

(51) Int Cl.:
F02D 41/02 (2006.01)

(22) Date of filing: 12.01.2011

(72) Inventors:

- **Kawashima, Kazuhito**
Tokyo Tokyo (JP)
- **Tashiro, Keisuke**
Tokyo Tokyo (JP)
- **Tsuda, Masahiro**
Tokyo Tokyo (JP)

(74) Representative: **Vossius & Partner**
Siebertstrasse 4
81675 München (DE)

(54) Exhaust emission control device for internal combustion engine

culates an occlusion quantity of the occluding member 2 from the quantity of trapped hydrocarbons for each type. Further, there is performed control for purifying the hydrocarbons occluded in the occluding member according to the occlusion quantity calculated by the first calculation means.

Description

[0001] The present invention relates to an exhaust emission control device for an internal combustion engine that estimates a quantity of hydrocarbon occluded in an occluding agent of an exhaust system.

[0002] Conventionally, an exhaust emission control system that purifies hydrocarbon emitted from an internal combustion engine includes catalytic converter rhodium, an oxidation catalyst, or the like, provided in a vehicle exhaust system is known. The catalyst includes a supported precious metal component exhibiting oxidation, such as platinum, palladium, and rhodium, and efficient hydrocarbon purification is implemented. Meanwhile, hydrocarbon oxidation effected by precious metal requires a predetermined catalyst temperature. Sufficient performance cannot be exhibited at cold start of an internal combustion engine during which a catalyst is cold. Accordingly, there has been developed a technique of using in combination an occluding member having a feature of temporarily occluding hydrocarbon emitted when an activating temperature of a catalyst is not reached, thereby enhancing emission purification performance.

[0003] For instance, JP-A-2005-240726 includes a description about an occluding catalyst (an HC trap catalyst) including a combination of catalytic converter rhodium with an occluding material (an HC trap material) that adsorbs or desorbs hydrocarbon emitted from an internal combustion engine. Under the technique, an occluding catalyst adsorbs (traps) hydrocarbon when the catalyst is at a comparatively low temperature. When the catalyst is at a comparatively high temperature, the catalyst oxidizes the hydrocarbon while desorbing the same, thereby purifying emissions.

[0004] Incidentally, a general hydrocarbon occluding member has a ceiling on the quantity of hydrocarbon capable of being occluded, and a predetermined quantity of hydrocarbon or more cannot be occluded. Accordingly, operation for periodically desorbing the occluded hydrocarbon is required. In particular, when a hydrocarbon occluding member is applied to an exhaust system of a diesel engine, hydrocarbon is likely to be excessively stored during idling operation performed at an extremely low emission temperature. Therefore, delayed desorbing operation may result in deterioration of the occluding member. Consequently, it is important to accurately ascertain the quantity of hydrocarbon in an occluding member and perform desorbing operation without a delay.

[0005] In relation to the problem, the technique described in connection with JP-A-2005-240726 provides a description including detecting combustion-related fuel property pertaining to a state of an internal combustion engine, calculating a quantity of hydrocarbon in emissions appropriate for the fuel property, and estimating a quantity of hydrocarbon occluded. Such control is said to make it possible to desorb hydrocarbon at appropriate timing from an occluding catalyst.

[0006] Since an overlap exists between a temperature range in which an occluding member induces reaction for trapping hydrocarbon and a temperature range in which the occluding member induces reaction for desorbing hydrocarbon, the temperature ranges cannot explicitly be separated from each other while a single threshold value is taken as a boundary between the temperature ranges. There is a case where hydrocarbon is slightly desorbed even when the occluding member is at a comparatively low temperature. Conversely, there is also a case where hydrocarbon is slightly trapped even when the occluding member is at a comparatively high temperature. Therefore, the quantity of hydrocarbon desorbed from the occluding member cannot be ascertained by means of the technique, such as that mentioned in connection with JP-A-2005-240726. An estimated quantity of occluded hydrocarbon may become inaccurate.

[0007] A desorbing characteristic of the hydrocarbon occluded in the occluding member varies according to the temperature at which the hydrocarbon was trapped. Specifically, a wide variety of types of hydrocarbon having different boiling points are occluded in the occluding member. A distribution of boiling points of these types of hydrocarbons is dependent on temperature conditions employed during trapping operation as well as on a distribution of boiling points of hydrocarbons in emissions. Provided that the quantity of occluded hydrocarbon is calculated without taking into account such temperature conditions and that an estimated quantity of desorbed hydrocarbon is simply subtracted from the thus-calculated quantity of occluded hydrocarbon, a quantity of hydrocarbon that has a high boiling point and that would not originally be desorbed will also be subtracted. Therefore, the quantity of occluded hydrocarbon is often underestimated, and desorbing operation cannot be performed at accurate timing.

[0008] One of objects of the present invention has been conceived in light of such a problem and is to enhance accuracy of estimation of a quantity of hydrocarbon occluded in an occluding member.

[0009] According to the present invention, there is provided an exhaust emission control device for an internal combustion engine comprising: an occluding member that is provided in an exhaust system of an internal combustion engine and that traps and desorbs a plurality of types of hydrocarbons having different boiling points in emissions; first calculation means that estimates a distribution of presence of each type of the hydrocarbons to be trapped by the occluding member and that calculates an occlusion quantity of the occluding member for each type of the hydrocarbons from the quantity of trapped hydrocarbons; and control means that performs control operation for purifying the hydrocarbons occluded in the occluding member according to the occlusion quantity calculated by the first calculation means.

[0010] The exhaust emission control device for an internal combustion engine may further have second calculation means that subtracts in sequence a quantity of the hydrocarbon desorbed from the occluding member from the quantity of occluded hydrocarbon having a lower boiling point among the occlusion quantities calculated by the first calculation means, thereby calculating the quantity of hydrocarbon occluded in the occluding member.

[0011] The exhaust emission control device for an internal combustion engine may also be configured so as to further have first catalyst temperature detection means for detecting a first catalyst temperature that is a catalyst temperature of the occluding member, and the first calculation means may calculate a quantity of trapped hydrocarbon having a boiling point that is equal to or higher than the first catalyst temperature detected by the first catalyst temperature detection means.

[0012] The second calculation means may also be configured so as to subtract the desorption quantity solely from the quantity of occluded hydrocarbon having a boiling point that is less than the first catalyst temperature detected by the first catalyst temperature detection means.

[0013] The exhaust emission control device for an internal combustion engine has an oxidation catalyst provided in an upstream position with reference to an occluding catalyst in the exhaust and second catalyst temperature detection means that detects a catalyst temperature of the oxidation catalyst as a second catalyst temperature. The first calculation means may also be configured so as to calculate a quantity of trapped hydrocarbon having a boiling point that is equal to or higher than either the first catalyst temperature detected by the first catalyst temperature detection means or the second catalyst temperature detected by the second catalyst temperature detection means, whichever is higher.

[0014] The exhaust emission control device for an internal combustion engine of the present invention makes it possible to enhance accuracy of estimation of an occlusion quantity by estimating a distribution of presence of a trapped hydrocarbon according to a distribution of boiling points of hydrocarbons included in emissions flowing into an occluding member.

[0015] In the following preferred embodiments of the present invention are described with reference to the drawings, in which:

Fig. 1 is a schematic diagram showing a vehicle intake and exhaust system to which there is applied an exhaust emission control device for an internal combustion engine of an embodiment;

Fig. 2 is a graph showing a hydrocarbon desorbing characteristic of an occluding catalyst in the exhaust emission control device of the internal combustion engine;

Fig. 3 is a conceptual rendering for describing a basic concept of the exhaust emission control device of the internal combustion engine;

Fig. 4 is a boiling point distribution diagram showing a modeled distribution ratio of hydrocarbon trapped into an occluding catalyst of the exhaust emission control device of the internal combustion engine;

Fig. 5A is a graph showing a trapping coefficient K_{adsorp} for explaining calculation performed by the exhaust emission control device of the internal combustion engine;

Fig. 5B is a graph showing an upstream slip coefficient K_{oxi} for explaining calculation performed by the exhaust emission control device of the internal combustion engine;

Fig. 5C is a graph showing a fundamental quantity of emitted hydrocarbon $M_{\text{hce}ng0}$ for explaining calculation performed by the exhaust emission control device of the internal combustion engine;

Fig. 5D is a graph showing a water temperature correction coefficient K_{THW} for explaining calculation performed by the exhaust emission control device of the internal combustion engine;

Fig. 5E is a graph showing an intake air temperature correction coefficient K_{THA} for explaining calculation performed by the exhaust emission control device of the internal combustion engine;

Fig. 5F is a graph showing a quantity of desorbed hydrocarbon M_{hcde} for explaining calculation performed by the exhaust emission control device of the internal combustion engine;

Fig. 5G is a graph explaining a fuel-air ratio correction coefficient K_{NOP} for explaining calculation performed by the exhaust emission control device of the internal combustion engine;

Fig. 6A is a pattern diagram of a distribution model of a quantity of trapped hydrocarbon that is calculated at a comparatively low temperature by the exhaust emission control device of the internal combustion engine;

Fig. 6B is a pattern diagram of a distribution model of a quantity of trapped hydrocarbon that is calculated at a comparatively high temperature by the exhaust emission control device of the internal combustion engine;

Fig. 7A is a pattern diagram of a method for adding, at a comparatively low temperature, the quantity of trapped hydrocarbon calculated by the exhaust emission control device of the internal combustion engine;

Fig. 7B is a pattern diagram of a method for adding, at a comparatively high temperature, the quantity of trapped hydrocarbon calculated by the exhaust emission control device of the internal combustion engine;

Fig. 8A is a pattern diagram that graphically represents a method for subtracting a quantity of desorbed hydrocarbon calculated by the exhaust emission control device of the internal combustion engine, the diagram showing an image of distribution of quantities of occluded hydrocarbons $Q_{(n)}$ acquired before subtraction;

Figs. 8B and 8C are pattern diagrams that graphically represent the method for subtracting the quantity of desorbed hydrocarbon calculated by the exhaust emission control device of the internal combustion engine, the diagrams showing an image of distribution of the quantities of occluded hydrocarbons $Q_{(n)}$ acquired after subtraction;

Fig. 9 is a flowchart illustrating procedures for controlling estimation of the quantity of occluded hydrocarbon that

are performed by the exhaust emission control device of the internal combustion engine; and

Fig. 10 is a flowchart illustrating procedures of purge control operation performed by the exhaust emission control device of the internal combustion engine.

[0016] An embodiment of an exhaust emission control device for an internal combustion engine is hereunder described by reference to the drawings. The embodiment provided below is a mere illustration and is not intended to eliminate various modifications and application of technology that are not expressly described in the embodiment provided blow.

[1. Overall configuration]

[0017] An engine 1 (an internal combustion engine) shown in Fig. 1 is a diesel engine that takes light oil containing various hydrocarbons (HC) as fuel. An exhaust passageway 6 and an intake passageway 7 are connected to the engine 1. Intake air is introduced into combustion chambers of cylinders of the engine 1 by way of the intake passageway 7, and an exhaust gas (hereinafter referred to simply as an "emission") resulting from combustion is discharged outside of the vehicle by way of the exhaust passageway 6. Hydrocarbons having a plurality of carbon numbers are mixedly present in the fuel of the engine 1. A plurality of types of hydrocarbons having different boiling points also mixedly exist in hydrocarbons contained in the emissions.

[0018] A controller 10 (control means) to be described later controls a fuel-air ratio, a quantity of intake air, a quantity of fuel injection, fuel injection timing, a quantity of post fuel injection, and others, that are related to combustion reaction occurred in the combustion chambers of the engine 1. The controller 10 is a so-called ECU (Electric Control Unit).

[0019] An oxidation catalyst 3 and an occluding catalyst 2 are placed in the exhaust passageway 6 in a decreasing sequence of emission flow from an upstream position.

[0020] The occluding catalyst 2 (an occluding member) is a catalyst unit that has an occluding layer provided on a surface of a catalyst support. In some instance, the unit additionally has a precious metal catalyst layer. The occluding layer is a layer containing various types of zeolites having a characteristic of occluding hydrocarbons contained in emissions. The precious metal catalyst layer is a layer that contains active alumina carrying a precious metal component for enhancing a hydrocarbon oxidation function. The occluding catalyst 2 traps hydrocarbon at a low catalyst temperature, and the thus-trapped hydrocarbon is occluded in the occluding layer. As the catalyst temperature increases, the occluding catalyst 2 desorbs the trapped hydrocarbon, and the precious metal catalyst layer eliminates the hydrocarbon through oxidation.

[0021] In the present embodiment, a state in which the hydrocarbon trapped by the occluding catalyst 2 is kept until it desorbs from the catalyst is called "occlusion," and the word "occlusion" is used as distinguished from the word "trap." The quantity of hydrocarbon acquired when hydrocarbon existing in the emissions is trapped by the occluding layer of the occluding catalyst 2 is called a "trap quantity." In a case where the hydrocarbon trapped in the occluding layer of the occluding catalyst 2 is discharged into emissions or eliminated through oxidation, the quantity of hydrocarbon thus discharged or eliminated is called a "desorption quantity." Further, a quantity of hydrocarbon held by the occluding catalyst 2 is called an "occlusion quantity Q." The occlusion quantity Q is assumed to be given as an integration of values that have been determined by subtraction of the desorption quantities from the trap quantities. The quantity of hydrocarbon that can be occluded in the occluding catalyst 2 is finite. A maximum value of the occlusion quantity Q is called a "hydrocarbon quantity Q_{MAX} ."

