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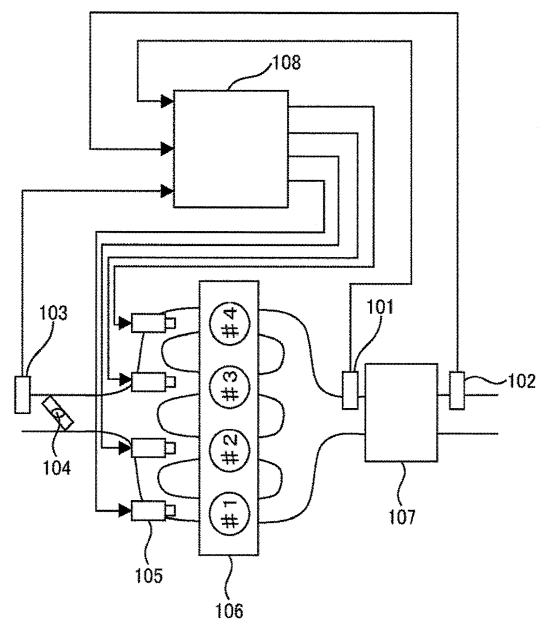
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(54) **Control diagnostic apparatus for internal combustion engine**

(57) To prevent the deterioration of exhaust emissions of an internal combustion engine due to air-fuel ratio variation among multiple cylinders, and to identify an abnormal cylinder during an abnormality of cylinder air-fuel ratio variation. An control apparatus 108 of an internal combustion engine comprising upstream air-fuel ratio detection means 101 for detecting upstream air-fuel ratio of the catalyst 107 that purifies exhaust emissions discharged from multiple cylinders, and configured to control air-fuel ratio of the multiple cylinders based on the upstream air-fuel ratio, wherein the air-fuel ratio variation among the multiple cylinders is increased and the upstream air-fuel ratio is controlled to become rich. Further, an abnormality of the air-fuel ratio variation among the multiple cylinders and an abnormal cylinder are identified based on an output of an air-fuel ratio sensor 102 in downstream of the catalyst 107 when the air-fuel ratio variation is increased, or an estimated value of an air-fuel ratio (central air-fuel ratio) at which the purification efficiency of the catalyst 107 becomes optimal.

FIG. 1



Description

BACKGROUND OF THE INVENTION

5 Field of the Invention

[0001] The present invention relates to a control apparatus for an internal combustion engine having multiple cylinders.

Background Art

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[0002] In an internal combustion engine having an exhaust gas purification system that utilizes a three-way catalyst, in order to perform the purification of HC, CO, and NOx in the exhaust gas with a catalyst, control of the air-fuel ratio of the gaseous mixture to be combusted in the internal engine is performed to achieve an air-fuel ratio (a central air-fuel ratio) at which the three components: HC, CO, and NOx are purified at a high efficiency in a good balance. Such control of air-fuel ratio is realized by providing an air-fuel ratio sensor in an exhaust passage of the internal combustion engine and performing a feedback control to make an air-fuel ratio detected by the sensor correspond to a predetermined target air-fuel ratio. (See JP Patent Publication (Kokai) No. 2009-30455.)

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SUMMARY OF THE INVENTION

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[0003] However, in an internal combustion engine having multiple cylinders, there is a drawback that the exhaust emission performance of the internal combustion engine may be deteriorated due to variation of the air-fuel ratio among the multiple cylinders (the air-fuel ratio of each cylinder).

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[0004] It is an object of the present invention to prevent the deterioration of the exhaust emission performance of an internal combustion engine due to air-fuel ratio variation among the multiple cylinders.

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[0005] A control apparatus of an internal combustion engine comprises: a catalyst for purifying exhaust gas discharged from multiple cylinders; upstream air-fuel ratio detection means for detecting an upstream air-fuel ratio of exhaust gas that flows into the catalyst; and/or air-fuel ratio control means for controlling a fuel injection amount of the multiple cylinders based on the upstream air-fuel ratio, wherein the control apparatus is adapted to control the fuel injection amount of the multiple cylinders when the air-fuel ratio among the multiple cylinders varies, such that the upstream air-fuel ratio is richer than the upstream air-fuel ratio detected before the air-fuel ratio among the multiple cylinders varies.

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[0006] Further, upon application of means relating to the present invention, it is possible to identify an abnormality of air-fuel ratio variation among the multiple cylinders and/or an abnormal cylinder based on an output of an air-fuel ratio sensor detected in a downstream of the catalyst when the air-fuel ratio variation is actively increased, or an air-fuel ratio (central air-fuel ratio) at which three exhaust emission components (HC, CO, and NOx) react with oxygen in the exhaust gas without excess or deficiency.

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[0007] According to the present invention, it is possible to prevent the deterioration of the exhaust emission performance of an internal combustion engine due to air-fuel ratio variation among the multiple cylinders.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0008]

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FIG. 1 is a general configuration diagram of an internal combustion engine.

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FIG. 2 is an explanatory diagram to illustrate the principle of air-fuel ratio variation among the multiple cylinders.

FIG. 3 illustrates the effects of air-fuel ratio variation among the multiple cylinders (air-fuel ratio sensor output and exhaust emissions).

FIG. 4 illustrates the effects of air-fuel ratio variation among the multiple cylinders (rear oxygen sensor output and exhaust emissions).

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FIG. 5 is an exemplary control block diagram of the present invention.

FIG. 6 illustrates an exemplary target air-fuel ratio computation section.

FIG. 7 illustrates an exemplary method of correcting the target air-fuel ratio and the central air-fuel ratio.

FIG. 8 illustrates the relationship between the degree of air-fuel ratio variation and an optimum purification air-fuel ratio.

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FIG. 9 is a time chart when the present invention is implemented (during normal time).

FIG. 10 is a time chart when the present invention is implemented (during a rich abnormality of the No. 1 cylinder).

FIG. 11 illustrates a change amount of the central air-fuel ratio during normal time.

FIG. 12 is a time chart during normal time.

FIG. 13 illustrates a change amount of the central air-fuel ratio during a rich abnormality of the No. 1 cylinder.

FIG. 14 is a time chart during a rich abnormality of the No. 1 cylinder.

FIG. 15 illustrates a change amount of the central air-fuel ratio during a lean abnormality of the No. 1 cylinder.

FIG. 16 is a time chart during a lean abnormality of the No. 1 cylinder.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0009] Hereafter, embodiments of the present invention will be described with reference to the drawings.

[0010] FIG. 1 is an exemplary general configuration diagram of an internal combustion engine to which the present invention is applied. At ECU 108 (control apparatus), control is performed such that the amount of air that flows into each cylinder is adjusted with a throttle 104, and a fuel injection amount of an injector 105 is adjusted such that an air-fuel ratio of each cylinder in the engine head 106 becomes a predetermined value (a target air-fuel ratio). In order to determine the fuel amount of the injector 105, a base injection amount which serves as a basics is determined by estimating the air amount in the cylinders from an air amount detected by an airflow rate sensor 103 and a rotational speed detected by a rotational speed sensor (not shown). The base injection amount is subject to a fuel correction such that an output (an upstream air-fuel ratio) of an air-fuel ratio sensor 101 placed in the upstream of a catalyst 107 corresponds to a target air-fuel ratio to be targeted. Further, a rear oxygen sensor 102 detecting a downstream air-fuel ratio in the downstream of the catalyst 107 is used to calculate (compute) an air-fuel ratio (a central air-fuel ratio) at which three exhaust components (HC, CO, NOx) fully react with oxygen without excess or deficiency. Then, controlling the target air-fuel ratio to be near the central air-fuel ratio allows the exhaust emission performance of the internal combustion engine to be maintained high even if there is a certain level of errors in the estimates of airflow amount and the output of the air-fuel ratio sensor. However, if for example the injector 105 is degraded resulting in variation of the injection amount of each cylinder, and an abnormality that the air-fuel ratio of each cylinder varies (air-fuel ratio variation among the multiple cylinders) occurs, deterioration of exhaust emissions will result through a mechanism to be described next.

[0011] FIG. 2 schematically shows the relationship between the output of the air-fuel ratio sensor in the upstream of the catalyst (measured values) and the actual air-fuel ratio of exhaust gas (true values) when the air-fuel ratio of a predetermined cylinder is intentionally shifted to the rich side or lean side thereby generating an air-fuel ratio variation among the multiple cylinders. Even if the air-fuel ratio among the multiple cylinders is varied, the measured value detected by the air-fuel ratio sensor 101 is controlled to become constant at a target value. This is because as described above, a feedback control serves to maintain measured values at the target value. However, as shown in FIG. 2, the air-fuel ratio of the exhaust gas that actually flows into the catalyst becomes leaner as the air-fuel ratio of a predetermined cylinder is shifted away from the stoichiometric value, and the air-fuel ratio variation among the multiple cylinders increases. In other words, a measured value will become richer than the true value due to the air-fuel ratio variation among the multiple cylinders. It is noted that the air-fuel ratio of exhaust gas described herein is an air-fuel ratio that can be calculated by a common method from the concentrations of exhaust components (HC, CO, CO₂) in the upstream of the catalyst and so on, and is calculated, for example, as the output of an exhaust gas analyzer.

[0012] FIG. 3 illustrates an example of experimental results that confirmed a "rich shift" in the air-fuel ratio sensor 101 output caused by an air-fuel ratio variation among the multiple cylinders. FIG. 3(a) shows output values of the air-fuel ratio sensor in the upstream of the catalyst in the abscissa axis, and measured values of HC, CO, and NOx in the downstream of the catalyst measured by an exhaust gas analyzer in the ordinate axis. If there is no air-fuel ratio variation among the multiple cylinders, the central air-fuel ratio of HC, CO, and NOx is 14.45. However, if the air-fuel ratio of the No. 1 cylinder is made richer by 20% than those of the other three cylinders, the central air-fuel ratio is shifted by 0.1 toward the rich side to be 14.35. That is, this experimental result shows that when there is an air-fuel ratio variation among the multiple cylinders, the exhaust gas air-fuel ratio becomes lean even if the air-fuel ratio sensor 101 output is maintained to be constant by air-fuel ratio control, thereby resulting in an increase in the NOx exhaust amount.

[0013] The reason why the measured value become richer than the true value is that the rich response of the air-fuel ratio sensor 101 is faster than the lean response thereof. Therefore, this phenomenon becomes noticeable as the difference between the rich response and the lean response of the sensor increases. On the other hand, this difference is small in the rear oxygen sensor 102 placed in the downstream of the catalyst, and a rich shift as described above will not occur.

