(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
13 March 2014 (13.03.2014)

(10) **International Publication Number**
WO 2014/038724 A1

(51) **International Patent Classification**:
F01N 3/022 (2006.01) ***F01N 9/00*** (2006.01)
F01N 3/023 (2006.01) ***F01N 3/029*** (2006.01)
F01N 3/20 (2006.01) *F01N 3/025* (2006.01)
F01N 3/28 (2006.01) *F01N 13/02* (2010.01)

(21) **International Application Number**:
PCT/JP2013/074606

(22) **International Filing Date**:
5 September 2013 (05.09.2013)

(25) **Filing Language**: English

(26) **Publication Language**: English

(30) **Priority Data**:
2012-195420 5 September 2012 (05.09.2012) JP

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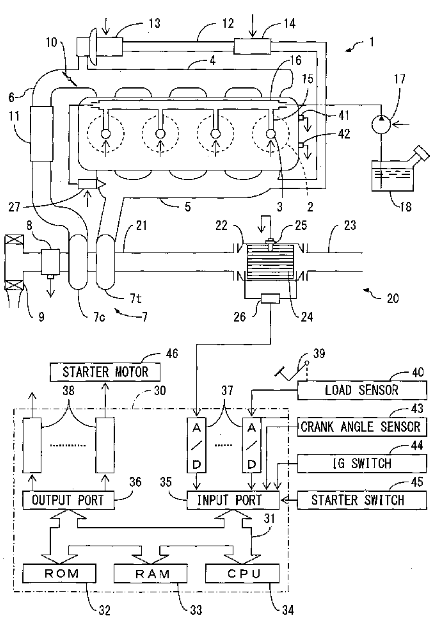
(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,

[Continued on next page]

(54) **Title**: Exhaust Purification System of Internal Combustion Engine

FIG. 1



(57) **Abstract**: A particulate filter (24) for trapping particulate filter which is contained in exhaust gas is arranged in an engine exhaust passage. The particulate filter is provided with exhaust gas inflow passages and exhaust gas outflow passages which are alternately arranged via porous partition walls. Movement promoting control is performed to promote movement of the ash which deposits on the inner circumferences of the exhaust gas inflow passages to the rear parts of the exhaust gas inflow passages. The pressure loss of the particulate filter is detected. When the detected pressure loss is larger than a predetermined upper limit value, PM removal control is performed to remove the particulate matter from the particulate filter.

WO 2014/038724 A1

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

DESCRIPTION

Title of Invention: Exhaust Purification System of Internal Combustion Engine

Technical Field

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

Background Art

[0002] Known in the art is an internal combustion engine which arranges a particulate filter for trapping particulate matter which is contained in exhaust gas in an engine exhaust passage. This particulate filter is provided with exhaust gas inflow passages and exhaust gas outflow passages which are arranged alternately via porous partition walls. As a result, exhaust gas first flows into the exhaust gas inflow passages, then passes through the partition walls and flows out into the exhaust gas outflow passages. Therefore, the particulate matter which is contained in the exhaust gas is trapped inside the partition walls or on the surfaces of the partition walls which form the inner circumference of the exhaust gas inflow passages.

[0003] As the amount of particulate matter which deposits on the particulate filter becomes greater, the pressure loss of the particulate filter becomes greater. If the pressure loss of the particulate filter becomes greater, the engine output is liable to fall. Therefore, known in the art is an exhaust purification system of an internal combustion engine which detects the pressure loss of the particulate filter and, when the pressure loss exceeds an upper limit value, performs PM removal control which removes the particulate matter from the particulate filter (see PLT 1).

Citations List

Patent Literature

[0004] PLT 1: Japanese Patent Publication No. 2005-

76462A

Summary of Invention

Technical Problem

[0005] In this regard, exhaust gas contains noncombustible ingredients called "ash". This ash is trapped together with the particulate matter by the particulate filter. In this regard, even if PM removal control is performed, the ash will not burn or will not vaporize. That is, the ash is not removed from the particulate filter, but remains on the particulate filter. As a result, the pressure loss of the particulate filter becomes larger by the amount of ash which is deposited on the particulate filter. For this reason, if performing PM removal control by the pressure loss of the particulate filter exceeding the upper limit value, PM removal control is liable to be performed regardless of the amount of the particulate filter which is deposited on the particulate filter being relatively small. That is, the timing of execution of PM removal control is liable to be advanced from the optimum timing. Therefore, PM removal control is liable to be unpreferably performed frequently and the energy which is consumed for PM removal control is liable to increase.

Solution to Problem

[0006] According to the present invention, there is provided an exhaust purification system of an internal combustion engine which is provided with a particulate filter for trapping particulate matter which is contained in exhaust gas inside an engine exhaust passage, which particulate filter is provided with exhaust gas inflow passages and exhaust gas outflow passages which are alternately arranged through porous partition walls, characterized in that the system comprises: a movement promoting means or a movement promoter for promoting movement of ash which deposited on inner circumferences of the exhaust gas inflow passages to rear parts of the exhaust gas inflow passages; a detecting means or a detector for detecting pressure loss of the particulate filter; and a PM removing means or a PM remover for performing PM removal control for removing particulate matter from the particulate filter when the detected pressure loss is greater than a predetermined upper limit value.

[0007] Preferably, the movement promoting means judges if the amount of ash which has deposited on the inner circumferences of the exhaust gas inflow passages is greater than a predetermined upper limit amount and performs movement promoting control when it is judged that the amount of ash is greater than the predetermined upper limit amount.

[0008] Preferably, the movement promoting means supplies a liquid to the particulate filter to perform the movement promoting control. More preferably, the liquid is comprised of at least one of water, an aqueous solution, and a liquid fuel. Still more preferably, at least one of an engine intake passage, engine exhaust passage upstream of the particulate filter, and exhaust gas recirculation passage which connects the engine intake passage and engine exhaust passage with each other is formed with a condensed water storage part which stores condensed water which is generated at the internal combustion engine, and the movement promoting means supplies condensed water which was stored in the condensed water storage part to the particulate filter, to perform the movement promoting control. Still more preferably, the system further comprises an NOx reducing catalyst which is arranged inside the particulate filter or in the engine exhaust passage downstream of the particulate filter; a reducing agent addition valve which secondarily adds a liquid reducing agent into the engine exhaust passage upstream of the particulate filter; and a NOx reducing means or a NOx reducer for adding the liquid reducing agent from the reducing agent addition valve with a NOx reduction addition pressure and NOx reduction addition time for reducing the NOx, and that the movement promoting means adds liquid reducing agent from the reducing agent addition valve with an addition pressure which is lower than the NOx reduction addition pressure or with an addition time which is longer than the NOx reduction addition time, to perform the movement promoting control.

[0009] Preferably, the movement promoting means makes the pressure inside of the particulate filter pulsate, to perform the movement promoting control.

[0010] Preferably, the movement promoting means makes the particulate filter vibrate, to perform the movement promoting control.

[0011] Preferably, the movement promoting means makes the temperature of the particulate filter rise to a temperature higher than that at the time of PM removal control, to perform the movement promoting control.

[0012] Preferably, the movement promoting means feeds a liquid to the particulate filter and makes the liquid solidify, to perform the movement promoting control.

Advantageous Effects of Invention

[0013] PM removal control can be performed at the optimum timing.

Brief Description of Drawings

[0014] FIG. 1 is an overall view of an internal combustion engine.

FIG. 2 is a schematic view of a cooling device.

FIG. 3A is a front view of a particulate filter.

FIG. 3B is a side cross-sectional view of a particulate filter.

FIG. 4 is a time chart which explains PM removal control.

FIG. 5A is a map which shows an amount of increase.

FIG. 5B is a map which shows an amount of decrease.

FIG. 6 is a flow chart which shows a routine for executing PM removal control.

FIG. 7 is a flow chart which shows a routine for calculating an amount of deposited particulate matter

QPM.

FIG. 8A is a graph which shows a relationship between a pressure difference PD and an amount of deposited particulate matter QPM.

FIG. 8B is a graph which shows a relationship between a pressure difference PD and an amount of deposited particulate matter QPM.

FIG. 8C is a graph which shows a relationship between a pressure difference PD and an amount of deposited particulate matter QPM.

FIG. 8D is a graph which shows a relationship between a pressure difference PD and an amount of deposited particulate matter QPM.

FIG. 9A is a partial enlarged cross-sectional view of a particulate filter which shows ash which is deposited on an inner circumference of an exhaust gas inflow passage.

FIG. 9B is a partial enlarged cross-sectional view which shows ash which is deposited at a rear part of an exhaust gas inflow passage.

FIG. 10 is a time chart which explains movement promoting control.

FIG. 11A is a graph which explains a difference between intercepts of two asymptotes.

FIG. 11B is a graph which explains a difference between intercepts of two asymptotes.

FIG. 12 is a flow chart which shows a routine for executing engine start control.

FIG. 13 is a flow chart which shows a routine for executing movement promoting control.

FIG. 14 is a flow chart which shows a routine for executing idling control.

FIG. 15 is a flow chart which shows a routine for calculating a ratio R.

FIG. 16 is a graph which explains another embodiment of the ratio R.

FIG. 17A is a view which shows another embodiment of a condensed water storage part.

FIG. 17B is a view which shows another embodiment of a condensed water storage part.

FIG. 17C is a view which shows another embodiment of a condensed water storage part.

FIG. 18 is an overview of an internal combustion engine which shows another embodiment of the present invention.

FIG. 19 is a time chart which explains movement promoting control of the embodiment which is shown in FIG. 18.

FIG. 20 is a flow chart which shows a routine for executing the movement promoting control which is shown in FIG. 19.

FIG. 21 is an overview of an internal combustion engine which shows still another embodiment according to the present invention.

FIG. 22 is a time chart which explains movement promoting control of the embodiment which is shown in FIG. 21.

FIG. 23 is a flow chart which shows a routine for executing the movement promoting control which is shown in FIG. 22.

FIG. 24A is an overview of an internal combustion engine which shows still another embodiment according to the present invention.

FIG. 24B is an overview of an internal combustion engine which shows still another embodiment according to the present invention.

FIG. 24C is an overview of an internal combustion engine which shows still another embodiment according to the present invention.

FIG. 25 is an overview of an internal combustion engine which shows still another embodiment according to the present invention.

FIG. 26 is a time chart which explains movement promoting control of the embodiment which is shown in FIG. 25.

FIG. 27 is a flow chart which shows a routine for executing the movement promoting control which is shown in FIG. 26.

FIG. 28 is an overview of an internal combustion engine which shows still another embodiment according to the present invention.

FIG. 29 is a time chart which explains movement promoting control of the embodiment which is shown in FIG. 28.

FIG. 30 is a flow chart which shows a routine for executing the movement promoting control which is shown in FIG. 29.

FIG. 31 is a time chart which explains still another embodiment according to the present invention.

FIG. 32 is a flow chart which shows a routine for executing the exhaust purification control which is shown in FIG. 31.

FIG. 33 is a flow chart which shows a routine for executing the movement promoting control which is shown in FIG. 31.

FIG. 34 is a time chart which explains still another embodiment according to the present invention.

FIG. 35 is a flow chart which shows a routine for executing engine stop control which is shown in FIG. 34.

FIG. 36 is a flow chart which shows a routine for executing engine start control which is shown in FIG. 34.

FIG. 37 is a flow chart which shows a routine for executing *movement promoting control during stop* which is shown in FIG. 34.

FIG. 38 is a flow chart which shows a routine for executing *movement promoting control during start* which is shown in FIG. 34.

FIG. 39 is an overview of an internal combustion engine which shows still another embodiment according to the present invention.

FIG. 40 is a time chart which explains movement promoting control of the embodiment which is shown in FIG. 39.

FIG. 41 is a flow chart which shows a routine for executing *movement promoting control during stop* which is shown in FIG. 40.

Description of Embodiments

[0015] Referring to FIG. 1, 1 indicates a body of a compression ignition-type internal combustion engine, 2 a combustion chamber of each cylinder, 3 an electronically controlled fuel injector which injects fuel into a 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 7c of an exhaust turbocharger 7, while an inlet of the compressor 7c is connected through an air flowmeter 8 to an air cleaner 9. Inside the intake duct 6, an electrically controlled throttle valve 10 is arranged. Furthermore, 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. On the other hand, the exhaust manifold 5 is connected to an inlet of an exhaust turbine 7t of the exhaust turbocharger 7, while an outlet of the exhaust turbine 7t is connected to an exhaust post-treatment device 20.

[0016] The exhaust manifold 5 and the intake manifold 4 are connected to each other through an exhaust gas recirculation (hereinafter referred to as "EGR") passage 12. Inside the EGR passage 12, an electrically controlled EGR control valve 13 is arranged. Further, in the EGR passage 12, a cooling device 14 is arranged for cooling the EGR gas which flows through the inside of the EGR passage 12. On the other hand, each fuel injector 3 is connected through a fuel runner 15 to a common rail 16. The inside of this common rail 16 is supplied with fuel from an electronically controlled variable discharge fuel pump 17. The fuel which is supplied to the inside of the common rail 16 is supplied through each fuel runner 15 to a fuel injector 3. In the embodiment which is shown in FIG. 1, this fuel is comprised of diesel oil. In another embodiment, the internal combustion engine is comprised of a spark ignition type internal combustion engine at which fuel is burned with a lean air-fuel ratio. In this case, the fuel is comprised of gasoline.

[0017] The exhaust post-treatment device 20 is provided with an exhaust pipe 21 which is connected to the outlet of the exhaust turbine 7t, a catalytic converter 22 which is connected to the exhaust pipe 21, and an exhaust pipe 23 which is connected to the catalytic converter 22. Inside of the catalytic converter 22, a wall flow type of particulate filter 24 is arranged.

[0018] The catalytic converter 22 is provided with a temperature sensor 25 for detecting the temperature of the particulate filter 24. In another embodiment, a temperature sensor is arranged in the exhaust pipe 21 to detect the temperature of the exhaust gas which flows into the particulate filter 24. Furthermore, in another embodiment, a temperature sensor for detecting the temperature of the exhaust gas which flows out from the particulate filter 24 is arranged in the exhaust pipe 23. The temperatures of the exhaust gas express the temperature of the particulate filter 24.

[0019] The catalytic converter 22 is further provided with a pressure loss sensor 26 for detecting the pressure loss of the particulate filter 24. In the example which is shown in FIG. 1, the pressure loss sensor 26 is comprised of a pressure difference sensor for detecting the pressure difference upstream and downstream of the particulate filter 24. In another embodiment, the pressure loss sensor 26 is comprised of a sensor which is attached to the exhaust pipe 21 and detects the engine back pressure.

[0020] On the other hand, the exhaust manifold 5 is provided with a fuel addition valve 27. This fuel addition valve 27 is supplied with fuel from the common rail 16. From the fuel addition valve 27, fuel is added inside of the exhaust manifold 5. In another embodiment, the fuel addition valve 27 is arranged in the exhaust pipe 21.

[0021] FIG. 2 shows a cooling device 14 which is provided in the EGR passage 12. The cooling device 14 is provided with a main passage 14a which is connected to the EGR passage 12, a cooler 14b which is arranged around the main passage 14a, a bypass passage 14c which branches from the main passage 14a upstream of the cooler 14b and returns to the main passage 14a downstream of the cooler 14b, and a bypass control valve 14d which selectively guides EGR gas to one of the main passage 14a and bypass passage 14c. When the EGR gas should be cooled, the bypass control valve 14d is controlled to the cooling position which is shown by the solid line in FIG. 2, therefore the EGR gas is guided to the cooler 14b. As opposed to this, when the EGR gas is not to be cooled such as at the time of cold operation, the bypass control valve 14d is controlled to the bypass position which is shown by the broken line in FIG. 2, therefore the EGR gas bypasses the cooler 14b. Furthermore, the bypass passage 14c is provided with a condensed water storage part 14e for storing condensed water which is formed in the EGR passage 12 and the cooling device 14. In the embodiment which is shown in FIG. 2, the condensed water storage part 14e is comprised of a recessed part which is formed at the bottom surface of the bypass passage 14c.

[0022] Referring again to FIG. 1, 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. The output signals of the air flowmeter 8, temperature sensor 25, and pressure difference sensor 26 are input through respectively corresponding AD converters 37 to the input port 35. Further, the accelerator pedal 39 is connected to a load sensor 40 which generates an output voltage which is proportional to the amount of depression L of the accelerator pedal 39. The output voltage of the load sensor 40 is input through a corresponding AD converter 37 to the input port 35. The engine body 1 has a water temperature sensor 41 for detecting the engine cooling water temperature and an oil temperature sensor 42 for detecting the engine lubrication oil temperature attached to it. The output voltages of these sensors 41 and 42 are input through the corresponding AD converters 37 to the input port 35. Furthermore, the input port 35 is connected to a crank angle sensor 43 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 43 is used as the basis to calculate the engine speed Ne. The input port 35 further receives as input the signals which show if the ignition switch 44 and the starter switch 45 are on or off. When the starter switch 45 is on, the starter motor 46 is actuated. On the other hand, the output port 36 is connected through corresponding drive circuits 38 to the fuel injectors 3, throttle valve 10 drive device, EGR control valve 13, bypass control valve 14d, fuel pump 17, fuel addition valve 27, and starter motor 46.

[0023] FIG. 3A and FIG. 3B show the structure of the wall flow type particulate filter 24. Note that, FIG. 3A shows a front view of the particulate filter 24, while FIG. 3B shows a side cross-sectional view of the particulate filter 24. As shown in FIG. 3A and FIG. 3B, the particulate filter 24 forms a honeycomb structure which is provided with a plurality of exhaust flow passages 71i, 71o which extend in parallel with each other and partition walls 72 which separate these exhaust flow passages 71i, 71o. In the embodiment which is shown in FIG. 3A, the exhaust flow passages 71i, 71o are comprised of exhaust gas inflow passages 71i which have upstream ends which are opened and have downstream ends which are closed by plugs 73d and exhaust gas outflow passages 71o which have upstream ends which are closed by plugs 73u and have downstream ends which are opened. Note that, in FIG. 3A, the hatched parts show plugs 73u. Therefore, the exhaust gas inflow passages 71i and exhaust gas outflow passages 71o are alternately arranged through thin partition walls 72. In other words, the exhaust gas inflow passages 71i and exhaust gas outflow passages 71o are comprised of exhaust gas inflow passages 71i each of which are surrounded by four exhaust gas outflow passages 71o and of exhaust gas outflow passages 71o each of which are surrounded by four exhaust gas inflow passages 71i. In another embodiment, the exhaust flow passages are comprised of exhaust gas inflow passages with upstream ends and downstream ends which are opened and exhaust gas outflow passages with upstream ends which are closed by plugs and with downstream ends which are open.

[0024] The partition walls 72 are formed from porous materials such as cordierite, silicon carbide, silicon nitride, zirconia, titania, alumina, silica, mullite, lithium aluminum silicate, zirconium phosphate, and other such ceramics. Therefore, as shown by the arrows in FIG. 3B, the exhaust gas first flows into the exhaust gas inflow passages 71i, then passes through the surrounding partition walls 72 and flows out to the adjoining exhaust gas outflow passages 71o. In this way, the partition walls 72 form the inner circumferences of the exhaust gas inflow passages 71i. Note that, the partition walls 72 have average pore sizes of 10 to 25 μm or so.

[0025] The partition walls 72 carry a catalyst which has an oxidation function at the two side surfaces and the surfaces inside the pores. The catalyst which has the oxidation function is comprised of palladium Pt, rhodium Rh, palladium Pd, or other such precious metal. In another embodiment, the catalyst which has an oxidation function is comprised of a composite oxide including cerium Ce, praseodymium Pr, neodymium Nd, lanthanum La, or other such base metal. Further, in another embodiment, the catalyst is comprised of a combination of a precious metal and composite oxide.

[0026] Now, the exhaust gas contains particulate matter which is formed mainly from solid carbon. This particulate matter is trapped on the particulate filter 24. In this combustion chamber 2, fuel is burned under an oxygen excess. Therefore, so long as fuel is not secondarily supplied from the fuel injector 3 and fuel addition valve 27, the particulate filter 24 is in an oxidizing atmosphere. Further, the particulate filter 24 carries a catalyst which has an oxidation function. As a result, the particulate matter which is trapped on the particulate filter 24 is successively oxidized. In this regard, if the amount of particulate matter which is trapped per unit time becomes greater than the amount of particulate matter which is oxidized per unit time, the amount of particulate matter which is trapped on the particulate filter 24 increases together with the elapse of the engine operation time.

[0027] Therefore, in the embodiment according to the present invention, PM removal control for removing particulate matter from the particulate filter 24 is repeatedly performed. As a result, the particulate matter on the particulate filter 24 is removed and the pressure loss of the particulate filter 24 is decreased.

[0028] In the embodiment which is shown in FIG. 1, PM removal control is comprised of temperature elevation control which raises and holds the temperature of the particulate filter 24 to the PM removal temperature (for example 600°C) to remove the particulate matter by oxidation. To execute temperature elevation control, in one embodiment, fuel is added from the fuel addition valve 27 and the fuel is burned at the exhaust passage or particulate filter 24. In another embodiment, fuel is injected from a fuel injector 3 in the compression stroke or exhaust stroke. This fuel is burned in the combustion chamber 2, exhaust passage, or particulate filter 24.

[0029] That is, as shown in FIG. 4, at the time ta1, if the pressure loss of the particulate filter 24, that is, the pressure difference PD, becomes larger than the upper limit value UPD, PM removal control, that is, temperature elevation control, is started. Therefore, the temperature TF of the particulate filter 24 is raised and held up the PM removal temperature TFPM. As a result, the pressure difference PD becomes smaller. Further, the amount of particulate matter QPM which is deposited on the particulate filter 24 also becomes smaller. Next, at the time ta2, if the amount of deposited particulate matter QPM becomes smaller than the lower limit value LQPM, the PM removal control is ended. Therefore, the temperature TF of the particulate filter 24 falls. Next, at the time ta3, if the pressure difference PD becomes larger than the upper limit value UPD, PM removal control is started. Next, at the time ta4, if the amount of deposited particulate matter QPM becomes smaller than the lower limit value LQPM, the PM removal control is ended. In this way, the PM removal control is repeatedly performed.