[0022] When the hydrocarbon occlusion quantity Q has reached the hydrocarbon quantity Q_{MAX} , any further trapping of hydrocarbon is not expected. Therefore, there is generally required operation for forcefully desorbing hydrocarbon before the occlusion quantity Q reaches the hydrocarbon quantity Q_{MAX} . In the present embodiment, a regeneration temperature T_c is set as a target value of a catalyst temperature to be operated for desorbing hydrocarbon from the occluding catalyst 2. The regeneration temperature T_c is a catalyst temperature that makes it possible to desorb nearly all occluded hydrocarbon without involvement of deterioration of the occluding catalyst 2, thereby purifying the occluding catalyst. The regeneration temperature T_c is set to; for instance, 400 [°C] or thereabouts. Moreover, controlling an exhaust temperature in such a way that the catalyst temperature of the occluding catalyst 2 reaches the regeneration temperature T_c is called purge control. The controller 10 to be described later implements purge control.

[0023] A hydrocarbon desorbing characteristic of the occluding catalyst 2 is now described by reference to Fig. 2. A solid-line plot in Fig. 2 denotes a test result showing a concentration of hydrocarbon detected at a downstream position with respect to the catalyst when the catalyst temperature of the occluding catalyst 2, which occludes hydrocarbon as a result of the engine 1 having continually performed idling operation for a predetermined time while the catalyst temperature is held at a predetermined temperature T_A [°C], is changed from a low temperature to a high temperature. Further, a broken-line plot in the drawing denotes a test result yielded when the idling operation is shortened while the catalyst temperature is maintained at a predetermined temperature T_B [°C] by means of changing conditions for letting the occluding catalyst 2 of the same type occlude hydrocarbon. A dashed line in the drawing denotes a reference line showing a concentration of hydrocarbon detected at an upstream position with respect to the catalyst.

[0024] The solid-line plot in Fig. 2 shows that hydrocarbon is desorbed over an entire temperature range from the predetermined temperature T_A employed during trapping operation to the regeneration temperature T_C . Even in a broken-line graph, hydrocarbons are desorbed over an entire temperature range from the predetermined temperature T_B employed during trapping operation to the regeneration temperature T_C . In short, when a catalyst temperature employed during trapping operation is constantly maintained, only hydrocarbons having boiling points that are equal to or higher than the catalyst temperature are occluded in the occluding catalyst 2, and hydrocarbons having boiling points that are less than the catalyst temperature are not occluded in the occluding catalyst 2. A correlation is acknowledged from these facts to exist between the catalyst temperature employed during trapping operation and boiling points of hydrocarbons actually occluded in the occluding catalyst 2. Moreover, when hydrocarbon is not desorbed within a temperature range that is equal to or higher than the regeneration temperature T_C , the regeneration temperature T_C can be considered to be the maximum value of a boiling point of the hydrocarbon trapped in the occluding catalyst 2.

[0025] The oxidation catalyst 3 is a catalyst that carries on its surface a precious metal component and has an ability to oxidize various components in emissions. Components in emissions purified by the oxidation catalyst 3 include carbon monoxide (CO), hydrocarbons, and others.

[0026] In general, when the catalyst temperature is a predetermined activating temperature or more, the oxidation catalyst 3 in a diesel engine exhaust system in which a fuel-air ratio in emissions is set to a lean atmosphere oxidizes nitrogen monoxide, carbon monoxide, and hydrocarbon, thereby producing nitrogen dioxide, carbon dioxide, and a moisture. In the meantime, when the catalyst temperature of the oxidation catalyst 3 is less than the predetermined activating temperature, hydrocarbon is not purified and captured by the occluding catalyst 2 disposed downstream.

[0027] In the exhaust passageway 6, a first temperature sensor 4 (first catalyst temperature detection means) is disposed downstream of the occluding catalyst 2, and a second temperature sensor 5 (second catalyst temperature detection means) is disposed downstream of the oxidation catalyst 3. The first temperature sensor 4 detects a catalyst temperature of the occluding catalyst 2, and the second temperature sensor 5 detects a catalyst temperature of the oxidation catalyst 3. The catalyst temperature of the occluding catalyst 2 is hereunder called a "first catalyst temperature T_1 ," and the catalyst temperature of the oxidation catalyst 3 is hereunder called a "second catalyst temperature T_2 ." The first catalyst temperature T_1 detected by the first temperature sensor 4 and the second catalyst temperature T_2 detected by the second temperature sensor 5 are input to the controller 10.

[0028] The engine 1 is also equipped, side by side, with an engine speed sensor 21 for detecting an engine speed N_E , an engine coolant temperature sensor 22 for detecting a temperature T_{HW} of an engine coolant, and a torque sensor 25 for detecting torque T_{OR} of a drive shaft of the engine 1. A linear fuel-air ratio sensor 23 for detecting a fuel-air ratio $R_{A/F}$ is disposed on the exhaust passageway 6, and an intake temperature sensor 24 for detecting a temperature T_{HA} of an intake air is disposed on the intake passageway 7. The engine speed N_E , the engine coolant temperature T_{HW} , the engine torque T_{OR} , the fuel-air ratio $R_{A/F}$, and the intake temperature T_{HA} detected by the various sensors are input to the controller 10. A vehicle speed sensor 26 for detecting a vehicle speed V is provided at an arbitrary position on a vehicle. The thus-detected vehicle speed V is also input to the controller 10.

[2. Control Specifics]

[0029] The controller 10 is an electronic controller offered as an LSI device that results from integration of known microprocessors, ROM, RAM, and the like. The engine speed sensor 21, the engine coolant temperature sensor 22, the linear fuel-air ratio sensor 23, the intake temperature sensor 24, the torque sensor 25, the vehicle speed sensor 26, the first temperature sensor 4, and the second temperature sensor 5 are connected to an input side of the controller 10. According to input information from these sensors, the controller 10 performs occlusion quantity estimation control and purge control.

[0030] Occlusion quantity estimation control is control operation for calculating, in an estimating manner, the quantity Q of hydrocarbon occluded in the occluding catalyst 2. The occlusion quantity Q is calculated according to the engine speed N_E , the engine coolant temperature T_{HW} , the fuel-air ratio $R_{A/F}$, the intake temperature T_{HA} , the engine torque T_{OR} , the vehicle speed V , the first catalyst temperature T_1 , and the second catalyst temperature T_2 . Basic idea of occlusion quantity estimation control is described by reference to Fig. 3.

[0031] A relationship, such as that designated by a solid line in Fig. 3, is assumed to exist between the catalyst temperature of the occluding catalyst 2 and a desorption speed V_{de} of hydrocarbon. Namely, when a catalyst temperature T is less than a predetermined temperature T_{01} , the desorption speed comes to $V_{de} = 0$, so that hydrocarbon is not desorbed. When the catalyst temperature is the predetermined temperature T_{01} or more, hydrocarbon is desorbed. The desorption speed V_{de} corresponds to a desorption quantity achieved per unit time. The desorption speed V_{de} is assumed to linearly increase within a range where the catalyst temperature T changes from the predetermined temperature T_{01} to a regeneration temperature T_{03} . The regeneration temperature T_{03} signifies a catalyst temperature identical with the regeneration temperature T_C . The desorption speed V_{de} achieved when the catalyst temperature T is a predetermined temperature T_{02} is assumed to be a predetermined speed V_1 .

[0032] When the catalyst temperature of the occluding catalyst 2 is the predetermined temperature T_{02} , hydrocarbons whose boiling points fall within a temperature range from the predetermined temperature T_{01} to the predetermined temperature T_{02} are assumed to be desorbed, and hydrocarbons whose boiling points fall within a temperature range from the predetermined temperature T_{02} to the regeneration temperature T_{03} are assumed to be trapped. Specifically, in relation to trapping of hydrocarbon by the occluding catalyst 2, hydrocarbons whose boiling points fall within a temperature range A shown in Fig. 3 are considered to be untrapped, and hydrocarbons whose boiling points fall within a temperature range B are considered to be trapped. Further, in relation to desorption of hydrocarbons from the occluding catalyst 2, the hydrocarbons whose boiling points fall within the temperature range A are considered to be desorbed, and the hydrocarbons whose boiling points fall within the temperature range B are considered not to be desorbed.

[0033] In connection with estimated calculation of a specific quantity of occluded hydrocarbon, hydrocarbons are classified into a plurality of types having different boiling points, and a trap quantity and a desorption quantity are calculated for each type.

[0034] As shown in Fig. 4, on occasion of calculation of a trap quantity, there is used a boiling point distribution model for hydrocarbons contained in the emissions flowing into the occluding catalyst 2. Hydrocarbons are herein supposed to have boiling points that range from a first temperature B_1 to a third temperature B_3 . A distribution profile assumes a shape of an isosceles triangle. In relation to hydrocarbons having boiling points that fall within a range from the first temperature B_1 to the second temperature B_2 , hydrocarbons having higher boiling points are distributed so as to become larger in quantity. By contrast, in relation to hydrocarbons having boiling points that fall within a range from the second temperature B_2 to the third temperature B_3 , hydrocarbons having lower boiling points are distributed so as to become larger in quantity.

[0035] In the present embodiment, the distribution of boiling points of hydrocarbons trapped in the occluding catalyst 2 is assumed to imitate the foregoing distribution patterns in a range in excess of a catalyst temperature of the occluding catalyst 2. Specifically, hydrocarbons trapped in the occluding catalyst 2 are first assumed to be limited to hydrocarbons having boiling points that are equal to or higher than the catalyst temperature T achieved at that time. Next, a quantity of trapped hydrocarbons is now calculated on the basis of assumptions provided below. In relation to hydrocarbons having boiling points that fall within a range from the first temperature B_1 to the second temperature B_2 , hydrocarbons having higher boiling points are trapped in larger quantity. By contrast, in relation to hydrocarbons having boiling points that fall within a range from the second temperature B_2 to the third temperature B_3 , hydrocarbons having lower boiling points are trapped in larger quantity.

[0036] In relation to calculation of a desorption quantity, hydrocarbons having lower boiling points among the hydrocarbons occluded in the occluding catalyst 2 are considered to be desorbed in an increasing sequence from a lower boiling point within a temperature range under the catalyst temperature of the occluding catalyst 2. The reason for this is that a degree of reactivity of desorption from the occluding catalyst 2 is dependent on a boiling point of hydrocarbon.

[0037] Purge control is for forcefully desorbing and purifying the hydrocarbons occluded in the occluding catalyst 2. Purge control is performed when the occlusion quantity Q estimated by means of occlusion quantity estimation control has exceeded a predetermined threshold value Q_{TH} . The predetermined threshold value Q_{TH} is set to an arbitrary value in a range that is the hydrocarbon quantity Q_{MAX} of the occluding catalyst 2 or less. An exhaust temperature is regulated by purge control in such a way that the catalyst temperature of the occluding catalyst 2 is maintained at the regeneration temperature T_C for a predetermined period of time.

[0038] One of objectives of purge control is to desorb hydrocarbons before the hydrocarbon occlusion quantity Q reaches the hydrocarbon quantity Q_{max} . The objective becomes easier to attain, so long as the predetermined threshold value Q_{TH} is set to a lower value. Namely, the objective becomes easier to attain with an increase in frequency of performance of purge control. However, purge control is performed so as to make an exhaust temperature higher than the exhaust temperature achieved during normal idling operation. For this reason, an increase in frequency of performance of purge control results in deterioration of fuel efficiency.

[0039] Therefore, it is preferable to set the predetermined threshold value Q_{TH} to a high level within a range where any practical inconvenience is not caused; therefore, highly accurate estimation of the occlusion quantity Q is desired. Occlusion quantity estimation control of the present embodiment can also be said to be control for effecting estimated operation of an occlusion quantity Q with high accuracy from the foregoing viewpoint.

[3. Configuration of the controller]

[0040] As shown in Fig. 1, the controller 10 has an estimation control block 11 and a purge control block 17 (control means) as a software configuration for implementing the respective control operations. These software programs are recorded in unillustrated memory and an unillustrated storage device. Functions which will be described below are implemented by reading the software program into a CPU, as required.

[0041] The estimation control block 11 is assigned the previously described occlusion quantity estimation control and calculates, in an estimating manner, the hydrocarbon occlusion quantity Q in the occluding catalyst 2, as necessary.

The estimation control block 11 is equipped with first calculation means including a trap quantity calculation block 12 and a distribution block 13; second calculation means including a desorption quantity calculation block 14 and a subtraction block 15; and a determination block 16.

[3-1. A trap quantity calculation block]

[0042] The trap quantity calculation block 12 is for calculating a quantity M_{hcad} [g/sec] of hydrocarbon trapped in the occluding catalyst 2 per unit time. The trap quantity M_{hcad} is given by the following equation.

$$M_{hcad} = K_{adsorp} \times M_{hcin} \quad (1)$$

[0043] The term K_{adsorp} is a trapping coefficient. Further, the term M_{hcin} is a quantity of inflow hydrocarbon.

