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

(11) **EP 3 070 286 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
31.05.2017 Bulletin 2017/22

(51) Int Cl.:
F01N 13/00 *(2010.01)* ***F01N 3/08*** *(2006.01)*
F01N 3/021 *(2006.01)*

(21) Application number: **16160185.1**

(22) Date of filing: **14.03.2016**

(54) ABNORMALITY DETECTION APPARATUS FOR FILTER

FEHLERERKENNUNGSVORRICHTUNG FÜR FILTER

APPAREIL DE DÉTECTION D'ANOMALIE POUR FILTRE

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

(30) Priority: **17.03.2015 JP 2015053754**

(43) Date of publication of application:
21.09.2016 Bulletin 2016/38

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Description

Technical Field

[0001] The present invention relates to an abnormality detection apparatus for a filter

Background Art

[0002] Some internal combustion engines have a filter provided in an exhaust passage to trap particulate matter (which will be sometimes referred to as PM hereinafter) in the exhaust gas and a PM sensor provided in the exhaust passage downstream of the filter to detect PM in the exhaust gas. The PM sensor outputs a signal representing the amount of PM deposited in the PM sensor if the amount of PM deposited in the PM sensor reaches or exceeds a certain amount. When the amount of deposited PM becomes too large, regeneration of the PM sensor is performed. The regeneration of the PM sensor is a process of removing PM from the PM sensor. In a known technology of PM sensor regeneration, regeneration of the PM sensor is performed by utilizing heat generated in filter regeneration and heating with a heater (see patent literature 1).

[0003] Patent literature 3 discloses a failure detection device for an exhaust gas purification filter including a PM sensor element that is provided in an exhaust channel of an internal combustion engine downstream of the exhaust gas purification filter and which is of an electrostatic dust collection type.

Citation List

Patent Literature

[0004]

PTL 1: Japanese Patent Application Laid-Open No. 2011-089430
PTL 2: WO2011/114499
PTL 3: US2011/0320171 A1

Summary of Invention

Technical Problem

[0005] The PM sensor detects the PM on the assumption that there is a correlation between the amount of PM deposited in the PM sensor and the quantity of PM in the exhaust gas. Therefore, if the amount of PM deposited in the PM sensor decreases for reasons other than the regeneration of the PM sensor or PM in the exhaust gas does not deposit in the PM sensor, the correlation between the amount of PM deposited in the PM sensor and the quantity of PM in the exhaust gas becomes low. In the case where a catalyst is provided upstream of the PM sensor, the temperature of the exhaust gas rises with reaction of HC in the catalyst. If high temperature exhaust gas reaches the PM sensor, there is a possibility that the PM deposited in the PM sensor may be oxidized. Moreover, the rise in the temperature of the exhaust gas causes the exhaust gas to expand, leading to an increase in the flow speed of the exhaust gas. This in turn leads to an increase in the quantity of PM passing through the PM sensor without depositing in it. As above, when the temperature and/or the flow speed of the exhaust gas becomes high, correlation between the amount of PM deposited in the PM sensor and the quantity of PM in the exhaust gas becomes low. Then, there is a possibility that the accuracy of the OBD (on-board diagnostics) of the filter utilizing the output value of the PM sensor may be deteriorated, or the time taken in the OBD of the filter may be prolonged.

[0006] The present invention has been made in view of the above-described problems, and an object of the present invention is to improve the diagnostic accuracy in determining an abnormality of a filter using a PM sensor.

Solution to Problem

[0007] To solve the above-described problem, there is provided an abnormality detection apparatus for a filter comprising a filter that is provided in an exhaust passage of an internal combustion engine to trap particulate matter in exhaust gas; a catalyst that is provided in the exhaust passage and removes NOx with supply of HC; an HC supply unit that supplies HC to the catalyst; a PM sensor that detects particulate matter in the exhaust gas at a location downstream of the filter and the catalyst and outputs a signal representing the particulate matter deposited in the PM sensor; a determination unit that is configured to determine whether or not the filter has an abnormality, on the basis of an output value of the PM sensor; and a control unit that is configured to cause the HC supply unit to supply HC to the catalyst, characterized in that the control unit is configured, while particulate matter is made to deposit in the PM sensor in order for the determination unit to determine whether or not the filter has an abnormality, to cause the HC supply unit to supply HC to the catalyst in such a way as to make the quantity of heat generated in the catalyst smaller when the temperature around the PM sensor is higher than a prescribed temperature than when the temperature around the PM sensor is lower than the prescribed temperature, or when the flow speed around the PM sensor is higher than a prescribed flow speed than when the flow speed around the PM sensor is lower than the prescribed flow speed, whereby preventing or reducing the rise in the temperature of the exhaust gas when the temperature around the PM sensor is higher than the prescribed temperature or when the flow speed around the PM sensor is higher than the prescribed flow speed.

[0008] When an abnormality such as cracking or chipping occurs in a filter, the quantity of PM passing through

the filter increases. Consequently, the amount of PM deposited in the PM sensor reaches a specific amount earlier. When the amount of PM deposited in the PM sensor reaches the specific amount, a signal is output from the PM sensor. Therefore, the larger the quantity of PM passing through the filter, the earlier the output value of the PM sensor starts to increase. Therefore, if the output value of the PM sensor starts to increase early, it may be determined that the filter is abnormal or faulty. However, if HC is supplied to the catalyst by the HC supply unit, and the temperature of the exhaust gas rises due to the reaction heat generated thereby to cause oxidation of PM deposited in the PM sensor, there is a possibility that the amount of PM deposited in the PM sensor may decrease. Moreover, if the flow speed of the exhaust gas increases due to the rise in the temperature of the exhaust gas, the quantity of PM that does not deposit in the PM sensor but passes through the PM sensor increases. As above, when a temperature that causes a decrease in the amount of PM deposited in the PM sensor is reached, or when a flow speed that causes an increase in the quantity of PM passing through the PM sensor is reached, the correlation between the amount of PM deposited in the PM sensor and the quantity of PM in the exhaust gas becomes low. As a countermeasure, supplying HC in such a way as to decrease the quantity of heat generated in the catalyst can prevent or reduce the rise in the temperature of the exhaust gas. Consequently, oxidation of PM deposited in the PM sensor can be prevented or reduced, and the passage of PM through the PM sensor due to an increase in the flow speed of the exhaust gas can be prevented or reduced. Therefore, the correlation between the amount of PM deposited in the PM sensor and the quantity of PM in the exhaust gas can be enhanced. Consequently, the accuracy in determining an abnormality of the filter using the PM sensor can be improved. When the temperature of the exhaust gas downstream of the catalyst becomes excessively high, the generation of heat in the catalyst may be reduced in order to prevent deterioration of parts in the exhaust system. The threshold temperature set for this is higher than the aforementioned prescribed temperature referred to during deposition of PM in the PM sensor.

[0009] The aforementioned prescribed temperature may be a temperature at which particulate matter deposited in the PM sensor is oxidized. Controlling the quantity of heat generated in the catalyst with a temperature threshold thus set enables prevention or reduction of oxidation of particulate matter deposited in the PM sensor.

[0010] The aforementioned prescribed flow speed may be a flow speed at which the ratio of the quantity of particulate matter depositing in the PM sensor to the quantity of particulate matter reaching the PM sensor becomes equal to a prescribed allowable value. This prescribed allowable value is set in such a way that the decrease in the correlation between the amount of PM deposited in the PM sensor and the quantity of PM in the exhaust gas is kept within an allowable range or that the accuracy in determining whether or not the filter is abnormal using the output value of the PM sensor is kept within an allowable range. The prescribed flow speed may be varied depending on required allowable ranges. Controlling the quantity of heat generated in the catalyst with a flow speed threshold thus set can prevent or reduce the passage of particulate matter through the PM sensor. The phrase "particulate matter reaching the PM sensor" may be considered to mean particulate matter flowing into a cover of the PM sensor, in the case where the PM sensor has a cover. Alternatively, the phrase "particulate matter reaching the PM sensor" may be considered to mean particulate matter reaching the proximity of the electrodes of the PM sensor.

[0011] A noble metal catalyst may be carried on the surface of the catalyst, a basic layer may be formed around the noble metal catalyst, the catalyst may have a property of reducing NOx in the exhaust gas with a reductive intermediate generated in the catalyst by supplying a prescribed quantity of HC periodically at a period in a prescribed range by the HC supply unit and
a property of being increased in storage quantity of NOx in the exhaust gas if the period of supply of HC by the HC supply unit is made longer than the prescribed range, and the control unit may be configured to prolong the period of supply of HC and increase the quantity of HC supplied in one supply without changing the quantity of HC supplied per unit time, when causing the HC supply unit to supply the prescribed quantity of HC periodically at a period in the predetermine range to thereby reduce NOx in the exhaust gas by the reductive intermediate generated in the catalyst in such a way as to decrease the quantity of heat generated in the catalyst.

[0012] In cases where a prescribed quantity of HC is supplied to the catalyst periodically at a period in the prescribed range to reduce NOx, the most part of HC reacts with oxygen in the catalyst. However, if the period of supply of HC is prolonged and the supply quantity in one supply is increased, the quantity of heat generated decreases due to temporary deficiency of oxygen in the catalyst. In such cases, as the quantity of HC supplied per unit time is not changed, the quantity of the reductive intermediate generated to reduce NOx does not change substantially. Consequently, NOx can be removed excellently even in such cases. Therefore, it is possible to decrease the temperature of the exhaust gas and the flow speed of the exhaust gas without decreasing the NOx removal rate. The quantity of HC supplied per unit time may be defined as the total amount of HC supplied in a prescribed time divided by the prescribed time. The control unit may be adapted to cause the HC supply unit to supply HC to the catalyst in such a way as to make the quantity of heat generated in the catalyst smaller when the temperature around the PM sensor is higher than a prescribed temperature than when the temperature around the PM sensor is lower than a prescribed temperature, or when the flow speed around the PM sensor is high than when the flow speed around the PM sen-

sor is low, when causing the HC supply unit to supply HC to the catalyst while particulate matter is made to deposit in the PM sensor in order for said determination unit to determine whether or not the filter has an abnormality, and only when causing the HC supply unit to supply a prescribed quantity of HC periodically at a period in the prescribed range to the catalyst to thereby reduce NOx in the exhaust gas with the reductive intermediate generated thereby in the catalyst. Then, the decrease of the NOx removal rate can be prevented or reduced.

Advantageous Effects of Invention

[0013] The present invention enables an improvement in the diagnostic accuracy in determining an abnormality of a filter using a PM sensor.

Brief Description of Drawings

[0014]

Fig. 1 is a diagram schematically showing the general configuration of an internal combustion engine and its air-intake and exhaust systems according to an embodiment.
Fig. 2 is a diagram showing a range in terms of the catalyst temperature and the engine rotational speed in which a first NOx removal method is employed and a range in which a second NOx removal method is employed.
Fig. 3 is a time chart showing the change of the output value of a PM sensor with time.
Fig. 4 is a time chart showing the change of the output value of the PM sensor with time in a case where a filter is abnormal.
Fig. 5 a time chart showing the change of the output value of the PM sensor with time in a case where the filter is abnormal.
Fig. 6 includes time charts in cases where the injection quantity in one injection and the period of injection are varied while the total injection quantity of a fuel addition valve per unit time is not varied.
Fig. 7 is a time chart showing the temperature of the exhaust gas and the injection quantity through the fuel addition valve in measurement of PM by the PM sensor, in a case where NOx is removed employing the first NOx removal method according to the embodiment.
Fig. 8 is a flow chart showing the control flow of an exhaust gas temperature control according to the embodiment.
Fig. 9 is a flow chart showing the control flow of a first temperature control.
Fig. 10 is a flow chart showing the control flow of a second temperature control.
Fig. 11 is a flow chart showing the control flow of a control of the exhaust gas flow speed according to the embodiment.
Fig. 12 is a flow chart showing the control flow of a first flow speed control.
Fig. 13 is a flow chart showing the control flow of a second flow speed control.
Fig. 14 is a flow chart showing the flow of controlling the temperature and the flow speed of the exhaust gas according to the embodiment.
Fig. 15 is a flow chart of another mode of the first temperature control.
Fig. 16 is a flow chart of another mode of the second temperature control.
Fig. 17 is a flow chart of another mode of the first flow speed control.
Fig. 18 is a flow chart of another mode of the second flow speed control.

Description of Embodiments

[0015] In the following, a mode for carrying out the present invention will be described based on an embodiment. The dimensions, materials, shapes, relative arrangements, and other features of the components that will be described in connection with the embodiment are not intended to limit the technical scope of the present invention only to them, unless particularly stated.

[0016] Fig. 1 is a diagram schematically showing the general configuration of an internal combustion engine and its air-intake and exhaust systems according to an embodiment. The internal combustion engine 1 of this embodiment may be either a gasoline engine or a diesel engine. The internal combustion engine 1 is connected with an exhaust passage 2. The exhaust passage 2 is provided with a fuel addition valve 3, a catalyst 4, and a filter 5, which are arranged in order from the upstream of the exhaust gas flow.

[0017] The fuel addition valve 3 injects fuel (HC) into the exhaust gas to supply HC to the catalyst 4. The filter 5 traps particulate matter (PM) in the exhaust gas. The catalyst 4 is what is called an NOx storage reduction catalyst. The catalyst 4 includes a catalyst carrier made of e.g. alumina and noble metal catalyst made of platinum Pt carried thereon. On the catalyst carrier, there is also provided a basic layer containing at least one substance selected from alkali metals such as potassium K, sodium Na, and cesium Cs, alkali earth metals such as barium Ba and calcium Ca, rare earths such as lanthanoids, and metals that can provide electrons to NOx such as silver Ag, copper Cu, iron Fe, and iridium Ir. The catalyst carrier may also carry rhodium Rh or palladium Pd in addition to platinum Pt.

[0018] A PM sensor 11 that measures the quantity of PM in the exhaust gas flowing out of the filter 5 is provided in the exhaust passage 2 downstream of the filter 5. The PM sensor 11 has a pair of electrodes and is adapted to output a signal representing the quantity of PM on the basis of the principle that the resistance between the electrodes varies depending on the amount of PM adhering (or deposited) between the electrodes. When the

amount of PM deposited between the electrodes reaches or exceeds a specific amount, an electrical current starts to flow between the electrodes and the output value of the PM sensor 11 starts to increase. Therefore, when the PM sensor 11 is in a state in which PM is not deposited in it at all, it takes some time until the output value starts to increase. Note that, the PM sensor 11 may be any sensor that outputs a signal representing the amount of PM deposited in the PM sensor 11, which may be a sensor that outputs a signal before the amount of PM deposited between the electrodes reaches or exceeds the specific amount. The signal output from the PM sensor 11 may include an electrical current or resistance. The exhaust passage 2 is also provided with a temperature sensor 12 arranged downstream of the filter 5. The temperature sensor 12 measures the temperature of the exhaust gas flowing out of the filter 5.

[0019] The internal combustion engine 1 is equipped with a fuel injection valve 6 that injects fuel directly into the cylinder. The internal combustion engine 1 is connected with an intake passage 7. The intake passage 7 is provided with an air flow meter 17, which is a sensor that measures the intake air quantity of the internal combustion engine 1.

[0020] An ECU 10 is provided for the internal combustion engine 1 having the above-described construction. The ECU 10 is an electronic control unit adapted to control the internal combustion engine 1. The ECU 10 is connected by electrical wiring with the above-mentioned sensors, an accelerator opening degree sensor 15 that outputs an electrical signal representing the amount of depression of an accelerator pedal 14 by the driver to measure the engine load, and a crank position sensor 16 that measures the engine rotational speed. The signals output from these sensors are input to the ECU 10. The ECU 10 is also connected with the fuel addition valve 3 and the fuel injection valve 6 by electrical wiring to control these components.

[0021] The ECU 10 determines the quantity of fuel to be injected through the fuel injection valve 6 on the basis of the operation state of the internal combustion engine 1. The relationship between the operation state of the internal combustion engine 1 and the fuel injection quantity is determined in advance by, for example, experiment and prepared as a map, which is stored in the ECU 10. The map is prepared in such a way as to make the air-fuel ratio in the cylinder equal to a target air-fuel ratio. The target air-fuel ratio is set in accordance with the operation state of the internal combustion engine 1. The target air-fuel ratio set in the internal combustion engine 1 according to this embodiment is a lean air-fuel ratio. However, the target air-fuel ratio may be set to a rich air-fuel ratio temporarily for removal of NOx, as will be described below.

[0022] Next, methods of removal of NOx using the catalyst 4 according to this embodiment will be described. In this embodiment, a first NOx removal method and a second NOx removal method are employed. In the first NOx removal method, NOx is reduced by a reductive intermediate that is generated by injecting a prescribed quantity of HC through the fuel addition valve 3 periodically at a period in a prescribed range and is supported on the basic layer of the catalyst 4. In the second NOx removal method, NOx is stored in the catalyst 4 when the air-fuel ratio of the exhaust gas is lean, and the air-fuel ratio of the exhaust gas flowing into the catalyst 4 is made rich periodically at a period longer than the aforementioned prescribed range so that NOx stored in the catalyst 4 is released from it. In the context of this specification, the meanings of the term "storage" (and its derivative "store") include temporal adsorption of NOx also. The first NOx removal method and the second NOx removal method are well known from, for example, WO2011/114499 and will not be described in detail. They will be described only briefly in the following.

[0023] Fig. 2 schematically shows a range in terms of the engine rotational speed and the temperature of the catalyst 4 in which the first NOx removal method is employed and a range in which the second NOx removal method is employed. With the first NOx removal method, the NOx removal rate becomes high when the temperature of the catalyst 4 is relatively high. With the second NOx removal method, the NOx removal rate becomes high when the temperature of the catalyst 4 is relatively low. Therefore, when the temperature of the catalyst 4 is relatively low, the second NOx removal method is employed to reduce NOx, and when the temperature of the catalyst 4 is relatively high, the first NOx removal method is employed to remove NOx. The relationship shown in Fig. 2 is determined in advance by experiment or simulation.

