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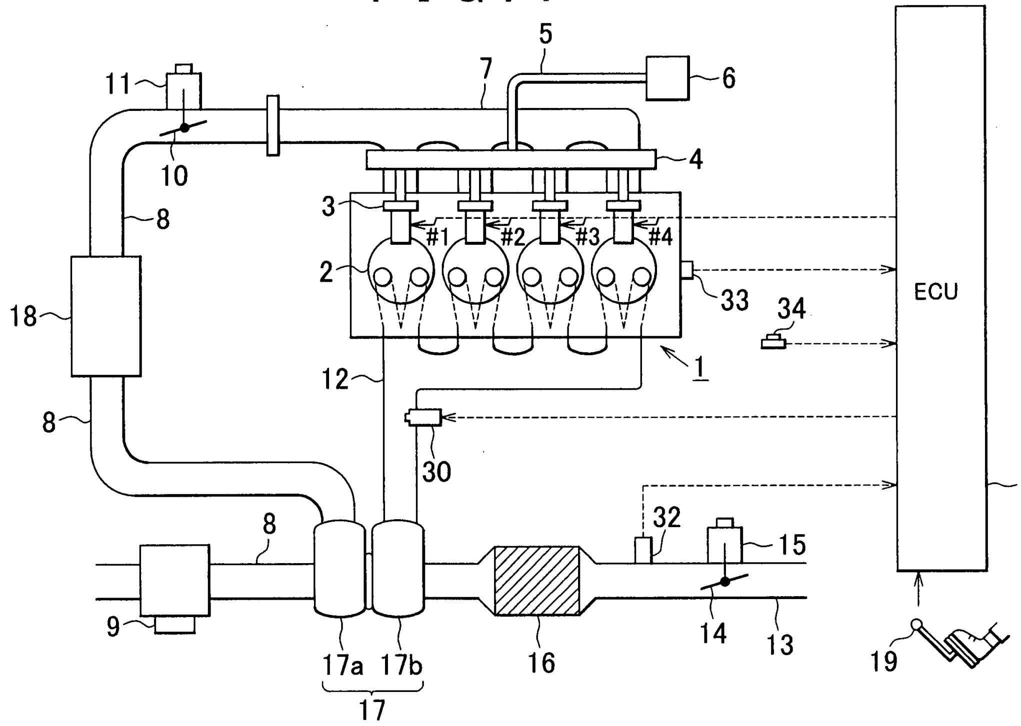
(54) Exhaust purification system of an internal combustion engine

(57) In an exhaust purification system of an internal combustion engine (1) that includes a NOx catalyst (16) for occluding and reducing NOx in exhaust, when removing SOx deposited in the NOx catalyst, a concentration of sulfur in a fuel is detected, and an amount of SOx deposited in the NOx catalyst is estimated taking into consideration the concentration of sulfur in the fuel. Further, an air-fuel ratio of exhaust flowing into the NOx catalyst (16) is changed to a richer side air-fuel ratio depending on a decrease in the estimated SOx amount, thereby adjusting an HC concentration of exhaust flowing out from the NOx catalyst (16) to a level equal to or less than a permissible HC concentration.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention relates to an exhaust purification system of an internal combustion engine.

2. Description of the Related Art

[0002] An occlusion and reduction type NOx catalyst (hereinafter simply referred to as NOx catalyst) has been developed in order to purify nitrogen oxides (NOx) in exhaust that is discharged from an internal combustion engine, more particularly, a lean-burn internal combustion engine. The NOx catalyst occludes NOx in exhaust into the catalyst when the atmosphere within range of the catalyst is in a high oxygen concentration state. In other cases such as when the atmosphere within range of the catalyst is in a low oxygen concentration state and unburned fuel constituents (hereinafter referred to as HC) that are reducing constituents exist, the catalyst purifies exhaust by reducing NOx occluded in the catalyst. The occlusion and reduction type NOx catalyst occludes and deposits sulfur oxides (SOx) in exhaust as well as NOx. However, a problem occurs in accordance with an increase in the SOx deposit amount in the NOx catalyst, whereby an exhaust purification function of the NOx catalyst deteriorates, and sufficient NOx purification is not performed. Moreover, a deterioration in an oxidation function of the NOx catalyst is another problem.

[0003] Hence, for example, an art disclosed in Japanese Patent Laid-Open Publication No. 07-217474 raises a temperature of a NOx catalyst in which a deposit amount of SOx is increased, and exposes the NOx catalyst to an atmosphere where HC exists with a constant air-fuel ratio, thereby removing SOx deposited in the NOx catalyst from the catalyst. Thus, control for recovering the exhaust purification function of the NOx catalyst (hereinafter referred to as SOx poisoning recovery control) is executed. Note that, in the SOx poisoning recovery control, in order to expose the NOx catalyst to an atmosphere where HC exists with a constant air-fuel ratio, for example, a method, is used in which an air-fuel ratio of exhaust is changed to a rich side by feeding additional fuel into an exhaust passage.

[0004] Further, in the SOx poisoning recovery control, when SOx deposited in the NOx catalyst is removed, hydrogen sulfide is generated in connection with the removal of SOx, thus leading to the problem of exhaust discharged to the outside air with an abnormal odor. As art to address this problem, for example, Japanese Patent Laid-Open Publication No. 2000-161107 discloses art that controls an operation of an internal combustion engine so as to suppress the degree of discharge of SOx based on a SOx amount deposited in the NOx catalyst, so as not to generate a large amount of SOx in a short time in the process of SOx removal.

[0005] Meanwhile, the exhaust purification function and the oxidation function of the NOx catalyst deteriorate along with the depositing of SOx. Therefore, when the deposited SOx is removed from the NOx catalyst by the poisoning recovery control, if an air-fuel ratio of the exhaust flowing into the NOx catalyst is a constant air-fuel ratio, HC that can not be covered by the oxidation function of the NOx catalyst flows into the catalyst as well as exhaust, depending on the amount of SOx deposited in the catalyst. In this situation, HC in exhaust can not be sufficiently oxidized by the NOx catalyst, thus HC is discharged to the atmosphere, and there is the possibility that white smoke will be generated. Here, it is to be understood that "occulusion" used herein means retention of a substance (solid, liquid, gas molecules) in the form of at least one of adsorption, adhesion, absorption, trapping, occlusion, and others.

SUMMARY OF THE INVENTION

[0006] In light of the foregoing situation, it is an object of the present invention to provide an exhaust purification system of an internal combustion engine that inhibits a large amount of HC from being discharged to the atmosphere, in addition to inhibiting the generation of white smoke, when SOx deposited in a NOx catalyst is removed by SOx poisoning recovery control.