[0044] The trapping coefficient K_{adsorp} designates a ratio of hydrocarbon trapped into the occluding catalyst 2 from emissions and is set according to the first catalyst temperature T_1 (the catalyst temperature of the occluding catalyst 2) and a characteristic of the occluding catalyst 2. The characteristic of the occluding catalyst 2 includes; for instance, a type, a composition, a structure, and the like, of a catalytic material. As shown in Fig. 5A, when the first catalyst temperature T_1 is under a predetermined temperature T_{11} , a predetermined value K_1 is given as the trapping coefficient K_{adsorp} . When the first catalyst temperature T_1 is a predetermined temperature T_{12} or more, the trapping coefficient is set to $K_{adsorp} = 0$. The predetermined value K_1 is given as; for instance, $K_1 = 0.6$, where $T_{10} < T_{11}$. When the first catalyst temperature T_1 is the predetermined temperature T_{11} or more and under the predetermined temperature T_{12} , settings are made in such a way that the coefficient becomes gradually smaller as the first catalyst temperature T_1 increases. Namely, when the catalyst temperature of the occluding catalyst 2 is the predetermined temperature T_{12} or more, hydrocarbons are not trapped from a calculation viewpoint. The specific predetermined temperature T_{12} may be determined according to a trapping characteristic of the occluding catalyst 2. For instance, a temperature of about 250 [°C] is conceivable for the predetermined temperature T_{12} .

[0045] The inflow hydrocarbon quantity M_{hcin} [g/sec] denotes a quantity of hydrocarbon flowing into the occluding catalyst 2 per unit time and is given by the following equation.

$$M_{hcin} = K_{OXI} \times M_{hcing} \quad (2)$$

[0046] The term K_{OXI} is an upstream slip coefficient. The term M_{hcing} is an engine discharge.

[0047] The upstream slip coefficient K_{OXI} designates a ratio of hydrocarbon flowing into the occluding catalyst 2 without being purified by the oxidation catalyst 3 and is determined by the second catalyst temperature T_2 that is a catalyst temperature of the oxidation catalyst 3 and the characteristic of the oxidation catalyst 3. As shown in Fig. 5B, when the second catalyst temperature T_2 is under a predetermined temperature T_{21} , $K_{OXI} = 1$ is given. When the second catalyst temperature T_2 is a predetermined temperature T_{22} or more, $K_{OXI} = K_2$ is given, where $T_{21} < T_{22}$. Moreover, settings are also made such that, when the second catalyst temperature T_2 is the predetermined temperature T_{21} or more and under the predetermined temperature T_{22} , the coefficient gradually decreases with an increase in the second catalyst temperature T_2 .

[0048] The upstream slip coefficient K_{OXI} is set according to hydrocarbon purification efficiency of the oxidation catalyst 3. For instance, when the purification efficiency of the oxidation catalyst 3 reached the activating temperature is 90[%], the coefficient K_2 is set to 0.1 in a range that is equal to or higher than the second catalyst temperature T_2 equivalent to the activating temperature. It is desirable to set the predetermined temperatures T_{21} and T_{22} such that the upstream slip coefficient K_{OXI} changes in a neighborhood of the activating temperature.

[0049] The engine discharge M_{hcing} [g/sec] designates a quantity of hydrocarbon discharged per unit time from the engine 1 and is given by the following equation.

$$M_{hcing} = M_{hcing0} \times K_{THW} \times K_{THA} \quad (3)$$

[0050] The term M_{hcing0} designates a basic discharge. Further, the term K_{THW} is a water temperature correction coefficient. The term K_{THA} is an intake temperature correction coefficient.

[0051] The basic discharge M_{hcing0} [g/sec] designates a standard hydrocarbon discharge per unit time estimated from

an operating state of the engine 1. As shown in Fig. 5C, the basic discharge $M_{h_{ceng0}}$ is calculated according to a map pertaining to the engine speed N_E detected by the engine speed sensor 21 and the engine torque T_{OR} detected by the torque sensor 25. The basic discharge $M_{h_{ceng0}}$ is set so as to become greater with an increase in the engine speed N_E or engine torque T_{OR} . Specifically, the basic discharge $M_{h_{ceng0}}$ is set so as to increase as an output of the engine 1 becomes greater.

[0052] The water temperature correction coefficient K_{THW} is a hydrocarbon discharge correction gain based on the engine coolant temperature T_{HW} . As shown in Fig. 5D, when the engine coolant temperature T_{HW} is a predetermined temperature T_{HW1} or more, the water temperature correction coefficient K_{THW} is set to $K_{THW} = 1$. Further, when the engine coolant temperature T_{HW} is less than the predetermined temperature T_{HW1} , the water temperature correction coefficient K_{THW} is set so as to increase as the temperature of the engine coolant is lower. The predetermined temperature T_{HW1} is set to; for instance, 85[°C].

[0053] The intake temperature correction coefficient K_{THA} is a hydrocarbon discharge correction gain based on the intake temperature T_{HA} . As shown in Fig. 5E, when the intake temperature T_{HA} is a predetermined temperature T_{HA1} or more (e.g., 25[°C] or more), the intake temperature correction coefficient K_{THA} is set to $K_{THA} = 1$. Further, when the intake temperature T_{HA} is less than the predetermined temperature T_{HA1} , the intake temperature correction coefficient K_{THA} is set so as to increase as the intake temperature is lower. The predetermined temperature T_{HA1} is set to; for instance, 25[°C].

[3-2. Distribution block]

[0054] The distribution block 13 classifies trapped hydrocarbon into a plurality of types of hydrocarbon having different boiling points and calculates a trap quantity M_{hcad} according to the types of hydrocarbon. The trap quantity M_{hcad} calculated by the trap quantity calculation block 12 is distributed for each of the boiling points.

[0055] Fig. 6A illustrates a distribution model of the trap quantity M_{hcad} previously recorded in the distribution block 13. A horizontal axis shown in Fig. 6A represents temperatures corresponding to boiling points of trapped hydrocarbons. A width of an individual temperature zone corresponds to a width of a boiling point of hydrocarbon classified into the zone. Further, a vertical axis shown in the drawing represents a distribution ratio of the trap quantity M_{hcad} . A distribution ratio for each temperature zone is proportional to an area of the temperature zone.

[0056] In the embodiment, a range from the first temperature B_1 to the third temperature B_3 is divided at uniform intervals into eleven areas along the vertical axis, whereby a plurality of strip-shaped temperature zones are formed. Moreover, the distribution ratio is determined in such a way that the largest quantity of hydrocarbon is distributed to the temperature zone including the second temperature B_2 . The hydrocarbon trapped into the occluding catalyst 2 exhibits a boiling point distribution analogous to the boiling point distribution of hydrocarbon in emissions flowing into the occluding catalyst 2. Therefore, the distribution model is formed into a shape that imitates an isosceles triangle taking a neighborhood of the second temperature B_2 as an apex, so as to follow a boiling point distribution of hydrocarbon in emissions shown in Fig. 4.

[3-2-1. Setting of a distribution ratio]

[0057] The distribution block 13 distributes the trap quantity M_{hcad} , which is calculated by the trap quantity calculation block 12, to the respective temperature zones that are distribution targets while taking the distribution model as a sample. A temperature zone to become a distribution target is a temperature zone that is equal to or higher than either the first catalyst temperature T_1 or the second catalyst temperature T_2 , whichever is higher. Hydrocarbon having a boiling point belonging to temperature zones that are lower than the temperature zone including a higher catalyst temperature [i.e., left-side temperature zones in Fig. 6A] is considered not to be trapped by the occluding catalyst 2 (or is considered not to flow into the occluding catalyst 2). Temperature areas that are equal to or higher than the third temperature B_3 are non-add areas to which the trap quantity M_{hcad} is not distributed. Specifically, hydrocarbon having a boiling point that is the third temperature B_3 or more is also considered not to be trapped by the occluding catalyst 2.

[0058] For instance, Fig. 6A shows a case where both the first catalyst temperature T_1 and the second catalyst temperature T_2 are less than the first temperature B_1 . In this case, the temperature zone to become a distribution target corresponds to an entire range from the first temperature B_1 to the third temperature B_3 . Therefore, a distribution ratio for a temperature zone sandwiched between the first temperature B_1 and a fourth temperature B_4 comes to 1/36. Fractions shown in Fig. 6A mean distribution ratios for respective temperature zones.

[0059] In the meantime, Fig. 6B shows a case where the first catalyst temperature T_1 is a fifth temperature B_5 and where the second catalyst temperature T_2 is a sixth temperature B_6 . In this case, temperature zones that are higher than the higher sixth temperature B_6 become a distribution target of the trap quantity M_{hcad} . Specifically, temperature zones from the first temperature B_1 to the fifth temperature B_5 are excluded from the distribution target, so that the area of the distribution target is diminished. Consequently, a distribution ratio of a temperature zone sandwiched between

the sixth temperature B_6 and a seventh temperature B_7 comes to 6/21. Fractions shown in Fig. 6B mean distribution ratios for respective temperature zones. The distribution ratios for the respective temperature zones increase with the first catalyst temperature T_1 and the second catalyst temperature T_2 become higher.

[3-2-2. Calculation of a trap quantity for each temperature zone]

[0060] The distribution block 13 subsequently calculates a trap quantity distributed to each of the temperature zones. Now, the respective temperature zones are assigned numbers from the lowest temperature zone by use of an ordinal number "n." A trap quantity distributed to each of the temperature zones is labeled $M_{\text{hcad}(n)}$. The distribution block 13 multiplies the trap quantity M_{hcad} , which has been calculated by the trap quantity calculation block 12, by the distribution ratio, to thus calculate the trap quantity $M_{\text{hcad}(n)}$ for each of the temperature zones. A total of distribution ratios for all of the temperature zones set in the distribution model comes to one. Therefore, the trap quantity M_{hcad} calculated by the trap quantity calculation block 12 is distributed, by means of the operation, according to a ratio of an area of a corresponding temperature zone.

[0061] In the case of the distribution ratios shown in Fig. 6A, a trap quantity $M_{\text{hcad}(1)}$ distributed to the temperature zone sandwiched between the first temperature B_1 and the fourth temperature B_4 is given $M_{\text{hcad}} \times (1/36)$. Further, a trap quantity $M_{\text{hcad}(5)}$ distributed to a temperature zone sandwiched between the fifth temperature B_5 and the sixth temperature B_6 is $M_{\text{hcad}} \times (5/36)$. In the case of the distribution ratios shown in Fig. 6B, for instance a trap quantity $M_{\text{hcad}(6)}$ distributed to a temperature zone sandwiched between the sixth temperature B_6 and the seventh temperature B_7 comes to $M_{\text{hcad}} \times (6/21)$.

[3-2-3. Calculation of an occlusion quantity]

[0062] The distribution block 13 further adds the trap quantity $M_{\text{hcad}(n)}$ distributed to each of the temperature zones to the occlusion quantity Q of hydrocarbon acquired by a previous operation period. Quantities of hydrocarbons occluded in each of the temperature zones are labeled $Q(n)$ by use of the same ordinal numbers "n" as those of the trap quantity $M_{\text{hcad}(n)}$. Figs. 7A and 7B show a distribution image of the occlusion quantities $Q(n)$ added with the distributed occluding quantity $M_{\text{hcad}(n)}$.

[0063] Fig. 7A is a distribution image to which the trap quantity $M_{\text{hcad}(1)}$ distributed at the distribution ratio shown in Fig. 6A is added. Fig. 7B is a distribution image to which the trap quantity $M_{\text{hcad}(1)}$ distributed at the distribution ratio shown in Fig. 6B is added. Fig. 7B shows a state in which the trap quantity $M_{\text{hcad}(n)}$ is added to only temperature zones to become distribution targets.

[3-3. Desorption quantity calculation block]

[0064] The desorption quantity calculation block 14 calculates a quantity $M_{\text{hcd}} [\text{g/sec}]$ of hydrocarbon desorbed from the occluding catalyst 2 per unit time. The desorption quantity M_{hcd} is determined according to the first catalyst temperature T_1 and the characteristic of the occluding catalyst 2. For instance, settings shown in Fig. 5F are made in light of the desorption characteristic of the occluding catalyst 2, such as that shown in Fig. 3. When the first catalyst temperature T_1 is less than the predetermined temperature T_{01} , the desorption quantity M_{hcd} is set to $M_{\text{hcd}} = 0$. Further, when the first catalyst temperature T_1 is the regeneration temperature T_{03} or more, the desorption quantity M_{hcd} is set to a predetermined desorption quantity $M_{\text{hcd}e1}$. When the first catalyst temperature T_1 is the predetermined temperature T_{01} or more and under the regeneration temperature T_{03} , settings are made in such a way that the desorption quantity M_{hcd} increases in a range that is the predetermined desorption quantity $M_{\text{hcd}e1}$ or less as the first catalyst temperature T_1 increases.