[0024] Firstly, the first NOx removal method will be described. NO (nitrogen monoxide) contained in the exhaust gas is converted into NO_2^- or NO_3 on platinum in the catalyst 4 when the air-fuel ratio is lean. NO, NO_2^-, and NO_3 have high activity. In the following, NO, NO_2^-, and NO_3 will be collectively referred to as active NOx.

[0025] As HC is injected through the fuel addition valve 3 to make the air-fuel ratio of the exhaust gas rich, HC gradually adheres to the entirety of the catalyst 4. The most part of this HC reacts with oxygen to burn, and a part of the HC is reformed in the catalyst 4 to become radical. In consequence, the HC concentration around active NOx becomes high. After active NOx is generated, if a state in which the oxygen concentration around the active NOx is high continues for a certain time or more, the active NOx is oxidized and absorbed in the basic layer as nitrate ion NO_3^-. However, if the HC concentration around the active NOx becomes high before the lapse of the aforementioned certain time, the active NOx reacts with HC radical on platinum in the catalyst 4, whereby a reductive intermediate is generated. The reductive intermediate thus generated adheres to or is adsorbed by the surface of the basic layer of the catalyst 4.

[0026] When HC adheres to the reductive intermediate thus generated, the reductive intermediate is blocked by

HC, and the reaction does not progress further. Then, the concentration of HC flowing into the catalyst 4 decreases, and then the HC adhering to the reductive intermediate is oxidized to vanish. As the oxygen concentration around the reductive intermediate becomes higher consequently, the reductive intermediate reacts with NOx or active NOx in the exhaust gas, reacts with oxygen around it, or autolyzes. Thus, the reactive intermediate is converted into N_2, CO_2, and H_2O. Thus, NOx is removed.

[0027] As above, with the catalyst 4, the reductive intermediate is generated by increasing the concentration of HC flowing into the catalyst 4. Thereafter, the concentration of HC flowing into the catalyst 4 is decreased, and when the oxygen concentration becomes high, NOx is removed. As above, to remove NOx by the first NOx removal method, it is necessary to change the concentration of HC flowing into the catalyst 4 periodically in order to generate the reductive intermediate and to cause the reaction of the reductive intermediate with NOx to occur.

[0028] In this connection, it is necessary to raise the concentration of HC to a concentration high enough to enable generation of the reductive intermediate. Moreover, it is necessary to lower the concentration of HC to a concentration low enough to enable the reaction of the reductive intermediate thus generated with NOx, active NOx, and oxygen in the exhaust gas or autolysis of the reductive intermediate. In other words, it is necessary to cause the concentration of HC flowing into the catalyst 4 to fluctuate or oscillate at an amplitude in a prescribed range.

[0029] If the period of oscillation of the HC concentration or the period of injection of HC is set longer than the aforementioned prescribed range, the period during which the oxygen concentration is high in the period from the supply of HC to the next supply of HC becomes long. Then, the reductive intermediate disappears from the surface of the basic layer, and active NOx generated on the platinum Pt at that time diffuses as nitrate ion NO_3^- in the basic layer to become nitrate. In other words, the active NOx is absorbed as nitrate by the basic layer of the catalyst 4 without generating the reductive intermediate. To avoid this, it is necessary to cause the concentration of HC flowing into the catalyst 4 to oscillate at a period within a prescribed range.

[0030] In this connection, if the period of injection of HC is longer than approximately 5 seconds, the active NOx starts to be absorbed as nitrate by the basic layer. Therefore, if the period of injection of HC becomes longer than approximately 5 seconds, the NOx removal rate is deteriorated. Therefore, in this embodiment, it is necessary that the period of injection of HC be set shorter than 5 seconds.

[0031] If the period of injection of HC is shorter than approximately 0.3 second, the injected HC starts to be deposited on the surface of the catalyst 4. Therefore, if the period of injection of HC becomes shorter than approximately 0.3 second, the NOx removal rate is deteriorated. Therefore, in the present invention, the period of injection of HC is set in the range between 0.3 second and 5 seconds. Moreover, the quantity and the period of injection of HC through the fuel addition valve 3 are controlled to optimum values adapted to the operation state of the internal combustion engine 1. In this embodiment, an injection quantity and a period of injection optimum for ensuring excellent removal of NOx by the first NOx removal method are determined in advance. Such an injection quantity and period of injection are stored in association with the operation state of the internal combustion engine 1 in the ECU 10 in advance. The values of the injection quantity and the period of injection through the fuel addition valve 3 stored in the ECU 10 in advance will be referred to as the first reference injection quantity and the first reference period respectively.

[0032] Next, the second NOx removal method will be described. In the second NOx removal method, the catalyst 4 is made to function as an NOx storage reduction catalyst. In the second NOx removal method, when the amount of NOx stored in the basic layer of the catalyst 4 (the NOx storage amount) exceeds a prescribed allowable amount, the air-fuel ratio of the exhaust gas flowing into the catalyst 4 is made rich temporarily. When the air-fuel ratio of the exhaust gas is made rich, NOx that has been stored in the basic layer when the air-fuel ratio of the exhaust gas is lean is released from the basic layer all at once and reduced. Thus, removal of NOx is achieved.

[0033] The NOx storage amount is calculated, for example, from the quantity of NOx discharged from the internal combustion engine 1. In this embodiment, the quantity of NOx discharged from the internal combustion engine 1 per unit time (discharged NOx quantity) is stored in the ECU 10 in advance in association with the operation state of the internal combustion engine 1 in the form of a map, and the NOx storage amount is calculated from the discharged NOx quantity. The cycle of making the air-fuel ratio of the exhaust gas rich is normally longer than one minute. In the case where the first NOx removal method is performed while the NOx storage amount is calculated, the NOx storage amount is corrected or adjusted to decrease in accordance with the period over which the first NOx removal method is exercised and the operation state of the internal combustion engine 1 during that period. The relationship with which the suitable correction amount of the NOx storage amount can be determined from the period over which the first NOx removal method is exercised and the operation state of the internal combustion engine 1 during that period, is also stored in the ECU 10 in advance in the form of a map.

[0034] In the second NOx removal method, the air-fuel ratio in the cylinder is made rich by additionally injecting fuel for removal of NOx in addition to the fuel injected by the fuel injection valve 6 in accordance with the engine load of the internal combustion engine 1. The fuel injection quantity for making the air-fuel ratio in the cylinder of the internal combustion engine rich is prepared in ad-

vance as a map in association with the operation state of the internal combustion engine 1, which is stored in the ECU 10. The value of the fuel injection quantity through the fuel injection valve 6 for making the air-fuel ratio in the cylinder rich stored in advance in the ECU 10 will be referred to as the second reference injection quantity in the second NOx removal method.

[0035] In the first NOx removal method as described above, the HC concentration is lowered by injecting fuel through the fuel addition valve 3. Alternatively, the HC concentration may be lower by injecting fuel into the cylinder through the fuel injection valve 6. In the second NOx removal method as described above, the air-fuel ratio of the exhaust gas is made temporarily rich by injecting fuel into the cylinder through the fuel injection valve 6. Alternatively, the air-fuel ratio of the exhaust gas may be made rich temporarily by injecting fuel through the fuel addition valve 3.

[0036] The ECU 10 detects an abnormality of the filter 5 based on the output signal of the PM sensor 11. If an abnormality such as cracking or chipping occurs in the filter 5, PM passes through the cracking or chipping portion, and the quantity of PM flowing downstream of the filter 5 increases accordingly. Consequently, the time taken in the state in which PM is not deposited in the PM sensor 11 until the signal is output from the PM sensor 11 is shortened. Thus, the time taken until the signal is output from the PM sensor 11 varies depending on the state of the filter 5.

[0037] Fig. 3 is a time chart showing the change of the output value of the PM sensor 11 with time. The broken line represents the output value in a case where the filter 5 is normal, and the solid line represents the output value in a case where the filter 5 is abnormal or faulty. In the case where the filter 5 is normal, the quantity of PM slipping through the filter 5 is small, and therefore the output value of the sensor is substantially zero throughout the period shown in Fig. 3. In Fig. 3, the point zero of the horizontal axis is the time point at which the regeneration of the PM sensor 11 is finished. The regeneration of the PM sensor 11 is performed by raising the temperature of the PM sensor by a heater built in the PM sensor 11 to a temperature at which PM is oxidized. The temperature at which PM is oxidized will be hereinafter referred to as the "PM oxidation temperature". The PM deposited in the PM sensor 11 is removed by the regeneration of the PM sensor 11.

[0038] The output value of the PM sensor 11 starts to increase when the deposited PM amount reaches or exceeds a certain amount. The quantity of PM deposited in the PM sensor 11 per unit time after the regeneration of the PM sensor is larger in the case where the filter 5 is abnormal than in the case where the filter 5 is normal. In consequence, in the case where the filter 5 is abnormal, the time taken after the regeneration of the PM sensor 11 until the output value of the PM sensor 11 starts to increase is shorter than in the case where the filter 5 is normal. Consequently, as shown in Fig. 3, in the case where the filter 5 is abnormal, the time at which the output value of the PM sensor 11 starts to increase is earlier than in the case where the filter 5 is normal. Therefore, it may be determined that the filter 5 is abnormal if the output value of the PM sensor 11 is larger than or equal to a threshold at the time T1 when a prescribed time has elapsed since the regeneration of the PM sensor 11. The aforementioned prescribed time can be determined in advance by experiment or simulation as a time after the lapse of which the output value of the PM sensor 11 is larger than or equal to the threshold if the filter 5 is abnormal and is smaller than the threshold if the filter 5 is normal.

[0039] As described above, when the amount of PM deposited in the PM sensor 11 reaches or exceeds a certain amount, the output value of the PM sensor 11 starts to increase. If HC is supplied to the catalyst 4 by the first NOx removal method or the second NOx removal method, there is a possibility that the temperature of the exhaust gas flowing out of catalyst 4 may be raised by the reaction heat to reach or exceed the PM oxidation temperature. Then, the temperature around the PM sensor 11 may reach the PM oxidation temperature even while the regeneration of the PM sensor 11 is not being performed. If this occurs, the amount of PM deposited in the PM sensor 11 decreases, and the time at which the output value of the PM sensor 11 starts to increase is delayed even if the filter 5 is abnormal. Then, there is a possibility that an erroneous determination that the filter 5 is normal may be made.

[0040] Fig. 4 is a time chart showing the change of the output value of the PM sensor 11 with time in a case where the filter 5 is abnormal. In Fig. 4, the solid line represents the output value in a case where the temperature of the exhaust gas flowing into the PM sensor 11 is kept lower than the PM oxidation temperature, and the broken line represents the output value in a case where the temperature of the exhaust gas flowing into the PM sensor 11 becomes higher than or equal to the PM oxidation temperature after the regeneration of the PM sensor 11. Even in the case where the filter 5 is abnormal, if HC is supplied to the catalyst for removal of NOx while PM is depositing, there is a possibility that the output value of the PM sensor 11 at the time T1 after the lapse of the prescribed time since the regeneration of the PM sensor 11 may be smaller than the threshold and an erroneous determination that the filter 5 is normal may be made.

[0041] As the temperature of the exhaust gas rises with reaction of HC in the catalyst 4, the volume of the exhaust gas increases, and the flow speed of the exhaust gas increases accordingly. As the flow speed of the exhaust gas increases, the ratio of the quantity of PM passing through the PM sensor 11 without depositing in the PM sensor 11 to the quantity of PM reaching the PM sensor 11 increases. Then, the time at which the output value of the PM sensor 11 starts to increase is delayed, and the correlation between the amount of PM deposited in

the PM sensor 11 and the quantity of PM in the exhaust gas becomes lower. In this embodiment, the correlation between the amount of PM deposited in the PM sensor 11 and the quantity of PM in the exhaust gas becomes lower than an allowable range when the flow speed of the exhaust gas exceeds a specific flow speed. In other words, if the flow speed of the exhaust gas exceeds the specific flow speed, the ratio of the quantity of PM passing through the PM sensor 11 without depositing in the PM sensor 11 to the quantity of PM reaching the PM sensor 11 exceeds a prescribed allowable value.

[0042] Fig. 5 is a time chart showing the change of the output value of the PM sensor 11 with time in a case where the filter 5 is abnormal. In Fig. 5, the broken line represents the output value in a case where the flow speed does not exceed the specific flow speed and is twice as high as that in the case for which the output value is represented by the solid line. In this case, as the flow speed is twice higher, the quantity of PM flowing into the PM sensor 11 is also twice larger. If the ratio of the quantity of PM deposited in the PM sensor 11 to the quantity of PM flowing into the PM sensor 11 is the same, the time taken until the output value of the PM sensor 11 starts to increase is decreased by half. In cases where the flow speed increases to exceed the specific flow speed, the ratio of the quantity of PM passing through the PM sensor 11 to the quantity of PM flowing into the PM sensor 11 becomes high, and the time taken until the output value of the PM sensor 11 starts to increase is prolonged (see the dash-dot line in Fig. 5). Then, the correlation between the amount of PM deposited in the PM sensor 11 and the quantity of PM in the exhaust gas is low.

[0043] In this embodiment, while removal of NOx is performed by the first NOx removal method or the second NOx removal method, the quantity of fuel injected through the fuel addition valve 3 or the quantity of fuel injected through the fuel injection valve 6 is controlled in such a way that the temperature of the exhaust gas flowing through the PM sensor 11 is kept lower than the PM oxidation temperature or that the flow speed of the exhaust gas is kept lower than the specific flow speed, thereby preventing the correlation between the amount of PM deposited in the PM sensor 11 and the quantity of PM in the exhaust gas becomes low.

[0044] In this embodiment, when the temperature of the exhaust gas flowing into the PM sensor 11 exceeds the PM oxidation temperature or when the flow speed of the exhaust gas exceeds the specific flow speed during reduction of NOx, the quantity of heat generated with fuel in the catalyst 4 is decreased. The quantity of heat generated in the catalyst 4 may be decreased when the temperature of the exhaust gas flowing into the PM sensor 11 actually exceeds the PM oxidation temperature or when the flow speed of the exhaust gas actually exceeds the specific flow speed. Alternatively, the quantity of heat generated in the catalyst 4 may be decreased when the temperature of the exhaust gas flowing into the PM sensor 11 is expected to exceed the PM oxidation temperature or when the flow speed of the exhaust gas is expected to exceed the specific flow speed.

[0045] In the first NOx removal method, if the injection quantity in one injection and the period of injection are varied with the total injection quantity of the fuel addition valve 3 per unit time being fixed, the larger the injection quantity in one injection is and the longer the period of injection is, the smaller the quantity of heat generated in the catalyst 4 is.

[0046] When the first NOx removal method is employed, the most part of the fuel injected through the fuel addition valve 3 is used to consume oxygen in the exhaust gas, and the remainder of the fuel is used to generate the reductive intermediate. In this case, NOx discharged from the internal combustion engine 1 is removed by this reductive intermediate. Therefore, in order to remove NOx discharged from the internal combustion engine1 satisfactorily, it is necessary to generate an appropriate quantity of reductive intermediate in accordance with the quantity of NOx discharged from the internal combustion engine 1. To achieve this, it is necessary to inject an appropriate quantity of fuel through the fuel addition valve 3 in accordance with the quantity of the reductive intermediate to be generated. Therefore, it is necessary to inject an appropriate quantity of fuel through the fuel addition valve 3 in accordance with the quantity of NOx discharged from the internal combustion engine 1 per unit time.

[0047] Therefore, when varying the fuel injection quantity in one injection or the period of fuel injection through the fuel addition valve 3 in the same operation state of the internal combustion engine 1 namely in the state in which the air-fuel ratio of the exhaust gas before the fuel injection is the same and the quantity of NOx in the exhaust gas is the same, it is necessary to vary the injection quantity in one injection and the period of injection in such a way that the total injection quantity of the fuel addition valve 3 per unit time does not change. Therefore, when the injection quantity in one injection and the period of injection through the fuel addition valve 3 are changed, the longer the period of injection is, the more the injection quantity in one injection is increased.

[0048] Fig. 6 includes time charts in cases where the injection quantity in one injection and the period of injection are varied while the total injection quantity of the fuel addition valve 3 per unit time is not varied. The upper chart shows a case in which the injection quantity in one injection is small and the period DT of injection is short, and the lower chart shows a case in which the injection quantity in one injection is larger than that in the upper chart and the period DT of injection is longer than that in the upper chart. Since the injection rate is the same between the upper chart and the lower chart, the injection quantity in one injection is determined by the duration of fuel injection through the fuel addition valve 3.

[0049] When the first NOx removal method is employed, the most part of the fuel injected through the fuel

addition valve 3 is used to consume oxygen in the exhaust gas. In other words, the most part of the fuel injected through the fuel addition valve 3 reacts with oxygen in the exhaust gas to be oxidized. In this case, if the quantity of fuel injected through the fuel addition valve 3 in one injection is large, the concentration of fuel in the exhaust gas becomes high, leading to an increase in the quantity of fuel that does not react with oxygen due to deficiency of oxygen. Consequently, the quantity of heat generated by oxidation reaction decreases. Thus, prolonging the period of fuel injection and increasing the fuel injection quantity will lead to a decrease in the quantity of heat generated by oxidation reaction. Even in this case, the reductive intermediate is generated so long as a prescribed quantity of HC is injected periodically through the fuel addition valve 3 at a period within a prescribed range, and NOx can be removed consequently. Therefore, when the first NOx removal method is employed, prolonging the period of fuel injection prevents or reduces the temperature rise of the exhaust gas, leading to a decrease in the temperature of the exhaust gas flowing into the PM sensor 11 and a decrease in the flow speed of the exhaust gas.

