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(54) **APPARATUS THAT ESTIMATES AN AMOUNT OF CONDENSED WATER IN AN INTAKE PASSAGE OF AN ENGINE SYSTEM**

VORRICHTUNG ZUR ABSCHÄTZUNG DER MENGE AN KONDENSWASSER IN EINEM EINLASSABSCHNITT EINES MOTORSYSTEMS

APPAREIL ESTIMANT LA QUANTITÉ D’EAU CONDENSÉE DANS UN PASSAGE D’ADMISSION D’UN SYSTÈME MOTEUR

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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to estimating an amount of condensed water produced in an intake passage of an engine system.

Description of the Background Art

[0002] In an engine system in an initial stage of warming-up when an intake passage is lower in temperature than a dew point, moisture included in a gaseous matter passing through the intake passage may condense and condensed water may thus be produced in the intake passage. The condensed water may cause corrosion of a component of the intake passage. Accordingly, estimating an amount of condensed water produced (hereinafter also referred to as an amount of condensed water) with high accuracy is required.

[0003] For thus estimating an amount of condensed water, for example, Japanese Patent Laid-Open No. 2018-188991 discloses subtracting an amount of saturated water vapor from an amount of moisture in a gaseous mixture as calculated using a sum of an intake air flow rate and an EGR gas flow rate, to calculate an amount of condensed water produced in an intercooler.

[0004] Document WO 2021/002240 A1 describes an internal combustion engine control device provided with an apparatus according to the preamble of independent claim 1.

SUMMARY OF THE INVENTION

[0005] Thus estimating an amount of condensed water may be performed using, for example, a map indicating a relationship between the intake air flow rate and the amount of condensed water. Improving accuracy of estimating an amount of condensed water, however, requires setting a map corresponding to various operating states of the engine system. Thus, accuracy of estimating an amount of condensed water may be inappropriately improved due to limitation on memory capacity for the map, the number of steps for adapting the map, and the like

[0006] An object of the present invention is to provide an apparatus that estimates with high accuracy an amount of condensed water produced in an intake passage of an engine system.

[0007] According to an aspect of the present invention, the above object is achieved by an apparatus that estimates an amount of condensed water produced in an intake passage of an engine system as defined in claim 1.

[0008] Further features and advantageous modifications are shown in the dependent claims.

[0009] In this way, the first amount of moisture included in the intake air passing through the intake passage can be estimated by the estimating expression with high accuracy. Thus, an estimated value of an amount of condensed water in the intake passage can be estimated with high accuracy by subtracting an amount of saturated water vapor from the first amount of moisture.

[0010] The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

Fig. 1 is a diagram showing an example of a schematic configuration of an engine system according to an embodiment.

Fig. 2 is a diagram for illustrating a relationship between a first amount of moisture included in intake air, a second amount of moisture included in EGR gas, an amount of saturated water vapor, and an amount of condensed water.

Fig. 3 is a flowchart showing an example of a process of estimating an amount of condensed water.

Fig. 4 is a diagram for illustrating an example of how an estimated value of a cumulative volume of condensed water varies under a fixed traveling condition in an environment with low outside air temperature.

Fig. 5 is a diagram for illustrating an example of how an estimated value of a cumulative volume of condensed water varies under a fixed traveling condition in an environment with high outside air temperature.

Fig. 6 shows an example of how an estimated value of a cumulative volume of condensed water varies when an engine system 1 operates since warm-up is started and even after warm-up is completed.

Fig. 7 shows an example of how an estimated value of a cumulative volume of condensed water varies when an operation state in which an operation of the engine system 1 stops before completion of warm-up is repeated.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] Hereinafter, an embodiment will be described with reference to the drawings. In the following description, identical components are identically denoted. Their names and functions are also identical. Accordingly, they will not be described repeatedly in detail.

[0013] Fig. 1 is a diagram showing an example of a schematic configuration of an engine system 1 according to the present embodiment. As shown in Fig. 1, the engine system 1 includes an engine body 2, an intake manifold 10, an intake pipe 12, an exhaust gas recirculation device (hereinafter referred to as an EGR device) 20, an exhaust manifold 50, an exhaust pipe 52, and a turbocharger 60. The engine system 1 is mounted in a mobile object such as a vehicle, for example.

[0014] The engine body 2 is an internal combustion engine such as a diesel engine or a gasoline engine including a cylinder 4 and a fuel injection device 6. In the present embodiment, it is assumed that the engine body 2 is, for example, a four-stroke engine in which an output shaft rotates twice for one cycle.

[0015] An intake port and an exhaust port (both not shown) are connected to the top of the cylinder 4 of the engine body 2, and the intake manifold 10 is connected to the intake port. The engine body 2 is provided for example with a plurality of cylinders 4, and the intake manifold 10 is connected to intake ports each connected to a cylinder 4.

[0016] The fuel injection device 6 supplies fuel into the cylinder 4 in response to a control signal C1 issued from a controller 100. The fuel injection device 6 is provided, for example, at the top of the cylinder 4 and injects fuel directly into the cylinder. When the engine body 2 is a spark-ignition gasoline engine, the fuel injection device 6 may be configured to supply fuel to the intake port, for example.

[0017] One end of the intake pipe 12 is connected to the intake manifold 10. An air cleaner (not shown) is connected to the other end of the intake pipe 12. When the engine system 1 operates, air sucked from the air cleaner (i.e., intake air) passes through the intake pipe 12 into the intake manifold 10. The intake manifold 10 and the intake pipe 12 constitute an "intake passage" of the engine system 1.

[0018] The exhaust manifold 50 is connected to the exhaust port of the engine body 2. More specifically, the exhaust manifold 50 is connected to each exhaust port of the plurality of cylinders of the engine body 2.

[0019] One end of the exhaust pipe 52 is connected to the exhaust manifold 50. The other end of the exhaust pipe 52 is provided with a silencing device such as a muffler. Various catalysts for purifying exhaust gas are provided at an intermediate portion of the exhaust pipe 52. The exhaust manifold 50 and the exhaust pipe 52 constitute an "exhaust passage."

[0020] The turbocharger 60 includes a compressor 62 provided in the intake pipe 12 and a turbine 64 provided in the exhaust pipe 52. The compressor 62 is provided with a rotatably supported compressor blade (not shown). The turbine 64 is provided with a turbine blade rotatably supported and coupled to the compressor blade via a shaft 66. Accordingly, when the turbine blade is rotated by exhaust energy supplied from the engine body 2 to the turbine 64, the compressor blade is rotated via the shaft 66, and intake air is compressed in the compressor 62. The thus compressed (supercharged) intake air is cooled by an intercooler (not shown) provided in the intake pipe 12, and supplied to the engine body 2 via the intake manifold 10.

[0021] In the engine body 2, a mixture of intake air sucked from the intake manifold 10 via the intake pipe 12 and fuel supplied from the fuel injection device 6 into the cylinder 4 is combusted in the cylinder 4. The air-fuel mixture combusted in the cylinder 4 generates combustion pressure, which causes a piston accommodated in the cylinder 4 to operate, and an output shaft (not shown) rotates via a crank mechanism (not shown) or the like. The air-fuel mixture combusted in the cylinder 4 produces exhaust gas, which is externally exhausted via the exhaust manifold 50 and the exhaust pipe 52.

[0022] The EGR device 20 is configured to return a portion of exhaust gas passing through the exhaust manifold 50 to the intake manifold 10. The portion of the exhaust gas returned to the intake manifold 10 flows from the intake manifold 10 to the cylinder 4 together with intake air. When the exhaust gas is introduced into the cylinder 4, combustion temperature is reduced and NOx is decreased. Further, intake air loss and cooling loss are reduced and fuel economy is improved. In the following description, a portion of exhaust gas returned to the intake passage may be referred to as EGR gas.

[0023] The EGR device 20 includes a first circulation passage 22, a second circulation passage 24, and an EGR cooler 30.

[0024] One end of the first circulation passage 22 is connected to the intake manifold 10. The other end of the first circulation passage 22 is connected to the EGR cooler 30.

[0025] The EGR cooler 30 includes a heat exchanger (not shown) accommodated therein. The heat exchanger is configured such that, for example, coolant water passing through the engine body 2 passes therethrough. Accordingly, in the heat exchanger, the EGR gas passing through the EGR cooler 30 exchanges heat with the coolant water. This reduces the temperature of the EGR gas passing through the EGR cooler 30. Cooling the EGR gas in the EGR cooler 30 can reduce in volume the EGR gas passing through the first circulation passage 22 and return a large amount of EGR gas to the intake passage.

[0026] The EGR device 20 is provided with an EGR valve (not shown). The EGR valve is an adjustment valve having a degree of opening adjusted in response to a control signal issued from the controller 100 to adjust a flow rate of EGR gas passing through the EGR device 20.

[0027] One end of the second circulation passage 24 is connected to the EGR cooler 30. The other end of the second circulation passage 24 is connected to the exhaust manifold 50.

[0028] In the EGR device 20 configured as described above, a portion of exhaust gas passing through the exhaust manifold 50 is received as EGR gas, and the received EGR gas is cooled in the EGR cooler 30, and adjusted in flow rate by the EGR valve and thus returned to the intake manifold 10.

[0029] To the controller 100 are connected an air flow meter 102, an intake air temperature sensor 104, an engine speed sensor 106, a water temperature sensor 108, an atmospheric pressure sensor 110, an intake manifold temperature sensor 112, a supercharging pressure sensor 114, an exhaust gas temperature sensor 116, and a notification device 130.

[0030] The air flow meter 102 is provided to the intake pipe 12 and detects a flow rate Q of intake air passing through the intake pipe 12 (hereinafter referred to as a quantity of intake air). The air flow meter 102 transmits a signal indicating a detected quantity Q of intake air to the controller 100.

[0031] The intake air temperature sensor 104 is provided to the intake pipe 12 and senses a temperature Tin of intake air passing through the intake pipe 12 (hereinafter referred to as an intake air temperature). The intake air temperature sensor 104 transmits a signal indicating the sensed intake air temperature Tin to the controller 100.

[0032] The engine speed sensor 106 is provided to the engine body 2, and senses a rotational speed Ne of the output shaft of the engine body 2 (hereinafter referred to as engine speed). The engine speed sensor 106 transmits a signal indicating the sensed engine speed Ne to the controller 100.

[0033] The water temperature sensor 108 is provided to the engine body 2, and senses a temperature Tw of coolant water passing through a coolant water passage (not shown) provided in the engine body 2 (hereinafter referred to as water temperature). The water temperature sensor 108 transmits a signal indicating the sensed water temperature Tw to the controller 100.

[0034] The atmospheric pressure sensor 110 senses an atmospheric pressure Pa. The atmospheric pressure sensor 110 transmits a signal indicating the sensed atmospheric pressure Pa to the controller 100.