[0014] FIG. 4 shows an example of the relationship between the rear oxygen sensor output and the exhaust gas in the downstream of the catalyst. In the present experiment, the air-fuel ratio of the No. 1 cylinder is set to be the same (normal) as, 20% richer, and 20% leaner than that of other cylinders. In the present experiment, the sensor output when HC, CO, NOx are best purified is about 600 mV regardless of the air-fuel ratio variation among the multiple cylinders. Therefore, setting a target air-fuel ratio for the air-fuel ratio control such that the output value of the rear oxygen sensor (the rear O₂ sensor) becomes constantly about 600 mV will allow the prevention of exhaust emission deterioration due to air-fuel ratio variation among the multiple cylinders.

Embodiment 1

[0015] A first embodiment of the present invention will be described by using FIGS. 5 to 10.

[0016] FIG. 5 is an exemplary control block diagram to implement the present invention. As will be described later in detail, a target air-fuel ratio computation section 501 calculates an oxygen storage amount (OS amount) in the catalyst from an air-fuel ratio sensor output (the upstream air-fuel ratio) and an airflow rate sensor output, and computes a target air-fuel ratio which causes the OS amount to stay in a predetermined range. A base injection amount computation section 503 estimates a cylinder air amount from an airflow rate sensor output and an engine revolutionary speed sensor (not shown) output, etc. and calculates a base injection amount based on the target air-fuel ratio. An air-fuel ratio control computation section 504 computes a correction value (an air-fuel ratio correction amount) for the base injection amount which will make the air-fuel ratio sensor output correspond to the target air-fuel ratio. Then, in an INJ injection amount setting section 506, a fuel pulse width which is obtained by applying the air-fuel ratio correction amount to the base injection amount is set for each cylinder. The present embodiment includes a cylinder variation control computation section 505 that computes a command value for variation of the upstream air-fuel ratio among the multiple cylinders (for cylinder air-fuel ratio variation) to realize a cylinder variation of each cylinder, and a cylinder air-fuel ratio variation determination section 502 that determines the cylinder air-fuel ratio variation from the command value for variation of the air-fuel ratio among the multiple cylinders and the output of the air-fuel ratio sensor in the downstream of the catalyst. Correcting the target air-fuel ratio by the control of the fuel injection amount to the rich side depending on the cylinder air-fuel ratio variation set value which has been set here allows the prevention of the deterioration of exhaust emissions due to air-fuel ratio variation among the multiple cylinders. Further, it is possible to determine an abnormality of cylinder air-fuel ratio variation based on the rear oxygen sensor output (the down stream air-fuel ratio) while an air-fuel ratio variation among the multiple cylinders is generated.

[0017] FIG. 6 illustrates an example of the target air-fuel ratio computation section. An oxygen storage amount calculation section 602 calculates an oxygen storage amount OS by the following equation 1 from an air-fuel sensor output RABF an airflow rate sensor output QA and a central air-fuel ratio CNTABF.

$$OS = \Sigma (RABF - CNTABF) * QA \quad \dots \text{Equation 1}$$

[0018] A target air-fuel ratio correction section 601 changes the target air-fuel ratio in the direction in which the oxygen storage amount and the rear oxygen sensor output return to predetermined ranges when the oxygen storage amount OS departs from the predetermined range or the output of the rear oxygen sensor placed behind the catalyst departs from the predetermined range. Further, a central air-fuel ratio estimation section 603 corrects the central air-fuel ratio when the oxygen storage amount is within the range and the rear oxygen sensor output departs from the predetermined range. An air-fuel ratio correction section 604 corrects the target air-fuel ratio and the central air-fuel ratio based on the cylinder air-fuel ratio variation.

[0019] FIG. 7 illustrates an example of the method of correcting the target air-fuel ratio and the central air-fuel ratio. For example, when the oxygen storage amount OS increases, the target air-fuel ratio is made richer. Since this will cause the air-fuel ratio of the exhaust gas that flows into the catalyst to become richer thereby reducing the oxygen storage amount, it is possible to prevent the decline of NOx purification rate before a decline of NOx purification rate is detected by the rear oxygen sensor. Moreover, when the rear oxygen sensor output exceeds a rich determination criterion even though the oxygen storage amount is increasing, the target air-fuel ratio is made richer and the central air-fuel ratio is corrected to become richer to modify the oxygen storage amount computation of Equation 1. This will allow the air-fuel ratio of the exhaust gas that flows into the catalyst to approach the central air fuel ratio at which the three exhaust components react with oxygen without excess or deficiency in the presence of the catalyst.

[0020] FIG. 8 illustrates the relationship between the degree of variation of air-fuel ratio and an optimum purification air-fuel ratio. In the present example, air-fuel ratio variation is realized by increasing the fuel pulse width in one predetermined cylinder. Moreover, the optimum purification air-fuel ratio represents an output value of the air-fuel ratio sensor in the upstream of the catalyst, which is detected when all of HC, CO, NOx are purified at a highest efficiency by the catalyst. In the present invention, the injection pulse width of a predetermined cylinder is increased and the target value of the air-fuel ratio control is shifted to the rich side. In particular, when the control apparatus graphically makes the air-fuel ratio variation among the multiple cylinders, the response of the control of the air-fuel ratio becomes faster by setting a rich shift amount from an optimum air-fuel ratio determined by experiment in advance, than by correcting the target air-fuel ratio to an optimum air-fuel ratio based on the rear oxygen sensor output. As a result, the above setting a rich shift prevents from the deterioration of exhaust emissions.

[0021] FIG. 9 is an example of a time chart when the present control is performed. The control apparatus starts to make an air-fuel ratio variation among the multiple cylinders by increasing the fuel pulse width of the No. 1 cylinder to

be larger than those of other cylinders, and terminates to make the variation among the multiple cylinders by stopping the above increase. In the present embodiment, the control apparatus starts to make an air-fuel ratio variation among the multiple cylinders and simultaneously controls the upstream air-fuel ratio (the output of the air-fuel ratio sensor) by sifting the target air-fuel ratio toward the rich side.

[0022] As a result, an actual air-fuel ratio at the entrance of the catalyst is maintained at an air-fuel ratio at which the purification efficiency of the catalyst is optimized, and the rear oxygen sensor output is maintained between a rich determination threshold value and a lean determination threshold value. On the other hand, when terminating the air-fuel ratio variation among the multiple cylinders, the target air-fuel ratio is controlled (shifted) conversely toward the lean side.

[0023] FIG. 10 is an example of the time chart when the present control is performed during the making of an air-fuel ratio variation among the multiple cylinders. In this case, the rear oxygen sensor output is lower than the lean determination value even though the target air-fuel ratio is controlled (shifted) to become rich. This indicates that the air-fuel ratio of the No. 1 cylinder is richer than those of other cylinders before the fuel injection amount (the injection pulse width) of the No. 1 cylinder is increased. In this case, the injection pulse widths of other cylinders are increased one cylinder by one cylinder to record whether the rear oxygen sensor output departs from the range toward the rich side or the lean side. If the rear oxygen sensor output becomes lean when the fuel injection is increased in the No. 1 cylinder, and becomes rich when the fuel injection is increased in other cylinders, it can be determined that the No. 1 cylinder is in a rich abnormality. The reason is that if a rich cylinder is made richer, the air-fuel ratio variation among the multiple cylinders increases more than expected, and the rich correction predetermined by experiment is insufficient causing the rear oxygen sensor output to be lean. On the contrary, if another cylinder which has been made lean to balance with a rich cylinder is made richer, the rear oxygen sensor output becomes rich since the air-fuel ratio variation among the multiple cylinders becomes smaller than expected and the rich correction is large. When the No. 1 cylinder is in a lean abnormality, vice versa the converse is true and if the control of air-fuel ratio variation among the multiple cylinders is performed for all the cylinders and the rear oxygen sensor output becomes rich only in one predetermined cylinder, the one cylinder can be determined to be in a lean abnormality. Further, inhibiting the determination when the oxygen storage amount OS departs from a predetermined range allows the prevention of erroneous determination due to external disturbances. The present control is preferably performed after the catalyst is sufficiently activated.

[0024] Implementing the above described embodiment will achieve the following advantages. It is possible to prevent the deterioration of exhaust emissions when an air-fuel ratio variation among the multiple cylinders is intentionally generated. Therefore, the present control can improve the purification efficiency of the catalyst and facilitate the activation of the catalyst by making the air-fuel ratio chatter around an optimum purification air-fuel ratio, thereby improving exhaust emission performance. Further, it is possible to detect an abnormality of air-fuel ratio variation among the multiple cylinders and to identify an abnormal cylinder of which air-fuel ratio is different from those of others based on the rear oxygen sensor output upon generating the air-fuel ratio variation among the multiple cylinders.

Embodiment 2

[0025] A second embodiment will be described by using FIGS. 11 to 16. In the second embodiment, a central air-fuel ratio is used to perform abnormality determination. In the present embodiment, as shown in FIG. 11 (a), when a particular cylinder is controlled to become richer by a proportion X, the target air-fuel ratio and the central air-fuel ratio are shifted to the rich side by Y0. The relation between X and Y0 is determined by the above described optimum purification air-fuel ratio. FIG. 11(b) shows a change amount of the central air-fuel ratio before and after the diagnostics. During normal time, air-fuel ratio among the multiple cylinders becomes uniform. Since the central air-fuel ratio is corrected from A to B of FIG. 11(a), the change amount of the central air-fuel ratio will be Y0 when whichever cylinder is made rich.

[0026] FIG. 12 illustrates a time chart during normal time. In this embodiment, only the No. 1 cylinder is controlled to become richer by a rich proportion X upon start of diagnostics, and the target air-fuel ratio and the central air-fuel ratio are made richer by Y0 depending on the rich proportion X. As described in FIG. 11(a), X and Y0 shown here are a rich proportion and a rich shift amount of air-fuel ratio for maintaining an optimum purification air-fuel ratio. As a result of this, the catalyst will not depart from the optimum purification air-fuel ratio, and the output voltage of the rear oxygen sensor for detecting the air-fuel ratio in the downstream of the catalyst will be maintained within a predetermined range (600 to 800 mV).

[0027] Next, description will be made on a case in which one cylinder is rich and an air-fuel ratio variation among the multiple cylinders has occurred. FIG. 13(a) illustrates an optimum air-fuel ratio when control of the air-fuel ratio variation among the multiple cylinders is performed, in an abnormality case in which one cylinder is rich. Ar represents an air-fuel ratio before performing cylinder air-fuel ratio variation control and the No. 1 cylinder is shifted toward the rich side by Xre. Then, in order to keep the air-fuel ratio at a target air-fuel ratio, other cylinders are shifted toward the lean side by $Xre/(n-1)$. Where, n represents the number of cylinders. The result of shifting the No. 1 cylinder which is in a rich abnormality toward the rich side by X is Br, and the result of shifting the normal cylinders excepting the No. 1 cylinder

toward the rich side by X is BI. Thus, a cylinder in which a rich abnormality has occurred becomes richer than an expected value of Y0. On the other hand, when other normal cylinders are made rich, they will become leaner than an expected value of Y0. FIG. 13(b) illustrates the record of the central air-fuel ratio change amount when each cylinder is shifted toward the rich side by X, in which only the cylinder of a rich abnormality changes its central air-fuel ratio toward the rich side by a significant amount. Thus, if the recorded value of the central air-fuel ratio change amount becomes as shown in FIG. 13(b), it can be determined to be an abnormality of central air-fuel ratio, and one cylinder can be determined to be in a rich abnormality because only it is richer than Y0.

