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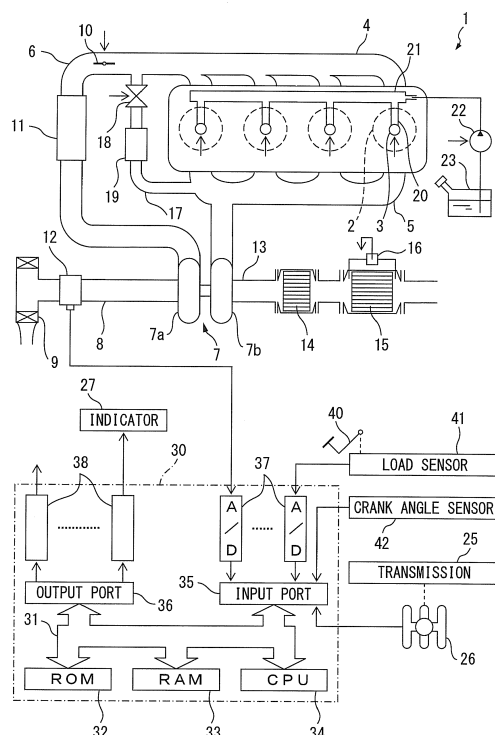
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(54) **EXHAUST PURIFICATION SYSTEM FOR INTERNAL COMBUSTION ENGINE**

(57) Opportunity for execution of rich control is secured whereby NO_x can be removed well. An NO_x storage catalyst (14) is arranged in an engine exhaust passage. When it is judged that rich control execution conditions stand, rich control is executed in order to release NO_x or SO_x from the NO_x storage catalyst. When it is judged that the rich control execution conditions do not stand, the gear position where the rich control execution conditions would stand when assuming the gear position of a transmission (25) were changed under a constant engine output is found as a target gear position. An indicator (27) is used to display an indication that the gear position should be changed to the target gear position to a vehicle operator. When the vehicle operator changes the gear position to the target gear position and it is thereby judged that the rich control execution conditions stand, rich control is executed.

FIG. 1



Description

Technical Field

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

Background Art

[0002] Known in the art is an exhaust purification system for an internal combustion engine, wherein an NO_x storage catalyst which stores NO_x in exhaust gas when the inflowing exhaust gas is lean in air-fuel ratio and releases the stored NO_x when the inflowing exhaust gas becomes rich in air-fuel ratio is arranged in an engine exhaust passage and wherein rich control which temporarily switches the air-fuel ratio of the exhaust gas which flows into the NO_x storage catalyst to be rich by injecting additional fuel in the combustion chamber in a combustion stroke or exhaust stroke in order to release NO_x or SO_x from the NO_x storage catalyst, is executed.

[0003] In this regard, when executing rich control when, for example, the torque is considerably low, the rich control is liable to cause the torque to greatly fluctuate and the drivability to deteriorate. Further, when the engine speed is considerably high, if rich control is executed, a large amount of additional fuel is liable to become necessary for switching the air-fuel ratio of the exhaust gas which flows into the NO_x storage catalyst to be rich or it becomes difficult for the NO_x storage catalyst to reliably release NO_x or SO_x.

[0004] Therefore, known in the art is an exhaust purification system for an internal combustion engine where when rich control should be executed, the engine operating state is used as the basis to judge if rich control execution conditions stand, rich control is allowed when it is judged that the rich control execution conditions stand and rich control is prohibited when it is judged that the rich control execution conditions do not stand (see PTL 1).

Citations List

Patent Literature

[0005] PTL: Japanese Patent Publication No. 2007-154771A

Summary of Invention

Technical Problem

[0006] However, in the above-mentioned exhaust purification system, whether the rich control execution conditions stand or not depends on the engine operating state, while the engine operating state depends on operation by the vehicle operator. Therefore, the rich control execution conditions are liable not to stand over a long

period of time, that is, the opportunity for execution of rich control is liable to be reduced. As a result, NO_x or SO_x is liable not to be released from the NO_x storage catalyst over a long period of time and NO_x is liable to not be removed well.

Solution to Problem

[0007] According to the present invention, there is provided an exhaust purification system for an internal combustion engine, the system arranging in an engine exhaust passage an NO_x storage catalyst which stores NO_x in exhaust gas when the inflowing exhaust gas is lean in air-fuel ratio and which releases the stored NO_x when the inflowing exhaust gas becomes rich in air-fuel ratio, the system comprising a rich control means for executing a rich control which temporarily switches the air-fuel ratio of the exhaust gas which flows into the NO_x storage catalyst to be rich by injecting additional fuel into a combustion chamber in a combustion stroke or exhaust stroke in order to release NO_x or SO_x from the NO_x storage catalyst, the system judging if rich control execution conditions stand when rich control should be executed, based on the engine operating state, the system executing rich control when it is judged that the rich control execution conditions stand and prohibits rich control when it is judged that rich control execution conditions do not stand, characterized in that the system comprises a transmission with a gear position which is changed by a vehicle operator and an indicator which displays an indication relating to a change of the gear position of the transmission to a vehicle operator, that when it is judged that the rich control execution conditions do not stand while rich control should be executed, a gear position, where the rich control execution conditions would stand when assuming that the gear position were changed under a constant engine output, is found, and that the indicator is controlled to display to the vehicle operator an indication to change the gear position to the found gear position, whereby rich control is executed when the rich control execution conditions stand due to the change of the gear position to the found gear position by the vehicle operator.

[0008] Preferably, it is judged that the rich control execution conditions stand when the engine operating state is in a rich control allowable area and it is judged that the rich control execution conditions do not stand when the engine operating state is outside the rich control allowable area.

[0009] Preferably, the engine operating state is expressed by an engine load and an engine speed.

[0010] Preferably, it is judged that the rich control execution conditions stand when the engine operating state is in the rich control allowable area and the gear position of the transmission is in a predetermined set gear position range and it is judged that the rich control execution conditions do not stand when the engine operating state is outside the rich control allowable area or the gear position

of the transmission is outside the set gear position range.

[0011] Preferably, it is judged that the rich control execution conditions stand when the engine operating state is in the rich control allowable area and the temperature of the NO_x storage catalyst is in a predetermined set temperature range and it is judged that the rich control execution conditions do not stand when the engine operating state is outside the rich control allowable area or the temperature of the NO_x storage catalyst is outside the set temperature range.

[0012] Preferably, it is judged that the rich control execution conditions stand when the engine operating state is in the rich control allowable area and the vehicle speed is in a predetermined set vehicle speed range and it is judged that the rich control execution conditions do not stand when the engine operating state is outside the rich control allowable area or the vehicle speed is outside the set vehicle speed range.

[0013] Preferably, it is judged if the rich control execution conditions would stand when assuming that the gear position were changed under a constant engine output when rich control is being executed and, when it is judged that the rich control execution conditions do not stand, the indicator is controlled to display to the vehicle operator an indication that the gear position should not be changed.

Advantageous Effects of Invention

[0014] It is possible to secure opportunities for rich control to be executed, therefore it is possible to remove NO_x well.

Brief Description of Drawings

[0015]

[FIG. 1] FIG. 1 is an overview of an internal combustion engine.

[FIG. 2] FIG. 2 is an overview of an indicator.

[FIG. 3] FIGS. 3(A) and 3(B) are views which show display patterns of indicators.

[FIG. 4] FIG. 4 is a cross-sectional view of a surface portion of an NO_x storage catalyst.

[FIG. 5] FIG. 5 is a view which explains injection of additional fuel.

[FIG. 6] FIG. 6 is a time chart which explains rich control for NO_x release.

[FIG. 7] FIG. 7 is a view which shows a map of an NO_x exhaust amount NOXA.

[FIG. 8] FIG. 8 is a time chart which explains rich control for SO_x release.

[FIG. 9] FIG. 9 is a view which shows a map of an SO_x exhaust amount SOXA.

[FIG. 10] FIG. 10 is a view which shows a rich control allowable area AA.

[FIG. 11] FIG. 11 is a view which explains a change of an engine operating state when a gear position is

changed.

[FIG. 12] FIG. 12 is a view which explains a change of an engine operating state when a gear position is changed.

[FIG. 13] FIG. 13 is a flow chart which shows a control routine of a flag XN.

[FIG. 14] FIG. 14 is a flow chart which shows a control routine of a flag XS.

[FIG. 15] FIG. 15 is a flow chart which shows a control routine of exhaust purification.

[FIG. 16] FIG. 16 is a flow chart which shows a control routine of an indicator.

[FIG. 17] FIGS. 17(A), 17(B), and 17(C) are views which show display patterns of an indicator of another embodiment according to the present invention.

[FIG. 18] FIG. 18 is a view which explains a change of an engine operating state when a gear position is changed.

[FIG. 19] FIG. 19 is a flow chart which shows a control routine of an indicator in another embodiment according to the present invention.