[0030] The amount of deposited particulate matter QPM, in one embodiment, is expressed by a counter value obtained by finding the amount of increase qPMi per unit time and the amount of decrease qPMd per unit time based on the state of engine operation, and accumulating the totals of the amount of increase qPMi and the amount of decrease qPMd (QPM=QPM+qPMi-qPMd). The amount of increase qPMi, as shown in FIG. 5A, is stored as a function of the fuel injection amount QF and the engine speed Ne in the form of a map in advance in the ROM 32 (FIG. 1). The fuel injection amount QF represents the engine load. On the other hand, the amount of decrease qPMd, as shown in FIG. 5B, is stored as a function of the intake air amount Ga and the temperature TF of the particulate filter 24 in the form of a map in advance in the ROM 32. The intake air amount Ga expresses the flow of exhaust gas or oxygen which flows into the particulate filter 24.

[0031] FIG. 6 shows a routine for executing the PM removal control which is shown in FIG. 4. Referring to

FIG. 6, at step 101, it is judged if the pressure difference PD of the particulate filter 24 is larger than the upper limit value UPD. When PD>UPD, next, the routine proceeds to step 102, where temperature elevation control is performed. That is, the target value TTF of the temperature TF of the particulate filter 24 is set to the PM removal temperature TFPM. In the embodiment which is shown in FIG. 1, the temperature of the particulate filter 24 is controlled so that the actual temperature of the particulate filter 24 becomes the target value TTF. At the next step 103, it is judged if the amount of deposited particulate matter QPM is smaller than the lower limit value LQPM. When QPM≥LQPM, the routine returns to step 102. When QPM<LQPM, the processing cycle is ended. Therefore, the temperature elevation control is ended. At step 101, when PD≤UPD, the processing cycle is ended. In this case, temperature elevation control is not performed.

[0032] FIG. 7 shows a routine for calculating the amount of deposited particulate matter QPM. Referring to FIG. 7, at step 111, the amount of increase qPMi is calculated from the map of FIG. 5A. At the next step 112, the amount of decrease qPMd is calculated from the map of FIG. 5B. At the next step 113, the amount of deposited particulate matter QPM is calculated (QPM=QPM+qPMi-qPMd).

[0033] In another embodiment, the PM removal control is comprised of NOx amount increasing control for increasing the amount of NOx in the exhaust gas which flows into the particulate filter 24, to remove the particulate matter by oxidation by NOx. To increase the amount of NOx, for example, the amount of EGR gas is decreased. In still another embodiment, the PM removal control is comprised of ozone supply control which supplies ozone to the particulate filter 24 from an ozone supplier which is connected with the exhaust passage upstream of the particulate filter 24, to remove the particulate matter by oxidation by ozone.

[0034] In this regard, exhaust gas also contains ash. This ash is also trapped at the particulate filter 24 together with the particulate matter. The fact that this ash is mainly formed from calcium salts such as calcium sulfate $CaSO_4$ and calcium zinc phosphate $Ca_{19}Zn_2(PO_4)_{14}$ was confirmed by the inventors. The calcium Ca, zinc Zn, phosphorus P, etc. are derived from the engine lubrication oil, while the sulfur S is derived from the fuel. That is, if explaining calcium sulfate $CaSO_4$ as an example, the engine lubrication oil flows into the combustion chamber 2 and burns. The calcium Ca in the lubrication oil bonds with the sulfur S in the fuel whereby calcium sulfate $CaSO_4$ is formed.

[0035] In this regard, even if PM removal control is performed, the ash is not burned or vaporized. That is, the ash is not removed from the particulate filter 24 and remains on the particulate filter 24. As a result, the pressure loss or the pressure difference PD of the particulate filter 24 increases by the amount of the ash which is deposited on the particulate filter 24.

[0036] That is, if the engine is started from the state of a new particulate filter 24, as shown in FIG. 8A, the pressure difference PD increases from its initial value PD0, while the amount of deposited particulate matter QPM increases from its initial value zero along the curve CT1. Next, if the pressure difference PD increases from the upper limit value UPD, PM removal control is started. As a result, as shown in FIG. 8B, the pressure difference PD decreases from the upper limit value UPD, while the amount of deposited particulate matter QPM decreases from the value QPM1 along the curve CR1. Next, if the amount of deposited particulate matter QPM becomes smaller than the lower limit value LQPM, the PM removal control is ended. As a result, as shown in FIG. 8C, the pressure difference PD is increased from the value PD1, while the amount of deposited particulate matter QPM increases from the lower limit value LQPM along the curve CT2. Next, if the pressure difference PD becomes larger than the upper limit value UPD, PM removal control is started. As a result, as shown in FIG. 8D, the pressure difference PD decreases from the upper limit value UPD, while the amount of deposited particulate matter QPM decreases from the value QPM2 along the curve CR2. Next, if the amount of deposited particulate matter QPM becomes smaller than the lower limit value LQPM, the PM removal control is ended. In this way, the increase and decrease of the pressure difference PD and the amount of deposited particulate matter QPM are alternately repeated.

[0037] From a separate viewpoint, FIG. 8A shows a first increasing action of the pressure difference PD and the amount of deposited particulate matter QPM, FIG. 8B shows a first decreasing action of the pressure difference PD and the amount of deposited particulate matter QPM, FIG. 8C shows a second increasing action of the pressure difference PD and the amount of deposited particulate matter QPM, and FIG. 8D shows a second decreasing action of the pressure difference PD and the amount of deposited particulate matter QPM.

[0038] In this way, as the engine operation time becomes longer, the amount of deposited particulate matter QPM decreases when the increasing action of the pressure difference PD and the amount of deposited particulate matter QPM is stopped, that is, when the PM removal control is started (QPM1>QPM2), while the pressure difference PD increases when the increasing action of the pressure difference PD and the amount of deposited particulate matter QPM is started (PD0<PD1<PD2). As a result, the timing of execution of PM removal control is liable to be advanced from the optimum timing. In this case, the PM removal processing is unpreferably performed frequently and the amount of fuel consumed unpreferably increases.

[0039] On the other hand, generally speaking, the ash which is deposited on the particulate filter 24 can be considered to be formed from one or both of the ash A which deposits in a dispersed manner on the inner circumferences 71is of the exhaust gas inflow passages 71i as shown in FIG. 9A, and the ash A which locally deposits at the rear parts or bottom parts 71ir of the exhaust gas inflow passages 71i as shown in FIG. 9B. On top of this, the ash A which deposits on the inner circumferences 71is of the exhaust gas inflow passages 71i has a large effect on the pressure loss or the pressure difference PD of the particulate filter 24. As opposed to this, the ash A which is deposited at the rear part 71ir of the exhaust gas inflow passage 71i has a small effect on the pressure loss or the pressure difference PD of the particulate filter 24.

[0040] This being so, if the ash A which is deposited on the inner circumferences 71is is moved to the rear parts 71ir, the effect of the ash on the pressure difference PD is weakened. On this point, there may be a case where part of the ash A which is deposited on the inner circumferences 71is is moved to the rear parts 71ir by the flow of the exhaust gas when the amount of exhaust gas which flows into the particulate filter 24 is large, like at the time of engine high load operation. However, in this case, it is difficult to move a sufficient amount of ash.

[0041] Therefore, in the embodiment according to the present invention, a movement promoting control is performed which promotes movement of the ash A which is deposited on the inner circumferences 71is of the exhaust gas inflow passages 71i to the rear parts 71ir of the exhaust gas inflow passages 71i. As a result, the amount of ash which deposits on the inner circumferences 71is of the exhaust gas inflow passages 71i can be decreased and the effect of the ash on the pressure difference PD can be kept small. Therefore, the timing of execution of the PM removal control can be maintained at the optimum timing.

[0042] In the embodiment which is shown in FIG. 1, the movement promoting control is performed by supplying liquid to the particulate filter 24. This liquid is comprised of condensed water which is stored in the condensed water storage part 14e.

[0043] Further, in the embodiment which is shown in FIG. 1, it is judged if the amount of ash which deposited on the inner circumferences 71is of the exhaust gas inflow passages 71i is larger than a predetermined upper limit amount. When it is judged that the amount of ash which deposited on the inner circumferences 71is is larger than the upper limit amount, the movement promoting control is performed at the time of engine cold start. As opposed to this, when it is not judged that the amount of ash which deposited on the inner circumferences 71is is larger than the upper limit amount, the movement promoting control is not performed. This movement promoting control will be explained with reference to FIG. 10.

[0044] In FIG. 10, the solid line shows the case where the movement promoting control is performed, while the broken line shows the case where the movement promoting control is not performed. Referring to FIG. 10, at the time tb1, the ignition switch 44 is turned on, the starter switch 45 is turned on, and therefore engine startup is started. As a result, the engine speed Ne rises. Next, at the time tb2, the engine speed Ne exceeds a predetermined set value NeC (for example 900 rpm) and complete explosion occurs. Next, in the case where movement promoting control is not performed, as shown by the broken line in FIG. 10, normal idling control is performed. That is, when the engine operation is cold operation, the engine speed Ne is maintained at the cold idling speed NeIC (for example, at the highest, 1000 rpm). Further, the EGR control valve 13 is closed, and therefore the feed of EGR gas is prohibited. Next, at the time tb4, when the engine operation is switched to warm operation, the engine speed Ne is maintained at the warm idling speed NeIW (for example 700 to 800 rpm). Further, the feed of EGR gas is allowed. That is, the opening degree DEGR of the EGR control valve 13 is controlled in accordance with the engine operating state. Note that, in the example which is shown in FIG. 1, when the engine cooling water temperature and engine lubricating oil temperature are both lower than a predetermined set temperature (for example 20°C), it is judged that the engine operation is cold operation, while when one or both of the engine cooling water temperature and engine lubricating oil temperature is higher than the set temperature, it is judged that the engine operation is warm operation.

[0045] As opposed to this, when movement promoting control is performed, as shown by the solid line in FIG. 10, after complete explosion at the time tb2, the engine speed Ne is maintained at a predetermined movement promoting idling speed NeIT (for example, 1500 rpm). This movement promoting idling speed NeIT is set higher than the normal idling speeds NeIC and NeIW. As a result, the amount of gas which flows through the intake manifold 4, combustion chambers 2, exhaust manifold 5, exhaust pipe 21, and particulate filter 24 is increased. Further, the opening degree DEGR of the EGR control valve 13 is increased. In the example which is shown in FIG. 10, the opening degree DEGR is made 100%, that is, the EGR control valve 13 is made full open. At this time, the engine operation is cold operation, so the bypass control valve 14d of the cooling device 14 is controlled to the bypass position (FIG. 2). As a result, a relatively large amount of EGR gas flows through the bypass passage 14c. This large amount of EGR gas causes the condensed water to be discharged from the condensed water storage part 14e. This condensed water successively flows together with the EGR gas through the intake manifold 4, combustion chambers 2, exhaust manifold 5, and exhaust pipe 21 and is fed to the inside of the particulate filter 24.

[0046] As a result, the ash on the inner circumference 71is of the exhaust gas inflow passage 71i is washed away by the condensed water and is moved to the rear part 71ir. Alternatively, the ash is wet by the condensed water whereby the ash layer which is formed on the inner circumference 71is of the exhaust gas inflow passage 71i is destroyed and the ash easily separates from the inner circumference 71is. The ash which separated from the inner circumference 71is is easily moved by the exhaust gas to the rear part 71ir during the subsequent engine operation.

[0047] In this case, since the engine operation is cold operation, the condensed water is fed as a liquid to the particulate filter 24, therefore movement of the ash can be reliably promoted. Note that, due to the movement promoting control, the amount of condensed water which passes through a combustion chamber 2 is relatively small and no water hammer phenomenon occurs. Further, if movement promoting control is performed, the particulate matter which is deposited on the inner circumference 71is also moves to the rear part 71ir. The particulate matter which was moved in this way is removed by the subsequent PM removal processing.

[0048] Next, if, at the time tb3, a predetermined set time tB has elapsed, the normal idling control is started. That is, when the engine operation is cold operation, the engine speed Ne is maintained at the cold idling speed NeIC and the EGR control valve 13 is closed. Next, if, at the time tb4, the engine operation switches to warm operation, the engine speed Ne is maintained at the warm idling speed NeIW and the feed of EGR gas is allowed.

[0049] If calling the fuel consumption rate when the particulate filter 24 is new the "new fuel consumption rate", according to the inventors, when the amount of ash which is deposited on the inner circumferences 71is of the exhaust gas inflow passages 71i becomes greater than a predetermined upper limit amount, the amount of increase in the fuel consumption rate over the new fuel consumption rate is about 13%. Next, the amount of increase in the fuel consumption rate over the new fuel consumption rate after the movement promoting control is performed is about 3%. In this way, by the movement promoting control, it is possible to reliably suppress the increase in the fuel consumption rate.

[0050] It is judged if the ash which deposited on the inner circumferences 71is of the exhaust gas inflow passages 71i is greater than the predetermined upper limit amount for example as follows. That is, as shown in FIG. 11A, the pressure difference PD and the amount of deposited particulate matter QPM change along the curve CT1 at the time of the first increasing action. The asymptote AST1 of this curve CT1 is represented by the following formula:

$$PD=A1 \cdot QPM+(B1+C1)$$

[0051] Further, the pressure difference PD and the amount of deposited particulate matter QPM change along the curve CR1 at the time of the first decreasing action. The asymptote ASR1 of this curve CR1 is represented by the following formula:

$$PD=A1 \cdot QPM+B1$$

[0052] The difference of the intercepts of these two formulas is represented by C1. Note that, B1 represents the pressure loss of the particulate filter 24 itself and corresponds to PD0.

[0053] In the same way, as shown in FIG. 11B, the pressure difference PD and the amount of deposited particulate matter QPM change along the curve CTi at the time of the i-th increasing action (i=1, 2,...). The asymptote ASTi of this curve CTi is represented by the following formula:

PD=Ai·QPM+(Bi+Ci)

[0054] Further, the pressure difference PD and the amount of deposited particulate matter QPM change along the curve CRi at the time of the i-th decreasing action. The asymptote ASRi of this curve CRi is represented by the following formula:

PD=Ai·QPM+Bi

[0055] The difference of the intercepts of these two formulas is represented by Ci.

[0056] The difference Ci of the intercepts represents the amount of particulate matter which has deposited on the particulate filter 24 at the time of the i-th increasing action of the pressure difference PD and the amount of deposited particulate matter QPM. Alternatively, it represents the amount of particulate matter which is removed from the particulate filter 24 at the time of the i-th decreasing action of the pressure difference PD and the amount of deposited particulate matter QPM. The amount of this particulate matter becomes smaller as the amount of the ash which is deposited on the inner circumferences 71is of the exhaust gas inflow passages 71i becomes greater. Therefore, as the amount of the ash which deposited on inner circumferences 71is of the exhaust gas inflow passages 71i increases, the difference Ci or the ratio R(=Ci/C1) becomes smaller. Note that, FIG. 11A shows the case where the difference Ci or the ratio R is large, while FIG. 11B shows the case where the difference Ci or the ratio R is small.

[0057] Therefore, in the embodiment which is shown in FIG. 1, when the ratio R is smaller than a predetermined lower limit value RL, it is judged that the amount of ash which is deposited on the inner circumferences 71is of the exhaust gas inflow passages 71i is greater than the predetermined upper limit amount, while when the ratio R is larger than the lower limit value RL, it is judged that the amount of ash which is deposited on the inner circumference 71is is smaller than the upper limit amount.

[0058] FIG. 12 shows a routine for executing the engine start control in the embodiment which is shown in FIG. 1. This routine is executed just once when the ignition switch 44 is turned on. Referring to FIG. 12, at the step 121, the flag X is reset (X=0). This flag X is set (X=1) when the normal idling control routine (FIG. 14) should be executed and is otherwise reset (X=0). At the next step 122, it is judged if the engine speed Ne is higher than the set speed NeC. When Ne≤NeC, the routine returns to step 122. When Ne>NeC, that is, when complete explosion occurs, next the routine proceeds to step 123 where it is judged if the ratio R is smaller than the lower limit value RL. When R<RL, next the routine proceeds to step 124 where it is judged if the engine operation is cold operation. When the engine operation is cold operation, next the routine proceeds to step 125 where the movement promoting control routine is executed. At the next step 126, the flag X is set (X=1). When, at the step 123, R≥RL and, at the step 125, the engine operation is warm operation, the routine proceeds to step 126. Therefore, in these cases, movement promoting control is not performed.

[0059] FIG. 13 shows a routine for executing movement promoting control in the embodiment which is shown in FIG. 1. This routine is for example executed at step 125 of FIG. 12. Referring to FIG. 13, at step 131, the target speed TNe is set to the movement promoting idling speed NeIT. In the embodiment which is shown in FIG. 1, the engine speed is controlled so that the actual engine speed becomes the target speed TNe. At the next step 132, the EGR control valve 13 is opened. At the next step 133, it is judged if the set time tB has elapsed. When the set time tB has not elapsed, the routine returns to step 131. When the set time tB has elapsed, the processing cycle is ended. That is, the movement promoting control is ended and the routine proceeds to step 126 of FIG. 12.

[0060] FIG. 14 shows the routine for executing the normal idling control. Referring to FIG. 14, step 141, it is judged if the amount of depression L of the accelerator pedal 39 is zero, that is, if the engine operation is in idling operation. When L>0, that is, when the engine operation is not idling operation, the processing cycle is ended. When L=0, that is, when the engine operation is idling operation, next the routine proceeds to step 142 where it is judged if the flag X has been set. When the flag X has been reset (X=0), the processing cycle is ended. As opposed to this, when the flag X has been set (X=1), next the routine proceeds to step 143. Therefore, from when engine startup is started to when the flag X is set at step 126 of the routine of FIG. 12, the routine does not proceed to step 143. At step 143, it is judged if the engine operation is cold operation. When the engine operation is cold operation, next the routine proceeds to step 144 where the target speed TNe is set to the cold idling speed NeIC. At the next step 146, the EGR control valve 13 is closed. As opposed to this, when the engine operation is warm operation, the routine proceeds to step 146 where the target speed TNe is set to the warm idling speed NeIW. At the next step 147, the feed of EGR gas is allowed.

[0061] FIG. 15 shows the routine for calculation of the ratio R. Referring to FIG. 15, at step 151, the pressure difference PD is read. At the next step 152, the amount of particulate matter QPM is read. At the next step 153, it is judged if the PM removal control has switched from execute to stop. When the PM removal control has not switched from execute to stop, next the routine proceeds to step 154 where it is judged if the PM removal control has switched from stop to execute. When the PM removal control has switched from stop to execute, the processing cycle is ended. When the PM removal control has switched from stop to execute, that is, when the i-th increasing action of the pressure difference PD and the amount of deposited particulate matter QPM ends, the routine proceeds to step 155 where the asymptote ASTi of the curve CTi for the i-th increasing action is determined. Next, when the PM removal control is switched from execute to stop, that is, when the i-th decreasing action of the pressure difference PD and the amount of deposited particulate matter QPM ends, the routine proceeds from step 153 to step 156 where the asymptote ASRi of the curve CRi for the i-th decreasing action is determined. At the next step 157, the difference Ci of the intercepts is calculated. At the next step 158, the ratio R is calculated (R=Ci/C1). At the next step 159, the parameter "i" is incremented by 1 (i=i+1). Note that, the parameter "i" is set to 1 at the time of engine startup.

[0062] Next, referring to FIG. 16, another embodiment of the ratio R will be explained. As shown in FIG. 16, the pressure difference PD decreases by Di (=UPD-PD(i+1)) due to the i-th decreasing action. The amount of decrease Di or ratio Di/D1 becomes smaller as the amount of ash which is deposited on the inner circumferences 71is of the exhaust gas inflow passages 71i becomes greater. Therefore, the ratio R is calculated in the form of Di/D1. In still another embodiment, when the difference Ci or the amount of decrease Di is smaller than a predetermined lower limit value, it is judged that the amount of ash which is deposited on the inner circumferences 71is of the exhaust gas inflow passages 71i is greater than the predetermined upper limit amount, while when the difference Ci or the amount of decrease Di is greater than the lower limit value, it is judged that the amount of ash which is deposited on the inner circumference 71is is smaller than the upper limit amount.

[0063] FIG. 17A to FIG. 17C show another embodiment of a condensed water storage part 14e. In the embodiment which is shown in FIG. 17A, the bypass passage 14c of the cooling device 14 is bent downward. The condensed water storage part 14e is configured by the bent part of the bypass passage 14c. In the embodiment which is shown in FIG. 17B, the condensed water storage part 14e is configured by a recessed part which is formed at the bottom surface of the intake manifold 4. In the embodiment which is shown in FIG. 17C, the condensed water storage part 14e is configured by a recessed part which is formed at the bottom surface of the exhaust manifold 5. Note that, in the embodiment which is shown in FIG. 17B and FIG. 17C, the EGR control valve 13 is closed at the time of movement promoting control. In still another embodiment, a condensed water storage part 14e is configured by a recessed part which is formed in the bottom surface of the housing of the exhaust turbocharger 7 or a recessed part which is formed in the bottom surface of the exhaust pipe 21.

[0064] FIG. 18 shows another embodiment according to the present invention. Referring to FIG. 18, the particulate filter 24 carries a NOx reducing catalyst 24a. This NOx reducing catalyst 24a has the function of reducing the NOx in the exhaust gas by a reducing agent in an oxidizing atmosphere in which the reducing agent is contained. The NOx reducing catalyst 24a is for example comprised of a carrier which is formed from titania on which vanadium oxide is carried, that is, a vanadium-titania catalyst, or of a carrier which is formed from zeolite on which copper is carried, that is, a copper-zeolite catalyst. In another embodiment, the NOx reducing catalyst is arranged downstream of the particulate filter 24.

[0065] In the exhaust pipe 21 upstream of the NOx reducing catalyst 24a, a reducing agent addition valve 50 is arranged for secondarily adding a reducing agent in the exhaust gas. The reducing agent addition valve 50 is connected through a reducing agent feed pipe 51 to a reducing agent tank 52. Inside the reducing agent feed pipe 51, a variable discharge pressure-type reducing agent pump 53 is arranged. In the example which is shown in FIG. 18, the reducing agent is comprised of a urea aqueous solution. The reducing agent tank 52 stores the urea aqueous solution.

[0066] At the time of normal operation after the engine startup has completed, a reducing agent is added from the reducing agent addition valve 50 for reducing the NOx. This reducing agent is next supplied to the NOx reducing catalyst 24a. As a result, NOx is reduced in the NOx reducing catalyst 24a. In this case, the reducing agent is added from the reducing agent addition valve 50 with the NOx reduction addition pressure and the NOx reduction addition time. These NOx reduction addition pressure and NOx reduction addition time are selected in accordance with the engine operating state so that the reducing agent, that is, the urea aqueous solution, can be sufficiently atomized.