[0007] To achieve the above object, according to an embodiment serving as an example of the present invention, an exhaust purification system of an internal combustion engine includes a NOx catalyst for occluding and reducing NOx in exhaust, and performs SOx poisoning recovery control for removing SOx deposited in the NOx catalyst by adjusting an air-fuel ratio of exhaust flowing into the NOx catalyst to a predetermined air-fuel ratio. The exhaust purifying system of an internal combustion engine further includes SOx deposit amount estimating means for estimating a SOx deposit amount of the NOx catalyst, detecting means for detecting a concentration of sulfur in a fuel used for the internal combustion engine, and air-fuel ratio control means for changing an air-fuel ratio of exhaust when performing the SOx poisoning recovery control to a richer side air-fuel ratio depending on a decrease in the estimated SOx deposit amount.

[0008] The NOx catalyst occludes NOx in exhaust into the catalyst in an atmosphere with a high oxygen concentration. The NOx catalyst purifies exhaust by reducing NOx occluded in the catalyst in an atmosphere with a low oxygen concentration and where unburned constituents of a fuel that are reducing constituents exist. Further, SOx in exhaust is also occluded and deposited in the NOx catalyst, and with an increase in the SOx deposit amount, an exhaust purification function and an oxidation function of the NOx catalyst deteriorate. Thus, the exhaust purification function and the oxidation function of the NOx catalyst are designed to be recovered by the SOx poisoning recovery control.

[0009] When such SOx poisoning recovery control is performed, an air-fuel ratio of exhaust flowing into the NOx catalyst is adjusted to the predetermined air-fuel ratio by adding fuel into exhaust or by adjusting an injection amount or injection timing of the fuel in a combustion chamber, or the like, whereby HC as a reducing agent is supplied to the NOx catalyst. As a result, SOx deposited in the NOx catalyst is removed. Note that the aforementioned predetermined air-fuel ratio is an air-fuel ratio of exhaust when HC required for removing SOx deposited in the NOx catalyst is supplied to the NOx catalyst.

[0010] Meanwhile, the oxidation function of the NOx catalyst varies depending on the SOx deposit amount. Accordingly, assuring that an air-fuel ratio of exhaust flowing into the NOx catalyst is a constant air-fuel ratio, since the oxidation function of the NOx catalyst deteriorates when the SOx deposit amount in the NOx catalyst is large, there is a possibility that HC in the exhaust subject to the SOx poisoning recovery control will not be oxidized by the NOx catalyst and discharged to the atmosphere.

[0011] However, according to the exhaust purification system of an internal combustion engine such as the above, during the SOx poisoning recovery control, the air-fuel ratio of the exhaust flowing into the NOx catalyst is controlled to a richer side depending on a decrease in the SOx deposit amount estimated by the SOx deposit amount estimating means so that a large amount of HC is not included in exhaust flowing out from the NOx catalyst.

[0012] For this reason, along with execution of the SOx poisoning recovery control, the SOx deposit amount of the NOx catalyst gradually decreases and the oxidation function of the NOx catalyst is also gradually recovered. Consequently, depending on a degree of the recovery, an air-fuel ratio of exhaust is changed to the rich side. In other words, when the SOx deposit amount is large and the oxidation function of the NOx catalyst is still low, that is, immediately after the SOx poisoning control is started or the like, the air-fuel ratio of exhaust flowing into the NOx catalyst is changed to a lean side air-fuel ratio. Along with the oxidation function of the NOx catalyst being gradually recovered by a decrease in the SOx deposit amount, the air-fuel ratio of exhaust flowing into the NOx catalyst is changed to a richer side air-fuel ratio. Accordingly, it is possible to supply the NOx catalyst with HC corresponding to the oxidation function of the NOx catalyst that is determined by the SOx deposit amount. As a result, it is possible to suppress a concentration of HC in exhaust flowing out from the NOx catalyst to a level that is equal to or less than a permissible HC concentration. Accordingly, it is possible to inhibit a large amount of HC from being discharged to the atmosphere, thereby inhibiting the generation of white smoke.

[0013] Moreover, the above SOx deposit amount estimating means is also suitable for application to estimation of the SOx deposit amount of the NOx catalyst, taking into consideration the concentration of sulfur in the fuel detected by the detecting means.

[0014] According to the exhaust purification system of an internal combustion engine such as the above, the concentration of sulfur in the fuel used for the internal combustion engine is detected by the detecting means, and when estimating the SOx deposit amount using the SOx deposit amount estimating means, the detected concentration of sulfur in the fuel is taken into consideration. In this case, an increase trend of the SOx deposit amount accompanied by the fuel consumption in the internal combustion engine becomes more distinct as the concentration of the sulfur in the fuel becomes higher. If the SOx deposit amount is estimated assuming that the amount of sulfur in the fuel is less than a predetermined rated value, in the case of feeding a fuel with a high sulfur concentration or the like, an estimated SOx deposit amount becomes less than an actual SOx deposit amount. Thus, in the case where the estimated SOx deposit amount is less than the actual SOx deposit amount, when an air-fuel ratio of exhaust is controlled depending on the estimated SOx deposit amount during the SOx poisoning recovery control, the air-fuel ratio becomes richer than an optimal value that corresponds to the actual SOx deposit amount. As a result, the concentration of HC in exhaust becomes high, and there is a possibility that white smoke will be generated.

[0015] However, as described above, when estimating the SOx deposit amount, the concentration of sulfur in the fuel detected by the detecting means is taken into consideration. Accordingly, for example, in the case where fuel with a sulfur concentration higher than normal is fed, the SOx deposit amount is estimated taking into consideration the concentration of sulfur in the fuel. Thus, the estimated SOx deposit amount is controlled so as not to deviate from the actual SOx deposit amount. Therefore, the air-fuel ratio during the SOx poisoning recovery control can be prevented from becoming richer than the optimal value due to this deviation, which increases the concentration of HC in exhaust, leading to the generation of white smoke.

[0016] Further, the air-fuel ratio control means is also suitable for correcting the air-fuel ratio based on the concentration of sulfur in the fuel detected by the detecting means. Furthermore, the detecting means may detect the concentration of sulfur in the fuel used for the internal combustion engine, and in the case where the concentration is high, the air-fuel ratio of the exhaust may be corrected to the lean side with respect to the case where the concentration is low.