Description of Embodiments

[0016] Referring to FIG. 1, 1 indicates a body of a compression ignition type internal combustion engine, 2 a combustion chamber of a cylinder, 3 an electromagnetic control type fuel injector for injecting fuel into a corresponding combustion chamber 2, 4 an intake manifold, and 5 an exhaust manifold. The intake manifold 4 is connected through an intake duct 6 to an outlet of a compressor 7a of an exhaust turbocharger 7, while the inlet of the compressor 7a is connected through an intake introduction pipe 8 to an air cleaner 9. Inside the intake duct 6, an electrical control type throttle valve 10 is arranged. Further, around the intake duct 6, a cooling device 11 is arranged for cooling the intake air which flows through the inside of the intake duct 6. Further, inside the intake introduction pipe 8, an intake air amount detector 12 is arranged.

[0017] On the other hand, the exhaust manifold 5 is connected to an inlet of an exhaust turbine 7b of the exhaust turbocharger 7, while an outlet of the exhaust turbine 7b is connected through an exhaust pipe 13 to an NO_x storage catalyst 14. An outlet of the NO_x storage catalyst 14 is connected to a particulate filter 15 for trapping particulate matter in the exhaust gas. At the particulate filter 15, a differential pressure sensor 16 is attached for detecting the differential pressure across the particulate filter 15.

[0018] The exhaust manifold 5 and the intake manifold 4 are connected with each other through an exhaust gas recirculation (hereinafter referred to as "EGR") passage 17. Inside the EGR passage 17, an electrical control type EGR control valve 18 is arranged. Further, around the EGR passage 17, a cooling device 19 is arranged for cooling the EGR gas which flows through the inside of the EGR passage 17. On the other hand, each fuel in-

jector 3 is connected through a fuel feed pipe 20 to a common rail 21. This common rail 21 is connected through an electronic control type variable discharge fuel pump 22 to the fuel tank 23. The fuel which is stored in the fuel tank 23 is supplied through the fuel pump 22 to the inside of the common rail 21, while the fuel which is supplied to the inside of the common rail 21 is supplied through the fuel feed pipes 20 to the fuel injectors 3. Note that, in another embodiment, the internal combustion engine 1 is comprised of a spark ignition type internal combustion engine. In this case, the fuel inside the fuel tank 23 is gasoline, CNG, hydrogen, etc.

[0019] The output shaft (not shown) of the internal combustion engine 1 is connected to the transmission 25. In the example which is shown in FIG. 1, the transmission 25 is comprised of a manual transmission. The gear position of the transmission 25 is changed by the vehicle operator operating the shift lever 26. In another example, the transmission 25 is comprised of an automatic transmission which is provided with a manual mode. In this manual mode, the gear position is changed by the vehicle operator operating the shift lever. Furthermore, an indicator 27 which displays an indication relating to the gear position of the transmission 25 to the vehicle operator is provided.

[0020] The electronic control unit 30 is comprised of a digital computer which is provided with components which are connected with each other by a bidirectional bus 31 such as a ROM (read only memory) 32, RAM (random access memory) 33, CPU (microprocessor) 34, input port 35, and output port 36. As shown in FIG. 1, the output signals of the intake air amount detector 12 and differential pressure sensor 16 are input through corresponding AD converters 37 to an input port 35. The accelerator pedal 40 is connected to a load sensor 41 which generates an output voltage proportional to the amount of depression L of the accelerator pedal 40. The output voltage of the load sensor 41 is input through a corresponding AD converter 37 to the input port 35. Furthermore, the input port 35 is connected to a crank angle sensor 42 which generates an output pulse each time the crankshaft rotates by for example 15°. At the CPU 34, the output pulse from the crank angle sensor 42 is used as the basis to calculate the engine speed N. Further, a signal indicating the position of the shift lever 26, that is, the gear position of the transmission 25, is input to the input port 35. On the other hand, the output port 36 is connected through a corresponding drive circuit 38 to the fuel injectors 3, an actuator for driving the throttle valve 10, EGR control valve 18, fuel pump 22, and indicator 27.

[0021] FIG. 2 shows one example of the indicator 27. The indicator 27 is provided with an upward facing arrow shaped light 27a and downward facing arrow shaped light 27b. In the embodiment according to the present invention, an indication to change the gear position is displayed by the indicator 27 to the vehicle operator. When displaying an indication to shift up, that is, that the gear position

should be changed to a higher speed, as shown in FIG. 3(A), the upward facing light 27a is for example lit up or flashed green and the downward facing light 27b is extinguished. As a result, the vehicle operator is prompted to shift up. On the other hand, when displaying an indication to shift down, that is, that the gear position should be changed to a lower speed, as shown in FIG. 3(B), the downward facing light 27b is for example lit up or flashed green and the upward facing light 27a is extinguished. As a result, the vehicle operator is prompted to shift down. Note that, FIG. 2 shows the case where the lights 27a and 27b are extinguished. At this time, an indication relating to the gear position is not displayed. In this way, in the embodiment according to the present invention, the indicator 27 uses light to display an indication relating to gear position to the vehicle operator. In another embodiment, the indicator 27 uses sound, vibration, etc. to provide indication. Furthermore, in another embodiment, the indicator 27 not only displays an indication relating to the gear position, but also displays the current gear position.

[0022] On the other hand, the substrate of the NO_x storage catalyst 14 which is shown in FIG. 1 carries a catalyst carrier which is comprised of for example alumina. FIG. 4 illustrates the cross-section of the surface part of this catalyst carrier 45. As shown in FIG. 4, on the surface of the catalyst carrier 45, a precious metal catalyst 46 is carried dispersed. Furthermore, a layer of an NO_x absorbent 47 is formed on the surface of the catalyst carrier 45.

[0023] In the example which is shown in FIG. 4, as the precious metal catalyst 46, platinum Pt is used. As the component which forms the NO_x absorbent 47, for example, at least one element which is selected from potassium K, sodium Na, cesium Cs, or other such alkali metal, barium Ba, calcium Ca, or other such alkali earth metal, lanthanum La, yttrium Y, or other such rare earth is used.

[0024] If referring to the ratio of the air and fuel (hydrocarbons) which are supplied into the engine intake passage and exhaust passage upstream of the combustion chambers 2 and NO_x storage catalyst 14 as the air-fuel ratio of the exhaust gas, the NO_x absorbent 47 absorbs NO_x when the air-fuel ratio of the exhaust gas is lean and releases the absorbed NO_x when the concentration of oxygen in the exhaust gas falls.

[0025] That is, if explaining the case of using barium Ba as an ingredient which forms the NO_x absorbent 47 as an example, when the air-fuel ratio of the exhaust gas is lean, that is, when the oxygen concentration of the exhaust gas is high, the NO which is contained in the exhaust gas is oxidized on the platinum Pt 46 and becomes NO₂ on the platinum Pt 46 as shown in FIG. 4, next is absorbed in the NO_x absorbent 47 where it bonds with the barium carbonate BaCO₃ while diffuses in the form of nitric acid ions NO₃ in the NO_x absorbent 47. In this way, the NO_x is absorbed in the NO_x absorbent 47. So long as the oxygen concentration in the exhaust gas is high, NO₂ is formed on the surface of the platinum Pt

46. So long as the NO_x absorption ability of the NO_x absorbent 47 does not become saturated, NO_2 is absorbed inside the NO_x absorbent 47 whereby sulfuric acid ions NO_3^- are generated.

[0026] As opposed to this, when the air-fuel ratio of the exhaust gas is switched from lean to rich or the stoichiometric air-fuel ratio, the oxygen concentration in the exhaust gas falls, so the reaction proceeds in the opposite direction ($\text{NO}_3^- \rightarrow \text{NO}_2$) and therefore the sulfuric acid ions NO_3^- in the NO_x absorbent 47 are released in the form of NO_2 from the NO_x absorbent 47. Next, the released NO_x is reduced by the HC and CO which are contained in the exhaust gas.

[0027] Note that, sometimes NO_x is temporarily adsorbed at the NO_x absorbent 47. Therefore, if using the term "storage" as a term including both absorption and adsorption, the NO_x storage catalyst 14 stores NO_x in the exhaust gas when the air-fuel ratio of the inflowing exhaust gas is lean and releases and reduces the stored NO_x when the air-fuel ratio of the inflowing exhaust gas becomes rich.

[0028] Now then, in the engine body 1, fuel is burned under an excess of oxygen. Therefore, the air-fuel ratio of the exhaust gas which flows into the NO_x storage catalyst 14 is lean, so at this time, the NO_x in the exhaust gas is stored in the NO_x storage catalyst 14. However, if the engine operating time becomes longer, the amount of NO_x which is stored in the NO_x storage catalyst 14 becomes greater and finally the NO_x storage catalyst 14 can no longer store NO_x .

[0029] Therefore, in the embodiment according to the present invention, to make the NO_x storage catalyst 14 release the NO_x , the air-fuel ratio of the exhaust gas which flows into the NO_x storage catalyst 14 is temporarily switched to rich. In this case, as shown in FIG. 5, separate from the main fuel Q_m which is injected around compression top dead center (TDC), additional fuel Q_a is injected from a fuel injector 3 to a combustion chamber 2 in the combustion stroke or exhaust stroke.