[0050] In this embodiment, when the first NOx removal method is employed while letting PM deposit in the PM sensor 11 for the purpose of determining whether the filter 5 is abnormal, the period of fuel injection through the fuel addition valve 3 is made longer and the fuel injection quantity in one injection is made larger when the temperature of the exhaust gas flowing into the PM sensor 11 is higher than the PM oxidation temperature than when the temperature of the exhaust gas flowing into the PM sensor 11 is not higher than the PM oxidation temperature, or when the flow speed of the exhaust gas is higher than the specific flow speed than when the flow speed of the exhaust gas is not higher than the specific flow speed. In this control, the injection quantity through the fuel addition valve 3 is made larger than the first reference injection quantity and the period of injection is made longer than the first reference period so that the total injection quantity through the fuel addition valve 3 per unit time does not change. Thus, it is possible to reduce the quantity of heat generated in the catalyst 4 while generating the reductive intermediate. When making the injection quantity through the fuel addition valve 3 larger than the first reference injection quantity and making the period of injection longer than the first reference period, the higher the temperature or the flow speed of the exhaust gas is, the larger the increase in the injection quantity through the fuel addition valve 3 from the first reference injection quantity may be made and the larger the increase in the period of injection from the first reference period may be made.

[0051] When the second NOx removal method is employed, there is a possibility that an increase in the quantity of heat generated in the catalyst 4 with HC discharged from the internal combustion engine 1 may make the temperature of the exhaust gas flowing into PM sensor 11 higher than the PM oxidation temperature or make the flow speed of the exhaust gas higher than the specific flow speed. If such circumstances occur, the fuel injection quantity in the fuel injection through the fuel injection valve 6 that is performed to make the air-fuel ratio rich is made smaller than the second reference injection quantity. Thus, the temperature and the flow speed of the exhaust gas can be made lower.

[0052] As above, when PM deposited in the PM sensor 11 is oxidized while letting PM deposit in the PM sensor 11 for the purpose of determining whether the filter 5 is abnormal, the temperature of the exhaust gas flowing into the PM sensor 11 is lowered, so that oxidation of PM can be controlled. Moreover, when the ratio of PM passing through the PM sensor 11 exceeds an allowable range, the flow speed of the exhaust gas flowing into the PM sensor 11 is decreased by lowering the temperature of the exhaust gas, so that the ratio of PM passing through the PM sensor 11 can be decreased. Thus, the correlation of the quantity of PM in the exhaust gas with the time taken until the output value of the PM sensor 11 starts to increase and the time taken until the output value of the PM sensor 11 reaches the threshold can be maintained. Therefore, an accurate determination as to whether the filter 5 is abnormal can be made.

[0053] As above, adjusting the injection quantity and the period of injection through the fuel addition valve 3 or the injection quantity through the fuel injection valve 6 enables the output value of the PM sensor 11 to increase in accordance with the quantity of PM in the exhaust gas. Therefore, the correlation between the amount of PM deposited in the PM sensor 11 and the quantity of PM in the exhaust gas can be enhanced. In consequence, the accuracy of determination of abnormality of the filter 5 can be enhanced.

[0054] Fig. 7 is a time chart of the temperature of the exhaust gas and the injection quantity through the fuel addition valve 3 in measurement of PM by the PM sensor 11, in a case where NOx is removed employing the first NOx removal method according to the embodiment. The temperature of the exhaust gas is assumed to be equal to the temperature of the PM sensor 11. A first prescribed temperature may be set to the PM oxidation temperature. In Fig. 7, the temperature of the exhaust gas reaches the first prescribed temperature at time TA and reaches a second prescribed temperature at time TB. When the temperature of the exhaust gas exceeds the first prescribed temperature, the injection quantity in one injection is made larger than the first reference injection quantity, and the period of injection is made longer than the first reference period. Consequently, the temperature of the exhaust gas lowers afterward. When the temperature of the exhaust gas becomes lower than the second prescribed temperature, the injection quantity in one injection is made equal to the first reference injection quantity, and the period of injection is made equal to the first reference period. Consequently, the temperature of the exhaust gas rises afterward. When the temperature of the

exhaust gas is higher than or equal to the second prescribed temperature and lower than or equal to the first prescribed temperature, the injection quantity in one injection and the period of injection are not changed. This temperature range is a dead zone. This dead zone prevents frequent changing of the injection period and the injection quantity. The second prescribed temperature is set in such a way that the decrease in the NOx removal rate is kept within an allowable range.

[0055] Fig. 8 is a flow chart showing the control flow of the exhaust gas temperature control according to the embodiment. The routine in this flow chart is executed by the ECU 10 at prescribed intervals.

[0056] In step S101, it is determined whether deposition of PM in the PM sensor 11 for making determination as to whether the filter 5 is normal is in progress. If the determination made in step S101 is affirmative, the process proceeds to step S102. If the determination made in step S101 is negative, the process proceeds to step S106, where a temperature flag is set to 0. The temperature flag is set to 1 when the period and the injection quantity in fuel injection through the fuel addition valve 3 are larger than the first reference period and the first reference injection quantity respectively in the first NOx removal method or when the fuel injection quantity through the fuel injection valve 6 is smaller than the second reference injection quantity in the second NOx removal method. On the other hand, the temperature flag is set to 0 when the period and the injection quantity in fuel injection through the fuel addition valve 3 are equal to the first reference period and the first reference injection quantity respectively in the first NOx removal method or when the fuel injection quantity through the fuel injection valve 6 is equal to the second reference injection quantity in the second NOx removal method. In short, when the quantity of supply of HC is controlled so as to reduce the quantity of heat generated in the catalyst 4, the temperature flag is set to 1, and when the quantity of supply of HC is not controlled in this way, the temperature flag is set to 0.

[0057] In step S102, it is determined whether or not a first control is in operation. The first control is a control executed to remove NOx by the first NOx removal method. When the first control is in operation, the injection quantity through the fuel addition valve 3 is set to the first reference injection quantity and the period of injection is set to the first reference period, in the initial state. If the determination made in step S102 is affirmative, the process proceeds to step S103. If the determination made in step S102 is negative, the process proceeds to step S104.

[0058] In step S103, a first temperature control is executed. The first temperature control is a temperature control executed while the first control is executed. The first temperature control will be described later.

[0059] In step S104, it is determined whether or not a second control is in operation. The second control is a control executed to remove NOx by the second NOx removal method. When the second control is in operation, the injection quantity in the fuel injection through the fuel injection valve 6 that is performed to make the air-fuel ratio rich is set to the second reference injection quantity. If the determination made in step S104 is affirmative, the process proceeds to step S105. If the determination made in step S104 is negative, the process proceeds to step S106.

[0060] In step S105, a second temperature control is executed. The second temperature control is a temperature control executed while the second control is executed. The second temperature control will be described later.

[0061] Now, the first temperature control executed in step S103 will be described. Fig. 9 is a flow chart showing the control flow of the first temperature control. This control is executed by the ECU 10.

[0062] In step S201, it is determined whether or not the temperature of the exhaust gas is higher than the first prescribed temperature. The first prescribed temperature may be set to the PM oxidation temperature or a temperature at which it is possible that PM deposited in the PM sensor 11 is oxidized (see Fig. 7). In other words, in step S201, a determination is made as to whether or not the exhaust gas is at a temperature at which PM deposited in the PM sensor 11 decreases or can decrease. The temperature of the exhaust gas is the temperature measured by the temperature sensor 12. If the determination made in step S201 is affirmative, the process proceeds to step S202. If the determination made in step S201 is negative, the process proceeds to step S204.

[0063] In step S202, the period of fuel injection through the fuel addition valve 3 is made longer than the first reference period, and the injection quantity in one injection is made larger than the first reference injection quantity. Thus, the period of injection is prolonged and the injection quantity is increased in order to reduce the quantity of heat generated in the catalyst 4. In step S202, the period of injection and the injection quantity may be increased from the first reference period and the first reference injection quantity by a prescribed rate. Alternatively, the larger the difference between the temperature of the exhaust gas and the first prescribed temperature is, the larger the increase in the period of injection from the first reference period and the increase in the injection quantity from the first reference injection quantity may be made. Then, in step S203, the temperature flag is set to 1. Thereafter, the process of the flow chart in Fig. 9 is terminated, and the processing of step S103 ends.

[0064] In step S204, it is determined whether or not the temperature flag is 1. In step S204, a determination is made as to whether or not the period and the injection quantity in fuel injection through the fuel addition valve 3 are increased from the first reference period and the first reference injection quantity respectively. If the determination made in step S204 is negative, the temperature of the exhaust gas is lower than or equal to the first prescribed temperature, and the period and the injection

quantity in fuel injection through the fuel addition valve 3 are not increased. Then, the process of the flow chart in Fig. 9 is terminated, and the processing of step S103 ends. Thus, the injection period and the injection quantity at that time are kept unchanged if step S204 is answered in the negative.

[0065] If the determination made in step S204 is affirmative, the process proceeds to step S205. In step S205, it is determined whether or not the temperature of the exhaust gas is lower than the second prescribed temperature. The second prescribed temperature is a temperature lower than the first prescribed temperature. The second prescribed temperature is set to return the period of injection and the injection quantity back to their initial values (see Fig. 7). When the temperature of the exhaust gas is not lower than the second prescribed temperature and not higher than the first prescribed temperature, the period of injection and the injection quantity are not changed. Therefore, if the determination made in step S205 is negative, the process of the flow chart in Fig. 9 is terminated, and the processing of step S103 ends. Thus, the injection period and the injection quantity at that time are kept unchanged if step S205 is answered in the negative.

[0066] If the determination made in step S205 is affirmative, the process proceeds to step S206, where the period of fuel injection through the fuel addition valve 3 is set to the first reference period, and the injection quantity in one injection is set to the first reference injection quantity. Thus, the period of injection and the injection quantity are returned back to their initial values to prevent the decrease in the temperature of the catalyst 4, thereby increasing the NOx removal rate. Then, in step S207, the temperature flag is set to 0. Thereafter, the process of the flow chart in Fig. 9 is terminated, and the processing of step S103 ends.

[0067] Now, the second temperature control executed in step S105 will be described. Fig. 10 is a flow chart showing the control flow of the second temperature control. This control is executed by the ECU 10. In Fig. 10, the steps in which the same processing as in the steps in Fig. 9 is performed are denoted by the same reference signs and will not be described further.

[0068] In the flow chart shown in Fig. 10, if the determination made in step S201 is affirmative, the process proceeds to step S301, where the fuel injection quantity in the fuel injection into the cylinder through the fuel injection valve 6 that is performed to make the air-fuel ratio rich is made smaller than the second reference injection quantity. In this process, the fuel injection quantity may be decreased from the second reference injection quantity by a prescribed quantity or prescribed rate. Alternatively, the higher the temperature of the exhaust gas is, the larger the decrease in the fuel injection quantity from the second reference injection quantity may be made. The fuel injection quantity is decreased in a range in which reduction of NOx is possible. While in the first temperature control the quantity of heat generated is decreased by deficiency of oxygen caused by increasing the injection quantity in one injection in a relatively short time, in the second temperature control the quantity of heat generated is decreased by deficiency of HC caused by decreasing the fuel injection quantity over a longer time than in the first temperature control. Thereafter, the process proceeds to step S203.

[0069] In the flow chart shown in Fig. 10, if the determination made in step S205 is affirmative, the process proceeds to step S302, where the fuel injection quantity in the fuel injection through the fuel injection valve 6 that is performed to make the air-fuel ratio rich is made equal to the second reference injection quantity. Thereafter, the process proceeds to step S207. In the flow chart shown in Fig. 10, if the determination made in step S204 or S205 is negative, the fuel injection quantity at that time is kept unchanged.

[0070] Next, the case in which the flow speed of the exhaust gas is controlled will be described. Fig. 11 is a flow chart showing the flow of a control of the exhaust gas flow speed according to the embodiment. The routine in this flow chart is executed by the ECU 10 at prescribed intervals. In Fig. 11, the steps in which the same processing as in the steps in Fig. 8 is performed are denoted by the same reference signs and will not be described further.

[0071] In the flow chart shown in Fig. 11, if the determination made in step S102 is affirmative, the process proceeds to step S401, where a first flow speed control is executed. The first flow speed control is an exhaust gas flow speed control executed while the first control is executed. The first flow speed control will be described later.

[0072] If the determination made in step S104 is affirmative, the process proceeds to step S402, where a second flow speed control is executed. The second flow speed control is an exhaust gas flow speed control executed while the second control is executed. The second flow speed control will be described later.

[0073] If the determination made in step S101 is negative and if the determination made in step S104 is negative, the process proceeds to step S403, where a flow speed flag is set to 0. The flow speed flag is set to 1 when the period and the injection quantity in fuel injection through the fuel addition valve 3 are larger than the first reference period and the first reference injection quantity respectively in the first NOx removal method or when the fuel injection quantity through the fuel injection valve 6 for making the air-fuel ratio rich is smaller than the second reference injection quantity in the second NOx removal method. On the other hand, the flow speed flag is set to 0 when the period and the injection quantity in fuel injection through the fuel addition valve 3 are equal to the first reference period and the first reference injection quantity respectively in the first NOx removal method or when the fuel injection quantity through the fuel injection valve 6 for making the air-fuel ratio rich is equal to the second reference injection quantity in the second NOx removal

method.

[0074] Now, the first flow speed control executed in step S401 will be described. Fig. 12 is a flow chart showing the control flow of the first flow speed control. This control is executed by the ECU 10.

[0075] In step S501, it is determined whether or not the flow speed of the exhaust gas is higher than a first prescribed flow speed. The first prescribed flow speed may be set to a flow speed of the exhaust gas at which the rate of PM passing through the PM sensor 11 exceeds an allowable range. In this step S501, a determination is made as to whether or not the correlation between the amount of PM deposited in the PM sensor 11 and the quantity of PM in the exhaust gas becomes low. The flow speed of the exhaust gas depends on factors such as the temperature measured by the temperature sensor 12, the intake air quantity of the internal combustion engine 1, the fuel injection quantity of the internal combustion engine 1 through the fuel injection valve 6, and the fuel injection quantity through the fuel addition valve 3. The flow speed of the exhaust gas is estimated from these factors. The relationship between the flow speed of the exhaust gas and these factors is prepared in advance by simulation and stored in the ECU 10. If the determination made in step S501 is affirmative, the process proceeds to step S502. If the determination made in step S501 is negative, the process proceeds to step S504.

[0076] In step S502, the period of fuel injection through the fuel addition valve 3 is made longer than the first reference period, and the injection quantity in one injection is made larger than the first reference injection quantity. Thus, the period of injection is prolonged and the injection quantity in one injection is increased in order to reduce the quantity of heat generated in the catalyst 4. In step S502, the period of injection and the injection quantity may be increased from the first reference period and the first reference injection quantity by a prescribed rate. Alternatively, the larger the difference between the flow speed of the exhaust gas and the first prescribed flow speed is, the larger the increase in the period of injection from the first reference period and the increase in the injection quantity from the first reference injection quantity may be made. As the quantity of heat generated in the catalyst 4 is decreased by the execution of step S502, the degree of expansion of the exhaust gas decreases, and the flow speed of the exhaust gas decreases consequently. Then, in step S503, the flow speed flag is set to 1. Thereafter, the process of the flow chart in Fig. 12 is terminated, and the processing of step S401 ends.

[0077] In step S504, it is determined whether or not the flow speed flag is 1. In this step S504, a determination is made as to whether the period and the injection quantity in fuel injection through the fuel addition valve 3 are larger than the first reference period and the first reference injection quantity respectively. If the determination made in step S504 is negative, the flow speed of the exhaust gas is lower than or equal to the first prescribed flow speed, and the period and the injection quantity in fuel injection through the fuel addition valve 3 are not increased. Then, the process of the flow chart in Fig. 12 is terminated, and the processing of step S401 ends. Thus, the injection period and the injection quantity at that time are kept unchanged if step S504 is answered in the negative.

[0078] If the determination made in step S504 is affirmative, the process proceeds to step S505. In step S505, it is determined whether or not the flow speed of the exhaust gas is lower than a second prescribed flow speed. The second prescribed flow speed is a flow speed lower than the first prescribed flow speed. The second prescribed flow speed is set to return the period of injection and the injection quantity back to their initial values. When the flow speed of the exhaust gas is not lower than the second prescribed flow speed and not higher than the first prescribed flow speed, the period of injection and the injection quantity are not changed. This flow speed range is a dead zone. This dead zone prevents frequent changing of the injection period and the injection quantity. Therefore, if the determination made in step S505 is negative, the process of the flow chart shown in Fig. 12 is terminated, and the processing of step S401 ends. Thus, the injection period and the injection quantity at that time are kept unchanged if step S505 is answered in the negative.

[0079] If the determination made in step S505 is affirmative, the process proceeds to step S506, where the period of fuel injection through the fuel addition valve 3 is set to the first reference period, and the injection quantity in one injection is set to the first reference injection quantity. Thus, the period of injection and the injection quantity are returned back to their initial values to prevent the decrease in the temperature of the catalyst 4, thereby increasing the NOx removal rate. Then, in step S507, the flow speed flag is set to 0. Thereafter, the process of the flow chart in Fig. 12 is terminated, and the processing of step S401 ends.

[0080] Now, the second flow speed control executed in step S402 will be described. Fig. 13 is a flow chart showing the control flow of the second flow speed control. This control is executed by the ECU 10. In Fig. 13, the steps in which the same processing as in the steps in Fig. 12 is performed are denoted by the same reference signs and will not be described further.

[0081] In the flow chart shown in Fig. 13, if the determination made in step S501 is affirmative, the process proceeds to step S601, where the fuel injection quantity in the fuel injection into the cylinder through the fuel injection valve 6 that is performed to make the air-fuel ratio rich is made smaller than the second reference injection quantity. In this process, the fuel injection quantity may be decreased from the second reference injection quantity by a prescribed quantity or prescribed rate. Alternatively, the higher the flow speed of the exhaust gas is, the larger the decrease in the fuel injection quantity from

the second reference injection quantity may be made. The fuel injection quantity is decreased in a range in which reduction of NOx is possible. While in the first flow speed control the quantity of heat generated is decreased to decrease the exhaust gas flow speed by deficiency of oxygen caused by increasing the injection quantity in one injection in a relatively short time, in the second flow speed control the quantity of heat generated is decreased to decrease the exhaust gas flow speed by deficiency of HC caused by decreasing the fuel injection quantity over a longer time than in the first flow speed control.

