution of the first sulfur elimination control, than during execution of the second sulfur elimination control.

[0041] More preferably, the method is further characterized by setting a repetition period at which the second sulfur elimination control is executed to a short time period, when it is determined that the fuel is high-sulfur fuel.

[0042] Preferably, the method is **characterized in that** the catalyst is configured to trap NO_x in exhaust gases under the oxidation atmosphere, and further characterized by executing reduction control for controlling exhaust gases flowing into the catalyst to the reduction atmosphere to reduce the NO_x trapped by the catalyst, and setting a repetition period at which the reduction control is executed to a short time period, when it is determined that the fuel is high-sulfur fuel.

[0043] With the configurations of these preferred embodiments, it is possible to obtain the same advantageous effects as provided by the respective corresponding preferred embodiments of the first aspect of the present invention.

[0044] The above and other objects, features, and advantages of the present invention will become more apparent from the following detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0045]

FIG. 1 is a schematic diagram of a catalyst deterioration determination device according to embodiments of the present invention, and an internal combustion engine to which the catalyst deterioration determination device is applied;

FIG. 2 is a flowchart of a ordinary poisoning recovery control process;

FIG. 3 is a flowchart of a deterioration determination process according to a first embodiment of the present invention;

FIG. 4 is a flowchart of a rich spike control process;

FIG. 5 is a timing diagram showing an example of operation of the catalyst deterioration determination device performed when the catalyst is normal, and fuel is high-sulfur fuel;

FIG. 6 is a flowchart of a deterioration determination process according to a second embodiment of the present invention;

FIG. 7 is a flowchart of a refueling determination process;

FIG. 8 is a flowchart of a variation of the refueling determination process.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0046] The invention will now be described in detail with reference to the drawings showing preferred embodiments thereof. FIG. 1 schematically shows a catalyst deterioration determination device 1 according to embodiments of the present invention, and an internal combustion engine 3 to which the catalyst deterioration determination device 1 is applied. The internal combustion engine (hereinafter simply referred to as "the engine") 3 is a diesel engine that is installed on a vehicle, not shown.

[0047] A cylinder head 3a of the engine 3 has an intake pipe 4 and an exhaust pipe 5 connected thereto, with a fuel injection valve (hereinafter referred to as "the injector") 6 mounted therethrough such that it faces a combustion chamber 3b.

[0048] The injector 6 is inserted into the combustion chamber 3b through a central portion of the top wall thereof, and injects fuel from a fuel tank (not shown) into the combustion chamber 3b. The amount QINJ (fuel injection amount) of fuel to be injected from the injector 6 is set by an ECU 2, referred to hereinafter, and a valve-opening time period of the injector 6 is controlled by a drive signal from the ECU 2 such that the set fuel injection amount QINJ can be obtained.

[0049] The engine 3 has a crank angle sensor 10. The crank angle sensor 10 delivers a CRK signal, which is a pulse signal, to the ECU 2 in accordance with rotation of a crankshaft 3c. The CRK signal is delivered whenever the crankshaft rotates through a predetermined angle (e.g. 30 °). The ECU 2 calculates the rotational speed NE of the engine 3 (hereinafter referred to as "the engine speed NE") based on the CRK signal.

[0050] Further, the intake pipe 4 has an air flow sensor 11 inserted therein, which detects the amount (intake air amount) GAIR of intake air sucked into the engine 3, and delivers a signal indicative of the sensed intake air amount GAIR to the ECU 2.

[0051] A catalyst 7 is disposed in the exhaust pipe 5. The catalyst 7 is formed e.g. by a NOx catalyst, and if exhaust gases flowing through the exhaust pipe 5 form an oxidation atmosphere in which the oxygen concentration is high, the catalyst 7 traps NOx in the exhaust gases. On the other hand, if exhaust gases contain lots of HC and CO and form a reduction atmosphere in which the oxygen concentration is low, the catalyst 7 reduces exhaust emissions by reducing the trapped NOx with reducing agent (unburned fuel). The catalyst 7 has a catalyst temperature sensor 14 which detects temperature thereof (hereinafter referred to as "the catalyst temperature") TCAT, and delivers a signal indicative of the sensed catalyst temperature TCAT to the ECU 2.

[0052] An upstream LAF sensor 12 and a downstream LAF sensor 13 are provided in the exhaust pipe 5 at respective locations upstream and downstream of the catalyst 7. The upstream LAF sensor 12, which is comprised of zirconia, linearly detects oxygen concentration in exhaust gases on the upstream side of the catalyst 7 over a wide range from a rich region to a lean region of the air-fuel ratio of a mixture supplied to the engine 3, and delivers a signal indicative of the sensed upstream oxygen concentration to the ECU 2. The downstream LAF sensor 13, which is comprised of zirconia, similarly to the upstream LAF sensor 12, linearly detects oxygen concentration in exhaust gases on the downstream side of the catalyst 7 over a wide range from the rich region to the lean region of the air-fuel ratio of the mixture supplied to the engine 3, and delivers a signal indicative of the sensed downstream oxygen concentration to the ECU 2.

[0053] Further, an accelerator pedal opening sensor 15 detects the stepped-on amount of an accelerator pedal, not shown, (hereinafter referred to as the "accelerator pedal opening") AP, and delivers a signal indicative of the sensed accelerator pedal opening AP to the ECU 2, and an ignition switch 16 delivers a signal indicative of an on/off state of an ignition key, not shown, to the ECU 2, respectively.

[0054] The ECU 2 is implemented by a microcomputer comprised of a CPU, a RAM, a ROM, and an I/O interface (none of which is shown). The ECU 2 determines operating conditions of the engine 3 according to the detection signals from the aforementioned sensors 10 to 15 and carries out various control processes, such as the control of the fuel injection amount according to the determined operating conditions of the engine. Particularly, the ECU 2 carries out an ordinary poisoning recovery control (second sulfur elimination control) for eliminating SOx (sulfur content) accumulated in the catalyst 7, and the deterioration determination process for the catalyst 7, as described hereinafter.

[0055] It should be noted that in the present embodiment, the ECU 2 corresponds to deterioration-determining means, first sulfur elimination control-executing means, deterioration determination-executing means, high sulfur-determining means, deterioration determination-inhibiting means, fuel consumption-calculating means, fuel consumption-determining means, deterioration determination-restarting means, refueling determining means, second sulfur elimination control-executing means, second sulfur elimination control period-setting means, reduction control means, and reduction control

period-setting means in the present invention.

[0056] FIG. 2 is a flowchart of an ordinary poisoning recovery control process. The present process is executed at predetermined time intervals. In the present process, first, in a step 1 (shown as S1 in abbreviated form in FIG. 2; the following steps are also shown in abbreviated form), an SOx accumulation amount S_QSOx is calculated. This SOx accumulation amount S_QSOx corresponds to an SOx which is accumulated in the catalyst 7, and is calculated in the following manner: First, the amount of SOx exhausted from the engine 3 during the current processing cycle is calculated by searching a predetermined map, not shown, according to the engine speed NE and a demanded torque PMCMD. Then, by adding the calculated SOx amount to the immediately preceding value of the SOx accumulation amount S_QSOx, the current value of the SOx accumulation amount S_QSOx is calculated. It should be noted that the demanded torque PMCMD is calculated by searching a predetermined map, not shown, according to the engine speed NE and the accelerator pedal opening AP.

[0057] Next, it is determined whether or not a high-sulfur fuel flag F_SH is equal to 1 (step 2). The high-sulfur fuel flag F_SH is, as described hereinafter, set to 1, when it is determined that the fuel in use is high-sulfur fuel which contains lot of sulfur content.

[0058] If the answer to this question is negative (NO), i.e. if the fuel is not high-sulfur fuel, but ordinary fuel, a threshold QSREF is set to a predetermined value QSS for ordinary fuel (step 3).

[0059] On the other hand, if the answer to the question of the step 2 is affirmative (YES), i.e. if the fuel is high-sulfur fuel, the threshold QSREF is set to a predetermined value QSH for high-sulfur fuel (step 4). The predetermined value QSH for high-sulfur fuel is set to a smaller value than the predetermined value QSS for ordinary fuel.

[0060] In a step 5 following the step 3 or 4, it is determined whether or not the SOx accumulation amount S_QSOx is not less than the threshold QSREF. If the answer to this question is negative (NO), the SOx amount accumulated in the catalyst 7 is small, so that the catalyst 7 is not poisoned, and hence the ordinary poisoning recovery control for eliminating SOx is not executed, and to indicate this fact, an ordinary poisoning recovering flag F_SPUR is set to 0 (step 6), followed by terminating the present process.

[0061] On the other hand, if the answer to the question of the step 5 is affirmative (YES), the catalyst 7 is poisoned, and hence it is judged that the ordinary poisoning recovery control for eliminating SOx should be executed, and to indicate this fact, the ordinary poisoning recovering flag F_SPUR is set to 1 (step 7), followed by terminating the present process. It should be noted that the ordinary poisoning recovery control is carried out by controlling the catalyst temperature TCAT to a target temperature which is not lower than a predetermined temperature, and then controlling the air-fuel ratio to a target air-fuel ratio which is richer than the stoichiometric air-fuel ratio by increasing the amount of fuel injected into the combustion chamber 3b, to thereby switch the exhaust gases from the oxidation atmosphere to the reduction atmosphere. By carrying out the ordinary poisoning recovery control, the SOx accumulated in the catalyst 7 is reduced, and hence the sulfur content is eliminated. Further, the ordinary poisoning recovery control is executed for a predetermined time period, and when the ordinary poisoning recovery control is terminated, the ordinary poisoning recovering flag F_SPUR is reset to 0, and the SOx accumulation amount S_QSOx is reset to 0.