[0017] According to the exhaust purification system of an internal combustion engine such as the above, when there is a gap between the estimated SOx deposit amount and the actual SOx deposit amount resulting from the concentration of sulfur in the fuel used for the internal combustion engine, to solve the problem, the air-fuel ratio of exhaust during the SOx poisoning recovery control is corrected depending on the concentration of sulfur in the fuel. More specifically, the detecting means detects the concentration of sulfur in the fuel used for the internal combustion engine. In the case where the concentration is high, the air-fuel ratio of the exhaust is corrected to the lean side with respect to the case where the concentration is low. By making such a correction, even if the estimated SOx deposit amount deviates from the actual SOx deposit amount, the air-fuel ratio of exhaust during the SOx poisoning recovery control is inhibited from deviating from the optimal value, thereby inhibiting the generation of the aforementioned white smoke and the like.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The above mentioned and other objects, features, advantages, technical and industrial significance of this invention will be better understood by reading the following detailed description of preferred embodiments of the invention, when considered in connection with the accompanying drawings, in which:

[FIG. 1] FIG. 1 is a schematic block diagram showing an exhaust purification system according to an embodiment of the present invention, and an internal combustion engine and a control system thereof that include the exhaust purification system.

[FIG. 2] FIG. 2 is a flow chart showing control of an air-fuel ratio of exhaust flowing into a NOx catalyst when performing SOx poisoning recovery control of the NOx catalyst in the exhaust purification system according to the embodiment of the present invention.

[FIG. 3] FIG. 3 is a graph showing a relationship between the air-fuel ratio of exhaust and a SOx deposit amount when performing the SOx poisoning recovery control.

[FIG. 4] FIG. 4 is a flow chart showing a specific procedure for estimating the SOx deposit amount.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0019] In the following description and the accompanying drawings, the present invention will be described in more detail in terms of exemplary embodiments.

[0020] FIG. 1 is a schematic block diagram showing an exhaust purification system to which the invention is applied, and an internal combustion engine 1 and a control system thereof that include the exhaust purification system.

[0021] The internal combustion engine 1 is an internal combustion engine having four cylinders 2. Further, the internal combustion engine 1 is provided with fuel injection valves 3 that directly inject fuel into combustion chambers of cylinders 2. The fuel injection valves 3 are connected to an accumulator 4 that accumulates and pressurizes fuel to a predetermined pressure. The accumulator 4 communicates with a fuel pump 6 through a fuel supply pipe 5.

[0022] Next, an intake branch pipe 7 is connected to the internal combustion engine 1, and each of sub-branch pipes of the intake branch pipe 7 communicates with the combustion chamber of each of the cylinders 2 through an intake port. Here, communication between the combustion chambers of the cylinders 2 and the intake ports is performed by opening and closing of intake valves (not shown). Further, the intake branch pipe 7 is connected to an intake pipe 8. The intake pipe 8 is mounted with an air flow meter 9 that outputs an electric signal corresponding to the mass of intake air flowing through the intake pipe 8. In a portion of the intake pipe 8 located upstream from and close to the intake branch pipe 7, an inlet throttle valve 10 is provided that adjusts a flow amount of the intake air flowing through the intake pipe 8. The inlet throttle valve 10 is provided with an actuator 11 for throttling intake air, which is structured with a step motor and the like, and actuates opening and closing of the inlet throttle valve 10.

[0023] Here, in a portion of the intake pipe 8 located between the air flow meter 9 and the inlet throttle valve 10, there is provided a compressor housing 17a of a centrifugal supercharger (turbocharger) 17 that operates using exhaust energy as a power source. Moreover, in a portion of the intake pipe 8 located downstream from the compressor housing 17a, there is provided an intercooler 18 for cooling intake air compressed in the compressor housing 17a that has reached a high temperature.

[0024] Meanwhile, an exhaust branch pipe 12 is connected to the internal combustion engine 1, and each of sub-branch pipes of the exhaust branch pipe 12 communicates with the combustion chamber of each of the cylinders 2 through an exhaust port. Here, communication between the combustion chambers of the cylinders 2 and exhaust ports are performed by opening and closing of exhaust valves (not shown). Further, the exhaust branch pipe 12 is provided with a fuel addition valve 30 that adds fuel into exhaust flowing through the exhaust branch pipe 12.

[0025] Further, the exhaust branch pipe 12 is connected to a turbine housing 17b of the centrifugal supercharger 17. The turbine housing 17b is connected to an exhaust pipe 13, and the exhaust pipe 13 is connected to a muffler (not shown) at a downstream portion thereof. Furthermore, in the midstream portion of the exhaust pipe 13, there is provided a NOx catalyst 16 that purifies exhaust by occluding and reducing NOx in exhaust discharged from the internal combustion engine. Note that instead of the NOx catalyst 16, an exhaust purification device that is a filter by which a NOx catalyst is supported, and which has a function for trapping particulate matter in exhaust may be used.

[0026] Moreover, the exhaust pipe 13 located downstream of the NOx catalyst 16 is provided with an exhaust throttle valve 14 that adjusts a flow amount of exhaust flowing through the exhaust pipe 13. The exhaust throttle valve 14 is mounted with an actuator 15 for throttling exhaust which is structured with the step motor and the like, and actuates opening and closing of the exhaust throttle valve 14.

[0027] Here, the fuel injection valve 3 and the fuel addition valve 30 open and close based on control signals from an electronic control unit (hereinafter referred to as ECU) 20. In other words, based on commands from the ECU 20, injection timing and an injection amount of fuel at the fuel injection valve 3 and the fuel addition valve 30 are controlled by the valves, respectively.

[0028] The ECU 20 is electrically connected to an accelerator opening degree sensor 19, a crank position sensor 33, and a high-sulfur-concentration fuel use switch 34.

The accelerator opening degree sensor 19 outputs a signal to the ECU 20 that corresponds to an accelerator opening degree, and the crank position sensor 33 outputs a signal to the ECU 20 that corresponds to a turning angle of an output shaft of the internal combustion engine 1. The ECU 20 receives the signal corresponding to the accelerator opening degree from the accelerator opening degree sensor 19, and based thereon, the ECU 20 calculates an engine output and the like required for the internal combustion engine 1. Further, the ECU 20 receives the signal corresponding to the turning angle of the output shaft of the internal combustion engine 1 from the crank position sensor 33, and calculates an engine rotational speed of the internal combustion engine 1, cycle condition in the cylinders 2 and the like.