[0082] In the flow chart shown in Fig. 13, if the determination made in step S505 is affirmative, the process proceeds to step S602, where the fuel injection quantity in the fuel injection through the fuel injection valve 6 that is performed to make the air-fuel ratio rich is made equal to the second reference injection quantity. Thereafter, the process proceeds to step S507. In the flow chart shown in Fig. 13, if the determination made in step S504 or S505 is negative, the fuel injection quantity at that time is kept unchanged.

[0083] A control taking account of both the temperature and flow speed of the exhaust gas may be employed. Fig. 14 is a flow chart showing the flow of controlling the temperature and the flow speed of the exhaust gas according to the embodiment. The routine in this flow chart is executed by the ECU 10 at prescribed intervals. In Fig. 14, the steps in which the same processing as in the steps in the aforementioned flow charts is performed are denoted by the same reference signs and will not be described further. In this control, the temperature and the flow speed of the exhaust gas are controlled in the first control and the second control.

[0084] If the quantity of heat generated in the catalyst 4 is decreased by the first temperature control or the second temperature control, the flow speed of the exhaust gas is affected by the decrease in the quantity of heat. Moreover, if the quantity of heat generated in the catalyst 4 is decreased by the first flow speed control or the second flow speed control, the temperature of the exhaust gas is also affected by the decrease in the quantity of heat. Therefore, if the temperature control and the flow speed control are performed at the same time, the control process is complicated. Therefore, in this embodiment, when the first temperature control or the second temperature control is performed, neither the first flow speed control nor the second flow speed control is performed. When the first flow speed control or the second flow speed control is performed, neither the first temperature control nor the second temperature control is performed.

[0085] Therefore, if the determination made in step S102 is affirmative, the processing of step S701 is executed. In step S701, it is determined whether or not the flow speed flag is 0. In other words, a determination is made as to whether or not the flow speed of the exhaust gas has already been decreased. If the flow speed of the exhaust gas has already been decreased, increasing the temperature of the exhaust gas by the first temperature control may make the amount of PM passing through the PM sensor 11 higher than an allowable range. In view of this, the first temperature control is executed subsequently in step S103 only when the flow speed flag is 0, or only when the determination made in step S701 is affirmative. On the other hand, if the determination made in step S701 is negative, the process proceeds to step S702.

[0086] In step S702, it is determined whether or not the temperature flag is 0. In other words, a determination is made as to whether the temperature of the exhaust gas has already been decreased. If the temperature of the exhaust gas has already been decreased, increasing the flow speed of the exhaust gas by the first flow speed control may cause the temperature of the exhaust gas to reach the PM oxidation temperature. In view of this, the first flow speed control is executed subsequently in step S401 only when the temperature flag is 0, or only when the determination made in step S702 is affirmative. On the other hand, if the determination made in step S702 is negative, the control of this flow chart is terminated.

[0087] In the case where the second control is performed, similarly, it is determined in step S703 whether or not the flow speed flag is 0. The second temperature control is executed subsequently in step S105 only when the determination made in step S703 is affirmative. If the determination made in step S703 is negative, the process proceeds to step S704. In step S704, it is determined whether or not the temperature flag is 0. The second flow speed control is executed subsequently in step S402 only when the determination made in step S704 is affirmative. If the determination made in step S704 is negative, the process of the flow chart in Fig. 14 is terminated.

[0088] The first temperature control may be performed according to the flow chart shown in Fig. 9. Alternatively, the first temperature control may be performed according to the flow chart shown in Fig. 15 as described in the following. In other words, the processing described below may be executed in step S103. Fig. 15 is a flow chart of another mode of the first temperature control. This control is performed by the ECU 10.

[0089] In step S801, it is determined whether or not the temperature of the exhaust gas is higher than a third prescribed temperature. The third prescribed temperature is a temperature lower than the first prescribed temperature and higher than the second prescribed temperature. The third prescribed temperature is determined so as to prevent the temperature of the exhaust gas from exceeding the PM oxidation temperature due to response delay in changing the temperature of the exhaust gas. In step S801, a determination is made as to whether or not the exhaust gas is at a temperature at which there is a possibility that the amount of PM deposited in the PM sensor 11 may decrease. The temperature of the exhaust gas is the temperature measured by the temperature sensor 12. If the determination made in step S801 is affirmative, the process proceeds to step S802. If the determination made in step S801 is negative, the process

proceeds to step S805.

[0090] In step S802, it is determined whether or not the temperature of the exhaust gas is rising. Even when the temperature of the exhaust gas is higher than the third prescribed temperature, if the temperature of the exhaust gas is constant or falling, the temperature of the exhaust gas will not exceed the first prescribed temperature. Then, therefore, it is concluded that it is not necessary to increase the period of injection or the injection quantity. Therefore, if the determination made in step S802 is negative, the process of this flow chart is terminated and the processing of step S103 ends. Thus, the period of injection and the injection quantity at that time are kept unchanged if the determination made in step S802 is negative. On the other hand, if the determination made in step S802 is affirmative, the process proceeds to step S803.

[0091] In step S803, the period of fuel injection through the fuel addition valve 3 is made longer than the first reference period, and the injection quantity in one injection is made larger than the first reference injection quantity. Thus, the period of injection is prolonged and the injection quantity is increased in order to reduce the quantity of heat generated in the catalyst 4. In step S803, the period of injection and the injection quantity may be increased from the first reference period and the first reference injection quantity by a prescribed rate. Alternatively, the larger the difference between the temperature of the exhaust gas and the third prescribed temperature is, the larger the increase in the period of injection from the first reference period and the increase in the injection quantity from the first reference injection quantity may be made. Then, in step S804, the temperature flag is set to 1. Thereafter, the process of the flow chart in Fig. 15 is terminated, and the processing of step S103 ends.

[0092] In step S804, it is determined whether or not the temperature of the exhaust gas is falling. In step S804, a determination is made as to whether or not it is necessary to raise the temperature of the exhaust gas. In cases where the temperature of the exhaust gas is lower than or equal to the third prescribed temperature and falling, there is a possibility that the temperature of the exhaust gas may become so low that the NOx removal rate is deteriorated. Therefore, the temperature of the exhaust gas is raised in such cases. If the determination made in step S805 is affirmative, the process proceeds to step S806. If the determination made in step S805 is negative, the process of the flow chart in Fig. 15 is terminated. Thus, the period of injection and the injection quantity at that time are kept unchanged if the determination made in step S805 is negative.

[0093] In step S806, the period of fuel injection through the fuel addition valve 3 is set to the first reference period, and the injection quantity in one injection is set to the first reference injection quantity. Thus, the period of injection and the injection quantity are returned back to their initial values to increase the quantity of heat generated in the catalyst 4. Then, the process proceeds to step S807, where the temperature flag is set to 0. Thereafter, the process of the flow chart shown in Fig. 15 is terminated, and the processing of the step S103 ends.

[0094] The second temperature control may be performed according to the flow chart shown in Fig. 10. Alternatively, the second temperature control may be performed according to the flow chart shown in Fig. 16 as described in the following. In other words, the processing described below may be executed in step S105. Fig. 16 is a flow chart of another mode of the second temperature control. This control is performed by the ECU 10. In Fig. 16, the steps in which the same processing as in the steps in the aforementioned flow chart in Fig. 15 is performed are denoted by the same reference signs and will not be described further. A third prescribed temperature set in the process according to the flow chart in Fig. 16 is equal to the third prescribed temperature set in the process according to the flow chart in Fig. 15. Alternatively, a different value may be set as the third prescribed temperature.

[0095] In the flow chart shown in Fig. 16, if the determination made in step S802 is affirmative, the process proceeds to step S901, where the fuel injection quantity in the fuel injection through the fuel injection valve 6 that is performed to make the air-fuel ratio rich is made smaller than the second reference injection quantity. In this process, the fuel injection quantity may be decreased from the second reference injection quantity by a prescribed quantity or prescribed rate. Alternatively, the higher the temperature of the exhaust gas is, the larger the decrease in the fuel injection quantity from the second reference injection quantity may be made. The fuel injection quantity is decreased in a range in which reduction of NOx is possible.

[0096] In the flow chart shown in Fig. 16, if the determination made in step S805 is affirmative, the process proceeds to step S902, where the fuel injection quantity in the fuel injection through the fuel injection valve 6 that is performed to make the air-fuel ratio rich is made equal to the second reference injection quantity. Thereafter, the process proceeds to step S807. If the determination made in step S802 or S805 is negative, the fuel injection quantity at that time is kept unchanged.

[0097] The first flow speed control may be performed according to the flow chart shown in Fig. 12. Alternatively, the first flow speed control may be performed according to the flow chart shown in Fig. 17 as described in the following. In other words, the processing described below may be executed in step S401. Fig. 17 is a flow chart of another mode of the first flow speed control. This control is performed by the ECU 10.

[0098] In step S1001, it is determined whether or not the flow speed of the exhaust gas is higher than a third prescribed flow speed. The third prescribed flow speed is lower than the first prescribed flow speed and higher than the second prescribed flow speed. The third prescribed flow speed is set so as to prevent the flow speed of the exhaust gas from exceeding the first prescribed

flow speed due to response delay in the change of the flow speed of the exhaust gas with the change of the temperature of the exhaust gas. In this step S1001, a determination is made as to whether the exhaust gas has a flow speed at which it is possible that the amount of PM passing through the PM sensor 11 may exceed an allowable range. If the determination made in step S1001 is affirmative, the process proceeds to step S1002. If the determination made in step S1001 is negative, the process proceeds to step S1005.

[0099] In step S1002, it is determined whether or not the flow speed of the exhaust gas is increasing. Even when the flow speed of the exhaust gas is higher than the third prescribed flow speed, if the flow speed of the exhaust gas is constant or decreasing, the flow speed of the exhaust gas will not exceed the first prescribed flow speed. Then, therefore, it is concluded that it is not necessary to increase the period of injection or the injection quantity. Therefore, if the determination made in step S1002 is negative, the process of this flow chart is terminated and the processing of step S401 ends. Thus, the period of injection and the injection quantity at that time are kept unchanged if the determination made in step S1002 is negative. On the other hand, if the determination made in step S1002 is affirmative, the process proceeds to step S1003.

[0100] In step S1003, the period of fuel injection through the fuel addition valve 3 is made longer than the first reference period, and the injection quantity in one injection is made larger than the first reference injection quantity. Thus, the period of injection is prolonged and the injection quantity in one injection is increased in order to reduce the quantity of heat generated in the catalyst 4. In step S1003, the period of injection and the injection quantity may be increased from the first reference period and the first reference injection quantity by a prescribed rate. Alternatively, the larger the difference between the flow speed of the exhaust gas and the third prescribed flow speed is, the larger the increase in the period of injection from the first reference period and the increase in the injection quantity from the first reference injection quantity may be made. Then, in step S1004, the flow speed flag is set to 1. Thereafter, the process of the flow chart in Fig. 17 is terminated, and the processing of step S401 ends.

[0101] In step S1005, it is determined whether or not the flow speed of the exhaust gas is decreasing. In this step S1005, a determination is made as to whether or not it is necessary to increase the flow speed of the exhaust gas. When the flow speed of the exhaust gas is lower than or equal to the third prescribed flow speed and decreasing, the temperature of the exhaust gas is raised to increase the NOx removal rate. If the determination made in step S1005 is affirmative, the process proceeds to step S1006. If the determination made in step S1005 is negative, the process of the flow chart in Fig. 17 is terminated. When the determination made in step S1005 is negative, the period of injection and the injection quantity at that time are kept unchanged.

[0102] In step S1006, the period of fuel injection through the fuel addition valve 3 is set to the first reference period, and the injection quantity in one injection is set to the first reference injection quantity. Thus, the period of injection and the injection quantity are returned back to their initial values to prevent the decrease in the temperature of the catalyst 4, thereby increasing the NOx removal rate. Then, in step S1007, the flow speed flag is set to 0. Thereafter, the process of the flow chart in Fig. 17 is terminated, and the processing of step S401 ends.

[0103] The second flow speed control may be performed according to the flow chart shown in Fig. 13. Alternatively, the second flow speed control may be performed according to the flow chart shown in Fig. 18 as described in the following. In other words, the processing described below may be executed in step S402. Fig. 18 is a flow chart of another mode of the second flow speed control. This control is performed by the ECU 10. In Fig. 18, the steps in which the same processing as in the steps in the aforementioned flow chart in Fig. 17 is performed are denoted by the same reference signs and will not be described further. A third prescribed flow speed set in the process according to the flow chart in Fig. 18 is equal to the third prescribed flow speed set in the process according to the flow chart in Fig. 17. Alternatively, a different value may be set as the third prescribed flow speed.

[0104] In the flow chart shown in Fig. 18, if the determination made in step S1002 is affirmative, the process proceeds to step S1101, where the fuel injection quantity in the fuel injection through the fuel injection valve 6 that is performed to make the air-fuel ratio rich is made smaller than the second reference injection quantity. In this process, the fuel injection quantity may be decreased from the second reference injection quantity by a prescribed quantity or prescribed rate. Alternatively, the higher the flow speed of the exhaust gas is, the larger the decrease in the fuel injection quantity from the second reference injection quantity may be made. The fuel injection quantity is decreased in a range in which reduction of NOx is possible.

[0105] In the flow chart shown in Fig. 18, if the determination made in step S1005 is affirmative, the process proceeds to step S1102, where the fuel injection quantity in the fuel injection through the fuel injection valve 6 that is performed to make the air-fuel ratio rich is made equal to the second reference injection quantity. Thereafter, the process proceeds to step S1007. If the determination made in step S1002 or S1005 is negative, the fuel injection quantity at that time is kept unchanged.

[0106] In steps S202, S502, S803, and S1003, since the quantity of heat generated in the catalyst 4 is decreased by making the period of injection through the fuel addition valve 3 longer than the first reference period and making the injection quantity larger than the first reference injection quantity, the total injection quantity per

unit time is not changed. However, in cases where making the determination as to whether the filter 5 is abnormal is given a higher priority than the reduction of NOx, the quantity of heat generated in the catalyst 4 may be decreased by decreasing the total injection quantity per unit time. In this case, the period of injection through the fuel addition valve 3 may be made longer than the first reference period and the injection quantity may be made larger than the first reference injection quantity, or alternatively the period of injection may be made equal to the first reference period and the injection quantity may be made smaller than the first reference injection quantity. Alternatively, the quantity of heat generated in the catalyst 4 may be decreased by suspending the supply of HC to the catalyst 4 through the fuel addition valve 3.

[0107] In steps S301, S601, S901, and S1101, the quantity of heat generated in the catalyst 4 is decreased by making the fuel injection quantity in the fuel injection into the cylinder through the fuel injection valve 6 that is performed to make the air-fuel ratio rich smaller than the second reference injection quantity. In this case, the removal of NOx by the second NOx removal method is continued. However, in cases where making the determination as to whether the filter 5 is abnormal is given a higher priority than the reduction of NOx, the removal of NOx by the second NOx removal method may be suspended. In other words, the supply of HC to the catalyst 4 may be suspended. Thus, the quantity of heat generated in the catalyst 4 can be decreased.

[0108] In this embodiment, one of the first and second NOx removal methods is selected based on the engine rotational speed and the temperature of the catalyst 4, and the first temperature control, the first flow speed control, the second temperature control, or the second flow speed control is performed to adjust the quantity of heat generated while the first NOx removal method is carried out or while the second NOx removal method is carried out. Alternatively, the first temperature control or the first flow speed control may be performed to adjust the quantity of heat generated only while the first NOx removal method is carried out. In other words, the second temperature control and the second flow speed control may not be performed while the second NOx removal method is carried out.

[0109] As described above, in this embodiment, when there is a possibility that the correlation between the amount of PM deposited in the PM sensor 11 and the quantity of PM in the exhaust gas may become low while letting PM deposit in the PM sensor 11 for the purpose of determining whether the filter 5 is normal or abnormal, the quantity of heat generated in the catalyst 4 is decreased. In consequence, the correlation between the amount of PM deposited in the PM sensor 11 and the quantity of PM in the exhaust gas can be maintained satisfactorily, and therefore it is possible to improve the accuracy of determination as to abnormality of the filter 5.

Reference Signs List

[0110]

1: internal combustion engine
2: exhaust passage
3: fuel addition valve
4: catalyst
5: filter
6: fuel injection valve
7: intake passage
10: ECU
11: PM sensor
12: temperature sensor
15: accelerator opening degree sensor
16: crank position sensor
17: air flow meter

Claims

1. An abnormality detection apparatus for a filter comprising:

a filter (5) that is provided in an exhaust passage (2) of an internal combustion engine (1) to trap particulate matter in exhaust gas;
a catalyst (4) that is provided in the exhaust passage (2) and removes NOx with supply of HC;
an HC supply unit (3) that supplies HC to the catalyst (4);
a PM sensor (11) that detects particulate matter in the exhaust gas at a location downstream of the filter (5) and the catalyst (4) and outputs a signal representing the particulate matter deposited in the PM sensor (11);
a determination unit that is configured to determine whether or not the filter (5) has an abnormality, on the basis of an output value of the PM sensor (11); and
a control unit (10) that is configured to cause the HC supply unit (3) to supply HC to the catalyst (4),
characterized in that the control unit (10) is configured, while particulate matter is made to deposit in the PM sensor (11) in order for the determination unit to determine whether or not the filter (5) has an abnormality, to cause the HC supply unit (3) to supply HC to the catalyst (4) in such a way as to make the quantity of heat generated in the catalyst (4) smaller when the temperature around the PM sensor (11) is higher than a prescribed temperature than when the temperature around the PM sensor (11) is lower than the prescribed temperature, or when the flow speed around the PM sensor (11) is higher than a prescribed flow speed than when the flow speed around the PM sensor (11) is lower than

the prescribed flow speed, whereby preventing or reducing the rise in the temperature of the exhaust gas when the temperature around the PM sensor (11) is higher than the prescribed temperature or when the flow speed around the PM sensor (11) is higher than the prescribed flow speed.