[0062] FIG. 3 is a flowchart of a deterioration determination process for the above-mentioned catalyst 7 according to the first embodiment of the present invention. The present process is executed at predetermined time intervals (e.g. of 10 msec). In the present process, first, in a step 11, it is determined whether or not a determination-use poisoning recovering flag F_SPURL has changed from 1 to 0 between the immediately preceding execution of this step and the present execution of the same. As described hereinafter, the determination-use poisoning recovering flag F_SPURL is set to 1 during execution of a determination-use poisoning recovery control (first sulfur elimination control). Further, the determination-use poisoning recovery control is executed separately from the ordinary poisoning recovery control, for eliminating SOx accumulated in the catalyst 7, in association with the deterioration determination for the catalyst 7. If the answer to this question is affirmative (YES), which means that the determination-use poisoning recovering flag F_SPURL has changed from 1 to 0, i.e. if it is immediately after the determination-use poisoning recovery control is terminated, both of a fuel consumption S_QIN, referred to hereinafter, and the high-sulfur fuel flag F_SH are set to 0 (step 25), followed by terminating the present process.

[0063] On the other hand, if the answer to the question of the step 11 is negative (NO), i.e. if it is not immediately after the determination-use poisoning recovery control is terminated, it is determined whether or not the high-sulfur fuel flag F_SH is equal to 1 (step 12). If the answer to this question is negative (NO), which means that the fuel is not high-sulfur fuel, but ordinary fuel, it is determined whether or not a rich spike flag F_RICH is equal to 1 (step 13).

[0064] This rich spike flag F_RICH is set to 1 during the execution of a rich spike, referred to hereinafter. FIG. 4 is a flowchart of a rich spike control process. In the present process, first, in a step 31, a NOx trapping amount S_QNOx is calculated. The NOx trapping amount S_QNOx corresponds to the amount of NOx trapped by the catalyst 7, and is calculated in the following manner: First, the amount of NOx which is exhausted from the engine 3 in the current processing cycle is calculated by searching a predetermined map, not shown, according to the engine speed NE and the demanded torque PMCMD. Then, by adding the calculated NOx amount to the immediately preceding value of the NOx trapping amount S_QNOx, the current value of the NOx trapping amount S_QNOx is calculated.

[0065] Next, it is determined whether or not the high-sulfur fuel flag F_SH is equal to 1 (step 32). If the answer to this question is negative (NO), a threshold QNREF is set to a predetermined value QNS for ordinary fuel (step 33). On the other hand, if the answer to the question of the step 32 is affirmative (YES), i.e. if the fuel is high-sulfur fuel, the threshold QNREF is set to a predetermined value QNH for high-sulfur fuel (step 34). The predetermined value QNH for high-sulfur fuel is set to a smaller value than the predetermined value QNS for ordinary fuel.

[0066] In a step 35 following the step 33 or 34, it is determined whether or not the NOx trapping amount S_QNOx is not less than the threshold QNREF. If the answer to this question is negative (NO), it is judged that the NOx amount trapped by the catalyst 7 is small, and hence the rich spike for reducing the NOx is not executed, and to indicate this fact, the rich spike flag F_RICH is set to 0 (step 36), followed by terminating the present process.

[0067] On the other hand, if the answer to the question of the step 35 is affirmative (YES), which means that the NOx trapping amount S_QNOx is not less than the threshold QNREF, it is judged that the NOx trapped by the catalyst 7 is relatively large, and hence the rich spike should be executed, and to indicate this fact, the rich spike flag F_RICH is set to 1 (step 37), followed by terminating the present process. It should be noted that the rich spike is carried out by controlling the air-fuel ratio to a richer value than the stoichiometric air-fuel ratio by increasing the amount of fuel injected into the combustion chamber 3b, to thereby switch the exhaust gases from the oxidation atmosphere to the reduction atmosphere. By carrying out the rich spike, the NOx trapped by the catalyst 7 is reduced, and is released into the atmosphere in a state reduced and made harmless. Further, the rich spike is executed for a predetermined time period, and after the rich spike is terminated, the rich spike flag F_RICH is reset to 0, and the NOx trapping amount S_QNOx is reset to 0.

[0068] Referring back to FIG. 3, if the answer to the question of the step 13 is negative (NO), i.e. if the rich spike is not being executed, the present process is immediately terminated.

[0069] On the other hand, if the answer to the question of the step 13 is affirmative (YES), i.e. if the rich spike is being executed, an oxygen storage capacity OSC of the catalyst 7 is calculated (step 14). The oxygen storage capacity OSC represents a capacity of the catalyst 7 for storing oxygen, and as the deterioration of the catalyst 7 is in a more advanced state, the capacity thereof for storing oxygen becomes lowered. Therefore, the oxygen storage capacity OSC is used as a parameter indicative of deterioration of the catalyst 7. The method of calculating the oxygen storage capacity OSC is the same as that proposed by the present applicant in Japanese Laid-Open Patent application (Kokai) No. 2008-154687, and hence hereinafter, the calculating method will be briefly explained.

[0070] First, a total amount of reducing agent flowing into the catalyst 7 after the atmosphere formed by the exhaust gases is changed into the reduction atmosphere is calculated as a first reducing agent amount-integrated value sumkact1. Further, a total amount of reducing agent which slip the catalyst 7 after the atmosphere formed by the exhaust gases flowing through the catalyst 7 is changed into the reduction atmosphere is calculated as a second reducing agent amount-integrated value sumkact2. Further, a first equivalent ratio average value avekact1 is calculated based on oxygen concentration in the exhaust gases on the upstream side of the catalyst 7, which is detected by the upstream LAF sensor 12 after a first equivalent ratio KACT1 reaches a steady state. Similarly, a second equivalent ratio average value avekact2 is calculated based on oxygen concentration in the exhaust gases on the downstream side of the catalyst 7, which is detected by the downstream LAF sensor 13 after a second equivalent ratio KACT2 reaches a steady state. Then, using the first and second reducing agent amount-integrated values sumkact1 and sumkact2, and the first and second equivalent ratio average values avekact1 and avekact2, the oxygen storage capacity OSC is calculated by the following equation (1):

$$OSC = (\text{sumkact1} / \text{avekact1}) - (\text{sumkact2} / \text{avekact2})$$

• • • (1)

[0071] Next, it is determined whether or not the oxygen storage capacity OSC is larger than a predetermined reference value OSCJUD (step 15). If the answer to this question is negative (NO), it is determined whether or not the fuel consumption S_QIN is larger than a first predetermined threshold IREF1 (e.g. 10L) (step 18). The fuel consumption S_QIN represents a total amount of fuel supplied to the combustion chamber 3b after the above-mentioned determination-use poisoning recovery control is terminated, and is calculated by adding the fuel injection amount QINJ to the immediately preceding value of the fuel consumption S_QIN. If the answer to the question of the step 18 is negative (NO), the oxygen storage capacity OSC is lowered in a state in which the oxygen the fuel consumption S_QIN is small. Therefore, it is judged that this is not caused by poisoning of the catalyst 7, and it is determined that the catalyst 7 is deteriorated. To indicate this fact, a deterioration flag F_CATNG is set to 1 (step 19), followed by terminating the present process.

[0072] On the other hand, if the answer to the question of the step 18 is affirmative (YES), i.e. if the fuel consumption S_QIN is relatively large, it is tentatively determined that the catalyst 7 is deteriorated, and to indicate this fact, a tentative deterioration flag F_CATNGV is set to 1 (step 20).

[0073] Next, the determination-use poisoning recovery control is executed (step 21), followed by terminating the present process. Similarly to the ordinary poisoning recovery control, the determination-use poisoning recovery control is carried out by controlling the catalyst temperature TCAT to the above-mentioned target temperature which is higher than the predetermined temperature, and then controlling the air-fuel ratio to the above-mentioned target air-fuel ratio which is richer than the stoichiometric air-fuel ratio, to thereby switch the exhaust gases flowing into the catalyst 7 from the oxidation atmosphere to the reduction atmosphere. Further, the determination-use poisoning recovery control is executed for a predetermined time period which is longer than a time period over which the ordinary poisoning recovery control is executed. During execution of the determination-use poisoning recovery control, the determination-use poisoning recovering flag F_SPURL is held set to 1, and after termination of the determination-use poisoning recovery control, the SOx accumulation amount S_QSOx is reset to 0. By thus performing the determination-use poisoning recovery control for a longer time period, SOx, which is accumulated in the catalyst 7, is positively eliminated.

[0074] If the answer to the question of the step 15 is affirmative (YES), it is determined whether or not the tentative deterioration flag F_CATNGV is equal to 1 (step 16). If the answer to this question is negative (NO), the high oxygen storage capacity OSC is obtained without carrying out the determination-use poisoning recovery control, so that it is determined that the catalyst 7 is not deteriorated, but is normal, and to indicate this fact, the deterioration flag F_CATNG is set to 0 (step 17), followed by terminating the present process.