[0035] The intake manifold temperature sensor 112 is provided to the intake manifold 10 and senses a temperature Tim inside the intake manifold 10 (hereinafter referred to as intake manifold temperature). The intake manifold temperature sensor 112 transmits a signal indicating the sensed intake manifold temperature Tim to the controller 100.

[0036] The supercharging pressure sensor 114 is provided in the intake manifold 10 and senses a pressure Pim inside the intake manifold 10 (hereinafter referred to as a supercharging pressure). The supercharging pressure sensor 114 transmits a signal indicating the sensed supercharging pressure Pim to the controller 100.

[0037] The exhaust gas temperature sensor 116 is provided to the exhaust pipe 52 and senses a temperature Tex of exhaust gas passing through the exhaust pipe 52 (hereinafter referred to as exhaust gas temperature). The exhaust gas temperature sensor 116 transmits a signal indicating the sensed exhaust gas temperature Tex to the controller 100.

[0038] The notification device 130 notifies the user of predetermined information. Notification may be done in a method for example by: displaying textual information on a screen to notify the user of the predetermined information; turning on a warning light to notify the user of the predetermined information; or generating a predetermined audio or a predetermined warning sound to notify the user of the predetermined information.

[0039] The controller 100 includes a CPU (Central Processing Unit) that performs various processes, a ROM (Read Only Memory) that stores programs and data, a RAM (Random Access Memory) that stores processing results of the CPU, and the like.

[0040] The controller 100 controls various devices (for example, the fuel injection device 6, the notification device 130, the EGR valve or the like), based on signals issued from various sensors (for example, the air flow meter 102, the intake air temperature sensor 104, the engine speed sensor 106, the water temperature sensor 108, the atmospheric pressure sensor 110, the intake manifold temperature sensor 112, the supercharging pressure sensor 114, the exhaust gas temperature sensor 116, and the like) and maps and programs stored in the memory, so that the engine system 1 is in a desired operating state. Note that various processes executed by the controller 100 are not limited to software processing, and may be performed by dedicated hardware (or electronic circuitry).

[0041] In the engine system 1 as described above, when the engine is cold-started with the water temperature Tw lower than a threshold value or the like and warm-up is thus started, and the engine system 1 operates for a longer period of time, the temperature of each component of the engine system 1 accordingly increases.

[0042] However, when the engine system 1 is being warmed up or the like and the intake manifold 10 has low temperature, condensed water may be produced in the intake manifold 10 as the EGR device 20 operates. This is because, when the EGR device 20 operates, EGR gas passes through the intake manifold 10, and the EGR gas passing through the intake manifold 10 comes into contact with an internal wall surface of the intake manifold 10 having a temperature lower than the dew point, whereby moisture in intake air indicated in Fig. 1 by an arrow (A) and that in EGR gas indicated in Fig. 1 by an arrow (B) condense and adhere as condensed water to the internal wall surface of the intake manifold 10 as indicated in Fig. 1 by an arrow (C). Further, when a prescribed amount of condensed water is produced before warm-up is completed, the condensed water is acidified by a chemical reaction with an exhaust gas component of the EGR gas, which can be a cause of corrosion inside the intake manifold 10. Accordingly, estimating an amount of condensed water produced (hereinafter referred to as an amount of condensed water), and restricting an operation of the EGR device 20 or notifying the user accordingly, as necessary, are required.

[0043] An amount of condensed water in the intake manifold 10 may be estimated for example by using a map indicating a relationship between a sum of a quantity of intake air and a flow rate of the EGR gas and the amount of condensed water. Improving accuracy of estimating an amount of condensed water, however, requires setting a map corresponding to various operating states of the engine system 1. Thus, accuracy of estimating an amount of condensed water may be inappropriately improved due to limitation on memory capacity for the map, the number of steps for adapting the map, and the like.

[0044] Accordingly, in the present embodiment, the controller 100 includes the following configuration.

[0045] That is, the controller 100 includes a calculator (1) 120 that calculates an amount Aw1 of moisture included in intake air passing through the intake manifold 10 by an estimating expression using an amount of the intake air, a concentration of water vapor included in the intake air, a humidity of the intake air, and a recirculation rate of exhaust gas returned to the intake manifold 10 (hereinafter referred to as a first amount of moisture).

[0046] Further, the controller 100 further includes a calculator (2) 122 that calculates an amount Aw2 of moisture included in EGR gas and produced by combustion of fuel by an estimating expression using an amount of fuel supplied to the cylinder 4 and the recirculation rate of the exhaust gas (hereinafter referred to as a second amount of moisture).

[0047] Further, the controller 100 further includes a calculator (3) 124 that calculates an amount Aw3 of saturated water vapor in the intake manifold 10 at a portion passing the EGR gas.

[0048] Further, the controller 100 further includes a calculator (4) 126 that calculates a sum of the first amount Aw1 of moisture and the second amount Aw2 of moisture minus the amount Aw3 of saturated water vapor as an estimated value Aw4 of an amount of condensed water. The apparatus that estimates an amount of condensed water according to the present embodiment is implemented by the controller 100.

[0049] Fig. 2 is a diagram for illustrating a relationship between the first amount Aw1 of moisture included in intake air, the second amount Aw2 of moisture included in EGR gas, the amount Aw3 of saturated water vapor, and the amount Aw4 of condensed water.

[0050] A sum of the first amount Aw1 of moisture included in the intake air, as indicated in Fig. 2 by (a), and the second amount Aw2 of moisture included in the EGR gas, as indicated in Fig. 2 by (b), will be a total sum of an amount of moisture included in a gaseous matter inside the intake manifold 10. And only a portion thereof that is the amount Aw3 of saturated water vapor indicated in Fig. 2 by (c) can exist as water vapor. Accordingly, the sum of the first amount Aw1 of moisture and the second amount Aw2 of moisture minus the amount Aw3 of saturated water vapor corresponds to the amount Aw4 of condensed water indicated in Fig. 2 by (d).

[0051] The first amount Aw1 of moisture included in the intake air passing through the intake manifold 10 and the second amount Aw2 of moisture included in the EGR gas passing through the intake manifold 10 can be estimated by the their respective estimating expressions with high accuracy. By subtracting the amount Aw3 of saturated water vapor from the sum of the first amount Aw1 of moisture and the second amount Aw2 of moisture, the estimated value Aw4 of the amount of condensed water in the intake manifold 10 can be estimated with high accuracy.

[0052] An example of processing executed by the controller 100 will now be described below with reference to Fig. 3. Fig. 3 is a flowchart showing an example of a process of estimating an amount of condensed water.

[0053] In step (S)100, the controller 100 (i.e., the calculator (1) 120) calculates the first amount Aw1 of moisture. An expression for estimating the first amount Aw1 of moisture [g/s] can be expressed by the following expression (1) using a quantity Qa of intake air [g/s], a water vapor concentration Cw1, a humidity H [%], and a recirculation rate R.

$$\mathrm{Aw1} = \mathrm{Qa} \times \mathrm{Cw1} \times \mathrm{H}/100\ [\%]/(1 - \mathrm{R}) \qquad \dots (1)$$

[0054] The controller 100 obtains the quantity Qa of intake air using a detection result of the air flow meter 102. The water vapor concentration Cw1 indicates a ratio of water vapor in the intake air. An expression for estimating the water vapor concentration Cw1 can be expressed by the following expression (2) using a saturated water vapor pressure Pw1 [kPa] of the intake air and an atmospheric pressure (the pressure of the intake air) Pa [kPa].

$$\mathrm{Cw1} = \mathrm{Pw1}/\mathrm{Pa} \qquad \dots (2)$$

[0055] Further, an expression for estimating the saturated water vapor pressure Pw1 [kPa] of the intake air can be expressed by the following expression (3) (Tetens' (1930) formula) using a temperature t [°C] of the atmosphere.

$$Pw1 = 0.61078 \times 10^{(7.5t/(t + 237.3))} \quad \ldots (3)$$

[0056] The controller 100 obtains the temperature t of the atmosphere using a result of sensing by the intake air temperature sensor 104. For example, the controller 100 calculates the temperature t of the atmosphere using a map indicating a relationship between an intake air temperature Ti and the temperature t of the atmosphere as well as the intake air temperature Tin sensed by the intake air temperature sensor 104. The map indicating the relationship between the intake air temperature Tin and the temperature t of the atmosphere is, for example, a one-dimensional map, adapted experimentally or in design, predetermined, and stored in a memory of the controller 100.

[0057] The controller 100 calculates the saturated water vapor pressure Pw1 of the intake air using the obtained temperature t of the atmosphere and the estimating expression as indicated as the expression (3). The controller 100 obtains the atmospheric pressure Pa using a result of sensing by the atmospheric pressure sensor 110. The controller 100 calculates the water vapor concentration Cw1 using the obtained atmospheric pressure Pa, the calculated Pw1, and the estimating expression as indicated as the expression (2).

[0058] The humidity H in the expression (1) is, for example, a predetermined humidity. In the present embodiment, the predetermined humidity is, for example, 100%.

[0059] The recirculation rate R in the expression (1) is a value indicating a ratio of EGR gas to a gaseous matter sucked into the cylinder 4 (i.e., an EGR ratio). The controller 100 estimates a flow rate Qegr of the EGR gas based on a value indicating an operating state of the engine system 1 such as a degree of opening of the EGR valve and divides the estimated EGR gas flow rate by the sum of the estimated EGR gas flow rate Qegr, the quantity Qa of intake air and an amount of fuel to calculate the recirculation rate R. The EGR ratio may be estimated using any well-known technique, and the above-described calculation method is not exclusive.

[0060] The first amount Aw1 of moisture includes an amount of moisture derived from the intake air, that is included in the recirculated portion of the EGR gas, in addition to an amount of moisture included in the air sucked from the air cleaner. Accordingly, a relationship between the first amount Aw1 of moisture, an amount A of moisture included in the intake air, and the recirculation rate R is expressed by an expression of $Aw1 = A + (Aw1 \times R)$, and a relational expression of $Aw1 = A/(1 - R)$ is established. In the expression (1), $1/(1 - R)$ is multiplied in order to include in the first amount Aw1 of moisture the amount of moisture derived from the intake air included in the EGR gas recirculated from the EGR device 20.

[0061] The controller 100 calculates the first amount Aw1 of moisture using the obtained quantity Qa of intake air and humidity H, the calculated water vapor concentration Cw1, humidity H and recirculation rate R, and the expression (1).