2. An abnormality detection apparatus for a filter according to claim 1, wherein the prescribed temperature is a temperature at which particulate matter deposited in the PM sensor (11) is oxidized.

3. An abnormality detection apparatus for a filter according to claim 1, wherein the prescribed flow speed is a flow speed at which the ratio of the quantity of particulate matter depositing in the PM sensor (11) to the quantity of particulate matter reaching the PM sensor (11) becomes a prescribed allowable value.

4. An abnormality detection apparatus for a filter according to any one of claims 1 to 3, wherein a noble metal catalyst is carried on the surface of the catalyst (4), a basic layer is formed around the noble metal catalyst, and the catalyst (4) has a property of reducing NOx in the exhaust gas with a reductive intermediate generated in the catalyst (4) by supplying a prescribed quantity of HC periodically at a period in a prescribed range by the HC supply unit (3) and has a property of being increased in storage quantity of NOx in the exhaust gas if the period of supply of HC by the HC supply unit (3) is made longer than the prescribed range, and
the control unit (10) is configured to prolong the period of supply of HC and increase the quantity of HC supplied in one supply without changing the quantity of HC supplied per unit time, when causing the HC supply unit (3) to supply the prescribed quantity of HC periodically at a period in the predetermine range to thereby reduce NOx in the exhaust gas by the reductive intermediate generated in the catalyst (4) in such a way as to decrease the quantity of heat generated in the catalyst (4).

Patentansprüche

1. Abnormalitätsdetektionsapparat für einen Filter, der aufweist:

einen Filter (5), der in einem Auslassdurchgang (2) eines Verbrennungsmotors (1) bereitgestellt ist, um Feinstaub in einem Abgas zu fangen,
einen Katalysator (4), der in dem Auslassdurchgang (2) bereitgestellt ist und NOx mit Zufuhr von HC entfernt,
eine HC-Zufuhreinheit (3), die HC an den Katalysator (4) liefert,
einen PM-Messwertgeber (11), der Feinstaub in dem Abgas an einer Stelle stromabwärts des Filters (5) und des Katalysators (4) detektiert und ein Signal, das den in dem PM-Messwertgeber (11) abgelagerten Feinstaub repräsentiert, ausgibt,
eine Bestimmungseinheit, die konfiguriert ist, um zu bestimmen, ob der Filter (5) eine Abnormalität hat oder nicht, und zwar auf der Grundlage eines Ausgabewerts des PM-Messwertgebers (11), und
eine Steuerungseinheit (10), die konfiguriert ist, um die HC-Zufuhreinheit (3) zu veranlassen, HC an den Katalysator (4) zu liefern,
dadurch gekennzeichnet, dass die Steuerungseinheit (10) konfiguriert ist, um, während Feinstaub in den PM-Messwertgeber (11) ablagern gelassen wird, damit die Bestimmungseinheit bestimmen kann, ob der Filter (5) eine Abnormalität hat oder nicht, die HC-Zufuhreinheit (3) zu veranlassen, HC an den Katalysator (4) zu liefern, und zwar in solch einer Weise, um die Menge von Wärme, die in dem Katalysator (4) erzeugt wird, kleiner zu machen, wenn die Temperatur um den PM-Messwertgeber (11) höher als eine vorgeschriebene Temperatur ist, im Vergleich dazu, wenn die Temperatur um den PM-Messwertgeber (11) niedriger als die vorgeschriebene Temperatur ist, oder wenn die Strömungsgeschwindigkeit um den PM-Messwertgeber (11) höher als eine vorgeschriebene Strömungsgeschwindigkeit ist, im Vergleich dazu, wenn die Strömungsgeschwindigkeit um den PM-Messwertgeber (11) niedriger als die vorgeschriebene Strömungsgeschwindigkeit ist, wodurch der Anstieg der Temperatur des Abgases verhindert oder reduziert wird, wenn die Temperatur um den PM-Messwertgeber (11) höher als die vorgeschriebene Temperatur ist oder wenn die Strömungsgeschwindigkeit um den PM-Messwertgeber (11) höher als die vorgeschriebene Strömungsgeschwindigkeit ist.

2. Abnormalitätsdetektionsapparat für einen Filter gemäß Anspruch 1, wobei die vorgeschriebene Temperatur eine Temperatur ist, bei der ein in dem PM-Messwertgeber (11) abgelagerter Feinstaub oxidiert wird.

3. Abnormalitätsdetektionsapparat für einen Filter gemäß Anspruch 1, wobei die vorgeschriebene Strömungsgeschwindigkeit eine Strömungsgeschwindigkeit ist, bei der das Verhältnis der Menge von Feinstaub, die sich in dem PM-Messwertgeber (11) ablagert, zu der Menge von Feinstaub, die den PM-Messwertgeber (11) erreicht, ein vorgeschriebener zulässiger Wert wird.

4. Abnormalitätsdetektionsapparat für einen Filter gemäß einem der Ansprüche 1 bis 3, wobei ein Edelmetallkatalysator auf der Oberfläche des Katalysators (4) getragen wird, eine Basisschicht um den Edelmetallkatalysator gebildet ist und der Katalysator (4) eine Eigenschaft eines Reduzierens von NOx in dem Abgas mit einem reduzierenden Zwischenprodukt, das in dem Katalysator (4) durch ein periodisches Zuführen einer vorgeschriebenen Menge von HC bei einem Zeitabschnitt in einem vorgeschriebenen Bereich durch die HC-Zufuhreinheit (3) erzeugt wird, hat und eine Eigenschaft eines Erhöhtwerdens bei einer Speichermenge von NOx in dem Abgas hat, falls der Zeitabschnitt einer Zufuhr von HC durch die HC-Zufuhreinheit (3) länger als der vorgeschriebene Bereich gemacht wird, und
die Steuerungseinheit (10) konfiguriert ist, um den Zeitabschnitt einer Zufuhr von HC zu verlängern und die Menge von HC, die in einer Zufuhr zugeführt wird, zu erhöhen, ohne die pro Einheit Zeit zugeführte Menge von HC zu ändern, wenn die HC-Zufuhreinheit (3) veranlasst wird, die vorgeschriebene Menge von HC periodisch bei einem Zeitabschnitt in dem vorgegebenen Bereich zuzuführen, um damit NOx in dem Abgas durch das reduzierende Zwischenprodukt, das in dem Katalysator (4) erzeugt wird, zu reduzieren, und zwar in solch einer Weise, um die Menge von in dem Katalysator (4) erzeugter Wärme zu verringern.

Revendications

1. Appareil de détection d'anomalie pour un filtre comprenant:

   un filtre (5) qui est disposé dans un passage d'échappement (2) d'un moteur à combustion interne (1) pour piéger les matières particulaires dans les gaz d'échappement;
   un catalyseur (4) qui est disposé dans le passage d'échappement (2) et retire NOx avec fourniture de HC;
   une unité de fourniture de HC (3) qui fournit HC au catalyseur (4);
   un capteur de MP (11) qui détecte les matières particulaires dans les gaz d'échappement à un emplacement en aval du filtre (5) et du catalyseur (4) et émet un signal représentant les matières particulaires déposées dans le capteur de MP (11);
   une unité de détermination qui est configurée pour déterminer si le filtre (5) a une anomalie, sur la base d'une valeur d'émission du capteur de MP (11); et
   une unité de commande (10) qui est configurée pour amener l'unité de fourniture de HC (3) à fournir HC au catalyseur (4),

   caractérisé en ce que l'unité de commande (10) est configurée, tandis que les matières particulaires sont amenées à se déposer dans le capteur de MP (11) pour que l'unité de détermination détermine si le filtre (5) a une anomalie, pour amener l'unité de fourniture de HC (3) à fournir HC au catalyseur (4) de manière à rendre la quantité de chaleur générée dans le catalyseur (4) plus faible quand la température autour du capteur de MP (11) est supérieure à une température prescrite que quand la température autour du capteur de MP (11) est inférieure à la température prescrite, ou quand la vitesse d'écoulement autour du capteur de MP (11) est supérieure à une vitesse d'écoulement prescrite que quand la vitesse d'écoulement autour du capteur de MP (11) est inférieure à la vitesse d'écoulement prescrite, pour empêcher ou réduire la montée en température des gaz d'échappement quand la température autour du capteur de MP (11) est supérieure à la température prescrite ou quand la vitesse d'écoulement autour du capteur de MP (11) est supérieure à la vitesse d'écoulement prescrite.

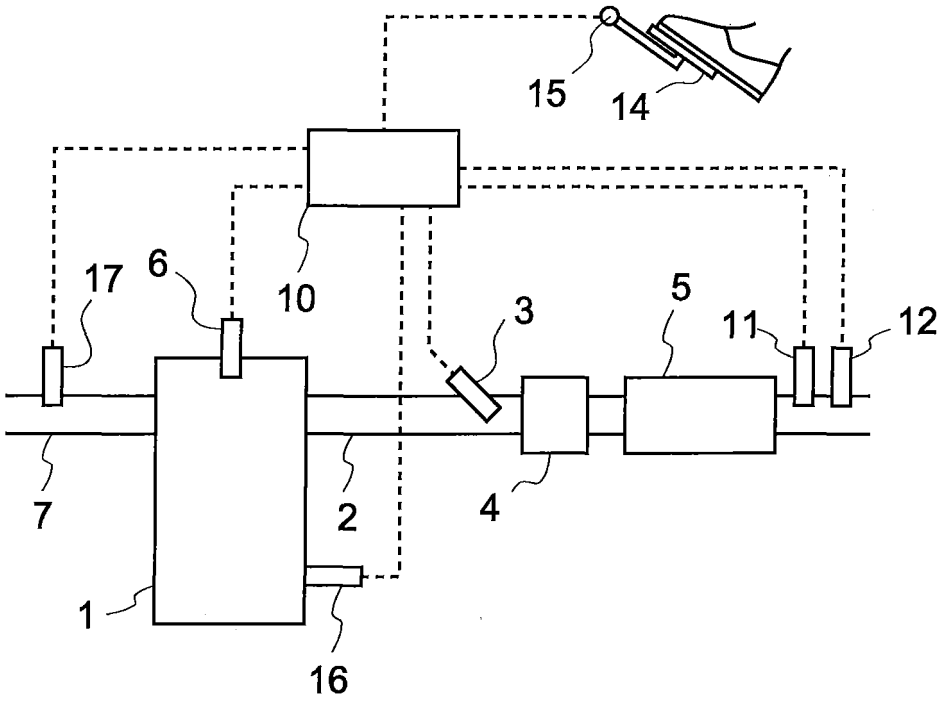
2. Appareil de détection d'anomalie pour un filtre selon la revendication 1, où la température prescrite est une température à laquelle les matières particulaires déposées dans le capteur de MP (11) sont oxydées.

3. Appareil de détection d'anomalie pour un filtre selon la revendication 1, où la vitesse d'écoulement prescrite est une vitesse d'écoulement à laquelle le rapport de la quantité de matières particulaires qui se déposent dans le capteur de MP (11) à la quantité de matières particulaires qui atteignent le capteur de MP (11) devient une valeur admissible prescrite.

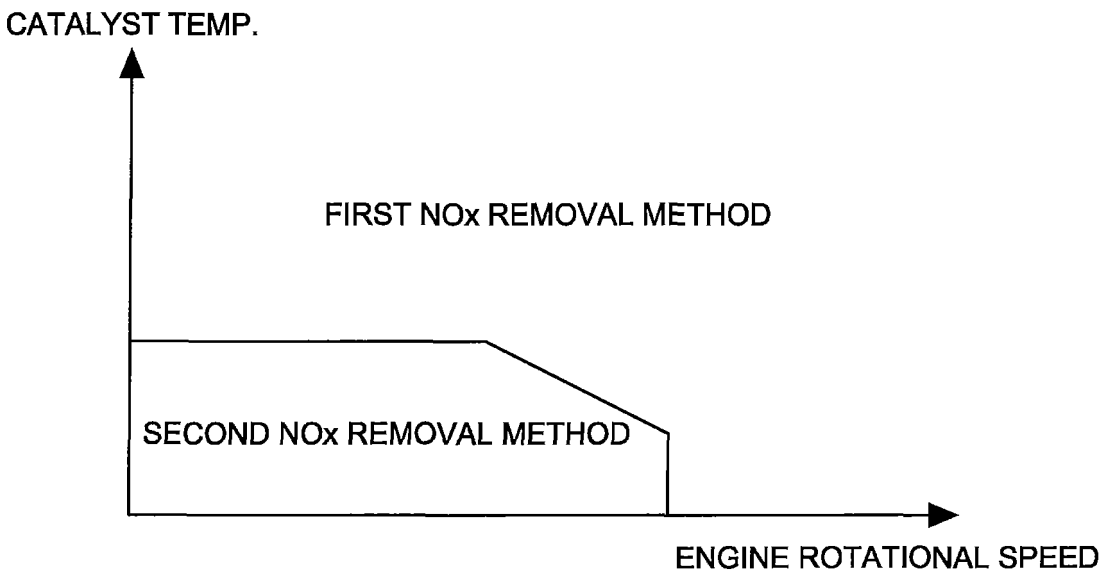
4. Appareil de détection d'anomalie pour un filtre selon l'une quelconque des revendications 1 à 3, où un catalyseur à métal noble est porté sur la surface du catalyseur (4), une couche basique est formée autour du catalyseur à métal noble, et le catalyseur (4) a une propriété de réduire NOx dans les gaz d'échappement avec un intermédiaire réducteur généré dans le catalyseur (4) par fourniture d'une quantité prescrite de HC périodiquement à une période dans une plage prescrite par l'unité de fourniture de HC (3) et a une propriété d'avoir une quantité de stockage de NOx dans les gaz d'échappement accrue si la période de fourniture de HC par l'unité de fourniture de HC (3) est rendue plus longue que la plage prescrite, et
   l'unité de commande (10) est configurée pour prolonger la période de fourniture de HC et augmenter la quantité de HC fournie dans une fourniture sans changer la quantité de HC fournie par unité de temps, quand l'unité de fourniture de HC (3) est amenée à

fournir la quantité prescrite de HC périodiquement à une période dans la plage prédéterminée pour réduire ainsi NOx dans les gaz d'échappement par l'intermédiaire réducteur généré dans le catalyseur (4) de manière à diminuer la quantité de chaleur générée dans le catalyseur (4).

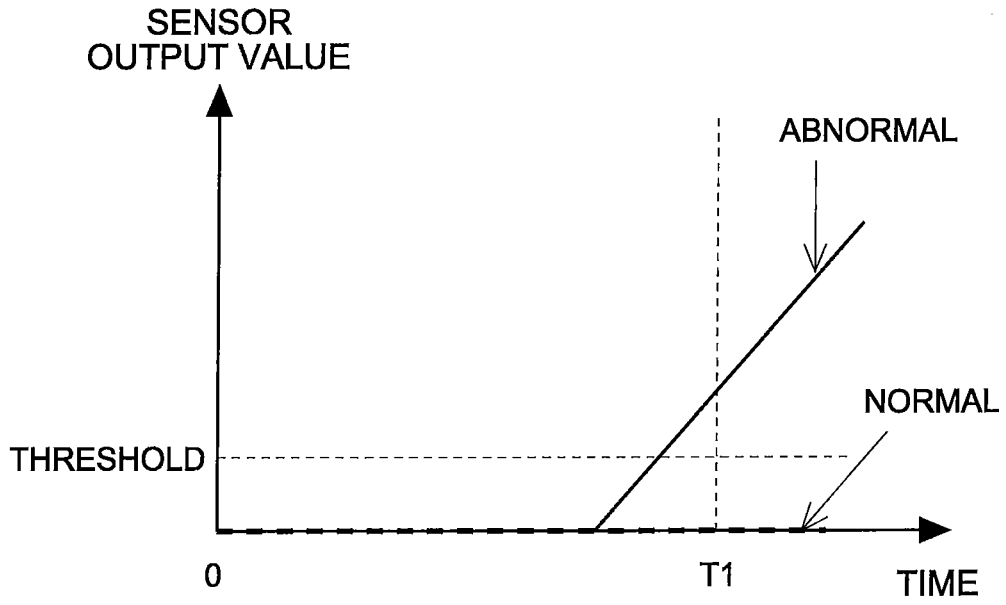
[FIG. 1]


15
14
17
6
10
3
5
11
12
7
2
4
1
16

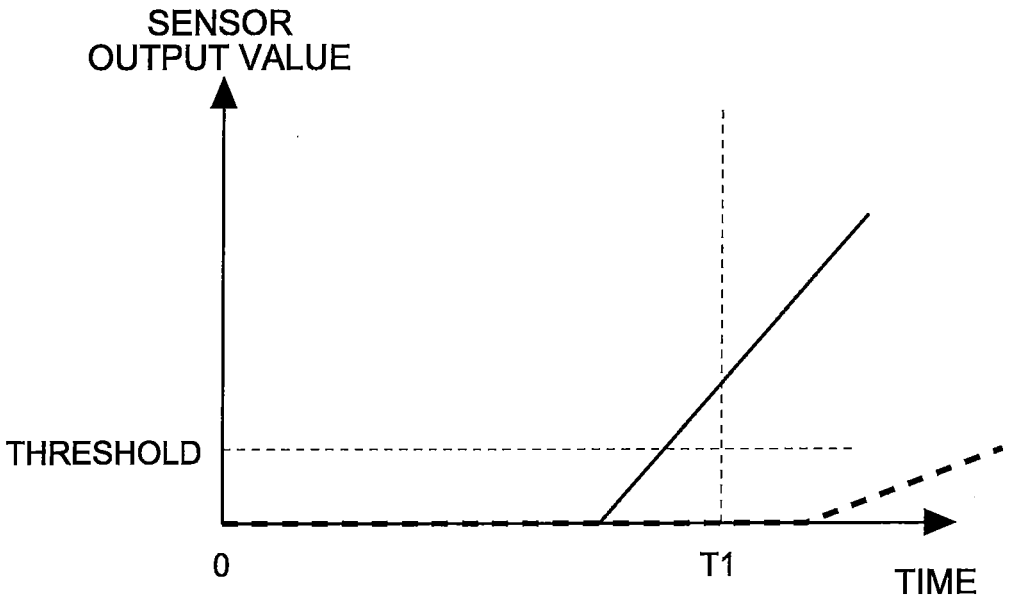
[FIG. 2]