[0028] FIG. 14 is an example of a time chart when the No. 1 cylinder is in a rich abnormality. Only the No. 1 cylinder is shifted toward the rich side by X, and the target air-fuel ratio and the central air-fuel ratio are controlled to become richer. However, since as shown in FIG. 13(a), the optimum purification air-fuel ratio at that time is further richer, NOx cannot be purified and at the same time the output of the rear oxygen sensor in the downstream of the catalyst will become lean. Moreover, since at this time, the oxygen storage amount is not out of a predetermined range, the target air-fuel ratio and the central air-fuel ratio are corrected toward the rich side. As a result of this correction, an abnormal cylinder is identified from the central air-fuel ratio when the rear oxygen sensor output is converged to a fixed value within the predetermined range, and the change amount of the central air-fuel ratio before diagnostics.

[0029] Lastly, description will be made on the case in which an air-fuel ratio variation among the multiple cylinders in which one cylinder is leaner than other cylinders has occurred. In FIG. 15(a), the air-fuel ratio of the No. 1 cylinder is shifted toward the lean side by an amount of Xle, and the air-fuel ratios of other cylinders are shifted toward the rich side by an amount of Xle/(n-1). An optimum purification air-fuel ratio is determined by the air-fuel ratio of a rich cylinder. A1 is the target air-fuel ratio before diagnostics, BI is the result of making a lean abnormality cylinder run rich, and Br is the result of making remaining normal cylinders run rich. As shown in FIG. 15(b) as well, in a lean abnormality cylinder, the change amount of the central air-fuel ratio is less than an expected value Y0 (lean), and is larger than Y0 in normal cylinders (rich). In this case as well, the No. 1 cylinder which exhibits a different tendency from others, showing a small change amount in the central air-fuel ratio is determined to be in a lean abnormality.

[0030] FIG. 16 shows a time chart when the No. 1 cylinder is in a lean abnormality. The air-fuel ratio of the No. 1 cylinder is controlled to become richer by an amount of X, and also the target air-fuel ratio and the central air-fuel ratio are controlled to become richer by an amount of Y0. In this case, since as shown in FIG. 15(a), the optimum purification air-fuel ratio is leaner, CO and HC will increase and thereby the output of the rear oxygen sensor in the downstream of the catalyst will become rich. For this reason, the target air-fuel ratio and the central air-fuel ratio are corrected toward the lean side.

[0031] Implementing the above described embodiments, the following advantages will be achieved. It is possible to detect an abnormal cylinder in an air-fuel ratio variation among the multiple cylinders from the central air-fuel ratio when a predetermined cylinder is controlled to become rich and a cylinder air-fuel ratio variation is intentionally generated. It is noted that abnormality of the upstream air-fuel ratio sensor will result in a nearly same change amount of the central air-fuel ratio since the degree of the air-fuel ratio variation is the same regardless of in which cylinder the injection amount is increased. Thus, by using the change amount of the central air-fuel ratio, it is possible to detect only the air-fuel ratio variation among the multiple cylinders according to the present embodiment.

[0032] Moreover, since the detection error of the upstream air-fuel ratio detection means due to air-fuel ratio variation among the multiple cylinders is compensated, exhaust emission performance will not be deteriorated even if the air-fuel ratio variation among the multiple cylinders is intentionally varied. Further, during an abnormality when the air-fuel ratio among the multiple cylinders has varied, not only an abnormality can be detected, but also an abnormal cylinder can be identified. As a result of this, the robustness of emission performance as well as the maintainability during failure can be improved.

[0033] Features, components and specific details of the structures of the above-described embodiments may be exchanged or combined to form further embodiments optimized for the respective application. As far as those modifications are readily apparent for an expert skilled in the art they shall be disclosed implicitly by the above description of preferred embodiments and examples without specifying explicitly every possible combination, for the sake of conciseness of the present description.

Claims

1. A control apparatus of an internal combustion engine, comprising:

a catalyst (107) for purifying exhaust emission discharged from multiple cylinders;
upstream air-fuel ratio detection means for detecting an air-fuel ratio of exhaust gas that flows into the catalyst;
and
air-fuel ratio control means for controlling a fuel injection amount of the multiple cylinders based on the upstream

air-fuel ratio, wherein

the control apparatus (108) is adapted to control the fuel injection amount of the multiple cylinders when the air-fuel ratio among the multiple cylinders varies, such that the upstream air-fuel ratio is richer than the upstream air-fuel ratio detected before the air-fuel ratio among the multiple cylinders varies.

2. The control apparatus of an internal combustion engine according to claim 1, wherein a degree of control to make the upstream air-fuel ratio richer is increased in accordance with a degree of the air-fuel ratio variation among the multiple cylinders.
3. The control apparatus of an internal combustion engine according to claim 1 or 2, wherein the internal combustion engine comprises downstream air-fuel ratio detection means for detecting an air-fuel ratio of an exhaust gas that flows out from the catalyst (107), and the control apparatus (108) determines an abnormality of the air-fuel ratio variation among the multiple cylinders based on the downstream air-fuel ratio detected after the air-fuel ratio among the multiple cylinders has varied.
4. The control apparatus of an internal combustion engine according to any one of claims 1 to 3, wherein the control apparatus (108) comprises means for increasing the air-fuel ratio variation among the multiple cylinders by increasing or decreasing a fuel injection amount of at least one cylinder by a predetermined proportion relative to fuel injection amounts of other cylinders.
5. The control apparatus of an internal combustion engine according to claim 4, wherein a determination of air-fuel variation abnormality among the multiple cylinders is made if the downstream air-fuel ratio detected after the air-fuel ratio among the multiple cylinders is varied departs from a predetermined range.
6. The control apparatus of an internal combustion engine according to any one of claims 1 to 5, the control apparatus (108) being configured to estimate an oxygen storage amount (OS) to be stored in the catalyst (107) from an accumulated value of differences between at least the upstream air-fuel ratio and a central air-fuel ratio at which three exhaust components consisting of HC, CO, and NO_x react with oxygen in exhaust gas without excess and deficiency, and control the upstream air-fuel ratio such that the oxygen storage amount (OS) comes into a predetermined range, wherein the central air-fuel ratio is corrected toward the rich side in accordance with the air-fuel ratio variation among the multiple cylinders.
7. The control apparatus of an internal combustion engine according to any one of claims 1 to 6, wherein the control apparatus is configured to
 - increase the air-fuel ratio variation among the multiple cylinders by increasing or decreasing a fuel pulse width only for one particular cylinder;
 - to correct the central air-fuel ratio toward the rich side when the downstream air-fuel ratio becomes richer than a predetermined range;
 - to correct the central air-fuel ratio toward the lean side when the downstream air-fuel ratio becomes leaner than a predetermined range; and
 - to determine an abnormality of the air-fuel ratio variation among the multiple cylinders based on a correction amount of the central air-fuel ratio, the central air-fuel ratio being calculated while the air-fuel ratio variation among the cylinders is increasing.