[0062] In S102, the controller 100 (that is, the calculator (2) 122) calculates the second amount Aw2 of moisture. An expression for estimating the second amount Aw2 of moisture [g/s] can be expressed by the following expression (4) using an amount Af of fuel [g/s], a constant Co, and the recirculation rate R.

$$Aw2 = Af \times Co \times R/(1 - R) \quad \ldots (4)$$

[0063] The amount Af of fuel indicates an amount of fuel (in mass) injected in the cylinder 4 per unit time. An expression for estimating the amount Af of fuel can be expressed by the following expression (5) using a volume Vf [mm^3/st] of fuel injected per stroke, the engine speed Ne [rpm], a number N of cylinders, and the fuel's density ρf [g/mm^3].

$$Af = Vf \times Ne/60\ [s]/2/N \times \rho f \quad \ldots (5)$$

[0064] For example, the controller 100 obtains the volume Vf of the fuel injected per stroke by using a control command value issued for the fuel injection device 6. The controller 100 obtains the engine speed Ne using a result of sensing by the engine speed sensor 106. The number N of cylinders and the fuel's density ρf in the expression (5) are predetermined values and previously stored in the memory of the controller 100. Accordingly, the controller 100 obtains the number N of cylinders and the fuel's density ρf from the memory.

[0065] The controller 100 calculates the amount Af of fuel using the obtained volume Vf, the engine speed Ne, the number N of cylinders, the fuel's density ρf, and the estimating expression as indicated as the expression (5).

[0066] The constant Co in the expression (4) represents an amount of water that can be produced from a predetermined amount (e.g., 1 g) of fuel, and is a value determined by a property of the fuel (e.g., a ratio in weight of carbon to hydrogen (a C/H ratio)). The constant Co is, for example, set to a value half the C/H ratio.

[0067] The recirculation rate R in the expression (4) is as has been described above, and will not be described repeatedly in detail. The second amount Aw2 of moisture includes an amount of moisture derived from combustion, that is included in the recirculated portion of the EGR gas, in addition to an amount of moisture produced by combustion of fuel. Accordingly, a relationship between the second amount Aw2 of moisture, an amount B of moisture produced by combustion of injected fuel, and the recirculation rate R is expressed by an expression of $Aw2 = (Aw2 + B) \times R$, and a relational expression of $Aw2 = B \times R/(1 - R)$ is established. Accordingly, in the expression (4), $R/(1 - R)$ is multiplied in order to include in the second amount Aw2 of moisture a combustion-derived amount of moisture out of an amount of moisture produced by combustion of fuel that is included in the EGR gas recirculated from the EGR device 20.

[0068] The controller 100 calculates the second amount Aw2 of moisture using the calculated amount Af of fuel, the recirculation rate R, the obtained constant Co, and the expression (4).

[0069] In S104, the controller 100 (that is, the calculator (3) 124) calculates the amount Aw3 of saturated water vapor. An expression for estimating the amount Aw3 of saturated water vapor [g/s] can be expressed by the following expression (6) using an amount M by mole [mol/s] of a gas in the intake manifold 10, a water vapor concentration Cw2 in the intake manifold 10, and a molecular weight L1 [g/mol] of water per mole.

$$Aw3 = M \times Cw2 \times L1 \quad \ldots (6)$$

[0070] The molecular weight L1 of water per mole in the expression (6) is 18 [g/mol]. An expression for calculating the amount M by mole [mol/s] of the gas in the intake manifold 10 can be expressed by the following expression (7) using a quantity Qb of air [g/s] sucked into the intake manifold 10 and an average molecular weight L2 [g/mol] of the gas.

$$M = Qb \times L2 \quad \ldots (7)$$

[0071] The controller 100 obtains the quantity Qb of air sucked into the intake manifold 10 from, for example, the quantity Qa of intake air and a supercharging pressure. The supercharging pressure may be sensed using, for example, a supercharging pressure sensor (not shown), or may be estimated from an operating state of the engine system 1.

[0072] The average molecular weight L2 of the gas in the expression (7) is, for example, a predetermined value experimentally set, and is previously stored in the memory of the controller 100. Accordingly, the controller 100 obtains the average molecular weight L2 of the gas from the memory.

[0073] The controller 100 calculates the amount M by mole of the gas in the intake manifold 10 using the obtained quantity Qb of air, the average molecular weight L2 of the gas, and the expression (7).

[0074] The water vapor concentration Cw2 indicates a ratio of water vapor in a gaseous matter present in the intake manifold 10. An expression for estimating the water vapor concentration Cw2 can be expressed by the following expression (8) using a saturated water vapor pressure Pw2 [kPa] of the gaseous matter in the intake manifold 10 and the pressure (a supercharging pressure) Pim [kPa] in the intake manifold 10.

$$Cw2 = Pw2/Pim \quad \ldots (8)$$

[0075] Further, an expression for estimating the saturated water vapor pressure Pw2 [kPa] of the gaseous matter in the intake manifold can be expressed by the following expression (9) (Tetens' (1930) formula) using a temperature T [°C] in the intake manifold 10.

$$Pw2 = 0.61078 \times 10^{(7.5T/(T + 237.2))} \quad \ldots (9)$$

[0076] The controller 100 estimates a wall surface temperature Twl [°C] at a prescribed portion in the intake manifold 10 where condensed water is produced. For example, the controller 100 calculates the temperature T inside the intake manifold 10 using a map indicating a relationship between the wall surface temperature Twl and the temperature T inside the intake manifold 10 as well as an estimation of the wall surface temperature Twl. The map indicating the relationship between the wall surface temperature Twl and the temperature T inside the intake manifold 10 is, for example, a one-dimensional map, adapted experimentally or in design, and previously determined and stored in the memory of the controller 100. The prescribed portion in the intake manifold 10 where condensed water is produced includes, for example, a portion of a pipe constituting the intake manifold 10 where temperature is most unlikely to rise during warm-up.

[0077] Furthermore, an expression for estimating the wall surface temperature Twl can be expressed by the following expression (10) using a flow rate Qb [g/s] of the gaseous matter in the intake manifold 10, the temperature Tim [°C] of the intake manifold 10, a temperature Tegr [°C] of the EGR gas, and the flow rate Qegr [g/s] of the EGR gas.

$$Twl = a \times (Qb \times Tim + Tegr \times Qegr) + b \quad \ldots (10)$$

[0078] The controller 100 sets *a* using the water temperature Tw and the intake air temperature Tin. For example, the controller 100 sets as *a* a base value Ba multiplied by a correction coefficient Ca1 set using the water temperature Tw and a correction coefficient Ca2 set using the intake air temperature Tin.

[0079] For example, the controller 100 sets the correction coefficient Ca1 using a map indicating a relationship between the water temperature Tw and the correction coefficient Ca1 as well as the water temperature Tw, and sets the correction coefficient Ca2 using a map indicating a relationship between the intake air temperature Tin and the correction coefficient Ca2 as well as the intake air temperature Tin. The map indicating the relationship between the water temperature Tw and the correction coefficient Ca1 and the map indicating the relationship between the intake air temperature Tin and the correction coefficient Ca2 are adapted experimentally or in design, predetermined and stored in the memory of the controller 100.

[0080] Further, the controller 100 sets *b* using the water temperature Tw and the intake air temperature Tin. For example, the controller 100 sets as *b* a base value Bb multiplied by a correction coefficient Cb1 set using the water temperature Tw and a correction coefficient Cb2 set using the intake air temperature Tin.

[0081] For example, the controller 100 sets the correction coefficient Cb1 using a map indicating a relationship between the water temperature Tw and the correction coefficient Cb1 as well as the water temperature Tw, and sets the correction coefficient Cb2 using a map indicating a relationship between the intake air temperature Tin and the correction coefficient Cb2 as well as the intake air temperature Tin. The map indicating the relationship between the water temperature Tw and the correction coefficient Cb1 and the map indicating the relationship between the intake air temperature Tin and the correction coefficient Cb2 are adapted experimentally or in design, predetermined and stored in the memory of the controller 100.

[0082] The flow rate Qb and the flow rate Qegr are obtained as has been described above, and will not be described repeatedly in detail. For example, the controller 100 obtains the temperature Tim of the intake manifold 10 using a result of sensing by the intake manifold temperature sensor 112. The controller 100 may estimate the temperature Tim of the intake manifold 10 using the water temperature Tw, for example.

[0083] The controller 100 calculates the temperature Tegr of the EGR gas using an estimating expression. The expression for estimating the temperature Tegr of the EGR gas can be expressed by the following expression (11) using the exhaust gas temperature Tex, the water temperature Tw, and a temperature Texm of exhaust gas passing through the exhaust manifold 50.

$$\mathrm{Tegr} = \mathrm{Tex} - \mathrm{Texm} \times (\mathrm{Tex} - \mathrm{Tw}) \qquad \ldots (11)$$

[0084] The controller 100 obtains the water temperature Tw and the exhaust gas temperature Tex using results of sensing by the water temperature sensor 108 and the exhaust gas temperature sensor 116. The controller 100 obtains the temperature Texm using, for example, the water temperature Tw and the exhaust temperature Tex. For example, the controller 100 may obtain the temperature Texm by a temperature sensor (not shown) provided at the exhaust manifold 50. The controller 100 calculates the EGR gas temperature Tegr using the obtained temperatures Tex, Texm and Tw, and the expression (11).

[0085] The controller 100 calculates the wall surface temperature Twl using the obtained flow rates Qb and Qegr, Tim, the calculated Tegr, the set values *a* and *b*, and the expression (10). The controller 100 obtains the pressure Pim inside the intake manifold 10 using a result of sensing by the supercharging pressure sensor 114.

[0086] The controller 100 calculates the temperature T inside the intake manifold 10 using the calculated wall surface temperature Twl, and calculates the saturated water vapor pressure Pw2 using the calculated temperature T and the expression (9). The controller 100 calculates the water vapor concentration Cw2 using the calculated Pw2, the pressure (supercharging pressure) Pim in the intake manifold 10, and the expression (8). The controller 100 calculates the amount Aw3 of saturated water vapor using the calculated amount M by mole of the gas in the intake manifold 10, the water vapor concentration Cw2, the molecular weight L1 of water per mole, and the expression (6).

[0087] In S106, the controller 100 (that is, the calculator (4) 126) calculates the amount Aw4 of condensed water. An expression for calculating the amount Aw4 of condensed water can be expressed by the following expression (12) using the first amount Aw1 of moisture, the second amount Aw2 of moisture, and the amount Aw3 of saturated water vapor.

$$\mathrm{Aw4} = \mathrm{Aw1} + \mathrm{Aw2} - \mathrm{Aw3} \qquad \ldots (12)$$

[0088] The controller 100 calculates the amount Aw4 of condensed water using the first amount Aw1 of moisture calculated in S100, the second amount Aw2 of moisture calculated in S102, the amount Aw3 of saturated water vapor calculated in S104, and the expression (12).