[0075] On the other hand, if the answer to the question of the step 16 is affirmative (YES), the lowered oxygen storage capacity OSC is recovered by execution of the determination-use poisoning recovery control, so that it is judged that lowering of the oxygen storage capacity OSC is caused by the poisoning of the catalyst 7. Therefore, it is determined that the fuel is high-sulfur fuel, and to indicate this fact, the high-sulfur fuel flag F_SH is set to 1 (step 22). Thereafter, the tentative deterioration flag F_CATNGV is reset to 0 (step 26), followed by terminating the present process.

[0076] After the above-mentioned step 22 is executed, the answer to the question of the step 12 becomes affirmative (YES), and in this case, the process proceeds to a step S23, wherein it is determined whether or not the fuel consumption S_QIN is larger than the above-mentioned first predetermined threshold IREF1. If the answer to this question is negative (NO), the step 13 et seq. are executed, followed by terminating the present process.

[0077] On the other hand, if the answer to the question of the step 23 is affirmative (YES), i.e. if $S_QIN > IREF1$, it is determined whether or not the fuel consumption S_QIN is larger than a second predetermined threshold IREF2 (e.g. 50L) which is larger than the first predetermined threshold IREF1 (step 24). If the answer to this question is negative (NO), i.e. if $IREF1 < S_QIN \leq IREF2$, the present process is immediately terminated without determining deterioration of the catalyst 7. As described above, when $IREF1 < S_QIN \leq IREF2$, the deterioration determination of the catalyst 7 is inhibited.

[0078] Further, if the answer to the question of the step 24 is affirmative (YES), i.e. if $S_QIN > IREF2$ holds, it is judged that the fuel has been supplied, and the fuel in the fuel tank has been consumed, so that the process proceeds to the step 21, wherein the determination-use poisoning recovery control is executed, followed by terminating the present process. Therefore, the high-sulfur fuel flag F_SH is reset to 0 after terminating the determination-use poisoning recovery control. Therefore, the answer to the question of the step 12 becomes negative (NO), which causes the deterioration determination of the catalyst 7 to be restarted.

[0079] It should be noted that in the above-described deterioration determination process, for example, if in a state in which the tentative deterioration flag F_CATNGV is set to 1, the ignition switch 16 is turned off, to interrupt the operation of the engine 3, the flags and the values of the fuel consumption S_QIN and the like which have been set at that time are stored in an EEPROM, and in the following operation cycle, the deterioration determination process continues to be executed using these values as initial values.

[0080] FIG. 5 shows an example of operation of the catalyst deterioration determination device 1, assuming that the catalyst 7 is normal and the fuel is high-sulfur fuel, which is performed according to the control processes described thus far. In FIG. 5, "IG" indicates the ON/OFF state of the ignition switch 16. It should be noted that in this illustrated example, the determination-use poisoning recovery control is terminated at time t1. Along with the termination of the determination-use poisoning recovery control, the fuel consumption S_QIN is reset to 0 (step 25 in FIG. 3), and the oxygen storage capacity OSC of the catalyst 7 is recovered by execution of the determination-use poisoning recovery control.

[0081] If the operation of the engine 3 proceeds from this state, the sulfur content of the high-sulfur fuel is accumulated in the catalyst 7, whereby the oxygen storage capacity OSC is gradually lowered. Further, during the operation of the engine 3, the ordinary poisoning recovery control is executed whenever the SOx accumulation amount S_QSOx reaches the threshold QSREF (step 5: YES), by the ordinary poisoning recovery control in FIG. 2. Further, by the rich spike control process in FIG. 4, the rich spike is executed whenever the NOx trapping amount S_QNOx reaches the threshold QNREF (step 35: YES), and during the execution of the rich spike, the deterioration determination of the catalyst 7 is performed based on the oxygen storage capacity OSC.

[0082] Until the oxygen storage capacity OSC becomes a value which is not more than the reference value OSCJUD (t2), the answer to the question of the step 15 in FIG. 3 becomes affirmative (YES), so that it is determined that the

catalyst 7 is normal. However if the deterioration determination of the catalyst 7 is carried out (t3) after time t2, the answer to the question of the step 15 becomes negative (NO), and the fuel consumption S_QIN is above the first predetermined threshold IREF1 at this time point, so that the answer to the question of the step 18 in FIG. 3 becomes affirmative (YES), so that the tentative deterioration flag F_CATNGV is set to 1 (step 20), and then the determination-use poisoning recovery control is executed (step 21). As described above, the determination-use poisoning recovery control is executed for a longer time period than a time period over which the ordinary poisoning recovery control is executed, whereby the lowered oxygen storage capacity OSC is fully recovered. Further, when the determination-use poisoning recovery control is terminated (t4), the fuel consumption S_QIN is reset to 0 (step 25).

[0083] Thereafter, if the deterioration determination of the catalyst 7 is carried out (t5), since the oxygen storage capacity OSC is recovered, the answer to the question of the step 15 becomes affirmative (YES), and at the same time, the tentative deterioration flag F_CATNGV has been set to 1, so that the answer to the question of the step 16 becomes affirmative (YES). As a result, it is determined that the fuel is high-sulfur fuel, so that the high-sulfur fuel flag F_SH is set to 1 (step 22), and the tentative deterioration flag F_CATNGV is reset to 0 (step 26).

[0084] If it is determined that the fuel is high-sulfur fuel as above, the answer to the question of the step 12 becomes affirmative (YES), the operation to be performed subsequently is determined according to the fuel consumption S_QIN. That is, until the fuel consumption S_QIN exceeds the first predetermined threshold IREF1 (t6), the answer to the question of the step 23 becomes negative (NO), so that the deterioration determination of the catalyst 7 is carried out in the step 13 et seq.

[0085] Further, after the fuel consumption S_QIN exceeds the first predetermined threshold IREF1 and until the fuel consumption S_QIN exceeds the second predetermined threshold IREF2 (t7), the answer to the question of the step 24 becomes negative (NO), so that the process in FIG. 3 is immediately terminated, that is, the deterioration determination of the catalyst 7 is inhibited.

[0086] Then, when the fuel consumption S_QIN exceeds the second predetermined threshold IREF2 (t7), the determination-use poisoning recovery control is executed again (step 21). The oxygen storage capacity OSC is recovered by the determination-use poisoning recovery control, and when the determination-use poisoning recovery control is terminated (t8), both of the fuel consumption S_QIN and the high-sulfur fuel flag F_SH are reset to 0 (step 25).

[0087] Thereafter, the answer to the question of the step 12 becomes negative (NO), so that the step 13 et seq. are executed, whereby the deterioration determination of the catalyst 7 is restarted.

[0088] As described above, when it is determined that the fuel is high-sulfur fuel, as shown in FIG. 5, the time period (between t6 and t8) after the fuel consumption S_QIN has exceeded the first predetermined threshold IREF1 until the determination-use poisoning recovery control is terminated is set as a time period over which the deterioration determination is inhibited. During this inhibition time period, the deterioration determination of the catalyst 7 is inhibited. Therefore, the determination-use poisoning recovery control resulting from tentative deterioration determination as a result of the deterioration determination is not carried out either. It should be noted that even during the inhibition time period, the ordinary poisoning recovery control and the rich spike are executed by the respective processes in FIGS. 2 and 4.

[0089] As described above, according to the present embodiment, when it is determined that the catalyst 7 is deteriorated, the determination-use poisoning recovery control is executed, and thereafter, when it is determined that the catalyst 7 is not deteriorated, it is determined that the fuel is high-sulfur fuel. Then, after it is determined that the fuel is high-sulfur fuel, the deterioration determination is inhibited during the inhibition time period after the fuel consumption S_QIN exceeds the first predetermined threshold IREF1 and until the determination-use poisoning recovery control is terminated, it is possible to prevent deterioration of the catalyst 7 from being erroneously determined due to poisoning, thereby making it possible to properly perform the deterioration determination. Further, since the deterioration determination is inhibited as described above, the determination-use poisoning recovery control responsive to the deterioration determination is not executed either, and hence it is possible to suppress the frequency of execution of the determination-use poisoning recovery control to the minimum, thereby making it possible to improve fuel economy.

[0090] Further, even when it is determined that the fuel is high-sulfur fuel, until the fuel consumption S_QIN reaches the first predetermined threshold IREF1, the execution of the deterioration determination of the catalyst 7 is permitted. This makes it possible to perform the deterioration determination of the catalyst 7 as much as possible, while maintaining the accuracy of the determination. Further, when the fuel consumption S_QIN exceeds the second predetermined threshold IREF2, the deterioration determination of the catalyst 7 is restarted, and therefore, it is possible to restart the deterioration determination in timing of completion of the consumption of the high-sulfur fuel, whereby it is possible to prevent the deterioration of the catalyst 7 from being erroneously determined.

[0091] Furthermore, before restarting the deterioration determination of the catalyst 7, the determination-use poisoning recovery control is executed, whereby it is possible to restart the deterioration determination in a state in which the catalyst 7 has been positively recovered from poisoning.

[0092] Further, since the determination-use poisoning recovery control is executed over a longer time period than a time period over which the ordinary poisoning recovery control is executed, it is possible to positively recover the catalyst 7 from poisoning, whereby it is possible to properly perform the subsequent deterioration determination of the catalyst 7.