[0030] If referring to this control as rich control for NO_x release, as shown in FIG. 6, when the NO_x amount NOX which is stored in the NO_x storage catalyst 14 exceeds the allowable amount MAXN , rich control for NO_x release is executed. As a result, the air-fuel ratio (A/F) in of the exhaust gas which flows into the NO_x storage catalyst 14 is temporarily switched to rich and the NO_x stored amount NOX is reduced. In the embodiment according to the present invention, the NO_x stored amount NOX is for example calculated from the amount of NO_x which is exhausted from the engine. That is, the NO_x exhaust amount NOXA which is exhausted from the engine per unit time is stored as a function of the amount of depression L of the accelerator pedal 40 and the engine speed N in the form of a map such as shown in FIG. 7 in advance in the ROM 32. This NO_x exhaust amount NOXA is repeatedly added to calculate the NO_x stored amount NOX .

[0031] In this regard, the exhaust gas contains SO_x , that is, SO_2 . If this SO_2 flows into the NO_x storage catalyst

14, this SO_2 is oxidized on the platinum Pt 46 and becomes SO_3 . Next, this SO_3 is absorbed in the NO_x absorbent 47 where it bonds with the barium carbonate BaCO_3 while diffusing in the NO_x absorbent 47 in the form of sulfuric acid ions SO_4^{2-} whereby stable sulfate BaSO_4 is generated. However, an NO_x absorbent 47 has a strong basicity, so this sulfate BaSO_4 is stable and hard to break down. If just making the air-fuel ratio of the exhaust gas rich, the sulfate BaSO_4 remains as it is without breaking down. Therefore, inside the NO_x absorbent 47, sulfate BaSO_4 increases as time elapses and therefore the amount of NO_x which the NO_x absorbent 47 can absorb falls along with the elapse of time.

[0032] On the other hand, if making the air-fuel ratio of the exhaust gas which flows into the NO_x storage catalyst 14 rich in the state of raising the temperature of the NO_x storage catalyst 14 to the 600°C or more, that is, SO_x release temperature, SO_x is released from the NO_x absorbent 47.

[0033] Therefore, in the embodiment according to the present invention, to make the NO_x storage catalyst 14 release the SO_x , additional fuel Q_A is injected into the combustion chamber 2 during the combustion stroke or exhaust stroke to maintain the temperature of the NO_x storage catalyst 14 at the SO_x release temperature or more while the air-fuel ratio of the exhaust gas which flows into the NO_x storage catalyst 14 is temporarily switched to rich.

[0034] If referring to this control as rich control for SO_x release, as shown in FIG. 8, rich control for SO_x release is executed when the SO_x amount SOX which is stored in the NO_x storage catalyst 14 exceeds the allowable amount MAXS . As a result, the temperature of the NO_x storage catalyst 14 is raised to the SO_x release temperature TS or more and the air-fuel ratio (A/F) in of the exhaust gas which flows into the NO_x storage catalyst 14 is temporarily switched to rich whereby the SO_x stored amount SOX is reduced. In the embodiment according to the present invention, the SO_x stored amount SOX is for example calculated from the amount of SO_x which is exhausted from the engine. That is, the SO_x exhaust amount SOXA which is exhausted from the engine per unit time is stored as a function of the amount of depression L of the accelerator pedal 40 and the engine speed N in the form of the map which is shown in FIG. 9 in advance in the ROM 32. This SO_x exhaust amount SOXA is repeatedly added to calculate the SO_x stored amount SOX .

[0035] Now then, in the embodiment according to the present invention, when rich control for NO_x release or SO_x release should be executed, it is judged based on the engine operating state if the rich control execution conditions stand. When the rich control execution conditions stand, rich control is executed, while when it is judged that the rich control execution conditions do not stand, rich control is prohibited.

[0036] Specifically, the rich control execution conditions are comprised of a first execution condition and a

second execution condition. First, it is judged if the first execution condition stands. When it is judged that the first execution condition stands, it is judged if the second execution condition stands. When it is judged that the second execution condition stands, rich control for NO_x release or release of SO_x is executed. When the first execution condition or the second execution condition does not stand, rich control for NO_x release or SO_x release is not executed.

[0037] In the embodiment according to the present invention, when the temperature TC of the NO_x storage catalyst 14 is in a predetermined set temperature range and the vehicle speed is within a predetermined set vehicle speed range, it is judged that the first execution condition stands, while when the temperature TC of the NO_x storage catalyst 14 is outside the set temperature range or the vehicle speed is outside the set vehicle speed range, it is judged that the first execution condition does not stand. Further, when the engine operating state is in the predetermined rich control allowable area and the gear position of the transmission 25 is within the predetermined set gear position range, it is judged that the second execution condition stands, while when the engine operating state is outside the rich control allowable area and the gear position of the transmission 25 is outside the set gear position, it is judged that the second execution condition does not stand. In the embodiment according to the present invention, the engine operating state is expressed by a combination of the torque TRQ which expresses the engine load and the engine speed N. FIG. 10 shows one example of the rich control allowable area AA.

[0038] By doing this, the NO_x storage catalyst 14 can reliably release NO_x and SO_x . Further, at this time, the drivability is kept from falling, the consumption of additional fuel Qa is reduced, and the NO_x storage catalyst 14 is kept from being damaged by heat.

[0039] In this regard, whether the rich control execution conditions, in particular, the second execution condition, stand depends on the engine operating state, so the rich control execution conditions are liable to not stand for a long period of time. As a result, the opportunity for performance of rich control is liable to be reduced.

[0040] Therefore, in the embodiment according to the present invention, when rich control should be executed and if it is judged that the second execution condition does not stand, the gear position where the second execution conditions would stand when assuming the gear position were changed under a constant engine output is found as a target gear position. This will be explained while referring to FIG. 11.

[0041] In FIG. 11, a point P shows the engine operating state when the gear position is the N speed. In this case, the point P is outside the rich control allowable area AA, therefore the second execution condition does not stand. In this state, if a shift up were performed under a constant engine output, that is, if the gear position were changed to the (N+1) speed, the engine operating state would be

changed to a point PU. This point PU is outside the rich control allowable area AA, therefore, the second execution condition still would not stand. As opposed to this, if a shift down were performed under a constant engine output, that is, if the gear position were changed to the (N-1) speed, the engine operating state would be changed to a point PD. The point PD is inside the rich control allowable area AA, therefore the second execution conditions would stand conditional on the (N-1) speed being in the set gear position range. As a result, the rich control execution conditions would stand. Therefore, in the example which is shown in FIG. 11, the (N-1) speed is found as the target gear position.

[0042] If the target gear position is found, the indicator 27 is used to display an indication that the gear position should be changed to the target gear position to the vehicle operator. Next, if the vehicle operator changes the gear position to the target gear position, the second execution conditions would stand, therefore the rich control execution conditions would stand. For this reason, rich control is executed. As a result, the opportunity for rich control to be executed is secured and NO_x can be removed well.

[0043] Therefore, generally speaking, when rich control should be executed and it is judged that rich control execution conditions do not stand, the gear position where the rich control execution conditions would stand when assuming the gear position were changed under a constant engine output is found, the indicator is controlled to display an indication that the gear position should be changed to the found gear position to the vehicle operator, and when the vehicle operator changes the gear position to the found gear position and it is thereby judged that the rich control execution conditions would stand, the rich control is executed.

[0044] The engine operating state after the gear position has been changed, that is, the combination of the torque TRQ and the engine speed N, is, for example, calculated from the engine operating state before change, the gear ratio at the gear position before change, and the gear ratio at the gear position after change. That is, if expressing the gear ratio, torque, and the engine speed before change of the gear position by R1, TRQ1, and N1 and expressing the gear ratio, torque, and the engine speed after change of the gear position by R2, TRQ2, and N2, the torque TRQ2 and the engine speed N2 after change of the gear position are expressed by $(R1/R2) \cdot \text{TRQ1}$ and $(R2/R1) \cdot N1$.

[0045] Note that, in the example which is shown in FIG. 12, the point PD and the point PU are both outside the rich control allowable area AA. Therefore, even after a shift down or even after a shift up, the second execution condition would still not stand. It is sometimes not possible to find the target gear position. In this case, the indicator 27 does not display an indication.

[0046] FIG. 13 shows a routine for control of a flag XN. This routine is executed by interruption every certain time interval.

[0047] Referring to FIG. 13, at step 100, the NO_x exhaust amount NOXA per unit time is calculated from the map which is shown in FIG. 7. The NO_x exhaust amount NOXA is cumulatively added to calculate the NO_x stored amount NOX ($\text{NOX}=\text{NOX}+\text{NOXA}$). At the next step 101, it is judged if the NO_x stored amount NOX has exceeded the allowable value MAXN . When $\text{NOX}\leq\text{MAXN}$, the processing cycle is ended. When $\text{NOX}>\text{MAXN}$, the routine proceeds from step 101 to step 102 where the flag XN is set ($\text{XN}=1$). This flag XN is set when rich control for NO_x release should be executed ($\text{XN}=1$) and is reset when otherwise ($\text{XN}=0$).