[0067] In the embodiment which is shown in FIG. 18, the liquid which is supplied in the movement promoting control is comprised of a reducing agent which is added from the reducing agent addition valve 50, that is, a urea aqueous solution. That is, as shown in FIG. 19, after engine startup at the time tc1, if complete explosion occurs at the time tc2, the engine speed Ne is maintained at the movement promoting idling speed NeIT. As a result, the amount of exhaust gas which runs through the particulate filter 24 is increased. At this time, the reducing agent is added from the reducing agent addition valve 50 with the movement promoting addition pressure in the form of a liquid. This liquid reducing agent is supplied by the exhaust gas to the particulate filter 24. As a result, movement of the ash on the inner circumferences 71is of the exhaust gas inflow passages 71i to the rear parts 71r is promoted. Next, if, at the time tc3, a movement promoting addition time tC has elapsed, the normal idling control is started. Further, addition of the liquid reducing agent is stopped. That is, the movement promoting control is stopped.

[0068] The movement promoting addition pressure and the movement promoting addition time are set so that the reducing agent is not atomized much at all and is supplied in the form of a liquid to the particulate filter 24. That is, the reducing agent is added with a movement promoting addition pressure which is lower than the NOx reduction addition pressure or with a movement promoting addition time which is longer than the NOx reduction addition time. Note that, the movement promoting addition pressure and the movement promoting addition time are set in accordance with the engine operating state. In the embodiment which is shown in FIG. 18, the movement promoting addition pressure becomes higher as the intake air amount becomes greater and becomes higher as the temperature of the exhaust gas which flows into the particulate filter 24 becomes higher. Further, the movement promoting addition time becomes longer as the pressure inside the exhaust pipe 21 becomes higher and becomes longer the greater the amount of ash which is deposited on the inner circumferences 71is of the exhaust gas inflow passages 71i.

[0069] FIG. 20 shows a routine for executing the movement promoting control which is shown in FIG. 19. This routine is for example executed at step 125 of FIG. 12. Referring to FIG. 19, at step 161, the target speed TNe is set at the movement promoting idling speed NeIT. At the next step 162, the movement promoting addition pressure is calculated. At the next step 163, the movement promoting addition time is calculated. At the next step 164, the reducing agent is added from the reducing agent addition valve 50 with the movement promoting addition pressure for the movement promoting addition time. Next, the processing cycle is ended. That is, the movement promoting control is ended, and the routine proceeds to step 126 of FIG. 12.

[0070] Next, another embodiment of the movement promoting control in the embodiment which is shown in FIG. 1 or FIG. 18 will be explained. In this embodiment, the liquid which is supplied to the movement promoting control is comprised of fuel which is added from the fuel addition valve 27. The fuel which is added from the fuel addition valve 27 is used for reducing the NOx at the catalyst which is carried on the particulate filter 24. Alternatively, it is used for the above-mentioned temperature elevation control.

[0071] When the movement promoting control must be performed, liquid fuel is added from the fuel addition valve 27. In this case, the fuel is added with an addition pressure which is lower than the addition pressure for NOx reduction or temperature elevation control or an addition time which is longer than the addition time for NOx reduction or temperature elevation control. As a result, the fuel is added in the form of a liquid to the particulate filter 24.

[0072] If, in this way, liquid is added from the reducing agent addition valve 50 (FIG. 18) or fuel addition valve 27 (FIG. 1) for movement promoting control, an additional configuration is not required.

[0073] FIG. 21 shows still another embodiment according to the present invention. Referring to FIG. 21, a liquid addition valve 55 is arranged in the EGR passage 12 to secondarily add liquid into the EGR gas. The liquid addition valve 55 is connected through a liquid feed pipe 56 to a liquid tank 57. Inside the liquid feed pipe 56, a variable discharge liquid pump 58 is arranged. In the example which is shown in FIG. 21, the liquid is comprised of water. The water is stored in the liquid tank 57. In another embodiment, the liquid is comprised of an aqueous solution or liquid fuel.

[0074] In the embodiment which is shown in FIG. 21, the liquid which is supplied in the movement promoting control is comprised of the liquid which is added from the liquid addition valve 55, that is, water. That is, as shown in FIG. 22, if, after engine startup at the time td1, complete explosion occurs at the time td2, the engine speed Ne is maintained at the movement promoting idling speed NeIT. Further, the EGR control valve 13 is opened. At this time, water is added from the liquid addition valve 55 with the movement promoting addition pressure. This water is supplied by the exhaust gas to the particulate filter 24. As a result, movement of the ash on the inner circumferences 71is of the exhaust gas inflow passages 71i to the rear parts 71r is promoted. In this case, the movement promoting addition pressure and the movement promoting addition time are set so that the water is supplied in the form of a liquid to the particulate filter 24. Next, if, at the time td3, a movement promoting addition time tD elapses, the normal idling control is started. Further, the addition of water is stopped. That is, the movement promoting control is stopped.

[0075] FIG. 23 shows a routine for executing the movement promoting control which is shown in FIG. 22. This routine is for example executed at step 125 of FIG. 12. Referring to FIG. 23, at step 171, the target speed TNe is set to the movement promoting idling speed NeIT. At the next step 172, the EGR control valve 13 is opened. At the next step 173, the movement promoting addition pressure is calculated. At the next step 174, the movement promoting addition time is calculated. At the next step 175, liquid is added from the liquid addition valve 55 with the movement promoting addition pressure for the movement promoting addition time. Next, the processing cycle is ended. That is, the movement promoting control is ended and the routine proceeds to step 126 of FIG. 12.

[0076] In the embodiment which is shown in FIG. 24A, a liquid addition valve 55 is arranged at the intake duct 6. In the embodiment which is shown in FIG. 24B, the liquid addition valve 55 is arranged at the exhaust manifold 5. In the embodiment which is shown in FIG. 24C, the liquid addition valve 55 is arranged at the exhaust pipe 21. Note that, in the embodiments which are shown from FIG. 24A to FIG. 24C, the EGR control valve 13 is closed at the time of movement promoting control.

[0077] FIG. 25 shows still another embodiment according to the present invention. Referring to FIG. 25, an exhaust control valve 60 which can open and close the exhaust pipe 23 is arranged in the exhaust pipe 23 downstream of the particulate filter 24. The exhaust control valve 60 is normally set full open.

[0078] In the embodiment which is shown in FIG. 25, the movement promoting control is comprised of generation of pressure pulsation in the particulate filter 24. That is, as shown in FIG. 26, if, after engine startup at the time te1, complete explosion occurs at the time te2, the engine speed Ne is maintained at the movement promoting idling speed NeIT. At this time, the exhaust control valve 60 is alternately repeatedly opened and closed. As a result, pulsation occurs in the pressure in the particulate filter 24. Due to this pressure pulsation, the ash layer which is formed at the inner circumferences 71is of the exhaust gas inflow passages 71i is destroyed and the ash easily peels off from the inner circumferences 71is. The ash which peeled off from the inner circumferences 71is is easily moved by the exhaust gas to the rear parts 71ir during the subsequent engine operation. Next, if, at the time te3, a predetermined set time tE has elapsed, the normal idling control is started. Further, the exhaust control valve 60 is maintained full open. That is, the movement promoting control is stopped.

[0079] FIG. 27 shows the routine for executing the movement promoting control which is shown in FIG. 26. This routine is for example executed at step 125 of FIG. 12. Referring to FIG. 27, at step 181, the target speed

TNe is set to the movement promoting idling speed NeIT. At the next step 182, the exhaust control valve 60 is opened and closed repeatedly. At the next step 183, it is judged if the set time tE has elapsed. When the set time tE has not elapsed, the routine returns to step 181. When the set time tE has elapsed, the processing cycle is ended. That is, the movement promoting control is stopped and the routine proceeds to step 126 of FIG. 12.

[0080] FIG. 28 shows still another embodiment according to the present invention. Referring to FIG. 28, the catalytic converter 22 has a vibrator 61 attached to it.

[0081] In the embodiment which is shown in FIG. 28, the movement promoting control is comprised of the generation of vibration at the particulate filter 24. That is, as shown in FIG. 29, after engine startup at the time tf1, if complete explosion occurs at the time tf2, the engine speed Ne is maintained at the movement promoting idling speed NeIT. At this time, the vibrator 61 is actuated. As a result, the particulate filter 24 is given vibration. Due to this vibration, the ash layer which is formed at the inner circumferences 71is of the exhaust gas inflow passages 71i is destroyed and the ash is easily separated from the inner circumferences 71is. The ash which is separated from the inner circumferences 71is is easily moved by the exhaust gas to the rear parts 71ir during the subsequent engine operation. Next, if, at the time tf3, a predetermined set time tF elapses, the normal idling control is started. Further, the vibrator 61 is stopped. That is, the movement promoting control is stopped.

[0082] FIG. 30 shows the routine for executing the movement promoting control which is shown in FIG. 29. This routine is for example executed at step 126 of FIG. 12. Referring to FIG. 30, at step 191, the target speed TNe is set to the movement promoting idling speed NeIT. At the next step 192, the vibrator 61 is actuated. At the next step 193, it is judged if the set time tF has elapsed. When the set time tF has not elapsed, the routine returns to step 191. When the set time tF has elapsed, the processing cycle is ended. That is, the movement promoting control is stopped and the routine proceeds to step 126 of FIG. 12.

[0083] FIG. 31 shows still another embodiment of the present invention. In the movement promoting control of the embodiment which is shown in FIG. 31, first, temperature elevation control for movement promotion is performed where the temperature TF of the particulate filter 24 rises to the movement promoting temperature TFT which is higher than the PM removal control. Next, exhaust gas amount increasing control is performed to temporarily make the amount of exhaust gas which runs through the particulate filter 24 increase. As a result, the ash shrinks due to the heating, the ash layer which is formed on the inner circumferences 71is of the exhaust gas inflow passages 71i is destroyed, and the ash easily peels off from the inner circumferences 71is. The ash which peeled off from the inner circumferences 71is is easily and reliably moved by the increased exhaust gas to the rear parts 71ir. Note that, the movement promoting temperature TFT is for example from 630°C to 1100°C or so.

[0084] The movement promoting control of this embodiment is performed at the time of normal operation after engine startup has been completed. That is, as shown in FIG. 31, at the time tg1, PM removal control is started, whereby the temperature TF of the particulate filter 24 is raised to the PM removal temperature TFPM. Next, at the time tg2, the amount of deposited particulate matter QPM becomes smaller than the lower limit value LQPM and the PM removal control is ended. Following the PM removal control, movement promoting control is started. Specifically, first, temperature elevation control for movement promotion is started. That is, the temperature TF of the particulate filter 24 is raised from the PM removal temperature TFPM to the movement promoting temperature TFT and held there. If doing this, the energy which is required for the temperature elevation control for movement promotion can be decreased. Next, if, at the time tg3, a predetermined set time tG1 elapses, the temperature elevation control for movement promotion is ended. Next, exhaust gas amount increasing control is started. As a result, the amount of exhaust gas QEX which flows through the particulate filter 24 is increased. Next, if, at the time tg4, a predetermined set time tG2 has elapsed, the exhaust gas amount increasing control is ended. Therefore, the movement promoting control is ended.

[0085] Note that, to execute the temperature elevation control for movement promotion, in one embodiment, fuel is added from the fuel addition valve 27. This fuel is burned in the exhaust passage or particulate filter 24. In another embodiment, fuel is injected from a fuel injector 3 in the compression stroke or the exhaust stroke and this fuel is burned in the combustion chamber 2, exhaust passage, or particulate filter 24. On the other hand, to execute exhaust gas amount increasing control, the engine speed or the throttle opening degree is increased.

[0086] FIG. 32 shows a routine for executing the exhaust purification control which is shown in FIG. 31. Referring to FIG. 32, at step 201, the PM removal control routine which is shown in FIG. 6 is executed. At the next step 202, it is judged if the ratio R is smaller than the lower limit value RL. When $R<RL$, next the routine proceeds to step 203 where the movement promoting control routine is executed. As opposed to this, when $R \geq RL$, the processing cycle is ended. Therefore, in this case, the movement promoting control routine is not executed.

[0087] FIG. 33 shows a routine for executing the movement promoting control which is shown in FIG. 31. This routine is for example executed at step 203 of FIG.

32. Referring to FIG. 33, at step 211, the target value TTF of the temperature TF of the particulate filter 24 is set to the movement promoting temperature TFT. At the next step 212, it is judged whether the set time tG1 has elapsed. When the set time tG1 has not elapsed, the routine returns to step 211. When the set time tG1 has elapsed, next the routine proceeds to step 213 where exhaust gas amount increasing control is performed. At the next step 214, it is judged if the set time tG2 has elapsed. When the set time tG2 has not elapsed, the routine returns to step 213. When the set time tG2 has elapsed, the processing cycle is ended. That is, exhaust gas amount increasing control ends, therefore the movement promoting control is ended.

[0088] In another embodiment, the exhaust gas amount increasing control is omitted. In this case, the ash which is peeled off from the inner circumferences 71is by the temperature elevation control for movement promotion is easily moved to the rear parts 71ir by the exhaust gas during the subsequent engine operation.

[0089] FIG. 34 shows another embodiment of the movement promoting control in the embodiment which is shown in FIG. 24C. In the embodiment which is shown in FIG. 34, the movement promoting control is comprised of *movement promoting control during stop* which is performed when the engine is stopped and *movement promoting control during start* which is performed when the engine is subsequently started.

[0090] That is, as shown in FIG. 34, if, at the time th1, the ignition switch 44 is turned off, the engine operation is stopped. As a result, the engine speed Ne falls to zero. Next, if a predetermined set time tH1 elapses, *movement promoting control during stop* is performed. That is, liquid is added from the liquid addition valve 55 with the movement promoting addition pressure. As a result, ash on the inner circumferences 71is of the exhaust gas inflow passages 71i is washed away by the condensed water and moved to the rear parts 71ir. Alternatively, the ash is wet by the condensed water, the ash layer which is formed at the inner circumferences 71is of the exhaust gas inflow passages 71i is destroyed, and the ash easily peels off from the inner circumferences 71is. Note that, the set time tH1 is set to the time necessary for lowering the temperature TF of the particulate filter 24 so that the liquid which is added from the liquid addition valve 55 does not vaporize at the particulate filter 24. Next, if, at the time th3, liquid is added for the movement promoting addition time tH2, the addition of liquid is stopped. That is, *movement promoting control during stop* is stopped.

[0091] Next, at the time th4, the ignition switch 44 is turned on and the engine is started. Next, if, at the time th5, complete explosion occurs, *movement promoting control during start* is started. That is, the engine speed Ne is maintained at the movement promoting idling speed NeIT. As a result, the amount of exhaust gas which runs through the particulate filter 24 is increased. Therefore, ash which peels off from the inner circumferences 71is of the exhaust gas inflow passages 71i is easily moved to the rear parts 71ir. Next, if, at the time th6, a predetermined set time tH3 has elapsed, the normal idling control is started. That is, the *movement promoting control during start* is stopped.

[0092] FIG. 35 shows a routine for executing the engine stop control which is shown in FIG. 34. This routine is executed just once when the ignition switch 44 is turned off. Referring to FIG. 35, at step 221, the flag XX is reset (XX=0). This flag XX is set (XX=1) when *movement promoting control during start* should be executed and is otherwise reset (XX=0). At the next step 222, the engine operation is stopped. At the next step 223, it is judged if the ratio R is smaller than the lower limit value RL. When R<RL, next the routine proceeds to step 224 where the *movement promoting control*

routine during stop is executed. At the next step 225, the flag XX is set (XX=1). At the next step 226, the powering of the electronic control unit 30 is stopped. Next, the processing cycle is ended. As opposed to this, when R≥RL, the routine proceeds from step 223 to step 226. Therefore, in this case, movement promoting control is not performed.

[0093] FIG. 36 shows a routine for executing the engine start control which is shown in FIG. 34. This routine is executed one time when the ignition switch 44 is turned on. Referring to FIG. 36, at step 231, the flag X which was explained referring to FIG. 12 is reset (X=0). At the next step 232, it is judged if the engine speed Ne is higher than a set speed NeC. When Ne≤NeC, the routine returns to step 232. When Ne>NeC, that is, when complete explosion occurs, next the routine proceeds to step 233 where it is judged if the flag XX explained with reference to FIG. 35 is set. When the flag XX is set (XX=1), next the routine proceeds to step 234 where the *movement promoting control routine during start* is executed. At the next step 235, the flag X is set (X=1). When, at step 233, the flag XX is reset (XX=0), the routine proceeds to step 235. Therefore, in this case, *movement promoting control during start* is not performed.

[0094] FIG. 37 shows the routine for executing the *movement promoting control during stop* which is shown in FIG. 34. This routine is for example executed at step 224 of FIG. 35. Referring to FIG. 37, at step 241, it is judged if the set time tH1 has elapsed from when the ignition switch 44 was turned off. When the set time tH1 has not elapsed, the routine returns to step 241. When the set time tH1 has elapsed, next the routine proceeds to step 242 where the movement promoting addition pressure is calculated. At the next step 243, the movement promoting addition time is calculated. At the next step 244, the liquid is added from the liquid addition valve 55 with the movement promoting addition pressure for the movement promoting addition time. Next, the processing cycle is ended. That is, the *movement promoting control during stop* is ended and the routine proceeds to step 225 of FIG. 35.

[0095] FIG. 38 shows a routine for execution of *movement promoting control during start* which is shown in FIG. 34. This routine is for example executed at step 234 of FIG. 36. Referring to FIG. 38, at step 251, the target speed TNe is set to the movement promoting idling speed NeIT. At the next step 252, it is judged if the set time tH3 has elapsed. If the set time tH3 has not elapsed, the routine returns to step 251. When the set time tH3 has elapsed, the processing cycle is ended. That is, the *movement promoting control during start* is stopped and the routine proceeds to step 235 of FIG. 36.

[0096] FIG. 39 shows still another embodiment according to the present invention. The embodiment which is shown in FIG. 39 differs from the embodiment which is shown in FIG. 34 in the point that the catalytic converter 24 has a cooler 62 attached to it and the liquid which is added to the particulate filter 24 is solidified by the cooler 62.

[0097] That is, as shown in FIG. 40, if, at the time tj1, the ignition switch 44 is turned off, the engine operation is stopped, then a predetermined set time tJ1 elapses, *movement promoting control during stop* is performed. That is, liquid is added from the liquid addition valve 55 with the movement promoting addition pressure. As a result, the ash on the inner circumferences 71is of the exhaust gas inflow passages 71i is washed away by the condensed water and is moved to the rear parts 71ir. Alternatively, the ash is wet by condensed water, the ash layer which is formed on the inner circumferences 71is of the exhaust gas inflow passages 71i is destroyed, and the ash easily separates from the inner circumferences 71is. Note that, the set time tJ1 is set in the same way as the above set time tH1.

[0098] Next, if, at the time tj3, the liquid is added for a movement promoting addition time tJ2, the addition of the liquid is stopped. Next, if, at tj4, a predetermined set time tJ3 elapses from the stopping of liquid addition, the cooler 62 is actuated and the liquid which is added to the particulate filter 24 solidifies. As a result, the liquid expands, so the ash layer which is formed on the inner circumferences 71is of the exhaust gas inflow passages 71i is further destroyed. Therefore, the ash is further easily peeled off from the inner circumferences 71is. Next, at the time tj5, if a predetermined set time tJ4 elapses, the cooler 62 is stopped. That is, the *movement promoting control during stop* is stopped. Note that, the set time tJ4 is set to the time which is required for the liquid which was added to the particulate filter 24 to sufficiently solidify.

[0099] Next, at the time tj6, the ignition switch 44 is turned on and the engine is started. At this time, the solidified liquid melts. Next, at the time tj7, if complete explosion occurs, *movement promoting control during start* is started. That is, the engine speed Ne is maintained at the movement promoting idling speed NeIT. As a result, the amount of exhaust gas which flows through the inside of the particulate filter 24 is increased. Therefore, the ash which is separated from the inner circumferences 71 of the exhaust gas inflow passages 71i is easily moved to the rear parts 71ir. Next, at the time tj8, when a predetermined set time tJ5 has elapsed, the normal idling control is started. That is, the *movement promoting control during start* is stopped.

[0100] FIG. 41 shows the routine for execution of the *movement promoting control during stop* which is shown in FIG. 39. This routine is for example executed at step 224 of FIG. 35. Referring to FIG. 41, at step 261, it is judged if the set time tJ1 has elapsed from when the ignition switch 44 was turned off. When the set time tJ1 has not elapsed, the routine returns to step 261. When the set time tJ1 has elapsed, next the routine proceeds to step 262, where the movement promoting addition pressure is calculated. At the next step 263, the movement promoting addition time is calculated. At the next step 264, the liquid is added from the liquid addition valve 55 with the movement promoting addition pressure for the movement promoting addition time. At the next step 265, it is judged if the set time tJ3 has elapsed from when addition of the liquid was stopped. When the set time tJ3 has not elapsed, the routine returns to step 265. When the set time tJ3 has elapsed, next the routine proceeds to step 266 where the cooler 62 is actuated. At the next step 267, it is judged if the set time tJ4 has elapsed from when the cooler 63 was actuated. When the set time tJ4 has not elapsed, the routine returns to step 266. When the set time tJ4 has elapsed, next the processing cycle is ended. That is, the *movement promoting control during stop* is ended, and the routine proceeds to step 225 of FIG. 35.

[0101] Note that, in the embodiment which is shown in FIG. 34, there may be a case where the atmospheric temperature becomes considerably low while the engine operation is stopped and the liquid which is added to the particulate filter 24 solidifies. In this case as well, the ash layer which is formed on the inner circumferences 71is of the exhaust gas inflow passages 71i is further destroyed, whereby the ash easily is moved to the rear parts 71ir.

Reference Signs List

[0102] 1 engine body

12 EGR passage

14e condensed water storage part

21 exhaust pipe

24 particulate filter

26 pressure difference sensor

71i exhaust gas inflow passage

71o exhaust gas outflow passage

72 partition wall

CLAIMS

Claim 1. An exhaust purification system of an internal combustion engine which is provided with a particulate filter for trapping particulate matter which is contained in exhaust gas inside an engine exhaust passage, which particulate filter is provided with exhaust gas inflow passages and exhaust gas outflow passages which are alternately arranged through porous partition walls, characterized in that the system comprises:

a movement promoting means for promoting movement of ash which has deposited on inner circumferences of the exhaust gas inflow passages to rear parts of the exhaust gas inflow passages;

a detecting means for detecting pressure loss of the particulate filter; and

a PM removing means for performing PM removal control for removing particulate matter from the particulate filter when the detected pressure loss is greater than a predetermined upper limit value.