[0029] The high-sulfur-concentration fuel use switch 34 is operated by a vehicle driver during fueling in accordance with the type of fuel used for the internal combustion engine 1. As fuel used for the internal combustion engine 1, a fuel with a sulfur concentration less than the predetermined rated value is commonly used. However, in the case where a fuel with a high sulfur concentration equal to or more than the predetermined value is fed for some reason, the high-sulfur-concentration fuel use switch 34 is turned on by the driver. In the case where a fuel with a sulfur concentration less than the predetermined rated value is fed, the high-sulfur-concentration fuel use switch 34 is turned off by the driver. The ECU 20 receives a signal from the high-sulfur-concentration fuel switch 34, and based thereon, the ECU 20 detects the sulfur concentration of the fuel used for the internal combustion engine 1.

[0030] Further, the ECU 20 is electrically connected to an exhaust air-fuel ratio sensor 32, which is provided in a portion downstream of the NOx catalyst 16 and detects an air-fuel ratio of exhaust flowing out from the catalyst 16. The exhaust air-fuel ratio sensor 32 transmits to the ECU 20 a voltage that corresponds to a concentration of oxygen in the exhaust, whereby the air-fuel ratio of the exhaust is detected. The exhaust purification system structured with this sensor, the NOx catalyst 16 and the like, purifies exhaust discharged from the internal combustion engine 1.

[0031] Here, the purification ability of the NOx catalyst deteriorates due to SOx occluded and deposited in the NOx catalyst 16. Accordingly, SOx poisoning recovery control for removing the SOx deposited in the NOx catalyst is performed by the ECU 20. In the SOx poisoning recovery control, the air-fuel ratio of exhaust flowing into the NOx catalyst 16 is adjusted to a predetermined air-fuel ratio, whereby a floor temperature of the NOx catalyst 16 is adjusted to a suitable temperature, and HC as a reducing agent is supplied to the NOx catalyst 16.

[0032] At this time, the ECU 20 issues an injection command to the fuel addition valve 30, and based thereon, fuel is added into exhaust by the fuel addition valve 30, whereby the air-fuel ratio of exhaust flowing into the NOx catalyst 16 is adjusted. A part of the fuel added into the exhaust by the fuel addition valve 30 iSOxidized by an oxidation function of the NOx catalyst 16, whereby the floor temperature of the NOx catalyst 16 is increased. Further, the remaining fuel is supplied to the NOx catalyst 16, whereby a reducing agent required for the SOx poisoning recovery control is supplied.

[0033] Control for the air-fuel ratio of exhaust is performed such that the air-fuel ratio of exhaust flowing into the NOx catalyst 16 is first estimated based on the air-fuel ratio detected by the exhaust air-fuel ratio sensor 32, and then, an amount of fuel added by the fuel addition valve 30 is controlled so that the estimated air-fuel ratio becomes the predetermined air-fuel ratio of exhaust. A relationship between the air-fuel ratio of the exhaust in the NOx catalyst 16 and the air-fuel ratio detected by the exhaust air-fuel ratio sensor 32 may be obtained in advance by an experiment or the like, and stored in a ROM of the ECU 20 as a map.

[0034] Here, in order to remove SOx deposited in the NOx catalyst 16 under the SOx poisoning recovery control, the air-fuel ratio of exhaust flowing into the NOx catalyst 16 is adjusted to the predetermined air-fuel ratio as described above. However, as the SOx amount deposited in the NOx catalyst 16 increases, the oxidation function of the NOx catalyst 16 deteriorates. Therefore, when the SOx amount deposited in the NOx catalyst 16 is large, for example, immediately after the SOx poisoning recovery control is started, if the air-fuel ratio of exhaust flowing into the NOx catalyst 16 is an excessively rich side air-fuel ratio, an amount of HC that should be oxidized in the NOx catalyst 16 under normal conditions is not oxidized and passes through the NOx catalyst 16. Thus, a large amount of HC is discharged to the atmosphere, which may generate white smoke.

[0035] Therefore, control that inhibits a large amount of HC from being discharged to the atmosphere during the SOx poisoning recovery control, thereby inhibiting the generation of white smoke, will be explained based on FIG.2. FIG. 2 is a flow chart showing the control for inhibiting the generation of white smoke during the SOx poisoning recovery control in the NOx catalyst 16. Note that the control is performed by the ECU 20 along with the SOx poisoning recovery control.

[0036] First, at S100, the amount of SOx deposited in the NOx catalyst 16 is estimated. More specifically, the amount of SOx deposited in the NOx catalyst 16 is estimated based on a fuel consumption amount in the internal combustion engine 1 consumed after completion of the last SOx poisoning recovery control, a driving distance of a vehicle equipped with the internal combustion engine 1 relevant to the fuel consumption amount, the sulfur concentration of the fuel for the internal combustion engine 1, or the like. When the processing at S100 is completed, the procedure proceeds to S101.

[0037] Then, at S101, it is determined whether the SOx deposit amount in the NOx catalyst 16 estimated at S100 is larger than a predetermined deposit amount. The predetermined deposit amount is a threshold value for determining that the deposited SOx should be removed, because the SOx amount deposited in the NOx catalyst 16 is large and an exhaust purification function of the NOx catalyst 16 has deteriorated. Therefore, if it is determined at S101 that the SOx deposit amount in the NOx catalyst 16 is larger than the predetermined deposit amount, processing from S103 onward is executed so as to remove the deposited SOx. On the other hand, if it is determined at S101 that the SOx deposit amount in the NOx catalyst 16 is equal to or less than the predetermined deposit amount, the processing at S100 is executed again.

[0038] At S103, based on the SOx deposit amount in the NOx catalyst 16, the air-fuel ratio of exhaust flowing into the NOx catalyst 16 is calculated such that the air-fuel ratio of exhaust flowing into the NOx catalyst 16 is suitable for removing SOx deposited in the NOx catalyst 16, and an HC concentration in exhaust passing through the NOx catalyst 16 does not exceed a predetermined HC concentration. More specifically, considering the deterioration in the oxidation function of the NOx catalyst 16 in accordance with the increase in the SOx deposit amount of the NOx catalyst 16, when the SOx deposit amount of the NOx catalyst 16 is large, the air-fuel ratio is changed to a lean side air-fuel ratio. As the removal of the SOx is facilitated, the air-fuel ratio is calculated so as to become a rich side air-fuel ratio. The relationship between the SOx deposit amount and the air-fuel ratio of the exhaust flowing into the NOx catalyst 16 is obtained in advance by an experiment or the like, and stored in the ROM of the ECU 20. The predetermined HC concentration referred to here is a threshold value of the HC concentration at which it is determined that white smoke is generated in the exhaust discharged to the atmosphere. Thus, when the SOx deposited in the NOx catalyst 16 is removed, a large amount of HC is inhibited from being discharged to the atmosphere, thereby inhibiting the generation of white smoke. When the processing at S103 is completed, the procedure proceeds to S104.