[0048] FIG. 14 shows a routine for control of a flag XS . This routine is executed by interruption every certain time interval.

[0049] Referring to FIG. 14, at step 200, the SO_x exhaust amount SOXA per unit time is calculated from the map which is shown in FIG. 9. The SO_x exhaust amount SOXA is cumulatively added to calculate the SO_x stored amount SOX ($\text{SOX}=\text{SOX}+\text{SOXA}$). At the next step 201, it is judged if the SO_x stored amount SOX has exceeded the allowable value MAXS . When $\text{SOX}\leq\text{MAXS}$, the processing cycle is ended. When $\text{SOX}>\text{MAXS}$, the routine proceeds from step 201 to step 202 where the flag XS is set ($\text{XS}=1$). This flag XS is set when rich control for SO_x release should be executed ($\text{XS}=1$) and is reset when otherwise ($\text{XS}=0$).

[0050] FIG. 15 shows the routine for execution of exhaust purification control. This routine is executed by interruption every certain time interval.

[0051] Referring to FIG. 15, at step 300, it is judged if the flag XS has been set. When the flag XS is reset ($\text{XS}=0$), that is, when rich control for SO_x release should not be executed, the routine proceeds to the next step 301 where it is judged if the flag XN has been set. When the flag XN has been reset ($\text{XN}=0$), that is, when rich control for NO_x release should not be executed, the processing cycle is ended. When the flag XN is set ($\text{XN}=1$), that is, when rich control for NO_x release should be executed, the routine proceeds to the next step 302 where it is judged if the first execution condition stands. When it is judged that the first execution condition does not stand, the processing cycle is ended. When it is judged that the first execution condition stands, the routine proceeds to the next step 303 where it is judged if the second execution condition stands. When it is judged that the second execution condition stands, the routine proceeds to the next step 304 where rich control for NO_x release is executed. At the following step 305, it is judged if rich control for NO_x release should be ended. When it is judged that rich control for NO_x release should be ended, the processing cycle is ended. When it is judged that the rich control should be ended, the routine proceeds to step 306 where the flag XN is reset ($\text{XN}=0$) and the NO_x stored amount NOX is cleared ($\text{NOX}=0$).

[0052] On the other hand, when the flag XS is set at step 300 ($\text{XS}=1$), that is, when rich control for SO_x release should be executed, the routine proceeds to the next step

307 where it is judged if the first execution condition stands. When it is judged that the first execution condition does not stand, the processing cycle ends. When it is judged that the first execution condition stands, the routine proceeds to the next step 308 where it is judged if the second execution condition stands. When it is judged that the second execution condition stands, the routine proceeds to the next step 309 where rich control for SO_x release is executed. At the following step 310, it is judged if rich control for SO_x release should be ended. When it is judged that rich control for SO_x release should be ended, the processing cycle is ended. When it is judged that rich control should be ended, the routine proceeds to step 311 where the flag XS is reset ($\text{XS}=0$) and the SO_x stored amount NOX is cleared ($\text{SOX}=0$). Next, the routine proceeds to step 306 where the flag XN is reset ($\text{XN}=0$) and the NO_x stored amount NOX is cleared ($\text{NOX}=0$). This is because, when rich control for SO_x release is executed, NO_x is released from the NO_x storage catalyst 14.

[0053] On the other hand, when it is judged at step 303 or step 308 that the second execution condition does not stand, the routine proceeds to the next step 312 where the target gear position GPT is calculated. At the following step 313, it is judged if the target gear position GPT could be calculated. When the target gear position GPT could not be calculated, the processing cycle is ended. When the target gear position GPT could be calculated, the routine proceeds to the next step 314 where an indication that the gear position of the transmission 25 should be changed to the target gear position GPT is displayed by the indicator 27. If changing the gear position to the target gear position GPT in accordance with the indication displayed on the indicator 27 by the vehicle operator, the first execution condition and the second execution condition stand. As a result, rich control for NO_x release or SO_x release is started.

[0054] FIG. 16 shows a routine for executing control of the indicator 27. This routine is executed by interruption every certain time interval.

[0055] Referring to FIG. 16, in step 400, it is judged if an indication that the gear position of the transmission 25 should be changed is being displayed by the indicator 27. When the indicator 27 does not display an indication, the processing cycle is ended. When the indicator 27 displays an indication, the routine proceeds to the next step 401 where it is judged if the current gear position GP matches the target gear position GPT . When the current gear position GP does not match the target gear position GPT , the processing cycle is ended. When the current gear position GP matches the target gear position GPT , the routine proceeds to the next step 402 where display of the indication by the indicator 27 is stopped.

[0056] Next, another embodiment according to the present invention will be explained.

[0057] In another embodiment according to the present invention, the indicator 27 displays not only an indication that the gear position of the transmission 25 should be changed, but also an indication that the gear

position should not be changed. That is, when displaying an indication that shift up should not be performed, as shown in FIG. 17(A), the upward facing light 27a is for example lit up or flashed red and the downward facing light 27b is extinguished. On the other hand, when displaying an indication that a shift down should not be performed, as shown in FIG. 17(B), the downward facing light 27b is, for example, lit up or flashed red and the upward facing light 27a is extinguished. When displaying an indication that neither a shift up or shift down should be performed, as shown in FIG. 17(C), the upward facing light 27a and downward facing light 27b are for example lit up or flashed red.

[0058] Now then, if the gear position of the transmission 25 is changed when rich control is being executed, the engine operating state is changed. In this case, the changed engine operating state is liable to be outside the rich control allowable area AA. That is, in the example which is shown in FIG. 18, if a shift down is performed when the point Q which shows the engine operating state is in the rich control allowable area AA, the engine operating state is changed to the point QD. This point QD is outside the rich control allowable area AA. Therefore, the second execution condition does not stand. Even when the gear position is changed to outside the set gear position during rich control, the second execution condition does not stand. If the rich control execution conditions do not stand during rich control in this way, rich control ends up being interrupted.

[0059] Therefore, in another embodiment according to the present invention, it is judged if the rich control execution conditions would stand when assuming the gear position were changed under a constant engine output when rich control for NO_x release or SO_x release was executed. When it is judged that the rich control execution conditions would not stand, an indication that the gear position should not be changed is displayed by the indicator 27 to the vehicle operator. As a result, if the vehicle operator does not change the gear position, the state where the rich control execution conditions stand is maintained and therefore rich control is continued.

[0060] FIG. 19 shows the routine for execution of control of the indicator 27 in another embodiment according to the present invention. This routine is executed by interruption every certain time interval.

[0061] Referring to FIG. 19, at step 500, it is judged if rich control is currently being executed. When rich control is not being executed, the processing cycle ends. When the rich control is being executed, the routine proceeds to the next step 501 where the engine operating state EOCU when assuming shift up under a constant engine output is estimated. At the following step 502, whether the second execution condition would not stand when assuming a shift up were performed under a constant engine output is judged based on the engine operating state EOCU and gear position when assuming shift up were performed. When it is judged that the second execution condition would continue to stand even when a

shift up was performed, the routine jumps to the next step 504. When the second execution condition would not stand if a shift up were performed, the routine proceeds to the next step 503 where an indication that a shift up should not be performed is displayed by the indicator 27. Next, the routine proceeds to step 504.

[0062] At step 504, the engine operating state EOCU when assuming that a shift down is performed under a constant engine output is estimated. At the following step 505, it is judged if the second execution condition would not stand when assuming that a shift down were performed under a constant engine output based on the engine operating state EOCU and gear position when assuming a shift down has been performed. When it is judged that the second execution condition continues to stand even when a shift down is performed, the processing cycle is ended. When it is judged that the second execution condition would not stand if a shift down were performed, the routine proceeds to the next step 506 where an indication that a shift down should not be performed is displayed by the indicator 27.

Reference Signs List

[0063]

- 1 engine body
- 2 combustion chamber
- 3 fuel injector
- 13 exhaust pipe
- 14 NO_x storage catalyst
- 25 transmission
- 26 shift lever
- 27 indicator

Claims

1. An exhaust purification system for an internal combustion engine, the system arranging in an engine exhaust passage an NO_x storage catalyst (14) which stores NO_x in exhaust gas when the inflowing exhaust gas is lean in air-fuel ratio and which releases the stored NO_x when the inflowing exhaust gas becomes rich in air-fuel ratio, the system comprising a rich control means for executing a rich control which temporarily switches the air-fuel ratio of the exhaust gas which flows into the NO_x storage catalyst to be rich by injecting additional fuel into a combustion chamber (2) in a combustion stroke or exhaust stroke in order to release NO_x or SO_x from the NO_x storage catalyst (14), the system judging if rich control execution conditions stand when rich control should be executed, based on the engine operating state, the system executing rich control when it is judged that the rich control execution conditions stand and prohibits rich control when it is judged that rich control execution conditions do not stand, **characterized in**

that the system comprises a transmission (25) with a gear position which is changed by a vehicle operator and an indicator (27) which displays an indication relating to a change of the gear position of the transmission (25) to a vehicle operator, that when it is judged that the rich control execution conditions do not stand while rich control should be executed, a gear position, where the rich control execution conditions would stand when assuming that the gear position were changed under a constant engine output, is found, and that the indicator (27) is controlled to display to the vehicle operator an indication to change the gear position to the found gear position, whereby rich control is executed when the rich control execution conditions stand due to the change of the gear position to the found gear position by the vehicle operator.