[0089] In S108, the controller 100 (e.g., the calculator (4) 126) sets a correction coefficient Cs. An amount of condensed water adhering inside the intake manifold 10 correlates with a surface area of that wall surface portion inside the intake manifold 10 to which the condensed water can adhere. Accordingly, for example, a one-dimensional map representing a relationship between a surface area of a planar portion and the correction coefficient is set experimentally or in design, and a reference value for the correction coefficient is preset using a surface area of a planar portion of the intake manifold 10 and stored in the memory of the controller 100. Further, the amount of condensed water adhering inside the intake manifold

10 correlates with an internal wall surface temperature of the intake manifold 10. Accordingly, the controller 100 sets the correction coefficient Cs by multiplying the reference value by a coefficient corresponding to the wall surface temperature, for example. The controller 100 for example uses a map or the like indicating a relationship between the wall surface temperature and a coefficient to set the coefficient depending on the wall surface temperature. A map or the like indicating the relationship between the wall surface temperature and the coefficient is for example adapted experimentally or in design to be corrected to an actual amount of condensed water, and is previously stored in the memory of the controller 100.

[0090] In S110, the controller 100 (e.g., the calculator (4) 126) calculates a cumulative volume Vw of condensed water (a cumulative value of an amount of condensed water). An expression for calculating the cumulative volume Vw of condensed water can be expressed by the following expression (13) using the current value Vw(n) of the cumulative volume of condensed water, the amount Aw4 of condensed water, the correction coefficient Cs, the current value Aw5(n) of an amount of scavenging (an amount of moisture sucked into the cylinder at the intake stroke) and the previous value Vw(n -1) of the cumulative volume of condensed water.

$$Vw(n) = Aw4 \times Cs + Vw(n - 1) - Aw5(n) \quad \ldots (13)$$

[0091] The controller 100 uses the amount Aw4 of condensed water calculated in S106, the correction coefficient Cs set in S108, the previous value Vw(n -1) of the cumulative volume of condensed water as stored in the memory of the controller 100, and the expression (13) to calculate the current value Vw(n) of the cumulative volume of condensed water as the cumulative volume Vw of condensed water. The controller 100 estimates the amount Aw5 of scavenging using the wall surface temperature Twl, the flow rate Qb in the intake manifold 10, and the water temperature Tw. The method of estimating the amount Aw5 of scavenging may use a known technique, and will not be described specifically.

[0092] An operation of the controller 100 based on the above-described structure and flowchart will be described with reference to Figs. 4 and 5.

[0093] For example, when the engine body 2 is warmed up, the intake pipe 12 and the intake manifold 10 are low in temperature, and when the EGR device 20 has the EGR valve opened and exhaust gas passes through the intake manifold 10, condensed water is produced in the intake manifold 10.

[0094] At the time, the first amount Aw1 of moisture is calculated by an estimating expression as indicated as the expression (1) using the quantity Qa of intake air, the water vapor concentration Cw1, the humidity H, and the recirculation rate R (S100). Further, the second amount Aw2 of moisture is calculated by an estimating expression as indicated as the expression (4) using the amount Af of fuel, the recirculation rate R, and the constant Co (S102). Then, an amount of saturated water vapor is calculated by an estimating expression as indicated as the expression (6) using the amount M by mole of gas in the intake manifold 10, the water vapor concentration Cw2, and the molecular weight L1 of water per mole (S104).

[0095] The amount Aw3 of saturated water vapor is subtracted from a sum of the calculated first amount Aw1 of moisture and second amount Aw2 of moisture to calculate the amount Aw4 of condensed water (S106). When the correction coefficient Cs is set based on the wall surface temperature Twl (S 108), the amount Aw4 of condensed water is corrected using the correction coefficient Cs. Then, the amount Aw5 of scavenging is subtracted from the corrected value (Aw4 × Cs) to calculate an amount of condensed water produced in the intake manifold. The calculated value is added to the previous value of the cumulative volume Vw of condensed water to calculate the current value of the cumulative volume Vw of condensed water (S110).

[0096] In this way, the first amount Aw1 of moisture and the second amount Aw2 of moisture are individually calculated by their respective estimating expressions, and the amount Aw3 of saturated water vapor is calculated using the wall surface temperature Twl. The cumulative volume Vw of condensed water can thus be estimated with high accuracy.

[0097] Accordingly, for example, when the EGR device 20 is controlled using the cumulative volume Vw of condensed water, EGR device 20 can be controlled with improved accuracy. Alternatively, appropriate notification can be made when a notification process is performed via the notification device 130 to notify a user of information for condensed water (hereinafter also referred to as condensed-water information) by using the cumulative volume Vw of condensed water.

[0098] Fig. 4 is a diagram for illustrating an example of how an estimated value of a cumulative volume of condensed water varies under a fixed traveling condition in an environment with low outside air temperature. In Fig. 4, the horizontal axis represents time. In Fig. 4, the vertical axis represents a cumulative volume of condensed water.

[0099] In Fig. 4, LN1 represents an example of how a cumulative volume of condensed water changes when an amount of condensed water is estimated using the quantity Qa of intake air and the engine speed Ne, for example. In Fig. 4, LN2 represents an example of how the cumulative volume of condensed water changes when a process of estimating an amount of condensed water, as described above, is performed.

[0100] For example, in an environment with low outside air temperature, calculating a cumulative volume of condensed water while considering the wall surface temperature can prevent an overestimated cumulative volume of condensed water, as indicated in Fig. 4 by LN1 and LN2. Accordingly, when a cumulative volume of condensed water exceeds a threshold value and accordingly, notification control is performed via the notification device 130 to notify a user of condensed-water information indicating that the cumulative volume of condensed water exceeds the threshold value, unnecessarily notifying the user of the information via the notification device 130 is prevented. Alternatively, when a cumulative volume of condensed water exceeds the threshold value and accordingly, EGR control is executed for example by controlling the EGR valve of the EGR device 20 toward a closing side to reduce EGR gas in flow rate to prevent condensed water from being produced in an increased amount, unnecessarily limiting an operation of the EGR device 20 and thus deteriorating fuel efficiency, NOx purification performance and the like are prevented.

[0101] Fig. 5 is a diagram for illustrating an example of how an estimated value of a cumulative volume of condensed water varies under a fixed traveling condition (the same travelling condition as that described above) in an environment with high outside air temperature. In Fig. 5, the horizontal axis represents time. In Fig. 5, the vertical axis represents a cumulative volume of condensed water.

[0102] In Fig. 5, LN3 represents an example of how a cumulative volume of condensed water changes when an amount of condensed water is estimated using the quantity Qa of intake air and the engine speed Ne, for example. In Fig. 5, LN4 represents an example of how the cumulative volume of condensed water changes when a process of estimating an amount of condensed water, as described above, is performed.

[0103] For example, in an environment with high outside air temperature, calculating a cumulative volume of condensed water while considering the wall surface temperature can prevent an underestimated cumulative volume of condensed water, as indicated in Fig. 5 by LN3 and LN4. When notification control is executed depending on a cumulative volume of condensed water, as described above, failing to notify a user of the condensed-water information via the notification device 130 while the cumulative volume of condensed water actually exceeds a threshold value is prevented. Alternatively, when the EGR control is executed depending on a cumulative volume of condensed water, as described above, failing to execute the EGR control while the cumulative volume of condensed water actually exceeds the threshold value is prevented. This suppresses acceleration of corrosion inside the intake manifold 10.

[0104] Fig. 6 shows an example of how an estimated value of a cumulative volume of condensed water varies when the engine system 1 operates since warm-up is started and even after warm-up is completed. In Fig. 6, the vertical axis represents a cumulative volume of condensed water. In Fig. 6, the horizontal axis represents time. In Fig. 6, LN5 represents an example of variation of a cumulative volume of condensed water. For example, it is assumed that an operation is started while the engine system 1 is cold.

[0105] At time zero, the engine system 1 starts to operate, and the EGR valve is opened and exhaust gas passes through the intake manifold 10 as EGR gas via the EGR device 20. When the intake manifold has an internal wall surface with low temperature, moisture in intake air and EGR gas condenses, and accordingly, an estimated value of a cumulative volume of condensed water varies to increase. As engine system 1 continues to operate, the temperature of the internal wall surface of the intake manifold increases. Accordingly, condensation of moisture in the intake air and the EGR gas is suppressed, and the amount of scavenging increases. As a result, at time t(0), the estimated value of the cumulative volume of condensed water changes to decrease. Then, at time t(1), after a time point when the water temperature Tw has a value indicating completion of warming-up, the estimated value of the cumulative volume of condensed water becomes zero. Thus an estimated value of a cumulative volume of condensed water is calculated with high accuracy when the engine system 1 operates since warming it up is started and even after doing so is completed.

[0106] Fig. 7 shows an example of how an estimated value of a cumulative volume of condensed water varies when an operation state in which an operation of the engine system 1 stops before completion of warm-up is repeated. In Fig. 7, the vertical axis represents a cumulative volume of condensed water. In Fig. 7, the horizontal axis represents time. In Fig. 7, LN6 indicates an example of how an estimated value of a cumulative volume of condensed water varies when an operation state in which an operation of the engine system 1 stops before completion of warm-up is repeated. In Fig. 7, LN7 indicates an example of how an estimated value of a cumulative volume of condensed water varies when an operation of the engine system 1 continues until completion of warm-up.

[0107] As indicated in Fig. 7 by LN6, for example, an operation of the engine system 1 starts at time zero, and an estimated value of a cumulative volume of condensed water changes to increase, as described above. Before warm-up is completed, the operation of the engine system 1 is stopped at time t(2) and continuously stopped until time t(3), and for this period of time from time t(2) to time t(3), the cumulative volume of condensed water is maintained at Aw(1). For this period of time, the temperature of the engine system 1 decreases and becomes cold again.

[0108] After time t(3) et seq., the same operation as that done from time zero to time t(3) is repeated, and a cumulative volume of condensed water of an extent similar to an amount accumulated for a period of time from time zero to time t(4) is additionally accumulated for a period of time from time t(3) to time (4), a period of time from time t(5) to time (6), a period of time t(7) to time t(8), and a period of time from time t(9) to time (10). As a result, the cumulative volume of condensed water attains Aw(2) at time t(4), Aw(3) at time t(6), Aw(4) at time t(8), and Aw(5) at time t(10).

[0109] When the operation of the engine system 1 continues after the time t(4) et seq., then, as has been described with reference to Fig. 6, the wall surface temperature increases, and accordingly, condensation of moisture in the intake air and that in the EGR gas is suppressed, and the amount of scavenging also increases. Accordingly, as indicated in Fig. 7 by LN7, the estimated value of the cumulative volume of condensed water changes to decrease after time t(4) et seq., and becomes zero when warm-up is completed or around completion of warm-up.