[0039] At S104, the fuel addition valve 30 adds fuel to exhaust discharged from the internal combustion engine 1, whereby the air-fuel ratio of exhaust flowing into the NOx catalyst 16 is controlled. More specifically, an amount of fuel added by the fuel addition valve 30 is controlled based on a value detected by the exhaust air-fuel ratio sensor 32 or the like, so that the air-fuel ratio of exhaust flowing into the NOx catalyst 16 is adjusted to the air-fuel ratio of exhaust calculated at S103. When the processing at S104 is completed, the procedure proceeds to S105.

[0040] At S105, an amount of SOx deposited in the NOx catalyst 16 is estimated. This is the SOx deposit amount for which an amount of SOx removed from the NOx catalyst 16 by the fuel addition at S104 is taken into consideration. Accordingly, from now on, for control based on the SOx deposit amount of the NOx catalyst 16, such as the air-fuel ratio control of exhaust, the SOx deposit amount of the NOx catalyst 16 estimated at S105 is utilized. When the processing at S105 is completed, the procedure proceeds to S106.

[0041] At S106, it is determined whether the SOx amount deposited in the NOx catalyst 16 is equal to or less than a permissible deposit amount. Here, the permissible deposit amount is a threshold value for determining that the exhaust purification function of the NOx catalyst 16 has been recovered based on the fact that the SOx amount deposited in the NOx catalyst 16 has decreased. Accordingly, when it is determined at S106 that the SOx amount deposited in the NOx catalyst 16 is equal to or less than the permissible deposit amount, it is determined that the deposited SOx of the NOx catalyst 16 has been removed, thus completing the control. On the other hand, when it is determined at S106 that the SOx amount deposited in the NOx catalyst 16 is larger than the permissible deposit amount, it is determined that the removal of SOx deposited in the NOx catalyst 16 has not yet been completed, thus processing from S103 onward is executed until the SOx deposit amount of the NOx catalyst 16 becomes equal to or less than the permissible deposit amount.

[0042] As described above, in the SOx poisoning recovery control, the air-fuel ratio of exhaust flowing into the NOx catalyst 16 is changed from a lean side air-fuel ratio to a rich side air-fuel ratio based on the decrease in the SOx deposit amount of the NOx catalyst 16. Therefore, it is possible to supress the concentration of HC in exhaust discharged to the atmosphere after passing through the NOx catalyst 16 to a level that is equal to or less than the predetermined concentration. Accordingly a large amount of HC is inhibited from being discharged to the atmosphere, and it is possible to inhibit the generation of white smoke.

[0043] Meanwhile, an actual SOx deposit amount of the NOx catalyst 16 is affected by the sulfur concentration of the fuel used for the internal combustion engine

1. As the sulfur concentration becomes higher, an increase trend of the SOx deposit amount becomes more distinct. Note that as fuel used for the internal combustion engine 1, a fuel with a sulfur concentration less than the predetermined rated value is commonly used. Accordingly, in the processing at S100 and S105 in the flow chart of the SOx poisoning recovery control shown in FIG. 2, the SOx deposit amount can be estimated, assuming that the sulfur concentration of the fuel is less than the predetermined rated value. In the SOx poisoning recovery control, the air-fuel ratio of exhaust is controlled to an optimal value corresponding to the estimated SOx deposit amount. Note that the optimal value for the air-fuel ratio of exhaust during the SOx poisoning recovery control is changed to the rich side as the SOx deposit amount decreases, as shown in FIG. 3.

[0044] Accordingly, if A1 is a value of the estimated SOx amount when assuming that the sulfur concentration of fuel is less than the predetermined rated value, an air-fuel ratio B1 of exhaust suitable for the SOx deposit amount A1 is calculated in the SOx poisoning recovery control. An amount of fuel added by the fuel addition valve 30 is then controlled so as to obtain the air-fuel ratio B1. However, in the case where a fuel with a sulfur concentration higher than the predetermined rated value is fed as a fuel for an internal combustion engine for some reason, the value of the actual SOx deposit amount becomes A2, which is larger than A1, if the SOx deposit amount is estimated as described above. This is because the actual SOx deposit amount is increased by an amount corresponding to the use of a fuel with a sulfur concentration higher than the rated value, while the estimated SOx deposit amount A1 is estimated assuming that the sulfur concentration of the fuel is less than the rated value.

[0045] Under such a situation, a value B2 is the air-fuel ratio of fuel suitable for performing the SOx poisoning recovery control, which corresponds to the actual SOx deposit amount A2. However, since the estimated SOx deposit amount A1 is smaller than the actual SOx deposit amount A2, the air-fuel ratio of exhaust is controlled to the value B1 that corresponds to the estimated SOx deposit amount A1. Accordingly, the air-fuel ratio of exhaust (here, B1) becomes richer than the optimal value (B2) that corresponds to the actual SOx deposit amount, and consequently the concentration of HC in exhaust becomes high, possibly leading to the generation of white smoke. In order to solve such a problem, a SOx deposit amount estimating routine as shown in FIG. 4 is executed as processing for estimating the SOx deposit amount at S100 and S105 in the flow chart of FIG. 2. The SOx deposit amount estimating routine is executed through the ECU 20 every time the procedure proceeds to the aforementioned S100 and S105.

[0046] In the SOx deposit amount estimating routine, as processing at step S301, it is determined whether a fuel has a sulfur concentration higher than the rated value. Such a determination is made based on a signal from the high-sulfur-concentration fuel use switch 34 operated by the vehicle driver. In this case, when a fuel with a sulfur concentration higher than the rated value is fed, the high-sulfur-concentration fuel use switch 34 is turned on by the driver. Thus, it is determined that the sulfur concentration of the fuel is high based on the signal from the switch 34 in response to the turning-on operation. In other words, the sulfur concentration of the fuel is detected based on the signal from the switch 34. Note that regarding the detection of the sulfur concentration of a fuel, for example, it is also possible to adopt a method in which a sensor for detecting the sulfur concentration of the fuel is provided in a fuel tank of the vehicle, and the detection is performed based on a signal output from the sensor.