[0065] As shown in Fig. 5A, when the first catalyst temperature T_1 is less than the predetermined temperature T_{12} , hydrocarbon is trapped by the occluding catalyst 2. Further, as shown in Fig. 5F, when the first catalyst temperature T_1 is the predetermined temperature T_{01} or more, hydrocarbon desorbs from the occluding catalyst 2. In connection with a relationship between the predetermined temperature T_{12} pertaining to the trapping characteristic and the predetermined temperature T_{01} pertaining to the desorption characteristic, the hydrocarbon desorbed from the occluding catalyst 2 is presumed not to be occluded again by the occluding catalyst 2, and the predetermined temperature T_{12} is set so as to become smaller than the predetermined temperature T_{01} in the embodiment. Therefore, when the first catalyst temperature T_1 is $T_{12} < T_1 < T_{01}$, a state in which trapping reaction and desorbing reaction occur simultaneously is simulated from a calculation viewpoint.

[3-4. Subtraction block]

[0066] The subtraction block 15 subtracts the desorption quantity M_{hcd} calculated by the desorption quantity calcu-

lation block 14 from the occlusion quantities $Q_{(n)}$ added with the trap quantity $M_{hcad(n)}$ by means of the distribution block 13. The desorption quantity M_{hcde} is subtracted, in an increasing sequence of a boiling point, from each of the trap quantities on the low boiling point side among the occlusion quantities $Q_{(n)}$.

[0067] The subtraction technique is now described by reference to Fig. 8A. The subtraction block 15 subjects a temperature zone, which is to become a subtraction target, to subtraction in sequence from a low temperature zone. At a point in time when a total cumulative quantity determined by subtraction has matched the desorption quantity M_{hcde} , subtraction operation ends. The temperature zone that is to become a subtraction target is a temperature zone that is less than the first catalyst temperature T_1 (a temperature zone that is located on a lower boiling point side as compared with the temperature zone corresponding to the first catalyst temperature T_1). Specifically, hydrocarbons having boiling points belonging to the temperature zone that is the first catalyst temperature T_1 or more are deemed to still remain trapped in the occluding catalyst 2 without desorption.

[0068] For instance, when the first catalyst temperature T_1 is the fifth temperature B_5 , temperature zones located on a lower boiling point side (on a left side with reference to a broken line in Fig. 8A) with reference to the fifth temperature B_5 become subtraction targets. Hydrocarbons for the desorption quantity M_{hcde} calculated by the desorption quantity calculation block 14 are subtracted from the range. When a total occlusion quantity of hydrocarbons $Q_{(1)} + Q_{(2)} + Q_{(3)} + Q_{(4)}$ having boiling points in a range from the first temperature B_1 to the fifth temperature B_5 is greater than the desorption quantity M_{hcde} calculated by the desorption quantity calculation block 14, an occlusion quantity $Q_{(n)}$ located on the lower boiling point side with reference to the fifth temperature B_5 remains as shown in Fig. 8B.

[0069] By contrast, when the total $Q_{(1)} + Q_{(2)} + Q_{(3)} + Q_{(4)}$ is less than the desorption quantity M_{hcde} , all of the hydrocarbons having lower boiling points with reference to the fifth temperature B_5 are deemed to have desorbed as shown in Fig. 8C, so that there are assured the occlusion quantities $Q_{(n)}$ located on the high boiling point side with reference to the fifth temperature B_5 . In this case, the subtraction quantity becomes smaller than the desorption quantity M_{hcde} calculated by the desorption quantity calculation block 14 from a calculation viewpoint.

[0070] As mentioned above, the subtraction block 15 subtracts the hydrocarbons for the description quantity M_{hcde} from the occlusion quantities $Q_{(n)}$ for the hydrocarbons occluded in the respective temperature zones on the lower boiling point side, thereby calculating an occlusion quantity Q that is a total of the occlusion quantities $Q_{(n)}$. An image of distribution of the occlusion quantities $Q_{(n)}$ acquired after subtraction, such as those shown in Figs. 8B and 8C, reflects on a boiling point distribution in which quantities of hydrocarbons actually occluded in the occluding catalyst 2 are classified according to a boiling point. The total area of the entire occlusion quantities corresponds to the occlusion quantity Q .

[0071] The method for calculating the occlusion quantity Q is generalized as follows. A term ΔT [sec] is a period for calculating the trap quantity M_{hcad} and the desorption quantity M_{hcde} . When the total of occlusion quantities $Q_{(n)}$ of the temperature zones that are to become subtraction targets is equal to or greater than the desorption quantity M_{hcde} , the left side of Equation 4 and the right side of the same become equal to each other.

$$Q \leq \sum \{ (M_{hcad} - M_{hcde}) \times \Delta T \} \quad (4)$$

[3-5. Determination block]

[0072] According to the occlusion quantities Q acquired as a result of subtraction of the desorption quantity M_{hcde} by the subtraction block 15, the determination block 16 controls setting or clearing of a purge control flag. When the occlusion quantity Q is the predetermined threshold value Q_{TH} or less, purge control is determined to be unnecessary, and a purge request flag F_1 is set to $F_1 = 0$ (off). In the meantime, when the occlusion quantity Q has exceeded the predetermined threshold value Q_{TH} , the purge request flag F_1 is set to $F_1 = 1$ (on). The purge control block 17 makes a reference to the thus-set purge request flag.

[3-6. Purge control block]

[0073] The purge control block 17 performs purge control, thereby forcefully desorbing and eliminating the hydrocarbon occluded in the occlusion catalyst 2. Requirements for commencing purge control are mentioned below.

- The purge request flag F_1 is $F_1 = 1$ (on).
- The second catalyst temperature T_2 is a predetermined temperature or less.
- The vehicle speed V is a predetermined speed or higher.

[0074] When all of these requirements are fulfilled, the purge control block 17 commences purge control, thereby

regulating the exhaust temperature in such a way that the catalyst temperature of the occlusion catalyst 2 is maintained at the regeneration temperature T_c . Commencement requirements pertaining to the second catalyst temperature T_2 and the vehicle speed V are requirements for determining whether or not the current state is an operating state that allows an increase in exhaust temperature which would be caused by purge control.

[0075] A specific technique for regulating an exhaust temperature under purge control is arbitrary. A conceivable technique includes changing of; for instance, a fuel-air ratio, an intake air quantity, a fuel injection quantity, fuel injection timing, a post injection quantity, and the like, that are relevant to combustion reaction occurred in the combustion chambers of the engine 1. A requirement to complete purge control is that the first catalyst temperature T_1 becomes continually equal to or higher than the regeneration temperature T_c for a predetermined period of time. The predetermined period of time is set to; for instance, several minutes. Preferable completion requirements are that hydrocarbon is deemed to be desorbed and purified substantially completely from the occlusion catalyst 2.

[0076] Since hydrocarbon occluded in the occluding catalyst 2 is eliminated under purge control, calculation of the occlusion quantity Q is unnecessary. In the embodiment, the purge control block 17 sets a purge implement flag F_2 to $F_2 = 1$ (on) at the start of purge control, thereby letting the estimation control block 11 suspend estimation operation. The purge implement flag F_2 is assumed to be set to $F_2 = 0$ (off) at the end of purge control. The purge control block 17 resets the occlusion quantities Q , which has been totalized by means of occlusion quantity estimation control performed by the estimation control block 11, to $Q = 0$ at the end of purge control.

[4. Flowchart]

[0077] Fig. 9 is a flowchart showing example occlusion quantity estimation control. Fig. 10 is a flowchart showing example purge control. Processing pertaining to these flows are concurrently in progress, thereby attempting to synchronize control specifics by way of the two types of flags F_1 and F_2 . A calculation period of an occlusion quantity estimation control flow is ΔT .

[4-1. Occlusion quantity estimation control]

[0078] The estimation control block 11 performs occlusion quantity estimation control. In step A10, the estimation control block 11 determines a state of the purge implement flag F_2 . When the purge implement flag F_2 is $F_2 = 1$, processing pertaining to the flow ends as it does, whereby occlusion quantity estimation control is suspended. Alternatively, when the purge implement flag F_2 comes to $F_2 = 0$, processing proceeds to step A20.

[0079] The trap quantity calculation block 12 performs control operation pertaining to steps A20 to A40. First, in step A20 the engine discharge $M_{h\text{ceng}}$ is calculated by means of Equation 3. In step A30 the hydrocarbon inflow quantity $M_{h\text{cin}}$ is calculated by means of Equation 2. Further, in step A40 the trap quantity $M_{h\text{cad}}$ is calculated by means of Equation 1.

[0080] The distribution block 13 performs control processing pertaining to steps A50 to 70. In step A50, either the first catalyst temperature T_1 or the second catalyst temperature T_2 , whichever is higher, is selected. The minimum value of the temperature zone that is to become a distribution target of the trap quantity $M_{h\text{cad}}$ is determined by the thus-selected temperature. In step A60, the trap quantity $M_{h\text{cad}}$ is distributed to each of the temperature zones as shown in Figs. 6A and 6B. In step A70, the trap quantity $M_{h\text{cad}(n)}$ distributed to each of the temperature zones is added to the hydrocarbon occlusion quantity Q acquired so far in the previous operation period, as shown in Figs. 7A and 7B.

[0081] In step A80 the desorption quantity calculation block 14 calculates the desorption quantity $M_{h\text{cde}}$ according to the first catalyst temperature T_1 . The subtraction block 15 performs processing pertaining to subsequent steps A90 and A100. In step A90, temperature zones located on a lower boiling point side with reference to the temperature zones of the first catalyst temperature T_1 or more are determined as subtraction targets. Specifically, the maximum value for zones that become subtraction targets is determined by the first catalyst temperature T_1 .

[0082] In step A100, the desorption quantity $M_{h\text{cde}}$ is subtracted from the temperature zones located on the lower boiling point side in increasing sequence from a low boiling point. A distribution of occlusion quantities $Q_{(n)}$ of the hydrocarbon actually occluded in the occluding catalyst 2 for respective temperature zones is thereby acquired. As shown in Figs. 8B and 8C, the occlusion quantity Q is calculated by addition of all of the occlusion quantities $Q_{(n)}$ for respective temperature zones.

[0083] In step A110, the determination block 16 determines whether or not the occlusion quantity Q is a predetermined threshold value Q_{TH} or less. When $Q \leq Q_{\text{TH}}$, processing pertaining to the flow ends as it does. When $Q > Q_{\text{TH}}$, processing proceeds to step A120, where the determination block 16 sets the purge request flag F_1 to $F_1 = 1$ (on).

[4-2. Purge control]

[0084] The purge control block 17 performs purge control. In step B10, a state of the purge request flag F_1 is determined.

When the purge request flag F_1 is $F_1 = 0$, processing pertaining to the flow ends as it does. By contrast, when the purge request flag F_1 comes to $F_1 = 1$, processing proceeds to step B20.

[0085] In step B20, remaining initiation requirements for purge control are determined. When the second catalyst temperature T_2 is a predetermined temperature or less and when the vehicle speed V is a predetermined speed or higher, purge control initiation requirements are fulfilled, and processing proceeds to step B30. When the initiation requirements are not fulfilled, processing pertaining to the flow ends as it does.

[0086] In step B30, the purge implement flag F_2 is set to $F_2 = 1$. The purge implement flag F_2 acts to let the estimation control block 11 suspend performance of occlusion quantity estimation control. In step B40, purge control is performed. The temperature of emissions flowing into the occluding catalyst 2 is thereby regulated, so that the first catalyst temperature T_1 is maintained at the regeneration temperature T_c .

[0087] In step B50, completion requirements for purge control are determined. When the first catalyst temperature T_1 is continually equal to or higher than the regeneration temperature T_c for a predetermined period of time, completion requirements for purge control are fulfilled, whereupon processing proceeds to step B60. When the completion requirements are not successfully fulfilled, processing proceeds to step B50, and purge control is continually performed until the completion requirements are fulfilled.

[0088] In step B60, the occlusion quantity Q totalized through occlusion quantity estimation control is reset to $Q = 0$. In subsequent step B70, both the purge request flag F_1 and the purge implement flag F_2 are set to $F_1 = F_2 = 0$, whereby purge control is completed.

[5. Operation and Advantage]

[0089] In occlusion quantity estimation control, at the time of addition of the trap quantity M_{hcad} of hydrocarbon trapped by the occluding catalyst 2, the trap quantity M_{hcad} is distributed solely to temperature zones that are higher than either the first catalyst temperature T_1 or the second catalyst temperature T_2 , whichever is higher. The trap quantity can be distributed by eliminating the hydrocarbons having low boiling points that should not have flowed into the occluding catalyst 2 or the hydrocarbons having low boiling points that should not be trapped by the occluding catalyst 2, whereby occurrence of miscalculation is prevented. Consequently, it is possible to accurately ascertain the occlusion quantity Q of hydrocarbons having high boiling points. Further, control is implemented by means of a simple configuration based on the catalyst temperature of the occluding catalyst 2 and the catalyst temperature of the oxidation catalyst 3, so that the accuracy of estimation of an occlusion quantity can be enhanced without involvement of an increase in system cost.