CATALYST TEMP.
FIRST NOx REMOVAL METHOD
SECOND NOx REMOVAL METHOD
ENGINE ROTATIONAL SPEED

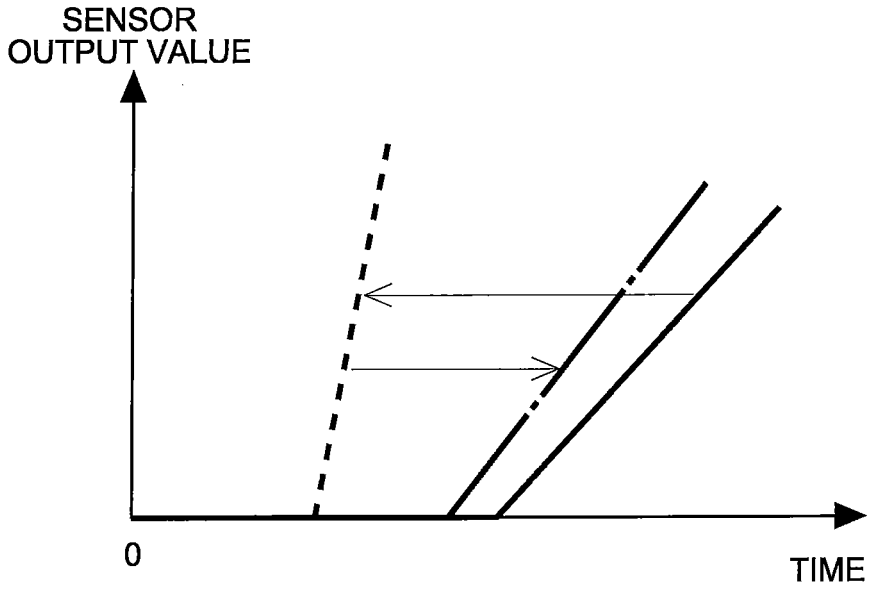
[FIG. 3]


SENSOR
OUTPUT VALUE
ABNORMAL
NORMAL
THRESHOLD
0
T1
TIME

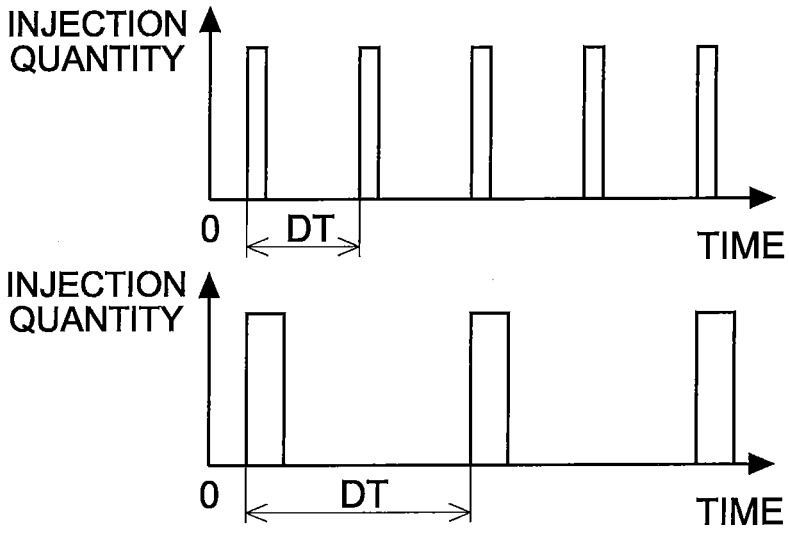
[FIG. 4]


SENSOR
OUTPUT VALUE
THRESHOLD
0
T1
TIME

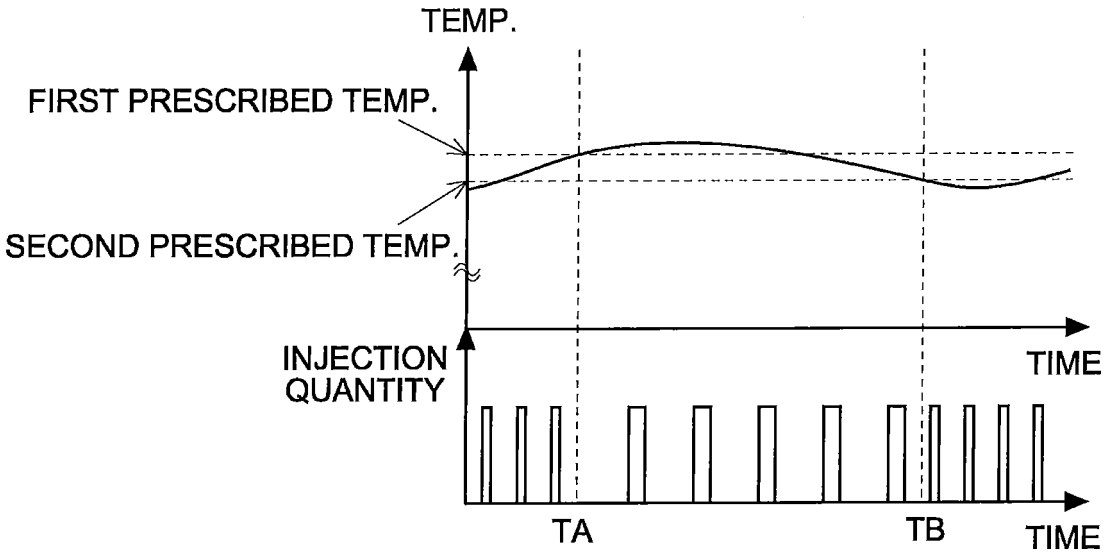
[FIG. 5]


SENSOR
OUTPUT VALUE
0
TIME

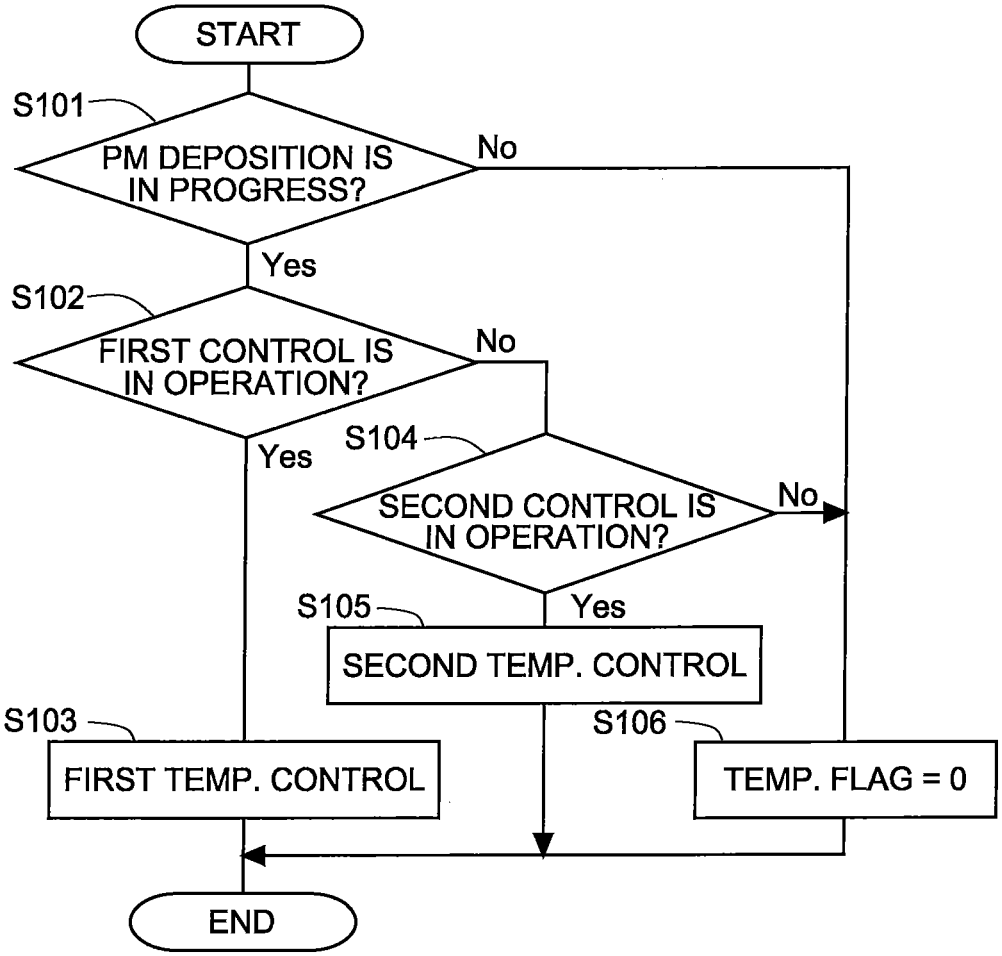
[FIG. 6]


INJECTION
QUANTITY
0
DT
TIME
INJECTION
QUANTITY
0
DT
TIME

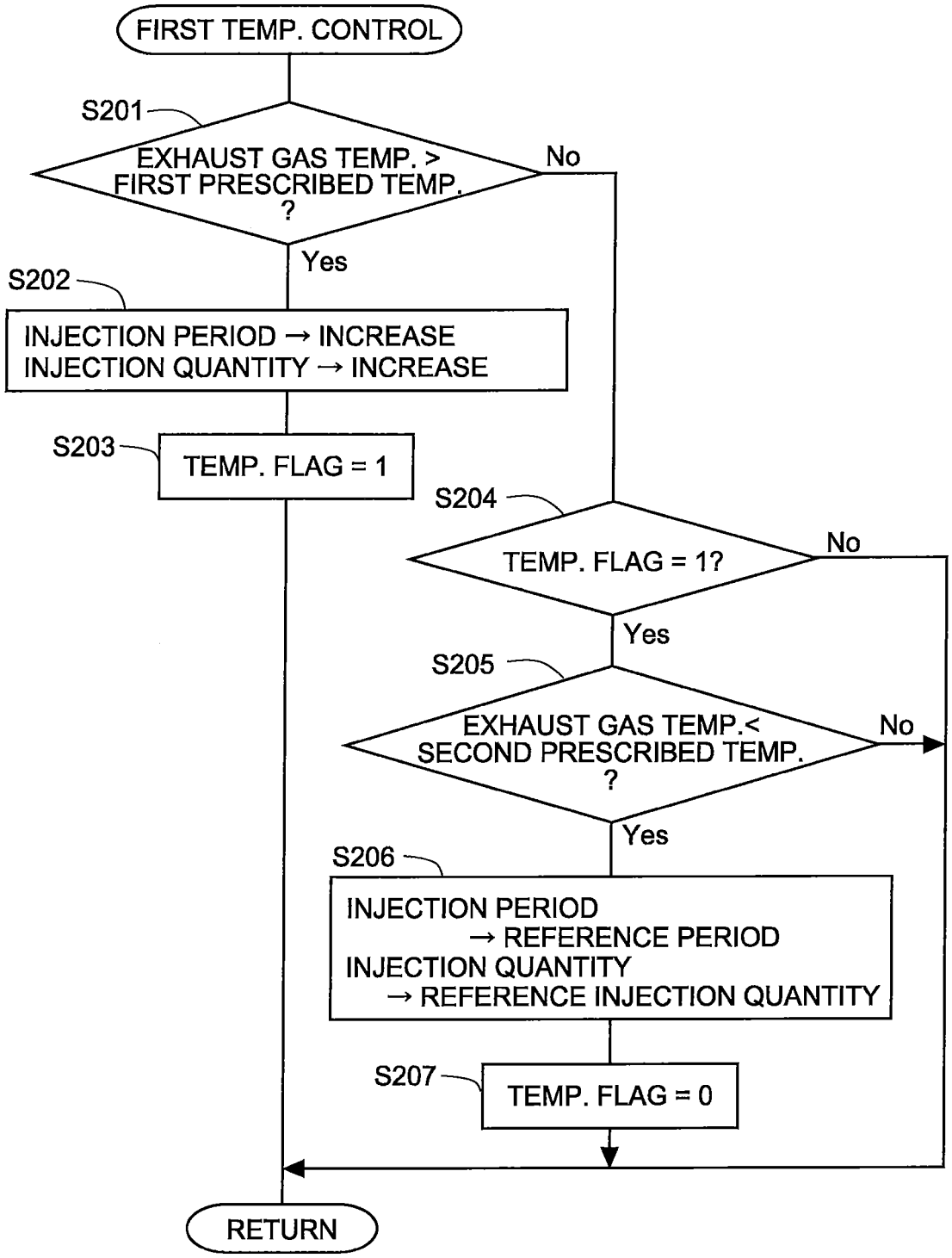
[FIG. 7]


TEMP.
FIRST PRESCRIBED TEMP.
SECOND PRESCRIBED TEMP.
INJECTION QUANTITY
TIME
TA
TB
TIME

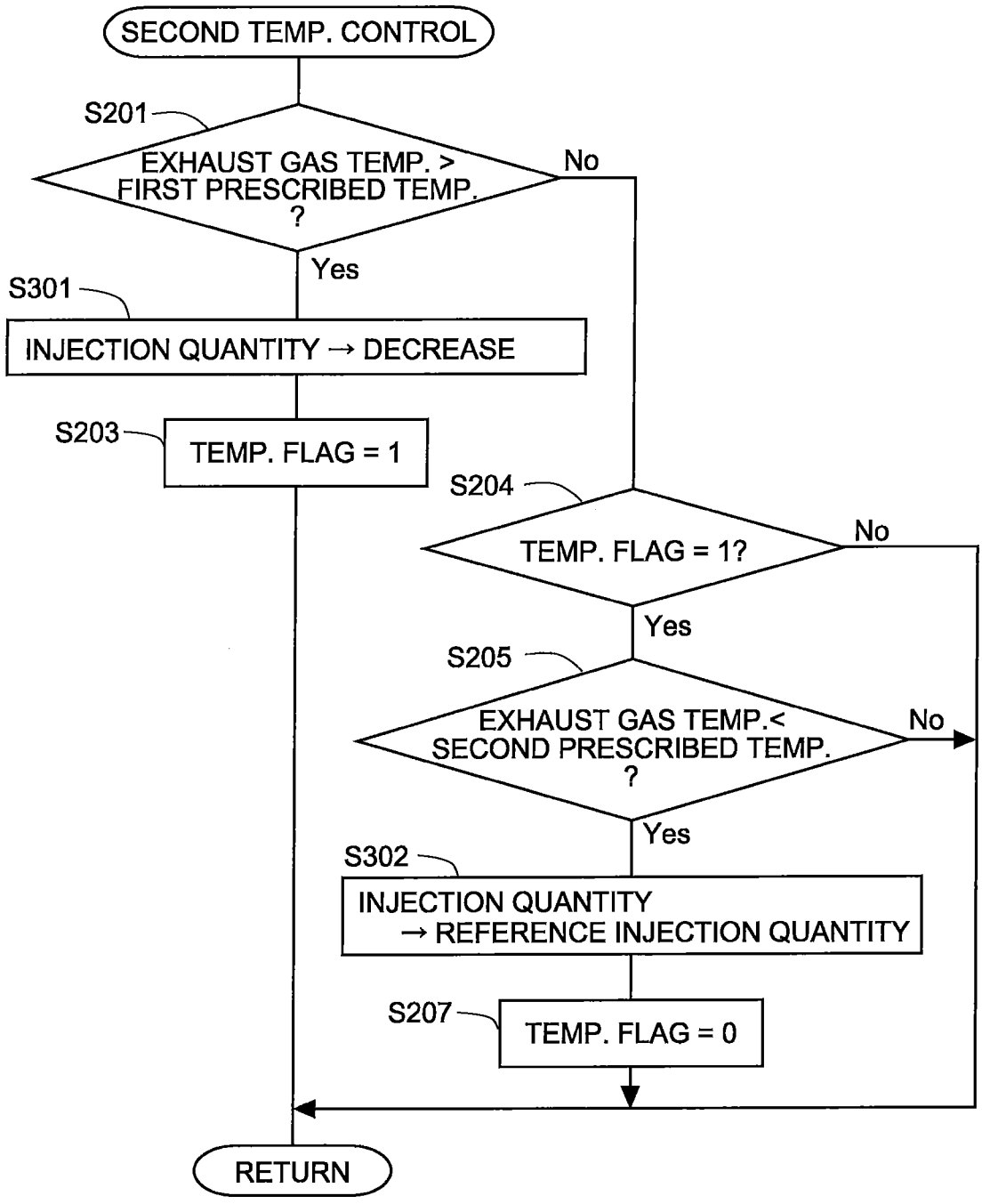
[FIG. 8]


START
S101
PM DEPOSITION IS IN PROGRESS?
No
Yes
S102
FIRST CONTROL IS IN OPERATION?
No
Yes
S104
SECOND CONTROL IS IN OPERATION?
No
Yes
S105
SECOND TEMP. CONTROL
S103
FIRST TEMP. CONTROL
S106
TEMP. FLAG = 0
END