Claim 2. The exhaust purification system of an internal combustion engine as set forth in claim 1, characterized in that the movement promoting means judges if the amount of ash which has deposited on the inner circumferences of the exhaust gas inflow passages is greater than a predetermined upper limit amount and performs movement promoting control when it is judged that the amount of ash is greater than the predetermined upper limit amount.

Claim 3. The exhaust purification system of an internal combustion engine as set forth in claim 1 or 2, characterized in that the movement promoting means supplies a liquid to the particulate filter, to perform the movement promoting control.

Claim 4. The exhaust purification system of an internal combustion engine as set forth in claim 3, characterized in that the liquid is comprised of at least one of water, an aqueous solution, and a liquid fuel.

Claim 5. The exhaust purification system of an internal combustion engine as set forth in claim 3 or 4, characterized in that at least one of engine intake passage, engine exhaust passage upstream of the particulate filter, and exhaust gas recirculation passage which connects the engine intake passage and engine exhaust passage with each other is formed with a condensed water storage part which stores condensed water which is generated at the internal combustion engine, and the movement promoting means supplies condensed water which was stored in the condensed water storage part to the particulate filter, to perform the movement promoting control.

Claim 6. The exhaust purification system of an internal combustion engine as set forth in any one of claims 3 to 5, characterized in that the system further comprises: an NOx reducing catalyst which is arranged inside the particulate filter or in the engine exhaust passage downstream of the particulate filter; a reducing agent addition valve which secondarily adds a liquid reducing agent into the engine exhaust passage upstream of the particulate filter; and a NOx reducing means for adding liquid reducing agent from the reducing agent addition valve with a NOx reduction addition pressure and NOx reduction addition time for reducing the NOx, and that the movement promoting means adds liquid reducing agent from the reducing agent addition valve with an addition pressure which is lower than the NOx reduction addition pressure or with an addition time which is longer than the NOx reduction addition time, to perform the movement promoting control.

Claim 7. The exhaust purification system of an internal combustion engine as set forth in any one of claims 1 to 6, characterized in that the movement promoting means makes the pressure inside of the particulate filter pulsate, to perform the movement promoting control.

Claim 8. The exhaust purification system of an internal combustion engine as set forth in any one of claims 1 to 7, characterized in that the movement promoting means makes the particulate filter vibrate, to perform the movement promoting control.

Claim 9. The exhaust purification system of an internal combustion engine as set forth in any one of claims 1 to 8, characterized in that the movement promoting means makes the temperature of the particulate filter rise to a temperature higher than that at the time of PM removal control, to perform the movement promoting control.

Claim 10. The exhaust purification system of an internal combustion engine as set forth in any one of claims 1 to 9, characterized in that the movement promoting means feeds a liquid to the particulate filter and makes the liquid solidify, to perform the movement promoting control.

FIG. 1

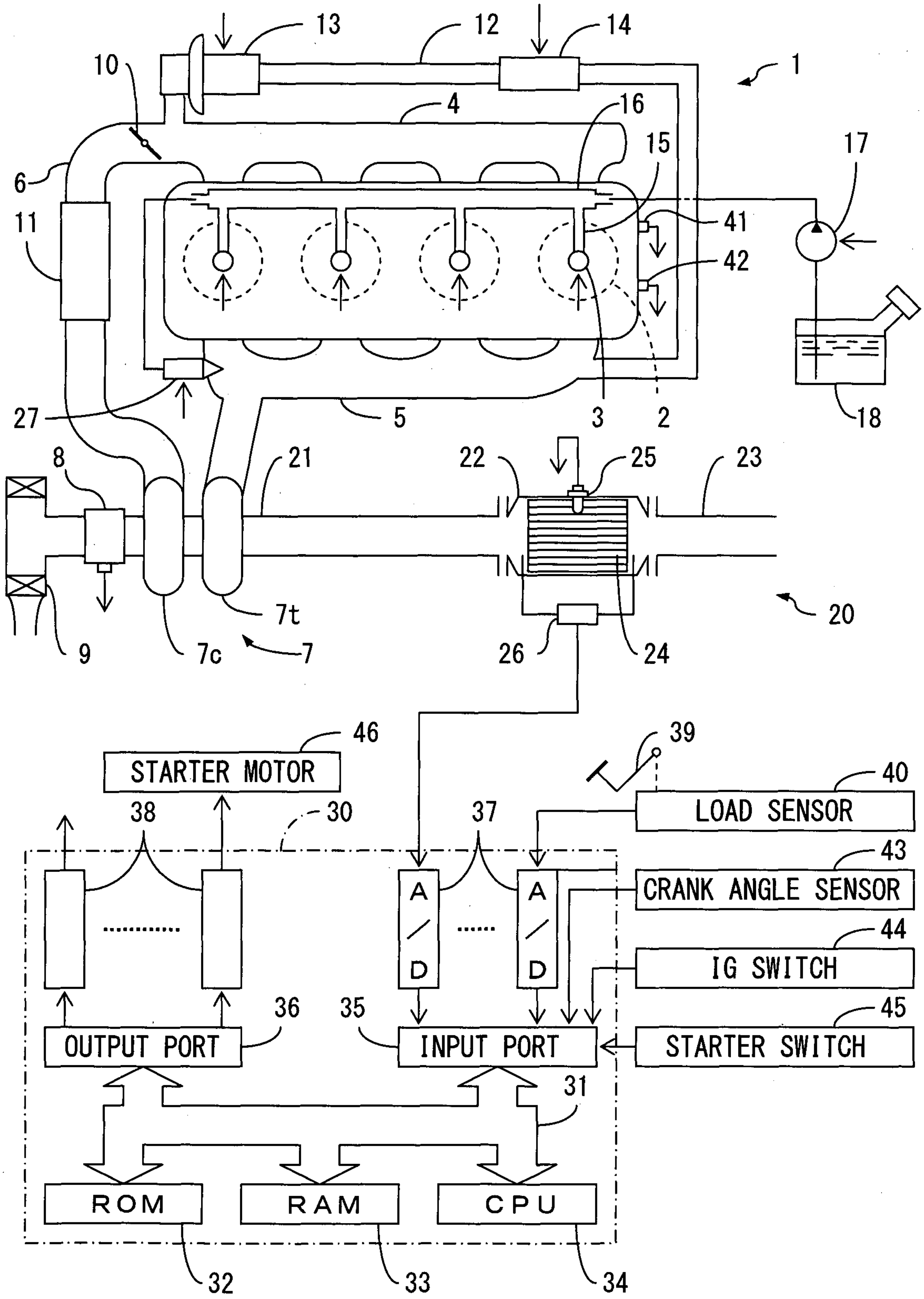

13
12
14
10
1
4
16
15
17
6
11
41
42
27
5
3
2
18
8
21
22
25
23
7t
20
9
7c
7
26
24
46
STARTER MOTOR
39
40
LOAD SENSOR
38
30
37
43
CRANK ANGLE SENSOR
A
D
44
IG SWITCH
36
35
45
OUTPUT PORT
INPUT PORT
STARTER SWITCH
31
ROM
RAM
CPU
32
33
34