[0090] In the present embodiment, the occluding catalyst 2 is situated at a downstream position on the exhaust passageway 6 with respect to the oxidation catalyst 3. Therefore, the first catalyst temperature T_1 is likely to be lower than the second catalyst temperature T_2 . Temperature zones that are to become distribution targets correspond to temperature zones on a high temperature boiling point side with reference to the first catalyst temperature T_1 . Therefore, it is possible to make a comparatively small estimate of the quantity of trapped hydrocarbon on the low boiling point side. Such a control configuration can also be said to contribute to accurate estimation of the trap quantity M_{hcad} and the occlusion quantity Q .

[0091] The distribution block 13 estimates a distribution of presence of hydrocarbons trapped by the occluding catalyst 2 for each type of hydrocarbon by means of taking as a model the distribution model imitating a boiling point distribution of hydrocarbons in emissions. As shown Fig. 4 and 6A, a model that takes as a model the boiling point distribution of hydrocarbons in emissions flowing into the occluding catalyst 2 is taken as a distribution model of the trap quantity M_{hcad} . Hence, it is possible to accurately ascertain the boiling point distribution of hydrocarbons trapped by the occluding catalyst 2. It is possible to accurately ascertain types of hydrocarbons on the occluding catalyst 2 and the occlusion quantity Q of each of the hydrocarbons.

[0092] At the time of subtraction of the quantity M_{hcds} of hydrocarbons desorbed from the occluding catalyst 2, the desorption quantity M_{hcds} is subtracted solely from the temperature zones on the lower boiling point side than from the temperature zones corresponding to the first catalyst temperature T_1 . Therefore, the quantities of hydrocarbons having high boiling points that should not originally be desorbed are not subtracted, and the occlusion quantity Q of hydrocarbons having high boiling points can be maintained from a calculation viewpoint, so that underestimation of the occlusion quantity Q can be inhibited.

[0093] Since the sequence of subtraction originates from a trap quantity of a hydrocarbon having a low boiling point toward a trap quantity of a hydrocarbon having a high boiling point, it is possible to accurately ascertain the distribution of occlusion quantities $Q_{(n)}$ of hydrocarbons actually occluded in the occluding catalyst 2. Therefore, the accuracy of estimation of the occlusion quantity Q can be enhanced.

[0094] Further, since purge control is performed according to an accurate estimation of the occlusion quantity Q , it is possible to minimize an increase in fuel consumption while deterioration of the occluding catalyst 2 is prevented, and also to enhance efficiency of emission purification.

[6. Example modifications or the like]

[0095] Regardless of the embodiments, the present invention can be implemented in various forms without departing the gist of the invention. The respective configurations of the embodiment can be adopted or rejected, as required, or used in combination if necessary.

[0096] The foregoing embodiment has exemplified the occluding catalyst 2 as a catalyst unit having a hydrocarbon occluding layer and a precious metal catalyst layer. In lieu of the configuration, there may also be adopted a configuration equipped solely with an occluding member, which acts as an occluding layer, in the exhaust passageway 6. Specifically, the precious metal catalyst layer is not an indispensable element. The minimum requirement is that a layer should trap and desorb hydrocarbons included in emission and trap and desorb a plurality of types of hydrocarbons having different boiling points.

[0097] A catalyst configuration of a specific exhaust system is not confined to the foregoing embodiment. For instance, the oxidation catalyst 3 can also be omitted, or the layout of the catalyst on the exhaust passageway 6 can also be changed. If the oxidation catalyst 3 is omitted, the second temperature sensor 5 will become unnecessary. Further, the upstream slip coefficient K_{OXI} will become unnecessary for calculation of the quantity M_{hcin} of inflow hydrocarbon. Alternatively, another catalyst or filter may also be interposed at a position on the exhaust passageway 6 between the occluding catalyst 2 and the oxidation catalyst 3.

[0098] When a nitrogen oxide occluding catalyst is interposed between the occluding catalyst 2 and the oxidation catalyst 3, it is preferable to add to calculation of the engine discharge M_{hcehg} a quantity of hydrocarbon serving as an additive used for reducing reaction in the nitrogen oxide occluding catalyst. As shown in; for instance, Fig. 5G, a conceivable way is to set a fuel-air ratio correction coefficient K_{NOP} according to a state of a fuel-air ratio, and a right side of Equation 3 is multiplied by the coefficient, thereby correcting the engine discharge M_{hcehg} . The operation makes it possible to accurately ascertain the quantity of hydrocarbon flowing into the occluding catalyst 2, whereby the precision of assumption of the hydrocarbon occlusion quantity Q can be further enhanced.

[0099] As shown in Figs. 4 and 6, the embodiment has illustrated a simplified illustration of a distribution model of boiling points of hydrocarbons included in emissions and a simplified illustration of a distribution model of the trap quantity M_{hcad} . Specific shapes of the models are arbitrary. The distribution model of boiling points and the distribution model of the trap quantity M_{hcad} are considered to be set, as required, according to the property of a fuel used in the engine 1, a structure and shape of an exhaust system, a configuration of the catalyst, and the like. Moreover, models that have previously been set by means of tests, or the like, may also be used for the distribution model of boiling points of hydrocarbons and the distribution model of the trap quantity M_{hcad} . Alternatively, there may also be adopted a model that is equipped with a sensor for detecting the property of a fuel, an operating condition of a system, or the like, and that is set or changed according to information from the sensor.

[0100] Classification of types of hydrocarbons performed during estimation and calculation of the occlusion quantity is based on boiling points in the embodiment. However, classification may also be performed according to the number of carbons or according to a molecular structure instead. Specifically, conceivable classification is based on a physical quantity correlating with boiling points. So long as the quantity Q of hydrocarbons occluded in the occluding catalyst 2 is classified at least by use of a physical quantity correlating with boiling points, control analogous to that described in connection with the embodiment is implemented, so that accuracy of estimation of the occlusion quantity can be enhanced.

[0101] In the embodiment, the first temperature sensor 4 provided downstream of the occluding catalyst 2 detects the first catalyst temperature T_1 , and the second temperature sensor 5 provided downstream of the oxidation catalyst 3 detects the second catalyst temperature T_2 . However, a technique for ascertaining the first catalyst temperature T_1 and the second catalyst temperature T_2 is not limited to that mentioned above. For instance, there may also be used a technique for estimating the first catalyst temperature T_1 and the second catalyst temperature T_2 according to a property of any exhaust. Alternatively, another catalyst temperature may also be estimated from one catalyst temperature.

[0102] Although the embodiment provided an exemplification of use of the torque sensor 25 for detection of torque of the drive shaft of the engine 1, the technique for calculating engine torque is not limited to the thus-exemplified technique. For instance, a combustion pressure sensor for detecting combustion pressure in cylinders may also be used. Alternatively, a torque estimation value calculated by an unillustrated engine ECU may also be utilized.

[0103] The disclosed exhaust emission control device of an internal combustion engine can be applied to both a diesel engine and a gasoline engine.

Claims

1. An exhaust emission control device for an internal combustion engine comprising:

an occluding member that is provided in an exhaust system of an internal combustion engine and that traps

and desorbs a plurality of types of hydrocarbons having different boiling points in emissions;
a first calculation means that estimates a distribution of presence of each type of the hydrocarbons to be trapped
by the occluding member and that calculates an occlusion quantity of the occluding member for each type of
the hydrocarbons from the quantity of trapped hydrocarbons; and
a control means that performs control operation for purifying the hydrocarbons occluded in the occluding member
according to the occlusion quantity calculated by the first calculation means.

2. The exhaust emission control device as set forth in Claim 1, further comprising:

a second calculation means that subtracts in sequence a quantity of the hydrocarbon desorbed from the occluding
member from the quantity of occluded hydrocarbon having a lower boiling point among the occlusion quantities
calculated by the first calculation means, thereby calculating the quantity of hydrocarbon occluded in the oc-
cluding member.

3. The exhaust emission control device as set forth in Claim 2, further comprising:

a first catalyst temperature detection means for detecting a first catalyst temperature that is a catalyst temperature
of the occluding member,
wherein the first calculation means calculates a quantity of trapped hydrocarbon having a boiling point that is
equal to or higher than the first catalyst temperature detected by the first catalyst temperature detection means.

4. The exhaust emission control device as set forth in Claim 3, wherein
the second calculation means subtracts the desorption quantity solely from the quantity of occluded hydrocarbon
having a boiling point that is less than the first catalyst temperature detected by the first catalyst temperature detection
means.

5. The exhaust emission control device as set forth in Claims 3 or 4, further comprising:

an oxidation catalyst provided in an upstream position with reference to an occluding catalyst in the exhaust; and
a second catalyst temperature detection means that detects a second catalyst temperature that is a catalyst
temperature of the oxidation catalyst,
wherein the first calculation means calculates a quantity of trapped hydrocarbon having a boiling point that is
equal to or higher than either the first catalyst temperature detected by the first catalyst temperature detection
means or the second catalyst temperature detected by the second catalyst temperature detection means,
whichever is higher.