[0093] Furthermore, when the fuel is high-sulfur fuel, as the threshold QSREF for determining whether or not the ordinary poisoning recovery control should be executed, the smaller predetermined value QSH is used (steps 2 to 4). Therefore, the SOx accumulation amount S_QSOx reaches the threshold QSREF earlier, and hence this shortens a repetition period at which the ordinary poisoning recovery control is executed, whereby it is possible to recover the poisoning of the catalyst 7 from poisoning in appropriate timing. This makes it possible to maintain the capability of trapping NOx by the catalyst 7, whereby it is possible to maintain exhaust emission characteristics.

[0094] Further, when the fuel is high-sulfur fuel, as the threshold QSREF for determining whether or not the rich spike should be executed, the smaller predetermined value QNH is used (steps 32 to 34). This shortens a repetition period at which the rich spike is executed, so that it is possible to execute the rich spike in appropriate timing before the catalyst 7 becomes saturated with NOx. This makes it possible to prevent the NOx from flowing through the catalyst 7 due to the saturation of the catalyst 7, whereby it is possible to maintain exhaust emission characteristics.

[0095] FIG. 6 is a flowchart of a deterioration determination process according to a second embodiment of the present invention. The second embodiment is mainly different from the first embodiment in the following point: In the first embodiment, the fuel consumption S_QIN is used as a condition for restarting the deterioration determination of the catalyst 7, while in the second embodiment, whether or not refueling is performed is used as the condition.

[0096] More specifically, in place of the step 24 in FIG. 3, a step 41 is executed in which it is determined whether or not a fuel consumption flag F_EXF is equal to 1. The fuel consumption flag F_EXF is set to 1 when it is determined in a refueling determination process, referred to hereinafter, that the fuel is consumed after refueling. If the answer to this question is negative (NO), it is judged that refueling has not been performed and the fuel in the fuel tank is not consumed, so that the present process is immediately terminated without carrying out the deterioration determination of the catalyst 7. Therefore, the deterioration determination of the catalyst 7 is inhibited.

[0097] On the other hand, if the answer to the question of the step 41 is affirmative (YES), it is judged that refueling has been performed and the fuel in the fuel tank has been consumed, so that the process proceeds to the step 21, wherein the determination-use poisoning recovery control is executed, and then, the fuel consumption flag F_EXF is set to 0 (step 42), followed by terminating the present process. As a result, the high-sulfur fuel flag F_SH is reset after the determination-use poisoning recovery control is terminated, so that the answer to the question of the step 12 becomes negative (NO), and hence the deterioration determination of the catalyst 7 is restarted.

[0098] FIG. 7 is a flowchart of the refueling determination process. The present process is executed at predetermined time intervals. In the present process, first, in a step 51, it is determined whether or not a refueling flag F_REFUEL is equal to 1. If the answer to this question is negative (NO), it is determined whether or not a timer value TM of a timer of an up-count type, not shown, is not less than a predetermined time period value TMREF (corresponding to e.g. 5 minutes) (step 52). If the answer to this question is negative (NO), an average value LVFAVE of a fuel level LEVELF is calculated (step 53), followed by terminating the present process. The fuel level LEVELF represents a fuel amount in the fuel tank, and is detected by a fuel level sensor 17 (see FIG. 1).

[0099] On the other hand, if the answer to the question of the step 52 is affirmative (YES), i.e. if $TM \geq TMREF$, it is determined whether or not the difference ($= LVFAVE - LVFAVEZ$) between the average value LVFAVE and the immediately preceding value LVFAVEZ of LVFAVE is larger than a predetermined value FREF (step 54). If the answer to this question is negative (NO), i.e. if $LVFAVE - LVFAVEZ \leq FREF$, it is judged that refueling has not been performed, so that the process directly proceeds to a step 57, referred to hereinafter. On the other hand, if the answer to the question of the step 54 is affirmative (YES), which means that there is a large change in the average value LVFAVE between the immediately preceding value and the present value, it is judged that refueling has just been performed, so that a post-refueling fuel consumption S_QINF is reset to 0 (step 55). The post-refueling fuel consumption S_QINF represents a total amount of fuel which has been supplied to the combustion chamber 3b after refueling, and is calculated as an integrated value of a post-refueling fuel injection amount QINJ indicative of the amount of fuel injection after refueling.

[0100] Next, to indicate the fact that the refueling has been performed, the refueling flag F_REFUEL is set to 1 (step 56). Then, after the average value LVFAVE is shifted to the immediately preceding value LVFAVEZ (step 57), the timer value TM is reset to 0 (step 58), followed by terminating the present process.

[0101] After the step 56 is executed, the answer to the question of the step 51 becomes affirmative (YES). In this case, it is determined whether or not the above-mentioned post-refueling fuel consumption S_QINF is larger than a predetermined value QREF (step 59). If the answer to this question is negative (NO), there is a fear that the high-sulfur fuel before refueling remains within a passage, not shown, which connects the fuel tank and the injector 6, so that the fuel consumption flag F_EXF held set to 0 (step 60), followed by terminating the present process.

[0102] On the other hand, if the answer to the question of the step 59 is affirmative (YES), i.e. if $S_QINF > QREF$, it is judged that the high-sulfur fuel remaining within the above-mentioned passage has been positively consumed, so that the fuel consumption flag F_EXF is set to 1 (step 61), and the refueling flag F_REFUEL is set to 0 (step 62), followed by terminating the present process.

[0103] As described above, according to the second embodiment, since the deterioration determination of the catalyst 7 is restarted when there is a large change in the average value LVFAVE of the fuel level LEVELF between the immediately

preceding value and the present value, it is possible to restart the deterioration determination in timing in which the high-sulfur fuel has been consumed after refueling, whereby it is possible to prevent an error in the determination. Further, after refueling, the deterioration determination of the catalyst 7 is restarted after waiting for the post-refueling fuel consumption S_QINF to exceed the predetermined amount $QREF$, and hence it is possible to restart the deterioration determination of the catalyst 7 in appropriate timing in which the high-sulfur fuel remaining in the passage and the like has been positively consumed.

[0104] FIG. 8 is an example of a variation of the refueling determination process. In the present process, first, in a step 71, it is determined whether or not the refueling flag F_REFUEL is equal to 1. If the answer to this question is negative (NO), it is determined whether or not a filler cap switch 18 (see FIG. 1) is on (step 72). The filler cap switch 18 outputs an on signal when a filler cap, not shown, for opening/closing a fuel filler is opened. If the answer to the question of the step 72 is negative (NO), the present process is immediately terminated. On the other hand, if the answer to the question of the step 72 is affirmative (YES), it is judged that the fuel filler has been opened, and refueling has been performed, so that the post-refueling fuel consumption S_QINF is reset to 0 (step 73), and the refueling flag F_REFUEL is set to 1 (step 74), followed by the process proceeding to a step 75.

[0105] Further, after the step 74 is executed, the answer to the question of the step 71 becomes affirmative (YES), and in this case, the process directly proceeds to the step 75.

[0106] In the step 75, similarly to the above-mentioned step 59 in FIG. 7, it is determined whether or not the post-refueling fuel consumption S_QINF is larger than the predetermined value $QREF$. If the answer to this question is negative (NO), the fuel consumption flag F_EXF is set to 0 (step 76), followed by terminating the present process. On the other hand, if the answer to the question of the step 75 is affirmative (YES), the fuel consumption flag F_EXF is set to 1 (step 77), and the refueling flag F_REFUEL is set to 0 (step 78), followed by terminating the present process.

[0107] As described above, according to this variation, it is determined that refueling is performed when the filler cap is opened, and the deterioration determination of the catalyst 7 is restarted in accordance with this determination. This makes it possible to prevent an error in the determination.

[0108] It should be noted that the present invention is by no means limited to the above-described embodiments, but it can be practiced in various forms. For example, although in the above-described embodiments, the catalyst 7 is the NOx catalyst, this is not limitative, but any other desired catalyst, e.g. a three-way catalyst may be employed insofar as it is a catalyst that traps NOx in exhaust gases when the oxidation atmosphere is formed by the exhaust gases, reduces the trapped NOx when the reduction atmosphere is formed by the exhaust gases, and purify the exhaust gases. Further, although in the above-described embodiments, the oxygen storage capacity OSC is employed as a parameter indicative of purification capability, this is not limitative, but any other desired parameters may be employed.

[0109] Further, although in the above-described embodiments, in the determination-use poisoning recovery control, to positively eliminate SOx accumulated in the catalyst 7, the time period over which the determination-use poisoning recovery control is performed is set to be longer than a time period over which the ordinary poisoning recovery control is executed, this is not limitative, but in place of this, any other method may be employed. For example, the target air-fuel ratio in the determination-use poisoning recovery control may be set to a richer value than that in the ordinary poisoning recovery control, whereby the degree of reduction of the exhaust gases may be increased. Alternatively, the target temperature in the determination-use poisoning recovery control may be set to a higher value than that in the ordinary poisoning recovery control, whereby the activity of the catalyst may be enhanced.

[0110] Further, although in the above-described embodiments, the rich spike is carried out by increasing the fuel amount supplied to the combustion chamber 3b, the rich spike may be carried out by directly supplying the fuel to the upstream side of the catalyst 7 of the exhaust pipe 5. Further, in this case, other reducing agent, e.g. urea may be employed in place of the fuel.