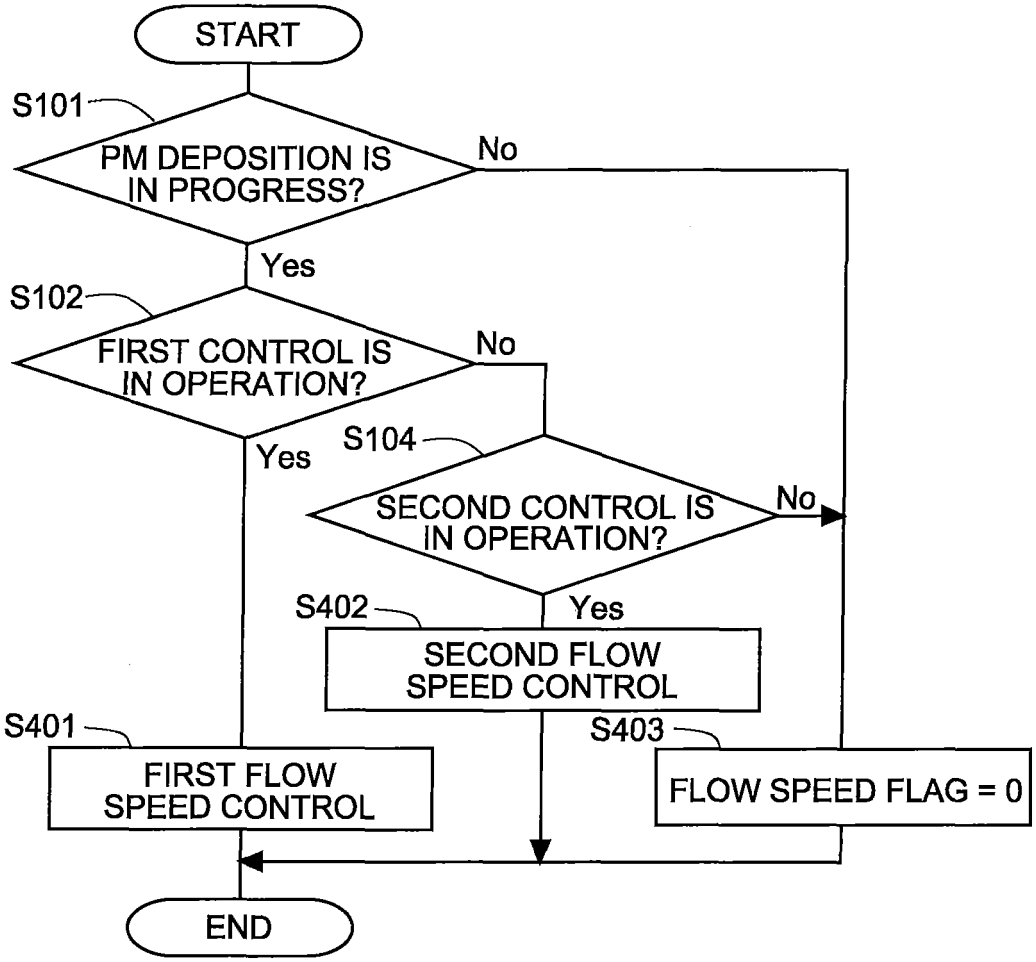
[FIG. 9]


FIRST TEMP. CONTROL
S201
EXHAUST GAS TEMP. > FIRST PRESCRIBED TEMP. ?
No
Yes
S202
INJECTION PERIOD → INCREASE
INJECTION QUANTITY → INCREASE
S203
TEMP. FLAG = 1
S204
TEMP. FLAG = 1?
No
Yes
S205
EXHAUST GAS TEMP.< SECOND PRESCRIBED TEMP. ?
No
Yes
S206
INJECTION PERIOD → REFERENCE PERIOD
INJECTION QUANTITY → REFERENCE INJECTION QUANTITY
S207
TEMP. FLAG = 0
RETURN

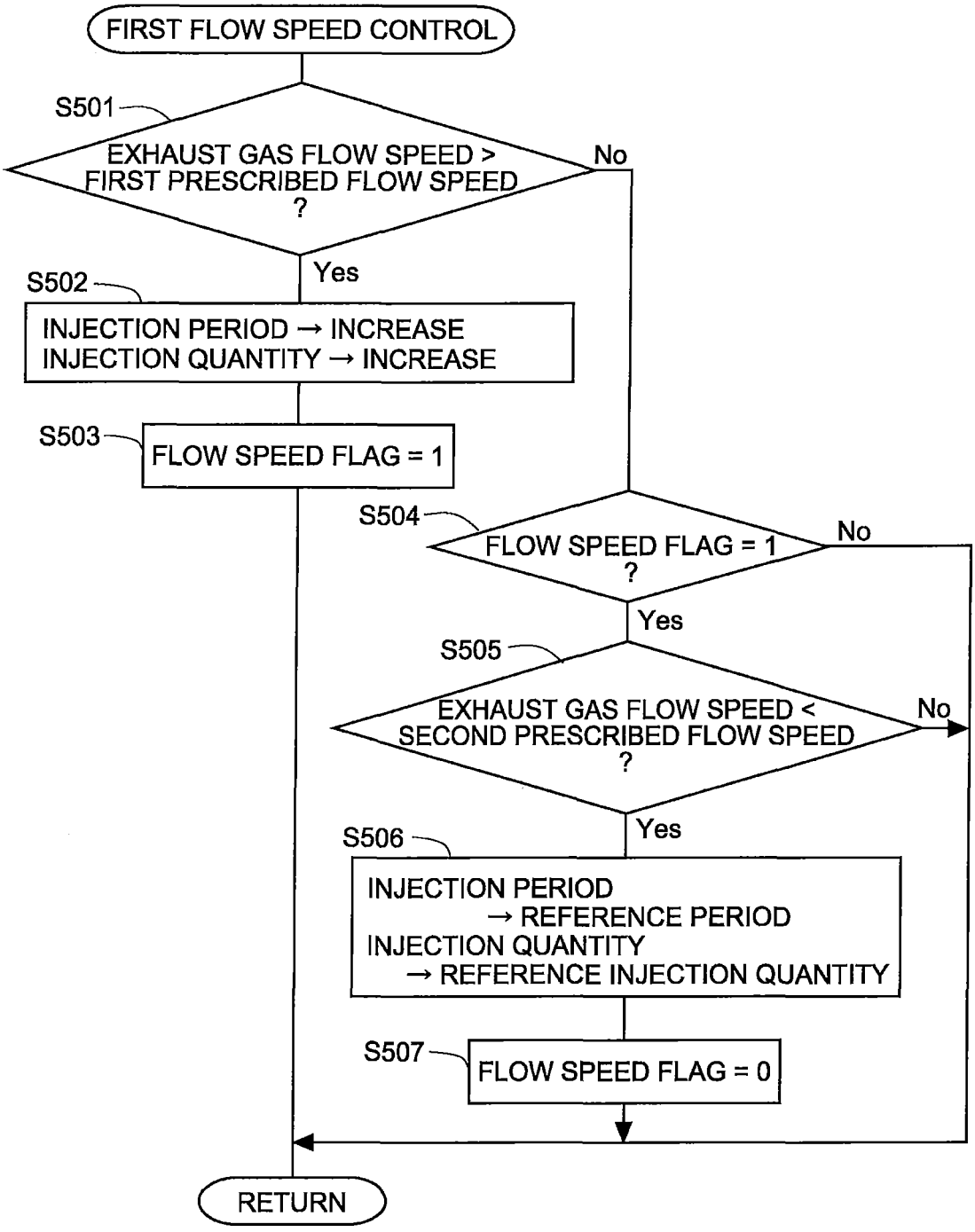
[FIG. 10]


SECOND TEMP. CONTROL
S201
EXHAUST GAS TEMP. > FIRST PRESCRIBED TEMP. ?
No
Yes
S301
INJECTION QUANTITY → DECREASE
S203
TEMP. FLAG = 1
S204
TEMP. FLAG = 1?
No
Yes
S205
EXHAUST GAS TEMP.< SECOND PRESCRIBED TEMP. ?
No
Yes
S302
INJECTION QUANTITY → REFERENCE INJECTION QUANTITY
S207
TEMP. FLAG = 0
RETURN

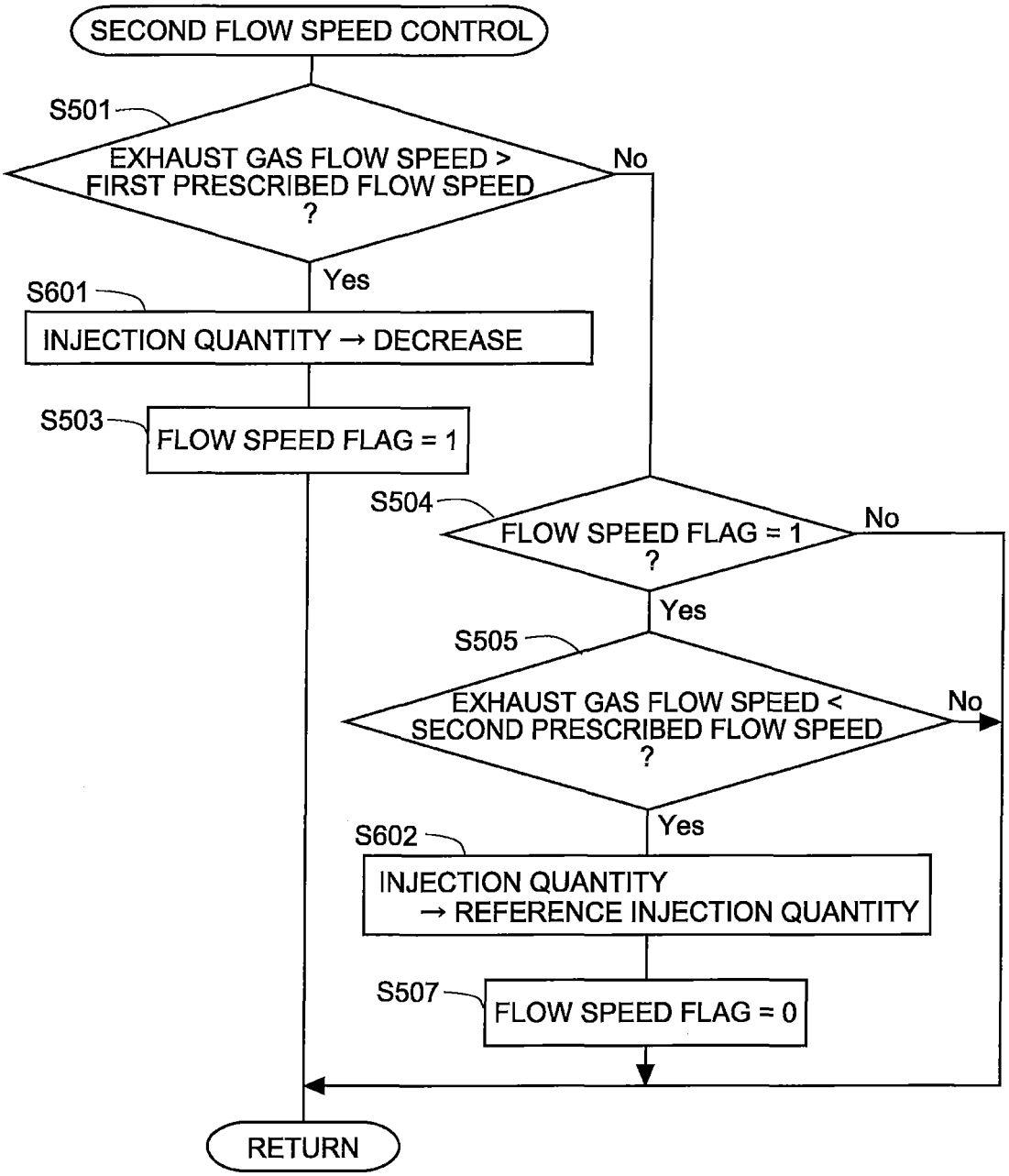
[FIG. 11]


START
S101
PM DEPOSITION IS IN PROGRESS?
No
Yes
S102
FIRST CONTROL IS IN OPERATION?
No
Yes
S104
SECOND CONTROL IS IN OPERATION?
No
Yes
S402
SECOND FLOW SPEED CONTROL
S401
FIRST FLOW SPEED CONTROL
S403
FLOW SPEED FLAG = 0
END

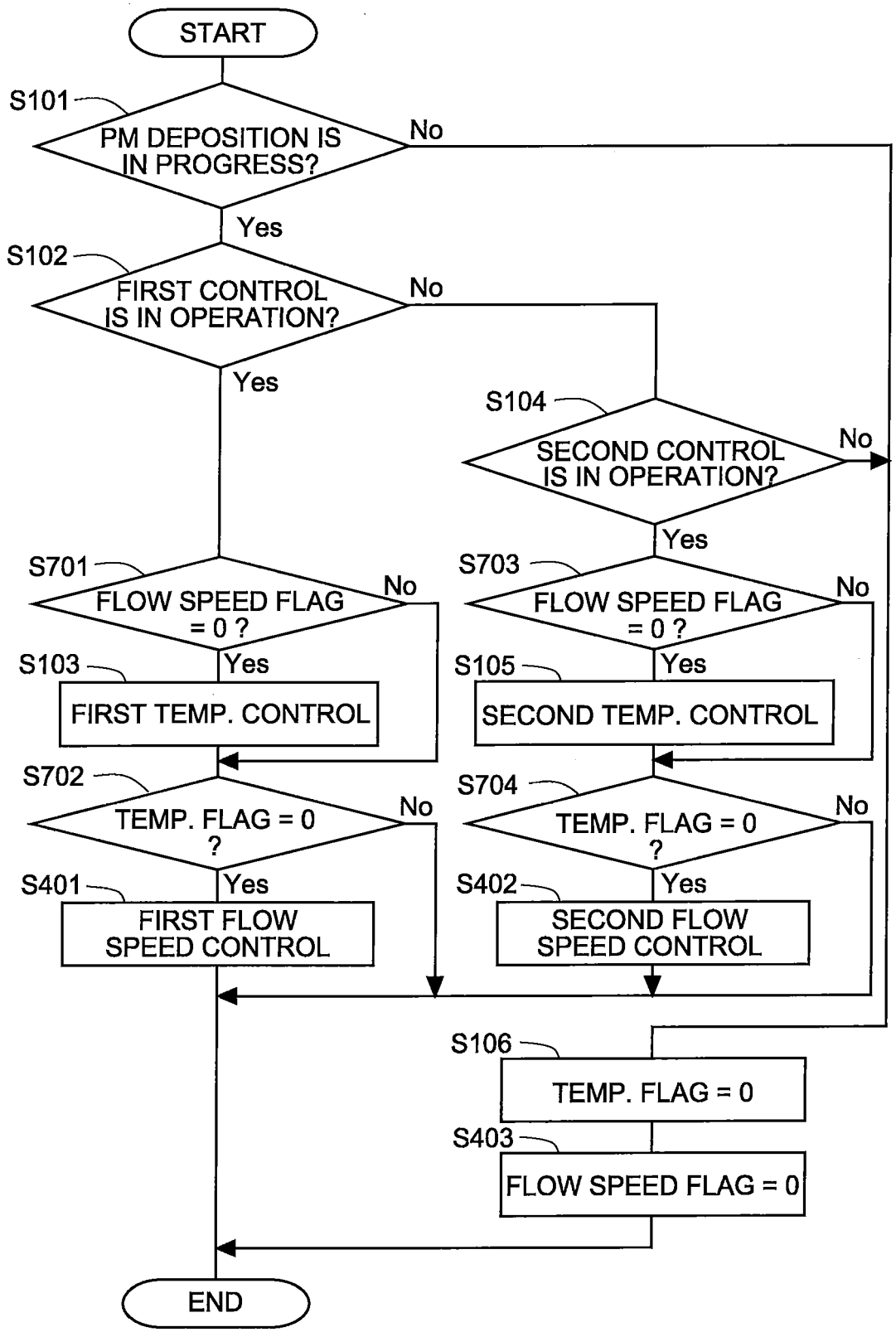
[FIG. 12]


FIRST FLOW SPEED CONTROL
S501
EXHAUST GAS FLOW SPEED > FIRST PRESCRIBED FLOW SPEED ?
No
Yes
S502
INJECTION PERIOD → INCREASE
INJECTION QUANTITY → INCREASE
S503
FLOW SPEED FLAG = 1
S504
FLOW SPEED FLAG = 1 ?
No
Yes
S505
EXHAUST GAS FLOW SPEED < SECOND PRESCRIBED FLOW SPEED ?
No
Yes
S506
INJECTION PERIOD → REFERENCE PERIOD
INJECTION QUANTITY → REFERENCE INJECTION QUANTITY
S507
FLOW SPEED FLAG = 0
RETURN