2. The exhaust purification system for an internal combustion engine according to claim 1 wherein it is judged that the rich control execution conditions stand when the engine operating state is in a rich control allowable area (AA) and it is judged that the rich control execution conditions do not stand when the engine operating state is outside the rich control allowable area.
3. The exhaust purification system for an internal combustion engine according to claim 1 or 2 wherein the engine operating state is expressed by an engine load (TRQ) and an engine speed (N).
4. The exhaust purification system for an internal combustion engine according to claim 2 or 3 wherein it is judged that the rich control execution conditions stand when the engine operating state is in the rich control allowable area (AA) and the gear position of the transmission (25) is in a predetermined set gear position range and it is judged that the rich control execution conditions do not stand when the engine operating state is outside the rich control allowable area (AA) or the gear position of the transmission is outside the set gear position range.
5. The exhaust purification system for an internal combustion engine according to any one of claims 2 to 4 wherein it is judged that the rich control execution conditions stand when the engine operating state is in the rich control allowable area and the temperature of the NO_x storage catalyst is in a predetermined set temperature range and it is judged that the rich control execution conditions do not stand when the engine operating state is outside the rich control allowable area or the temperature of the NO_x storage catalyst is outside the set temperature range.
6. The exhaust purification system for an internal combustion engine according to any one of claims 2 to

5 wherein it is judged that the rich control execution conditions stand when the engine operating state is in the rich control allowable area and the vehicle speed is in a predetermined set vehicle speed range and it is judged that the rich control execution conditions do not stand when the engine operating state is outside the rich control allowable area (AA) or the vehicle speed is outside the set vehicle speed range.

7. The exhaust purification system for an internal combustion engine according to any one of claims 1 to 6 wherein it is judged if the rich control execution conditions would stand when assuming that the gear position were changed under a constant engine output when rich control is being executed and, when it is judged that the rich control execution conditions would not stand, the indicator (27) is controlled to display to the vehicle operator an indication that the gear position should not be changed.