FIG. 2

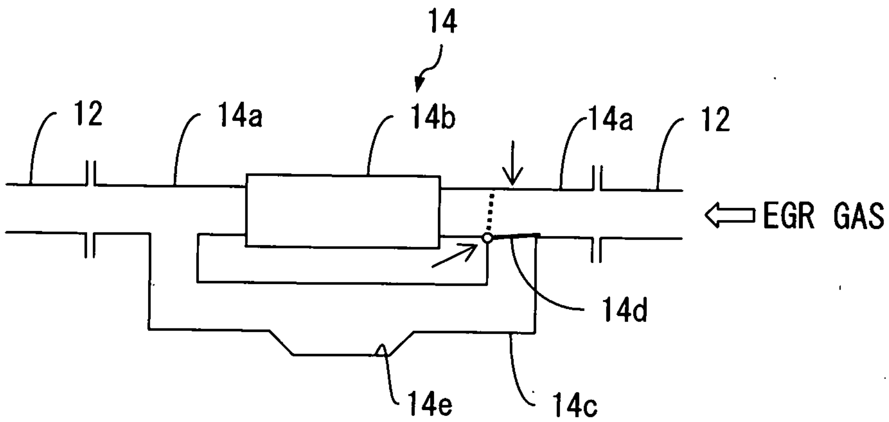


FIG. 3A

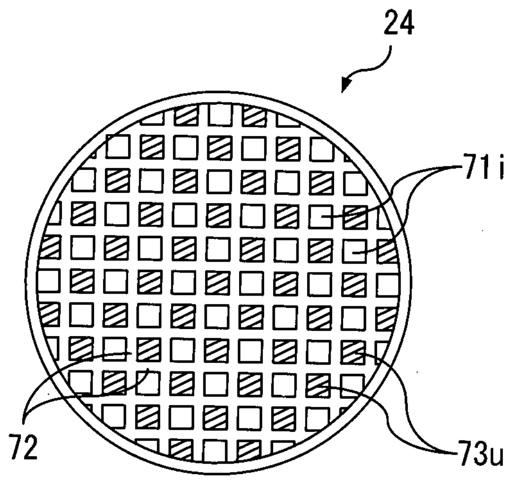


FIG. 3B

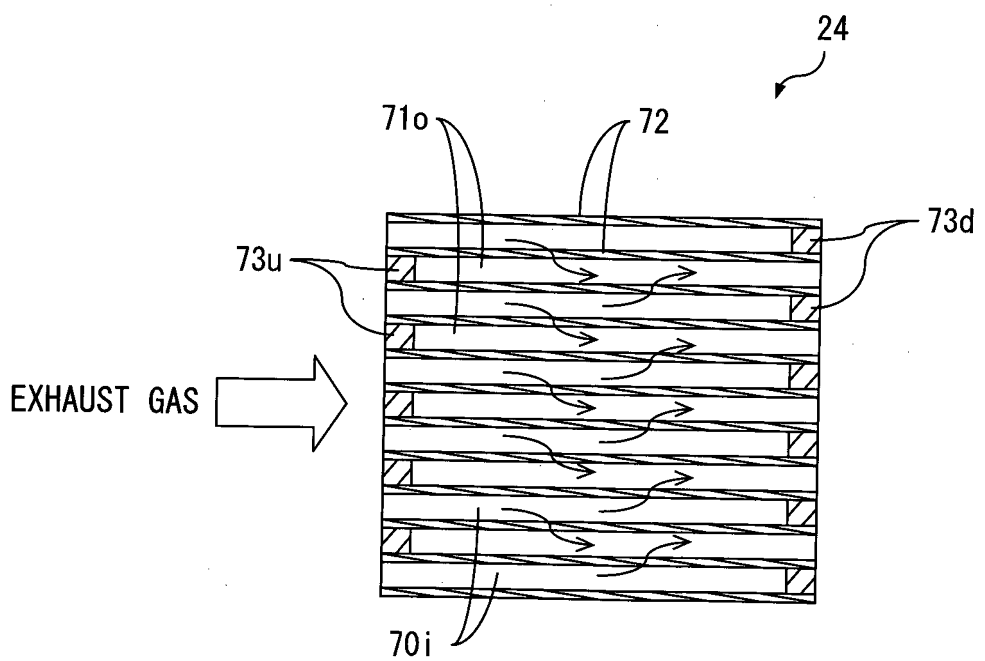


FIG. 4

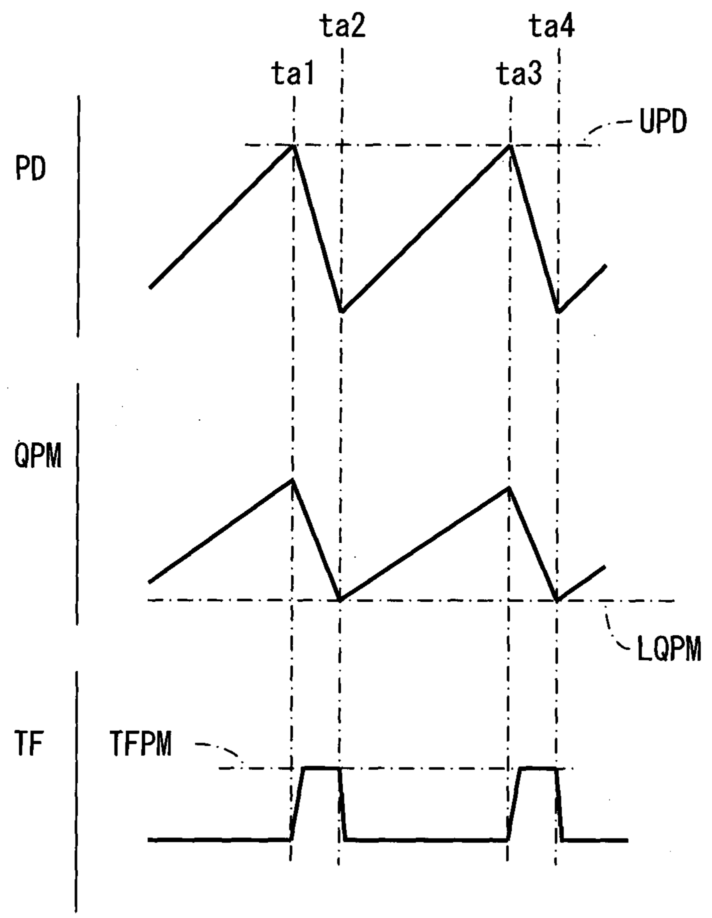


FIG. 5A

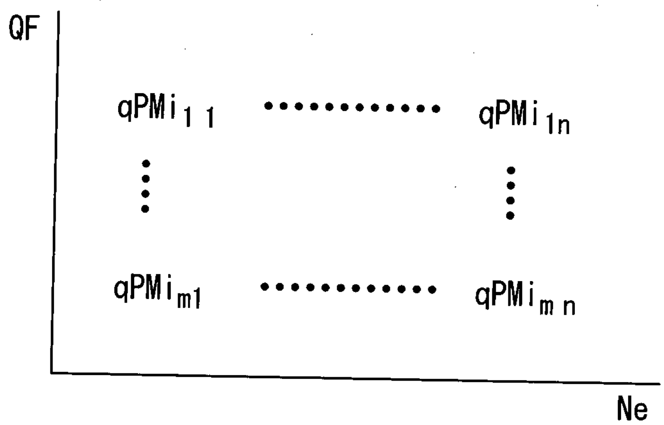

QF
qPMi11
qPMi1n
qPMim1
qPMimn
Ne

FIG. 5B

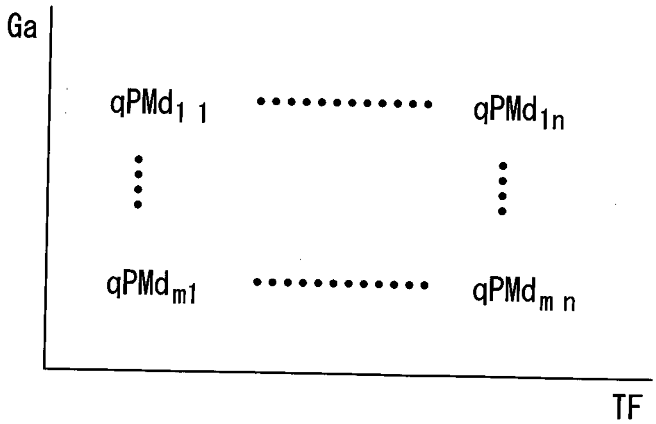

Ga
qPMd11
qPMd1n
qPMdm1
qPMdmn
TF

FIG. 6

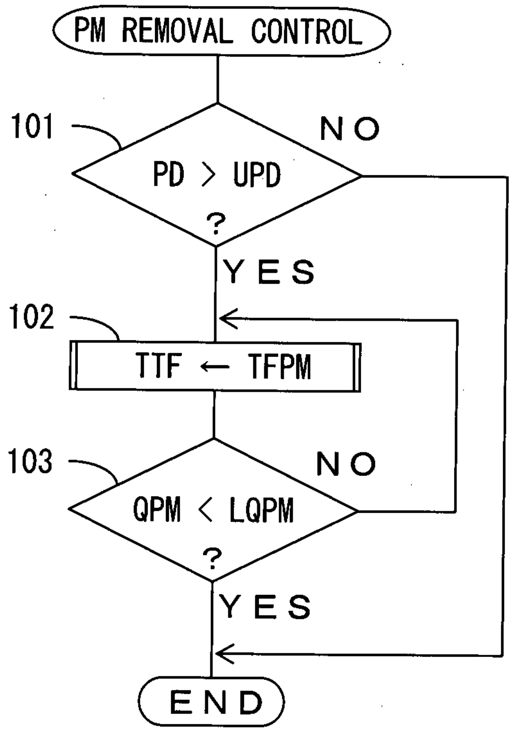

PM REMOVAL CONTROL
101
PD > UPD ?
NO
YES
102
TTF ← TFPM
103
QPM < LQPM ?
NO
YES
END

FIG. 7

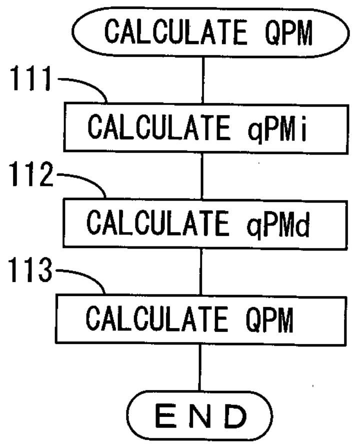

CALCULATE QPM
111
CALCULATE qPMi
112
CALCULATE qPMd
113
CALCULATE QPM
END

FIG. 8A

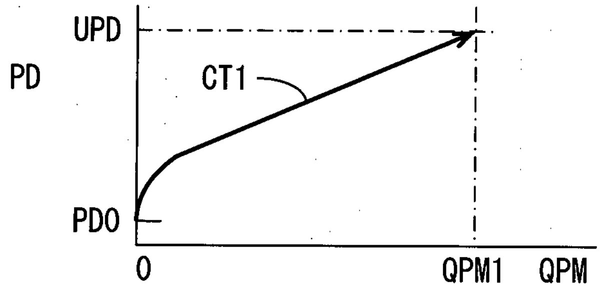


FIG. 8B

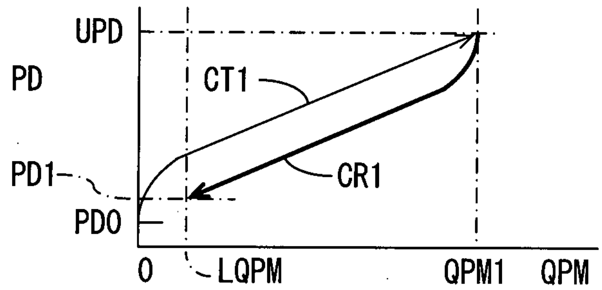


FIG. 8C

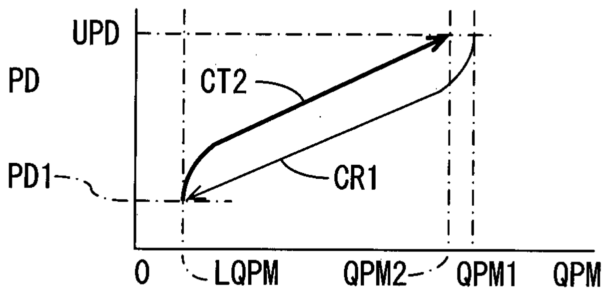


FIG. 8D

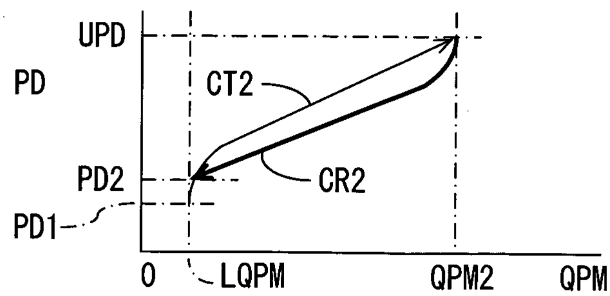


FIG. 9A

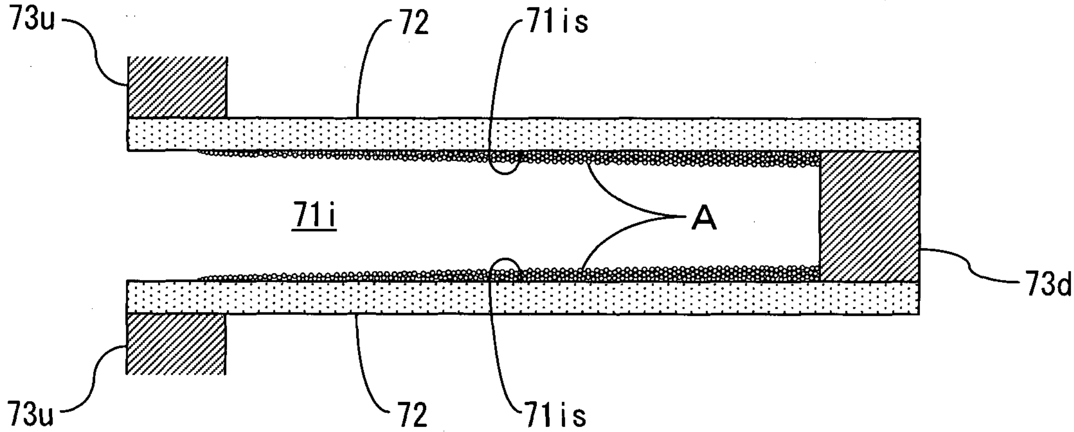


FIG. 9B

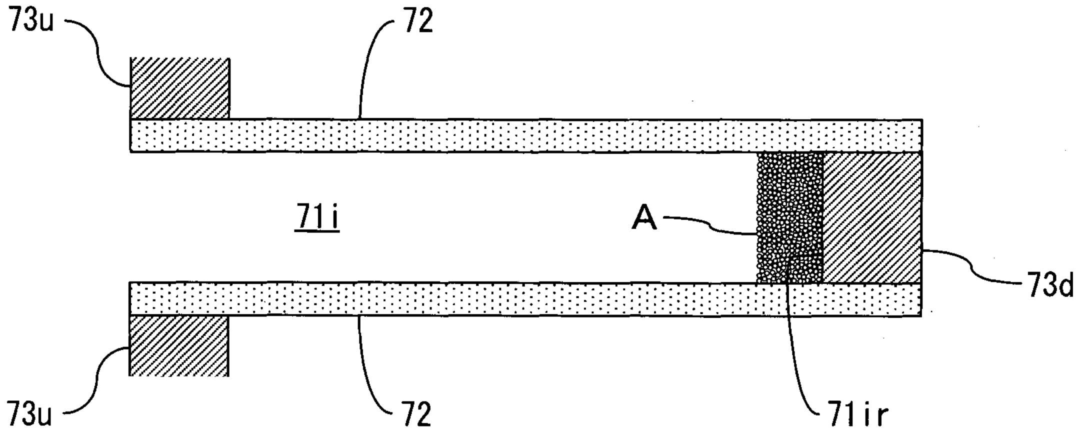


FIG. 10

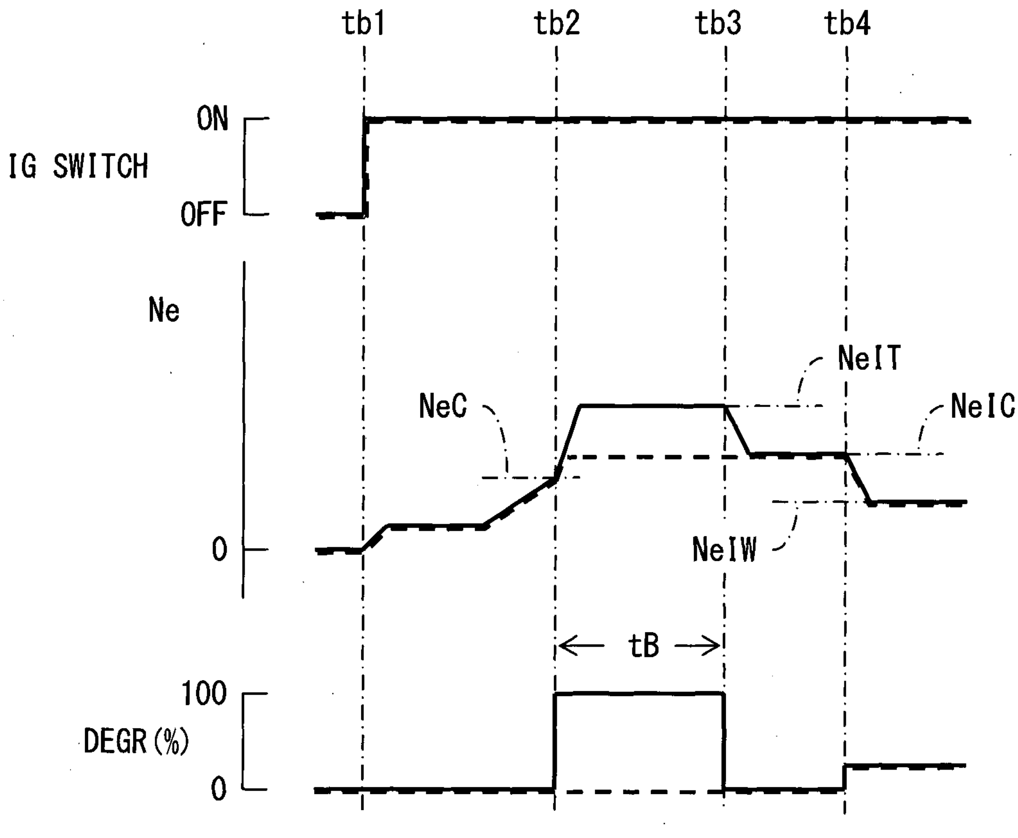

tb1
tb2
tb3
tb4
ON
IG SWITCH
OFF
Ne
NeIT
NeC
NeIC
0
NeIW
tB
100
DEGR(%)
0

FIG. 11A

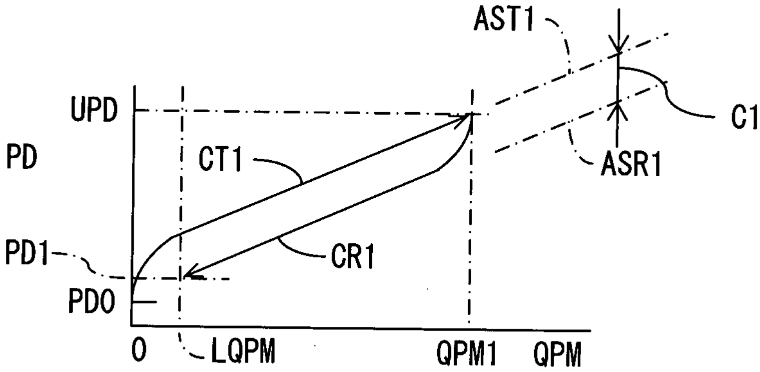


FIG. 11B

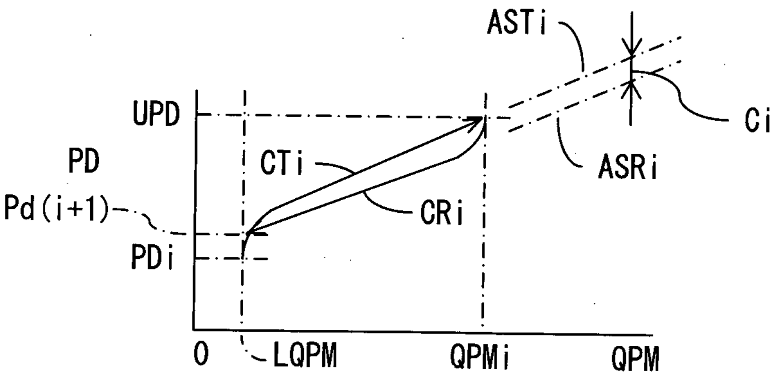


FIG. 12

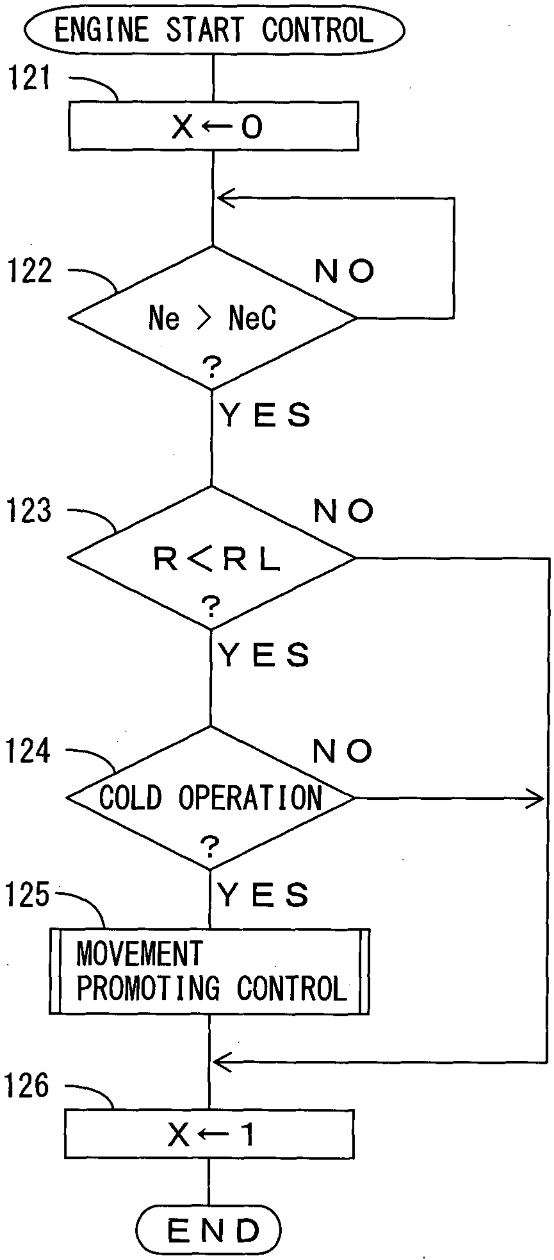

ENGINE START CONTROL
121
X←0
122
Ne > NeC ?
NO
YES
123
R<RL ?
NO
YES
124
COLD OPERATION ?
NO
YES
125
MOVEMENT PROMOTING CONTROL
126
X←1
END

FIG. 13

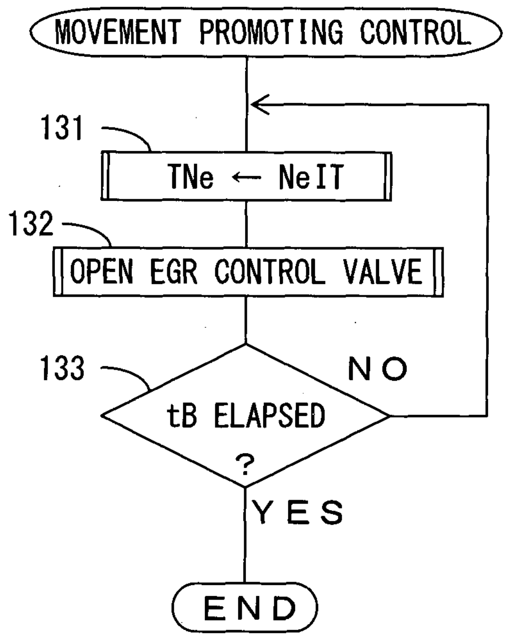

MOVEMENT PROMOTING CONTROL
131
TNe ← NeIT
132
OPEN EGR CONTROL VALVE
133
tB ELAPSED ?
NO
YES
END

FIG. 14

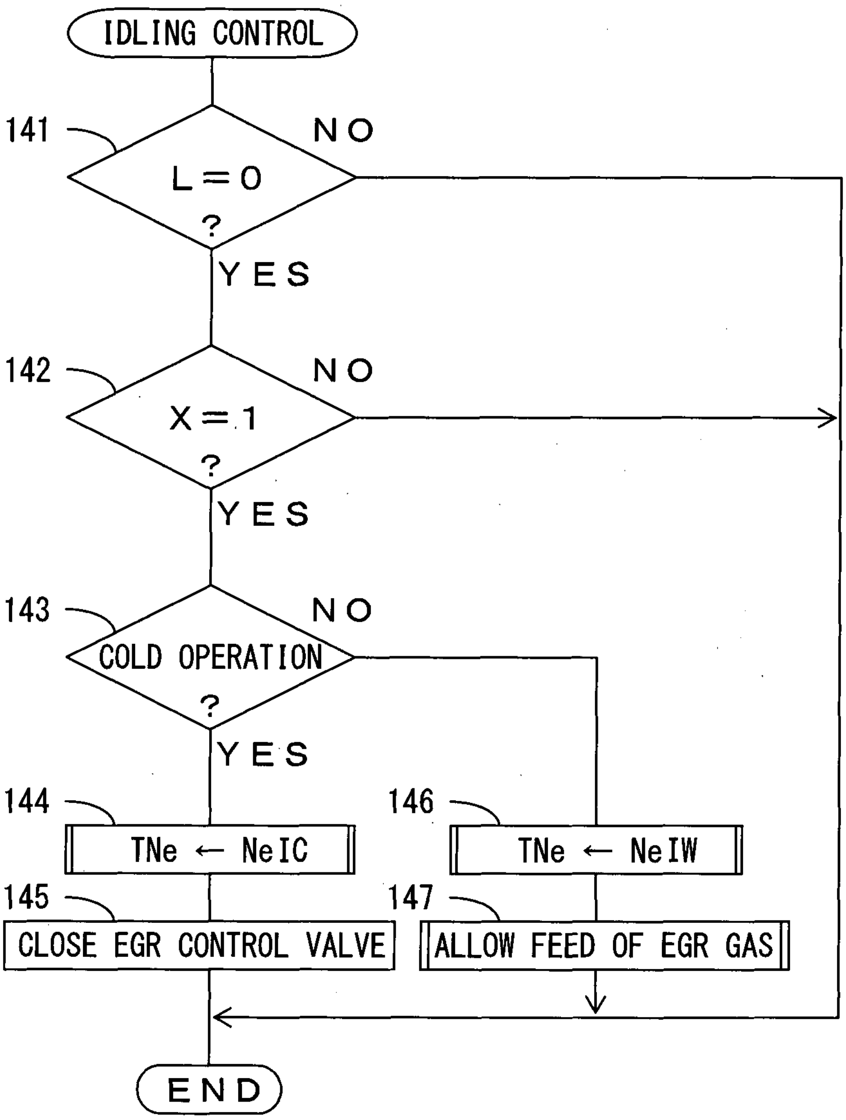

IDLING CONTROL
141
L=0
?
NO
YES
142
X=1
?
NO
YES
143
COLD OPERATION
?
NO
YES
144
TNe ← NeIC
146
TNe ← NeIW
145
CLOSE EGR CONTROL VALVE
147
ALLOW FEED OF EGR GAS
END

FIG. 15

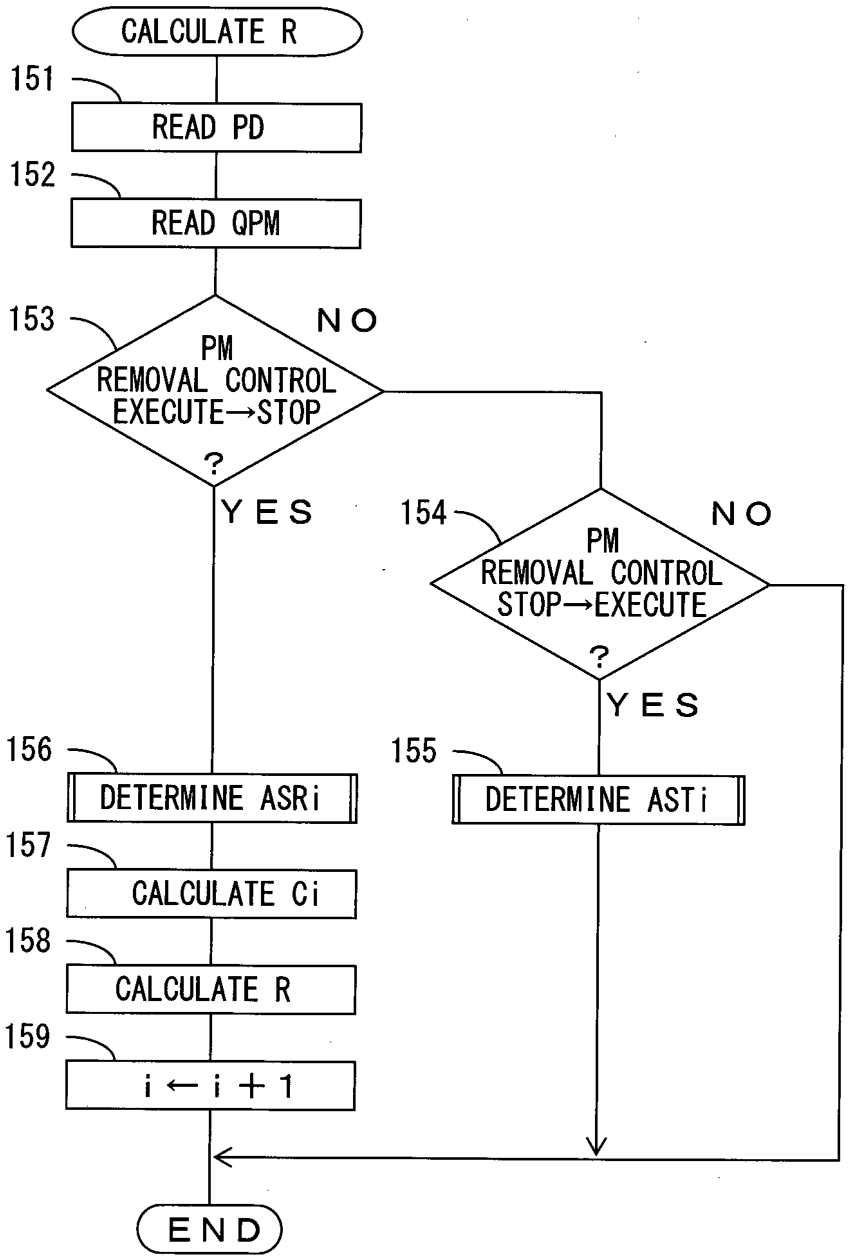

CALCULATE R
151
READ PD
152
READ QPM
153
PM REMOVAL CONTROL EXECUTE→STOP ?
NO
YES
154
PM REMOVAL CONTROL STOP→EXECUTE ?
NO
YES
155
DETERMINE ASTi
156
DETERMINE ASRi
157
CALCULATE Ci
158
CALCULATE R
159
i←i+1
END

FIG. 16

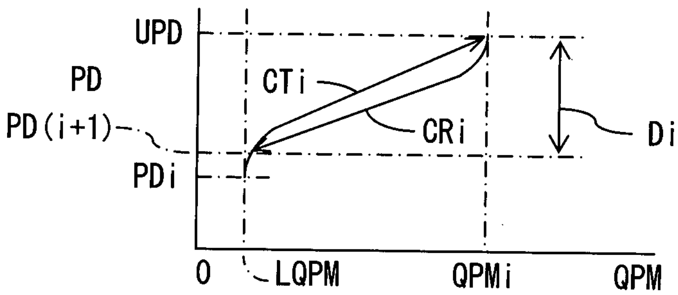


FIG. 17A

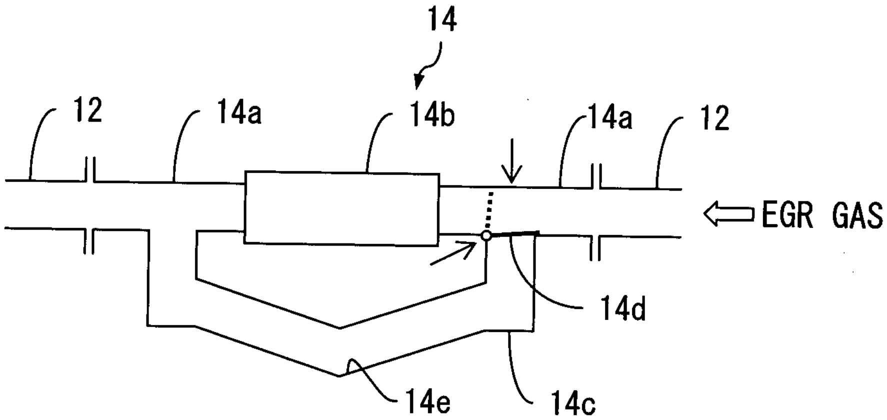


FIG. 17B

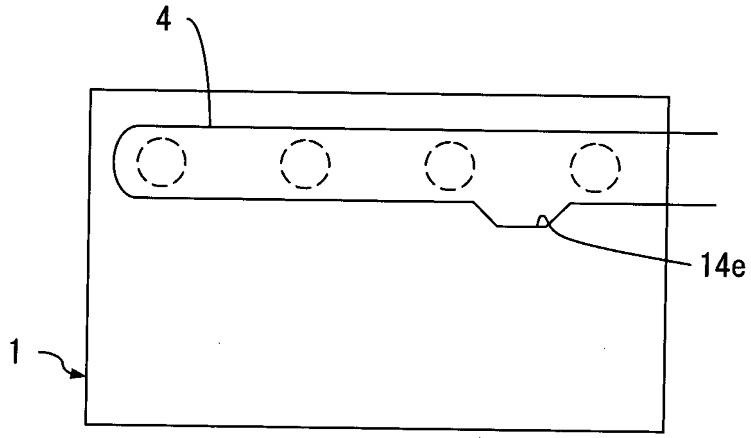


FIG. 17C

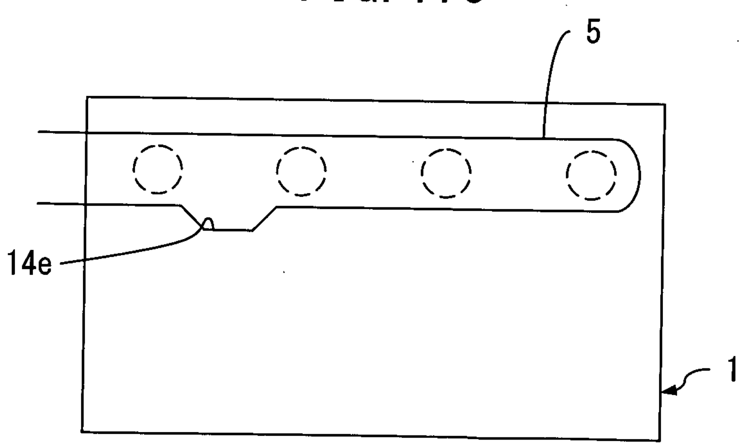
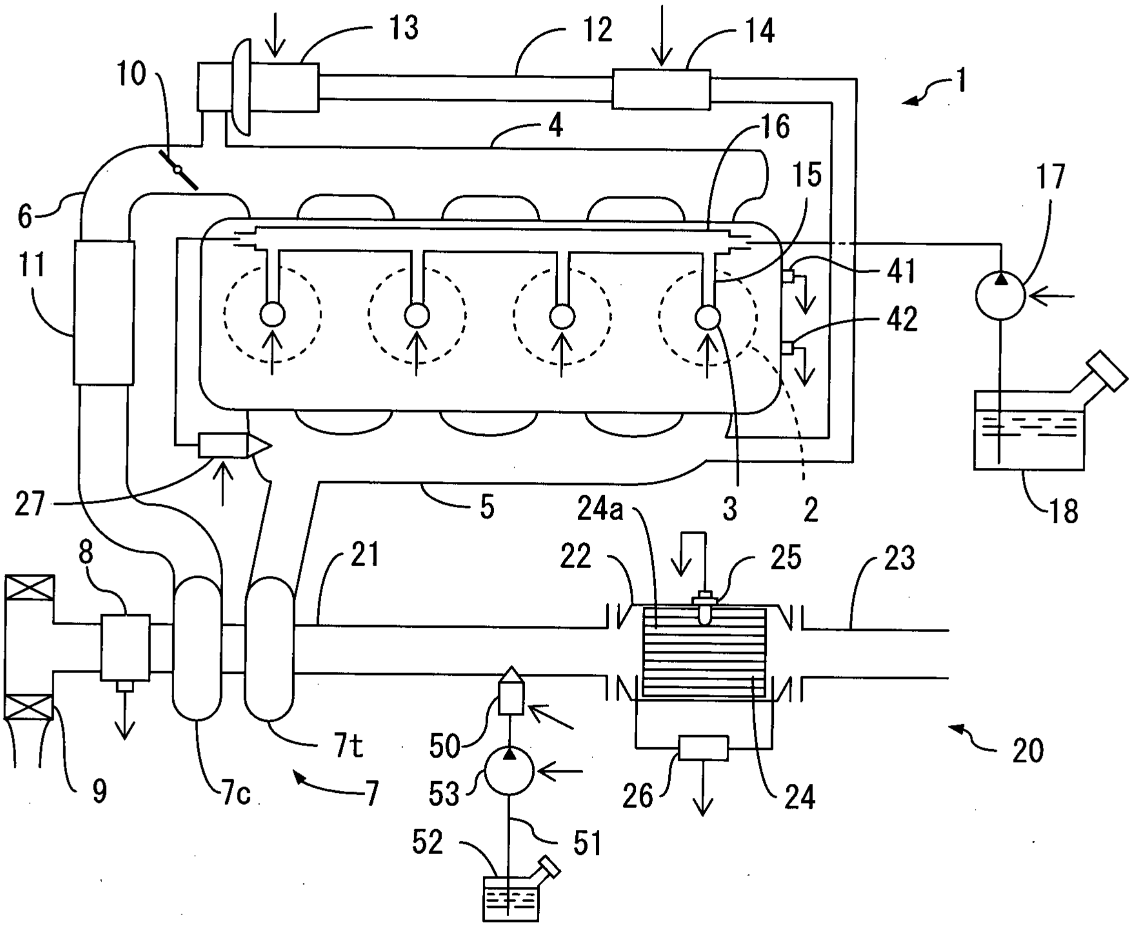