[0047] When a negative judgement is made at step S301, assuming that a fuel with a normal sulfur concentration, that is, a fuel with a sulfur concentration less than the rated value is used, the SOx deposit amount is estimated based on a sulfur concentration less than the rated value. When a positive judgement is made at S301, assuming that a fuel with a sulfur concentration equal to or more than the rated value is used, the SOx deposit amount is estimated based on a sulfur concentration equal to or more than the rated value. The SOx deposit amount thus estimated does not become a value excessively deviated to the rich side with respect to the actual SOx deposit amount even if a fuel with a sulfur concentration that is equal to or more than the rated value is used.

[0048] Accordingly, when the actual SOx deposit amount is, for example, A2 as shown in FIG. 3, even if a fuel with a sulfur concentration equal to or more than the rated value is used, the estimated SOx deposit amount can have the value that is the same as A2 or close thereto. Therefore, during the SOx poisoning recovery control, it does not occur that the air-fuel ratio Blof exhaust that is controlled corresponding to the estimated SOx deposit amount A1 does not excessively deviate to the rich side with respect to the optimal value B2 for the air-fuel ratio of exhaust, which corresponds to the actual SOx deposit amount A2. Thus, it is possible to inhibit the HC concentration in exhaust from becoming high as a result of the deviation, thereby inhibiting the generation of white smoke.

[0049] Note that the above embodiment may be modified, for example, in the following manner.

Instead of estimating the SOx deposit amount taking into consideration the detected sulfur concentration of a fuel, the air-fuel ratio of exhaust may be corrected during the SOx poisoning recovery control based on the sulfur concentration. In this case, the estimation of the SOx deposit amount is performed assuming that the sulfur concentration of the fuel is less than the rated value. In the control of the air-fuel ratio of exhaust, which is performed based on the SOx deposit amount during the SOx poisoning recovery control, the air-fuel ratio is corrected depending on the sulfur concentration of the fuel.

For example, when the sulfur concentration of the fuel is higher than the rated value, the estimated SOx deposit amount becomes smaller than the actual SOx deposit amount. However, the air-fuel ratio of exhaust, which is controlled based on the estimated SOx deposit amount during the SOx poisoning recovery control, is corrected to the lean side depending on the sulfur concentration of the fuel. Accordingly, the same effect as the above embodiment can be obtained.

[0050] In the exhaust purification system of the internal combustion engine (1) that includes the NOx catalyst (16) for occluding and reducing NOx in exhaust, when removing SOx deposited in the NOx catalyst, the concentration of sulfur in the fuel is detected, and the amount of SOx deposited in the NOx catalyst is estimated taking into consideration the concentration of the sulfur in the fuel. Further, the air-fuel ratio of exhaust flowing into the NOx catalyst (16) is changed to a rich side air-fuel ratio depending on a decrease in the estimated SOx deposit amount, whereby the HC concentration of exhaust flowing out from the NOx catalyst (16) is adjusted to a level equal to or less than the permissible HC concentration.

Claims

1. An exhaust purification system of an internal combustion engine including a NOx catalyst (16) for occluding and reducing NOx in exhaust and performing SOx poisoning recovery control for removing SOx deposited in the NOx catalyst by adjusting an air-fuel ratio of exhaust flowing into the NOx catalyst (16) to a predetermined air-fuel ratio, **characterised by** comprising:

SOx deposit amount estimating means (20) for estimating a SOx deposit amount of the NOx catalyst;
detecting means (34) for detecting a concentration of sulfur in a fuel used for the internal combustion engine; and
air-fuel ratio control means (20) for changing an air-fuel ratio of exhaust when performing the SOx poisoning recovery control to a richer side air-fuel ratio depending on a decrease in the estimated SOx deposit amount.

2. The exhaust purification system of an internal combustion engine according to claim 1, **characterised in that**
the SOx deposit amount estimating means (20) estimates the SOx deposit amount of the NOx catalyst taking into consideration the concentration of sulfur in the fuel detected by the detecting means (34).

3. The exhaust purification system of an internal combustion engine according to claim 1 or 2, **characterised in that**
the air-fuel ratio control means (20) corrects the air-fuel ratio based on the concentration of sulfur in the fuel detected by the detecting means (34).

4. The exhaust purification system of an internal combustion engine according to claim 3, **characterised in that**
the concentration of sulfur in the fuel used by the internal combustion engine (1) is detected by the detecting means (34), and when the concentration is high, the air-fuel ratio of exhaust is corrected to a lean side compared to when the concentration is low.