FIG. 1

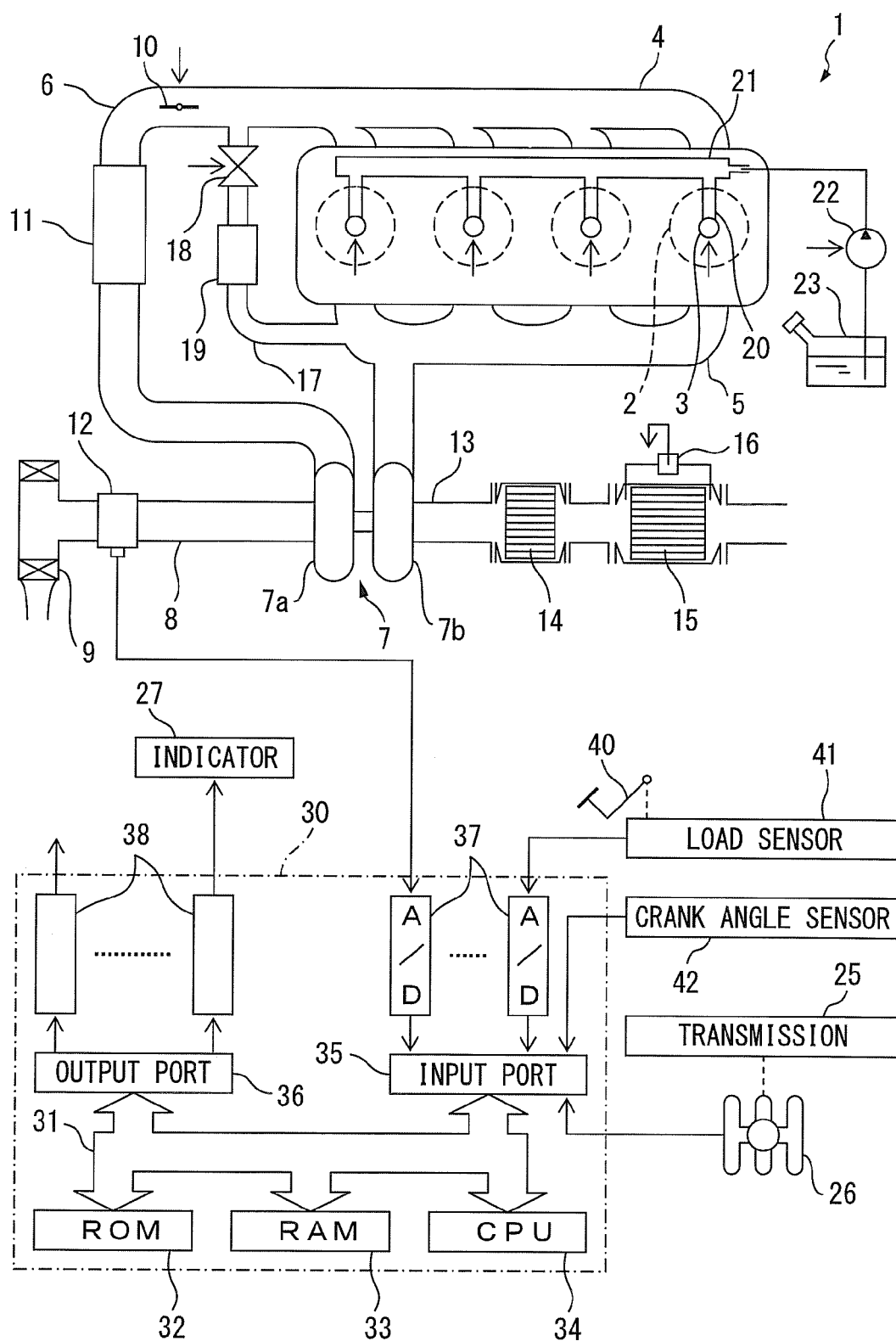


FIG. 2

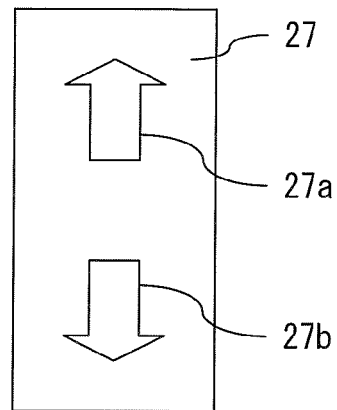


FIG. 3

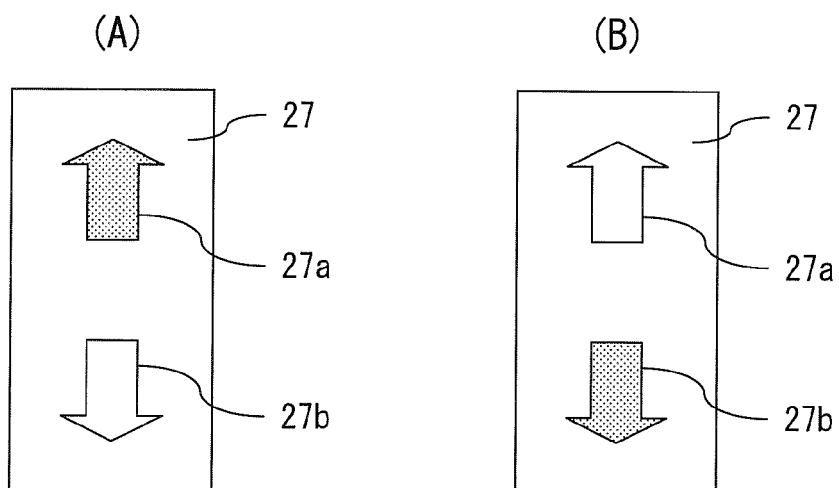


FIG. 4

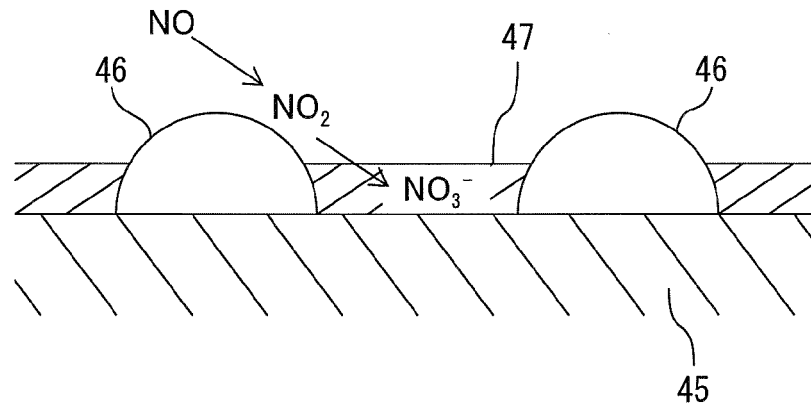


FIG. 5

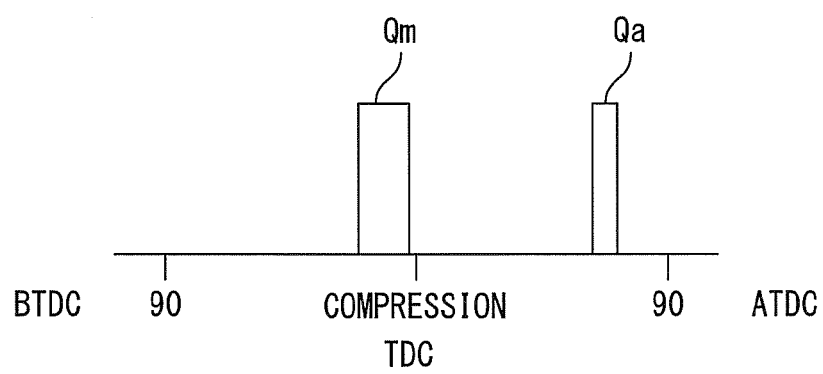


FIG. 6

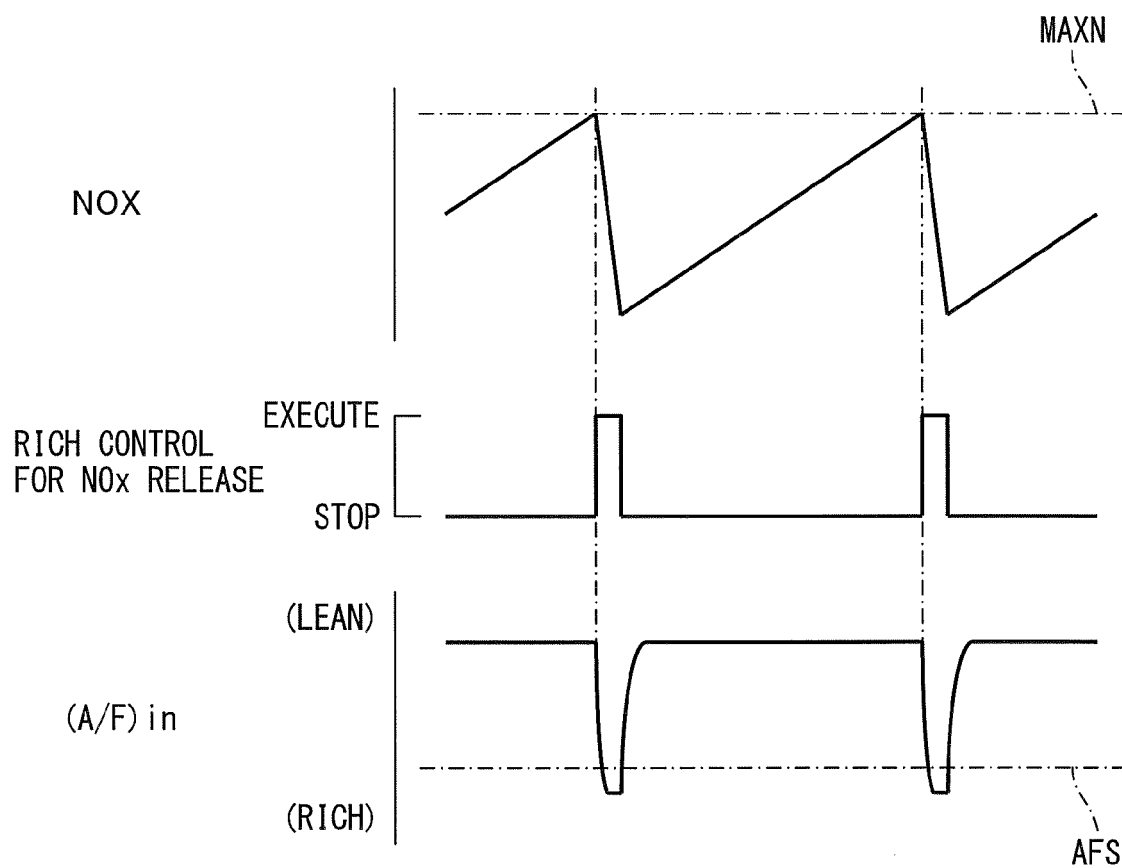


FIG. 7

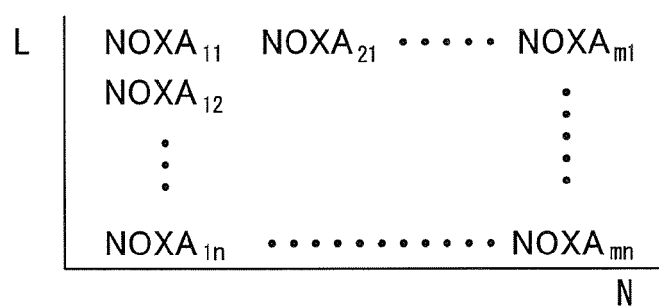