[0111] Further, although in the above-described embodiments, when the fuel is high-sulfur fuel, both of the threshold (step 23) for determining whether the deterioration determination of the catalyst 7 is permitted or inhibited and the threshold (step 18) for determining whether or not to tentatively determine that the catalyst 7 is deteriorated are set to the same first predetermined threshold $IREF1$, these thresholds may be set to different values from each other.

[0112] Furthermore, although in the above-described embodiments, the deterioration determination of the catalyst 7 is inhibited when the fuel consumption S_QIN of the fuel reaches the first predetermined threshold $IREF1$ after it is determined that the fuel is high-sulfur fuel, the deterioration determination may be immediately inhibited when it is determined that the fuel is high-sulfur fuel.

[0113] Furthermore, although in the above-described embodiment, the engine 3 as the internal combustion engine in the present invention is the diesel engine installed on a vehicle, this is not limitative, but the present invention may be applied to various engines other than the diesel engine, such as a gasoline engine, and further, to engines other than those for vehicles, including engines for ship propulsion machines, such as an outboard motor having a vertically-disposed crankshaft.

[0114] It is further understood by those skilled in the art that the foregoing are preferred embodiments of the invention, and that various changes and modifications may be made without departing from the spirit and scope thereof.

[0115] A catalyst deterioration determination device capable of determining whether or not fuel is high-sulfur fuel containing much sulfur content, and properly determining whether a catalyst is deteriorated while suppressing the frequency of execution of control for recovering the catalyst from the poisoned state to the minimum. The device determines whether or not a catalyst which purifies exhaust gases exhausted from an internal combustion engine is deteriorated based on the capacity of the catalyst for purifying exhaust gases. If it is determined that the catalyst is deteriorated, first sulfur elimination control is executed for eliminating sulfur content accumulated in the catalyst. Further, when the first sulfur elimination control is terminated, the deterioration determination of the catalyst is executed. Then, when it is determined by the deterioration determination that the catalyst is not deteriorated, it is determined that the fuel is high-sulfur fuel containing lots of sulfur content.

Claims

1. A catalyst deterioration determination device that determines deterioration of a catalyst disposed in an exhaust passage of an internal combustion engine, for purifying exhaust gases exhausted from the engine, **characterized by** comprising:

first deterioration-determining means for determining whether or not the catalyst is deteriorated based on a capacity of the catalyst for purifying exhaust gases;

first sulfur elimination control-executing means for executing first sulfur elimination control for eliminating sulfur content accumulated in the catalyst, when it is determined by said first deterioration-determining means that the catalyst is deteriorated;

second deterioration-determining means for determining whether or not the catalyst is deteriorated, when the first sulfur elimination control is terminated; and

high sulfur-determining means for determining that the fuel is high-sulfur fuel containing lots of sulfur content, when it is determined by said second deterioration-determining means that the catalyst is not deteriorated.

2. A catalyst deterioration determination device as claimed in claim 1, further **characterized by** deterioration determination-inhibiting means for inhibiting the deterioration determination of the catalyst by said first deterioration-determining means, when it is determined by said high sulfur-determining means that the fuel is high-sulfur fuel.

3. A catalyst deterioration determination device as claimed in claim 2, further **characterized by** further comprising fuel consumption-calculating means for calculating consumption of fuel, and wherein said deterioration determination-inhibiting means inhibits the deterioration determination, when the calculated fuel consumption reaches a first predetermined threshold.

4. A catalyst deterioration determination device as claimed in claim 2, **characterized by** further comprising:

fuel consumption-determining means for determining whether or not the fuel which is determined as high-sulfur fuel is consumed, and

deterioration determination-restarting means for restarting the deterioration determination of the catalyst by said first deterioration-determining means, when it is determined by said fuel consumption-determining means that the fuel is consumed during inhibition of the deterioration determination of the catalyst.

5. A catalyst deterioration determination device as claimed in claim 4, **characterized in that** said fuel consumption-determining means determines that the fuel is consumed when the fuel consumption reaches a second predetermined threshold which is larger than the first predetermined threshold.

6. A catalyst deterioration determination device as claimed in claim 4, **characterized by** further comprising refueling determining means for determining whether or not refueling is performed, and wherein said fuel consumption-determining means determines that fuel is consumed when it is determined by said refueling determining means that refueling is performed.

7. A catalyst deterioration determination device as claimed in claim 4, **characterized in that** the first sulfur elimination control is executed prior to restarting the deterioration determination of the catalyst by said deterioration determination-restarting means.

8. A catalyst deterioration determination device as claimed in claim 1, **characterized by** further comprising second

sulfur elimination control-executing means for executing second sulfur elimination control separately from the first sulfur elimination control, for eliminating sulfur content accumulated in the catalyst in accordance with progress of operation of the engine, and
 wherein a time period over which the first sulfur elimination control is executed is longer than a time period over which the second sulfur elimination control is executed.

9. A catalyst deterioration determination device as claimed in claim 1, **characterized by** further comprising second sulfur elimination control-executing means for executing second sulfur elimination control separately from the first sulfur elimination control, for eliminating sulfur content accumulated in the catalyst in accordance with progress of operation of the engine, and
 wherein said first and second sulfur elimination control-executing means control the exhaust gases flowing into the catalyst to a reduction atmosphere, and
 wherein a degree of reduction of the exhaust gases is controlled to a higher value during execution of the first sulfur elimination control, than during execution of the second sulfur elimination control.

10. A catalyst deterioration determination device as claimed in claim 1, **characterized by** further comprising second sulfur elimination control-executing means for executing second sulfur elimination control separately from the first sulfur elimination control, for eliminating sulfur content accumulated in the catalyst in accordance with progress of operation of the engine, and
 wherein temperature of the catalyst is controlled to a higher value during execution of the first sulfur elimination control, than during execution of the second sulfur elimination control.

11. A catalyst deterioration determination device as claimed in claim 8, **characterized by** further comprising second sulfur elimination control period-setting means for setting a repetition period at which the second sulfur elimination control is executed to a short time period, when it is determined by said high sulfur-determining means that the fuel is high-sulfur fuel.

12. A catalyst deterioration determination device as claimed in claim 1, **characterized in that** the catalyst is configured to trap NOx in exhaust gases under the oxidation atmosphere, and
characterized by further comprising:

reduction control means for executing reduction control for controlling exhaust gases flowing into the catalyst to the reduction atmosphere to reduce the NOx trapped by the catalyst, and
 reduction control repetition period-setting means for setting a repetition period at which the reduction control is executed to a short time period, when it is determined by said high sulfur-determining means that the fuel is high-sulfur fuel.

13. A method of determining deterioration of a catalyst disposed in an exhaust passage of an internal combustion engine, for purifying exhaust gases exhausted from the engine,
characterized by:

executing first deterioration determination for determining whether or not the catalyst is deteriorated, based on a capacity of the catalyst for purifying exhaust gases;
 executing first sulfur elimination control for eliminating sulfur content accumulated in the catalyst, when it is determined by the first deterioration determination that the catalyst is deteriorated;
 executing second deterioration determination for determining whether or not the catalyst is deteriorated, when the first sulfur elimination control is terminated; and
 determining that the fuel is high-sulfur fuel containing lots of sulfur content, when it is determined by the second deterioration determination that the catalyst is not deteriorated.

14. A method as claimed in claim 13, further **characterized by** inhibiting the first deterioration determination of the catalyst, when it is determined that the fuel is high-sulfur fuel.

15. A method as claimed in claim 13, **characterized in that** the catalyst is configured to trap NOx in exhaust gases under the oxidation atmosphere, and
 further **characterized by:**

executing reduction control for controlling exhaust gases flowing into the catalyst to the reduction atmosphere

EP 2 151 555 A1

to reduce the NO_x trapped by the catalyst, and
setting a repetition period at which the reduction control is executed to a short time period, when it is determined
that the fuel is high-sulfur fuel.