[0110] **In** this way, an estimated value of a cumulative volume of condensed water is calculated with high accuracy, whether an operation of the engine system 1 may stop after warming up the engine system 1 is started before doing so is completed or the operation of the engine system 1 may continue since warming up the engine system 1 was started until doing so is completed.

[0111] Accordingly, for example, when there is a possibility that corrosion may be accelerated when a cumulative volume of condensed water is increased to Aw(5), then in response to the cumulative volume of condensed water having increased to Aw(3), notification may be made via the notification device 130 to inform that condensed water is being accumulated or that it is desirable to continue the operation of the engine system 1 in order to eliminate accumulation of condensed water. Alternatively, when a cumulative volume of condensed water increases to Aw(4), operation of the EGR device 20 may be stopped (that is, the EGR valve may be closed), or the EGR gas may be reduced in flow rate (that is, the EGR valve may have a reduced degree of opening) to suppress production of condensed water.

[0112] Thus, the apparatus that estimates an amount of condensed water according to the present embodiment calculates the first amount Aw1 of moisture included in intake air and the second amount Aw2 of moisture included in exhaust gas and produced by combustion of fuel by using their respective estimating expressions. This allows highly accurate calculation of an amount of moisture in the intake manifold 10 that is a portion of an intake passage through which exhaust gas passes. Therefore, the amount Aw4 of condensed water in the intake manifold 10 can be calculated with high accuracy by subtracting the amount Aw3 of saturated water vapor from the sum of the first amount Aw1 of moisture and the second amount Aw2 of moisture. An apparatus that estimates with high accuracy an amount of condensed water produced in an intake passage of an engine system can thus be provided.

[0113] Further, as condensed water is produced on a wall surface of the intake manifold 10, an amount of condensed water in the intake manifold 10 can be calculated with high accuracy by calculating an amount of saturated water vapor corresponding to the wall surface's temperature.

[0114] Further, an amount of produced condensed water that adheres may vary depending on the surface area of the intake manifold 10. Accordingly, an amount of condensed water can be estimated with high accuracy by setting the correction coefficient Cs for correcting the amount Aw4 of condensed water corresponding to the surface area of the intake manifold 10, and using the set correction coefficient Cs to correct the amount Aw4 of condensed water.

[0115] Further, the amount of produced condensed water that adheres may vary depending on the wall surface temperature of the intake manifold 10 in addition to the surface area of the intake manifold 10. Accordingly, an amount of condensed water can be estimated with high accuracy by using in addition to the surface area of the intake manifold 10 the wall surface temperature of the intake manifold 10 to set the correction coefficient Cs for correcting the amount Aw4 of condensed water, and using the set correction coefficient Cs to correct the amount Aw4 of condensed water.

[0116] Hereinafter, an exemplary variation will be described. While the above-described embodiment has been described such that the amount Aw4 of condensed water is calculated assuming that the humidity H is 100% by way of example, it is not limited to 100% and may be set at a predetermined value smaller than 100%. Alternatively, the humidity H in the intake manifold 10 may be sensed with a humidity sensor (not shown), and the amount Aw4 of condensed water may be calculated using the sensed result.

[0117] Further, while the above-described embodiment has been described such that the controller 100 executes the process shown in the flowchart of Fig. 3, regardless of the operation state of the engine system 1, to calculate a cumulative volume of condensed water, the cumulative volume of condensed water may be calculated for example while the engine system 1 is warmed up. For example, when the water temperature Tw is lower than the threshold value, the controller 100 may execute the process shown in the flowchart of Fig. 3 to calculate a cumulative volume of condensed water.

[0118] Further, while the above-described embodiment has been described for estimating a cumulative volume of condensed water with the engine system 1 provided with the EGR device 20 by way of example, the engine system 1 may be configured without the EGR device 20 or may be configured to stop the EGR device 20 from operating when the engine is warmed up.

[0119] In this case, the controller 100 can estimate the cumulative volume of condensed water in the same manner as described above, for example, by setting the recirculation rate R and the flow rate Qegr of the EGR gas to zero. That is, the controller 100 can accurately estimate a value of an amount of condensed water in an intake passage by subtracting an amount of saturated water vapor from a first amount of moisture calculated by an estimating expression using the flow rate of intake air sucked into the intake passage, the concentration of water vapor included in the intake air, the humidity of the intake air, the temperature of the intake air, and the atmospheric pressure.

[0120] The above-described exemplary variations may entirely or partially be combined together and implemented.

[0121] According to an aspect of the present invention an apparatus that estimates an amount of condensed water is an apparatus that estimates an amount of condensed water produced in an intake passage of an engine system. The engine system includes a cylinder connected to the intake passage. The apparatus that estimates an amount of condensed water comprises a first calculator that calculates a first amount of moisture included in intake air sucked into the intake passage by an estimating expression using a flow rate of the intake air, a concentration of water vapor included in the intake air, a humidity of the intake air, a temperature of the intake air, and an atmospheric pressure, a second calculator that calculates an amount of saturated water vapor in the intake passage, and a third calculator that calculates the first amount of moisture minus the amount of saturated water vapor as an estimated value of the amount of condensed water.

[0122] In this way, the first amount of moisture included in the intake air passing through the intake passage can be estimated by the estimating expression with high accuracy. Thus, an estimated value of an amount of condensed water in the intake passage can be estimated with high accuracy by subtracting an amount of saturated water vapor from the first amount of moisture.

[0123] In an embodiment, the engine system includes an exhaust gas recirculation device that returns a portion of exhaust gas to the intake passage. The apparatus further comprises a fourth calculator that calculates a second amount of moisture that is included in the exhaust gas passing through the intake passage and is produced by combustion of fuel by an estimating expression using an amount of fuel supplied to the cylinder and a recirculation rate of exhaust gas returned to the intake passage. The first calculator calculates the first amount of moisture by an estimating expression using the recirculation rate of the exhaust gas returned to the intake passage in addition to the flow rate of the intake air sucked into the intake passage, the concentration of the water vapor included in the intake air, the humidity of the intake air, the temperature of the intake air, and the atmospheric pressure. The second calculator calculates an amount of saturated water vapor in a portion of the intake passage which passes the exhaust gas. The third calculator calculates a sum of the first amount of moisture and the second amount of moisture minus the amount of saturated water vapor as the estimated value of the amount of condensed water.

[0124] In this way, the first amount of moisture and the second amount of moisture that is included in the exhaust gas passing through the intake passage and is produced by combustion of fuel can be estimated with high accuracy by their respective estimating expressions. Accordingly, the estimated value of the amount of condensed water in the intake passage can be estimated with high accuracy by subtracting the amount of saturated water vapor from the sum of the first amount of moisture and the second amount of moisture.

[0125] In an embodiment, the second calculator calculates an amount of saturated water vapor corresponding to a wall surface temperature at a portion of the intake passage that exhaust gas comes into contact with.

[0126] As condensed water is produced on a wall surface of that portion of the intake passage which passes exhaust gas, the amount of condensed water produced at the portion of the intake passage which passes the exhaust gas can be estimated with high accuracy by calculating the amount of saturated water vapor corresponding to the wall surface temperature.

[0127] In one embodiment, the third calculator sets a correction coefficient for the estimated value corresponding to a surface area of a wall surface of the intake passage to which condensed water can adhere. The third calculator corrects the estimated value using the correction coefficient.

[0128] An amount of condensed water produced at that portion of the intake passage which passes exhaust gas, that adhere, may vary depending on the surface area of the wall surface of that portion. Accordingly, an amount of condensed water can be estimated with high accuracy by setting a correction coefficient for correcting an estimated value of an amount of condensed water corresponding to the surface area of the wall surface of the portion, and using the set correction coefficient to correct the estimated value.

[0129] In one embodiment, the third calculator sets a correction coefficient using the temperature of a wall surface of a portion of the intake passage that exhaust gas comes into contact with.

[0130] An amount of condensed water produced at that portion of the intake passage which passes exhaust gas, that adhere, may vary depending on the wall surface temperature of the wall surface of that portion in addition to the surface area of the wall surface of that portion. Accordingly, an amount of condensed water can be estimated with high accuracy by using the wall surface temperature in addition to the surface area to set a correction coefficient for correcting an estimated value of an amount of condensed water, and using the set correction coefficient to correct the estimated value.

[0131] Further, in an embodiment, the apparatus that estimates an amount of condensed water indicates, via a notification device, predetermined information regarding the amount of condensed water when the estimated value of the amount of condensed water exceeds a threshold value.

[0132] This allows the user to be notified of predetermined information on an amount of condensed water and thus recognize the information.

[0133] In a further embodiment, when the estimated value of the amount of condensed water exceeds a threshold value, the apparatus that estimates an amount of condensed water decreases a flow rate of exhaust gas returned to the intake passage by the exhaust gas recirculation device or stops returning the exhaust gas to the intake passage.

[0134] This can suppress an increase in an amount of condensed water produced, and hence corrosion of the intake passage.

[0135] While the present invention has been described in embodiments, it should be understood that the embodiments disclosed herein are illustrative and non-restrictive in any respect. The scope of the present invention is defined by the terms of the claims, and is intended to include any modifications within the scope of the claims.

[0136] A controller executes a process including: calculating a first amount of moisture included in intake air using an estimating expression (S 100); calculating a second amount of moisture included in exhaust gas and produced by combustion of fuel using an estimating expression (S 102); calculating an amount of saturated water vapor (S104); calculating an amount of condensed water (S106); setting a correction coefficient (S 108); and calculating a cumulative volume of condensed water (S110).

Claims

1. An apparatus (100) that estimates an amount of condensed water produced in an intake passage (10) of an engine system (1), the engine system (1) including a cylinder (4) connected to the intake passage (10), wherein the engine system (1) includes an exhaust gas recirculation device (20) that returns a portion of exhaust gas to the intake passage (10),
the apparatus (100) comprising:

a first calculator (120) that calculates a first amount of moisture (Aw1) included in intake air sucked into the intake passage (10) by an estimating expression using at least a flow rate of the intake air, a concentration of water vapor included in the intake air, a humidity of the intake air, a temperature of the intake air, and an atmospheric pressure;
a second calculator (122) that calculates a second amount of moisture (Aw2) that is included in the exhaust gas passing through the intake passage (10) and is produced by combustion of fuel by an estimating expression using an amount of fuel supplied to the cylinder (4) and a recirculation rate of exhaust gas returned to the intake passage (10),
a third calculator (124) that calculates an amount (Aw3) of saturated water vapor in the intake passage (10); and
a fourth calculator (126) that calculates the sum of the first amount of moisture (Aw1) and the second amount of moisture (Aw2) minus the amount of saturated water vapor (Aw3) as an estimated value of the amount of condensed water (Aw4),
the apparatus being **characterized in that** the third calculator (124) estimates a wall surface temperature (Twl) of a portion of the intake passage (10) which comes into contact with the recirculated exhaust gas and calculates the amount of saturated water vapor (Aw3) at least based on the estimated wall surface temperature (Twl).