FIG. 1

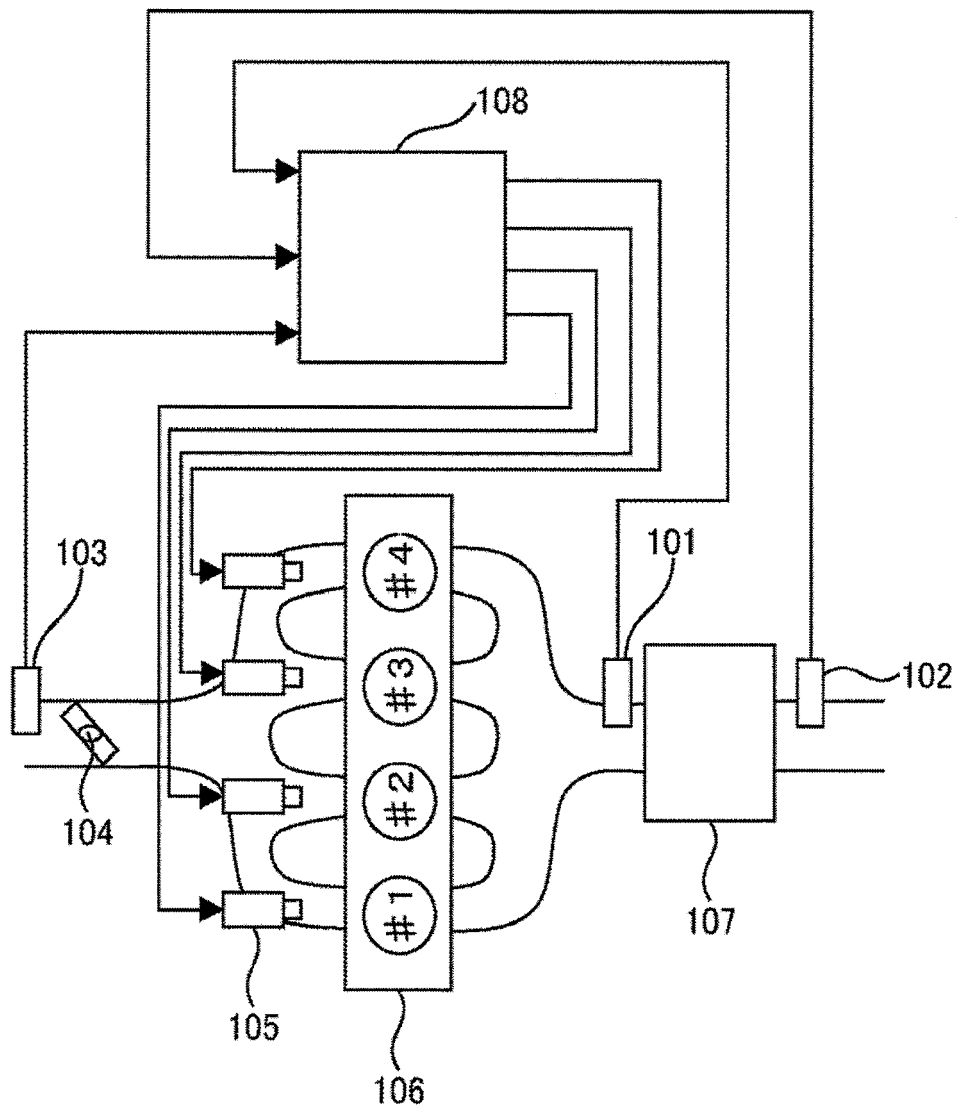


FIG. 2

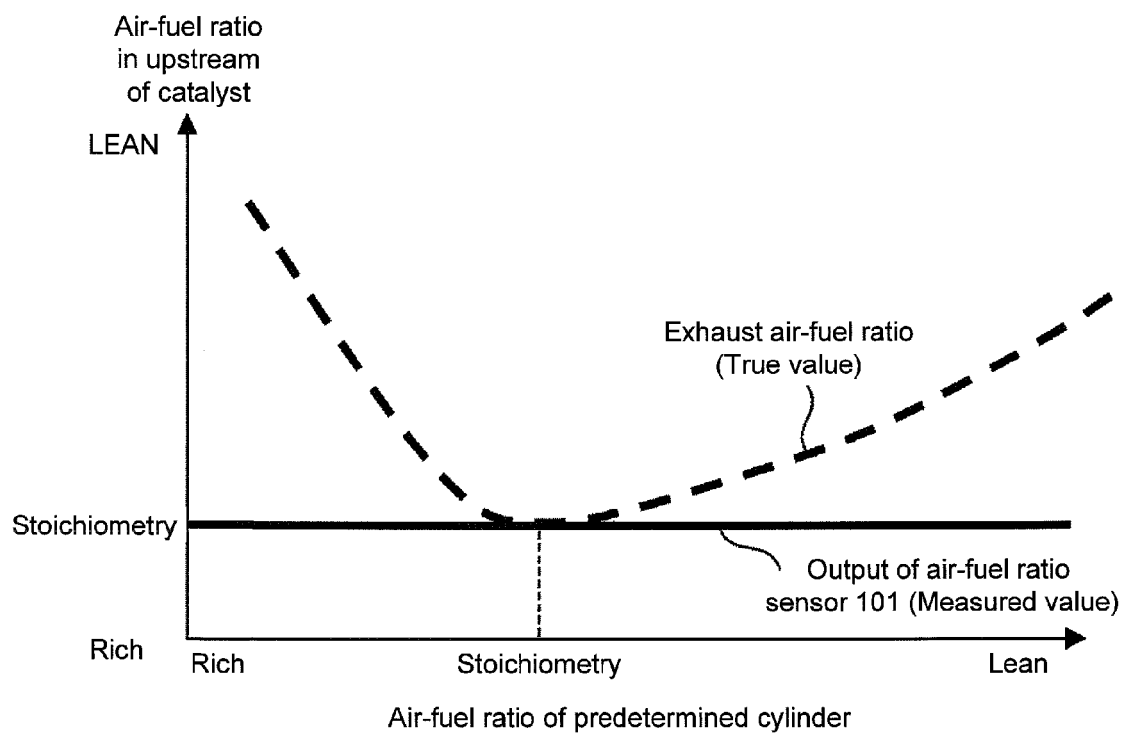


FIG. 3

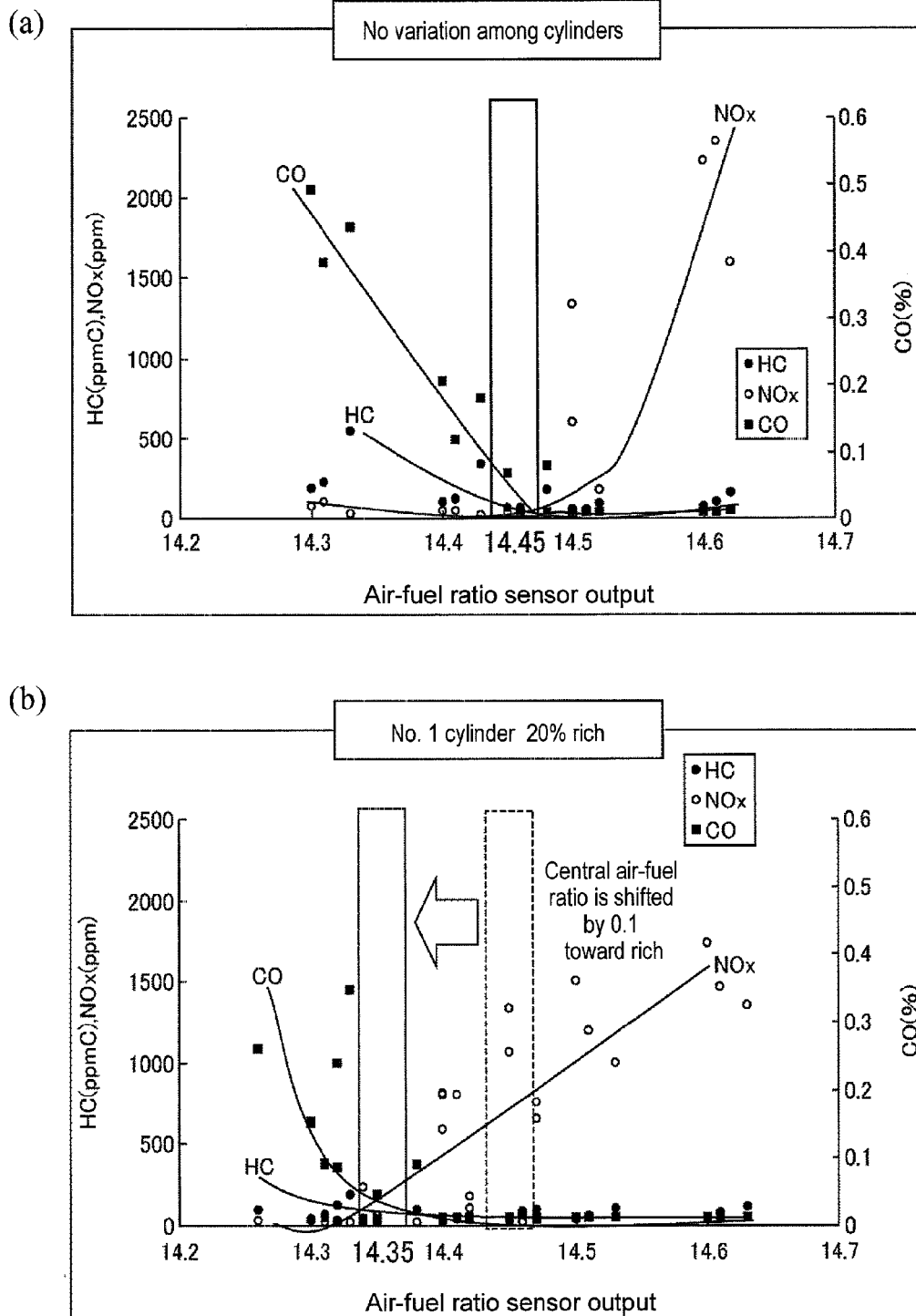


FIG. 4

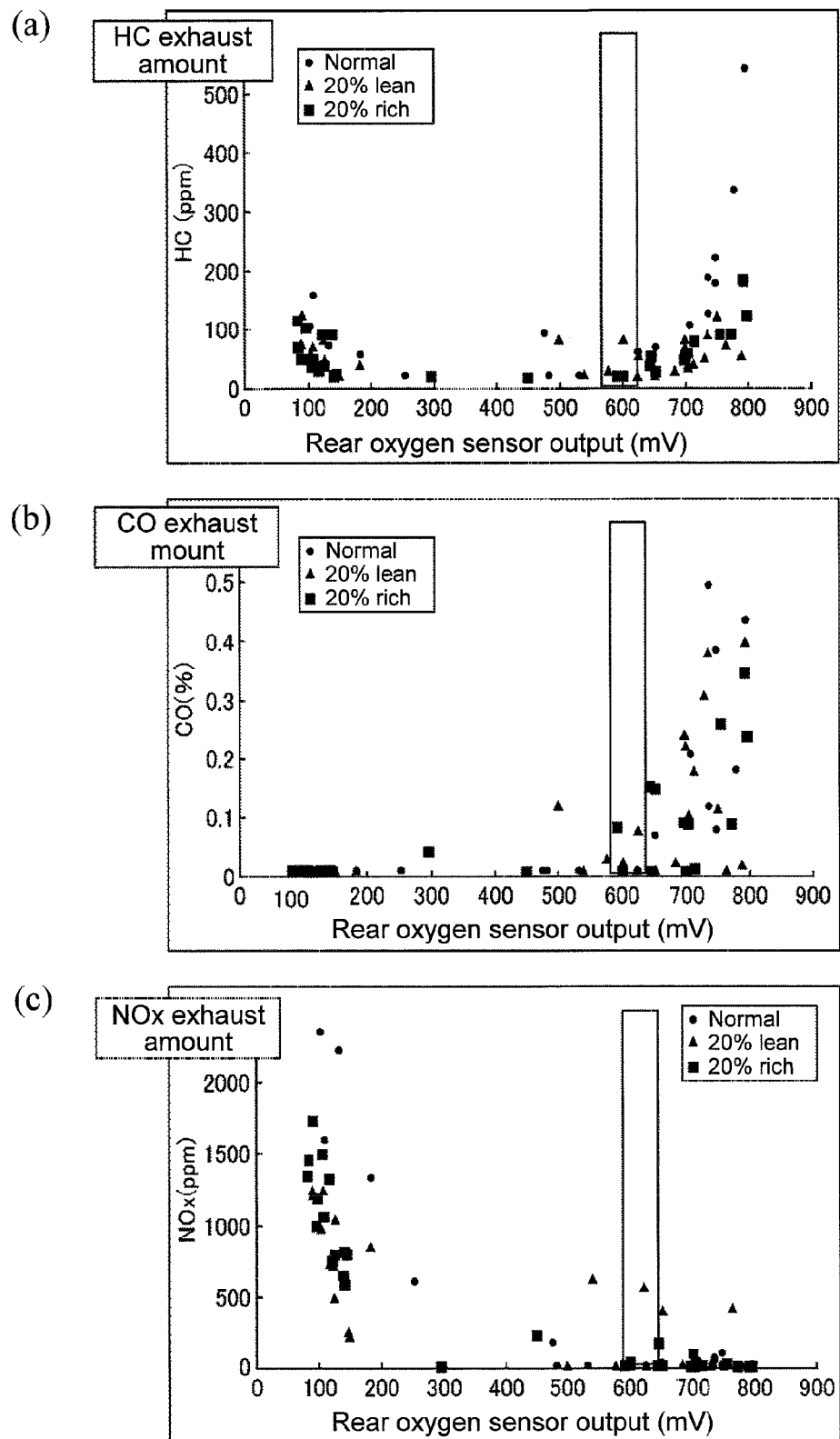