FIG. 18



13
12
14
1
10
4
16
15
17
6
11
41
42
18
27
5
24a
3
2
8
21
22
25
23
50
7t
20
53
9
7c
7
26
24
52
51

FIG. 19

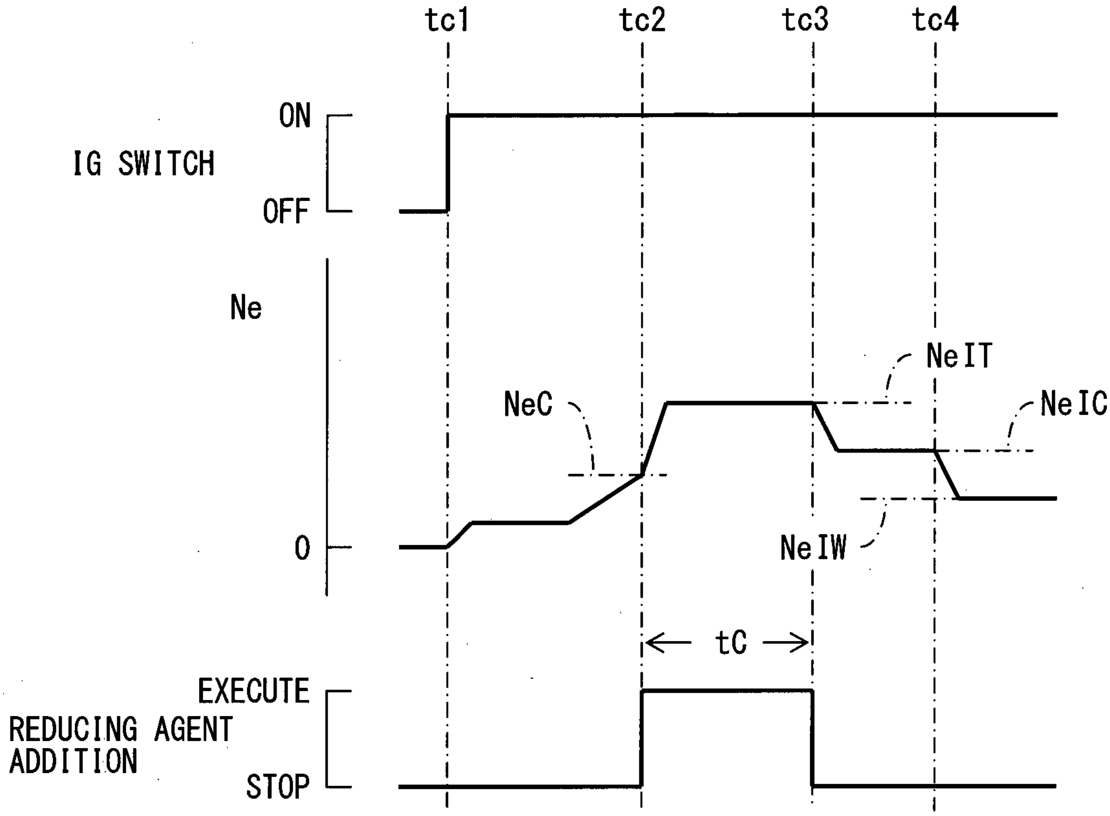

tc1
tc2
tc3
tc4
ON
IG SWITCH
OFF
Ne
NeIT
NeC
NeIC
0
NeIW
tC
EXECUTE
REDUCING AGENT ADDITION
STOP

FIG. 20

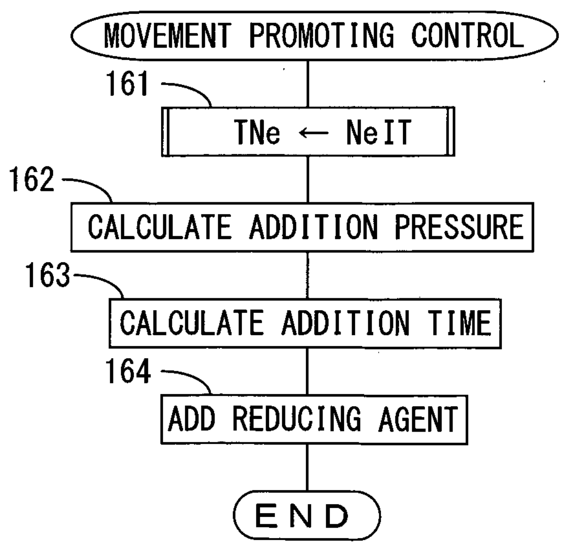

MOVEMENT PROMOTING CONTROL
161
TNe ← NeIT
162
CALCULATE ADDITION PRESSURE
163
CALCULATE ADDITION TIME
164
ADD REDUCING AGENT
END

FIG. 21

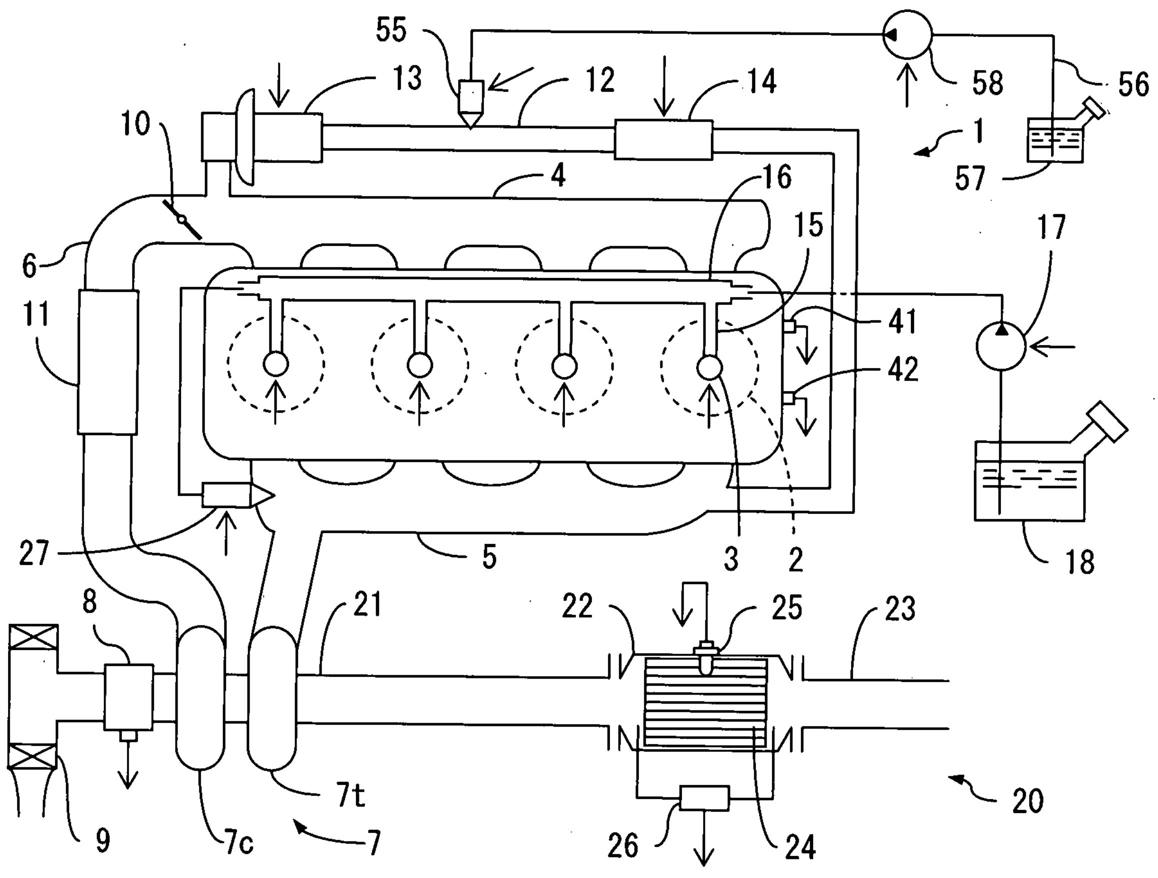

55
13
12
14
58
56
10
1
4
16
57
15
17
6
11
41
42
27
5
3
2
18
8
21
22
25
23
7t
20
9
7c
7
26
24

FIG. 22

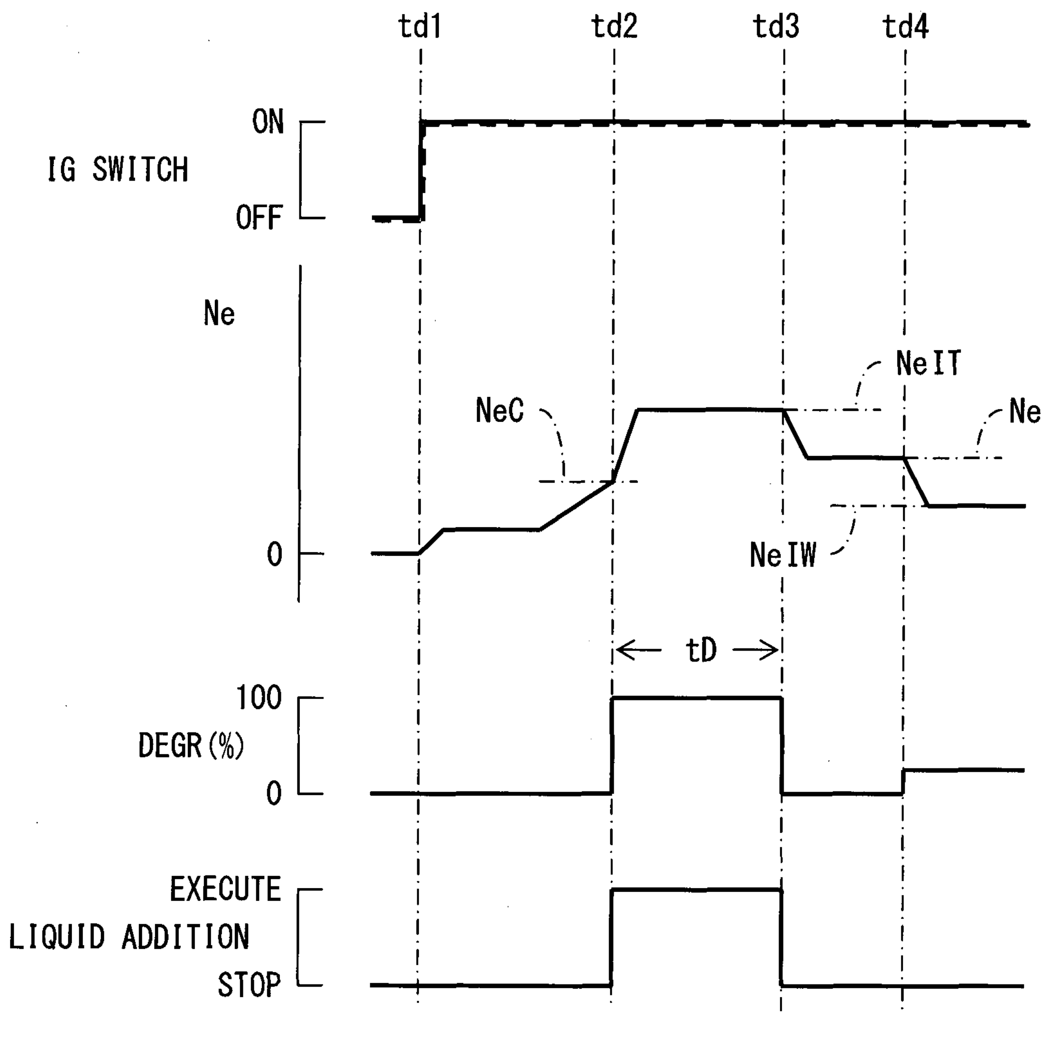

td1
td2
td3
td4
ON
IG SWITCH
OFF
Ne
NeIT
NeC
NeIC
0
NeIW
tD
100
DEGR (%)
0
EXECUTE
LIQUID ADDITION
STOP

FIG. 23

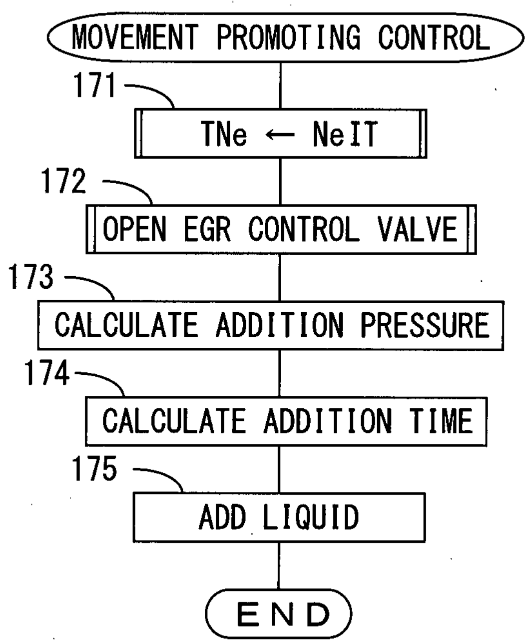

MOVEMENT PROMOTING CONTROL
171
TNe ← NeIT
172
OPEN EGR CONTROL VALVE
173
CALCULATE ADDITION PRESSURE
174
CALCULATE ADDITION TIME
175
ADD LIQUID
END