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FIG. 1

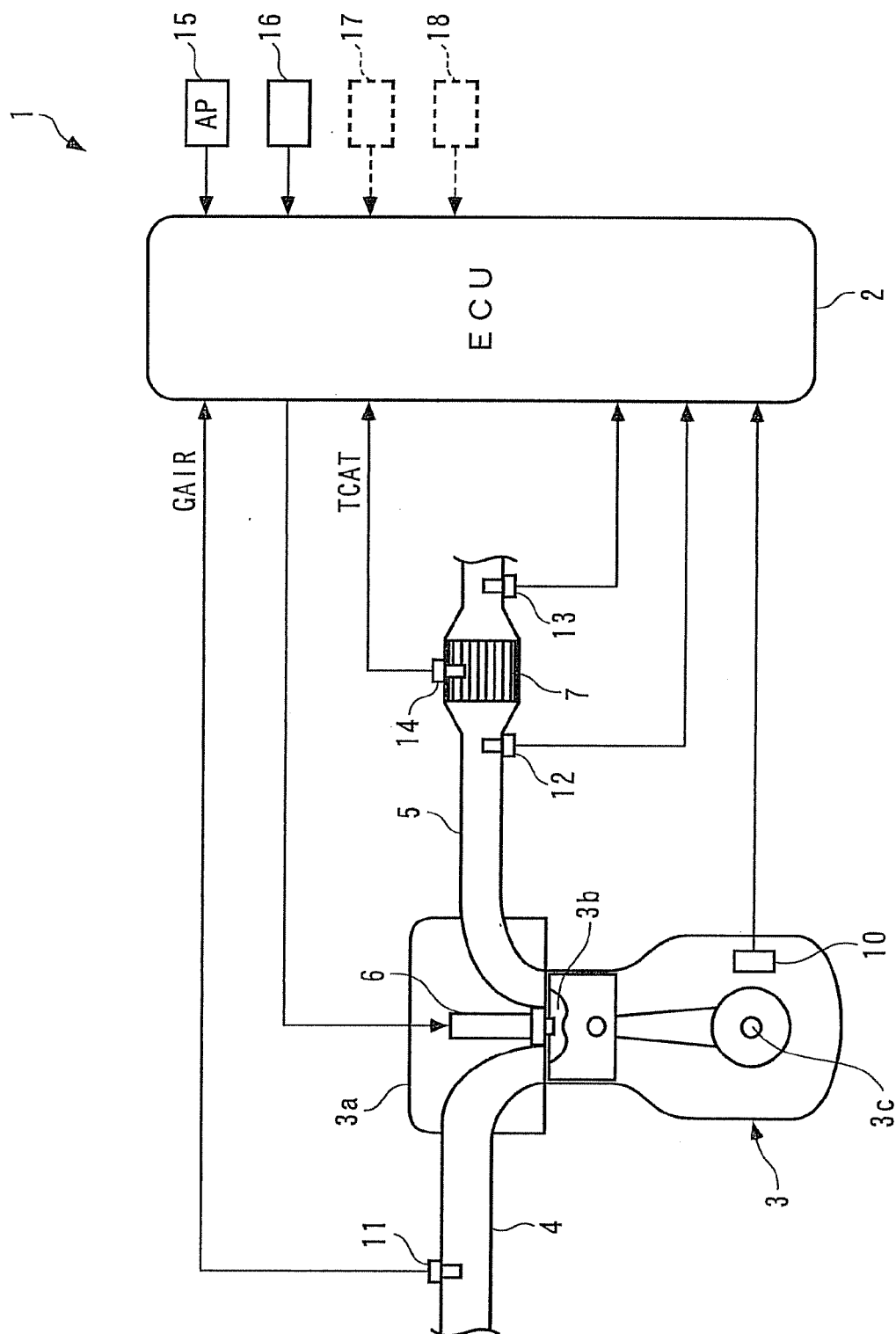


FIG. 2

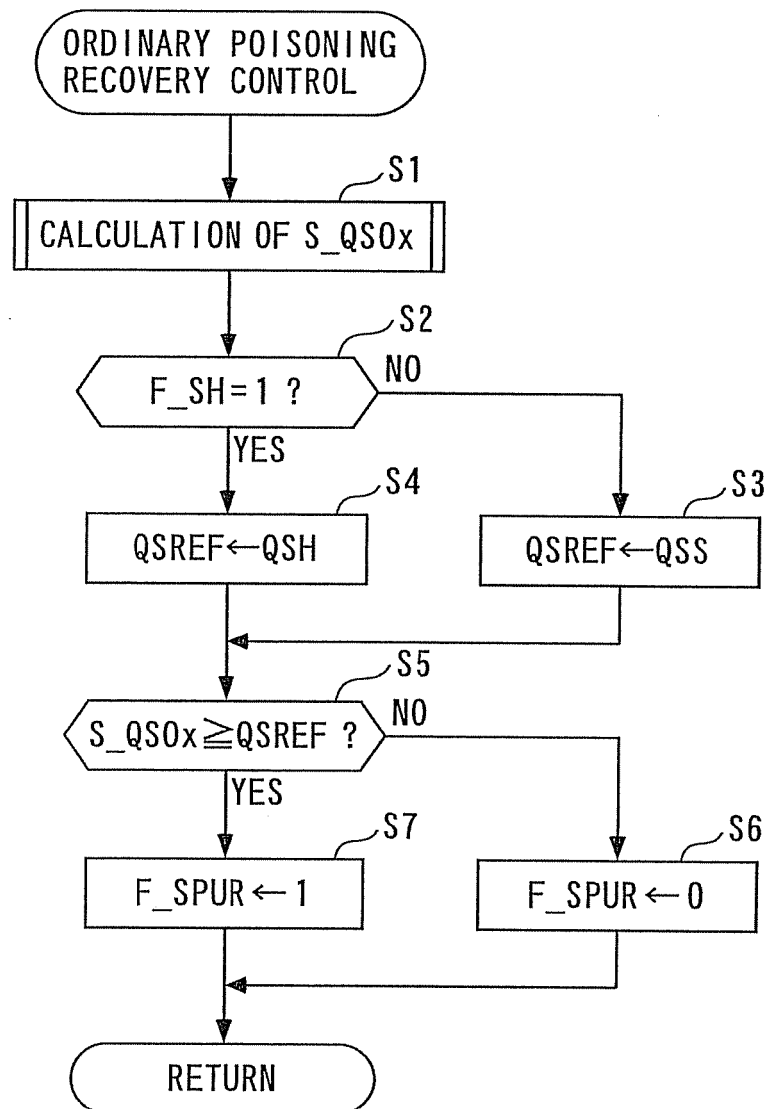


FIG. 3

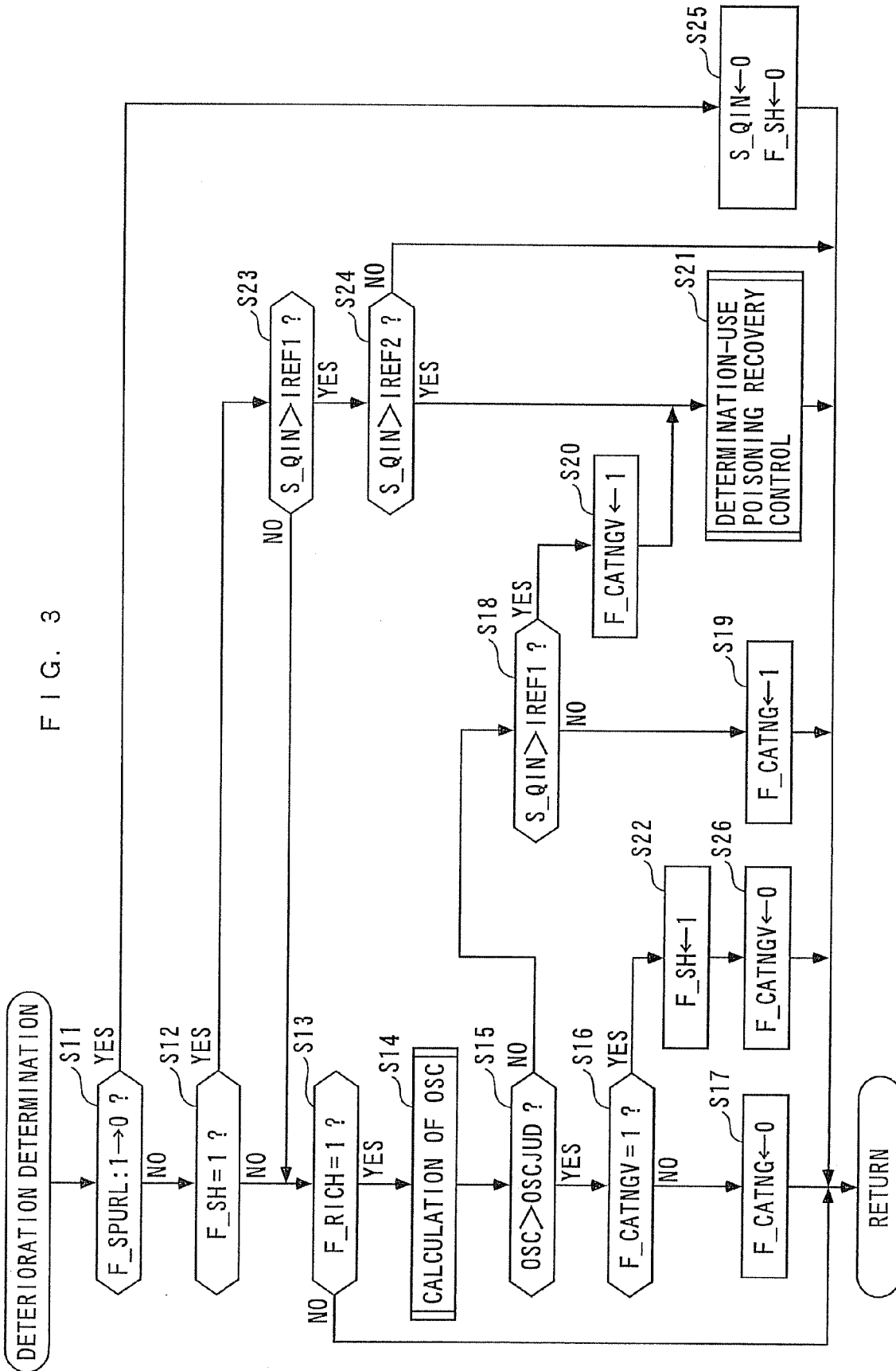


FIG. 4

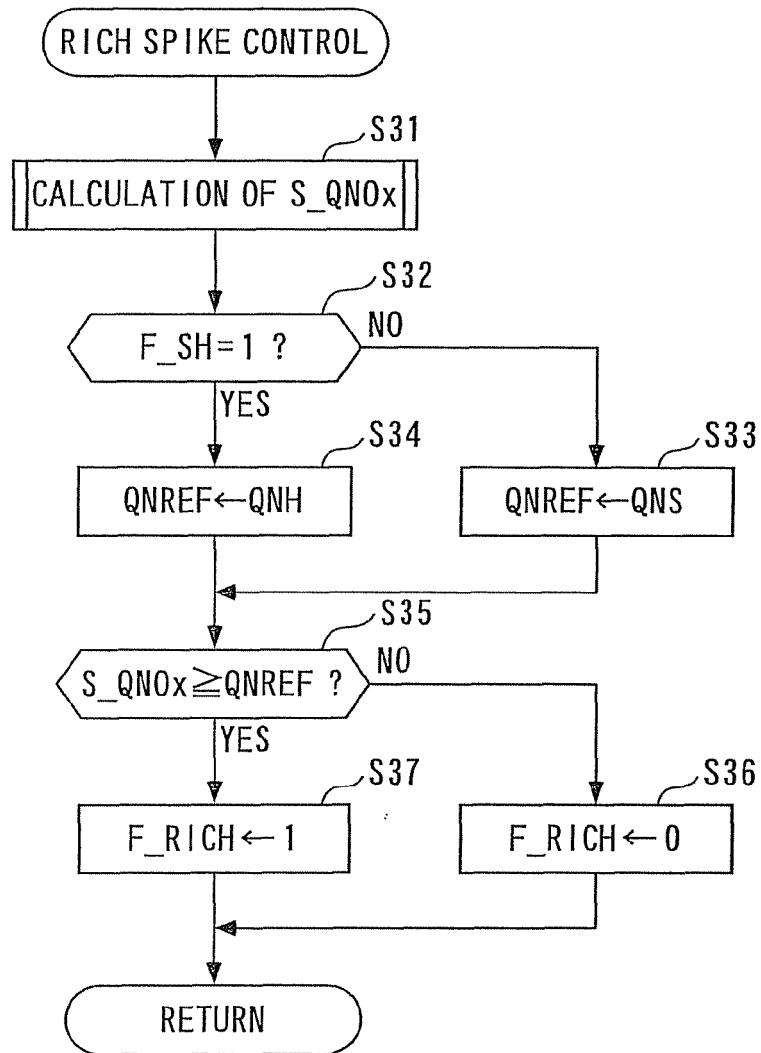


FIG. 5.