FIG. 5

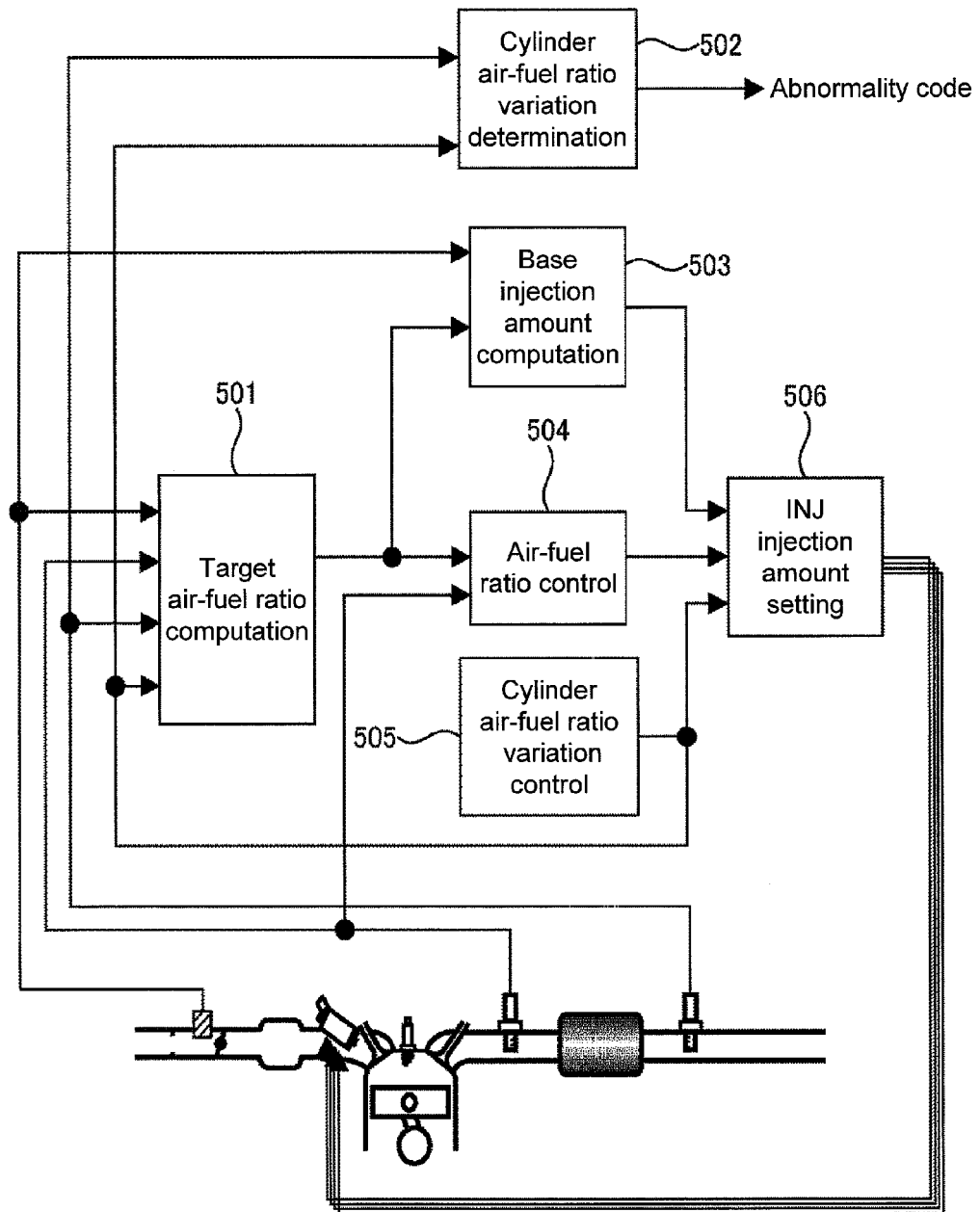


FIG. 6

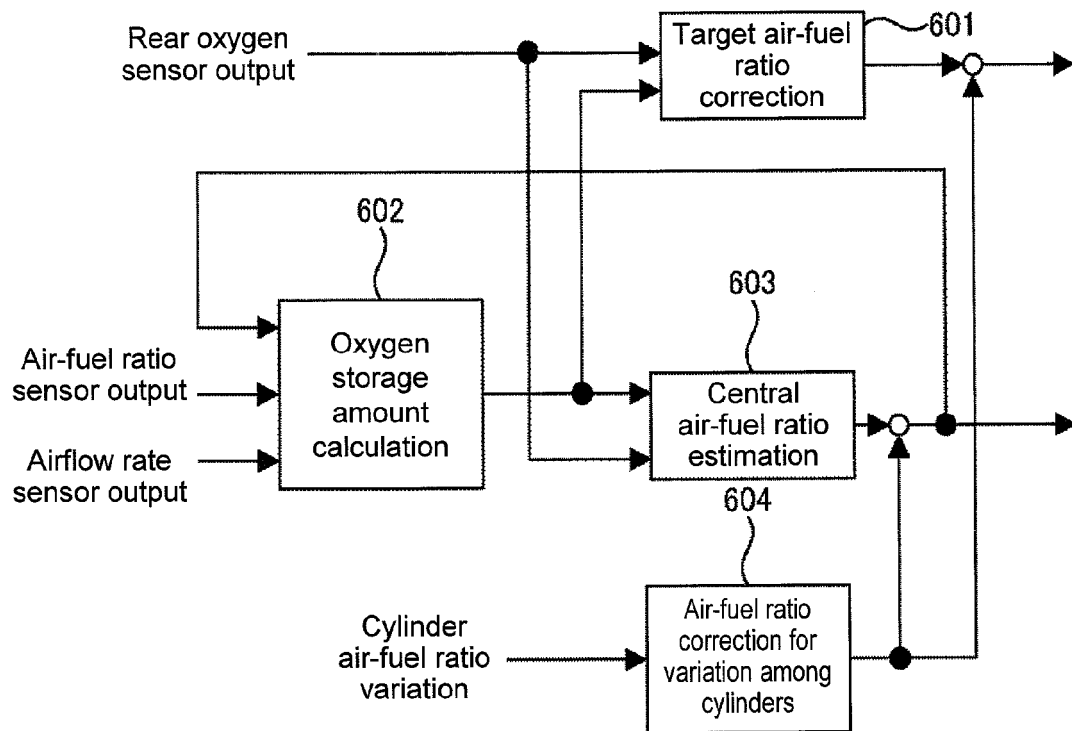


FIG. 7

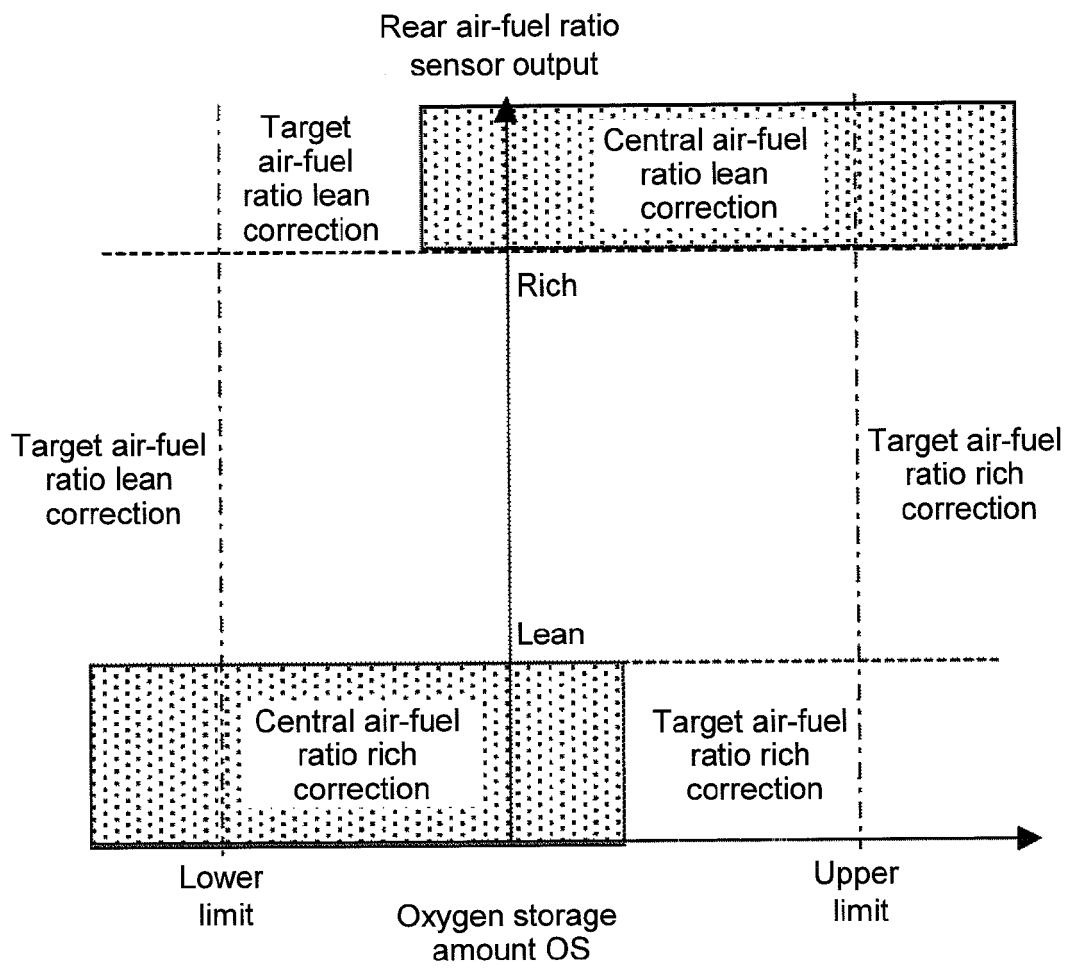


FIG. 8

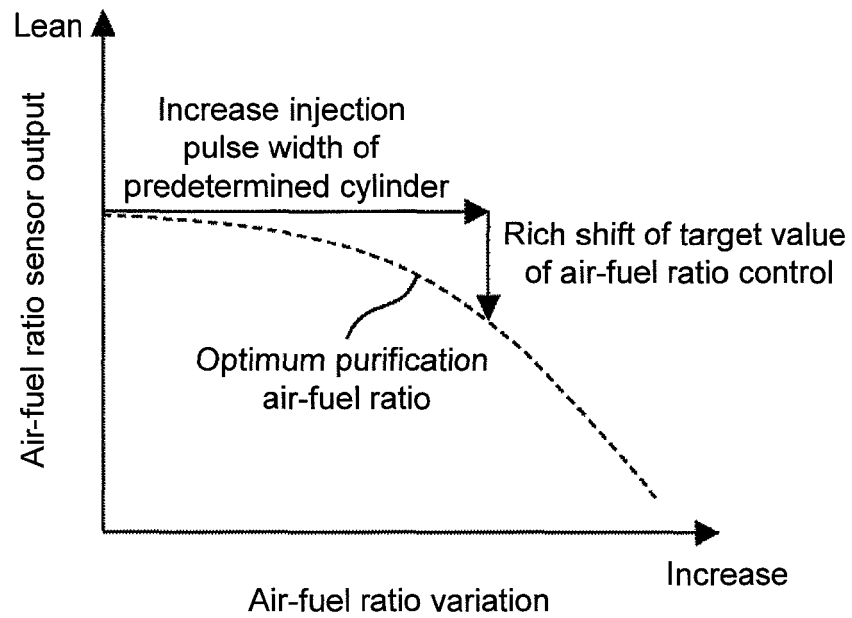