FIG. 24A

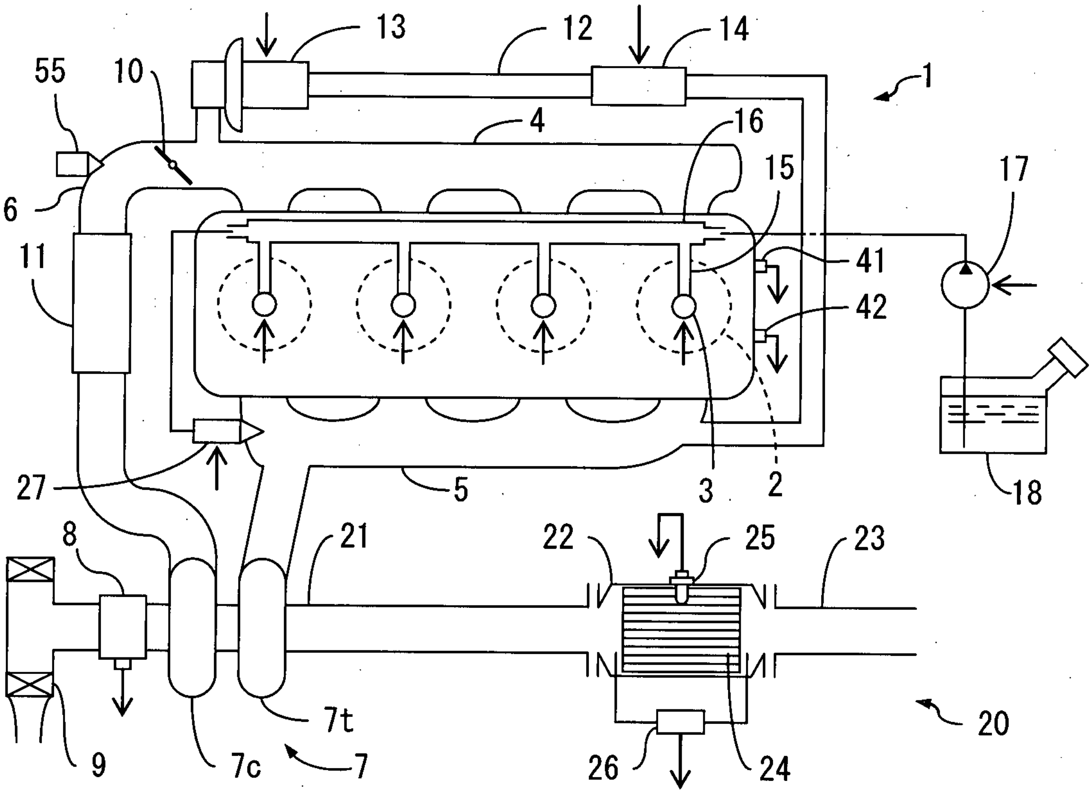


FIG. 24B

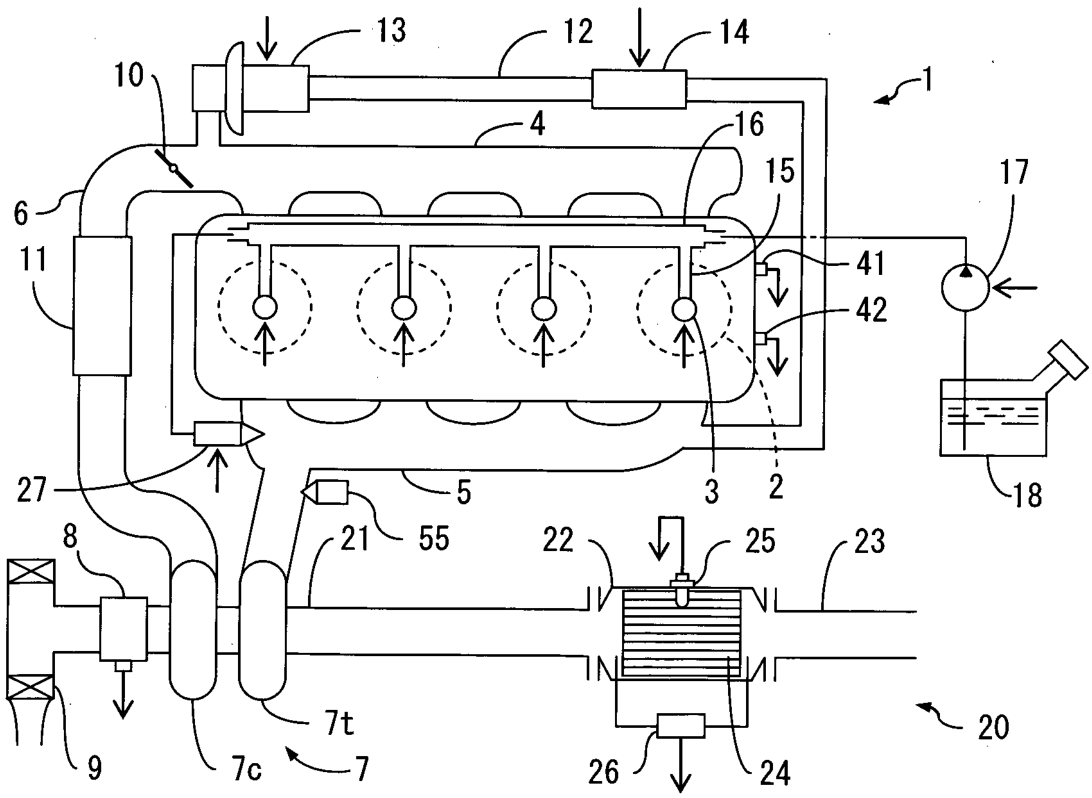


FIG. 24C

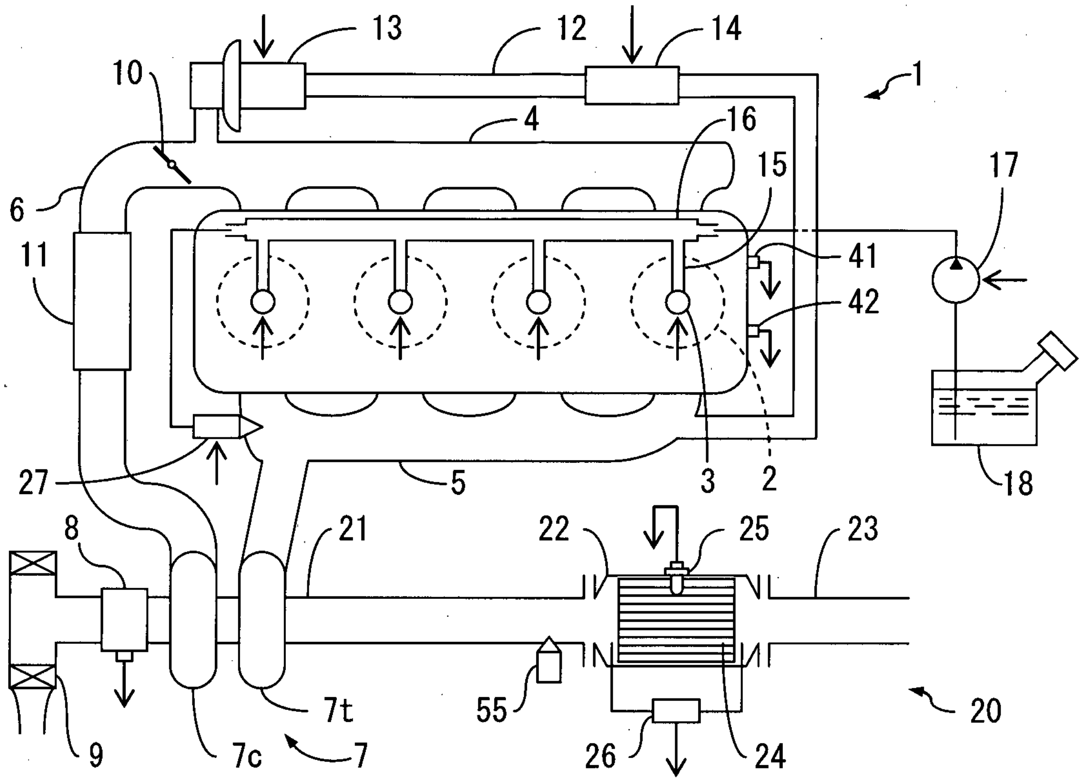


FIG. 25

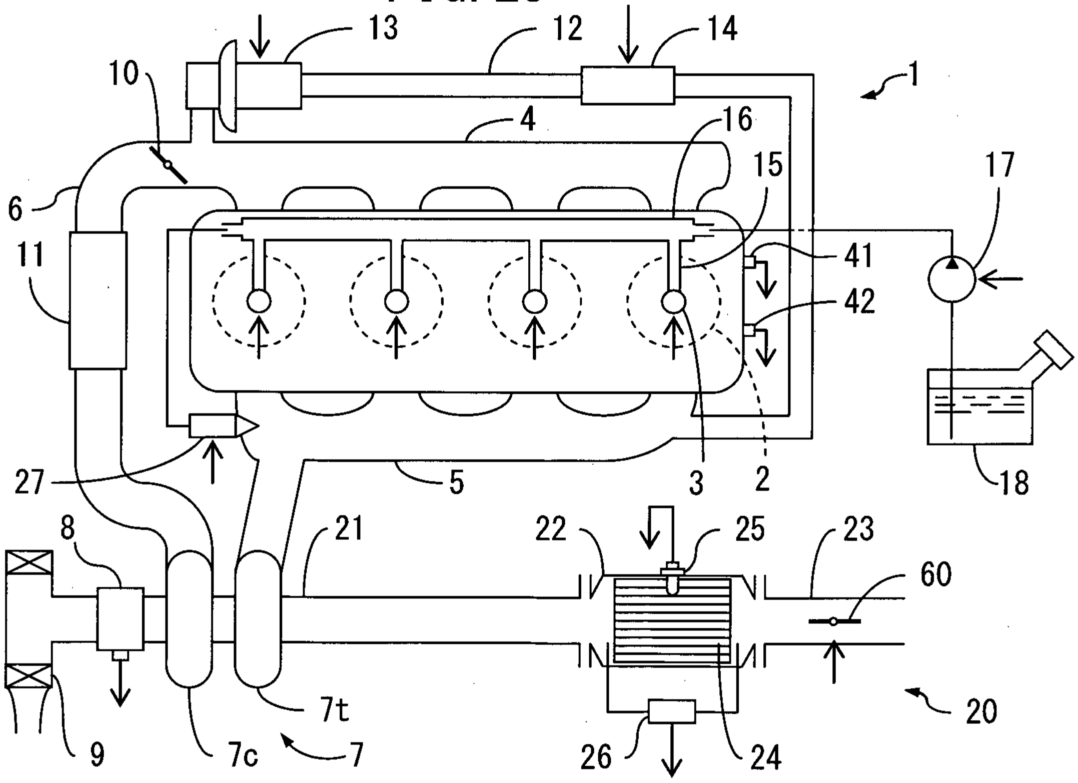


FIG. 26

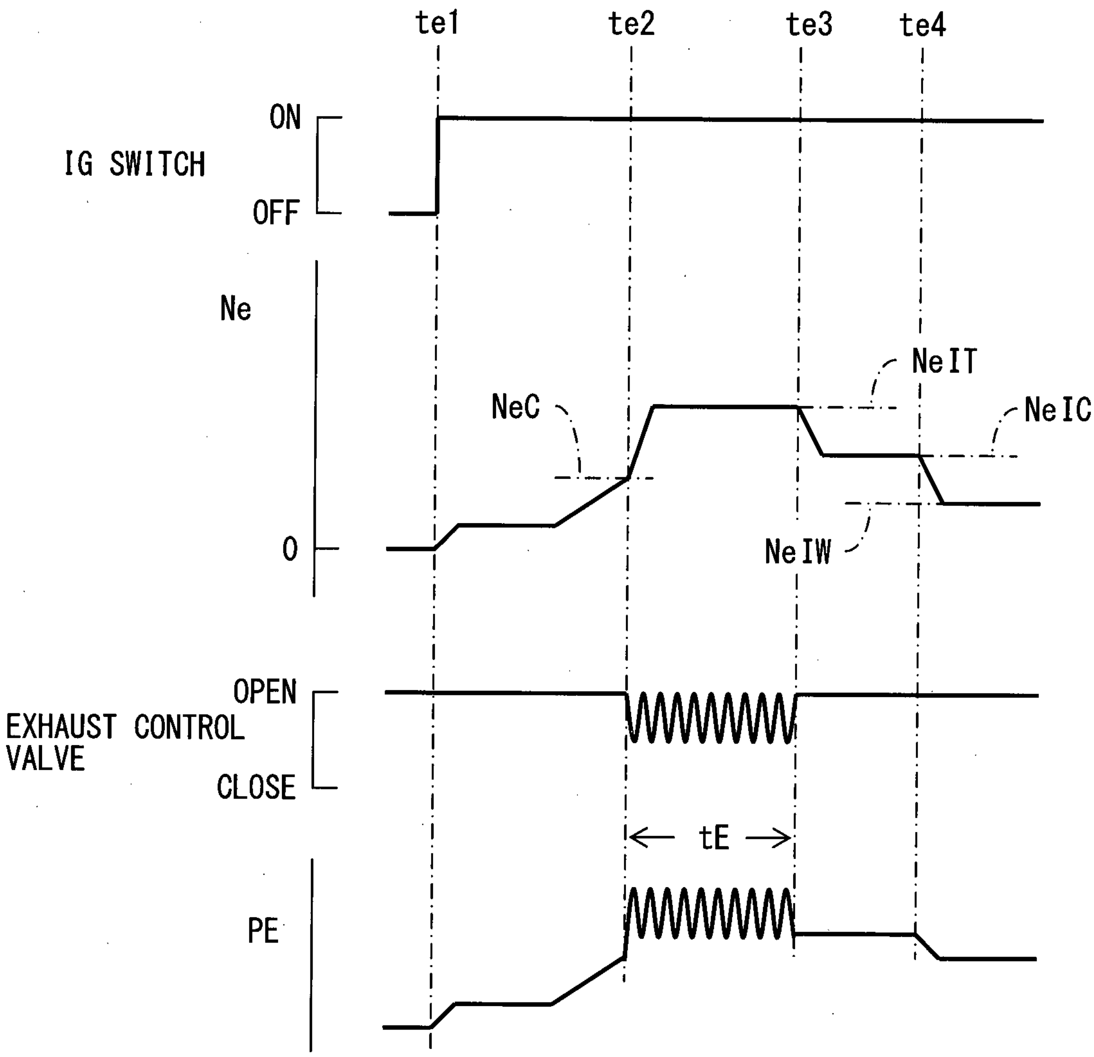

te1
te2
te3
te4
ON
IG SWITCH
OFF
Ne
NeC
NeIT
NeIC
NeIW
0
OPEN
EXHAUST CONTROL VALVE
CLOSE
tE
PE

FIG. 27

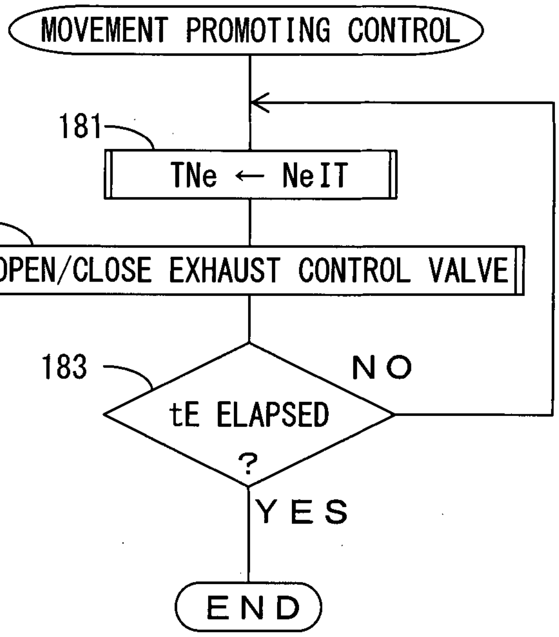

MOVEMENT PROMOTING CONTROL
181
TNe ← NeIT
182
OPEN/CLOSE EXHAUST CONTROL VALVE
183
tE ELAPSED ?
NO
YES
END

FIG. 28

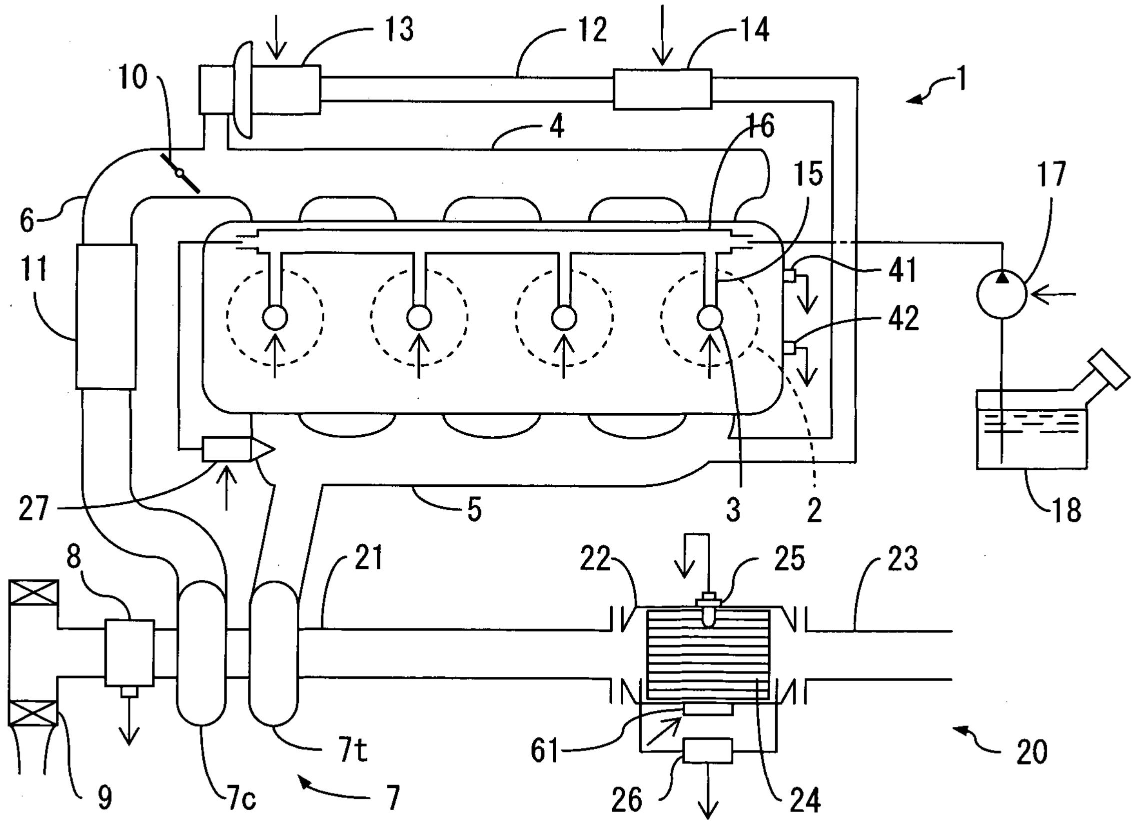

13
12
14
1
10
4
16
15
17
6
11
41
42
27
5
3
2
18
8
21
22
25
23
7t
61
20
9
7c
7
26
24

FIG. 29

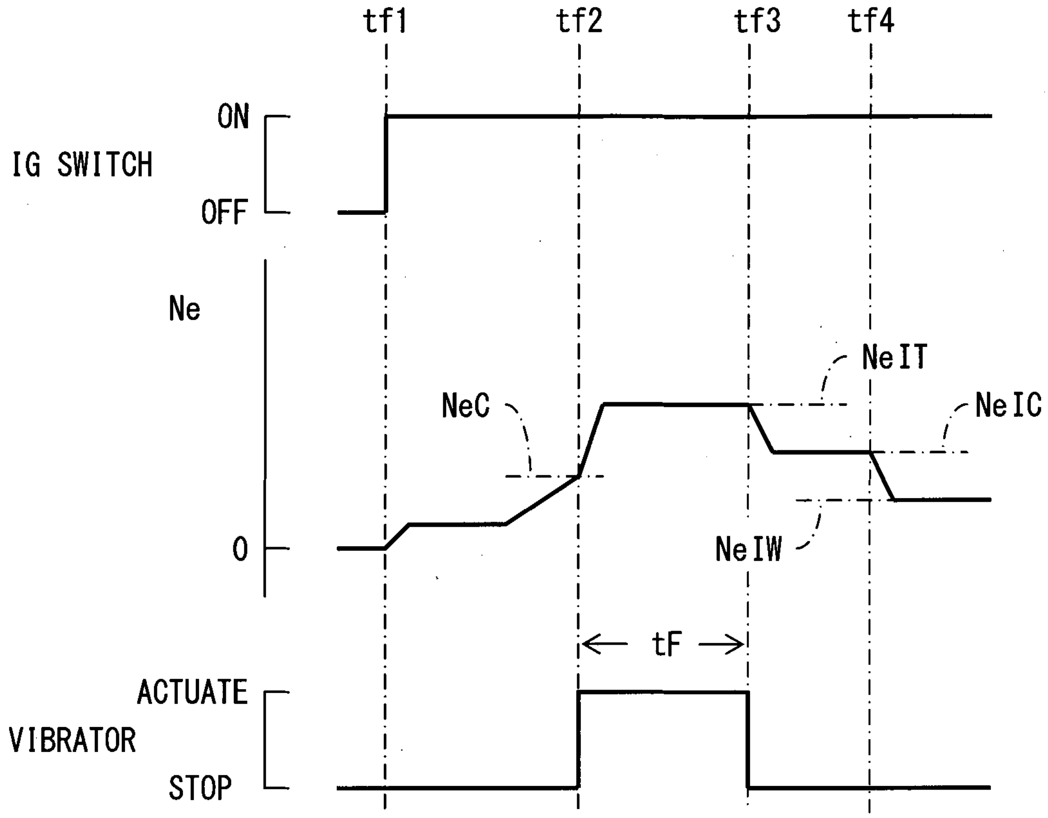

tf1
tf2
tf3
tf4
ON
IG SWITCH
OFF
Ne
NeIT
NeC
NeIC
0
NeIW
tF
ACTUATE
VIBRATOR
STOP

FIG. 30

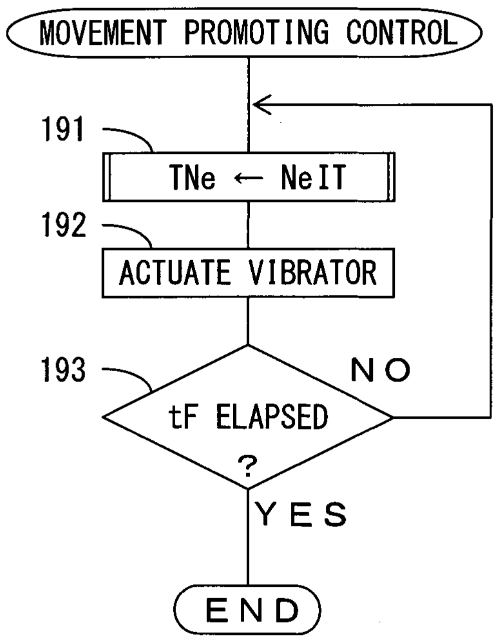

MOVEMENT PROMOTING CONTROL
191
TNe ← NeIT
192
ACTUATE VIBRATOR
193
NO
tF ELAPSED ?
YES
END

FIG. 31

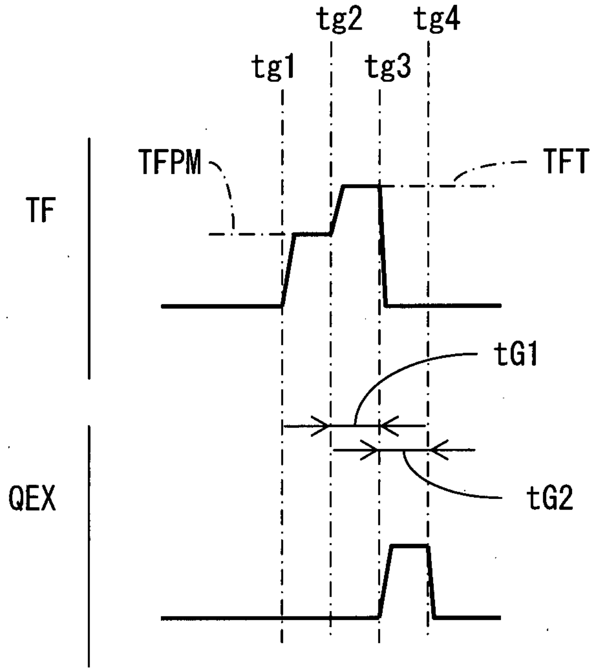

tg2
tg4
tg1
tg3
TFPM
TFT
TF
tG1
QEX
tG2

FIG. 32

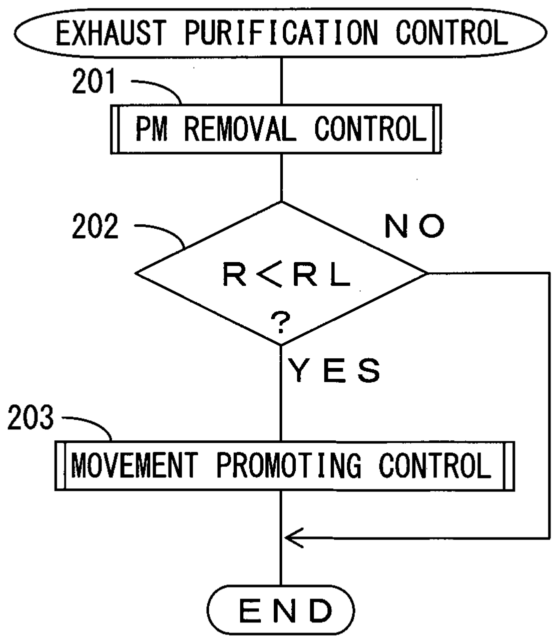

EXHAUST PURIFICATION CONTROL
201
PM REMOVAL CONTROL
202
NO
R<RL ?
YES
203
MOVEMENT PROMOTING CONTROL
END

FIG. 33

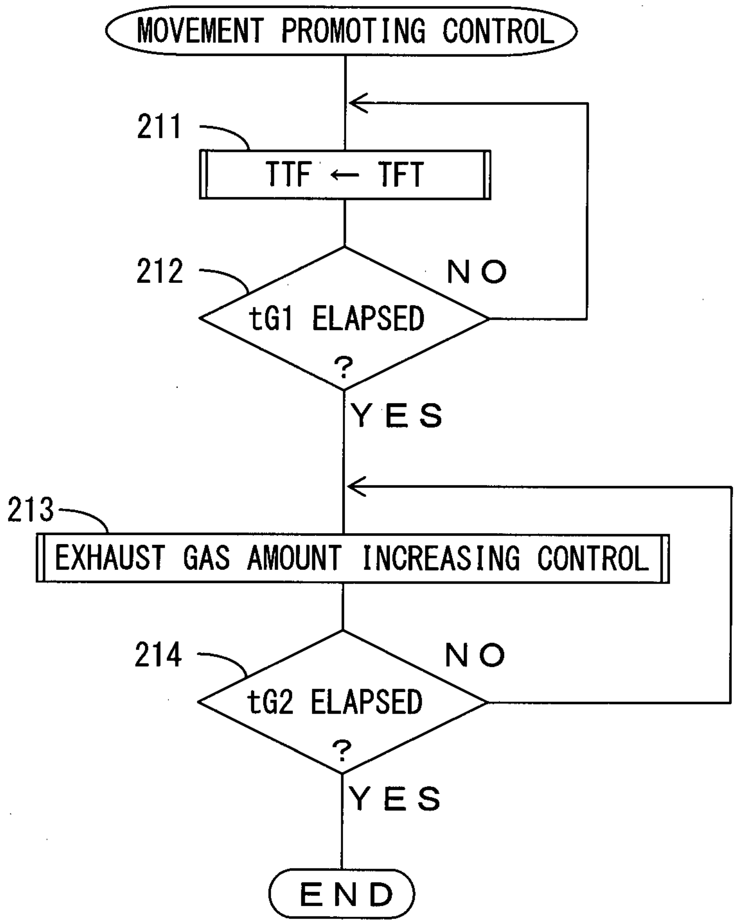

MOVEMENT PROMOTING CONTROL
211
TTF ← TFT
212
tG1 ELAPSED ?
NO
YES
213
EXHAUST GAS AMOUNT INCREASING CONTROL
214
tG2 ELAPSED ?
NO
YES
END