2. The apparatus (100) that estimates an amount of condensed water according to claim 1, wherein

the estimating expression is an estimating expression using the recirculation rate of the exhaust gas returned to the intake passage (10) in addition to the flow rate of the intake air sucked into the intake passage (10), the concentration of the water vapor included in the intake air, the humidity of the intake air, the temperature of the intake air, and the atmospheric pressure, and
the amount of saturated water vapor is an amount of saturated water vapor in a portion of the intake passage (10) which passes the exhaust gas.

3. The apparatus (100) that estimates an amount of condensed water according to claim 1, wherein the fourth calculator (126) sets a correction coefficient for the estimated value corresponding to a surface area of a wall surface of the intake passage (10) to which the condensed water can adhere, and corrects the estimated value using the correction coefficient.

4. The apparatus (100) that estimates an amount of condensed water according to claim 3, wherein the fourth calculator (126) sets the correction coefficient using a temperature of a wall surface of a portion of the intake passage (10) that the exhaust gas comes into contact with.

5. The apparatus (100) that estimates an amount of condensed water according to claim 3 or 4, wherein

an amount of scavenging (Aw5) is estimated using the wall surface temperature, the flow rate of the intake air and a water temperature,
the amount of scavenging (Aw5) is subtracted from the corrected estimated value to calculate an amount of condensed water produced in the intake passage (10), which is added to a previous value of a cumulative volume (Vw) of condensed water to calculate a current value of the cumulative volume (Vw) of condensed water.

6. The apparatus (100) that estimates an amount of condensed water according to any one of claims 1 to 5, wherein the apparatus (100) indicates, via a notification device (130), predetermined information regarding the amount of condensed water when the estimated value of the amount of condensed water exceeds a threshold value.

7. The apparatus (100) that estimates an amount of condensed water according to any one of claims 2 to 5, wherein when the estimated value of the amount of condensed water exceeds a threshold value, the apparatus (100) decreases a flow rate of exhaust gas returned to the intake passage (10) by the exhaust gas recirculation device (20) or stops returning the exhaust gas to the intake passage (10).

8. The apparatus (100) that estimates an amount of condensed water according to claim 1, wherein the estimated value of the amount of condensed water is calculated while the engine system (1) is warmed up.

Patentansprüche

1. Vorrichtung (100), die eine in einem Einlasskanal (10) eines Kraftmaschinensystems (1) erzeugte Menge von kondensiertem Wasser schätzt, wobei das Kraftmaschinensystem (1) einen mit dem Einlasskanal (10) verbundenen Zylinder (4) umfasst, wobei das Kraftmaschinensystem (1) eine Abgasrückführungseinrichtung (20) umfasst, die einen Teil des Abgases in den Einlasskanal (10) zurückführt,
wobei die Vorrichtung (100) aufweist:

eine erste Berechnungseinrichtung (120), die eine erste Menge an Feuchtigkeit (Aw1), die in Ansaugluft enthalten ist, die in den Einlasskanal (10) gesaugt wird, durch einen Schätzausdruck berechnet, der mindestens eine Strömungsrate der Ansaugluft, eine Konzentration von Wasserdampf, der in der Ansaugluft enthalten ist, eine Feuchtigkeit der Ansaugluft, eine Temperatur der Ansaugluft und einen atmosphärischen Druck verwendet;
eine zweite Berechnungseinrichtung (122), die eine zweite Feuchtigkeitsmenge (Aw2), die in dem durch den Einlasskanal (10) strömenden Abgas enthalten ist und durch Verbrennung von Kraftstoff erzeugt wird, durch einen Schätzausdruck unter Verwendung einer dem Zylinder (4) zugeführten Kraftstoffmenge und einer Rezirkulationsrate des zum Einlasskanal (10) zurückgeführten Abgases berechnet,
eine dritte Berechnungseinrichtung (124), die eine Menge (Aw3) an gesättigtem Wasserdampf im Einlasskanal (10) berechnet; und
eine vierte Berechnungseinrichtung (126), die die Summe aus der ersten Feuchtigkeitsmenge (Aw1) und der zweiten Feuchtigkeitsmenge (Aw2) abzüglich der Menge an gesättigtem Wasserdampf (Aw3) als Schätzwert für die Menge an kondensiertem Wasser (Aw4) berechnet,
wobei die Vorrichtung **dadurch gekennzeichnet ist, dass** die dritte Berechnungseinrichtung (124) eine Wandoberflächentemperatur (Twl) eines Abschnitts des Einlasskanals (10) schätzt, der mit dem rückgeführten Abgas in Kontakt kommt, und die Menge an gesättigtem Wasserdampf (Aw3) zumindest auf der Grundlage der geschätzten Wandoberflächentemperatur (Twl) berechnet.

2. Vorrichtung (100), die eine Menge von kondensiertem Wasser schätzt, gemäß Anspruch 1, wobei

der Schätzungsausdruck ein Schätzungsausdruck ist, der die Rezirkulationsrate des in den Einlasskanal (10) zurückgeführten Abgases zusätzlich zur Strömungsrate der in den Einlasskanal (10) angesaugten Ansaugluft, die Konzentration des in der Ansaugluft enthaltenen Wasserdampfs, die Feuchtigkeit der Ansaugluft, die Temperatur der Ansaugluft und den atmosphärischen Druck verwendet, und
die Menge an gesättigtem Wasserdampf eine Menge an gesättigtem Wasserdampf in einem Teil des Einlasskanals (10) ist, der das Abgas passiert.

3. Vorrichtung (100), die eine Menge von kondensiertem Wasser schätzt, gemäß Anspruch 1, wobei die vierte Berechnungseinrichtung (126) einen Korrekturkoeffizienten für den geschätzten Wert entsprechend einem Oberflächenbereich einer Wandfläche des Einlasskanals (10) festlegt, an dem das kondensierte Wasser anhaften kann, und den geschätzten Wert unter Verwendung des Korrekturkoeffizienten korrigiert.

4. Vorrichtung (100), die eine Menge von kondensiertem Wasser schätzt, gemäß Anspruch 3, wobei die vierte Berechnungseinrichtung (126) den Korrekturkoeffizienten unter Verwendung einer Temperatur einer Wandoberfläche eines Abschnitts des Einlasskanals (10), mit dem das Abgas in Kontakt kommt, einstellt.

5. Vorrichtung (100), die eine Menge von kondensiertem Wasser schätzt, gemäß Anspruch 3 oder 4, wobei

eine Spülmenge (Aw5) unter Verwendung der Wandoberflächentemperatur, der Strömungsrate der Ansaugluft und einer Wassertemperatur geschätzt wird,
die Spülmenge (Aw5) von dem korrigierten Schätzwert subtrahiert wird, um eine im Einlasskanal (10) erzeugte Menge von kondensiertem Wasser zu berechnen, die zu einem früheren Wert eines kumulativen Volumens (Vw) von Kondenswasser addiert wird, um einen aktuellen Wert des kumulativen Volumens (Vw) von kondensiertem Wasser zu berechnen.

6. Vorrichtung (100), die eine Menge von kondensiertem Wasser schätzt, gemäß einem der Ansprüche 1 bis 5, wobei die Vorrichtung (100) über eine Benachrichtigungsvorrichtung (130) eine vorbestimmte Information bezüglich der Menge von kondensiertem Wasser anzeigt, wenn der geschätzte Wert der Menge von kondensiertem Wasser einen Schwellenwert überschreitet.

7. Vorrichtung (100), die eine Menge von kondensiertem Wasser schätzt, gemäß einem der Ansprüche 2 bis 5, wobei die Vorrichtung (100), wenn der geschätzte Wert der Menge an kondensiertem Wasser einen Schwellenwert überschreitet, eine Strömungsrate von Abgas, das durch die Abgasrückführungsvorrichtung (20) in den Einlasskanal (10) zurückgeführt wird, verringert oder die Rückführung des Abgases in den Einlasskanal (10) stoppt.

8. Vorrichtung (100), die eine Menge von kondensiertem Wasser schätzt, gemäß Anspruch 1, wobei der Schätzwert der Menge von kondensiertem Wasser berechnet wird, während das Kraftmaschinensystem (1) aufgewärmt wird.

Revendications

1. Appareil (100) qui estime une quantité d'eau condensée produite dans un passage d'admission (10) d'un système de moteur (1), le système de moteur (1) comprenant un cylindre (4) connecté au passage d'admission (10), dans lequel le système de moteur (1) comprend un dispositif de recirculation des gaz d'échappement (20) qui renvoie une partie des gaz d'échappement vers le passage d'admission (10),
l'appareil (100) comprenant :

un premier calculateur (120) qui calcule une première quantité d'humidité (Aw1) contenue dans l'air d'admission aspiré dans le passage d'admission (10) par une expression d'estimation utilisant au moins un débit de l'air d'admission, une concentration de vapeur d'eau contenue dans l'air d'admission, une humidité de l'air d'admission, une température de l'air d'admission et une pression atmosphérique ;
un deuxième calculateur (122) qui calcule une deuxième quantité d'humidité (Aw2) contenue dans les gaz d'échappement passant par le passage d'admission (10) et produite par la combustion du carburant par une expression d'estimation utilisant une quantité de carburant fournie au cylindre (4) et un taux de recirculation des gaz d'échappement renvoyés vers le passage d'admission (10),
un troisième calculateur (124) qui calcule une quantité (Aw3) de vapeur d'eau saturée dans le passage d'admission (10) ; et
un quatrième calculateur (126) qui calcule la somme de la première quantité d'humidité (Aw1) et de la deuxième quantité d'humidité (Aw2) moins la quantité de vapeur d'eau saturée (Aw3) comme valeur estimée de la quantité d'eau condensée (Aw4),
l'appareil étant **caractérisé par le fait que** le troisième calculateur (124) estime une température de surface de la paroi (Twl) d'une partie du passage d'admission (10) qui entre en contact avec les gaz d'échappement recirculés et calcule la quantité de vapeur d'eau saturée (Aw3) au moins sur la base de la température de surface de la paroi (Twl) estimée.

2. Appareil (100) qui estime une quantité d'eau condensée selon la revendication 1, dans lequel

l'expression d'estimation est une expression d'estimation utilisant le taux de recirculation des gaz d'échappement renvoyés vers le passage d'admission (10) en plus du débit de l'air d'admission aspiré dans le passage d'admission (10), la concentration de la vapeur d'eau contenue dans l'air d'admission, l'humidité de l'air d'admission, la température de l'air d'admission et la pression atmosphérique, et
la quantité de vapeur d'eau saturée est une quantité de vapeur d'eau saturée dans une partie du passage d'admission (10) où passent les gaz d'échappement.