FIG. 1

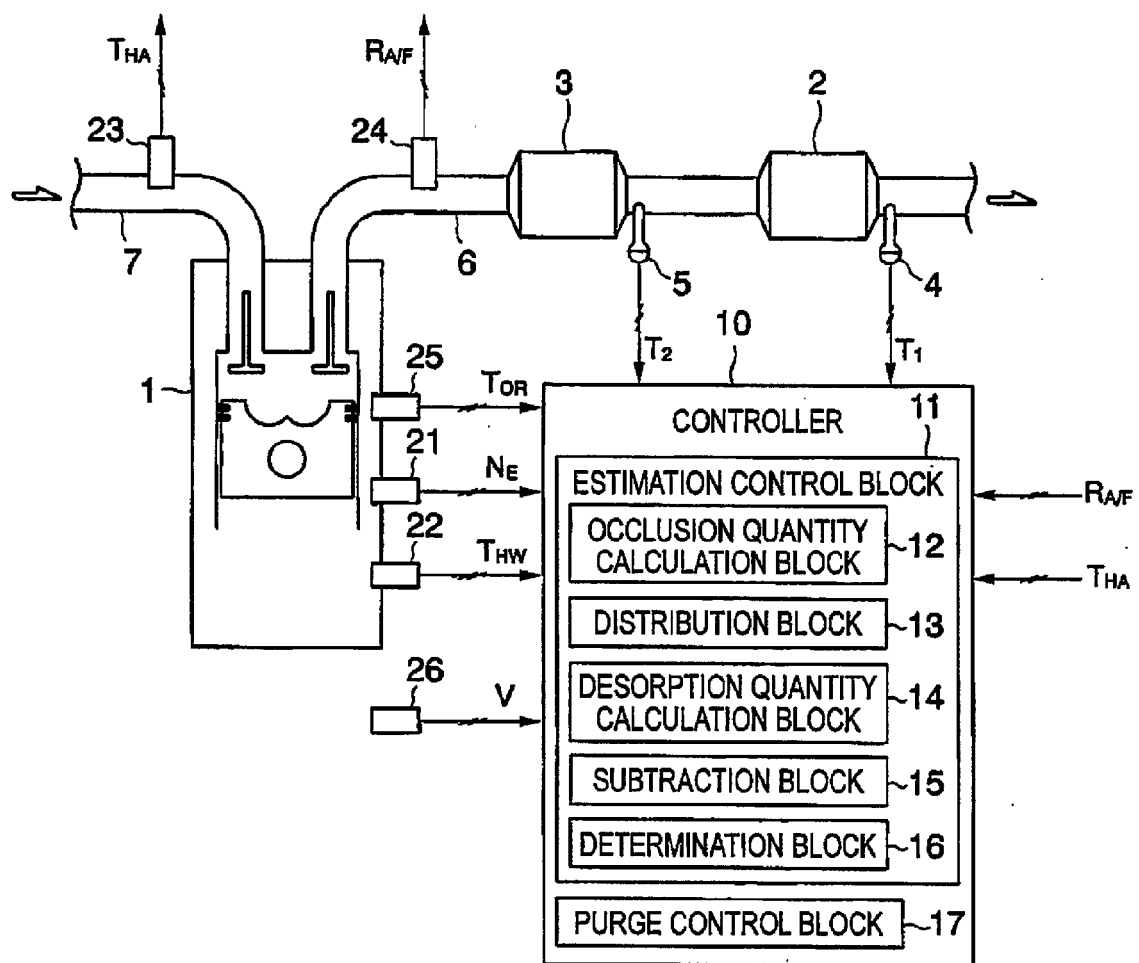


FIG. 2

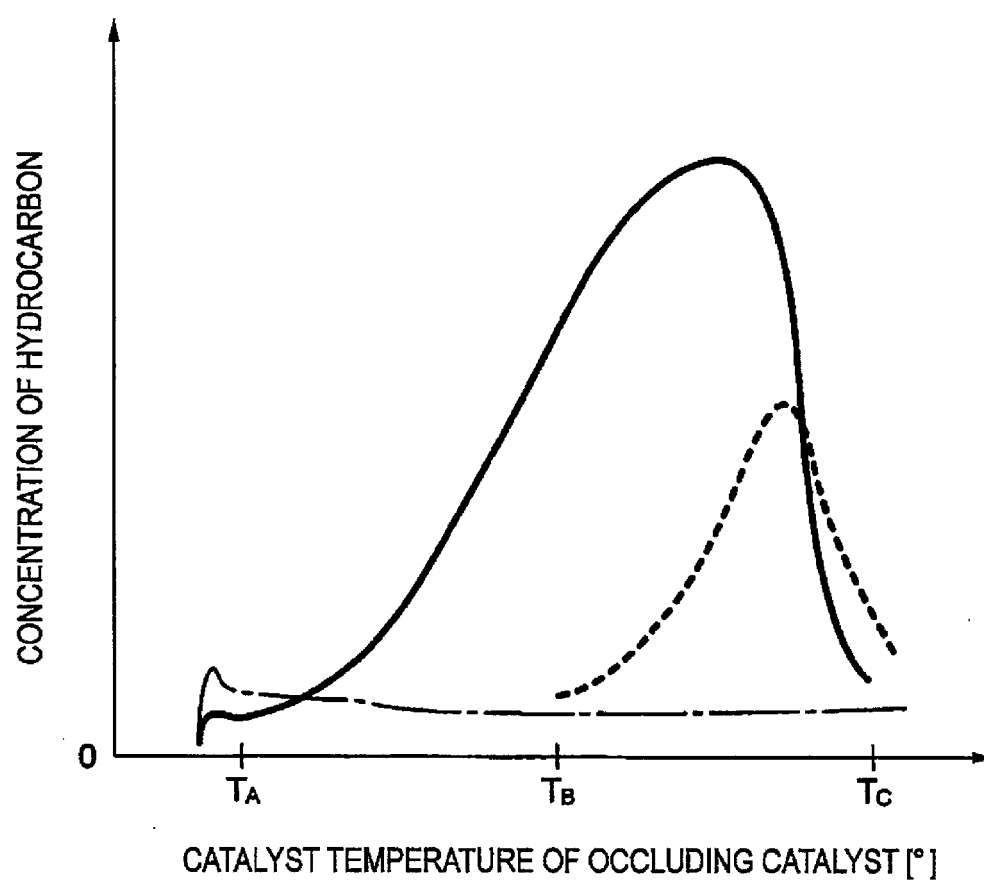


FIG. 3

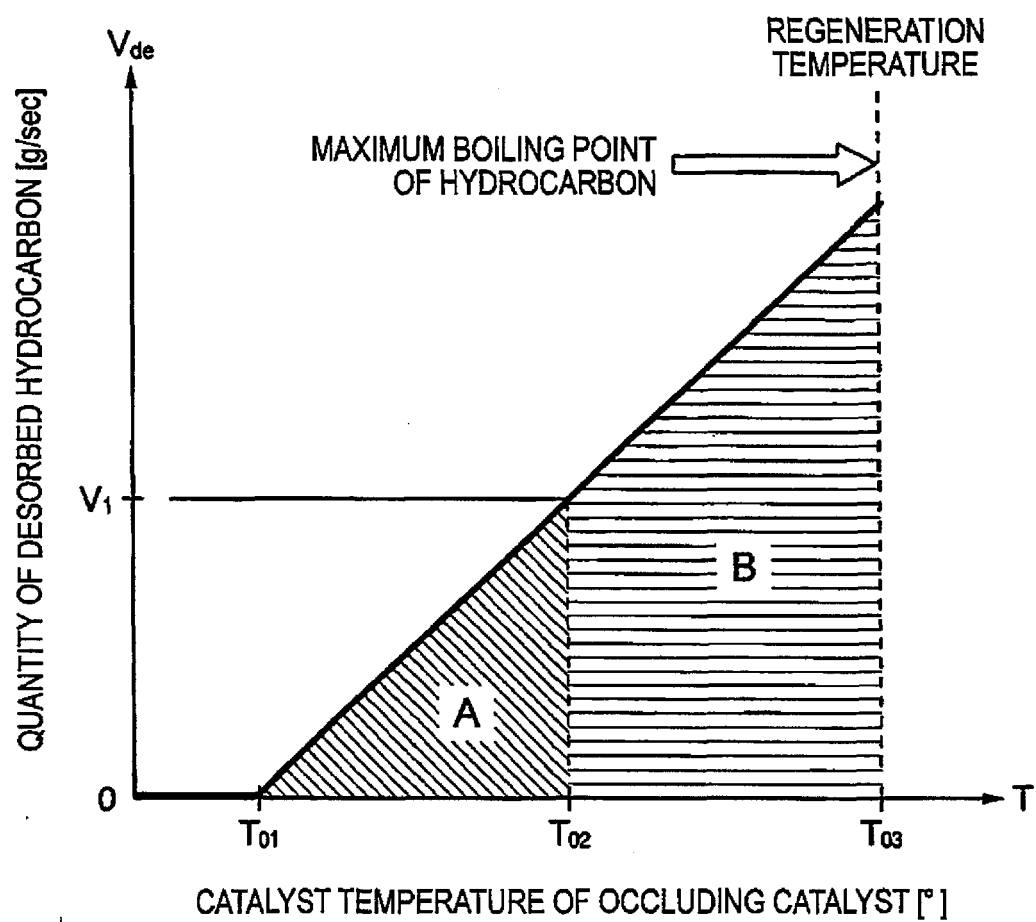


FIG. 4

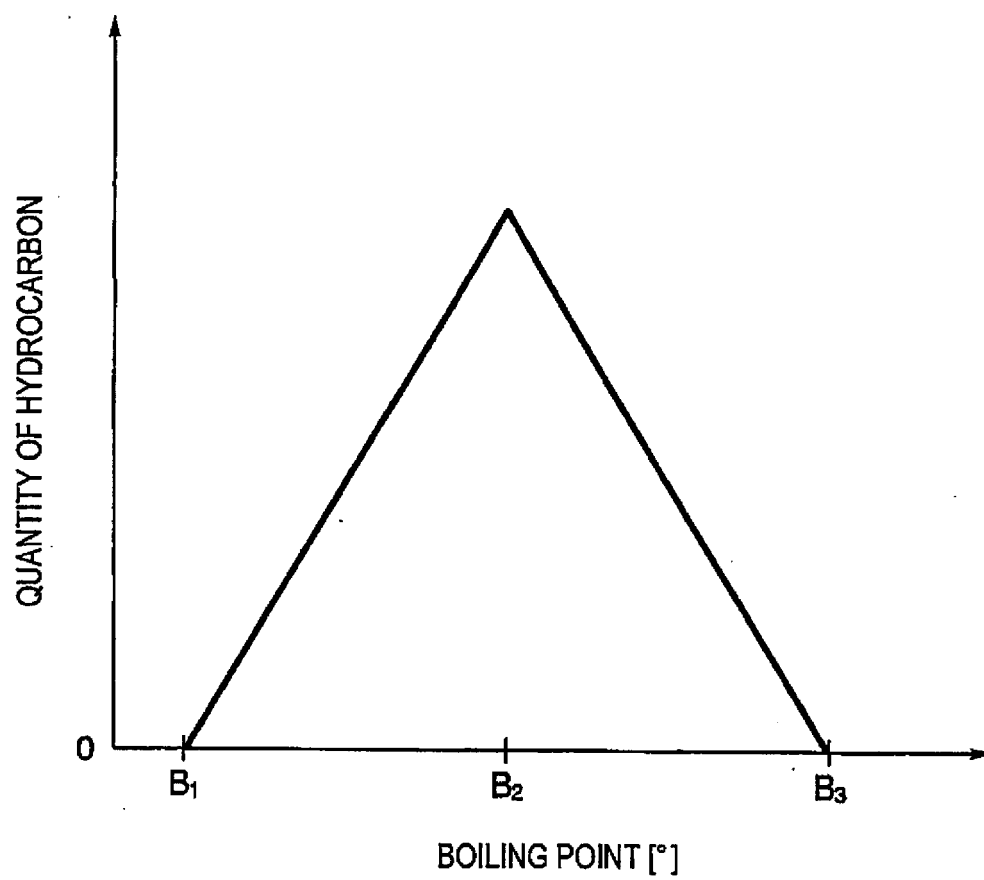


FIG. 5A

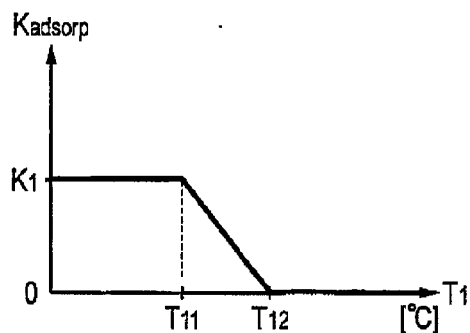


FIG. 5E

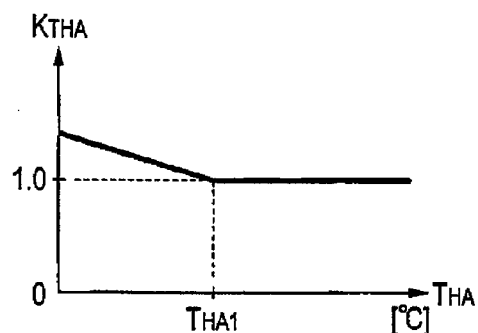


FIG. 5B

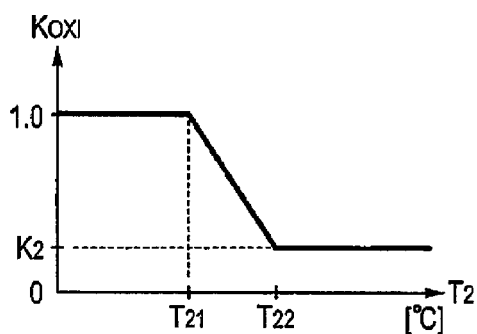


FIG. 5F