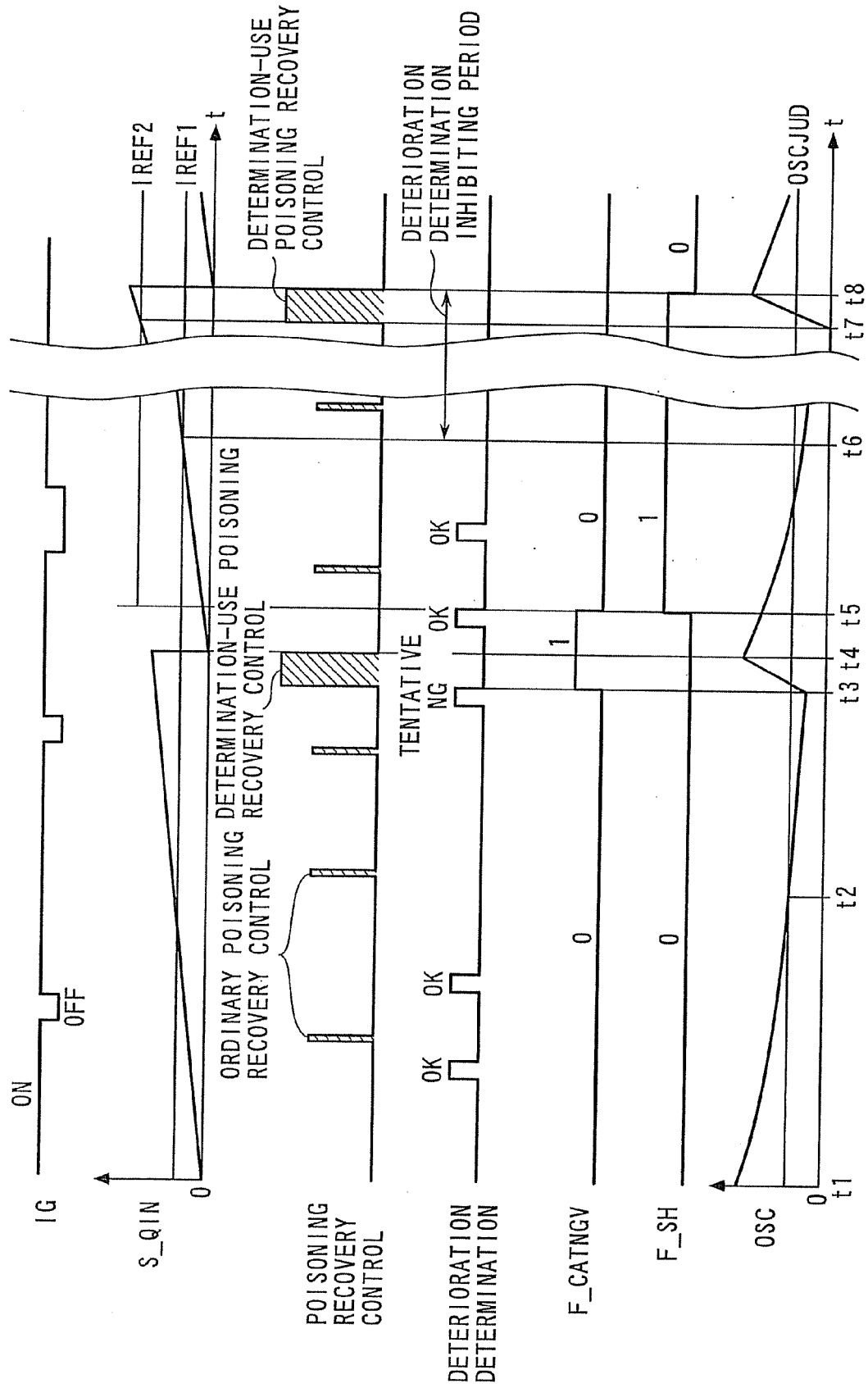


FIG. 6

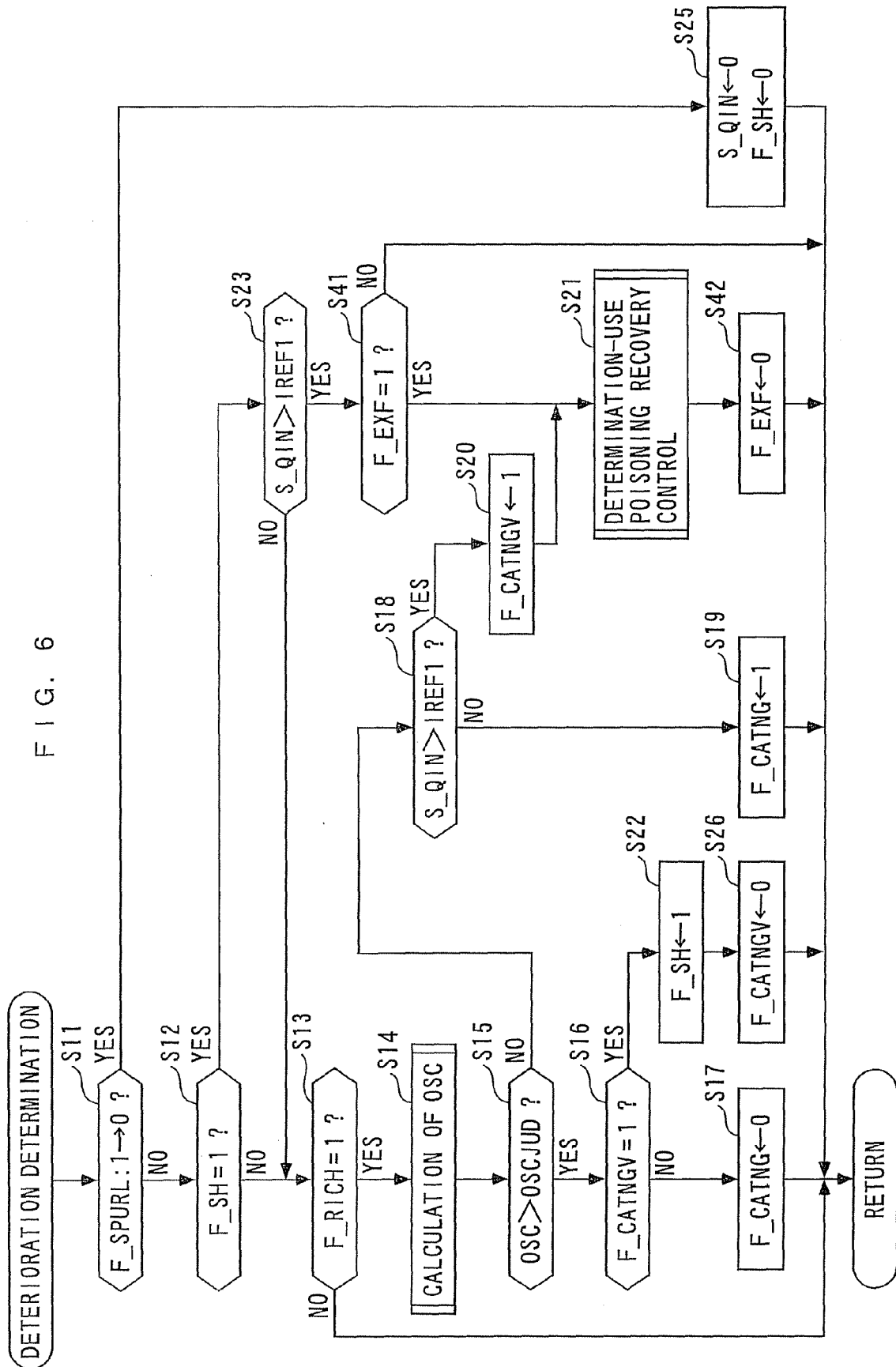


FIG. 7

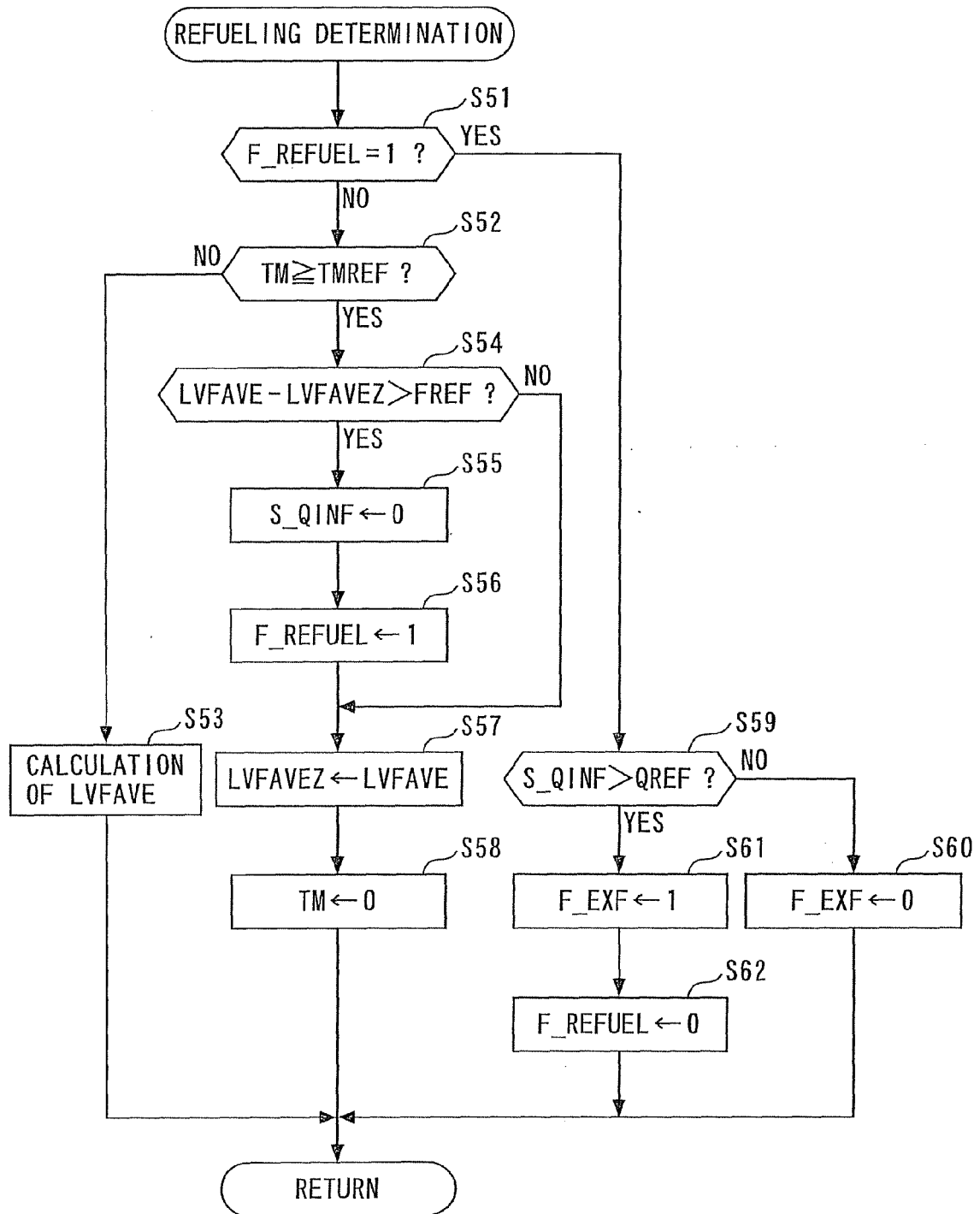
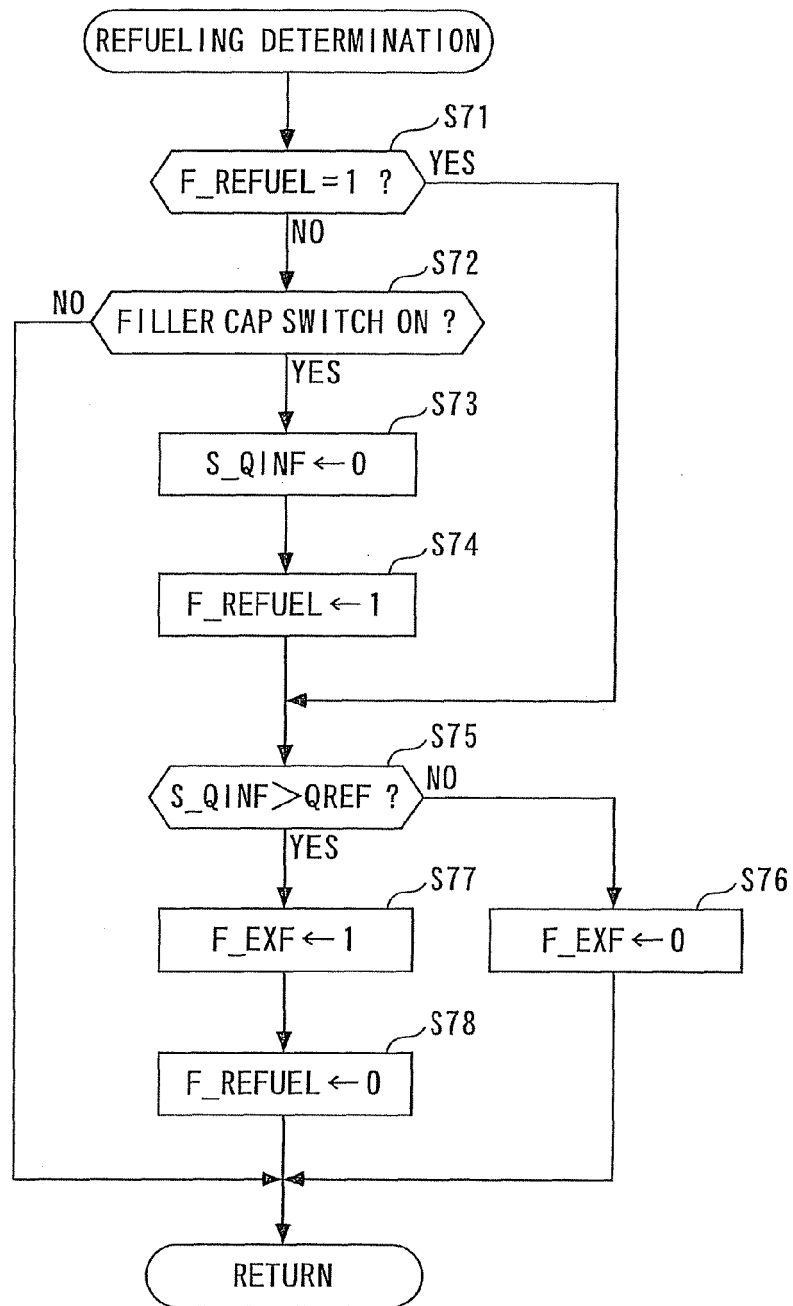


FIG. 8





EUROPEAN SEARCH REPORT

Application Number
EP 09 16 6370

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 01/49988 A (BOSCH GMBH ROBERT [DE]; SCHNAIBEL EBERHARD [DE]; SCHLESIGER OLIVER [DE]) 12 July 2001 (2001-07-12)	1-13	INV. F01N3/08
Y	* page 7, line 21 - page 11, line 30; figures *	14	
Y	DE 10 2005 060830 A1 (UMICORE AG & CO KG [DE]) 28 June 2007 (2007-06-28) * abstract *	14	
D,A	JP 2002 195089 A (DENSO CORP) 10 July 2002 (2002-07-10) * abstract *	1,13	
			TECHNICAL FIELDS SEARCHED (IPC)
			F01N F02D
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 26 August 2009	Examiner Torle, Erik
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 3
EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 09 16 6370

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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26-08-2009

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 0149988 A	12-07-2001	BR 0008627 A	18-12-2001
		CN 1341191 A	20-03-2002
		DE 19963921 A1	12-07-2001
		EP 1230471 A1	14-08-2002
		JP 2003519319 T	17-06-2003
		US 6626033 B1	30-09-2003

DE 102005060830 A1	28-06-2007	CN 101341323 A	07-01-2009
		EP 1963647 A1	03-09-2008
		WO 2007071301 A1	28-06-2007
		JP 2009520145 T	21-05-2009
		US 2008314030 A1	25-12-2008

JP 2002195089 A	10-07-2002	NONE	

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2002195089 A [0002]
- JP 2008154687 A [0069]