3. Appareil (100) qui estime une quantité d'eau condensée selon la revendication 1, dans lequel le quatrième calculateur (126) établit un coefficient de correction pour la valeur estimée correspondant à une superficie d'une surface de paroi du passage d'admission (10) à laquelle l'eau condensée peut adhérer, et corrige la valeur estimée à l'aide du coefficient de correction.

4. Appareil (100) qui estime une quantité d'eau condensée selon la revendication 3, dans lequel le quatrième calculateur (126) établit le coefficient de correction en utilisant une température d'une surface de paroi d'une partie du passage d'admission (10) avec laquelle les gaz d'échappement entrent en contact.

5. Appareil (100) qui estime une quantité d'eau condensée selon la revendication 3 ou 4, dans lequel

une quantité à évacuer (Aw5) est estimée en utilisant la température de la surface de paroi, le débit de l'air d'admission et une température de l'eau,
la quantité de à évacuer (Aw5) est soustraite de la valeur estimée corrigée pour calculer une quantité d'eau condensée produite dans le passage d'admission (10), qui est ajoutée à une valeur précédente d'un volume cumulé (Vw) de l'eau condensée pour calculer une valeur actuelle du volume cumulé (Vw) de l'eau condensée.

6. Appareil (100) qui estime une quantité d'eau condensée selon l'une des revendications 1 à 5, dans lequel l'appareil (100) indique, via un dispositif de notification (130), des informations prédéterminées concernant la quantité d'eau condensée lorsque la valeur estimée de la quantité d'eau condensée dépasse une valeur seuil.

7. Appareil (100) qui estime une quantité d'eau condensée selon l'une des revendications 2 à 5, dans lequel, lorsque la valeur estimée de la quantité d'eau condensée dépasse une valeur seuil, l'appareil (100) diminue un débit des gaz d'échappement renvoyés vers le passage d'admission (10) par le dispositif de recirculation des gaz d'échappement (20) ou arrête de renvoyer les gaz d'échappement vers le passage d'admission (10).

8. Appareil (100) qui estime une quantité d'eau condensée selon la revendication 1, dans lequel la valeur estimée de la quantité d'eau condensée est calculée alors que le système de moteur (1) est réchauffé.

FIG.1

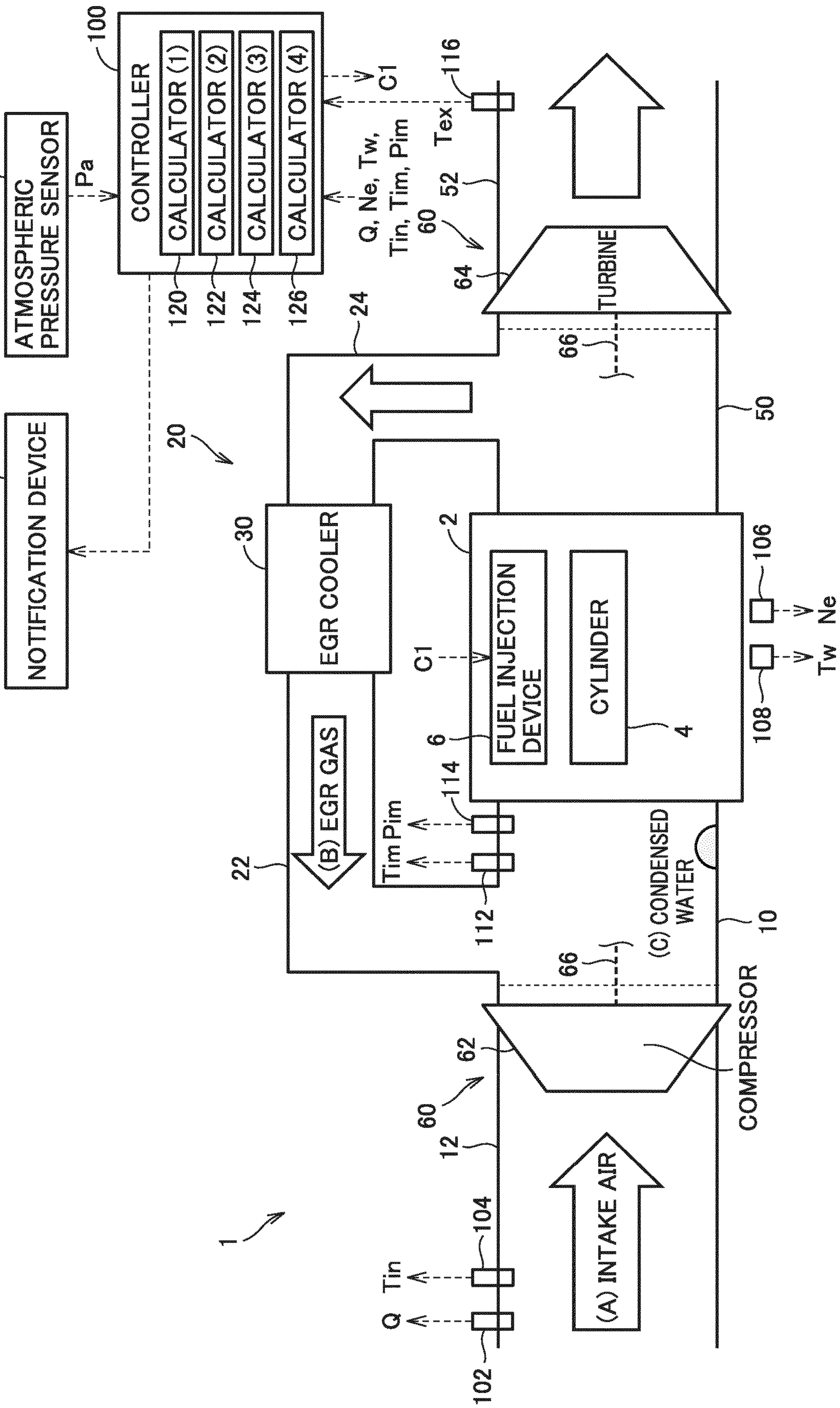

ATMOSPHERIC PRESSURE SENSOR
110
Pa
CONTROLLER
100
CALCULATOR (1)
CALCULATOR (2)
CALCULATOR (3)
CALCULATOR (4)
120
122
124
126
C1
116
Q, Ne, Tw, Tin, Tim, Pim
Tex
52
60
64
TURBINE
24
66
50
NOTIFICATION DEVICE
130
20
30
EGR COOLER
2
FUEL INJECTION DEVICE
CYLINDER
106
Ne
Tw
108
4
6
C1
(B) EGR GAS
114
Tim Pim
112
22
(C) CONDENSED WATER
10
66
COMPRESSOR
62
60
12
(A) INTAKE AIR
104
Tin
Q
102
1

FIG.2

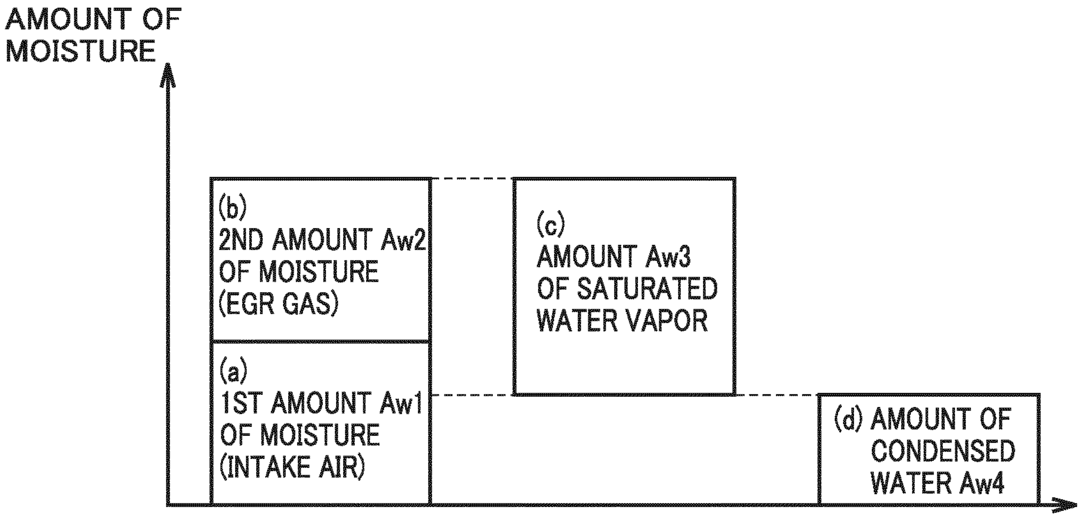

AMOUNT OF MOISTURE
(b) 2ND AMOUNT Aw2 OF MOISTURE (EGR GAS)
(a) 1ST AMOUNT Aw1 OF MOISTURE (INTAKE AIR)
(c) AMOUNT Aw3 OF SATURATED WATER VAPOR
(d) AMOUNT OF CONDENSED WATER Aw4

FIG.3

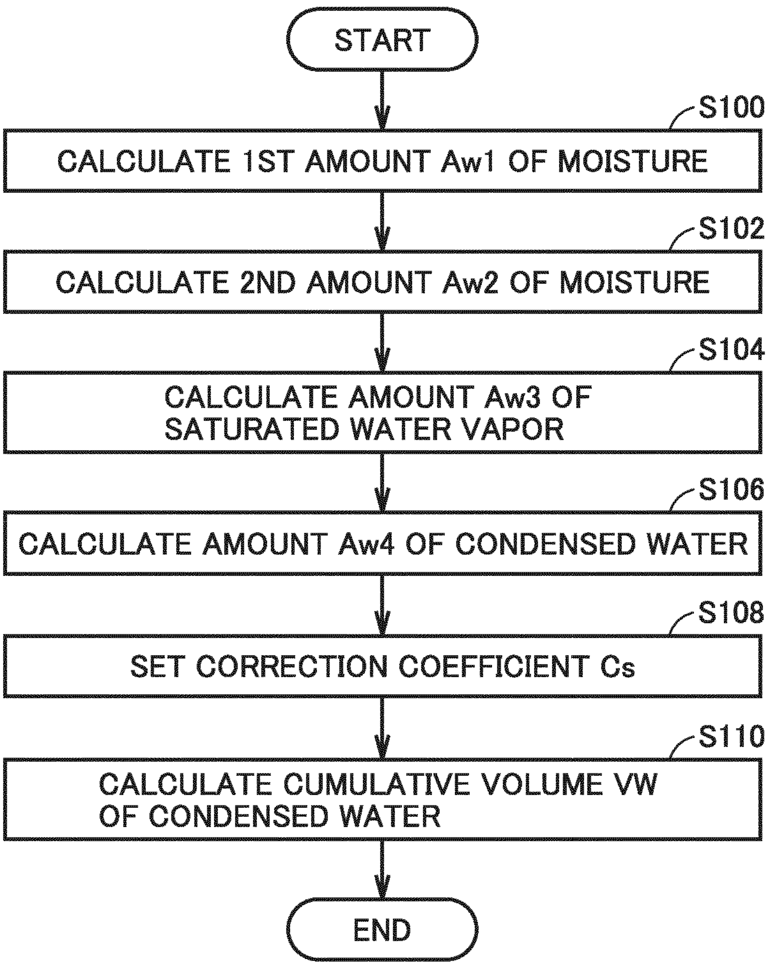

START
S100
CALCULATE 1ST AMOUNT Aw1 OF MOISTURE
S102
CALCULATE 2ND AMOUNT Aw2 OF MOISTURE
S104
CALCULATE AMOUNT Aw3 OF SATURATED WATER VAPOR
S106
CALCULATE AMOUNT Aw4 OF CONDENSED WATER
S108
SET CORRECTION COEFFICIENT Cs
S110
CALCULATE CUMULATIVE VOLUME VW OF CONDENSED WATER
END