FIG. 8

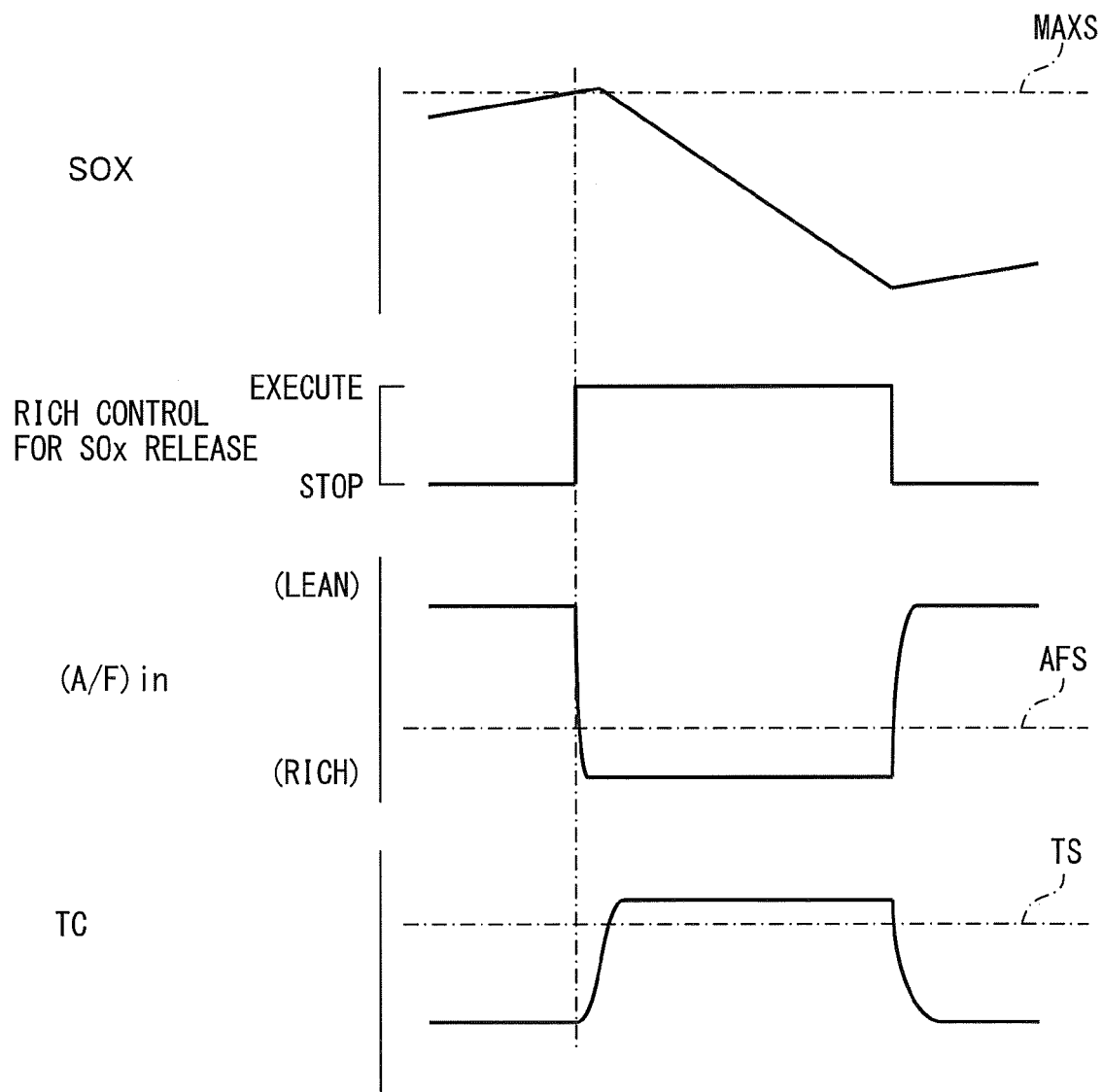


FIG. 9

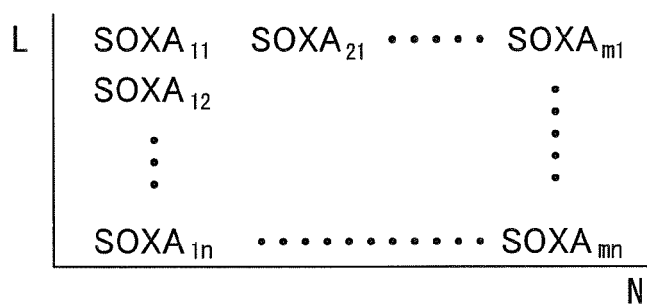


FIG. 10

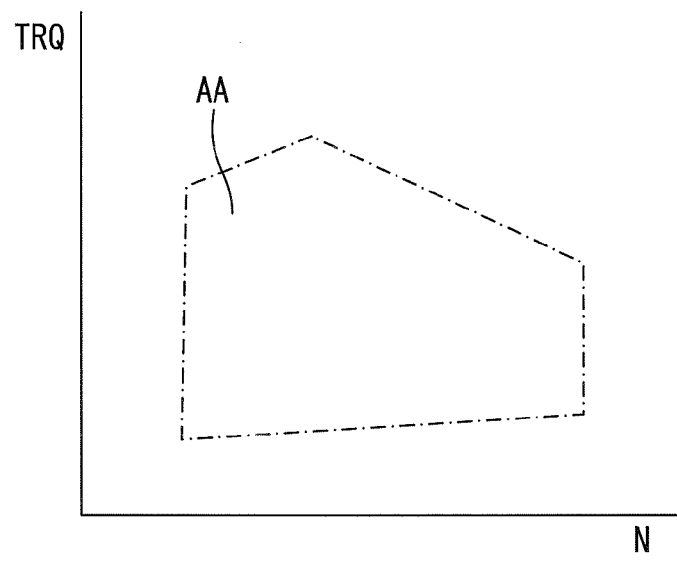


FIG. 11

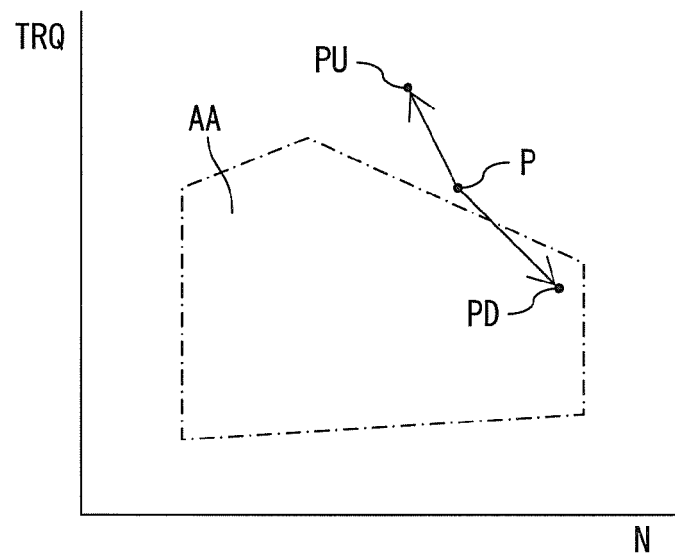


FIG. 12

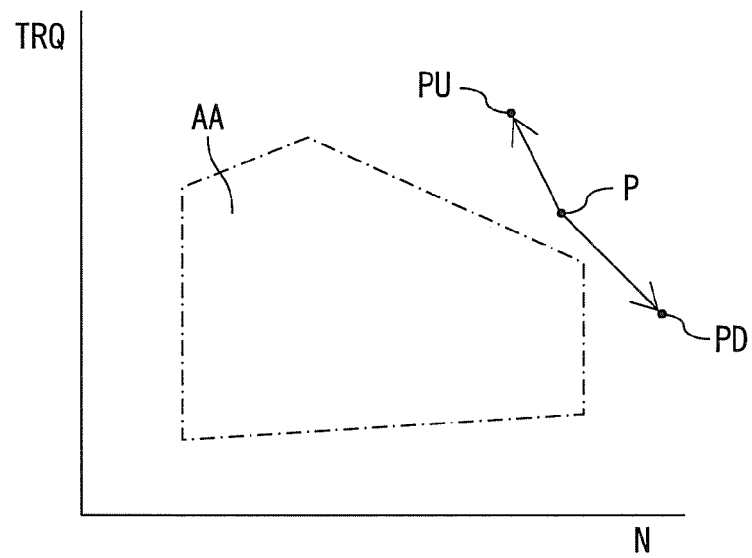


FIG. 13

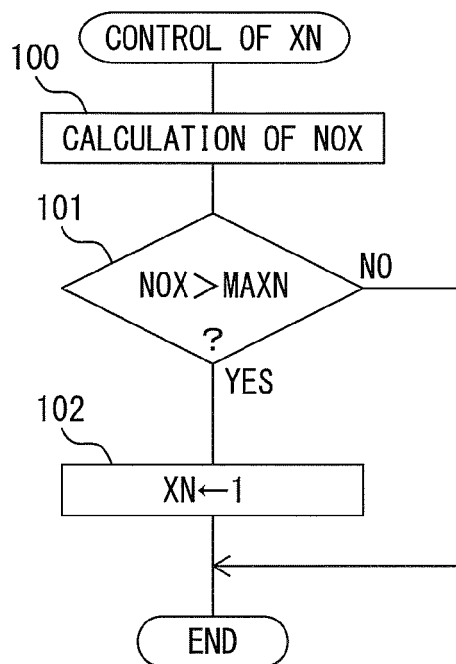


FIG. 14

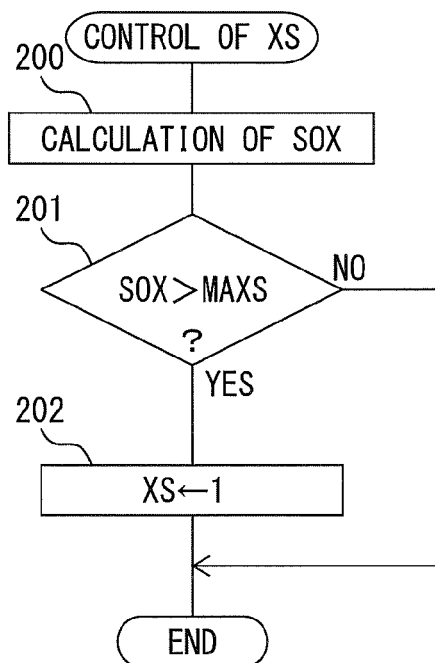