FIG. 9

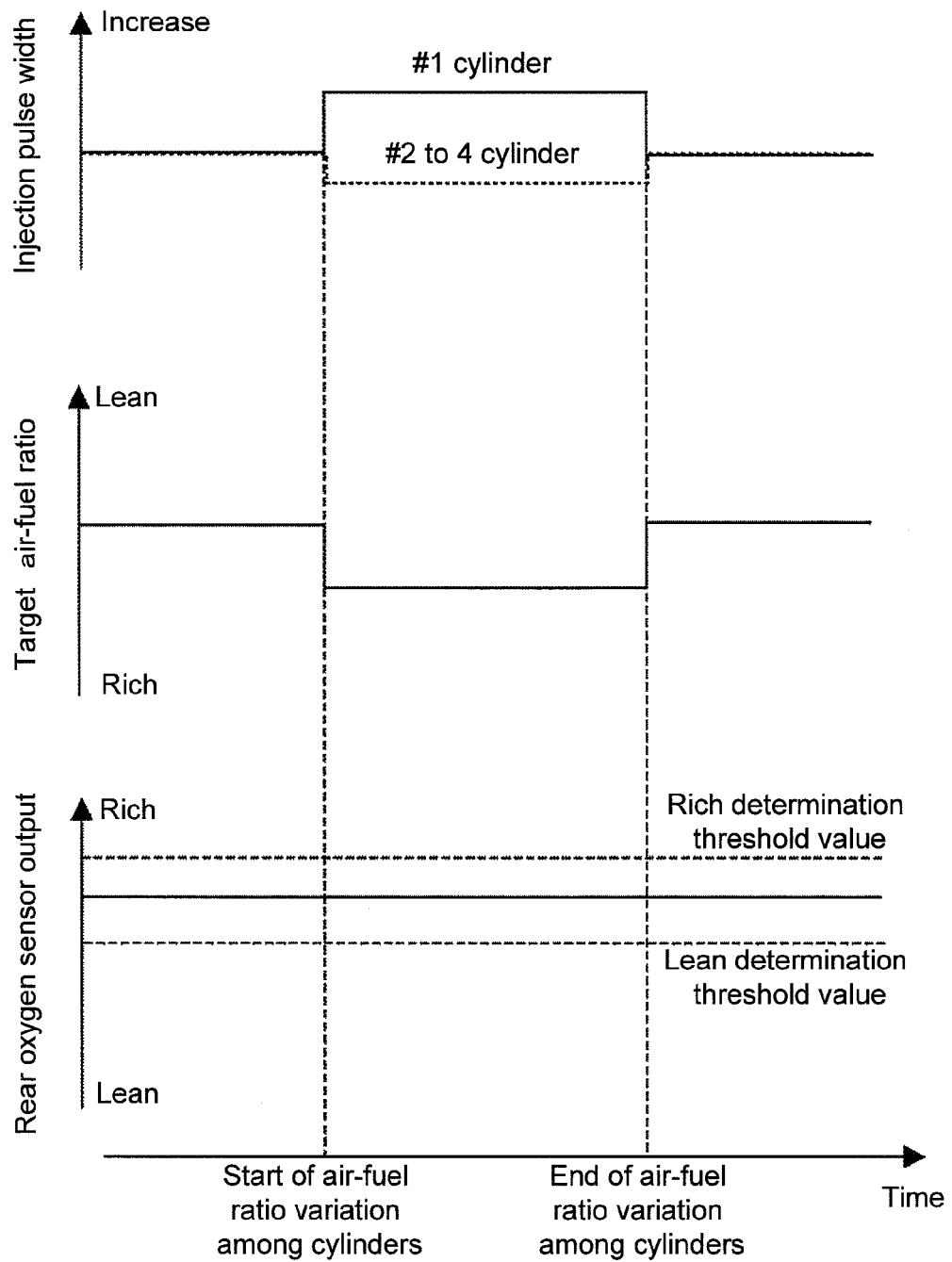


FIG. 10

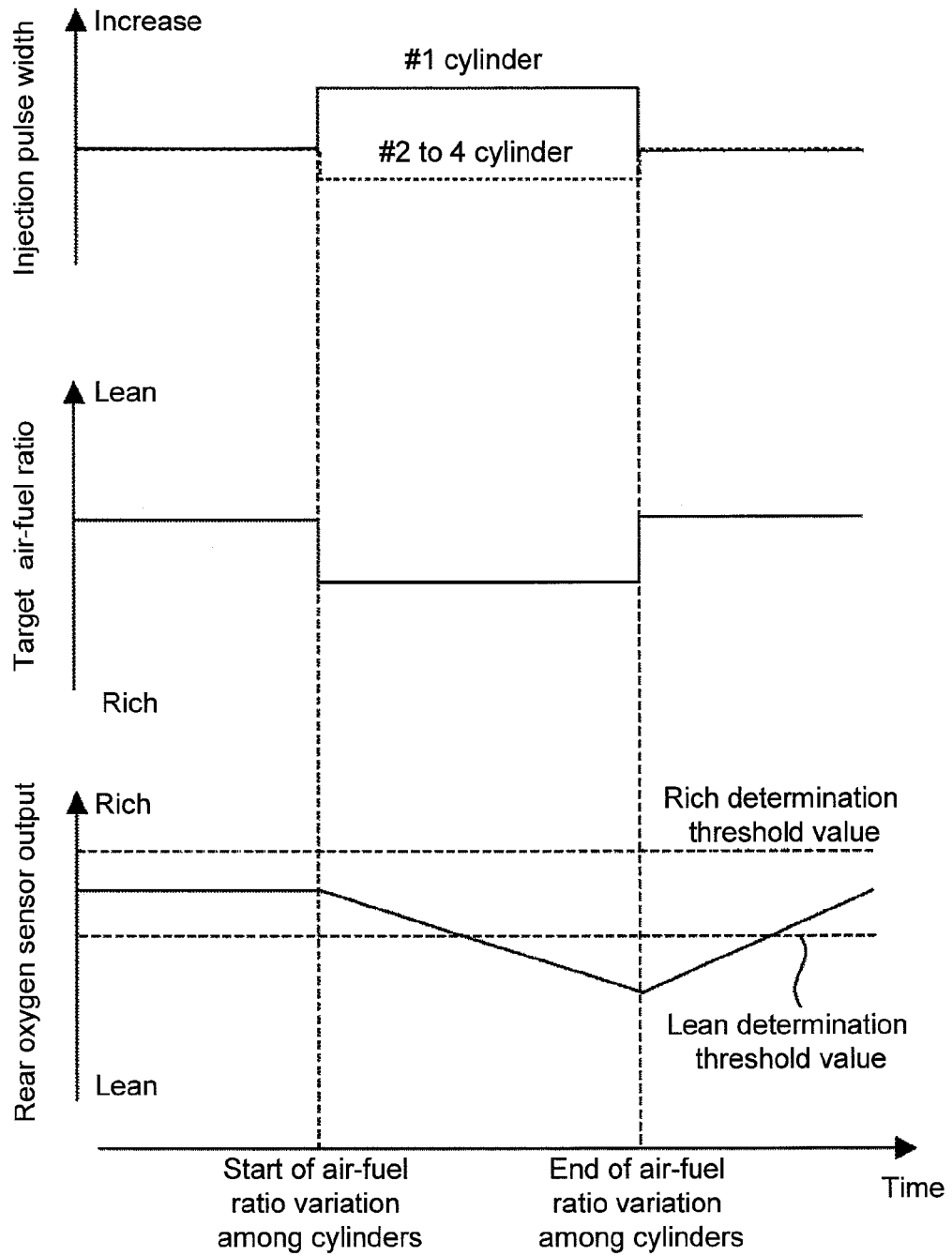


FIG. 11

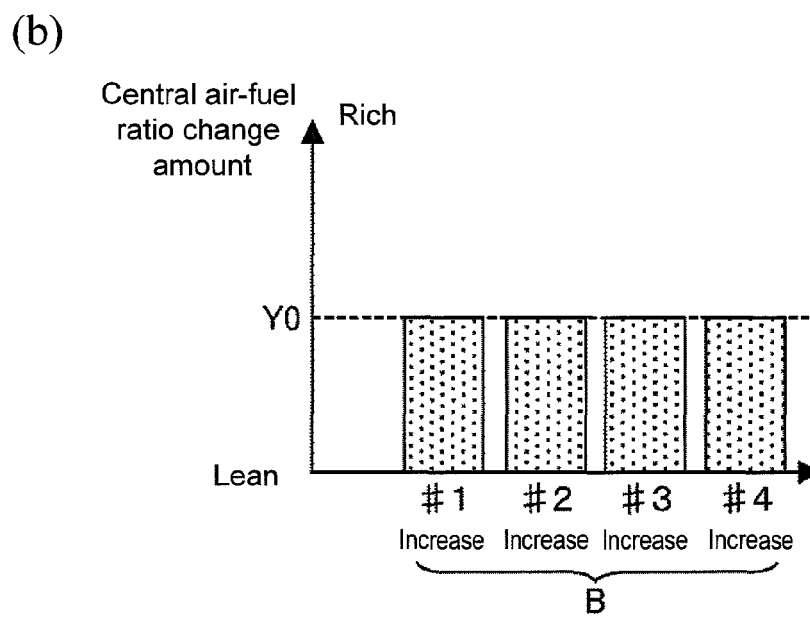
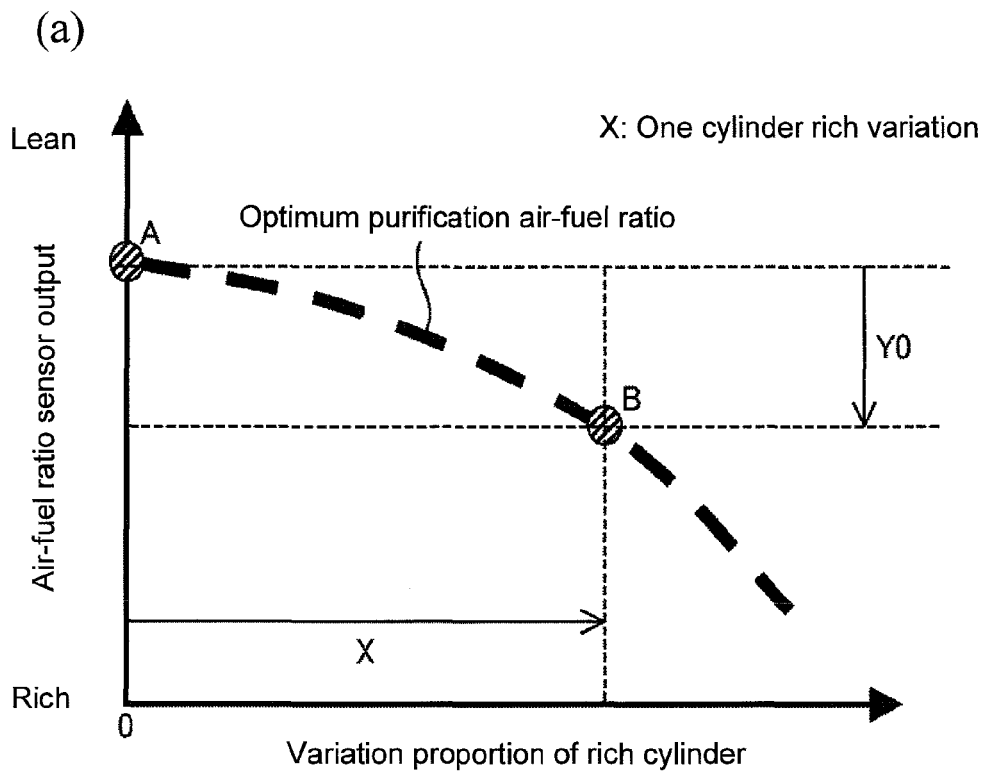