FIG.4

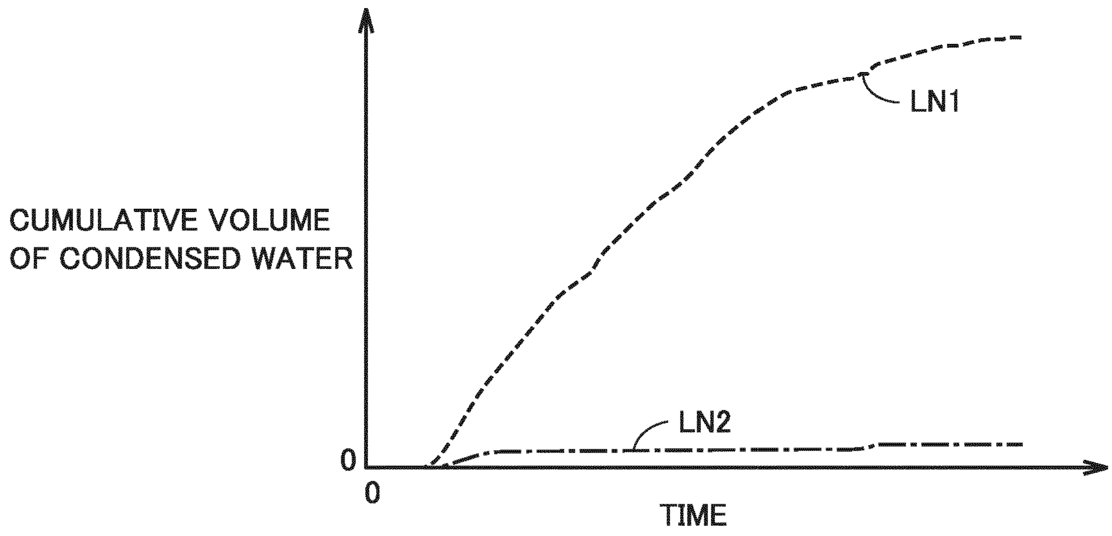

CUMULATIVE VOLUME
OF CONDENSED WATER
LN1
LN2
0
0
TIME

FIG.5

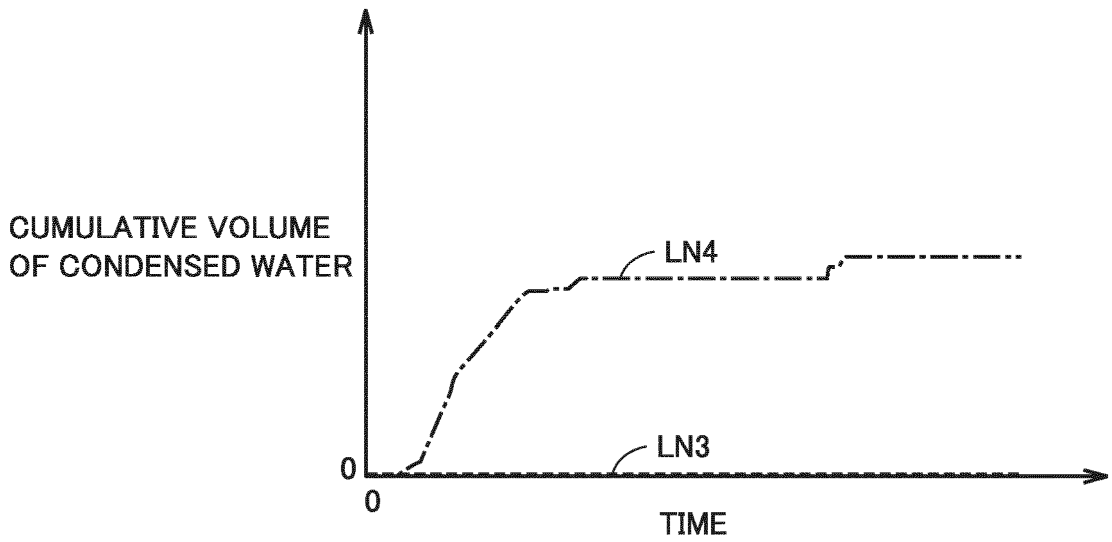

CUMULATIVE VOLUME
OF CONDENSED WATER
LN4
LN3
0
0
TIME

FIG.6

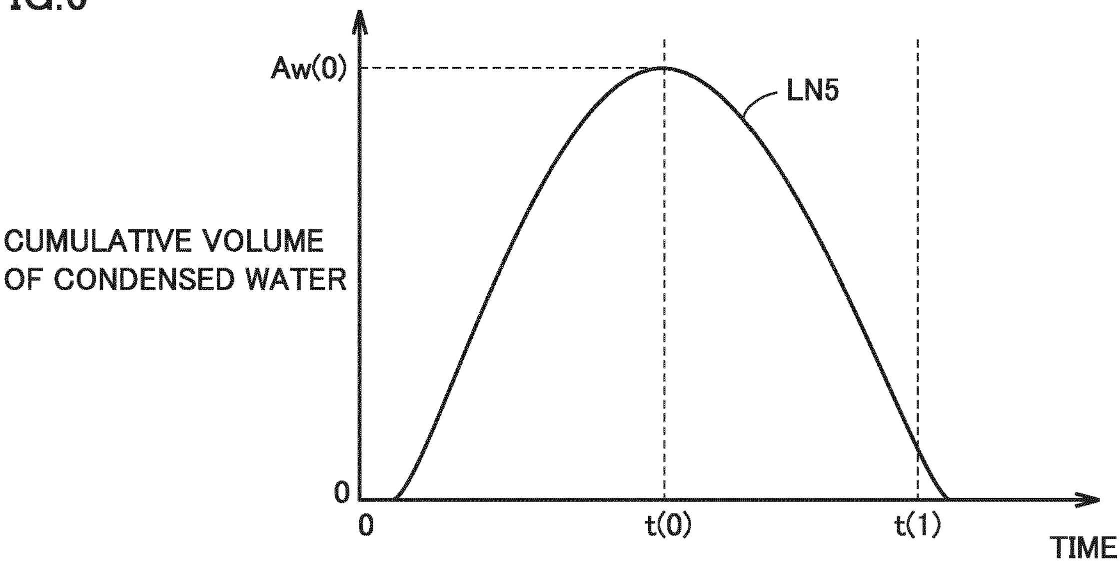
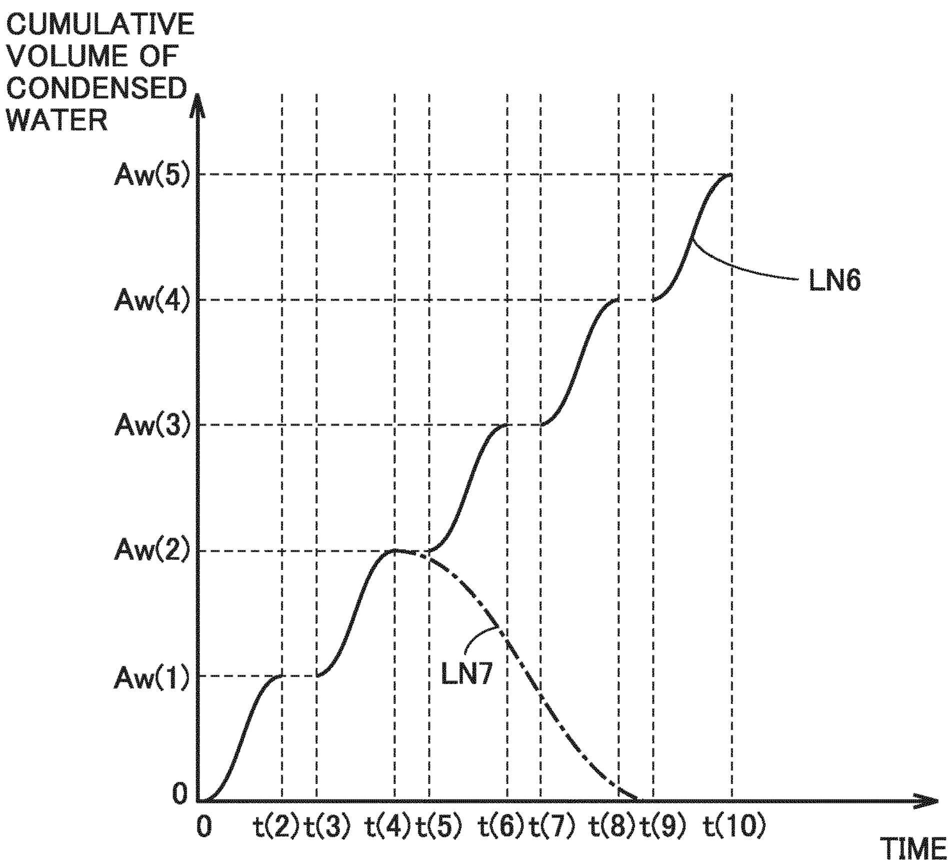

Aw(0)
LN5
CUMULATIVE VOLUME
OF CONDENSED WATER
0
0
t(0)
t(1)
TIME

FIG.7


CUMULATIVE
VOLUME OF
CONDENSED
WATER
Aw(5)
LN6
Aw(4)
Aw(3)
Aw(2)
Aw(1)
LN7
0
0
t(2) t(3) t(4) t(5) t(6) t(7) t(8) t(9) t(10)
TIME

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2018188991 A **[0003]**
- WO 2021002240 A1 **[0004]**