FIG. 34

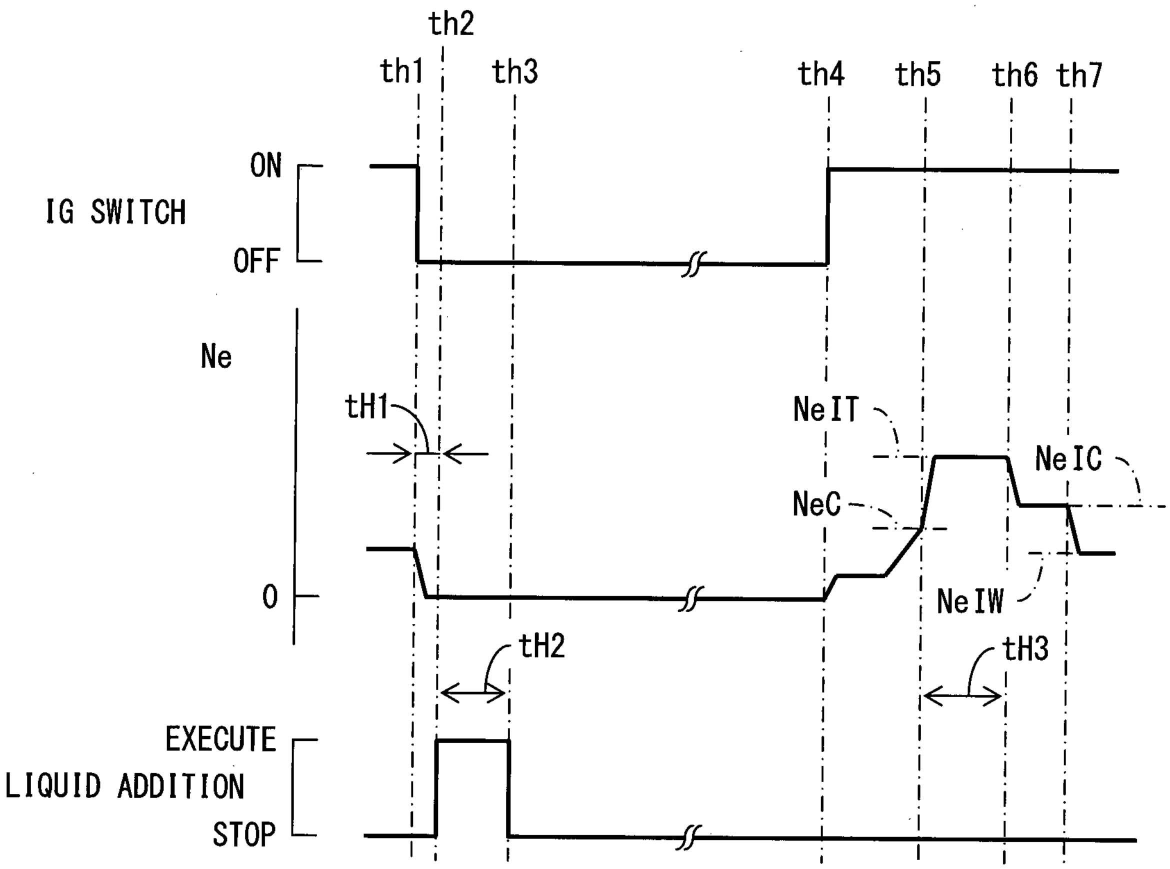

th2
th1
th3
th4
th5
th6
th7
ON
IG SWITCH
OFF
Ne
tH1
NeIT
NeIC
NeC
0
NeIW
tH2
tH3
EXECUTE
LIQUID ADDITION
STOP

FIG. 35

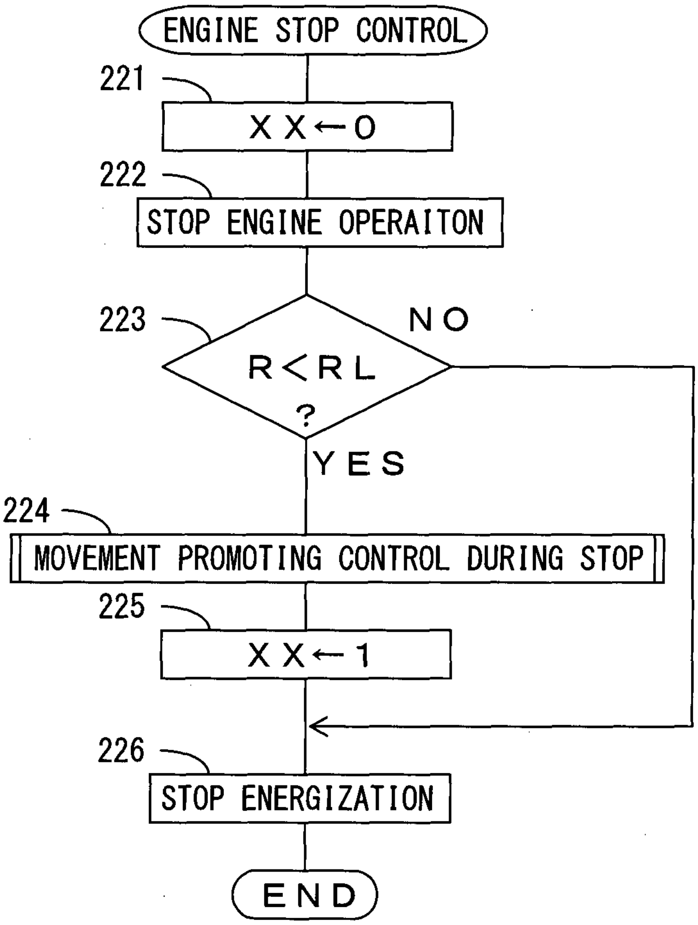

ENGINE STOP CONTROL
221
XX←0
222
STOP ENGINE OPERAITON
223
R<RL?
NO
YES
224
MOVEMENT PROMOTING CONTROL DURING STOP
225
XX←1
226
STOP ENERGIZATION
END

FIG. 36

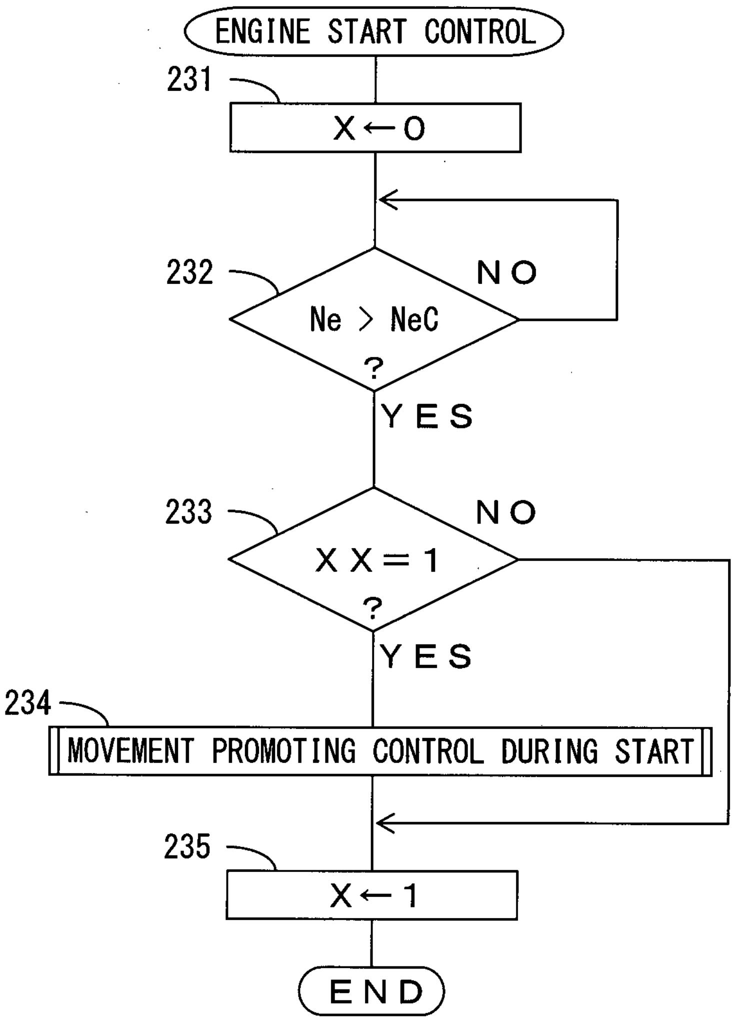

ENGINE START CONTROL
231
X←0
232
Ne > NeC ?
NO
YES
233
XX=1 ?
NO
YES
234
MOVEMENT PROMOTING CONTROL DURING START
235
X←1
END

FIG. 37

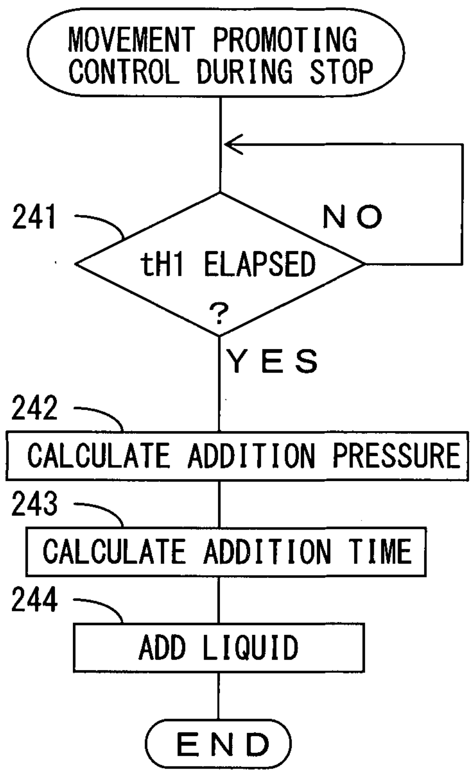

MOVEMENT PROMOTING CONTROL DURING STOP
241
tH1 ELAPSED ?
NO
YES
242
CALCULATE ADDITION PRESSURE
243
CALCULATE ADDITION TIME
244
ADD LIQUID
END

FIG. 38

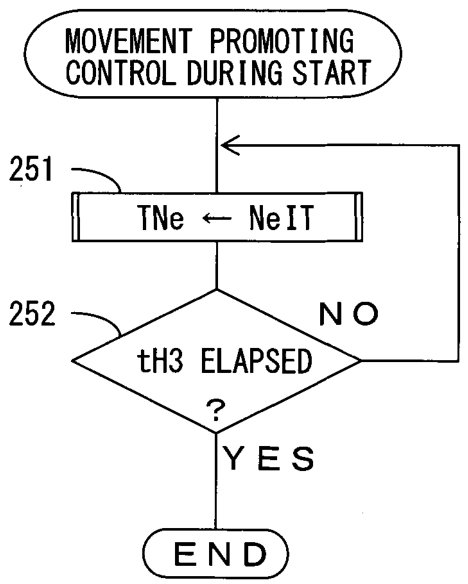

MOVEMENT PROMOTING CONTROL DURING START
251
TNe ← NeIT
252
tH3 ELAPSED ?
NO
YES
END

FIG. 39

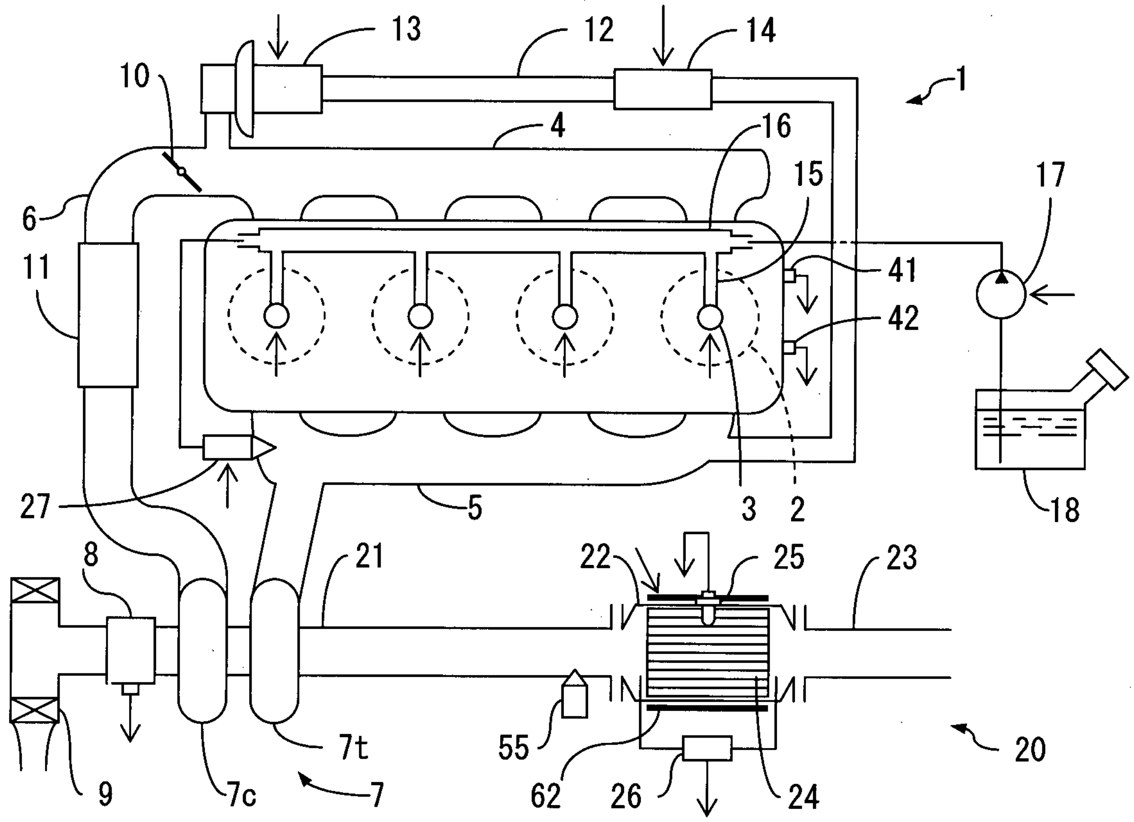

13
12
14
10
1
4
16
15
17
6
41
11
42
27
5
3
2
18
8
21
22
25
23
55
7t
20
9
7c
7
62
26
24

FIG. 40

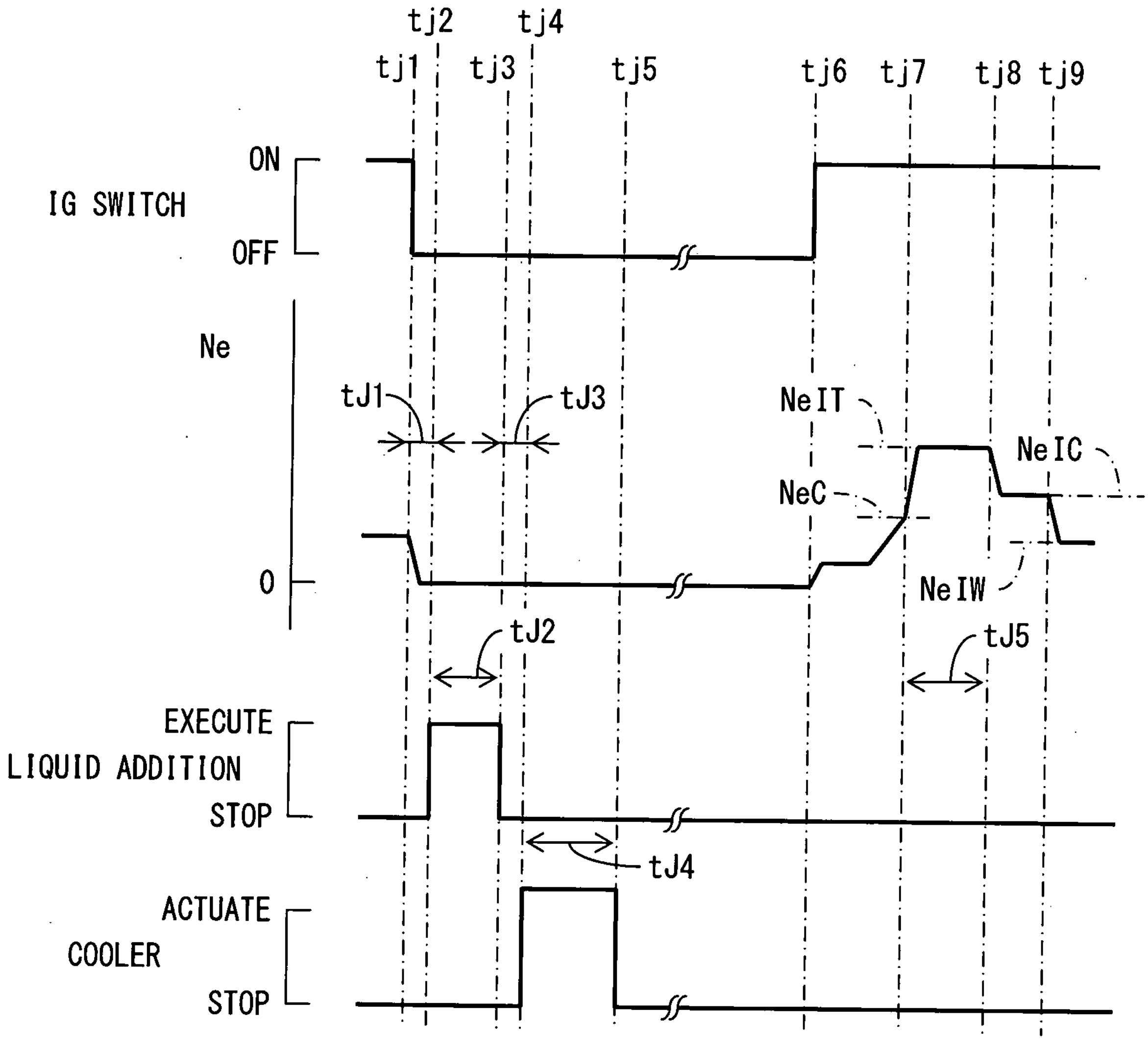
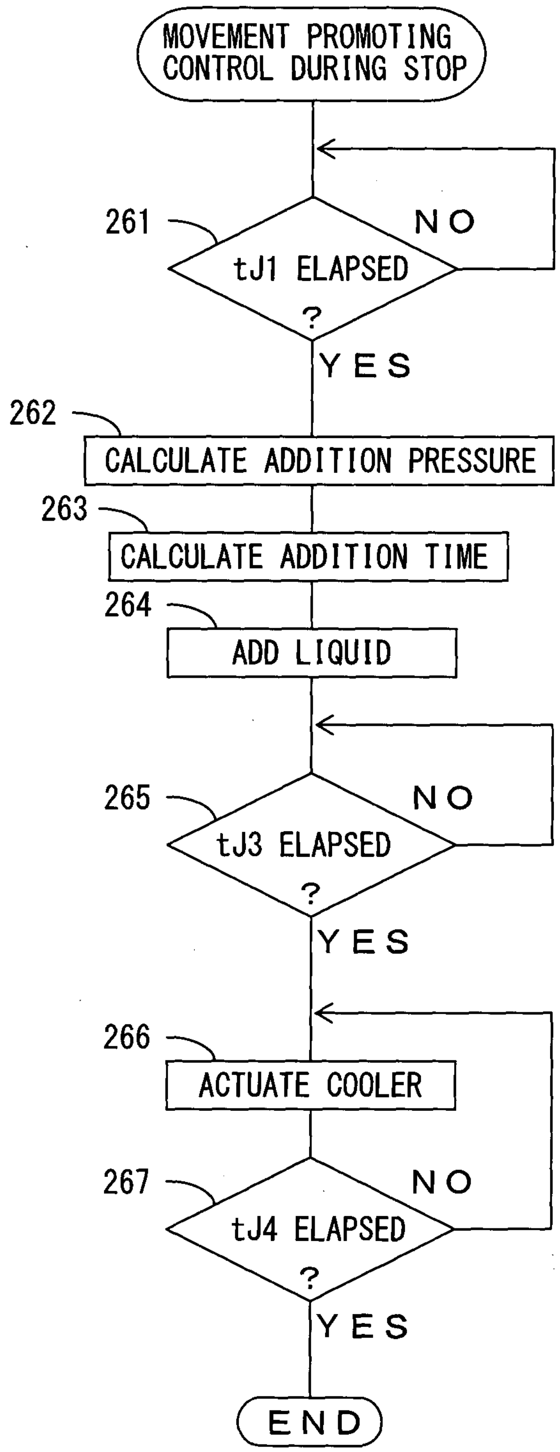

tj2
tj4
tj1
tj3
tj5
tj6
tj7
tj8
tj9
ON
IG SWITCH
OFF
Ne
tJ1
tJ3
NeIT
NeIC
NeC
0
NeIW
tJ2
tJ5
EXECUTE
LIQUID ADDITION
STOP
tJ4
ACTUATE
COOLER
STOP

FIG. 41


MOVEMENT PROMOTING CONTROL DURING STOP
261
tJ1 ELAPSED ?
NO
YES
262
CALCULATE ADDITION PRESSURE
263
CALCULATE ADDITION TIME
264
ADD LIQUID
265
tJ3 ELAPSED ?
NO
YES
266
ACTUATE COOLER
267
tJ4 ELAPSED ?
NO
YES
END

INTERNATIONAL SEARCH REPORT

International application No
PCT/JP2013/074606

A. CLASSIFICATION OF SUBJECT MATTER
INV. F01N3/022 F01N3/023 F01N3/20 F01N3/28 F01N9/00
F01N3/029
ADD. F01N3/025 F01N13/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2005 076462 A (TOYOTA MOTOR CORP) 24 March 2005 (2005-03-24) cited in the application the whole document -----	1,3-6,9
X	EP 1 978 219 A1 (ISUZU MOTORS LTD [JP]) 8 October 2008 (2008-10-08) paragraph [0030] - paragraph [0041]; figure 1 -----	1,2
X	EP 1 211 392 A1 (TOYOTA MOTOR CO LTD [JP]) 5 June 2002 (2002-06-05) paragraphs [0001], [0007], [0082]; figure 21 -----	1,2,8
X	EP 1 182 332 A1 (TOYOTA MOTOR CO LTD [JP]) 27 February 2002 (2002-02-27) paragraphs [0048], [0049] -----	1,2,7
	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 December 2013	18/12/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Tortosa Masiá, A

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 172 533 A1 (TOYOTA MOTOR CO LTD [JP]; SUMITOMO ELECTRIC INDUSTRIES [JP]) 16 January 2002 (2002-01-16) paragraph [0116] - paragraph [0117] -----	1,2,8

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/JP2013/074606

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EP 1978219 A1	08-10-2008	CN 101371015 A EP 1978219 A1 JP 3956992 B1 JP 2007198283 A US 2009165445 A1 WO 2007086252 A1	18-02-2009 08-10-2008 08-08-2007 09-08-2007 02-07-2009 02-08-2007
EP 1211392 A1	05-06-2002	AU 763255 B2 AU 4282101 A CA 2374752 A1 CN 1365424 A DE 60113040 D1 DE 60113040 T2 EP 1211392 A1 ES 2243467 T3 KR 100493996 B1 US 2002157387 A1 WO 0173272 A1	17-07-2003 08-10-2001 04-10-2001 21-08-2002 06-10-2005 22-06-2006 05-06-2002 01-12-2005 10-06-2005 31-10-2002 04-10-2001
EP 1182332 A1	27-02-2002	AU 761059 B2 AU 4282001 A CA 2374749 A1 CN 1365423 A DE 60131510 T2 EP 1182332 A1 ES 2292571 T3 JP 3714251 B2 US 2002157385 A1 WO 0173271 A1	29-05-2003 08-10-2001 04-10-2001 21-08-2002 23-10-2008 27-02-2002 16-03-2008 09-11-2005 31-10-2002 04-10-2001
EP 1172533 A1	16-01-2002	CN 1366575 A DE 60115999 T2 EP 1172533 A1 JP 3445775 B2 JP 2001317326 A KR 100445822 B1 US 2002157361 A1 WO 0163102 A1	28-08-2002 27-07-2006 16-01-2002 08-09-2003 16-11-2001 30-08-2004 31-10-2002 30-08-2001