FIG. 1

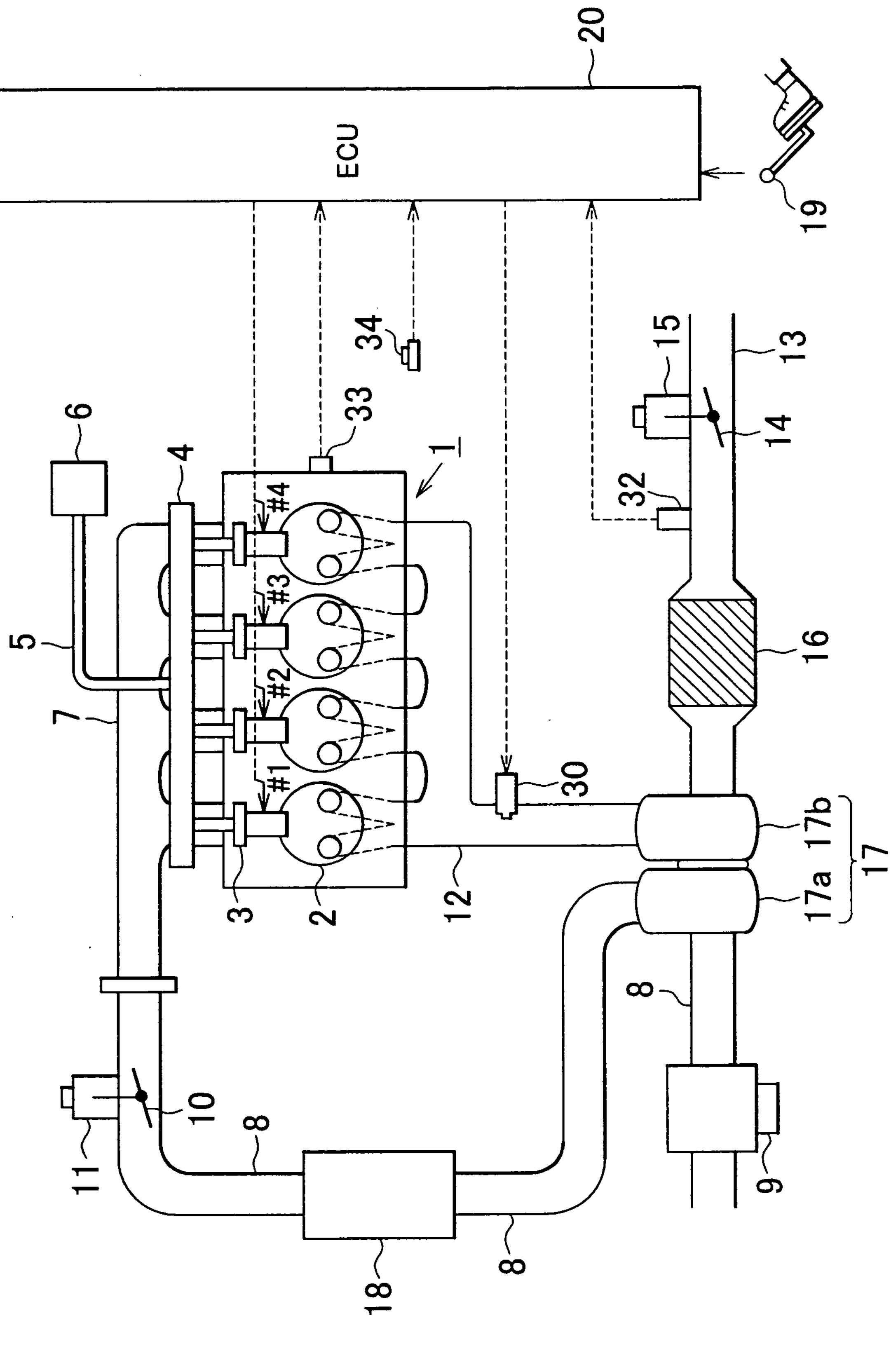

ECU
20
19
34
33
6
4
5
7
1
#1
#2
#3
#4
2
3
12
30
17a
17b
17
8
9
10
11
18
13
14
15
16
32

FIG. 2

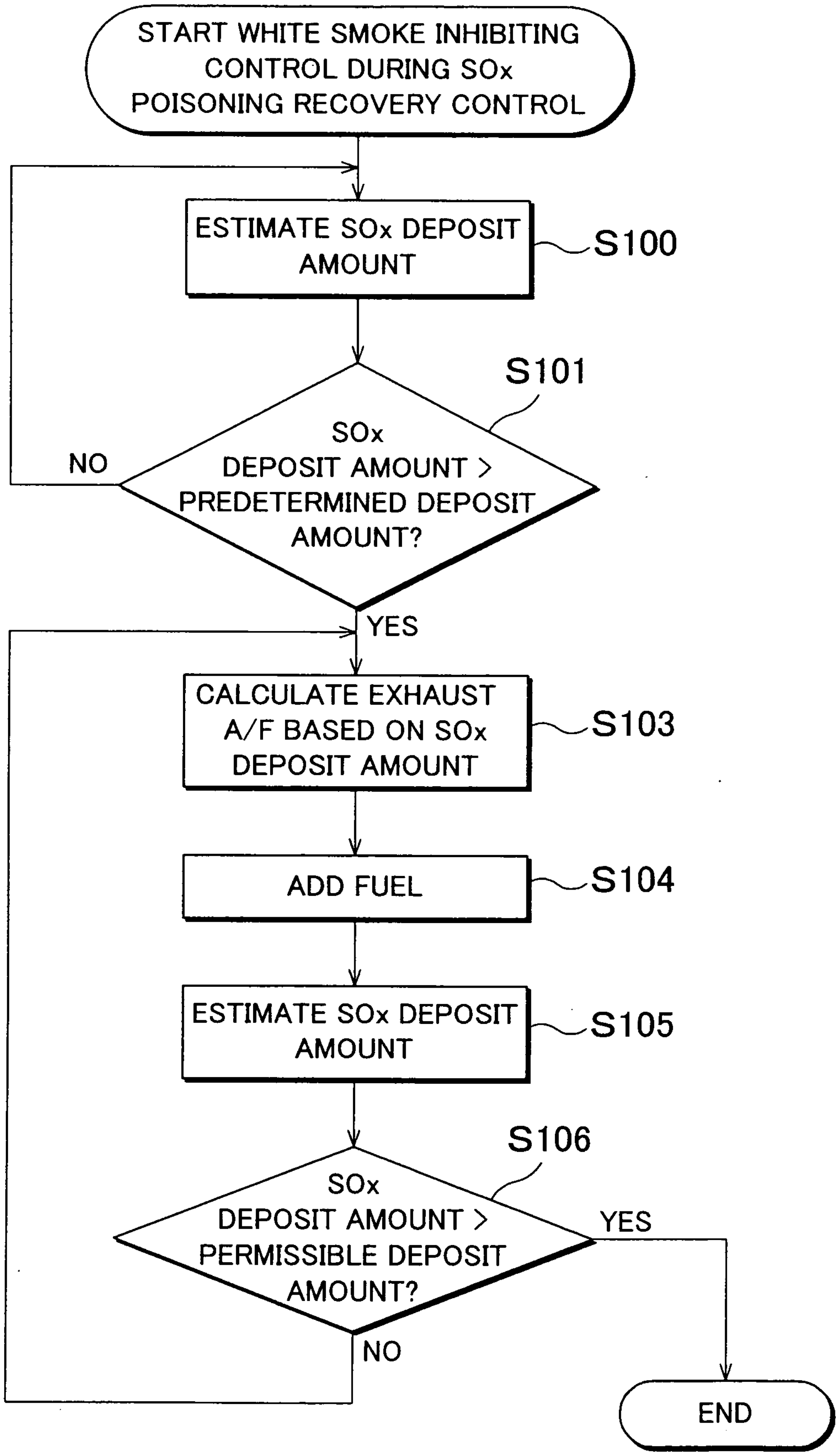

START WHITE SMOKE INHIBITING CONTROL DURING SOx POISONING RECOVERY CONTROL
ESTIMATE SOx DEPOSIT AMOUNT
S100
S101
SOx DEPOSIT AMOUNT > PREDETERMINED DEPOSIT AMOUNT?
NO
YES
CALCULATE EXHAUST A/F BASED ON SOx DEPOSIT AMOUNT
S103
ADD FUEL
S104
ESTIMATE SOx DEPOSIT AMOUNT
S105
S106
SOx DEPOSIT AMOUNT > PERMISSIBLE DEPOSIT AMOUNT?
YES
NO
END