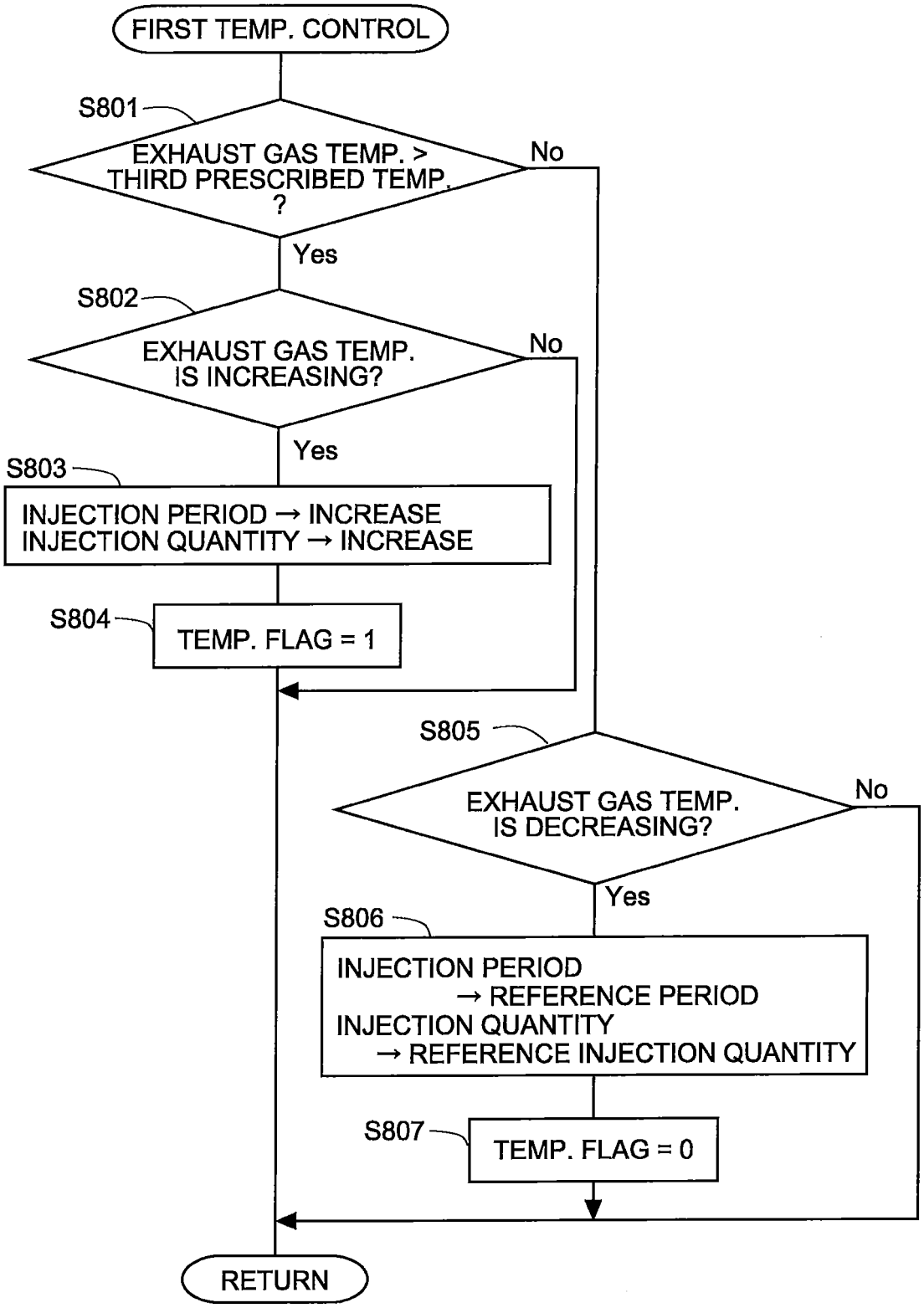
[FIG. 13]


SECOND FLOW SPEED CONTROL
S501
EXHAUST GAS FLOW SPEED > FIRST PRESCRIBED FLOW SPEED ?
No
Yes
S601
INJECTION QUANTITY → DECREASE
S503
FLOW SPEED FLAG = 1
S504
FLOW SPEED FLAG = 1 ?
No
Yes
S505
EXHAUST GAS FLOW SPEED < SECOND PRESCRIBED FLOW SPEED ?
No
Yes
S602
INJECTION QUANTITY → REFERENCE INJECTION QUANTITY
S507
FLOW SPEED FLAG = 0
RETURN

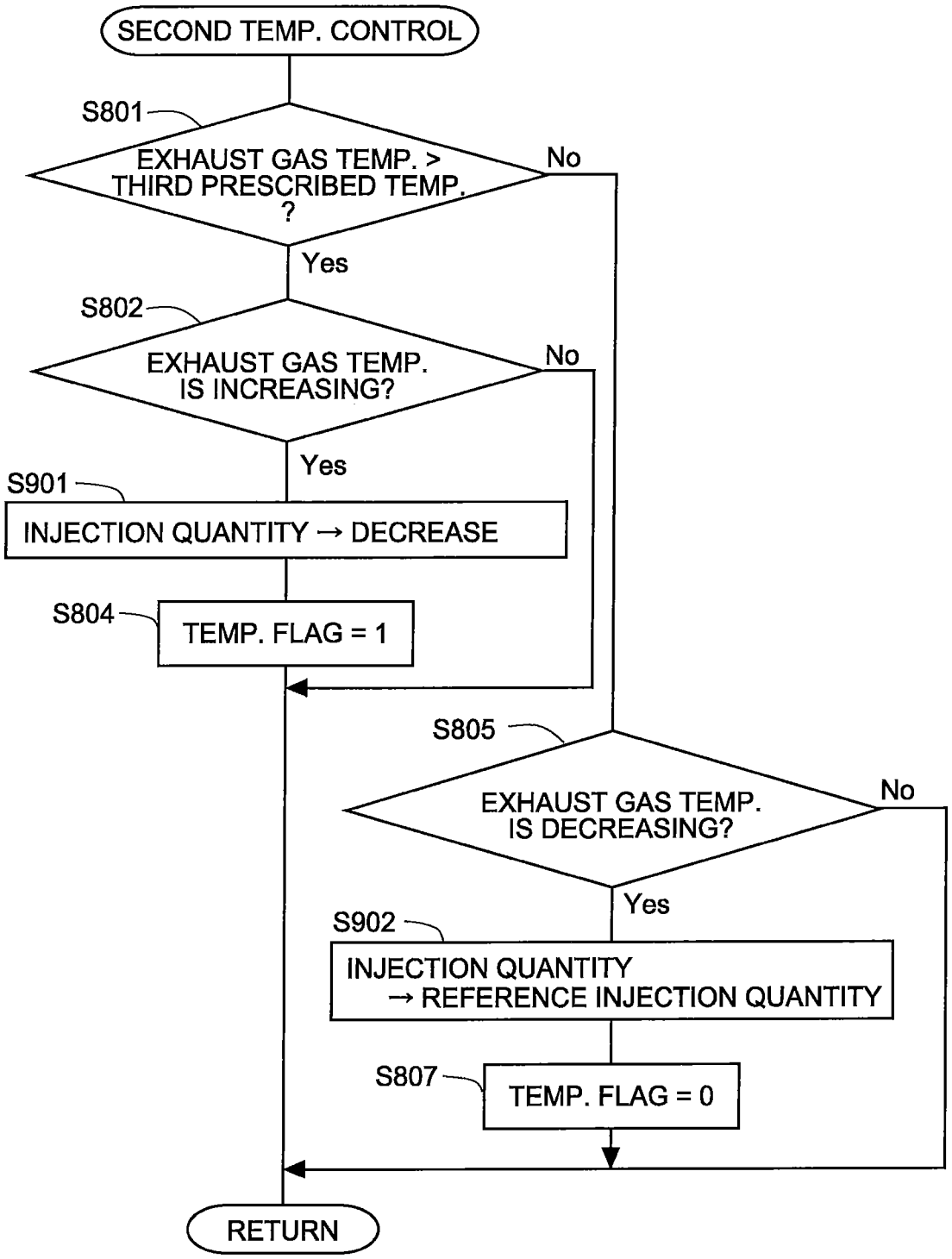
[FIG. 14]


START
S101
PM DEPOSITION IS IN PROGRESS?
No
Yes
S102
FIRST CONTROL IS IN OPERATION?
No
Yes
S104
SECOND CONTROL IS IN OPERATION?
No
Yes
S701
FLOW SPEED FLAG = 0 ?
No
Yes
S103
FIRST TEMP. CONTROL
S703
FLOW SPEED FLAG = 0 ?
No
Yes
S105
SECOND TEMP. CONTROL
S702
TEMP. FLAG = 0 ?
No
Yes
S401
FIRST FLOW SPEED CONTROL
S704
TEMP. FLAG = 0 ?
No
Yes
S402
SECOND FLOW SPEED CONTROL
S106
TEMP. FLAG = 0
S403
FLOW SPEED FLAG = 0
END

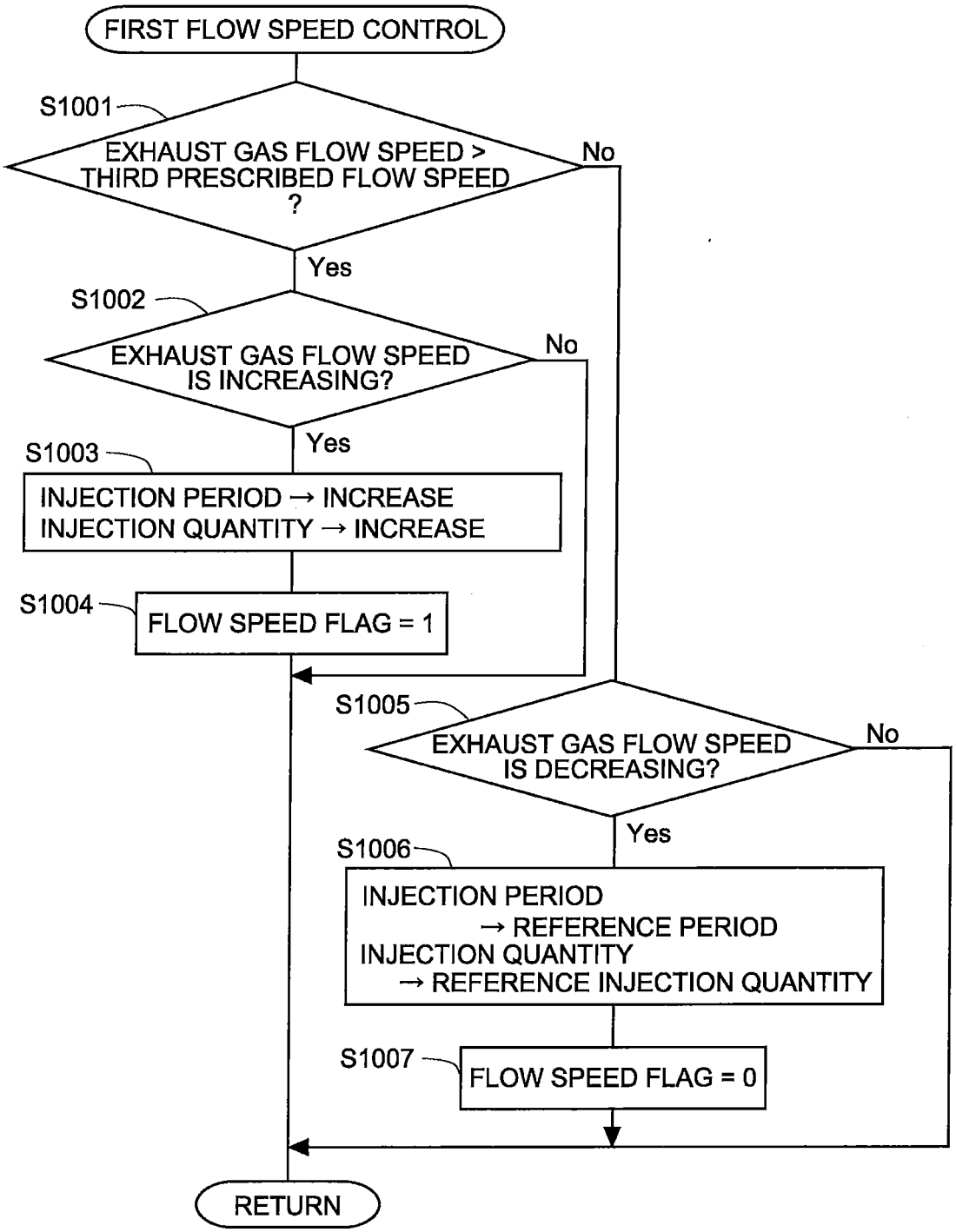
[FIG. 15]


FIRST TEMP. CONTROL
S801
EXHAUST GAS TEMP. > THIRD PRESCRIBED TEMP. ?
No
Yes
S802
EXHAUST GAS TEMP. IS INCREASING?
No
Yes
S803
INJECTION PERIOD → INCREASE
INJECTION QUANTITY → INCREASE
S804
TEMP. FLAG = 1
S805
EXHAUST GAS TEMP. IS DECREASING?
No
Yes
S806
INJECTION PERIOD → REFERENCE PERIOD
INJECTION QUANTITY → REFERENCE INJECTION QUANTITY
S807
TEMP. FLAG = 0
RETURN

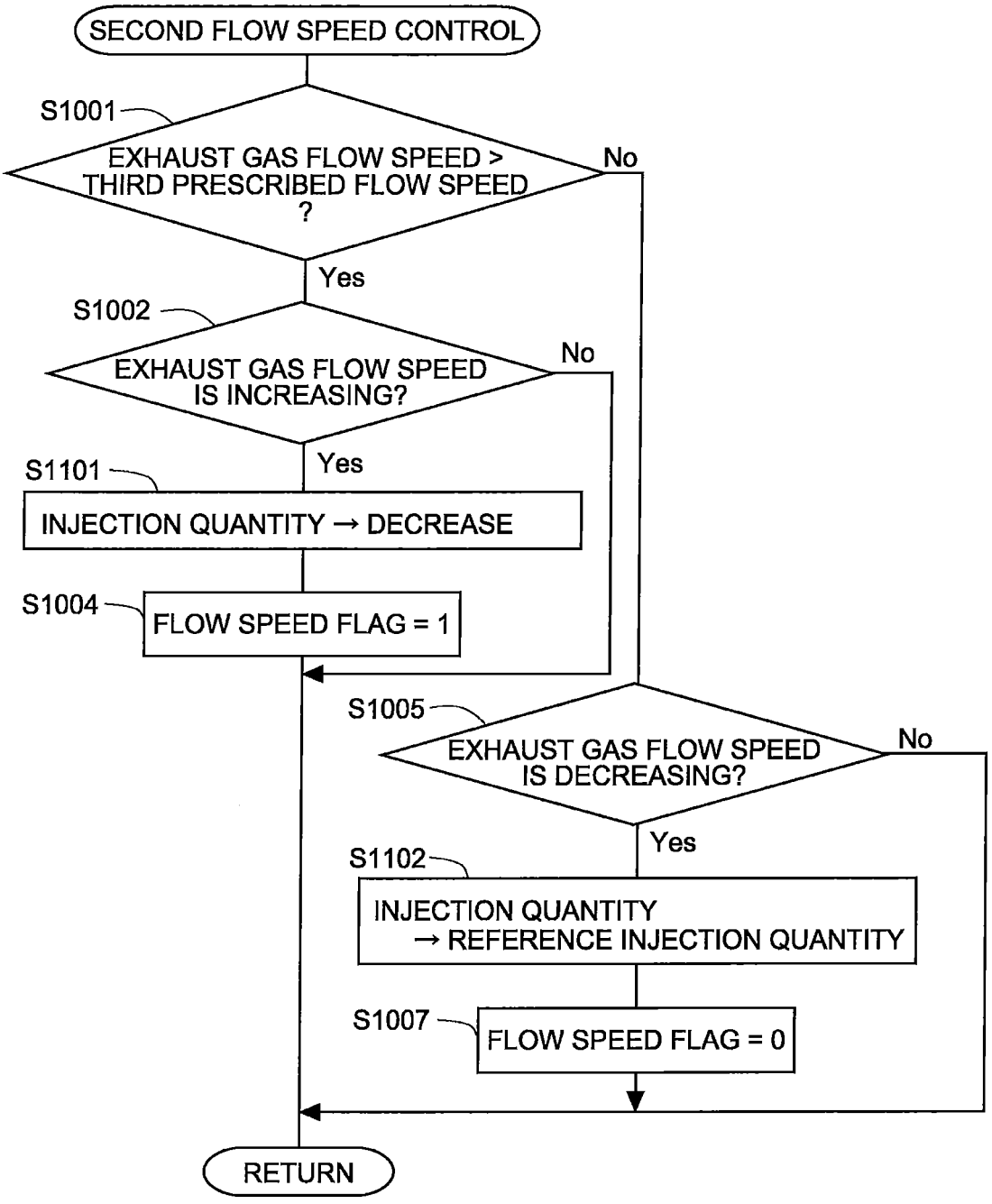
[FIG. 16]


SECOND TEMP. CONTROL
S801
EXHAUST GAS TEMP. > THIRD PRESCRIBED TEMP. ?
No
Yes
S802
EXHAUST GAS TEMP. IS INCREASING?
No
Yes
S901
INJECTION QUANTITY → DECREASE
S804
TEMP. FLAG = 1
S805
EXHAUST GAS TEMP. IS DECREASING?
No
Yes
S902
INJECTION QUANTITY → REFERENCE INJECTION QUANTITY
S807
TEMP. FLAG = 0
RETURN

[FIG. 17]


FIRST FLOW SPEED CONTROL
S1001
EXHAUST GAS FLOW SPEED > THIRD PRESCRIBED FLOW SPEED ?
No
Yes
S1002
EXHAUST GAS FLOW SPEED IS INCREASING?
No
Yes
S1003
INJECTION PERIOD → INCREASE
INJECTION QUANTITY → INCREASE
S1004
FLOW SPEED FLAG = 1
S1005
EXHAUST GAS FLOW SPEED IS DECREASING?
No
Yes
S1006
INJECTION PERIOD → REFERENCE PERIOD
INJECTION QUANTITY → REFERENCE INJECTION QUANTITY
S1007
FLOW SPEED FLAG = 0
RETURN

[FIG. 18]


SECOND FLOW SPEED CONTROL
S1001
EXHAUST GAS FLOW SPEED > THIRD PRESCRIBED FLOW SPEED ?
No
Yes
S1002
EXHAUST GAS FLOW SPEED IS INCREASING?
No
Yes
S1101
INJECTION QUANTITY → DECREASE
S1004
FLOW SPEED FLAG = 1
S1005
EXHAUST GAS FLOW SPEED IS DECREASING?
No
Yes
S1102
INJECTION QUANTITY → REFERENCE INJECTION QUANTITY
S1007
FLOW SPEED FLAG = 0
RETURN

REFERENCES CITED IN THE DESCRIPTION

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- WO 2011114499 A **[0004] [0022]**
- US 20110320171 A1 **[0004]**