FIG. 12

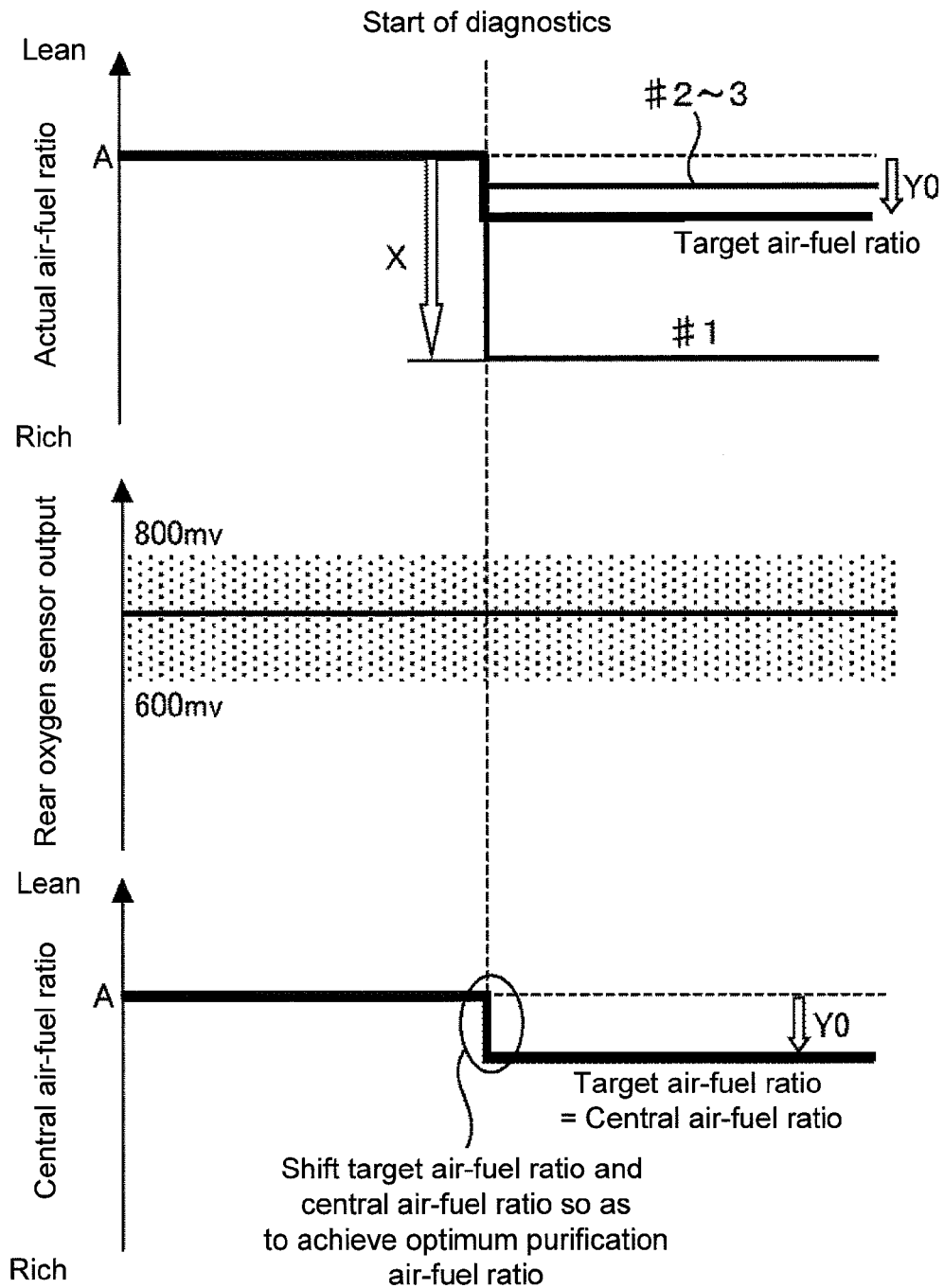


FIG. 13

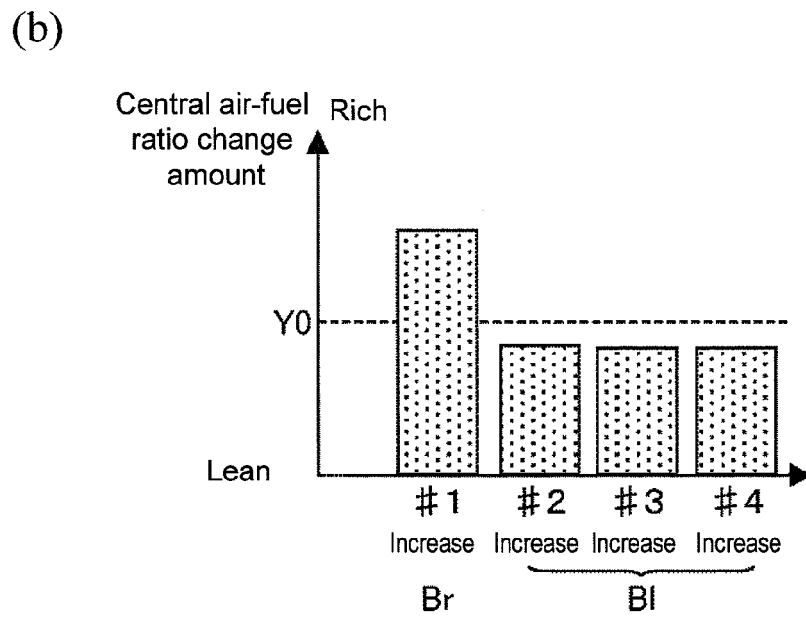
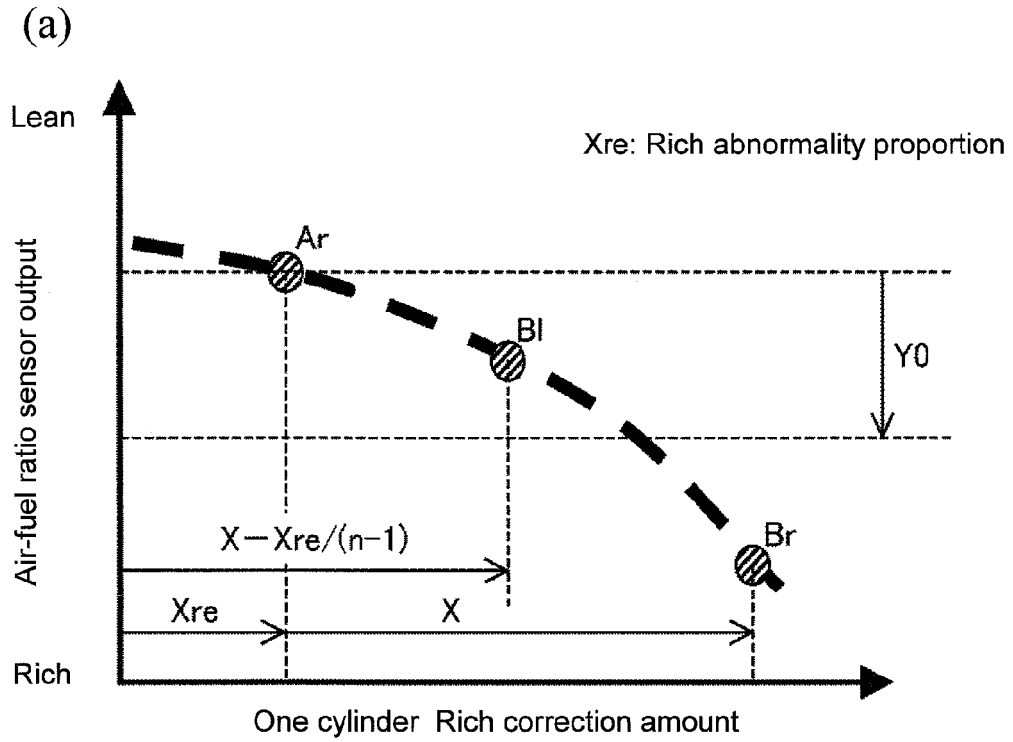