FIG. 15

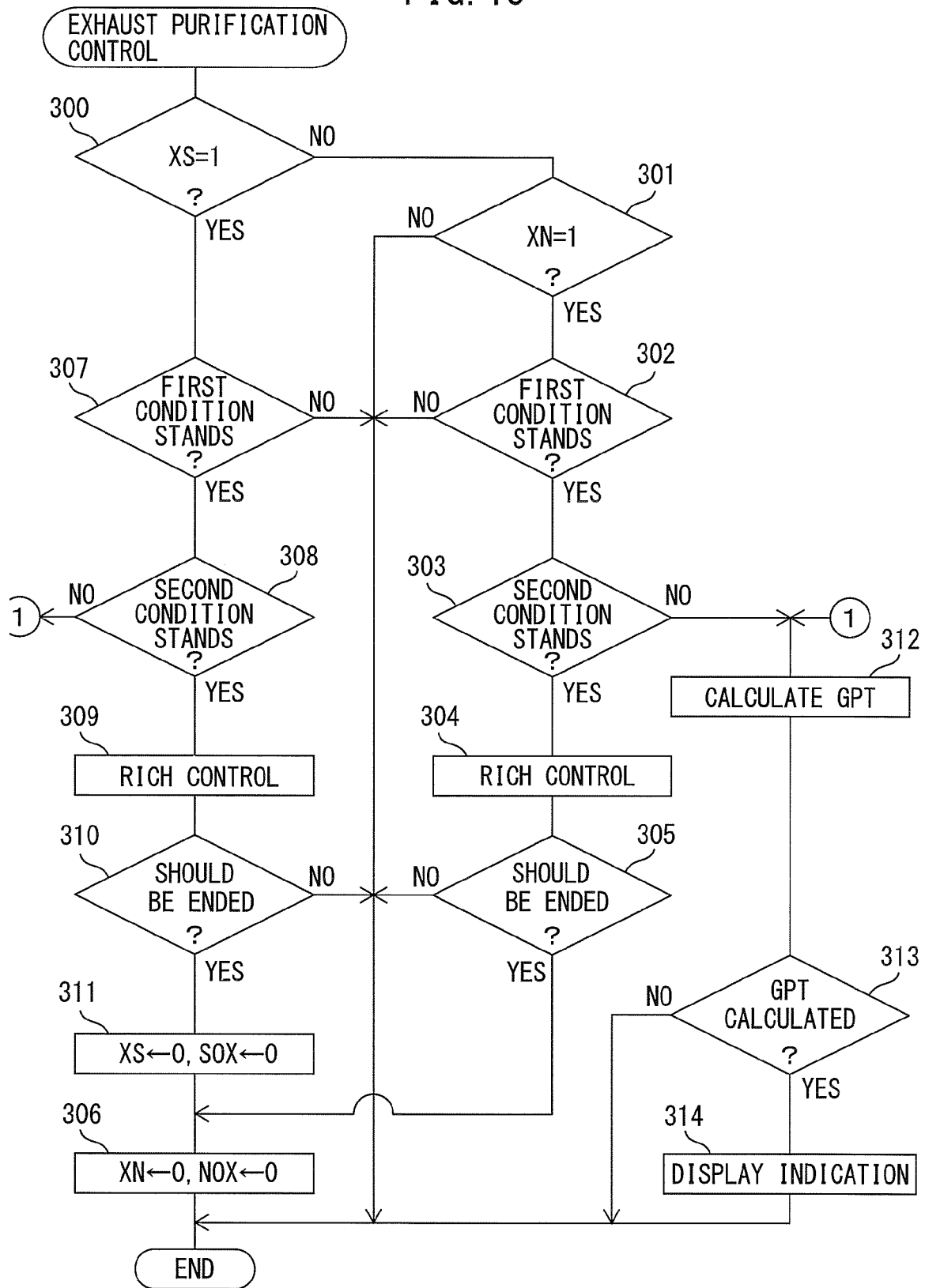


FIG. 16

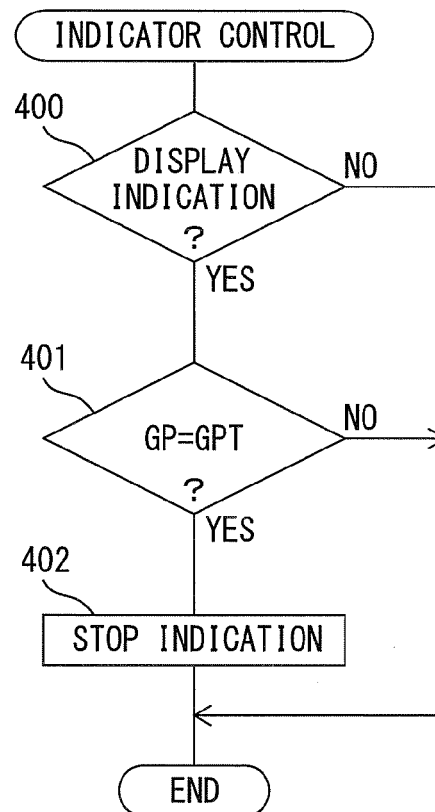


FIG. 17

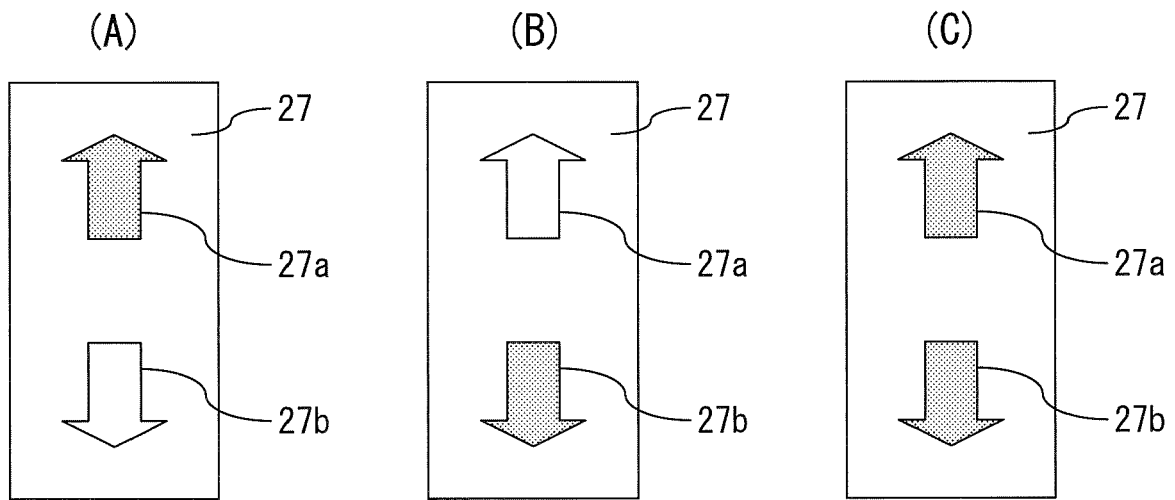


FIG. 18

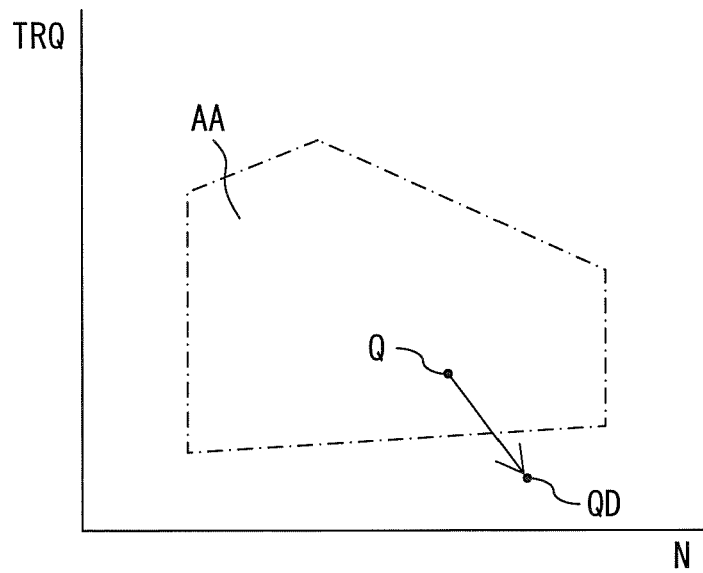
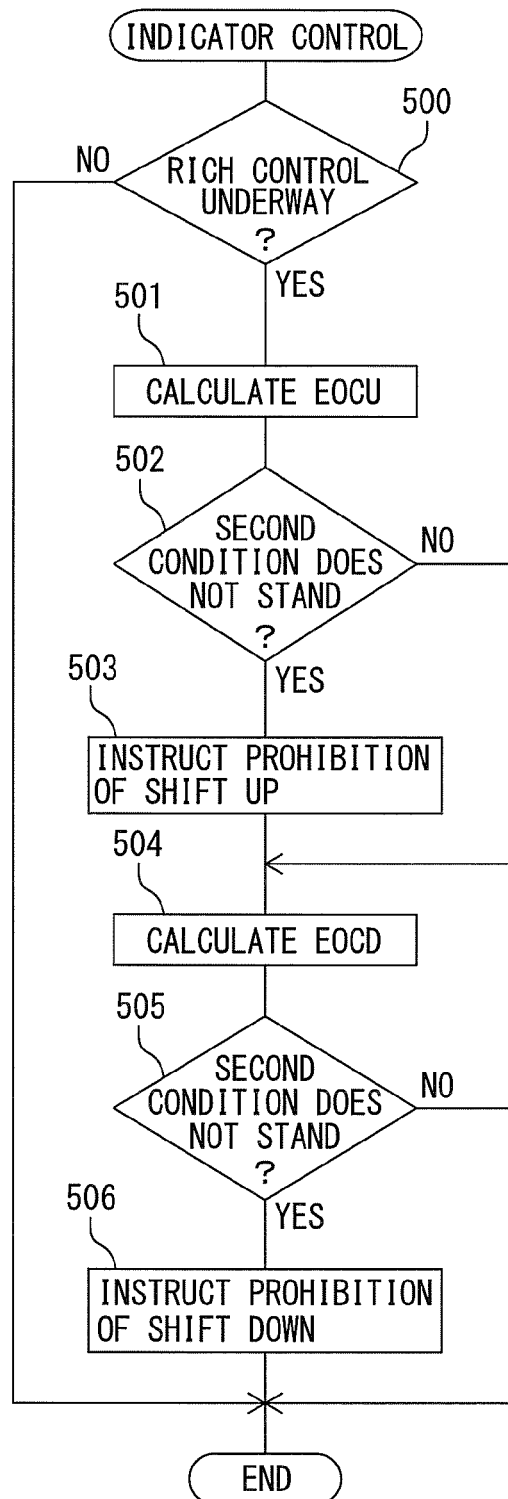


FIG. 19



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2007154771 A [0005]