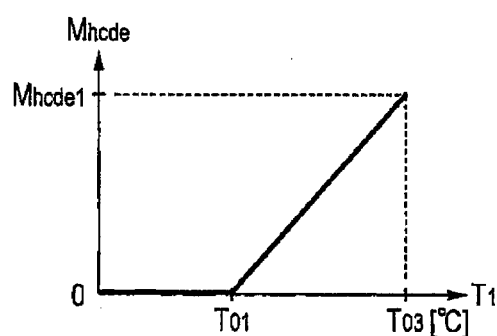


FIG. 5C

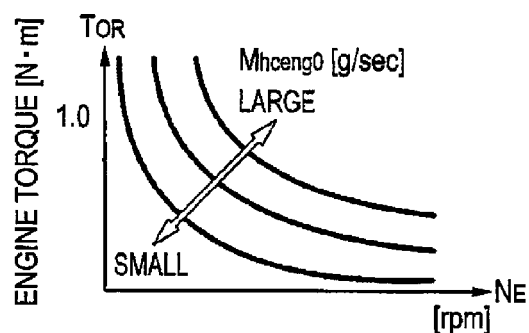


FIG. 5G

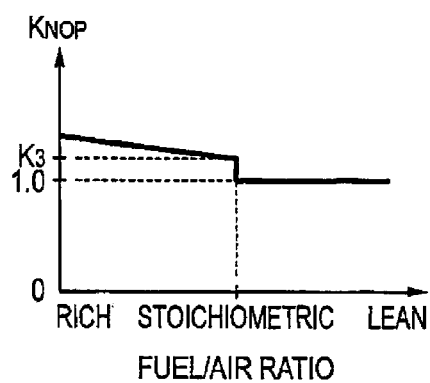


FIG. 5D

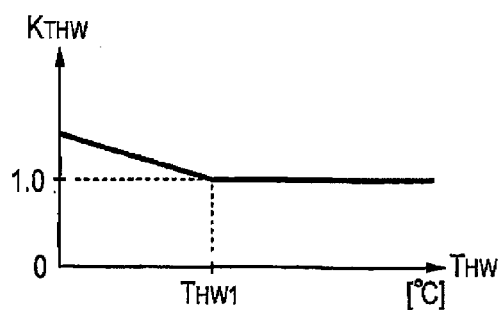


FIG. 6A

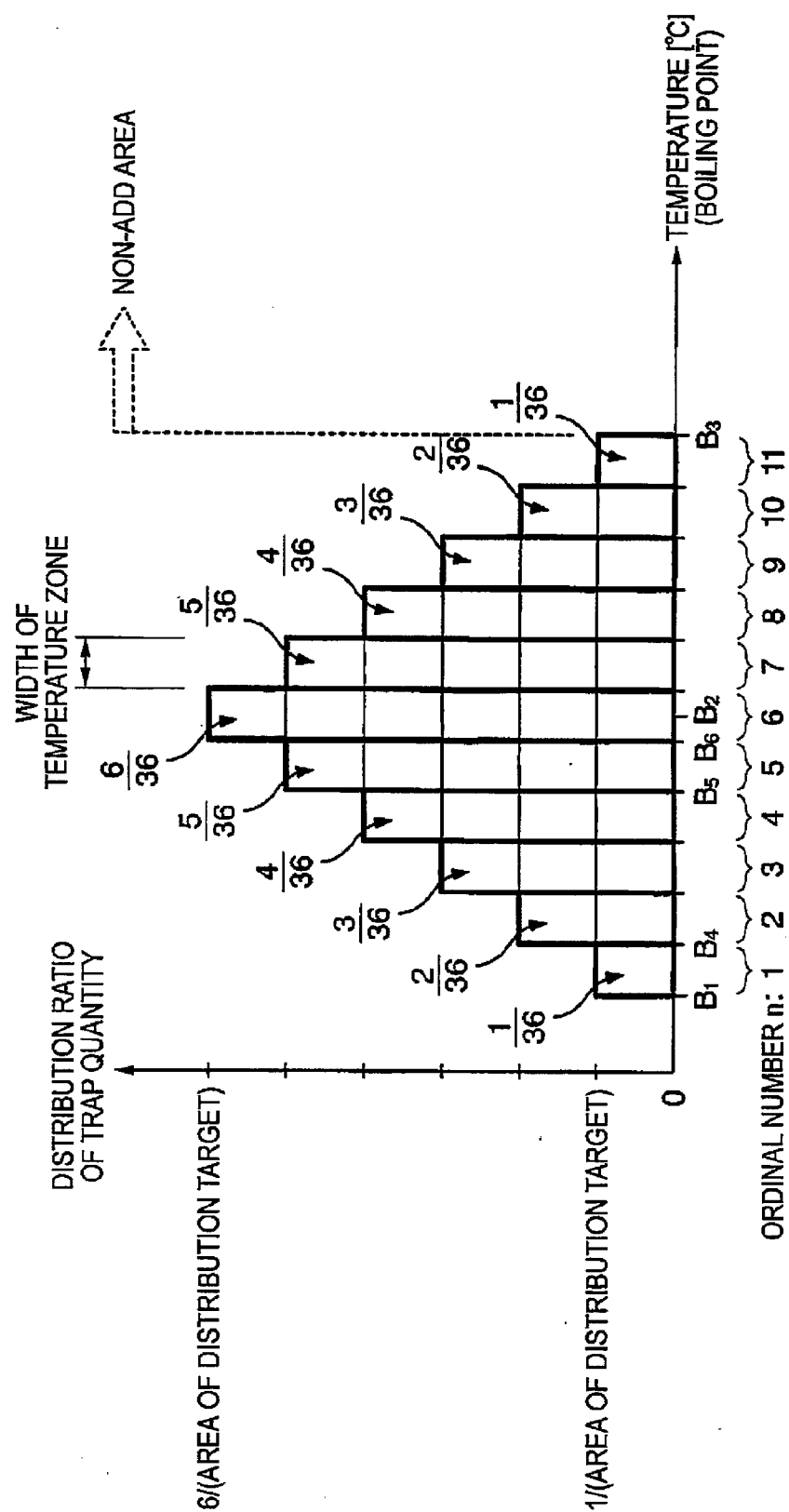


FIG. 6B

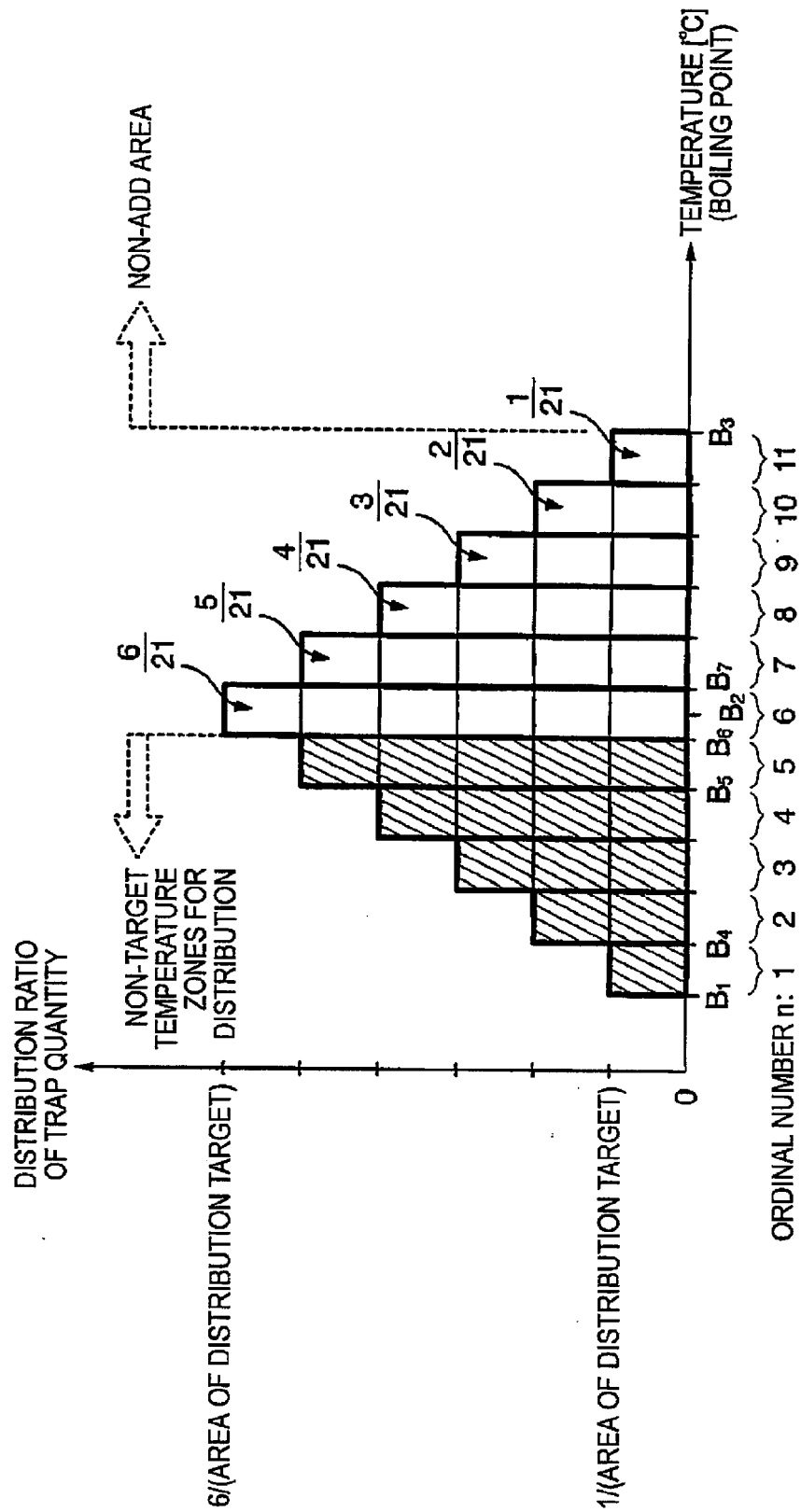


FIG. 7A

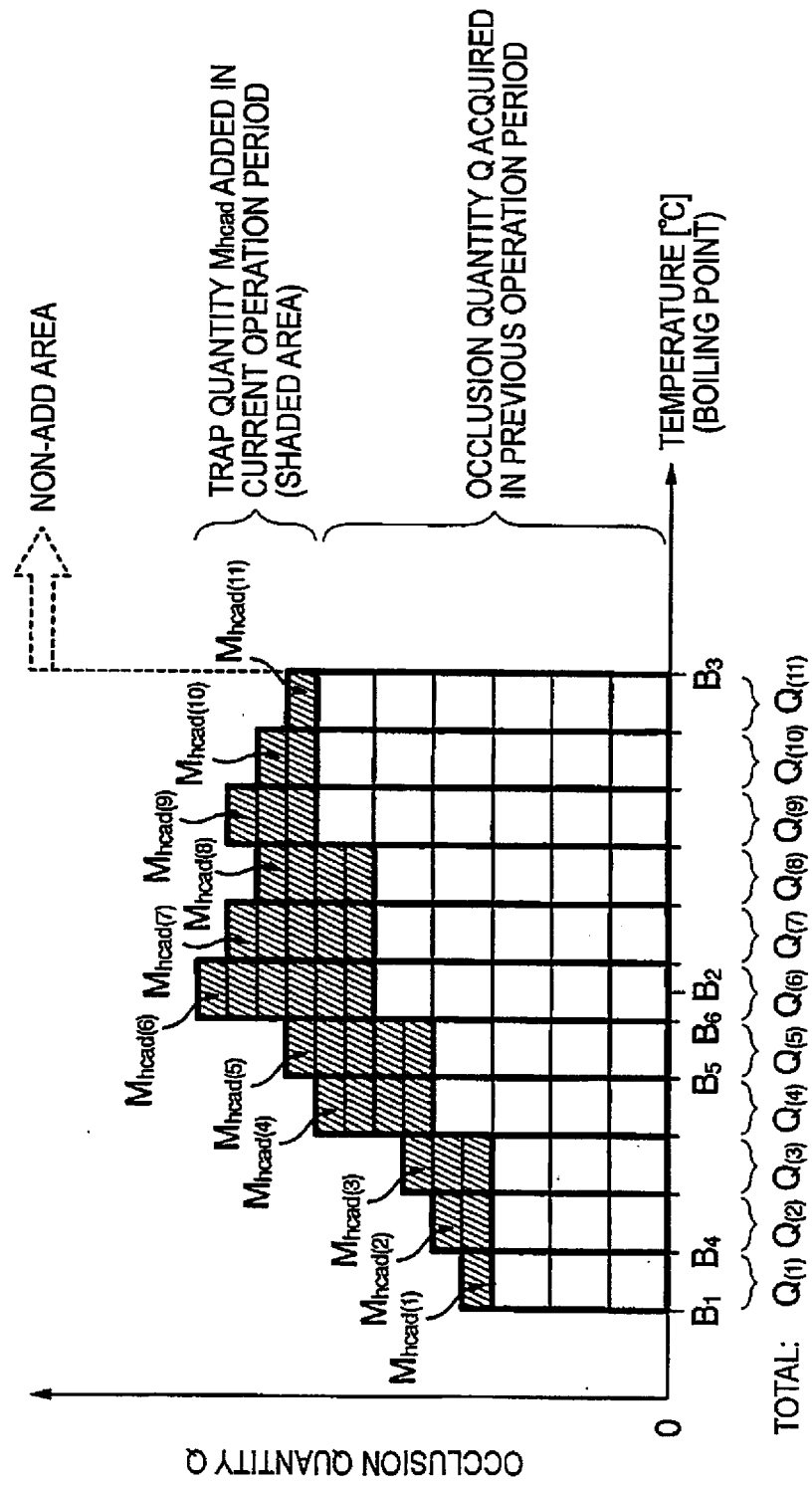


FIG. 7B