FIG. 3

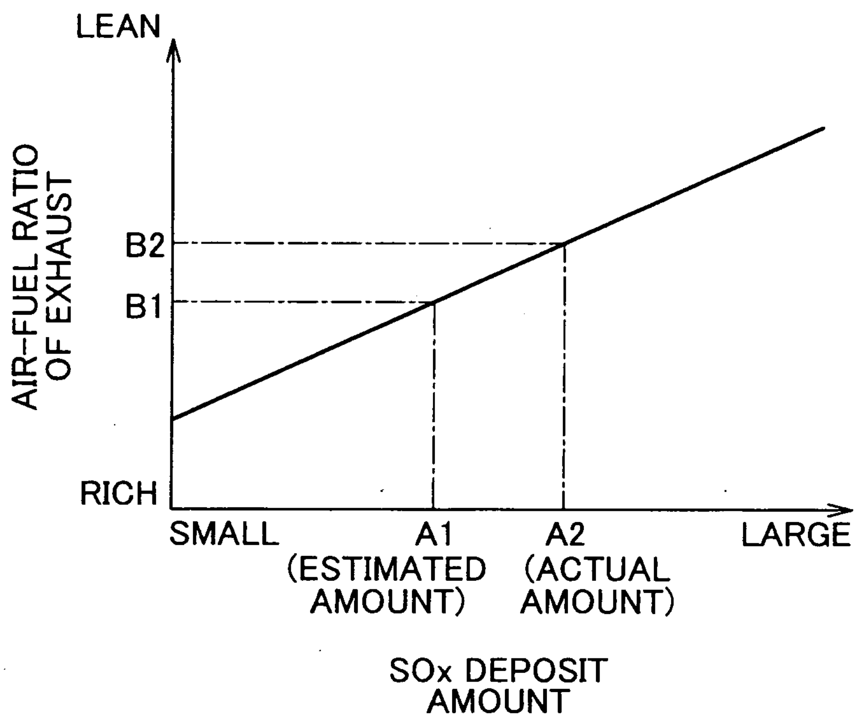
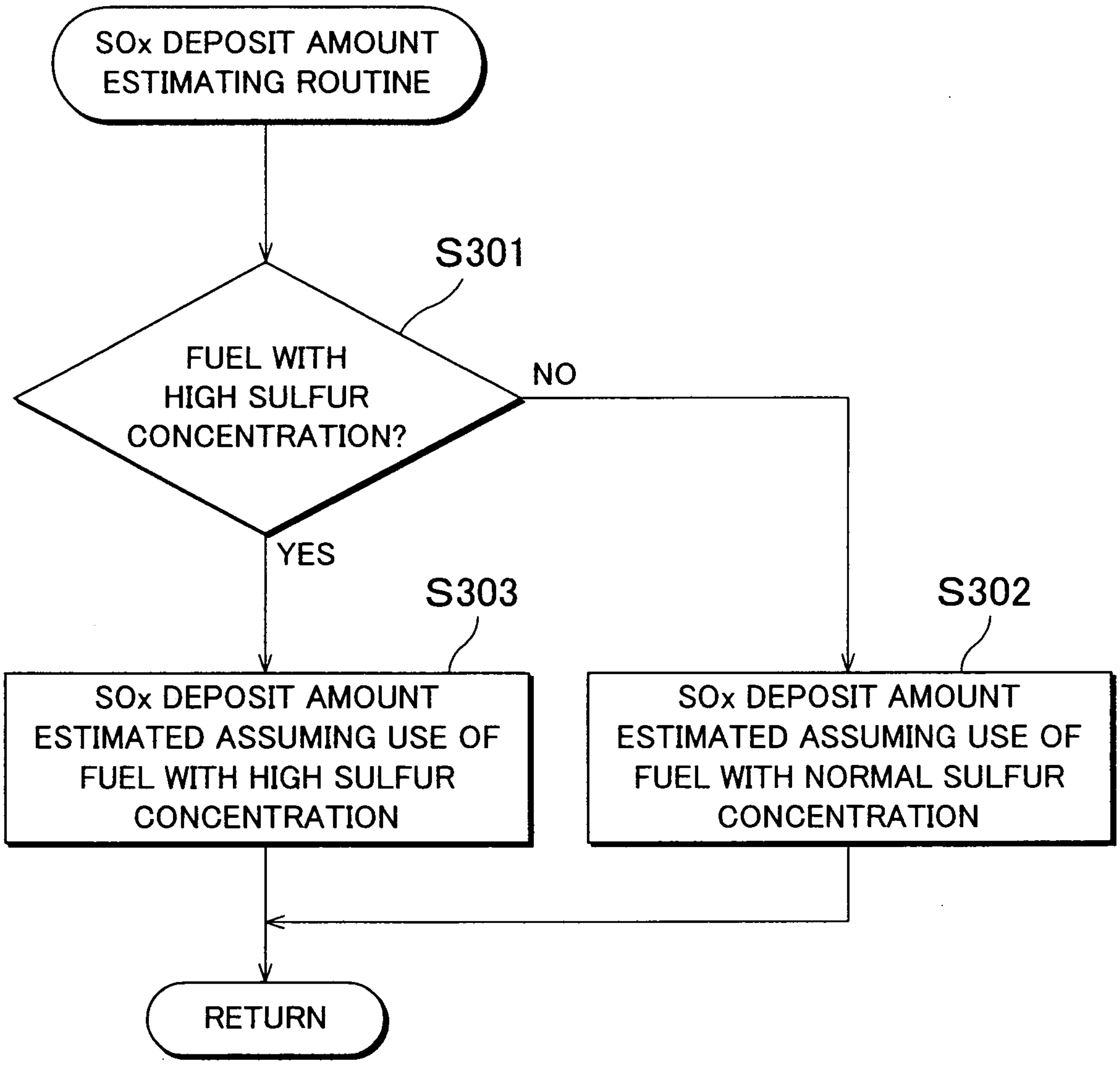

LEAN
AIR-FUEL RATIO OF EXHAUST
B2
B1
RICH
SMALL
A1 (ESTIMATED AMOUNT)
A2 (ACTUAL AMOUNT)
LARGE
SOx DEPOSIT AMOUNT

FIG. 4


SOx DEPOSIT AMOUNT ESTIMATING ROUTINE
S301
FUEL WITH HIGH SULFUR CONCENTRATION?
NO
YES
S303
S302
SOx DEPOSIT AMOUNT ESTIMATED ASSUMING USE OF FUEL WITH HIGH SULFUR CONCENTRATION
SOx DEPOSIT AMOUNT ESTIMATED ASSUMING USE OF FUEL WITH NORMAL SULFUR CONCENTRATION
RETURN