FIG. 14

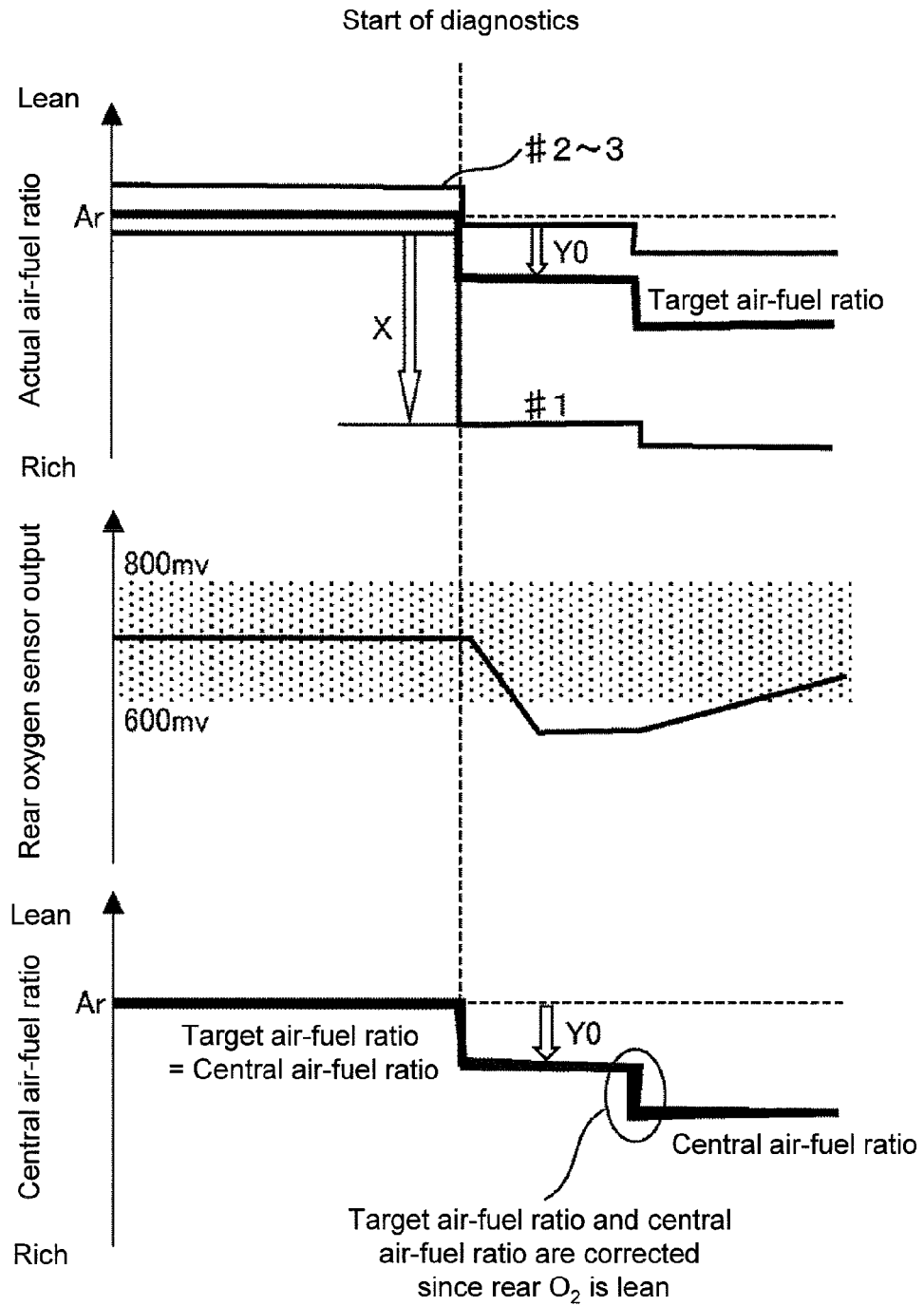


FIG. 15

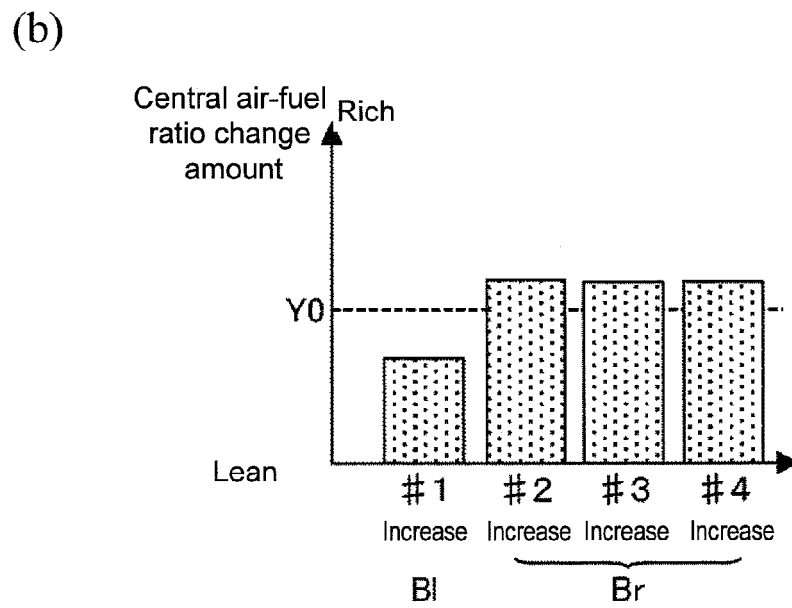
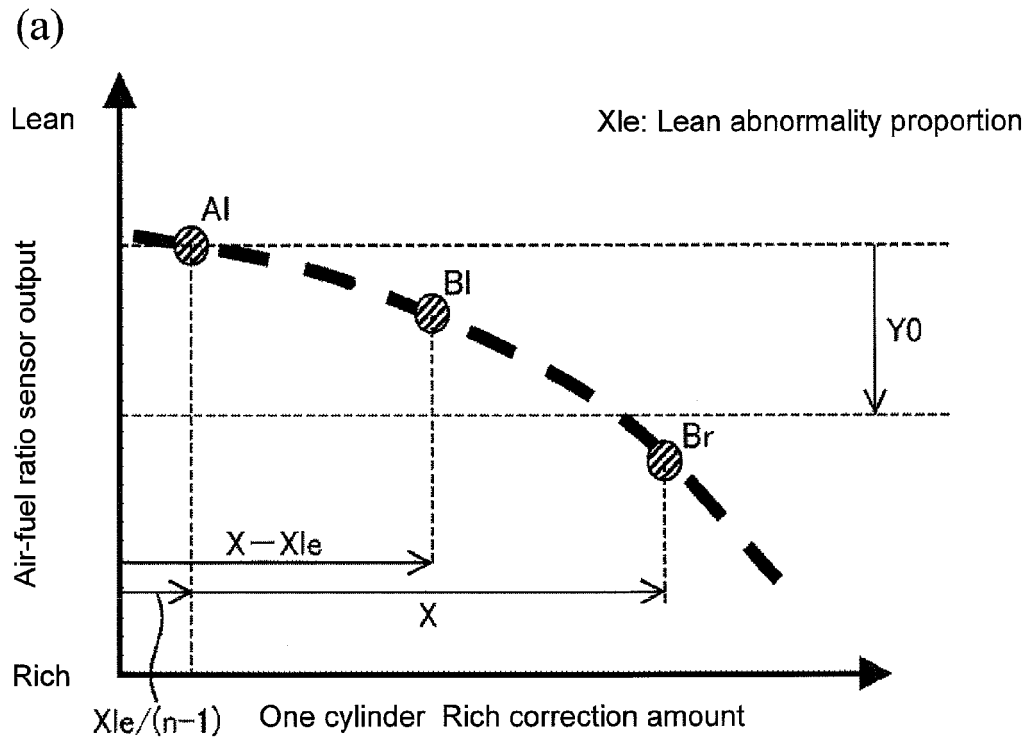
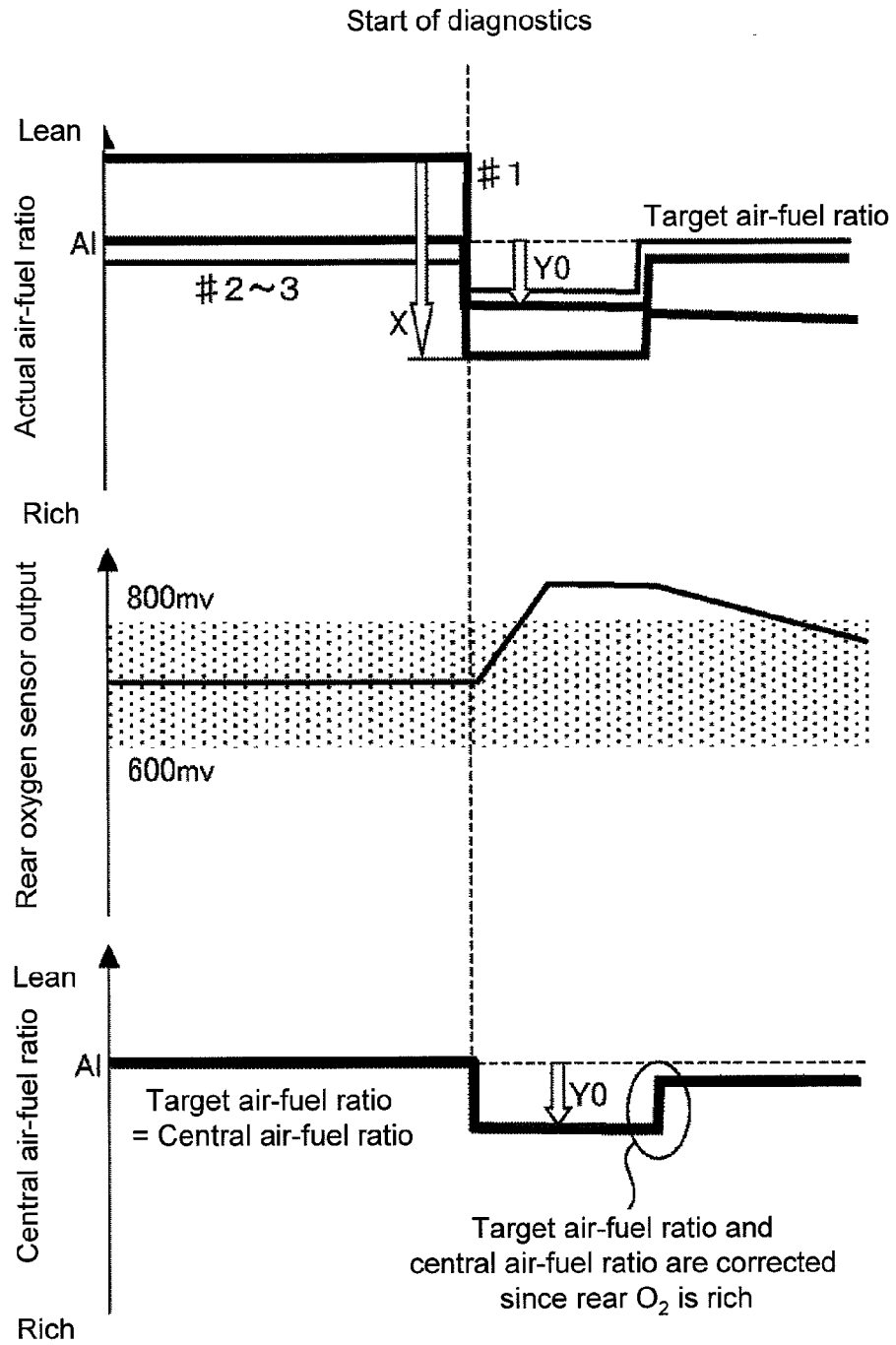


FIG. 16





EUROPEAN SEARCH REPORT

Application Number
EP 11 15 1591

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			TECHNICAL FIELDS SEARCHED (IPC)
			F02D
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 19 April 2011	Examiner Jackson, Stephen
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