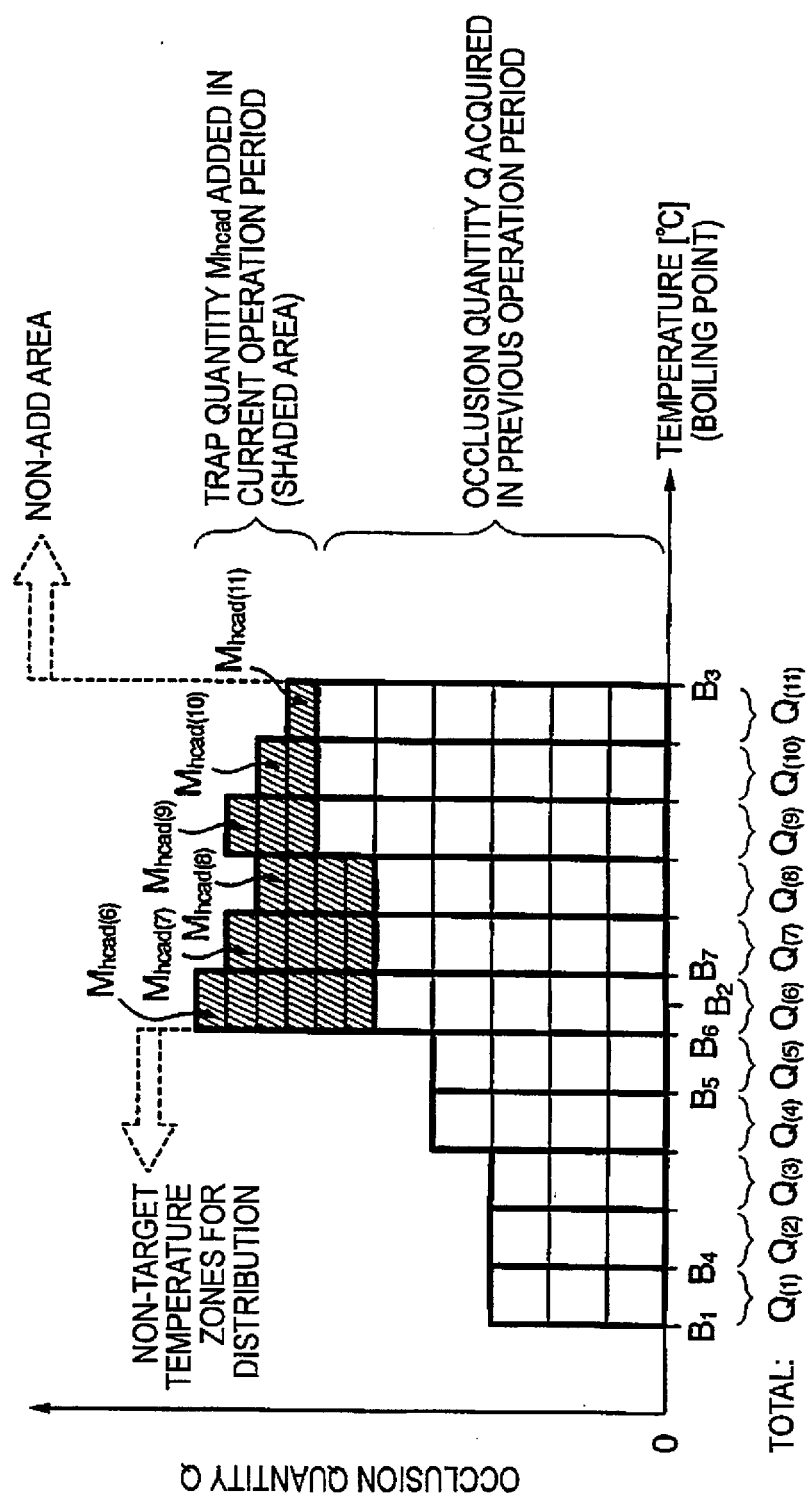


FIG. 8A

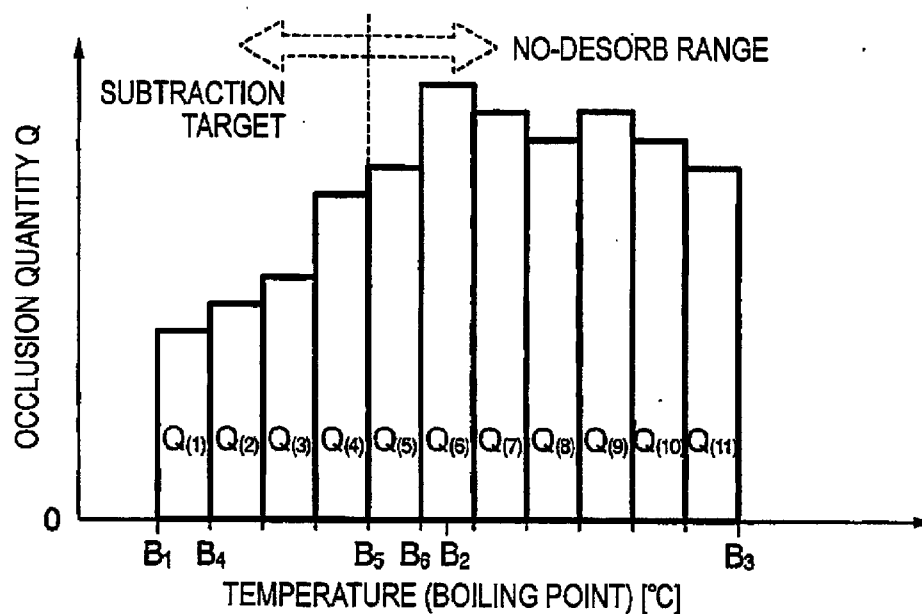


FIG. 8B

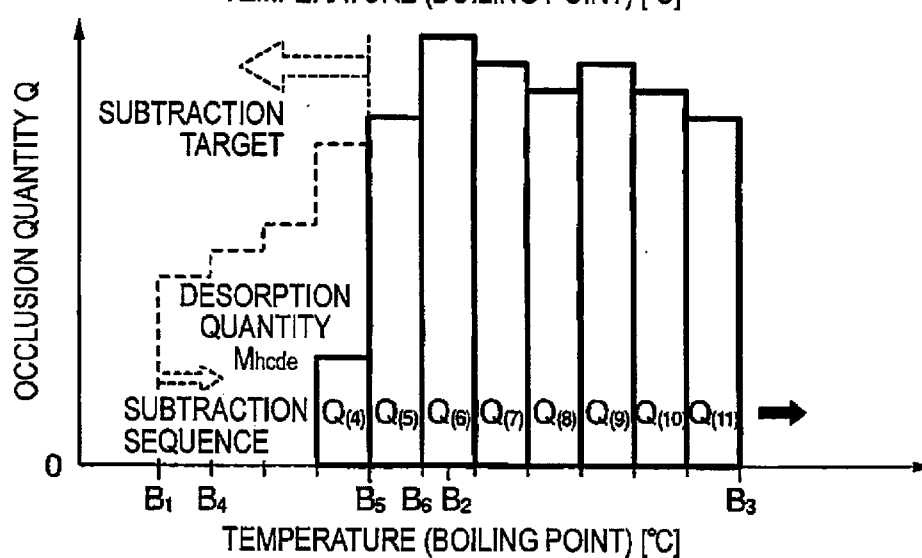


FIG. 8C

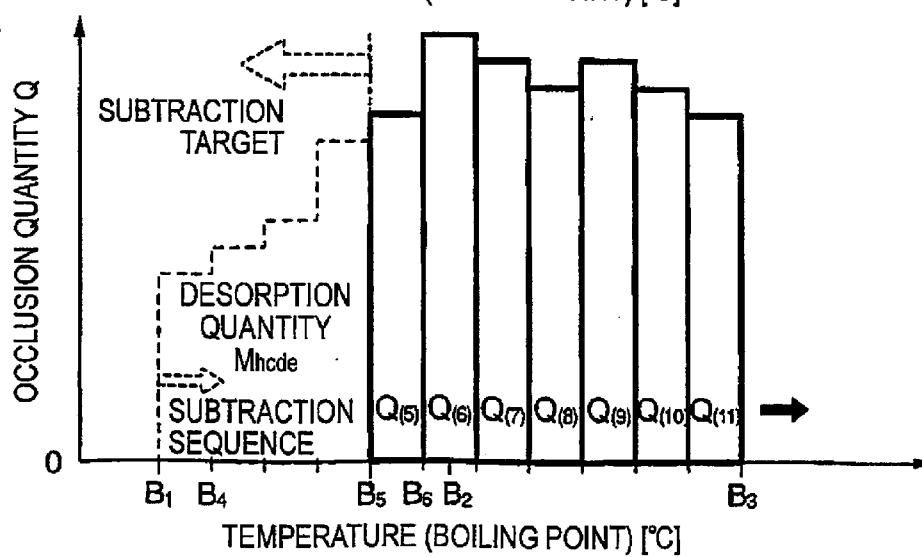


FIG. 9

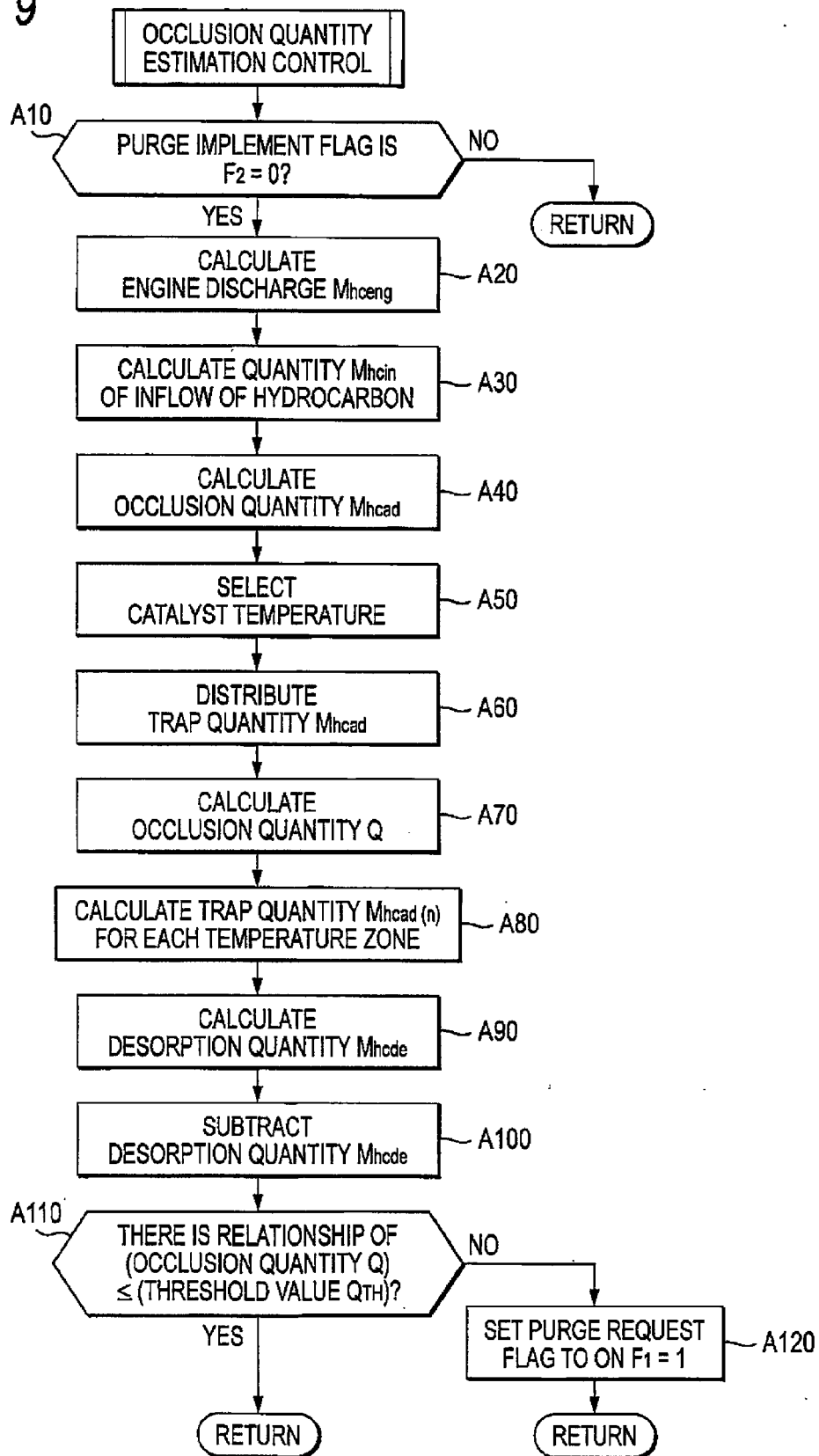
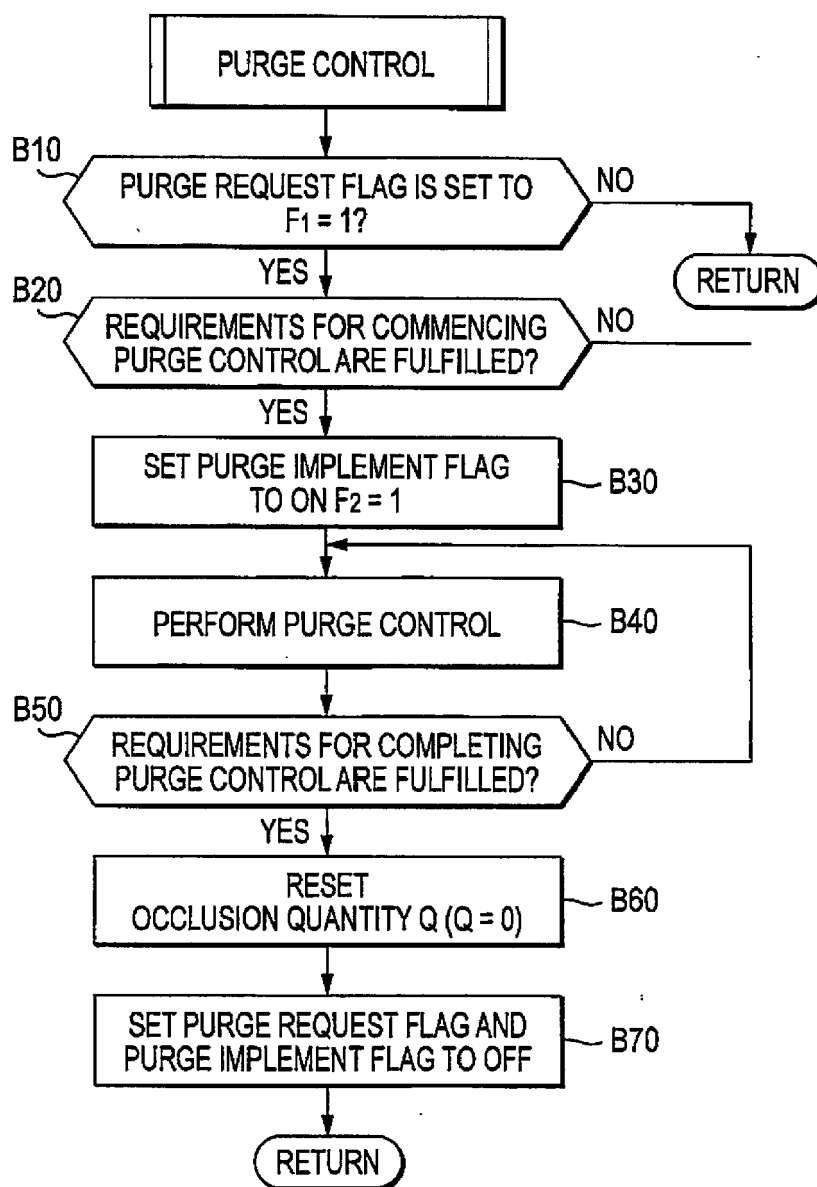


FIG. 10



REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2005240726 A [0003] [0005] [0006]